Sub-seasonal variability and teleconnections in ECMWF ensemble predictions and historical multi-decadal runs for the PRIMAVERA project

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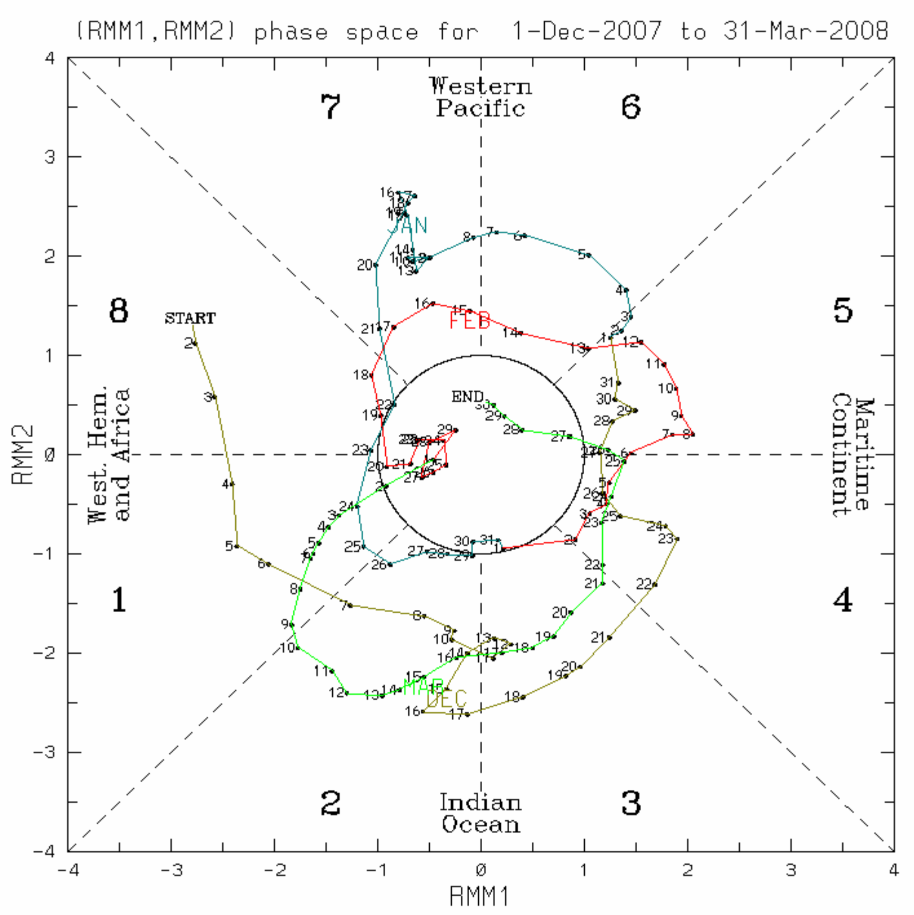
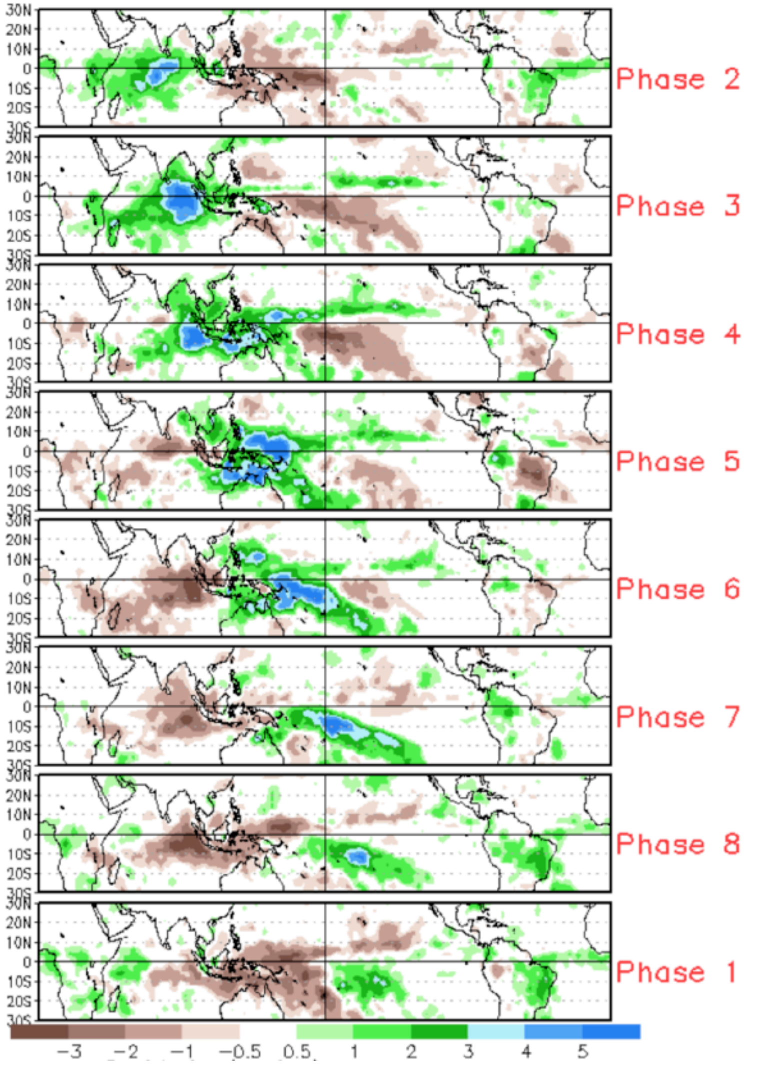
Teleconnections in the sub-seasonal scale: the Madden-Julian Oscillation

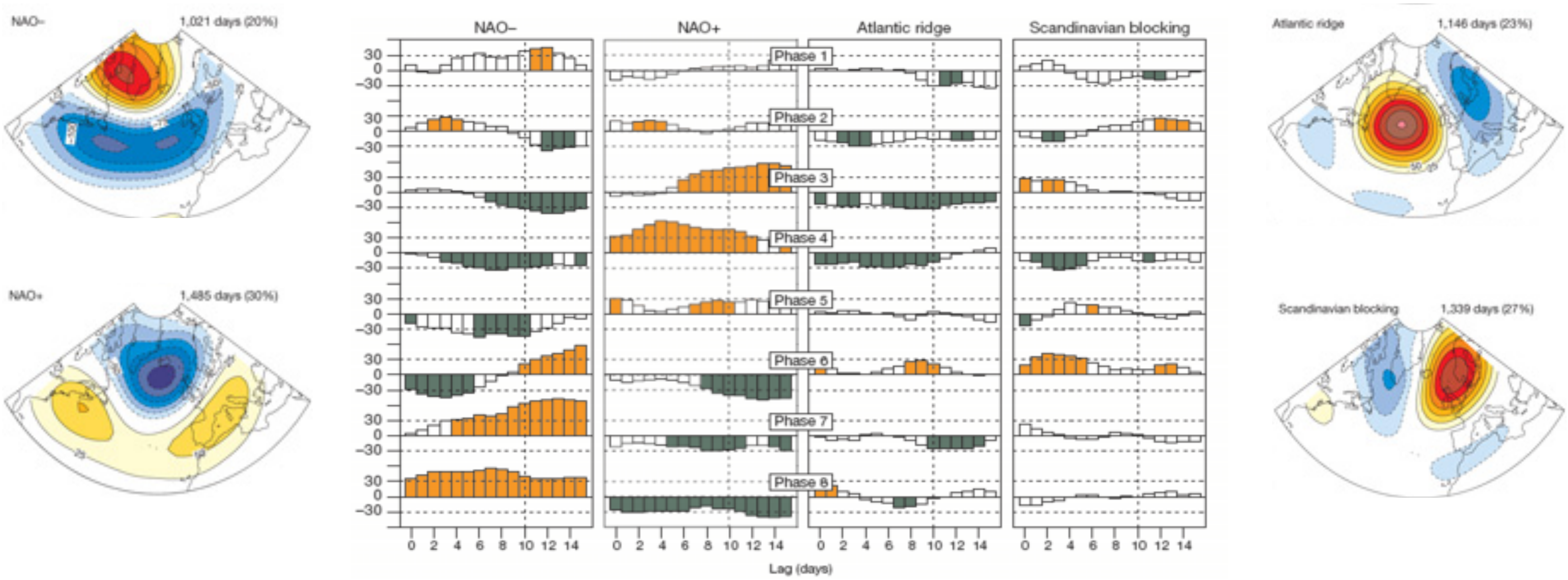
Wheeler-Hendon (2004) phase diagram



composites of rainfall anomalies (from NOAA)

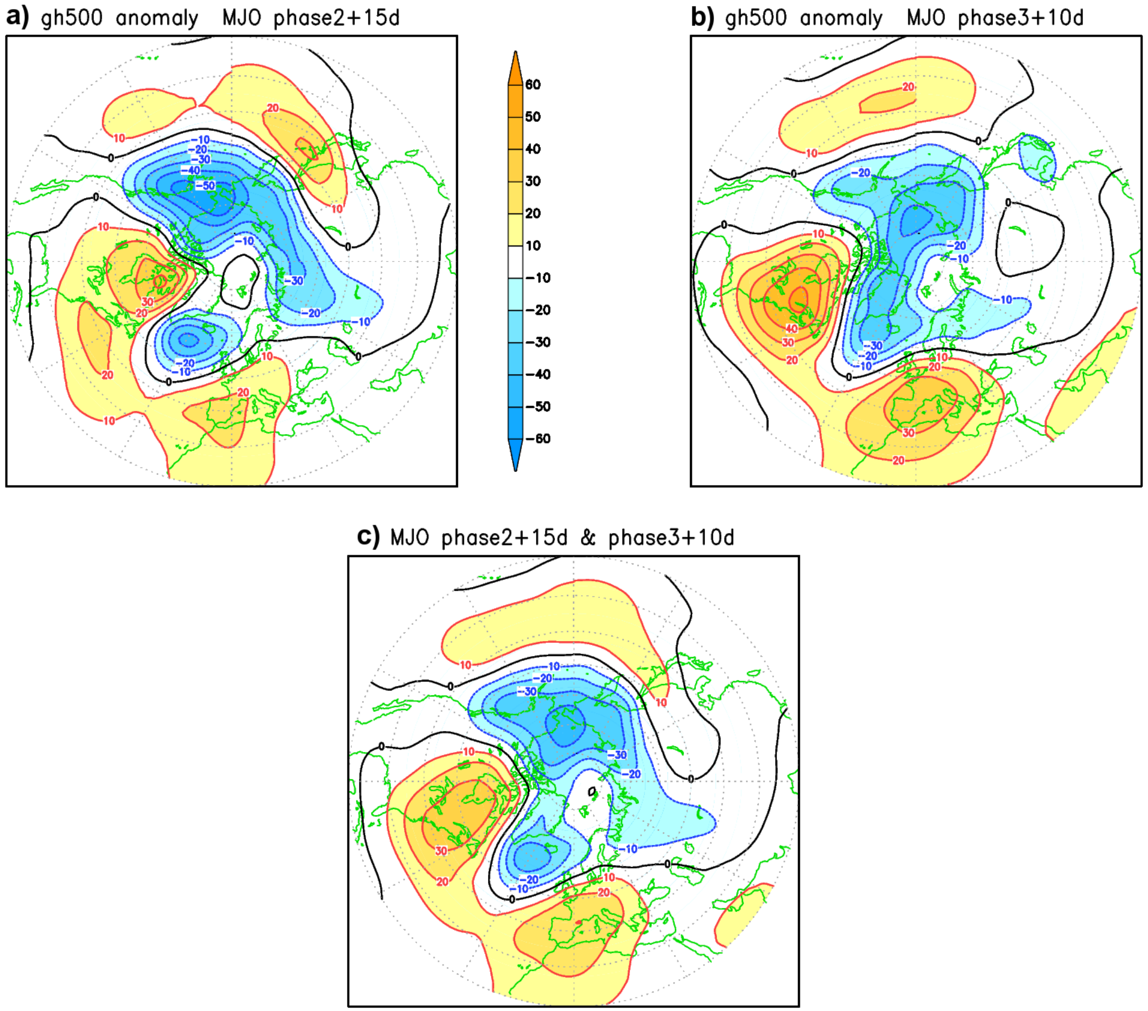


Impact of MJO on Euro-Atlantic regimes *(Cassou 2008)*



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

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

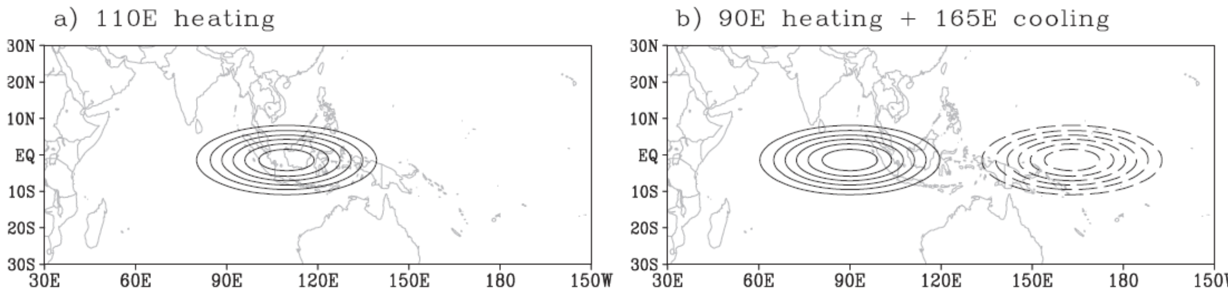
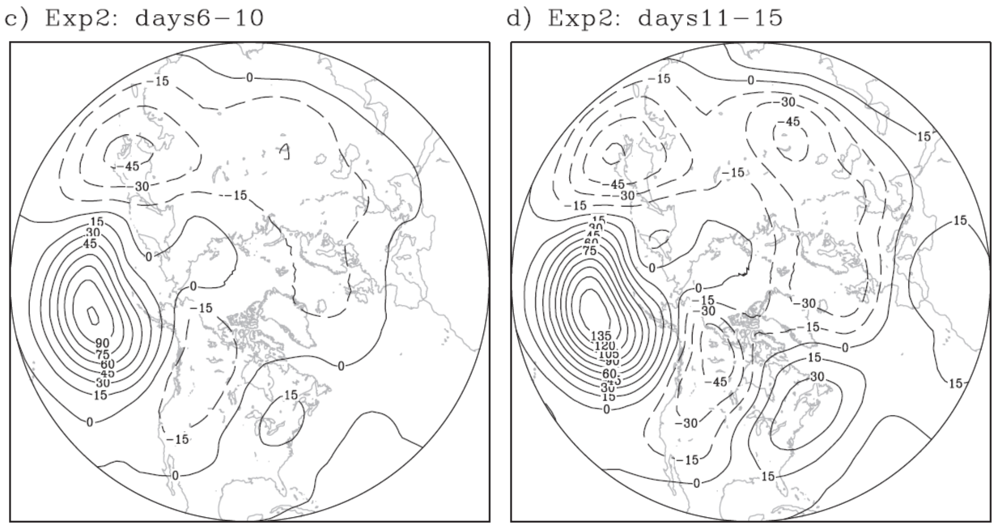


FIG. 12. Vertically averaged anomalous heating rate for (a) Exp1 and (b) Exp2. The contour interval is 0.5°C day^{-1}. The 0 contour is not plotted and contours with negative values are dashed.



