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Regional influences of ocean-atmosphere interaction on climate variability using partial coupling

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Introduction

- Sources of climate variability include
  - intrinsic atmospheric variability
  - atmospheric response to ocean variability
  - coupled ocean/atmosphere interactions
- Attribution difficult in fully coupled simulations
- Objective: distinguish regional contributions of air-sea coupling to climate variability and predictability through model runs using *partial coupling* in specified regions
- Multimodel study (CCCma CGCM3.7 and SINTEX-F)
- Look at (i) Seasonal/Interannual and (ii) Subseasonal var.
- Preliminary results presented here

Models

- CCCma CGCM3.7

-
  - AGCM3 (T63L31), filtered physics
  - OGCM3.7 1.4° lon × 0.94° × lat L33
    (Δz = 15 m in upper ocean), anisotropic viscosity,
    KPP mixed layer, penetrative solar radiation

- SINTEX-F

  - AGCM *(MPI, Germany)* : ECHAM4 (T106L19)
  - OGCM *(LODYC, France)* : OPA8 (2° x 0.5°~2°, L31)
  - Coupler *(CERFACS, France)* : OASIS2

Partial coupling

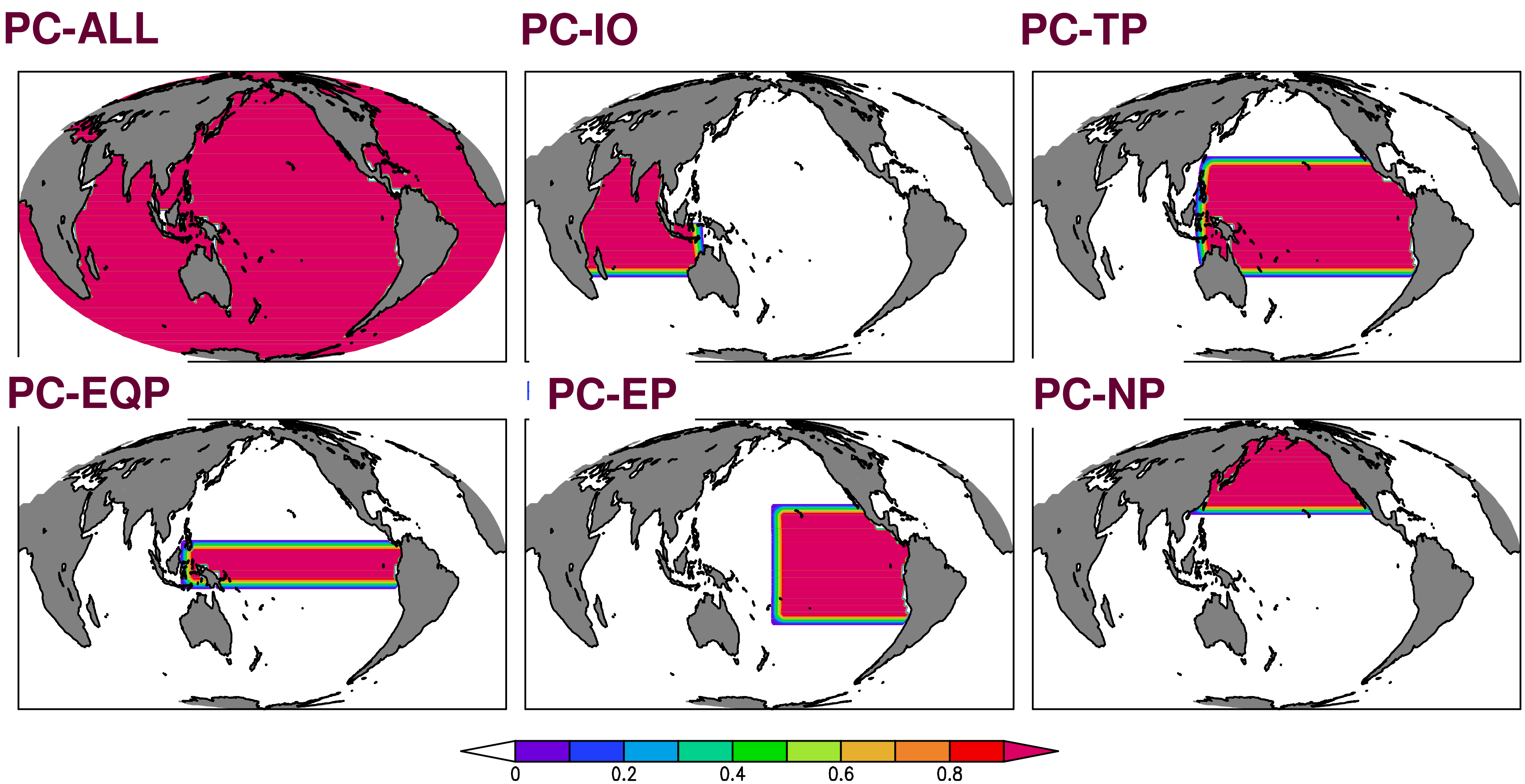
- Atmosphere sees *specified* SSTs instead of interactive SSTs in specific regions

- Specified SSTs consist of model climatological SSTs obtained from a fully coupled control run (→ SSTA = 0)

- Results presented here are based on 50 years of model output:
  - years 21-70 (discard first 20 years)
  - CCCma runs ongoing

