



Understanding Indo-Pacific teleconnections on seasonal to decadal scales

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*Acknowledgements to: T. Stockdale, F. Vitart
and colleagues in the Predictability Division*



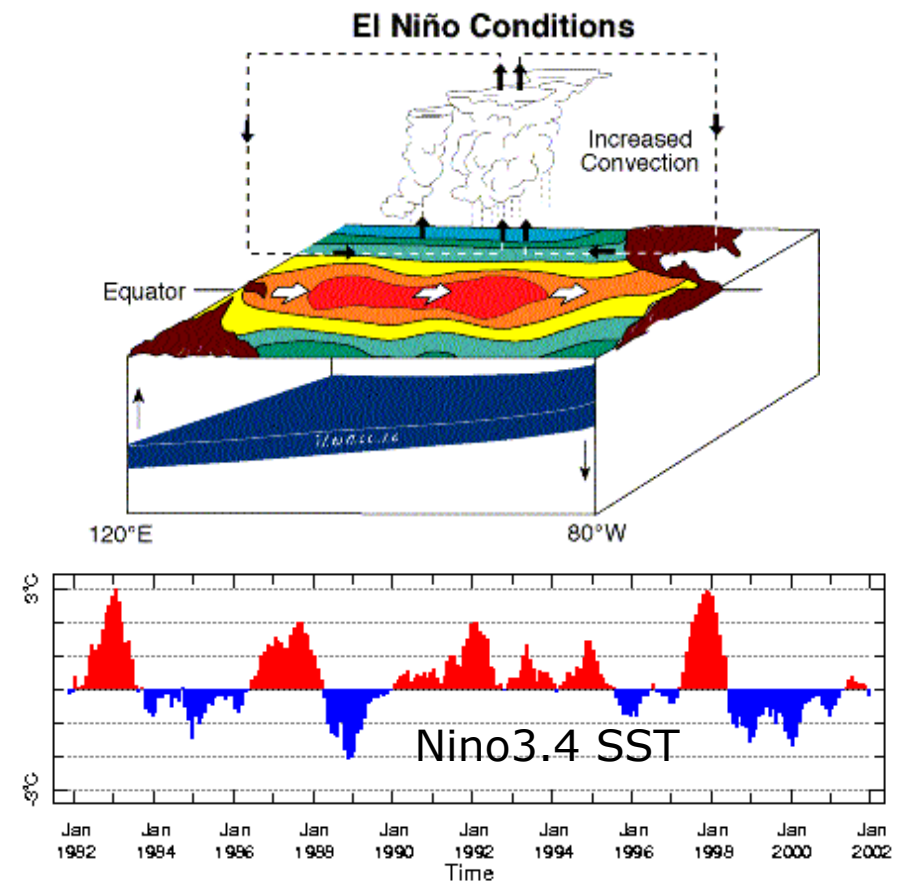
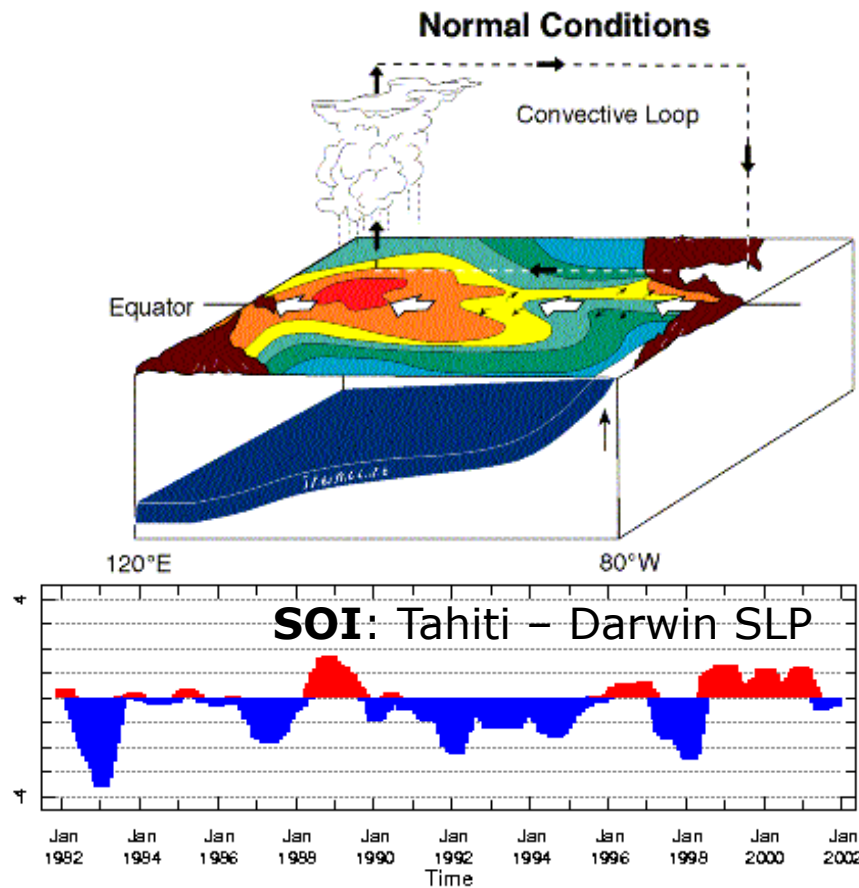
Outline

- Seasonality in the connections between the tropical Pacific and Indian Oceans: limitations of the SST viewpoint
- Understanding the impact of Indo-Pacific SST anomalies in AGCM experiments
- Comparison between teleconnections in observational datasets and the ECMWF System-4 re-forecasts:
 - Covariances with SST indices
 - Covariances with rainfall indices
 - Predictability of Indo-Pacific SST and rainfall anomalies
- Analogies between intra-seasonal and inter-annual teleconnections, and links with decadal variability
- Conclusions: a rainfall-oriented view of Indo-Pacific teleconnections



Major teleconnection drivers: ENSO

The El Niño - Southern Oscillation

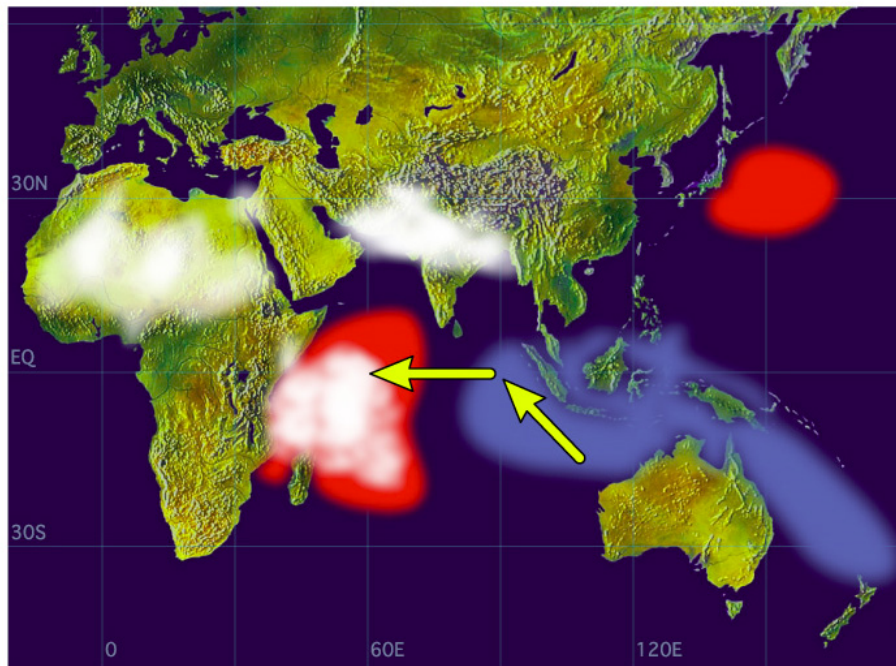




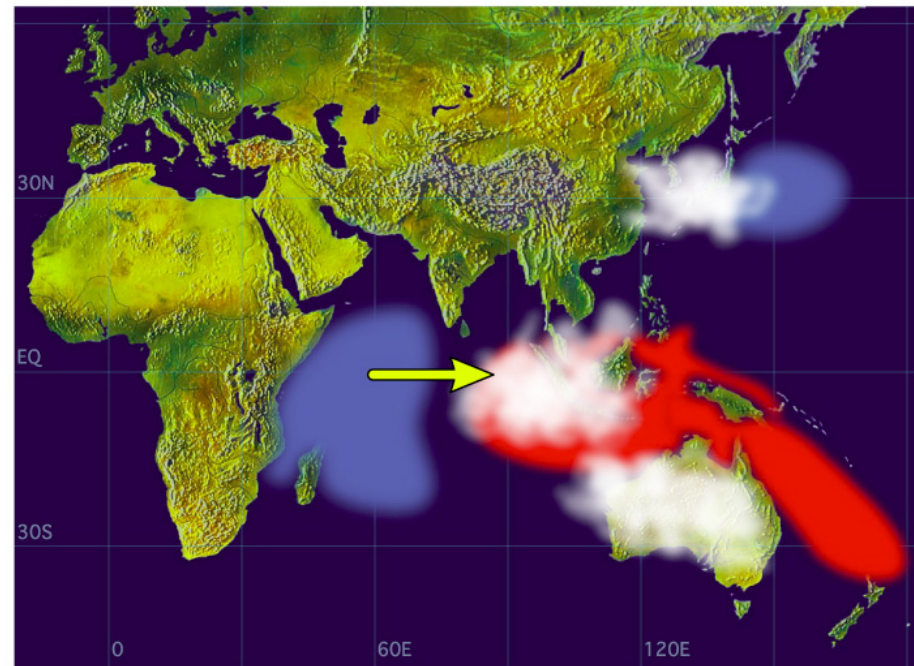
Major teleconnection drivers: IOD

The Indian Ocean Dipole (or I.O. Zonal Mode)

Positive Dipole Mode

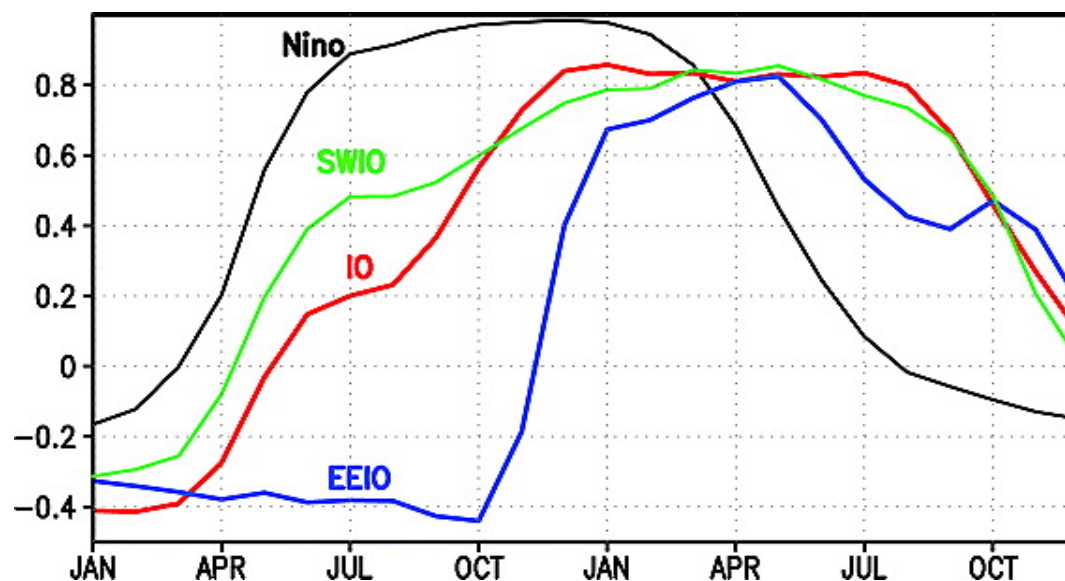
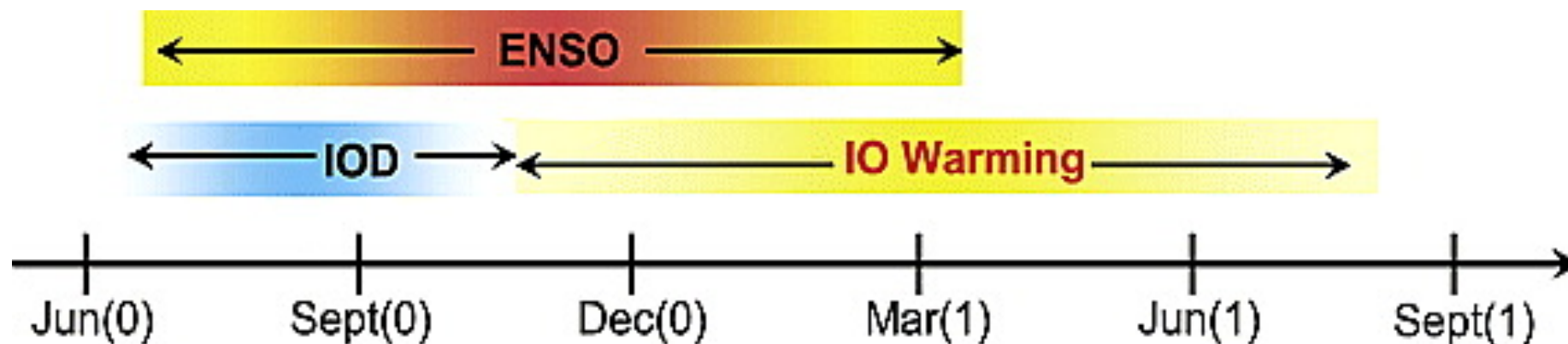