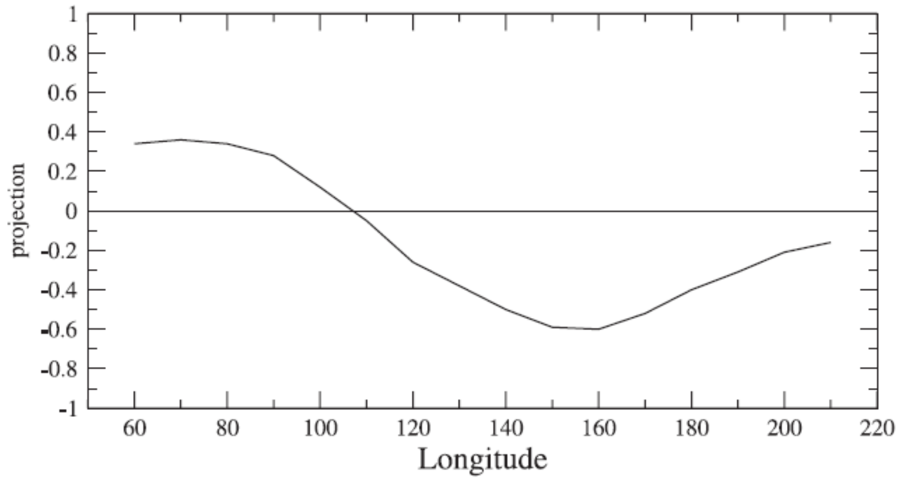
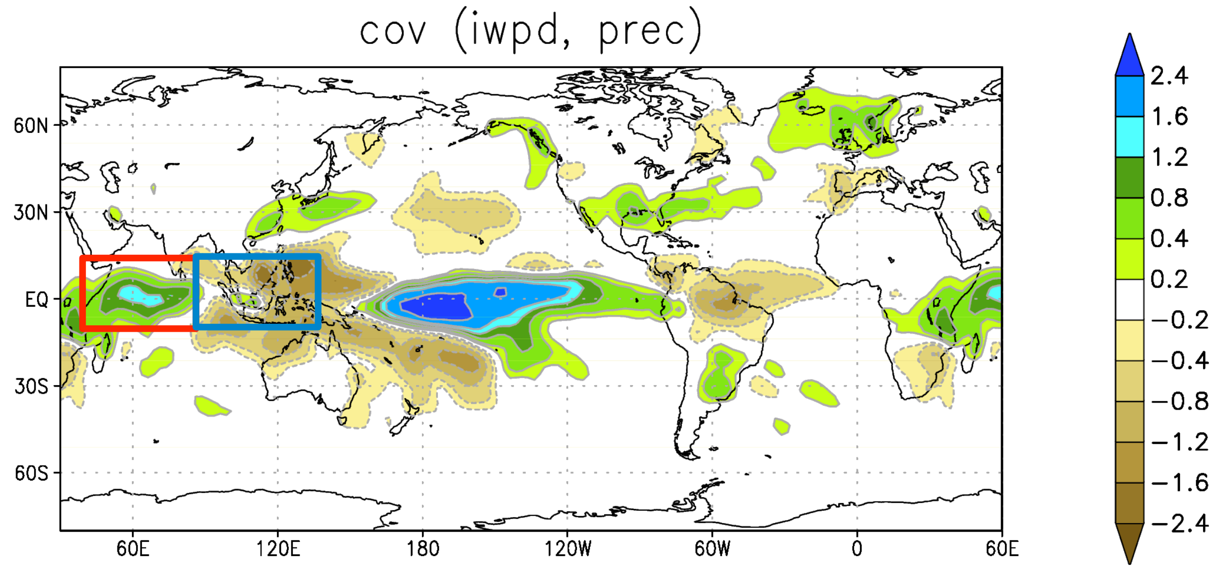


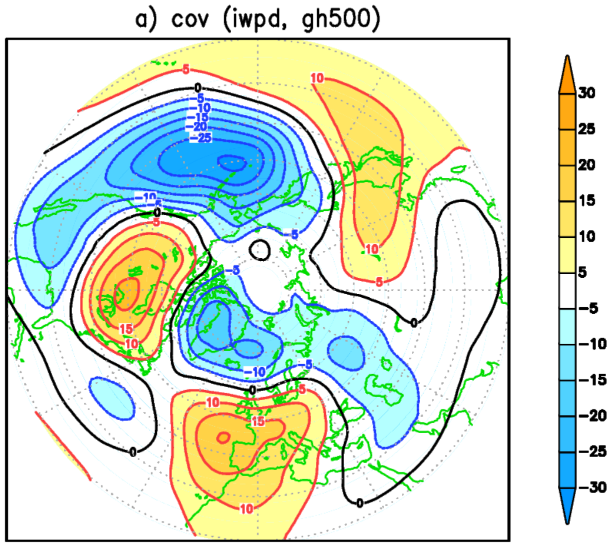
FIG. 15. Projection of 500-hPa geopotential height response averaged between days 11 and 15 onto the height field of Fig. 13d as a function of longitude for the heating center location.

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

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

from Molteni, Stockdale & Vitart 2015





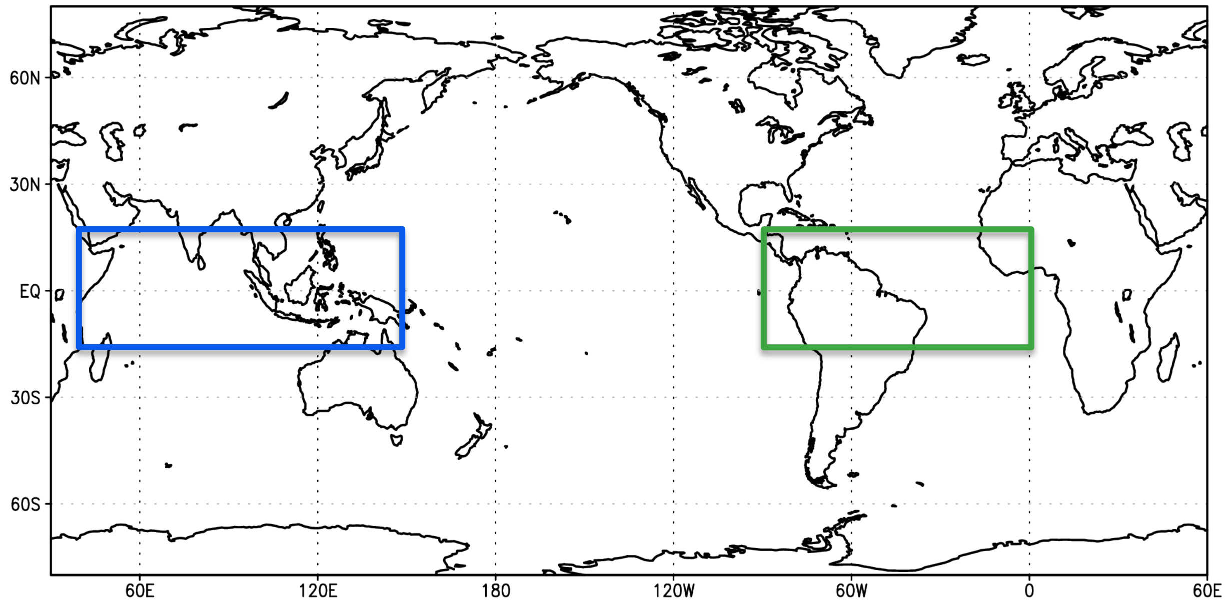
Are these teleconnections important on either shorter or longer time scales ?

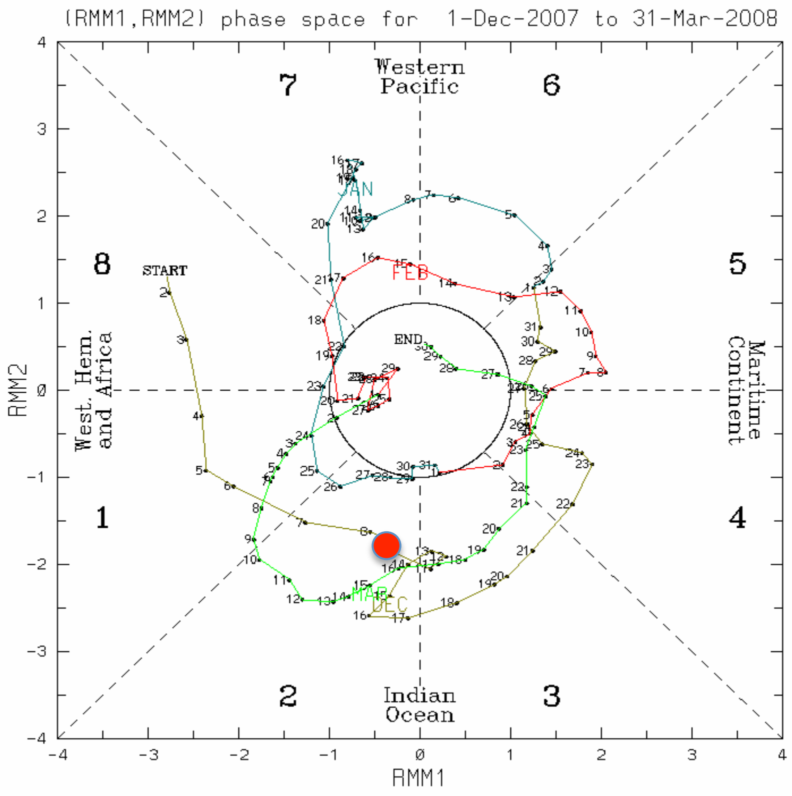
- The sub-seasonal time scale (15 ~ 90 days)
- The decadal time scale (see: https://www.ecmwf.int/sites/default/files/elibrary/2017/17619-tropical-extratropical-interactions-ensemble-predictions-sub-seasonal-decadal-scales.pdf)

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

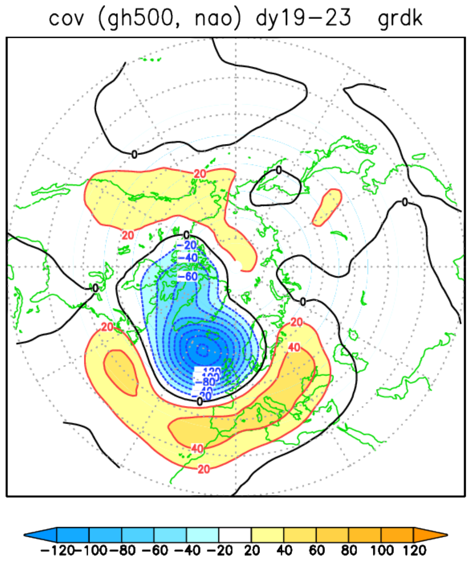
Three 51-member ensemble forecasts, start date: 10 Dec. 2007 (MJO phase 2)
No perturbation in initial conditions, spread induced by SPPT only

