High-Resolution Dynamic Downscaling of CMIP5 Output Over Bolivia

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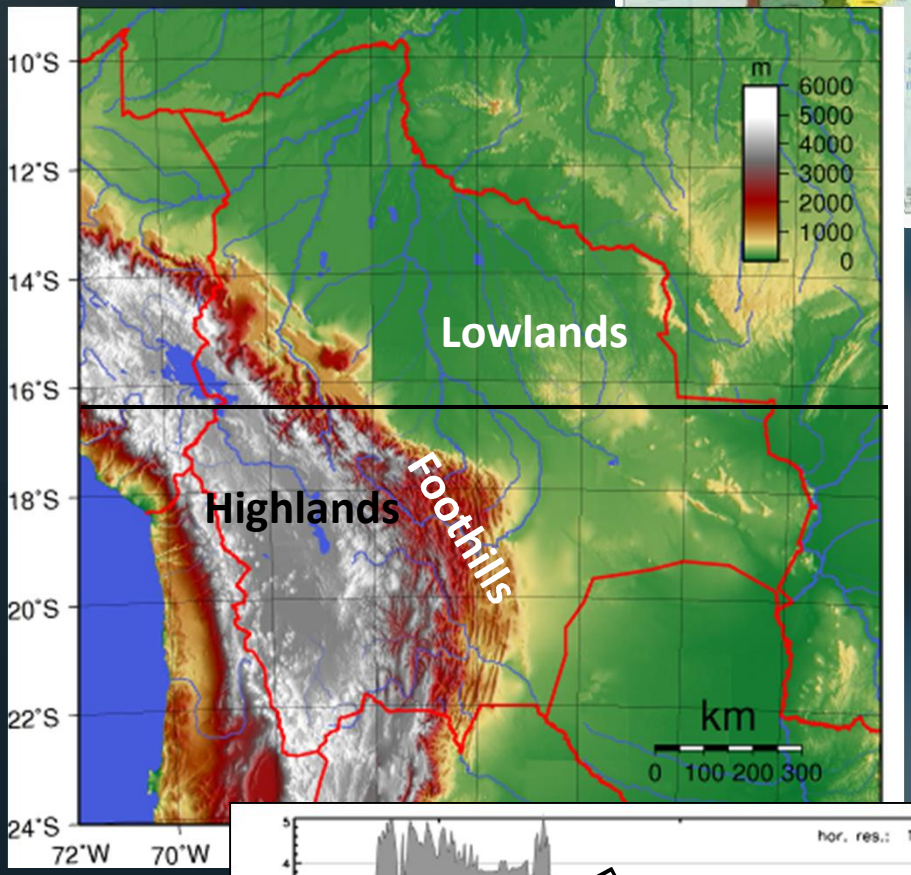
Outline

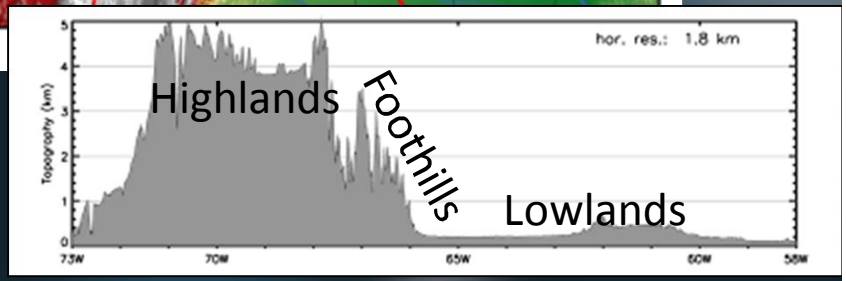
- Background
- Technical Implementation
  - domains
  - coupling
  - climate model selection
- Optimal WRF Configuration:
  - Sensitivity Experiments and Results
- Outlook

Motivation

- 10 Mio. inhabitants
- 1 Mio. Sq. km
- Main threat change in hydrological cycle

- Complex topography
- Three distinct climate zones
- Tropical physics and dynamics

