Strengthening Institutional Capacity to Improve the Assessment of Impacts of Climate Change in Latin America and the Caribbean

Contract # INE/CCS-RG-T2612-SN1

Technical Report #1

Proceedings of the First Workshop and Summary of Planned *MapMaker* Development

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Technical Report #1

Proceedings of the First Workshop and Summary of Planned *MapMaker* Development

prepared by

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Contents

Workshop 1: Initiation of the Regional Climate Change Consortium (June 6-10 2016)

Overview

The first Consortium Workshop was held at the facilities of CATHALAC on the campus of the City of Knowledge in Panama City, Panama from 6-10 June 2016 (see Appendix A for agenda). Eleven representatives from 10 countries, as well as two participants from CATHALAC, were in attendance and the Workshop was directed by three scientists from the University of Nebraska-Lincoln (see Appendix B for list of participants).

The purpose of the first Workshop was to initiate the Consortium and identify user's needs. The WRF IPCC AR5 simulations and other relevant data both for the region and individual countries were reviewed, followed by a participant-led discussion of their individual country issues and needs. Based on this, Working Groups were formulated, focused on specific impact areas that were identified at previous workshops along with new input from current participants. The *MapMaker* app was presented and described (many but not all of the participants already had some familiarity with it). Importantly, the participants were asked to provide initial input on what enhancements and new features they would like to see added to *MapMaker*.

Prior to the Workshop, a survey was sent to all country representatives to gauge their data needs and wants for climate change planning. Of course, not all user needs/wants will be possible to meet, but

Workshop participants and leaders in front of CATHALAC facilities. (front row): Rachindra Mawalagedara, Gabriela Alfaro, Bob Oglesby, Alberto López, Marcos Andrade, Alan LLacza, Clint Rowe, Jayaka Campbell; (back row): Luis Alvarado, Josué Batista, Alberto Cumbrera, Franklyn Ruiz, Juan José Nieto, Francisco Argeñal; (not present for photo): Alejandro del Castillo, Marcelo Oyuela.

these survey results were used to inform the discussion at the Workshop on what types of data it will be possible to include under this project.

The first two days of the Workshop were organized primarily as plenary sessions to introduce participants to each other (many already knew some or all of the others) and to hear presentations by UNL scientists to familiarize the participants with the overall structure and plans for the Consortium and the Workshops, review past activities, and organize the Working Groups (see Appendix D for UNL presentation slides). The remaining three days of the Workshop were largely breakout sessions for the Working Groups, with short plenary sessions interspersed for Working Group update reports to the entire Consortium.

Summary and Discussion of Survey Responses

Prior to the Workshop, a survey was sent to all country representatives to gauge their data needs and wants for climate change planning. Responses to the surveys illustrate a number of common interests and goals, and resources that can be utilized for research activities in the Regional Consortium as well as complimentary skill sets that could potentially enhance the experience of the participants over the course of the five Workshops.

Summary of the Survey Responses (See Appendix C)

All participants identified agriculture as the key sector impacted by climate change in their respective countries (Table 1). Water resources, health services and utilities were among the other top ranked sectors impacted be climate change. A majority of participants listed precipitation extremes (including floods and droughts) and tropical cyclones as the top climate events that impact their countries. Together, the responses for priority economic sectors and climate events indicating that water availability – either too much or too little – represents a major regional concern, as reflected in the high-priority economic sectors of Agriculture and Water Resources and high-priority climate events of extreme precipitation, drought, and floods.

Table 1: Summary of economic sectors and climate events of concern.

Sector	#	Average Rank	Event	#	Average Rank
Agriculture	10	1.5	Extreme Temperature	3	2.3
Water Resources	7	1.7	Extreme Precipitation	7	1.7
Fishing/Aquaculture	0		Drought	10	1.9
Forestry	1	3.0	Floods	7	2.4
Construction	1	1.0	Heat Waves	0	
Transportation	0		Windstorms	0	
Manufacturing	0		Tropical Cyclones	4	1.5
Health Services	6	2.5	Sea Level Rise	2	3.0
Tourism/Outdoor Recreation	1	3.0			
Utilities	4	2.8			

According to the survey, 9 out of the 10 participating countries currently have a country-level adaptation or mitigation plan for climate change and 7 countries have provided information on how to access the data/reports. Further, 6 of the participating countries have ongoing international collaborations regarding climate change.

Responses to the questions designed to gauge the expertise of the participating countries on the generation and use of global and regional climate model output show that previous knowledge and skill varies from country to country. While all participating countries (either the institution the participant is affiliated with or a different organization) use regional climate models, with 7 countries having prior experience with WRF.

According to the survey results most participating countries/institutions (8) collect and archive climate data and are willing to make the data available (6) to the Consortium for use in model verification and other research activities. Four countries/institutions either create or use statistically downscaled climate data, out of which three countries are willing to share the data.

The survey also identified other institutions in the participating countries that work with climate models and/or have access to climate data as well collaborators on climate change research activities.

A summary of the expectations and goals for the first Workshop as stated by the participants:

Expectations of the Workshop

- Better understanding of regional climate modelling and the RCP emission scenarios used for future climate projections
- Build regional collaborations, share knowledge and experience and develop research activities
- Exposure to latest climate modelling strategies and data analysis

Primary Learning Goals for the First Workshop

- Utilizing *MapMaker* for data analysis
- Understanding and using WRF output to identify climate change and climate change impacts
- Understanding uncertainties associated with model output and presenting results in a format relevant for decision makers

Discussion of the Survey Responses

Responses from the participants clearly show that there are a number of key climate events and climate impacts that are central to all 10 countries. These common goals and interests are clearly illustrated in the formation of the Working Groups. The expectations and goals that were stated by the participants in the surveys were all addressed during the Workshop through a combination of presentations, question and answer sessions and Working Group discussions.

The willingness of most of the participating institutions/countries to share country-level adaptation and mitigation plans as well as climate data will allow participants to fine tune their research problems so that the outcomes would be relevant and useful in the decision making process of each country. Also, the information regarding other collaborations and ongoing research activities in the participating countries will allow the participants to foster new collaborations and provide new networking opportunities that can then be leveraged for the activities of the Regional Consortium.

Bob Oglesby in consultation with Working Group 2, (left to right) Gabriela Alfaro, Luis Alvarado, Juan José Nieto, Franklyn Ruiz, and Alberto Cumbrera.

Working Groups

Based on the survey responses and discussions during the morning of the first day of the Workshop, the participants chose to form three Working Groups on Monday afternoon, with each participant self-identifying the most appropriate Group given their backgrounds and concerns. The membership of each Working Group is given in Appendix E, though all participants were urged to be familiar with each Group, and contribute accordingly. The three Working Groups are:

Working Group 1: Tropical Systems

This Working Group focuses on weather systems that start as tropical waves, and subsequently may develop into tropical storms and possibly then into a hurricane. Both the Atlantic and eastern Pacific basins are considered, as either can affect the LAC, especially Central America, Mexico, and the Caribbean. Because of the large geographic area involved, this Working Group is initially focused on the region-wide simulations for Mesoamerica and the Caribbean.

Working Group 2: ENSO

This Working Group focuses on El Nino and La Nina events, which can have major impacts on Central America and the Pacific coast of northern South America (Peru, Ecuador, and Colombia. Because of the availability of WRF simulations of sufficient length, at least initially the Working Group is concentrating on Guatemala and surrounding regions.

Clint Rowe having a discussion with Working Group 1 (left to right) Francisco Argeñal, Alberto López (back to camera), and Jayaka Campbell during a working session.

Working Group 3: Mountain Precipitation and Glaciers
This Working Group focuses on precipitation in the very mountainous terrain that comprises much of the region. In Central America this is primarily rainfall, but in the northern Andes of Bolivia, Peru, and Ecuador snowfall and the resultant impacts on mountain glaciers is also extremely important. At least initially the Working Group is concentrating on Bolivia (and surrounding regions) because of the availability of a catalog of long and relevant simulations with WRF.

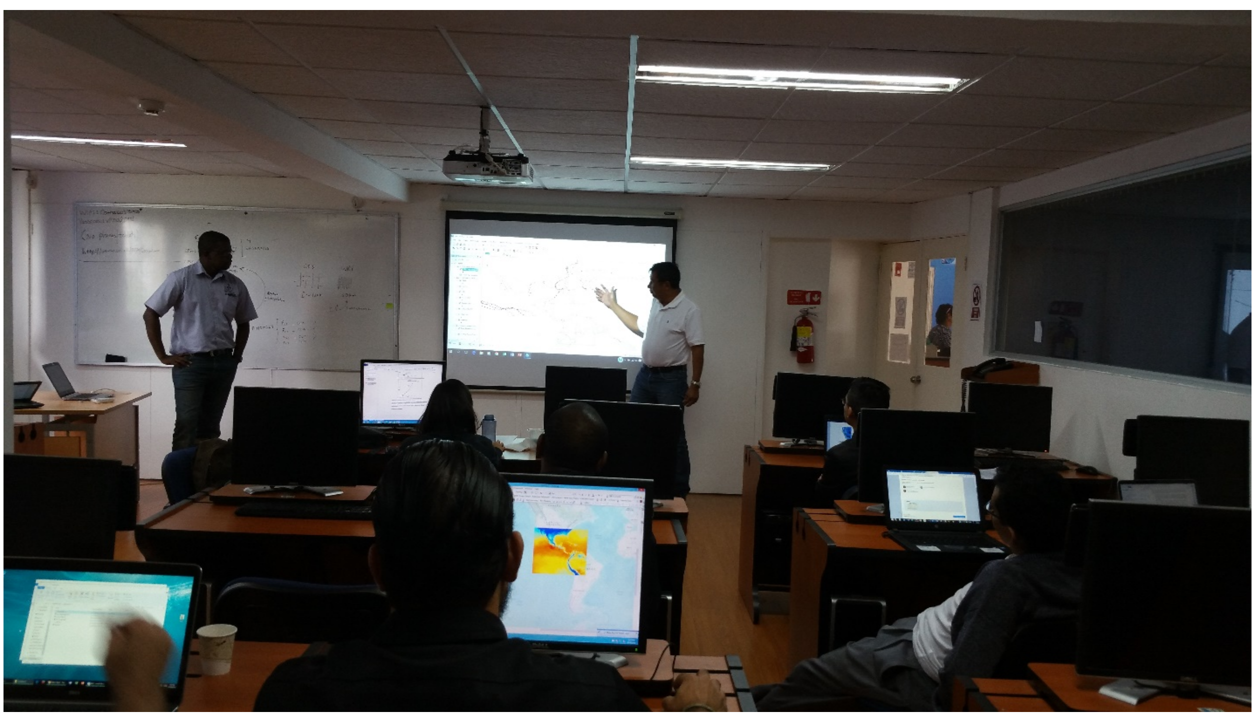
With the formation of the Working Groups on Monday afternoon, breakout sessions for discussion began almost immediately thereafter. After the lectures by University of Nebraska staff Tuesday morning, most of the remainder of the week was devoted to the individual Working Groups meetings, including providing progress reports to all Workshop participants.

Each Working Group provided an interim report on Wednesday morning, by which time each had been able to make considerable progress in defining their goals and objectives. Wednesday afternoon, in addition to their ongoing deliberations, each Working Group was asked to consider what *MapMaker* improvements and enhancements would be required to satisfactorily complete their objectives.

Deliberations by each Working Group continued all day Thursday and Friday morning. As always, the staff from the University of Nebraska circulated among the Working Groups, answering questions and providing advice and guidance. We emphasize that, while there were a number of important questions from the Working Groups, relatively little guidance was required; each Working Group did an amazing job at identifying their key issues and how to address them.

Working Group 2 giving a progress report during the Workshop.

On Friday afternoon, before the close of the Workshop, each Working Group presented a report that described progress made during the Workshop. In addition, each Working Group discussed their plans until the next (second) Workshop schedule for late October or early November of this year. These plans



Working Group 1 presenting a progress report during the Workshop.

Working Group 2 presenting their draft report on the final day of the Workshop.

included activities, a time line by which they would occur, and an outline of the scientific papers and reports they expect to produce. The presentation slides and other material presented are collected in Appendix E.

We were extremely pleased with the progress each Working Group was able to make during the week of this first Workshop. Each Working Group has a coherent plan for moving forwarded and, especially once relevant *MapMaker* enhancements are implemented, appear to have the knowledge, capabilities, and resources necessary to carry out their plans.

Planned MapMaker Development

Day 2 of the Workshop included a review of the *MapMaker* suite of tools and previous recommendations for *MapMaker* development. These previous recommendations have included:

- (i) adding additional data such as evapotranspiration, number of precipitation days, among others;
- (ii) including the ability to download data subsets (specific variables, times, areas, points, etc.);
- (iii) scaling changes to intermediate times (i.e., < 50 years);
- (iv) improving the user's manual section as well as the online help tool;
- (v) making it have better integration so that only a single version needs to be maintained, rather than several project-specific versions,
- (vi) assessing new technologies for improving map visualization options; and
- (vii) including the possibility to visualize outputs from other climate models.

Participants were asked to identify and propose any additional capabilities they would like to see added to *MapMaker*. Existing capabilities and proposed additional functionality are summarized in Table 2.

MapMaker development work is already underway and will continue between Workshops. WRF output already has been re-processed to add additional parameters, including 5 new atmospheric variables, 12 new surface variables, 2 new soil variables, and 8 new surface and top-of-atmosphere fluxes to the daily datasets. A significant design change will make direct use of daily, rather than monthly, dataset as the underlying basis for *MapMaker*. This change will require that monthly averages be computed prior to display but will, more importantly, allow the calculation of additional parameters as needed. These additional parameters could include such things as the number of days per month (or season or year) with temperature or precipitation exceeding assigned thresholds (*e.g.*, maximum temperature > 35 °C or precipitation > 25 mm) or the number of consecutive dry days in a given time period.

One of the major changes requested at the Workshop is the ability to extract subsets of the model data to decrease the time required and increase the reliability of data downloads. This sub-setting capability should include the ability to extract only some variables from the datasets, limit the geographic extent to only some portion of a WRF domain (including a single point), or limit the time period to something other than the current complete year of monthly data. This capability will be given the highest priority in the coming months.

Another frequently requested capability is the ability to scale the projected climate changes to intermediate times (*i.e.*, less than the 50-60 years between the "present-day" and "future" periods). Our project was designed with this in mind and we have already done this offline for Guatemala, at their request. It must be noted that this scaling makes sense only for present-day and future climatologies, not individual model years, and that the scaling will use a simple linear model. This model, using temperature as an example, is given as

$$\bar{T}_{INT} = \bar{T}_{PD} + (\bar{T}_{FT} - \bar{T}_{PD})\left(\frac{t_{INT} - t_{PD}}{t_{FT} - t_{PD}}\right)$$

where $\bar{T}$ and t are temperature and time, respectively, and the subscripts PD, FT, and INT refer to the present-day, future, and intermediate climatologies, respectively.

Major *MapMaker* developments will be announced to the Consortium as they are implemented and feedback from participants will be solicited.

Activities Between Workshops

Project activities will not be restricted to just the Workshops, and preparations for them. In the time between Workshops we will maintain steady contact via monthly Skype sessions with the participants, especially via the Working Groups but also individually as needed. This contact will be done via video conferencing, email, and other methods as appropriate. Moreover, *MapMaker* development will be on-going during the contract period.

Table 2: Summary of current *MapMaker* suite capabilities and proposed additional functions.

***MapMaker* Capabilities – Present & Proposed**				
	Overall	***MapMaker***	**Data Download**	**Verification**
Present capabilities		monthly maps	full files only (1 year of monthly data/domain)	GSOD “only” – just WM stations
		basic variables	netCDF only	pre-processed
		averaging months (2-12)		5 variables
		zoom		basic statistics table
		change plot parameters		basic plot types
		change color tables		
		several graphic formats		
Proposed additions	utilize daily data	“get map data” button	sub-setting by time, latitude-longitude box, point, etc.	“country” data & metadata (units, QC, etc.)
	add more data (GSOD, “country”, other model) for additional time periods	% change for precipitation	averaging	ability to select begin/end times for verification (within available data/model times)
	statistics (distributions, percentiles, etc.)	cross-model averaging	additional data formats (e.g., CSV)	“get data” button
		custom plot titles		
		storage (temporary) of data from other sources for comparison		
		better overlay capability		

Assumptions going forward:

- capacity to store all UNL WRF daily data and use these to compute requested parameters (e.g., averages, threshold exceedances, dry/wet runs)
    - might be desirable to pre-process and store some standard monthly and climatological parameters (speed vs. storage)
- sufficient processing power to perform some computations “on the fly”
- countries will need to provide their data in some simple, standardized format with standardized naming convention
    - metadata (units, QC, etc.) must be provided, as well
- rename “years” for GCM-driven simulations from nominal years to “model years” to avoid a common source of confusion (e.g., nominal 2006 becomes MY01, nominal 2056 becomes MY51), based on discussion at the Workshop

Overall Workshop Summary

In summary, the Workshop was a highly successful start to the Regional Consortium. Workshop accomplishments include:

1) Participants all were introduced to each other and established good relationships. (Many but not all of the Participants had been involved in our prior activities.)
2) Several background lectures were presented by personnel from the University of Nebraska on topics that included: regional climate modeling basics, and the WRF simulations that are available to the Consortium. Much of this material was familiar to some participants, but was

entirely new to other participants. These lectures ensured that all participants had the same information and knowledge.

3) Three key Working Group topics were identified, and the participants for each identified. Much of the Workshop involved these Working Groups meeting, identifying key issues, and the means by which these issues will be addressed.
4) The *MapMaker* app for accessing, processing, and visualizing was presented. The participants were then invited to identify needs for improving and enhancing *MapMaker*, especially as they concern the goals of each Working Group. Determining how realistic these improvements are to implement will be a key task for the University of Nebraska staff.
5) A timeline for progress between now and the next Workshop (tentatively scheduled for late October or early November of this year) was established for the overall project, and importantly for each individual Working Group.

Overall, the Consortium seems well positioned not just for the next Workshop, but also for the entirety of the current IDB-funded project.

Working Group 3 during a breakout session, discussing their project.

Appendix A: Workshop Agenda

- AGENDA –

Workshop 1

Day 1: *Developing the Regional Consortium*		
Morning	***Introductions and Developing the Consortium***	
8:30 am	Registration	
9:00 am	Workshop and Participant Introductions	(plenary)
10:00 am	Rationale for the Regional Consortium	(plenary)
10:30 am	***Break***	
10:45 am	WRF regional model scenarios refresher	(plenary)
11:15 am	Participant discussion – what climate change impacts are most important for your country?	(plenary)
12:30 pm	***Lunch***	
Afternoon	***Determining Consortium Working Groups***	
2:00 pm	Potential Working Group topics	(plenary)
2:45 pm	Group Discussion of Working Group topics	(plenary)
3:30 pm	***Break***	
3:45 pm	Finalizing the Working Groups: themes and composition	(plenary)
5:00 pm	***Adjourn for the day***	

Day 2: *How to Use Regional Climate Model Scenarios for Each Working Group*		
Morning	***The IPCC AR5 WRF Downscaling Simulations***	
8:30 am	The CMIP5/AR5 Global model runs: what do they say for Latin America and the Caribbean?	(plenary)
9:30 am	Review of the WRF AR5 downscaling results for Latin America and the Caribbean	(plenary)
10:30 am	***Break***	
10:45 am	Working Groups meet separately to begin discussions	(breakout)
12:30 pm	***Lunch***	
Afternoon	***Mapmaker Status and Needs***	
2:00 pm	What is *MapMaker*?	(plenary)
2:45 pm	Current status and future needs	(plenary)
3:30 pm	***Break***	
3:45 pm	Working Groups meet separately – how can *MapMaker* help?	(breakout)
5:00 pm	***Adjourn for the day***	

Day 3: ***Working Group Meetings***		
Morning		
8:30 am	Status reports from each Working Group	(plenary)
9:15 am	Working Groups meet	(breakout)
10:30 am	***Break***	
11:00 am	Working Groups meet	(breakout)
12:30 pm	***Lunch***	
Afternoon		
2:00 pm	Working Groups meet	(breakout)
3:30 pm	***Break***	
4:00 pm	Group discussion: key themes, ideas, and needs identified so far	(plenary)
5:00 pm	***Adjourn for the day***	

Day 4: ***Working Group Meetings & MapMaker***		
Morning		
8:30 am	Working Groups meet	(breakout)
10:30 am	***Break***	
11:00 am	Working Groups meet	(breakout)
11:45 am	Status reports from each Working Group	(plenary)
12:30 pm	***Lunch***	
Afternoon		
2:00 pm	*MapMaker* revisited	(plenary)
3:30 pm	***Break***	
4:00 pm	Group discussion: *MapMaker* needs	(plenary)
5:00 pm	***Adjourn for the day***	

Day 5: ***Workshop Conclusions and Next Steps***		
Morning		
8:30 am	Working Groups finalize plans	(breakout)
10:30 am	***Break***	
11:00 am	Working Groups report	(plenary)
12:30 pm	***Lunch***	
Afternoon		
2:00 pm	What we have accomplished during this workshop	(plenary)
2:30 pm	Group discussion: key needs moving forward	(plenary)
3:30 pm	***Break***	
4:00 pm	Next steps	(plenary)
4:30 pm	Workshop conclusions: Future objectives, tasks, and goals	(plenary)
5:00 pm	***Adjourn the workshop***	

Appendix B: List of Participants

	LISTA DE PARTICIPANTES			
	Nombre del Evento:	Primer Taller Regional del Programa "Fortalecimiento de capacidades institucionales para mejorar la evaluación de los impactos del cambio climático en América Latina y el Caribe"		
	Fechas:	6 al 10 Junio 2016		
	Lugar:	Ciudad de Panamá, Panamá		
	Nombre	**Cargo**	**Organización**	**email**
1	**Alan Gerardo LLacza Rodríguez**	**Dirección de Meteorología Aplicada**	**Servicio Nacional de Meteorología e Hidrología (SENAMHI), Perú**	allacza@senamhi.gob.pe llagues@gmail.com
2	**Marcos Andrade Flores**	**Laboratorio de Física de la Atmósfera**	**Universidad Mayor de San Andrés, Bolivia**	mandrade@atmos.umd.edu mandrade@fiumsa.edu.bo
3	**Luis Fernando Alvarado Gamboa**	**Climatología**	**Instituto Meteorológico Nacional, Costa Rica**	luis@imn.ac.cr
4	**Jose Franklyn Ruiz Murcia**	**Subdirección de Meteorología**	**Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Colombia**	jruiz@ideam.gov.co
5	**Gabriela Alfaro Marroquín**	**Directora Interina**	**Centro de Estudios Ambientales y Biodiversidad, Universidad del Valle de Guatemala**	gabyalfaro@yahoo.com
6	**Francisco Javier Argeñal Pinto**	**Sub Jefe del Centro Nacional de Estudios Atmosféricos, Oceanográficos y Sísmicos**	**Comisión Permanente de Contingencias (COPECO), Honduras**	fjargenal@gmail.com

	Nombre	Cargo	Organización	email
7	**Alberto López López**	**Investigador**	**Instituto de Investigaciones Eléctricas, México**	alopezl@iie.org.mx
8	**Jayaka Campbell**	**Research Fellow, Climate Studies Group**	**University of the West Indies, Jamaica**	jayaka.campbell02@uwimona.edu.jm
9	**Juan José Nieto**	**Jefe de Servicios Climáticos**	**Centro Internacional para la Investigación del Fenómeno de El Niño (CIIFEN), Ecuador**	j.nieto@ciifen.org
10	**Josué Iván Batista Lao**	**Dirección de Hidrometeorología**	**ETESA**	jbatista@ETESA.com.pa
11	**Alberto Cumbrera**	**Dirección de Hidrometeorología**	**ETESA**	ACumbrera@ETESA.com.pa
12	**Luis Alejandro del Castillo**	**IT Manager**	**CATHALAC**	luis.delcastillo@cathalac.int
13	**Marcelo Oyuela**	**GIS Specialist**	**CATHALAC**	Marcelo.Oyuela@cathalac.int
14	**Robert Oglesby**	**Professor**	**University of Nebraska-Lincoln**	roglesby2@unl.edu
15	**Clint Rowe**	**Professor**	**University of Nebraska-Lincoln**	crowe1@unl.edu
16	**Rachindra Mawalagedara**	**Postdoctoral Researcher**	**University of Nebraska-Lincoln**	rac_mw@yahoo.com

Appendix C: Pre-workshop Survey Results

Pre-workshop survey

- survey was distributed to all confirmed participants as a form-fillable PDF, for ease of use and collation of responses

Survey Responses

- For sectors and events, average rankings and the number of countries that ranked the given sector or event are given above the individual rankings. Only those countries that included the given sector or event among their top three are listed.
- For Yes/No questions and Global/Regional modeling activities, the tabulated responses are given in **bold**.

CUESTIONARIO PRE-TALLER / *PRE-WORKSHOP QUESTIONNAIRE*

Nombre: *Name:*	
País: *Country:*	
Institución: *Institution:*	
Título profesional: *Job title:*	
E-mail: *E-mail:*	

Por favor, identificar y rango los tres principales sectores afectados (en la actualidad o que se espera) por el cambio climático en su país. Utilizar "Otros" para incluir sectores no mencionados. Incluya una breve descripción de los impactos.	*Please identify and rank the top three sectors impacted (currently or expected) by climate change in your country. Use "Other" to include sectors not listed. Include a brief description of the impacts.*

RANGO ***RANK***	**SECTOR** ***SECTOR***	**DESCRIPCIÓN** ***DESCRIPTION***
_______	Agricultura *Agriculture*	
_______	Los recursos hídricos *Water Resources*	
_______	Pesca / acuicultura *Fishing / Aquaculture*	
_______	Silvicultura *Forestry*	
_______	Construcción *Construction*	
_______	Transportación *Transportation*	
_______	Fabricación *Manufacturing*	
_______	Servicios de salud *Health Services*	
_______	Turismo / ocio al aire libre *Tourism / Outdoor Recreation*	
_______	Servicios públicos (electricidad, agua, saneamiento, etc.) *Utilities (electricity, water, sanitation, etc.)*	
_______	Otro (por favor especifica) *Other (please specify)*	
_______	Otro (por favor especifica) *Other (please specify)*	
_______	Otro (por favor especifica) *Other (please specify)*	

Por favor, identificar y rango los tres principales eventos climáticos que impactan (en la actualidad o que se espera) en su país. Utilizar "Otros" para incluir eventos no mencionados. Incluir una breve descripción de los eventos.	*Please identify and rank the top three climate events that impact (currently or expected) your country. Use "Other" to include events not listed. Include a brief description of the events.*

RANGO ***RANK***	**EVENTO** ***EVENT***	**DESCRIPCIÓN** ***DESCRIPTION***
_______	Las temperaturas extremas *Temperature extremes*	
_______	Las precipitaciones extremas Precipitation extremes	
_______	Sequía *Drought*	
_______	Las inundaciones *Floods*	
_______	Olas de calor *Heat waves*	
_______	Las tormentas de viento *Windstorms*	
_______	Ciclones tropicales *Tropical cyclones*	
_______	El aumento del nivel del mar *Sea level rise*	
_______	Otro (por favor especifica) *Other (please specify)*	
_______	Otro (por favor especifica) *Other (please specify)*	
_______	Otro (por favor especifica) *Other (please specify)*	

COLABORACIÓN Y PLANIFICACIÓN / *COLLABORATION & PLANNING*	
¿Tiene su institución climático en curso o colaboraciones cambio climático con organizaciones fuera de su país? *Does your institution have ongoing climate or climate change collaborations with organizations outside your country?*	◯ Sí / *Yes* ◯ No / *No*
En caso afirmativo, el nombre de la organización u organizaciones? *If yes, please name the organization or organizations?*	
¿Tiene su país una adaptación o plan de mitigación para el cambio climático? *Does your country have an adaptation or mitigation plan for climate change?*	◯ Sí / *Yes* ◯ No / *No*
En caso afirmativo, ¿puede proporcionar una copia (o URL) al consorcio? *If yes, can you provide a copy (or URL) to the consortium?*	◯ Sí / *Yes* ◯ No / *No*
URL:	

<table>
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<tr><td colspan="3">¿Su institución utiliza proyecciones de modelos climáticos globales?
Does your institution use global climate model projections?</td><td>○ Sí / Yes
○ No / No</td></tr>
<tr><td colspan="3">¿Su institución utiliza proyecciones de modelos climáticos regionales?
Does your institution use regional climate model projections?</td><td>○ Sí / Yes
○ No / No</td></tr>
<tr><td colspan="3">¿Su institución crear proyecciones de modelos climáticos?
Does your institution make climate model projections?</td><td>○ Sí / Yes
○ No / No</td></tr>
<tr><td colspan="2">En caso afirmativo, ¿son global o regional?
If yes, are they global or regional?</td><td>☐ Global
Global</td><td>☐ Regional
Regional</td></tr>
<tr><td colspan="2">En caso afirmativo a cualquiera de las anteriores, en la que las escalas de tiempo (marque todo lo que corresponda)?
If yes to any of the above, on which time scales (check all that apply)?</td><td>Utilizar
Use</td><td>Crear
Make</td></tr>
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Long term climate projections (50-100 years)</td><td>☐</td><td>☐</td></tr>
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Seasonal climate predictions (3-12 months)</td><td>☐</td><td>☐</td></tr>
<tr><td colspan="2">La predicción del clima intraestacional (1-3 meses)
Intraseasonal climate prediction (1-3 months)</td><td>☐</td><td>☐</td></tr>
<tr><td>Otro (por favor especifica):
Other (please specify):</td><td></td><td>☐</td><td>☐</td></tr>
<tr><td colspan="4">En caso afirmativo a cualquiera de las anteriores, ¿qué modelo o modelos se utilizan?
If yes to any of the above, what model or models do you use?</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Por favor indicar cualesquiera otras entidades, organizaciones, instituciones (incluida la investigación) en su país que utiliza o hacer proyecciones de modelos climáticos:
Please indicate any other entities, organizations, institutions (including research) in your country that use or make climate model projections:</td></tr>
<tr><td colspan="4"></td></tr>
</table>

LOS DATOS CLIMÁTICOS / *CLIMATE DATA*	
¿Tiene su organización recoger y archivar los datos climáticos? *Does your organization collect and archive climate data?*	○ Sí / *Yes* ○ No / *No*
En caso afirmativo, se pueden hacer estos datos a disposición del consorcio para su uso en la verificación de modelos y otros usos? *If yes, can these data be made available to the consortium for use in model verification and other uses?*	○ Sí / *Yes* ○ No / *No*
¿Su institución crear o utilizar datos climáticos estadísticamente a escala reducida? Do*es your institution create or use statistically downscaled climate data?*	○ Sí / *Yes* ○ No / *No*
En caso afirmativo, se pueden hacer estos datos a disposición del consorcio? *If yes, can these data be made available to the consortium?*	○ Sí / *Yes* ○ No / *No*
Por favor indicar cualesquiera otras entidades, organizaciones, instituciones (incluida la investigación) en su país que recogen y archivo los datos climáticos: *Please indicate any other entities, organizations, institutions (including research) in your country that collect and archive climate data:*	

EXPECTATIVAS Y OBJETIVOS TALLER / *WORKSHOP EXPECTATIONS AND GOALS*
¿Cuáles son sus expectativas de este taller? ¿Qué beneficios que espera de su participación en ella? *What are your expectations of this workshop? What benefits do you expect from participating in it?*
¿Cuál es la única cosa que le gusta más que aprender en el taller? *What is the one thing that you would most like to learn during the workshop?*

CUESTIONARIO PRE-TALLER / *PRE-WORKSHOP QUESTIONNAIRE*

Nombre/*Name:*	See Appendix B for list of participants
País/*Country:*	
Institución/*Institution:*	
Título profesional/*Job title:*	
E-mail/*E-mail:*	

Por favor, identificar y rango los tres principales sectores afectados (en la actualidad o que se espera) por el cambio climático en su país. Utilizar "Otros" para incluir sectores no mencionados. Incluya una breve descripción de los impactos.	*Please identify and rank the top three sectors impacted (currently or expected) by climate change in your country. Use "Other" to include sectors not listed. Include a brief description of the impacts.*

RANGO ***RANK***	**SECTOR** ***SECTOR***	**DESCRIPCIÓN** ***DESCRIPTION***
1.5 (10)	Agricultura *Agriculture*	
2	Bolivia	The effects of climate with more extremes could strongly affect agriculture in Bolivia
1	Colombia	La toma de decisión de importar alimentos, leche y otros productos dependen en gran medida de la variabilidad climática asociada a eventos El Niño y La Niña. El primero reduce significativamente las precipitaciones llevando a condiciones de sequía. La Niña por su parte aumenta las precipitaciones causando inundaciones y pérdidas económicas en este sector.
2	Costa Rica	Impactos en menor producción y calidad del grano y por lo tanto una mayor inseguridad alimentaria.
1	Ecuador	Reducción de los rendimientos por presencia de plagas y cambios en los niveles de precipitación
1	Guatemala	Debido a eventos extremos como lluvias intensasque ocasionan inundaciones o sequías prolongadas, se pierde gran porcentaje de cultivos básicos y de supervivencia anualmente, poniendo en riesgo la seguridad alimentaria.
1	Honduras	
2	Jamaica	Yields are affected and entire crops lost due to extremes in precipitation
2	Mexico	Las sequinas prolongadas y las inundaciones extremas han generado grandes perdidas en este sector
1	Panamá	Mucha perdidas de producción anual; debido a factores como la sequía, inundaciones
2	Peru	Debido al cambio en régimen de lluvia y las zonas de temperatura apropiada para ciertos cultivos.

