Comparing seasonal forecast downscaling methodologies for the agriculture sector in South Eastern South America

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MOTIVATIONS

One of the goals of the SNIA project: to **improve** seasonal forecasts over Uruguay

to **improve** their **spatial and temporal resolution** for the use in the *agricultural sector*

Why?

- **daily** temperature and precipitation are **needed** to force crop models
- Crop yields are affected by **'weather-within-climate'**
  (e.g.: dry spells, extreme heat during flowering, etc)
- Some of this processes are strongly **location-dependent** and spatially-restricted
  (e.g.: convective storms affecting vineyards, a given soil type flooded by a wet spell)

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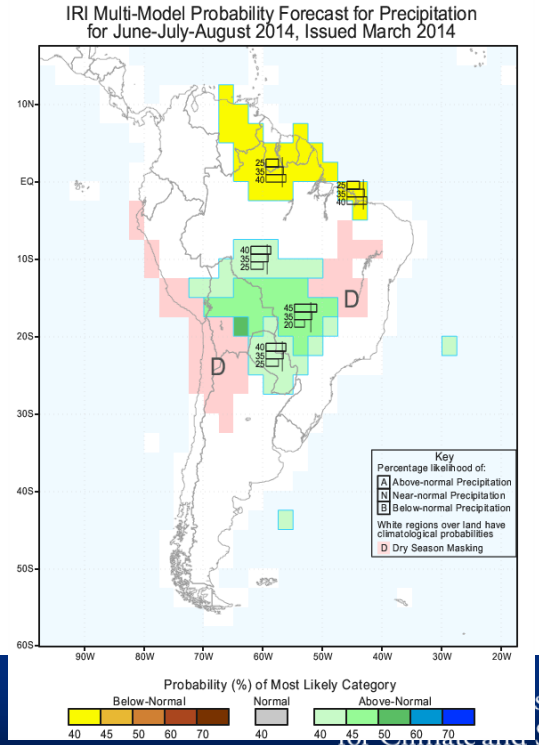
What is the baseline ?

Seasonal forecast + **downscaling methodology**

weather generator

tercile re-sampler



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Determine the sub-seasonal variability

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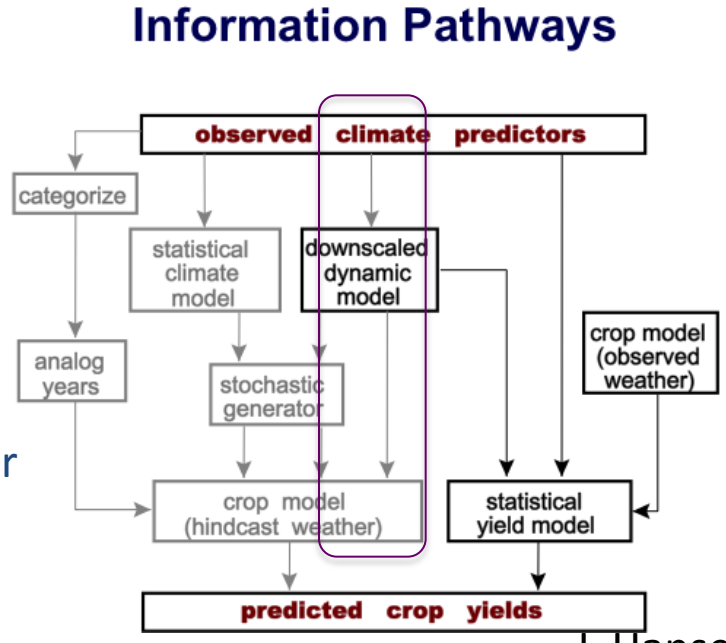


J. Hansen

Can seasonal forecasts provide any skillful information on **sub-seasonal** timescales ?

OBJECTIVES AND PREVIOUS RESULTS - RAINFALL

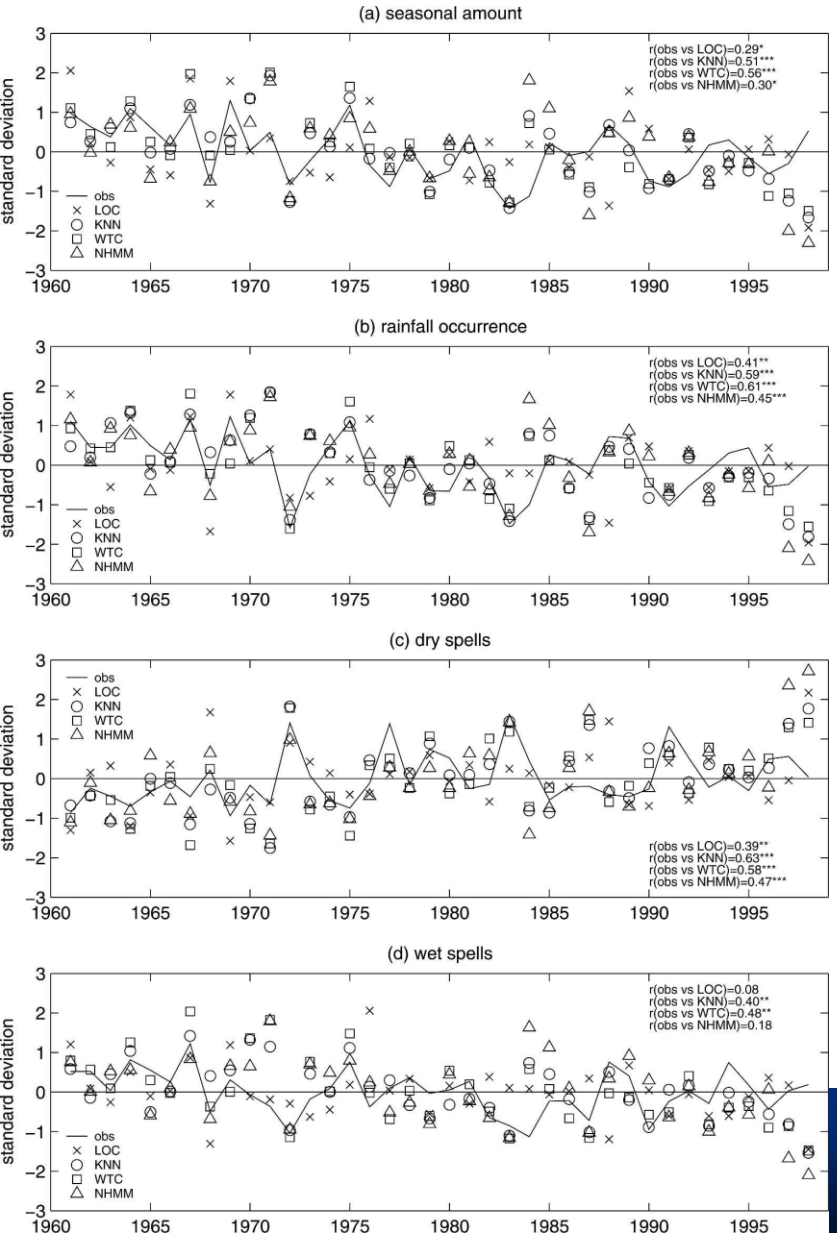
- To compare different seasonal GCM downscaling methodologies that can capture **seasonal rainfall statistics** affecting crops :
    - seasonal amount (S)
    - Rainfall occurrence (O)
    - average length of wet spells (W)
    - Average length of dry spells (D)