Negative Dipole Mode





Seasonal evolution of ENSO and IOD

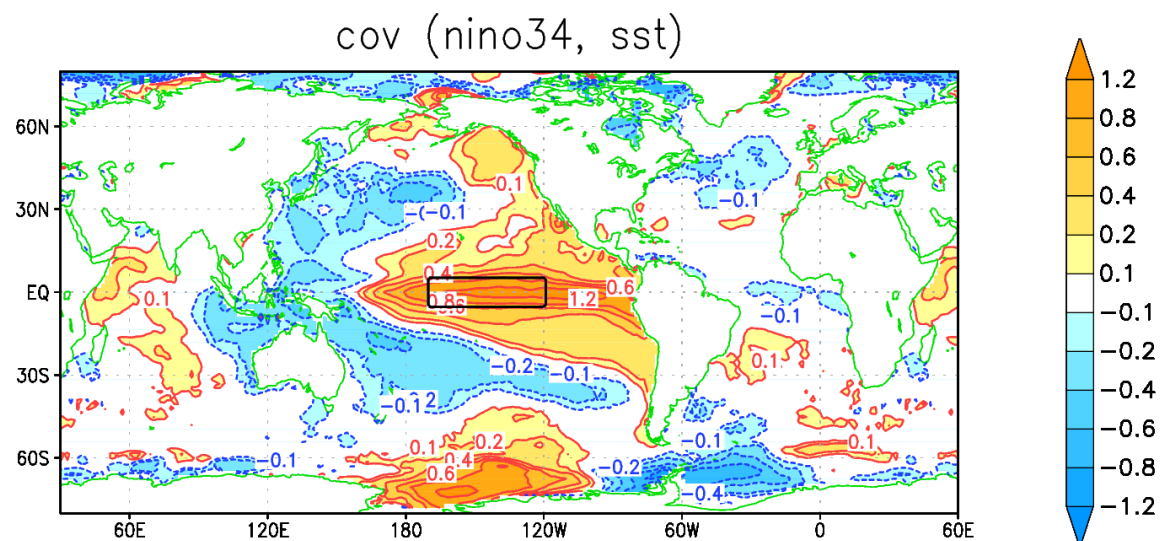


Correlation with
Nino3 SST in NDJ

*From Schott et al.
Rev. Geoph. 2009*

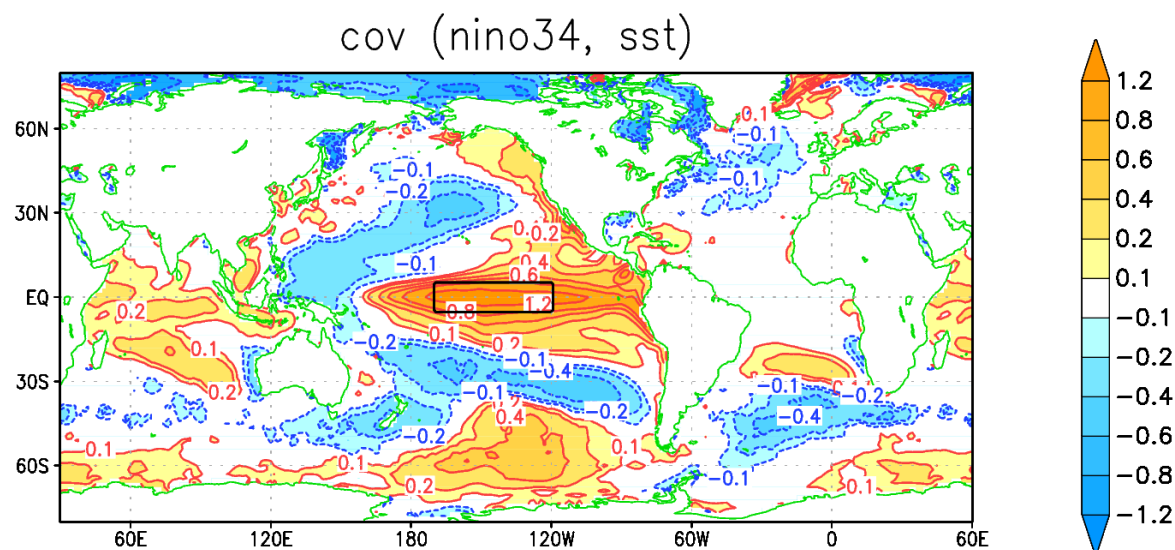


Covariance of global SST with stand. Nino3.4 index



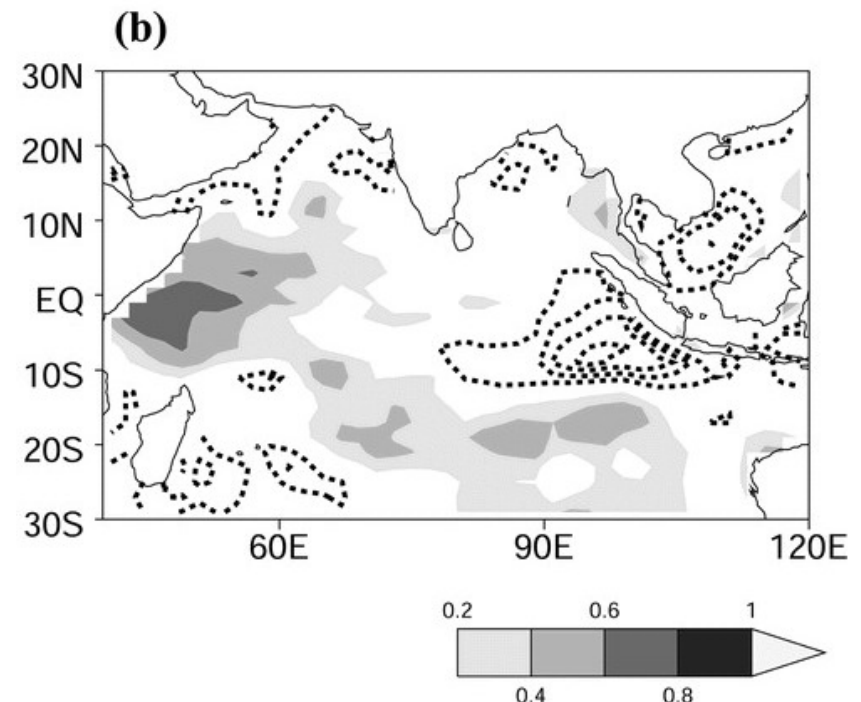
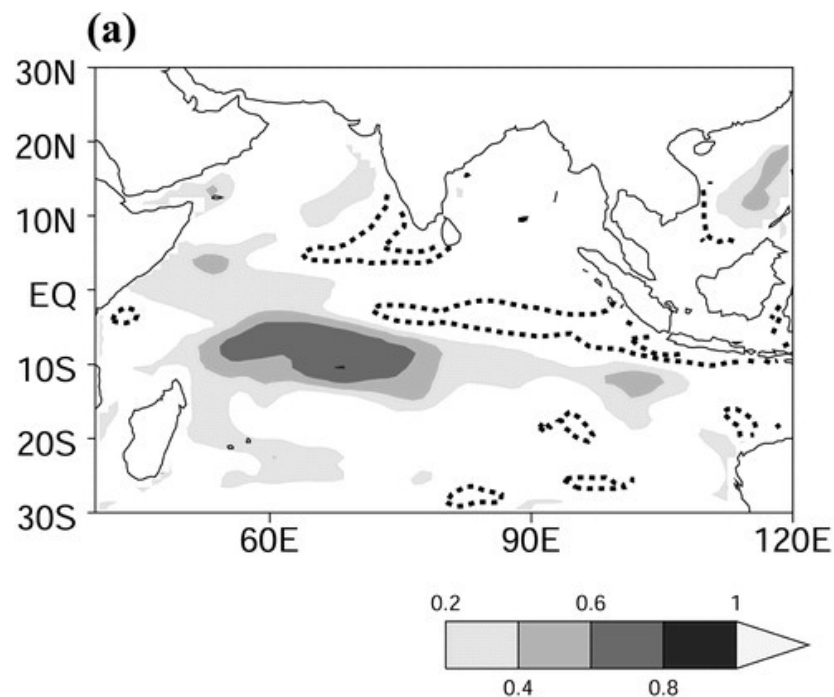
ERA Interim,
1981-2010

SON

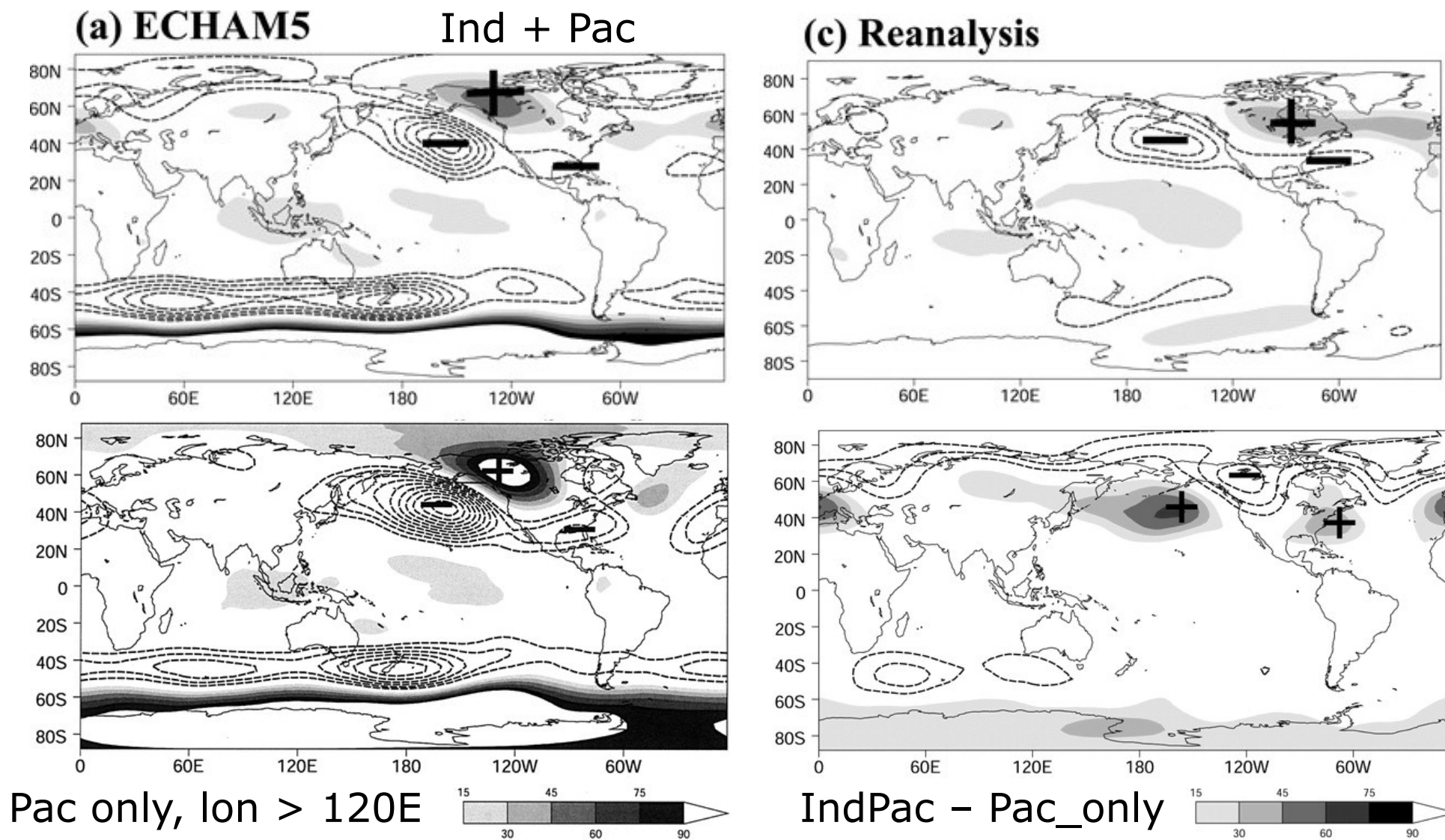


DJF

Local correlation between JFM SST and:
a) 20-C isotherm depth b) precipitation

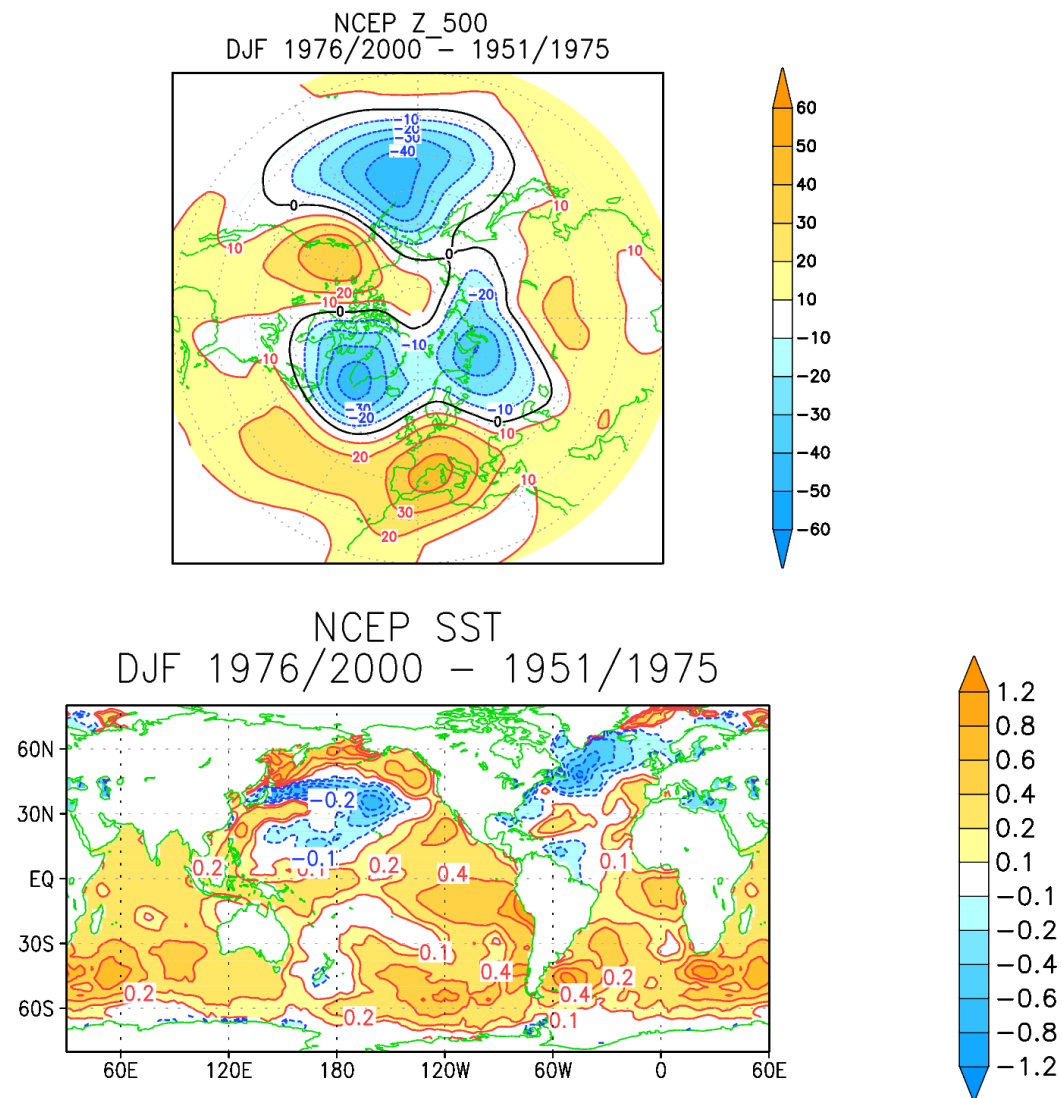


AGCM exp.: response to ENSO SST, Annamalai et al. 2007





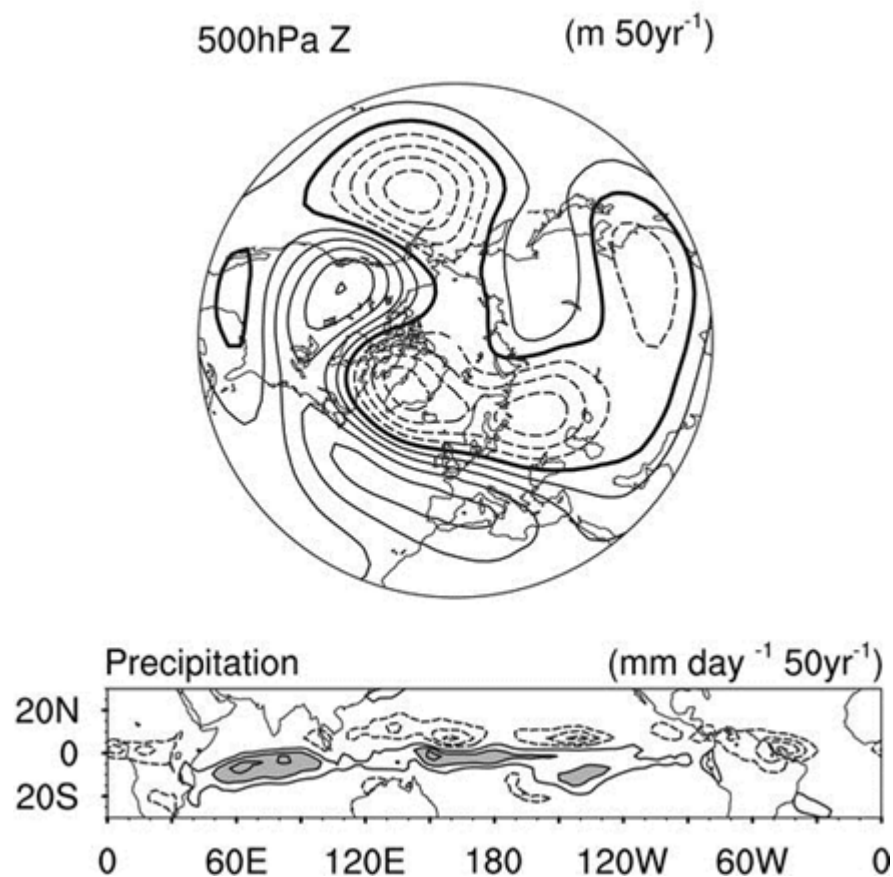
Decadal variability in the late 20th century