1.7 (7)	Los recursos hídricos *Water Resources*	
1	Bolivia	A large part of the drinking water come from glaciers
1	Costa Rica	El incremento en frecuencia de la sequía en la región del Pacífico afectaría la generación hidroeléctrica(futuro) y el consumo de agua potable (actual y futuro).
3	Ecuador	Deshielo de glaciares
3	Guatemala	La prolongación de eventos como El Niño, ocasiona que el país sufra de perirodos prolongados de sequía, ocasionando escasez de agua.
2	Honduras	
1	Jamaica	Public supply, agricultural supply in droughts
1	Peru	Cambio en el régimen de lluvias y uso del agua de glaciares.
	Pesca / acuicultura *Fishing / Aquaculture*	
3.0 (1)	Silvicultura *Forestry*	
3	Honduras	
1.0 (1)	Construcción *Construction*	
1	Mexico	Los huracanes han sido cara vez mas intensos por factores de la variabilidad climatica natura y anthrogenica, causando grades perdides en las obras civiles.
	Transportación *Transportation*	
	Fabricación *Manufacturing*	
2.6 (5)	Servicios de salud *Health Services*	
3	Colombia	Si bien el cambio climático apunta en general al aumento de la temperatura de aire no sólo a nivel global sino también a nivel país, es importante destacar que de nuevo son los eventos de variabilidad climática los que tienen incidencia en la salud. Aunque falta tener una mejor evidencia científica el fenómeno El Niño favorece la aparición de malaria, dengue, cinkunkuña y zika. Entre tanto La Niña, parece favorecer enfermedades respiratorias, gripa, entre otros.
3	Costa Rica	Aumento en la cantidad de enfermedades (dengue, Zika, Chikungunya) ocasionadas por vectores a lo largo de todo el año.
2	Ecuador	Incremento de enfermedades tropicales
3	Jamaica	Dengue, malaria
2	Panamá	Cáncer de piel en aumento, radiones ultravioletas con afectaciones en la vista como cataratas.
3.0 (1)	Turismo / ocio al aire libre *Tourism / Outdoor Recreation*	
3	Peru	Eventos extremos que afecten el acceso a construcciones (ejemplo Machu Picchu) o reservas naturales.

2.8 (4)	Servicios públicos (electricidad, agua, saneamiento, etc.) *Utilities (electricity, water, sanitation, etc.)*	
3	Bolivia	An important part of the electricity generated in Bolivia comes from small dams
2	Colombia	El sector eléctrico esta dominando por fenómenos de variabilidad climática asociados al El Niño y La Niña. El último fenómeno El Niño 2015-2016 por poco lleva a un razonamiento energético. Así mismo, Colombia como país comprometido con mitigar efectos de cambio climático, está apuntando a explorar energías alternativas como la solar y la eólica; por lo tanto, es importante a parte de modelar la lluvia, es modelar el campo de viento a diferentes altura y la radiación solar.
3	Mexico	Inundaciones y vientos extremos afectan servicios publicos ya que se interrumpen servicios indispensibles en situaciones de disastre y emergencia
3	Panamá	Crisis en la estación seca, por disminución de los niveles de ríos y lagos, provocando raciocinio en el uso del vital liquido y crisis energética.
2.0 (1)	Otro (por favor especifica) *Other (please specify)*	
2	Guatemala	Salud, mayor incidencia de vectores y propagación de enfermedades.

Por favor, identificar y rango los tres principales eventos climáticos que impactan (en la actualidad o que se espera) en su país. Utilizar "Otros" para incluir eventos no mencionados. Incluir una breve descripción de los eventos.		*Please identify and rank the top three climate events that impact (currently or expected) your country. Use "Other" to include events not listed. Include a brief description of the events.*
RANGO ***RANK***	**EVENTO** ***EVENT***	**DESCRIPCIÓN** ***DESCRIPTION***
2.3 (3)	Las temperaturas extremas *Temperature extremes*	
1	Colombia	Desde 2012 hasta 2015, las temperaturas máximas han estado batiendo récords históricos, no obstante, esta situación en particular se presentó entre diciembre de 2015 y enero de 2016 cuando El Niño en su fase madura alcanzó su intensidad máxima y registraron de la misma forma valores altos de radiación solar. El año 2015 fue el año más caliente de los últimos 35 años para Colombia.
2	Jamaica	
4	Peru	Las heladas en la zona sur de Perú, causan perdidas en el sector ganadero.
1.7 (7)	Las precipitaciones extremas Precipitation extremes	
1	Bolivia	In a country with a complex topography extreme precipitation could cause a lot of damage
3	Colombia	Los eventos extremos de precipitación son las más difíciles de pronosticar. Sin embargo, el último fenómeno La Niña 2010-2011favoreció esta situación causando numerosas inundaciones, rompimiento de canales (Canal del Dique), deslizamientos que rompió infraestructura vial y petrolera, entre otros.
2	Costa Rica	Irregularidad en la intensidad, distribución temporal y espacial de las precipitaciones.
1	Ecuador	Precipitación extrema en zonas vulnerables
2	Jamaica	
2	Panamá	Indundaciones, deslizamiento de tierra, desvorde de los ríos,
1	Peru	Ocasionando perdidas materiales y economicas.

1.9 (10)	Sequía *Drought*	
3	Bolivia	Historically there are regions in Bolivia where droughts have been a problem. With more droughts those regions could become very problematic
2	Colombia	Similar, desde 2012, la tendencia de la precipitación se ha venido reduciendo en gran parte del territorio colombiano, situación que se acentúo con la ocurrencia del fenómeno El Niño 2015-2016 que por poco lleva al país a un racionamiento en el sector energético, importación de alimentos, disparo en zika. Con base en datos de alrededor 500 estaciones verificadas y validadas, 2015 fue el año más seco de los últimos 35 años.
1	Costa Rica	Aumento de la frecuencia, intensidad y extensión de la sequía en las zonas del Pacífico y norte del país.
2	Ecuador	Aumento de sequías en zonas vulnerables
1	Guatemala	Debido a sequías prolongadas, desde hace ya varios años, el país sufre de crisis en cuanto a seguridad alimentaria.
3	Honduras	
1	Jamaica	
3	Mexico	Los periodes de sequia son mas largos y hay nuevas regiones que ahora tienen sequias
1	Panamá	Afecta la siembra de legumbres, granos, frutas y la ganadería; provocando crisis alimentaria.
2	Peru	Uno de los principales problemas para la agricultura
2.4 (7)	Las inundaciones *Floods*	
2	Bolivia	Bolivia is very prone to flooding and landslides
3	Costa Rica	Aumento de la frecuencia, intensidad y extensión de las inundaciones en las zonas del Caribe.
3	Ecuador	Incremento de precipitaciones en zonas bajas que provoquen inundaciones
2	Guatemala	La lata precipitación en periódos cortos de tiempo, ocasionan inundaciones debido a la mla infraestructura de las ciudades y pueblos
2	Honduras	
2	Mexico	La cantidad de precipitaciones y regimen ha cambiado
3	Peru	
	Olas de calor *Heat waves*	
	Las tormentas de viento *Windstorms*	

1.5 (4)	Ciclones tropicales *Tropical cyclones*	
3	Guatemala	Por estar Guatemala situada en medio de los dos océanos Atlántico y Pacífico, somos altamente vulnerables a ciclones y/o tormentas tropicales, lo que ocasiona inundaciones y por consecuencia pérdida de cultivos, poniendo en riesgo la seguridad alimentaria del país.
1	Honduras	
1	Jamaica	
1	Mexico	La intensidad de los cclones ha augmentado
3.0 (2)	El aumento del nivel del mar *Sea level rise*	
3	Costa Rica	El aumento del nivel del mar visto como un caso de inundación está ocasionando erosión en la costa del Pacífico.
3	Panamá	Ya estamos siendo afectados en las islas que conforman la Comarca Guna Yala y eventos de precipitaciones extremas con marea alta.
	Otro (por favor especifica) *Other (please specify)*	

COLABORACIÓN Y PLANIFICACIÓN / *COLLABORATION & PLANNING*	
¿Tiene su institución climático en curso o colaboraciones cambio climático con organizaciones fuera de su país? *Does your institution have ongoing climate or climate change collaborations with organizations outside your country?*	**6** Sí / *Yes* **4** No / *No*
En caso afirmativo, el nombre de la organización u organizaciones? *If yes, please name the organization or organizations?*	

Bolivia	
Colombia	Universidad de Nebraska Lincoln; TNC (The nature Conservancy); WWF
Costa Rica	PNUD; GEF; CEPAL; SICA; USAID; UE; AECI
Ecuador	Japan Meteorological Agency JMA; Royal Meteorological Institute of Netherland KNMI
Guatemala	INECC, México; AILAC; IAI
Honduras	UNCCC; NOAA; World Bank; IDB; FICLIMA; CARE; Adaptation Fund
Jamaica	We are a member of the Caribbean Modeling Initiative which spans more than 7 institutions Caribbean Community Climate Change Centre || INSMET || Antom De Kum University || Caribbean Institute of Meteorology and Hydrology
Mexico	
Panamá	
Peru	

¿Tiene su país una adaptación o plan de mitigación para el cambio climático? *Does your country have an adaptation or mitigation plan for climate change?*	**9** Sí / *Yes* **1** No / *No*
En caso afirmativo, ¿puede proporcionar una copia (o URL) al consorcio? *If yes, can you provide a copy (or URL) to the consortium?*	**7** Sí / *Yes* **3** No / *No*

URL:		
	Bolivia	
	Colombia	https://www.minambiente.gov.co/index.php/component/content/article?id=476:plantilla-cambio-climatico-32
	Costa Rica	http://www.cambioclimaticocr.com/2012-05-22-19-42-06/estrategia-nacional-de-cambio-climatico http://www.cambioclimaticocr.com/biblioteca-virtual/doc_download/116-estrategia-nacional-de-cambio-climatico http://www.cambioclimaticocr.com/biblioteca-virtual/doc_download/214-plan-de-accion-estrategia-nacional-cambio-climatico
	Ecuador	http://suia.ambiente.gob.ec/planes-cc
	Guatemala	*Agenda de Investigación en Adaptación y Reducción de la Vulnerabilidad ante el Cambio Climático*
	Honduras	http://cambioclimaticohn.org/
	Jamaica	
	Mexico	http://www.diputados.gob.mx/LeyesBiblio/pdf/LGCC_130515.pdf http://iecc.inecc.gob.mx/documentis-descarga/Estrategio-Nacional-Cambio-Climatico-2013.pdf http://iecc.inecc.gob.mx/documentos-descarga/2015_indc_ing.pdf
	Panamá	http://www.miambiente.gob.pa/index.php/cambio-climatico http://www.miambiente.gob.pa/index.php/conaccp
	Peru	http://unfccc.int/resource/docs/natc/pernc3.pdf

<table>
<tr><th colspan="4">LA MODELIZACIÓN DEL CLIMA / CLIMATE MODELING</th></tr>
<tr><td colspan="3">¿Su institución utiliza proyecciones de modelos climáticos globales?
Does your institution use global climate model projections?</td><td>7 Sí / Yes
3 No / No</td></tr>
<tr><td colspan="3">¿Su institución utiliza proyecciones de modelos climáticos regionales?
Does your institution use regional climate model projections?</td><td>7 Sí / Yes
3 No / No</td></tr>
<tr><td colspan="3">¿Su institución crear proyecciones de modelos climáticos?
Does your institution make climate model projections?</td><td>7 Sí / Yes
3 No / No</td></tr>
<tr><td colspan="2">En caso afirmativo, ¿son global o regional?
If yes, are they global or regional?</td><td>3 Global
Global</td><td>6 Regional
Regional</td></tr>
<tr><td colspan="2">En caso afirmativo a cualquiera de las anteriores, en la que las escalas de tiempo (marque todo lo que corresponda)?
If yes to any of the above, on which time scales (check all that apply)?</td><td>Utilizar
Use</td><td>Crear
Make</td></tr>
<tr><td colspan="2">Las proyecciones climáticas a largo plazo (50-100 años)
Long term climate projections (50-100 years)</td><td>5</td><td>5</td></tr>
<tr><td colspan="2">Las proyecciones climáticas a medio plazo (10-30 años)
Medium term climate projections (10-30 years)</td><td>7</td><td>6</td></tr>
<tr><td colspan="2">Predicción decadal (10 años)
Decadal forecasting (10 years)</td><td>1</td><td>1</td></tr>
<tr><td colspan="2">Las predicciones climáticas estacionales (3-12 meses)
Seasonal climate predictions (3-12 months)</td><td>2</td><td>0</td></tr>
<tr><td colspan="2">La predicción del clima intraestacional (1-3 meses)
Intraseasonal climate prediction (1-3 months)</td><td>5</td><td>3</td></tr>
<tr><td>Otro (por favor especifica):
Other (please specify):</td><td>Colombia: use weather forecast
Costa Rica: make muy corto plazo (1 hora – 2 dias)</td><td>1</td><td>1</td></tr>
<tr><td colspan="4">En caso afirmativo a cualquiera de las anteriores, ¿qué modelo o modelos se utilizan?
If yes to any of the above, what model or models do you use?</td></tr>
<tr><td colspan="4">
<table>
<tr><td>Bolivia</td><td>PRECIS and later WRF</td></tr>
<tr><td>Colombia</td><td>Global: GFS, CFS, (CMIP5)
Regional: MM5, WRF, PRECIS
Estadísticos: CPT</td></tr>
<tr><td>Costa Rica</td><td>PRECIS (10-100 años), ETA(1-3 meses, CPTEC-INPE), NMME(1-12 meses, NOAA), IMME (1-12 meses, NOAA), LC-MME (1-9 meses, WMO), GloSea5 (1-6 meses, MetOffice-UK), WRF (1h-2 días)</td></tr>
<tr><td>Ecuador</td><td>CMIP-5 (global climate projections)
REMO (regional climate projections)
CPT (statistical model for intraseasonal prediction)</td></tr>
<tr><td>Guatemala</td><td>Los proporcionados por el IPCC
Los modelos de Nebraska</td></tr>
<tr><td>Honduras</td><td>HadCM3, PRECIS, CM2, WRF</td></tr>
<tr><td>Jamaica</td><td>PRECIS, REGCM, WRF, MRI</td></tr>
<tr><td>Mexico</td><td></td></tr>
<tr><td>Panamá</td><td>PRECIS
Climate Predictability Tool (CPT/IRI)</td></tr>
<tr><td>Peru</td><td>modelo WRF: Para la generación de escenarios climáticos.
Climate Predictability Tool (CPT): Para pronostico estacional.</td></tr>
</table>
</td></tr>
</table>

Por favor indicar cualesquiera otras entidades, organizaciones, instituciones (incluida la investigación) en su país que utiliza o hacer proyecciones de modelos climáticos: Please indicate any other entities, organizations, institutions (including research) in your country that use or make climate model projections:	
Bolivia	Ministries, FAN other universities
Colombia	Universidad Nacional de Colombia Departamento de Geografía
Costa Rica	Universidad de Costa Rica (UCR), Instituto Tecnológico de Costa Rica (ITCR), Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Unión Internacional para la Conservación de la Naturaleza (UICN), Organization for Tropical Studies (OTS), Instituto Costarricense de Electricidad (ICE), Instituto del Café de Costa Rica (ICAFE), Coorporación Bananera Nacional (CORBANA)
Ecuador	INAMHI inamhi.gob.ec
Guatemala	Instituto Nacional de Sismología, Vulcanología, Metereología e Hidrología. INSIVUMEH Ministerio de Ambiente y Recursos Naturales MARN Instituto Privado de Cambio Climático ICC
Honduras	Universidad Nacional Autonoma de Honduras (IHCIT)
Jamaica	Climate Studies Group Mona, CSGM; Planning Institute of Jamaica; Water Resources Authority; Forestry Department; Meteorological Service of Jamaica; Caribbean Agricultural Research and Development Institute
Mexico	Centro de Ciencias de la Atmosfera - UNAM Instituto Nacional de Ecologia y Cambio Climatico - INECC Instituto Mexicano de Technologia del Agua - IMTA
Panamá	Secretaría de Energía CATHALAC Ministerio de Ambiente
Peru	

LOS DATOS CLIMÁTICOS / *CLIMATE DATA*	
¿Tiene su organización recoger y archivar los datos climáticos? *Does your organization collect and archive climate data?*	**8** Sí / *Yes* **2** No / *No*
En caso afirmativo, se pueden hacer estos datos a disposición del consorcio para su uso en la verificación de modelos y otros usos? *If yes, can these data be made available to the consortium for use in model verification and other uses?*	**6** Sí / *Yes* **4** No / *No*
¿Su institución crear o utilizar datos climáticos estadísticamente a escala reducida? Do*es your institution create or use statistically downscaled climate data?*	**4** Sí / *Yes* **6** No / *No*
En caso afirmativo, se pueden hacer estos datos a disposición del consorcio? *If yes, can these data be made available to the consortium?*	**3** Sí / *Yes* **7** No / *No*

Por favor indicar cualesquiera otras entidades, organizaciones, instituciones (incluida la investigación) en su país que recogen y archivo los datos climáticos:
Please indicate any other entities, organizations, institutions (including research) in your country that collect and archive climate data:

Bolivia	
Colombia	Corporaciones regionales
Costa Rica	Instituto Costarricense de Electricidad (ICE), Instituto del Café de Costa Rica (ICAFE), Coorporación Bananera Nacional (CORBANA), Universidad de Costa Rica (UCR).
Ecuador	INAMHI inamhi.gob.ec
Guatemala	INSIVUMEH ICCC WWF ANACAFE Fundación Defensores de la Naturaleza FDN
Honduras	Direccion General de Recursos Hidricos, Universidad Nacional Autonoma de Honduras, Meteorologia Aeronautica
Jamaica	Climate Studies Group Mona
Mexico	Comision Nacional del Agua - Servicio Meteorologico Nacional Secretaria de Marina Comision Federal de Electricidad - CFE Petroleos Mexicanos - Pemex Secretaria de Comunicaciones - Seneam - Servicio de Meteorologia Jagarpa - Inifap - Red Nacional de estaciones Agroclimatologicas Sct - IMT - Rencom
Panamá	1. Aeronáutica civil 2. CATHALAC
Peru	

EXPECTATIVAS Y OBJETIVOS TALLER / *WORKSHOP EXPECTATIONS AND GOALS*
¿Cuáles son sus expectativas de este taller? ¿Qué beneficios que espera de su participación en ella? *What are your expectations of this workshop? What benefits do you expect from participating in it?*
• To find a tool for easy manipulating climate data • Si bien es cierto que el tema central es cambio climático, la prioridad nacional es mejorar la predicción estacional tanto con modelo dinámicos como estadísticos, pues de acuerdo con los modelos internacionales consolidados por IRI (International Research Institute for Climate and Society) el sistema océano-atmósfera esta evolucionando hacia un fenómeno La Niña. Por lo tanto, el beneficio es poder aplicar los conocimientos que se adquieran en el taller para resolver estos problemas tal vez a problemas más inmediatos que debe enfrentar el país en temas de clima. • Conocer los nuevos escenarios climáticos a partir de los nuevos escenarios de emisiones de gases de efecto invernaderos (RCP´s). Utilizar los datos del modelo regional de cambio climático WRF para crear escenarios de cambio climático de alta resolución espacial y temporal. Obtener de estos datos series de tiempo de indicadores de cambio climático. Determinar cambios en la posición intensidad de la Zona de Convergencia Intertropical del Pacífico y de los ciclones tropicales en el mar Caribe. • Compartir experiencias para aplicarlas al trabajo que hace la institución • Aprender a utilizar los modelos de cambio climático, a diferentes escalas de tiempo a un nivel más detallado, es decir a mejor resolución, esto para que las proyecciones estén más adaptadas a los condiciones reales del país y se puedan tomar decisiones más acertadas en cuanto a medidas de adaptación. De ser posible, poder utilizar datos climatológicos generados a nivel nacional. • Conocer mejor las herramientas del Downscaling de los modelos Globales de Circulacion General como el WRF y utilizar las corridas disponibles en la Universidad de Lincon Nebraska para su utilizacion en la elaboracion de posibles escenarios de cambio climatico • Utilizar modelos de cambio climatico Hacer proyecciones bajo ciertos escenarios de cambio climatico en Mexico Estimar valores extremos de variable meteorolgicas como precipitacion, velocidad del viento y temperaturas" • Adquirir nuevos conocimientos es este temática, para crear escenarios que ayuden a los tomadores de decisiones a enfrentar este problema que nos afecta a todos. • Aprender nuevas metodologías para el uso de modelos para el análisis de escenarios futuros, y iniciar estudios en cooperación con otras instituciones. • Enhanced collaborations Possible development of research activities

¿Cuál es la única cosa que le gusta más que aprender en el taller? *What is the one thing that you would most like to learn during the workshop?*
• More details about the runs performed by our colleagues in Bolivia. • Potenciar el uso de los modelos regionales dinámicos WRF • 1. Las proyecciones climáticas de los nuevos escenarios de emisiones RCP´s. 2. El mapmaker 3. Scripts para analisis de series de tiempo y mapas de los resultados del modelo WRF. • Una metodología para evaluar impactos del cambio climático que pueda ser replicada • Generar predicciones a futuro de cambio climático a nivel regional y de ser posible a nivel local. • Como hacer reanalisis de eventos especificos utilizando el WRF, para conocer si simula bien la climatologia de Honduras • conocer los modelos y herramientas de cambio climatico y so aplicacion a casos de estudio • Todos los temas del taller son importantes; pero en particular nos resulta de mucha importancia adquirir la destreza para correr los modelos y la confiabilidad de los resultados. • Manejo de incertidumbres o rangos de confianza de los datos ara escenarios climáticos y presentación de resultados a las personas que toman decisiones. • Better integration of WRF in what we do

Appendix D: University of Nebraska-Lincoln Presentations

1: Introduction

2: Regional Climate Model Scenarios

3: Working Groups

4: CMIP5 Results

5: WRF Downscaling Results

6: *MapMaker* History

7: *MapMaker* Replacement

8: Conclusions

Program to Strengthen Institutional Capacity to better assess Climate Impacts in Latin America and the Caribbean (LAC)

Workshop 1: Initiation of the Regional Climate Change Consortium

Bob Oglesby, Clint Rowe, and Rachindra Mawalagedara
University of Nebraska, Lincoln

6-10 June 2016 CATHALAC, Panama City, Panama

Rationale

The "Program to strengthen institutional capacity to better assess climate impacts in Latin America and the Caribbean" supports the improvement of climate change modeling related knowledge in Latin America and the Caribbean (LAC)

Develop a regional network of climate scientists from different hydro-met institutions, agencies, and universities.

Contribute to filling existing knowledge gaps in LAC on climate change impacts on infrastructure and rural/urban communities, their livelihoods and associated risks.

Help generate and gather theoretical and practical expertise in complex areas of climate modeling such as simulating the climate of mountainous regions and hurricanes (among others).

Workshop 1: Initiation of the Regional Climate Change Consortium

- Initiate the Regional Climate Change Consortium
- Review of available WRF IPCC AR5 simulations and other relevant data
- Participant discussion of individual country issues and needs
- Formulate relevant Working Groups focused on specific impact areas
- Preliminary assessment and call for suggested improvements of MapMaker
- Design of the remainder of the Project

INTRODUCTIONS

The Plan for the Week

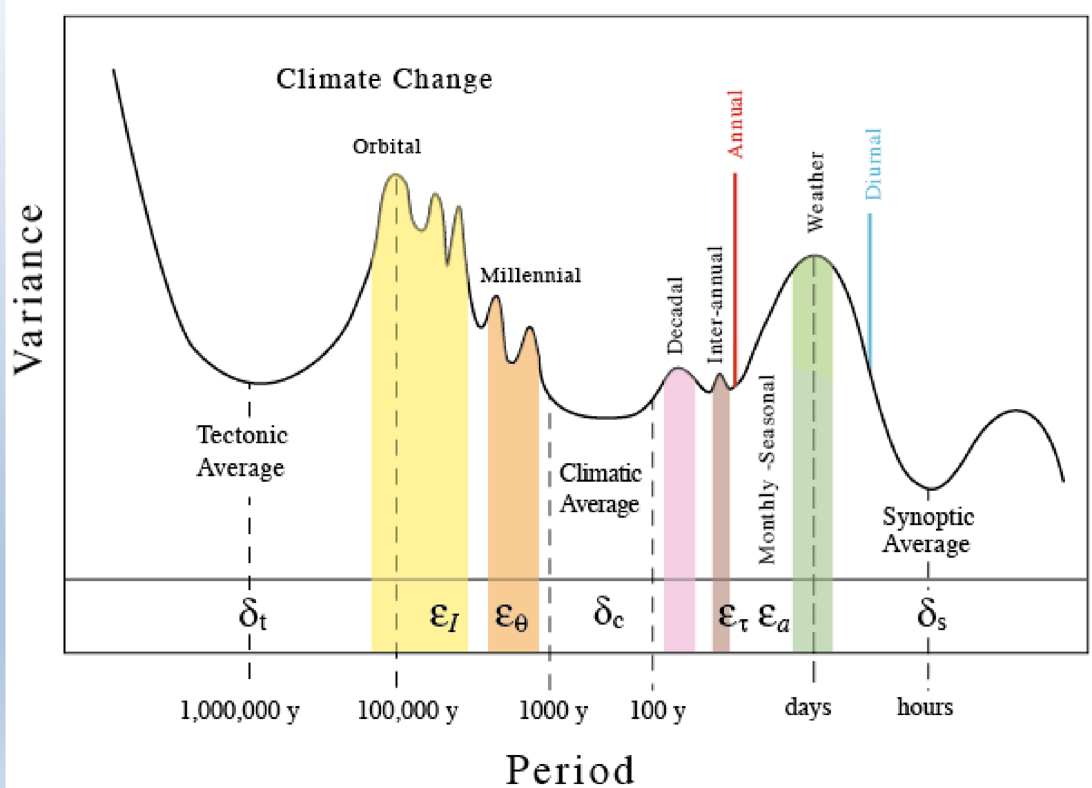
Monday	WRF refresher and Working Group Discussion
Tuesday	IPCC AR5 and WRF results for LAC; MapMaker; Working Groups meet
Wednesday	Working Group Meetings and Joint Discussions
Thursday	Working Group Meetings; Discussion of MapMaker needs
Friday	Working Group meetings and reports; Workshop conclusions and future objectives, tasks, and goals. PARTY!!! (It is also Bob's birthday!)

WRF Regional Model Scenarios Refresher

Climate Variability versus Climate Change

- Climate is defined in terms of ***30 year means***, and higher-order moments about those means. This assumes ***stationarity*** of a given climate state
- In practice, climate ***varies*** on time-scales both ***longer*** and ***shorter***. On the shortest time scales, we enter the realm of weather.
- Variability on time scales of a *few years to a few decades* (i.e., shorter than a climatic averaging period) is usually referred to as ***climatic variability***
- Variability on *time scales longer than a few decades* (longer than a standard climatic averaging period) is usually referred to as ***climatic change***

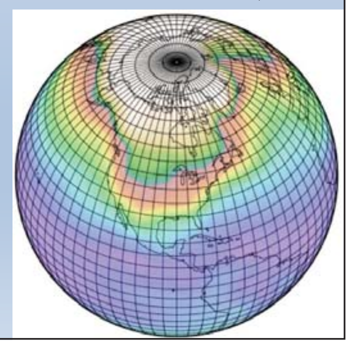
Schematic Spectrum of Climate Change



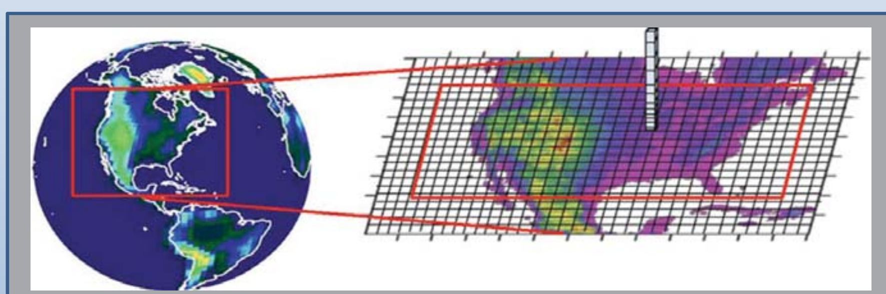
Understanding and Predicting Climate and Climate Change: The Role of Climate Models

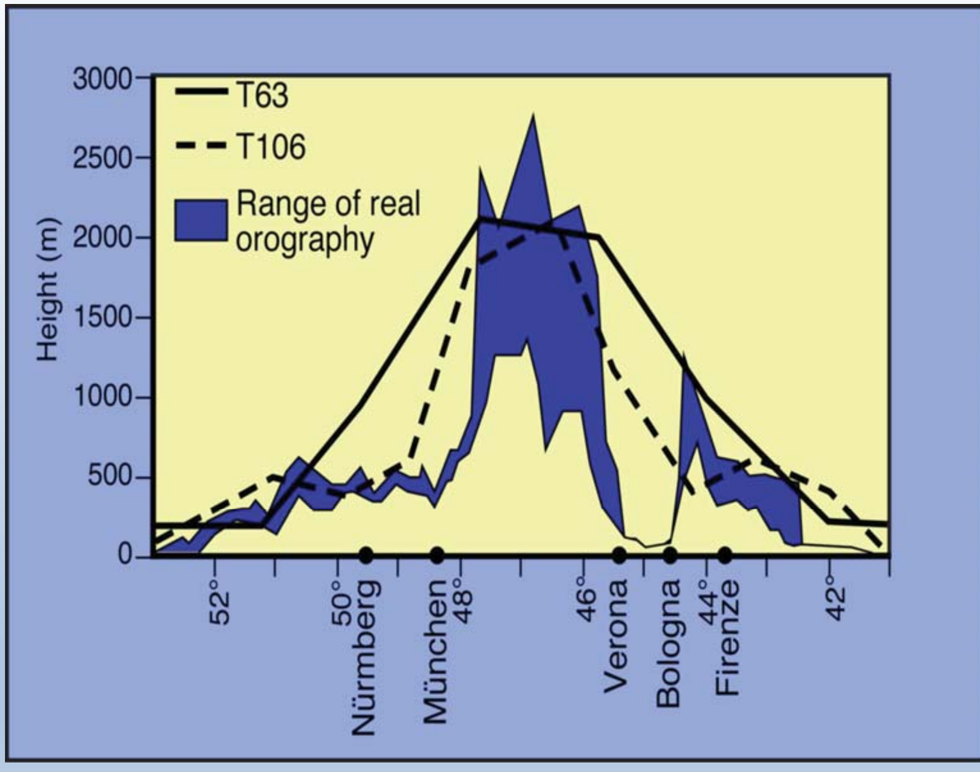
General Circulation Models

- The General Circulation Model (GCM) is a sophisticated, 3D model that simulates all relevant components and processes of the climate system
- Sometimes referred to as 'Global Climate Models'
- Not a true climate model; simulates daily weather patterns which are statistically aggregated to obtain climatic states, in the same manner by which we use daily weather observations to obtain actual climatic states.

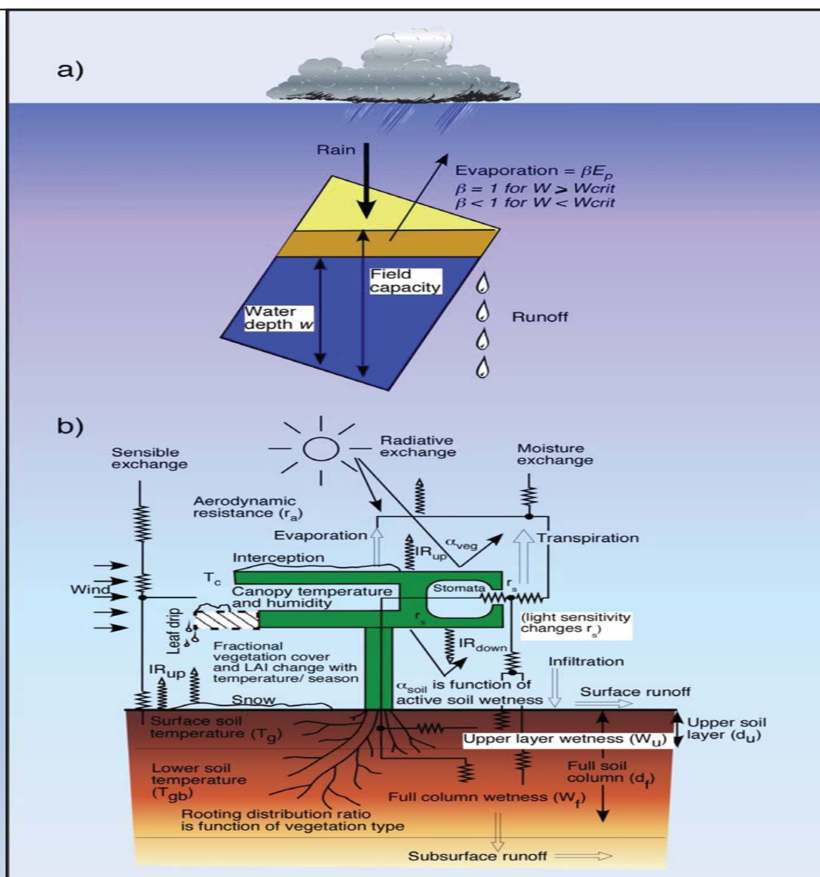


Why Do We Need Regional Climate Models?



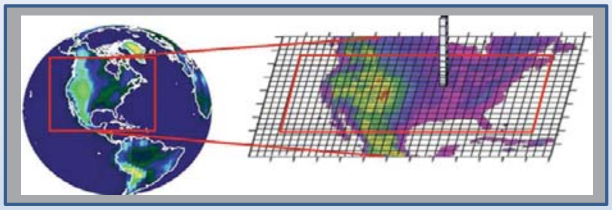


T63 - approx. 200 km resolution; T106 - approx. 100 km resolution (same as IPCC AR5)



Regional Climate Models

- Regional climate models (RCMs) are *limited domain* GCMs.



- These models are used to address the *horizontal scale limitations of the global GCM*;
  - The GCM has a horizontal resolution of about 100 km while the RCM can be run at a horizontal resolutions as *fine as 4 km*.
- They can be used to *dynamically-downscale* global model results to the regional and even local scale.
- Because of the global nature of climate, the RCM must be forced at its lateral boundaries; *either a GCM or observations (reanalyses) can be used for this.*

Historic Simulations for Model Verification

- Purpose is to verify model capabilities by comparing to actual station observations
- WRF driven by NCEP reanalyses as a proxy for real large-scale forcing
- Three year simulation for 1991-1993 for entire region

Climate Change Downscaling Simulations

- Forced by NCAR CCSM4 GCM simulation of the RCP 8.5 (‘Business as usual)’ emission scenario
  - ‘Present-day’ control 2006-2010
  - Future Climate Change 2056-2060*

*Differences can be linearly-scaled to any period between 2020 and 2060, e.g., 2040

Individual Country Simulations

- More extensive simulations have been made for Guatemala and Bolivia
- Simulations nearing completion for Honduras
- We’d be happy to discuss possibilities for your country

THE WORKING GROUPS

- Plan is to divide into small groups organized around common themes important to your own country
- Aiming for 3-4 robust groups with 3-4 members each

POTENTIAL WORKING GROUP TOPICS

1) Hurricanes and tropical systems in the Caribbean;

2)ENSO affects, especially along Pacific coast;

3) Precipitation, including glaciers, in high mountains.

