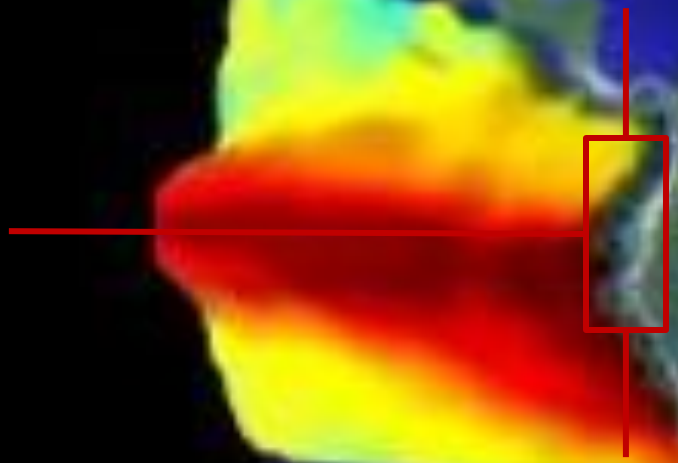
Seasonal predictability of daily rainfall for catchment hydrology in NW South America

Using an NHMM model



Luis PINEDA and P. WILLEMS

Department of Civil Engineering

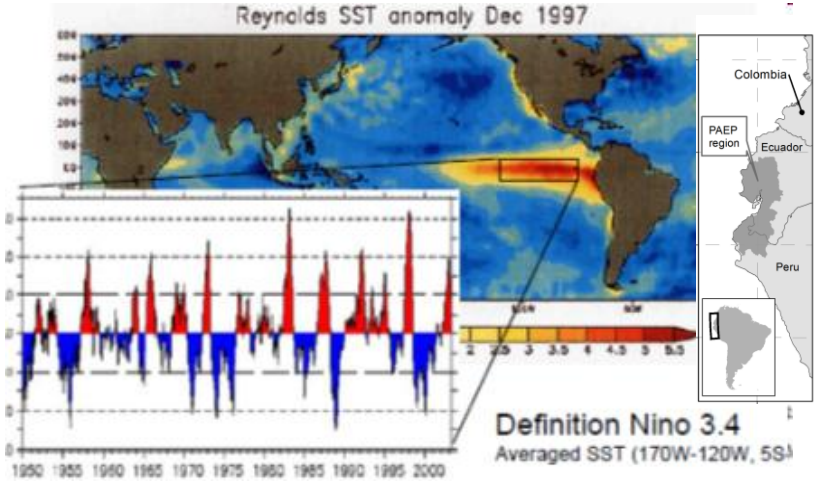
Hydraulic Section

HEPEX Seasonal Hydrological Forecasting Workshop
22nd September 2015, Norrköping, Sweden

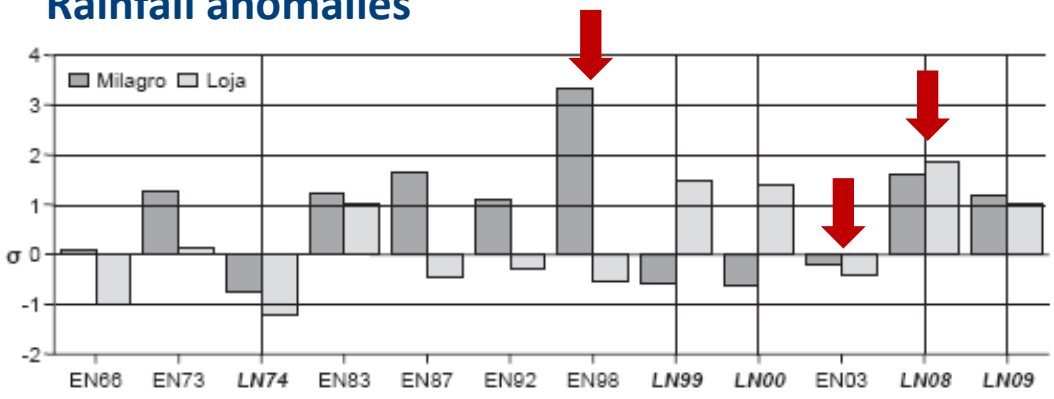
KU LEUVEN

UTPL
UNIVERSIDAD TÉCNICA PARTICULAR DE LOJA

Motivation



Rainfall anomalies



Bendix et al. 2011

Water Management related problems

EN 97-98 **PERU-Piura**

6 economía

EXPRESO DE GUAYAQUIL • VIERNES, 11 DE ABRIL DEL 2003

Litigio por ausencia de El Niño

Agricultores demandarán a quienes predijeron fuertes lluvias en invierno

ROSA ELENA GORDILLO

Los agricultores perjudicados por la sequía no quieren limosna, ellos exigen la retribución de la inversión hecha para contrarrestar los efectos de El Niño y del anticipado verano.

Los perjudicados van más allá de una declaratoria de alerta y proponen dos medidas de solución: líneas de créditos inmediatas para financiar los gastos adicionales que demandan ante la sequía, como por ejemplo la compra o reparación urgente de bombas de agua; o en su defecto la indemnización de sus bienes, cosechas, pérdidas por el anticipado invierno.

Los productores están convencidos de que las paralizaciones y huelgas no les solucionan el problema, por ello insisten en los créditos, porque no están en capacidad de financiar una nueva siembra o comprar combustible para los bombas, para evitar que cultivos -como la caña de azúcar- disminuyan sus

Puente Quebrada Chiquita, en Palmales, Zaruma, se construyó en provención a El Niño.

LAS CLAVES

MONITOREOS. Los informes preliminares señalan que las zonas más afectadas son: Colimes, Balzar y El Empalme. Los resultados finales se conocerán el lunes. Una vez analizada la situación real de cada provincia las autoridades se reunirán para determinar las posibles soluciones.

LLUVIAS. Aunque en las últimas 72 horas se registraron 12 precipitaciones fuertes en Los Ríos y Guayas, las autoridades del Ministerio de Agricultura y Ganadería no descartan la posibilidad de bombardear las nubes.

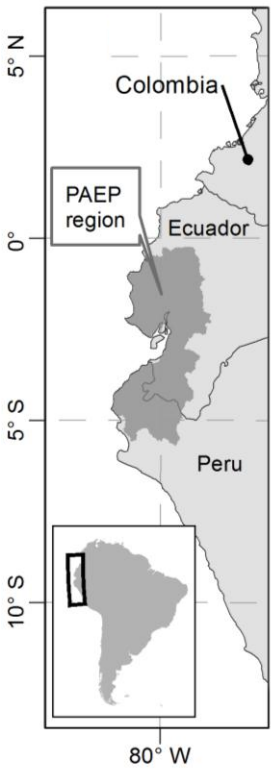
GREMIOS En El Triunfo se reunieron ayer 35 gremios de agricultores para analizar la crisis que afecta al sector por la falta de lluvias.

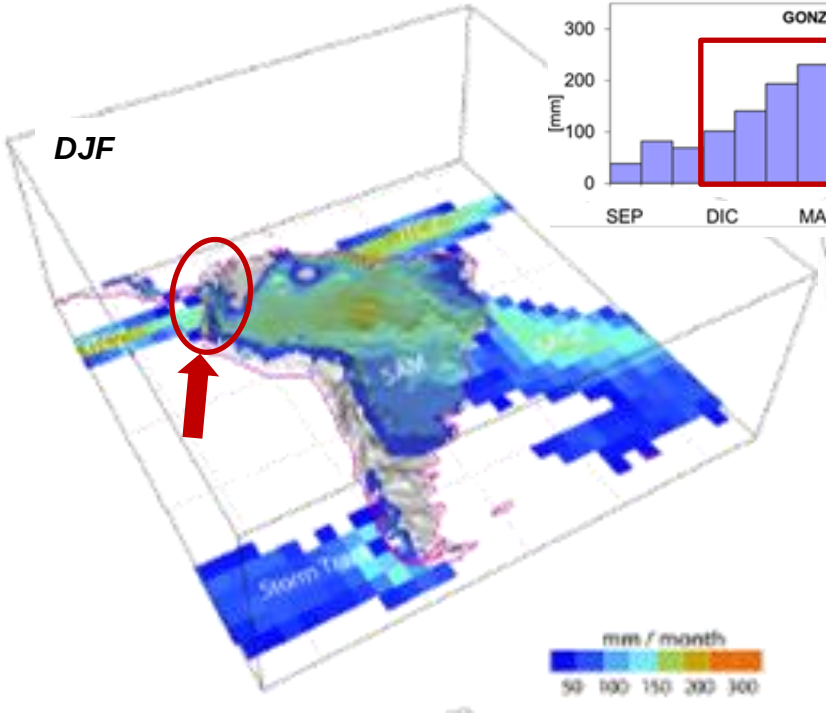
EN 02-03 **"Litigation because the absence of EN. Farmers will sue those who predicted rains"**