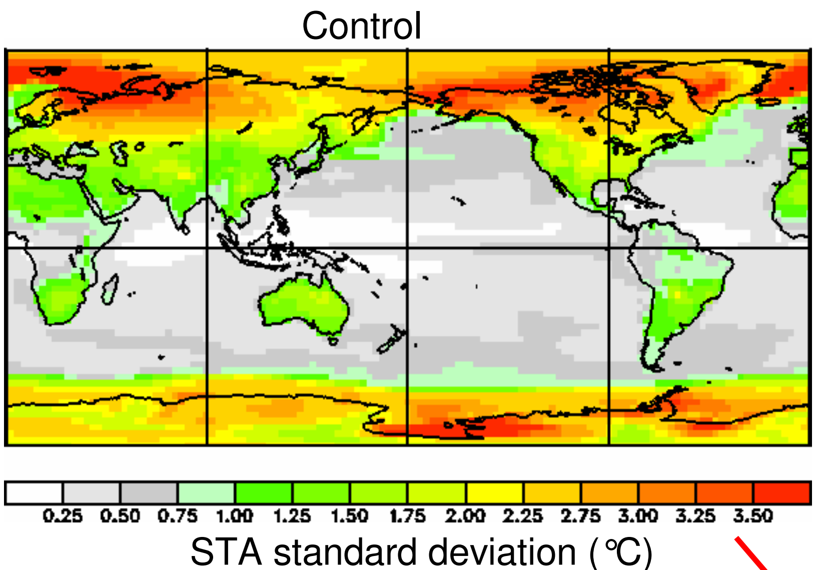
- Examine impacts on climate variability first (potential *predictability* to be considered later)

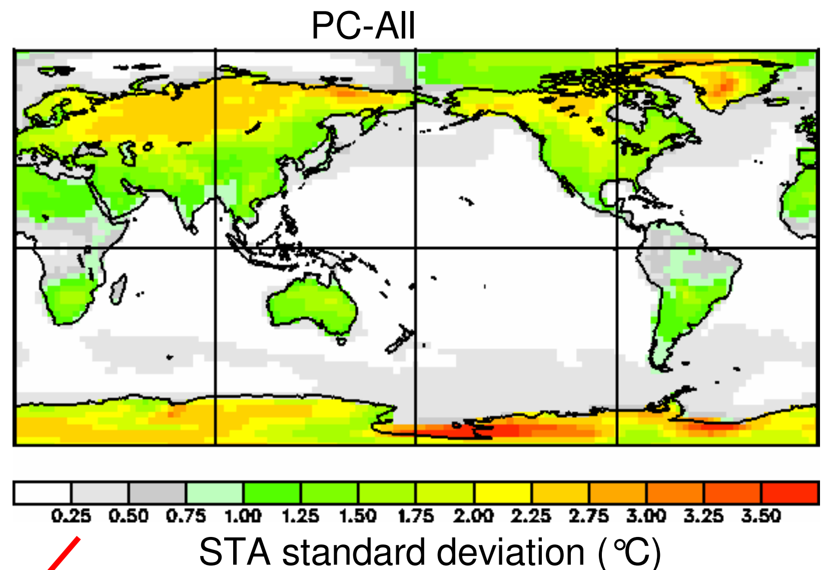
Partial Coupling Experiments

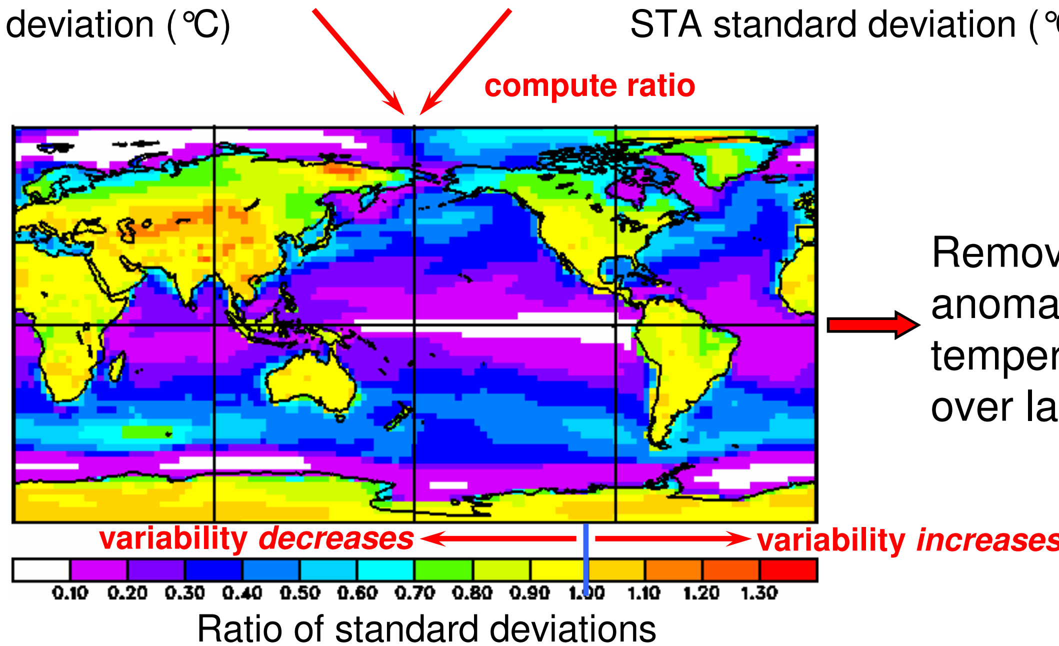


I. Seasonal/Interannual Variability in CGCM3.7

Example 1: Effect of SSTA on standard deviation of monthly surface temperature anomalies