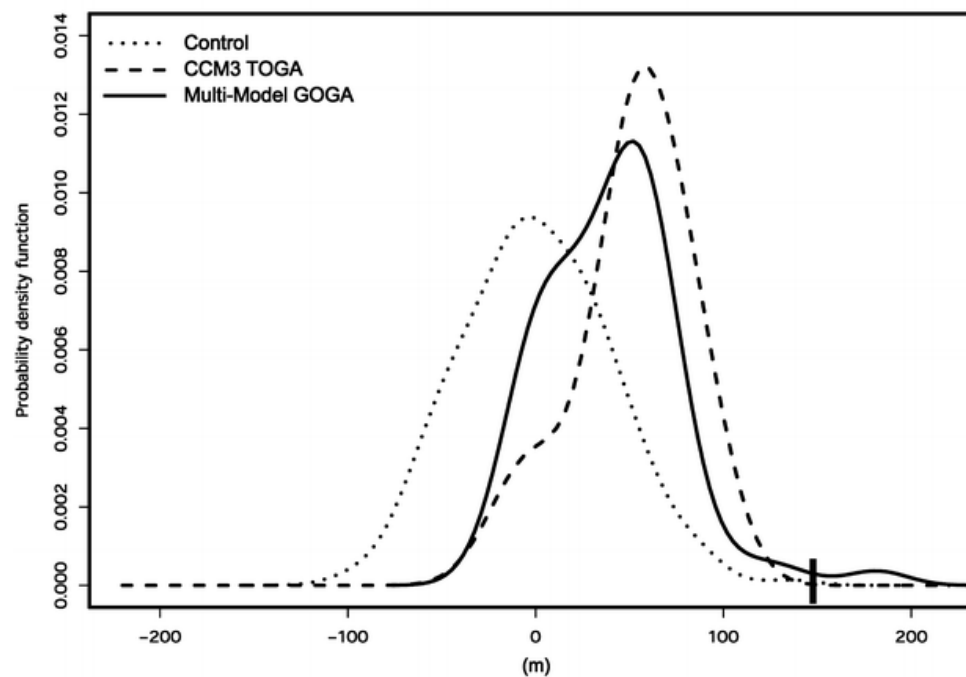


AGCM exp: late 20th cen. trends, Hurrell et al. 2004

Linear Trend (JFM) Multi-AGCM 1950-99



Trend of JFM 500hPa NAO index (1950-99)



JFM NAO index



AGCM exp: late 20th cen. trends, Hoerling et al. 2004

Responses (JFM) to Tropical SST Trends 1950-99

Tropic-wide

-0.27

Eastern Hemisphere

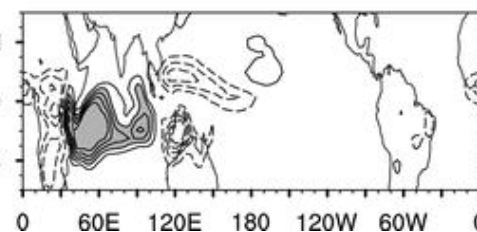
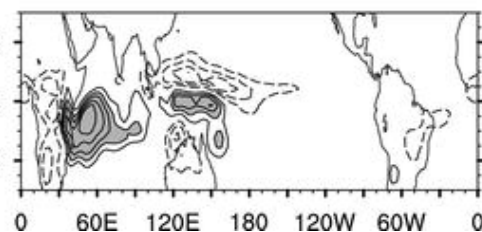
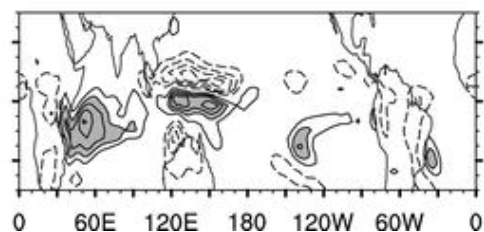
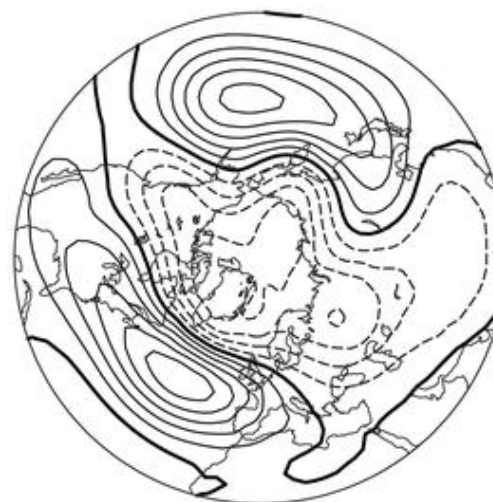
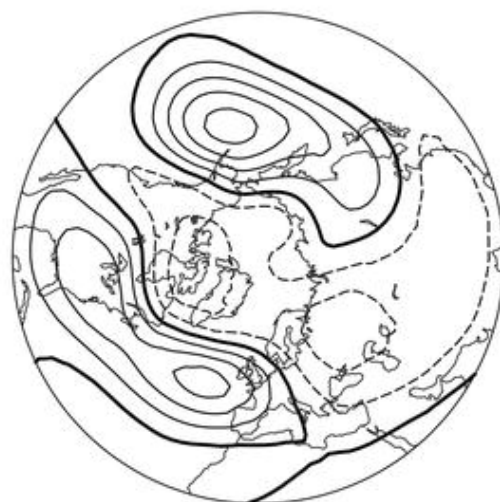
-0.36

Indian Ocean

-0.25

CCM3

Z 500



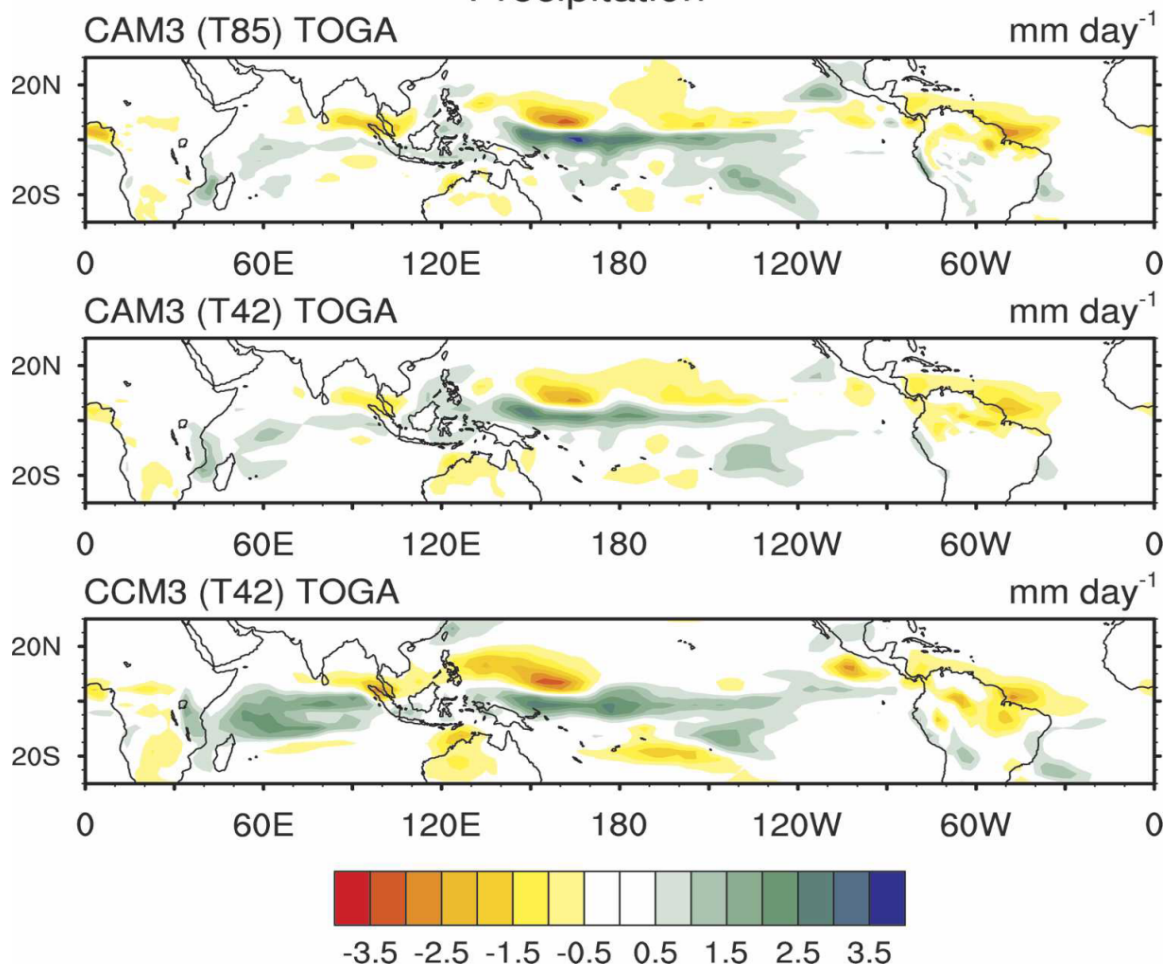
Prec.



AGCM exp: mid-1970s transition, Deser & Phillips 2006

Epoch Differences: 1977-2000 minus 1950-1976

Precipitation

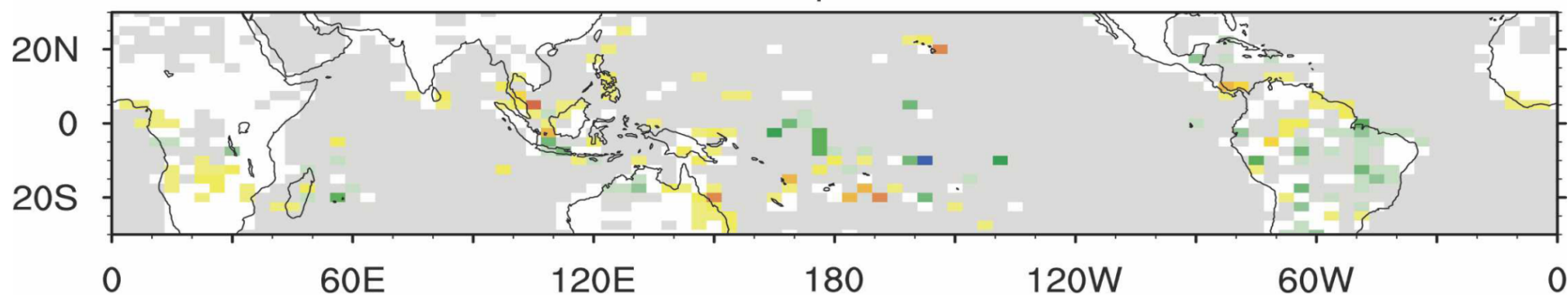




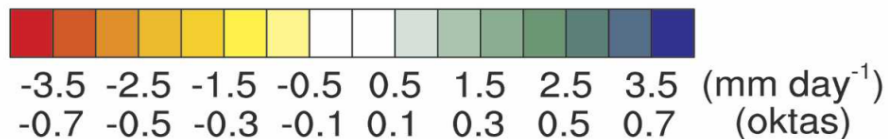
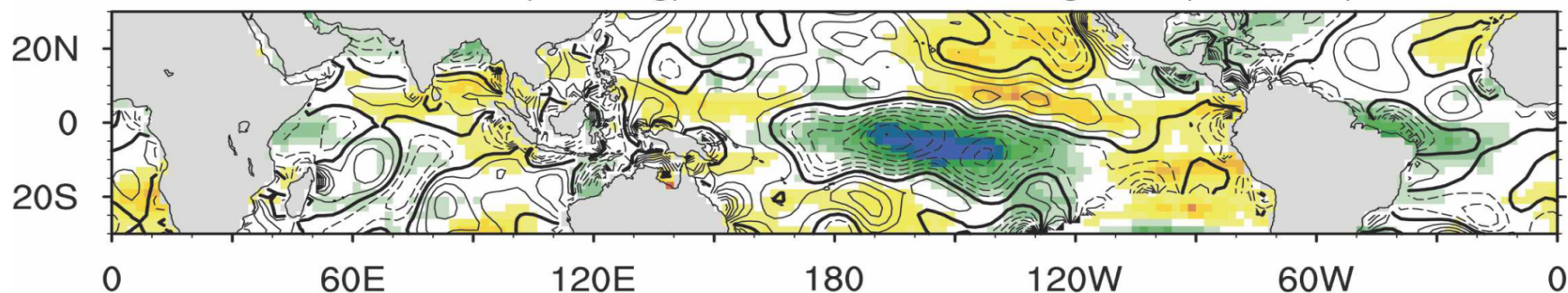
Obs. change in prec + clouds, Deser & Phillips 2006

Epoch Differences: 1977-2000 minus 1950-1976

Precipitation

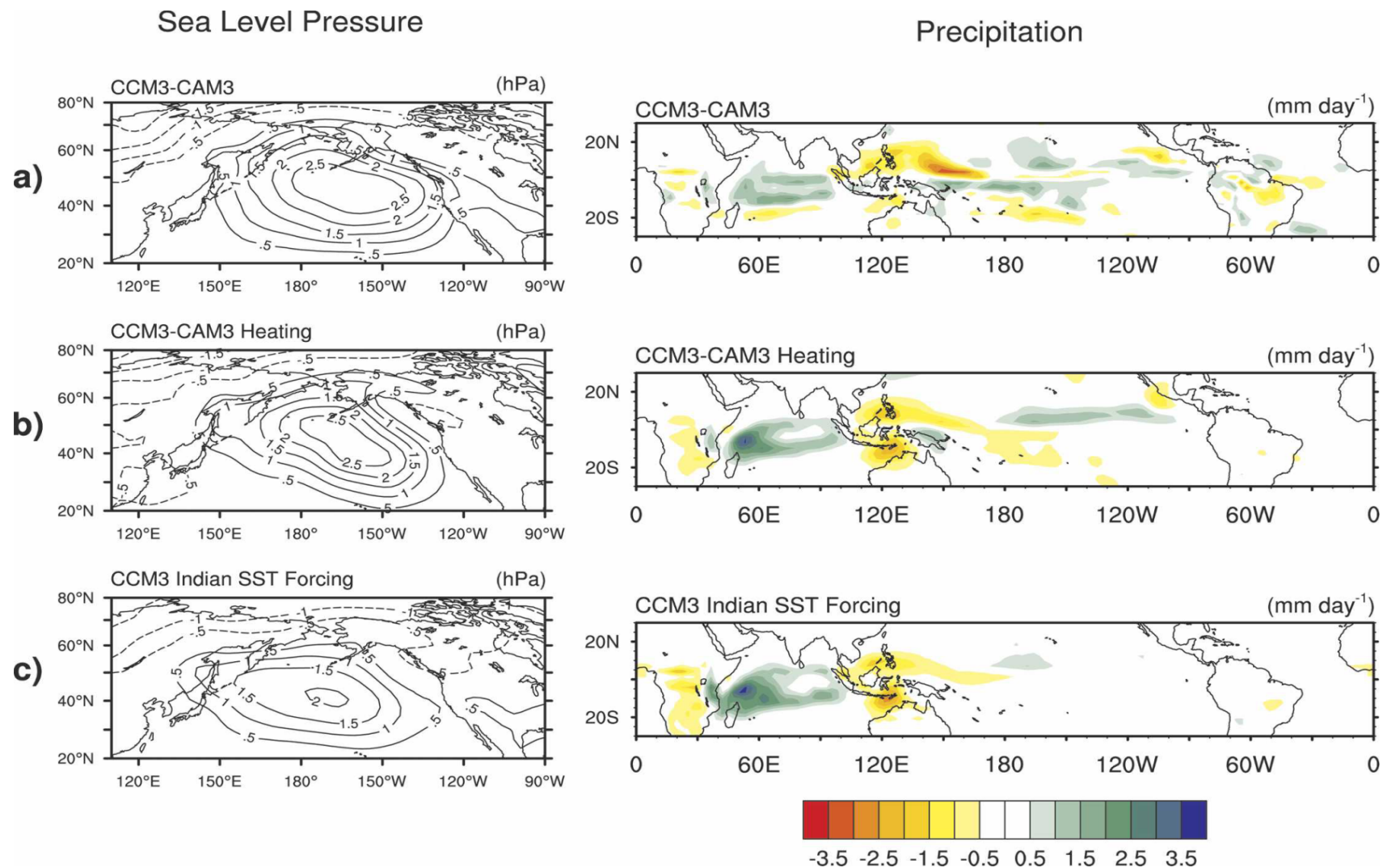


ISCCP Cloudiness (shading) / Surface Wind Divergence (contours)





