Tropical-extratropical interactions in ensemble predictions from sub-seasonal to decadal scales

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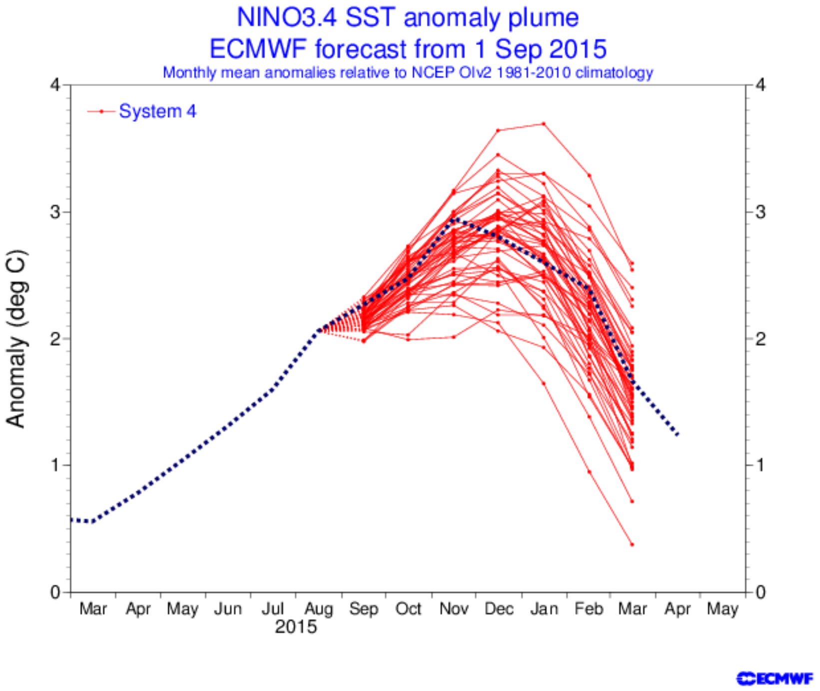
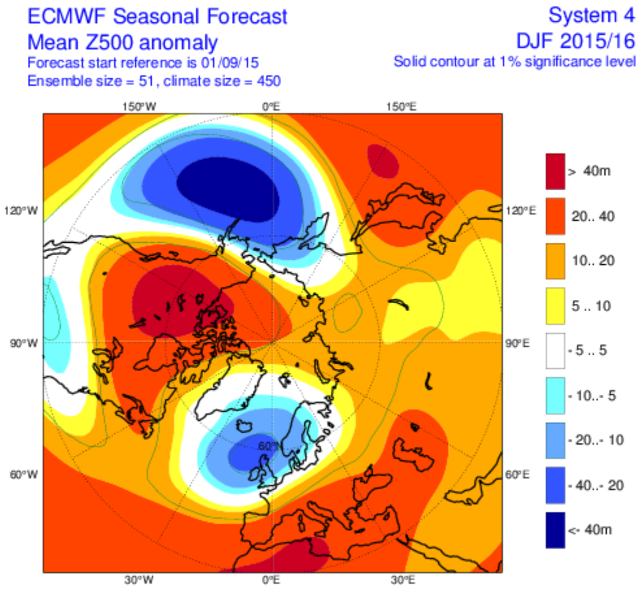
ECMWF, Reading, U.K. / ICTP, Trieste, Italy

ECMWF Seminar on Ensemble Prediction, 11-14 Sep. 2017

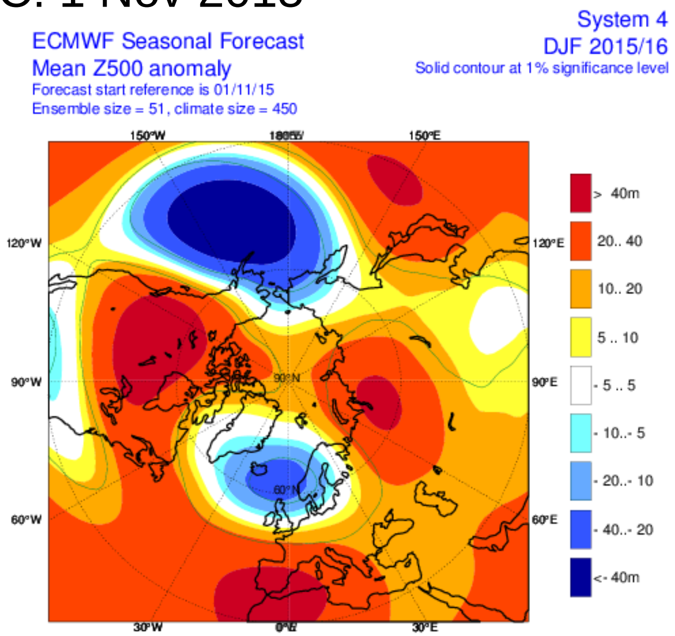
ECMWF seasonal forecasts for the El Niño event of winter 2015/16

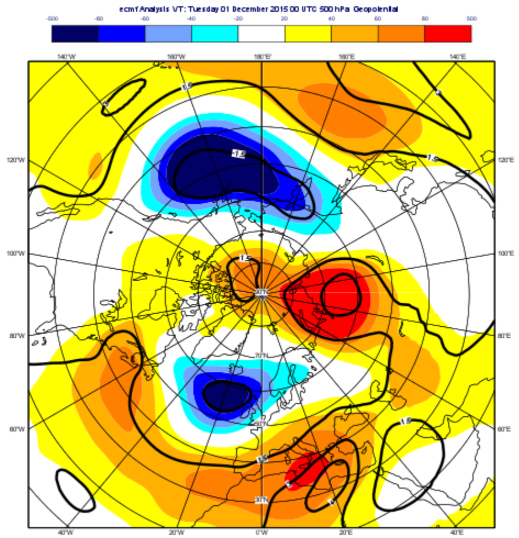


IC: 1 Sep 2015



IC: 1 Nov 2015

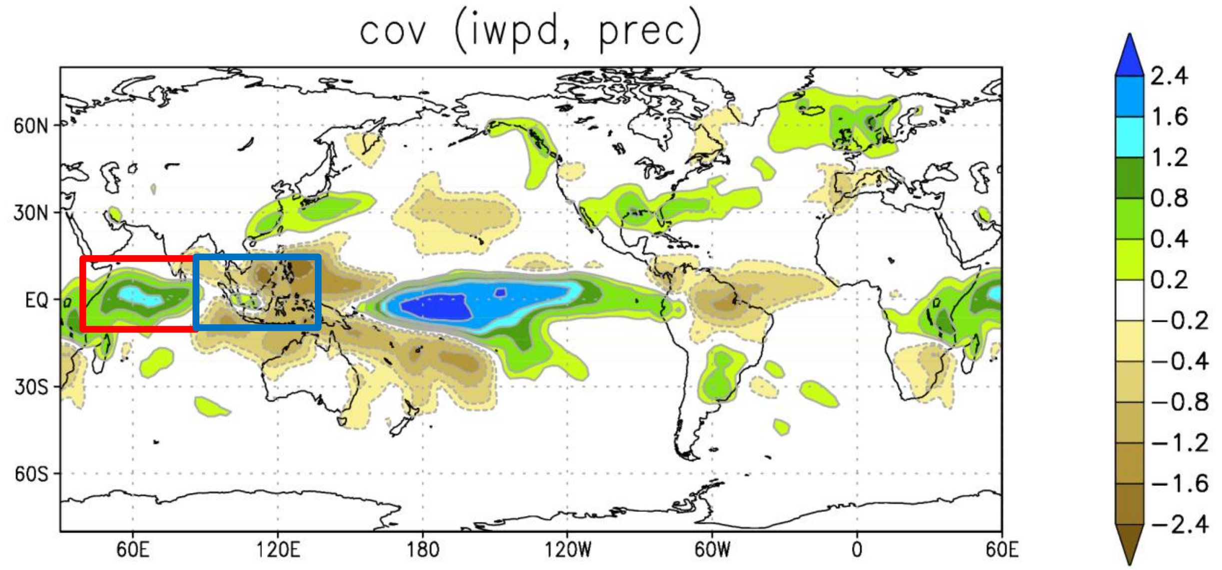


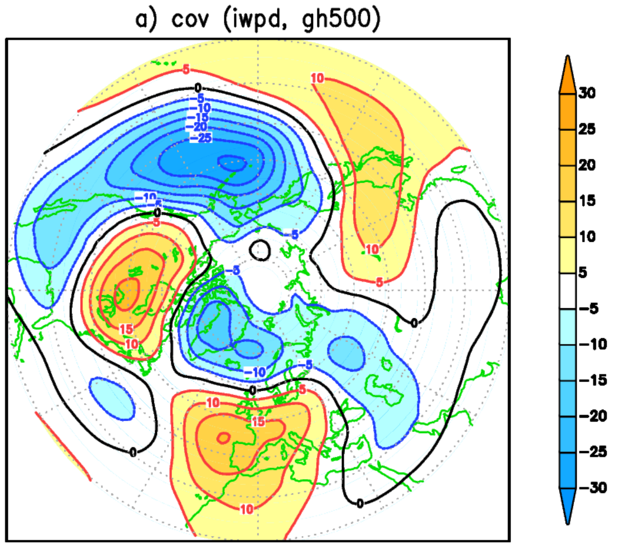


ERA Interim

Teleconnection from seasonal rainfall anomalies in the Indian – W. Pacific ocean (DJF)

from Molteni, Stockdale & Vitart 2015



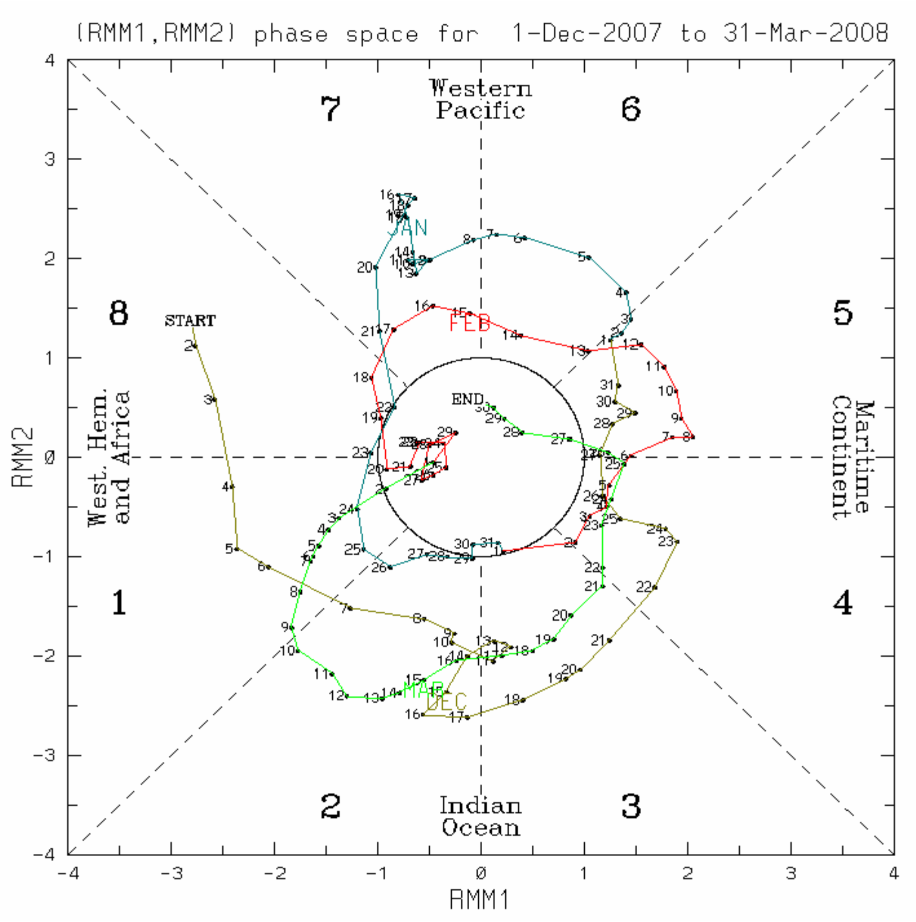


Are these teleconnections important on either shorter or longer time scales ?

