The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1968-34

Conference on Teleconnections in the Atmosphere and Oceans

17 - 20 November 2008

Deriving South American austral summer rainfall from upper level circulation seasonal prediction.

COELHO Caio Augusto dos Santos
Instituto de Pesquisas Espaciais I.N.P.E.
Centro de Previsao de Tempo e Estudos Climaticos CPTEC
Rodovia Presidente Dutra Km 40, Cachoeira Paulista, Sp
12630 000 Sao Paulo
BRAZIL

Deriving South America seasonal rainfall from upper level circulation predictions

Caio A. S. Coelho
Centro de Previsão de Tempo e Estudos Climáticos (CPTEC)
Instituto Nacional de Pesquisas Espaciais (INPE)
caio.coelho@cptec.inpe.br

Plan of talk
1. Rationale for using circulation patterns as predictor for seasonal rainfall
2. How well coupled models simulate upper level circulation
3. Procedure for deriving rainfall from upper level circulation predictions
4. Skill of rainfall predictions derived from upper level circulation
5. Summary

Conference on Teleconnections in the Atmosphere and Oceans
ICTP, Trieste, 17-20 November 2008

Rationale for the use of circulation patterns as predictor for seasonal rainfall

Rainfall is influenced by atmospheric circulation patterns

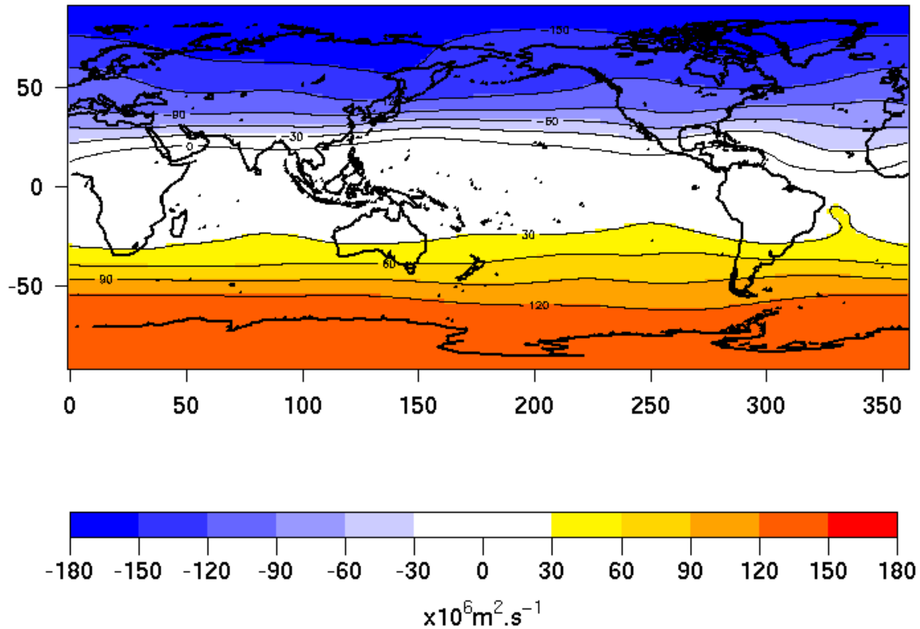
On seasonal timescales the frequency of occurrence of such patterns is influenced by anomalous patterns of sea surface temperatures (particularly in the tropics)

The link between tropical SSTs and global circulation patterns involves the generation of quasi-stationary upper level wave trains from tropical diabatic heat sources to remote regions (e.g. ENSO teleconnections to South America)

