Fotos: Manuel Roca

Efforts and challenges of climate modeling in Bolivia

Marcos Andrade

Laboratorio de Física de la Atmósfera
Instituto de Investigaciones Físicas
Universidad Mayor de San Andrés

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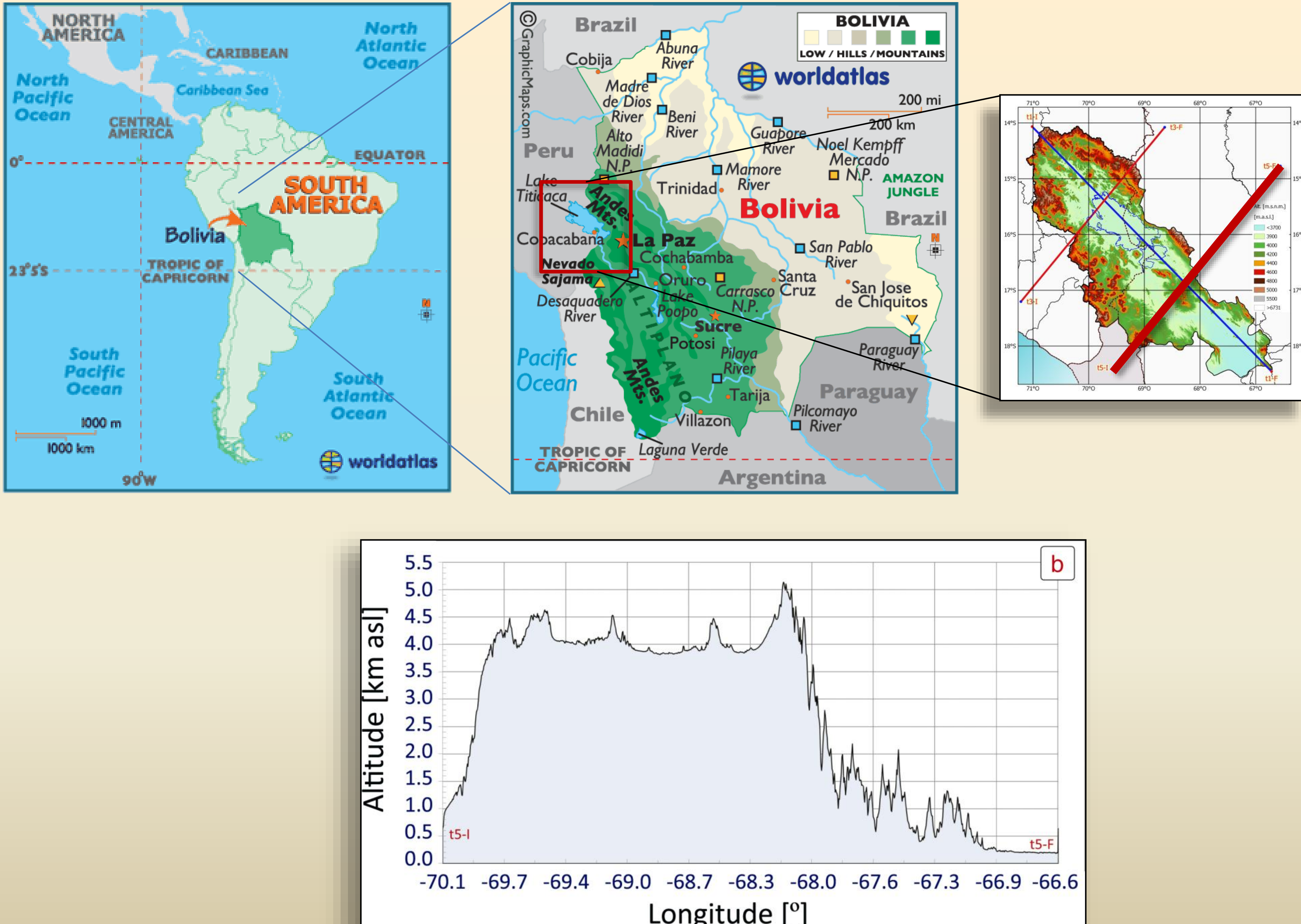
Introduction

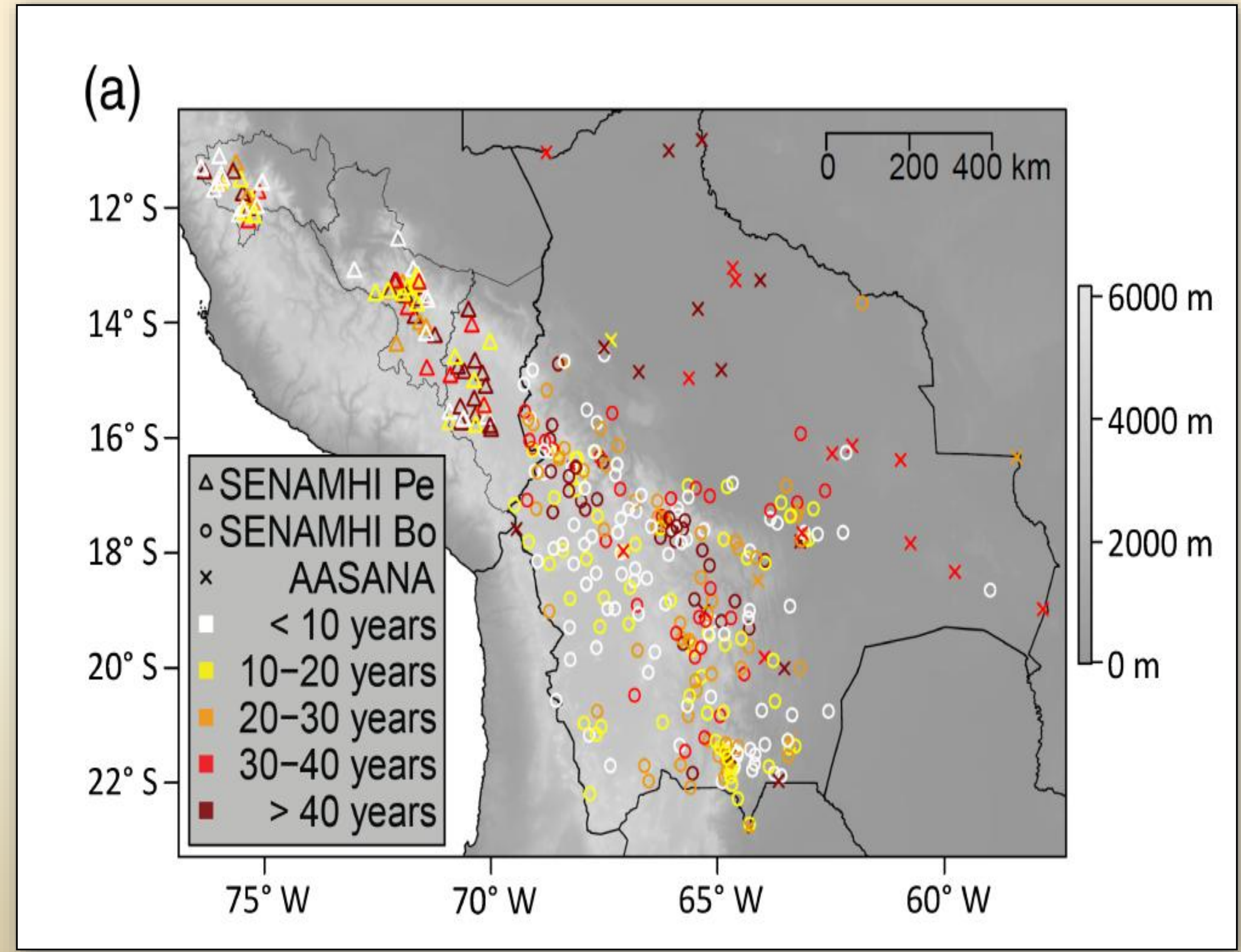
- Bolivia has an extended territory: 1 098 581 km^2
- Only ~11 million of inhabitants (5 living in the three main cities)
- Complex topography with large altitudinal gradients: Andes to lowlands
- Tropical physics and dynamics


NORTH AMERICA
CARIBBEAN
North Atlantic Ocean
North Pacific Ocean
Caribbean Sea
CENTRAL AMERICA
EQUATOR
0°
SOUTH AMERICA
Bolivia
23°5'S
TROPIC OF CAPRICORN
South Pacific Ocean
South Atlantic Ocean
1000 m
1000 km
90°W
worldatlas
©GraphicMaps.com
Brazil
BOLIVIA
LOW / HILLS / MOUNTAINS
worldatlas
200 mi
200 km
Cobija
Abuna River
Madre de Dios River
Beni River
Alto Madidi N.P.
Guapore River
Noel Kempff Mercado N.P.
AMAZON JUNGLE
Peru
Lake Titicaca
Andes Mts.
Trinidad
Mamore River
Bolivia
Brazil
Copacabana
La Paz
Cochabamba
San Pablo River
Nevado Sajama
Oruro
Carrasco N.P.
Santa Cruz
San Jose de Chiquitos
Desaquadero River
Lake Poopo
ALTIPLANO
Sucre
Potosi
Pilaya River
Paraguay River
Pacific Ocean
Andes Mts.
Tarija
Paraguay
Chile
Villazon
Pilcomayo River
TROPIC OF CAPRICORN
Laguna Verde
Argentina
b
Altitude [km asl]
Longitude [º]
t5-I
t5-F
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-70.1
-69.7
-69.4
-69.0
-68.7
-68.3
-68.0
-67.6
-67.3
-66.9
-66.6

Introduction (cont.)