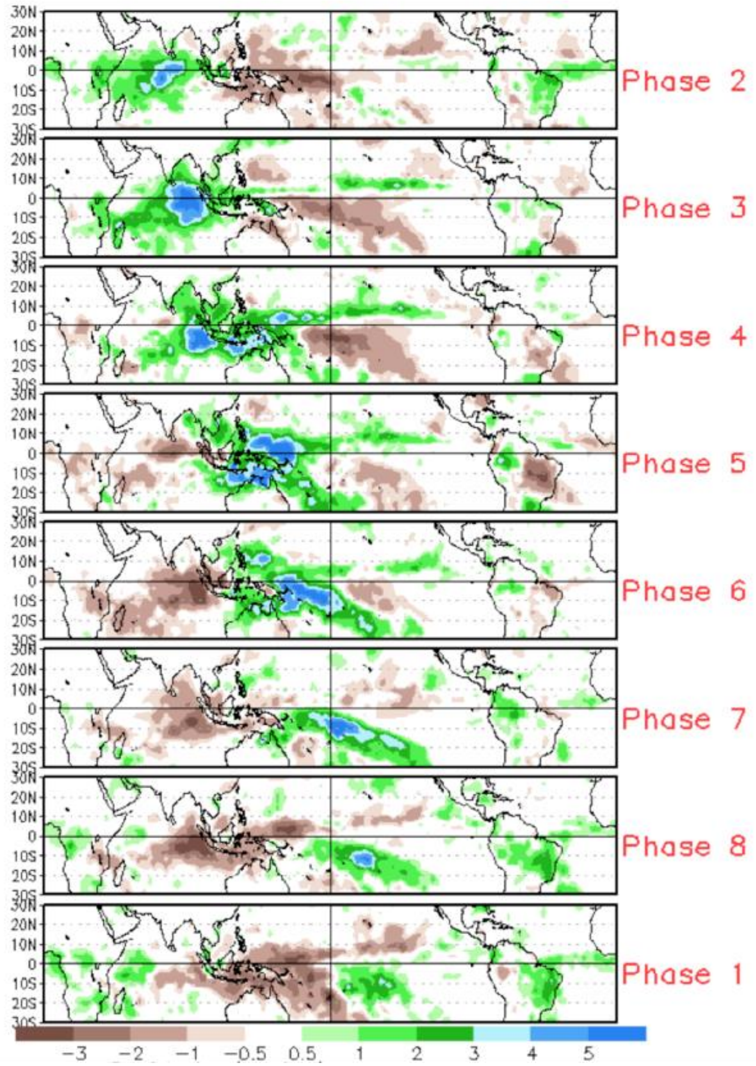
- The sub-seasonal time scale (15 ~ 90 days)
- The decadal time scale

Teleconnections in the sub-seasonal scale: the Madden-Julian Oscillation

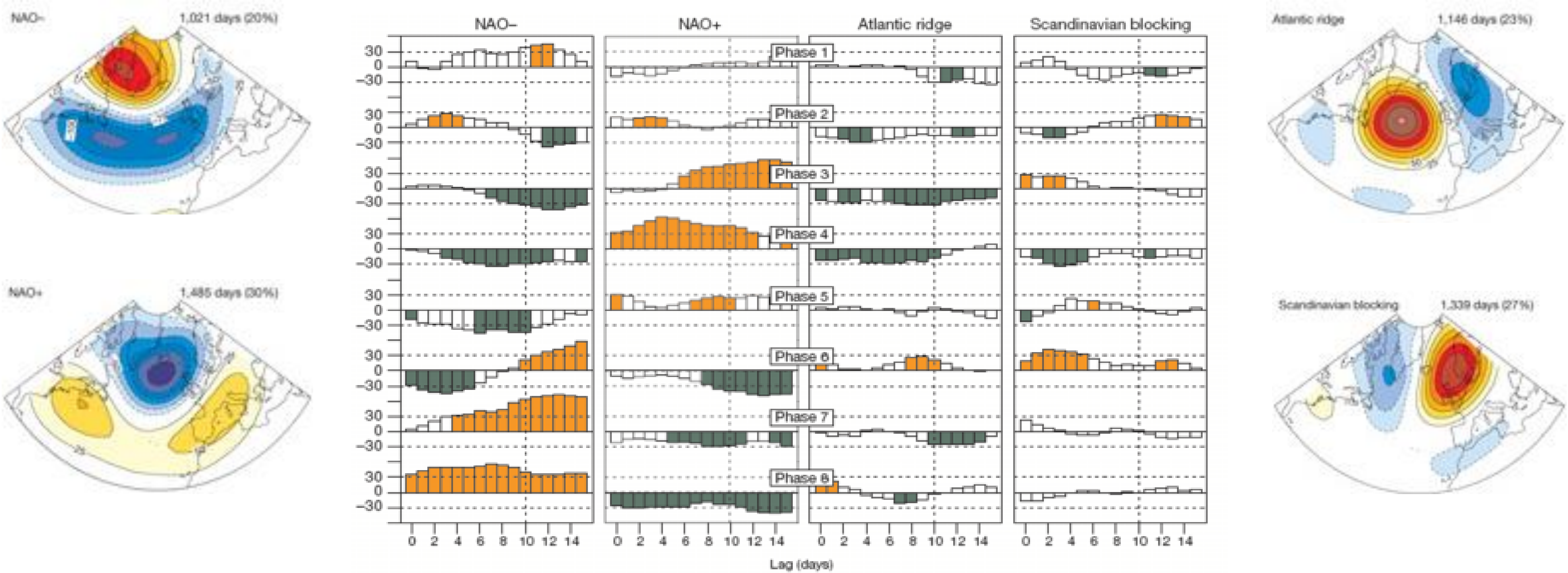
Wheeler-Hendon (2004) phase diagram



composites of rainfall anomalies (from NOAA)

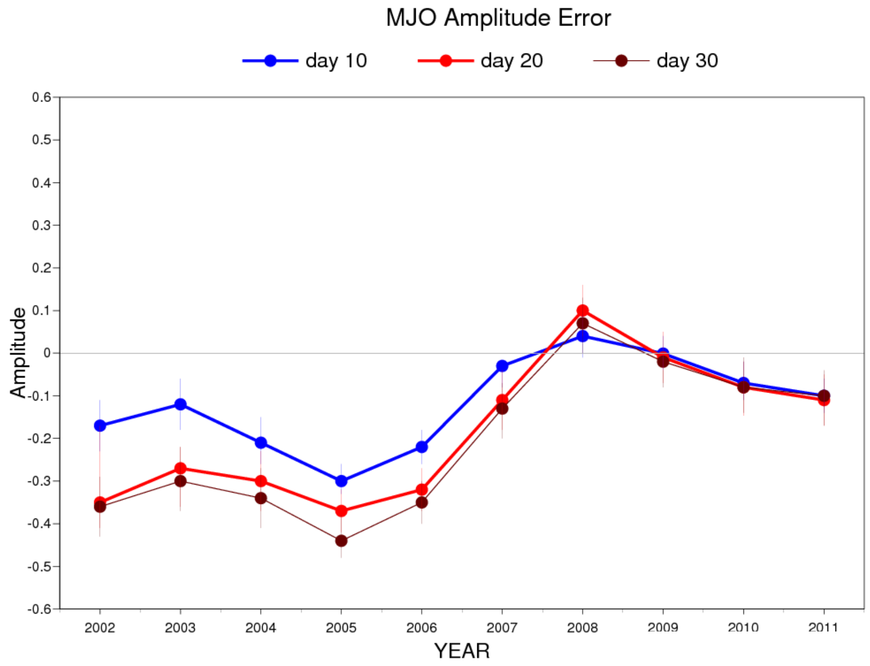


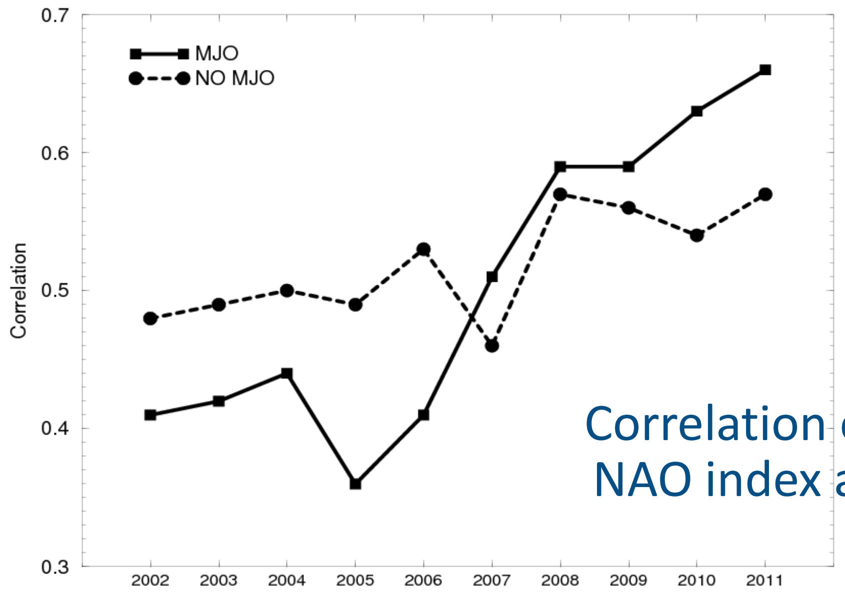
Impact of MJO on Euro-Atlantic regimes *(Cassou 2008)*



Cassou C,2008: Intraseasonal interaction between the Madden-Julian Oscillation and the North Atlantic Oscillation. *Nature*, **455,** 523-527.

A success story: forecasting the Madden-Julian Oscillation



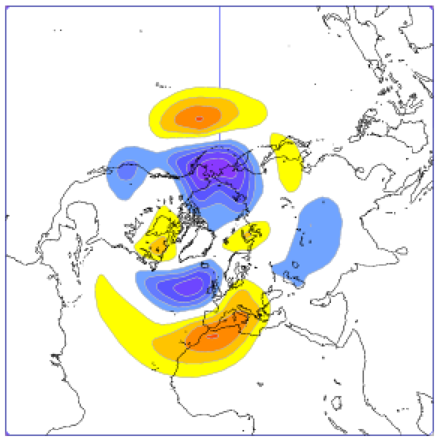


Correlation of ens-mean NAO index at day 19-25

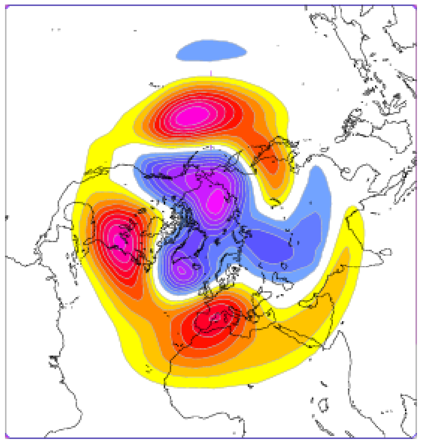
500 hPa height,
MJO phase 3 + 10 days

see Vitart 2014

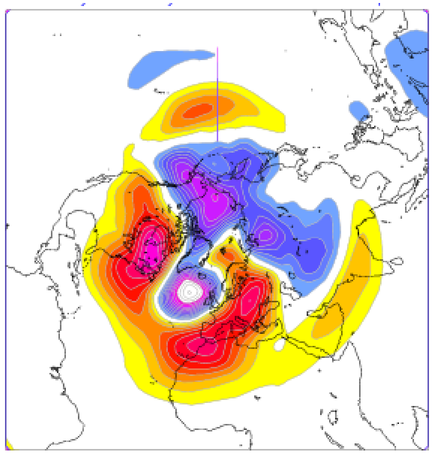
2002 MOFC hindcasts



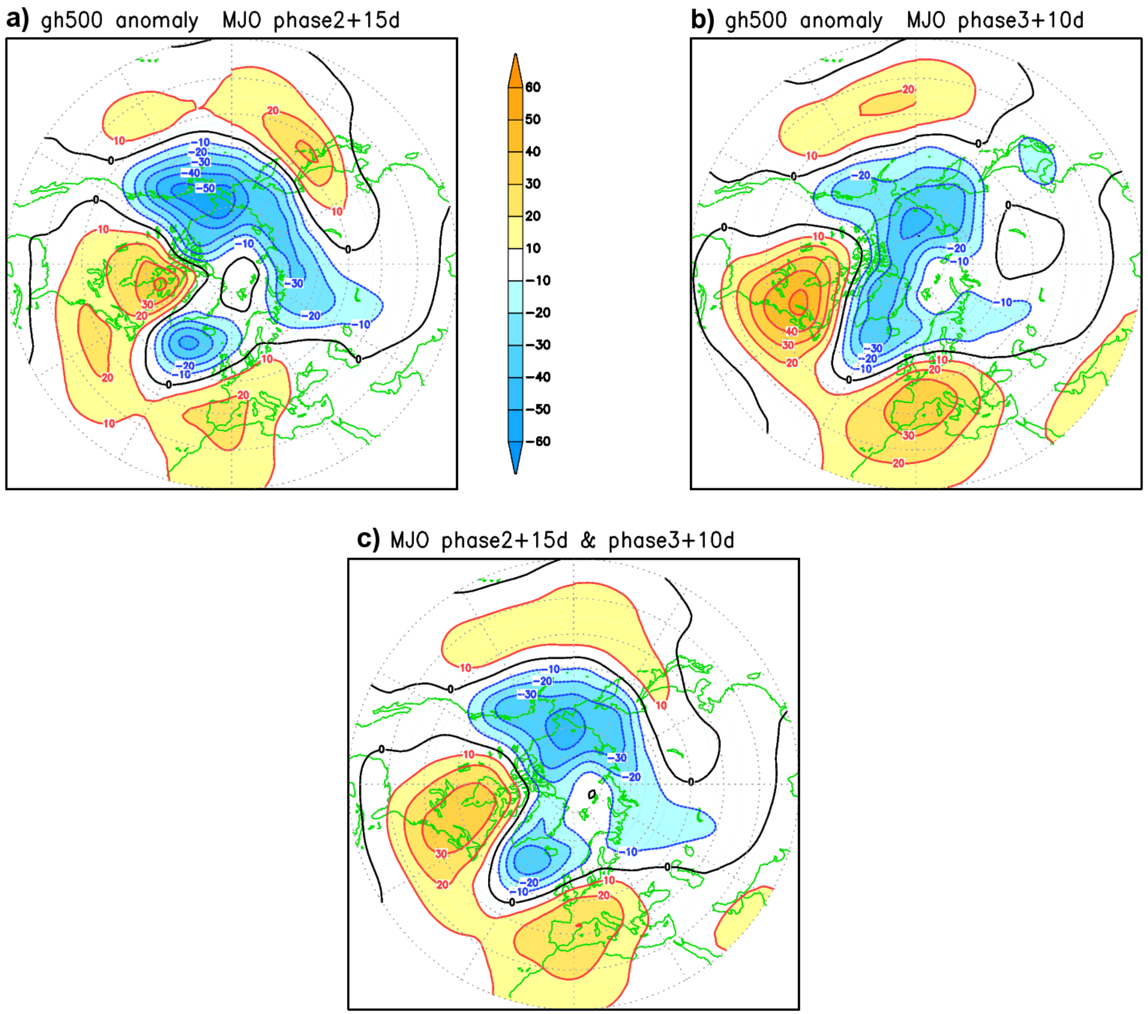
2011 MOFC hindcasts



ERA Interim



Where does the signal start from, and how long it takes to reach the North Atlantic?