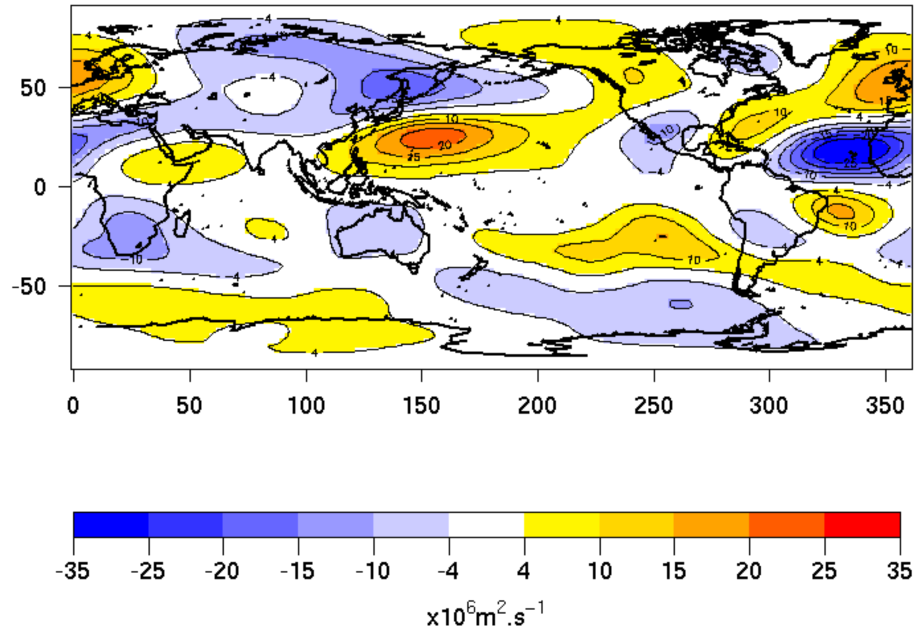
If upper level circulation is well simulated by seasonal climate models, it may then be possible to use upper level circulation predictions to produce rainfall predictions for South America (i.e. rainfall downscaling from upper level circulation)

Upper level circulation represented by 200 hPa stream function

Stream function (ψ)



Perturbed (eddy) stream function (ψ')



- Dominant zonally symmetric structure

- highlights wavelike structures
- used to study teleconnections

$$\psi = \overline{\psi} + \psi'$$

$\overline{\psi}$: zonal mean of ψ

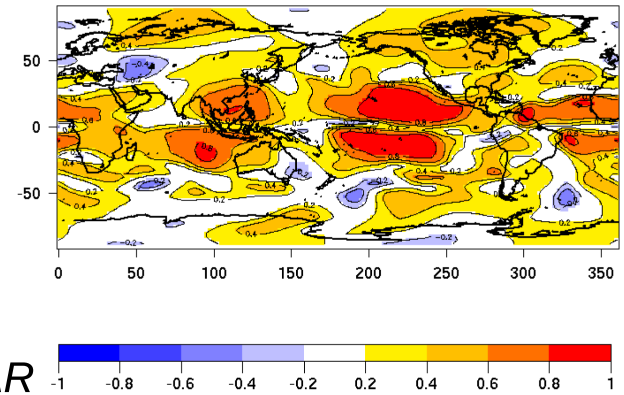
How well do coupled seasonal forecast models simulate upper level circulation?

Two EUROSIP coupled ocean-atmosphere models:
- *ECMWF System 3* *(Anderson et al. 2007, ECMWF Tech Memo, 503, pp 56)*
- *UK Met Office (GloSea)* *(Graham et al. 2005, Tellus A, Vol. 57, 320-339)*

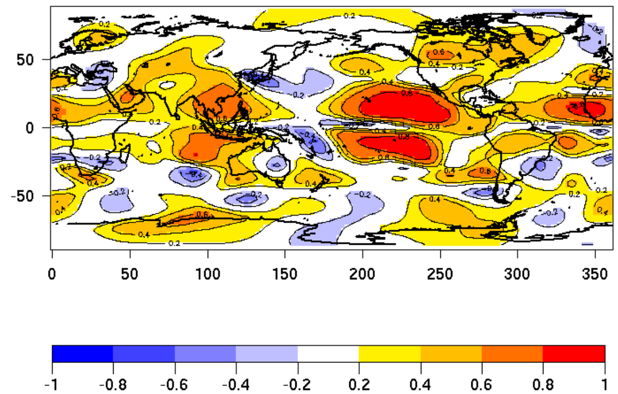
Common hindcast period: 1987-2005 (19 years)
Start date: November
Target season: DJF (i.e. 1-month lead predictions for DJF)