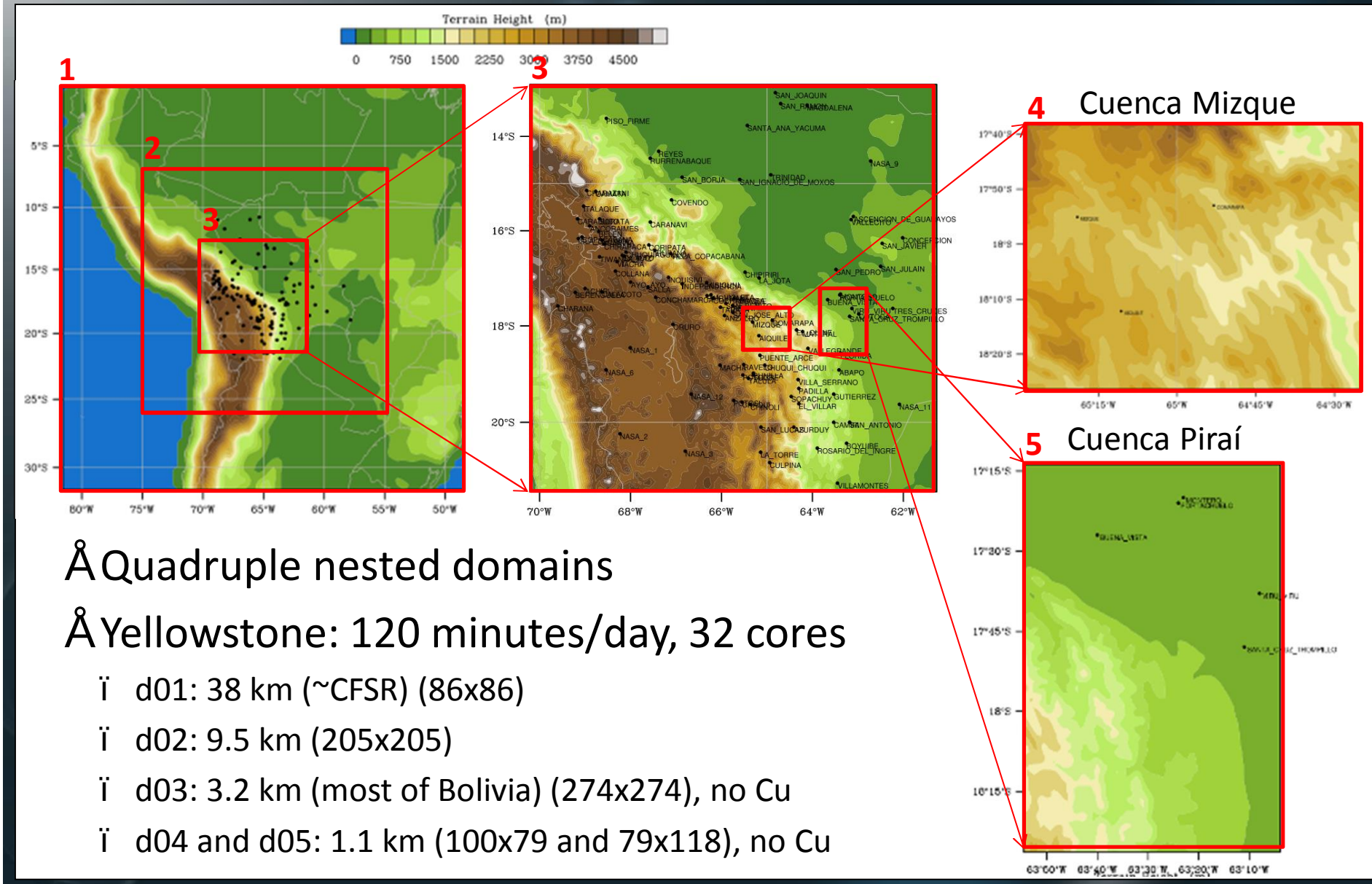




Technical Implementation

- WRF-ARW V3.X; NOAH LSM
- Dynamical regional downscaling at **3** and **1** km
  - NCEP-CFSR (38 km)
    - 6 hourly
    - 20 years: 1991-2010
  - CMIP5 models
    - RCP8.5
    - 20 years: 2041-2060
    - 4 selected models
- 100 simulation years
- New NCAR's Yellowstone system