Where does the signal start from, and how long it takes to reach the North Atlantic?

from Lin, Brunet & Mo 2010

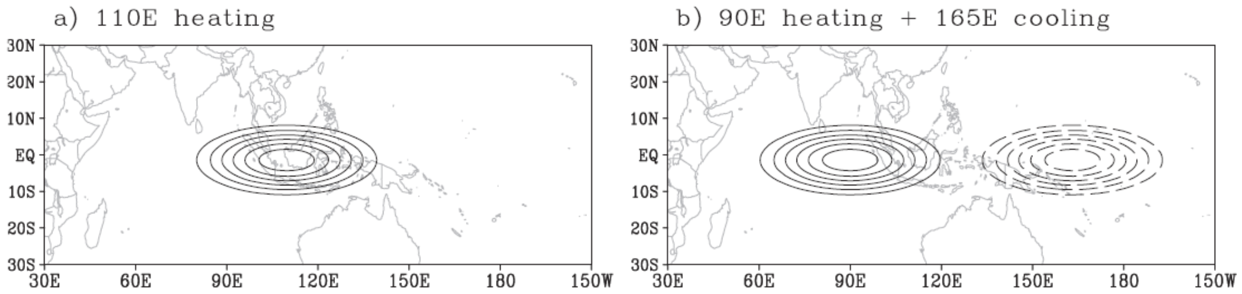
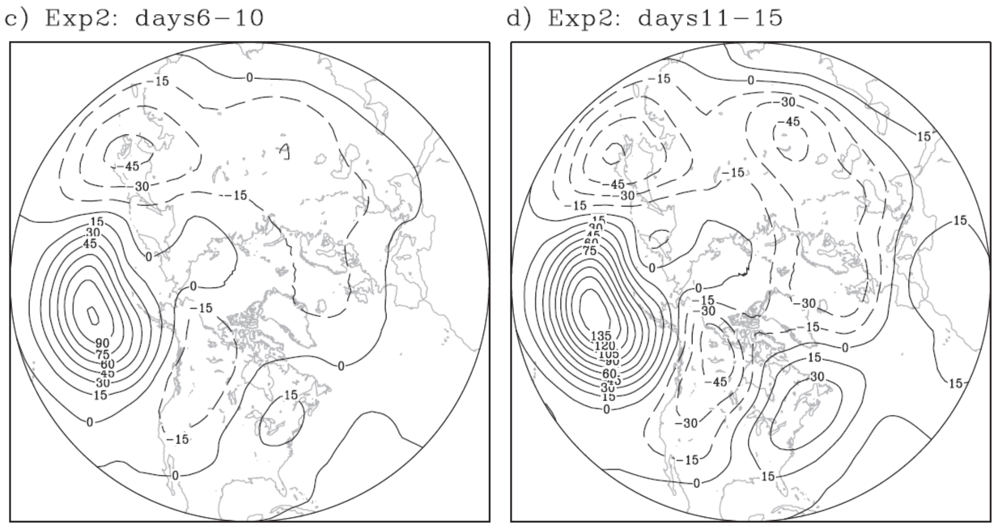


FIG. 12. Vertically averaged anomalous heating rate for (a) Exp1 and (b) Exp2. The contour interval is 0.5°C day^{-1}. The 0 contour is not plotted and contours with negative values are dashed.



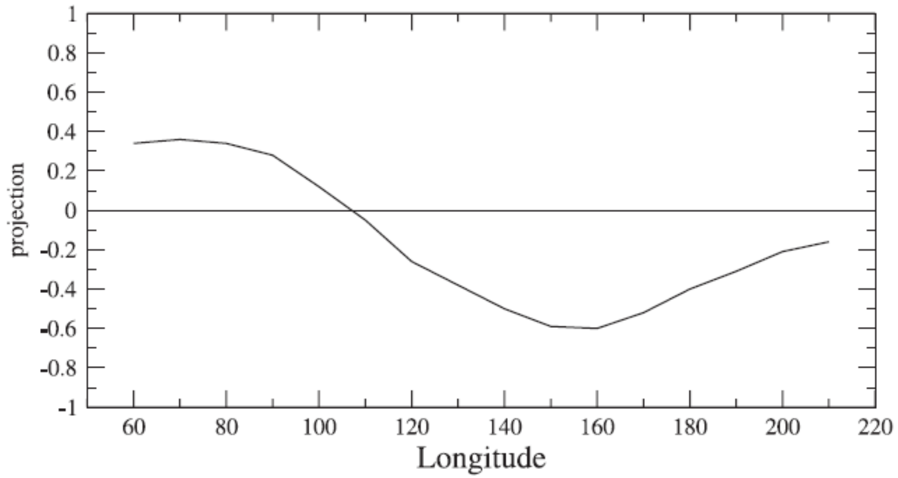


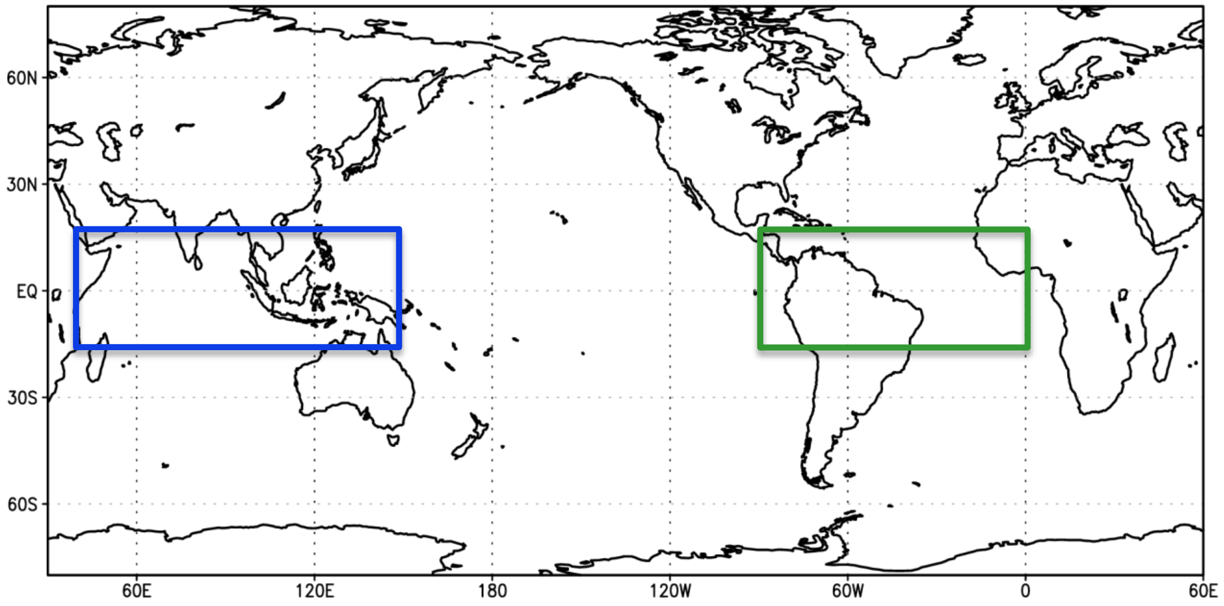
FIG. 15. Projection of 500-hPa geopotential height response averaged between days 11 and 15 onto the height field of Fig. 13d as a function of longitude for the heating center location.

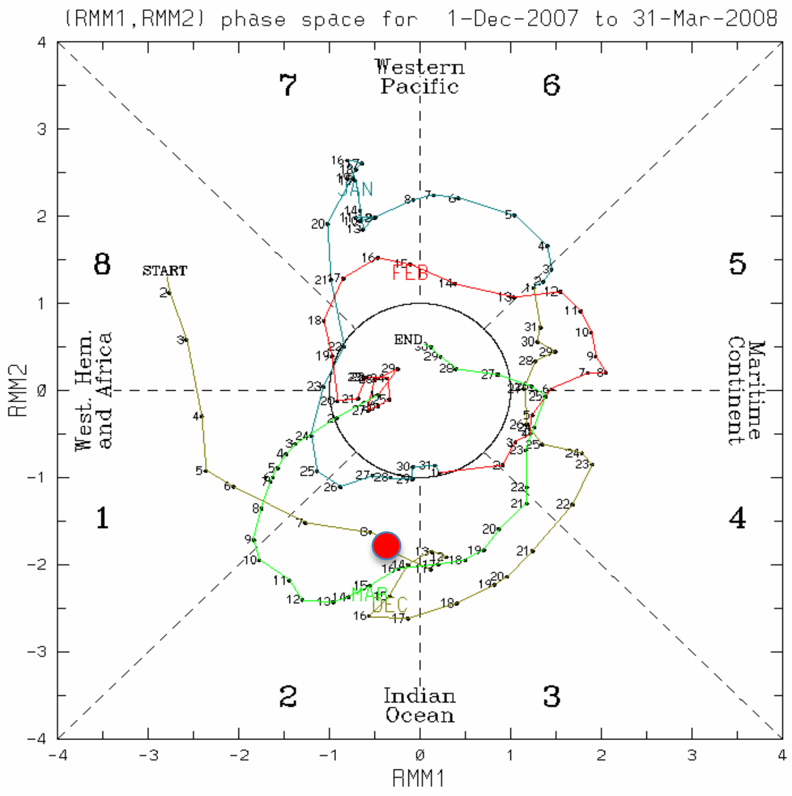
see *Straus, Swenson & Lappen 2015* for experiments with time-varying thermal forcing

Experiments with stochastic perturbations to physical tendencies (SPPT) in selected regions
(from Sarah-Jane Lock)

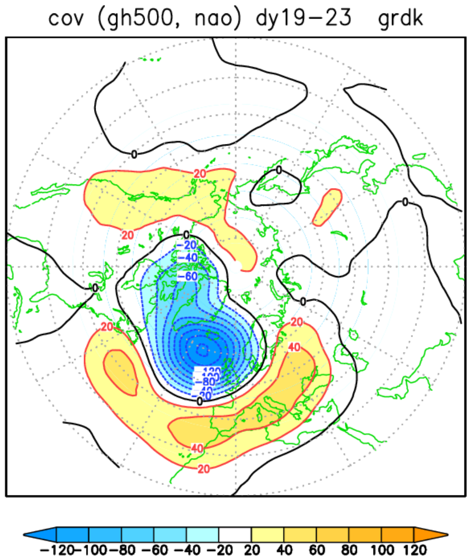
Three 51-member ensemble forecasts, start date: 10 Dec. 2007 (MJO phase 2)
No perturbation in initial conditions, spread induced by SPPT only

