# 14th session of WGSIP

Nudging as a diagnostic tool for a better understanding
of seasonal variability and predictability

Hervé Douville

(Météo-France/CNRM-GAME)

Acknowledgements: S. Bielli, G. Ouzeau, Y. Peings, B. Pohl, D. Saint Martin
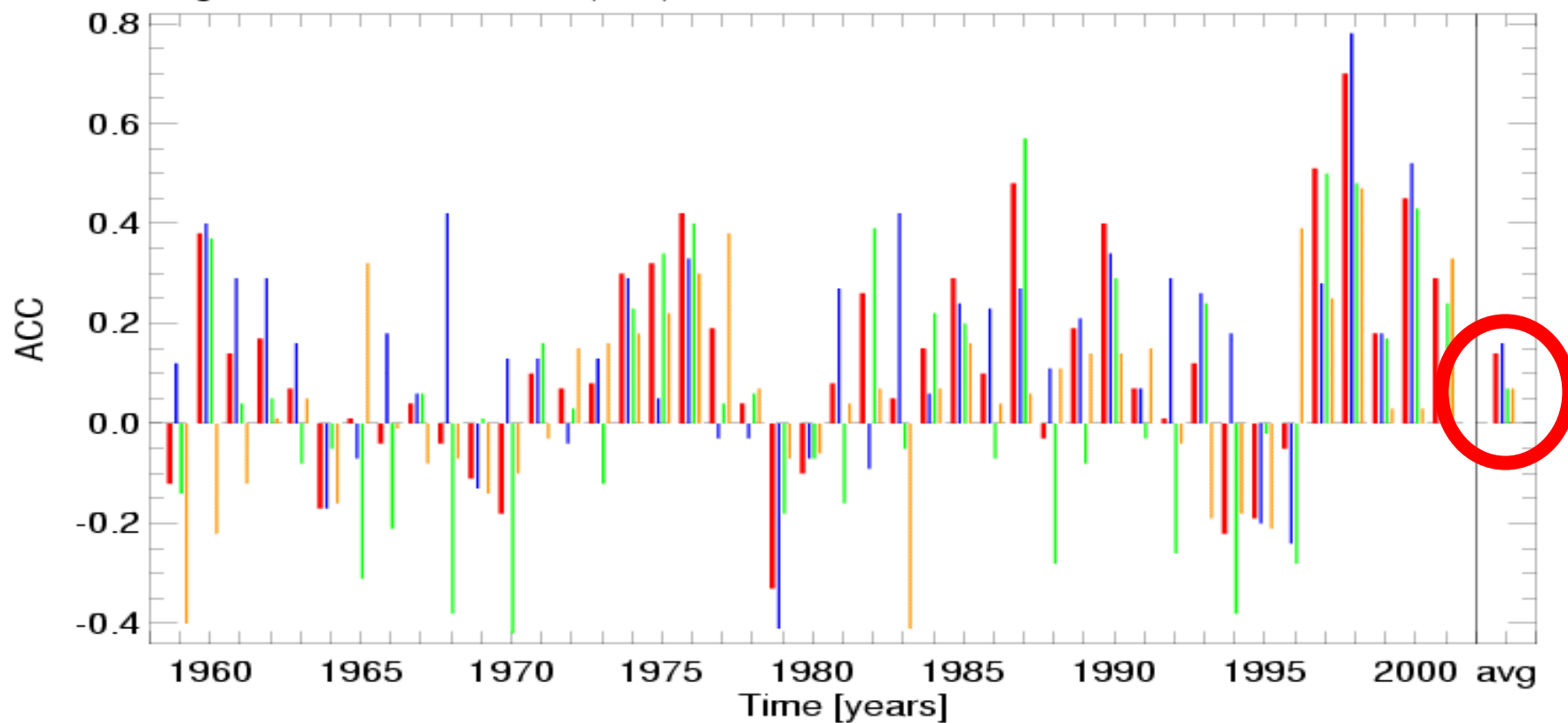
CENTRE NATIONAL
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SCIENTIFIQUE

METEO
FRANCE

# JJA Z500 ACC over the Northern Extratropics

500 hPaGeopotential, ACC over Northern Extratropics (land+sea)
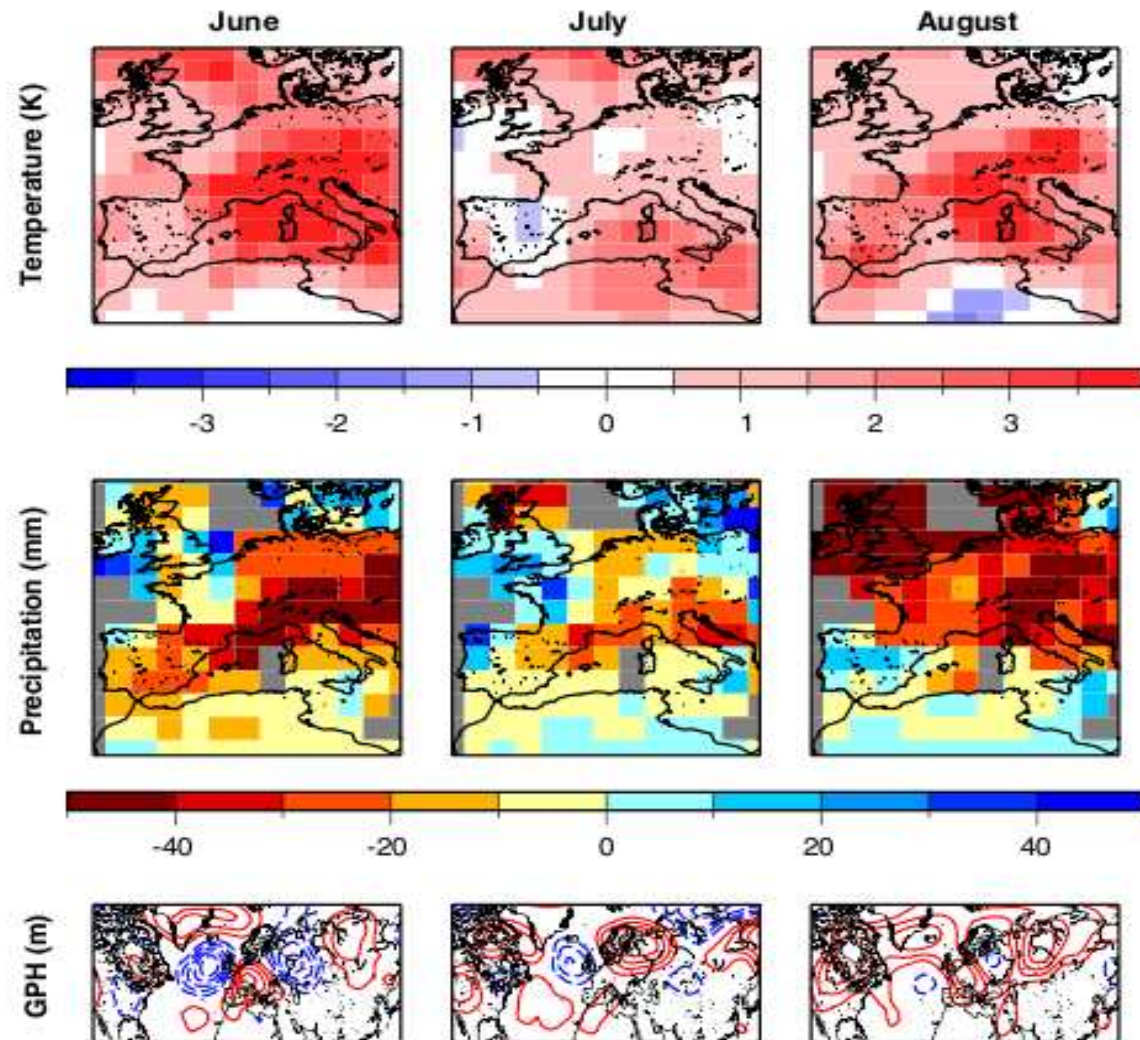Model: DEMETER II   ECMWF   UKMO   CNRM
Start dates: May
Avg. over 2-4 months FC (JJA)



*D'après http://www.ecmwf.int.research/demeter*

# Summer 2003 case study

- What caused this hot summer? Was it predictable?

- Role of tropical & extratropical SST, soil moisture?

- e.g. Cassou et al. 2005, Black and Sutton 2006, Weisheimer et al. 2011, Douville et al. 2011



Black and Sutton, 2006

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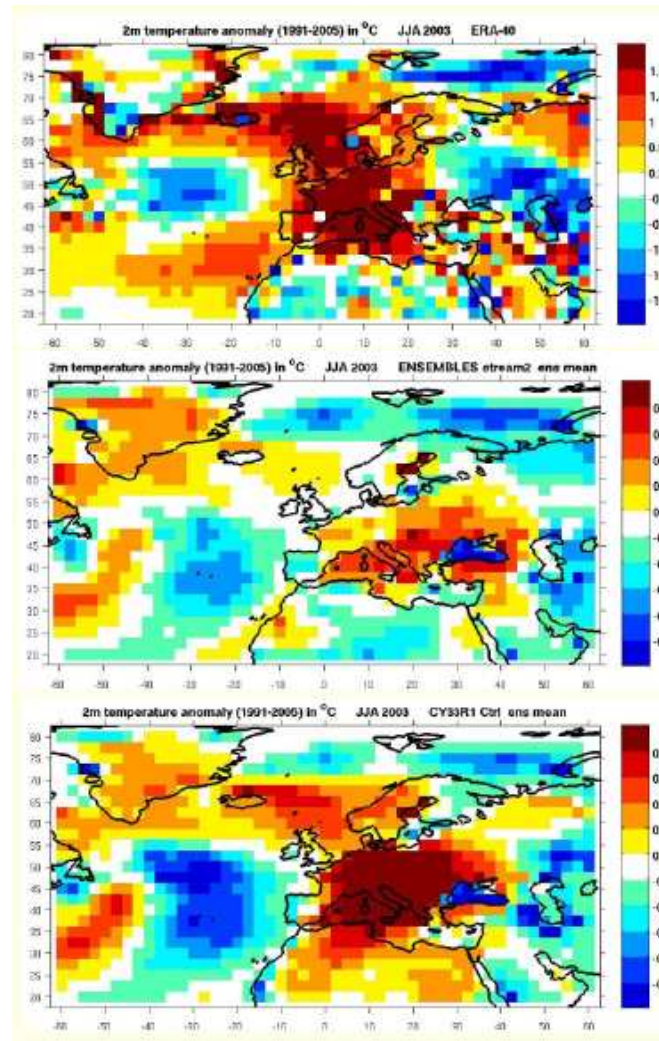