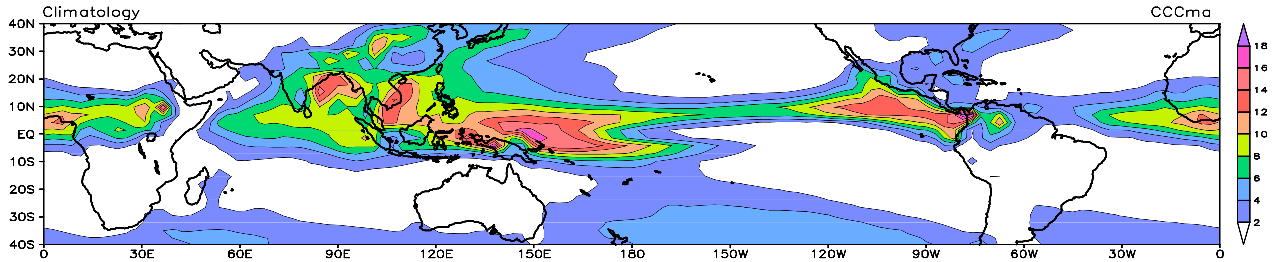




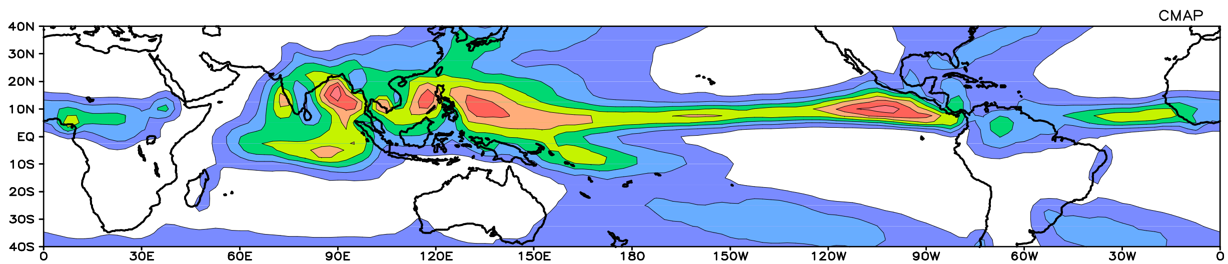


Removal of SST anomalies damps temperature variability over land

Summer Tropical Precipitation Climatology: Skill of the model

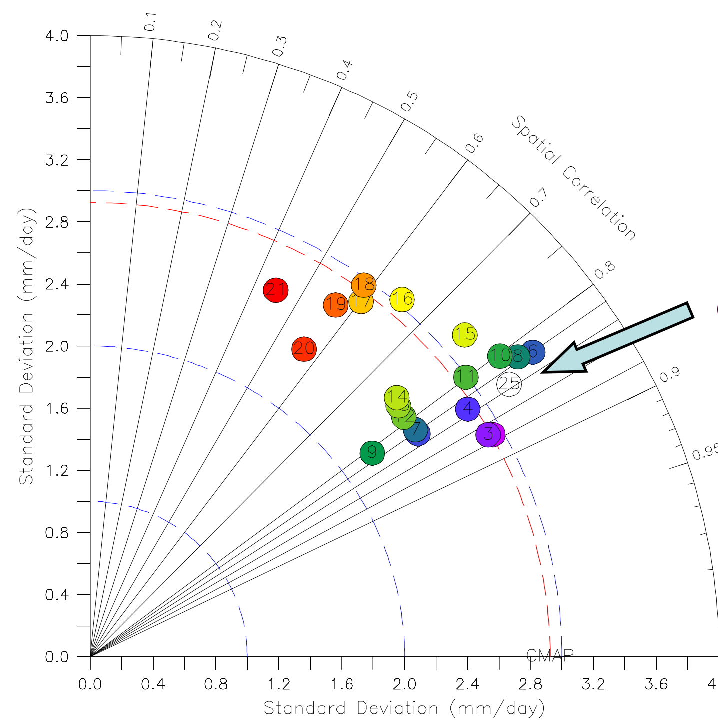


Model



Observations

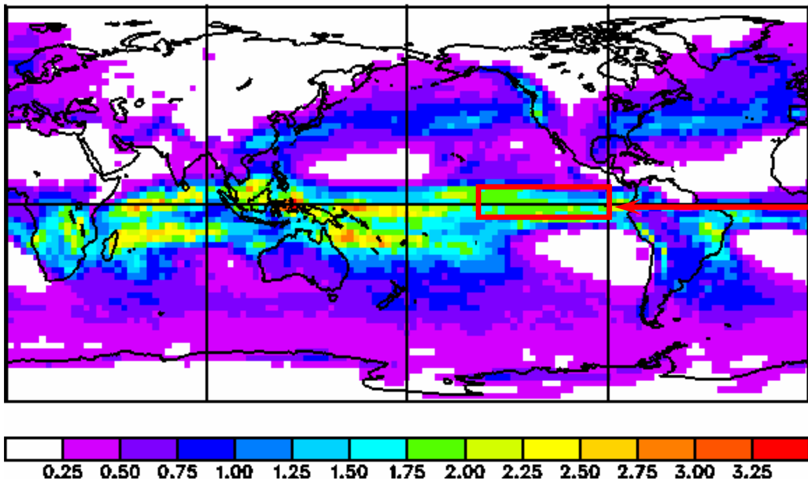
CGCMs	No:	CGCMs	No:
cccma_cgcm3_1_t63	2	giss_aom	14
cccma_cgcm3_t47	3	miroc3_2_hires	15
mri_cgcm2_3_2a	4	inmcm3_0	16
miub_echo_g	5	csiro_mk3_5	17
mpi_echam5	6	ncar_pcm1	18
ingv_echam4	7	ncar_ccsm3_0	19
gfdl_cm2_0	8	csiro_mk3_0	20
iap_fgoals1_0_g	9	ipsl_cm4	21
gfdl_cm2_1	10	giss_model_e_r	22
miroc3_2_medres	11	giss_model_e_h	23
cnrm_cm3	12	bcc_cm1	24
bccr_bcm2	13	CNTRL	25