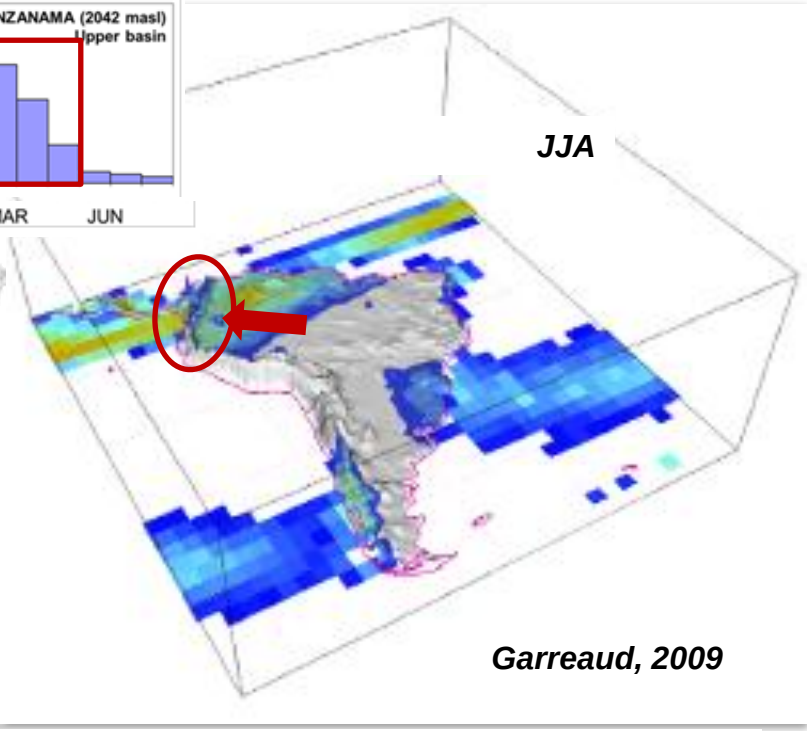
Photo 1: Flooding close to Guayaquil (province Guayas) on 10 March 2008 (Photo: J. Bendix)

LN 07 **ECUADOR-Guayas**

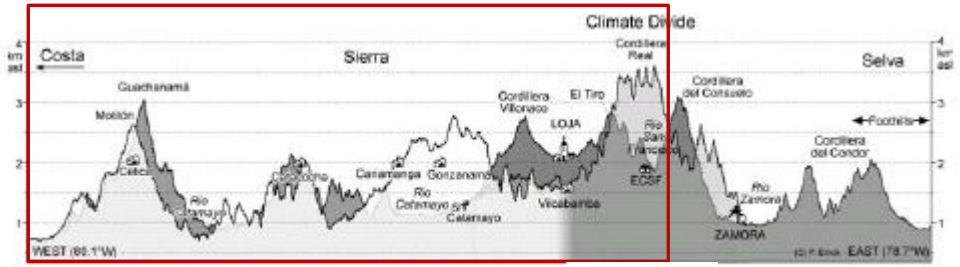
The regional climate

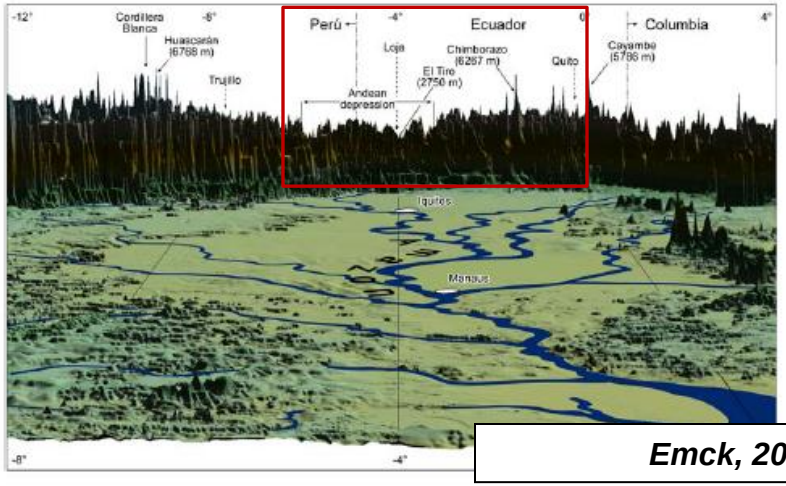






Garreaud, 2009

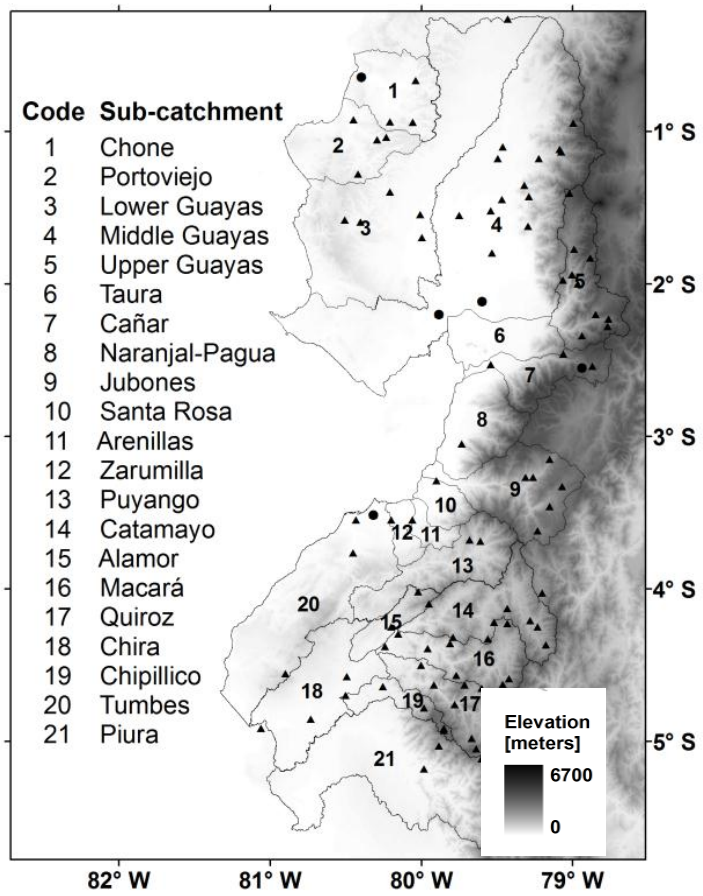




Emck, 2007

The Pacific-Andean Basin in Ecuador and Peru

- 21 hydrological units c.a.100,800 km2
- ~70 % Ecuadorian crop production



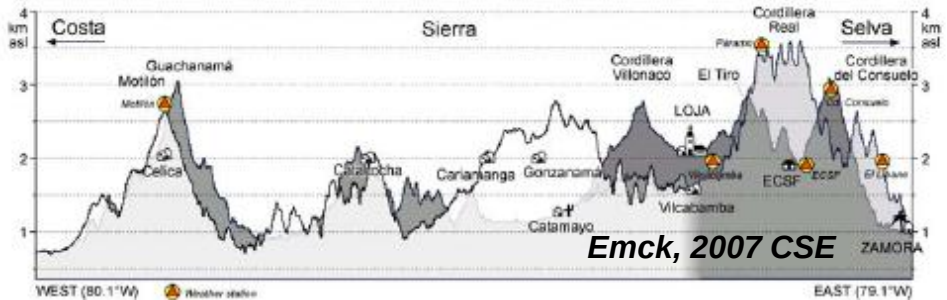
User needs of S2S forecast

Hydro-meteo hazards

- Slope stability
- Landslide models

Water resources

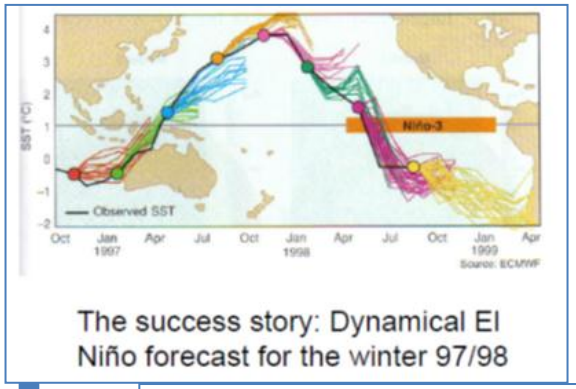
- Inflow for reservoirs
- Flood / drought prediction



