Working Group 3:
Precipitation at the Altiplano in the Central Andes

Marcos Andrade: Universidad Mayor de San Andrés, Bolivia
Alan Llacza: Servicio Nacional de Meteorología e Hidrología del Perú

Tentative title: **Results from a regional high-resolution model for evaluating possible climate changes at the Central Andean region**

Resultados de un modelo regional de alta resolución espacial para la evaluación de posibles cambios del clima en los Andes centrales

Outline

1. Introduction
2. Data
3. Methodology
4. Results and discussion
5. Conclusions
6. References
7. Acknowledments
8. Annex

The regions with glaciers (above 4500 masl) have not been considered in this study. Solid precipitation has some problems and time series for those stations have not been QA/QC checked. In addition not too many stations are available for a long period

2. Description of the data

2.1. Regional model WRF

2.2. Surface data: QA/QC ok from a DECADE project (Univ. Of Bern MetoSwiss, SENAMHI's Peru and Bolivia, and UMSA)

2.3. Gridded data for precipitation (PISCO v11) and maximum and minimum temperature (Serrano et al 2017)

2.4. Winds at regional level for 200 and 850 mb from the ERA-Interim reanalysis: Aim -> moisture transport (converge and divergence)

3. Methodology

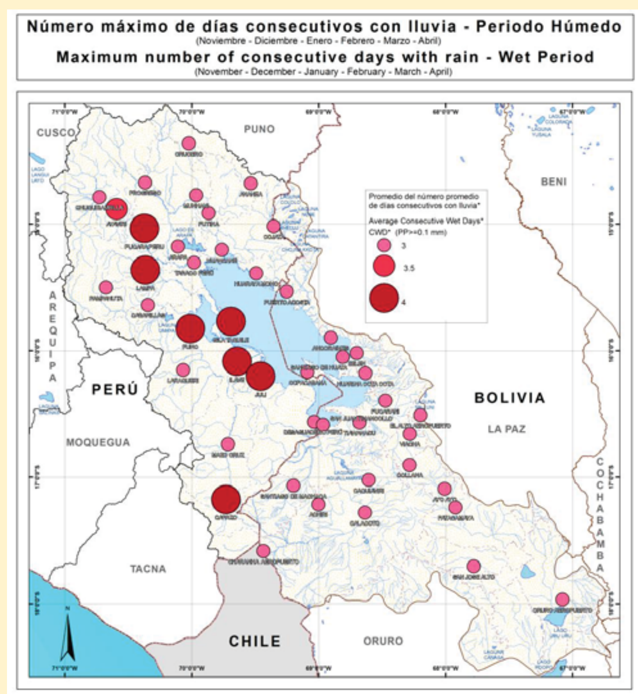
3.1. Evaluation of the model

3.1.1. Selection of the region of interest:

- Central Andes, the South American Altiplano
- There are previous works for the region,
- Other projects interested in the region
- Bi-national interest
- Observations of good quality available for the region

3.1.2 Selected period: 1981-2010

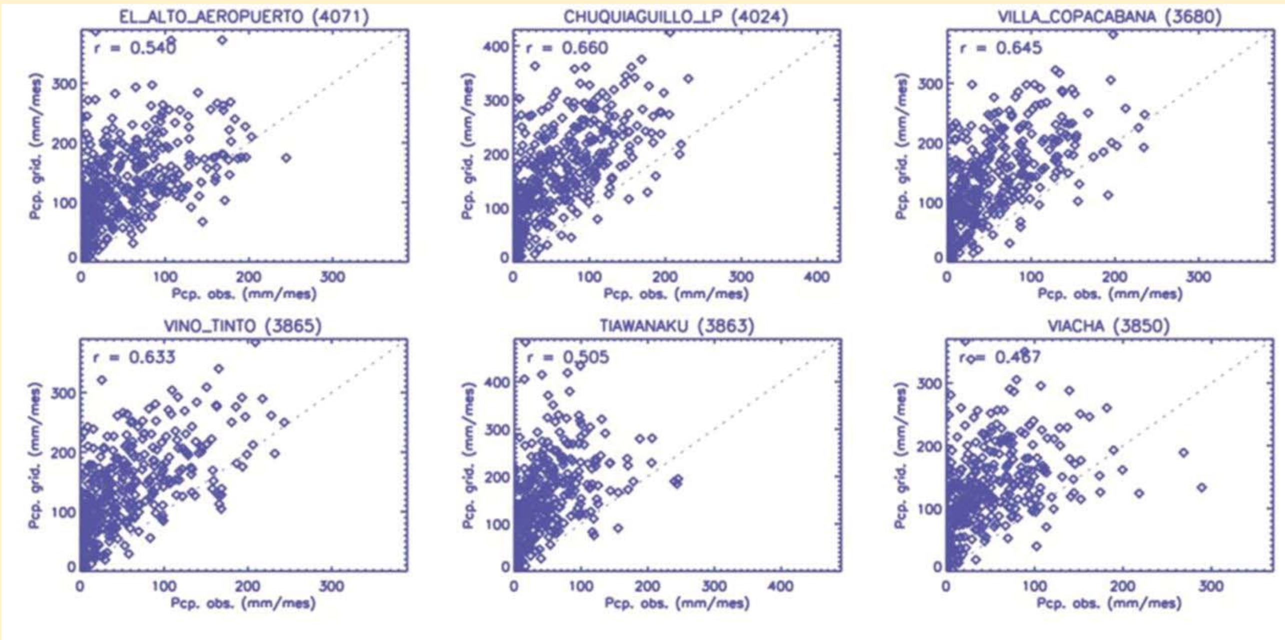
- Observational and model data available for this period