Response over N. Pacific: Deser & Phillips 2006



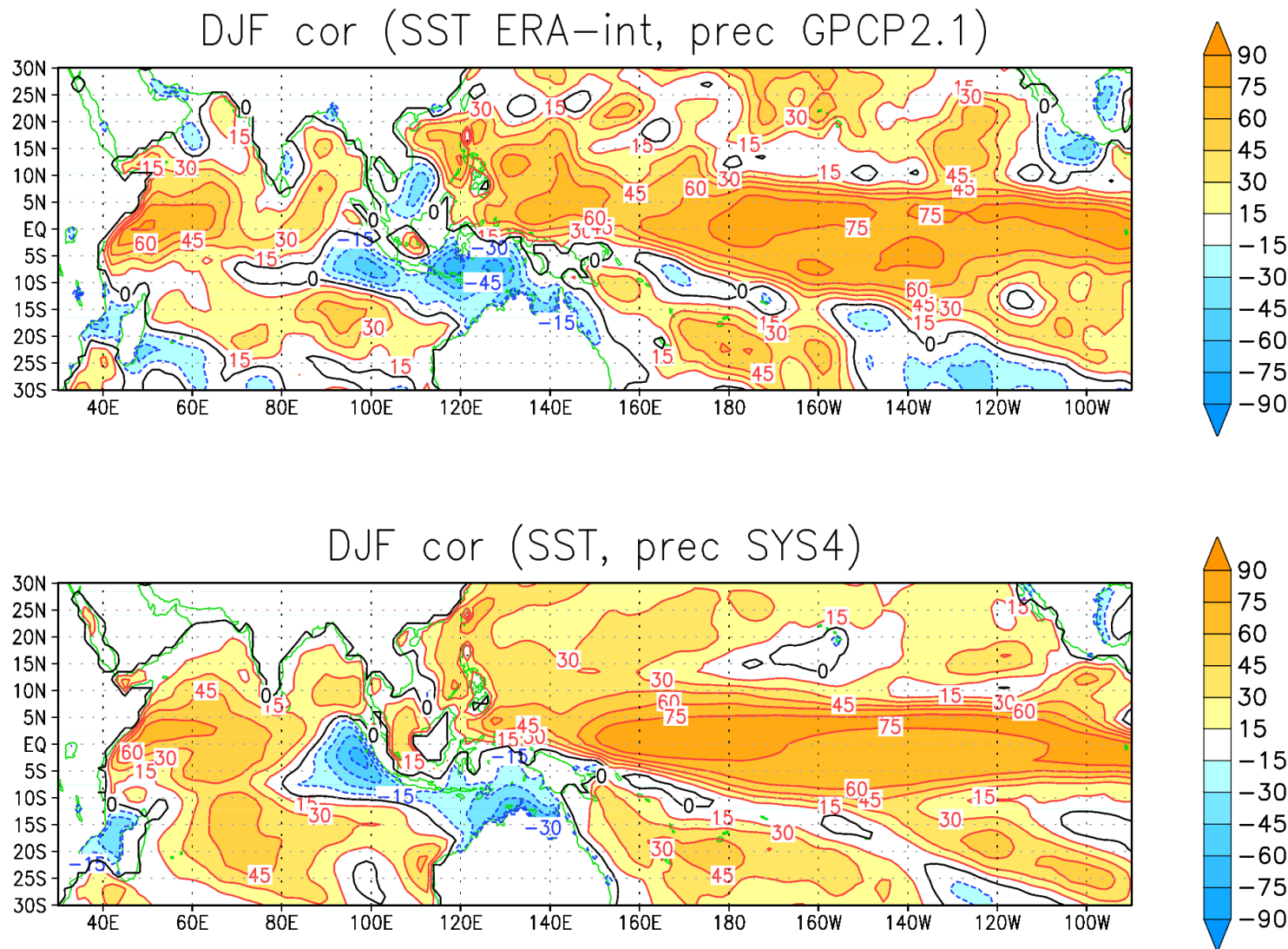


ECMWF seasonal fc. System 4: main features

- **IFS model cycle: 36r4** (op. Nov. 2010-May 2011), **T255-L91**
- **Ocean model : NEMO (v. 3.0 + 3.1 coupling interface)**
 - ORCA-1 configuration (~ 1 -deg. resol., ~ 0.3 lat. near the equator)
 - 42 vertical levels, 20 levels with $z < 300$ m
- **Variational ocean data assimilation (NEMOVAR)**
 - FGAT 3D-var, re-analysis (ORA-S4) and near-real-time system
 - Collaboration with CERFACS, UK Met Office, INRIA
- **Operational forecasts**
 - 51-member ensemble from 1st day of the month, released on the 8th
 - 7-month integration
 - 13-month extension (with 15 ens. members) from 1st Feb/May/Aug/Nov
- **Re-forecast set**
 - 30 years, start dates from 1 Jan 1981 to 1 Dec 2010
 - 15-member ensembles, 7-month integrations
 - 13-month extension from 1st Feb/May/Aug/Nov

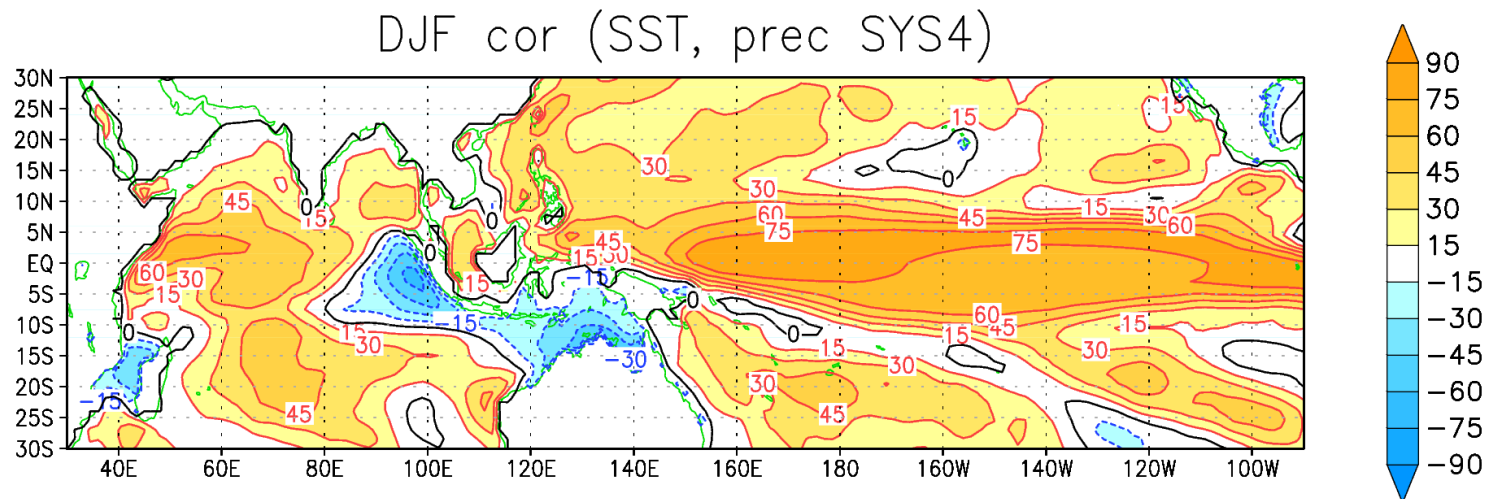
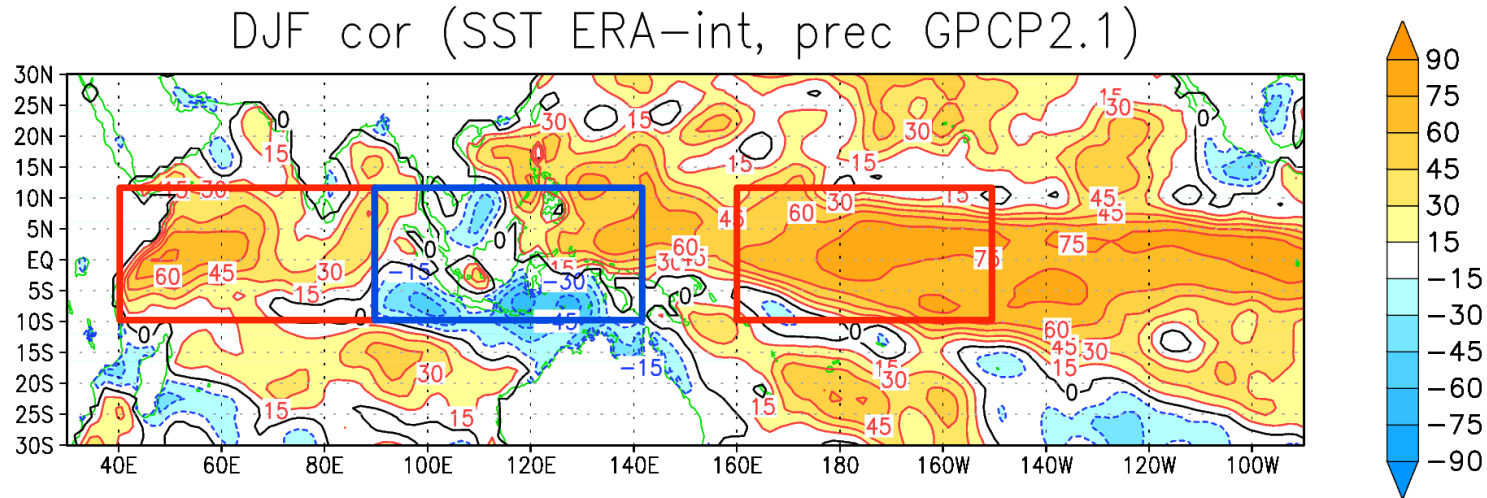