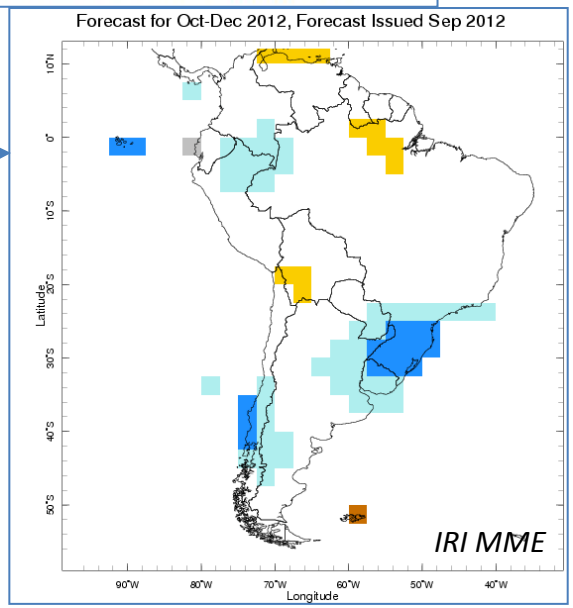
Emck, 2007 CSE

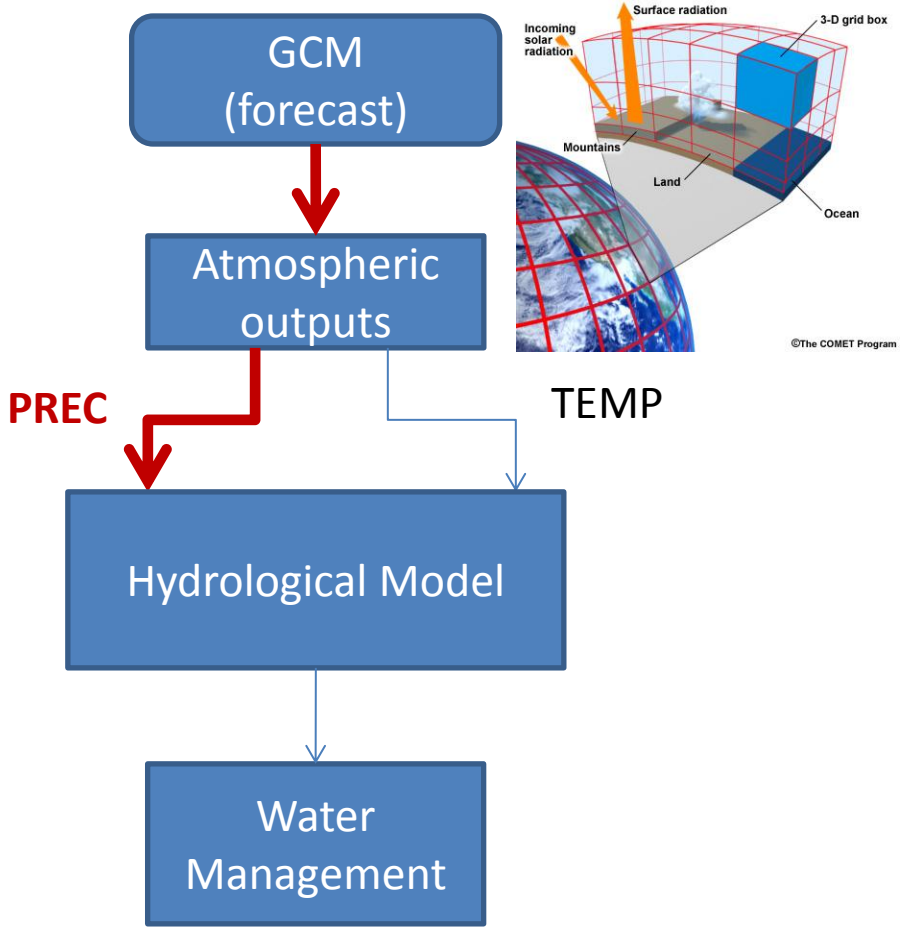
Objectives

- **Provide theoretical basis for seasonal climate prediction**
- **Tailor GCM seasonal climate forecasts for hydrological applications**



The success story: Dynamical El Niño forecast for the winter 97/98

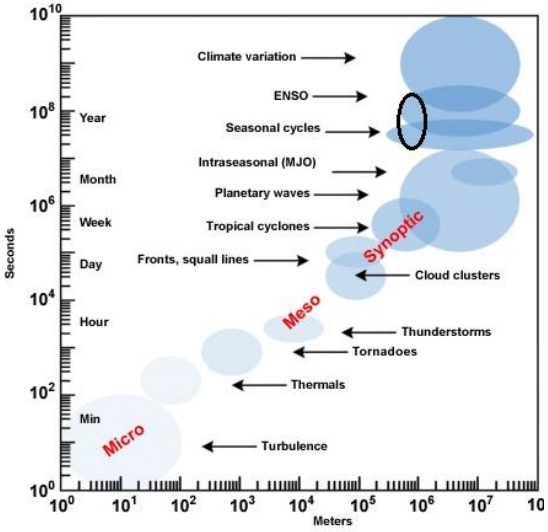




Barnston, 1999: Predictive Skill of Statistical and Dynamical Climate Models in SST Forecasts during the 1997–98 El Niño Episode and the 1998 La Niña Onset, BAMS, p.217

Work flow

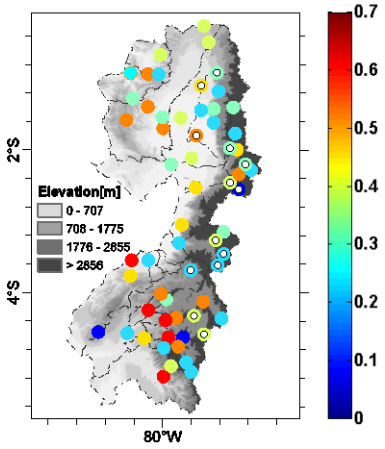
WP1 Weather type sub-seasonal diagnosis



Explore rainfall data

HMM

WP3 Dec-May daily rainfall conditioned on GCM forecasts

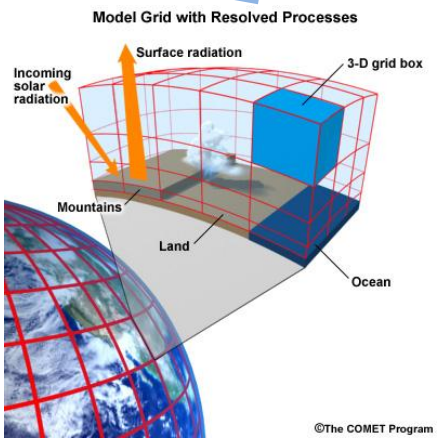


WP2 Process-based downscaling

CGCM vs. AGCM

GCM predictors

NHMM

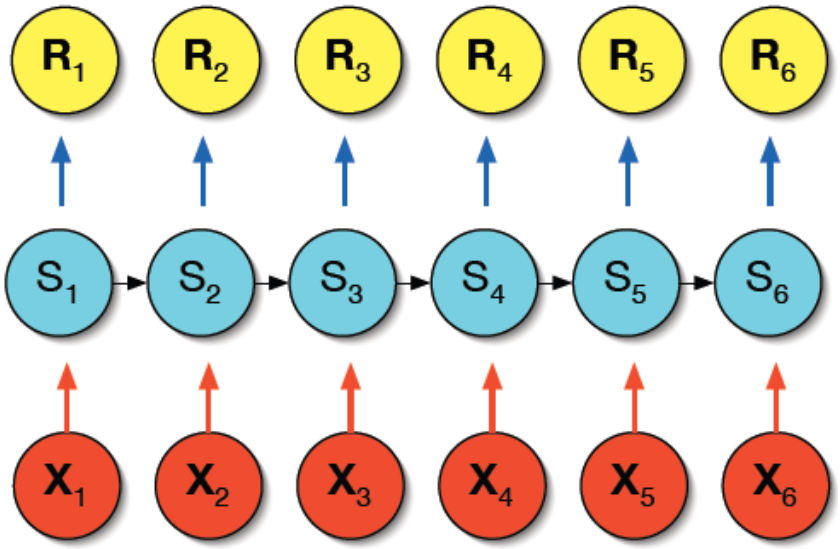


Why NHMM for downscaling?