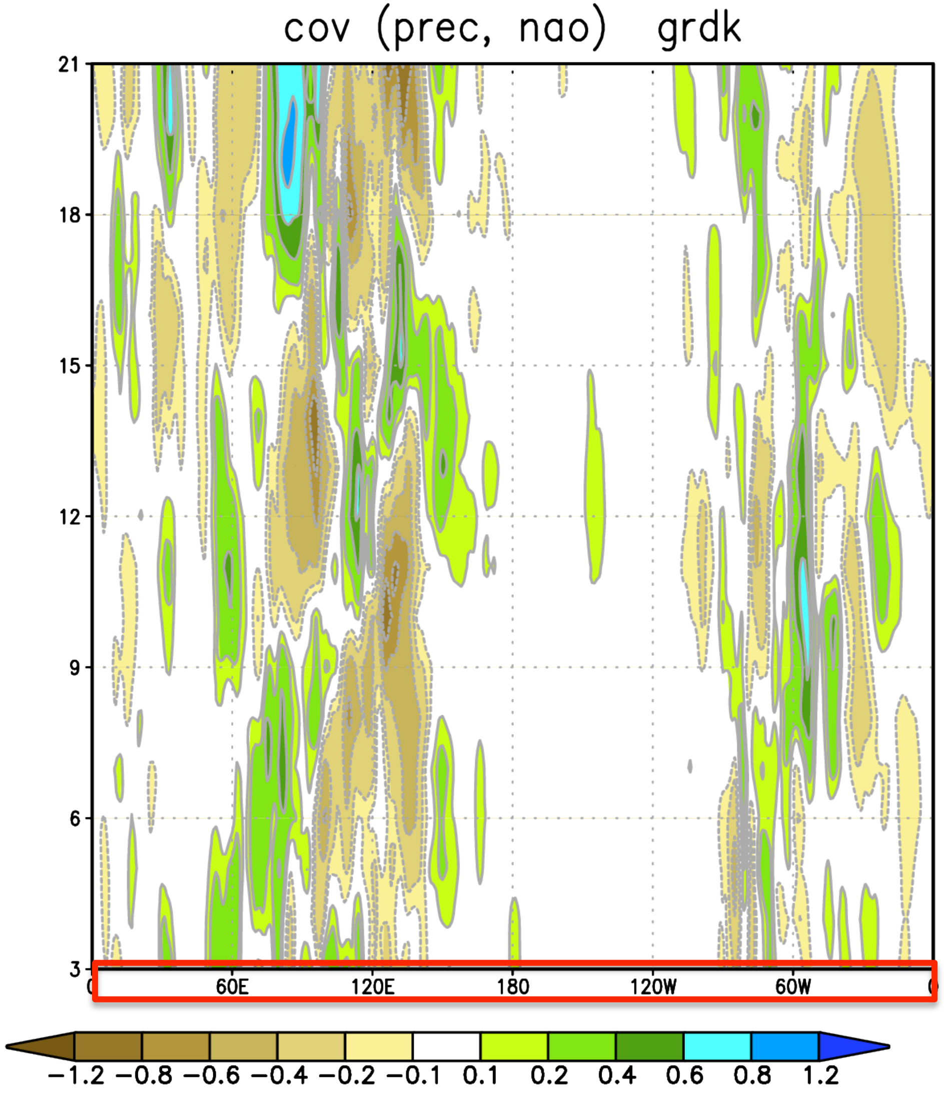
1. SPPT applied over the whole globe
2. SPPT only over tropical Indian Ocean – Maritime Continents (35-145E, 15N-15S)
3. SPPT only over tropical South America – Atlantic Ocean (90W-0, 15N-15S)



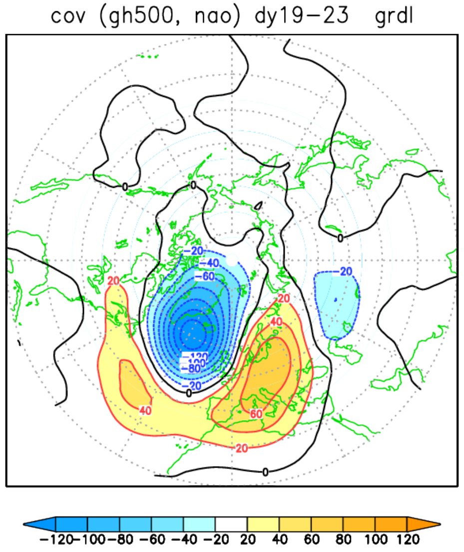


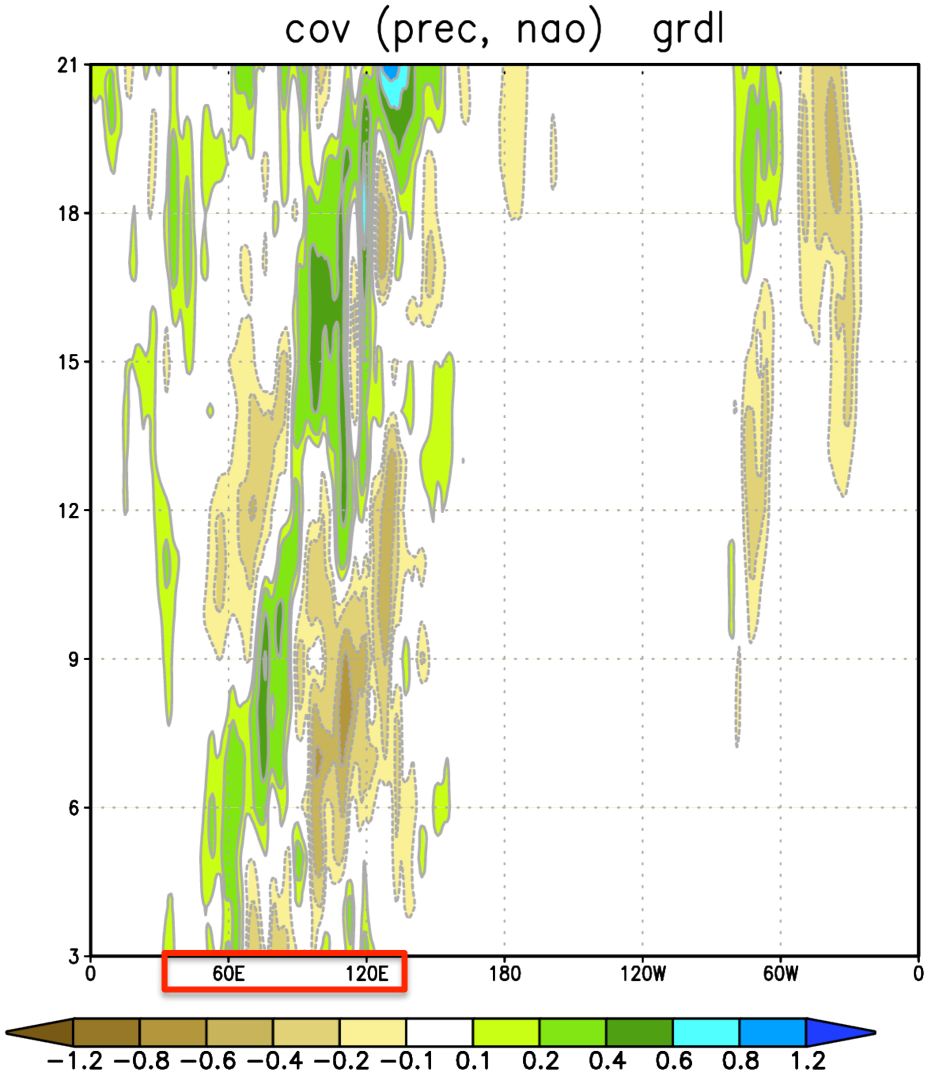
Lagged covariance of NAO index with tropical rainfall (10S-10N): global SPPT

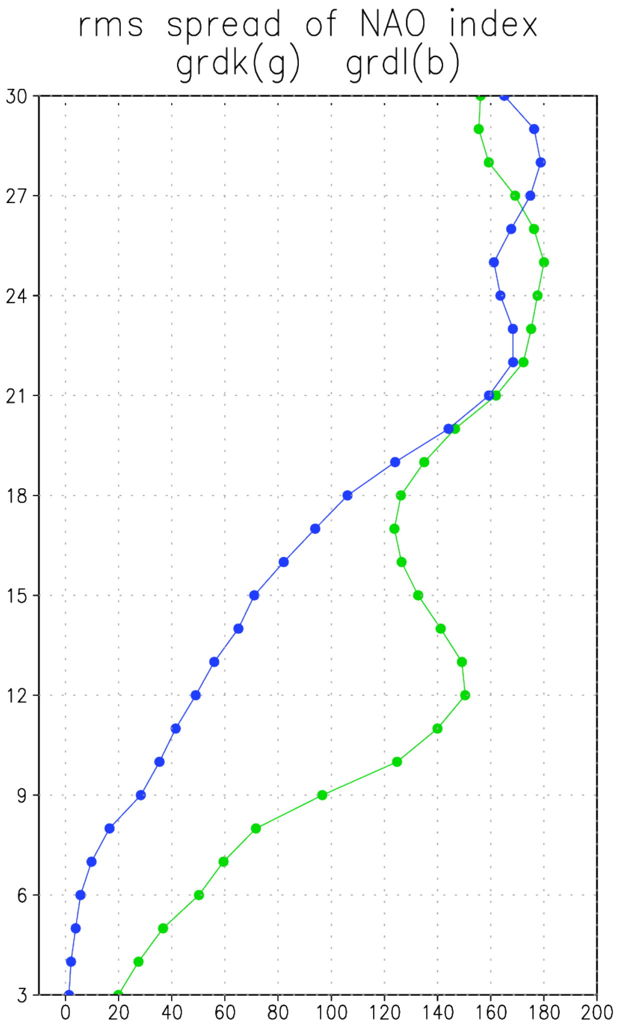




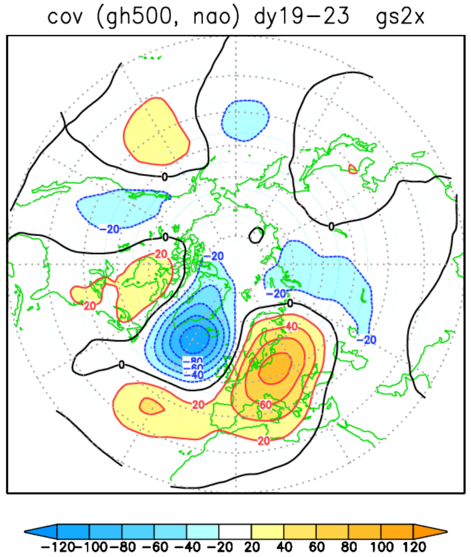
Lagged covariance of NAO index with tropical rainfall (10S-10N): SPPT in Indian-W.Pac. ocean