ERA40
(JJA anomalies)

ECMWF model
(CY31R1)

ECMWF model
(CY33R1)

Weisheimer et al., 2011

# DJF anomalies of the NAO index

Projection onto NAO
Model: DEMETER II
Start dates: November
Avg. over 2-4 months FC (DJF)

Ratio of total st-dev: model/ERA-40 = 0.99
Signal/Noise ratio [Conf.-Level] = 0.31 [ 0.00]
RMSE = 0.15
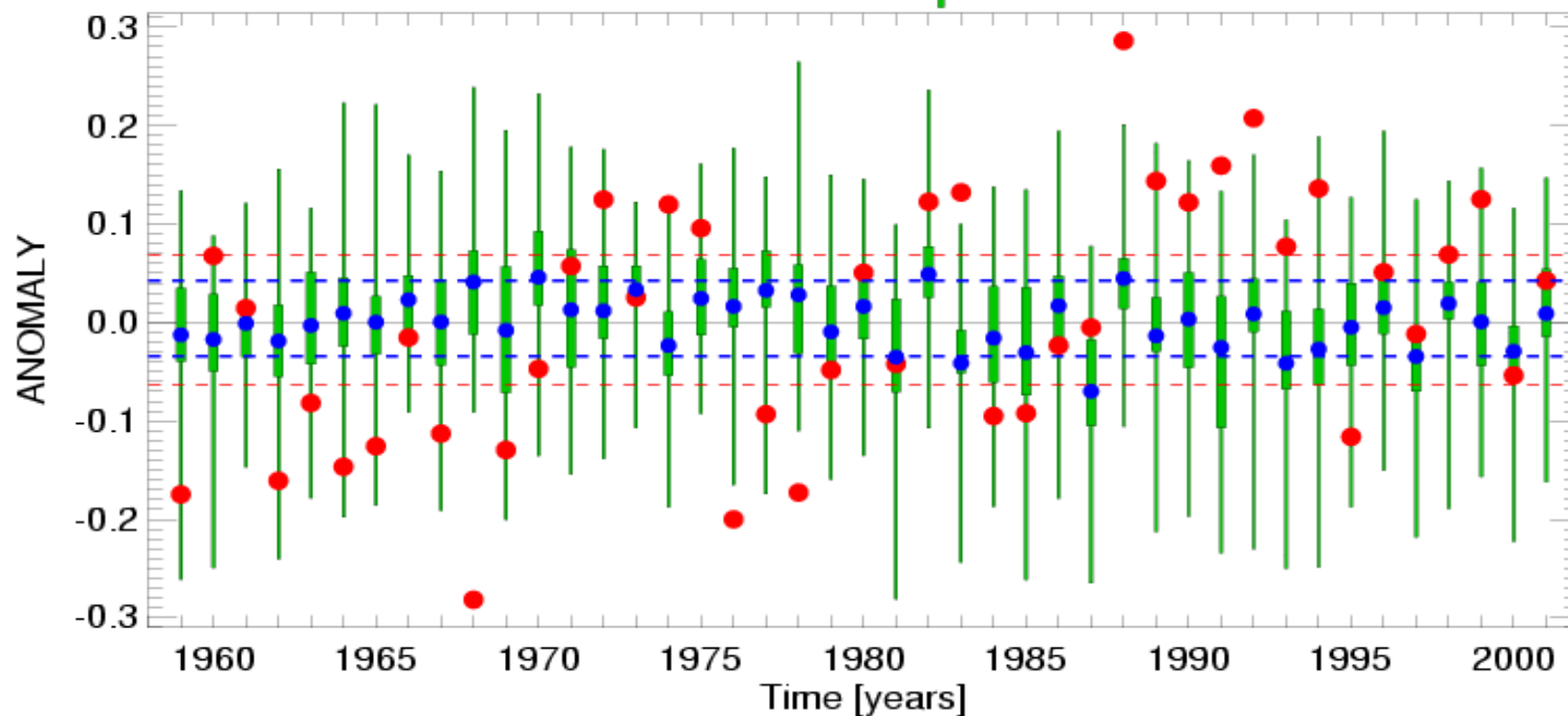Correlation [Conf.-Level] = -0.03 [ 0.00]
RPSS [Conf.-Level] = 0.00 [ 0.00]

dashed lines: tercile boundaries for whole dataset of ERA-40 and hindcasts
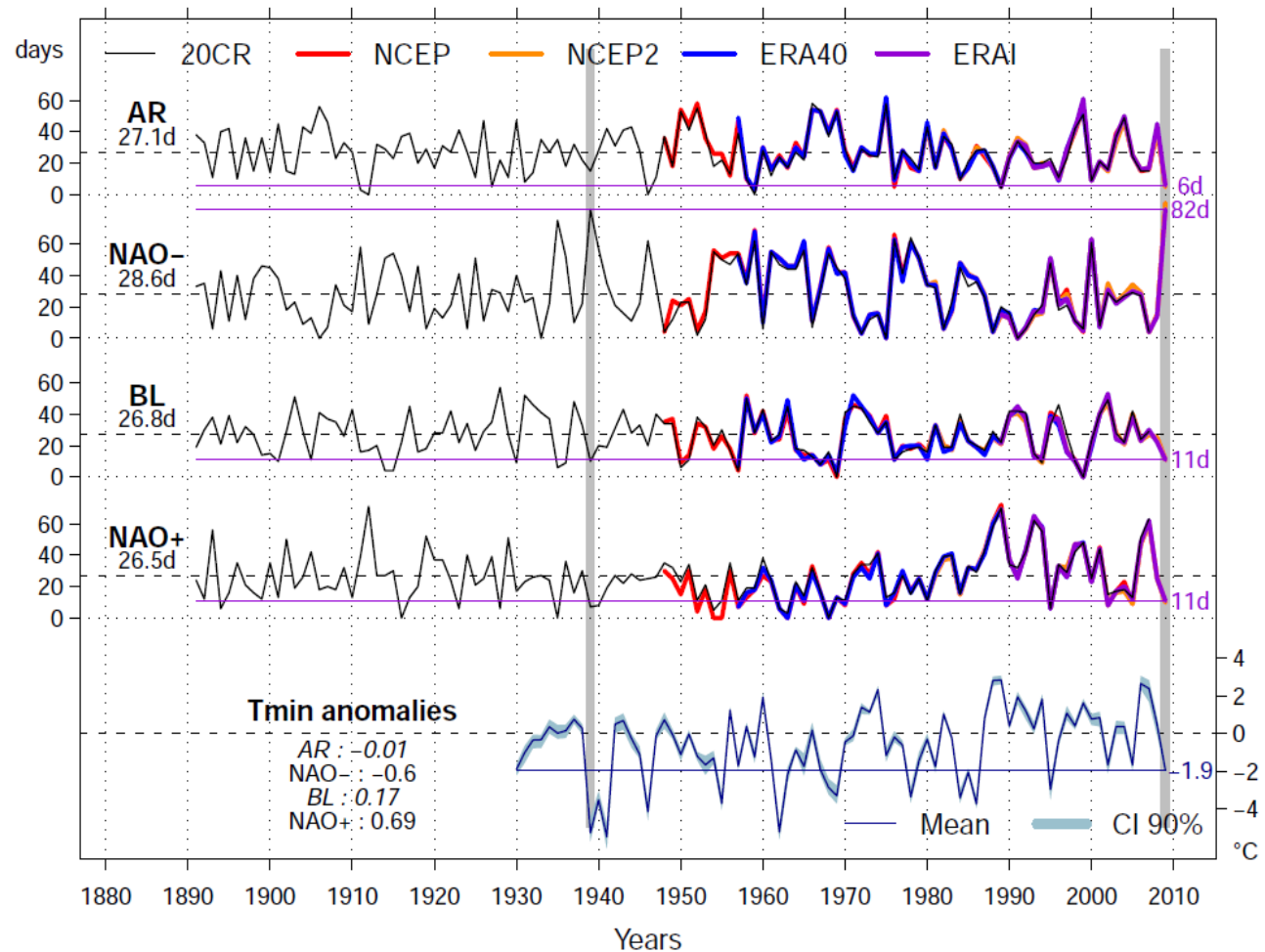
● ERA-40      ● Ensemble-mean      ▮ Ensemble Spread / Tercile



*D'après http://www.ecmwf.int.research/demeter*

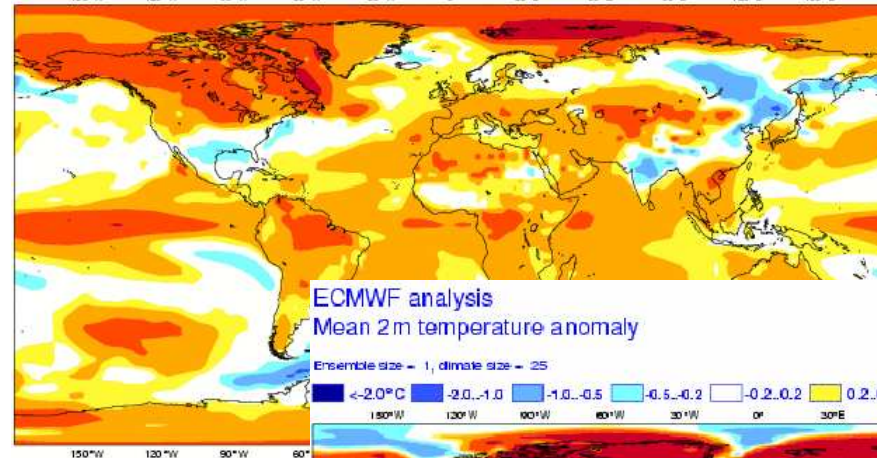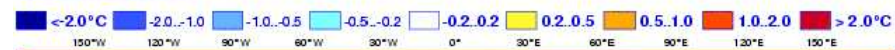METEO FRANCE 5