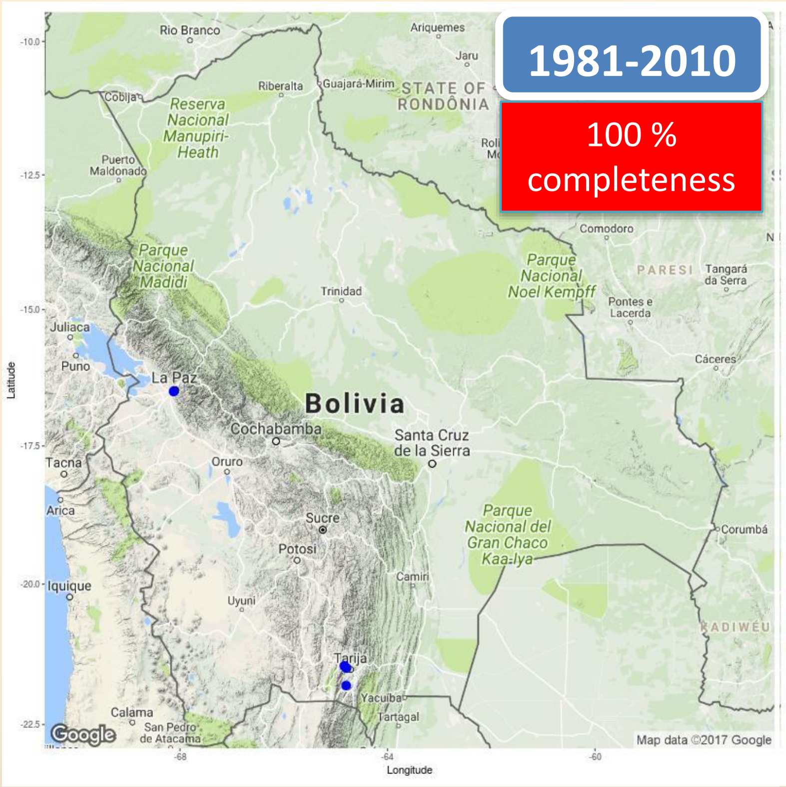
- In addition, little information for validating the model outputs
- Few ground stations measuring meteorological variables (mainly temperature and precipitation)
- Several of them with problems (quality and completeness)
- Re-analyses also with problems
- As well as satellite products

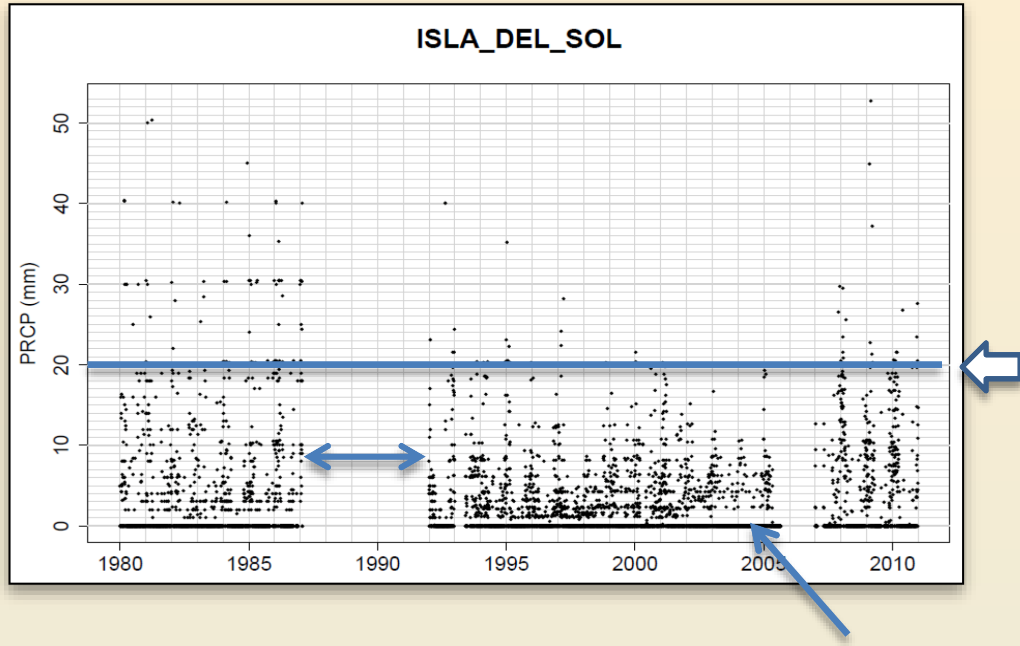
Ground observations in Bolivia



(Hunziker et al., 2017)

Ground observations in Bolivia





- ✓ Problems with instruments
- ✓ No transcription of original books
- ✓ Data discarded due to quality control
- ✓ Observation errors
- ✓ Some stations do not collect data all the time

Blue: PCP (4)

Model and runs

- Thanks to efforts of the Bolivian government, through the PPCR project, WRF has been used for climate modeling at a ~3-4 km of horizontal resolution
- Mainly PCP, TN and TX have been used for the analysis

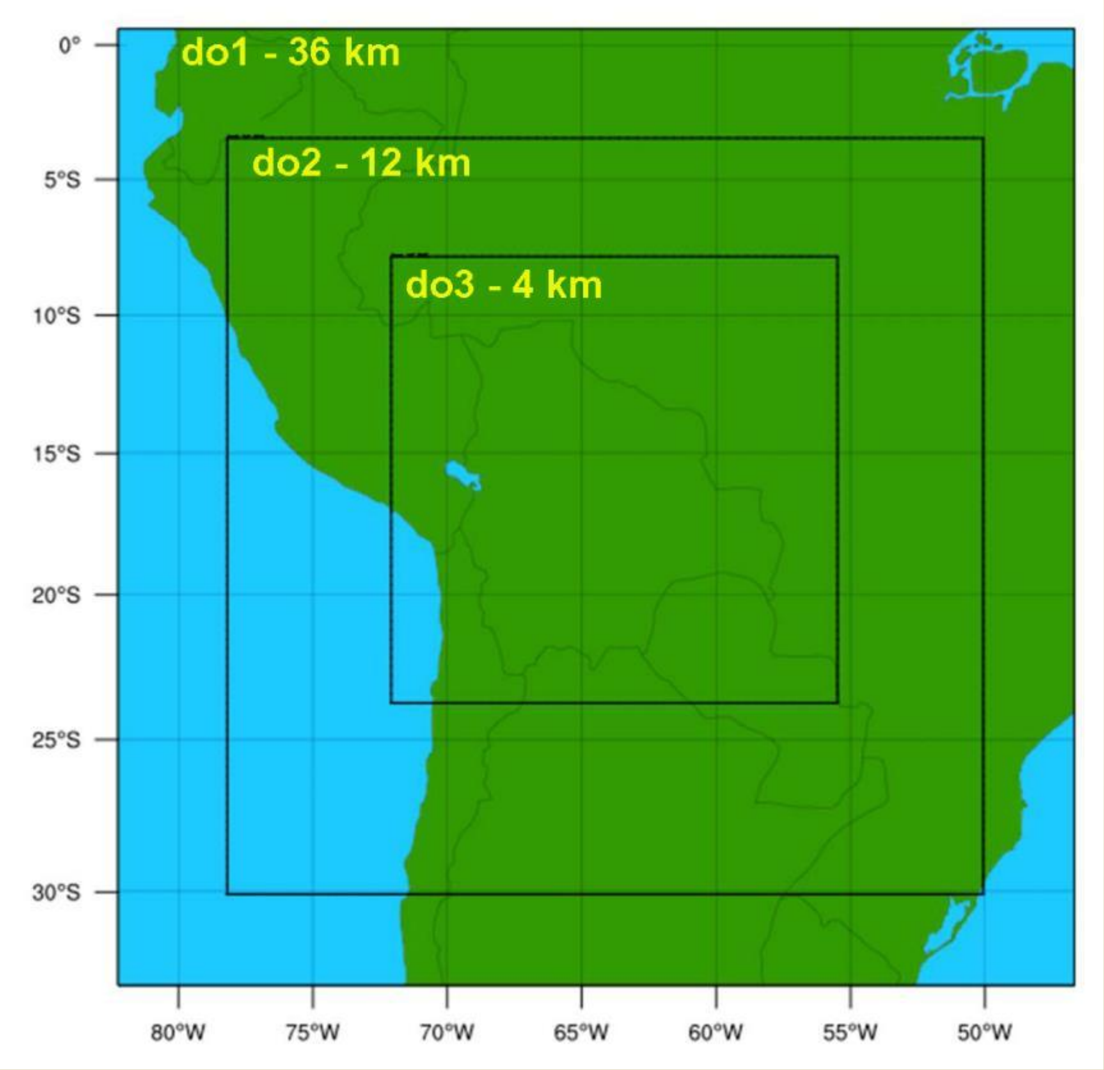
University of Utah
Thomas Reichler

	University of Utah	University of Nebraska, Lincoln
Model	WRF	WRF
Present	1991-2010	1979-2012
Forcing	NCEP-CFSR	NNRP R1
Resolution	38 km	2.5º
Future	2041-2060	2056-2080
Scenario	RCP8.5	RCP2.6, RCP4.5, RCP8.5
Forcing GCM	CSIRO	CCSM4
	MPI	MPI
	GFDL	MIROC
	MMM (Ensemble)	
	World Bank	*Inter-American Development Bank*