4) ***GROUP SUGGESTIONS – THE SURVEYS***

DISCUSSION - what climate change impacts are most important for your country?

Working Group Goals

- Contributions to required BID reports
- Contributions to published scientific papers and technical reports
- Contributions to your own country's climate change actions and impacts plans
- Any other way the results can prove useful

Finalizing the Working Groups: Themes and Composition

The CMIP5/AR5 Global Climate Model Runs: What Do They Say For Latin America And The Caribbean?

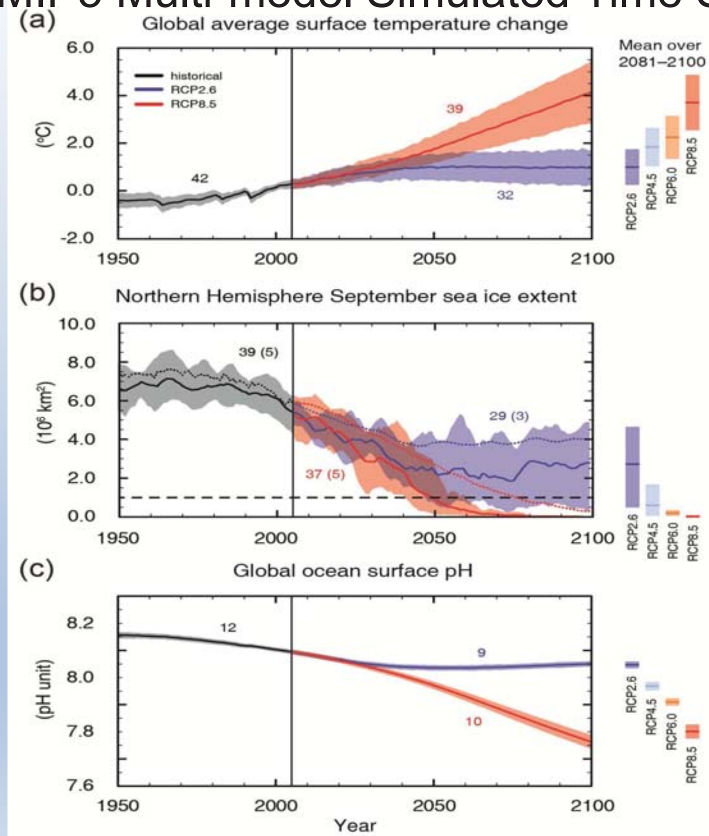
Workshop 1: **Initiation of the Regional Climate Change Consortium**

6-10 June 2016 CATHALAC, Panama City, Panama

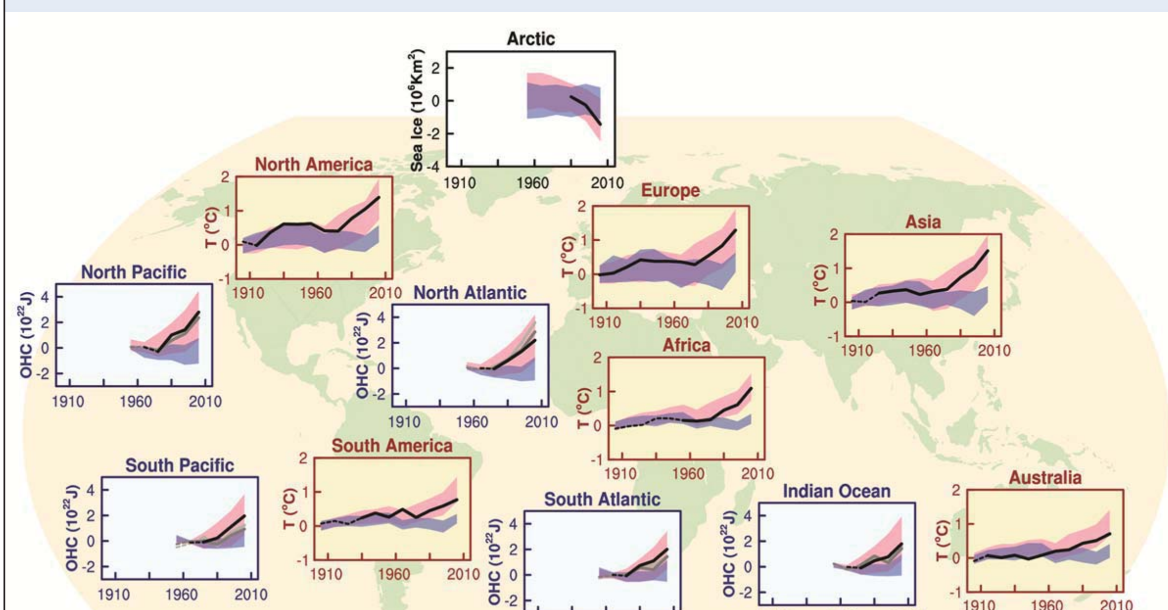
Coupled Model Intercomparison Project Phase 5

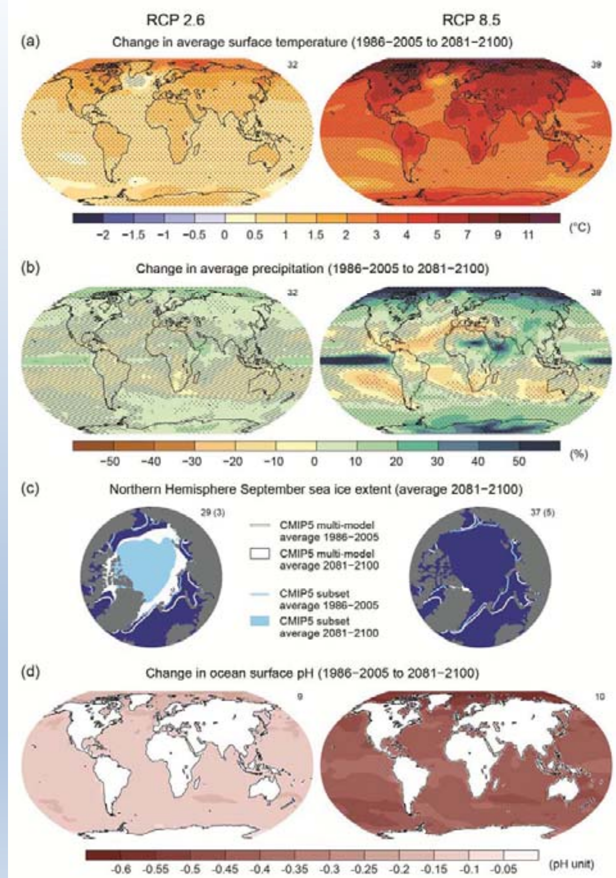
- Multi-model experiment (coordinated through the World Climate Research Programme) presents an unprecedented level of information on which to base assessments of climate variability and change.
- Much more comprehensive than the preceding *CMIP3* multi-model experiment that was available at the time of the *IPCC AR4*.
- Has more than twice as many models, many more experiments (that also include experiments to address understanding of the responses in the future climate change scenario runs), and nearly 2 □ 1015 bytes of data (as compared to over 30 □ 1012 bytes of data in *CMIP3*).

CMIP5 Multi-model Simulated Time Series



Comparison of Observed and Simulated Climate Change



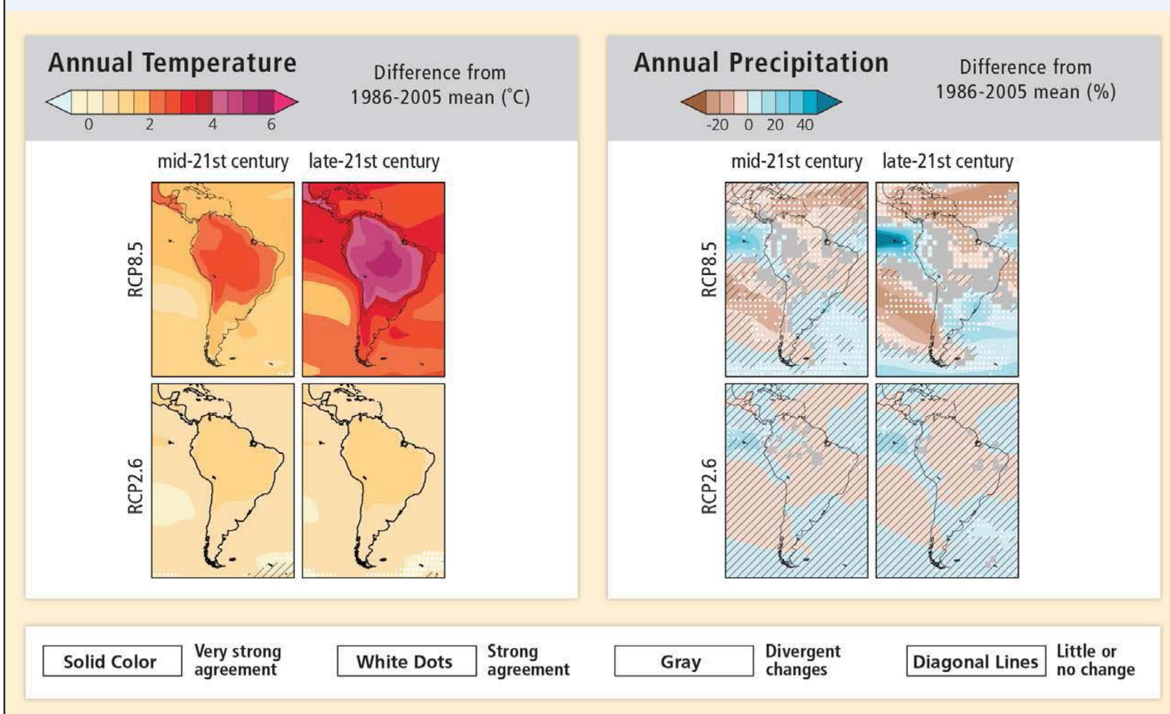


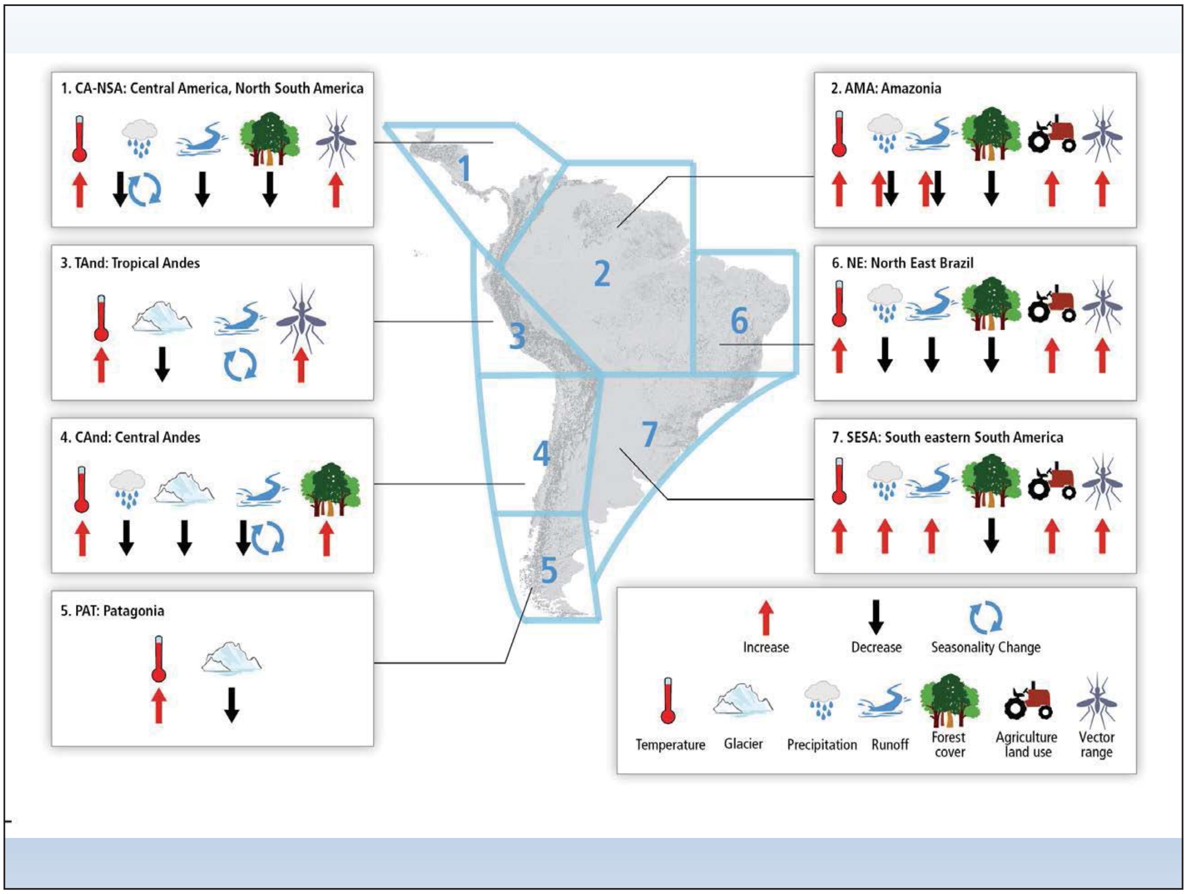
A CRITICAL POINT

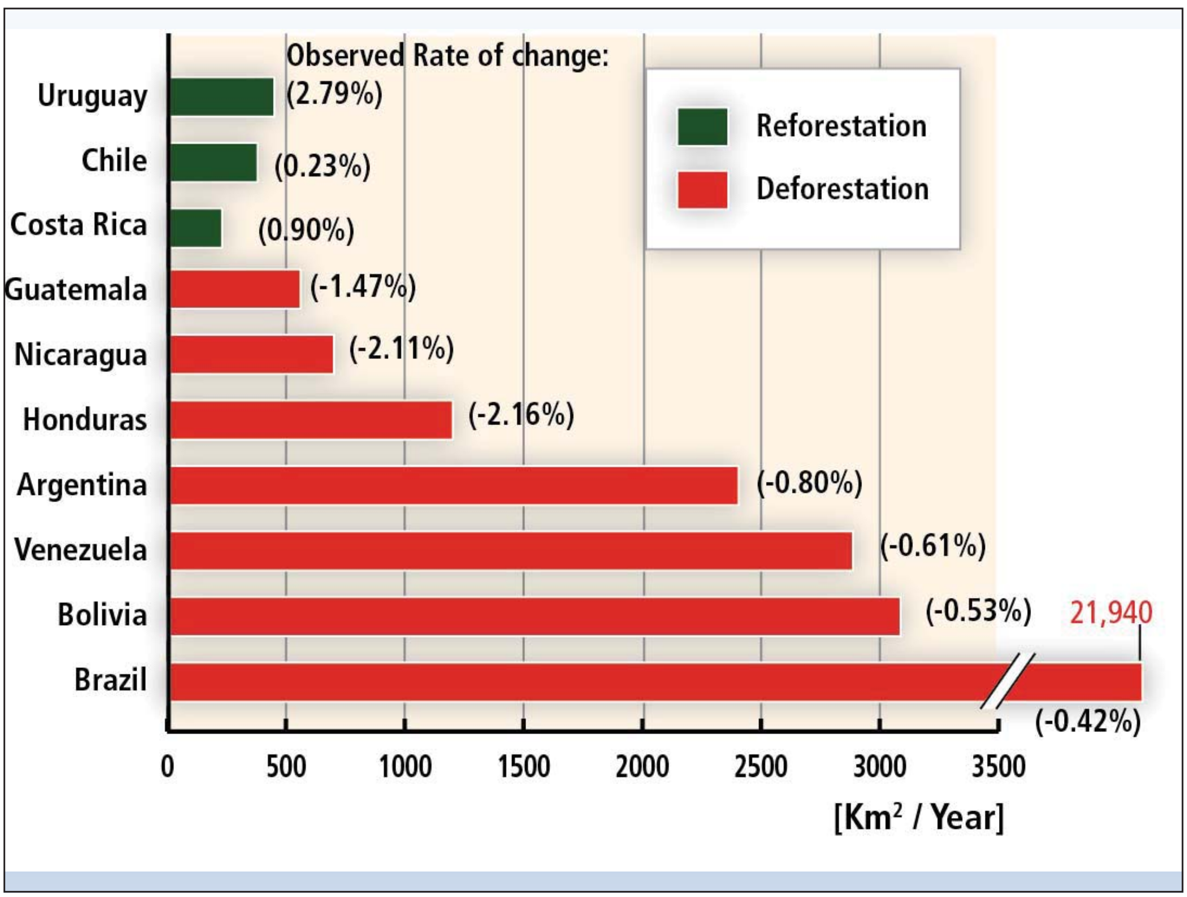
- The assessment of the mean values and ranges of global mean temperature changes in **AR4** *would not have been substantially different* if the **CMIP5** models had been used in that report.
- ***The differences in global temperature projections can largely be attributed to the different emission scenarios.***
- The global mean temperature response simulated by CMIP3 and CMIP5 models *is very similar*, both in the mean and the model range, transiently and in equilibrium.

RESULTS WITH IMPLICATIONS FOR LATIN AMERICA AND THE CARIBBEAN

- Significant trends in precipitation and temperature have been observed in Central America (CA) and South America (SA) (*high confidence*).
- Changes in climate variability and in extreme events have severely affected the region (*medium confidence*).
- Climate projections suggest increases in temperature, and increases or decreases in precipitation for CA and SA by 2100 (*medium confidence*).




1. CA-NSA: Central America, North South America
2. AMA: Amazonia
3. TAnd: Tropical Andes
4. CAnd: Central Andes
5. PAT: Patagonia
6. NE: North East Brazil
7. SESA: South eastern South America
1
2
3
4
5
6
7
Increase
Decrease
Seasonality Change
Temperature
Glacier
Precipitation
Runoff
Forest cover
Agriculture land use
Vector range


Observed Rate of change:
Reforestation
Deforestation
Uruguay
(2.79%)
Chile
(0.23%)
Costa Rica
(0.90%)
Guatemala
(-1.47%)
Nicaragua
(-2.11%)
Honduras
(-2.16%)
Argentina
(-0.80%)
Venezuela
(-0.61%)
Bolivia
(-0.53%)
21,940
Brazil
(-0.42%)
0
500
1000
1500
2000
2500
3000
3500
[Km² / Year]

CLIMATE EXTREMES

- For climate extremes such as *droughts, floods and heat waves*, several factors need to be combined to produce an extreme event.
- Analyses of rarer extremes such as 1-in-20 to 1-in-100 year events using *Extreme Value Theory* are making their way into a growing body of literature.
- Other recent advances concern the notion of "**fraction of attributable risk**" that aims to link a particular extreme event to specific causal relationships.
- We have a project using this concept to examine drought in the central U.S.

Climate Extremes, continued

- It is likely that the *number of heavy precipitation events over land has increased* in more regions than it has decreased *since the mid-20th century*
- There has been *substantial progress between CMIP3 and CMIP5* in the ability of models *to simulate more realistic precipitation extremes*.
- However, evidence suggests that the *majority of models underestimate the sensitivity of extreme precipitation* to temperature variability or trends *especially in the tropics* which implies that *models may underestimate the projected increase in extreme precipitation in the future*.

Climate Extremes, continued

- It is likely that the magnitude of extreme *high sea level events has increased* since 1970 and that most of this rise can be explained *by increases in mean sea level.*
- Projections indicate that it is likely that the global frequency of tropical cyclones will either decrease or remain essentially unchanged, concurrent with a likely increase in both global mean tropical cyclone maximum wind speed and rainfall rates
  - Lower confidence in region-specific projections of frequency and intensity.
- Due to improvements in model resolution and downscaling techniques, it is *more likely than not that the frequency of the most intense storms will increase substantially in some basins under projected 21st century warming*

Nine Cross-Cutting Issues

- *Consistent Evaluation of Uncertainties and Risks*, to serve as useful input for policymakers
- *Costing and Economic Analysis*, to develop common language and common fundamentals in all valuation efforts, including finance and investment
- *Regional Aspects*, based on a geographical approach as suggested in Part B of the WG II contribution
- *Scenarios* and their use in the AR5
- *Water and the Earth System*: changes, impacts and responses to answer the need for a water cycle theme in the AR5

Cross-Cutting Issues, cont.

- *Carbon Cycle* including *Ocean Acidification*, identified as a critical topic
- *Ice Sheets and Sea Level Rise*, with implications for vulnerability and adaptation in coastal zones and islands
- *Mitigation, Adaptation and Sustainable Development*; addressing the human side of the implications of climate change, including human security
- Issues related to Article 2 of the UNFCCC Convention on *stabilization of greenhouse gas concentrations* in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system

'Heard in the Hallway'

- The decadal-scale predictability runs for CMIP5 have been very problematic
- This means IPCC AR5 does –not- expect a more robust 'signal' (century-scale climate change) versus 'noise' (decadal-scale variability) than in the past…

Review of the WRF AR5 downscaling results for Latin America and the Caribbean

A High-Resolution Modeling Strategy to Assess Impacts of Climate Change for Mesoamerica and the Caribbean

R. Oglesby[1,2], C. Rowe[1], A. Grunwaldt[3], I. Ferreira[3], F. Ruiz[4], J. Campbell[5], L. Alvarado[6], F. Argenal[7], B. Olmedo[8], M. del Castillo[9], P. Lopez[8], E. Matos[6], Y. Nava[10], C. Perez[11], J. Perez[9]

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- [3]Climate Change and Sustainability Division, Inter-American Development Bank
- [4]Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia, Bogota, Colombia
- [5]University of the West Indies
- [6]Instituto Meteorológico Nacional Costa Rica
- [7]National Weather Service, Honduras
- [8]Empresa de Transmisión Eléctrica Panameña
- [9]Water Center for the Humid Tropics of Latin America and the Caribbean
- [10]Instituto Nacional de Ecología y Cambio Climático, Mexico
- [11]National Weather Service, MARN, El Salvador
- Email: roglesby2@unl.edu

American Journal of Climate Change, *In Press*

Climate Change Impacts for Mesoamerica Using WRF

1) Three-year control run, forced by NCEP reanalyses - for evaluation of model uncertainties and biases (made using previous domains)

2) Five year run for the 'present-day' (2006-2010) forced by the NCAR CCSM GCM (new)

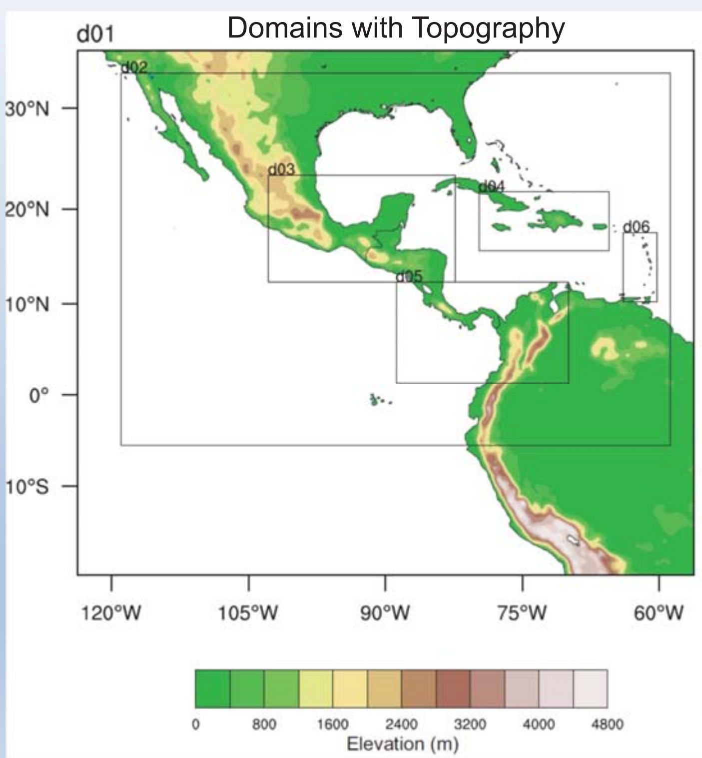
3) Five year climate change run for 2056-2060 using the RCP8.5 ensemble Member #6 (MOAR) 'business as usual' scenario (new)

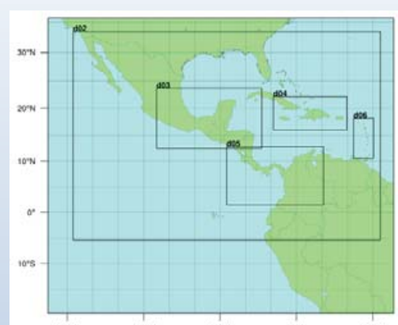
4) Outer domain of 36 km primarily intended to step down the large-scale forcing

5) All of Mesoamerica covered by 12 km domain

6) As much as possible covered at 4 km, focusing on regions of complex topography/land use

Domains for the WRF Runs





Resolution of domains:

d01 – 36 km

d02 – 12 km

d03-06 – 4 km

Verifying Model Results Against Observations

- The most basic question of any model:

  How well does it do what we want it to?

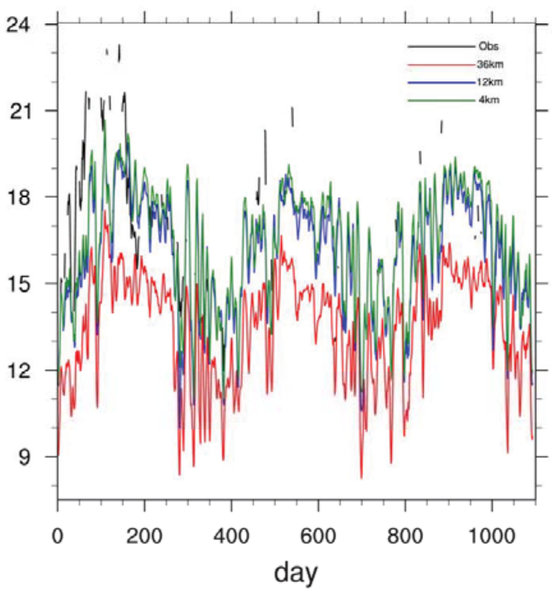
This tells us

- o How much confidence we can have in the model results
- o How well we understand the problem at hand
- o What in the model needs to be improved

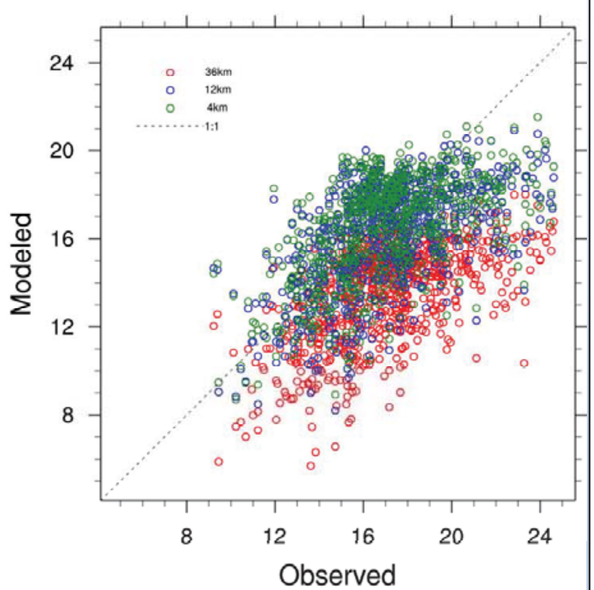
- Because the point to regional modeling is to better simulate local controls on climate, we focus on using station observations to evaluate the WRF control simulation (forced by NCEP reanalyses)

Mexico City, Mexico: Temperature

a) time series (5-day running average)

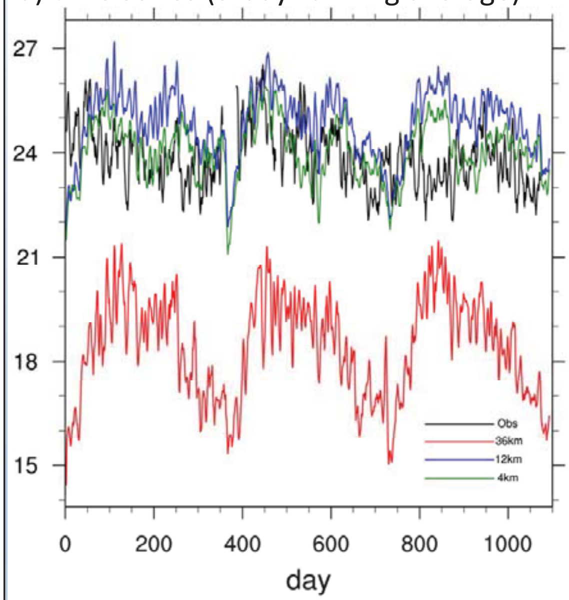


b) scatterplot.

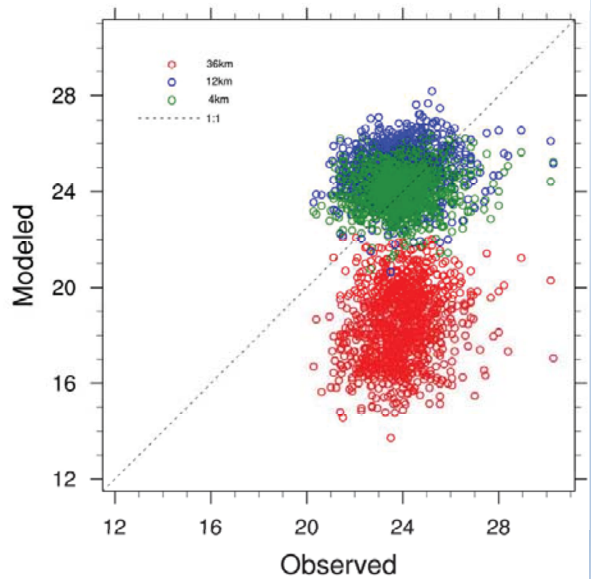


Cali, Colombia: Temperature

a) time series (5-day running average)

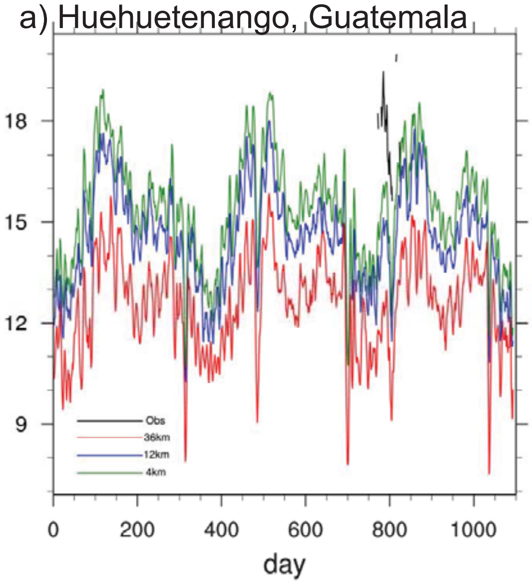


b) scatterplot.