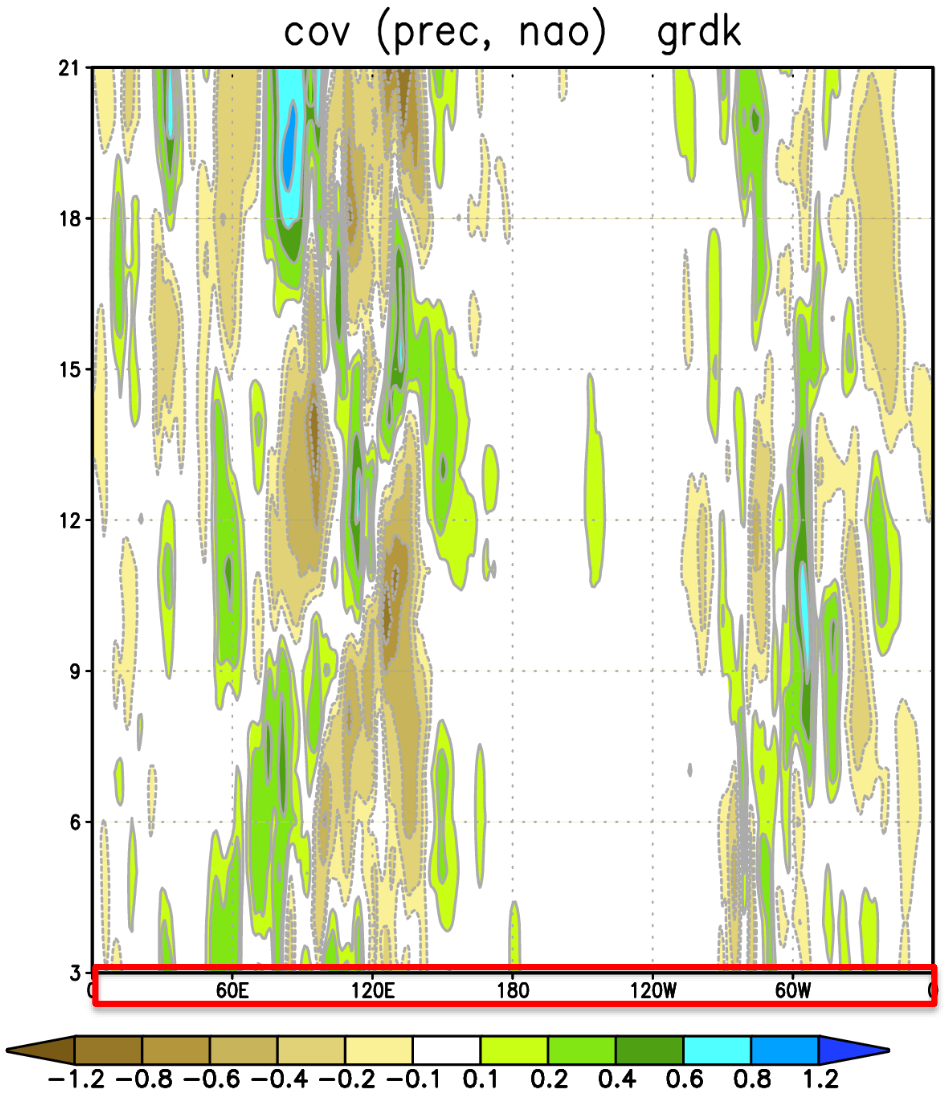
1. SPPT applied over the whole globe
2. SPPT only over tropical Indian Ocean – Maritime Continents (35-145E, 15N-15S)
3. SPPT only over tropical South America – Atlantic Ocean (90W-0, 15N-15S)



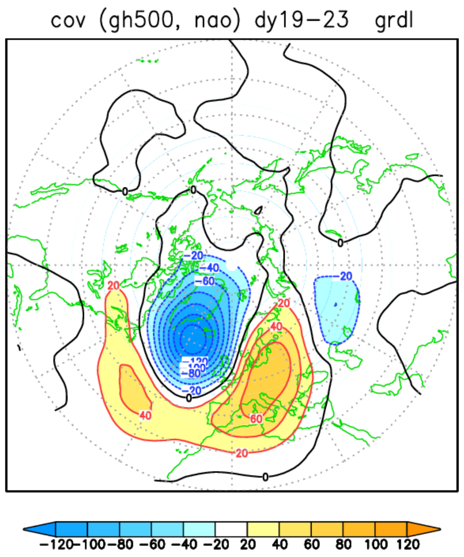


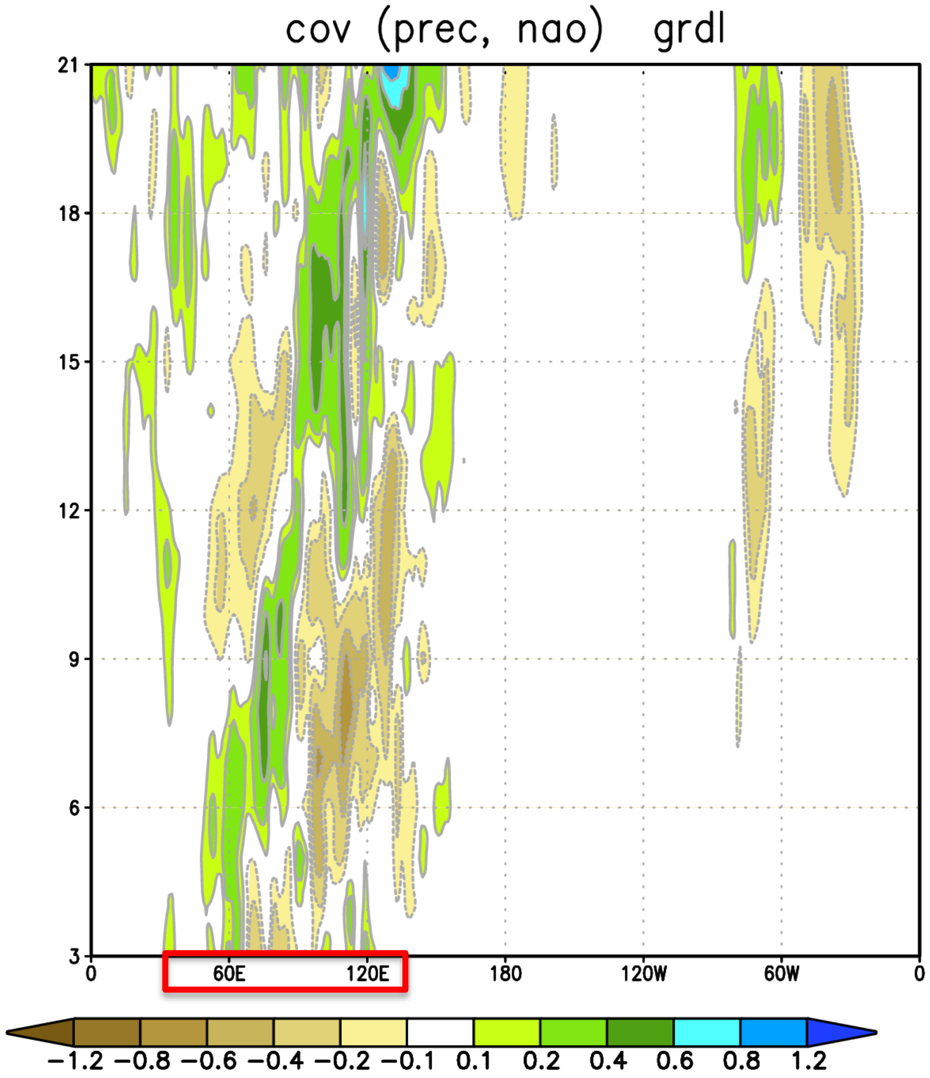
Lagged covariance of NAO index with tropical rainfall (10S-10N): global SPPT

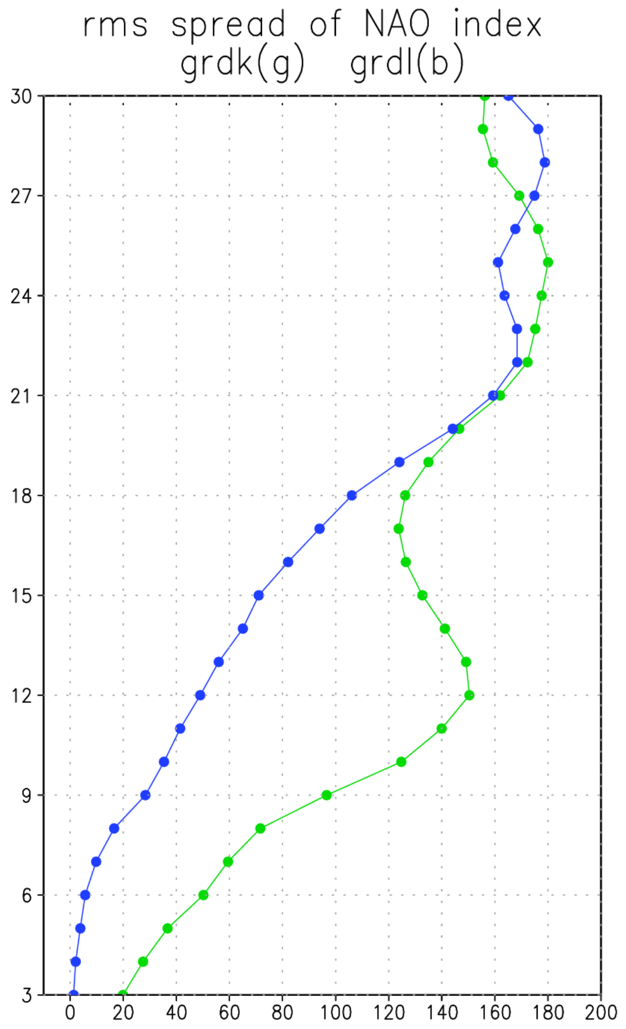




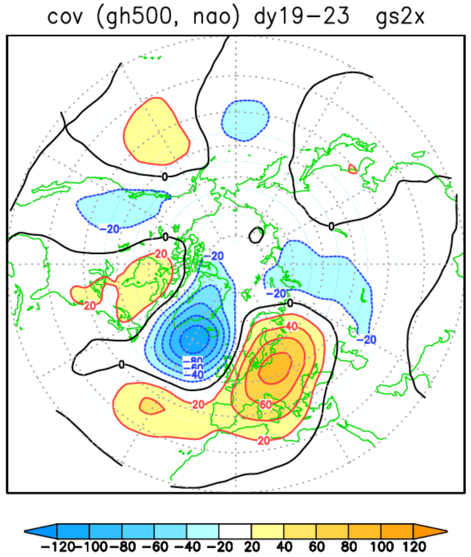
Lagged covariance of NAO index with tropical rainfall (10S-10N): SPPT in Indian-W.Pac. ocean