$P(\mathbf{R}_t)$

$P(\mathbf{R}_t|S_t)$

$P(S_t|S_{t-1})$



$$P(S_t|S_{1:t-1}, \mathbf{X}_{1:T}) = P(S_t|S_{t-1}, \mathbf{X}_t)$$

Robertson et al. 2004

- Describes spatio-temporal dependencies in **multi-site / catchment rainfall data**
- The hidden weather states allow **"upscaling"** of rainfall processes
- Input variable ***X1:T*** can play the role of **predictor** on the spatial scale of **the weather state**

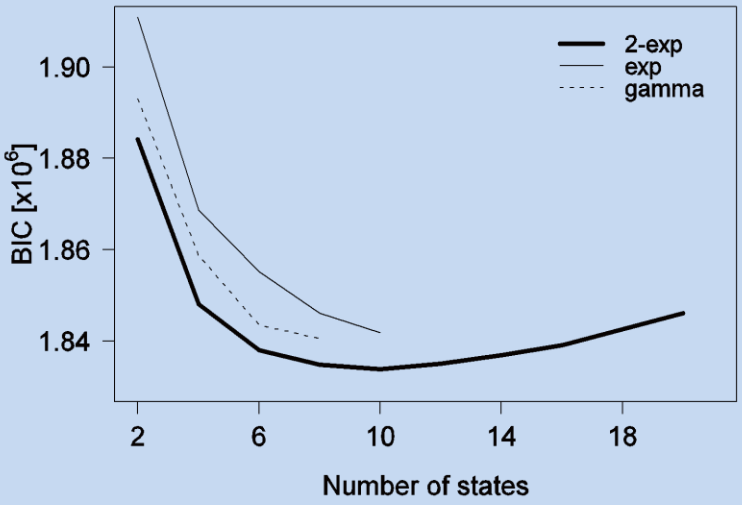
Robertson, A. W., S. Kirshner, and P. J. Smyth, 2004: Downscaling of daily rainfall occurrence over northeast Brazil using a hidden Markov model. J. Climate, 17, 4407-4424.

1. Dec-May weather characterization

HMM assumptions

- ✓ Number states
- ✓ Emission distributions for daily intensities and occurrences (pdf's)

  → ML parameter estimation EM[1] algorithm



Weather diagnosis

- ✓ States evolution sequence (Viterbi algorithm [2])
- ✓ Clustering of days falling into each state
- ✓ Mapping states as atmospheric composites:

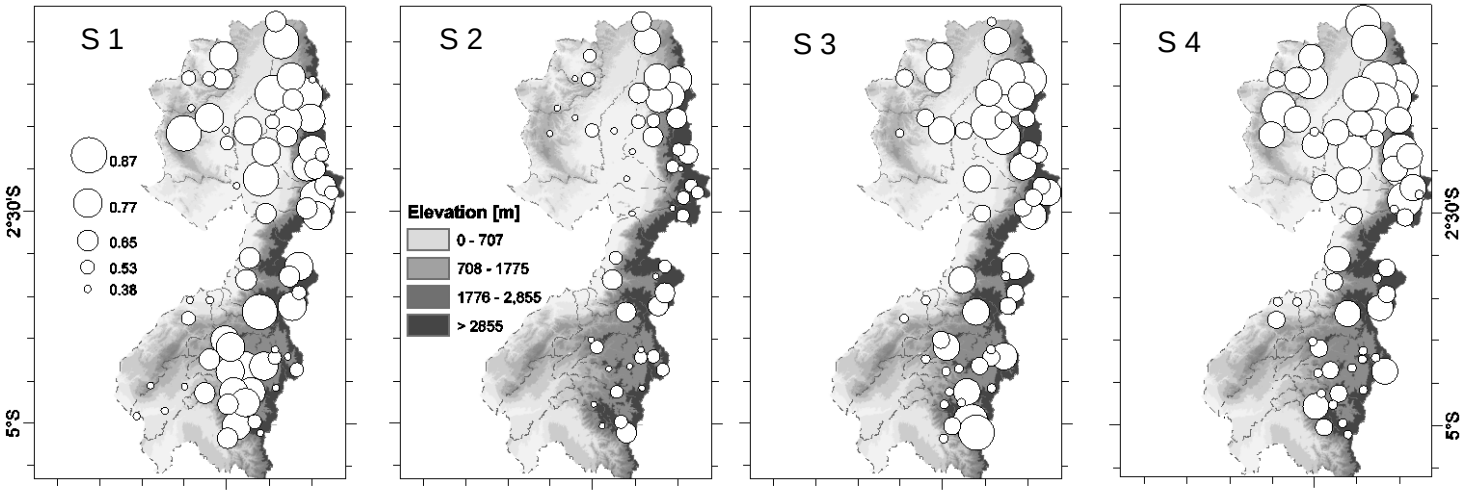
  uv850, q 850 anomalies from the Dec-May climatology