3. Methodology (cont)

3.1.3 Comparison observations vs model outputs

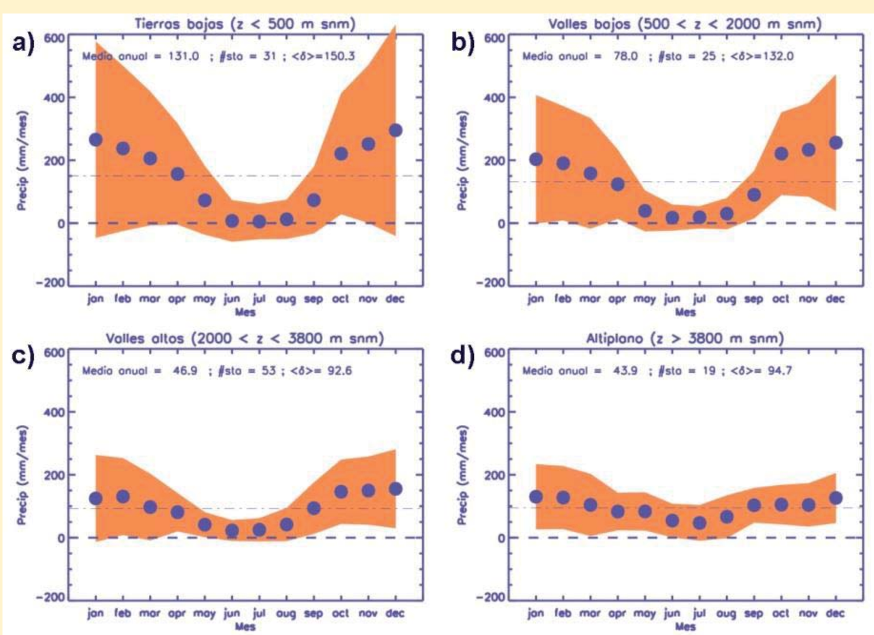
3.1.3.1 Dispersion plots for temperature and precipitation (to be updated)



3. Methodology (cont)

3.1.3 Comparison observations vs model outputs

3.1.3.2 Monthly mean differences model-observations (to be updated)



PCP

3. Methodology (cont)

3.1.3 Comparison observations vs. model outputs (Precipitation)

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D J F

M A M

J J A

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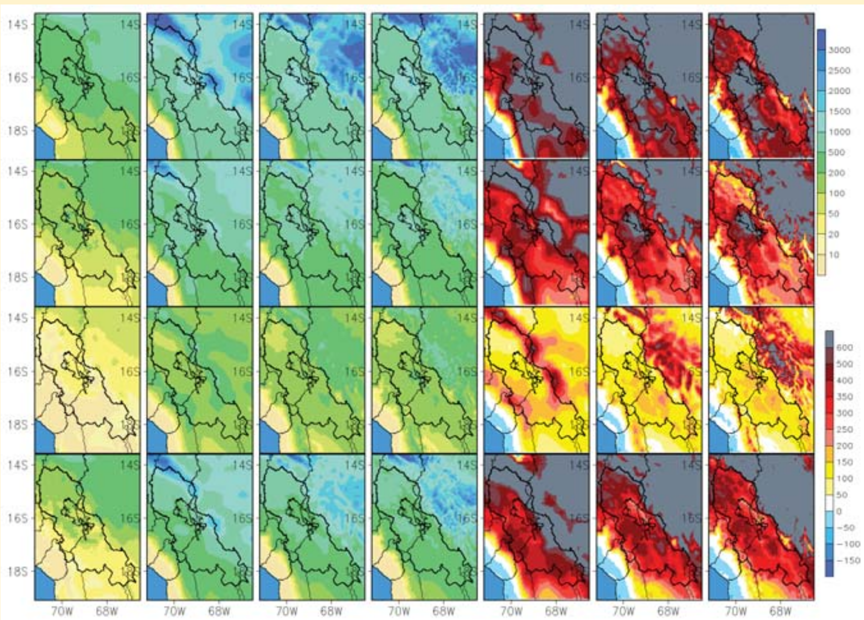

3.1.3.3 Maps of differences model-observations: monthly and by season (wet and dry)

Conclusions:

1) Hay estacionalidad
2) La mejora de la resolucion especial mejora la distribucion especial de precipitacion.
3) Hay una sobrestimacion en todos los trimestres.