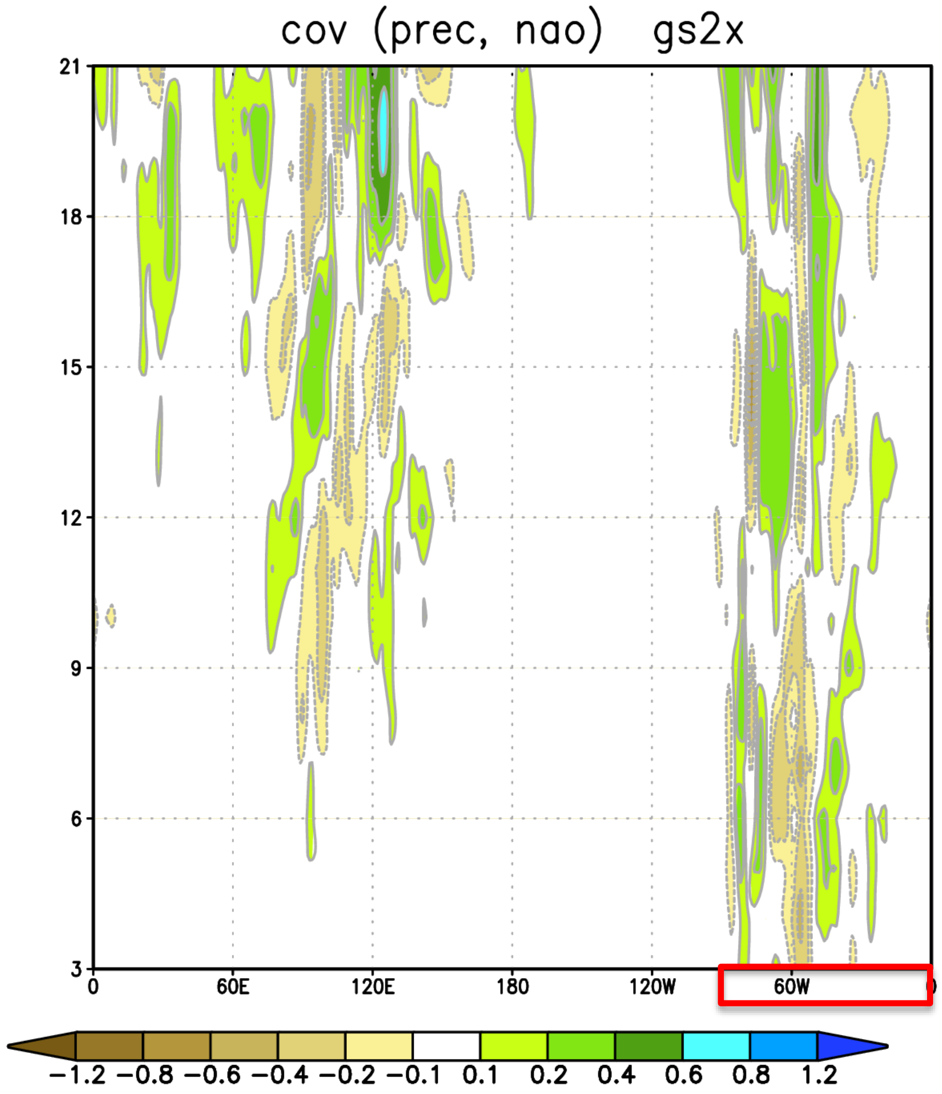


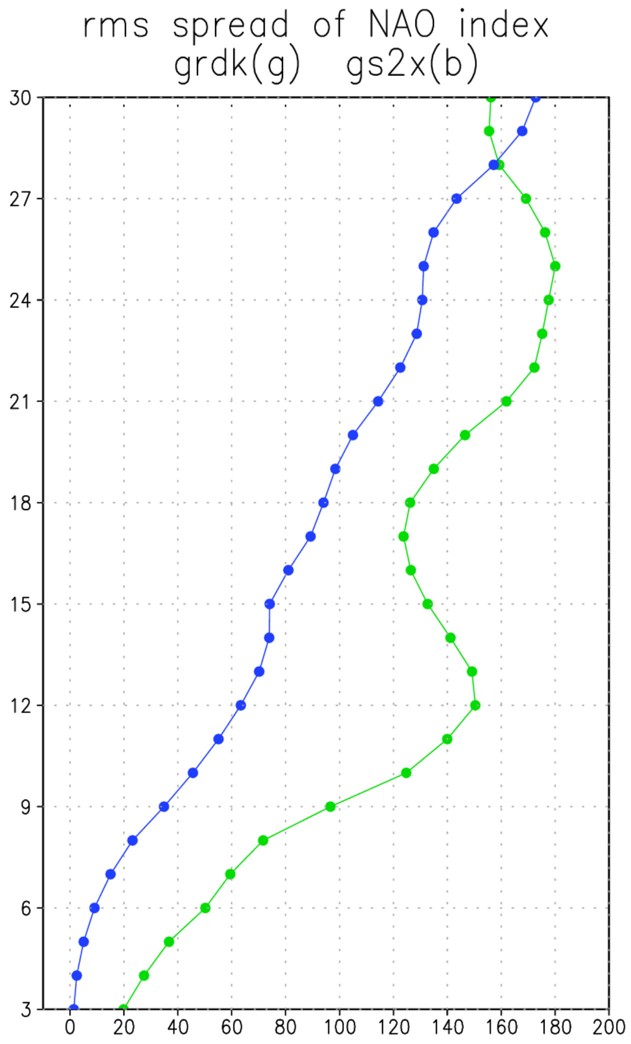




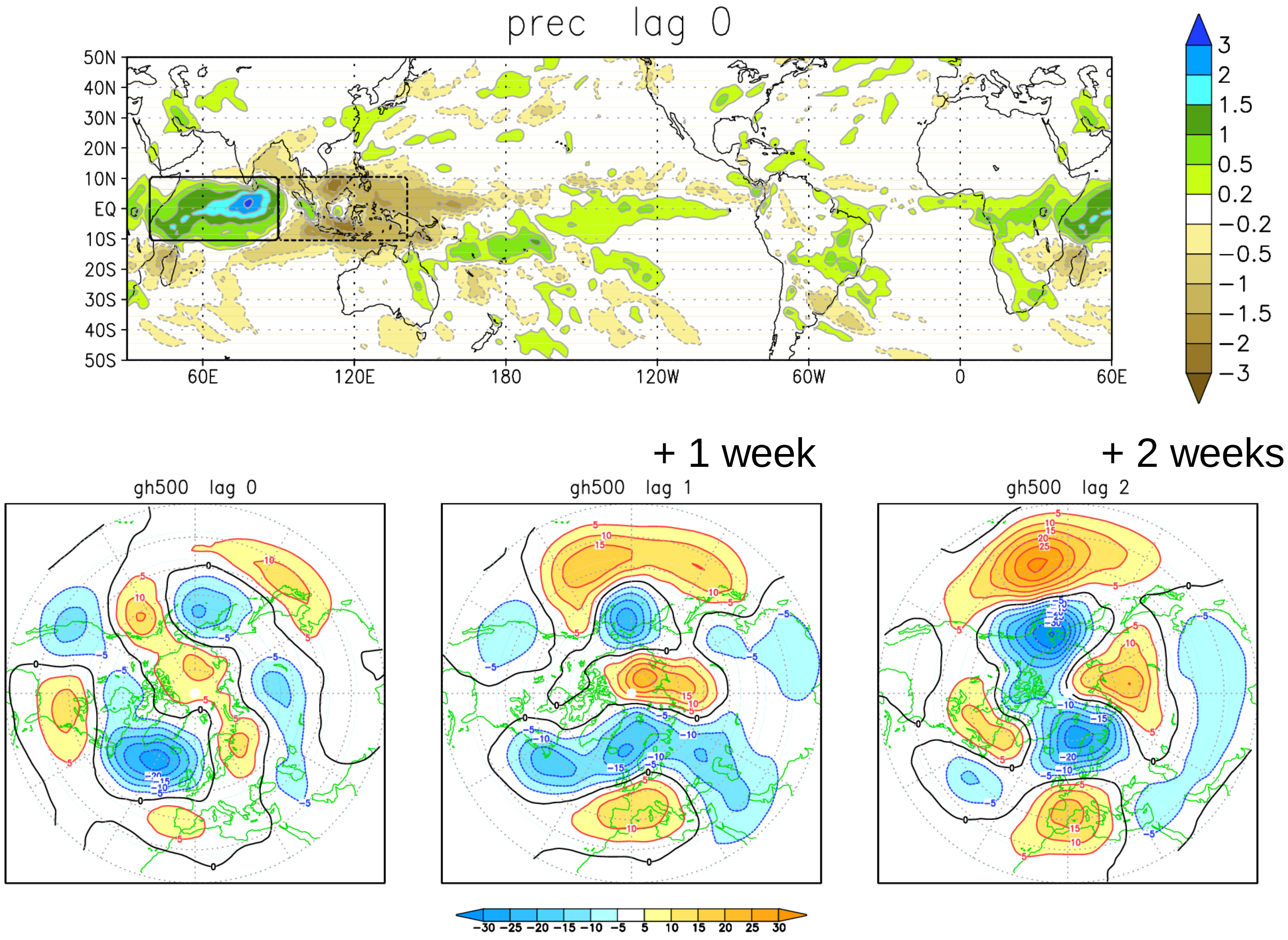
Lagged covariance of NAO index with tropical rainfall (10S-10N): SPPT in S. America/Atl. ocean



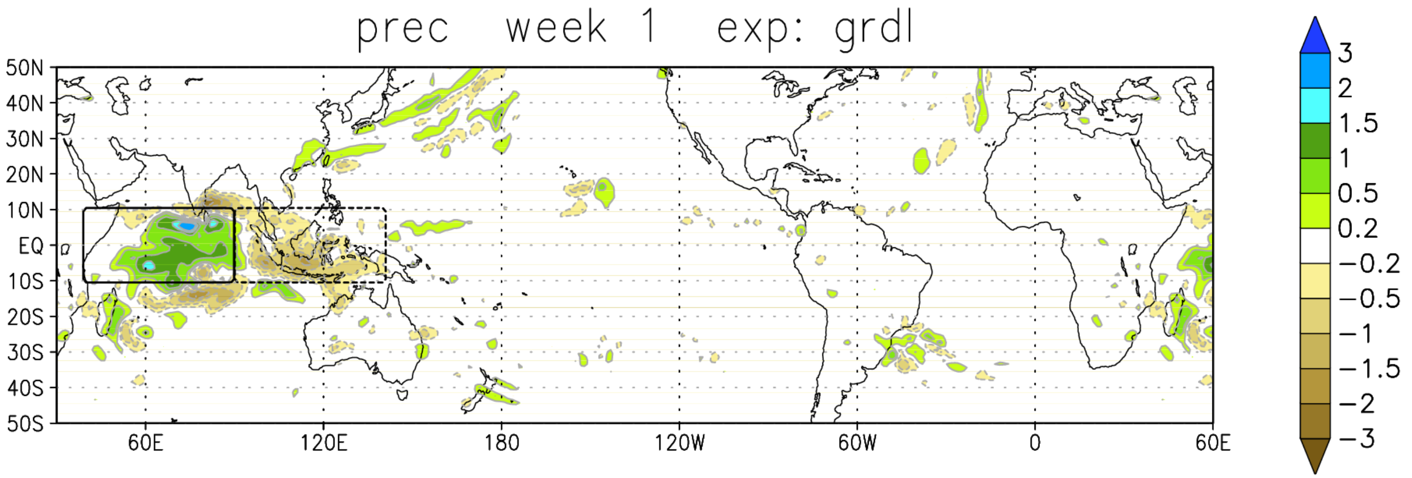




Lagged covariance of Indo-Pacific rainfall (10S-10N) with NH Z 500 hpa: ERA-Int. 1995-2015

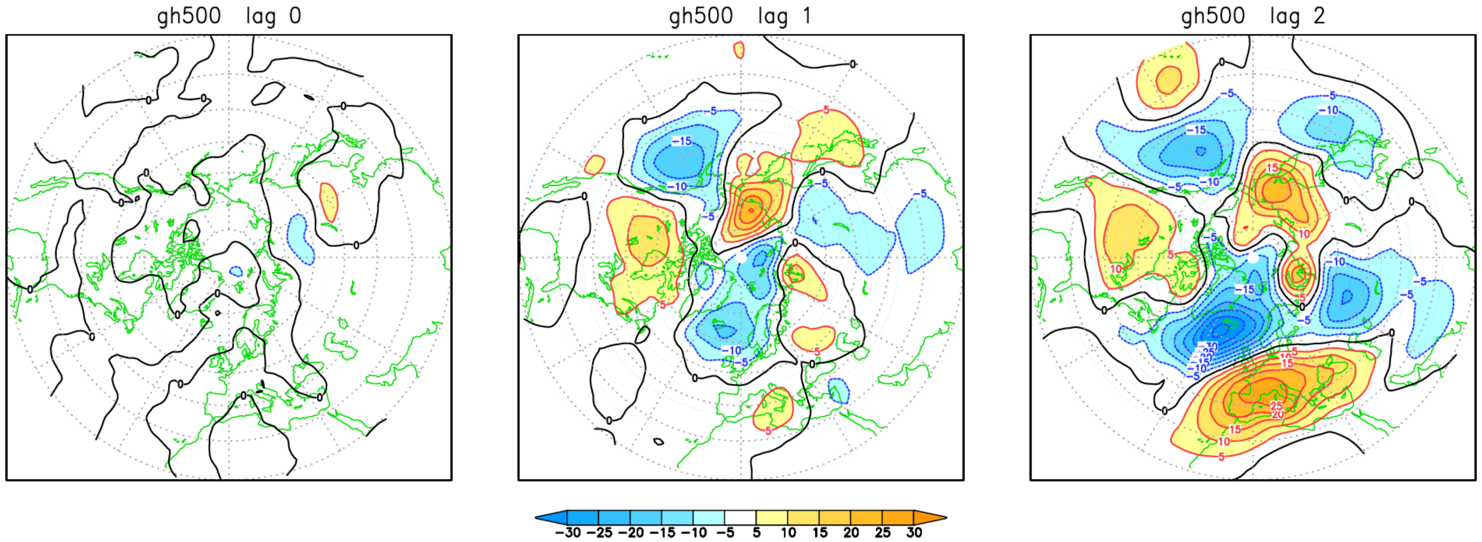


Lagged covariance of Indo-Pacific rainfall (10S-10N) with NH Z 500 hpa: Indo-W.Pac. SPPT