# Winter 2009-2010 case study

- What caused this « cold » winter? Was it predictable?
- Role of polar stratosphere (+ Eurasian snow cover) vs SST boundary conditions?
- e.g. Jung et al. 2011, Ouzeau et al. 2011



Ouzeau et al., GRL 2011

# Winter 2009-2010 case study

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EUROSIP multi-model seasonal forecast — ECMWF/Met Office/Météo-France
Mean 2m temperature anomaly — DJF 2009/10
Forecast start reference is 01/11/09 — No significance test applied
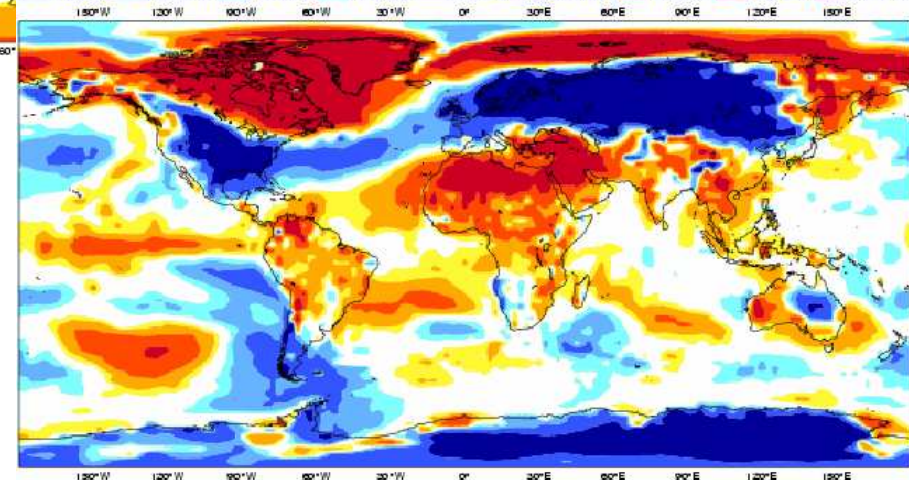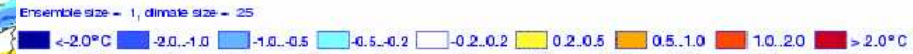Variance-standardized mean

Forecasted DJF T2m anomalies

ECMWF analysis
Mean 2m temperature anomaly — DJF 2009/10
Ensemble size = 1, climate size = 25

ECWMF analysis

# Brief history of nudging in climate studies

- Tropical nudging for teleconnection and predictability studies (early 1990s): Klinker, Ferranti, …

- Grid point nudging of the QBO in atmospheric GCMs (1990s): Kodera, Hamilton, Giorgetta, …

- Spectral nudging for evaluation of physical parametrizations in atmospheric GCMs (late 1990s): the POTENTIALS european project

- Spectral nudging in RCMs (early 2000s): Von Storch, Laprise, …

- Nudging of land surface hydrology in ARPEGE-Climat (early 2000s): Douville

- RCM-like simulations with AGCMs (2000s): Genthon, Pohl, …

- Tropical and stratospheric nudging revisited (late 2000s): Jung, Douville

# Grid point nudging methodology (in ARPEGE/IFS)

$$\delta X/\delta t = D(X) + P(X) - \lambda(X - X_{ref})$$

- Relaxation coefficient $\lambda$ can be varied with:
  - Historic variable: U, V, ln(Ps), T, q, …
  - Location: 2D mask + vertical profile
  - Timescale (possible low-pass filtering of the relaxation fields)

- 3 types of application will be here considered:
  - Tropical nudging: the whole tropical band or a monsoon domain
  - Stratospheric nudging: northern extratropics or QBO (equator)
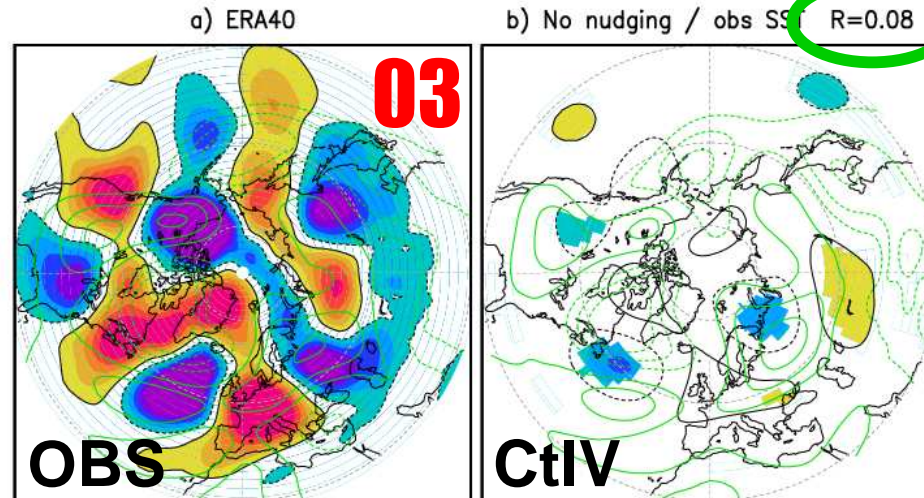  - Quasi-global domain: RCM-like application over West Africa

# The IRCAAM project (French ANR)



*Douville et al. (Clim. Dyn. 2011)*
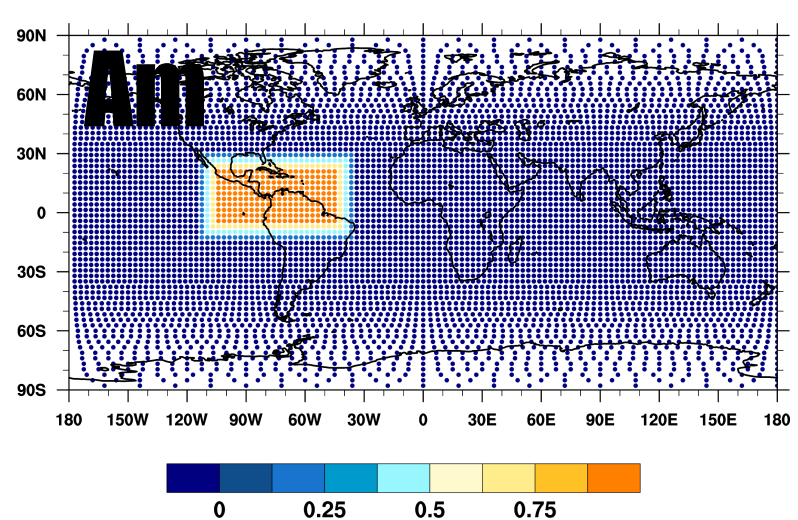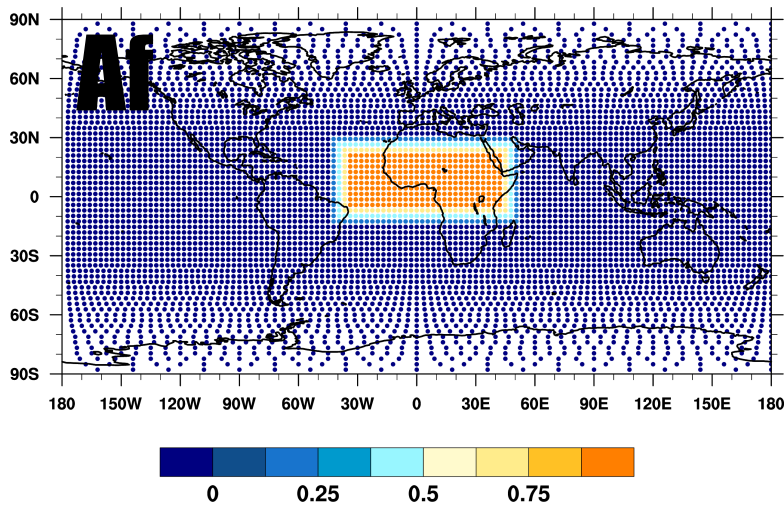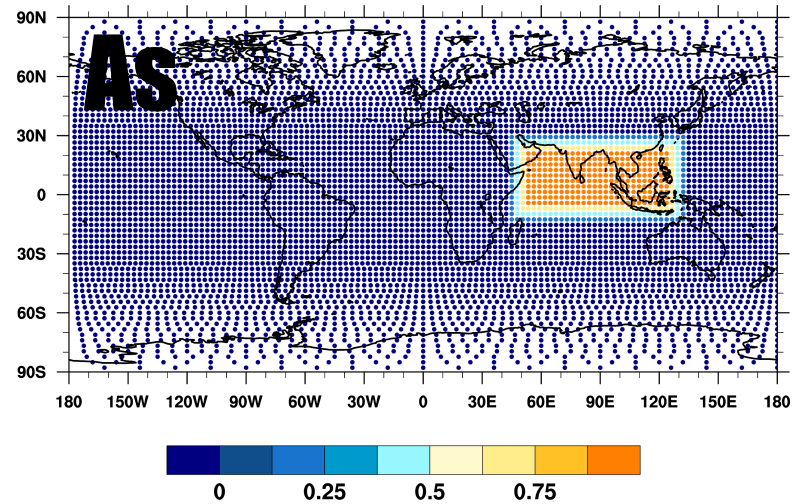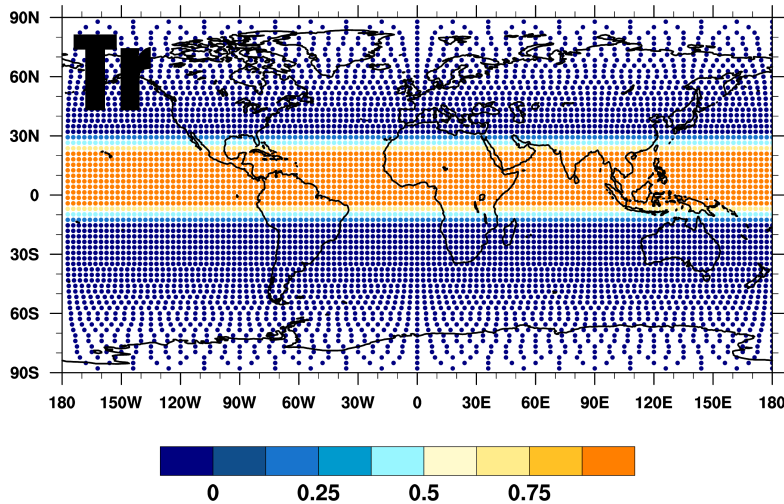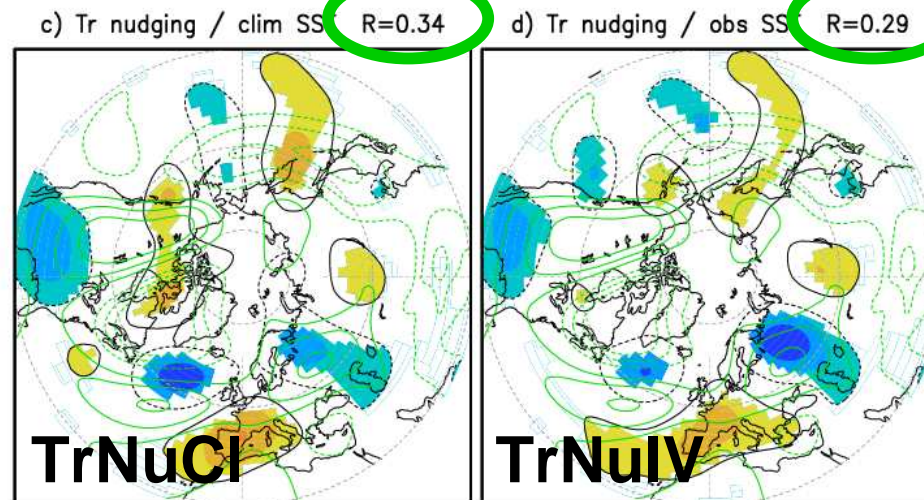
# Impact on Northern Hemisphere stationary waves
## Some JJAS case studies