[1] ***Dempster et al. 1977; Ghanhramani, 2001***

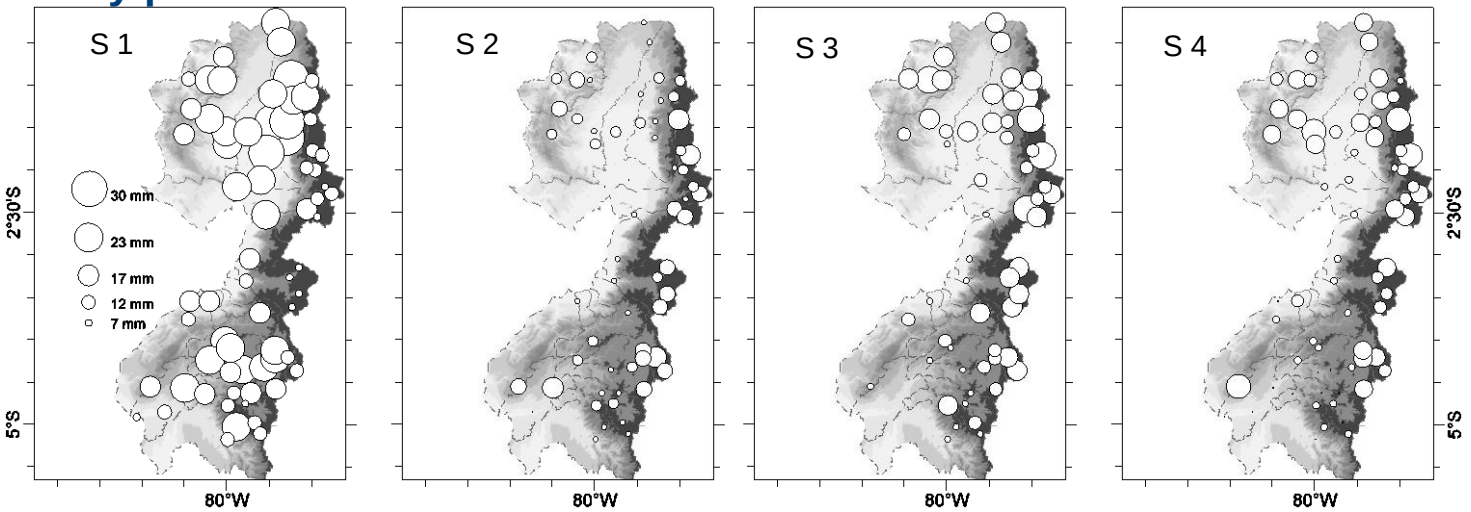
[2] ***Forney Jr., 1978***

Dec-May weather characterization

Mean intensities



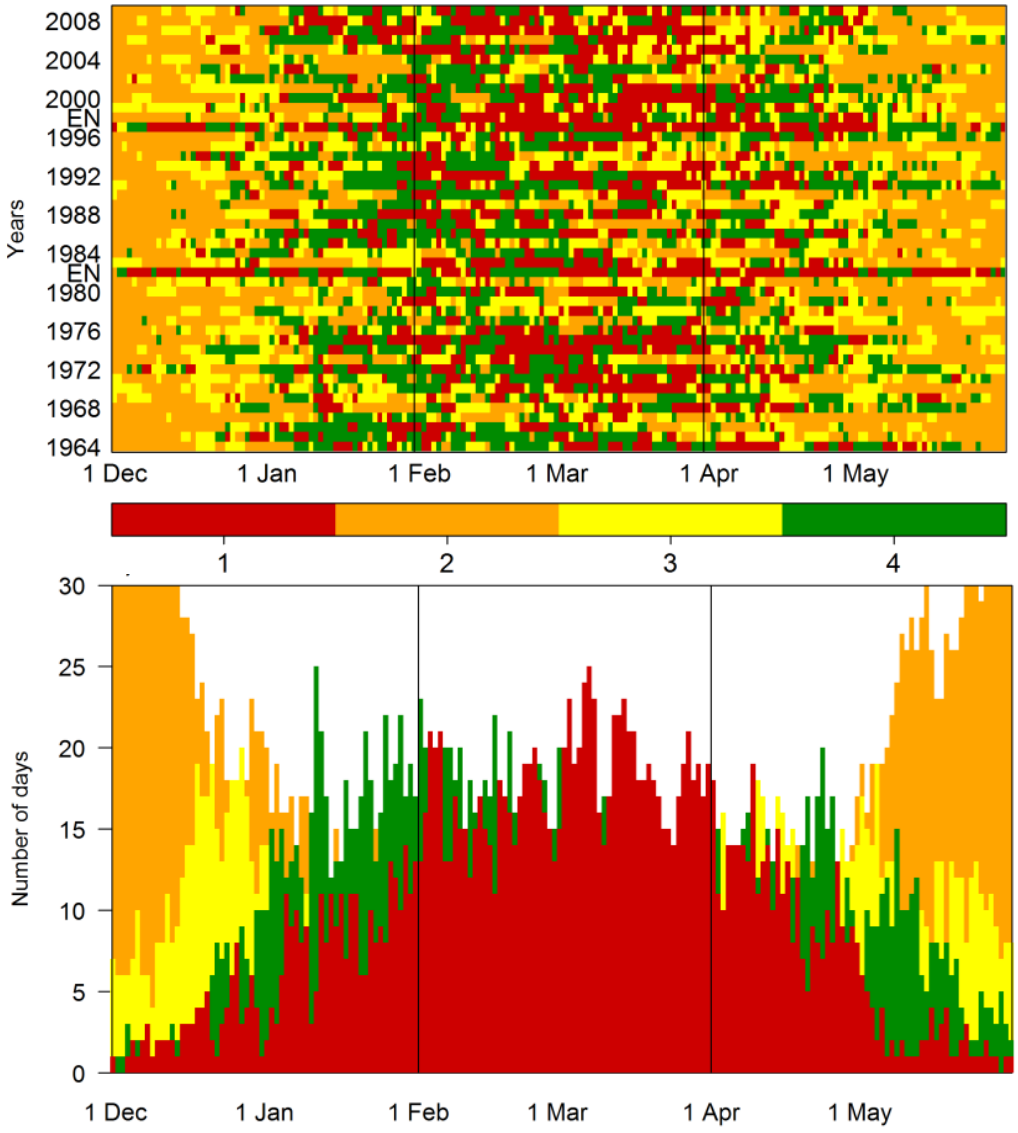
Wet-day probabilities



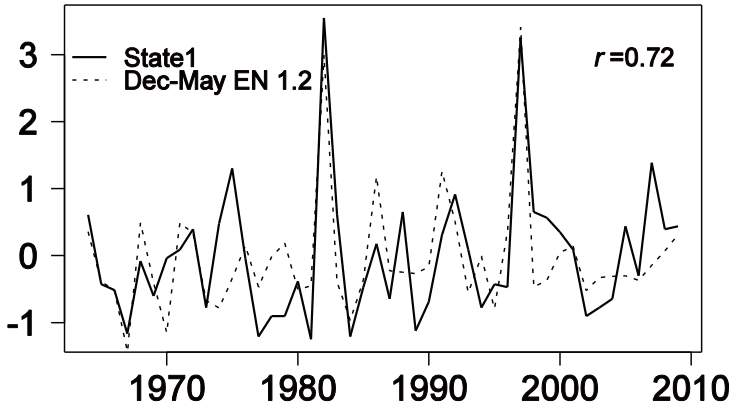
S1: Wet (+) **S2: Dry (+)** **S3: Dry-wet (-)** **S4: Wet (++)**