Corr. between forecast and obs. pert. stream function 200 hPa (ψ')

ECMWF



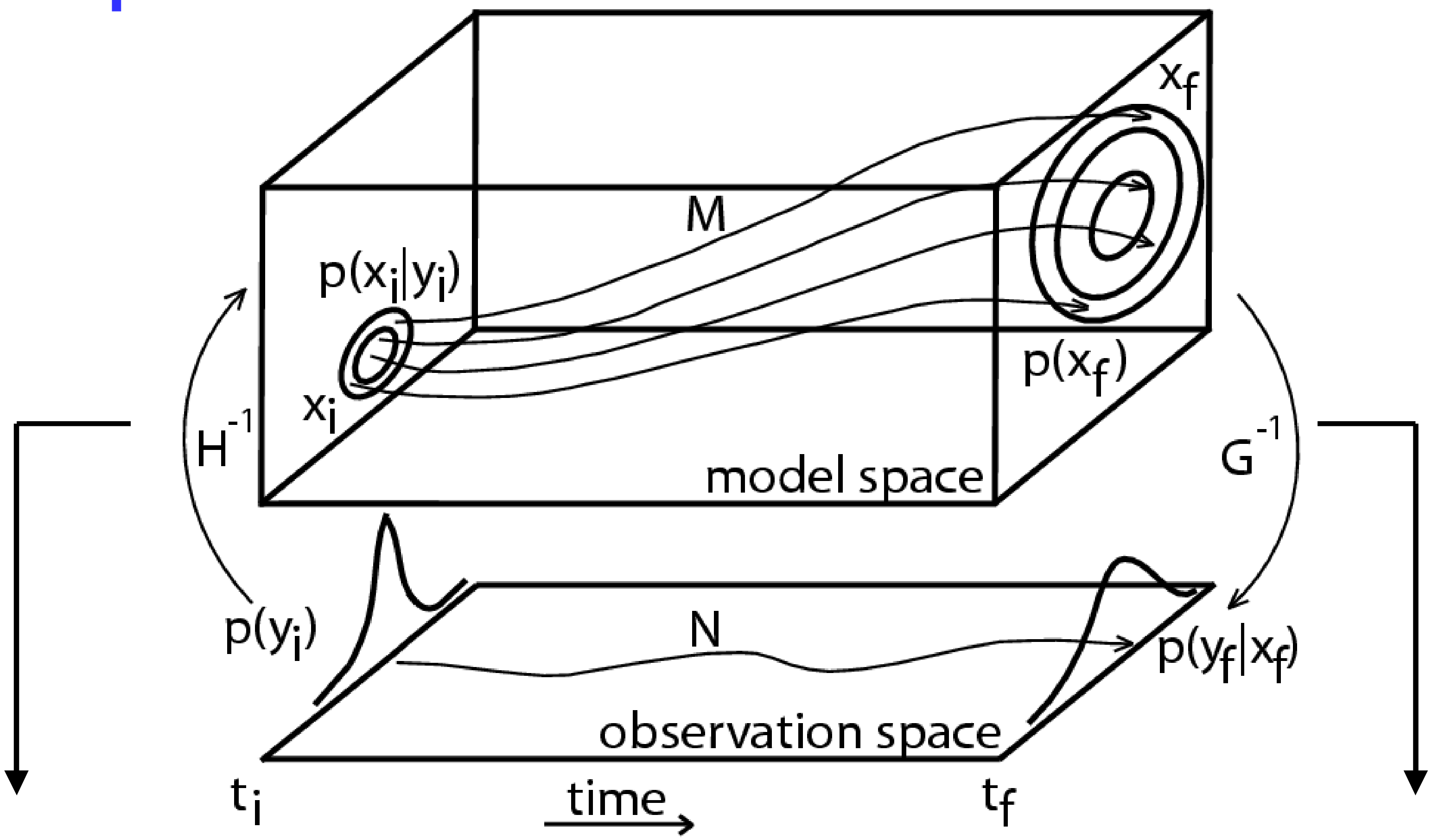
UK Met Office (GloSea)