ERA40 anomalies

No nudging and observed SST

Tropical nudging and climatol. SST
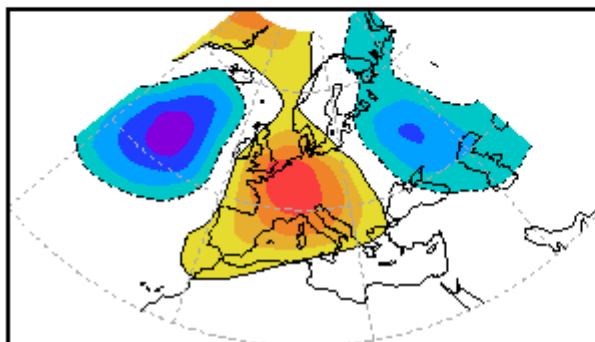
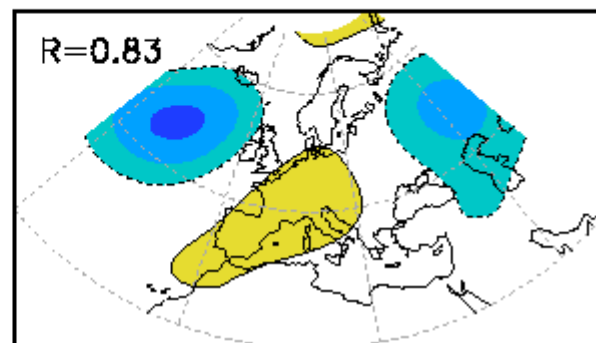Tropical nudging and observed SST



a) ERA40      b) No nudging / obs SST   R=0.08
**OBS**       **CtlV**

c) Tr nudging / clim SS   R=0.34   d) Tr nudging / obs SS   R=0.29
**TrNuCl**    **TrNulV**

−25  −20  −15  −10  −5    5   10   15   20   25
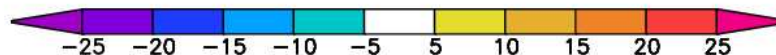
# JJAS 2003 case study
# CNRM & LMD results (SST clim.)

JJAS 2003 Z500*



a) ECMWF

b) TrNuO3Cl−TrNuCl
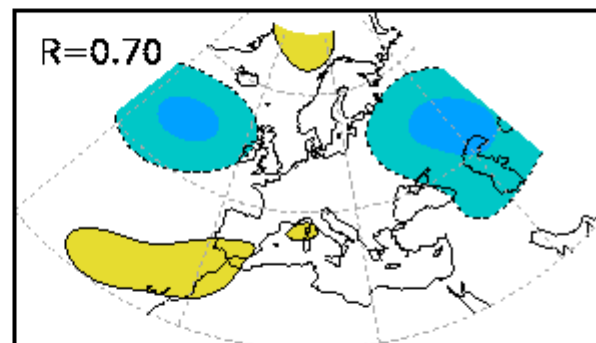R=0.83

c) AsNuO3Cl−AsNuCl
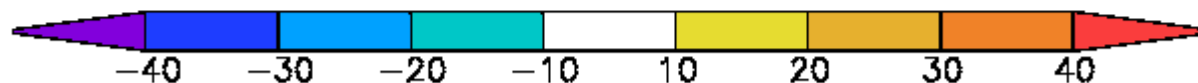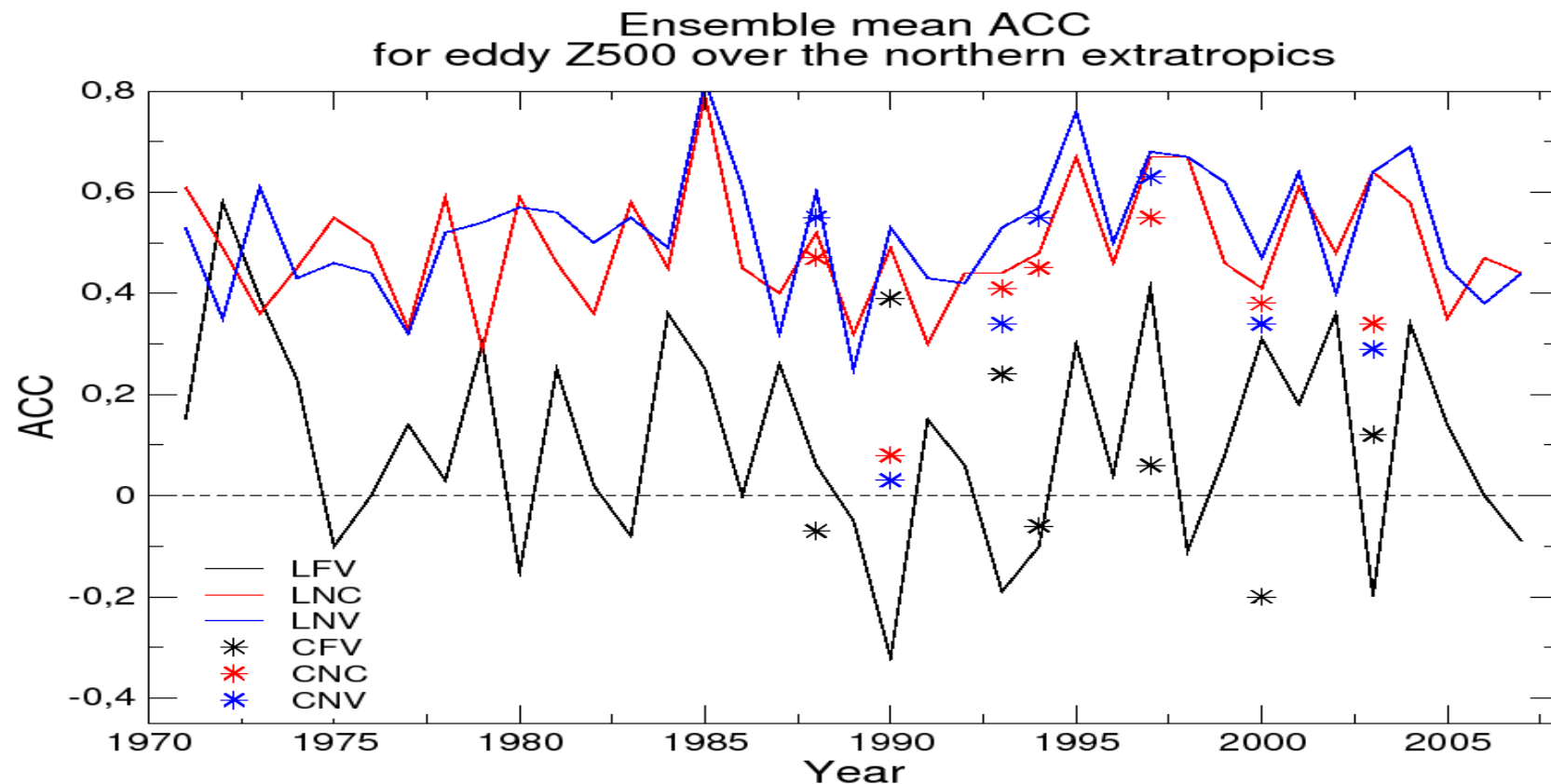R=0.44

d) AfNuO3Cl−AfNuCl
R=0.70

Tr

As

Af

−40 −30 −20 −10 10 20 30 40
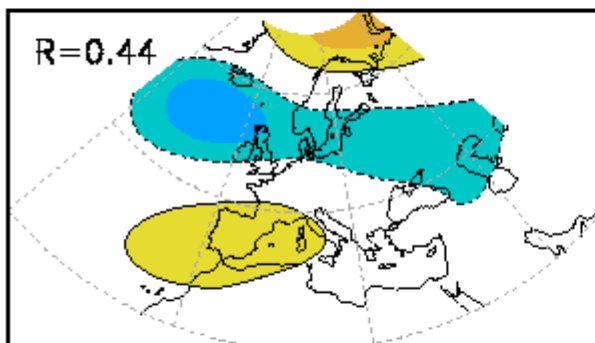
# Northern Extratropics JJAS Z500* ACC



Ensemble mean ACC
for eddy Z500 over the northern extratropics

Spatial ACC of ensemble mean eddy Z500 anomalies over the northern extratropics against ERA40 and ECMWF data for each summer season simulated by the CNRM (stars) and LMDZ (solid lines) models. **Black**: No nudging & observed SST. **Blue**: Tropical nudging & observed SST. **Red**: Tropical nudging & climatological SST.