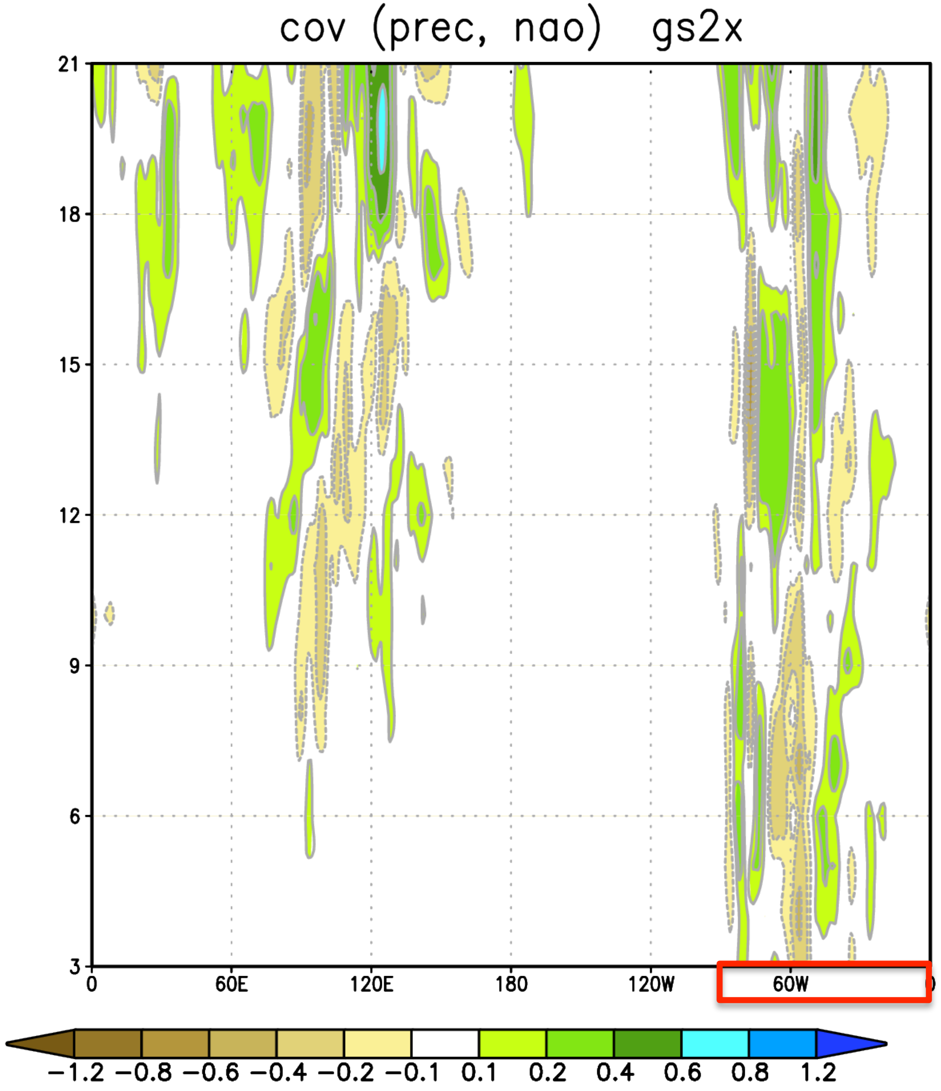


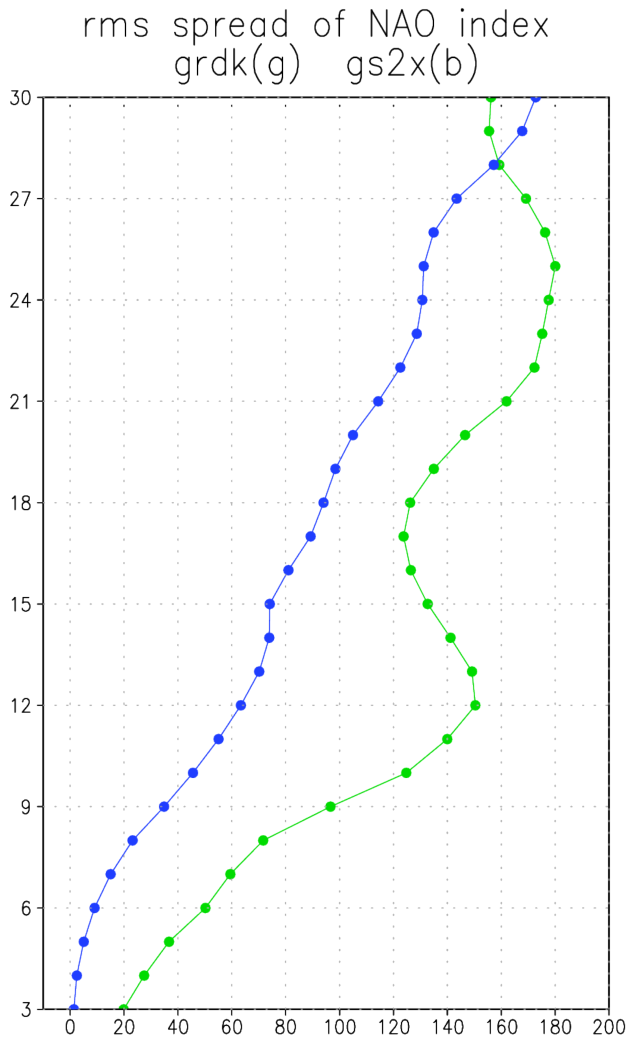




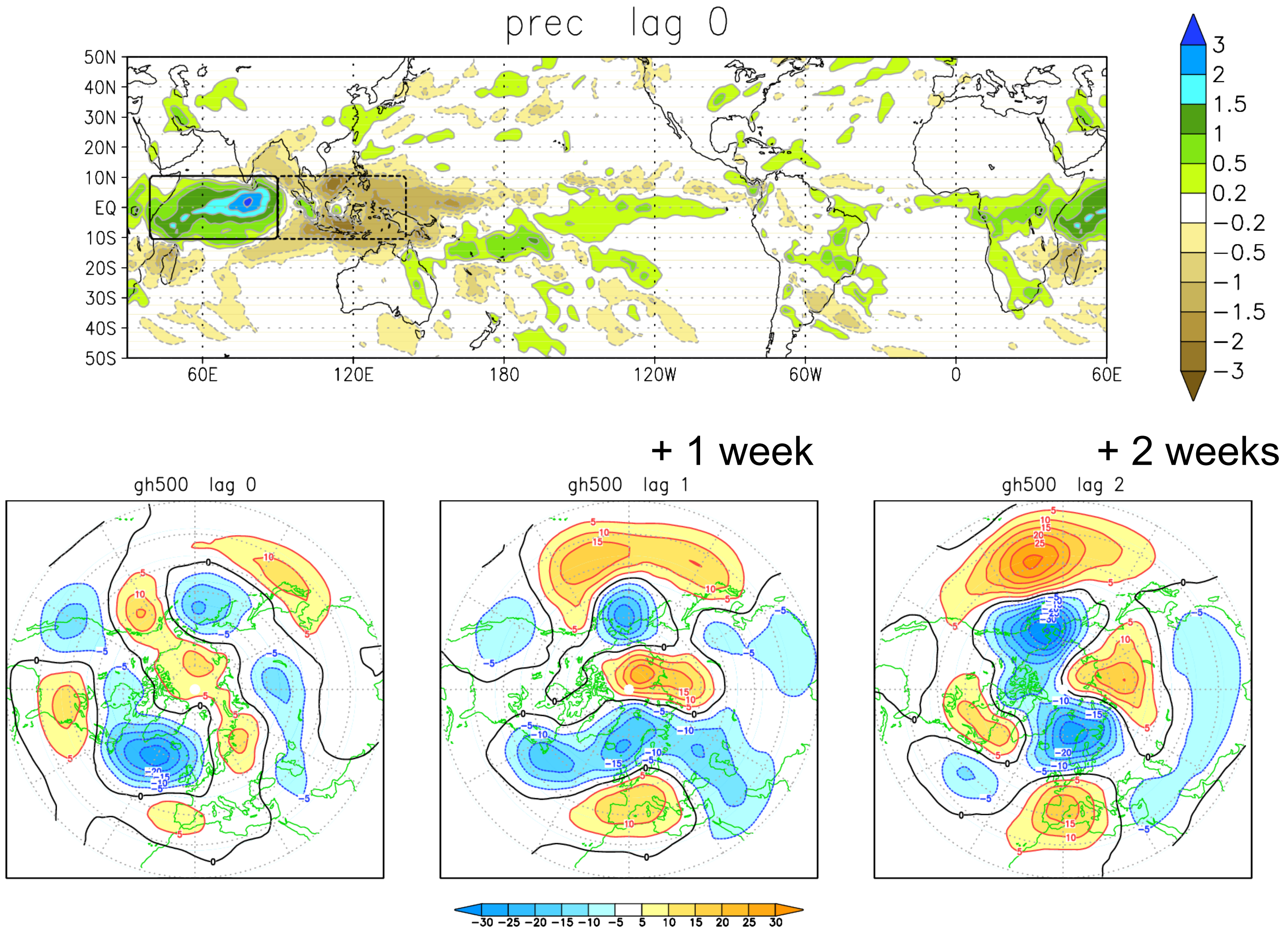
Lagged covariance of NAO index with tropical rainfall (10S-10N): SPPT in S. America/Atl. ocean



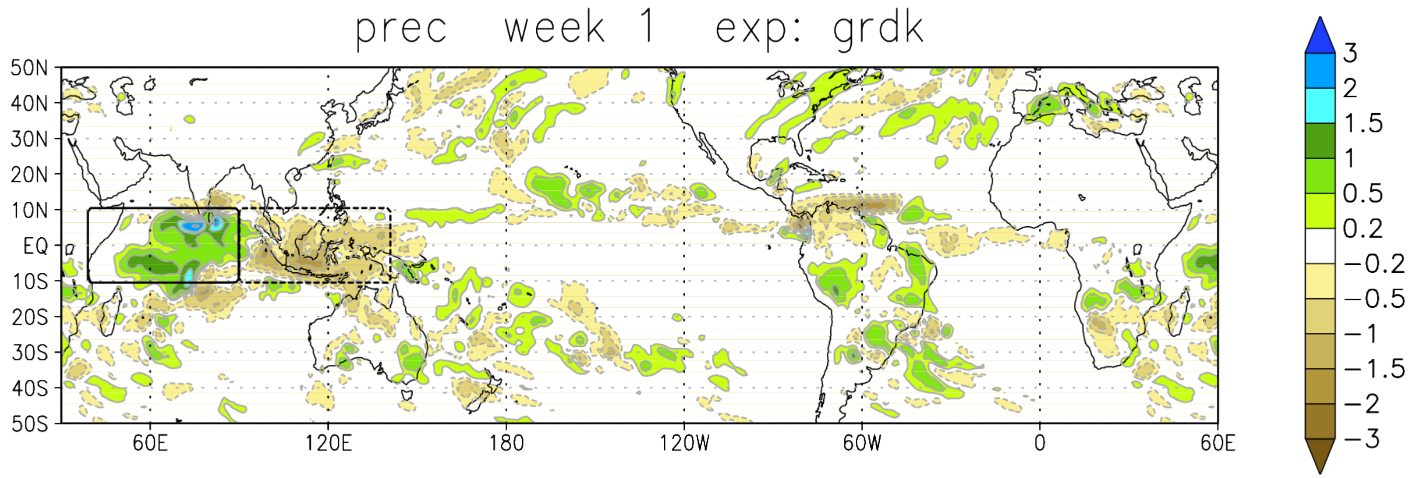


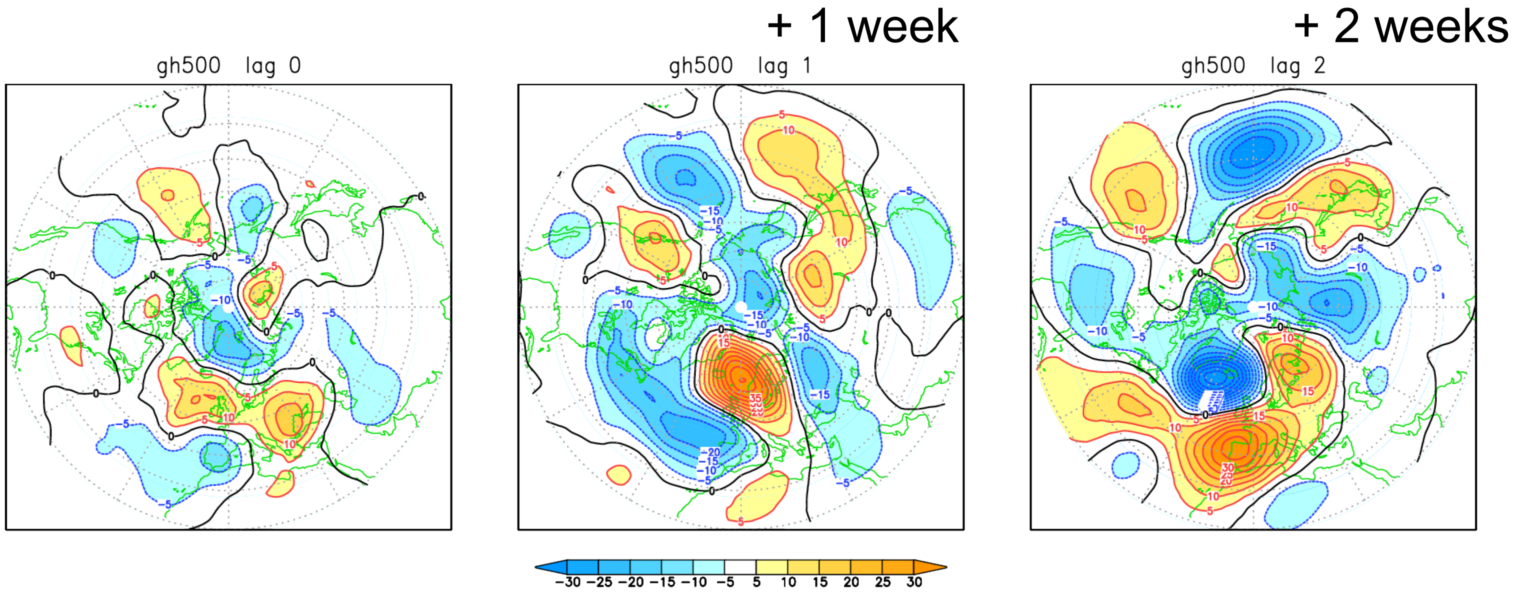


Lagged covariance of Indo-Pacific rainfall (10S-10N) with NH Z 500 hpa: ERA-Int. 1995-2015

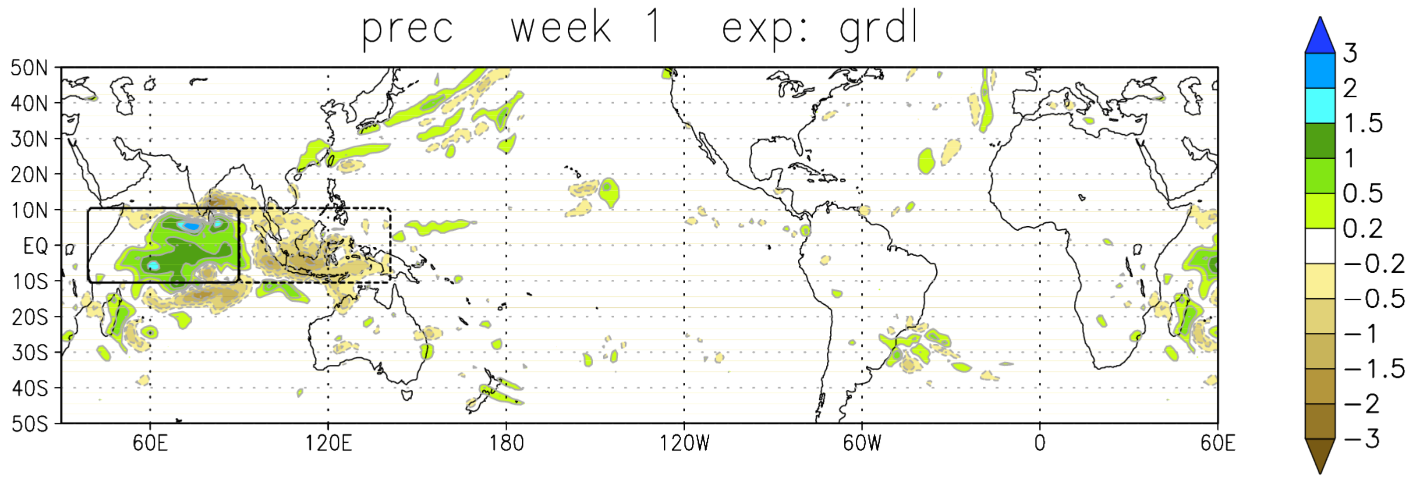


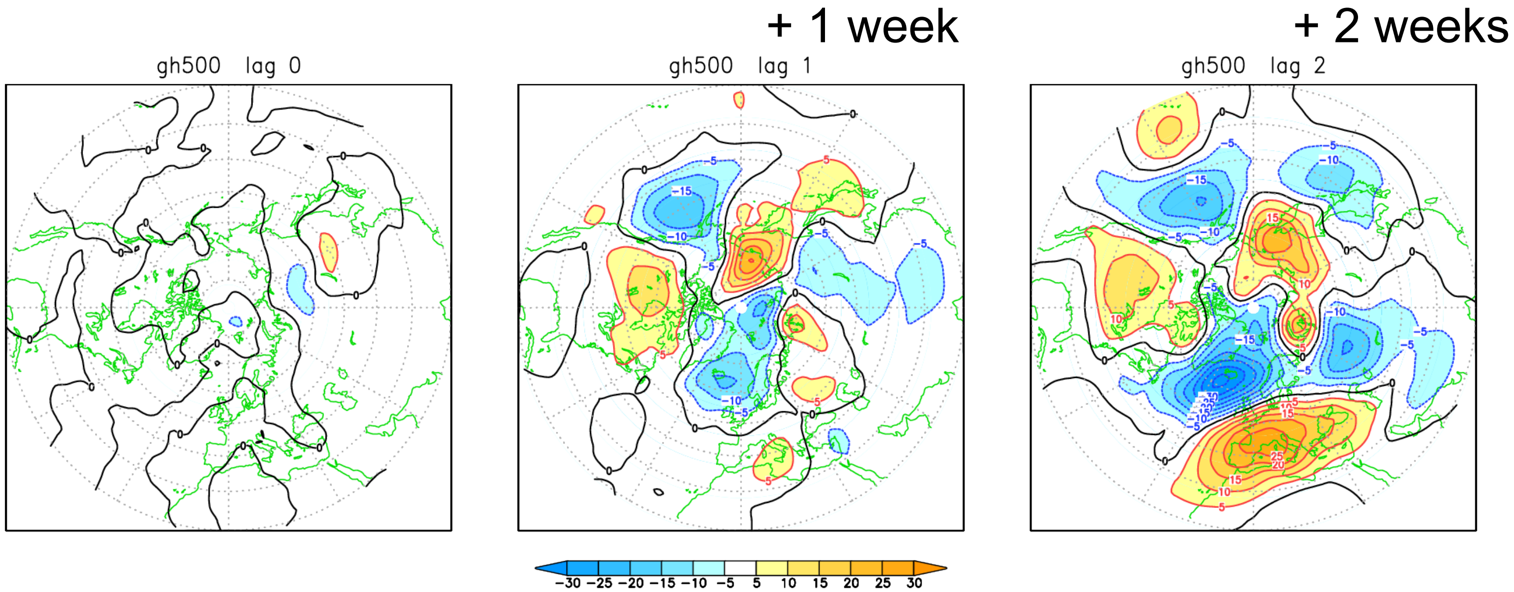
Lagged covariance of Indo-Pacific rainfall (10S-10N) with NH Z 500 hpa: global SPPT