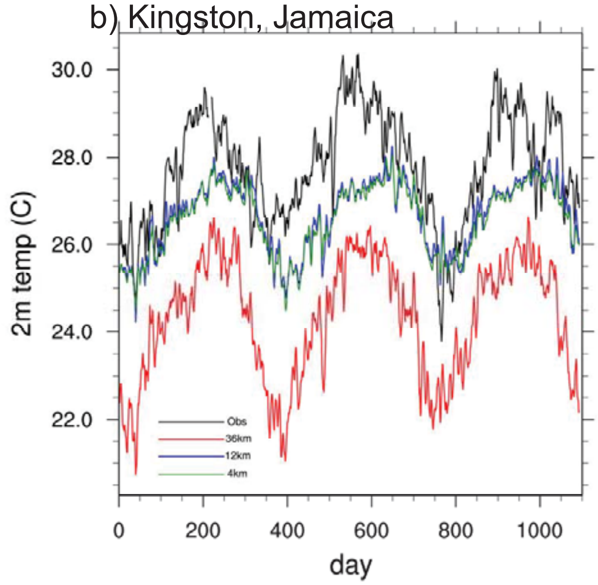


Temperature Time Series (5-day running average)

a) Huehuetenango, Guatemala



b) Kingston, Jamaica

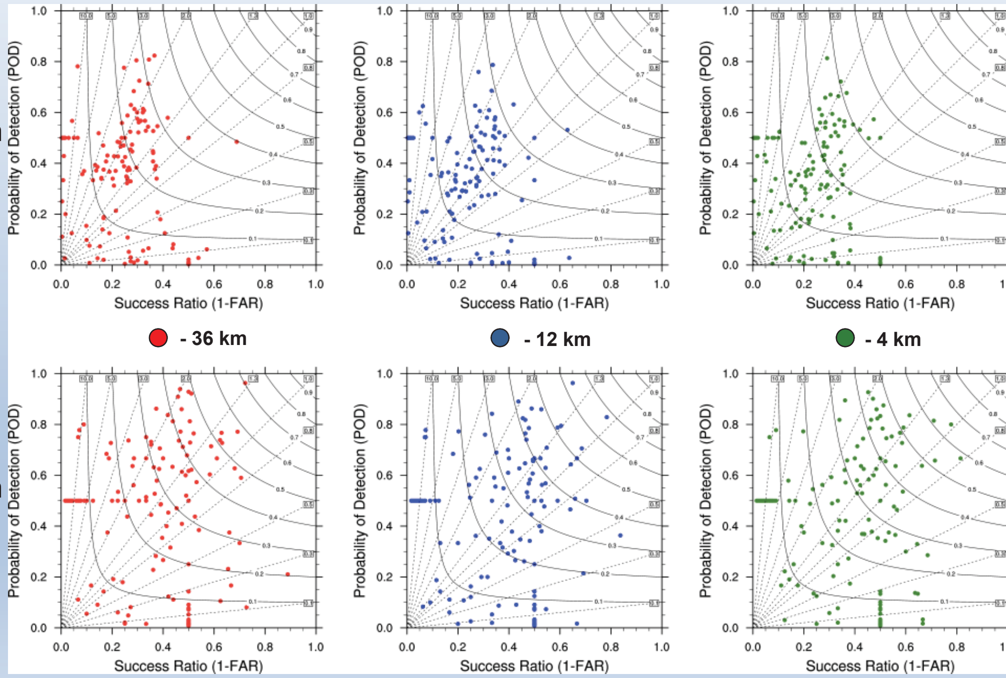


Skill scores

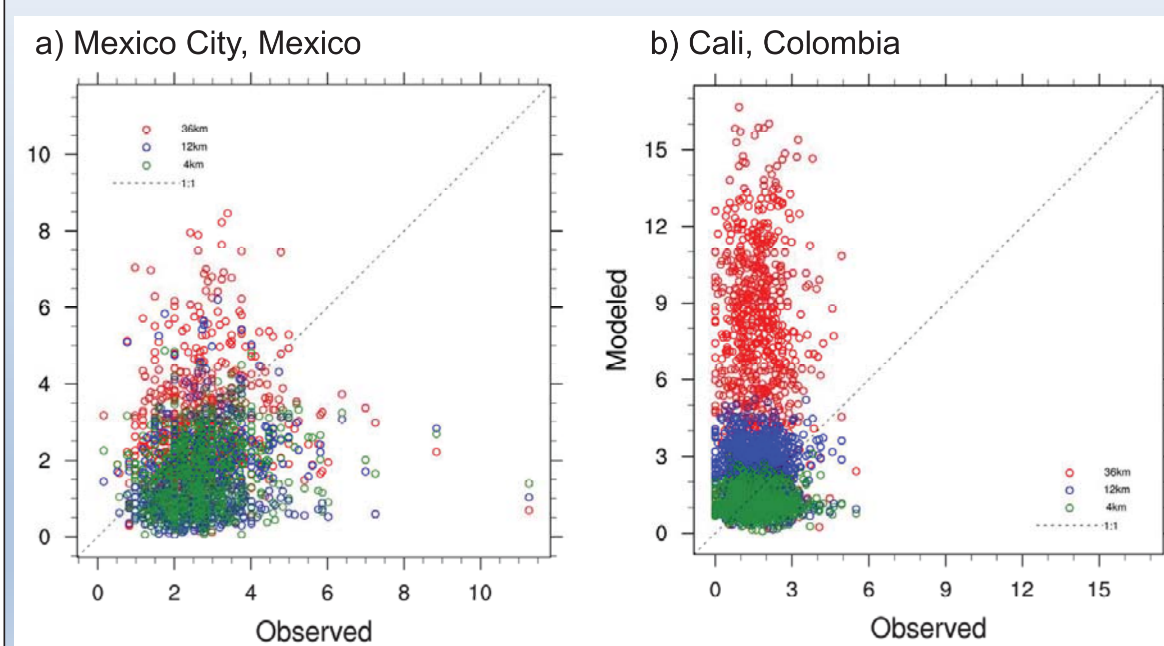
For all stations with more than 200 non-missing observations of precipitation

1-day precipitation > 2 mm

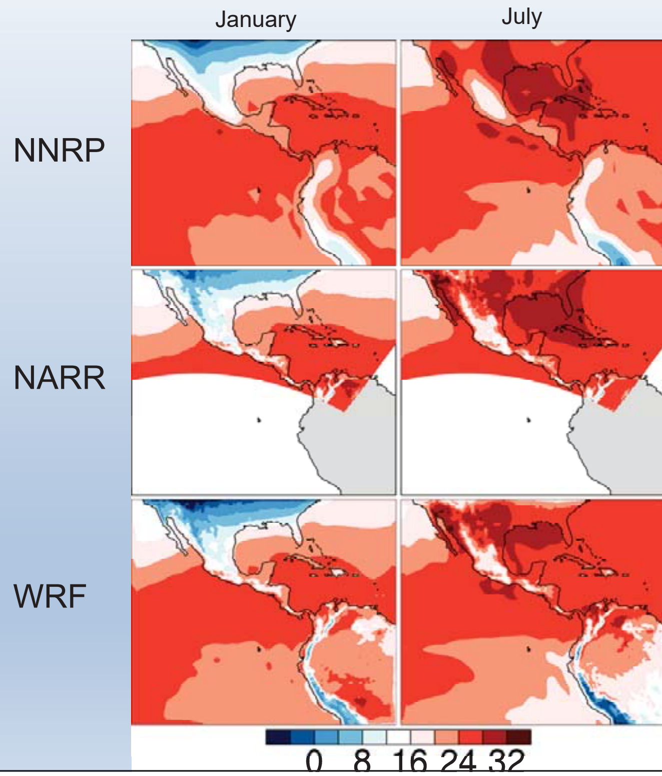
5-day precipitation > 10 mm



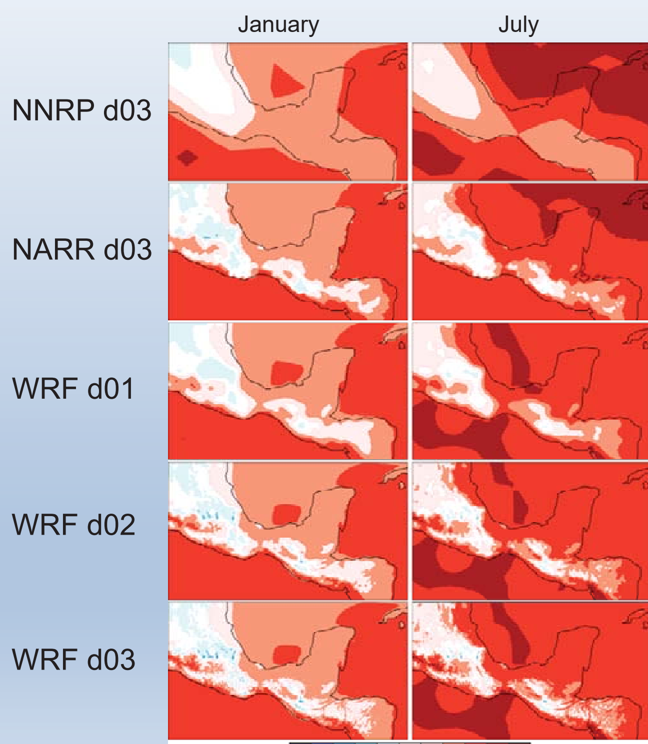
Wind Scatterplots



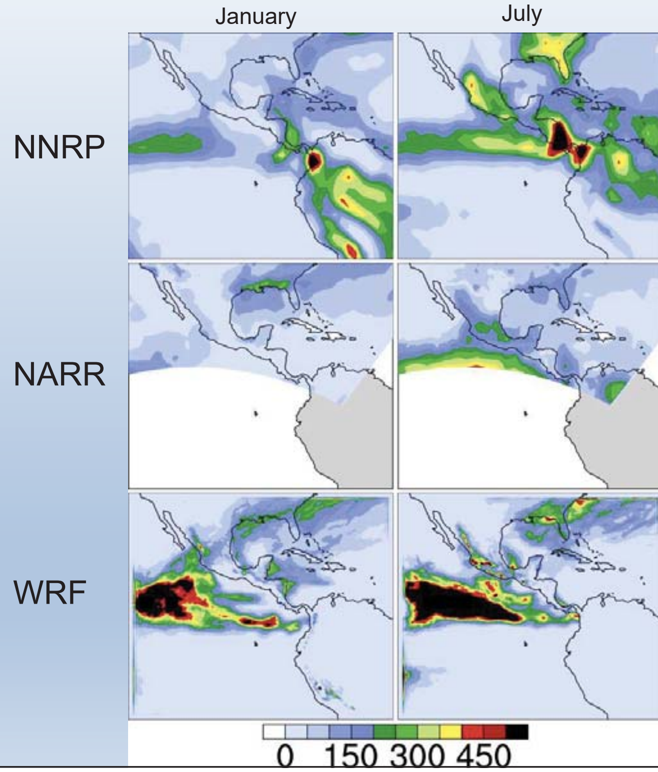
Monthly climatological mean temperature for 1991-1993 plotted over domain 01



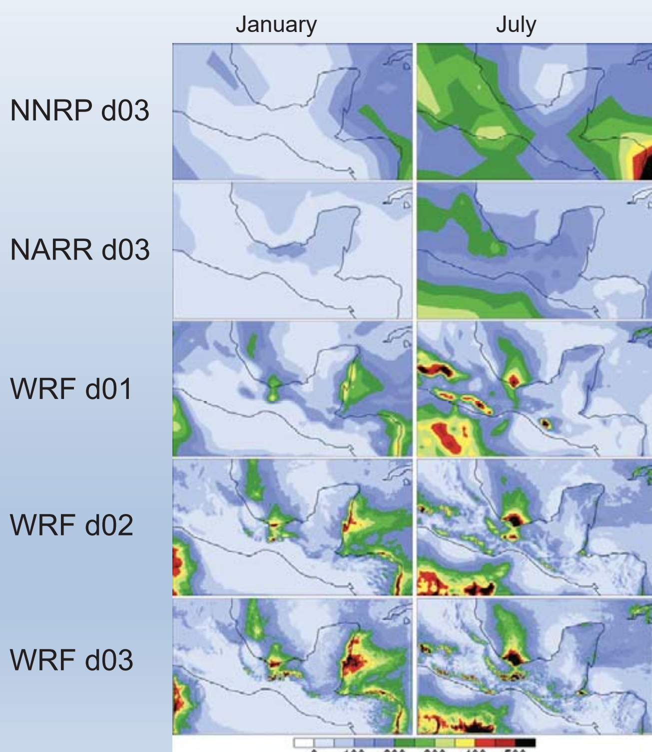
Monthly climatological mean temperature for 1991-1993



Monthly climatological total precipitation for 1991-1993 plotted over domain 01



Monthly climatological total precipitation for 1991-1993



KEY RESULTS – VERIFICATION

1) Accuracy of the temperature simulation is strongly dependent on altitude. In regions of complex topography a resolution of 4 km is required. In larger, more homogeneous regions, such as the Mexico City basin, 12 km may be sufficient.

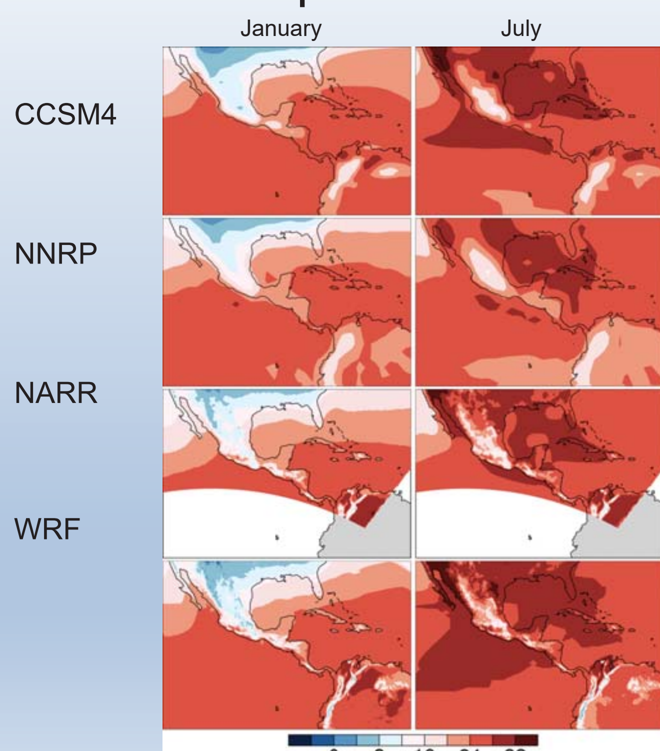
2) Precipitation and wind are complex fields and more difficult to simulate. Lack of sufficient observational data at small spatial scale, is an impediment for verification. The CCSM4 broadly captures overall precipitation features, but spatial details are lacking, and magnitudes are generally underestimated.

3) Evaluation of the winds points to a problem - due to insufficient resolution of topography along the Atlantic coast, trade winds blow unimpeded across Central America towards the Pacific. This will be of major significance when evaluating model simulations of future climate change for the region.

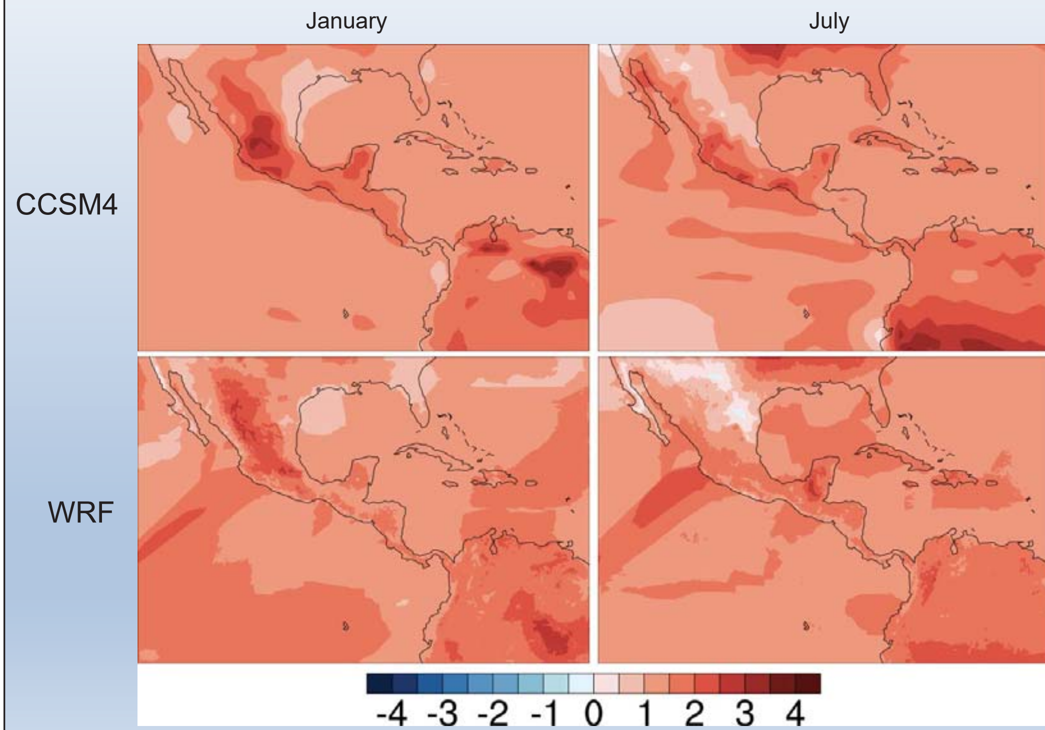
4) The comparison of actual weather events to mean climate for the region helps support the robustness of the model results. WRF was able to simulate quite well actual station surface temperatures observed from 1991-1993, especially when the station elevation was properly resolved. Precipitation was also generally well simulated.

5) The climate simulated by CCSM4 is not as robust as that provided by the quasi-observational NNRP.

Monthly climatological mean temperature for 2006-2010 plotted over domain 02



Monthly climatological mean temperature difference for January (left) and July (right) plotted over domain 02



KEY RESULTS – FUTURE CLIMATE CHANGES

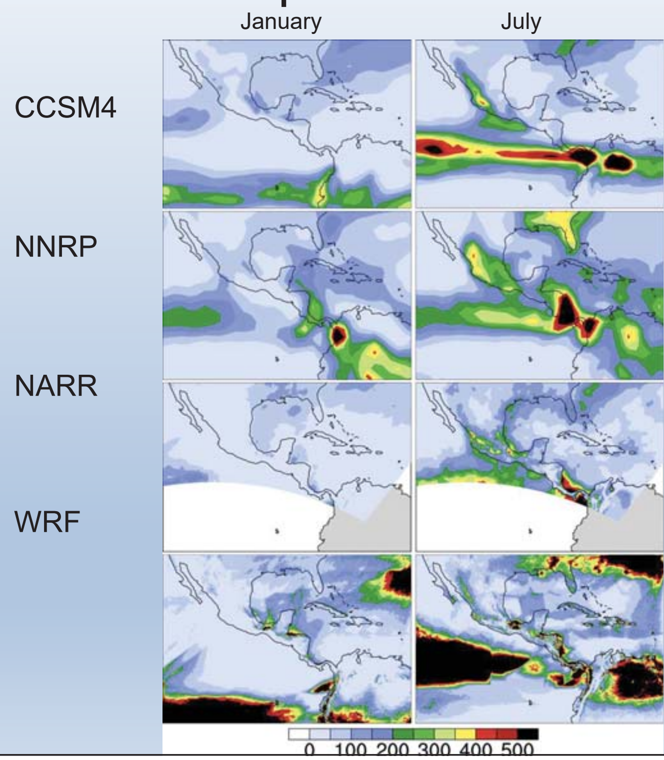
TEMPERATURE

1) CCSM4 results show warming over all of Mesoamerica between the present and the 2050’s, ranging from less than 1°C to more than 3°C, The largest warming occurs over interior and highland regions; coastal regions show the least change.

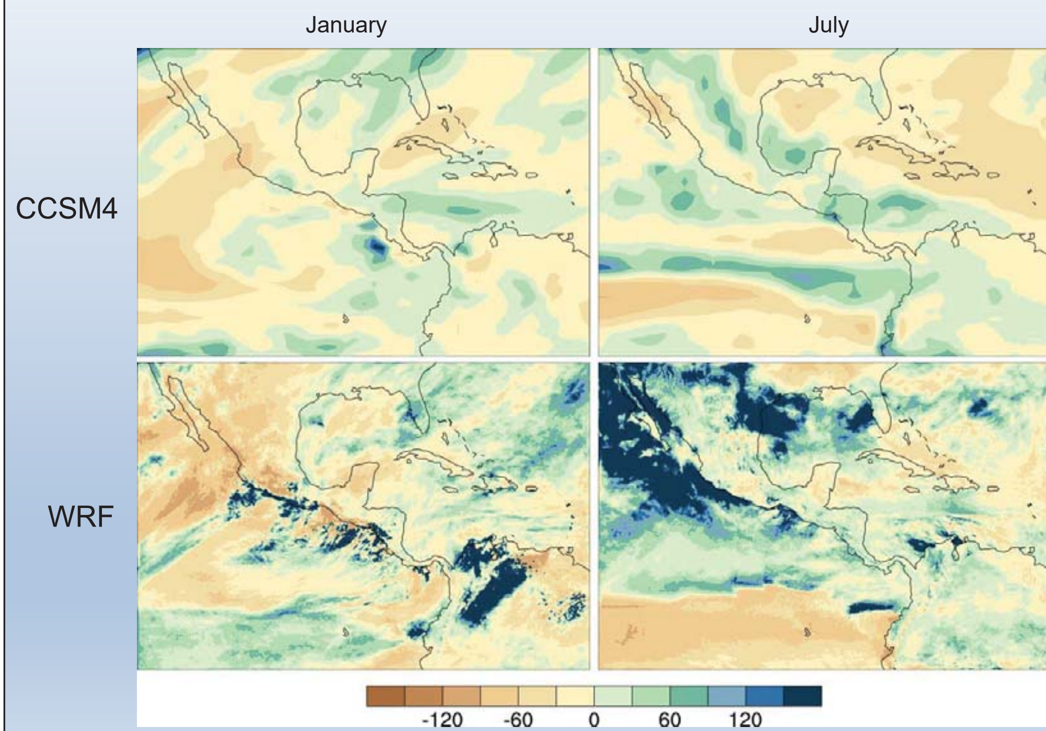
2) The same general patterns hold with WRF downscaling, though additional detail and changes are seen. Effects of topography are much better resolved, with patterns of surface temperature difference largely follow the topography.

3)Coastal regions show lesser change, presumably because of the strong ocean influence.

Monthly climatological total precipitation for 2006-2010 plotted over domain 02



Monthly climatological percentage precipitation difference for January (left) and July (right) plotted over domain 02



KEY RESULTS – FUTURE CLIMATE CHANGES, cont.

PRECIPITATION

1) The global model results for precipitation are at odds with those from WRF, indicating a complex situation.

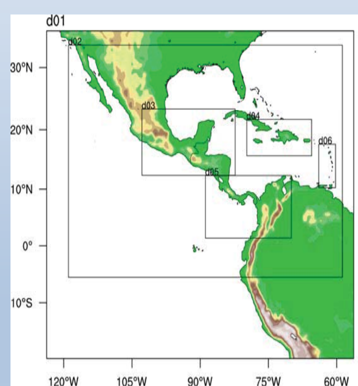
2) Topography has a strong influence on precipitation. Over windward slopes air is forced to rise, enhancing condensation and precipitation; over leeward slopes, air descends, inhibiting precipitation.

3) Changes in the wind regime are also important. Observed trade wind precipitation is restricted to the immediate Atlantic coast, while in GCM simulations it spreads across all of Central America from the Gulf of Tehuantepec to the Darien Gap.

4) Results for precipitation from WRF are very different than those from the GCM, and are consistent with better resolution of topographic effects, especially along the Atlantic coast.

5) WRF is able to take a large-scale forcing associated with changes in the trade winds and simulate instead a very different precipitation regime for inland and Pacific coast regions of Mesoamerica.

CONCLUSIONS



CONCLUSIONS: Verification

- Because of the very strong impact of topography on surface temperature, the results clearly demonstrate the need for high resolution in order for it to be properly simulated.
- Precipitation is more difficult to evaluate, being composed of discrete events highly variable in time and space (as opposed to the much smoother, continuous temperature).
- Simulation of the surface winds tends to be too strong at 36 km resolution and much improved at 12 km and, especially, 4 km.
- A suite of standard verification statistics were computed and show that the biases are sharply reduced at higher resolutions, while standard errors are little changed
- Overall, the CCSM4/WRF combination appears to adequately simulate the preset-day climate of Mesoamerica, lending credence to its ability to simulate future climate change in coming decades

CONCLUSIONS: Climate Change

Temperature

- All regions will warm.
  - In general the warming is larger with higher topographic elevations and distance from the coast, such as the western Amazon basin. Surrounding ocean waters moderate the warming over the Caribbean islands.

Precipitation

- The results for precipitation are less straightforward. In general a decrease occurs along the Atlantic coast
  - pressure and wind changes suggest a weakening of trade wind-induced precipitation.
- Elsewhere, most of the region sees little difference, or even a slight increase.
  - This is at odds with the GCM and 36 km WRF results, but at these lower resolutions, the trade winds blow from the Atlantic to the Pacific, instead of being blocked by mountains near the Atlantic coast. A resolution of 12 km appears sufficient to resolve this latter effect.

NEXT STEPS

1. Global warming due to increased greenhouse gas emissions not the only agent of climate change.
   - Temperature changes due to land use alterations, especially deforestation, may be as large, at least locally.

2. Further evaluation of topographic complexity – is 4 km resolution sufficient? What is the relationship between explicit resolution of convection and microphysics parameterization schemes at higher resolutions?

3. Can our modeling strategy be fine-tuned, or adapted to the changing software and hardware configurations prevalent in climate modeling?

4. How best to use these results to provide robust input into regional and national climate assessments? Such usage ultimately is the primary purpose of this research.

MapMaker History

How we got to what we have now

before MapMaker

- July 2009 workshop, Boulder, CO, USA
  - included training on tools to access, analyze and display climate model data
- September 2009 workshop, Mexico City, MEXICO
  - same as above
- August 2010 workshop, Panama City, PANAMA
  - same as above, with added exercises on using these tools
- May 2012 workshop, Panama City, PANAMA
  - same as above, with modifications
- September 2012 workshop, Cuernavaca, MEXICO
  - same as above, with modifications
- January 2013 workshop, Guatemala City, GUATEMALA
  - same as above, with modifications

something needed to change!

- after 3½ years and 6 workshops, it had become clear that we could not teach participants to use these tools in less than one week
- needed tools that would allow participants to ***use*** the data more easily and get initial results quickly
- initial development of MapMaker over Summer 2013
  - added basic capability to download WRF monthly output files
  - separate web portal for model verification

Original MapMaker Development

- MapMaker was originally developed to allow workshop participants to view downscaled climate and climate change simulation output
- Development goals:
  - No programming required
  - No need to understand netCDF format
  - Easy-to-use web-based interface
  - Basic mapping capability with presentation/publication quality graphical output
  - Access to monthly model output

MapMaker rollout

- first used at 2nd Guatemala workshop (November 2013)
  - participants were able to quickly create maps and other plots to illustrate climate change in different regions of Guatemala for specific impacts (hydrological, agricultural, natural resources)
  - downloaded data were also imported into ArcGIS

MapMaker use and evolution

- have used MapMaker (and its friends, the verification and data download pages) at workshops in Guatemala, Honduras, Bolivia, and Lincoln
- Improvements:
  - "zooming" to specific regions
  - on-the-fly calculation of relative humidity
  - access to underlying datasets
  - multiple month (including annual) averaging
  - additional graphics output options

MapMaker limitations

- features and improvements have developed in an *ad hoc* fashion as needs arose (*e.g.*, relative humidity added *during* 3rd Guatemala workshop, at user request)
- this has resulted in multiple versions and much "ugly" software coding that is difficult to maintain
- separate webpage for each project
  - requires "kludges", as projects are added, to handle different numbers of domains, different time periods, etc.

kludge [klooj]
noun, Computer Slang.
1. a software or hardware configuration that, while inelegant, inefficient, clumsy, or patched together, succeeds in solving a specific problem or performing a particular task.

MapMaker limitations

- With one exception, limited to post-processed, monthly data from UNL WRF downscaling runs
  - exception: gridded monthly temperature and precipitation observations for Bolivia (M. Andrade)

Sideline developments

- Model verification with observations
  - Graphical and statistical output
- Requires pre-processing of observed and model data
  - Uses Global Summary of Day (GSOD) observations
    - Reports to World Meteorological Organization (WMO) from individual countries
    - Problems with missing data and limited number of stations reporting for many regions
  - Difficult to incorporate observations from other sources

it all starts with WRF …

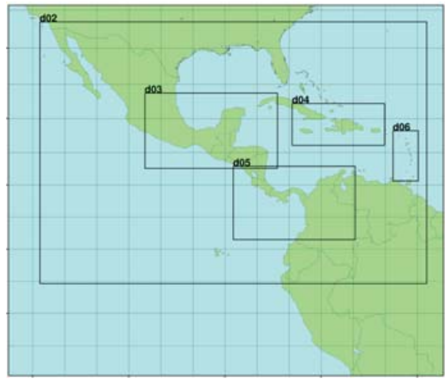
- 3-hourly output from downscaling (reanalysis or global climate model)

  → daily averages and totals

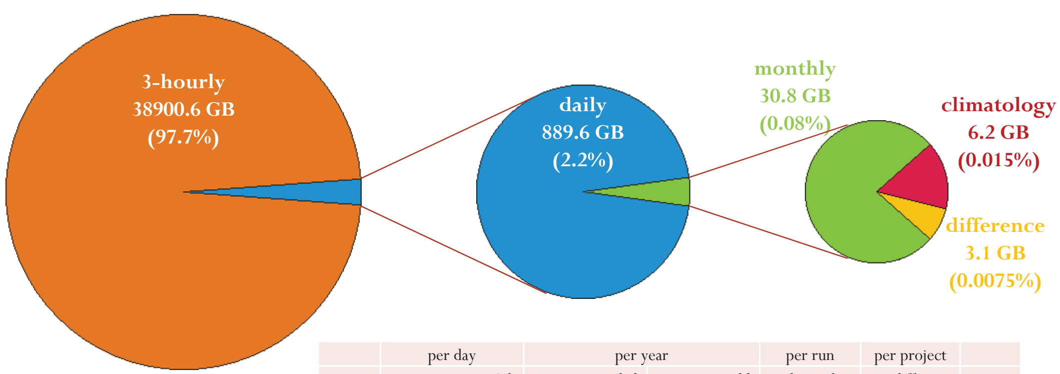
  → monthly averages and totals

  → climatologies (and climate change differences)

- 30+ variables available for mapping, some at multiple levels in the atmosphere or multiple layers in the soil



Domain	Size NS x WE	Resolution (km)	Center Latitude	Center Longitude
1	178 x 208	36	9.00°N	90.00°W
2	376 x 553	12	14.77°N	88.85°W
3	322 x 565	4	18.02°N	92.57°W
4	178 x 394	4	18.75°N	72.62°W
5	307 x 529	4	6.89°N	79.40°W
6	211 x 103	4	13.98°N	62.08°W



	per day	per year		per run	per project	
Domain	3-hr	daily	monthly	climatology	difference	
1	621852844	5188950560	179396296	179396296	179396296	
2	3511759852	29315475380	1013483752	1013483752	1013483752	
3	3071502124	25639586660	886403176	886403176	886403176	
4	1180412332	9851364200	340582408	340582408	340582408	
5	2694416524	22491374060	777565096	777565096	777565096	
6	363659212	3033635780	104884072	104884072	104884072	
Total	11443602888	95520386640	3302314800	3302314800	3302314800	bytes
	10.66	88.96	3.08	3.08	3.08	GB
TOTAL	41769150541200	955203866400	33023148000	6604629600	3302314800	bytes
	38900.55	889.60	30.76	6.15	3.08	GB
GRAND TOTAL	38.90	TB				

2 runs x 5 years x 365 days
= 3650 days

Dimension Variables

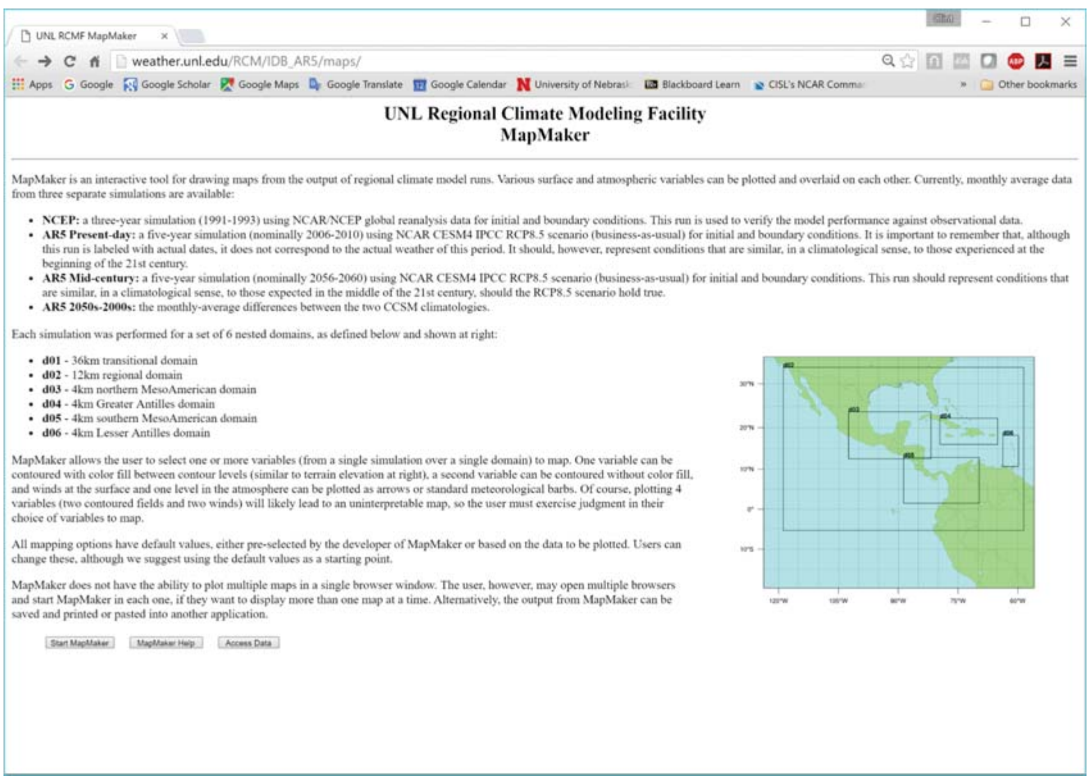
VARIABLE	DESCRIPTION	UNITS	DIMENSIONS
TIME	Ttime	YYYYMMDD	time
PRES_LEV	Mandatory pressure levels	hPa	pres_lev
DZS	Thicknesses of soil layers	m	soil_layers
XLAT	Latitude, south is negative	°N	time, S_N, W_E
XLONG	Longitude, west is negative	°E	time, S_N, W_E

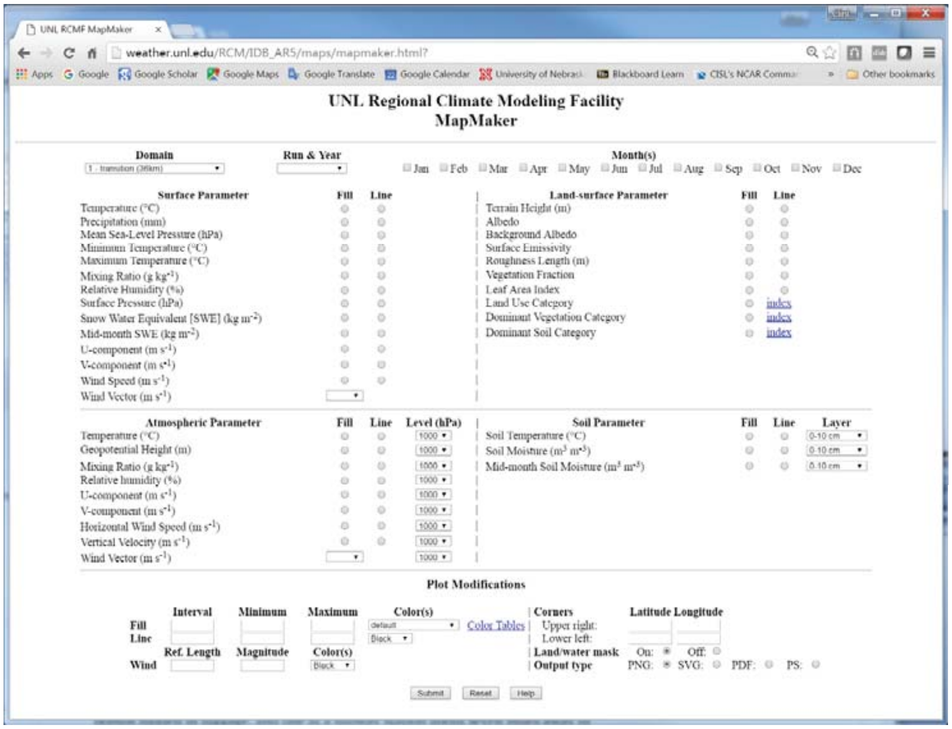
Original MapMaker Variables

VARIABLE	DESCRIPTION	UNITS	DIMENSIONS
LU_INDEX	Land use category		time, S_N, W_E
LANDMASK	Land mask (1 for land, 0 for water)		time, S_N, W_E
IVGTYP	Dominant vegetation category		time, S_N, W_E
ISLTYP	Dominant soil category		time, S_N, W_E
VEGFRA	Vegetation fraction		time, S_N, W_E
LAI	Leaf area index	$m^2\ m^{-2}$	time, S_N, W_E
HGT	Terrain height	m	time, S_N, W_E
ALBEDO	Albedo		time, S_N, W_E
ALBBCK	Background albedo		time, S_N, W_E
EMISS	Surface emissivity		time, S_N, W_E
XLAND	Land mask (1 for land, 2 for water)		time, S_N, W_E
T	Temperature	K	time, level, S_N, W_E
Z	Height	m	time, level, S_N, W_E
Q	Water vapor mixing ratio	$kg\ kg^{-1}$	time, level, S_N, W_E
U	X-wind component	$m\ s^{-1}$	time, level, S_N, W_E