# Stratospheric nudging

- **Motivations:**

  – Downward propagation of stratospheric zonal wind anomalies (e.g. Baldwin and Dunkerton 2001)

  – QBO and its potential impact on both tropical (e.g. Claud and Terray 2007) and extratropical (e.g. Boer and Hamilton 2008, Marshall and Scaife 2009) climate

  – Failure of state-of-the-art dynamical seasonal forecasting systems to exhibit predictability in the stratosphere (e.g. Maycock et al. 2011)

- **2 domains of nudging:**

  – Northern extratropics (P<100hPa, Lat>25°N)

  – QBO (P<100hPa, 15°S<Lat<15°N)
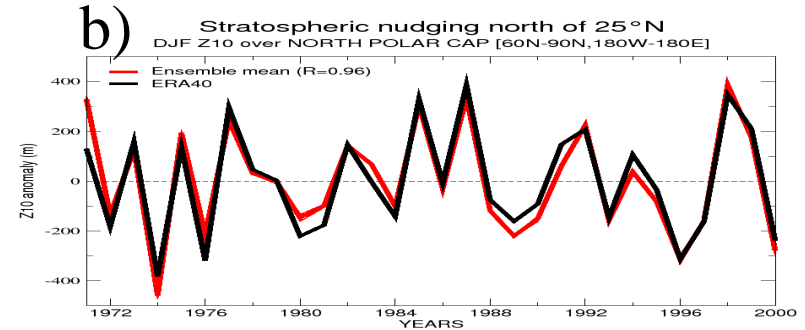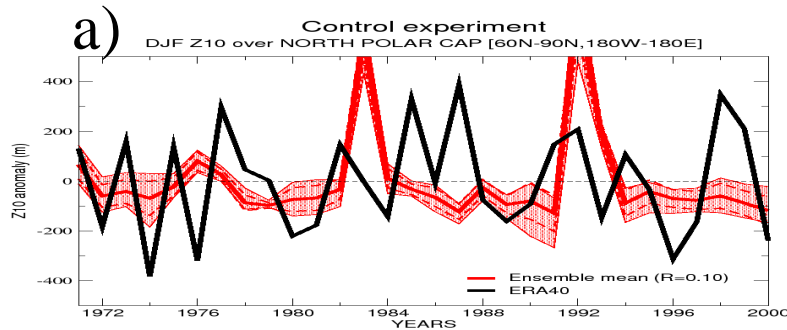
  – NB: Most expts with ARPEGE-Climat T63L31

# Extratopical nudging
# Impact on DJF interannual variability

Control ensemble          Nudged ensemble
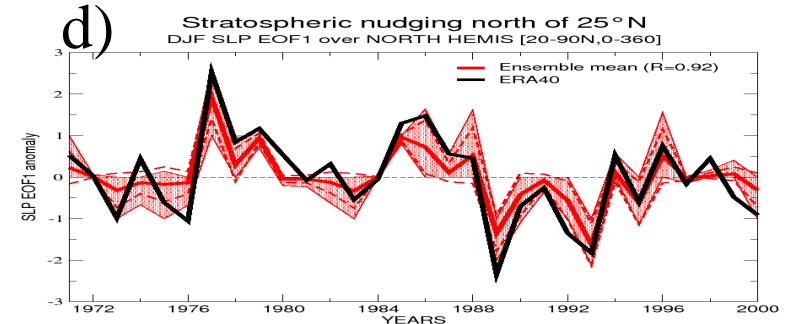


*Douville (GRL 2009)*

# Extratropical nudging
# Impact on DJF T2m and P interannual variability

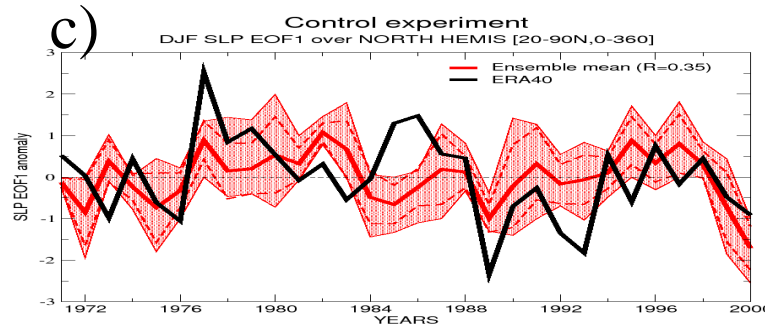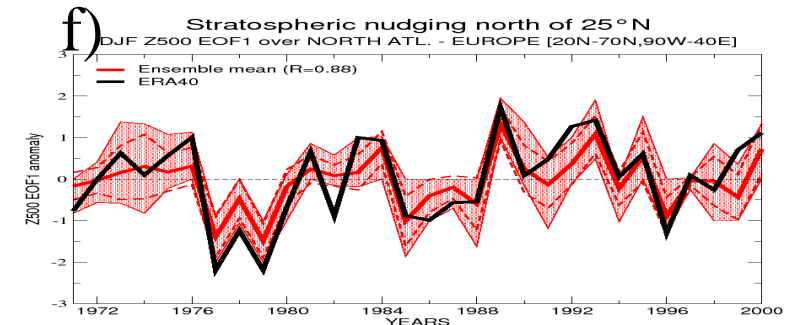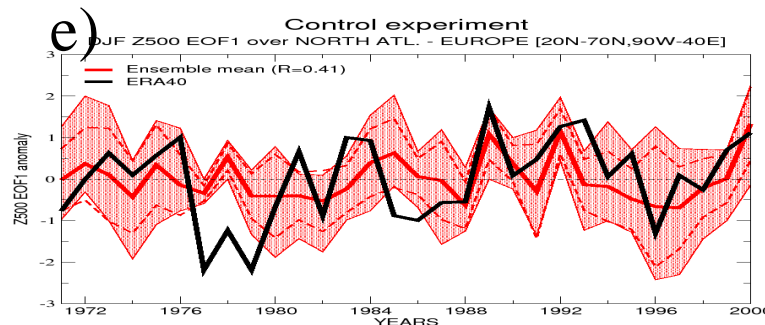Northern extratropics distribution of land grid cell temporal correlations over the 1971-2000 period between ensemble mean and observed anomalies for DJF temperature (left) and DJF precipitation (right).
a,b) Control experiment (Mean is the average correlation over the domain).
c,d) Impact of the nudging (Diff is the average difference over the domain).