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





PRIMAVERA: a European Union Horizon-2020 project (www.primavera-h2020.eu)

Main goal: To develop a new generation of advanced and well-evaluated high-resolution global climate models, capable of simulating and predicting regional climate with unprecedented fidelity

Motivation for ECMWF: to explore the climatological attractor of the ECMWF Earth System model (mean state and variability) in a state of near-equilibrium (as opposed to the transient, drifting state experienced during sub-seasonal and seasonal forecasts)

ECMWF contribution based on multi-decadal historical runs (as in CMIP6 HighResMIP) with:

- **IFS Tco199 L91 + NEMO 1.0^o Z75 + LIM-2**
- **IFS Tco399 L91 + NEMO 0.25^o Z75 + LIM-2**

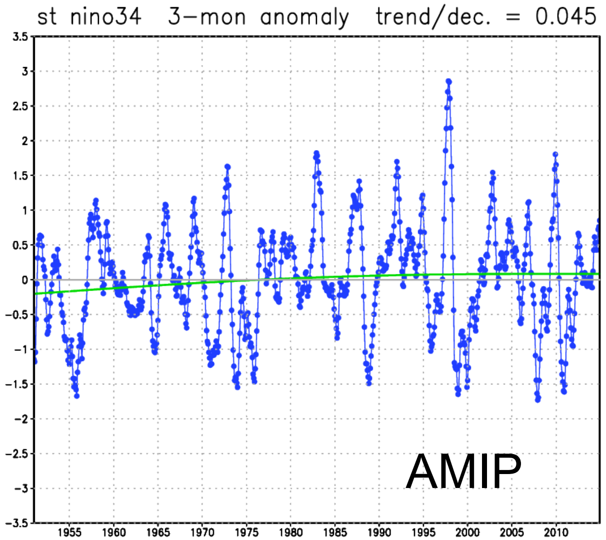
WP2: Provide a systematic assessment of the benefits of simultaneously increased atmospheric and oceanic resolutions and increased atmospheric resolution only in global coupled climate models for processes affecting European climate and its variability

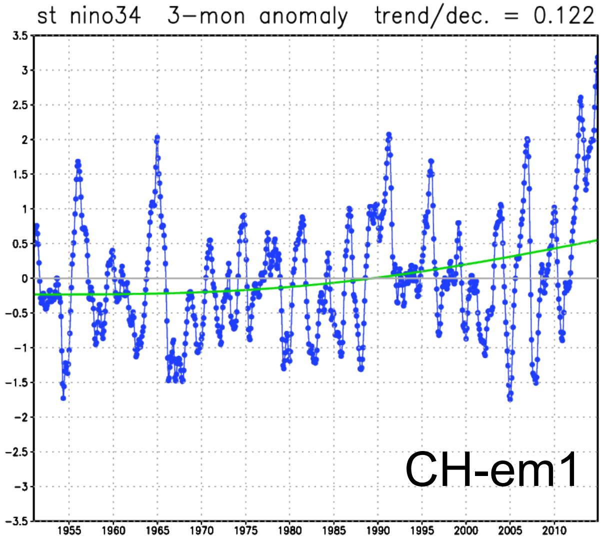
WP3: Quantify the need for improved representation or levels of complexity of a range of physical processes within the atmosphere, ocean, land and *sea ice* in a high resolution environment

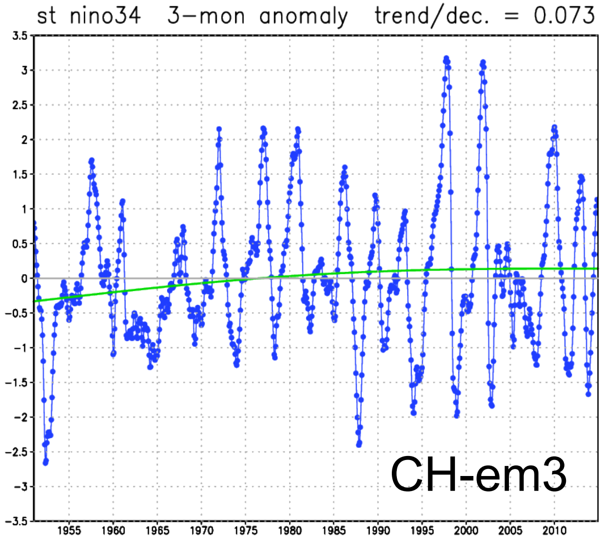
WP4: Develop the next generation of coupled models by testing different approaches to the representation of sub-gridscale processes and exploring the benefits of explicit representation at very high resolution

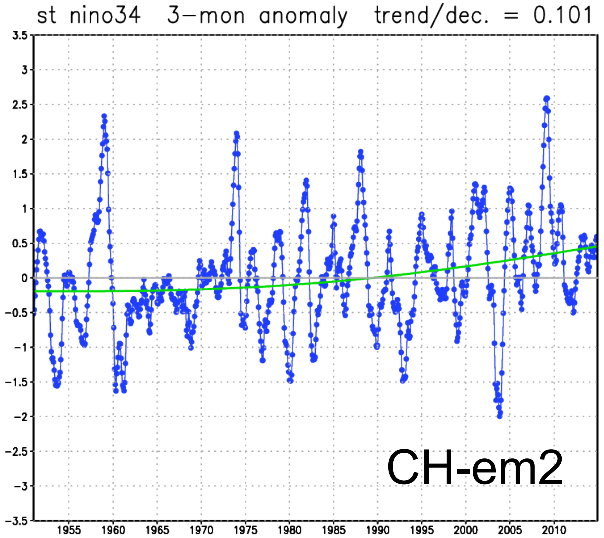
WP5: Improve understanding of the key oceanic physical and dynamical drivers and mechanisms leading to decadal variability of European climate, and assess the influences of regional climate phenomena such as the summer Arctic sea ice decline and Siberian snow cover reduction.

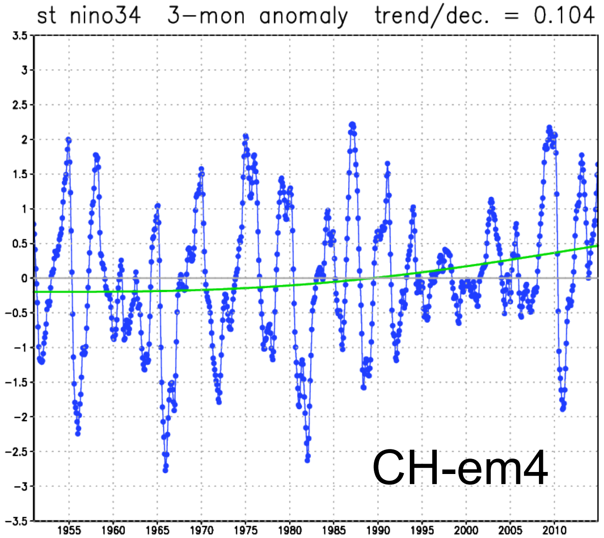
Nino 3.4 SST anomaly in the coupled historical runs







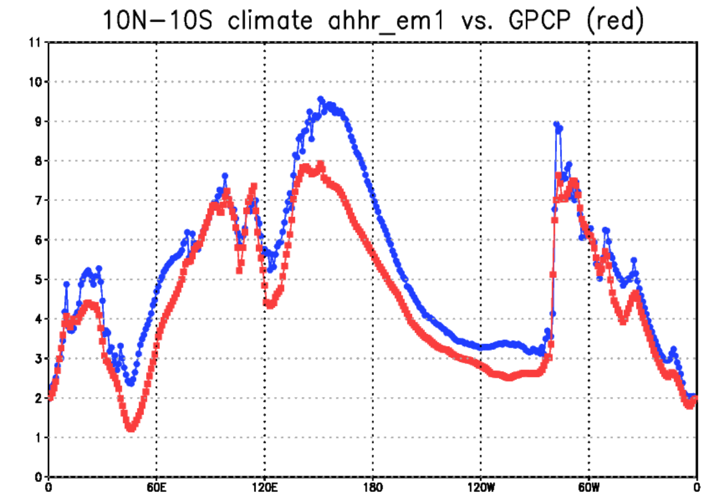




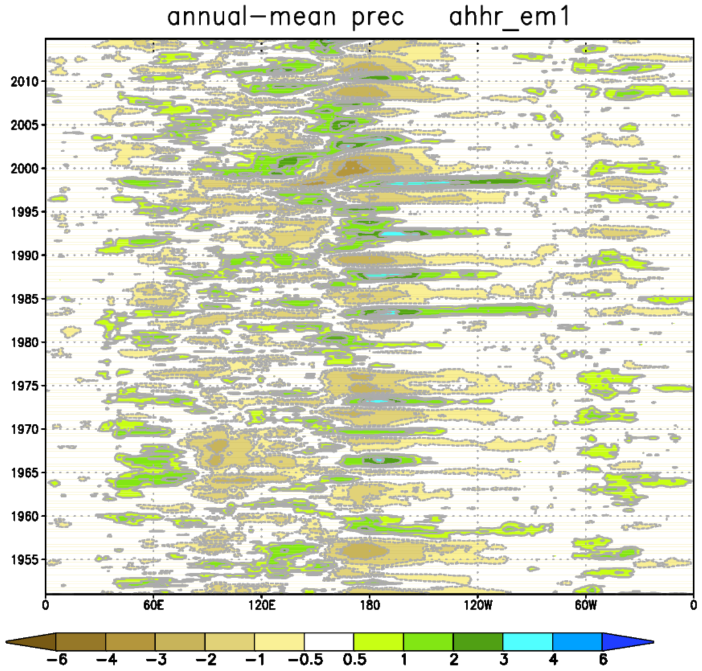
Annual-mean rainfall in the 10N-10S band