Resolution and Domains



- Quadruple nested domains
- Yellowstone: 120 minutes/day, 32 cores
  - d01: 38 km (~CFSR) (86x86)
  - d02: 9.5 km (205x205)
  - d03: 3.2 km (most of Bolivia) (274x274), no Cu
  - d04 and d05: 1.1 km (100x79 and 79x118), no Cu

Coupling Strategy

Initial and lateral Boundary Conditions for outer WRF domain:

- Present-day control simulation: 6-hourly CFSR
- Climate change simulation: 6-hourly CFSR, anomaly corrected with monthly mean CMIP5 (RCP8.5)

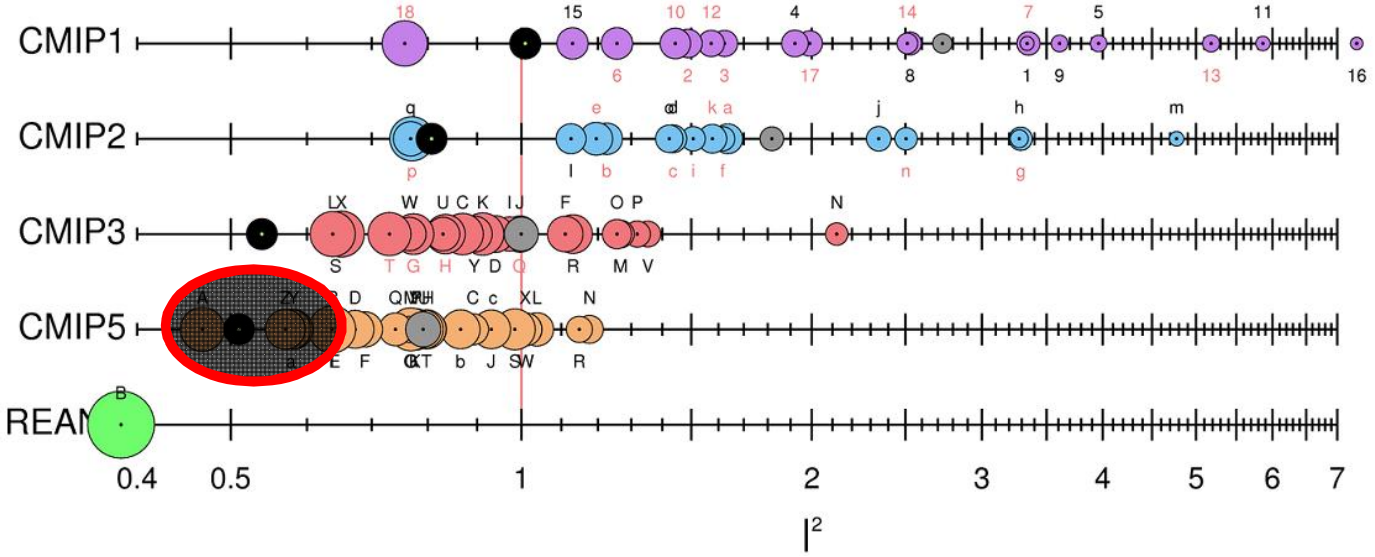
$$ICBC_i = CFSR + \overline{CC_i}$$

$\overline{CC_i}$: mean climate change signal from model i
$CFSR$: 6-hourly CFSR reanalysis, present climate

- Primary impact is on large-scale planetary waves and thermodynamics
- Weather patterns entering domain boundary are structurally identical in control and climate change simulation
- Rasmussen et al. (2011), Schär et al. (1996), Kawase et al. (2009), and Hara et al. (2008)

Selection of Climate Models

- We use four climate models. Which ones?
- Model performance test for mean climate; globally and over South America (Reichler and Kim, 2008):