CNTRL

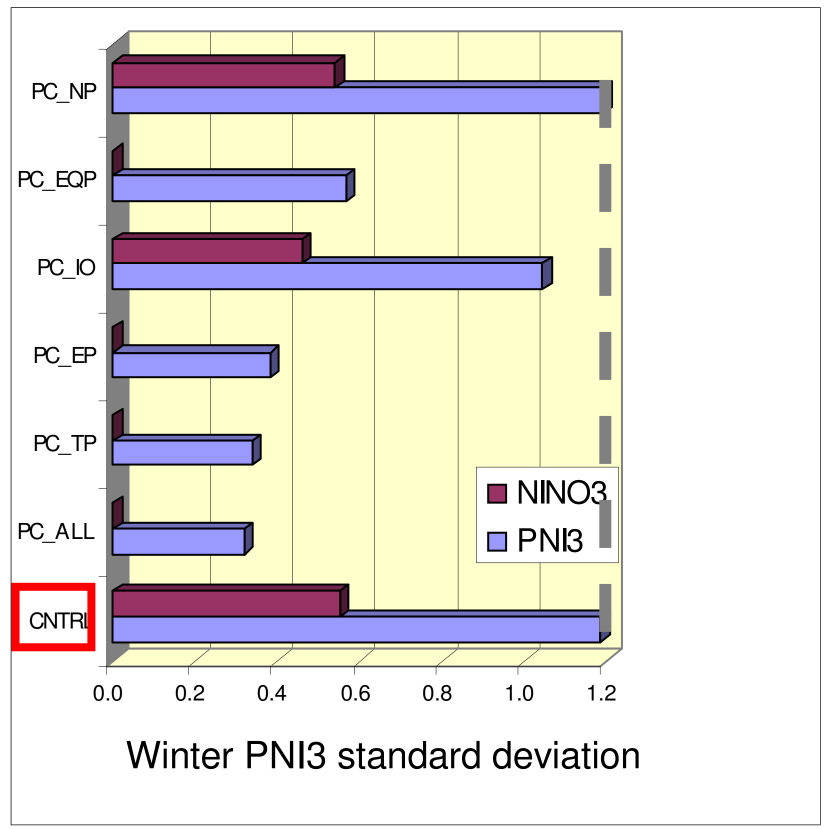
Example 2: Variability of equatorial Pacific annual precipitation

Control



Winter precipitation standard deviation (mm/day)

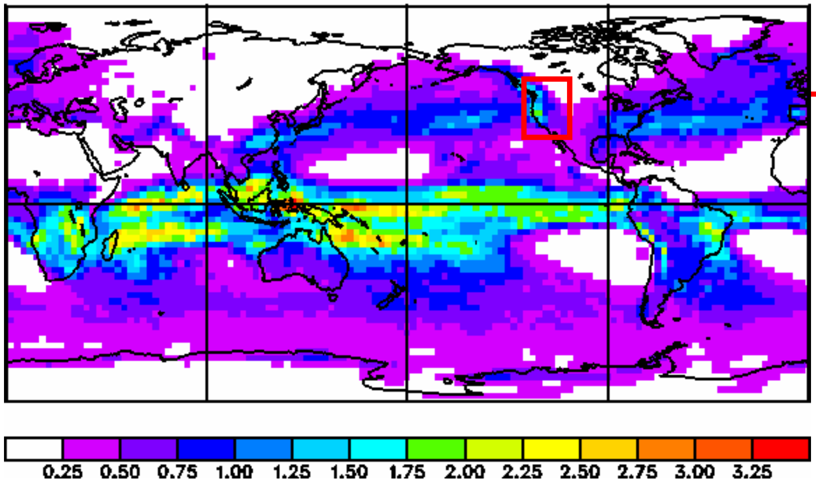
NINO3 region Precipitation (PNI3)



Strong ***local control*** of precipitation anomalies by SSTA (SSTA account for ~75% of variability)

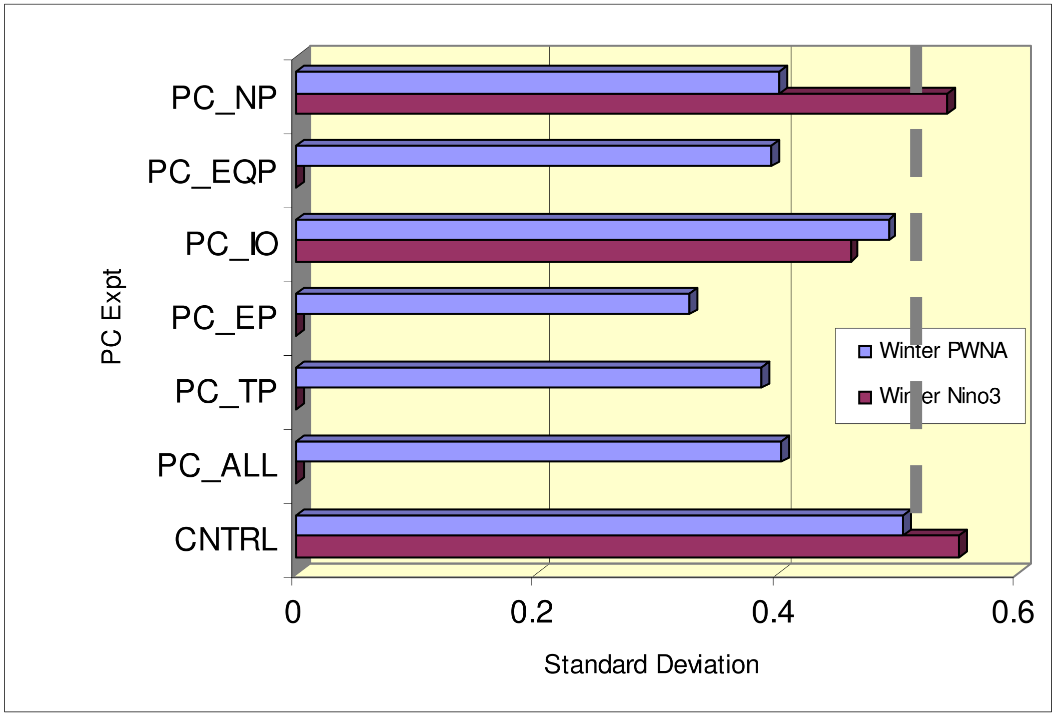
Example 3: Variability of western North America winter precipitation