AMIP
em1

climate

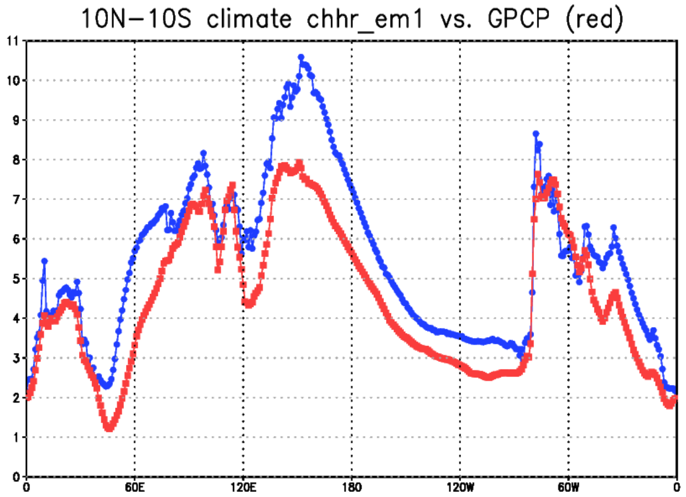


annual-mean
anomaly

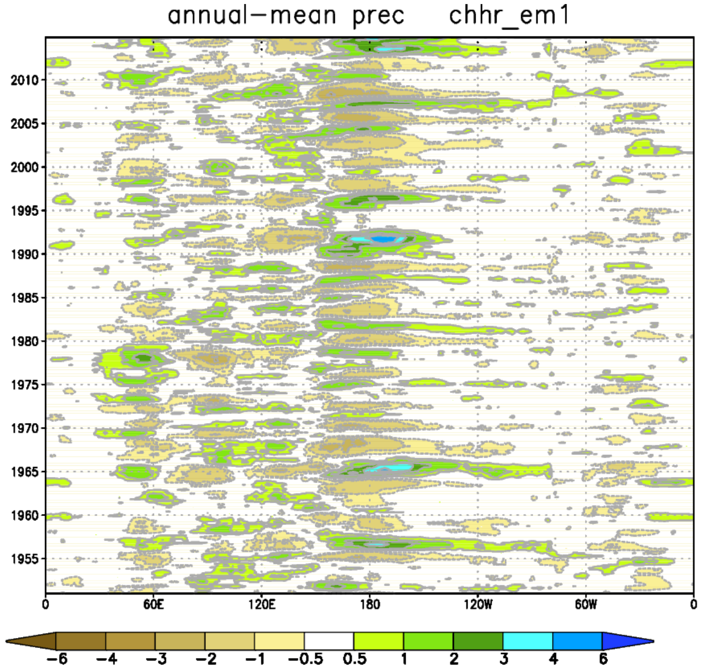


CHist
em1

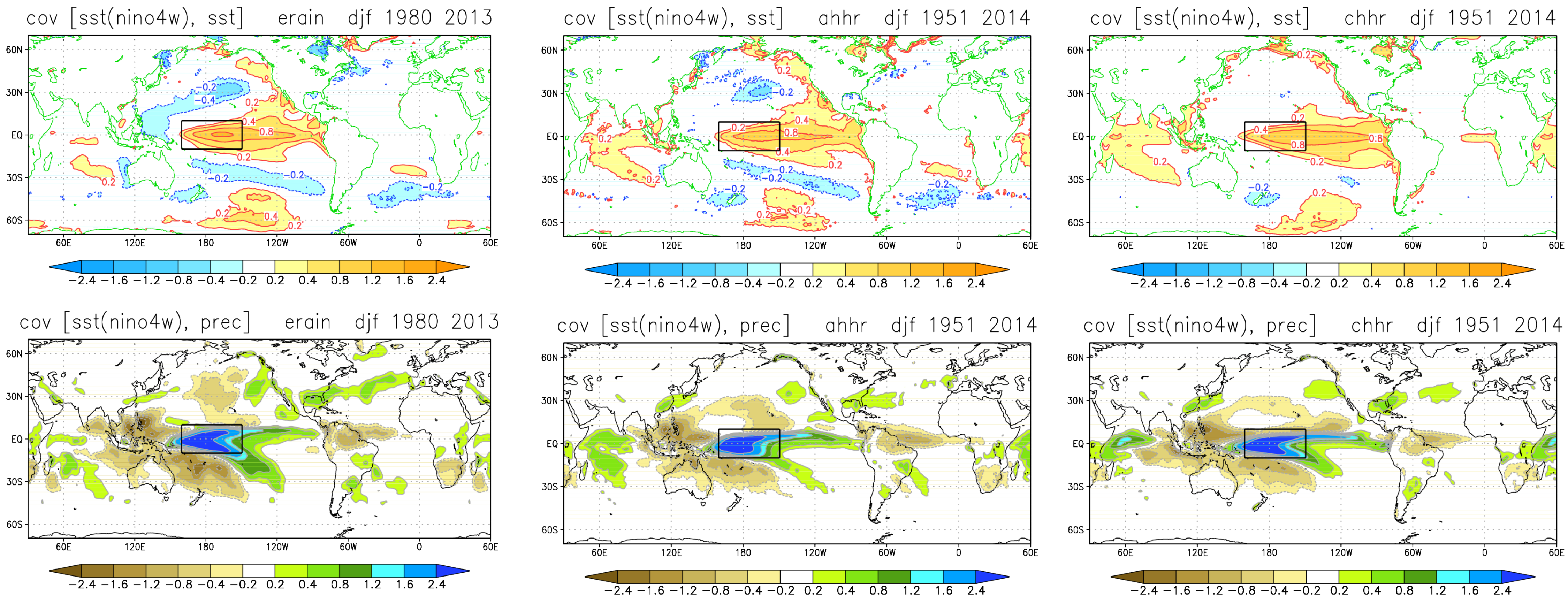
climate



annual-mean
anomaly

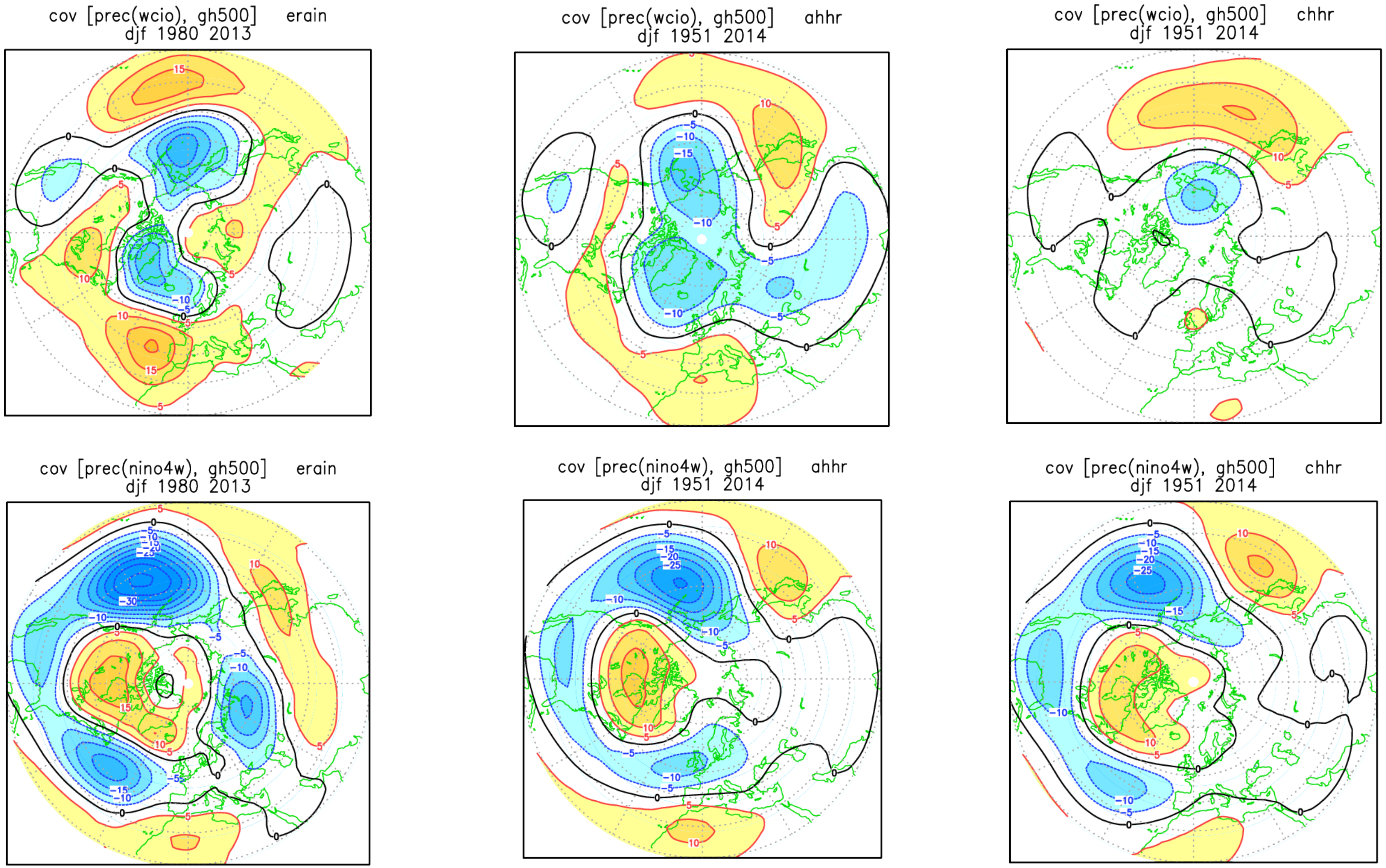


Covariance of Nino4 SST anomaly with SST and rainfall



ERA-int/GPCP **AMIP** **CHist**

Covariance of W. Ind. Ocean and Nino4 rainfall anomalies with Z 500



W. Indian Ocean

Nino-4

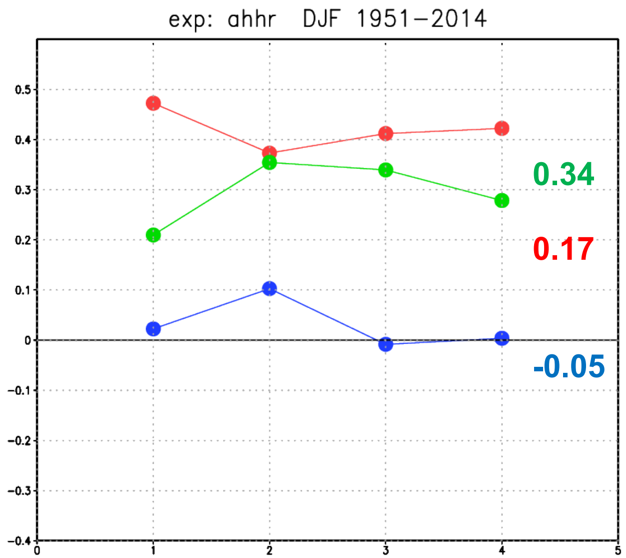
ERA-int/GPCP **AMIP** **CHist**

Correlation between W. Ind. Ocean rainfall, Nino3.4 SST and NAO index

Cor (WIO rainfall, Nino3.4 SST)

Cor (WIO rainfall, NAO index)

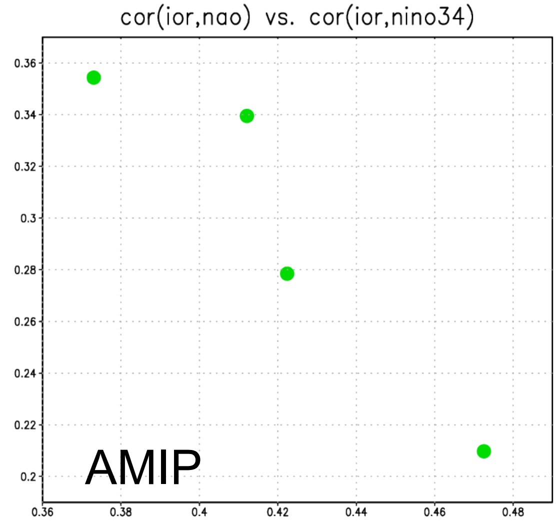
Cor (Nino3.4 SST, NAO index)



0.34

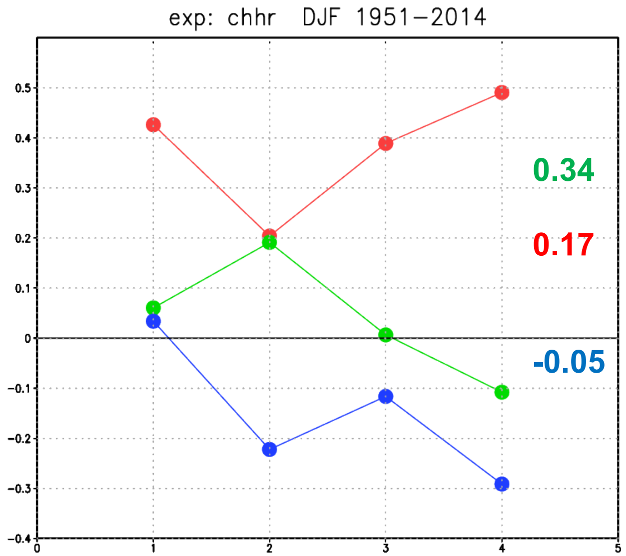
0.17

-0.05



X: Cor (WIO rainfall, Nino3.4 SST)

Y: Cor (WIO rainfall, NAO index)