3.1.3 Comparison observations vs. model outputs (Maximum Temperature)

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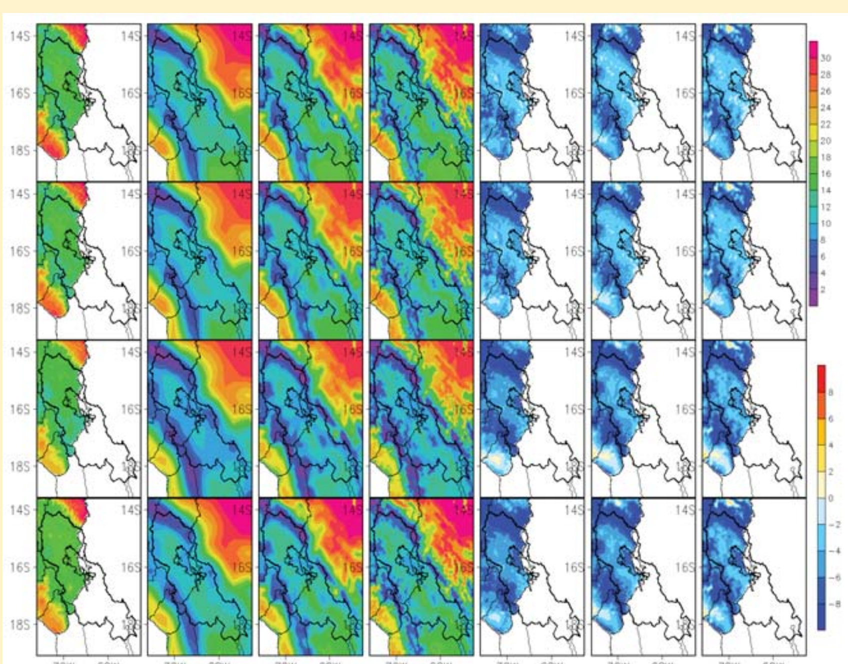
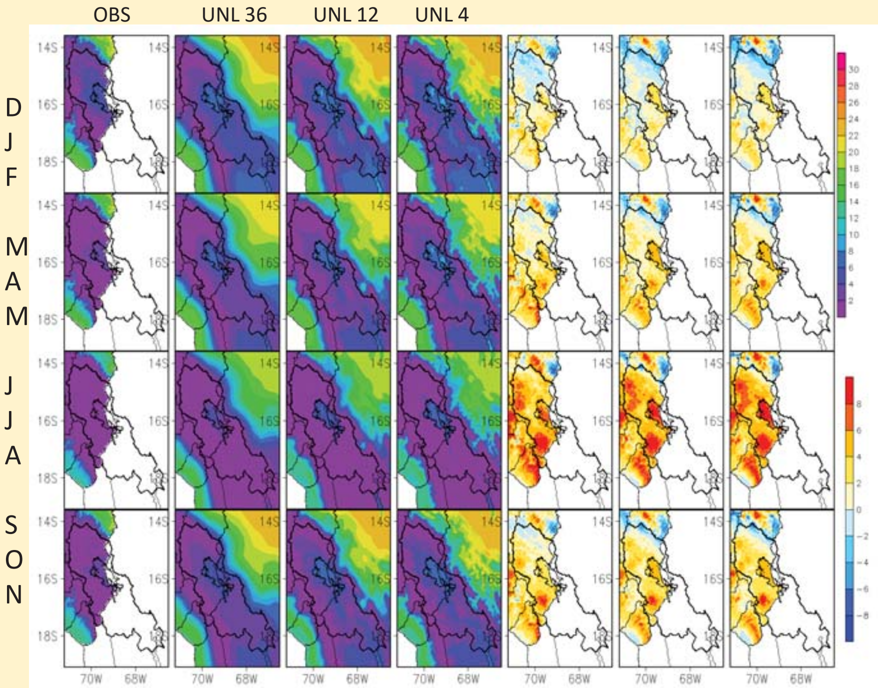


3.1.3.3 Maps of differences model-observations: monthly and by season (wet and dry)

Conclusions:

1) Hay estacionalidad.
2) Hay una subestimacion en toda el area de estudio.

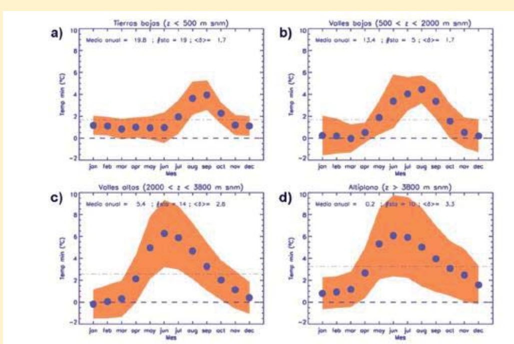
3.1.3 Comparison observations vs. model outputs (Minimum Temperature)

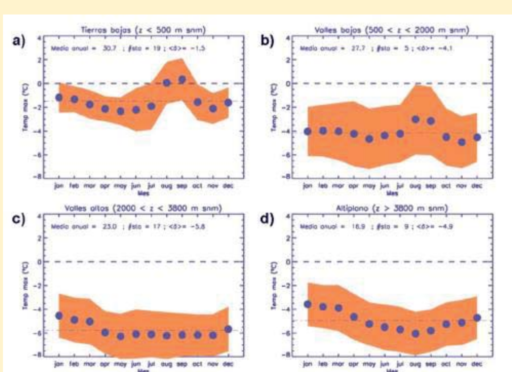


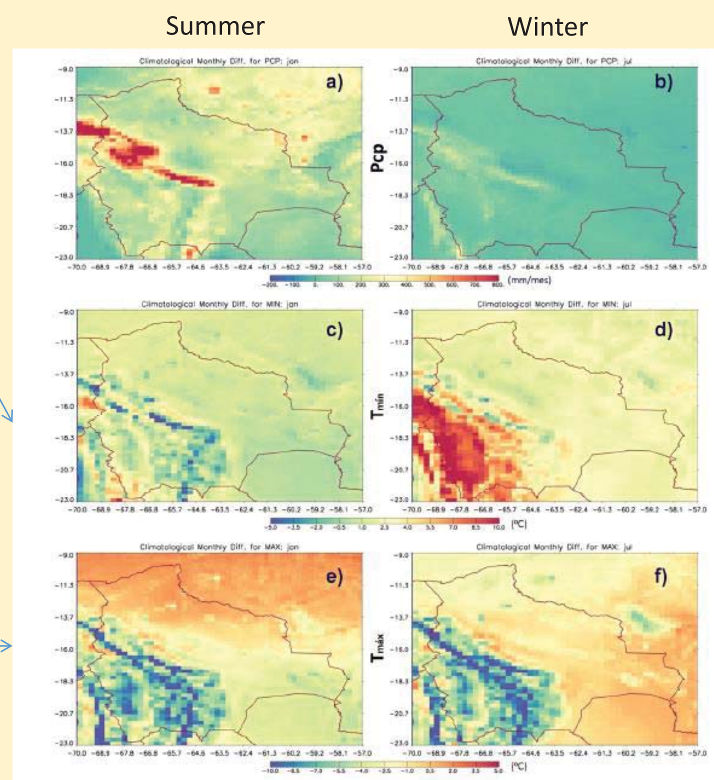
3.1.3.3 Maps of differences model-observations: monthly and by season (wet and dry)

Conclusions:

1) Hay estacionalidad.
2) Hay una sobrestimacion que depende del lugar principalmente en JJA, except en la region norte del area de studio en DJF.