*Douville, GRL 2009*



CTN/CRU2 ACC for DJF T2M — Mean=0.318

CTN/CRU2 ACC for DJF P — Mean=0.133

EXN/CRU2 minus CTN/CRU2 — Diff=0.154

EXN/CRU2 minus CTN/CRU2 — Diff=0.117
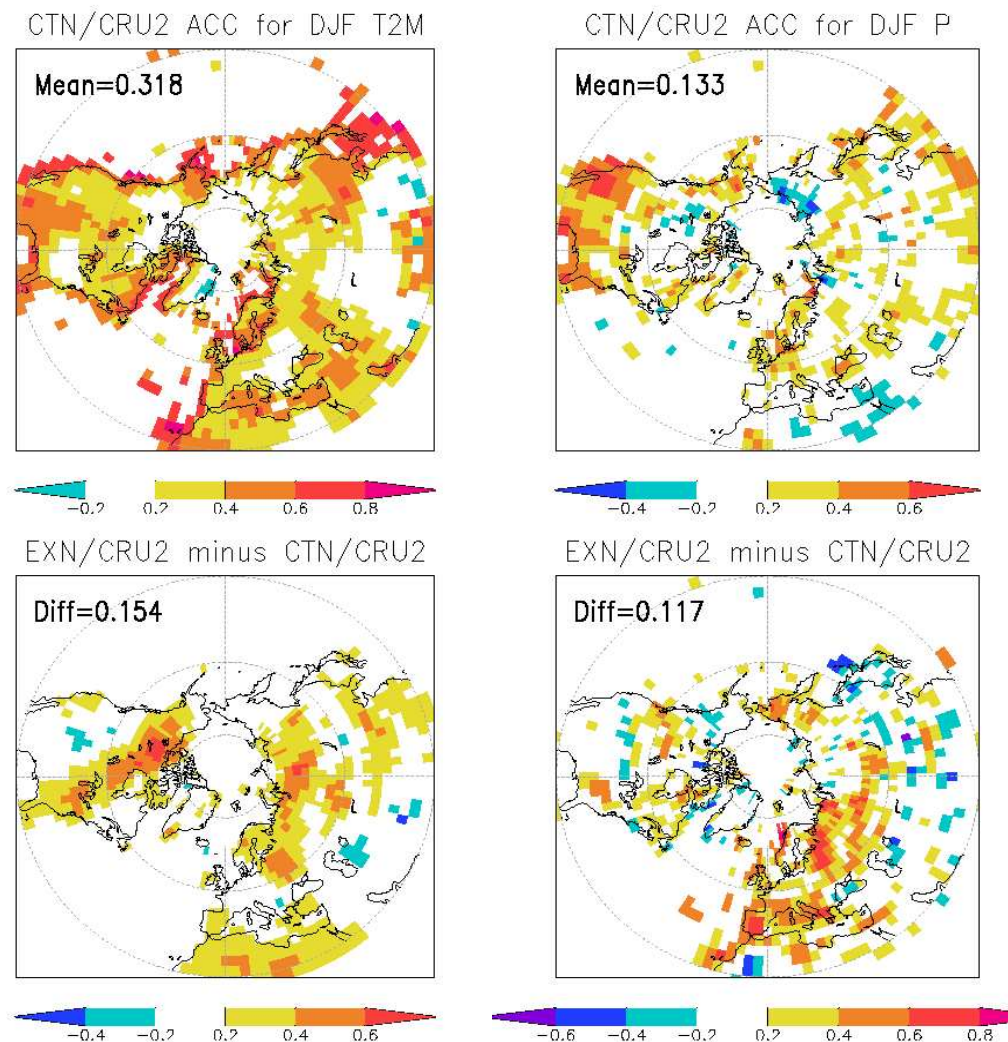
# Winter 2009-2010 case study (Ouzeau et al. 2011) DJFM Z500, Tmin and #days with Tmin<Q10
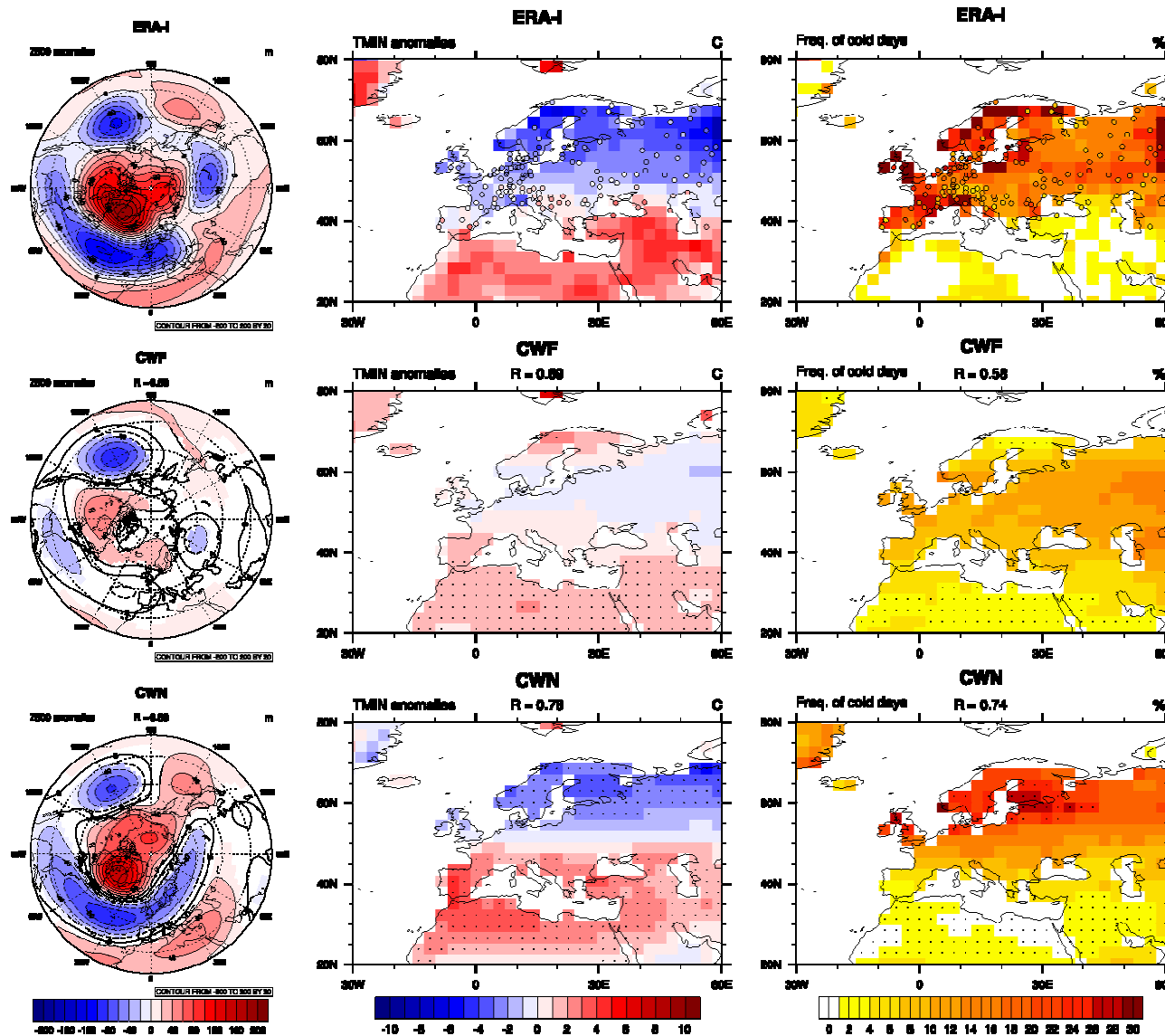


Observed anomalies

CWF-CTF
No nudging

CWN-CTN
Nudging
(P<100 hPa)

# Winter 2009-2010 case study
# DJFM Z500, Tmin and #days with Tmin<Q10



Observed anomalies

CWF-CTF
No nudging

CWN-CTN
Nudging
(P<30 hPa)

# Nudging of the QBO
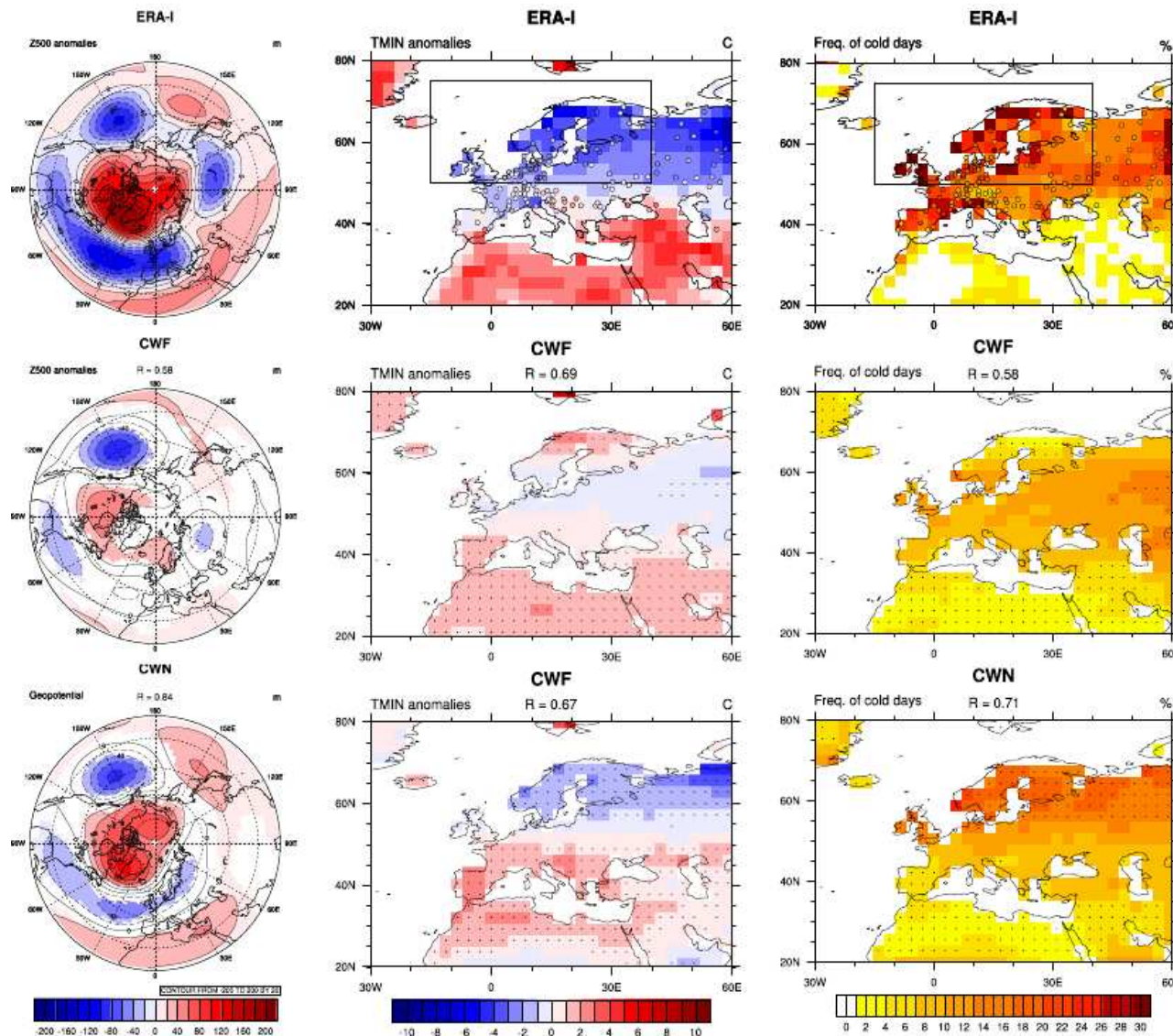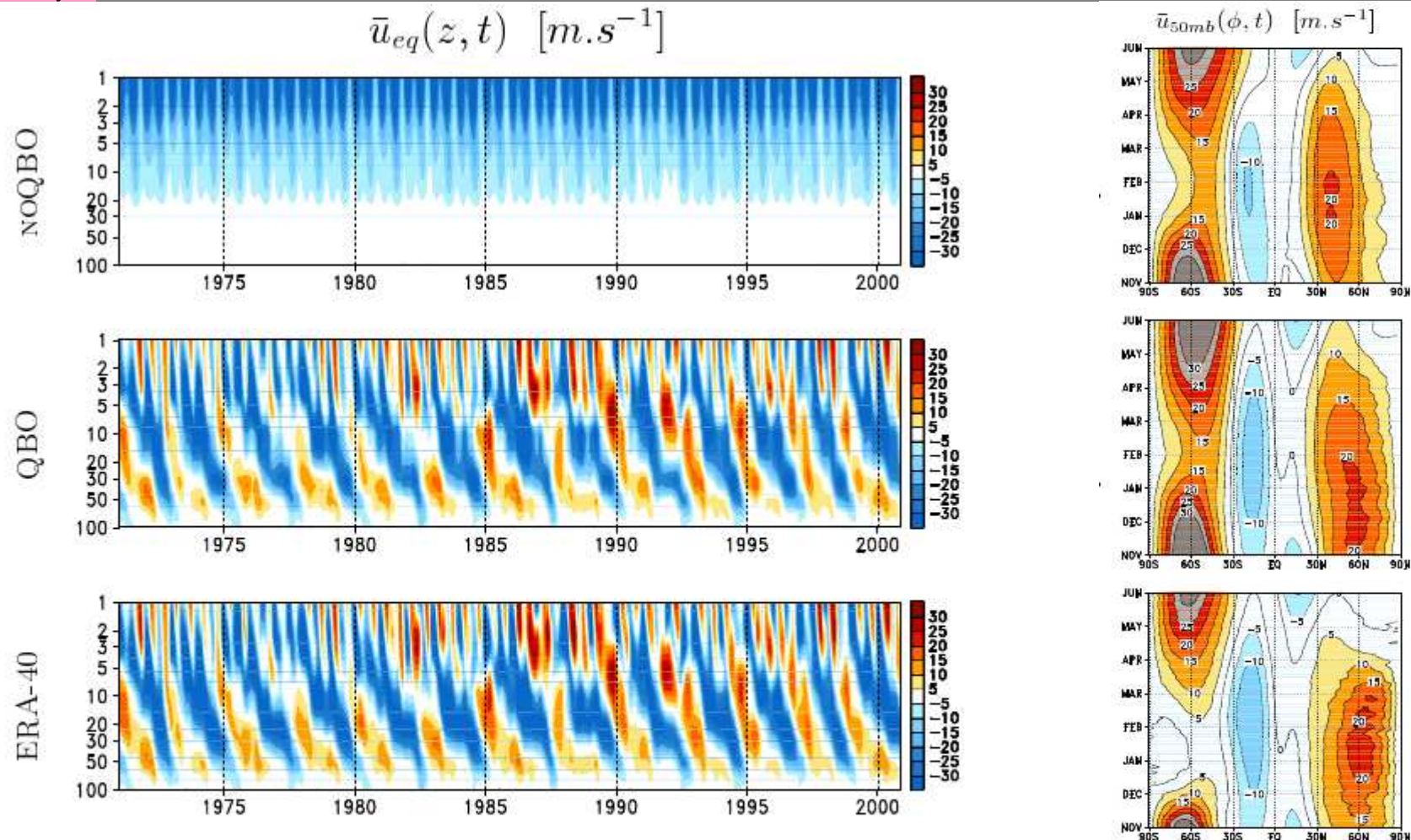# Impact on 50hPa zonal mean zonal wind climatology