Original MapMaker Variables

VARIABLE	DESCRIPTION	UNITS	DIMENSIONS
V	Y-wind component	m s^{-1}	time, level, S_N, W_E
W	Z-wind component	m s^{-1}	time, level, S_N, W_E
CLD	Cloud fraction		time, level, S_N, W_E
PSFC	Sfc pressure	hPa	time, S_N, W_E
PMSL	Sea level pressure	hPa	time, S_N, W_E
T2	Temp at 2 m	K	time, S_N, W_E
T2_MIN	Min temp at 2 m	K	time, S_N, W_E
T2_MAX	Max temp at 2 m	K	time, S_N, W_E
Q2	Qv at 2 m	kg kg^{-1}	time, S_N, W_E
U10	U at 10 m	m s^{-1}	time, S_N, W_E
V10	V at 10 m	m s^{-1}	time, S_N, W_E
PRCP	Daily total precipitation	mm	time, S_N, W_E
TSLB	Soil temperature	K	time, layer, S_N, W_E
SMOIS	Soil moisture	m^3 m^{-3}	time, layer, S_N, W_E
SNOW	Snow water equivalent	kg m^{-2}	time, S_N, W_E





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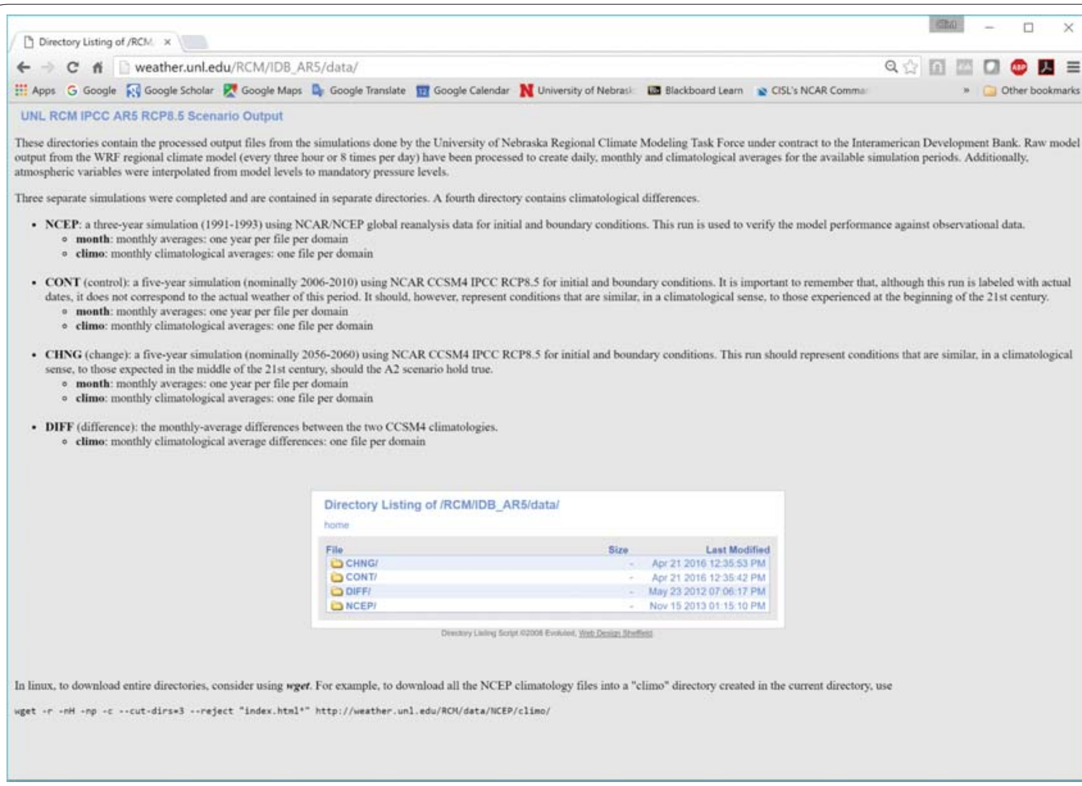
Directory Listing of /RCM/

weather.unl.edu/RCM/IDB_AR5/data/

UNL RCM IPCC AR5 RCP8.5 Scenario Output

These directories contain the processed output files from the simulations done by the University of Nebraska Regional Climate Modeling Task Force under contract to the Interamerican Development Bank. Raw model output from the WRF regional climate model (every three hour or 8 times per day) have been processed to create daily, monthly and climatological averages for the available simulation periods. Additionally, atmospheric variables were interpolated from model levels to mandatory pressure levels.

Three separate simulations were completed and are contained in separate directories. A fourth directory contains climatological differences.

- **NCEP**: a three-year simulation (1991-1993) using NCAR/NCEP global reanalysis data for initial and boundary conditions. This run is used to verify the model performance against observational data.
  - **month**: monthly averages: one year per file per domain
  - **climo**: monthly climatological averages: one file per domain
- **CONT** (control): a five-year simulation (nominally 2006-2010) using NCAR CCSM4 IPCC RCP8.5 for initial and boundary conditions. It is important to remember that, although this run is labeled with actual dates, it does not correspond to the actual weather of this period. It should, however, represent conditions that are similar, in a climatological sense, to those experienced at the beginning of the 21st century.
  - **month**: monthly averages: one year per file per domain
  - **climo**: monthly climatological averages: one file per domain
- **CHNG** (change): a five-year simulation (nominally 2056-2060) using NCAR CCSM4 IPCC RCP8.5 for initial and boundary conditions. This run should represent conditions that are similar, in a climatological sense, to those expected in the middle of the 21st century, should the A2 scenario hold true.
  - **month**: monthly averages: one year per file per domain
  - **climo**: monthly climatological averages: one file per domain
- **DIFF** (difference): the monthly-average differences between the two CCSM4 climatologies.
  - **climo**: monthly climatological average differences: one file per domain

Directory Listing of /RCM/IDB_AR5/data/

home

File	Size	Last Modified
CHNG/	-	Apr 21 2016 12:35:53 PM
CONT/	-	Apr 21 2016 12:35:42 PM
DIFF/	-	May 23 2012 07:06:17 PM
NCEP/	-	Nov 15 2013 01:15:10 PM

Directory Listing Script ©2008 Evoluted, Web Design Sheffield

In linux, to download entire directories, consider using *wget*. For example, to download all the NCEP climatology files into a "climo" directory created in the current directory, use

```
wget -r -nH -np -c --cut-dirs=3 --reject "index.html*" http://weather.unl.edu/RCM/data/NCEP/climo/
```

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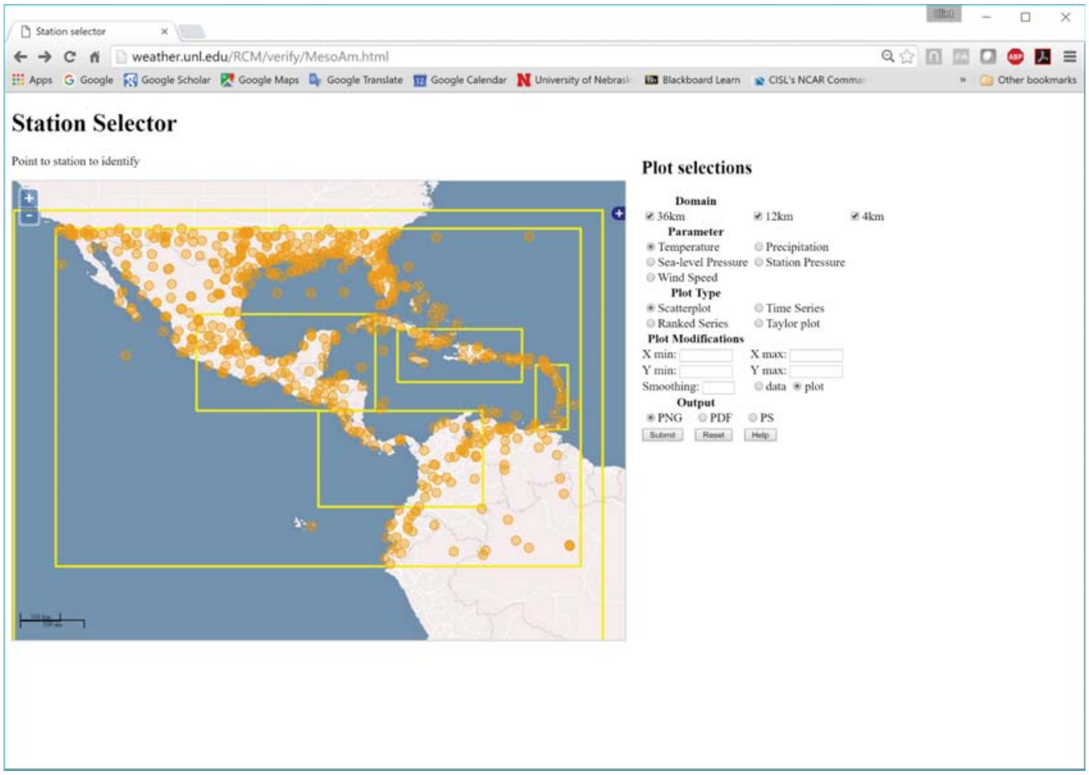


Live demonstrations

- MapMaker
  - http://weather.unl.edu/RCM/IDB_AR5/maps/
- Data download
  - http://weather.unl.edu/RCM/IDB_AR5/data/
- Verification
  - http://weather.unl.edu/RCM/verify/MesoAm
- Open your favorite browser and follow along …

MapMaker v2

What we want

First, the name …

- MapMaker (in various forms) has been used by a number of companies
  - Google Map Maker (https://www.google.com/mapmaker)
  - National Geographic Mapmaker Interactive (http://mapmaker.nationalgeographic.org)
  - Map Maker Ltd. (www.mapmaker.com)
  - Map Maker (http://mapmaker.donkeymagic.co.uk)
  - Mapmaker (2001) (Ireland)
    - An imaginative thriller about a mapmaker who uncovers the body of an alleged informer while mapping a border beauty spot in Ireland. As local tensions are stirred by the discovery, the …

It doesn't describe our goals

- We want to be able to provide more than just maps; all through a single web portal
  - data downloads
  - model verification
  - data analysis
  - more … ?

~~MapMaker v2~~

What we want

Some already in place …

… Some to be developed!

Component 2.

- **Improvement of an interactive tool to analyze and visualize regional climate models' outputs.** This component will further develop, enhance and extend the capabilities of the existing web-based tool *MapMaker* for processing, analyzing, verifying, and visualizing model outputs. The tool will be improved based on recommendations received from national scientists participating in the meetings (Component 1) and who have experience in the use of the tool as well as IDB specialists over the course of the project.

~~MapMaker~~ Tasking

- In addition, a number of recommendations already received from participants will be incorporated in to *Mapmaker*. These recommendations include, but are not limited to:
  i. add additional data such as evapotranspiration, number of precipitation days, among others;
  ii. include the ability to download data subsets (specific variables, times, areas, points, etc.);
  iii. scale changes to intermediate times (i.e., < 50 years);
  iv. improve the user's manual section as well as the online help tool;
  v. make it have better integration so that only a single version needs to be maintained, rather than several project-specific versions;
  vi. assess new technologies for improving maps visualization options; and
  vii. include the possibility to visualize outputs from other climate models.

- The main objective is to make the current prototype fully operational and more user-friendly by adding new functionalities (to be determined accordingly based on the recommendations received) and giving users access to more information through better maps with high-resolution (12 km and 4 km specifically).

i. add additional variables

- beyond spatial and temporal variables (time, latitude, longitude, pressure levels and soil layers) 29 variables were included in original MapMaker datasets
  - 9 land-surface parameters
  - 10 surface climate variables
  - 6 atmospheric variables
  - 2 soil variables
  - plus a few derived variables

- monthly values only
  - multiple month and annual averages computed as requested

- WRF output has been reprocessed to make additional variables available
  - 5 additional atmospheric variables
    - cloud, rain, ice and snow mixing ratios; cloud cover
  - 12 additional surface climate variables
    - convective, shallow convective and non-convective precipitation
    - snow and ice, graupel, hail precipitation
    - snow depth and canopy water
    - surface and underground runoff
    - sea-surface temperature and surface skin temperature
  - 2 additional soil variables
    - soil liquid water and relative soil moisture
  - 8 surface and top-of-atmosphere energy and mass fluxes
    - downward shortwave and longwave radiation at ground surface
    - top-of atmosphere outgoing longwave radiation
    - ground heat flux, upward sensible and latent heat fluxes
    - upward moisture flux at surface and snow phase change energy flux

Plans and feasibility

- we plan to store all these data as daily values
- monthly, seasonal and annual values can be computed from the daily values, as needed
- additional parameters could be computed "on the fly"
  - number of days exceeding various thresholds (*e.g.*, $T > 35°C$; precipitation > 10 cm)
  - number of consecutive dry days
- will depend on having the computing power to do the necessary computations quickly

ii. download data subsets

- currently, only complete datasets can be downloaded
- plan to develop tools to subset available data by
  - time period
  - geographic region (latitude / longitude box)
  - specific location
- plan to develop tools to perform some computations prior to download
- investigate alternate output formats

iii. scale to intermediate times

- we have structured our present-day (PD) and future (FT) climate downscaling runs to make this possible
  - 50-60 years between time slices allows for linear scaling to intermediate times
  - already have done this for our Guatemalan colleagues
- can only be applied to climatologies
  - linear temporal scaling of differences between PD and FT endmembers, added to PD

$$\bar{T}_{INT} = \bar{T}_{PD} + (\bar{T}_{FT} - \bar{T}_{PD})\left(\frac{t_{INT} - t_{PD}}{t_{FT} - t_{PD}}\right)$$

- other scaling methods could be implemented, but would require greater knowledge of future trends than are currently known

ii. & iii. feasibility

- should be relatively straightforward to implement "under the hood"
  - NCO (netCDF operators) is a fast, powerful and free suite of tools for manipulating netCDF (and other) datasets
  - CDO (Climate Data Operators) is a collection of tools to analyze climate and weather model data, including GriB and netCDF
- benefits
  - WRF output in netCDF format
  - netCDF format widely used in climate modeling community
  - GriB format used as international exchange format for numerical weather models
  - NCO and CDO include OPeNDAP (more later)

iv. improve manual and online help

- better descriptions of available data
- "best practices" for use of data

- this will be an evolving part of the project, as much cannot be done until the software system is built

- will require active involvement of users
  - will try to log as many questions and answers as possible to incorporate into the manual and help system

v. improve software integration

- already underway
  - database of runs
    - domains
    - historical periods
    - present-day and future periods
  - new portal will use this database to locate appropriate data
- will develop local naming standards for directories and files that will alleviate many issues
  - replace previous *ad hoc* naming of project directories
- integrate model verification and mapping functions into a single website portal

vi. improve map visualization

- need input from users here

vi. add additional data

- country-suppled observations for verification and other analyses
- additional model output
  - GCM climate runs
  - other downscaling results
- copies on UNL server hosting new portal or links to other servers – pros and cons
  - speed of access versus need for storage
  - use OPeNDAP-enabled software (http://www.opendap.org)
    - Open-source Project for a Network Data Access Protocol

Most importantly …

- We need your input on how to improve this tool

Workshop Conclusions and Next Steps

What We Accomplished This Week:

- Formed three working groups:

WG 1: Tropical Systems

WG 2: ENSO

WG 3: Mountain Precipitation

The Working Groups

Each WG made incredible progress towards their ultimate goals

Keep the momentum going even once you return home!

The Next Steps

- Next Workshop tentatively scheduled for October or November 2016
- Three more workshops pending for 2017
- It's all about the Working Groups; their results and importantly, recommendations

Appendix E: Working Group Draft Reports

Working Group 1: Tropical Systems

(Jayaka Campbell, Alberto López, Alejandro del Castillo, Francisco Argeñal)

- Working Group 1: Tropical Systems

- Jay Campbell, Alberto Lopez, Alejandro del Castillo, Francisco Argenal

Background

- What is a Tropical Systems
  - Tropical Cyclones Tropical Storms, Tropical Depressions and Hurricanes,
    - Tropical cyclones (TCs)
      - Non-frontal synoptic-scale low pressure systems, which develop over warm pools of the tropical or subtropical oceans and have organized convection and a distinct cyclonic surface wind circulation
    - Tropical Depression (TD)
      - A tropical cyclone having sustained surface winds of less than 39 miles per hour (34 knots; 63 kilometers per hour)
    - Tropcial Storm (TS)
      - A cyclonic storm originating in the tropics and having winds ranging from 39 to 73 miles per hour (34 to 63 knots; 63 to 117 kilometers per hour)
    - Hurricanes
      - a meteorological Phenomena that has a relatively calm centre, an eye, around which winds with a constant speed of 119km/hr blow. The winds are typically contained in a large spiral.

Importance

- According to Goldenberg et al 2001
  - Comparing the 24 years (1971 to 1994) with 6 years of (1995-2000), the later 6 years saw a
    - doubling of overall activity for the whole basin,
    - 2.5-fold increase in major hurricanes (≥50 meters per second),
    - fivefold increase in hurricanes affecting the Caribbean.

    - Combining this with the fact that the economies of the Latin America and the Caribbean are largely dependent of climate sensitive activities, agriculture and tourism
      - The shift in climate calls for a re-evaluation of preparedness and mitigation strategies.

Methodology

Step 1

Generate an estimate of TC activity using seasonal means and large scale fields using the methodology established by Gray 1979, Royer et al 1998.

- A general approach to detect the presence of TC.
- This will be done using the driving Reanalysis
  - For a period longer than the model period.
  - For model period
  - For model simulations at 36, 12 and 4 km

Methodology

Step 2

Catalogue all Tropical Systems that occurred historically within the domain of interest.

- Sub-divide the storms into Atlantic and Pacific occurrences.
  - For each domain
    - For each basin (Atlantic and Pacific)
    - Select the highest intensity Tropical System for each year of the period of interest. To facilitate detection in tropical step 4 the storm must existed within domain of interest for approximately 48 hours.

Methodology

Step 3

Attempt to identify individual Tropical Systems.

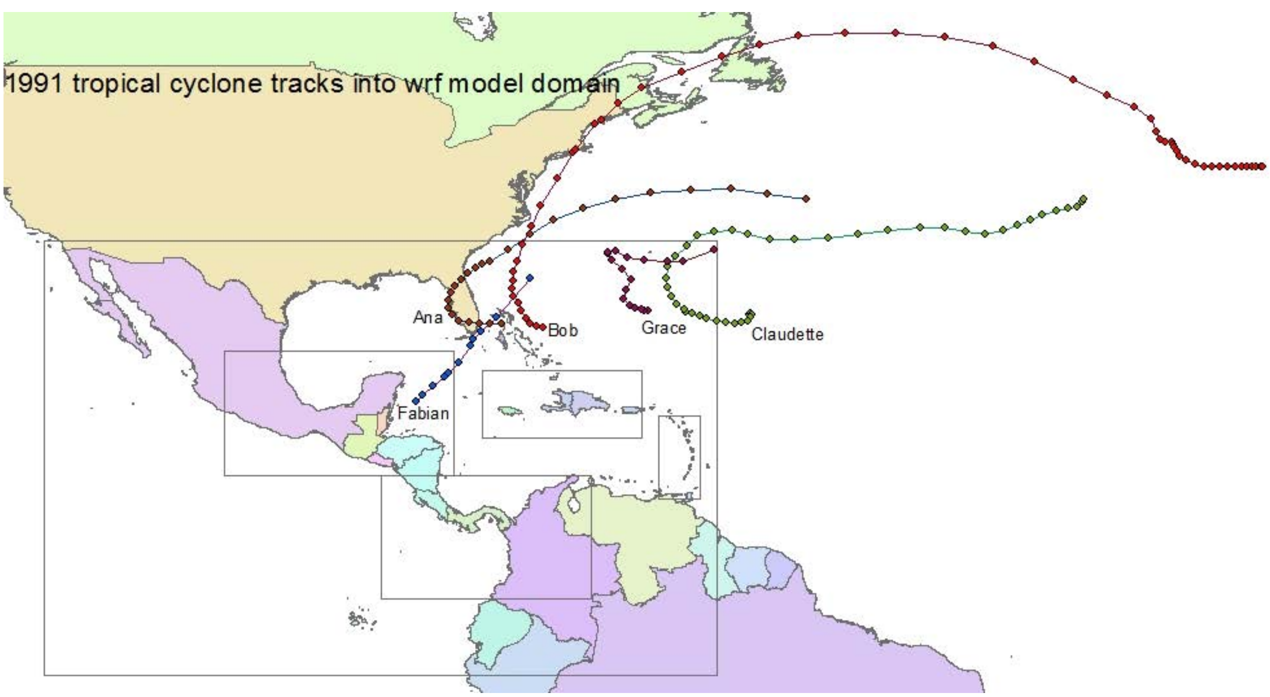
- Attempt to detect the presence of each Tropical Systems
  - Tropcial Depressions
  - Tropical Storms
  - Hurricanes
- Evaluate each model resolution for limits of detection if possible.

Methodology

Step 4

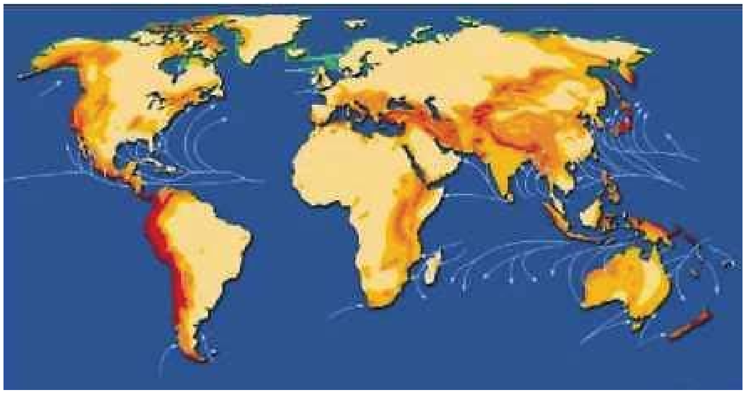
Attempt to identify individual TC's identified in Step 2.

- For each Domain. (Gauldi et al. 2008)
  - We assume that a model TC is active over a certain gridpoint A if the following conditions are satisfied:
    - in A, relative vorticity at 850 hPa is >3 × 10^-5 s^-1 ;
    - there is a relative minimum surface pressure and wind velocity is >14 m s^-1 in an area of **2.25°** around A; **(metric to be adjusted for each domain)**
    - the wind velocity at 850 hPa is > wind velocity at 300 hPa;
    - the sum of temperature anomalies at 700, 500, and 300 hPa is > 2°K, where the anomalies are defined as the deviation from a spatial mean computed over an area of **13 grid points in the east–west and 2 grid points in the north–south direction**;
    - the temperature anomaly at 300 hPa is greater than the temperature anomaly at 850 hPa;
    - the above conditions persist for a period longer than 1.5 days.

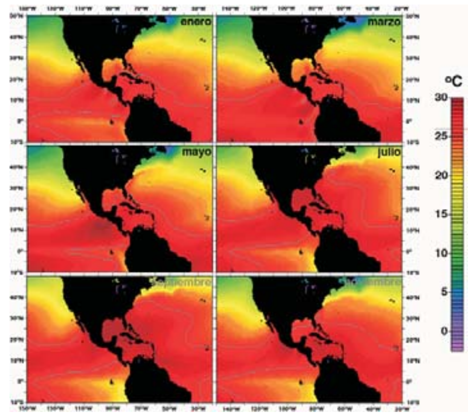


An evaluation of tropical projections from 1991 to 1993

Hurricane Hazard in the World



Average hurricane tracks in the world



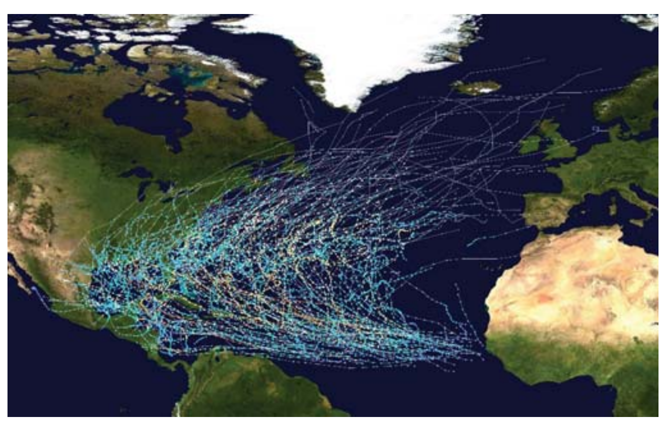
There are two cyclogenetic areas at both sides of America Continent

Motivation

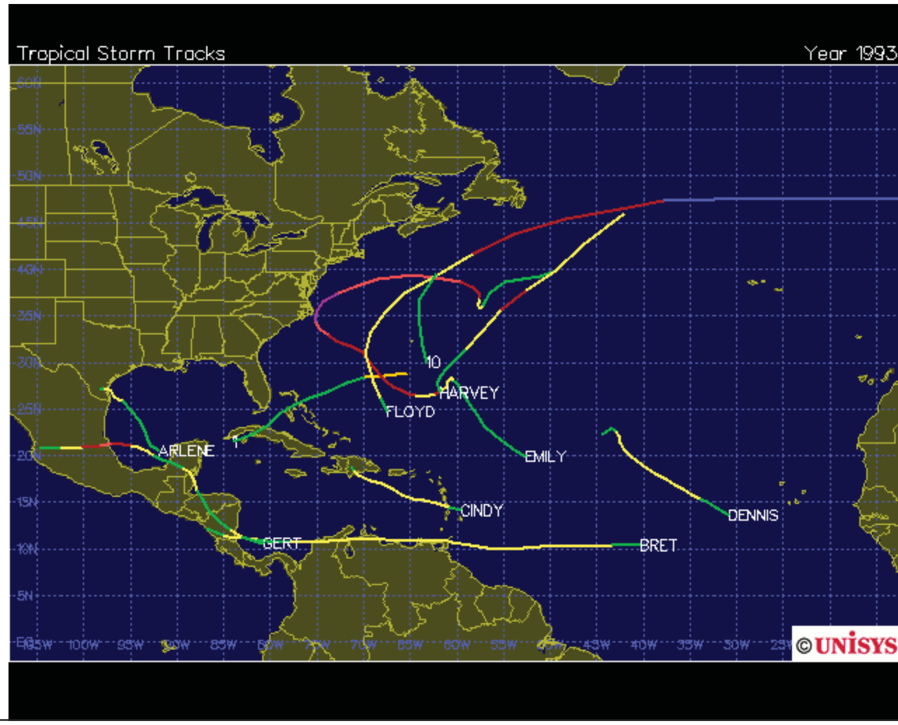
The Pacific, Gulf of Mexico and the Caribbean are sources of tropical systems scenarios. It is of interest to estimate the impacts due to climate change effects on the tropical systems in the countries sourrinding this region.

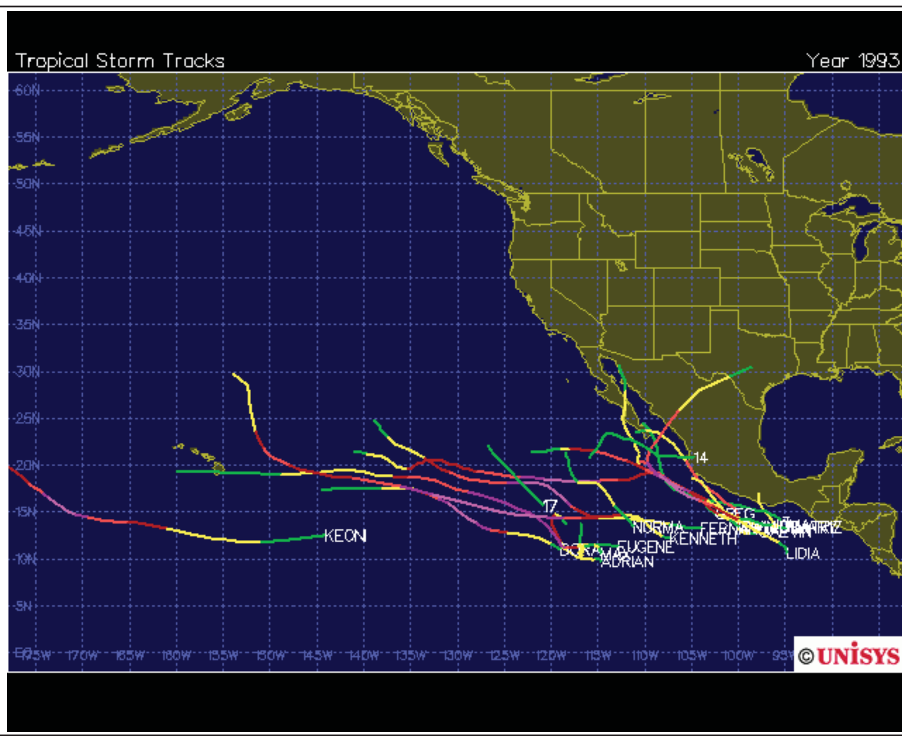
Tropical storms in North Pacific region

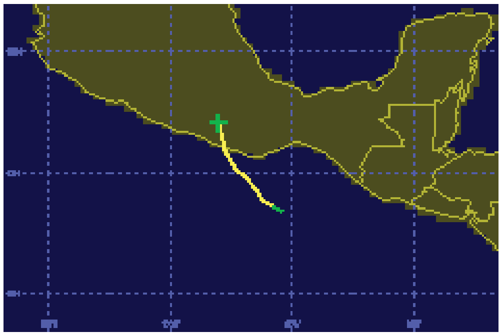
Tropical storms in North Atlantic region