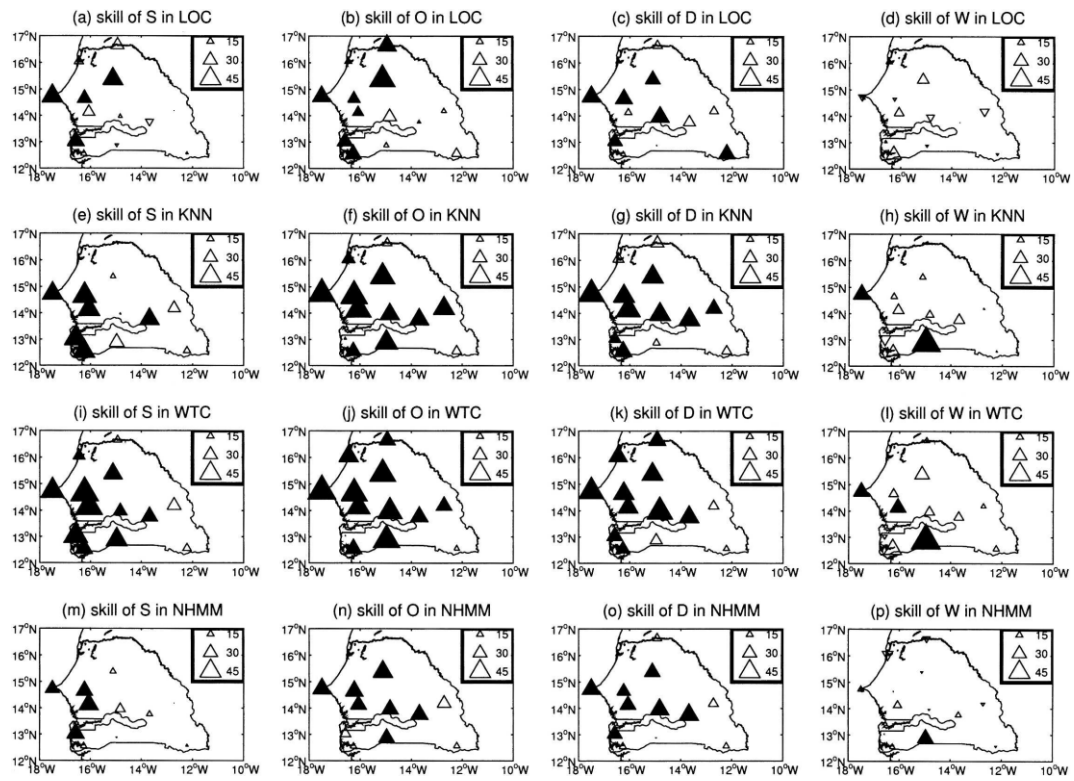
- **Based on results by Moron et al. we tested…**

1. Local scaling of GCM output (LOC)
2. K-nearest neighbors classification scheme (KNN)
3. Weather-type classification (WTC)
4. Non-homogeneous Hidden Markov Model (NHMM)

PREVIOUS RESULTS - RAINFALL

Previous results have shown these methods to be skillful for different regions, like Senegal:





- NHMM showed only slight improvements w.r.t. LOC
- KNN and WTC have higher skills and are equivalent

Moron et al. 2008

OBSERVATIONS

- 14 INUMET (Uruguay) **precipitation stations** with almost complete records for the period **1980-2013** and the **DJF** season.

- Different daily fields from the **NCEP/NCAR Reanalysis** (NNR)

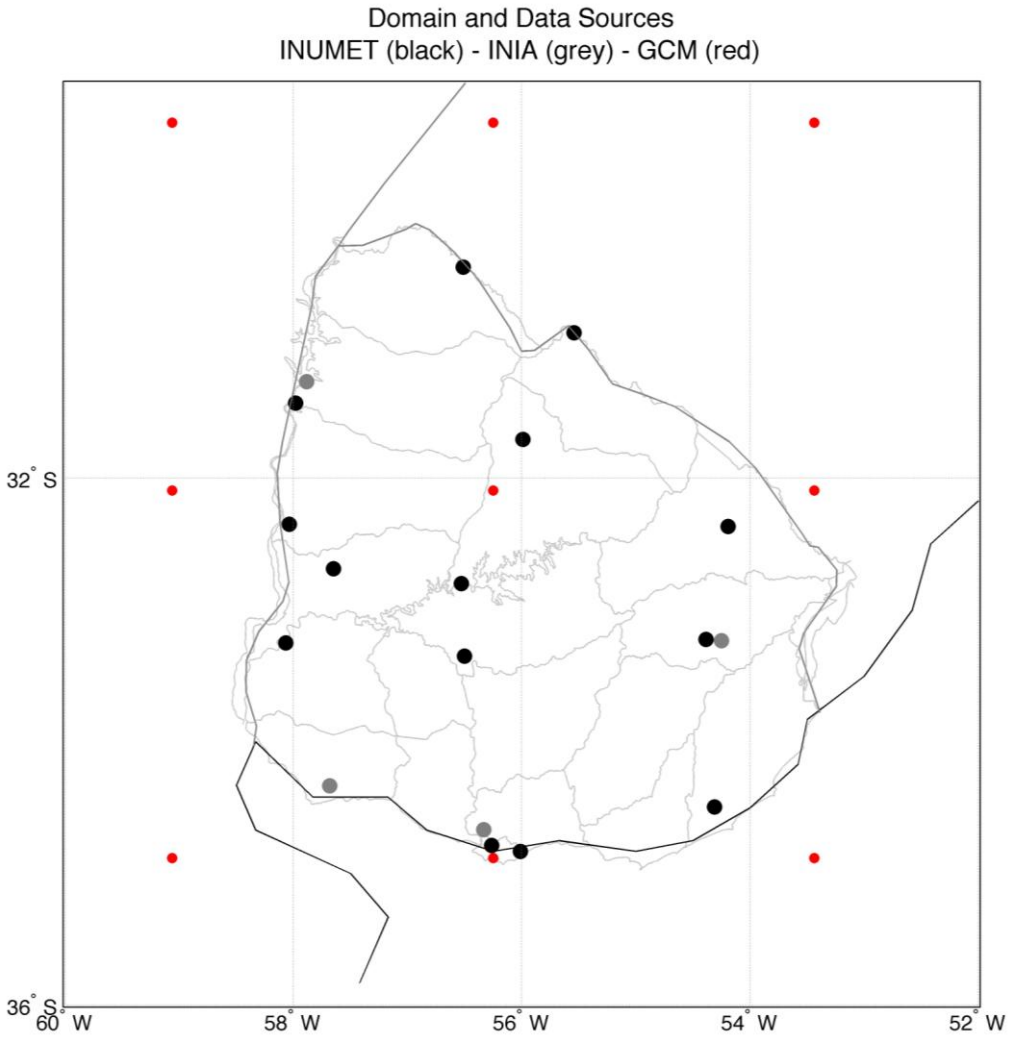
GCM

ECHAM4.5

IRI

Historical hindcasts operational

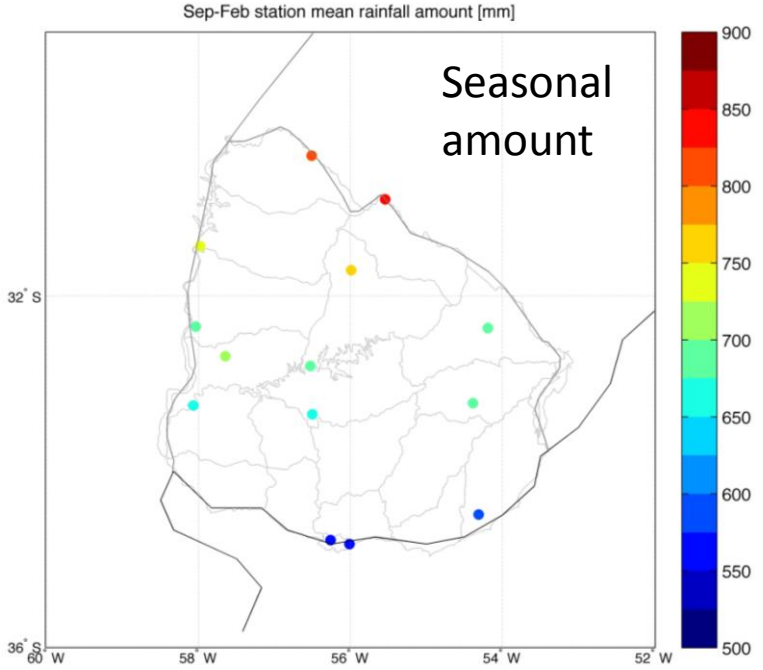
24-member ensemble forced with observed SSTs → red dots are locations of grid points 'affecting' Uruguay