University of Nebraska
Bob Ogblesby & Clint Rowe

Nebraska

Domains and resolution

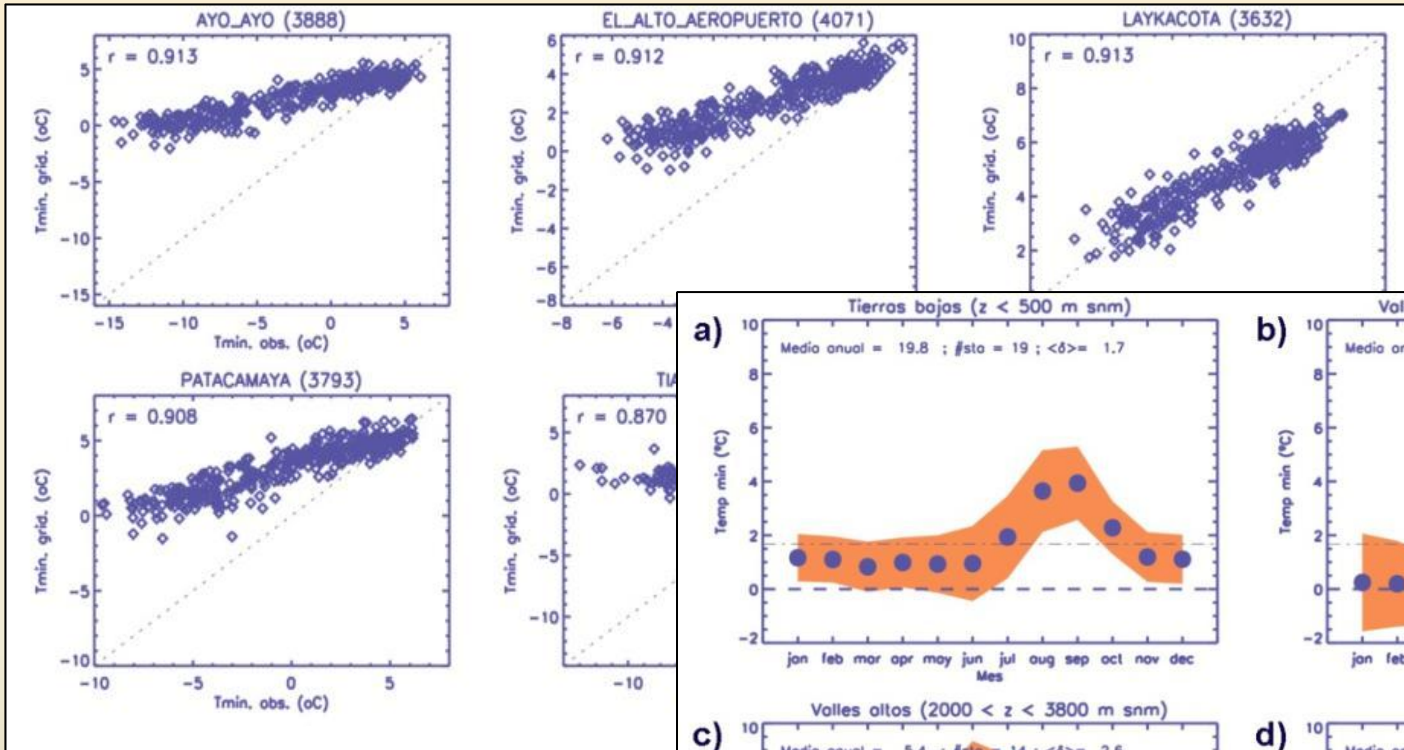


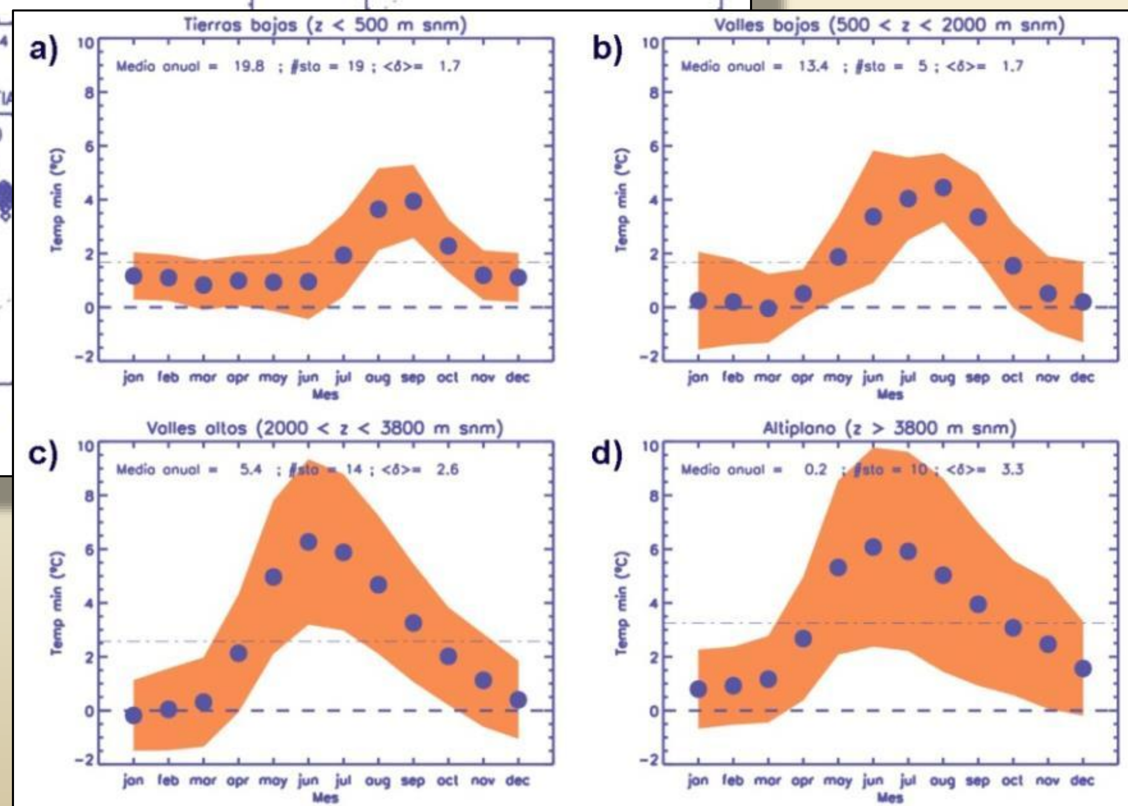
GCMs

Verification

Nebraska

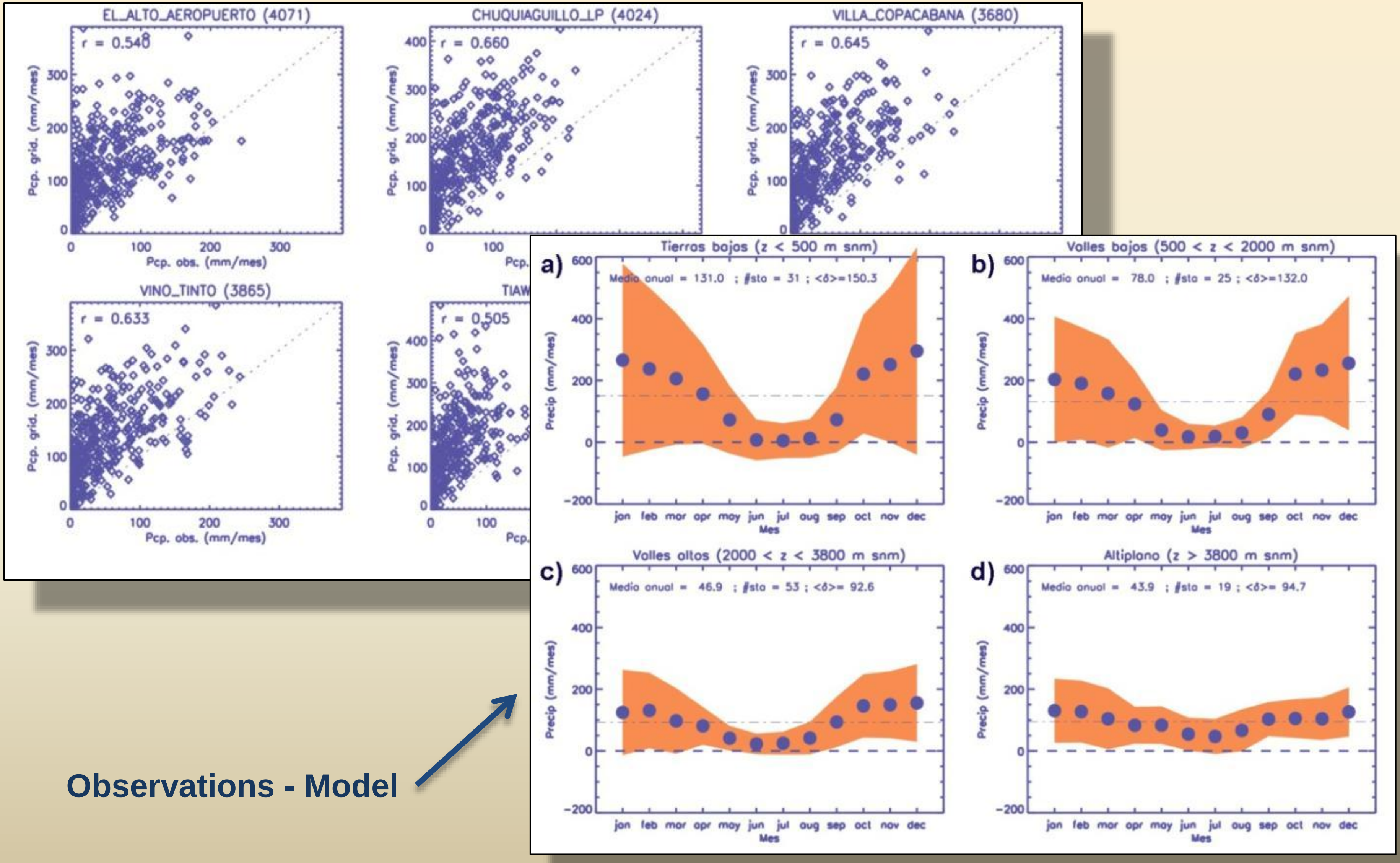
Minimum temperature





Nebraska

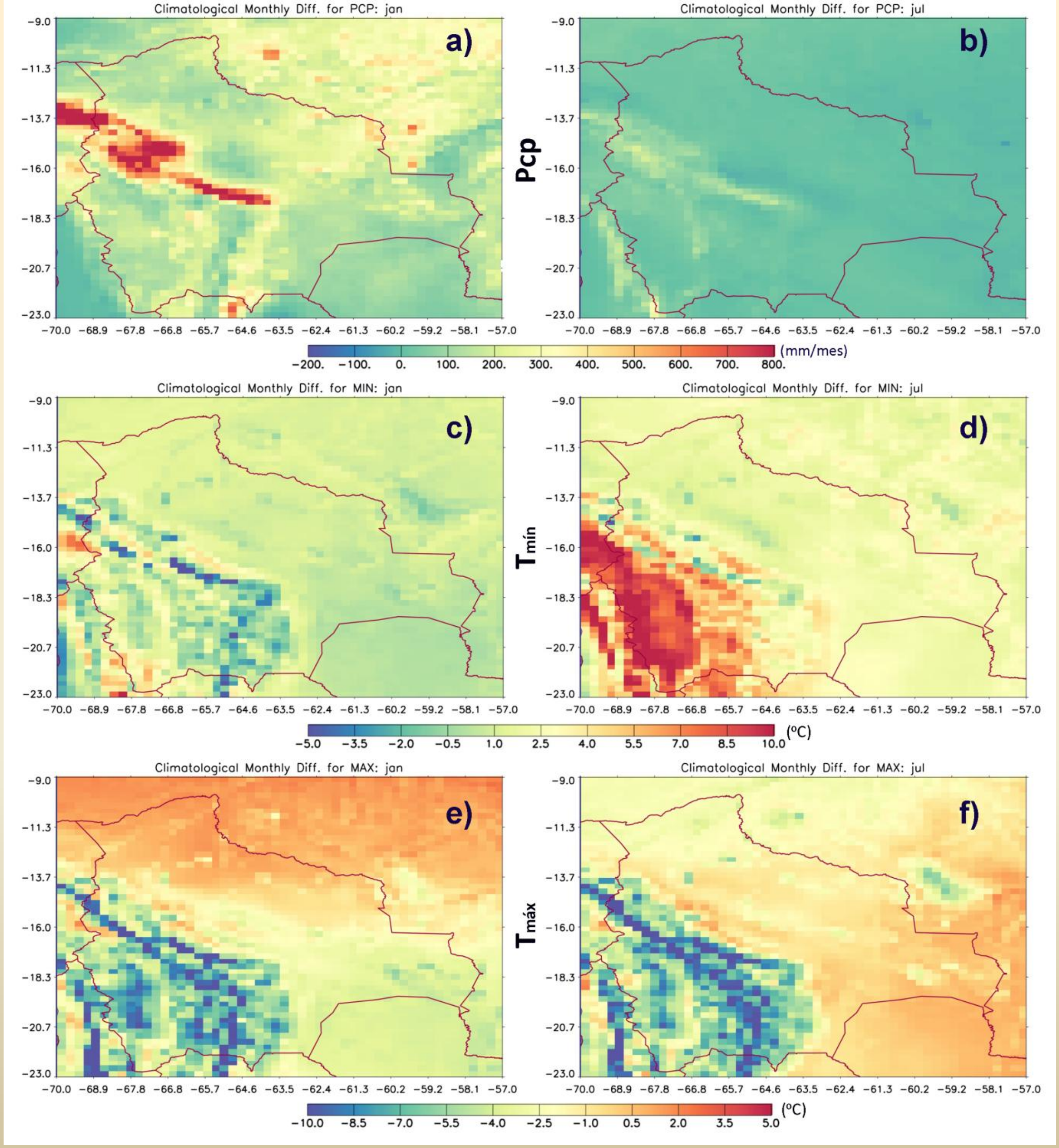
Precipitation



Observations - Model

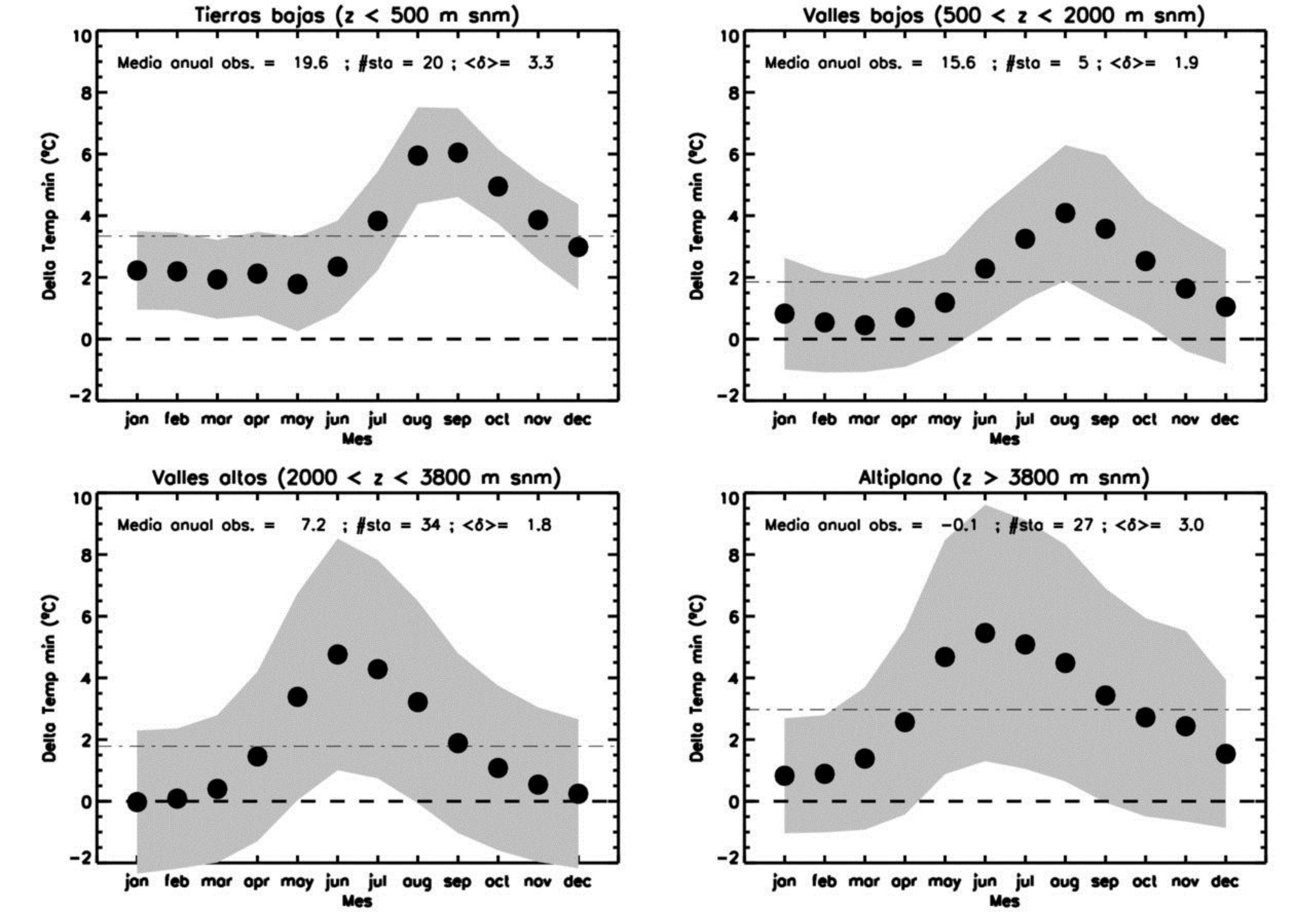
Nebraska

Obs - Mod



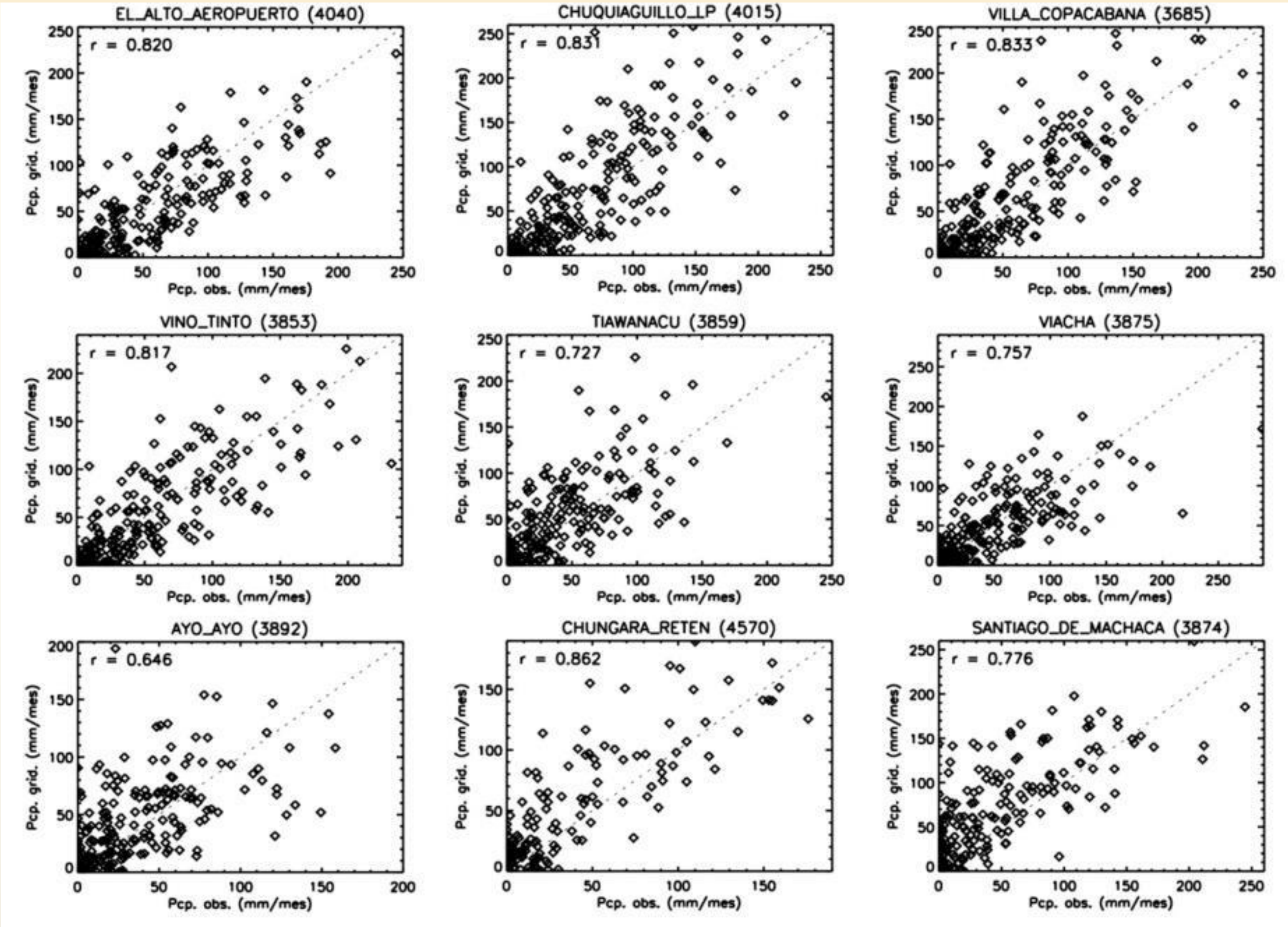
Utah

Minimum temperature



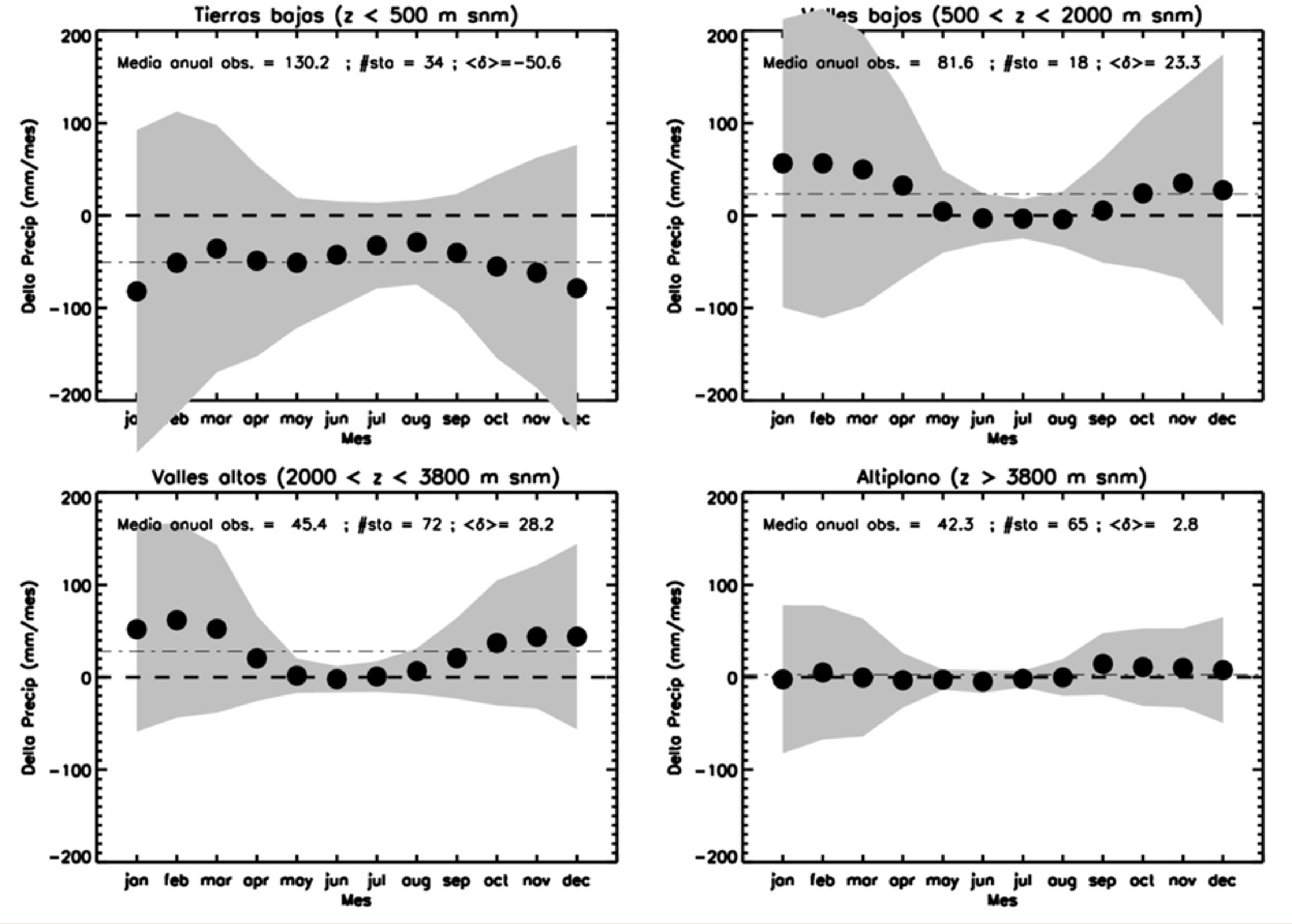
Utah

PCP: Different locations