0.34

0.17

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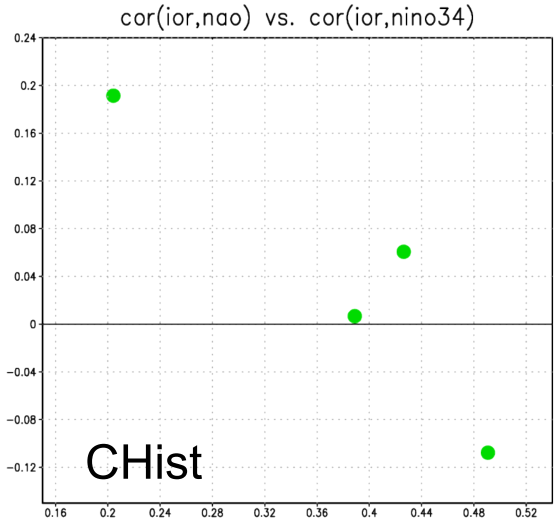
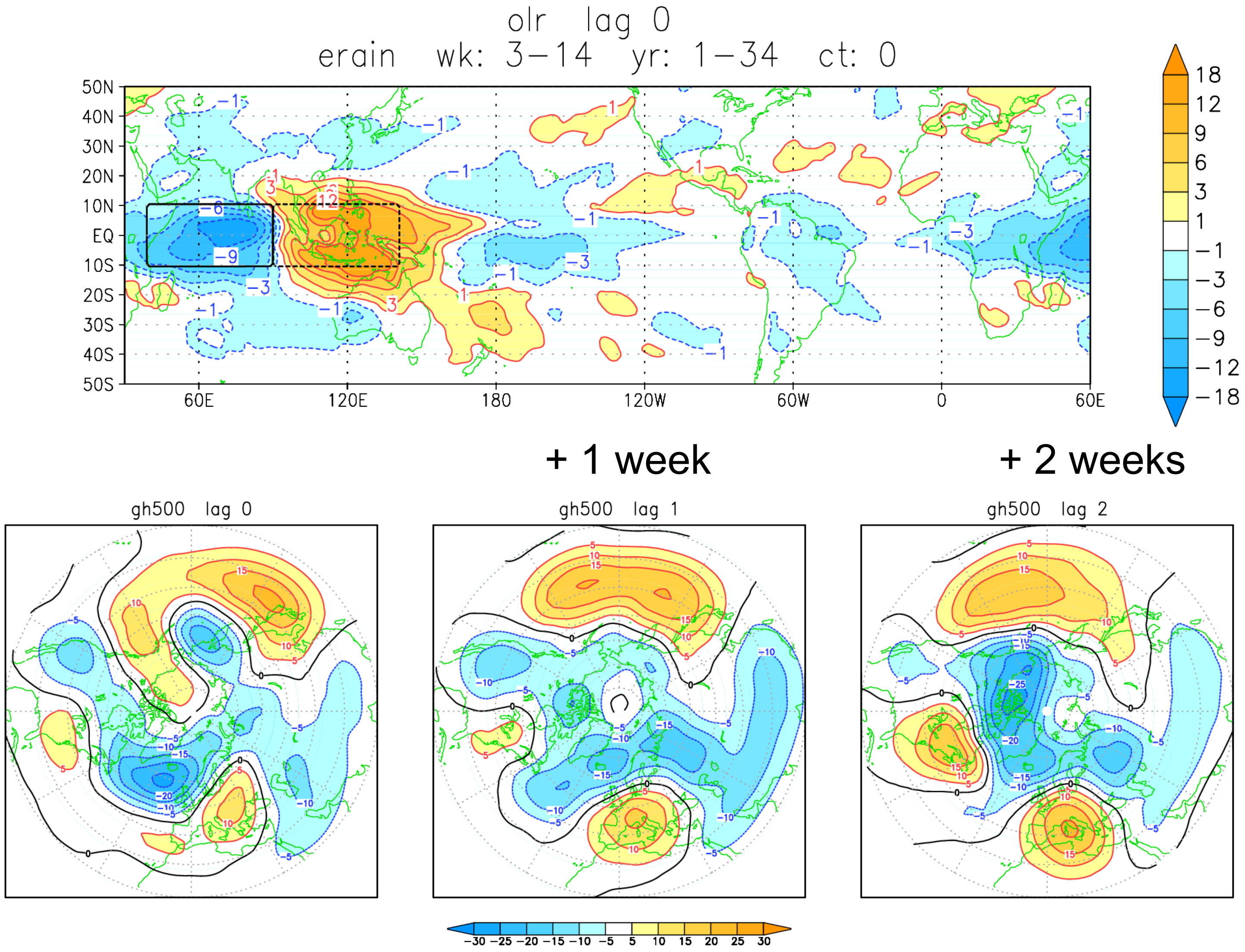
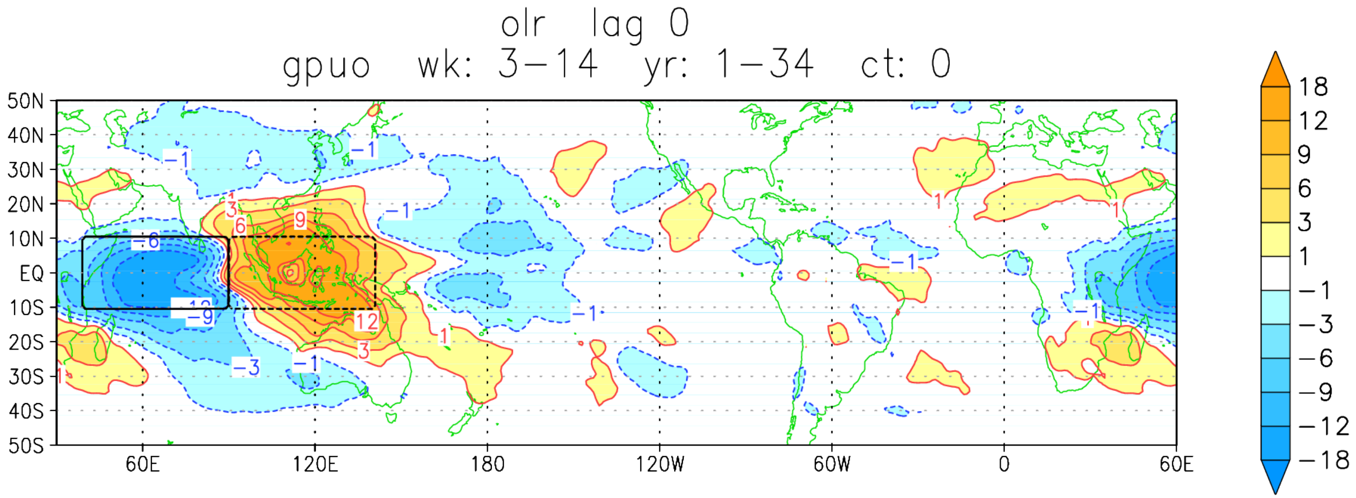


Lagged covariance of Indo-Pacific OLR (10S-10N) with NH Z 500 hpa: ERA-Int. 1980-2013



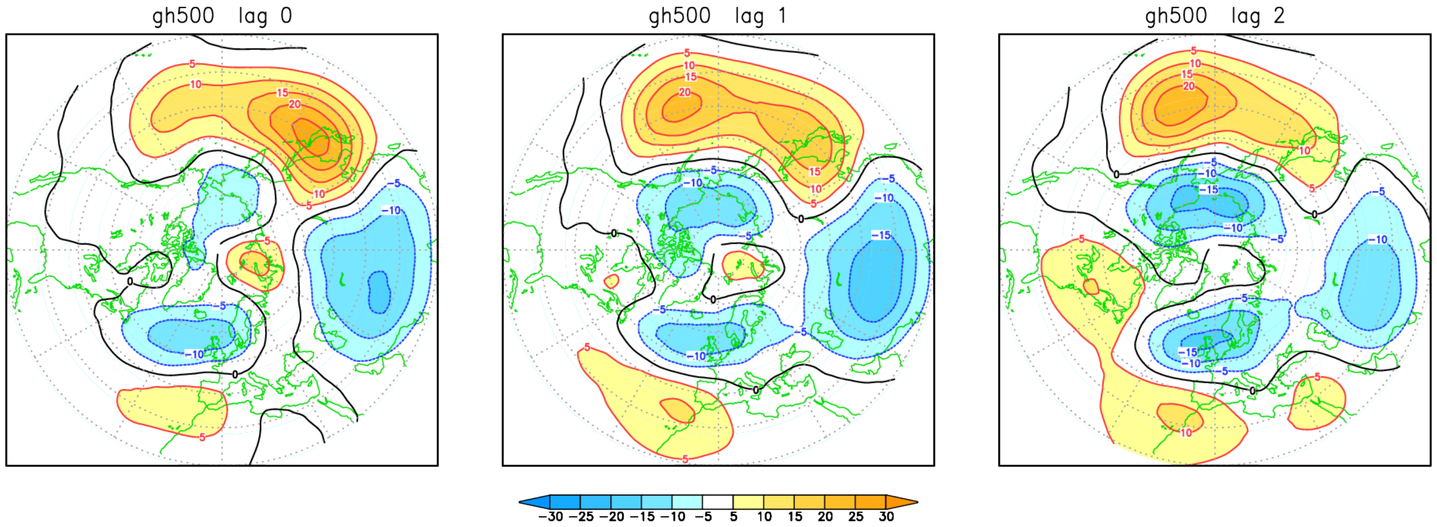
ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Lagged covariance of Indo-Pacific OLR (10S-10N) with NH Z 500 hpa: AMIP 1980-2013

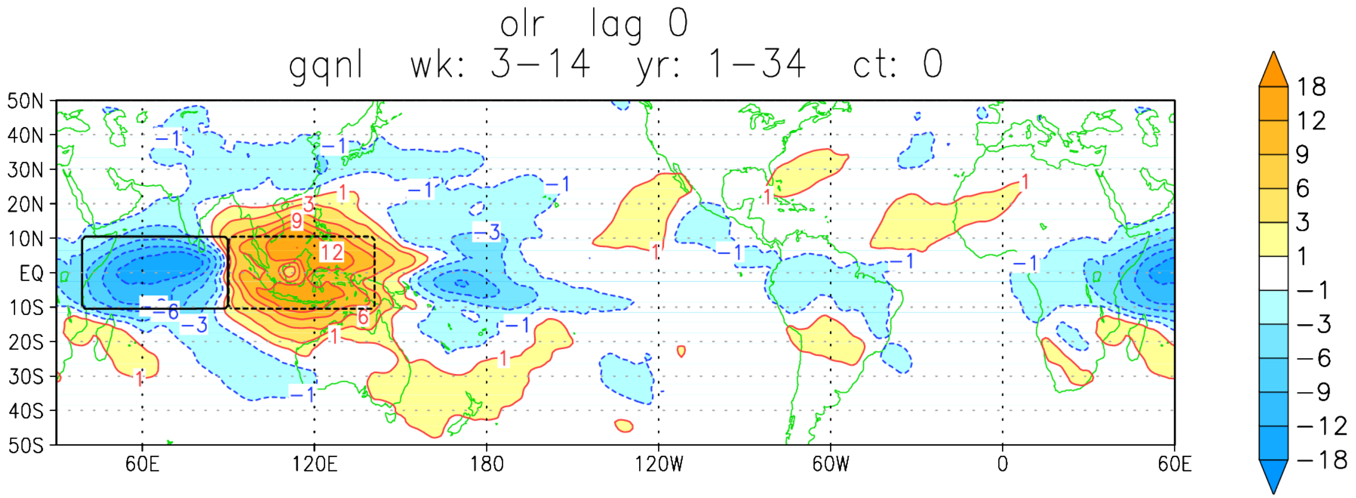


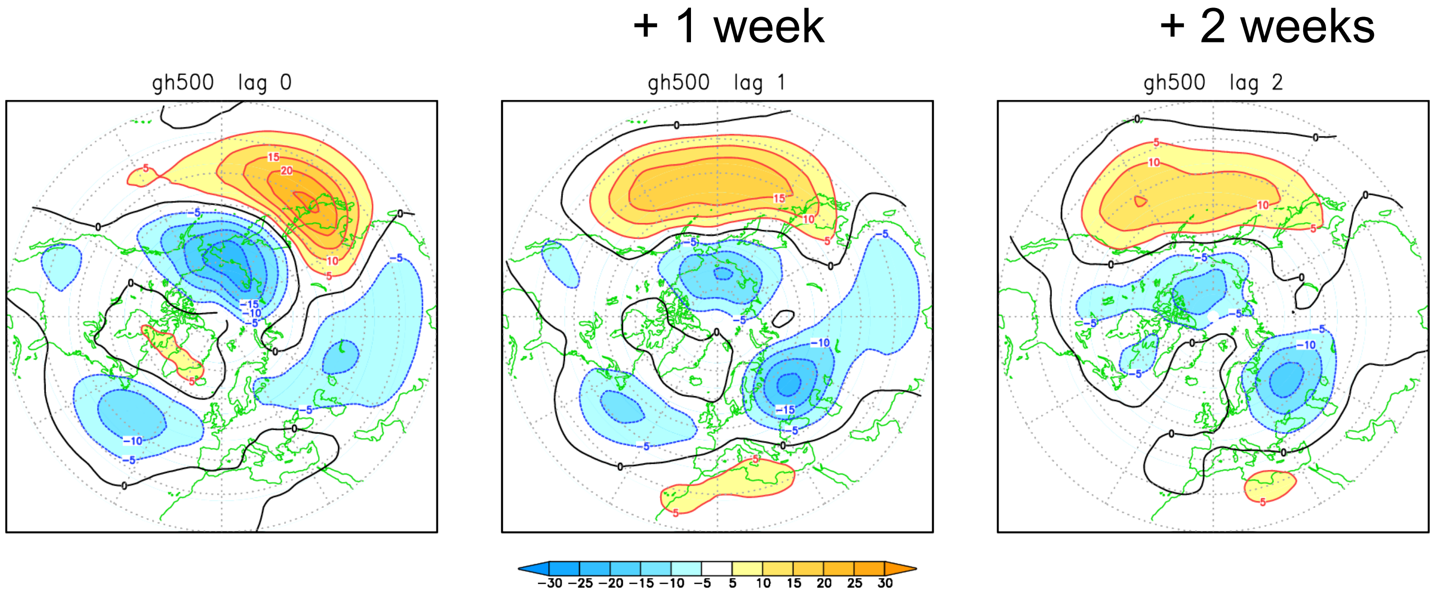
+ 1 week

+ 2 weeks

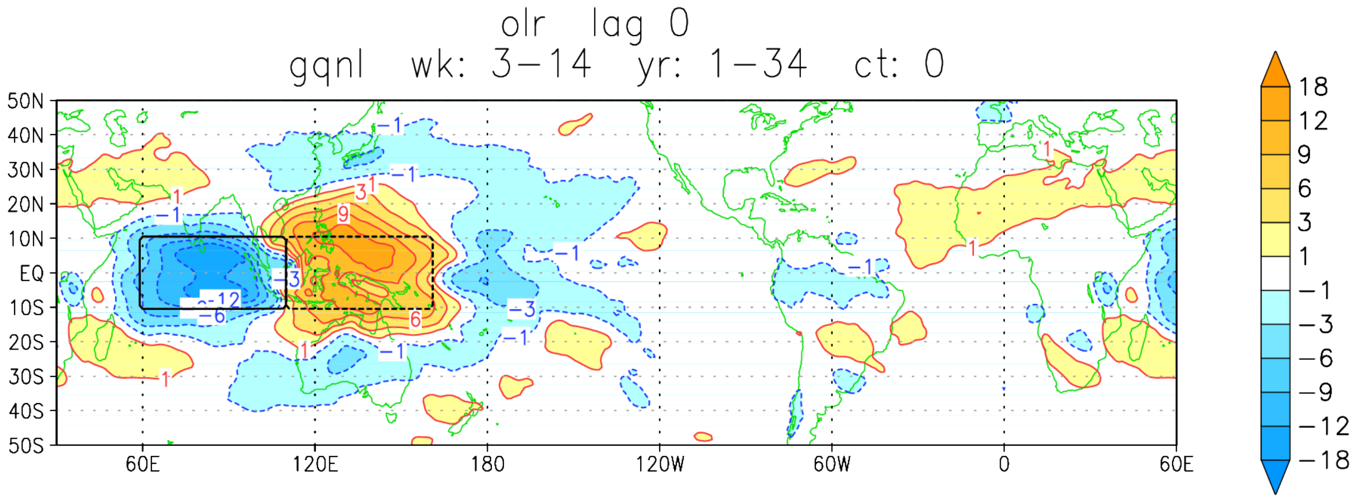


Lagged covariance of Indo-Pacific OLR (10S-10N) with NH Z 500 hpa: C-hist 1980-2013