3. Methodology (cont)

3.1.3 Comparison observations vs model outputs

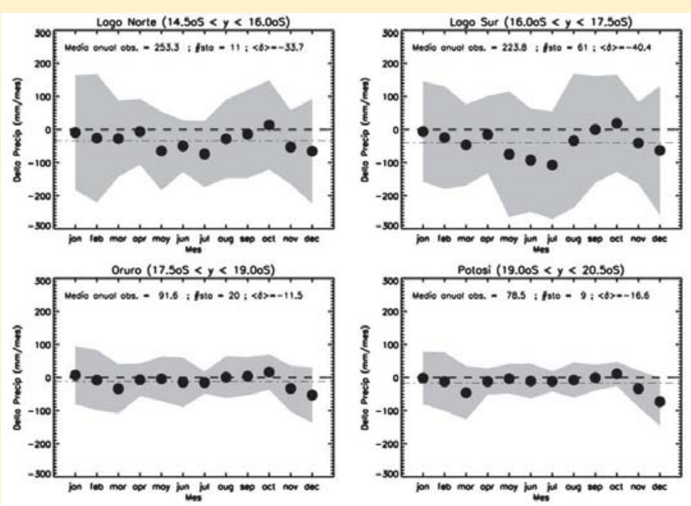
3.1.3.4. Maps of differences for winds at 200 mb

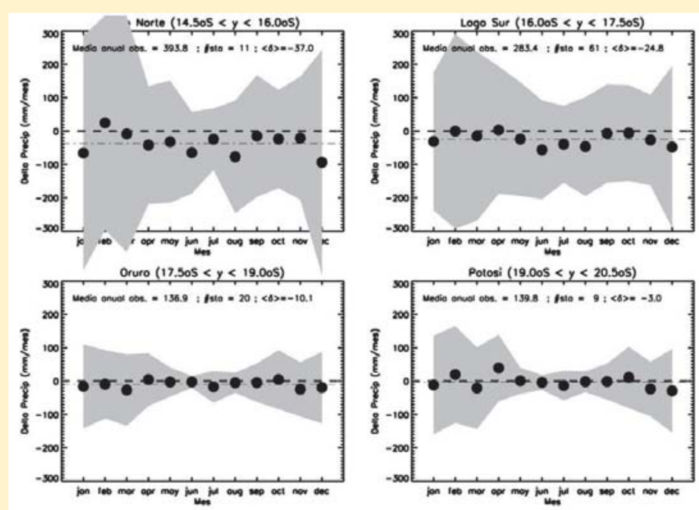
3.1.3.5. Moisture either integrated or at different levels (?)

3. Metodology (cont)

3.2 Projected changes: RCP8.5 on main text (but RCP4.5 & RCP2.6 in annex)

3.2.1. Annual evolution of monthly changes FUTURE-PRESENT (both absolute and relative for TMP and PCP respectively)



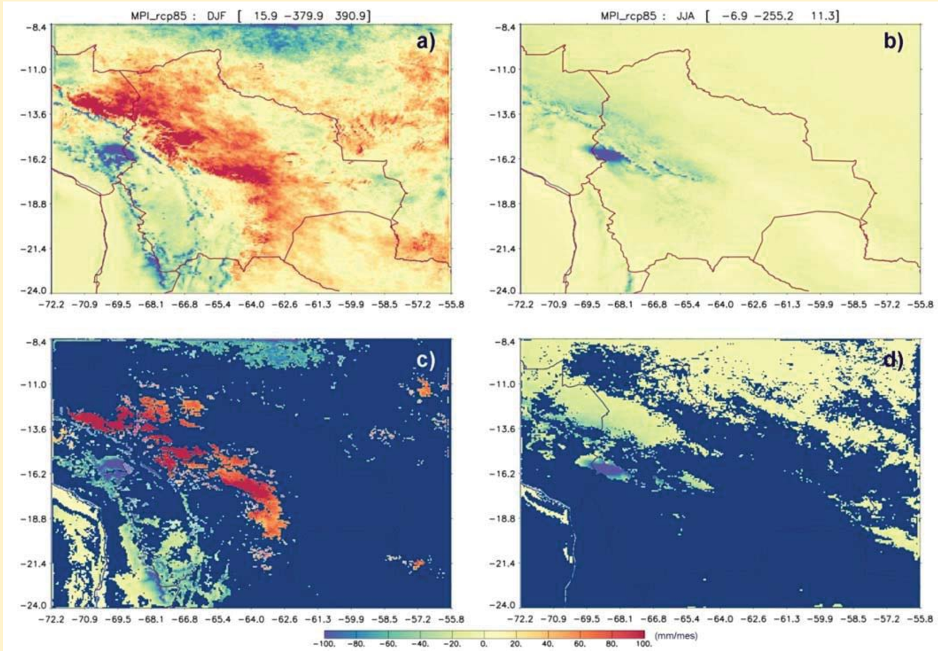


MPI **CCSM4**

3. Methodology (cont)

3.2 Projected changes: RCP8.5 on main text (but RCP4.5 & RCP2.6 in annex)

3.2.2 Maps of change both in PCP and TMP with statistical significance



4. Results and discussion

4.1. Evaluation

4.2. Differences future-present: implications

4.3. Uncertainties

Tabla 3. Valores de cambio entre futuro y presente (en mm) y en porcentaje por franja latitudinal para cada GCM forzante de WRF. Se colocan los valores promedio 9en %) por modelo o por franja.