Obs NCEP/NCAR Reanalysis (Kalnay et al. 1996)

→ Generally good skill in the tropics

Conceptual framework



Data Assimilation

$$p(x_i \mid y_i) = \frac{p(y_i \mid x_i)p(x_i)}{p(y_i)}$$

"*Forecast Assimilation*"

$$p(y_f \mid x_f) = \frac{p(x_f \mid y_f)p(y_f)}{p(x_f)}$$

Stephenson et al. (2005), Tellus A . Vol. 57, 253-264.

Downscaling procedure: Forecast Assimilation

Stephenson et al. (2005), Tellus A . Vol. 57, 253-264.

$$p(Y \mid X) = \frac{p(X \mid Y)\, p(Y)}{p(X)}$$

Y: DJF rainfall (Adler et al. 2003, J. Hydrometeor., 4,1147-1167*)*
X: 1-month lead 200 hPa ψ' predictions for DJF (ECMWF + UKMO)

Matrices

$$\mathrm{Y} : \mathrm{n} \times \mathrm{q}$$

$$\mathrm{X} : \mathrm{n} \times \mathrm{p}$$

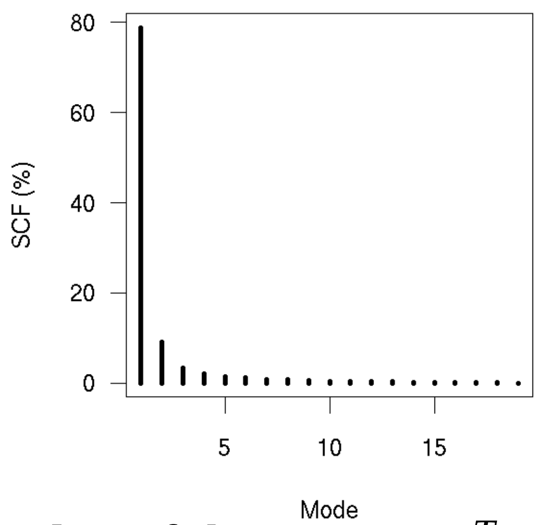
Prior: $\mathrm{Y} \sim \mathrm{N}(\mathrm{Y_b}, \mathrm{C})$

Likelihood: $\mathrm{X} \mid \mathrm{Y} \sim \mathrm{N}(\mathrm{G}(\mathrm{Y} - \mathrm{Y_o}), \mathrm{S})$