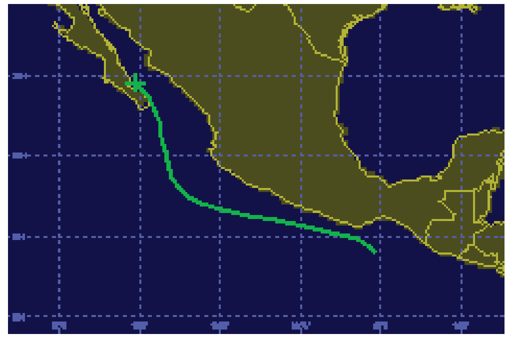


Strong Tropical storms for 1993
In the Pacific and the Atlantic

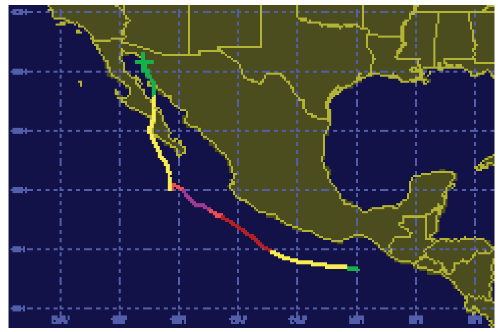




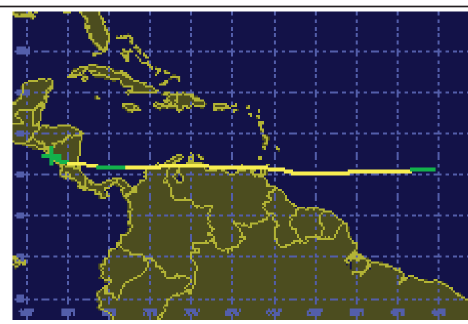

Beatriz (18_20Jun 1993) 55 knots

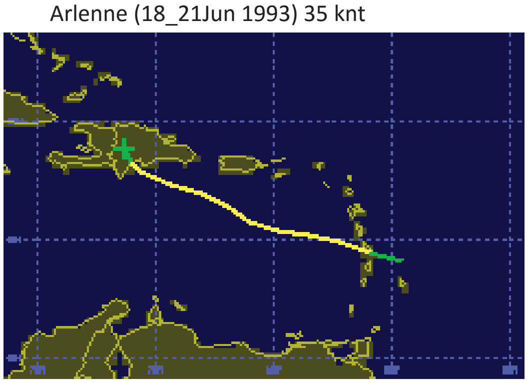

DT 3 (27Jun_2Jul 1993) 30 knt

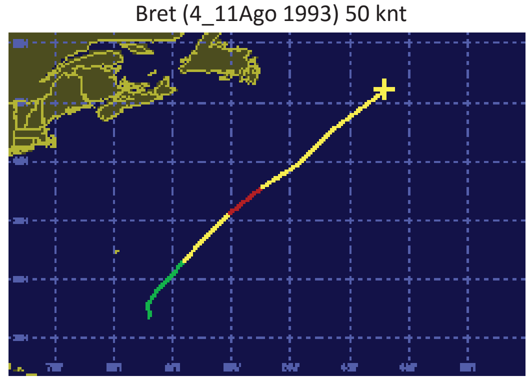

Calvin (04_09Jul 1993) 95 knots

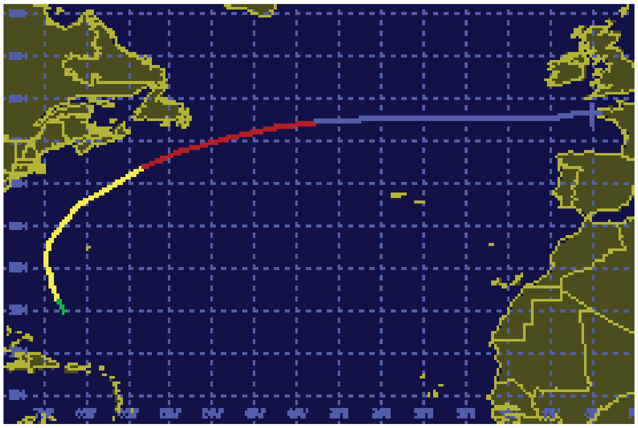

Hilary (17_27Ago 1993) 105 knots


Arlenne (18_21Jun 1993) 35 knt


Bret (4_11Ago 1993) 50 knt


Cindy (14_17Ago 1993) 40 knt

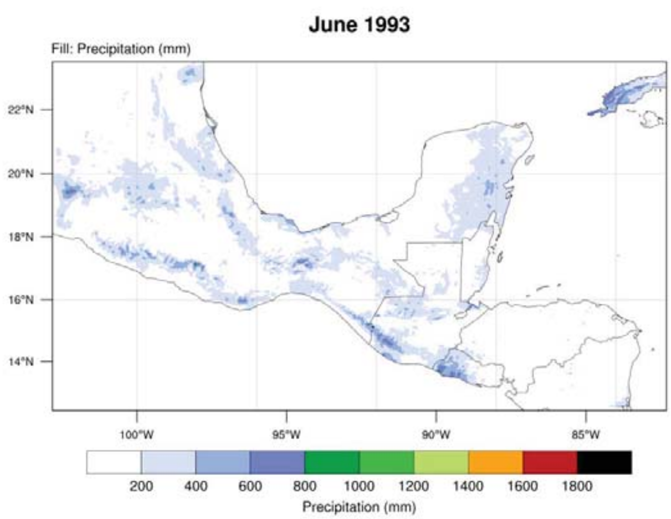

Harvey (18_21Sep 1993) 65 knt

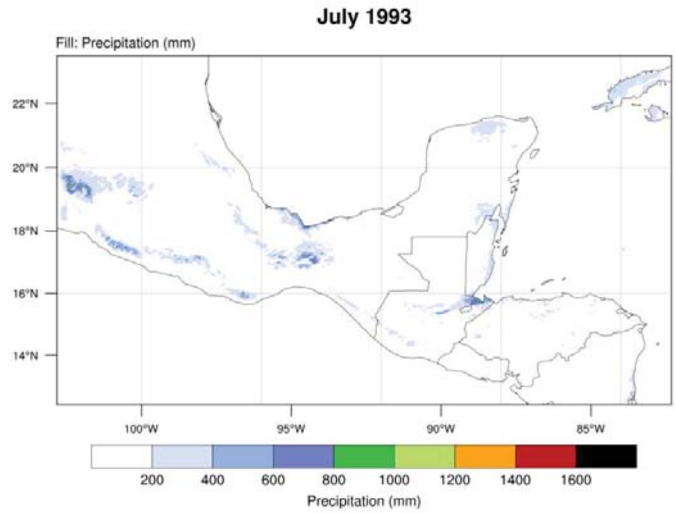


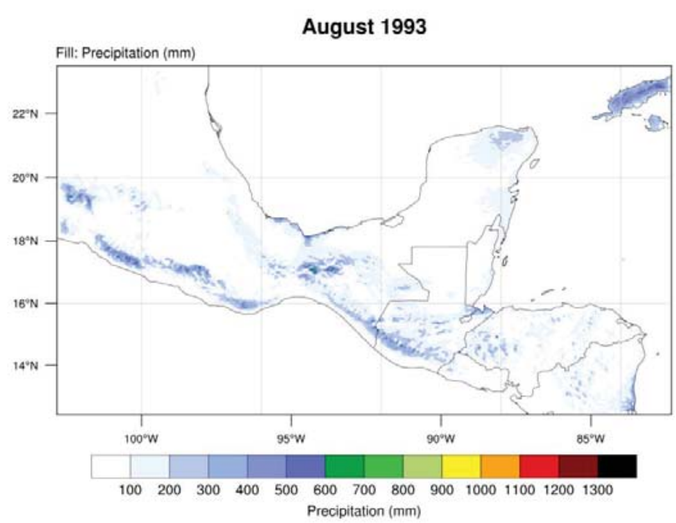
Floyd (7_13Sep 1993) 70 knt

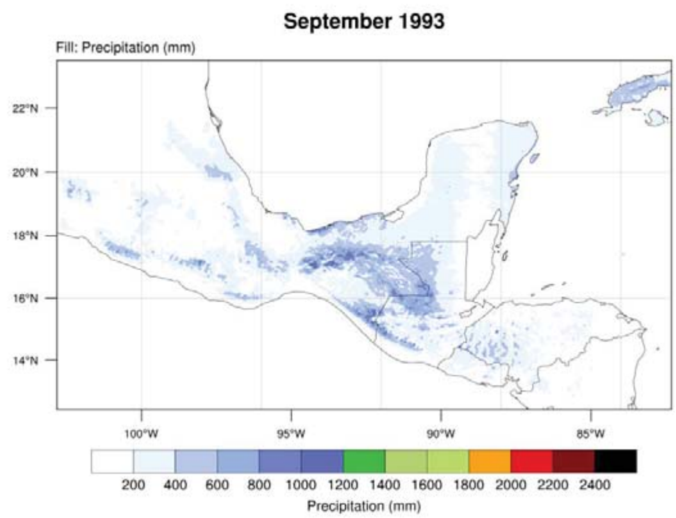
SS1 (21_24Abr 1993) 45 knt

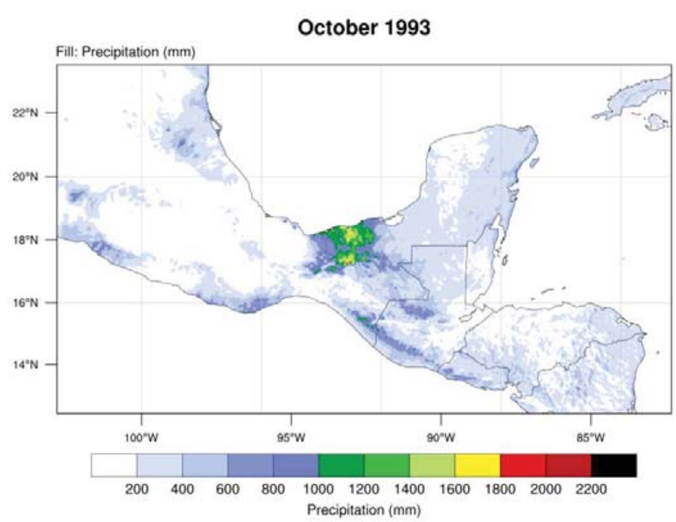
Precipitation and wind results from MapMaker

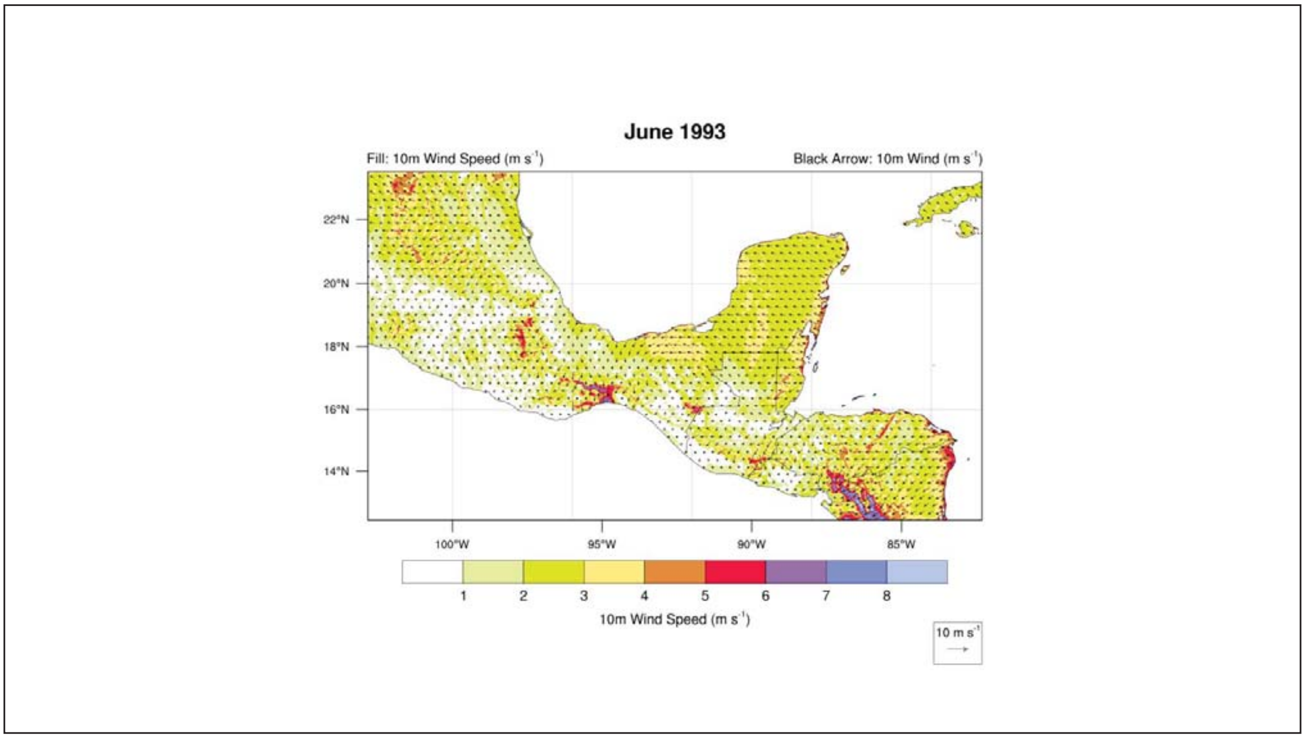


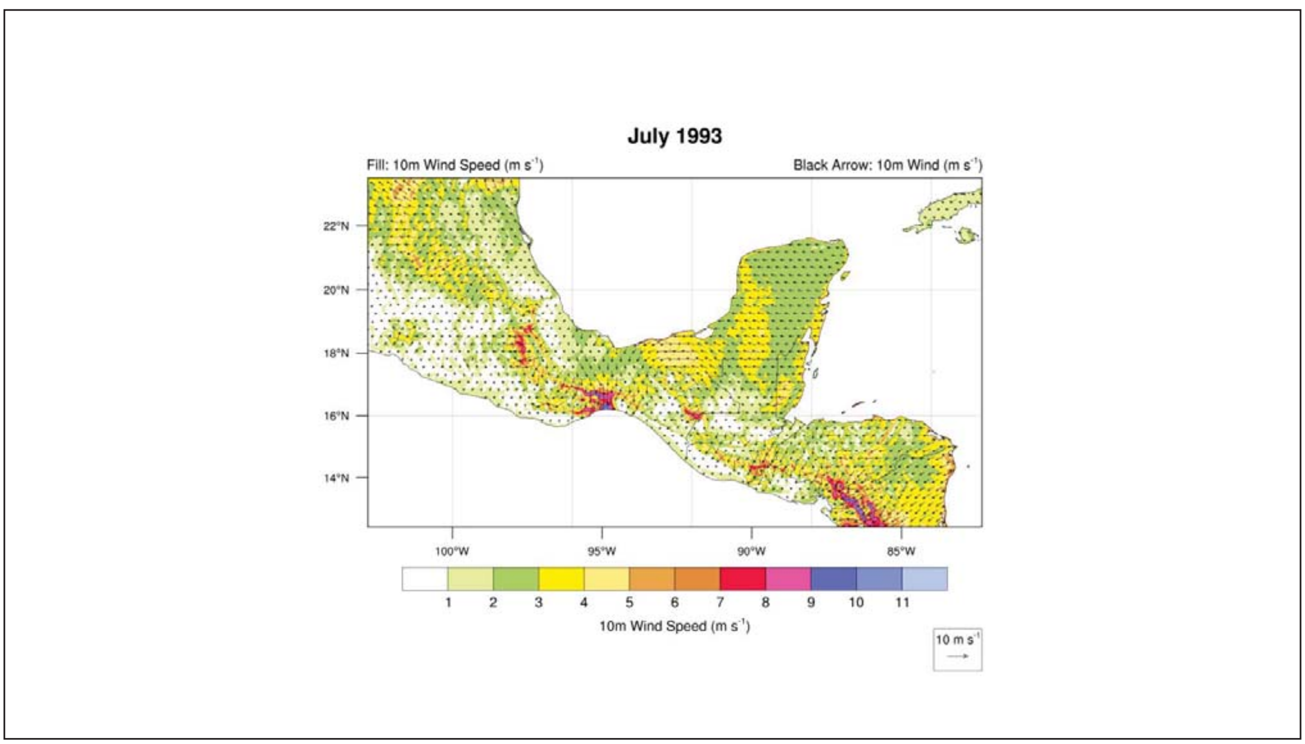

July 1993
Fill: Precipitation (mm)
22°N
20°N
18°N
16°N
14°N
100°W
95°W
90°W
85°W
200 400 600 800 1000 1200 1400 1600
Precipitation (mm)

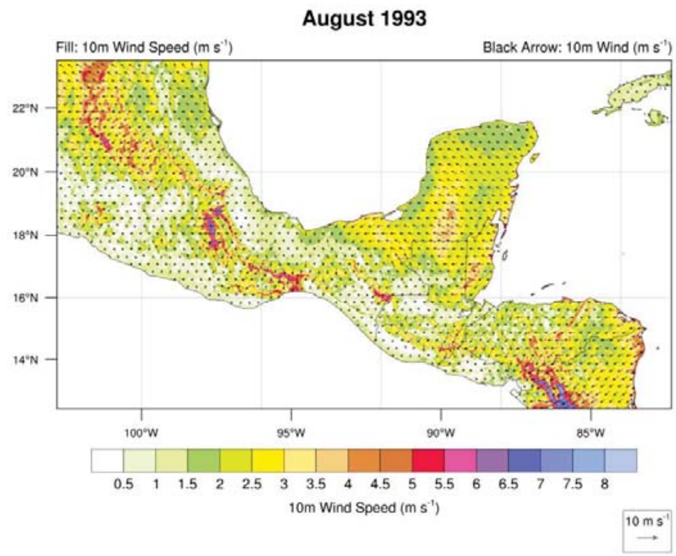

August 1993
Fill: Precipitation (mm)
22°N
20°N
18°N
16°N
14°N
100°W
95°W
90°W
85°W
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300
Precipitation (mm)

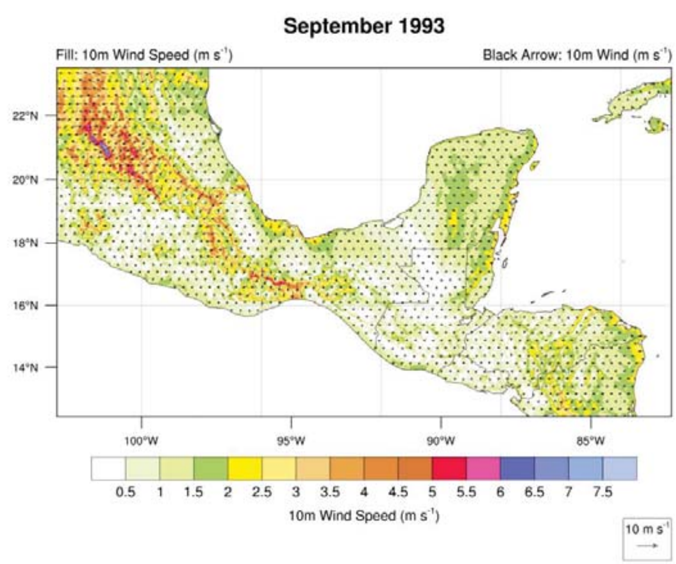

September 1993
Fill: Precipitation (mm)
22°N
20°N
18°N
16°N
14°N
100°W
95°W
90°W
85°W
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400
Precipitation (mm)

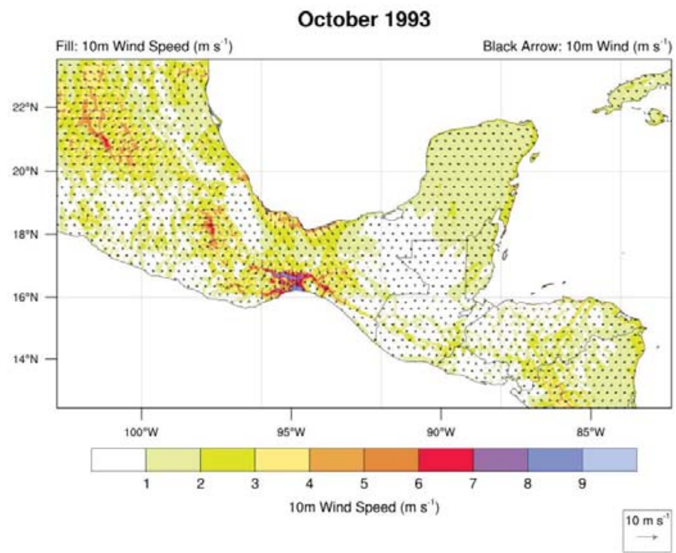

October 1993
Fill: Precipitation (mm)
22°N
20°N
18°N
16°N
14°N
100°W
95°W
90°W
85°W
200 400 600 800 1000 1200 1400 1600 1800 2000 2200
Precipitation (mm)


June 1993
Fill: 10m Wind Speed (m s⁻¹)
Black Arrow: 10m Wind (m s⁻¹)
22°N
20°N
18°N
16°N
14°N
100°W
95°W
90°W
85°W
1 2 3 4 5 6 7 8
10m Wind Speed (m s⁻¹)
10 m s⁻¹


July 1993
Fill: 10m Wind Speed (m s⁻¹)
Black Arrow: 10m Wind (m s⁻¹)
22°N
20°N
18°N
16°N
14°N
100°W
95°W
90°W
85°W
1 2 3 4 5 6 7 8 9 10 11
10m Wind Speed (m s⁻¹)
10 m s⁻¹


August 1993
Fill: 10m Wind Speed (m s-1)
Black Arrow: 10m Wind (m s-1)
22°N
20°N
18°N
16°N
14°N
100°W
95°W
90°W
85°W
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8
10m Wind Speed (m s-1)
10 m s-1


September 1993
Fill: 10m Wind Speed (m s-1)
Black Arrow: 10m Wind (m s-1)
22°N
20°N
18°N
16°N
14°N
100°W
95°W
90°W
85°W
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
10m Wind Speed (m s-1)
10 m s-1



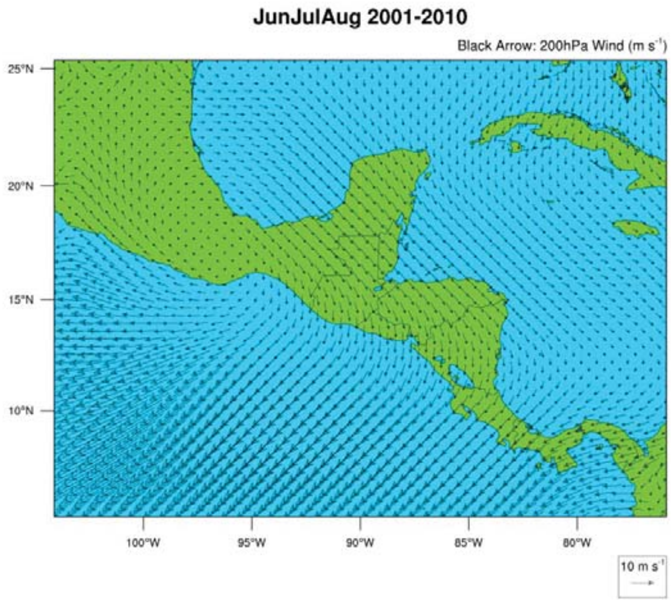
Some points to consider:

- There exists more storms information in the Atlantic than in the Pacific so results can be better approximated for the Atlantic
- It will be important to define another domain for the California Peninsula and Pacific due to the important number of hurricanes occur in this region
- It will be necessary to define a methodology to evaluate impacts in relation what are the interests

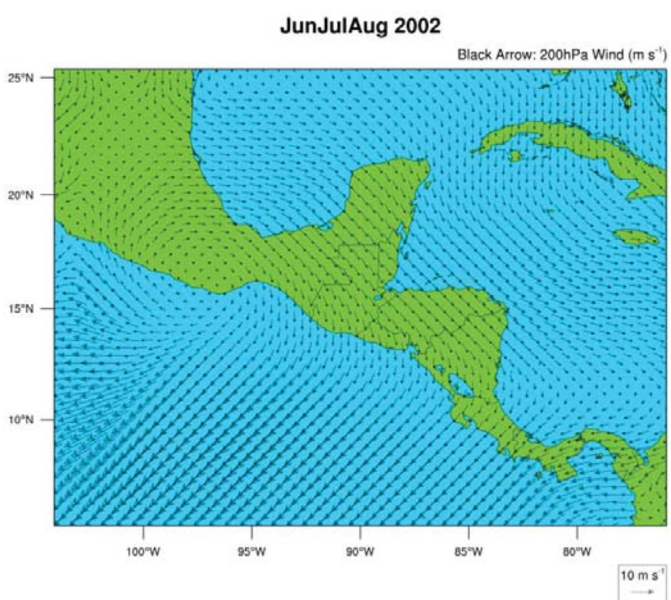
Working Group 2: ENSO

(Luis Alvarado, Gabriela Alfaro, Franklyn Ruiz, Juan José Nieto, Alberto Cumbrera)

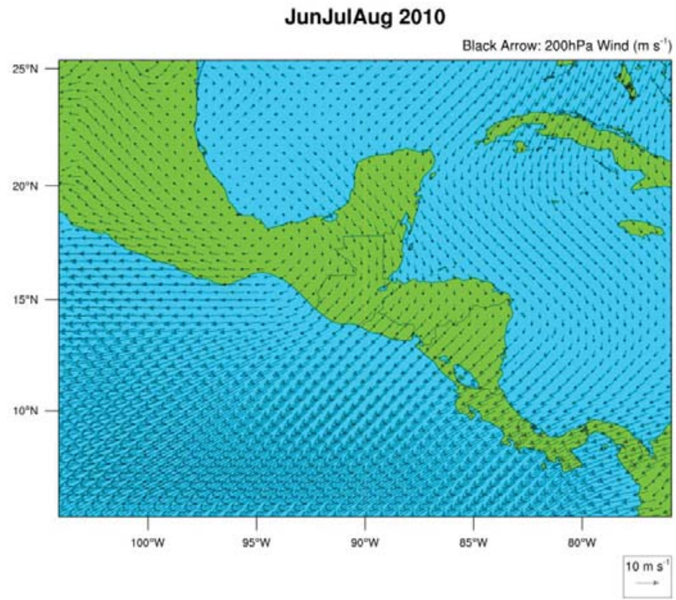
Climatología
2001-2010
Viento
200 hPa



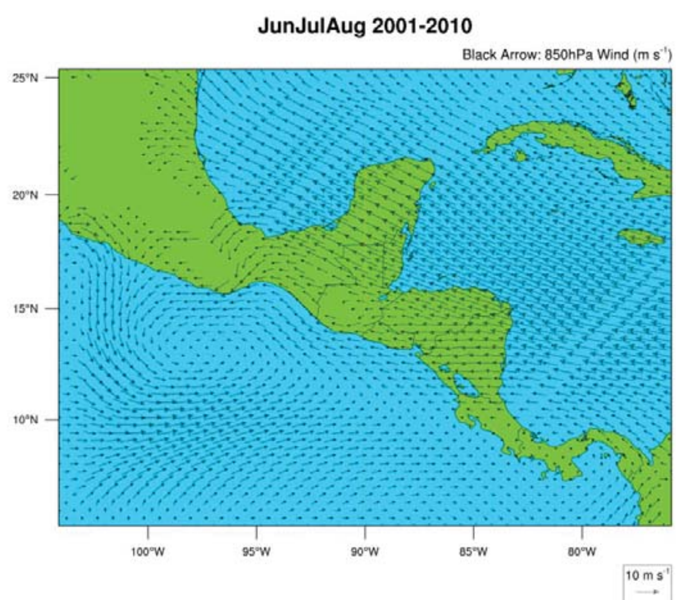
El Niño
2002
Viento
200 hPa



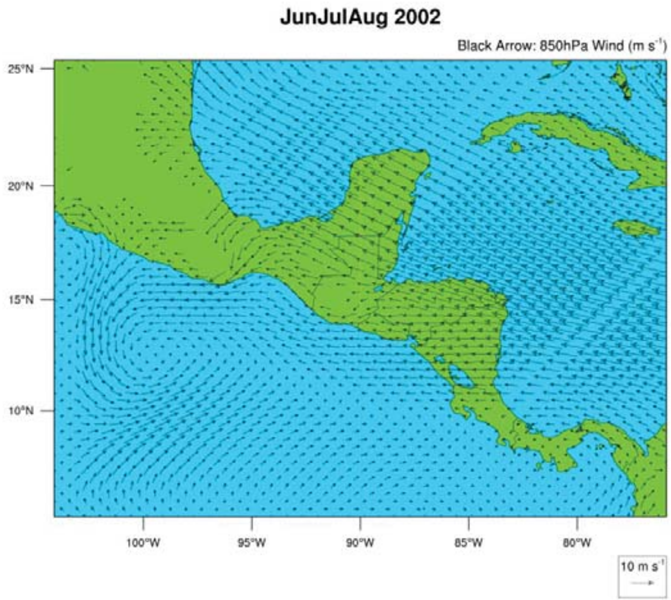
La Niña
2010
Viento
200 hPa



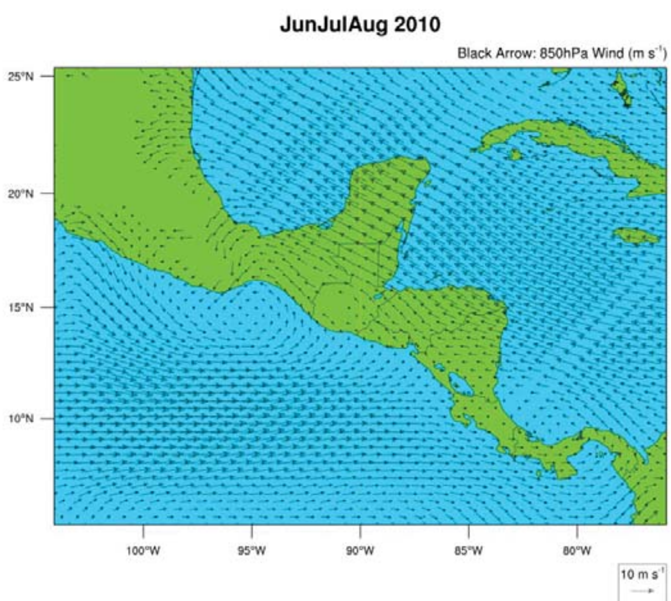
Climatología
2001-2010
Viento
850 hPa



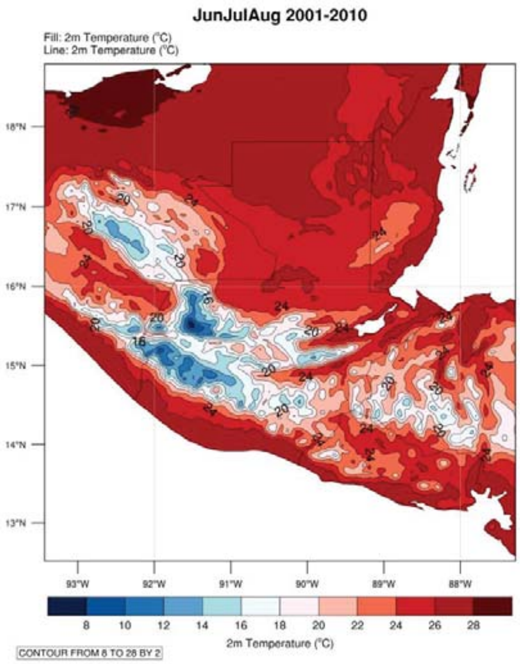
El Niño
2002
Viento
850 hPa



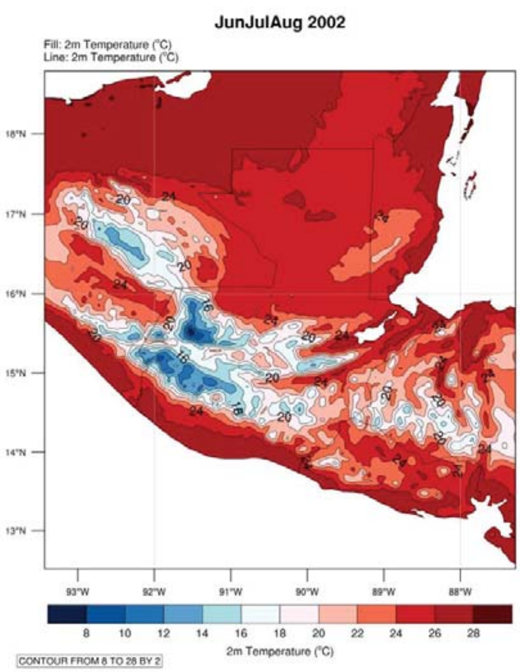
La Niña
2010
Viento
850 hPa



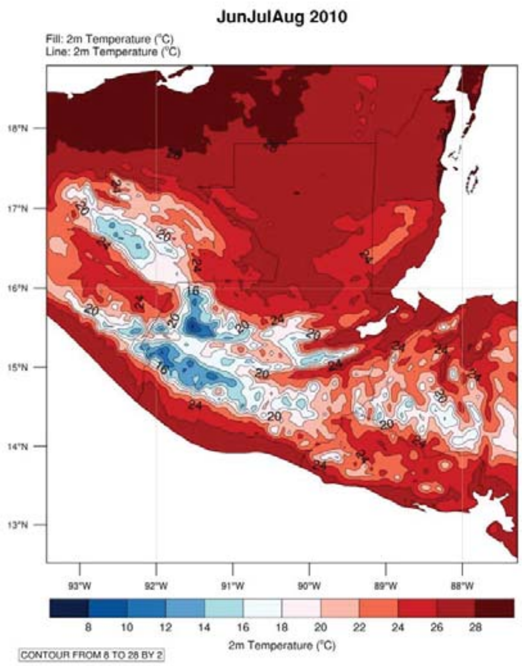
Climatología 2001-2010 Temperatura



El Niño 2002 Temperatura



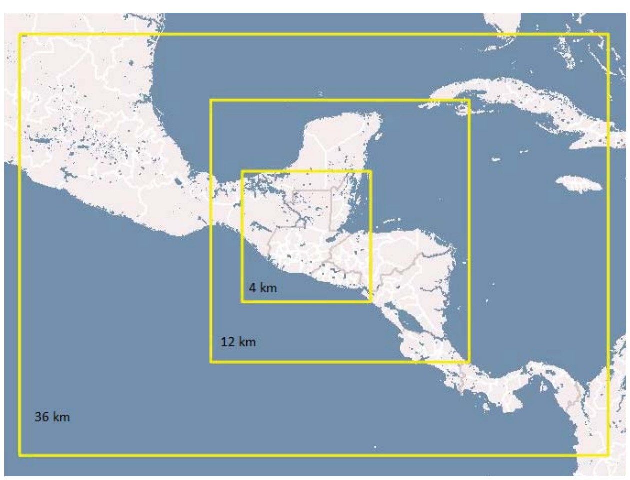
La Niña 2010
Temperatura



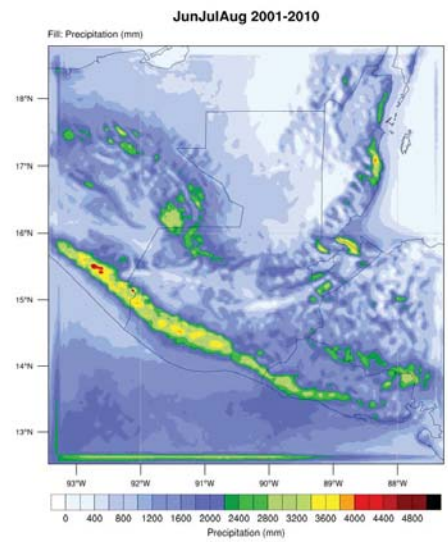
VERIFICACIÓN DE LA HABILIDAD DEL MODELO WRF PARA SIMULAR LA ALTERACIÓN CLIMÁTICA EN EL VERANO DE GUATEMALA

Luis Alvarado, Gaby Alfaro, Franklyn Ruiz, Juan José Nieto, Alberto Cumbrera

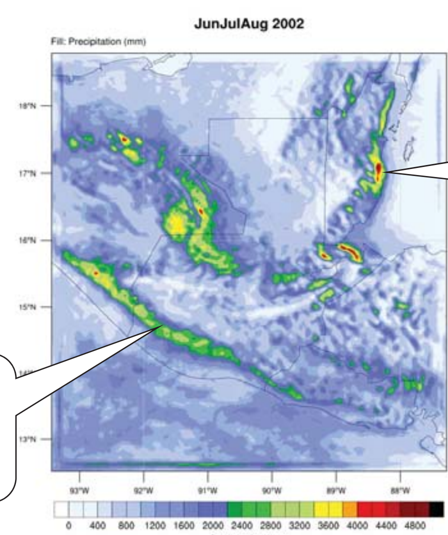
DOMINIOS



CLIMATOLOGIA LLUVIA (2001-2010)



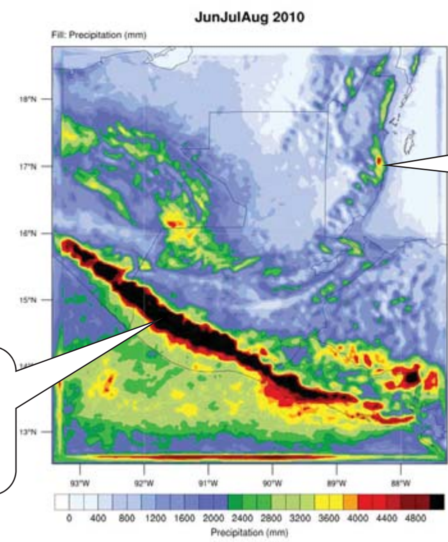
LLUVIA EL NIÑO (JJA-2002)