MODELO	Lago Norte			Lago Sur			Oruro			Potosí			
	δ	Media Pres	Cambio %	δ	Media Pres	Cambio %	δ	Media Pres	Cambio %	δ	Media Pres	Cambio %	
MPI	-33.7	253.3	**-13.3**	-40.4	223.8	**-18.1**	-11.5	91.6	**-12.6**	-16.6	78.5	**-21.1**	**-16.3**
MIROC	-46.9	187	**-25.1**	-19.6	120	**-16.3**	-12.9	56	**-23.0**	-20.5	80.2	**-25.6**	**-22.5**
CCSM4	-37	393.8	**-9.4**	-24.8	283.4	**-8.8**	-10.1	136.9	**-7.4**	-3	139.8	**-2.1**	**-6.9**
			-15.9			**-14.4**			**-14.3**			**-16.3**	

	RCP2.6	RCP4.5	RCP8.5
MPI			
CCSM4			
MIROC			

5. Conclusions

6. References

7. Annex

Results for RCP2.6 and RCP4.5

About how well the models perform

IN BOX

INSIGHTS and INNOVATIONS

How Well Do Coupled Models Simulate Today's Climate?

BY THOMAS REICHLER AND JUNSU KIM

BAMS 2009

TABLE 1. Climate variables and corresponding validation data. Variables listed as "zonal mean" are latitude–height distributions of zonal averages on twelve atmospheric pressure levels between 1000 and 100 hPa. Those listed as "ocean," "land," or "global" are single-level fields over the respective regions. The variable "net surface heat flux" represents the sum of six quantities: incoming and outgoing shortwave radiation, incoming and outgoing longwave radiation, and latent and sensible heat fluxes. Period indicates years used to calculate observational climatologies.

Variable	Domain	Validation data	Period
Sea level pressure	ocean	ICOADS (Woodruff et al. 1987)	1979–99
Air temperature	zonal mean	ERA-40 (Simmons and Gibson 2000)	1979–99
Zonal wind stress	ocean	ICOADS (Woodruff et al. 1987)	1979–99
Meridional wind stress	ocean	ICOADS (Woodruff et al. 1987)	1979–99
2-m air temperature	global	CRU (Jones et al. 1999)	1979–99
Zonal wind	zonal mean	ERA-40 (Simmons and Gibson 2000)	1979–99
Meridional wind	zonal mean	ERA-40 (Simmons and Gibson 2000)	1979–99
Net surface heat flux	ocean	ISCCP (Zhang et al. 2004), OAFLUX (Yu et al. 2004)	1984 (1981) –99
Precipitation	global	CMAP (Xie and Arkin 1998)	1979–99
Specific humidity	zonal mean	ERA-40 (Simmons and Gibson 2000)	1979–99
Snow fraction	land	NSIDC (Armstrong et al. 2005)	1979–99
Sea surface temperature	ocean	GISST (Parker et al. 1995)	1979–99
Sea ice fraction	ocean	GISST (Parker et al. 1995)	1979–99
Sea surface salinity	ocean	NODC (Levitus et al. 1998)	variable

Reichler and Kim (2008)

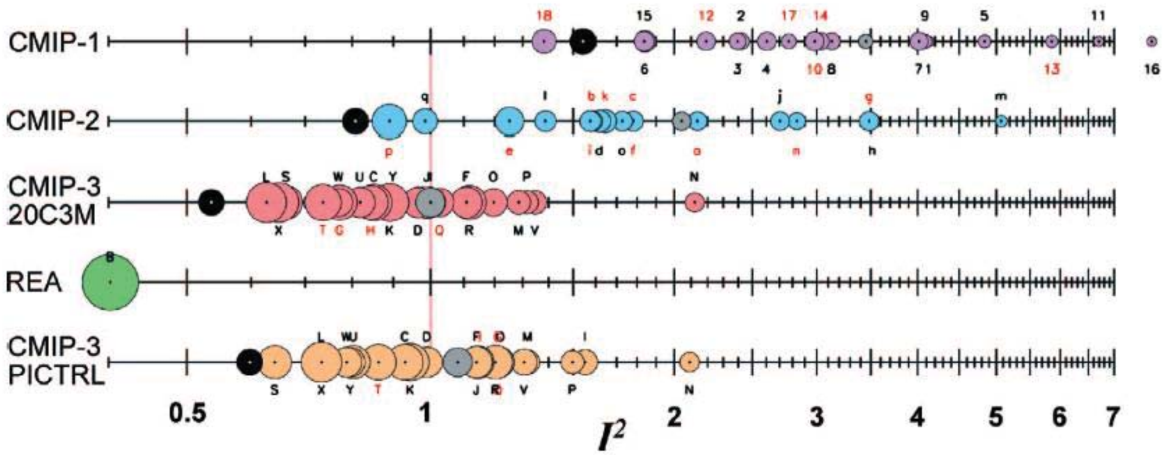
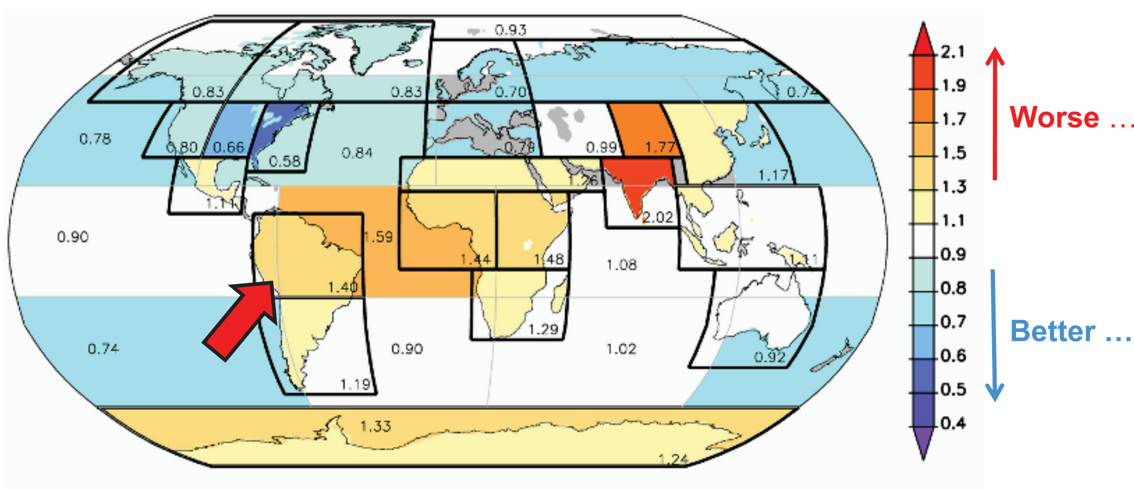