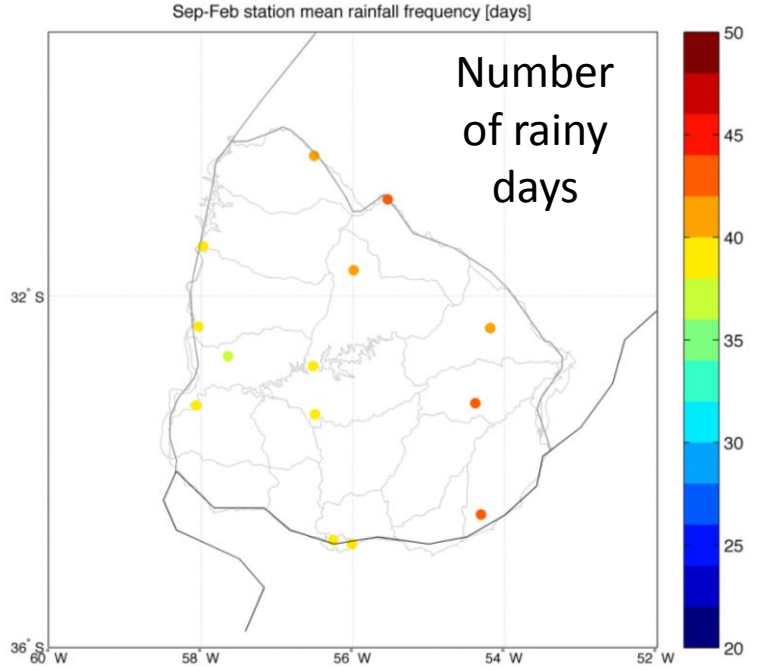


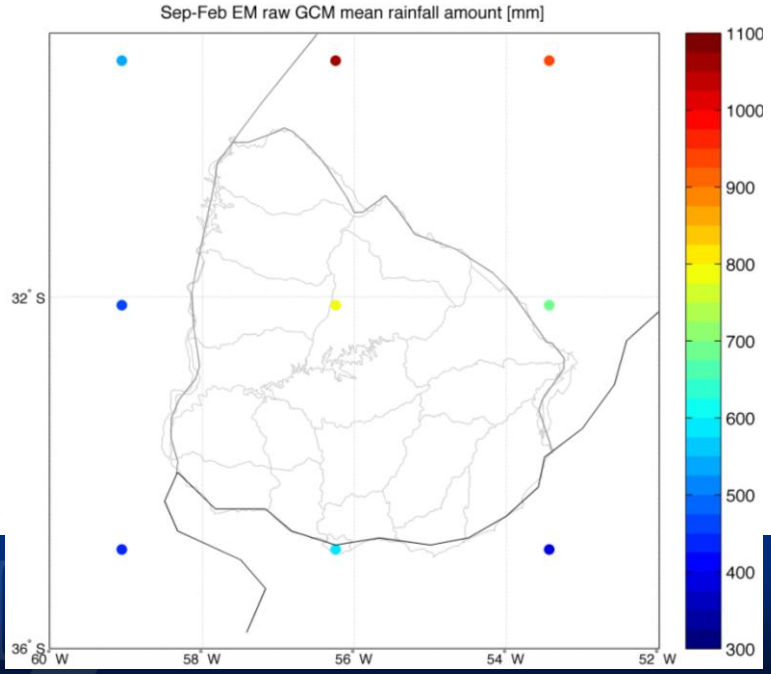
STATION DATA VS. ECHAM 4.5

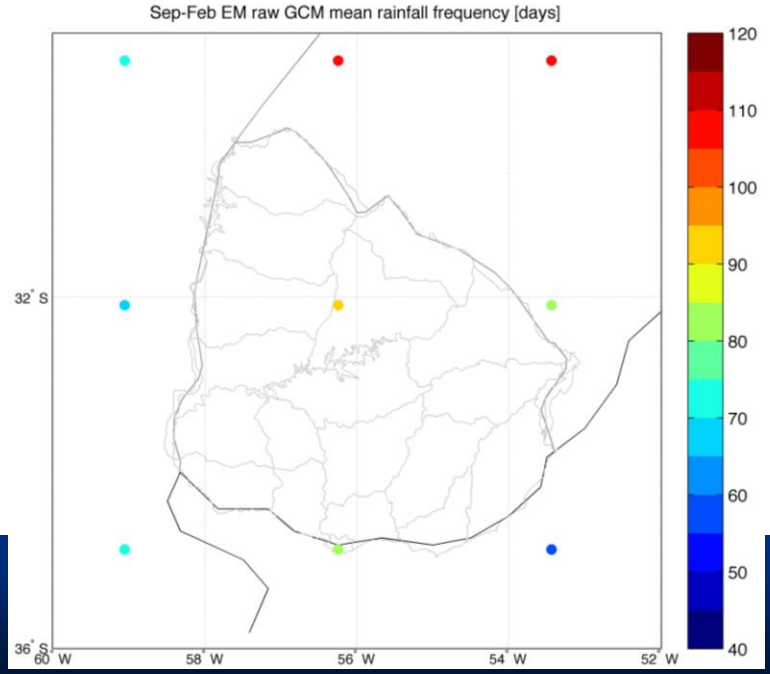
OBS

ECHAM 4.5 Ensemble mean









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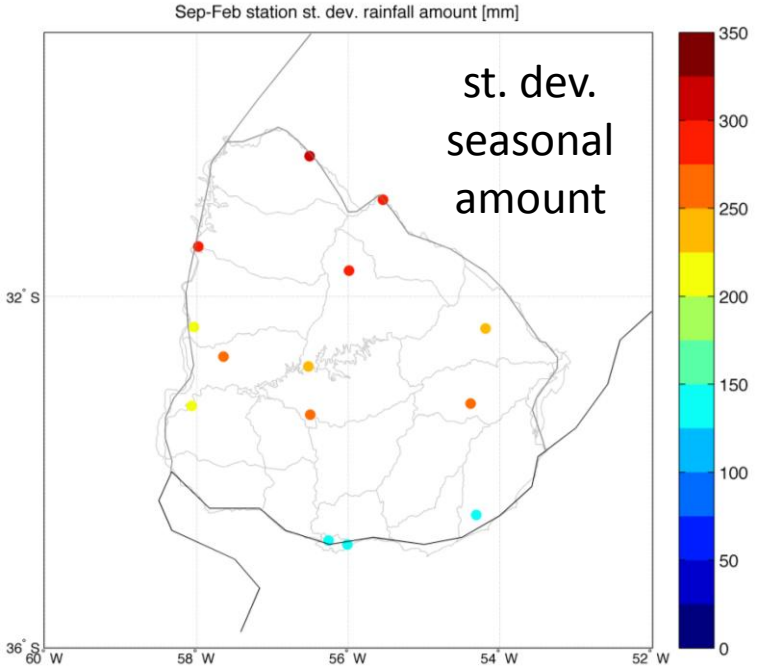
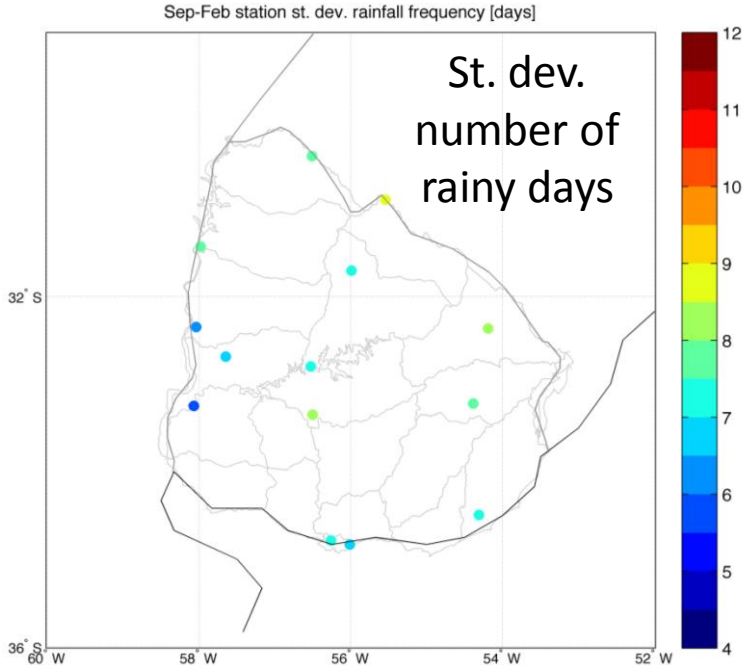
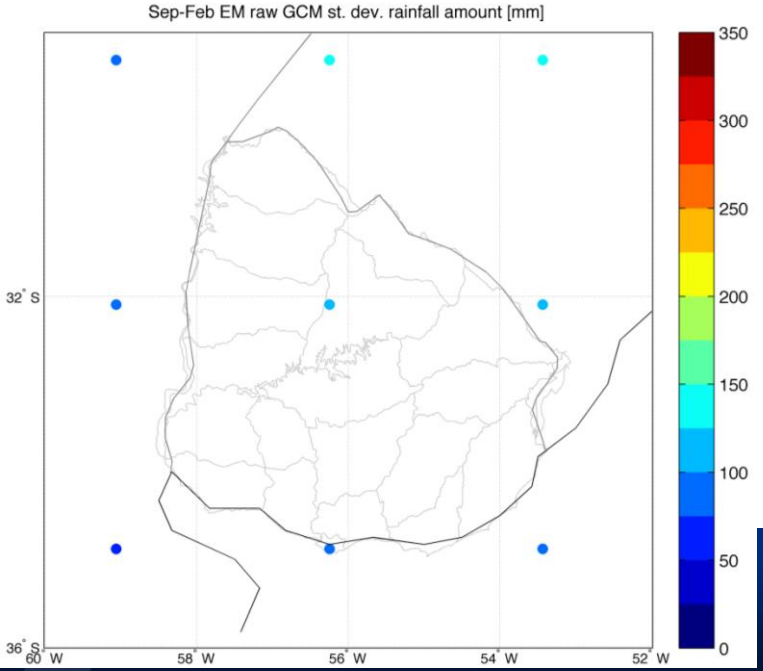