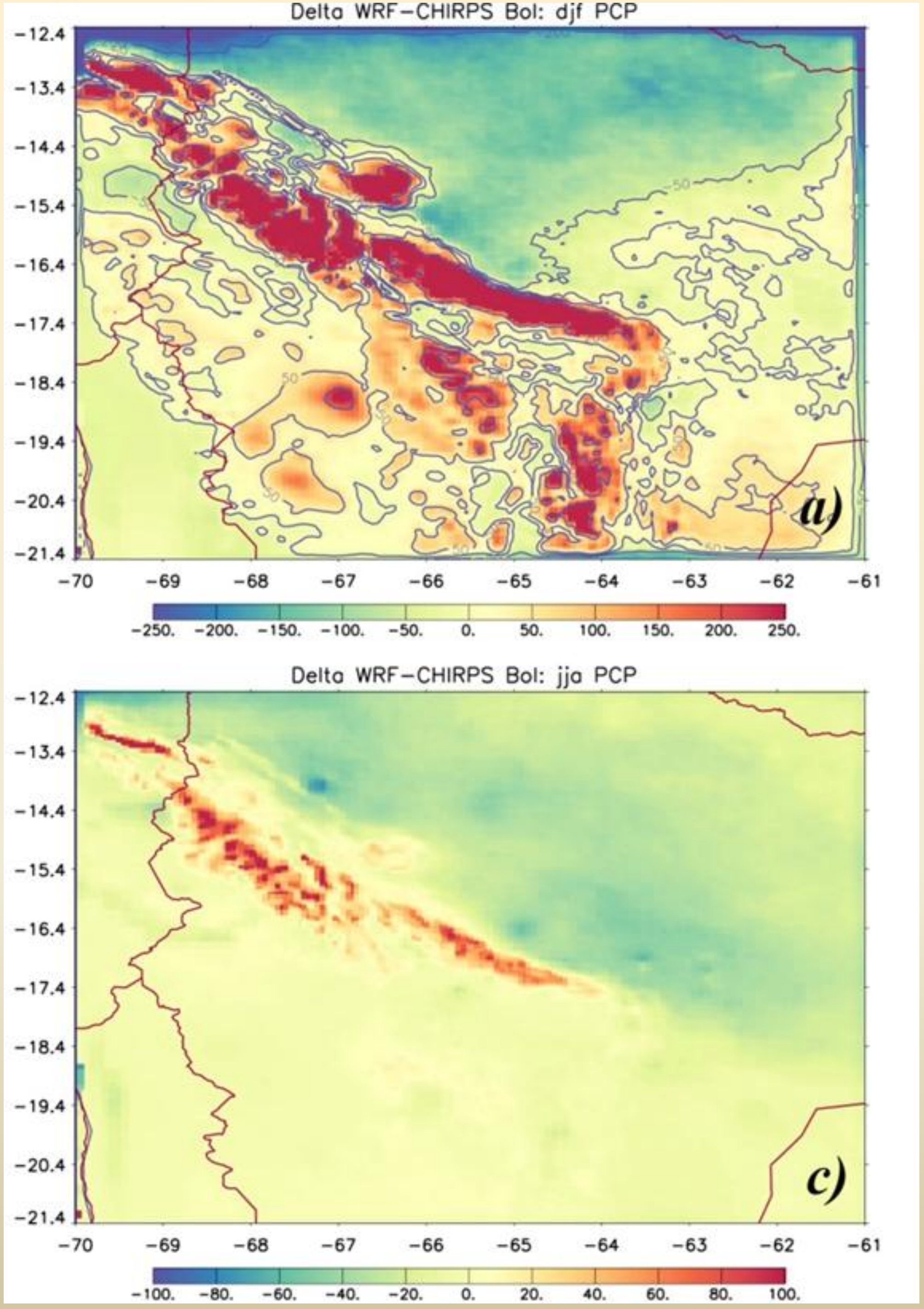
Utah

Precipitation



Utah

Obs - Mod



Delta WRF−CHIRPS Bol: djf PCP
−12.4
−13.4
−14.4
−15.4
−16.4
−17.4
−18.4
−19.4
−20.4
−21.4
−70 −69 −68 −67 −66 −65 −64 −63 −62 −61
−250. −200. −150. −100. −50. 0. 50. 100. 150. 200. 250.
a)
Delta WRF−CHIRPS Bol: jja PCP
−12.4
−13.4
−14.4
−15.4
−16.4
−17.4
−18.4
−19.4
−20.4
−21.4
−70 −69 −68 −67 −66 −65 −64 −63 −62 −61
−100. −80. −60. −40. −20. 0. 20. 40. 60. 80. 100.
c)

Conclusions of verification

- Poor work for temperature (TN y TX) for both runs