$$G = S_{XY} S_{YY}^{-1}$$

$$-GY_o = \overline{X} - \overline{Y}G$$

$$S = S_{XX} - G S_{YY} G^T$$

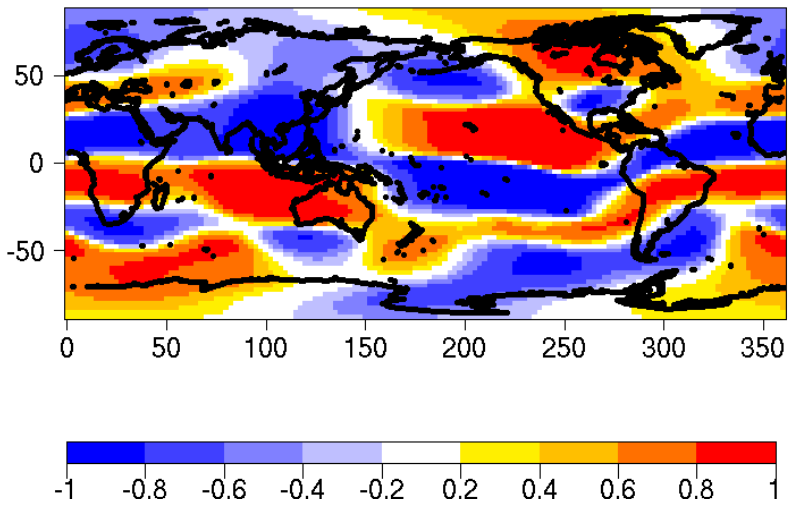


Posterior: $Y \mid X \sim N(Y_a, D)$

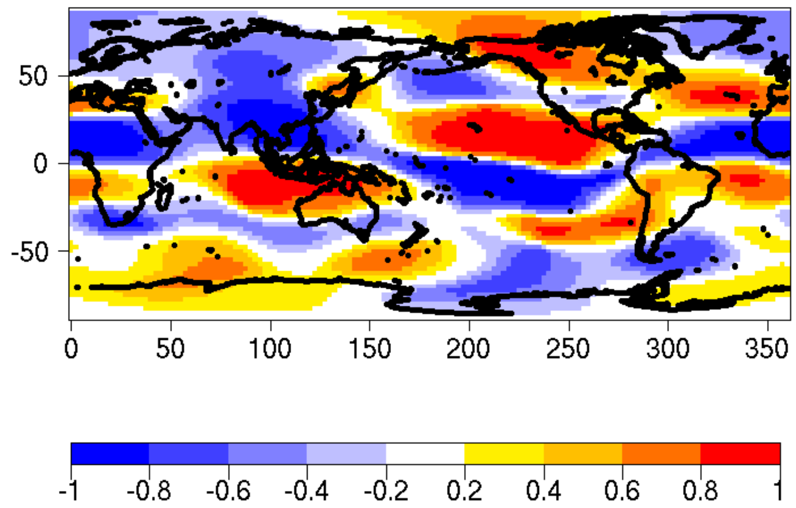
Forecast assimilation uses first three leading MCA modes of the matrix $Y^T X$.

Forecast Assimilation: First MCA mode (79%)

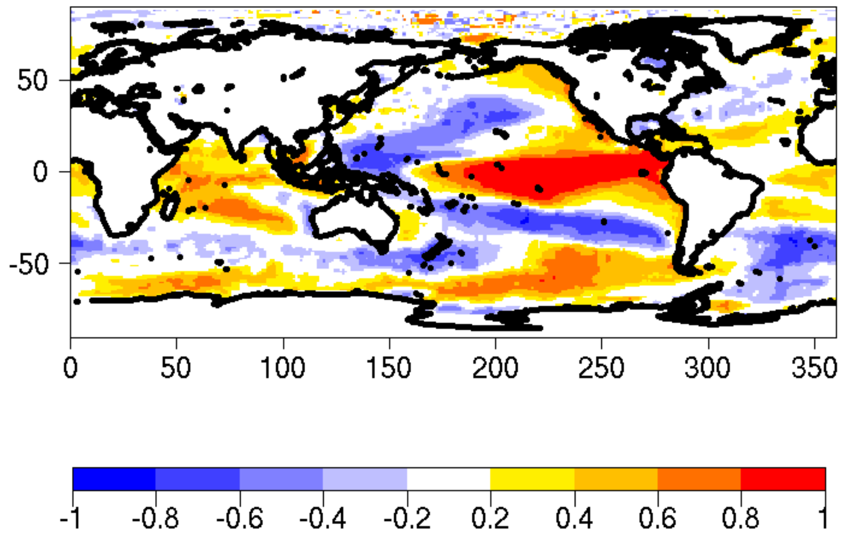
ECMWF



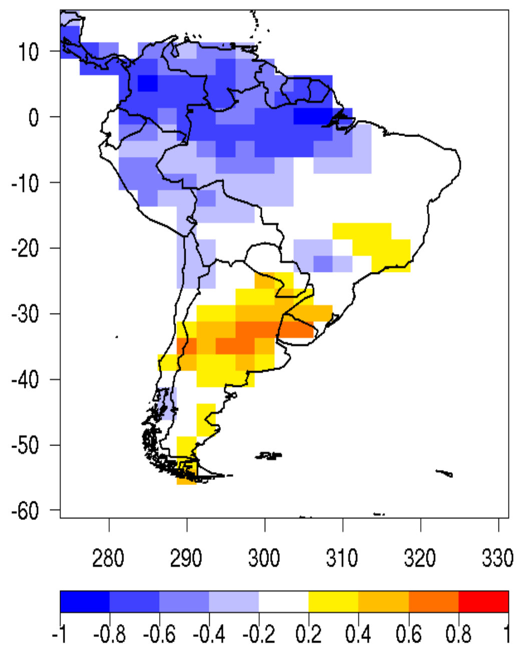
UK Met Office (GloSea)