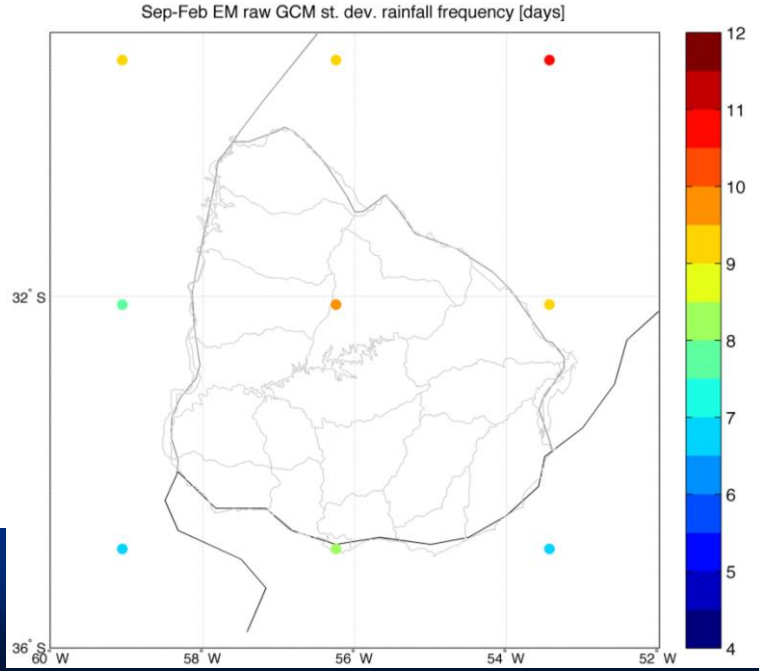




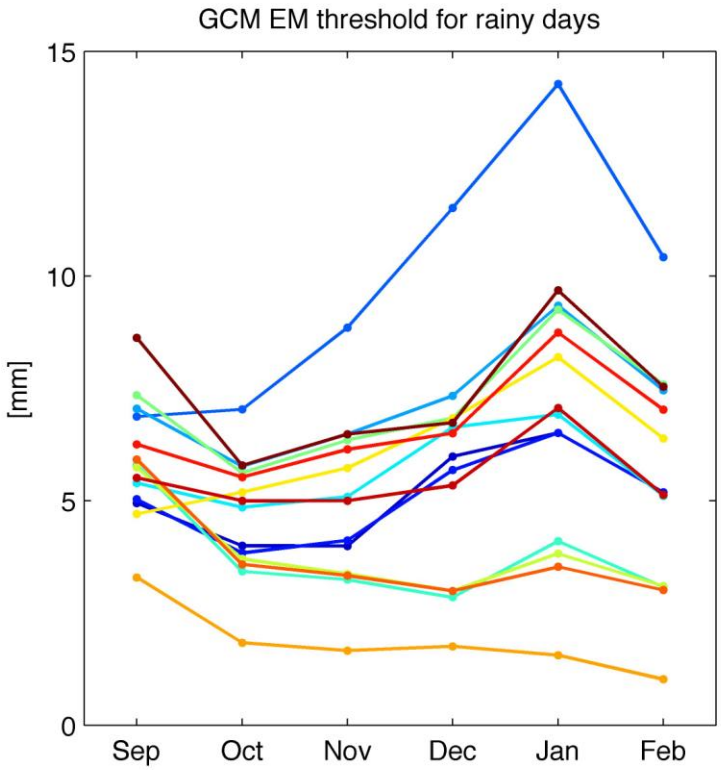


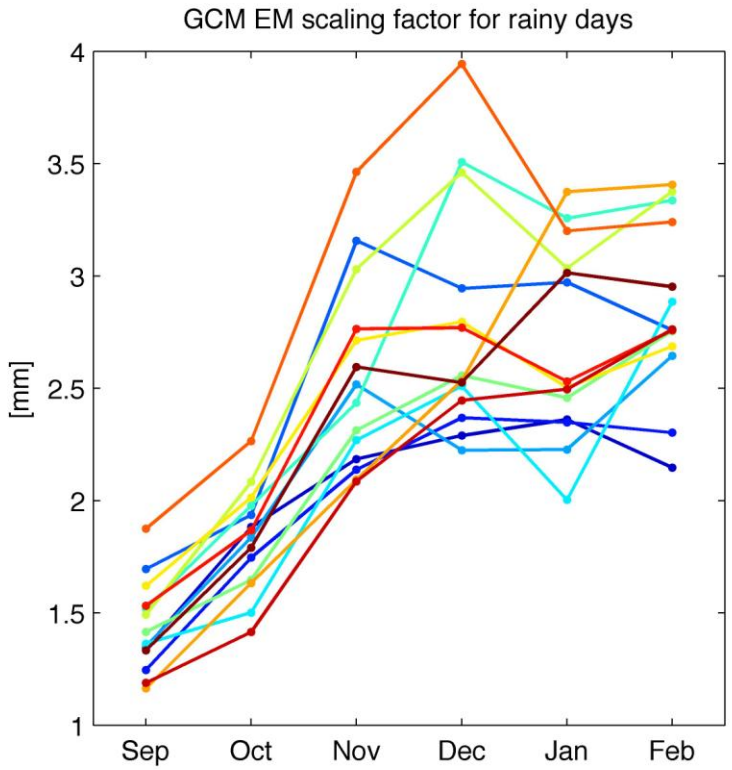


METHOD 1: local scaling

Precipitation is taken from the closest GCM grid point and the corrected for two factors:

- Rainfall threshold for rainy days
- Magnitude of rainfall accumulation in rainy days