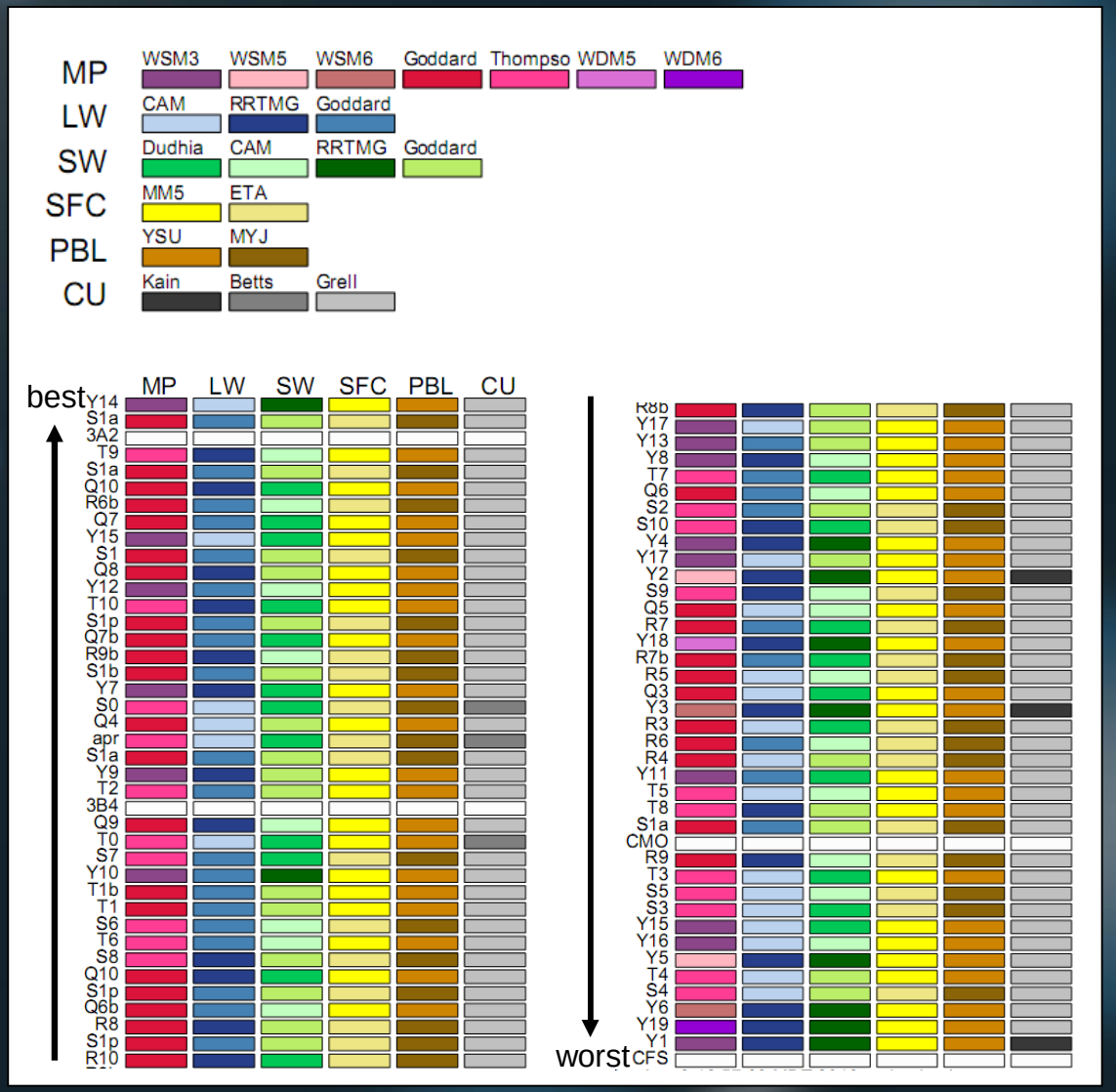
- Selected models:
  - CSIRO-ACESS1-0, MPI-ESM-MR, GFDL-CM3, NCAR CCSM4

WRF is Not Just One Model!