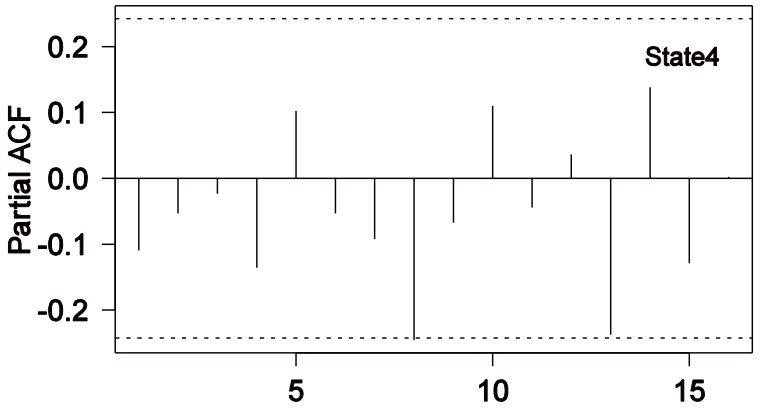
Dec-May weather characterization

Intra-season variability



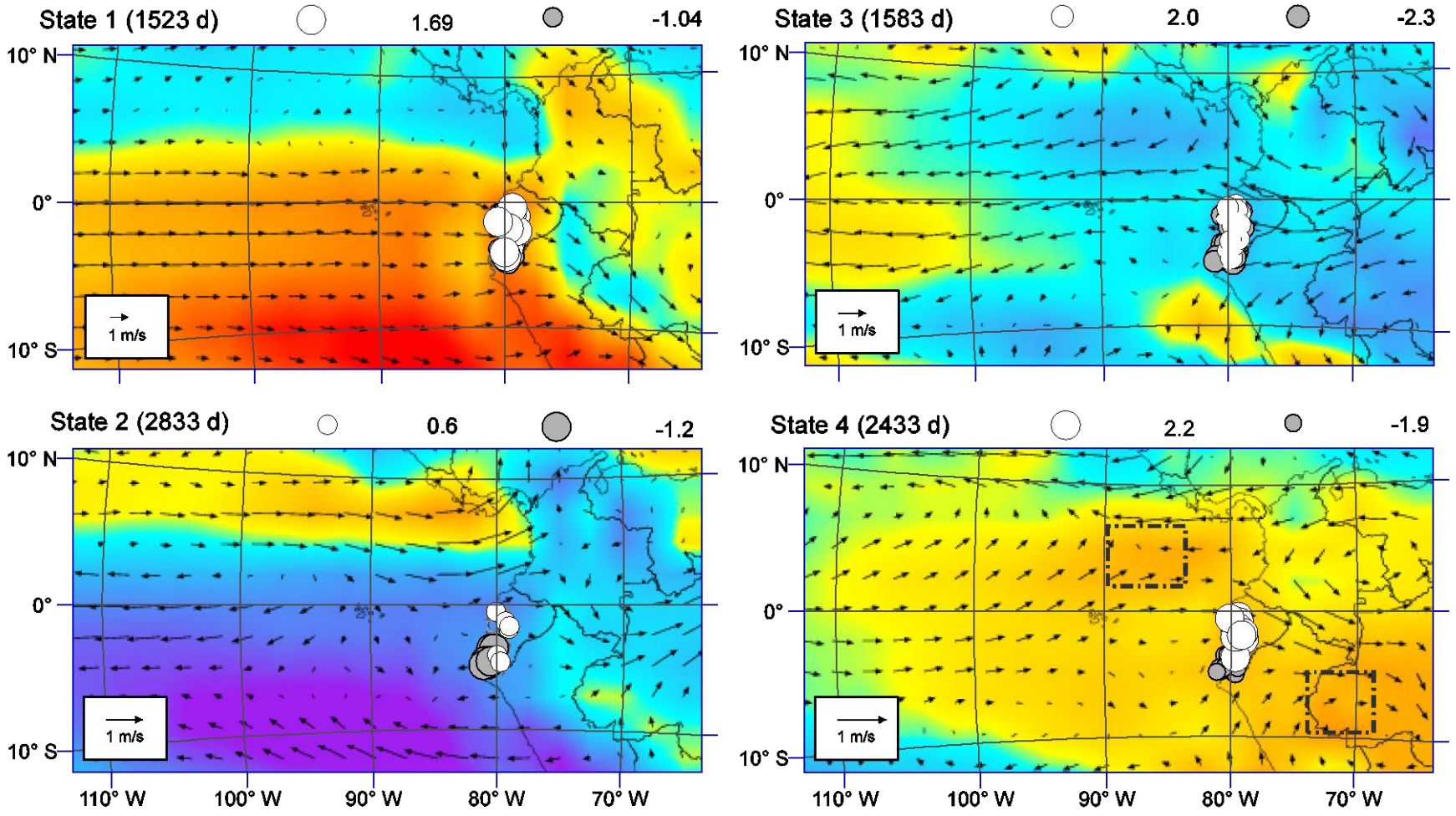
Interannual variability





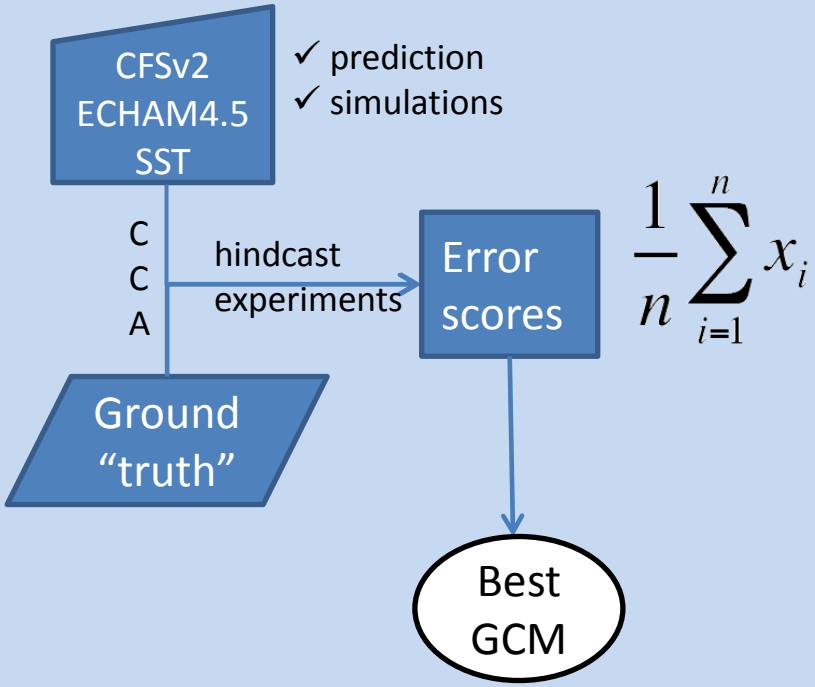
Dec-May weather characterization

Weather state - synoptic identity



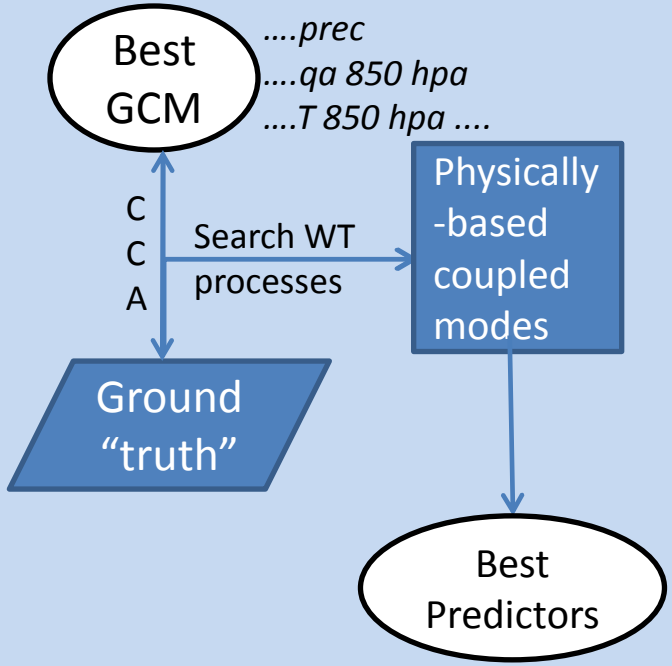
2. GCM evaluation & Predictors identification