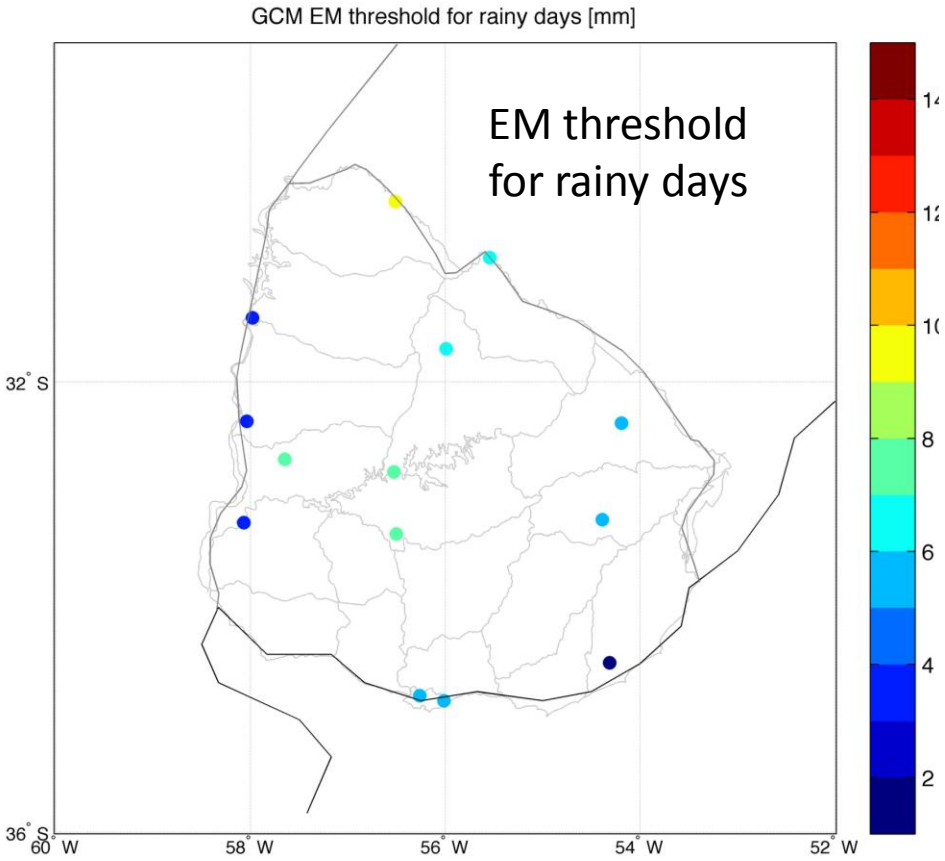


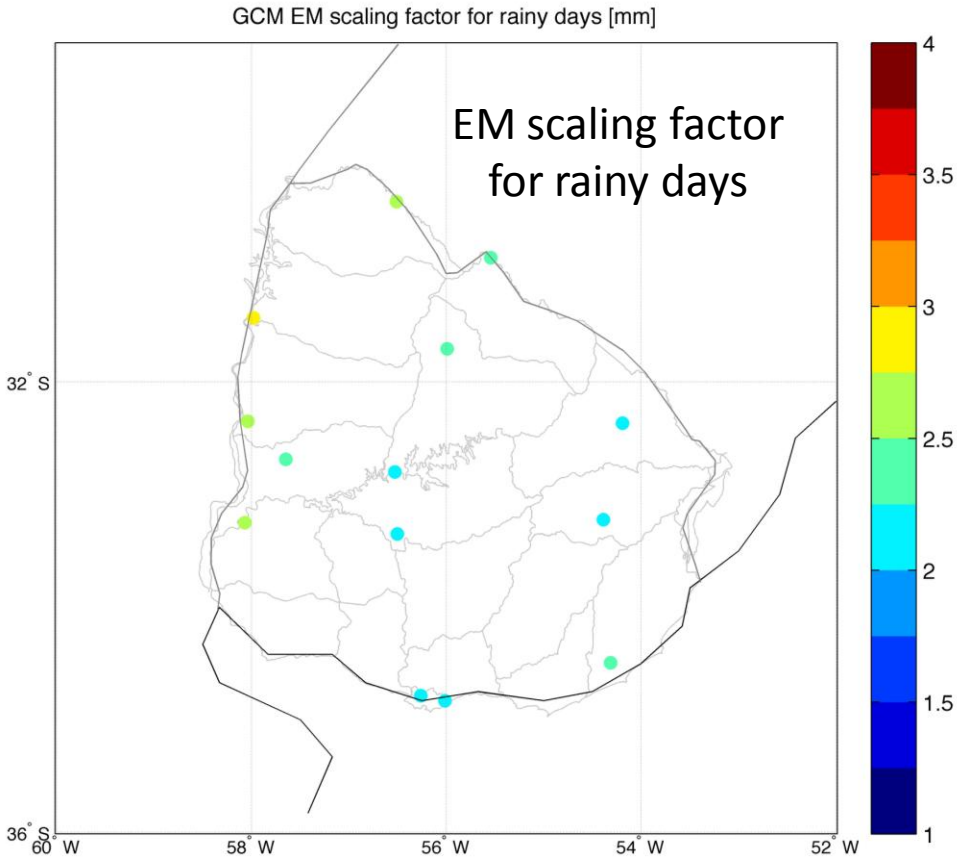


The scaling is applied monthly and the following figures show the variability of the param