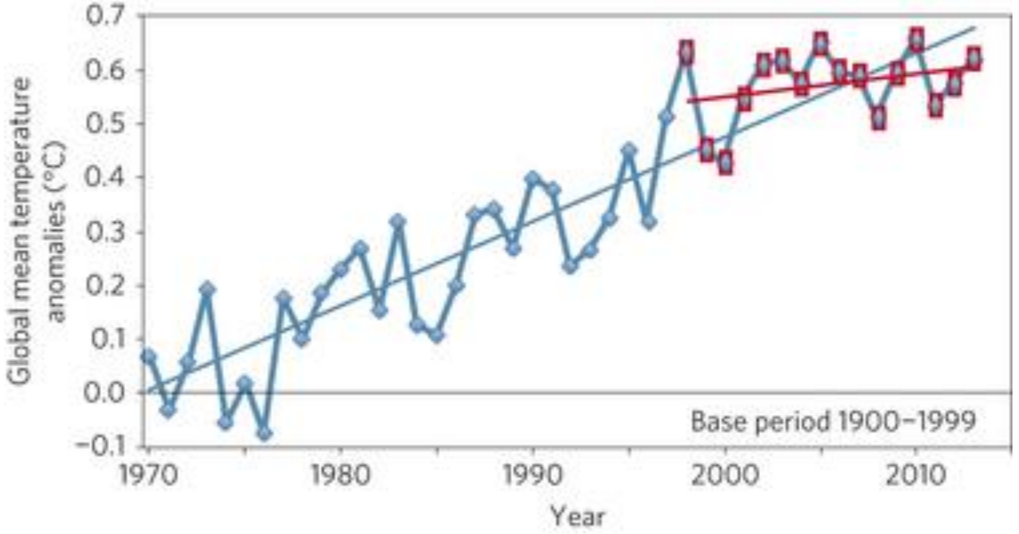


+ 1 week

+ 2 weeks

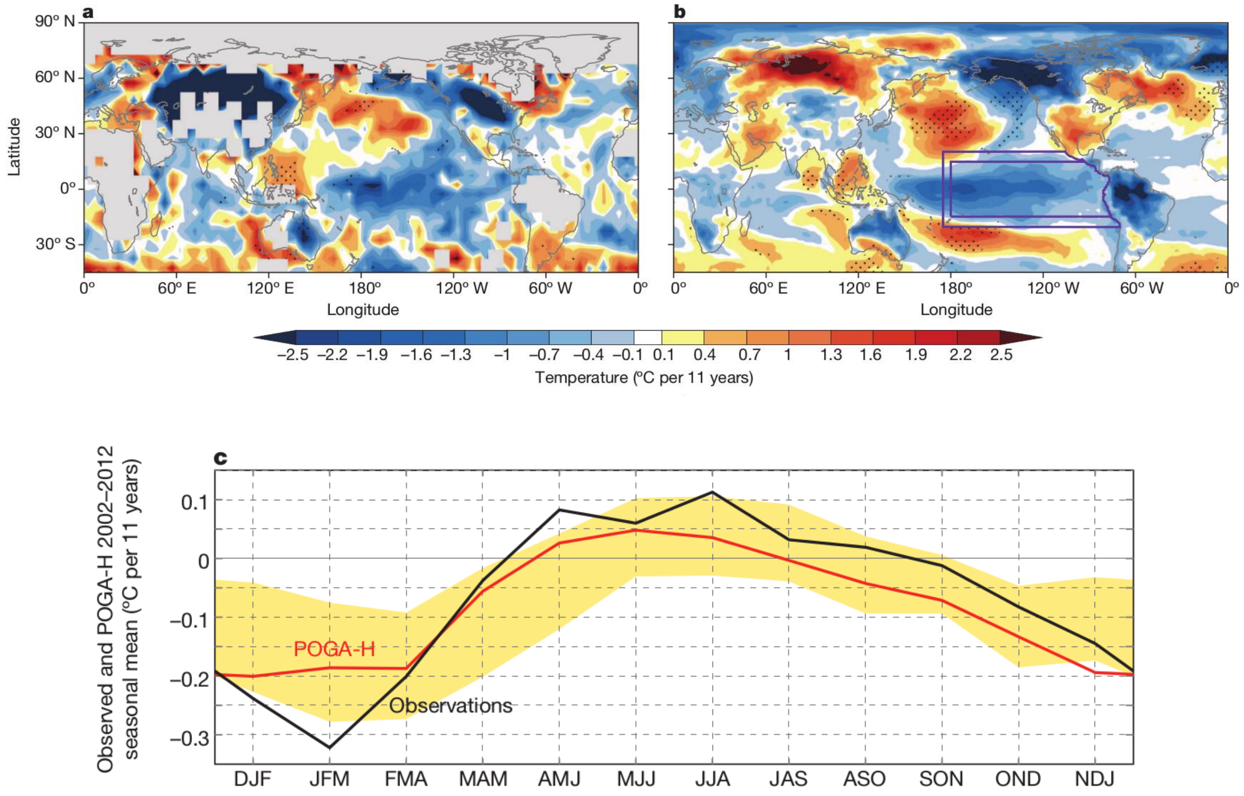


Modelling decadal variability on near-surface temperature trends



Kosaka and Xie (Nature 2013):

“pacemaker” experiment for 2002-2012

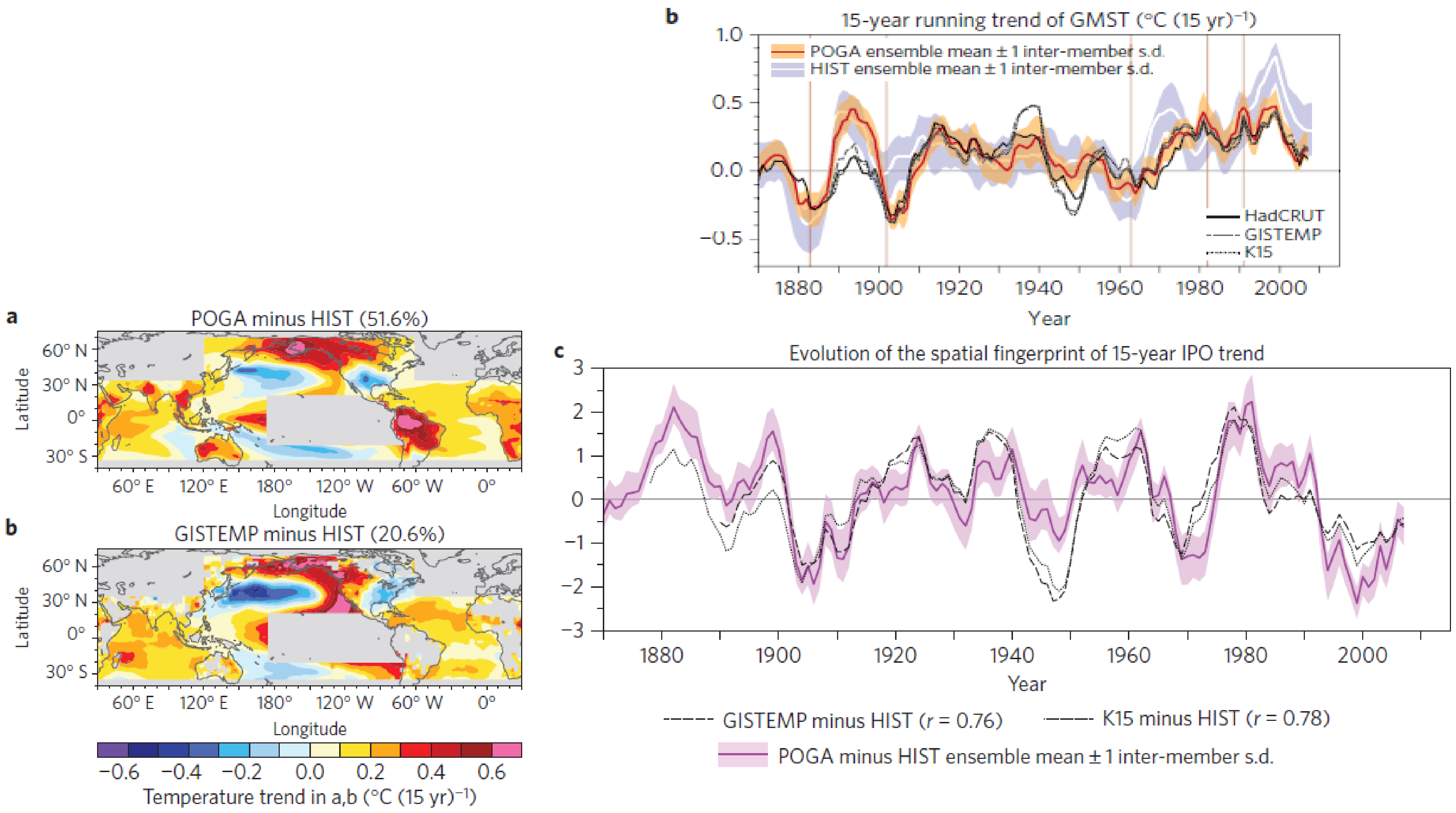


Linear trends from HadCRUT:

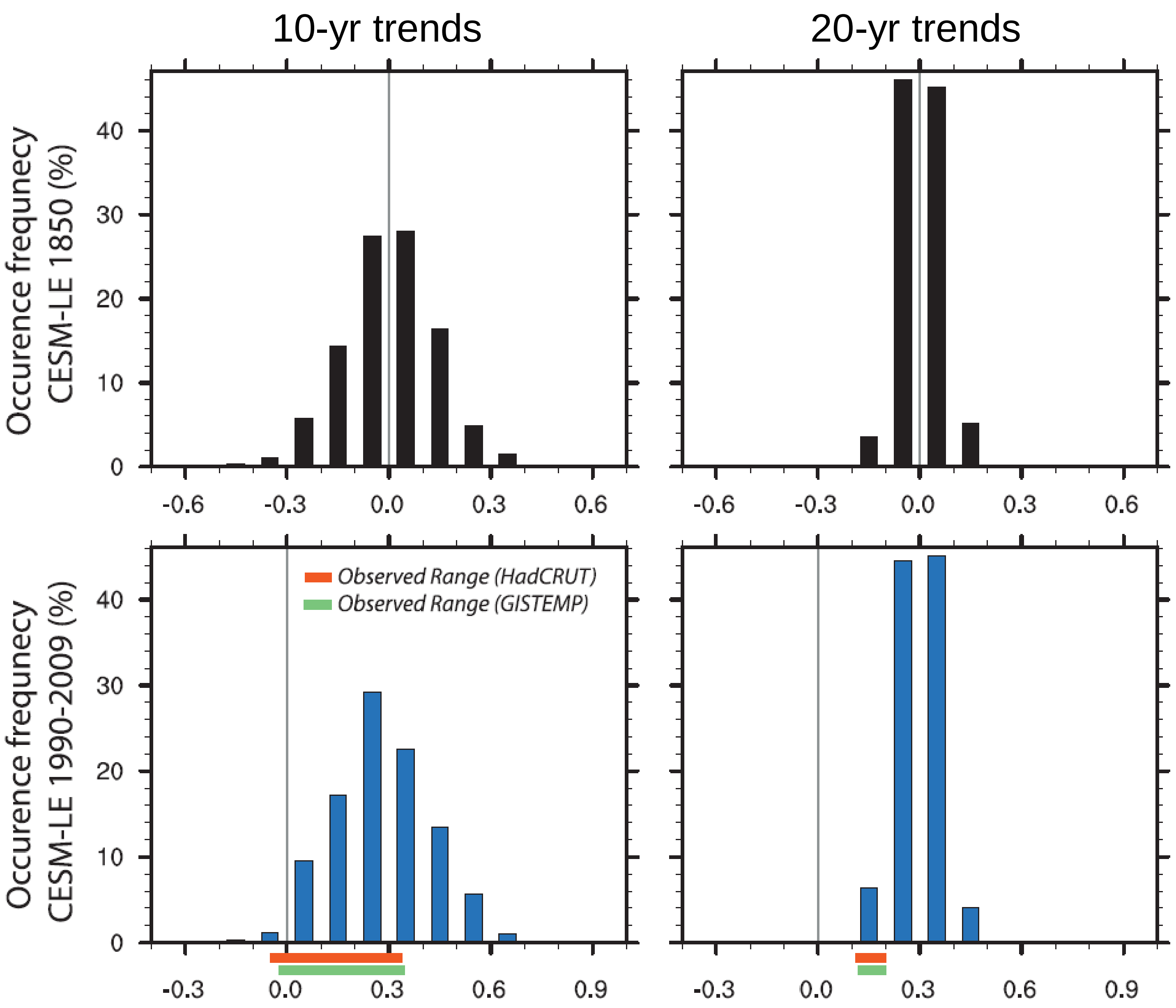
1984-1998: 0.26 °C/decade

1998-2012: 0.04 °C/decade

Kosaka & Xie 2016: extended pacemaker exp. for tropical Pacific (1870-2014)



Kay et al. 2015: the CESM Large Ensemble (1920-2100, 30 members, historical + RCP8.5 forcings)



Kay et al. 2015: the CESM large ensemble (1920-2100, 30 members)

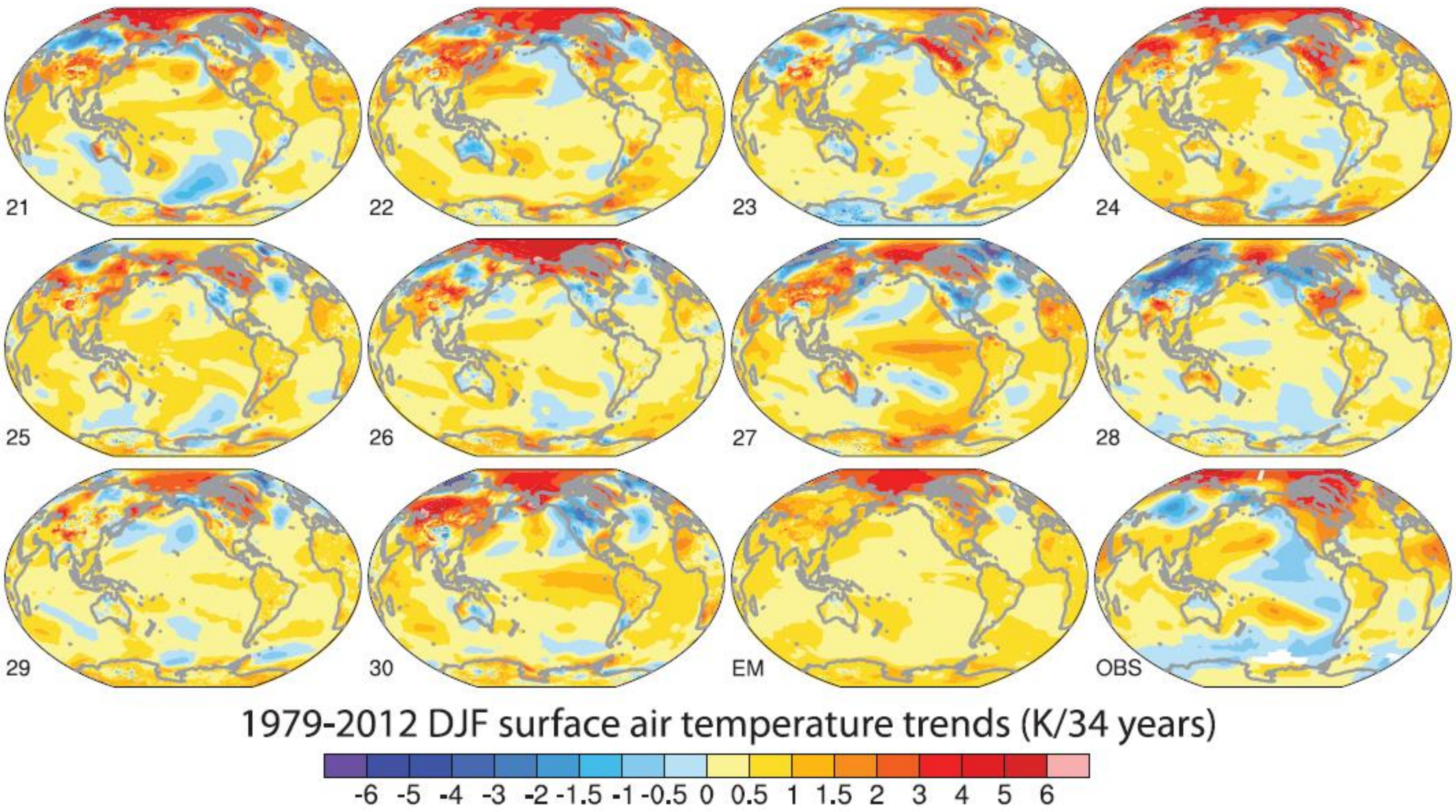


Fig. 4. Global maps of historical (1979–2012) boreal winter (DJF) surface air temperature trends for each of the 30 individual CESM-LE members, the CESM-LE ensemble mean (denoted EM), and observations (denoted OBS based on GISTEMP; Hansen et al. 2010).