Seasonal GCM forecast evaluation

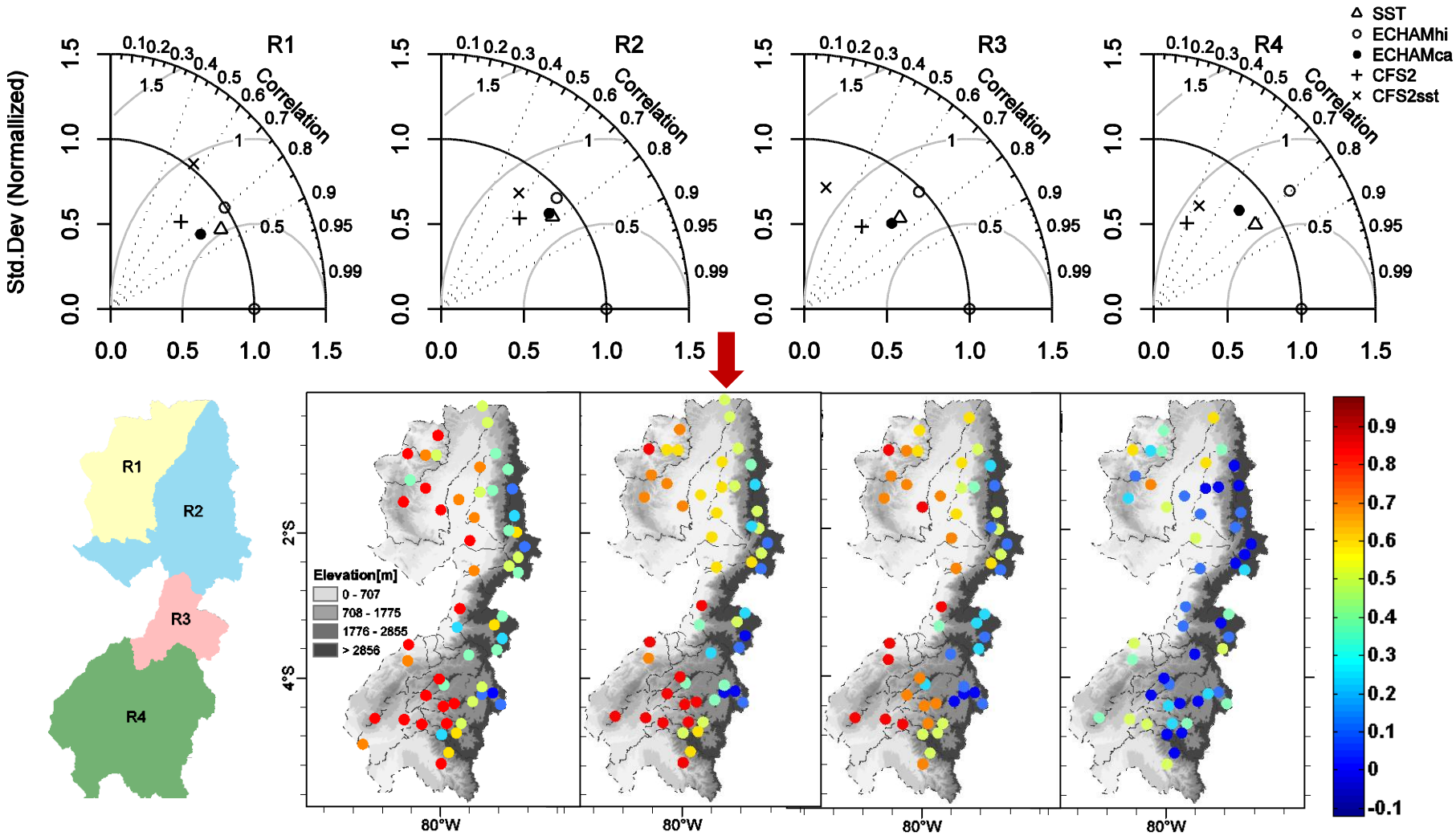


$$\frac{1}{n}\sum_{i=1}^{n} x_i$$

Processes Upscaling Predictor calibration



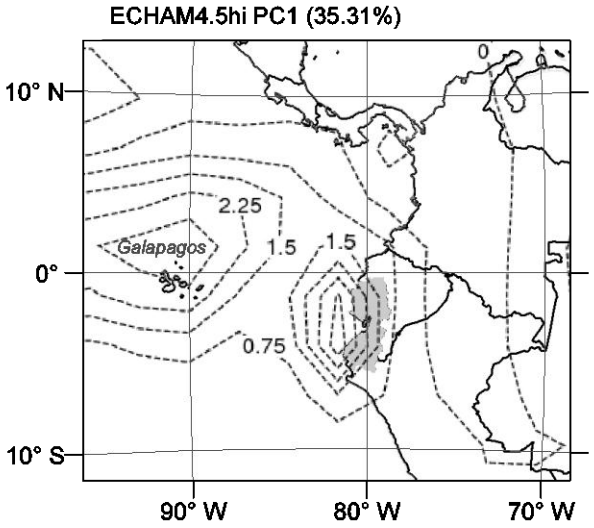
Seasonal GCM forecast evaluation



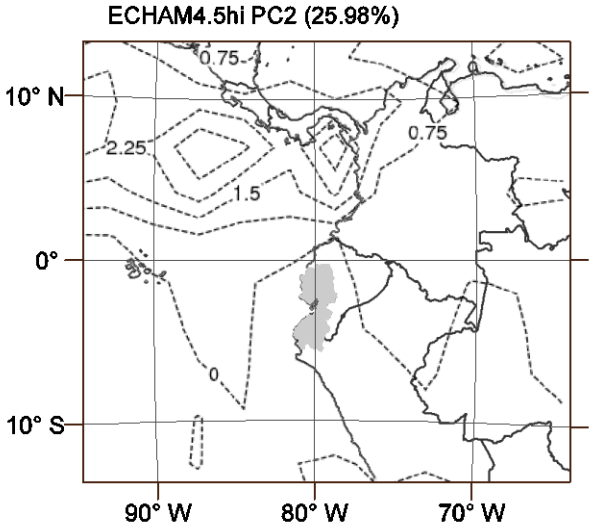
- CFSv2 skill (-) underestimation “double ITCZ syndrome”.
- ECHAM4.5ca skill(+) fails to emulate thermal rainfall as 1st mode → *qa(850hPa)*
- ECHAM4.5his skill (++) Separates thermal (signal) and dynamic (noise) → *p* highly skilful

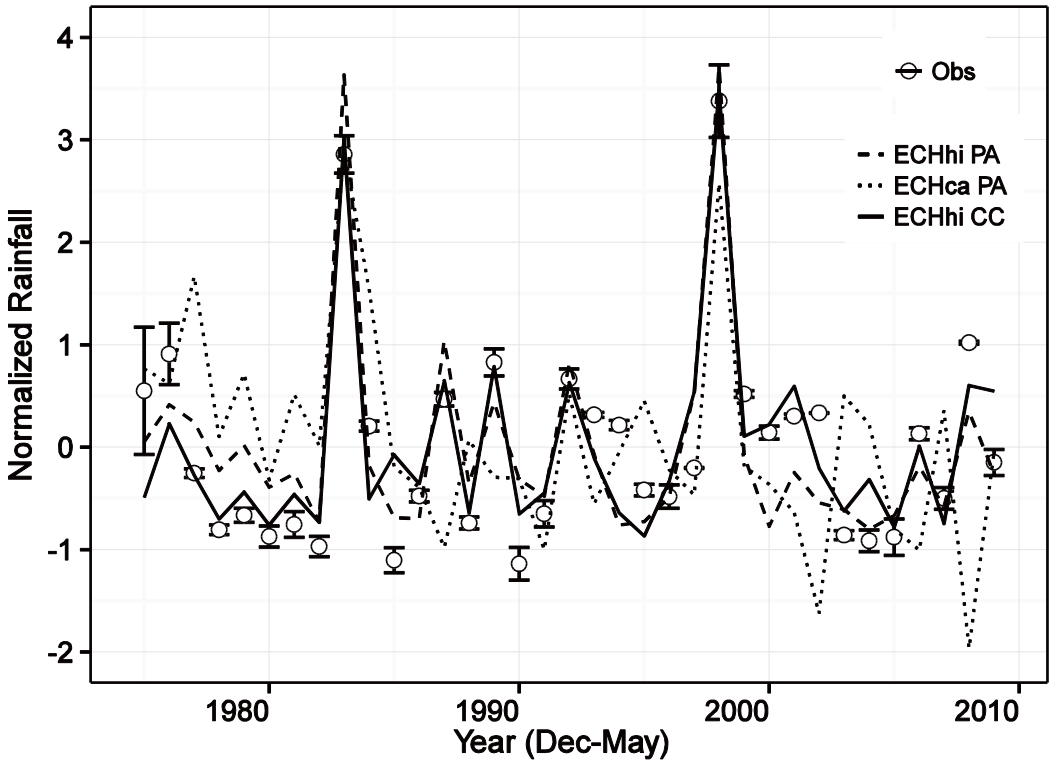
Processes Upscaling - Predictors identification

S1: Wet (+)



S4: Wet (++)

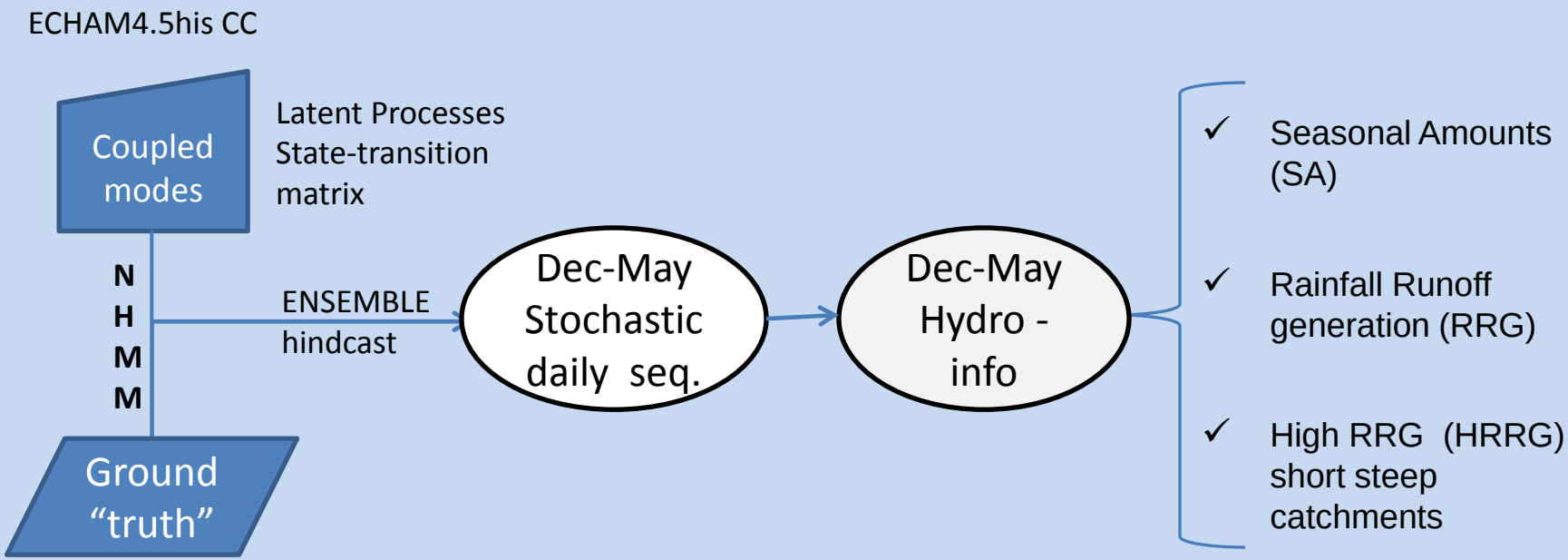




- ECHAM4.5 (historical-simulations) pixel → spatial-bias
- ECHAM4.5 (historical-simulations)
  1st Canonical variate (2 PCs)
  1st PC ITCZ during EN years - 2nd PC ITCZ no EN years