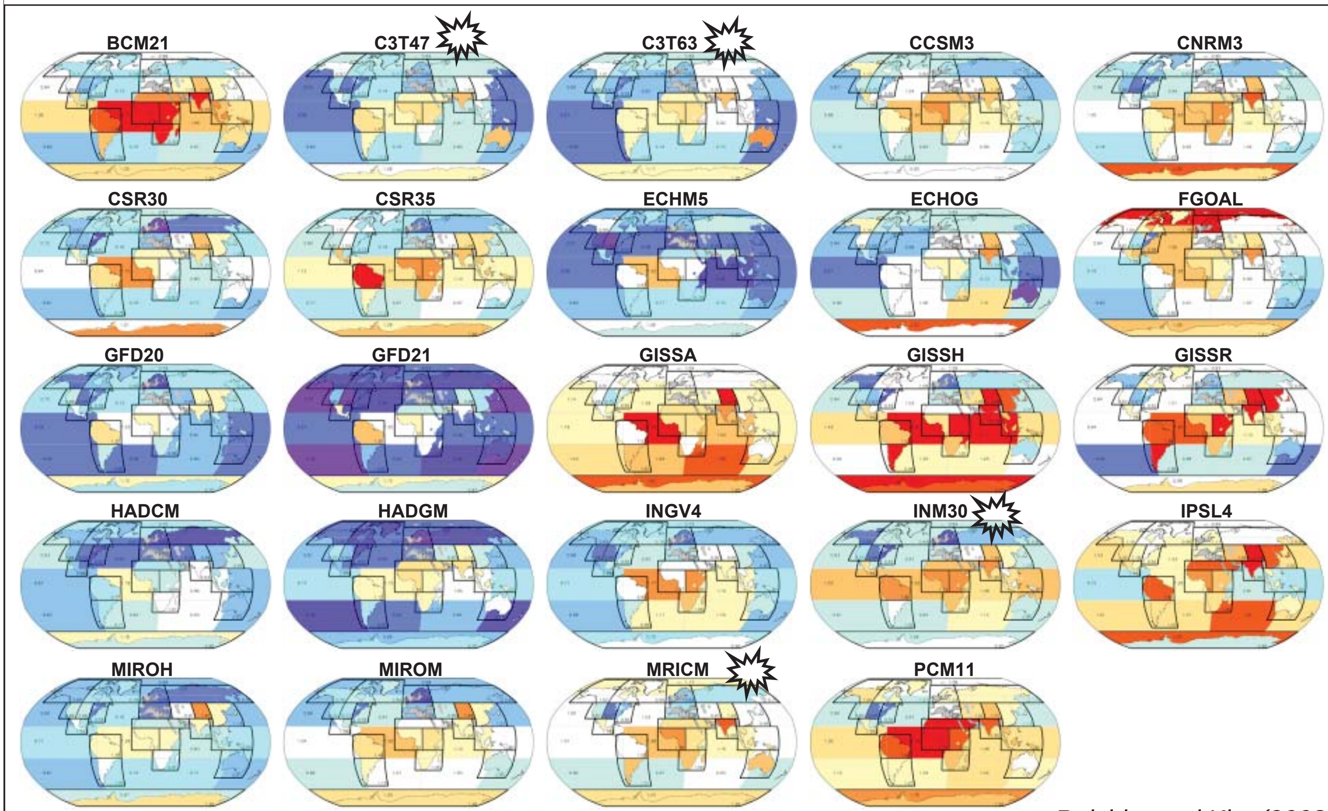
Fig. 1. Performance index I^2 for individual models (circles) and model generations (rows). Best performing models have low I^2 values and are located toward the left. Circle sizes indicate the length of the 95% confidence intervals. Letters and numbers identify individual models (see supplemental online material at doi:10.1175/BAMS-89-3-Reichler); flux-corrected models are labeled in red. Grey circles show the average I^2 of all models within one model group. Black circles indicate the I^2 of the multimodel mean taken over one model group. The green circle (REA) corresponds to the I^2 of the NCEP/NCAR reanalyses. Last row (PICTRL) shows I^2 for the preindustrial control experiment of the CMIP-3 project.