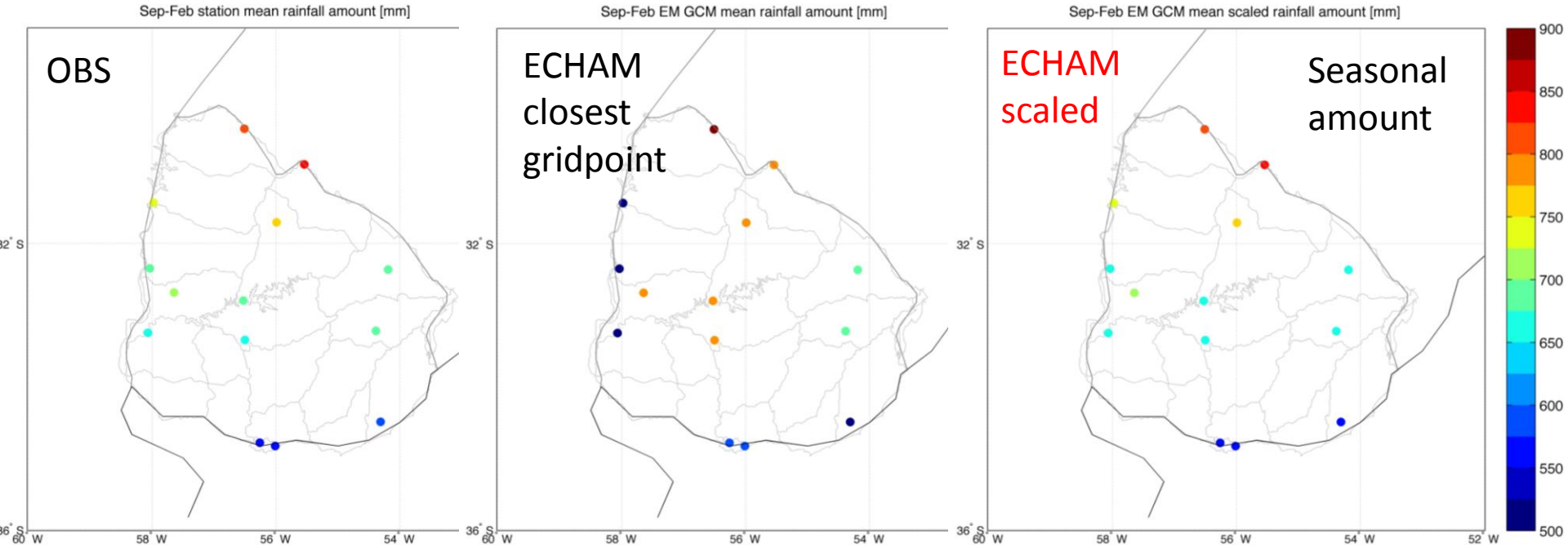
METHOD 1: local scaling

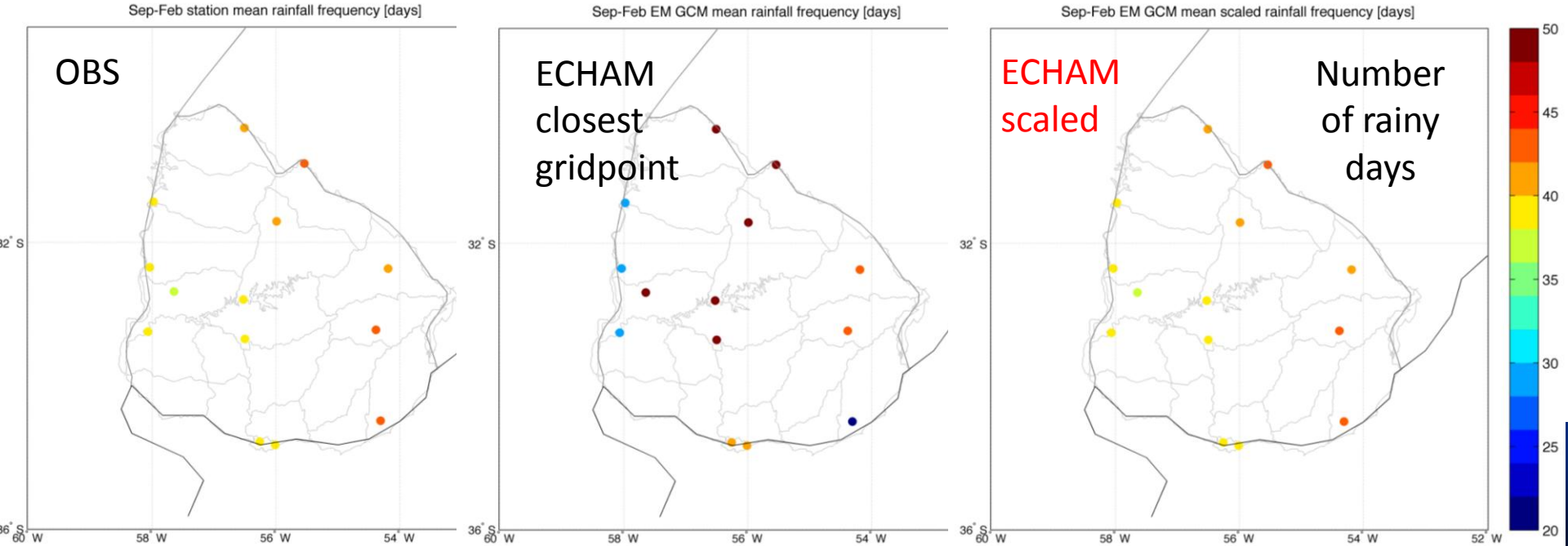
This is the spatial distribution of the local scaling parameters after averaging over the sea





AFTER LOCAL SCALING

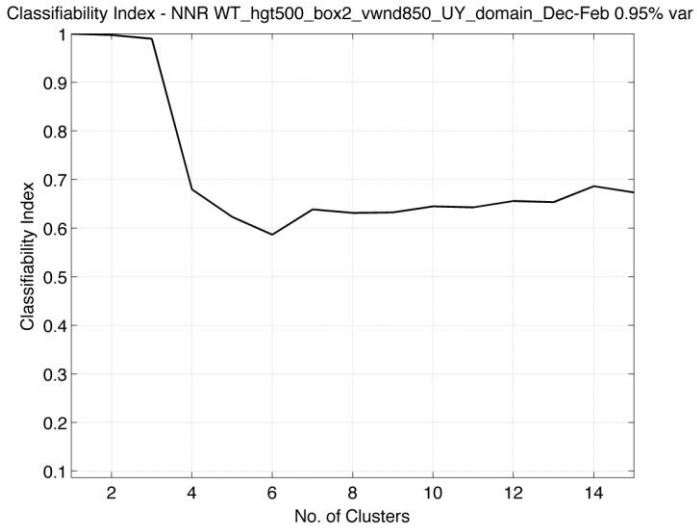




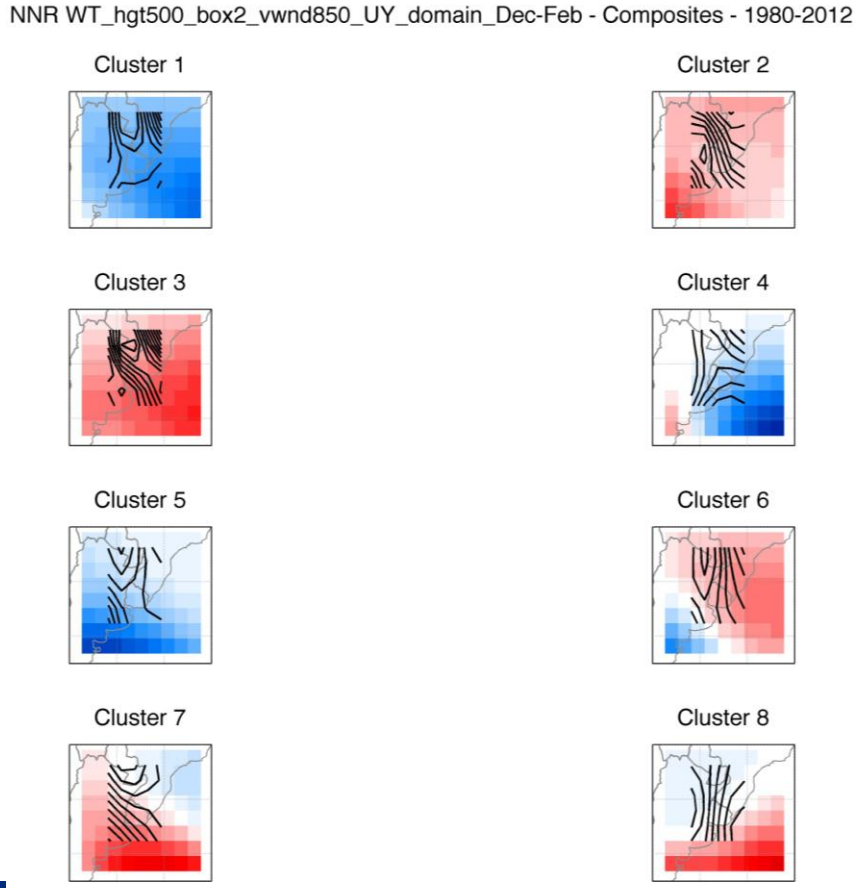
Method 2: WEATHER TYPE CLASSIFICATION

The basic principle is to make use of the fact that even if the GCM is not skillful at forecasting rainfall properties, it might still be capturing the dominant circulation patterns that control precipitation in the region.

A variable or a sets of variables are classified in 'types' and then used to **discriminate precipitation states.**



I'm showing results from the combined use of 500hPa geopotential heights in a **South American domain**, and 850hPa meridional wind in a regional SESA domain



Visit Angel Munoz's poster on the use of WTC for the analysis of precipitation extremes !