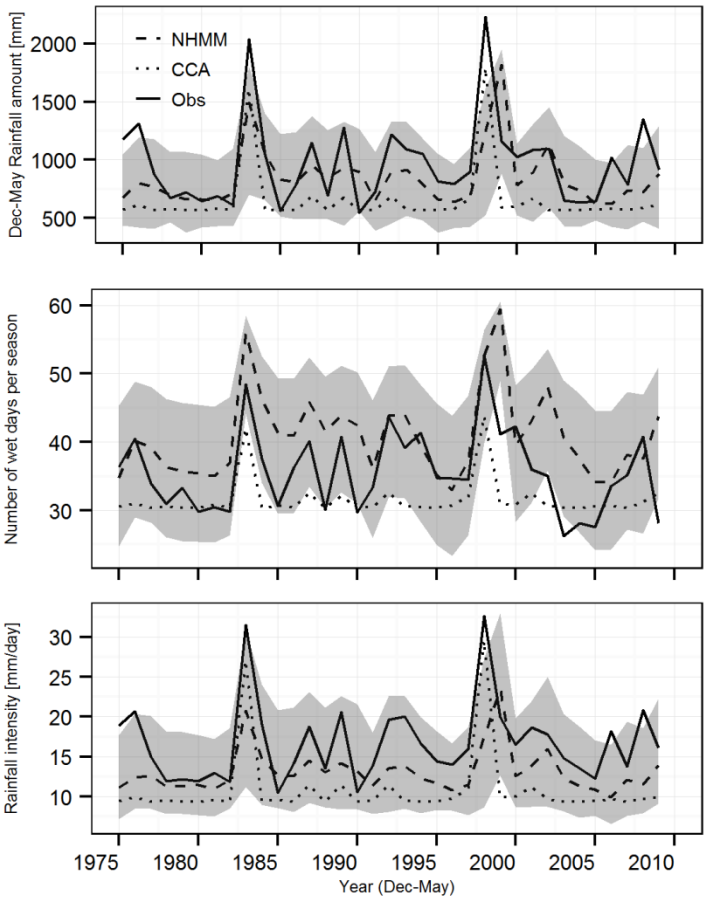
3. Dec-May process-based downscaling

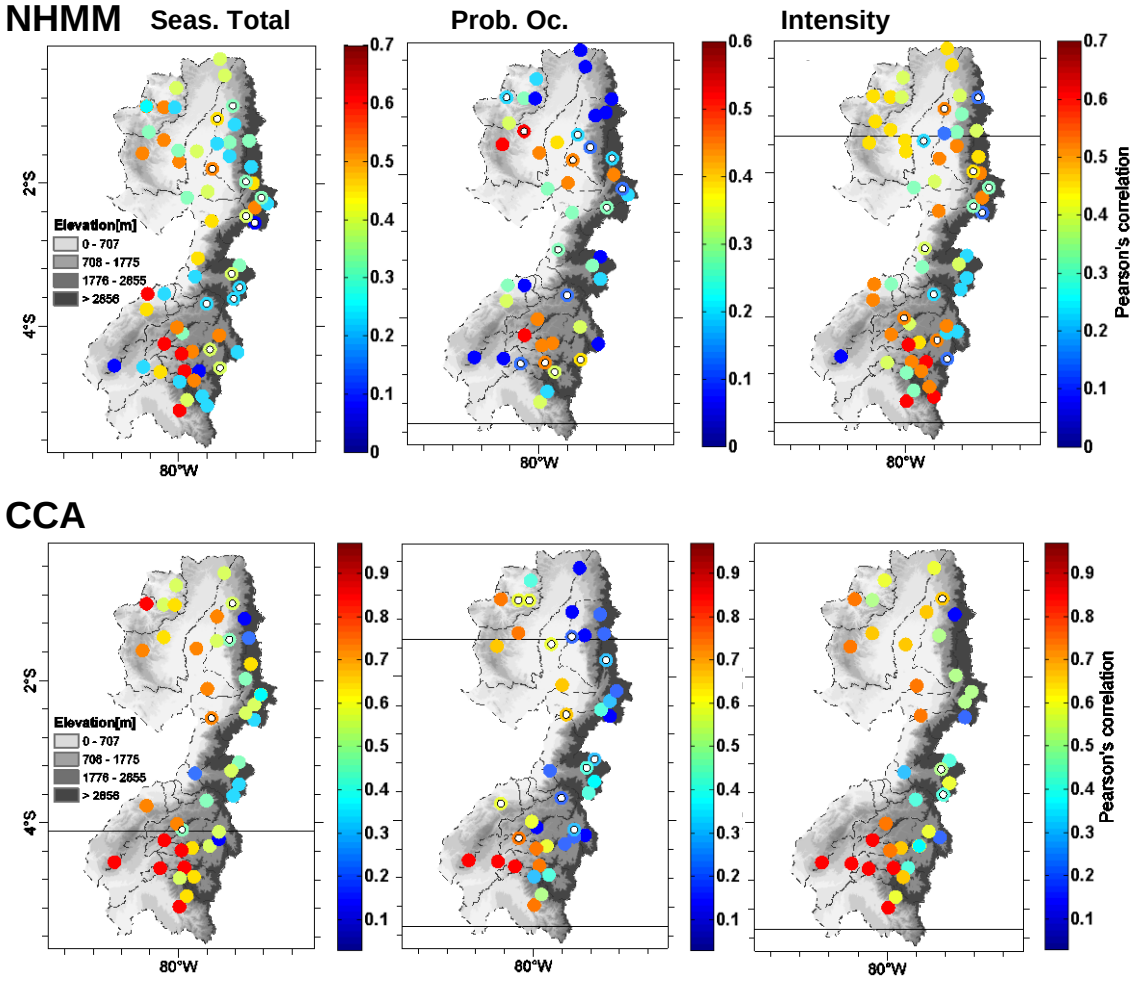
Weather-type daily rainfall downscaling using a NHMM



Process-based downscaling (Dec-May)

NHMM vs. CCA (correlation)





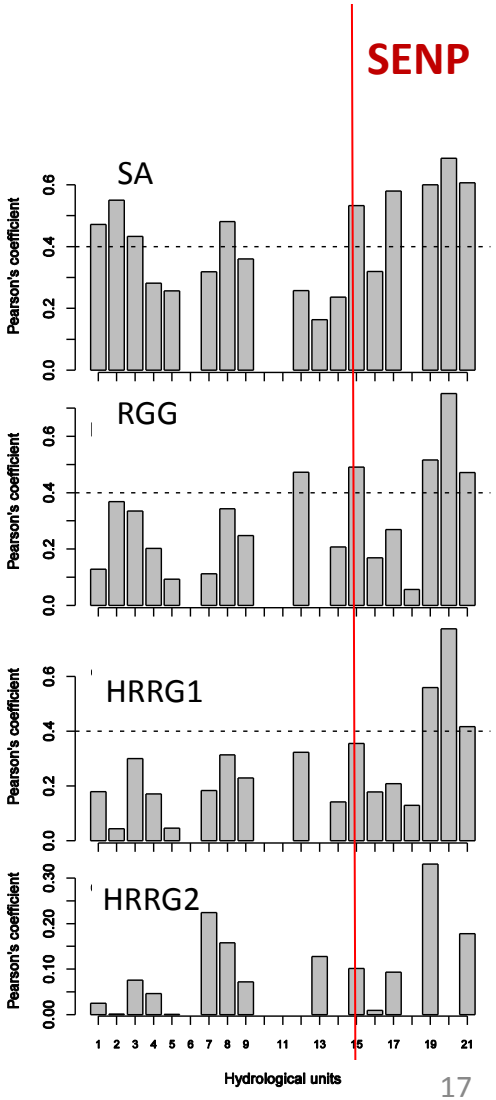
- 100 stochastic daily simulation of 36 Dec-May rainfall
- Better skills over SENP: Seas Total (+), Intensity w/d (++), Prob. Occur. (-)

Conclusions

- ECHAM4.5 performs better than CFSv2
  - → AGCM: SSTs lower boundary forcing is crucial for regional climate prediction
  - → Challenge: predict SSTs (east of 105W)

- Extraction of the AGCM process-related signal is key to input the NHMM
  - → Onset (Dec-Jan): dynamic (ITCZ/SAM) > thermal
  - → Mature(Feb-Mar) : dynamic =~ Thermal
  - → Retreat (Apr-May): thermal > dynamic (ITCZ)

- GCM-NHMM shows potential to produce daily rainfall info for catchment hydrology
  - → Challenge: complex spatial dependences over inner Andean catchments




Thanks