Control



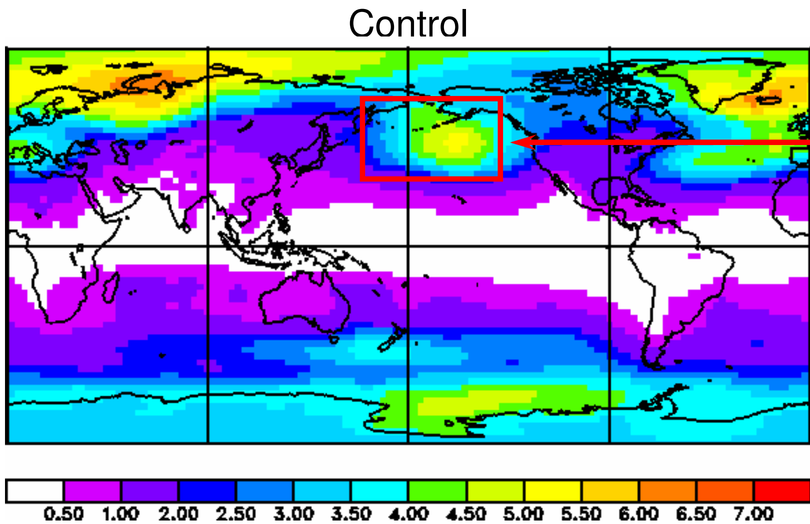
Winter precipitation standard deviation (mm/day)

Western North America
Precipitation (WNAP)



Variability decreases by 20-30% in absence of ENSO, North Pacific SST anomalies

Example 4: Variability of Aleutian Low

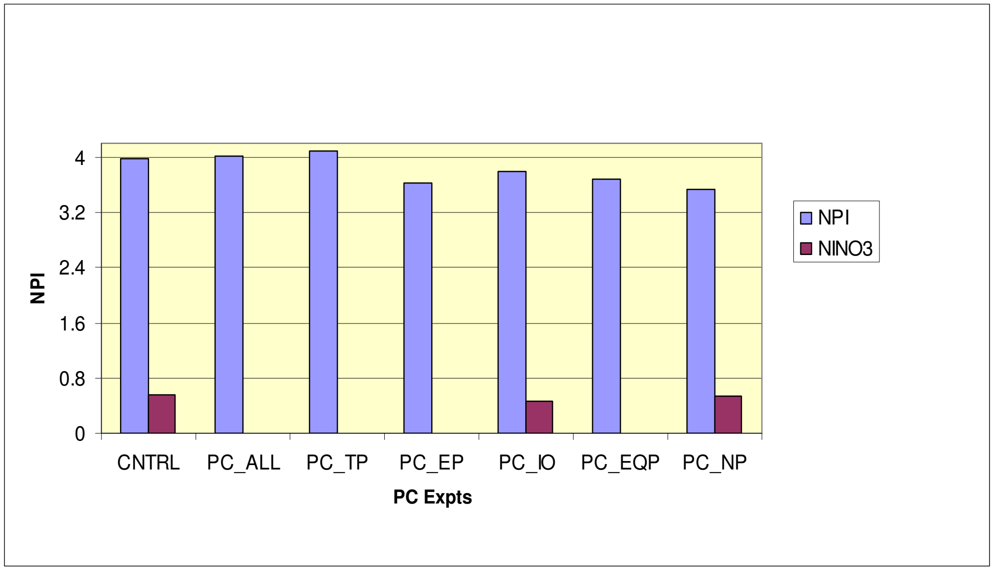


Winter surface pressure standard deviation (mb)