Average Model Performance



Reichler and Kim (2008)

Individual models(IPCC 2007)



Reichler and Kim (2008)

About observations used for validating model performance

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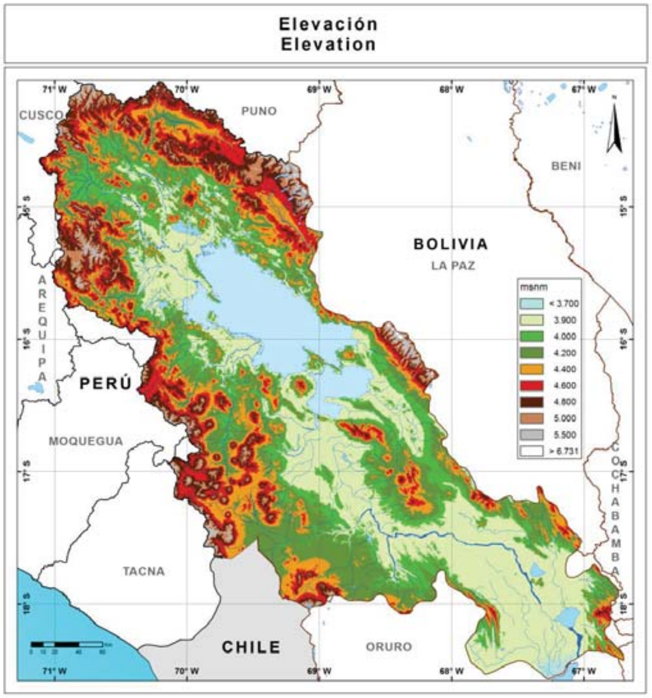
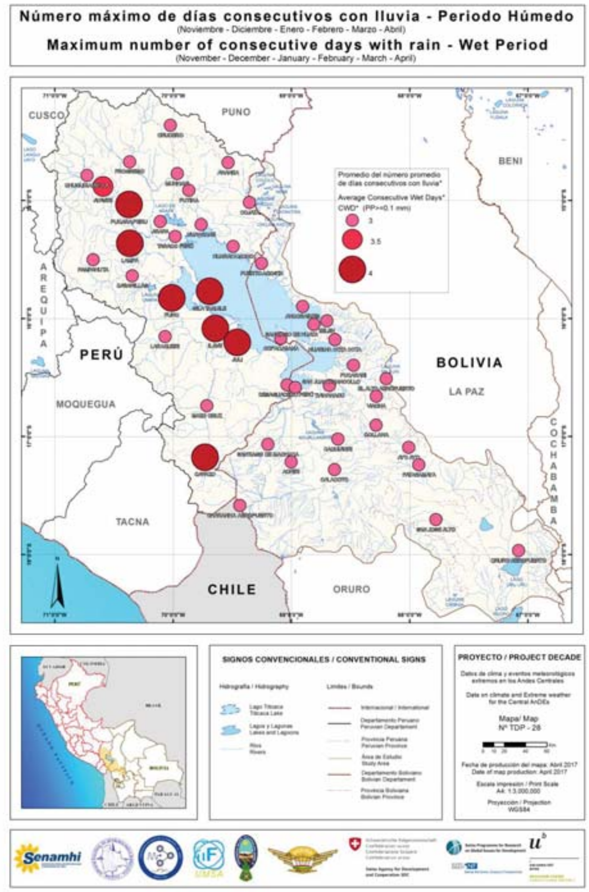
Identifying, attributing, and overcoming common data quality issues of manned station observations

Stefan Hunziker,[a,b]* Stefanie Gubler,[c] Juan Calle,[d] Isabel Moreno,[d] Marcos Andrade,[d] Fernando Velarde,[d] Laura Ticona,[d] Gualberto Carrasco,[e] Yaruska Castellón,[e] Clara Oria,[f] Mischa Croci-Maspoli,[c] Thomas Konzelmann,[c] Mario Rohrer[g] and Stefan Brönnimann[a,b]

[a] *Institute of Geography, University of Bern, Switzerland*
[b] *Oeschger Centre for Climate Change Research, University of Bern, Switzerland*
[c] *Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland*
[d] *Laboratorio de Física de la Atmósfera, Instituto de Investigaciones Físicas, Universidad Mayor de San Andrés, La Paz, Bolivia*
[e] *Servicio Nacional de Meteorología e Hidrología de Bolivia (SENAMHI), La Paz, Bolivia*
[f] *Servicio Nacional de Meteorología e Hidrología del Perú (SENAMHI), Lima, Peru*
[g] *Meteodat GmbH, Zurich, Switzerland*