Local correlation SST – precip, DJF 1981-2008



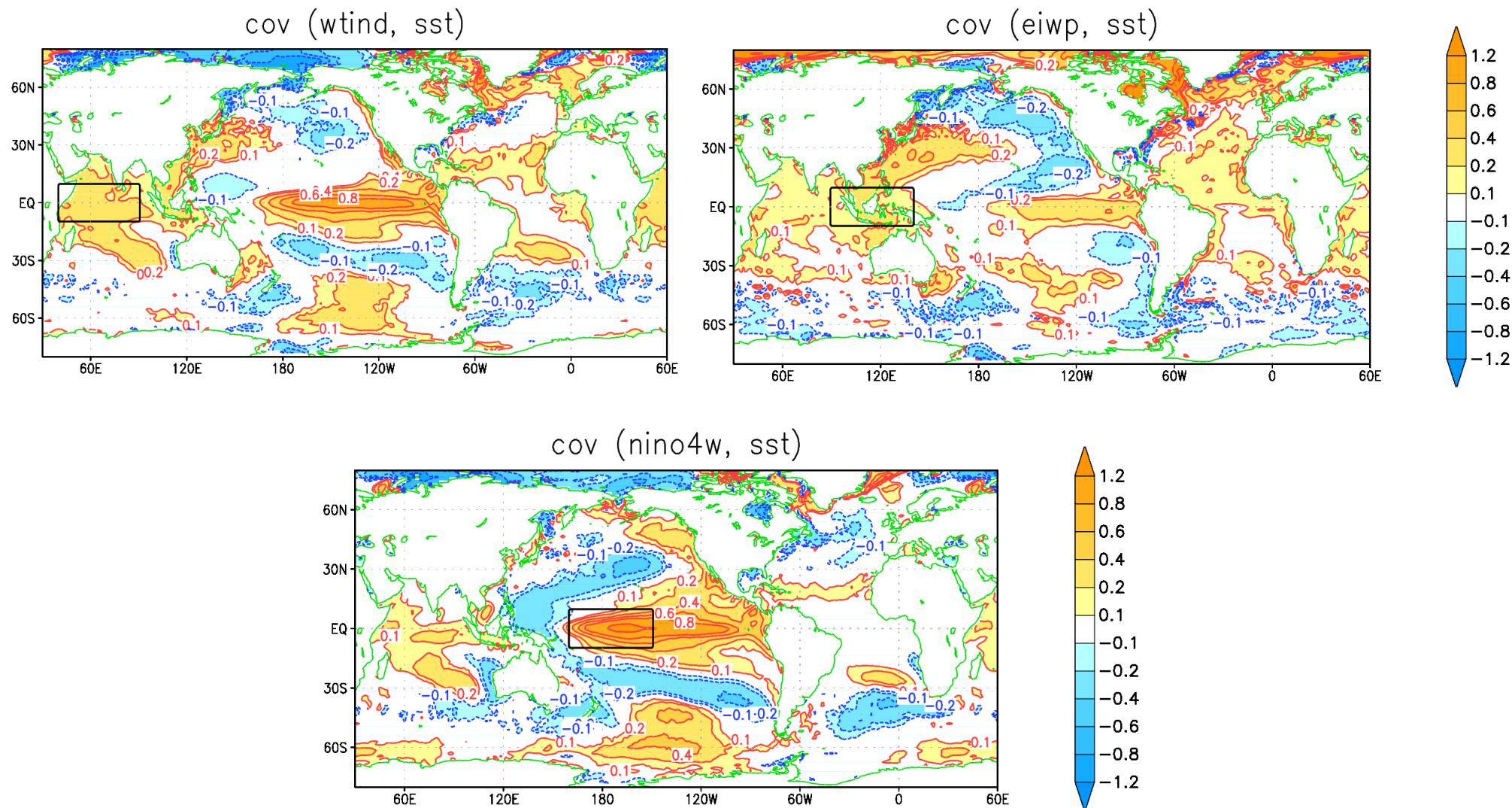


Local correlation SST – precip, DJF 1981-2008



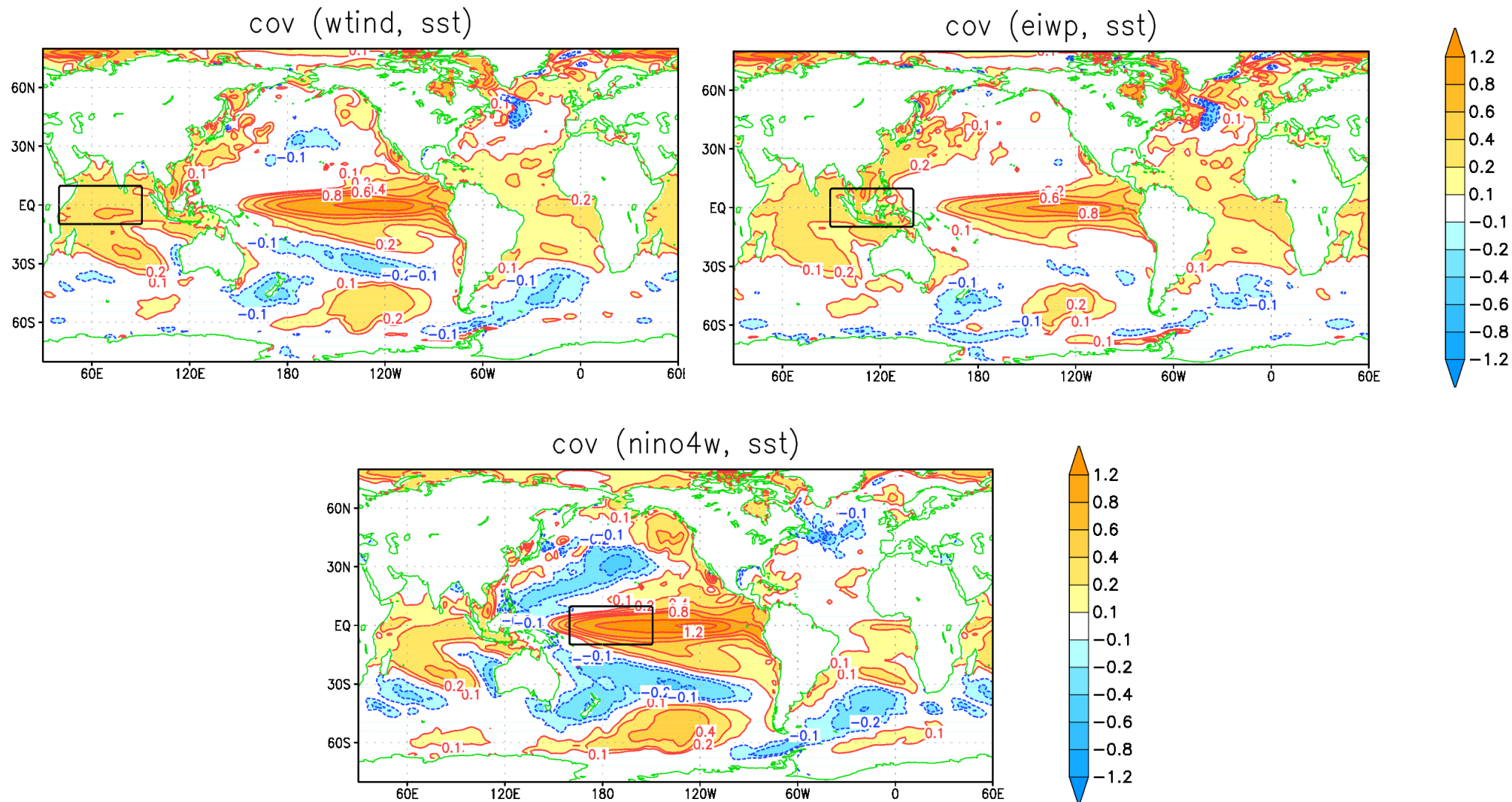


SST teleconnections in DJF: ERA Interim



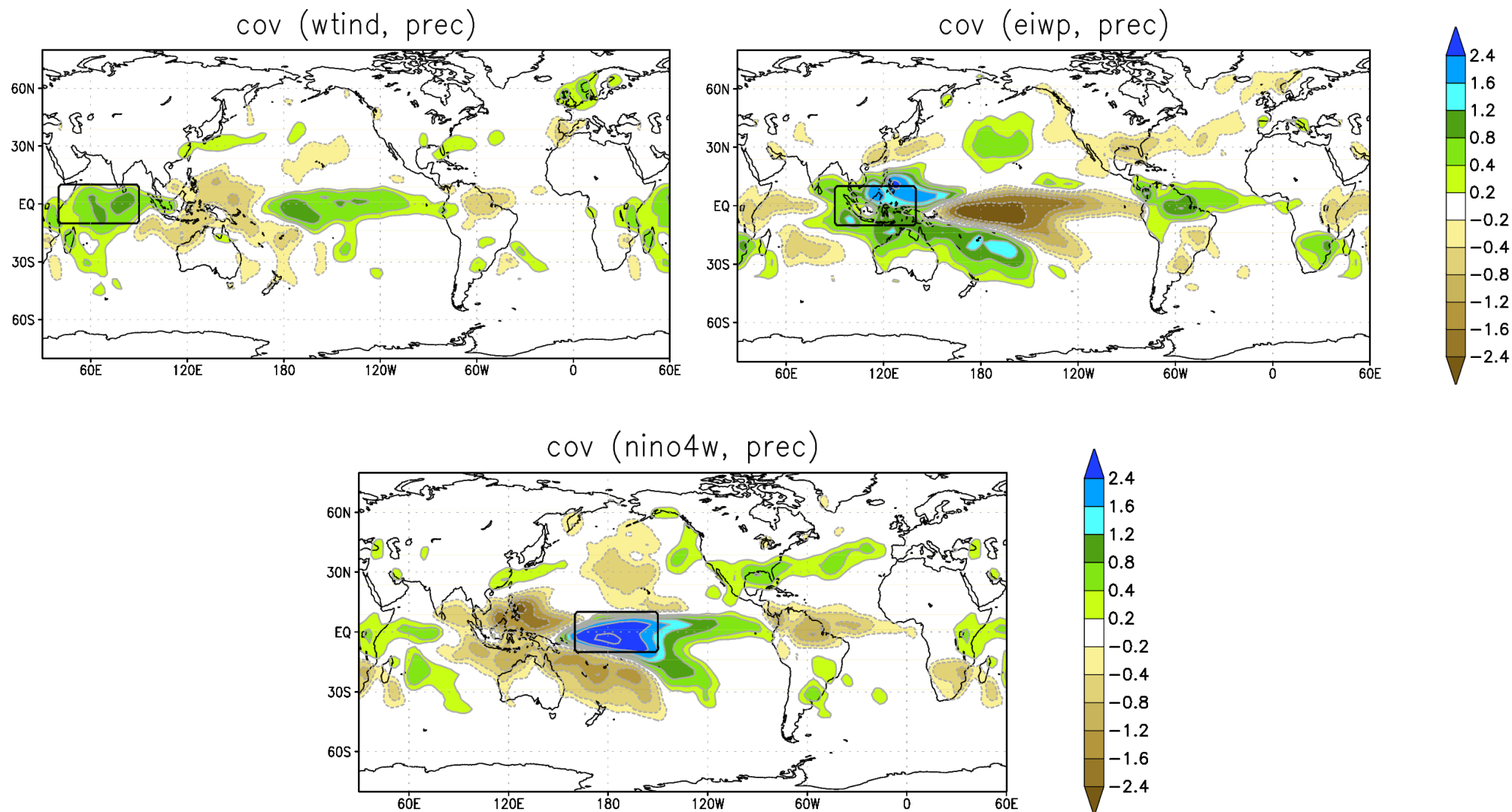


SST teleconnections in DJF: System 4 (from Nov.)

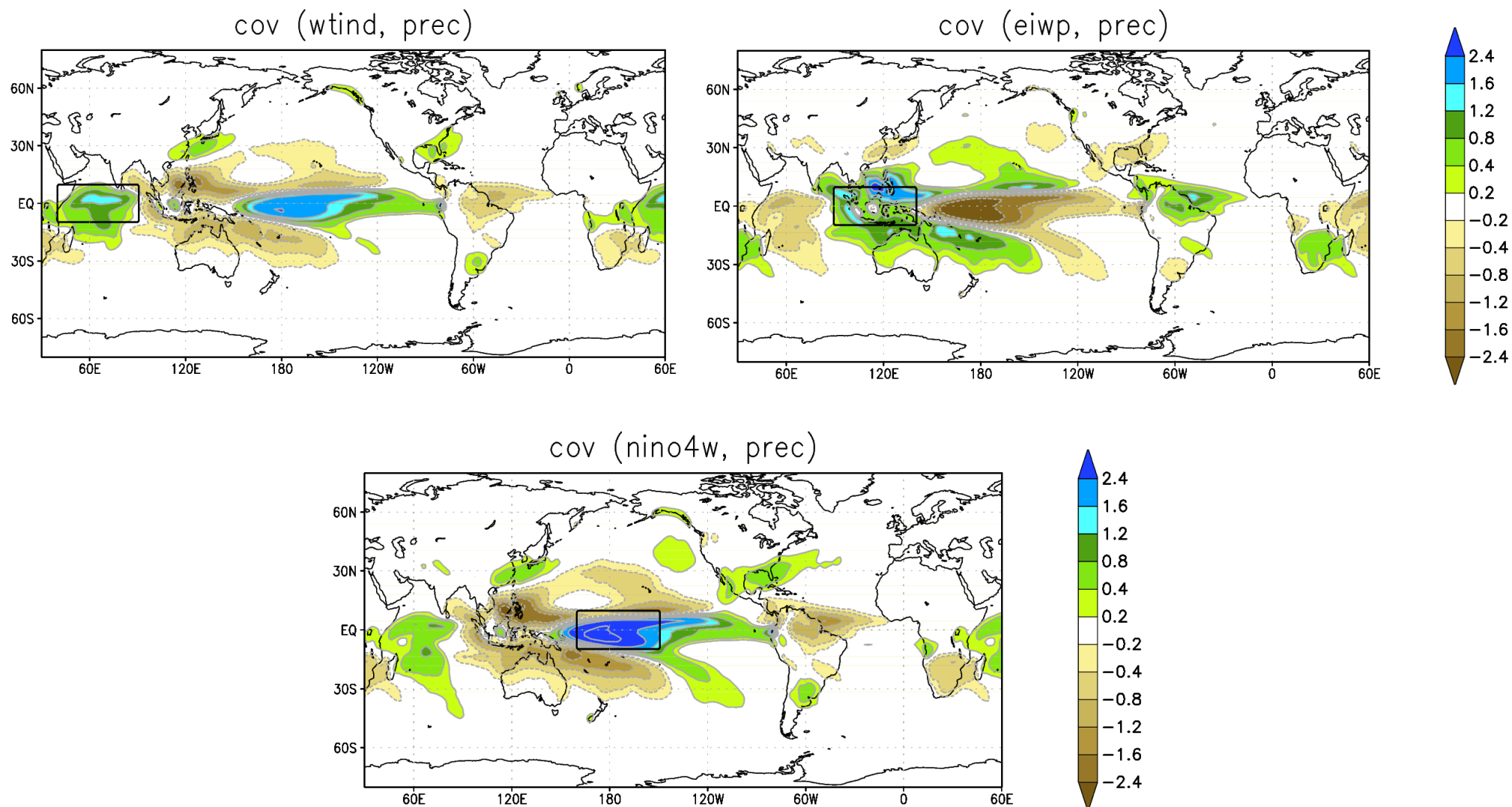




Precip. teleconnections in DJF: GPCP 2.2



Precip. teleconnections in DJF: System 4 (from Nov.)

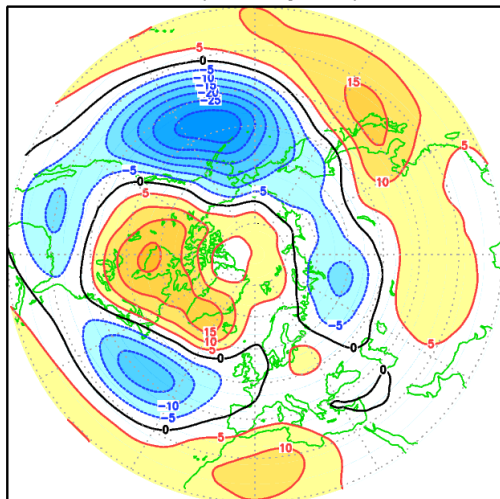




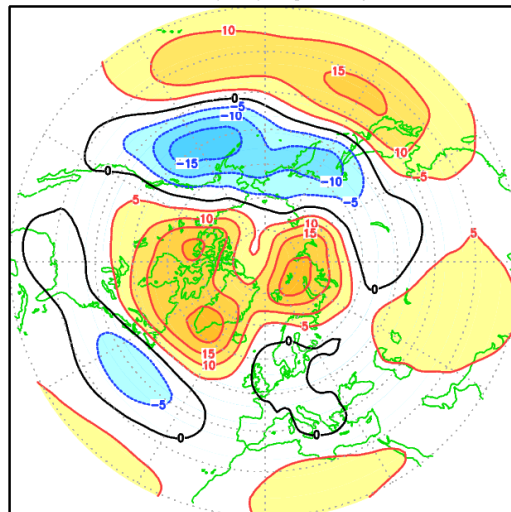
Z 500_hPa vs. SST: ERA-Int. and System-4

ERA

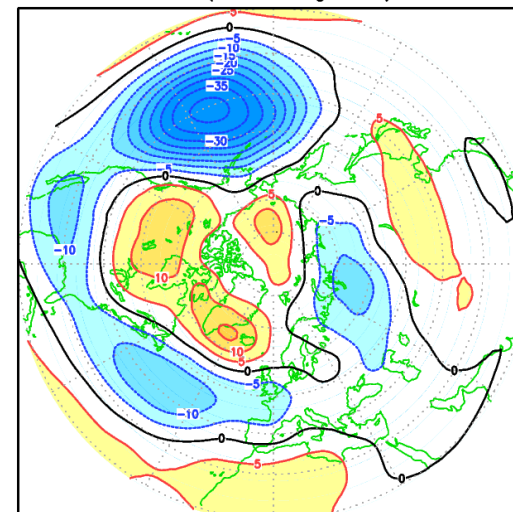
cov (wtind, gh500)



cov (eiwp, gh500)

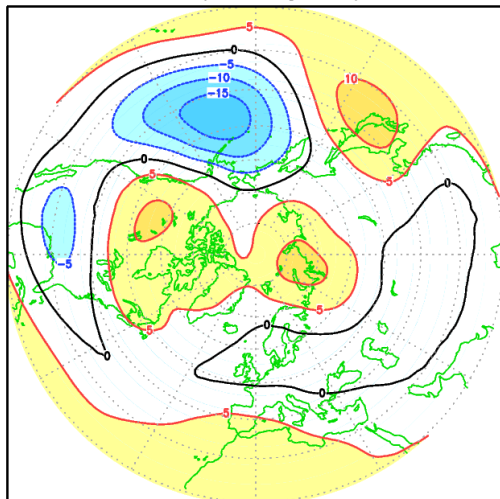


cov (nino4w, gh500)

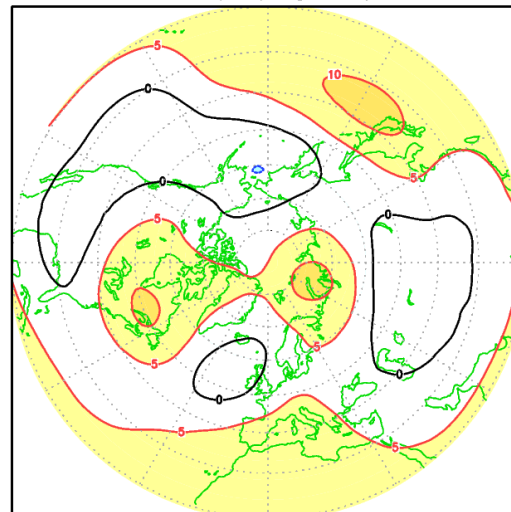


Sys4

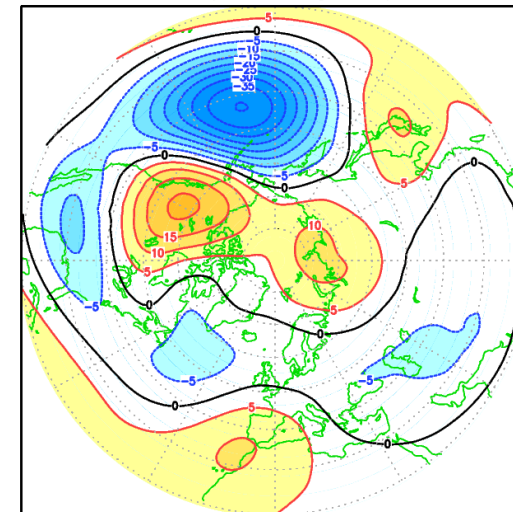
cov (wtind, gh500)



cov (eiwp, gh500)



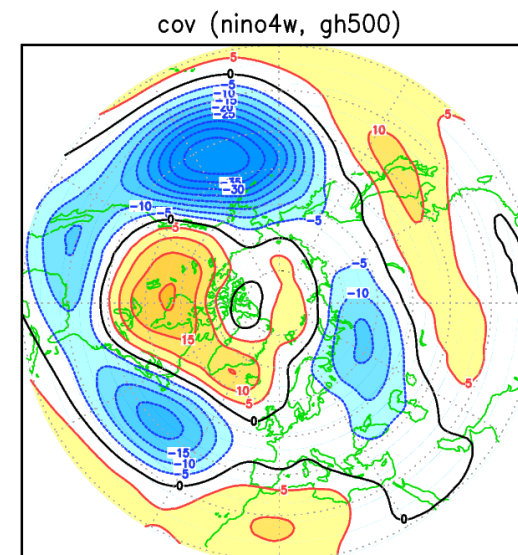
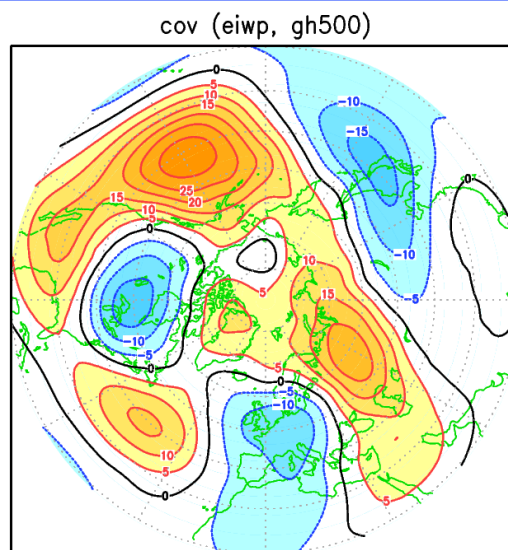
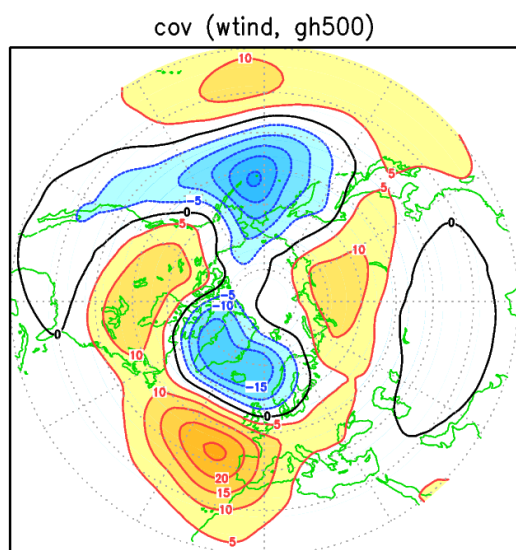
cov (nino4w, gh500)