ECMWF

Spread in the magnitude of climate model interdecadal global temperature variability traced to disagreements over high-latitude oceans

Patrick T. Brown[1], **Wenhong Li**[1], **Jonathan H. Jiang**[2], **and Hui Su**[2]

[1]Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Durham, North Carolina, USA, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA

Abstract: … efforts to constrain the climate model produced range of unforced interdecadal variability in global SAT would be best served by focussing on air-sea interactions at high latitudes.

Key Points:

- Climate models show substantial disagreement on the magnitude of natural global mean surface temperature variability
- The spread in the simulated magnitude of global temperature variability is not due to model disagreement over the tropical Pacific
- The spread in the simulated magnitude of global temperature variability is linked strongly to model disagreement over high-latitude oceans

Key Points:

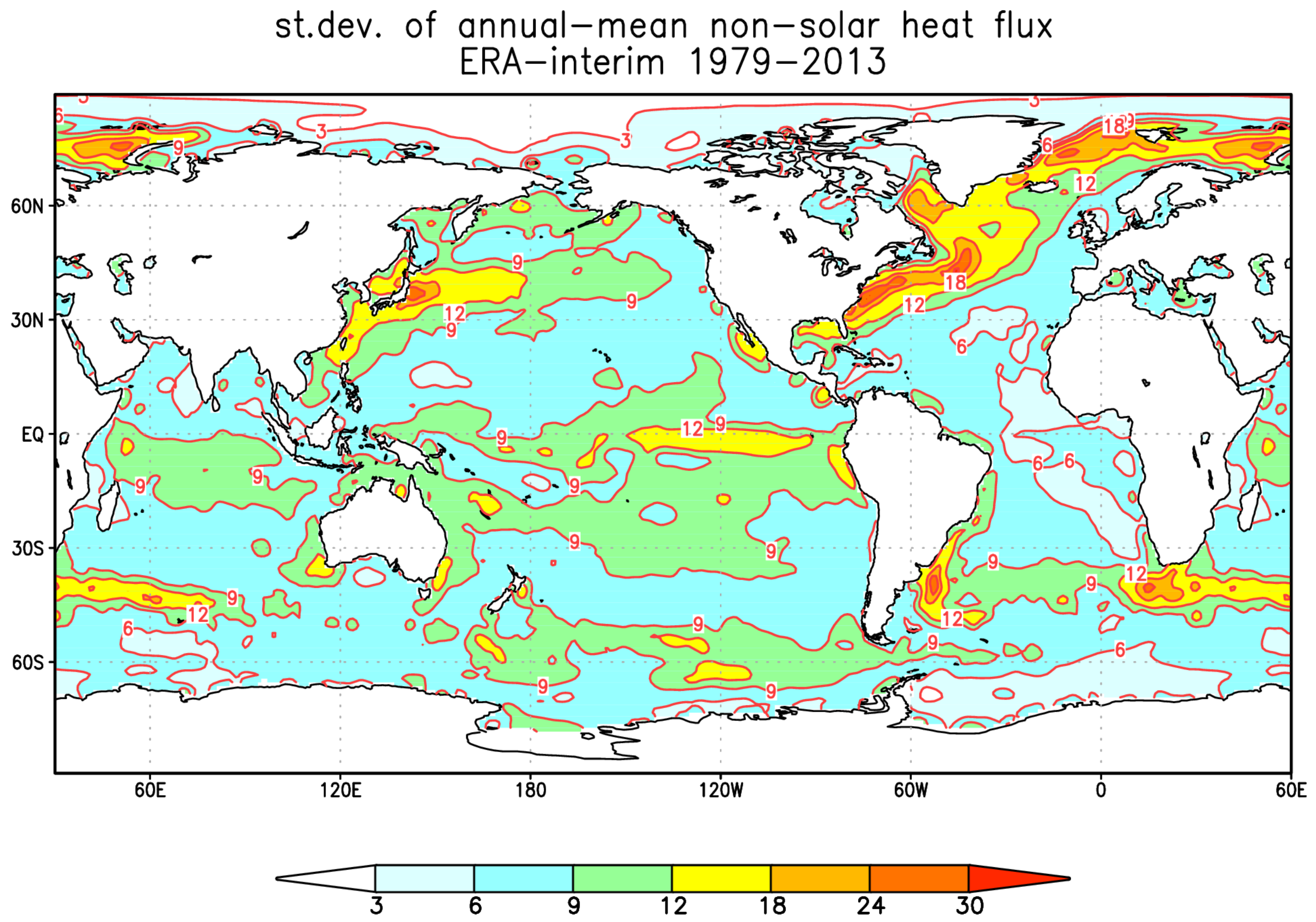
- Ocean model is forced with air-sea fluxes from CMIP5 models to examine the drivers of uncertainty in ocean circulation and heat uptake (OHU)
- High-latitude air-sea fluxes are the dominant source of uncertainty in the spread of Atlantic MOC and OHU over model structural uncertainty
- Subgrid-scale parameters lead to large uncertainty in the circulation and OHU, especially in the Pacific and Southern Oceans

Drivers of uncertainty in simulated ocean circulation and heat uptake

Markus B. Huber[1] **and Laure Zanna**[1]

[1]Department of Physics, University of Oxford, Oxford, UK

Abstract: … This study demonstrates that model biases in air-sea fluxes are one of the key sources of uncertainty in climate simulations.


st.dev. of annual−mean non−solar heat flux
ERA−interim 1979−2013
60N
30N
EQ
30S
60S
60E
120E
180
120W
60W
0
60E
3
6
9
12
18
24
30

Co-variability of NH ocean heat fluxes and circulation patterns in ERA-Interim

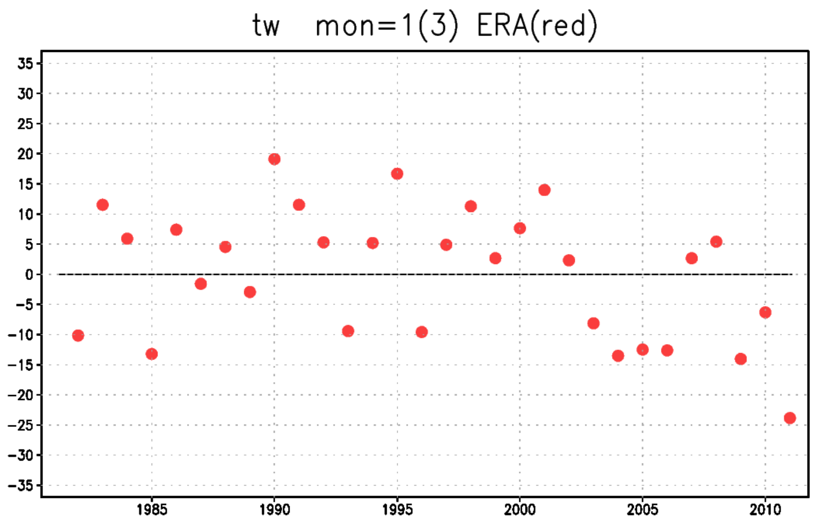
Thermal forcing
Wave index (TW)
in DJF 1982 – 2011

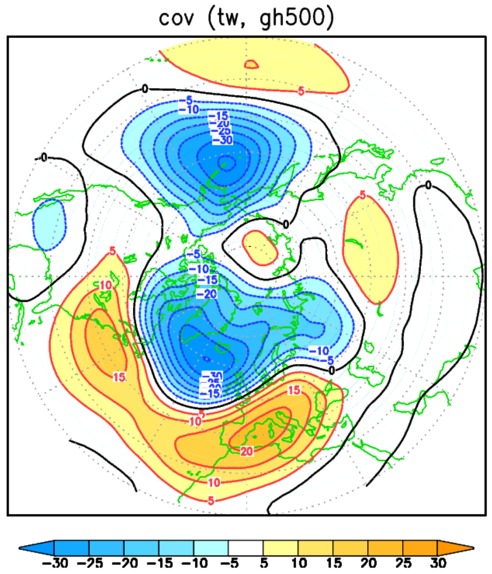
Positive =
Increased heat flux
from oceans to atm. in
40N-70N band

(Molteni et al. 2011)

inspired by theories on
thermal equilibration
of planetary waves:

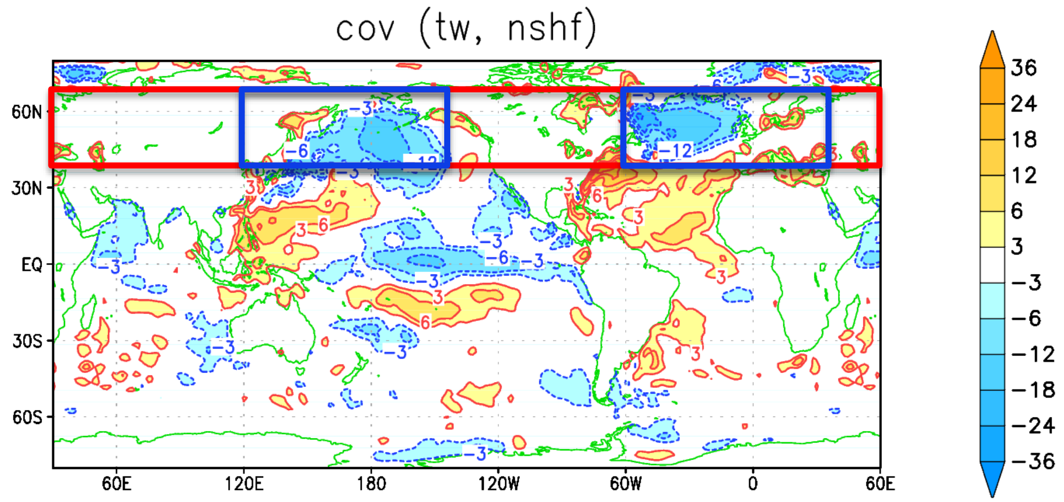
Mitchell and Derome 1983
Shutts 1987
Marshall and So 1990





Covariance with TW index in DJF:

Z 500 hPa



Net downward surface heat flux

DJF variability in weighted System-4 ensembles

(Molteni, Farneti, Kucharski & Stockdale 2017)