- WRF contains different physics and dynamics parameterizations
  - microphysics
  - longwave radiation
  - shortwave radiation
  - surface layer physics
  - land surface physics
  - planetary boundary layer
  - cumulus clouds
  - shallow convection
  - diffusion and damping
  - etc.
- Large number of different model configuration
- Finding the best configuration is difficult and unphysical, but it allows optimizing WRF to the specific domain

Sensitivity Experiments

- 75 experiments
- January 2003
- Mostly physics: MP, LW, SW, SFC, PBL, CU
- Also: spectral nudging and perturbed initial conditions

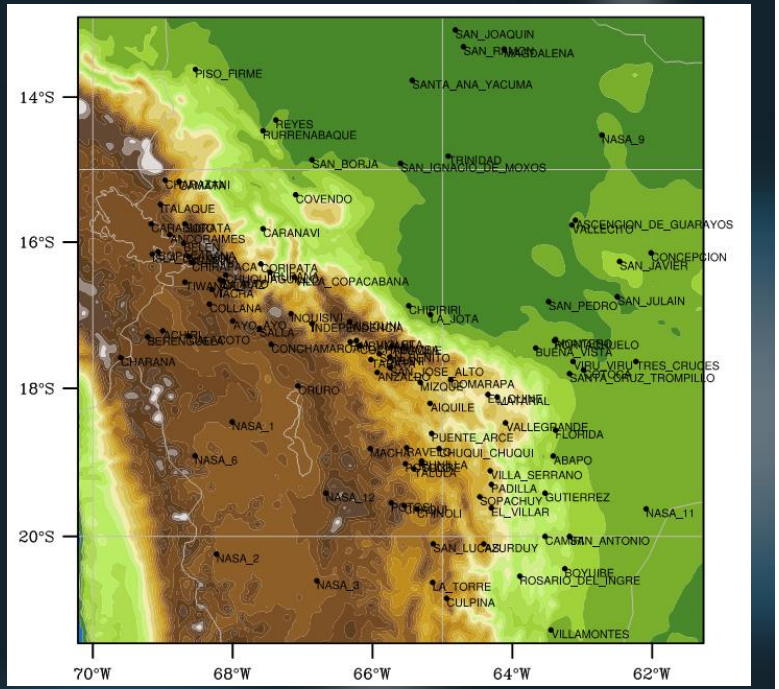


Validation Data

Å Precipitation only:

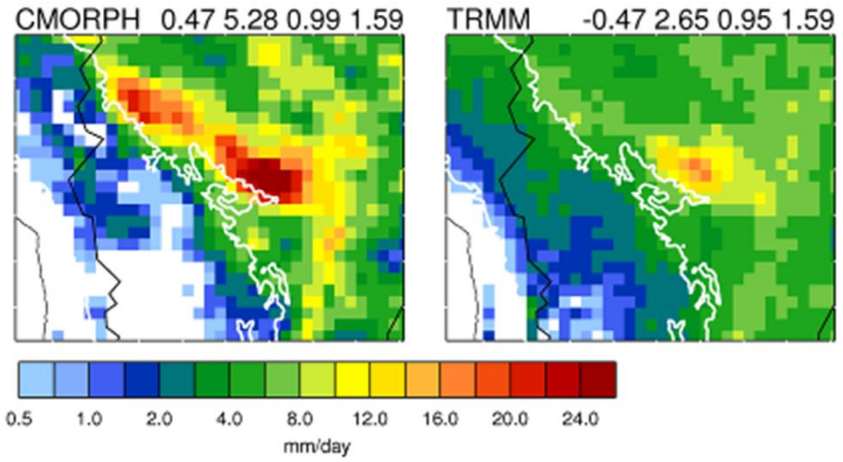
- ï January 2003

1. Gridded satellite-data
   - ï CMORPH
   - ï TRMM: 2A25, 3B42, 3B43
2. In-situ station data from Bolivian National Weather Service