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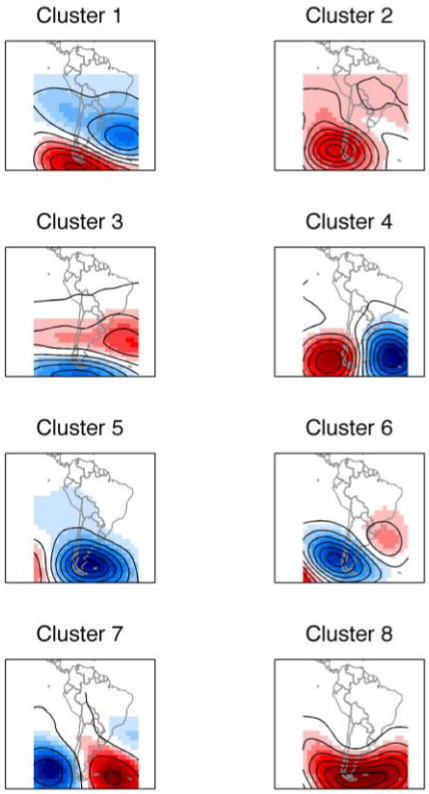

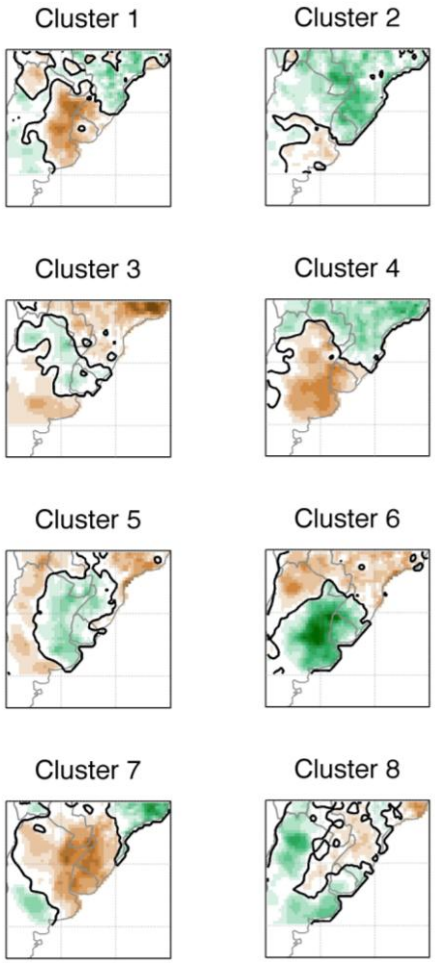

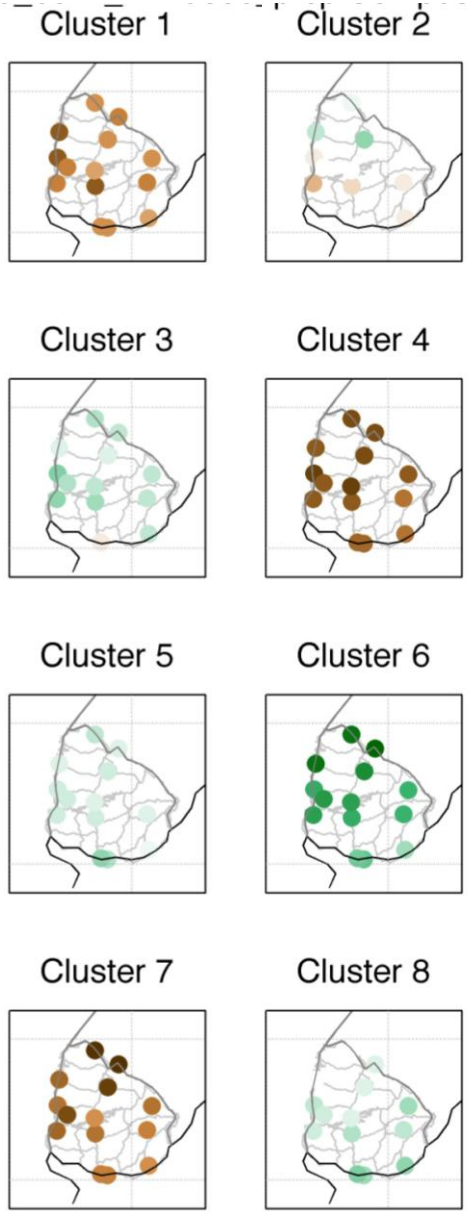

If a daily GCM state is determined to be **'closests'** to a given weather type, a sample (31 states) of station daily precipitation values is drawn from within the pool corresponding to that cluster → **new ensemble of rainfall forecasts**

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Method 3: K-NEAREST NEIGHBORS

The same combination of circulation 'predictors' is pre-filtered using a principal component analysis that retains 95% of the variance (20 daily PCs) → NNR PCs

The obtained reanalysis EOFs are projected onto each ensemble member of the GCM to obtain a set of ECHAM PCs

Without going through the extra WTC step, each occurrence of a GCM daily predictor field is linked to a set of **k-nearest neighbors** (31) , within the pool of station precipitation states corresponding to the observed reanalysis states.

new ensemble of rainfall forecasts

Method 4: NONHOMOGENEOUS HIDDEN MARKOV CHAINS

As a second benchmark to measure the performance of KNN and WTC methods against, we apply the NHMM. This model is based on the station rainfall records together with the **same set of predictors** that modulate the occurrence of the model's hidden states.

Homogeneous HMM → describes the joint distribution of historical daily rainfall amounts in terms of a few discrete states, by making **two assumptions of conditionality**:

- rainfall on a given day only depends **on the state active on that** day,
- that the state active on a given day depends only on the **previous day's state**.

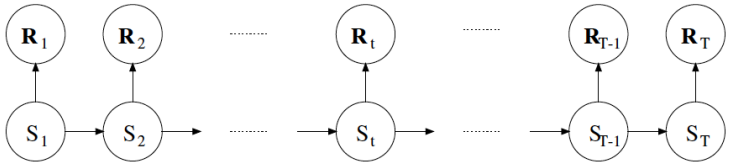


Figure 1: Graphical model interpretation of a hidden Markov model

Nonhomogeneous HMM → enables downscaling from a set of **predictors** that then **modulate the Markovian transition probabilities** between the states "nonhomogeneously" over time. Once the model's parameters have been learned, stochastic simulations of rainfall can be generated at all the stations on the network (100) → **new ensemble of rainfall forecasts**