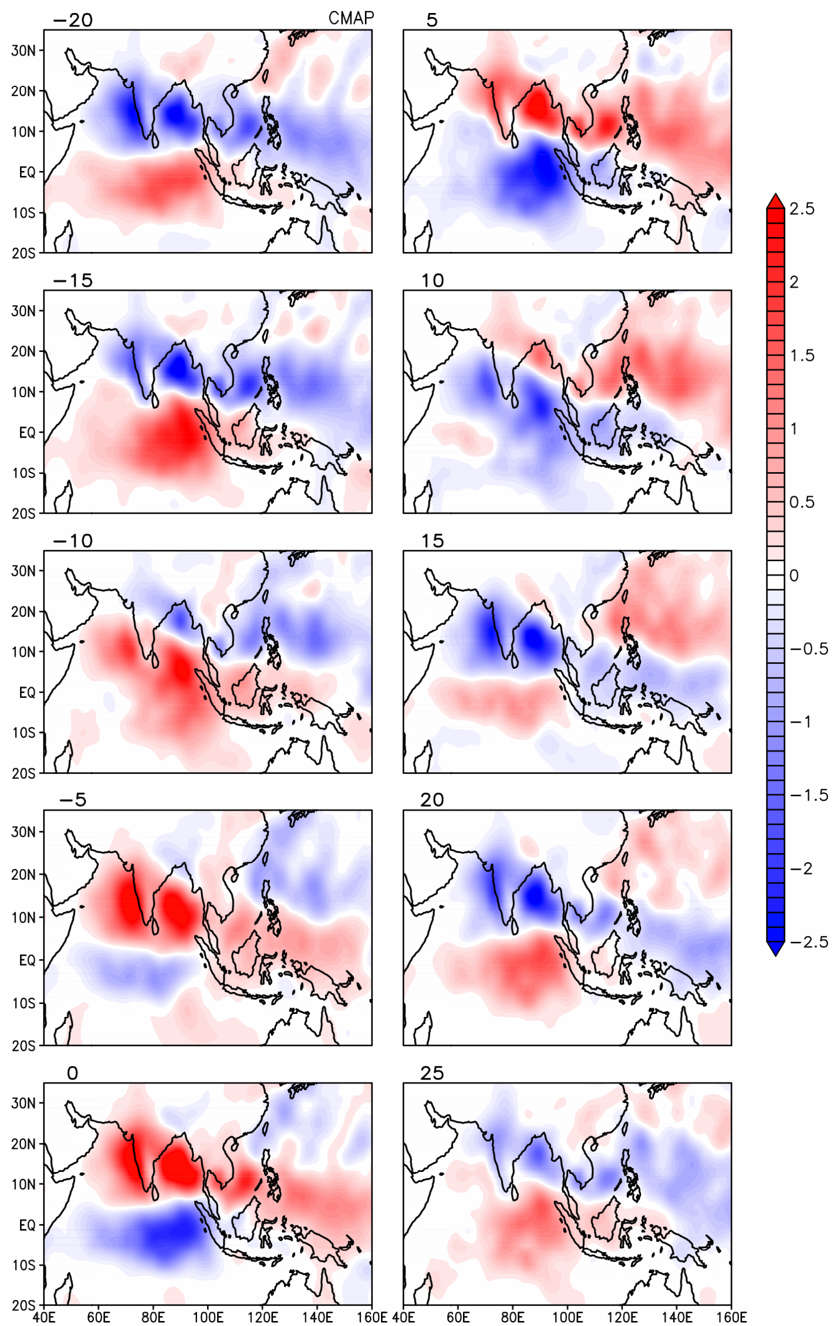
North Pacific Index (NPI)

Corr(winter NPI, winter NINO3)= -0.55

Winter NPI variability does not decrease when there is no ENSO!



II. Sub-seasonal Variability in SINTEX-F



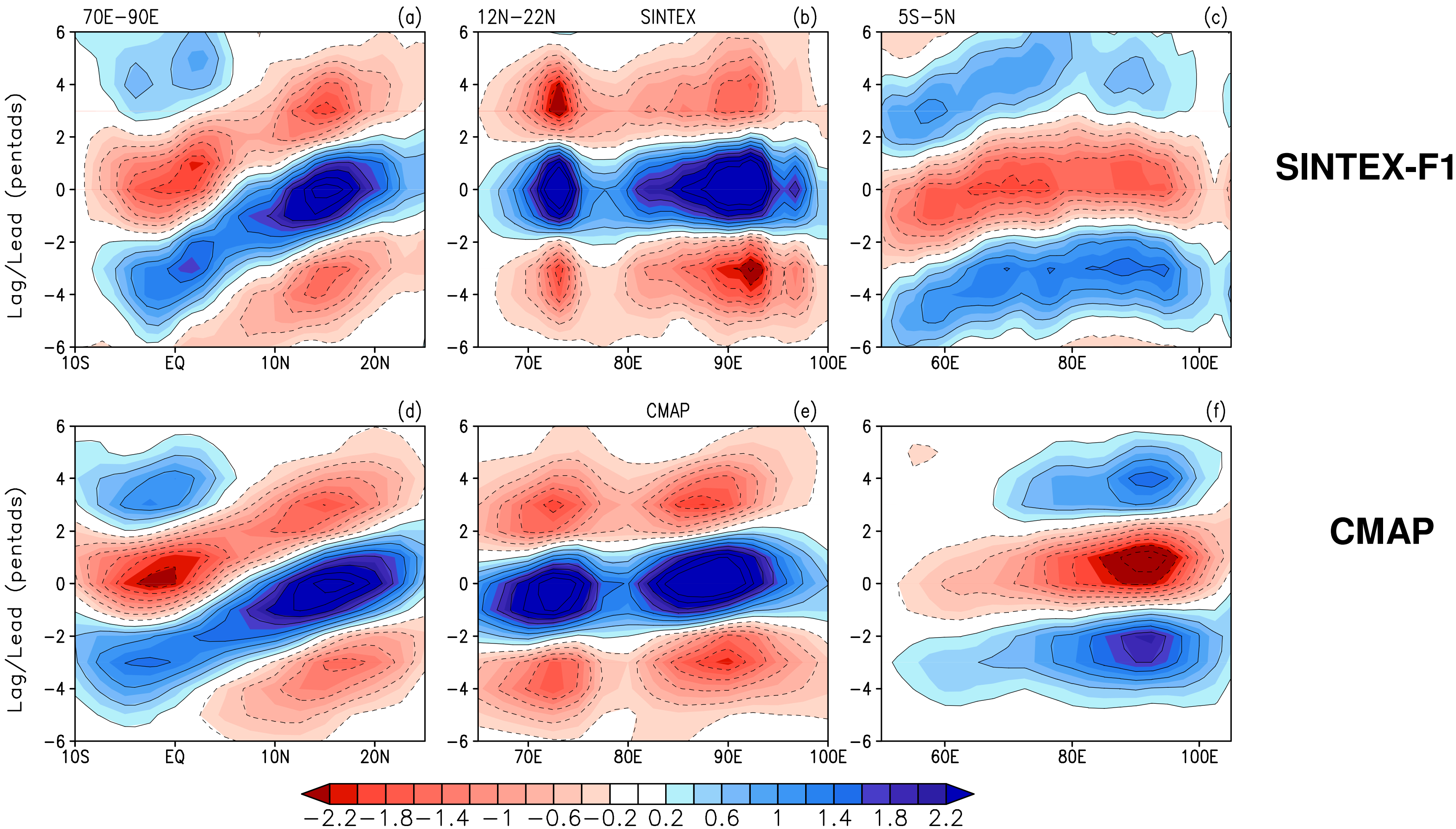
Northward propagating MJO in the Indian Ocean:

Also termed as Boreal Summer Intraseasonal Oscillations (BSISO)

- BSISO Characteristics:

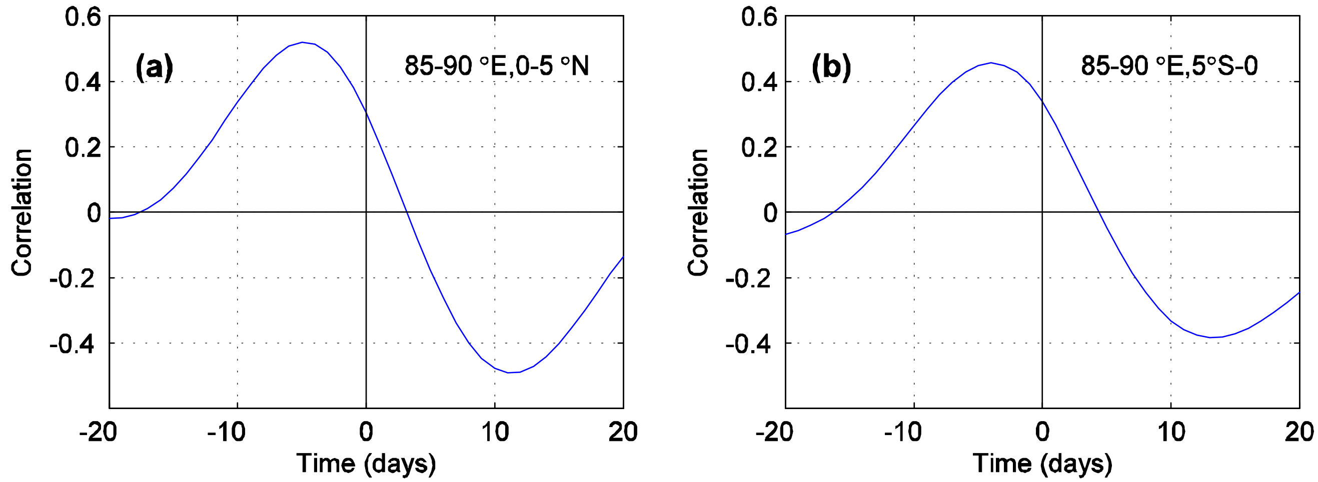
Note the clear northeastward propagation of precipitation anomalies.

Simulation of BSISO Characteristics by SINTEX-F1



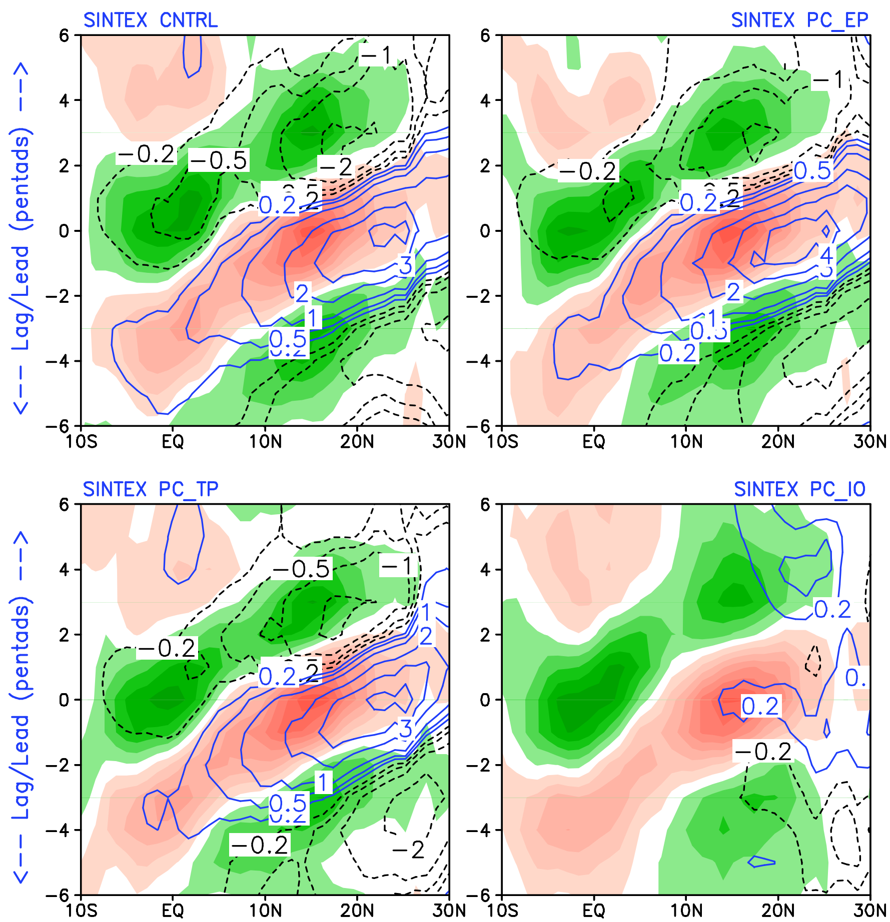
Regressed filtered anomalies of precipitation (mm.day^{-1}) averaged over the domain mentioned above. Regression is calculated with respect to a base region 70-90E;12-22N.