  - Maybe the time that represents TN & TX produces in part the difference?
  - Quality of data (bad data) used for verification?
- Nebraska: Strong overestimation of PCP
- Utah: Better behavior of PCP although strangely underestimates PCP in the lowlands

Future

Future: Temperature

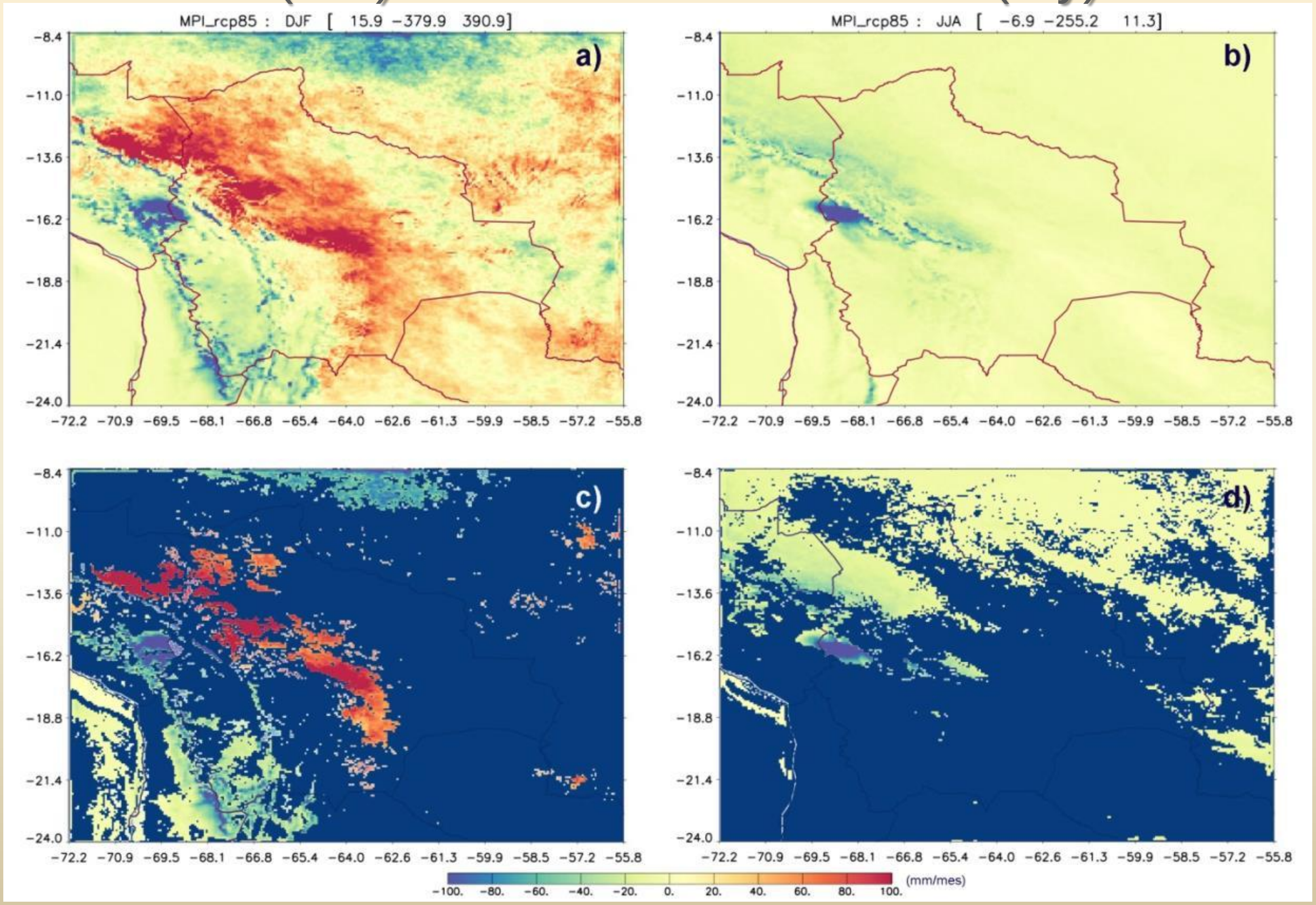
- Both runs show a clear increment of temperature (TN & TX) over Bolivia (2.5-3.0^{o}C)
- This change is statistically significant for the whole country
- Even though the mean increment is similar for both runs, the spatial distribution between them is different