En el Caribe la lluvia es mayor que la climatología

En el Pacífico la lluvia es menor que la climatología

LLUVIA LA NIÑA (JJA-2010)

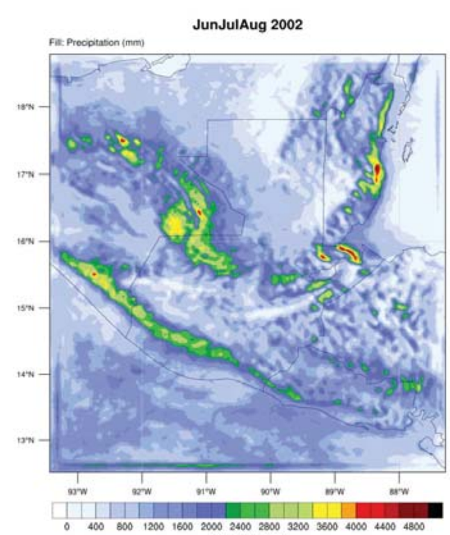


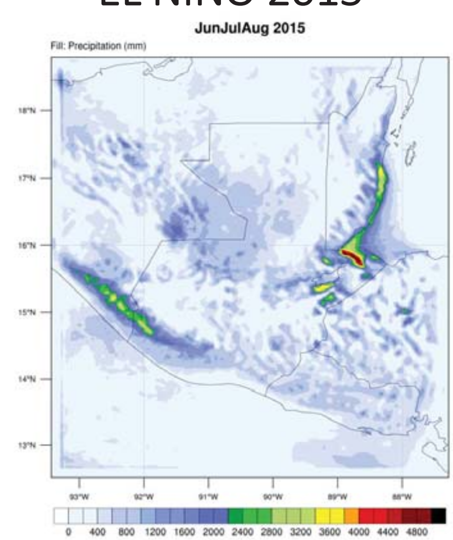
En el Caribe la lluvia es menor que la climatología

En el Pacífico la lluvia es mayor que la climatología

LLUVIA (JJA)

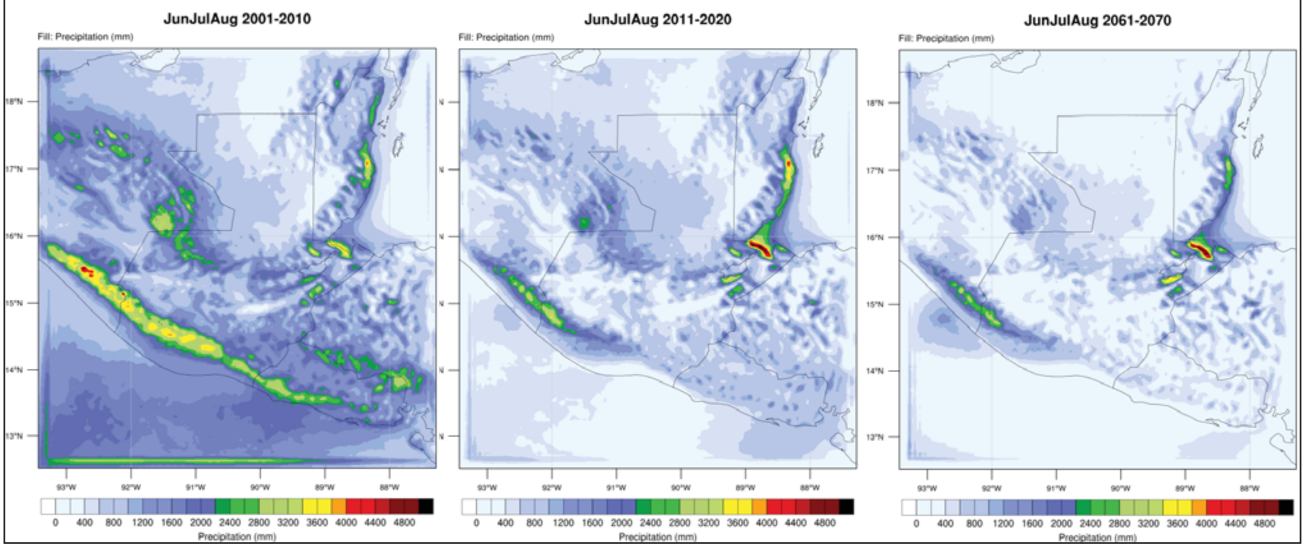
EL NIÑO 2002 VS EL NIÑO 2015





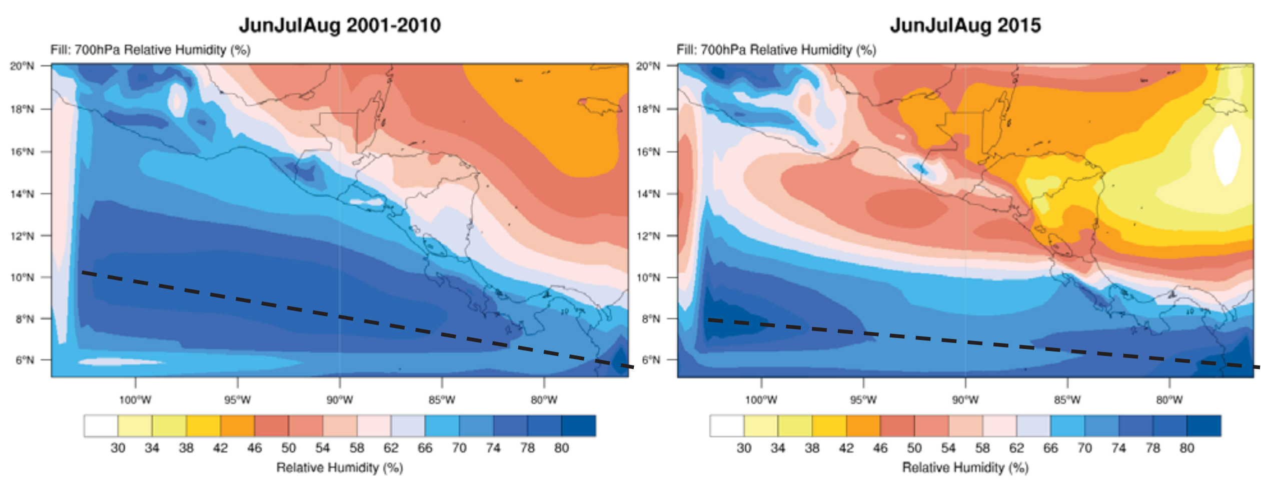
LLUVIA TOTAL (JJA)

2000´s 2010´s 2060´s



ZCIT (JJA)

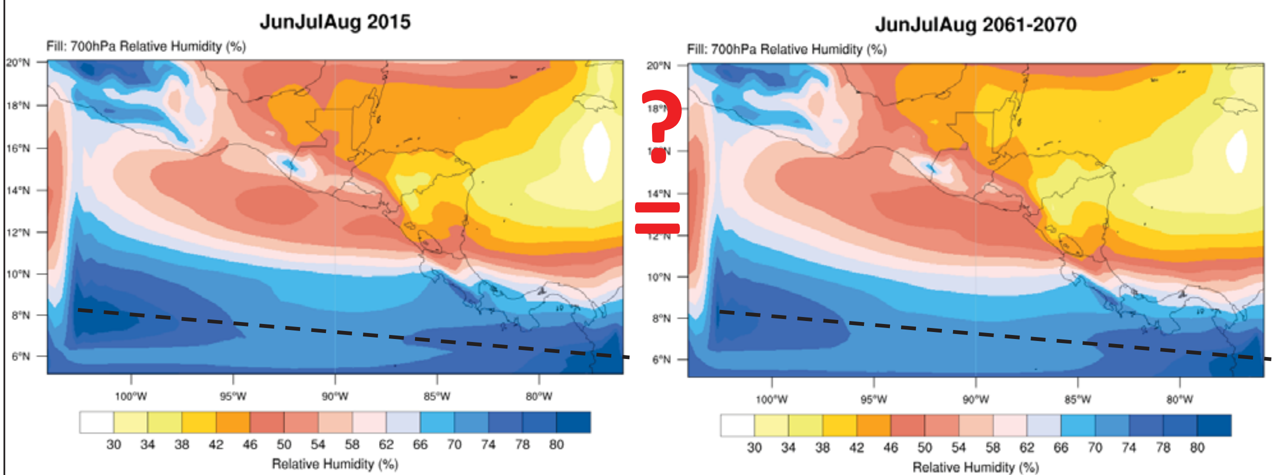
2000´s EL NIÑO 2015



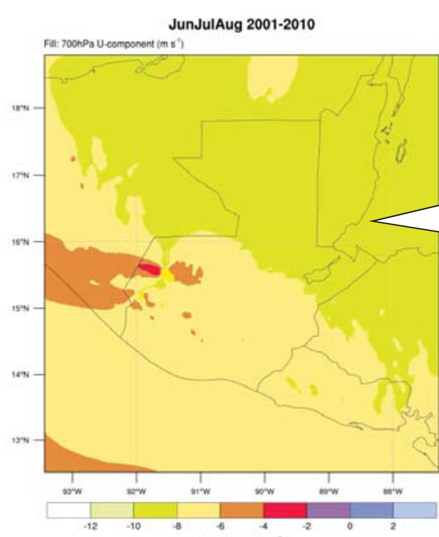
ZCIT (JJA)

EL NIÑO 2015

EL NIÑO 2060´s

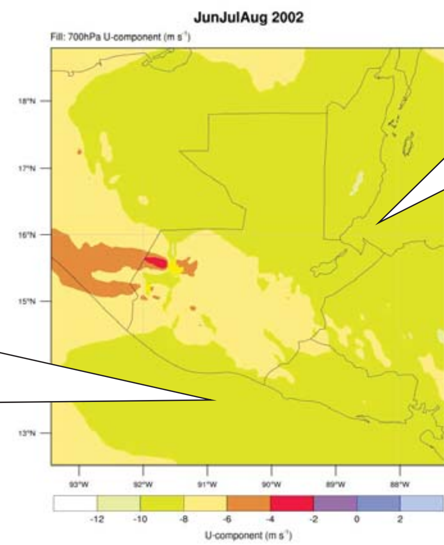


CLIMA U700 (2001-2010)



Vientos dominantes con componente del este, de mayor magnitud en el Caribe

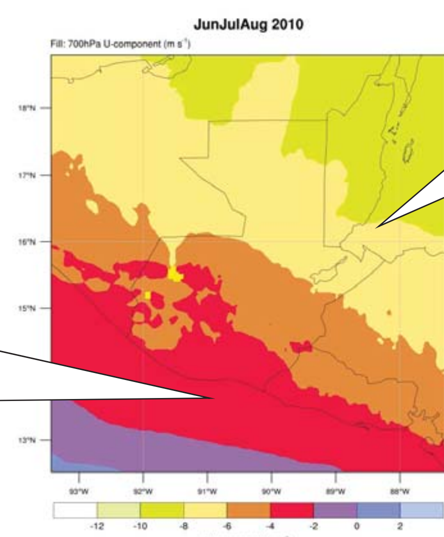
EL NIÑO U700 (JJA-2002)



Magnitud del viento del este sin cambios apreciables respecto a la climatología

En el Pacífico la magnitud de viento es mayor a la climatología

LA NIÑA U700 (JJA-2010)

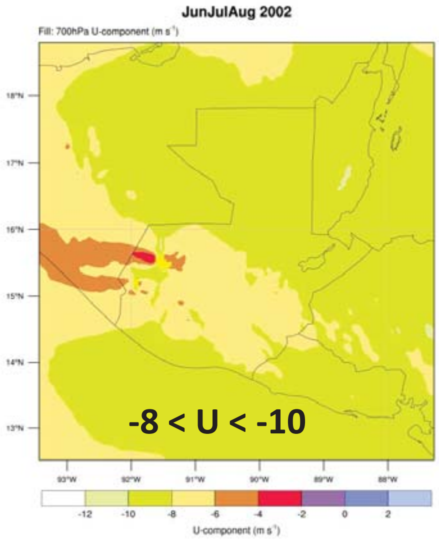


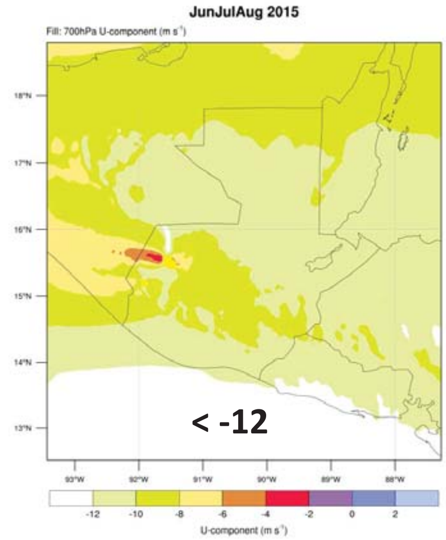
Viento del este con una ligera disminución relativo a la climatología

En el Pacífico el viento es de magnitud menor a la clima

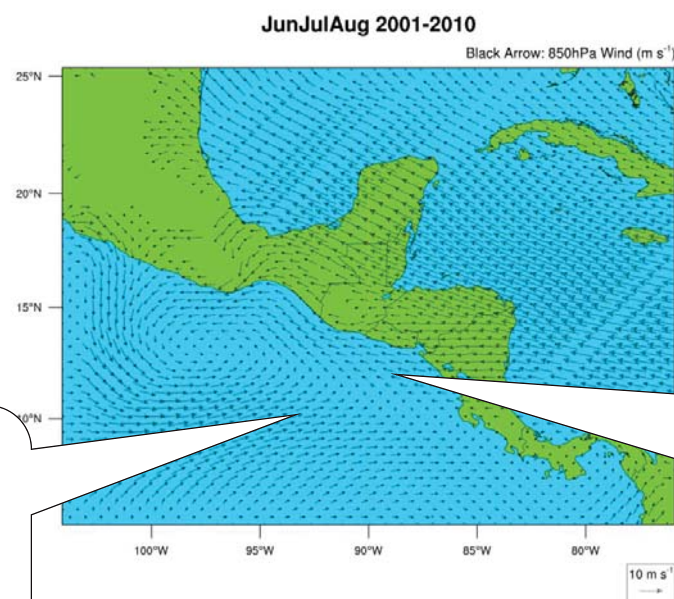
U700 (JJA)

EL NIÑO 2002 VS EL NIÑO 2015





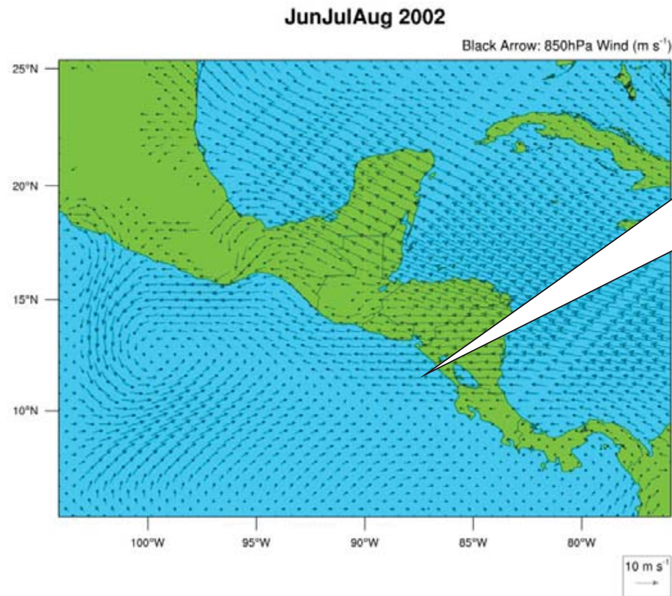
Climatología
2001-2010
Viento
850 hPa



En Pacífico predominan vientos del oeste

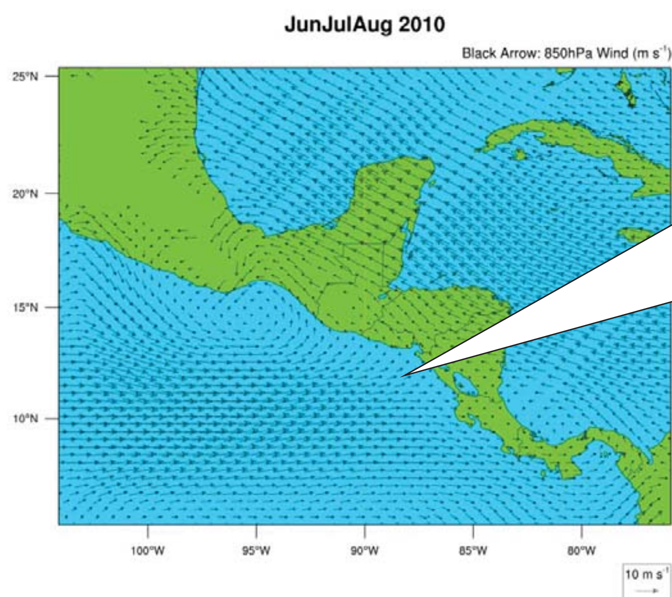
En el mar Caribe hasta la costa Pacifica de Centroamérica el viento dominante es del este

El Niño
2002
Viento
850 hPa



En toda la región aumenta la magnitud del viento del este

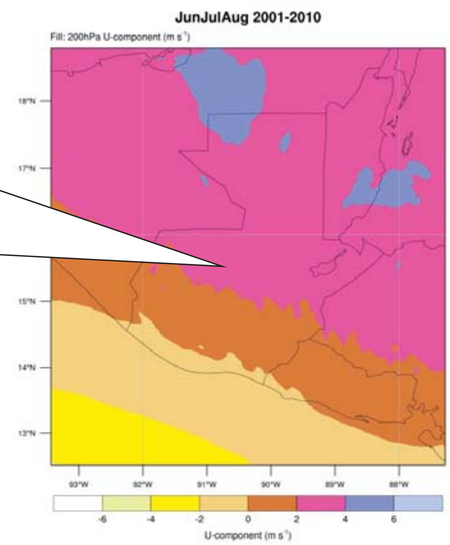
La Niña
2010
Viento
850 hPa



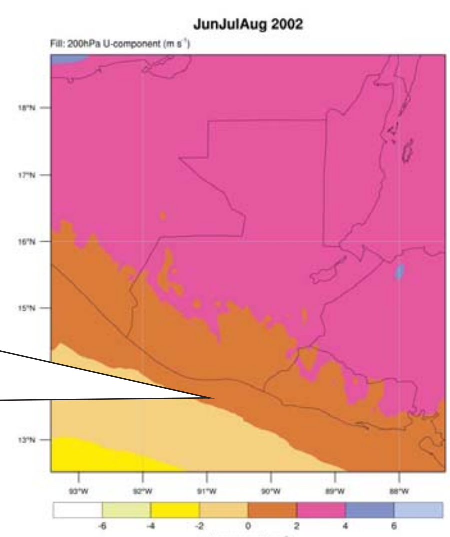
En el Pacífico colapasan los vientos del este y sos sustituidos por vientos del sur-oeste

CLIMA U200 (2001-2010)

Dominio de vientos con componente del oeste en el Caribe y del este en el Pacífico.

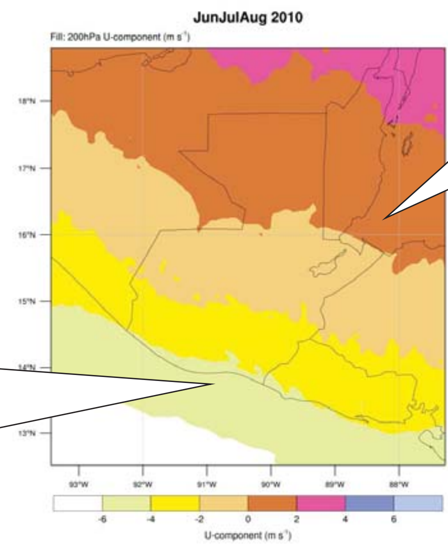


EL NIÑO U200 (JJA-2002)



Vientos con componente del oeste en todo el país.

LA NIÑA U200 (JJA-2010)

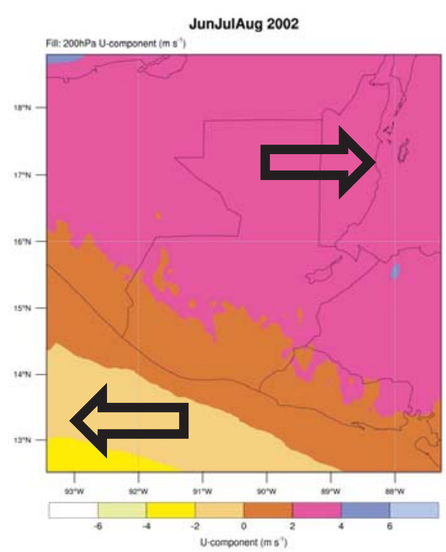


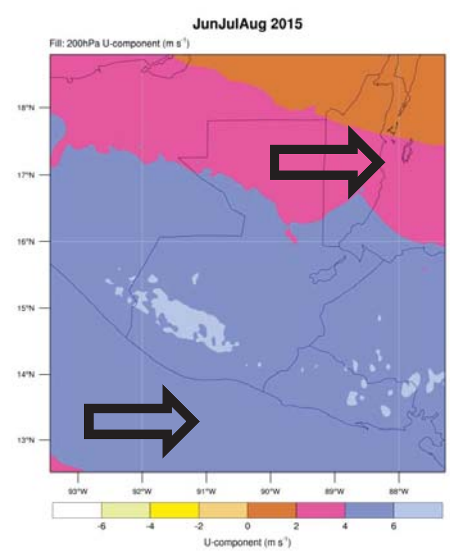
En el Caribe, viento del oeste ligeramente menor a la clima

En la costa del Pacífico vientos con componente del este mayor a la clima.

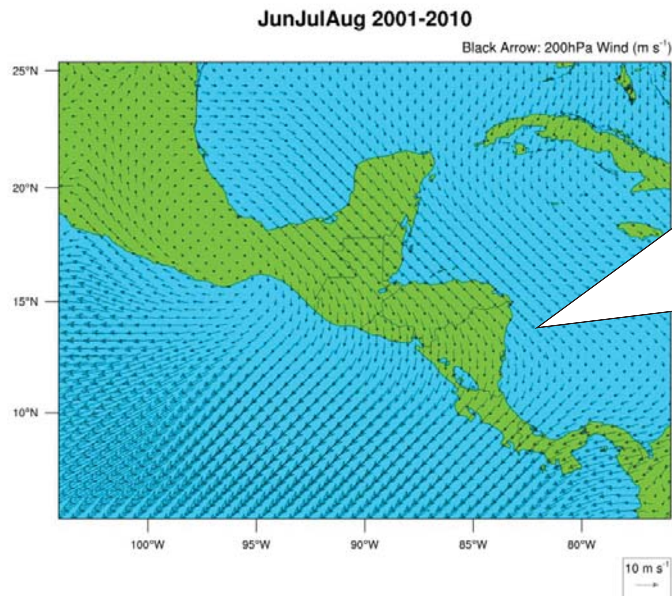
U200 (JJA)

EL NIÑO 2002 VS EL NIÑO 2015



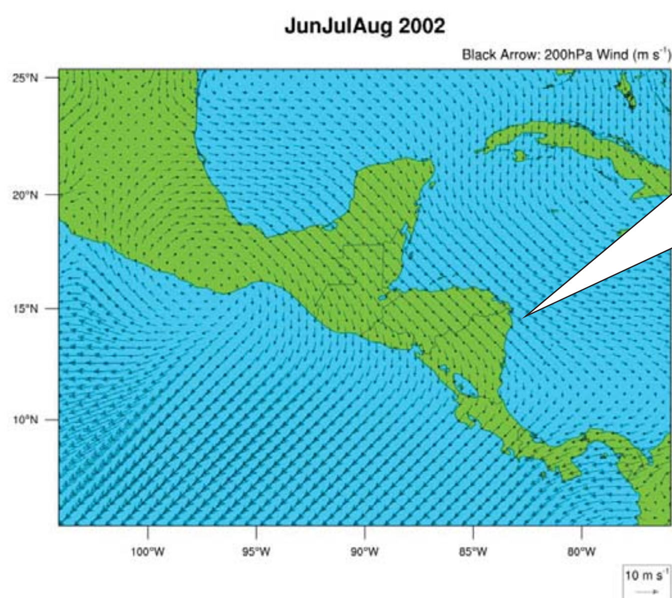


Climatología
2001-2010
Viento
200 hPa



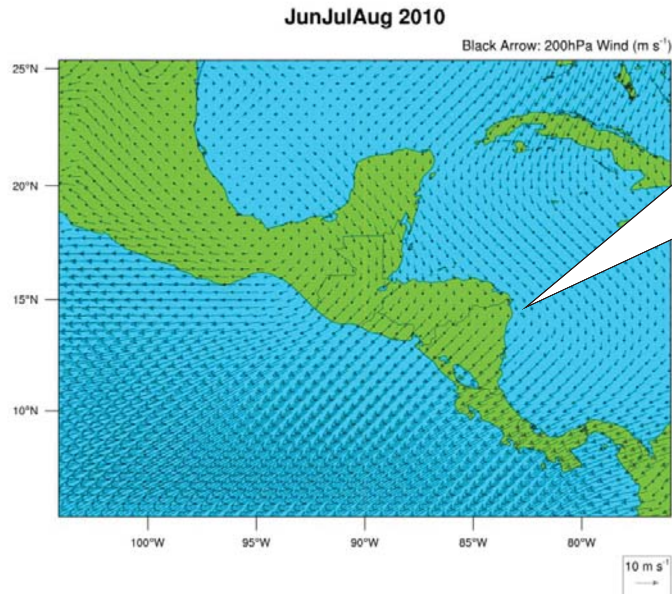
En el Caribe y norte de Centroamérica predominan vientos del norte y noroeste. Al sur y el Pacífico los vientos son del noreste

El Niño
2002
Viento
200 hPa



El patrón es el mismo que la clima, pero con magnitudes más bajas.

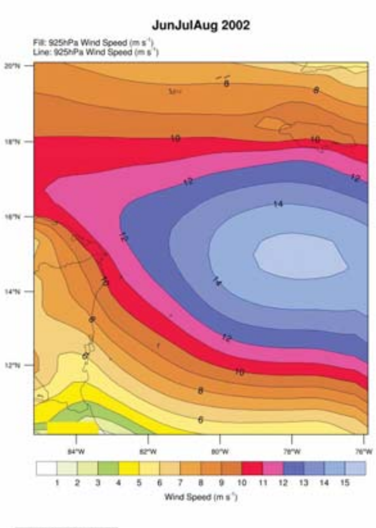
La Niña
2010
Viento
200 hPa

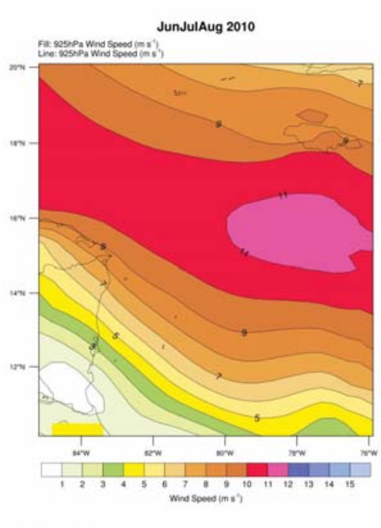


El patrón es el mismo que la clima, pero con magnitudes más altas.

CORRIENTE EN CHORRO DEL CARIBE

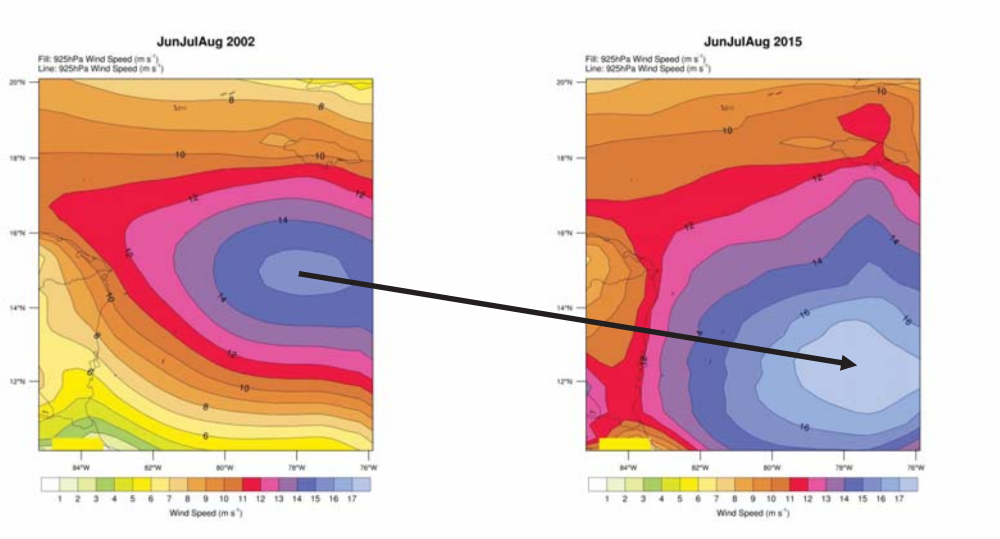
EL NIÑO 2002 VS LA NIÑA 2010





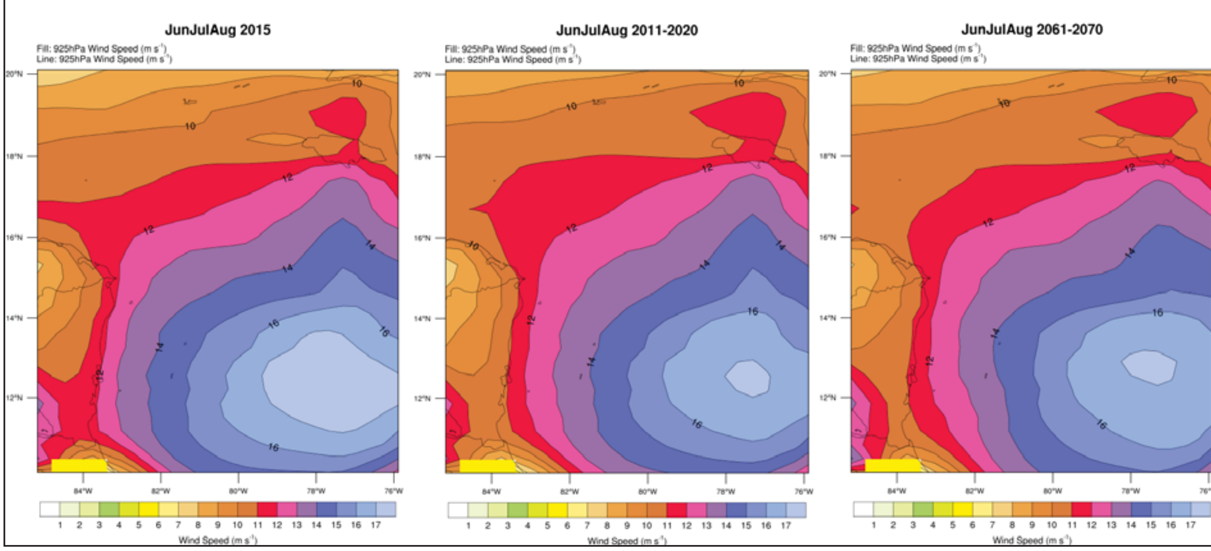
CORRIENTE EN CHORRO DEL CARIBE

EL NIÑO 2002 VS EL NIÑO 2015

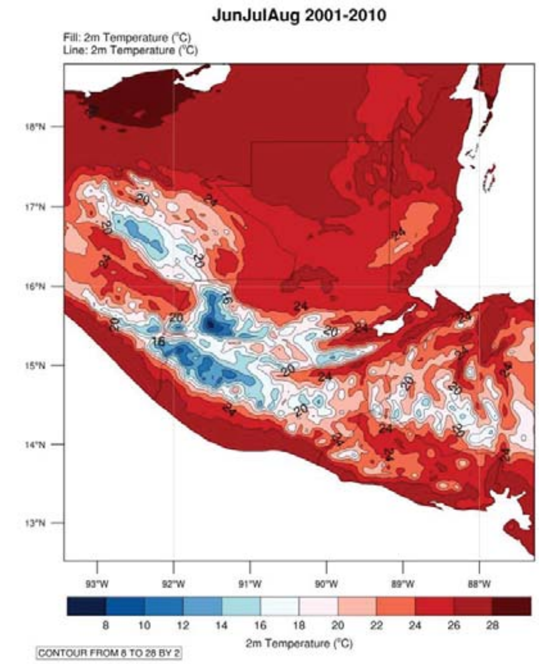


CORRIENTE EN CHORRO DEL CARIBE

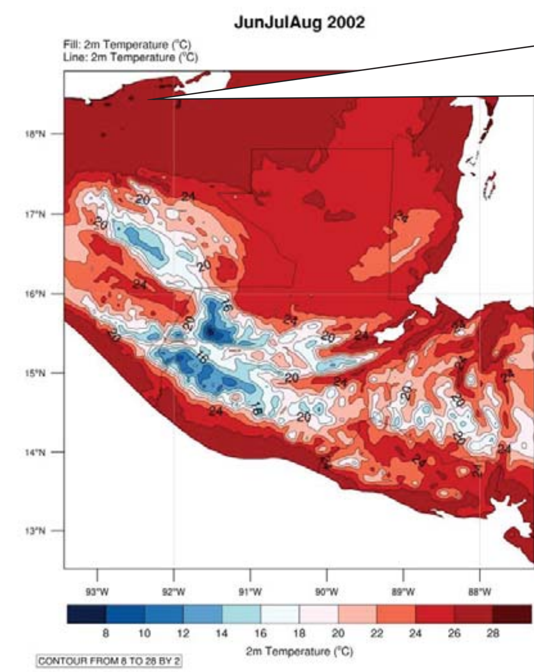
2015 2010´s 2060´s



Climatología
2001-2010
Temperatura 2m

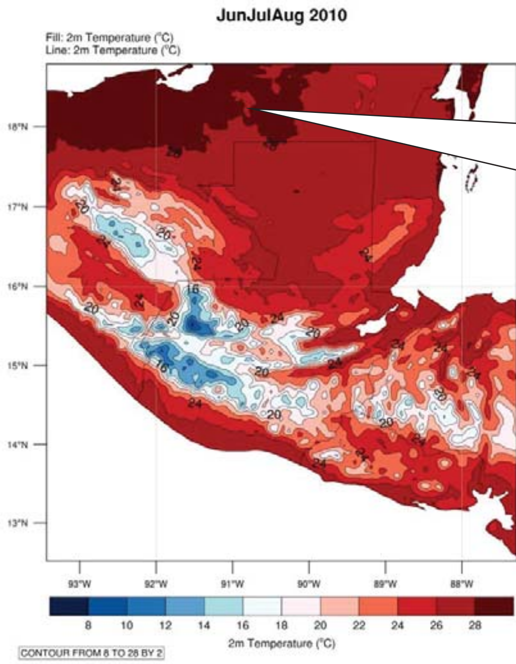


El Niño 2002
Temperatura 2m



La temperatura media en las zonas aledañas al golfo de México son menores a la climatología

La Niña 2010 Temperatura 2m



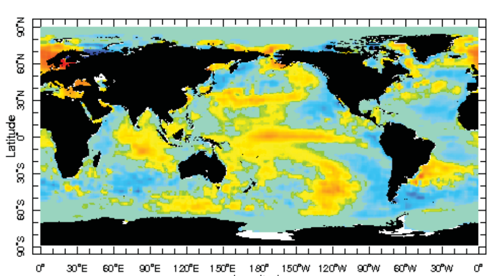
La temperatura media en las zonas aledañas al golfo de México son mayores a la climatología

Durante la Niña la temperatura aumentó!!