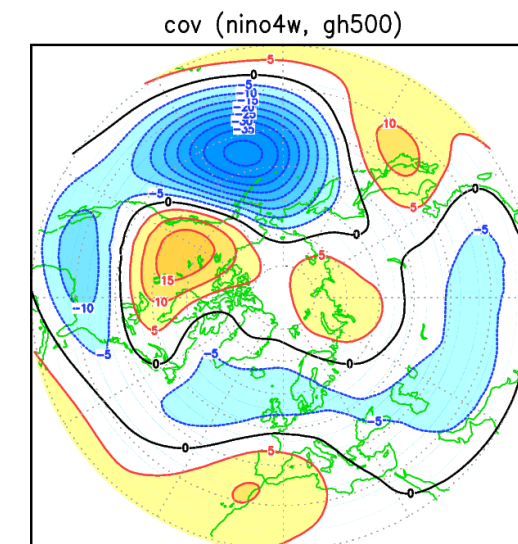
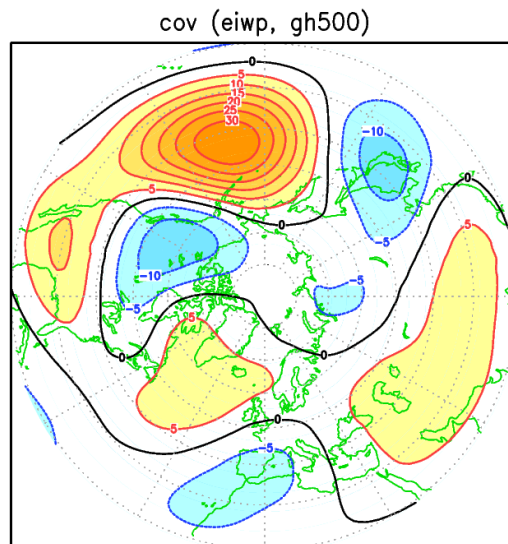
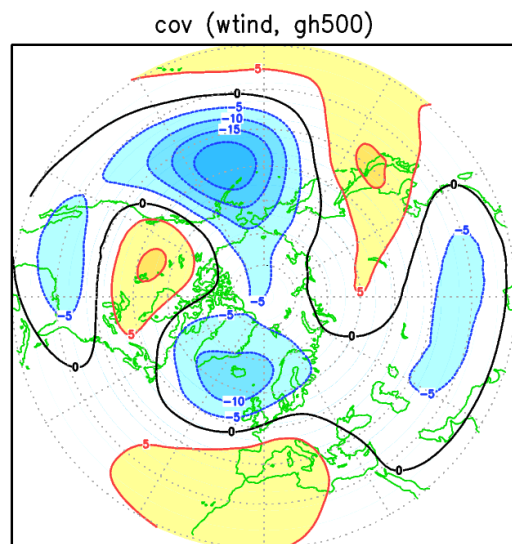


Z 500_hPa vs. precip: ERA-Int. and System-4

ERA



Sys4

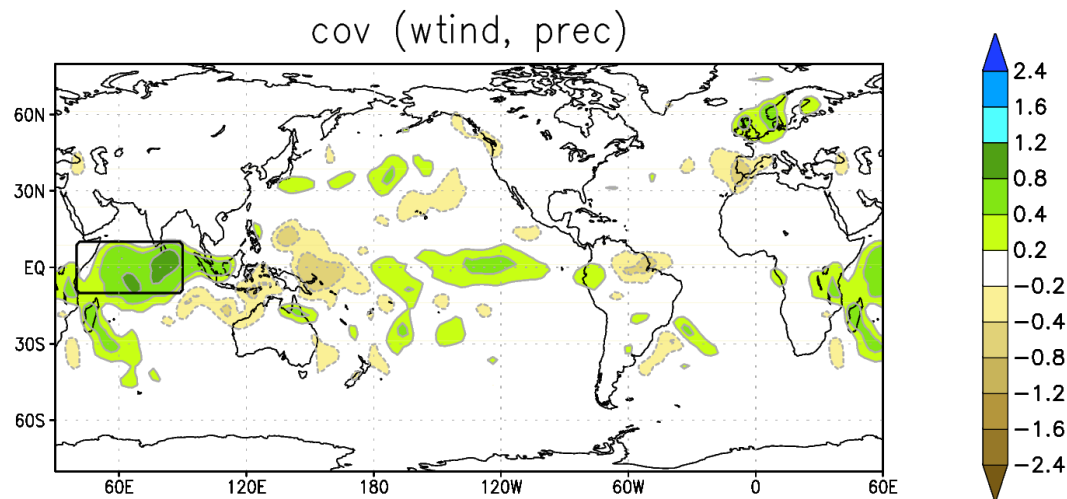
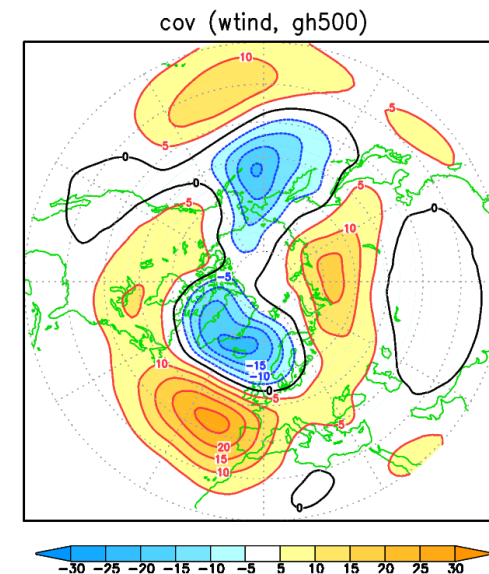
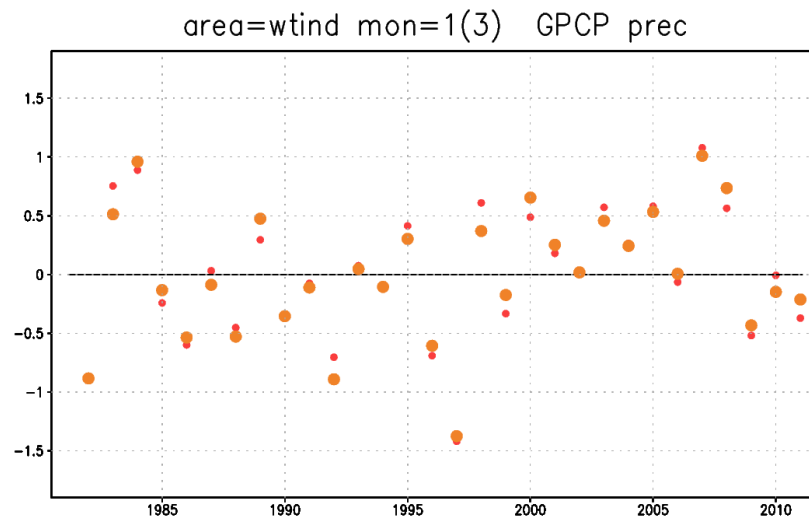




W. Indian Oc. teleconnections, ENSO removed

Full precip
anomaly

Anomaly
orthogonal
to Nino3.4 SST

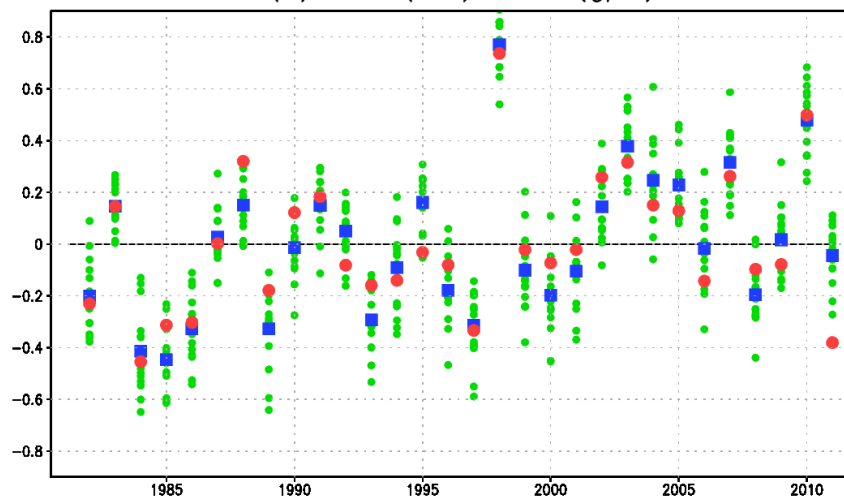




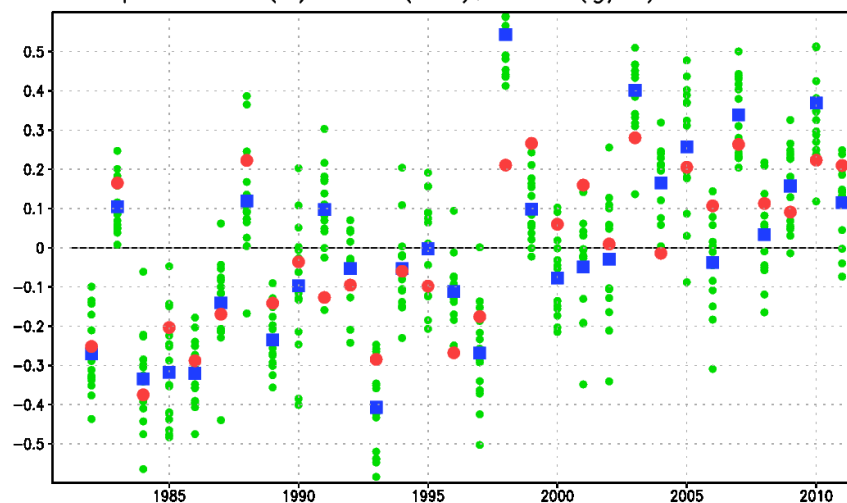
Predictive skill for W.Ind and E.Ind-W.Pac SST/precip

SST

wtind mon=1(3) ERA(red), SYS4(g/b) ac=0.910

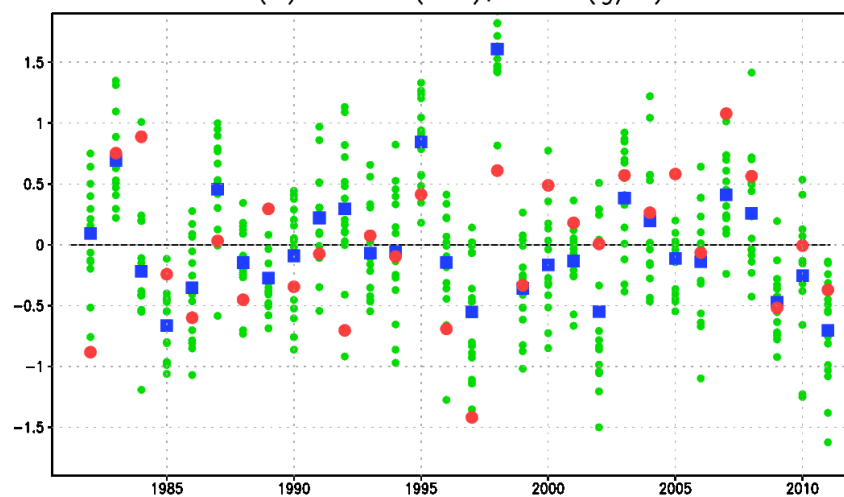


eiwp mon=1(3) ERA(red), SYS4(g/b) ac=0.842

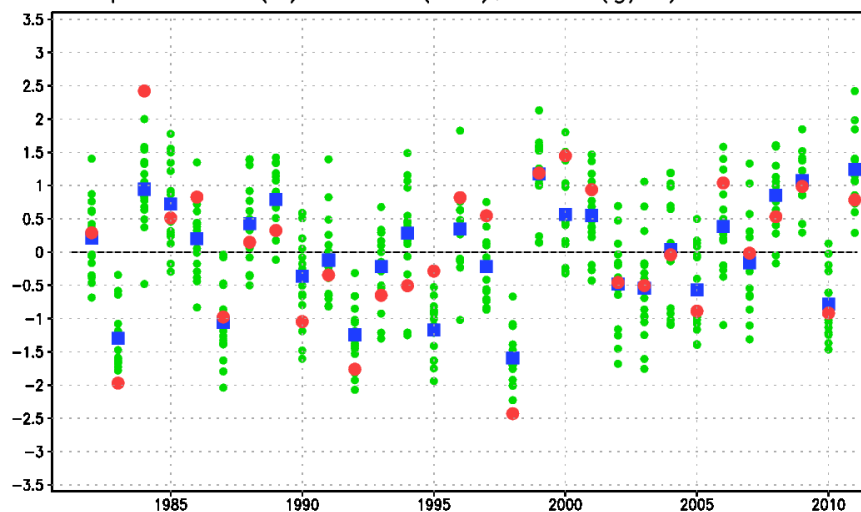


prec

wtind mon=1(3) GPCP(red), SYS4(g/b) ac=0.489



eiwp mon=1(3) GPCP(red), SYS4(g/b) ac=0.861



MJO impact on DJF precipitation in EPS (Vitart & Molteni 2010)