Nebraska

Changes in PCP

Summer (wet) | (dry) Winter

MPI



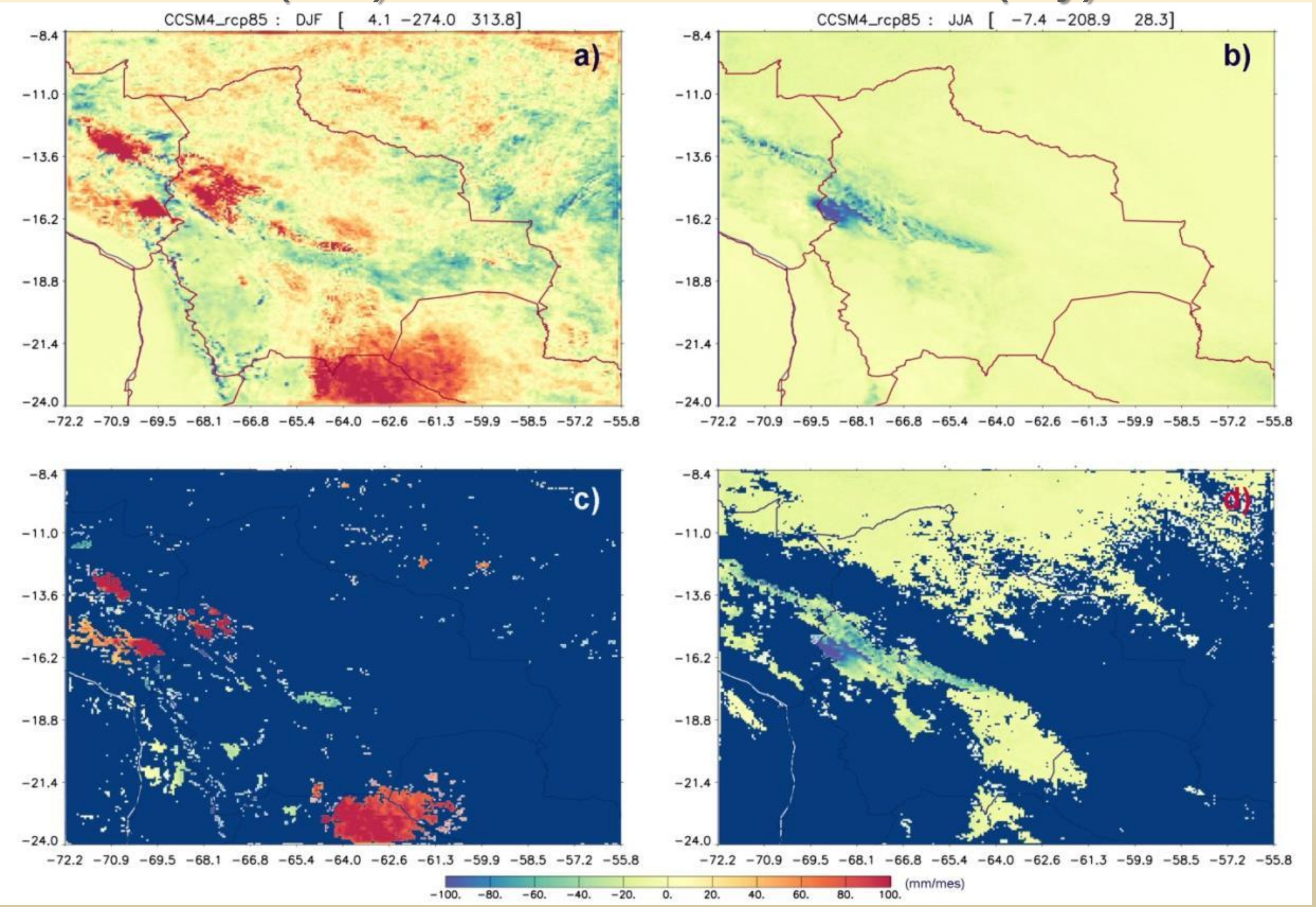
Nebraska

Changes in PCP

Summer (wet)