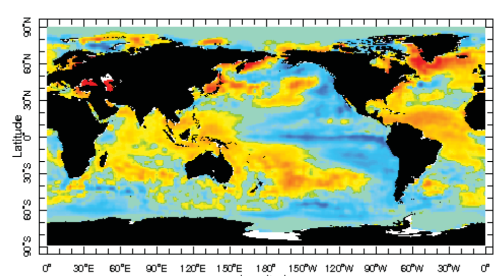
El calentamiento global opacó y superó la señal de enfriamiento de la Niña.

Anomalías TSM

2002



2010



VERIFICACIÓN DE LA HABILIDAD DEL MODELO WRF PARA SIMULAR LA ALTERACIÓN CLIMÀTICA EN EL VERANO DE GUATEMALA

Luis Alvarado, Gaby Alfaro, Franklyn Ruiz, Juan José Nieto, Alberto Cumbrera
Program to Strengthen Institutional Capacity to better asses Climate Impacts in latin America and the Caribbea (LAC) - Regional Consortium – Workshop 1
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RESUMEN

El presente trabajo tuvo como objetivo revisar si la salida en alta resolución obtenida con el modelo WRF del re-análisis NCEP, tuvo la habilidad de simular la dinámica del evento ENSO (El Niño- Southern Oscillation) y la alteración de la precipitación y la temperatura en la época de verano para Guatemala. Para ello, se utilizaron las salidas gráficas, de las variables meteorológicas, que se pueden generar a partir del aplicativo ubicado en http://weather.unl.edu/RCM/Guatemala/Phase2/maps/mapmaker.html para la serie de tiempo 2001-2010. Los resultados permiten ver cambios en la dinámica de los vientos en niveles bajos y altos de la atmósfera en las fases extremas del ENSO. Descenso (ascenso) de las precipitaciones con respecto a la climatología de referencia en el fenómeno El Niño (La Niña) considerados. No obstante, bajo los dos eventos extremos del ENSO para el caso de la temperatura del aire, el modelo resolvió valores por encima de lo normal respecto al promedio de verano 2001-2010, posiblemente asociado a la señal tendencial y de largo plazo asociado al actual cambio climático.

INTRODUCCIÓN

Uno de los eventos climáticos de mayor impacto en Guatemala es el fenómeno de El Niño, con importantes implicaciones en el clima, que se ha reflejado en la variación de los regímenes de lluvia. Bajo eventos severos se ha registrado una disminución importante en los acumulados de lluvia el inicio de la época lluviosa, con implicaciones de menor disponibilidad de agua, incendios, etc.

El fenómeno se ha asociado a mayor incidencia de frentes fríos, aumento del número de huracanes en el Pacífico mientras que disminuyen en el Atlántico, Caribe y golfo de México, tal como se ha venido observando en los últimos años.

Estas condiciones atmosféricas causan inundaciones importantes en las cuencas de los ríos, principalmente las correspondientes a la vertiente del Pacífico, las cuales se ven agravadas por la alta vulnerabilidad de muchas zonas pobladas establecidas en áreas de alto riesgo como márgenes de ríos y laderas propensas a deslizamientos. Al igual que a muchos otros países, este impacto climático podría ocasionar una gran catástrofe, difícil de superar.

El Niño es un fenómeno climático relacionado con el calentamiento del Pacífico oriental ecuatorial, el cual se manifiesta erráticamente cíclico, que consiste en realidad en la fase cálida del patrón climático del Pacífico ecuatorial denominado El Niño-Oscilación del Sur (El Niño-Southern Oscillation, ENSO por sus siglas en inglés), donde la fase de enfriamiento recibe el nombre de La Niña. Este fenómeno, en sus manifestaciones más intensas, provoca estragos en la zona intertropical y ecuatorial debido a las intensas lluvias, afectando principalmente a la región costera del Pacífico de América del Sur.

Físicamente El Niño es una irrupción ocasional de aguas superficiales cálidas, ubicadas en el océano Pacífico junto a la costa de los territorios de Perú y Ecuador, debido a inestabilidades en la presión atmosférica localizada entre las secciones Oriental y Occidental del océano Pacífico cercanas a la línea del Ecuador. El fenómeno del Niño es el supuesto causante de más de una anomalía climática. El meteorólogo Jacob Bjerknes postuló en 1969 que El Niño está normalmente relacionado con la Oscilación del Sur, ya que está presente una relación física entre la fase de alta presión anómala en el Pacífico occidental, con la fase de calentamiento poco frecuente del Pacífico oriental, lo que va acompañado con un debilitamiento de los vientos alisios del este; por lo que la baja presión del Pacífico occidental se vincula con un enfriamiento del Pacífico oriental (fenómeno de La Niña), con el fortalecimiento de los vientos del este.

DATOS UTILIZADOS Y METODOLOGÍA

Para este proyecto piloto se utilizaron como datos de entrada los resultados publicados de la corrida del re-análisis NNRP en alta resolución realizada con el modelo WRF para la serie de tiempo 2001-2010, la cual presenta sus resultados en el siguiente enlace web: http://weather.unl.edu/RCM/Guatemala/Phase2/maps/mapmaker.html. Dichas salidas están disponibles en tres resoluciones espaciales: 36kmX36km (transición), 12kmX12km (Regional) y 4kmX4m (Guatemala) tal como se muestran en la Fig. 1. La resolución espacial es a nivel mensual, sin embargo, para este proyecto piloto se analizó el ciclo correspondiente al verano del Hemisferio Norte para Guatemala (Junio-Julio-Agosto JJA). No sobra mencionar que este sitio web además de lo anterior, presenta salidas para 14 variables de superficie, 9 variables en altura; 10 parámetros de superficie y 3 de suelo.

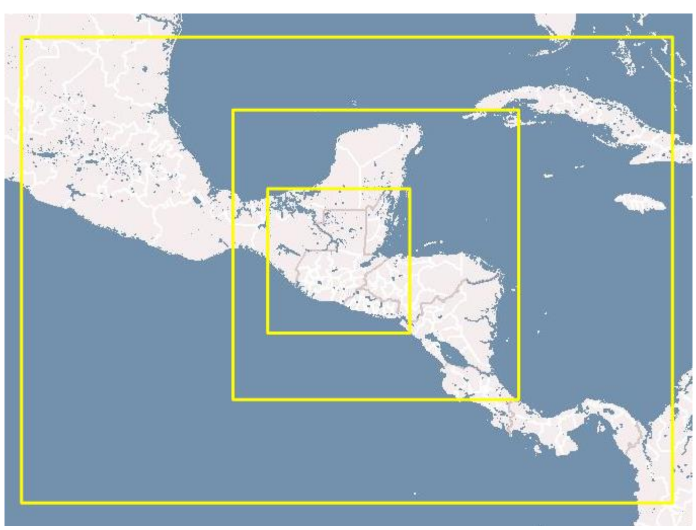


Figura 1. Dominios utilizados

Se tomó como climatología de referencia el promedio 2001-2010 para el trimestre JJA y revisando el principal indicador de variabilidad climática que define las fases extremas del ENSO a nivel mundial, Índice Oceánico El Niño (ONI por sus siglas en inglés), se escogieron como año El Niño, 2001, y como año La Niña, 2010 para los análisis finales.

Teniendo en cuenta que la idea fue identificar si las fases extremas asociadas al evento ENSO la simularon estos resultados en alta resolución, se procedió primero con el dominio más amplio (36kmX36km) a explorar el comportamiento de los vientos en niveles bajos (700 hPa.) y en niveles bajos (200 hPa.) para ver si al menos en la costa occidental de Centroamérica, patrones de circulación general relacionados con la Celda de Walker en sus tres fases de ENSO (El Niño, Neutral, La Niña) eran representadas por el modelo.

Una vez revisados los procesos con la parte atmosférica que explica el ENSO, se precedió a revisar la alteración de los campos de precipitación y temperatura del aire debida a los cambios de circulación del viento para Guatemala con el dominio de más alta resolución (4kmX4m).

RESULTADOS

La climatología resuelta por el WRF con datos de re-análisis de NCEP en el campo del viento en altura (200 hPa.) indica que sobre el Pacífico Tropical predominan vientos del oeste, mientras que en el mar Caribe hasta la costa Pacífica de Centroamérica el viento dominante es del este (Ver Fig. 2); en niveles bajos (850 hPa.) predominan vientos del norte y noroeste en el Caribe y norte de Centroamérica. Al sur y el Pacífico los vientos son del noreste (Ver Fig. 3).

La salida del modelo sugiere que cuando El Niño ocurre, el viento en niveles altos mantiene el mismo patrón con intensidades de la velocidad del viento menores que la climatología de referencia; entre tanto, cuando La Niña se presenta, se intensifica la dinámica de la condición neutral. Para los niveles bajos, y en la época de El Niño, el viento del este aumenta en toda la región mientras que cuando La Niña ocurre, en el Pacífico colapsan los vientos del este y son sustituidos por vientos del sur-oeste

Lo anterior sugiere que la simulación está de acuerdo con la Circulación de Walker para la situación del ENSO en condiciones de neutralidad e incluso para sus fases extremas (El Niño – La Niña) en los campos de viento en altura; no obstante, en niveles bajos, su comportamiento es errático y contrario al modelo conceptual de este fenómeno de interacción océano-atmosfera de escala interanual.

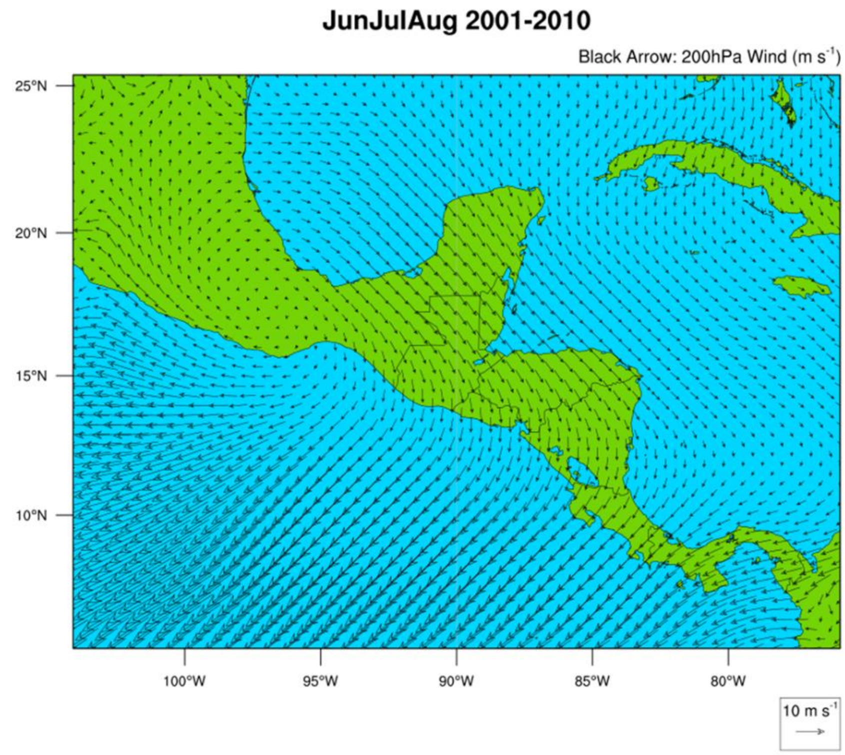


Figura 2. Vientos en niveles altos (200 hPa)

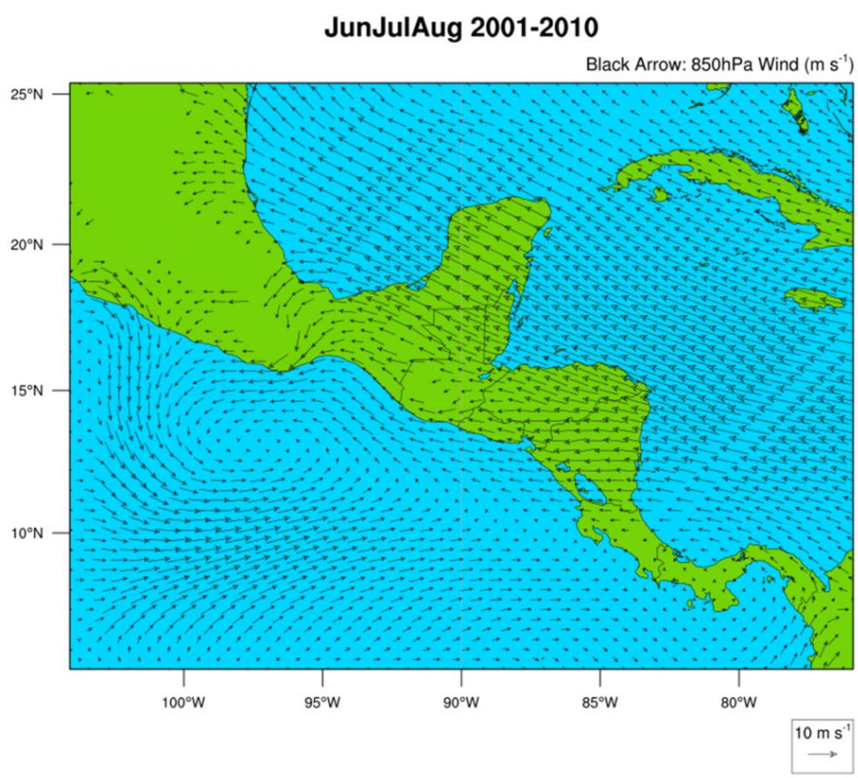


Figura 3. Vientos en niveles bajos (850 hPa.)

Como respuesta a esta dinámica, la temperatura de aire en verano y bajo las fases extremas del ENSO para Guatemala presentó un aumento de sus valores con respecto al período de referencia 2001-2011 como se presenta en la Fig. 4, sin embargo, se esperaba que bajo el fenómeno La Niña las temperaturas decrecieran sus valores respecto al clima normal, no obstante, se encontró una respuesta contraria en la simulación. Lo anterior puede deberse a que al año 2010 fue el tercer año más caliente de acuerdo con la OMM después de 2015 y 2014 respectivamente y, por lo tanto, este hecho puede obedecer al rápido aumento de la temperatura del aire debido al incremento de emisiones de gases de efecto invernadero a escala global reportados en los distintos informes de evaluación del Panel Intergubernamental de Cambio Climático.

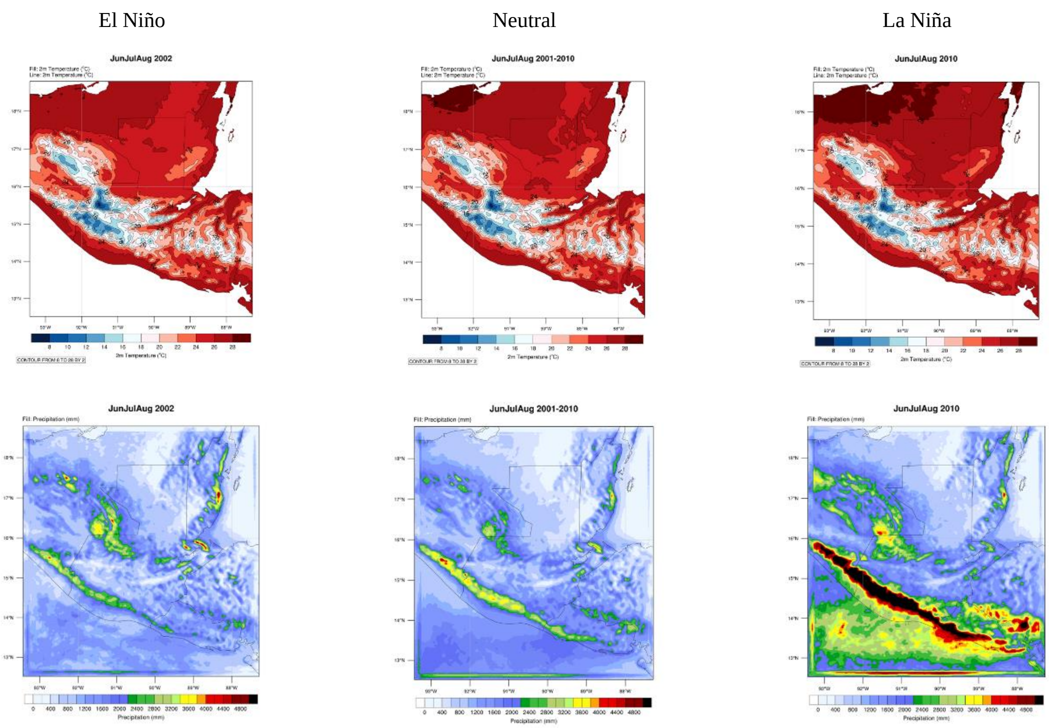


Figura 4. Temperatura del aire (superior) y precipitación (inferior) bajo las tres fases de ENSO

Para el caso de la precipitación, la salida del modelo WRF represento la señal que se esperaba; mostrando descenso en las cantidades de precipitación bajo el fenómeno El Niño y aumento de las mismas bajo condiciones La Niña.

CONCLUSIONES Y RECOMENDACIONES

1. La salida del modelo WRF para simular clima presente, mostró que fue capaz de resolver la dinámica de la Celda de Walker sobre la cuenca del Océano Pacífico Tropical Oriental, especialmente para la fase neutra y en el campo de viento en altura para las fases extremas (El Niño – La Niña). En niveles bajos de la atmósfera, la circulación no obedece al modelo conceptual del este fenómeno de escala interanual.

2. La salida del modelo indicó que la temperatura del aire para Guatemala aumento en las dos fases extremas del ENSO, posiblemente asociado a la señal tendencial de largo plazo asociado al cambio climático; sin embargo, es importante verificar este resultado con las observaciones para reducir incertidumbre frente al resultado obtenido en la simulación.
3. En el caso de la precipitación, la señal presentada por el modelo corresponde a lo que las observaciones han registrado bajo la influencia tanto de El Niño como de La Niña; en el primer caso reduce los volúmenes de precipitación mientras que en el segundo los aumenta respectos a sus valores de referencia.
4. Para futuros análisis se hace necesario tener corridas de períodos más largos, al menos de 20 años, para analizar este tipo de variabilidad climática interanual.
5. Es importante resaltar la verificación de la salida o resultados del modelo respecto a las observaciones, con el fin de conocer sus correlaciones, sesgos, distribuciones simuladas de las variables meteorológicas y otros estadísticos que permitan al usuario identificar habilidad del modelo y recomendar usar o no sus salidas.

1. **Definición tema de Investigación:**

Efecto del Cambio Climático en Guatemala sobre las variables meteorológicas, usando el modelo WRF

Objetivo General

Evaluación del ciclo estacional (precipitación, temperatura) y sus posibles cambios bajo escenarios de cambio climático (comparación climatología 2010 con 2060) en Guatemala.

Objetivos Específicos

- Determinación de la intensidad, duración y frecuencia de precipitación, tomando en cuenta los periodos de lluvia y canícula de Guatemala para clima presente y futuro.
- Evaluación de extremos según percentiles para temperatura.
- Evaluación del nivel de influencia de la región Niño 3.4 sobre el comportamiento de lluvia, temperatura y vientos para clima presente.
- Estudiar la distribución de las frecuencias de precipitación y temperatura para identificar y describir el comportamiento de los eventos extremos en presente y futuro.

Sugerencias para Map Maker

- Que grafique ciclos anuales y series de tiempo específicos.
- Para corridas largas que pueda calcular tendencias de índices climáticos .

Actividades:

No	Actividad	Fechas de entrega	Responsables
1	Definición tema de investigación	9 junio	TODOS
2	Elaboración de un borrador del esquema para publicación	9 junio	TODOS
3	Definir los periodods estacionales a trabajar	9 junio	TODOS
4	Verificar si el modelo captura el ciclo estacional		TODOS
	4c. Conseguir datos relaes de estaciones (2001-2010) y calcularles los ciclos en R o NCL (Skype)	9 junio	Gaby
	4a. Evaluar las estaciones que tienen observaciones para saber si se pueden utillizar	10 julio	Gaby
	4b. Descargar datos de estaciones disponibles, ponerlos en acumulados mensuales	10 julio	Alberto
5	Cálculo de anomalías para los ciclos lluviosos y de canícula (ENSO)	20 julio	Juan José
6	Análisis de eventos extremos		Frank
	6a. Calcular la distribución de frecuencias de lo observado versus lo simulado para identificar cómo representan los extremos		
	6b. Hacer histogramas de frecuencia y definir los umbrales con R Climdex en Temperaturas max y min	31 agosto	
	6c. Calcular las tendencias de índices climáticas para el clima presente.	31 julio	Juan José
7	Generación de gráficas bimensual espacial por T, lluvia y viento	10 julio	Luis
8	Análisis de la información y continuación del documento	1-29 sept	TODOS
9	Primer Borrador oficial del documento	30-Sep	TODOS

Working Group 3: Mountain Precipitation and Glaciers

(Marcos Andrade, Alan LLacza, Marcelo Oyuela, Josué Batista)

Informe de participación del Workshop del programa

Fortalecimiento de capacidades institucionales para mejorar la evaluación de los impactos del Cambio climático en América Latina y el Caribe.

(Panamá, 6 al 10 de junio del 2016)

Durante el presente Workshop se ha presentado la plataforma online MapMaker, una herramienta para el análisis de escenarios de cambio climático a nivel regional y local para países dentro de América Latina y el Caribe.

1. Objetivos:

- Conformación del grupo de estudio 3: Lluvia, incluyendo glaciares, en alta montaña.
- Evaluación de las simulaciones de modelos del CMIP5 regionalizadas dinámicamente mediante le modelo WRF disponibles en la plataforma de MapMaker.
- Generar una lista de sugerencias para la mejora de la plataforma de MapMaker.

2. Integrantes:

El grupo 3, encargado del estudio "**Lluvia, incluyendo glaciares, en alta montaña**", está conformado por 4 profesionales de Bolivia, Panamá y Perú, cuyos nombres se presentan a continuación:

	Nombre	**País**	**Institución**
1	Marcos Andrade	Bolivia	Universidad Mayor de San Adres
2	Josué Batista	Panamá	ETESA
3	Marcelo Oyuela	Panamá	CATHALAC
4	Alan LLacza	Perú	SENAMHI

3. Evaluación de MapMaker:

MapMaker es una plataforma online que permite analizar los resultados de simulaciones climáticas y evaluar el error sistemático del modelo WRF y los cambios futuros de la lluvia, temperatura y más de 15 variables adicionales.

MapMaker dispone de 3 páginas web con información para 3 dominios:

Página web	**Dominio**
http://weather.unl.edu/RCM/IDB_AR5/maps/	Desde México hasta Colombia.
http://weather.unl.edu/RCM/Guatemala/Phase2/maps/	Centro América centrado en Guatemala.
http://weather.unl.edu/RCM/Bolivia/	Sudamérica centrado en Bolivia.

Para el presente informe evaluamos la representación de la lluvia sobre el Perú, utilizando el dominio a 36km centrado en Bolivia como muestra la Figura 1. Se ha de tener presente que este es el único dominio que contiene a todo el dominio de Perú, mientras que los dominios de resolución más fina contienen solo la parte sur de Perú principalmente el Altiplano.

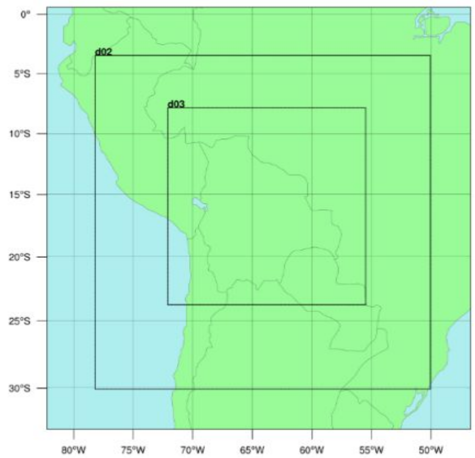


Figura 1: Dominios de simulación. d01 a 36km, d02 a 12km y d03 a 4km.

3.1. Representación de la lluvia en el periodo 2001 al 2010.

La Figura 2, representa la distribución de la lluvia para verano (diciembre, enero y febrero (DEF)) e invierno (junio, julio y agosto (JJA)), respecto a datos "observados" provenientes de PISCO (Peruvian Interpolated data of the SENAMHI's Climatological and hydrological Observations), en el periodo de 2001-2010, la cual representa la primera columna.

La segunda columna (2^{da} y 3^{ra} fila) pertenece a la simulación regionalizada del reanálisis NCEP/NCAR con el modelo WRF a una resolución espacial de 36 km (d01 en la Figura 1) realizada sobre el periodo 2001-2010. Para verano se observa una sobrestimación de la lluvia especialmente en la zona centro y sur de los Andes peruanos. Por otro lado, aparecen unos núcleos de lluvia sobre los Andes centrales desplazados hacia el sur oeste respecto a su posición climática donde se supera los 3000 metros de altitud. Adicionalmente, hay un núcleo de lluvia en la costa norte sobre una región que supera los 2400 metros. Mientras que para el invierno se presenta una sobre-estimación principalmente sobre la selva norte. Se presenta también núcleos de lluvia no presentes en el mapa de lluvia observada sobre la parte central y sur de los Andes peruanos sobre regiones que superan los 4000 metros.

La tercera columna (2^{da} y 3^{ra} fila) pertenece a la simulación regionalizada del modelo CCSM4 en el escenario de emisión RCP 8.5 con el modelo WRF a una resolución espacial de 36 km (d01 en la Figura 1) realizada sobre el periodo 2006-2015. Para verano se observa sobre-estimación de la lluvia en las mismas zonas que en la simulación con el reanalisis. Mientras que para invierno la simulación tiene una representación mas cercana a lo observado que la simulación con el reanalisis, sin embargo se mantiene la presencia de un núcleo de lluvia sobre la zona central y sur de los Andes peruanos no observada en lo observado.

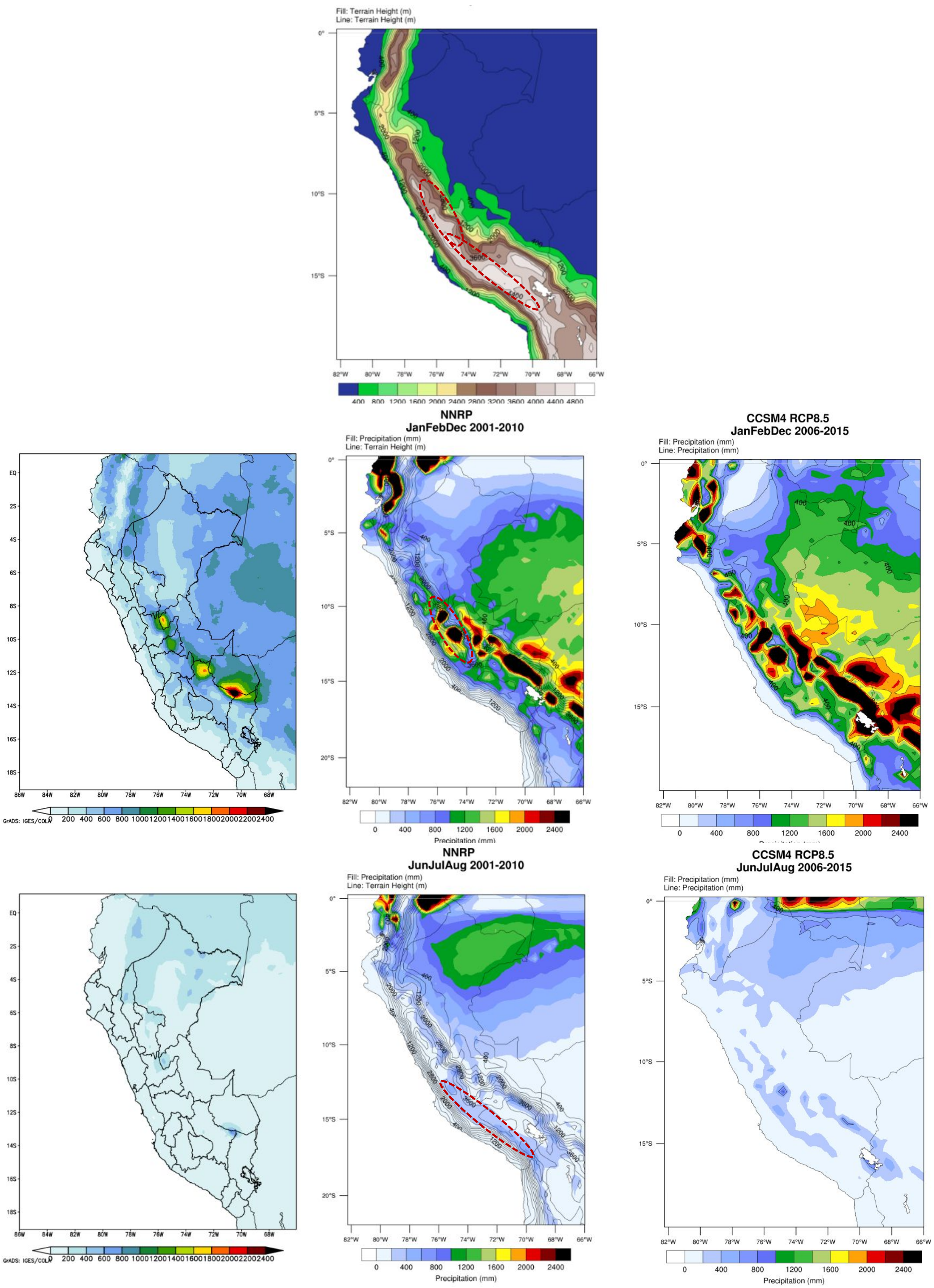
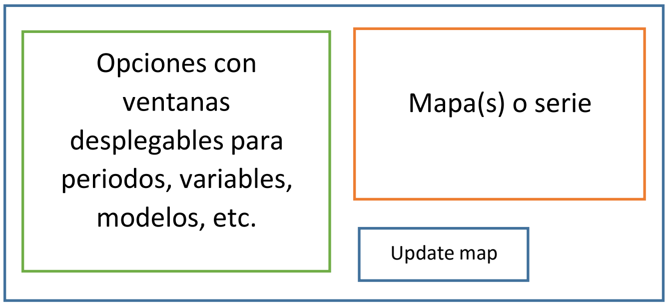


Figura 2: Topografía y Distribución climática de la lluvia para observado (izquierda), NNRP (centro) y Present-day (Derecha) para DEF (2 fila) y JJA (3 fila).

4. Sugerencias para mejora del uso de MapMaker:

Luego de la revisión de la plataforma de MapMaker, se presentan a continuación sugerencias para la mejora de las páginas:

4.1. Interface MapMaker



- La graficas debe estar en la misma página y actualizarse mediante un botón “update map”.

- Implementar ventanas desplegables para agrupar las variables.

- En “Run&Year”: Obviar la selección de cada año en el periodo futuro.

- En la opción “Month(s)”, especificar para la lluvia (sial elegir los meses se usa un acumulado o promedio.

- MapMaker debe ser una plataforma de comparación de resultados (uno o varios modelos y/o escenarios).

- Luego de generada una gráfica, debe existir la opción de descargar en formato NetCDF, Geotiff o KML).

4.2. Interfaz de descarga de datos.

Establecer como prioridad la selección de un área para la descarga de datos.

4.3. Interface Verify.

Dar prioridad a la opción de ingresar data observada para comparación.

Especificar función de la opción “data”, dentro de “Plot Modifications”.

Revisar estación Morochata (área Bolivia).

Posibilidad de 2 mapas nuevos luego de seleccionar el país: Bias, RMSE y CORR para ver distribución espacial de esas variables.

Dar información sobre el periodo y porcentaje de datos.

5. Cronograma a desarrollar:

El grupo 3, "**Lluvia, incluyendo glaciares, en alta montaña**", considera desarrollar la evaluación de la lluvia a escala mensual para el dominio de los países Panamá, Bolivia y Perú. A continuación se presenta el cronograma preliminar de trabajo desarrollado durante los días del taller:

Actividad	Julio				Agosto				Setiembre				Octubre			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Control de calidad de los datos observados	X	X														
Evaluacion de lluvia para el periodo 2001-2010 (A nivel pais) - Mapas mensuales en promedio multianual 2001 al 2010.			X	X												
Evaluacion de regiones de alta montaña (ver regiones que contengan glaciares) - 2001 al 2010 - Cada pais debe indicar el limite inferior a considerar alta montaña. - Evaluacion grillada y en punto de estacion.					X	X										
Analisis de cambios de la lluvia (2060s - 2010s) - Mapas mensuales y valores en punto de estacion.							X	X								
Analisis de la circulacion y humedad regional y su relacion con la lluvia.									X	X						
Generacion del reporte grupal.											X	X	X	X		

Este cronograma se actualizara durante el mes de junio para iniciar las actividades en el mes de julio del 2016.