System-4 re-forecasts: DJF from 1 Nov 1981-2012, 51 members

Ens_A : stronger weight to members with TW index close to re-Analysis

Ens_0: stronger weight to members with TW index close to 0

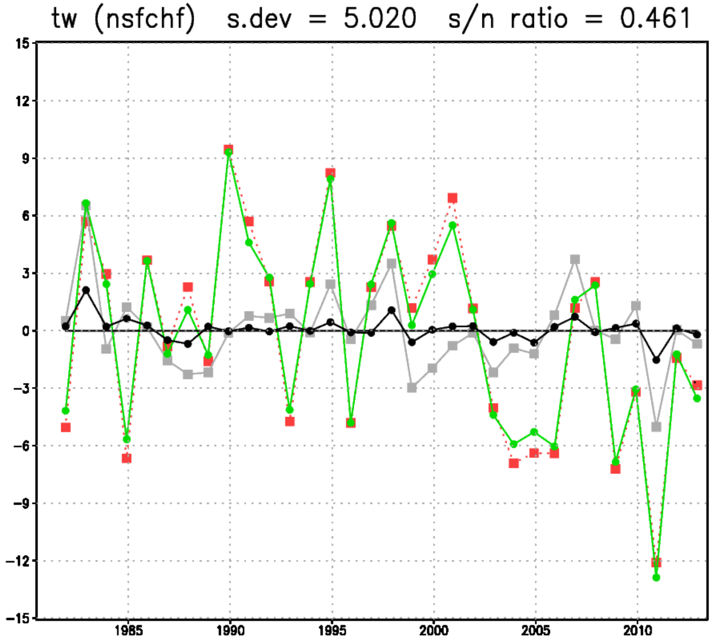
TW index

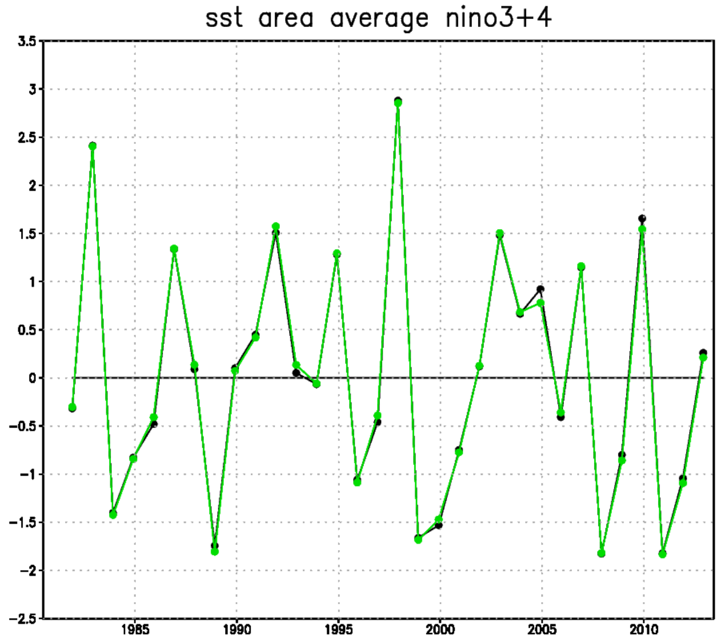
ERA-int

Ens_mean

Ens_A

Ens_0



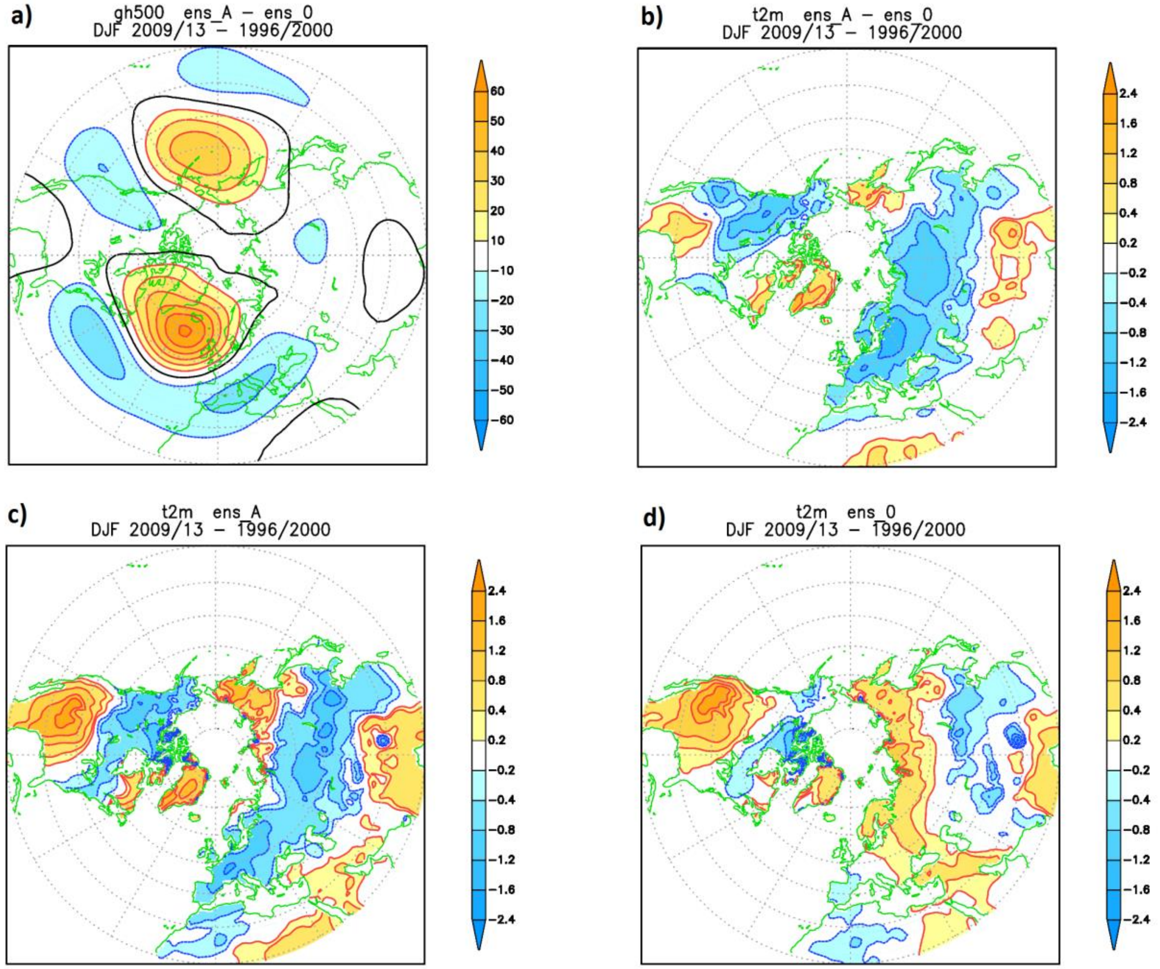


SST Nino3+4

Ens_A

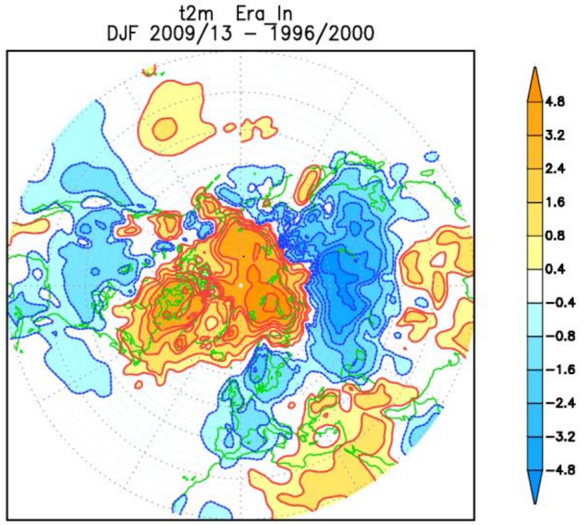
Ens_0

Decadal change: DJF 2009/13 – 1996/2000: GH 500, T 2m



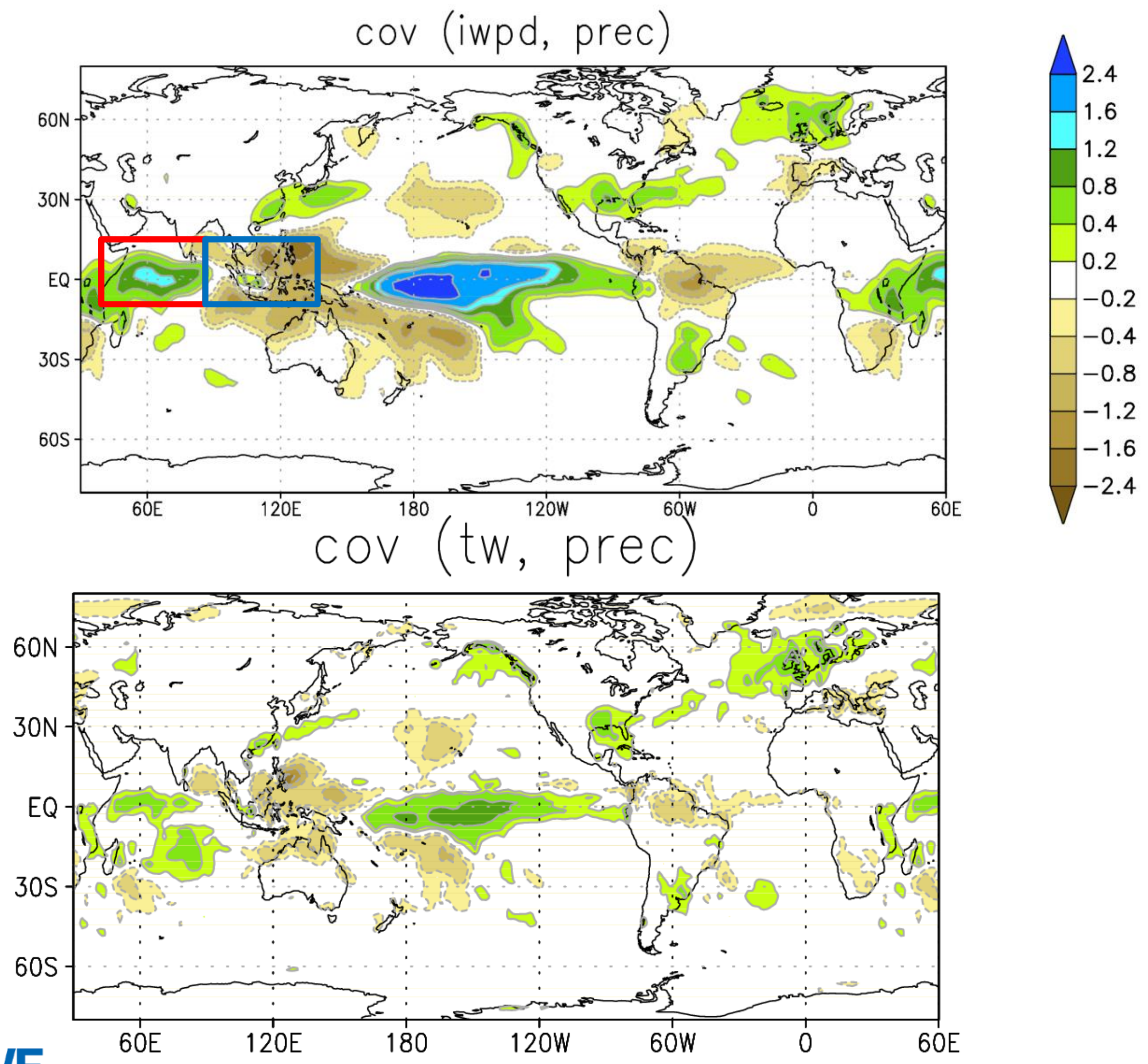
Ens_A: -0.49˚C

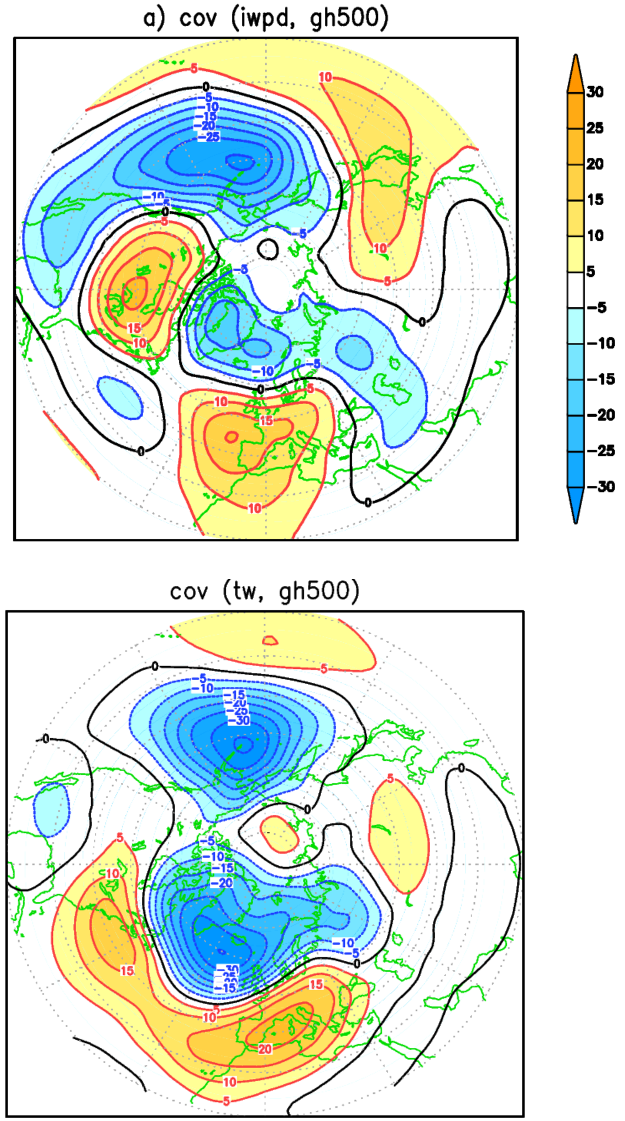
Ens_0: 0.21˚C



Europe
(20W-40E, 30N-70N):
ERA-In: -0.34˚C

NH heat flux variability and teleconnections from the Indo-Pacific ocean





Conclusions

- Large ensembles of long-range forecasts and climate simulations allow the investigation of dynamical connections which play a role on sub-seasonal, interannual and interdecadal scale. Ensembles can be stratified according to their representation of a specific processes, in order to highlight the relationship with possible sources of variability and/or the impacts on regional near-surface conditions.

- The teleconnection pattern associated with rainfall variability in the tropical Indian Ocean and the Maritime Continent, which affects the sub-seasonal and interannual variability of the North Atlantic Oscillation, shows a close similarity to the NH planetary-wave pattern which modulates the surface heat flux from the northern oceans to extra-tropical atmosphere on interannual and interdecadal scales.

- Ensemble sizes of the order of 30 ~ 50 members, as in operational sub-seasonal and seasonal forecasts, are also needed for historical climate simulations in order to explore the impact of tropical-extratropical interactions on decadal scales, and separate the effects of different model formulations from those of unforced, internal variability.

Thanks !