Monthly Mean Precipitation

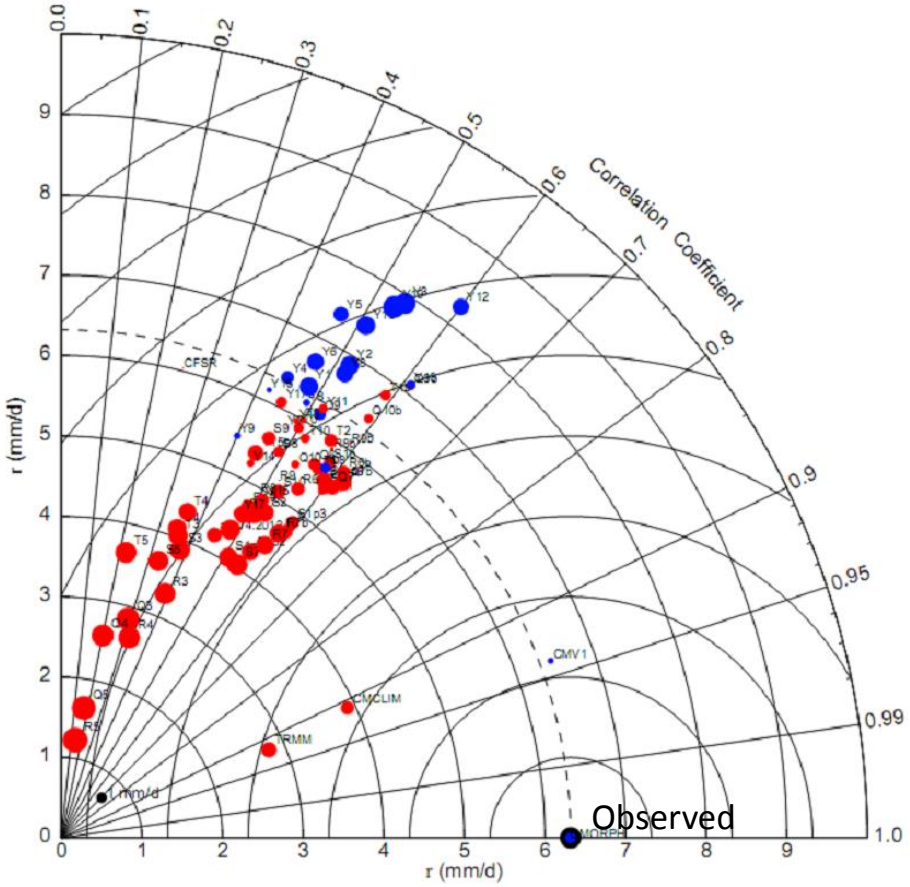
January 2003



1. bias
2. stddev
3. corr
4. crms

Monthly Mean Precipitation

Å Jan 2003, domain 3



modified from: Taylor 2001

Combined Ranks

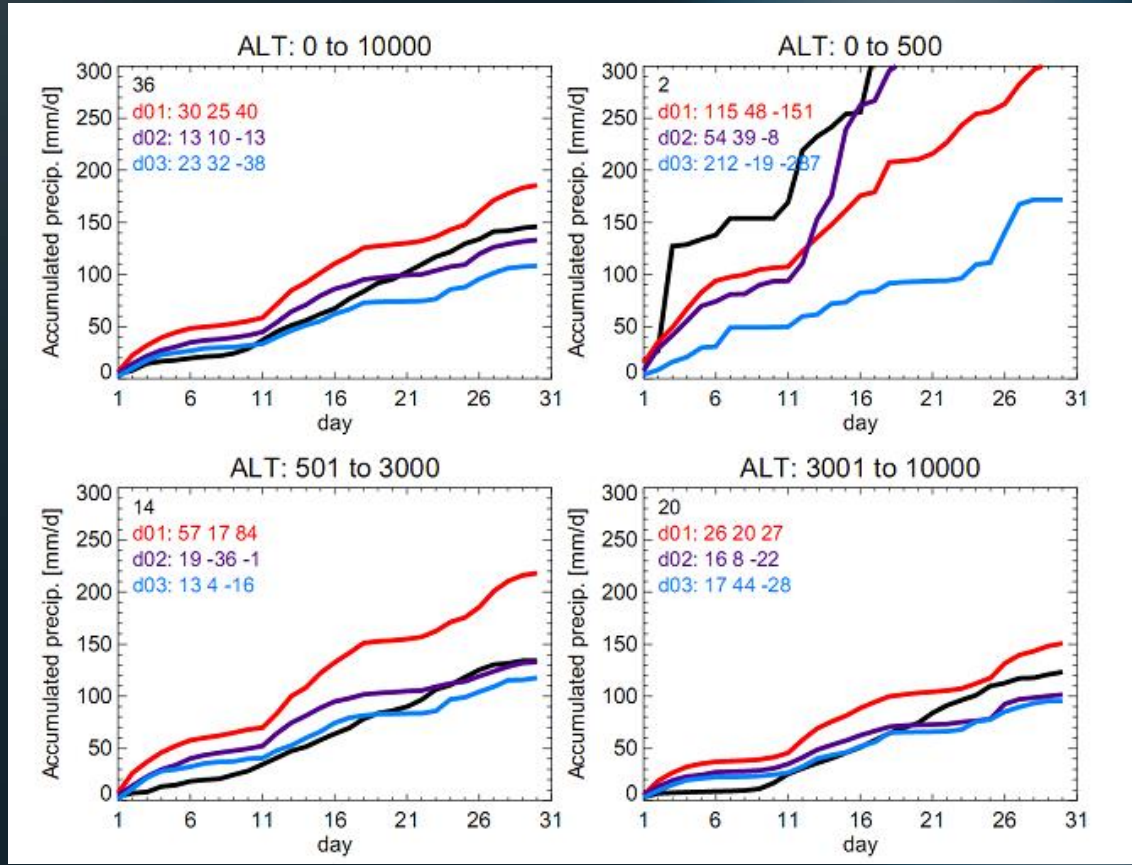
- Rank models according to simulation performance for Jan monthly mean precip.
  - 3 statistics: mean bias, spatial correlation, and center RMS error
  - all three model domains

CMORP 237	CMV1 224	CMCLI 200	TRMM 198	S1p3 191	S1 191	S1p1 187	Q7 183	R6 175	T1 173	S1p2 169	Q6 168	R7 164	Q10 163	Y17 162
R6b 160	S1a 160	R9 158	S1ap3 157	R8 157	Y15 156	S1b 154	Y11 152	R9b 151	Y10 149	T2 147	Q6b 146	Y13 145	Q10b 143	Q8 143
R10 142	T1b 140	Q7b 140	Y7 139	R8b 139	R7b 135	S1ap1 135	Y14 134	S2 129	T10 128	T8 128	T9 127	S8 123	Q9 119	Y9 118
Y16 117	S10 115	T7 112	T6 109	S7 108	Y17b 108	Y12 104	S9 102	Y15b 95	S6 93	T0 91	S1ap2 81	Y4 80	Y8 78	CFSR 75
Y5 73	T4 73	apr14 69	Y6 69	S4 63	R3 62	Y2 58	T3 58	S3 58	Y18 57	Y1 53	Y3 53	Y19 51	S5 45	R4 38
Q3 32	Q4 21	T5 19	Q5 18	R5 13										

Cumulative rank range: max 237 (= 79*3*1)

Validation Against Station Data

- We also validated against rain gauge observations at specific stations
- Example: temporal evolution of simulation S1 precipitation at different altitude ranges