Wheeler-
Hendon 2004

Phase 2-3

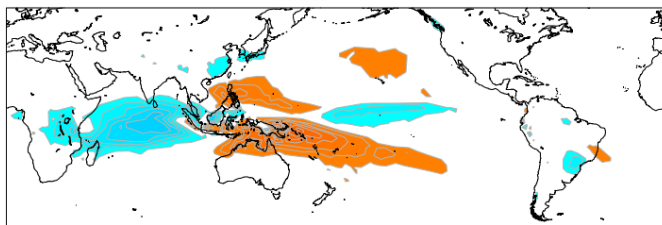
Phase 4-5

Phase 6-7

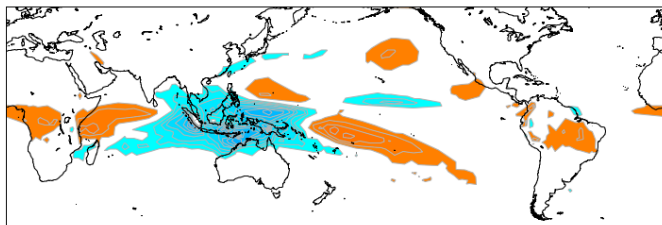
Phase 8-1

EPS

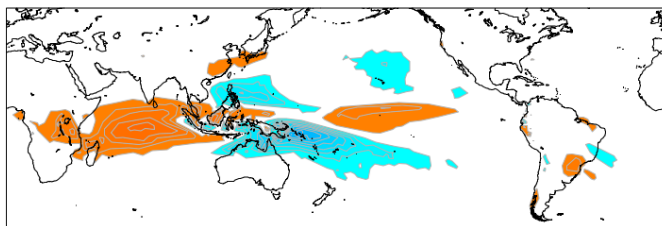
A) Model Phase 23



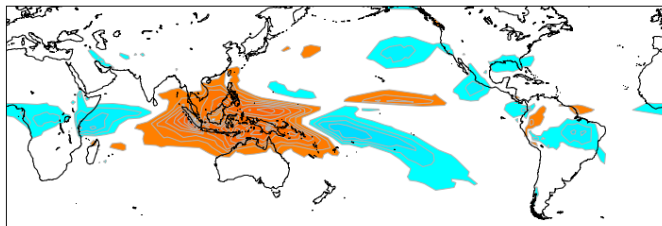
B) Model Phase 45



C) Model Phase 67

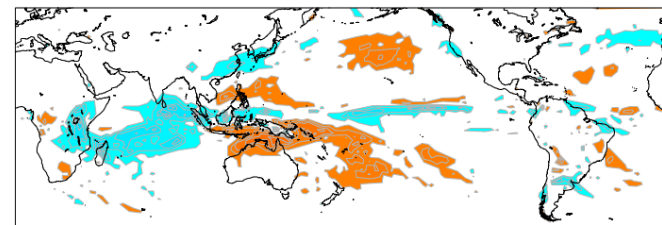


D) Model Phase 81

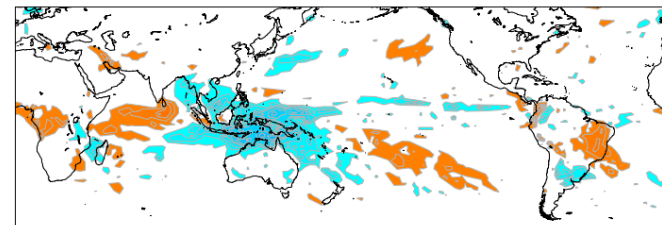


ERA-Interim

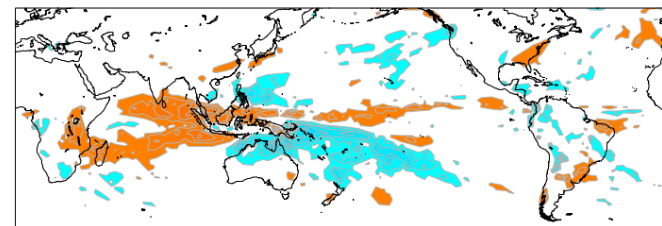
E) ERA Phase 23



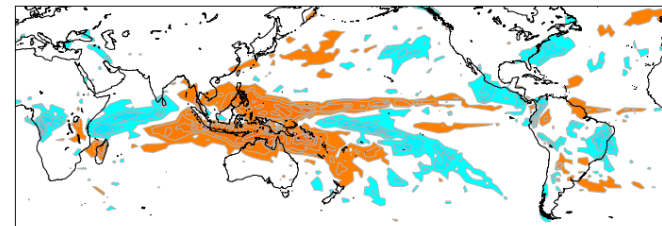
F) ERA Phase 45



G) ERA Phase 67



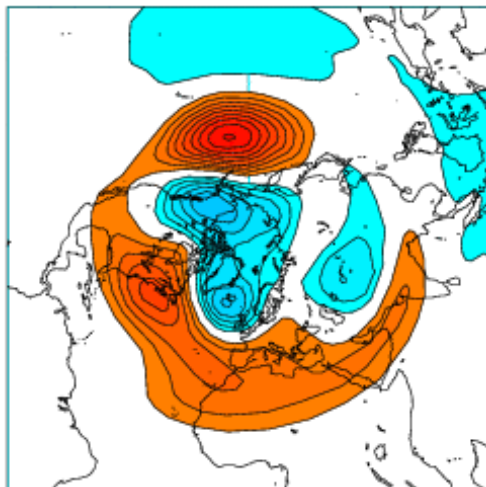
H) ERA Phase 81



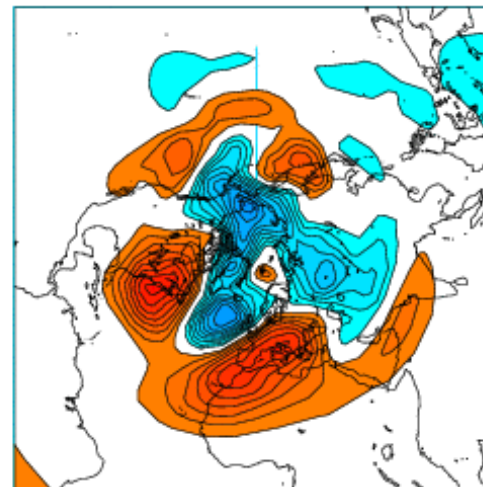


MJO impact on DJF Z_500hPa in EPS (Vitart & Molteni 2010)

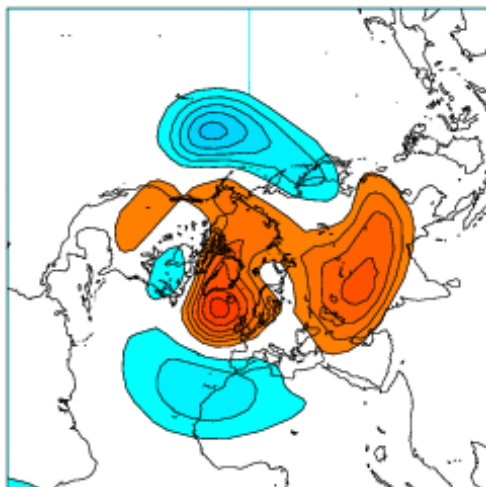
MODEL Phase 3 + 10 days



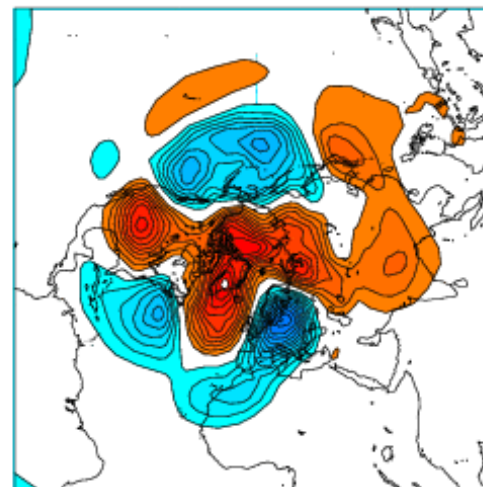
ERA Phase 3 + 10 days



MODEL Phase 6 + 10 days



ERA Phase 6 + 10 days

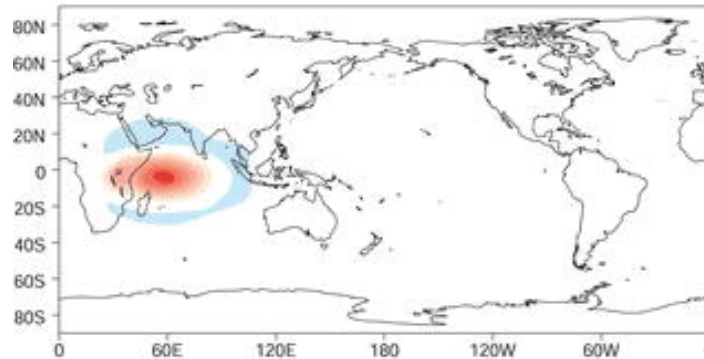




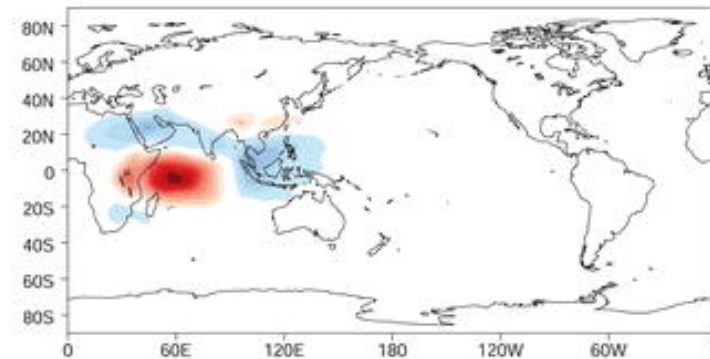
Response to WIO heating, Annamalai et al. 2007

200 hPa divergence response in a linearized PE model

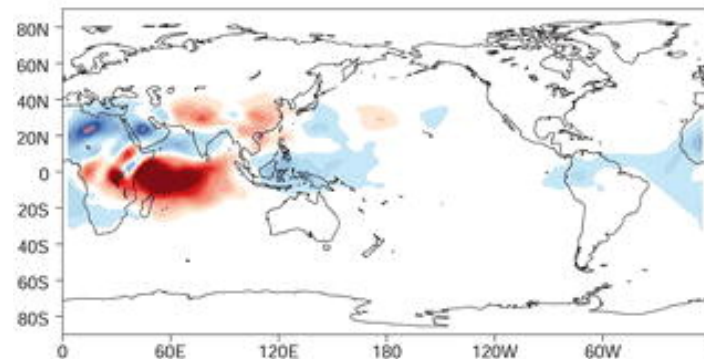
(a) $t = 1$ day



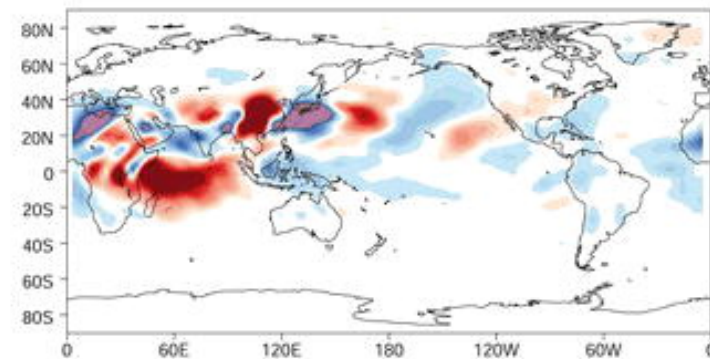
(b) $t = 2$ days



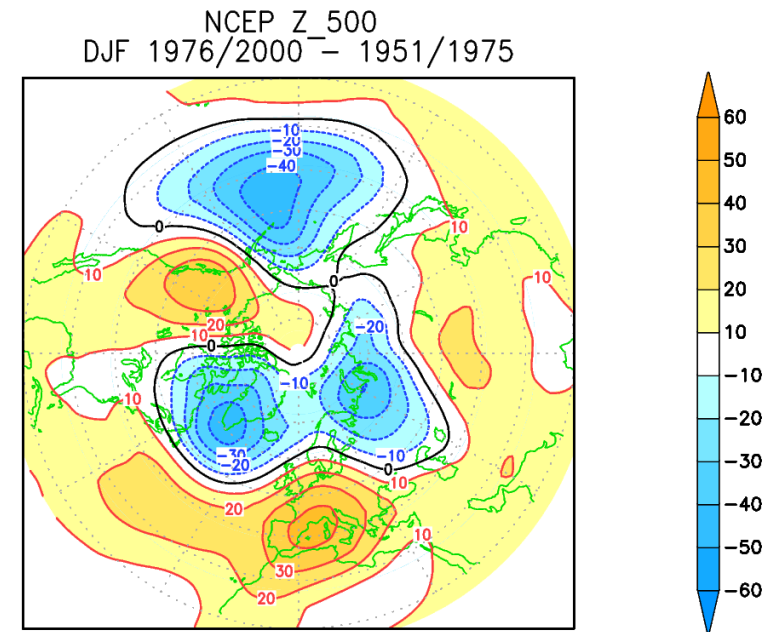
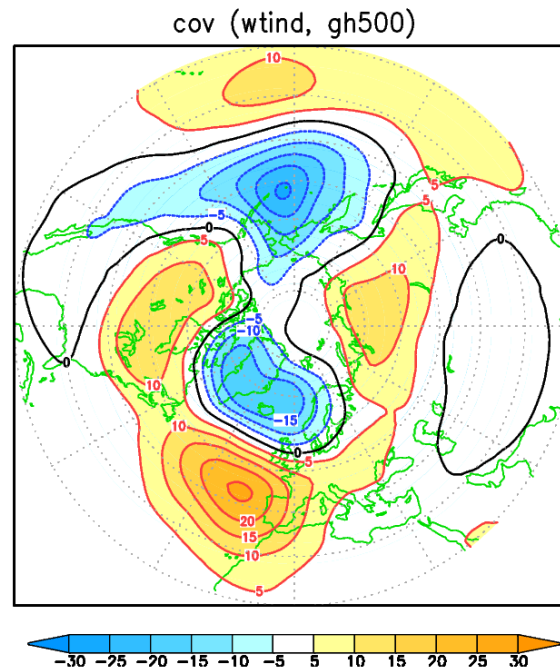
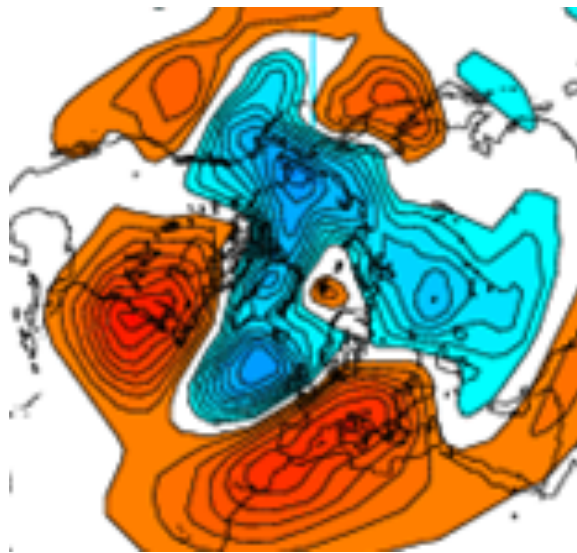
(c) $t = 7$ days



(d) $t = 15$ days



A planetary-wave signal common to different time scales?



Z 500hPa anomaly

MJO phase3 + 10d

DJF W. Indian Oc. Rain

20th C. decadal variability

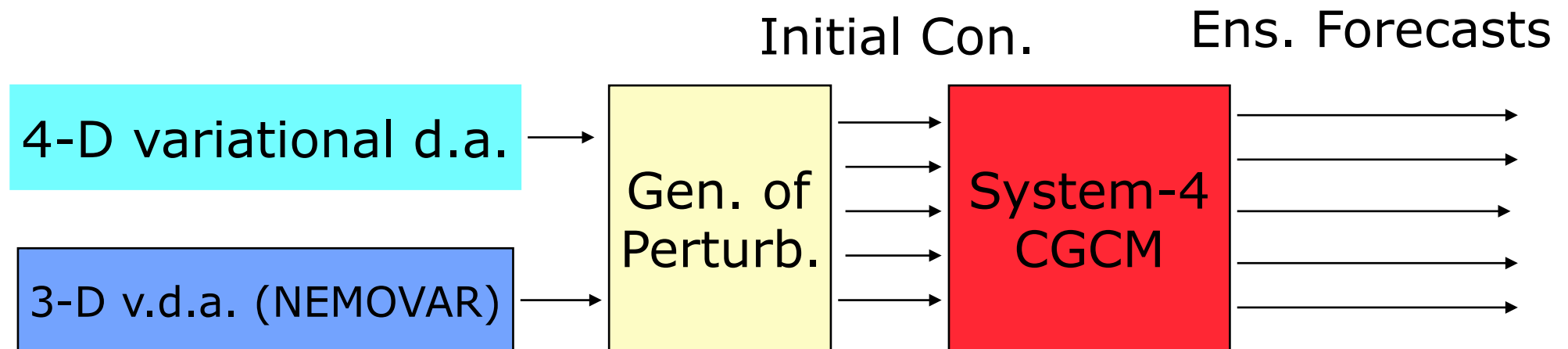
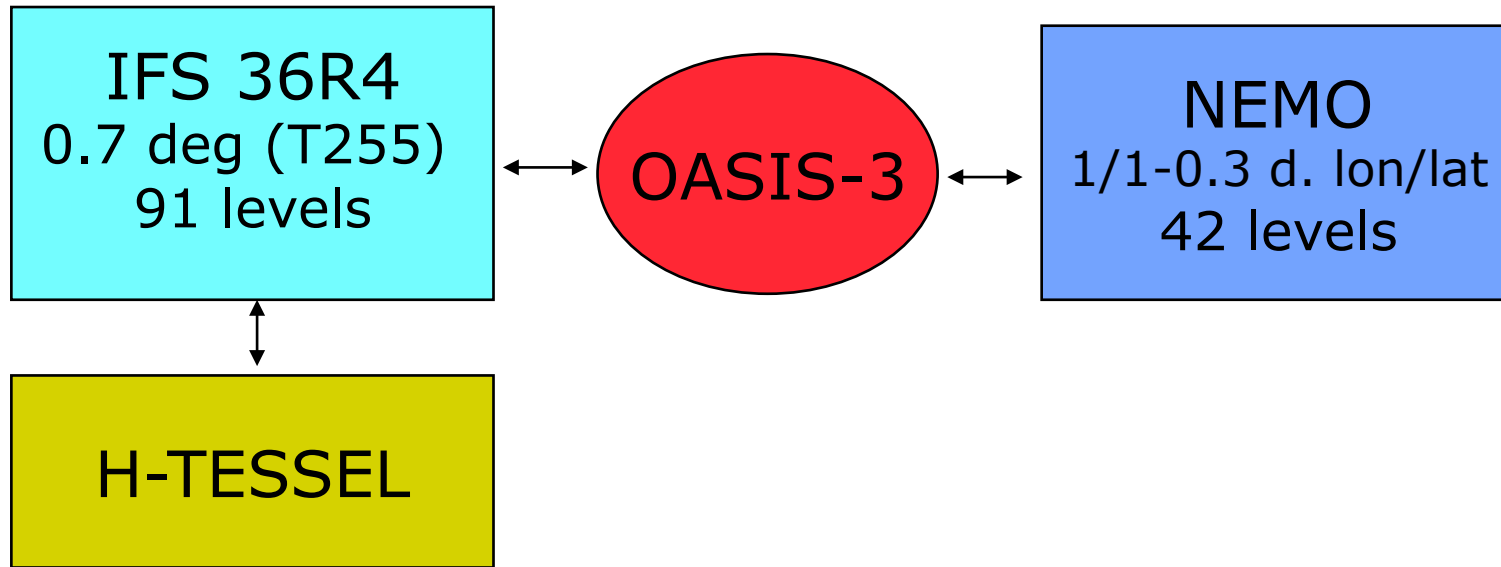