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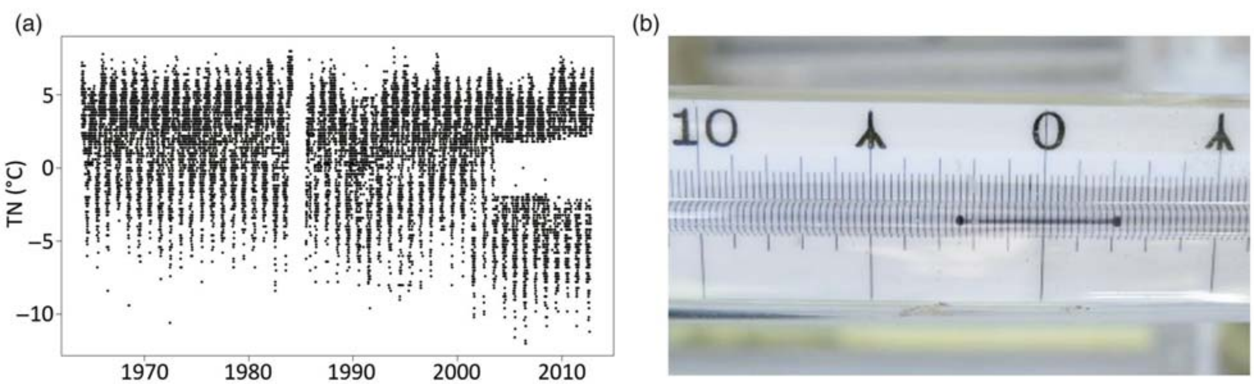

Figure 2. (a) Minimum temperature (TN) time series of Progreso (Peru). Since 2003, a missing temperature interval between approximately −2 and +2 °C is observed. (b) Liquid-in-glass minimum thermometer at the station Progreso. Values to the right of the zero point are positive, to the left negative. The temperature must be read on the right side of the rod (slightly above +2 °C for the case shown). However, if the centre of the rod was below 0 °C, the observer erroneously read the temperature on the rod's left side. Hence, the length of the rod (corresponding to about 4.2 °C) determines the missing temperature range. [Colour figure can be viewed at wileyonlinelibrary.com].

(Hunziker et al., 2017a)

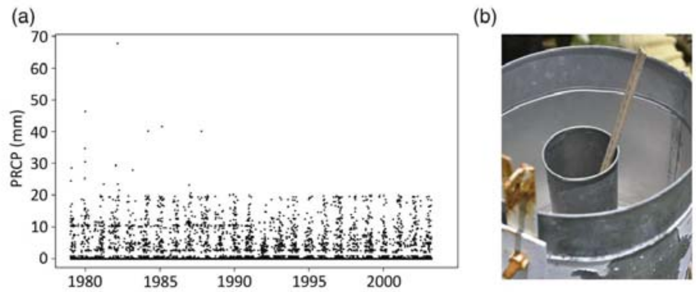

Figure 3. (a) Precipitation (PRCP) observations of the station in Aguirre (Bolivia). Only a few PRCP values above 20 mm are reported until 1988, followed by a complete truncation. The time series is temporarily affected by further errors, namely an excess of values around 10 mm and a missing interval of values between 1 and 2 mm. (b) Hellmann rain gauge as usually used by SENAMHI Bolivia. It is topped by a cone that directs the precipitation into the inner container of the instrument. Overflowing rainwater of the inner container is collected by the outer container. The observer measures precipitation by sticking a scale into the inner container and reading the water mark on the scale. The volume of the 20 cm high inner container corresponds to 20 mm of precipitation. [Colour figure can be viewed at wileyonlinelibrary.com].

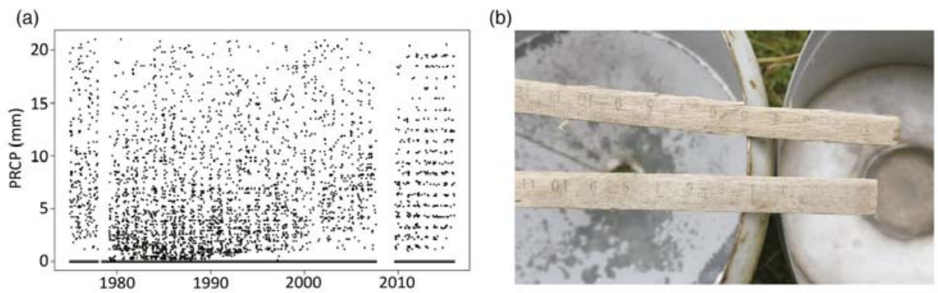

Figure 4. (a) In the data of the Bolivian station Chorocona, precipitation (PRCP) values between 0 and up to about 3 mm are largely missing until the early 1980s and from the 1990s onward. Values >21 mm are not shown in the plot. (b) Precipitation in Bolivia is measured by sticking a scale in the inner container of the Hellmann rain gauge and reading the water mark on the scale (1 cm on the scale corresponds to 1 mm of PRCP). Some scales are aged and have faded scale marks, especially towards the ends. [Colour figure can be viewed at wileyonlinelibrary.com].

(Hunziker et al., 2017a)

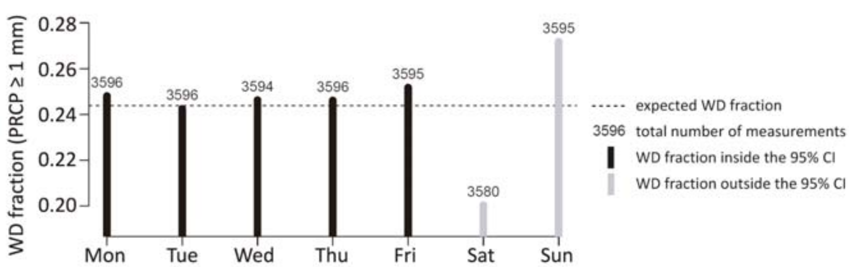

Figure 5. Fraction of wet days (WD) in San Calixto (Bolivia). WD fractions outside the 95% confidence interval (CI) are marked in grey. The fraction of WDs on Saturdays (Sundays) is significantly lower (higher) than the expectation. The number of reported measurements on Saturdays (3580) is only negligibly lower (0.4%) than on the other days of the week.

(Hunziker et al., 2017a)