(dry) Winter

CCSM4

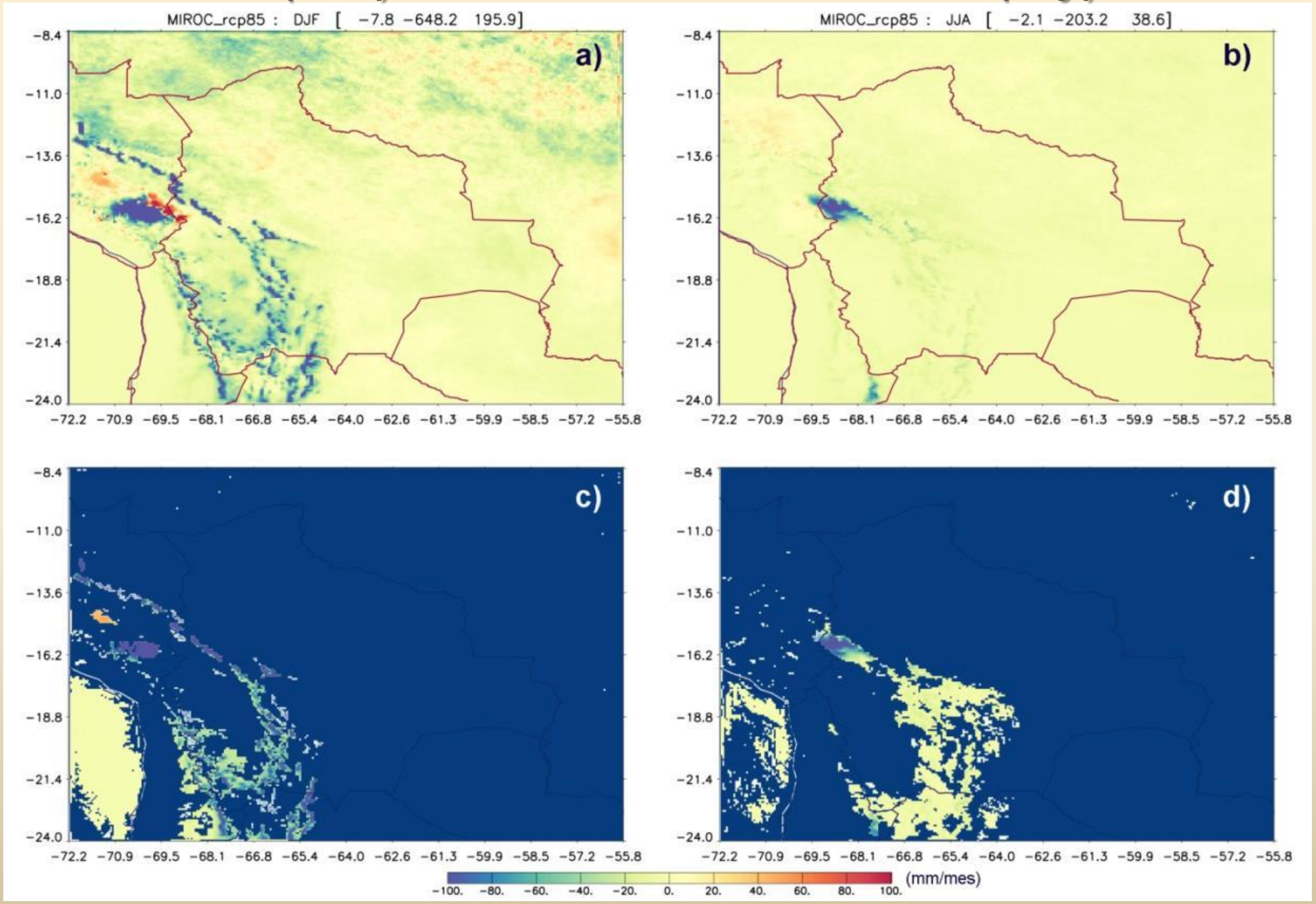


Nebraska

Changes in PCP

Summer (wet) (dry) Winter

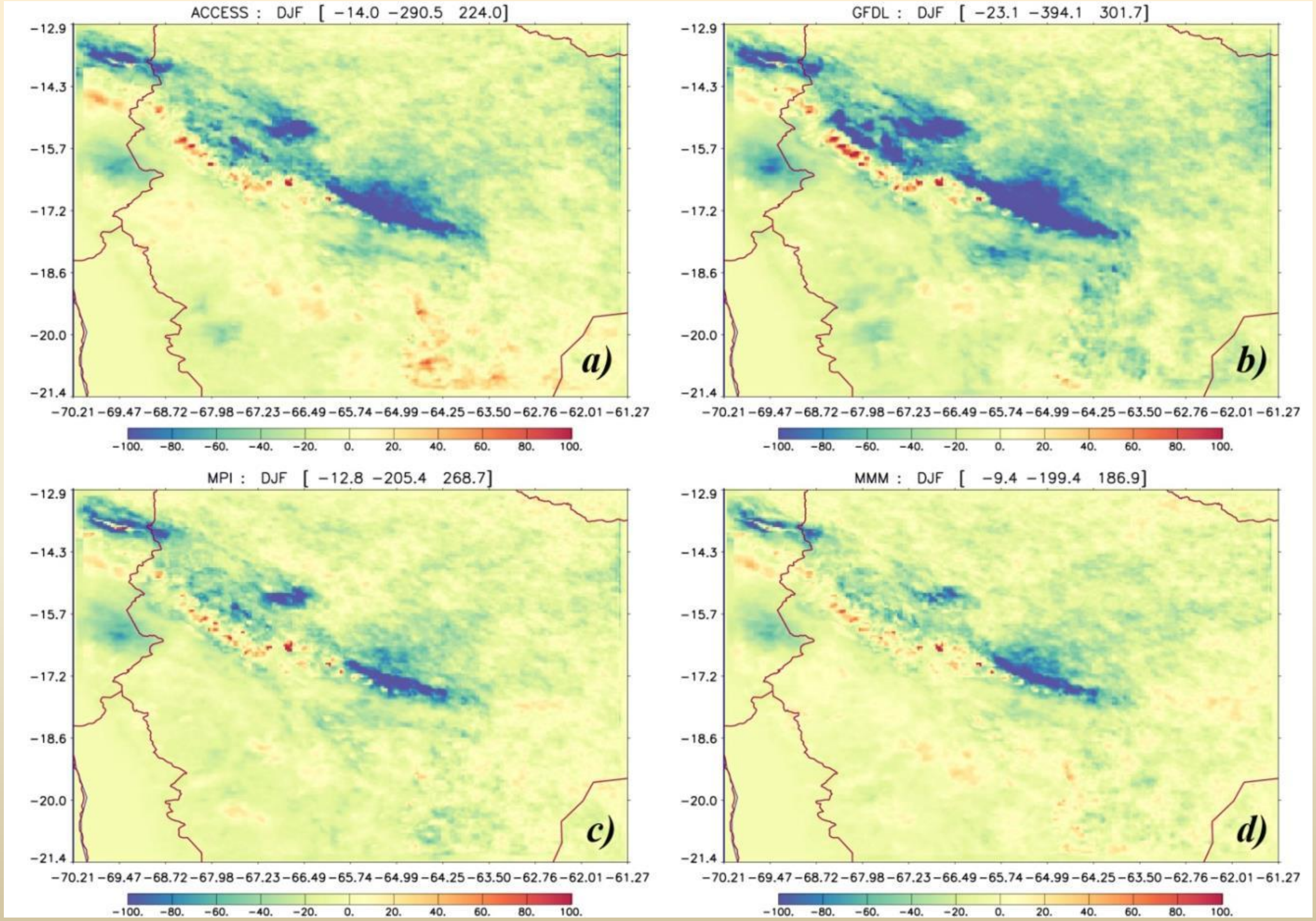
MIROC



Utah

Changes in PCP

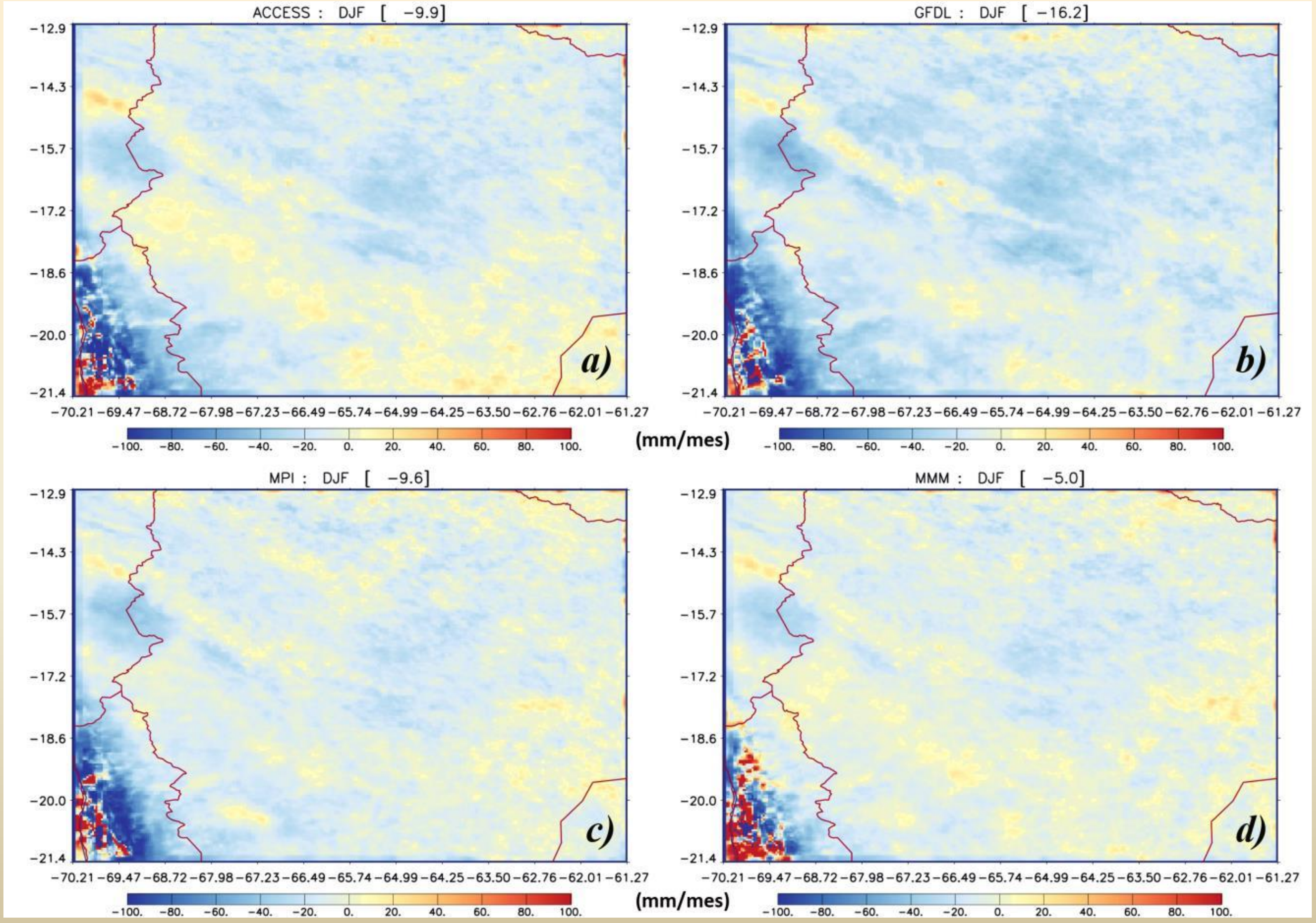
Summer (wet)



Utah

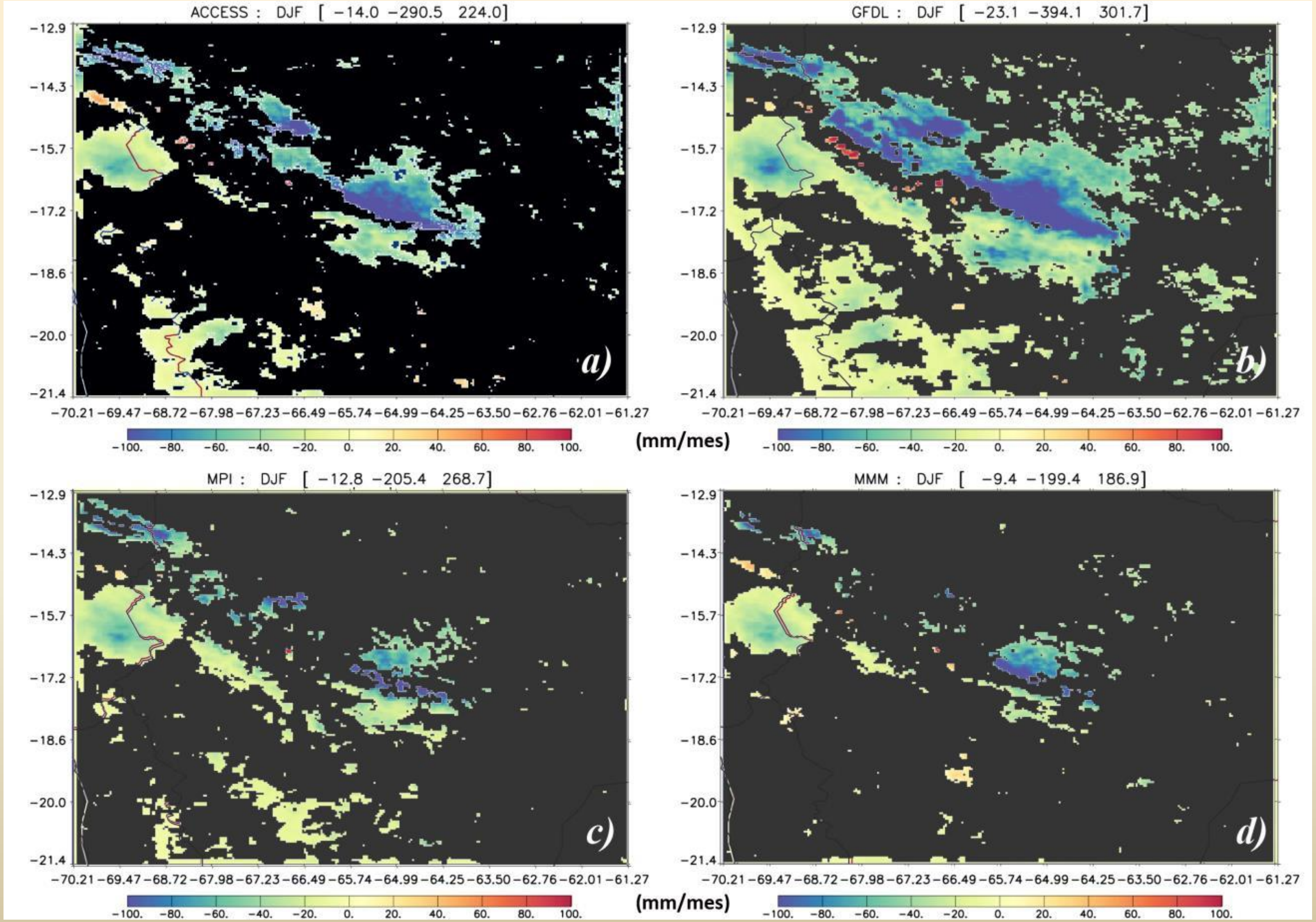
Relative changes in PCP

ΔPCP (%)