Conclusions

- Indo-Pacific teleconnections during the northern winter cannot be understood simply on the basis of the “SST forces the atmosphere” framework; results from AGCM exp. should be taken with caution.
- Differences between Western and Eastern trop. Indian ocean still exist during winter in terms of rainfall anomalies and rain-SST correlation.
- A 3-modal anomaly in the Walker circulation (and rainfall) can be forced either from either the western or the eastern side of the Indo-Pacific domain; over the tropical E. Indian - W. Pacific ocean, SST-rainfall correlation is weak or negative.
- Looking at Indo-Pacific teleconnections in relation to rainfall anomalies (rather than SST) produces more coherent results:
 - between observational and model data;
 - across different time scales (intraseasonal – interannual – interdecadal)
- Periods with increased rainfall over the Western Indian Ocean and reduced rainfall over the equat. E. Indian – W. Pacific are associated with a COWL-like, +NAO anomaly in N.Hem. geopotential height.



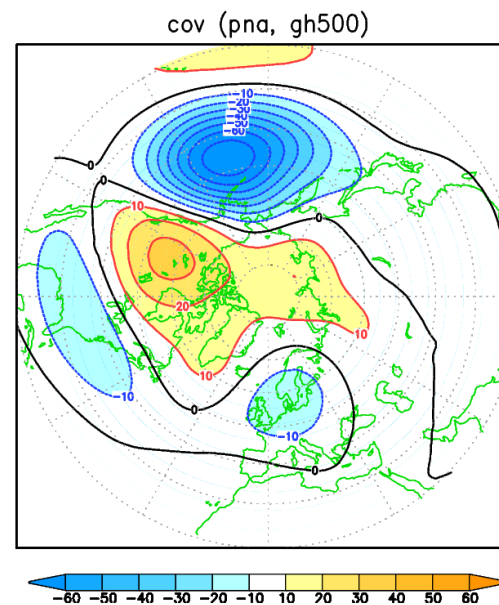
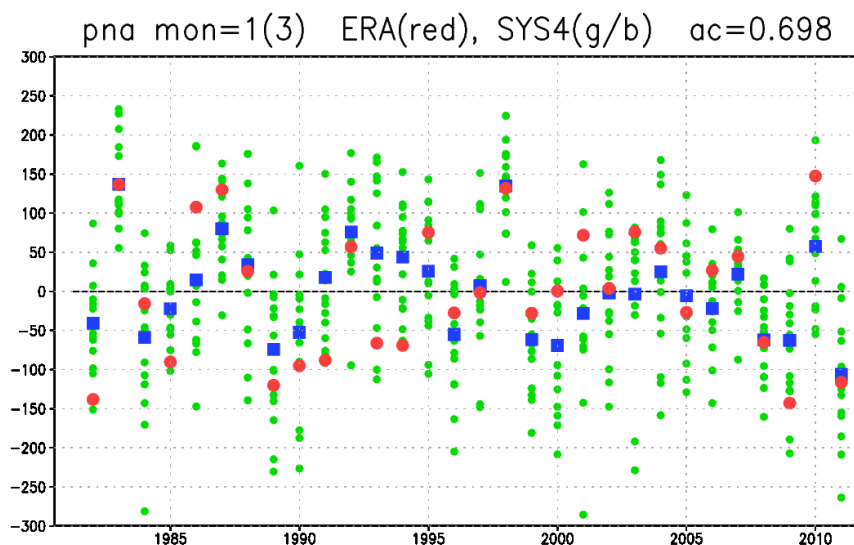
The new ECMWF Seasonal fc. system (Sys-4)



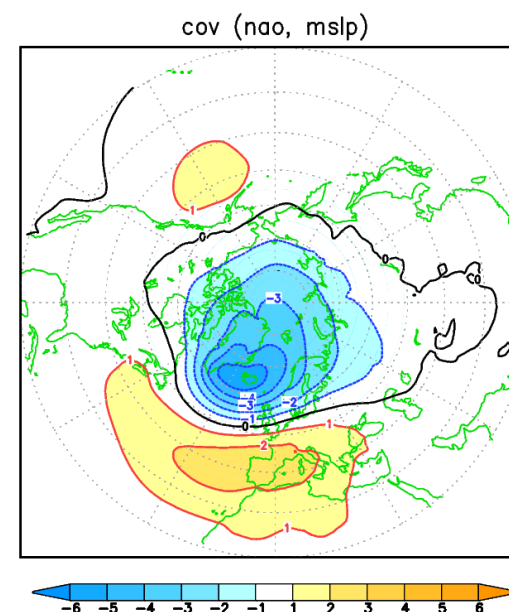
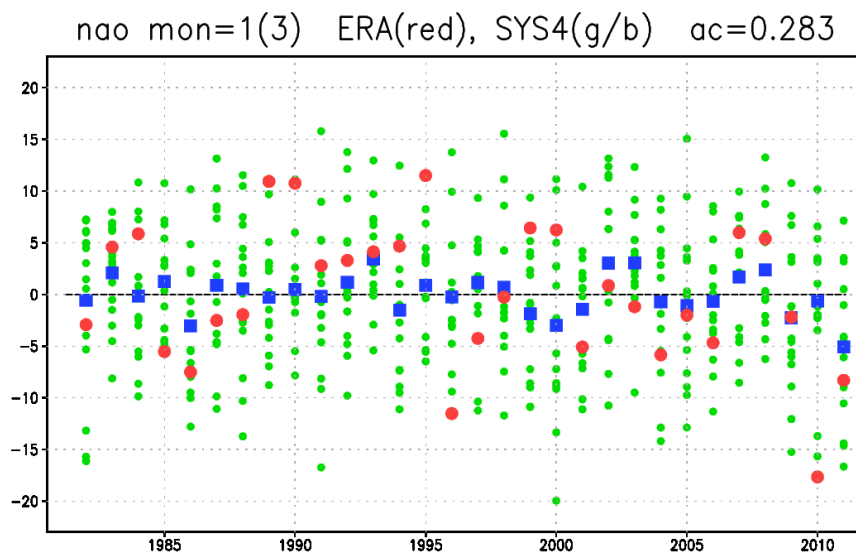


Predictability of teleconnections in Sys4: PNA, NAO (DJF)

PNA

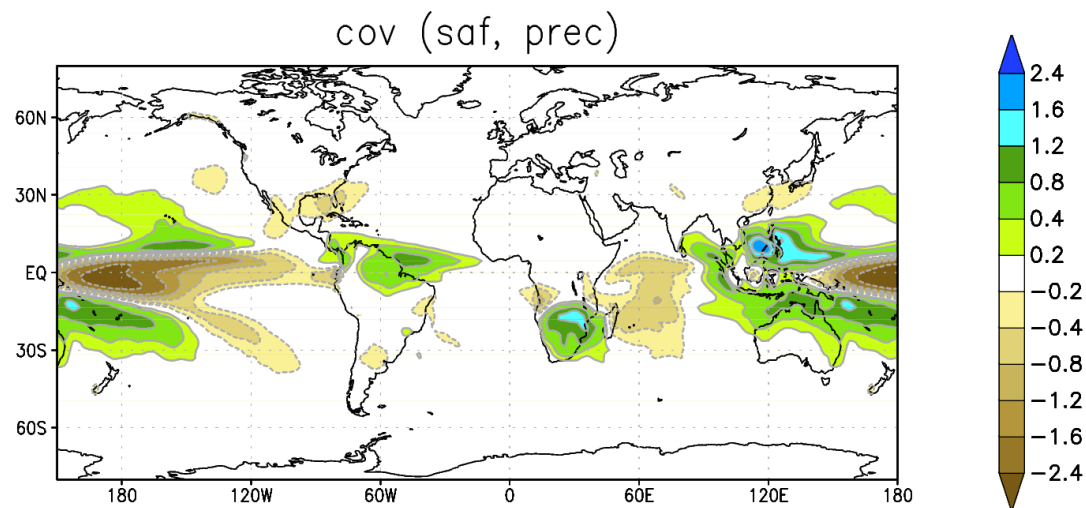
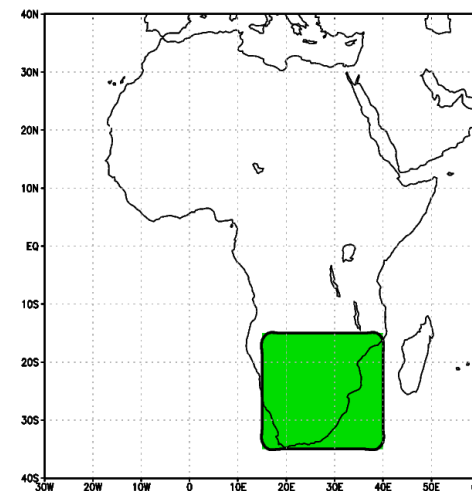
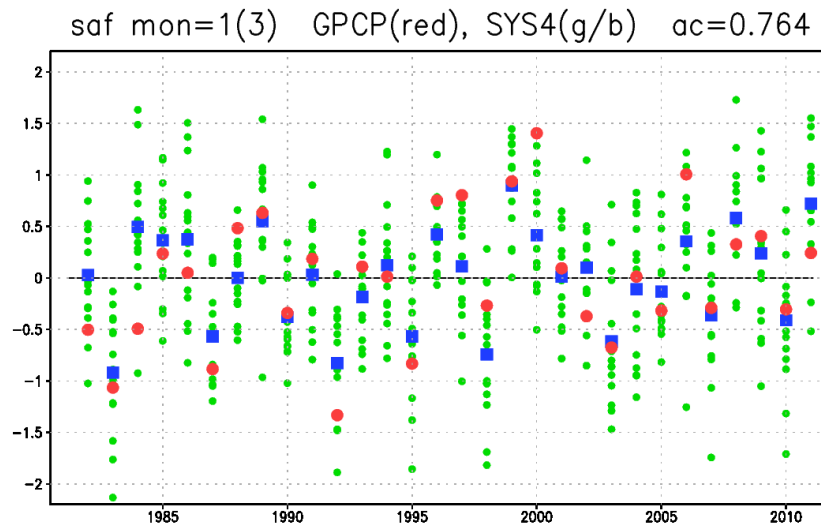


NAO

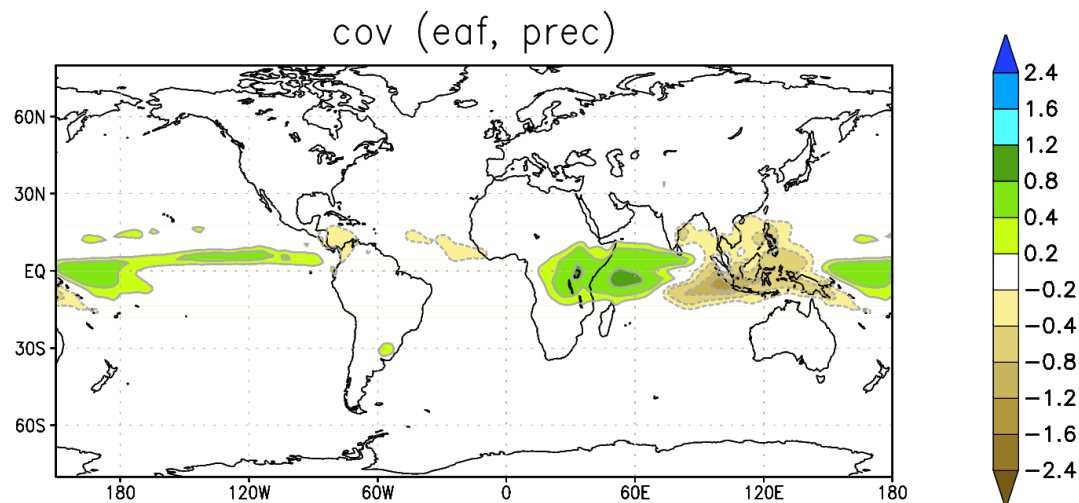
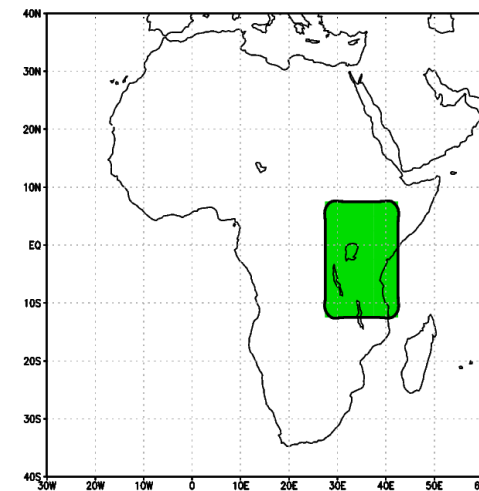
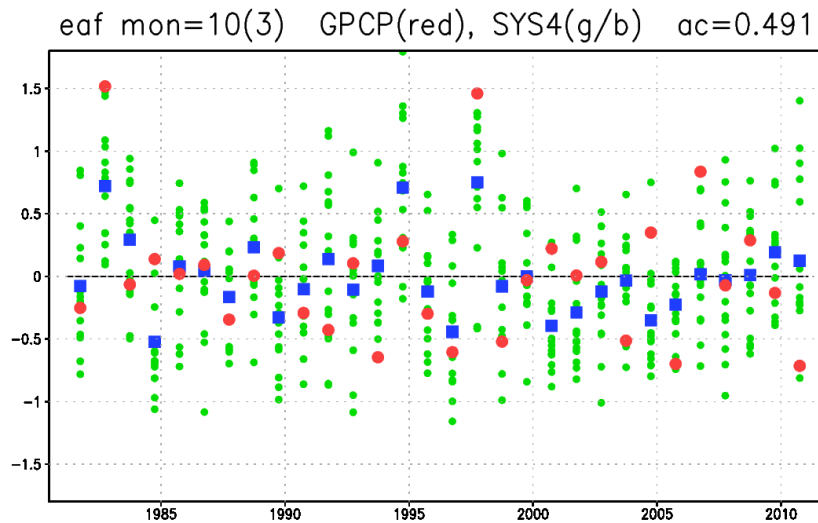




Predictability of telecon. in Sys4: South Africa rain (DJF)



Predictability of telecon. in Sys4: East Africa rain (SON)





Predictability of teleconnections in Sys4: Sahel rain (JJA)