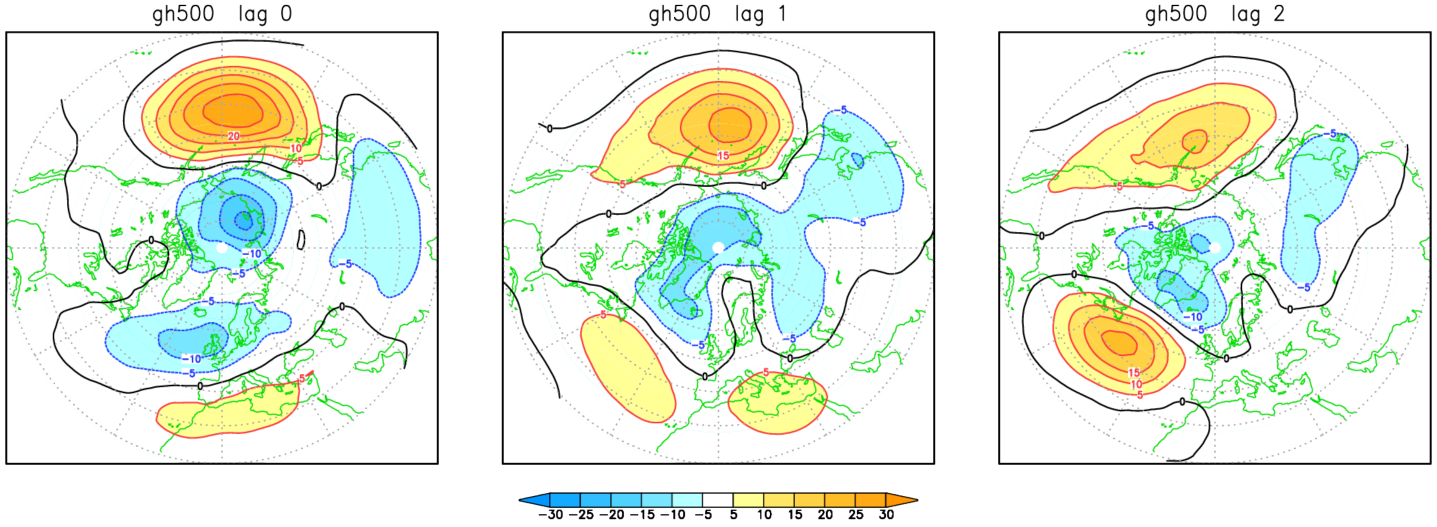


Lagged covariance of Indo-Pacific OLR (10S-10N) with NH Z 500 hpa: C-hist 1980-2013

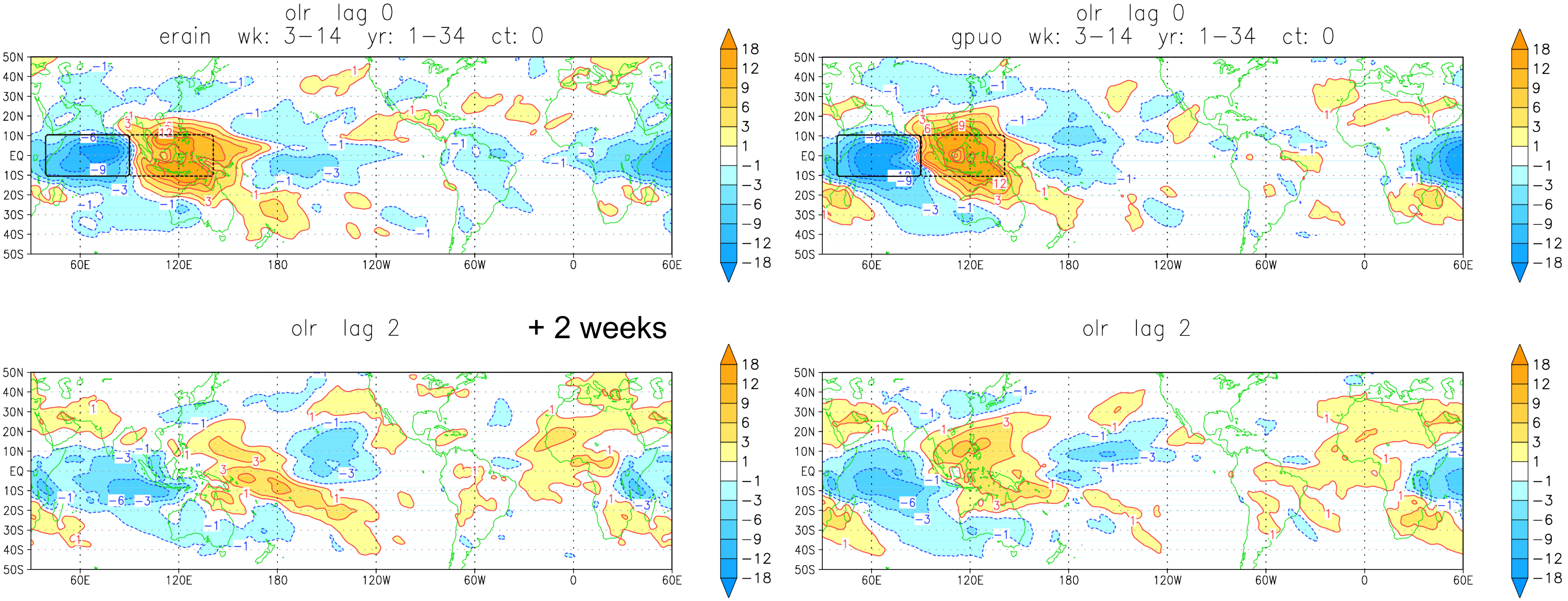


+ 1 week

+ 2 weeks



Lagged covariance of Indo-Pacific OLR (10S-10N): ERA-int vs. AMIP 1980-2013

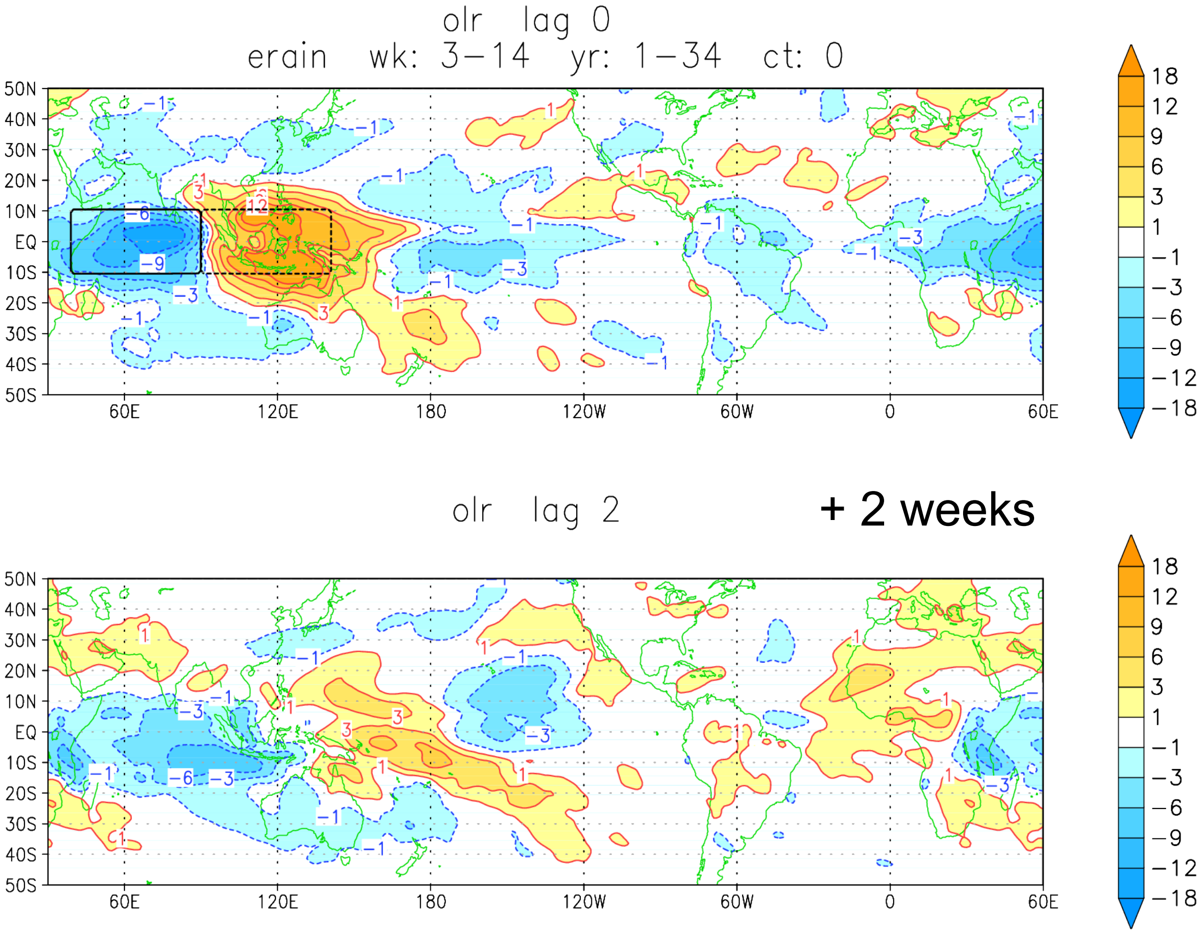


ERA-interim

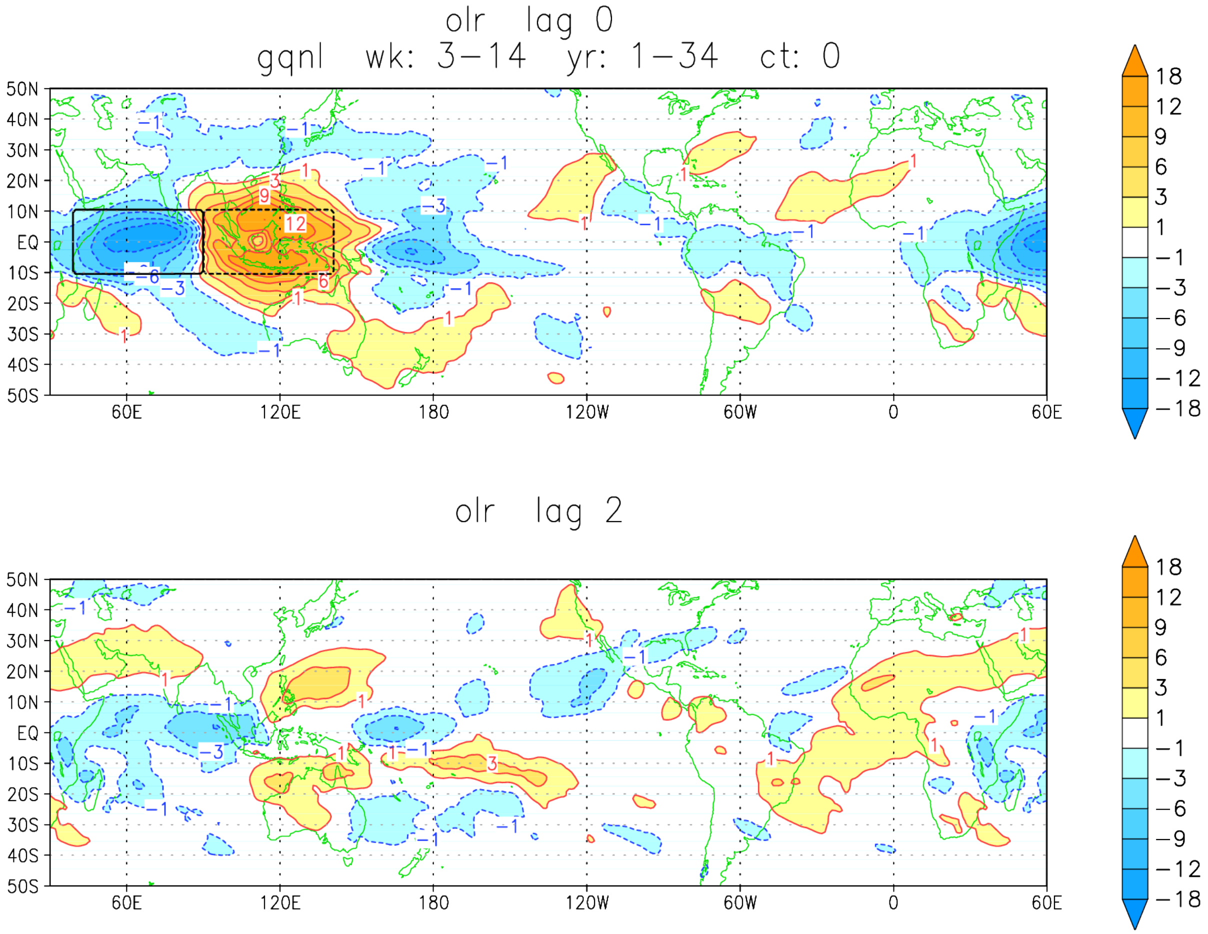
AMIP

AMIP: very slow MJO propagation, good NAO teleconnection: see Yadav and Straus 2017

Lagged covariance of Indo-Pacific OLR (10S-10N): ERA-int vs. C-hist 1980-2013



ERA-interim



C-hist

Conclusions

- The teleconnection pattern associated with rainfall variability in the tropical Indian Ocean and the Maritime Continent can be reproduced in sub-seasonal ensemble experiments by stochastically perturbing the tendencies produced by physical parametrizations in the Indo-Pacific in cases in active MJO. The maximum NAO variability is reached about two weeks after anomalous heating is established in the western Indian Ocean.

- Multi-decadal runs with historical CMIP forcings for 1950-2014, run with the coupled ECMWF model (IFS-NEMO) for the PRIMAVERA project, show a realistic simulation of ENSO variability and the associated teleconnections, but on sub-seasonal scale convective activity in the Indo-Pacific does not show a coherent propagation. This strongly weakens teleconnections associated with Indian Ocean rainfall anomalies. On the other hand, in AMIP runs the absence of coupling increases the persistence of MJO-like heating anomalies, and stronger teleconnections are detected in the northern extratropics.

- On the seasonal time-scales, teleconnections from the Indian Ocean in both AMIP and coupled runs are also affected by an excessively strong correlation between western Indian Ocean rainfall and SST anomalies induced by ENSO in the central and east Pacific.