Corr. between forecast time series and DJF sea surface temperature



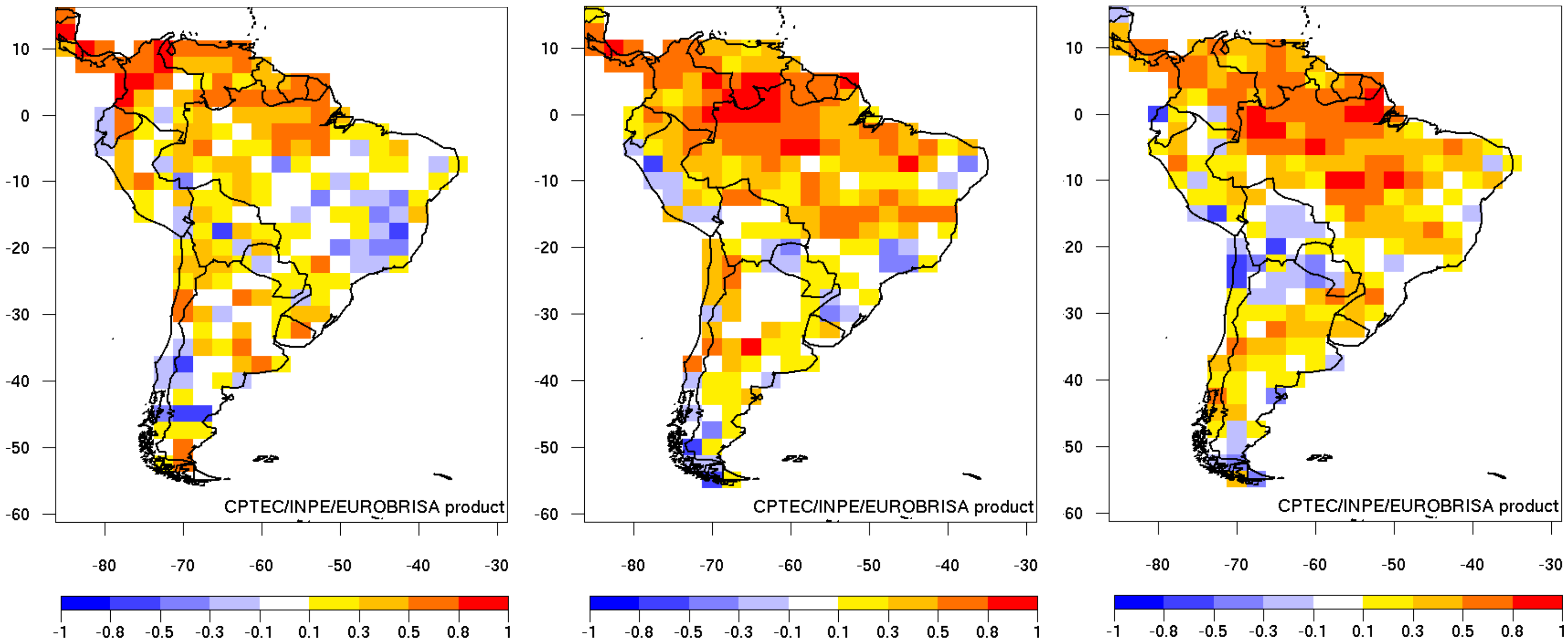
Rainfall



Cross-validated skill assessment: 1-month lead rainfall prediction for DJF

ROC skill score (2A-1) for the event positive precip. anomaly

ECMWF | UK Met Office (GloSea) | Downscaled with forecast assimilation



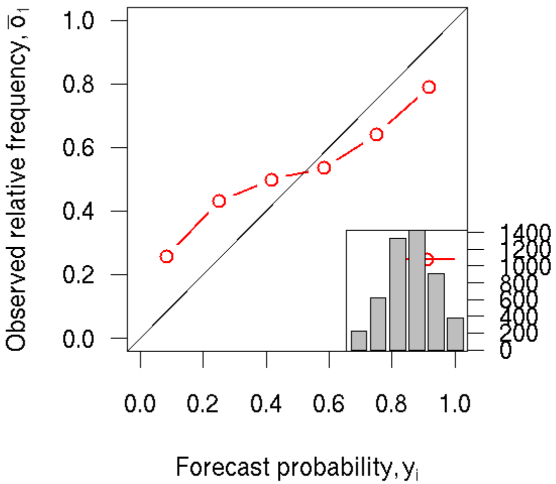
Hindcast period: 1987-2005

→ Upper level ψ' predictions alone account for a large portion of skill

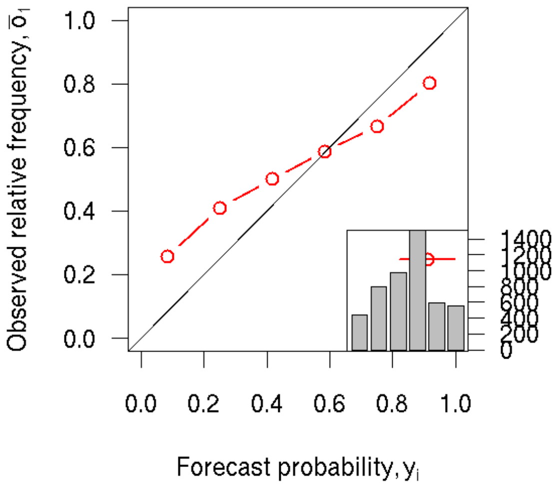
Cross-validated skill assessment: 1-month lead rainfall prediction for DJF

Reliability diagrams for the event positive precipitation anomaly over South America

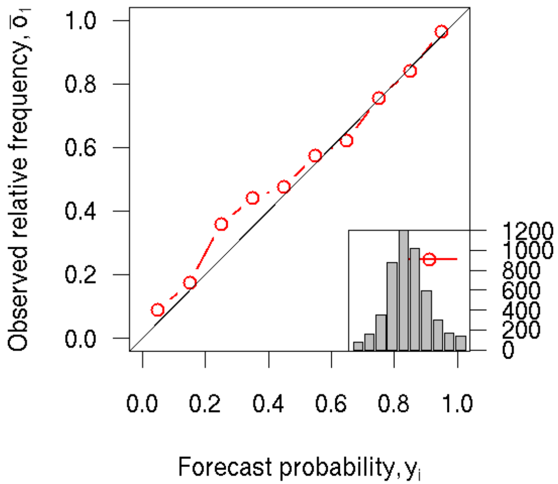
ECMWF



UK Met Office (GloSea)



Downscaled with forecast assimilation



Hindcast period: 1987-2005

→ Forecast assimilation improves prediction reliability
→ Downscaled predictions are better calibrated than single model rainfall predictions

Summary

- Forecast assimilation is a useful framework for exploring atmospheric teleconnections in seasonal forecasts. ENSO atmospheric teleconnections: main source of skill for South America rainfall predictions

- Downscaled (circulation derived) predictions obtained with forecast assimilation have superior skill to ECMWF and comparable skill to UK Met Office rainfall predictions, and downscaled predictions are better calibrated

- Coupled ocean-atmosphere model upper level perturbed stream function predictions alone account for a large portion of austral summer rainfall skill in South America

Acknowledgements

- ECMWF and UK Met Office for providing the seasonal forecast data used in this study as part of the EUROBRISA project license agreement

THANK YOU FOR YOUR ATTENTION!