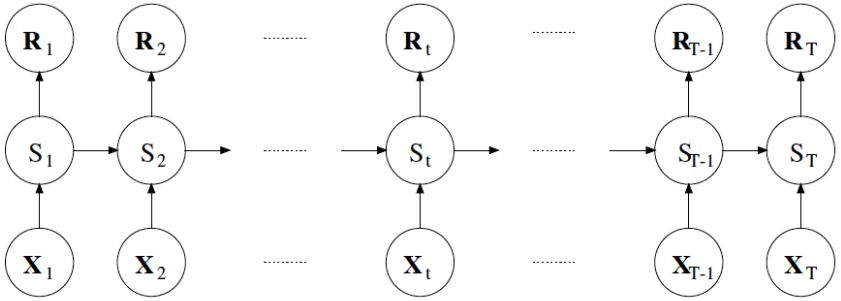
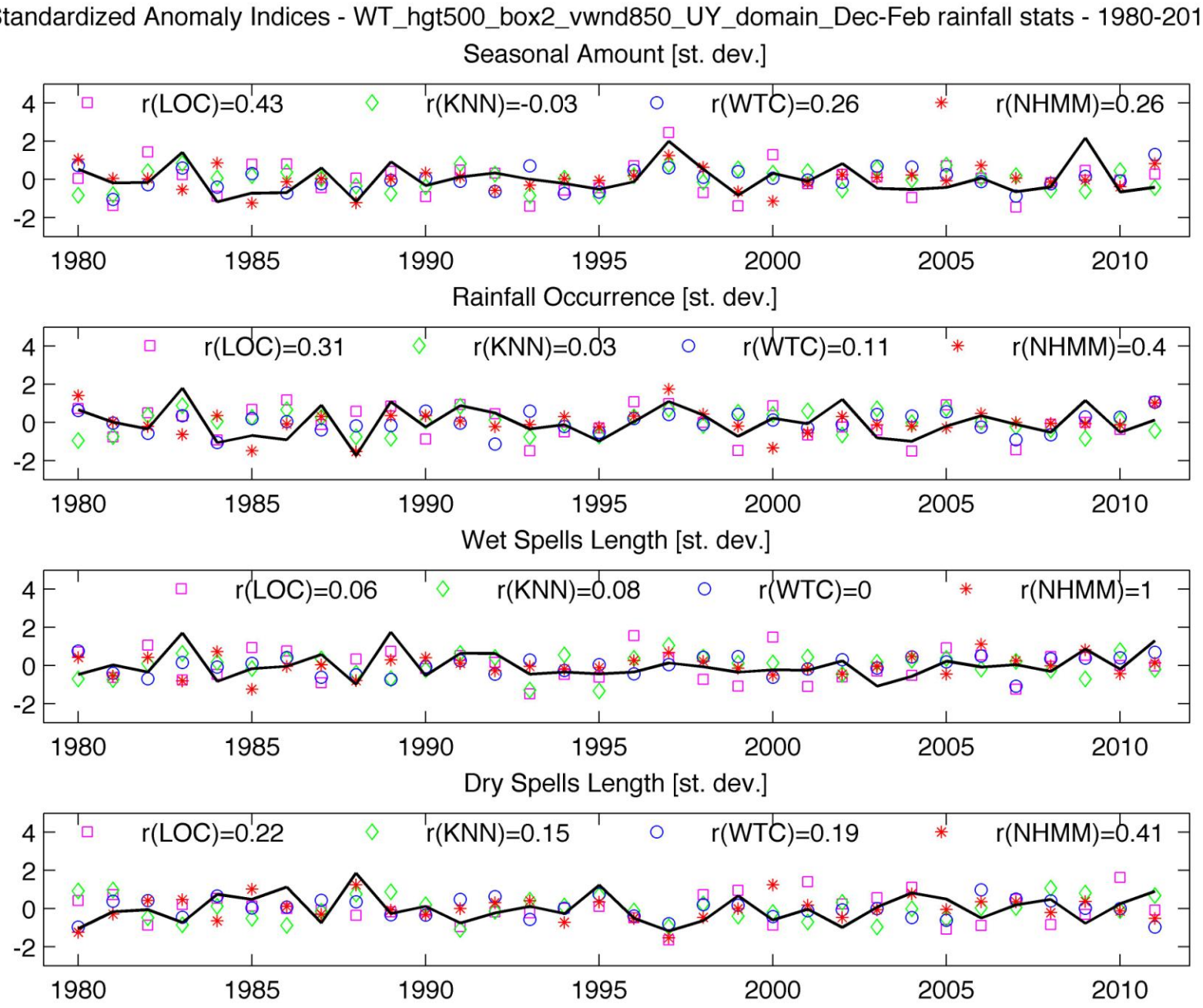
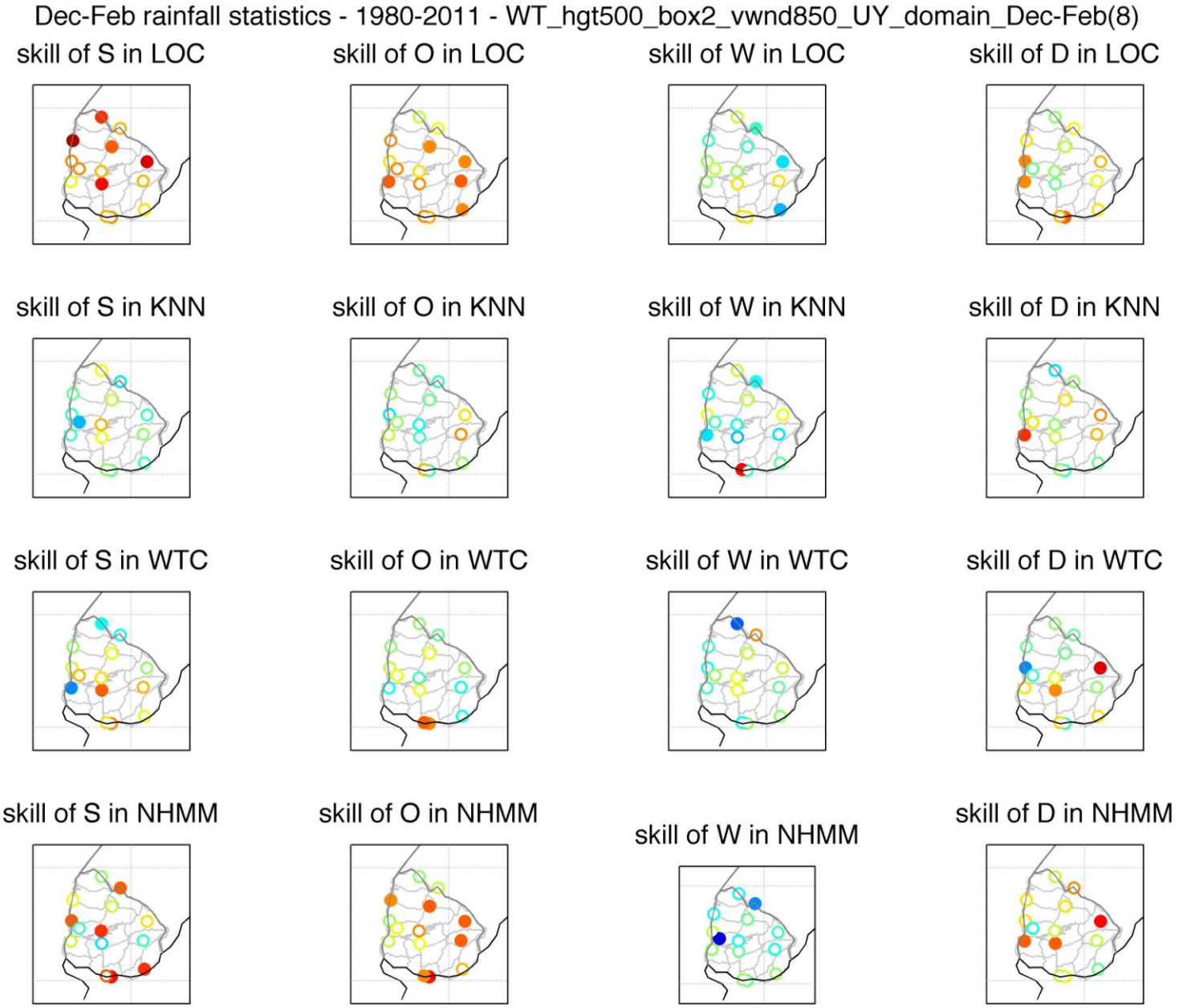


Figure 2: Graphical model interpretation of a nonhomogeneous hidden Markov model

RESULTS


Standardized Anomaly Indices - WT_hgt500_box2_vwnd850_UY_domain_Dec-Feb rainfall stats - 1980-2011
Seasonal Amount [st. dev.]
r(LOC)=0.43
r(KNN)=-0.03
r(WTC)=0.26
r(NHMM)=0.26
Rainfall Occurrence [st. dev.]
r(LOC)=0.31
r(KNN)=0.03
r(WTC)=0.11
r(NHMM)=0.4
Wet Spells Length [st. dev.]
r(LOC)=0.06
r(KNN)=0.08
r(WTC)=0
r(NHMM)=1
Dry Spells Length [st. dev.]
r(LOC)=0.22
r(KNN)=0.15
r(WTC)=0.19
r(NHMM)=0.41
4
2
0
-2
1980
1985
1990
1995
2000
2005
2010

RESULTS


Dec-Feb rainfall statistics - 1980-2011 - WT_hgt500_box2_vwnd850_UY_domain_Dec-Feb(8)
skill of S in LOC
skill of O in LOC
skill of W in LOC
skill of D in LOC
skill of S in KNN
skill of O in KNN
skill of W in KNN
skill of D in KNN
skill of S in WTC
skill of O in WTC
skill of W in WTC
skill of D in WTC
skill of S in NHMM
skill of O in NHMM
skill of W in NHMM
skill of D in NHMM
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

WHAT NEXT ???

- **Persevere!** There still might be **predictor combinations, domains and periods** for which we might get better skill
- Consider other GCMs and Multi-model ensembles
- Move to MOS-based downscaling methodologies (e.g., CCA)
  CPT training in Montevideo next week!!!
- Explore the output and potential tailoring of **WCRP/WWRP S2S** program database for **subseasonal hindcasts database**

¡Muchas gracias!
Thank You!

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