FIG. 1 – Time-height section of the monthly-mean zonal-mean stratospheric equatorial zonal wind $(m.s^{-1})$ over the period 1971-2000. (top) Free-running experiment; (middle) QBO experiment; (bottom) ERA-40 reanalysis. The contour interval is 5 $m.s^{-1}$ and the band between $-5$ and $5$ $m.s^{-1}$ is unshaded.

Courtesy of
D. Saint-Martin

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# Siberian snow cover influence on winter NAO

## October albedo
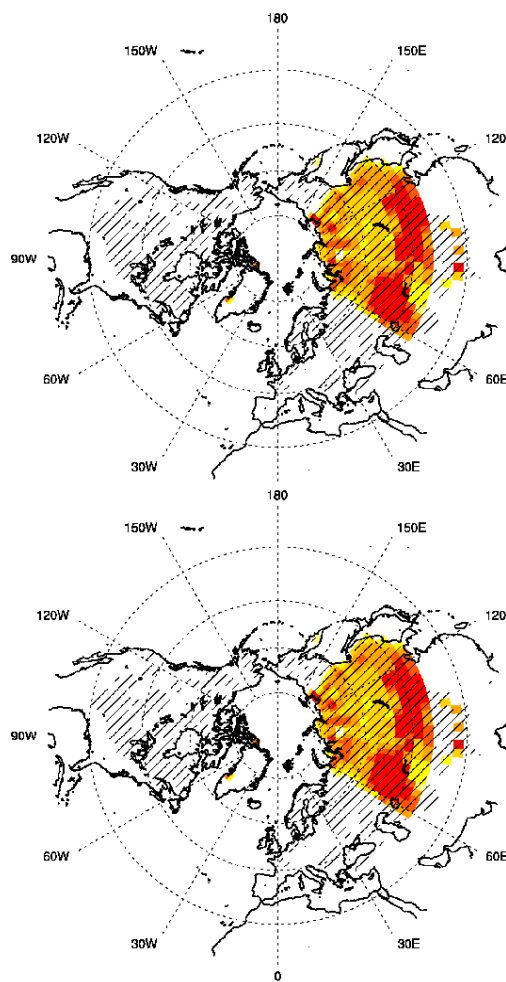
## DJFM SLP

## DJFM zonal mean Z
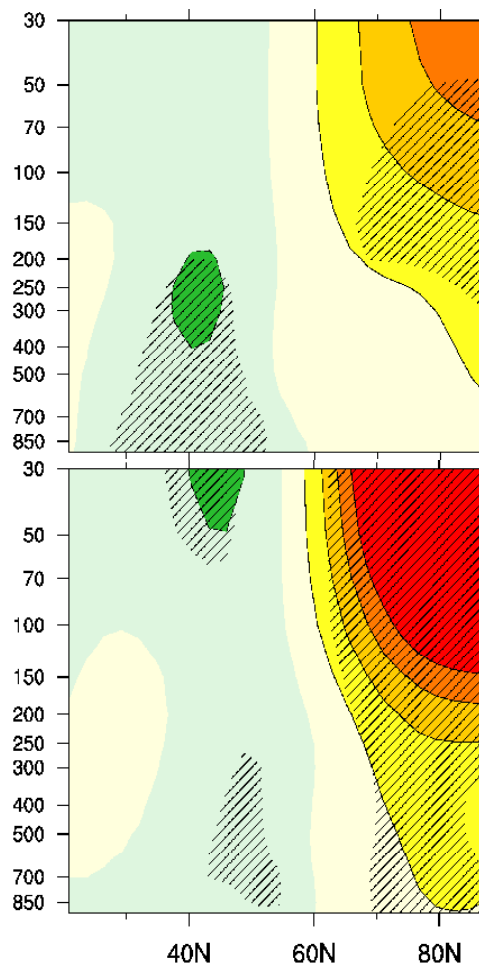
**HSL-CTL**
No nudging

**HSN-CTN**
Equatorial nudging
(P<100 hPa)

Peings et al.
JGR, 2011

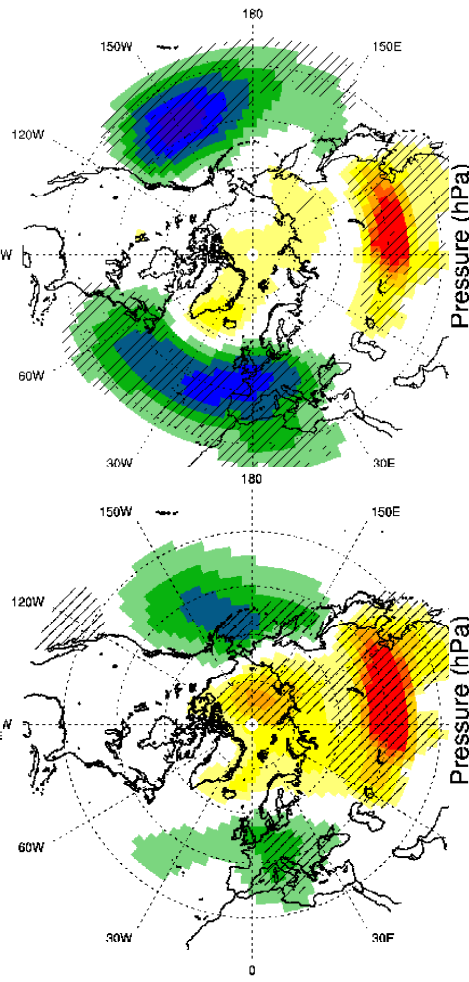# RCM-like application over West Africa:
# A contribution to the AMMA project



libre        nudgé
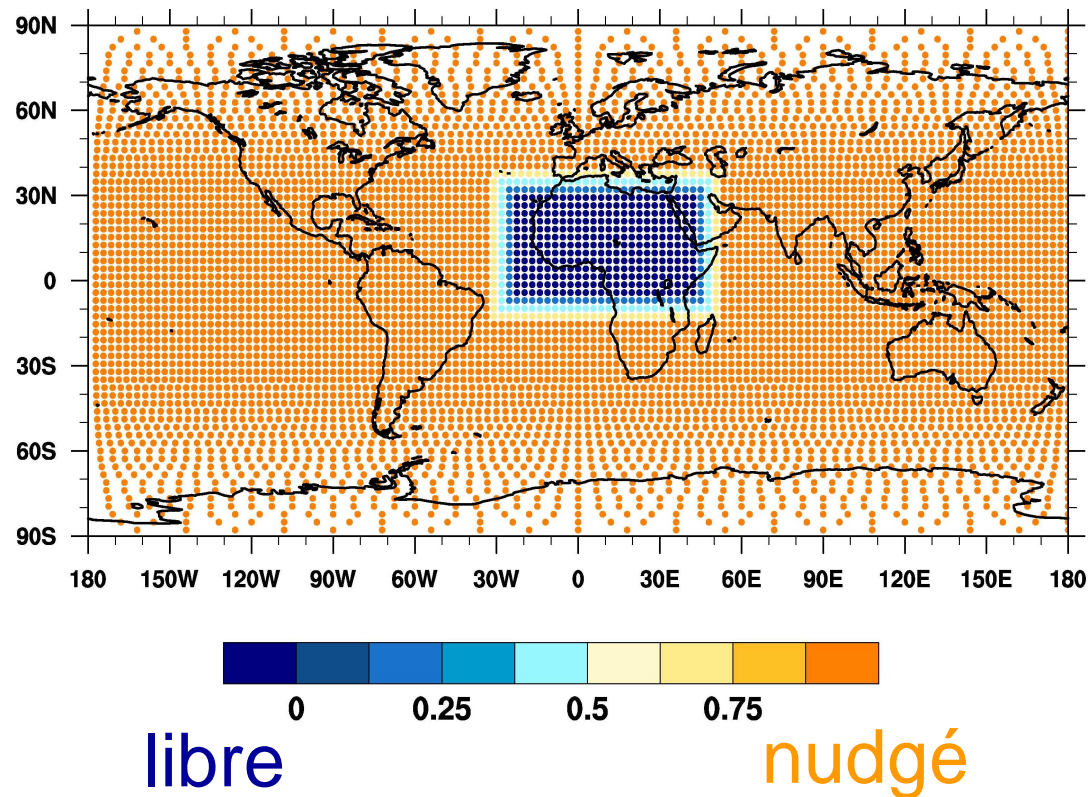
*Bielli et al. (Clim. Dyn. 2010)*