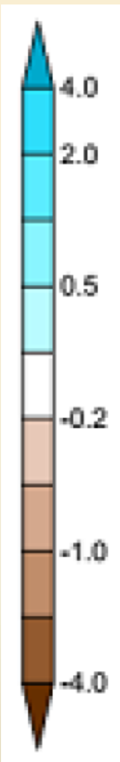
Utah

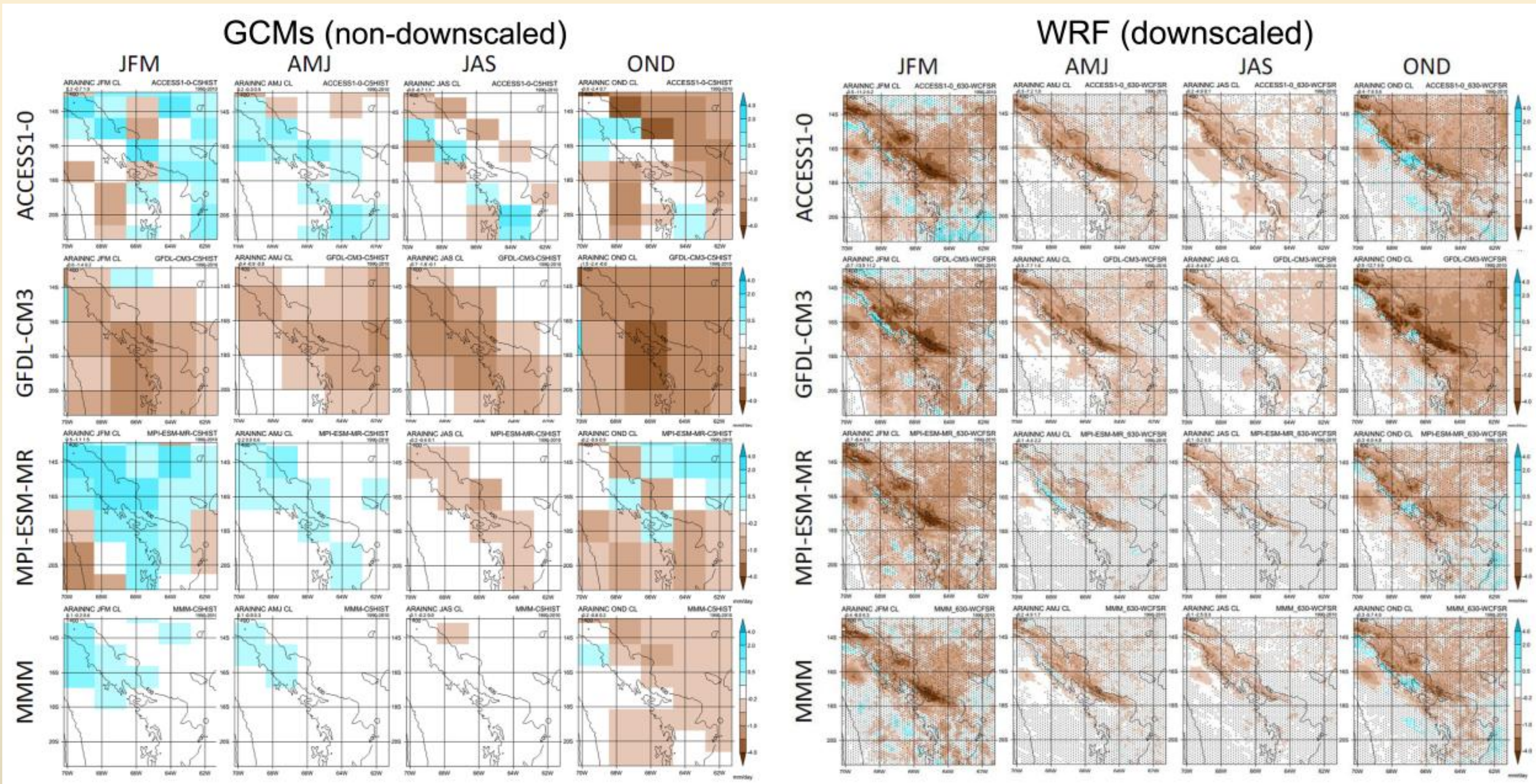
And those statistically significant…



Utah

Comparison GCM vs RCM





(Reichler, 2014)

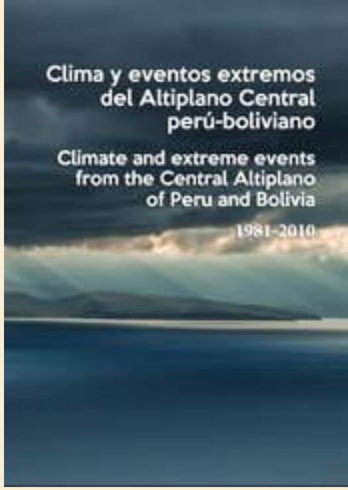
Conclusions of results for the future

- Temperatures consistently show an increment of ~2-4^{o}C in both runs
- In the case of precipitation, however, the results show:
  - Nebraska: Large differences among the different forcing GCMs
  - Utah: Consistent reduction of PCP with all GCMs, especially in winter and spring
  - The results among GCMs and RCMs show clear differences with RCMs showing the same sign for the change

Questions arising from these examples

- What can we say for the future if the model does not perform well for the present?
- Especially if these differences are not just systematic differences but depend on season and space?
- What about different results (even in sign)?

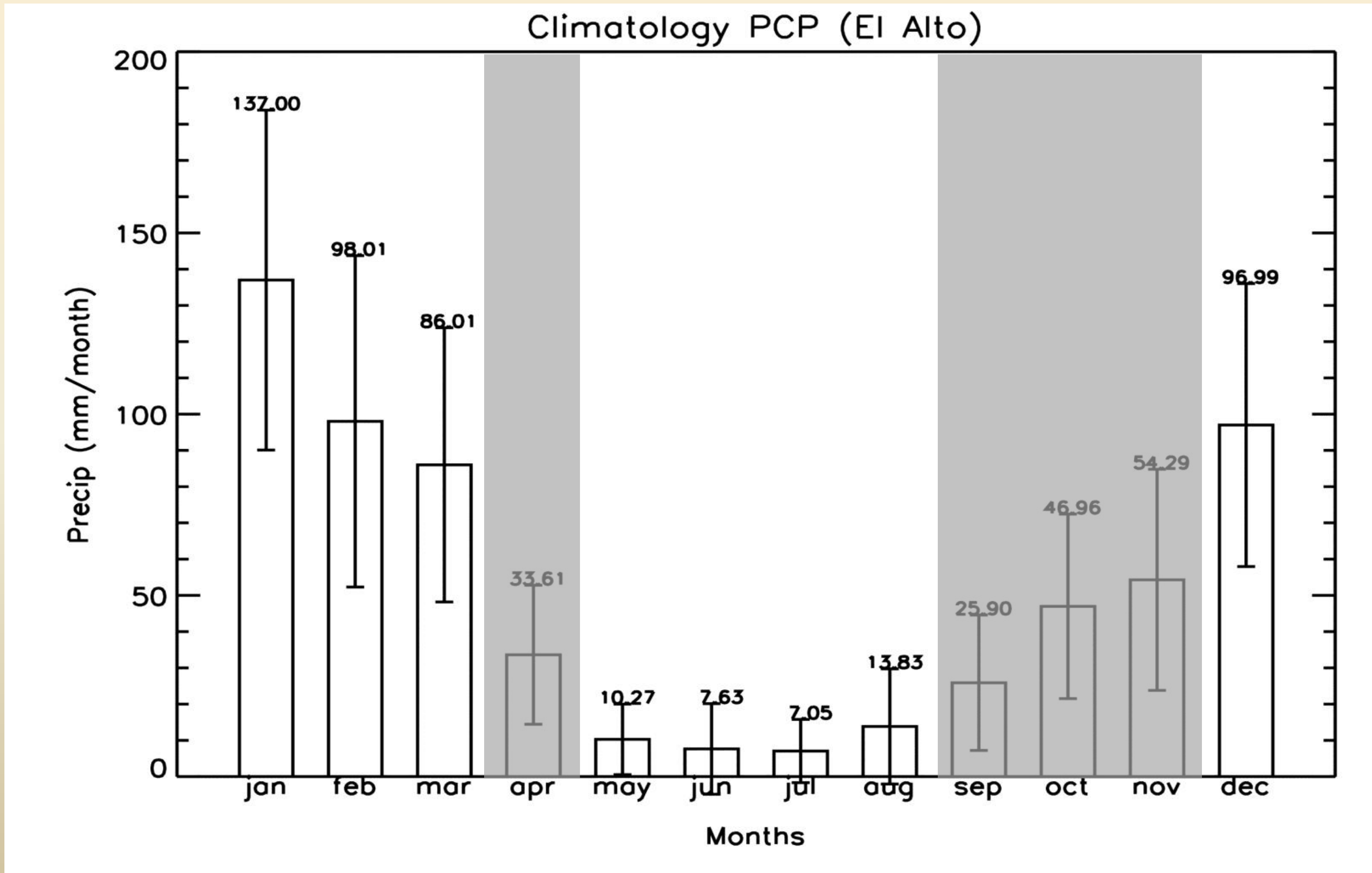
Associated challenges



- Observational data (ground based) could be a problem. For sure, in the case of Bolivia.
- This is true for other data sets as well. Which is the truth ("the egg or the chicken")?
- Steps taken for solving the problem:
  - Tackle the quality of the data directly (not always easy and time consuming)
  - Smart schemes for gridding observations (not classic interpolation) due to the complex topography (NCAR GMET tool for example)

Thank you

Definition of seasons



Utah

Estrategia para simulaciones del futuro

Condiciones iniciales y de contorno vienen de CFSR (presente):

- Para el futuro se utilizan los valores del presente corregidos por las anomalías de los GCMs para ese periodo (RCP8.5)

$$Cond.\,Laterales_{futuro} = Cond.\,Laterales_{presente} + (Futuro - Presente)_{GCM}$$

- El mayor impacto se da en ondas planetarias de larga escala
- Los patrones de tiempo (weather) que entran al dominio (d01) son estructuralmente idénticos tanto en la corrida de control (presente) como en las simulaciones de cambio climático
- Rasmussen et al. (2011), Schär et al. (1996), Kawase et al. (2009), and Hara et al. (2008)

Utah

Strategy for simulations for the future

- Decompose Q into climatological mean + 6-hourly deviations:

$$Q(t) = \bar{Q} + Q'(t)$$

- $ICBC$: WRF initial and boundary conditions
  - control $\boxed{ICBC_{control} = \bar{R} + R'}$
  - future $\boxed{ICBC_{future} = \bar{R} + (\bar{C}_{future} - \bar{C}_{today}) + R'}$

R: reanalysis
C: CMIP5 climate model

- Anomaly coupling eliminates climate model biases
- Primary impact is on change in large-scale circulation and thermodynamics
- Transient weather patterns entering domain boundary are structurally identical in control and future simulation (= R')
- Rasmussen et al. (2011), Schär et al. (1996), Kawase et al. (2009), and Hara et al. (2008)

Utah

Changes in PCP

PCP (mm/mes)					(a)
	DJF	MAM	JJA	SON	
ACCESS	-14.0	-12.1	-3.9	-14.5	*-11.1*
GFDL	-23.1	-16.5	-5.2	-22.2	*-16.8*
MPI	-12.8	-9.8	-2.6	-11.0	*-9.1*
MMM	-9.4	-8.9	-3.0	-9.3	*-7.7*
	-14.8	*-11.8*	*-3.7*	*-14.3*	

PCP (%)					(b)
	DJF	MAM	JJA	SON	
ACCESS	-9.9	-11.9	-43.1	-24.8	*-22.4*
GFDL	-16.2	-23.6	-56.3	-30.4	*-31.6*
MPI	-9.6	-12.2	-23.0	-17.2	*-15.5*
MMM	-5.0	-7.0	-30.9	-14.2	*-14.3*
	-10.2	*-13.7*	*-38.3*	*-21.7*	