black: station data

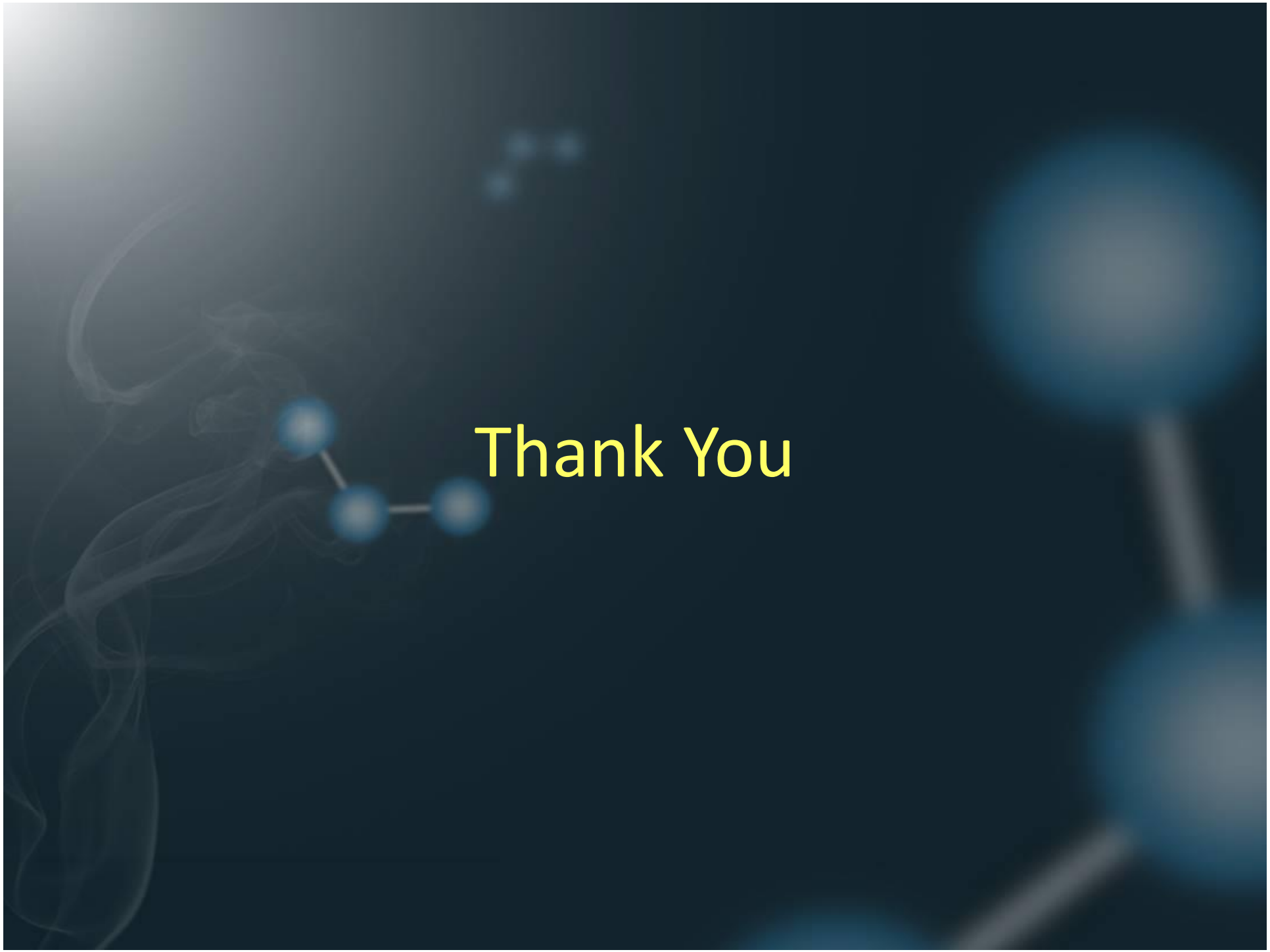
Validation Results

- Based on our sensitivity experiments, we decided to use the following model configuration

parametrización / option	esquema / scheme
microphysics	Goddard
longwave radiation	Goddard
shortwave radiation	Goddard
surface layer	ETA
land surface	Noah
planetary boundary layer	Mellor-Yamada-Janjic
cumulus convection	Grell-Devenyi
spectral nudging	yes (grid_fdda=2)
nudging coefficient	0.0003
xwavenum	4
ywavenum	3

Current Project Status

- We just finished the 20 year simulations for present-day climate, using CFSR reanalysis as boundary conditions
- Next: 4 climate model simulations
- Projected to be finished by the end of this year


Thank You