# No impact on mean regional climate

## AGCM biases in JJAS winds (925 hPa) and precipitation (mm/d)



CtlV – GPCP/ERA40 [1979–2000]

AmmalVlV – GPCP/ERA40 [1979–2000]

control experiment

nudging experiment
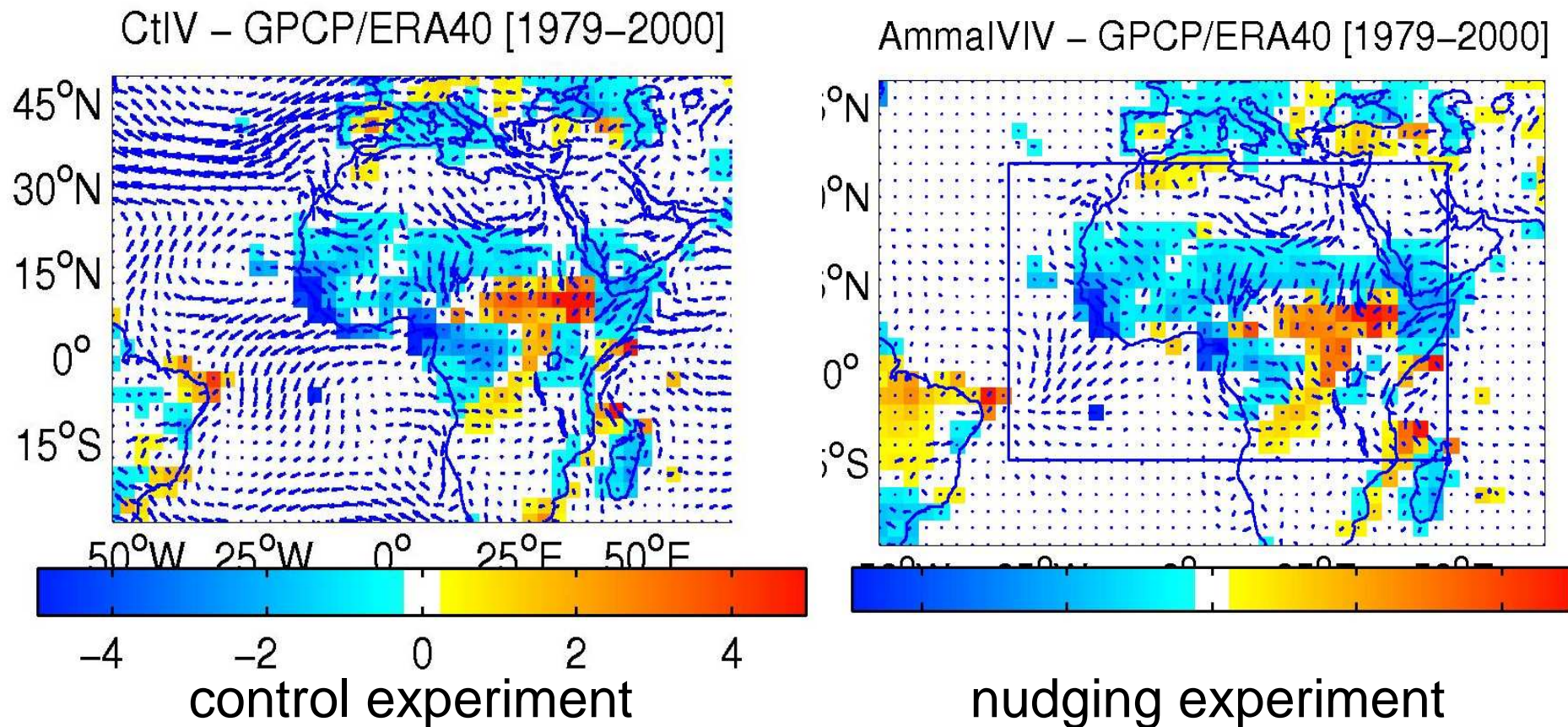
*Bielli et al. (Clim. Dyn. 2010)*

# Limited impact on interannual variability
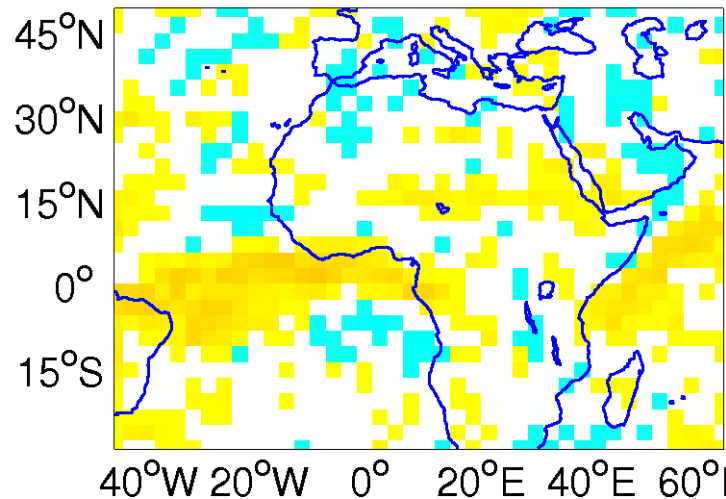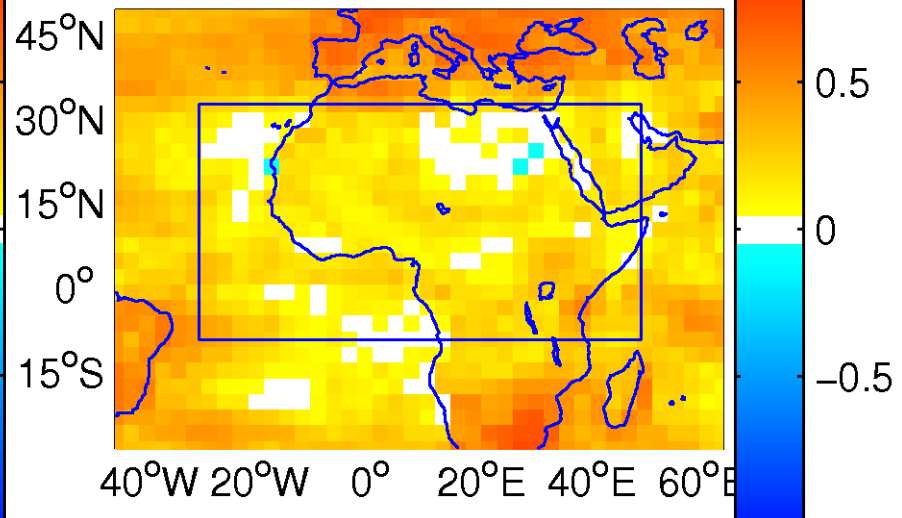


Control experiment    Nudging experiment

Point-wise 1979-2000 correlations between simulated
and observed (GPCP) JJAS precipitation anomalies

*Pohl et al., Climate Dyn. 2011*

# Summary

- Nudging is a flexible diagnostic tool:
  - Prognostic variable
  - Domain and vertical profile
  - Temporal and/or spatial scales

- Nudging is useful for understanding:
  - Model biases
  - Climate variability
  - Climate predictability

- Limits:
  - It's a poor man assimilation technique
  - It is not a surrogate for model improvement
  - Results are model dependent => Do we need another MIP ?

# Related CNRM publications

1. Bielli S., H. Douville, B. Pohl (2010) Understanding the West African monsoon variability and its remote effects: an illustration of the grid point nudging methodology. Clim. Dyn., doi:10.1007/s00382-009-0667-8

2. C. Cassou, S. Bielli, H. Douville, E. Maisonnave (2011) Influence of tropical circulation on the summer 2003 heat wave over Europe. J. Clim. (to be submitted)

3. Douville (2009) Stratospheric polar vortex influence on Northern Hemisphere winter climate variability. GRL, doi:10.1029/2009GL039334

4. Douville H., S. Bielli, C. Cassou, M. Déqué, N. Hall, S. Tyteca, A. Voldoire (2011) Tropical influence on boreal summer mid-latitude stationary waves. Clim. Dyn., doi:10.1007/s00382-011-0997-1

5. Douville H., S. Bielli, L. Li (2010) Boreal summer stationary wave variability: Assessment of tropical forcing in two atmospheric GCMs. Geophys. Res. Lett. (under progress)

6. Gaetani M., B. Pohl, H. Douville, B. Fontaine (2011) West African Monsoon influence on the summer Euro-Atlantic circulation. GRL, doi:10.1029/2009GL047150

7. Ouzeau G., J. Cattiaux, H. Douville, D. Saint-Martin, A. Ribes (2011) European winter 2009/2010: How unusual and predictable ? GRL, doi:10.1029/2011GL039334

8. Pohl B., H. Douville (2011) Diagnosing GCM errors over West Africa using relaxation experiments. Part I: climatology and interannual variability. Clim. Dyn., doi:10.1007/s00382-010-0911-2

9. Pohl B., H. Douville (2011) Diagnosing GCM errors over West Africa using relaxation experiments. Part II: Intraseasonal variability. Clim. Dyn., doi:10.1007/s00382-011-1106-1

10. Saint-Martin D., D. Cariolle, H. Douville (2011) Sensitivity of the northern hemisphere winter circulation to the equatorial stratosphere. Clim. Dyn. (submitted)