SST-Precipitation Lead-Lag Correlation



To what extent do local and remote air-sea interactions govern BSISO?

(Air-sea interaction plays a crucial role in guiding the poleward propagating MJO (Fu et al., 2002, 2003, Wang et al, 2006, etc)



Poleward Propagating MJO in the Indian Ocean

- Shading: Precipitation Anomalies
- Contour: SST Anomalies

Even without an SST lead, precipitation propagates poleward !

Summary

- Partial coupling procedure enables effects of local and remote air-sea interactions to be distinguished from intrinsic atmospheric variability.
- Initial results presented here (will be evaluated for long runs)
- ENSO SSTA are responsible for much (but not all) of precipitation variability both locally (in tropical Pacific) and remotely (e.g. western N America)
- Though ENSO correlated with Aleutian Low variability, *amount* of variability similar without ENSO.
- Air-sea interaction appears to be not so crucial in guiding the poleward propagating MJO.

Ongoing work

- Longer time series, Initial results presented here.
- Diagnostic measures of *potential predictability, in different cases.*
- Comparison with CGCM3.8 which has a stronger ENSO.

Mechanism for poleward propagation

- Several theories and hypothesis were proposed in the past to explain poleward propagation. [*Review articles in Lau and Waliser, and references therein*]

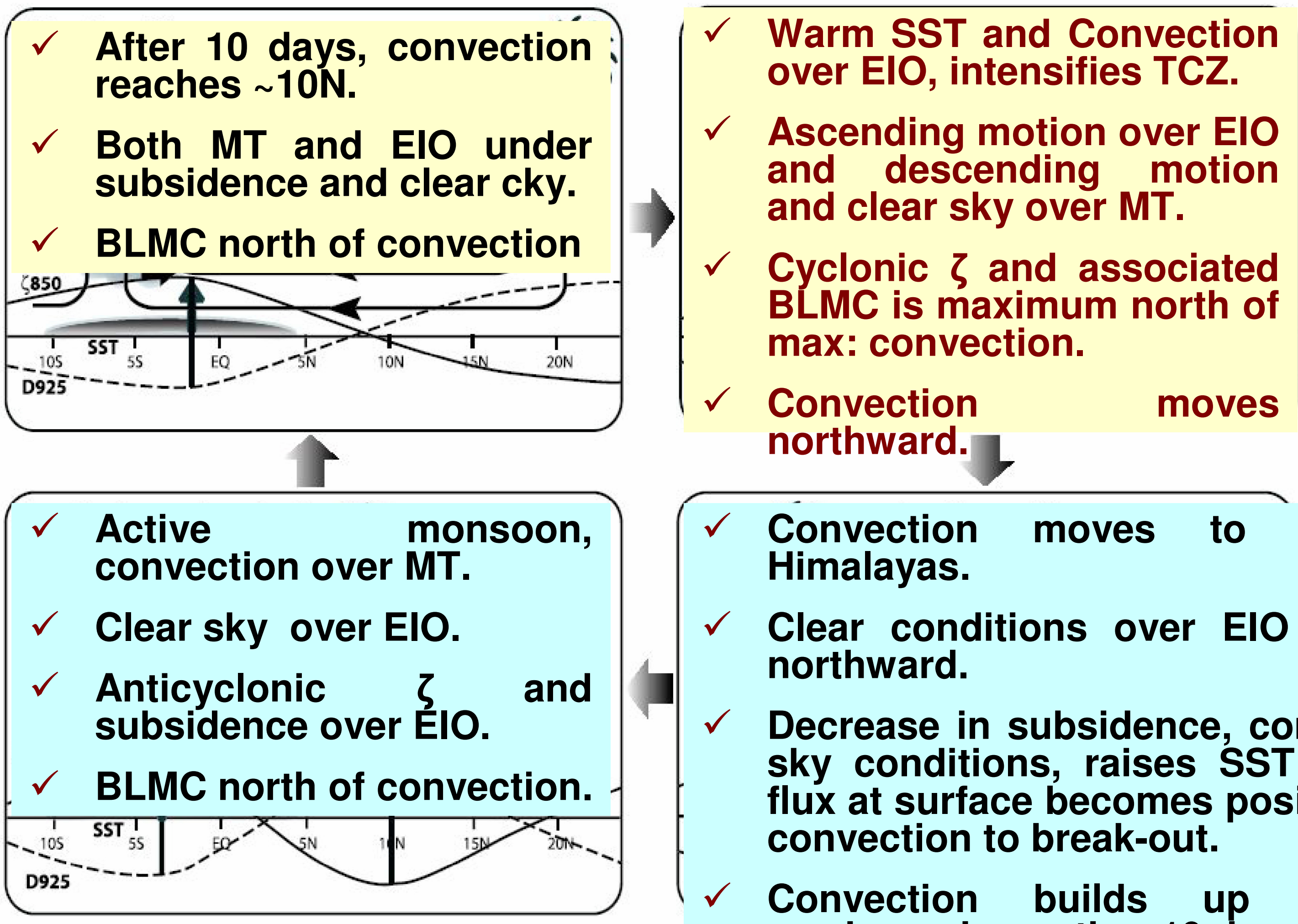
- Cyclonic vorticity at low-levels and associated boundary layer convergence must be maximum north of convection maximum to initiate poleward propagation of BSISO.

- Summer mean flow and mean boundary layer humidity is the key factor.

- Large easterly vertical shear seen over monsoon region is an important factor, north of equator.

- Near the equator, asymmetric specific humidity contributes to the northward shift of the convection.

- Intraseasonal variation of SST. Warm (cool) SST ahead of enhanced (suppressed) convection.



- ✓ After 10 days, convection reaches ~10N.
- ✓ Both MT and EIO under subsidence and clear cky.
- ✓ BLMC north of convection

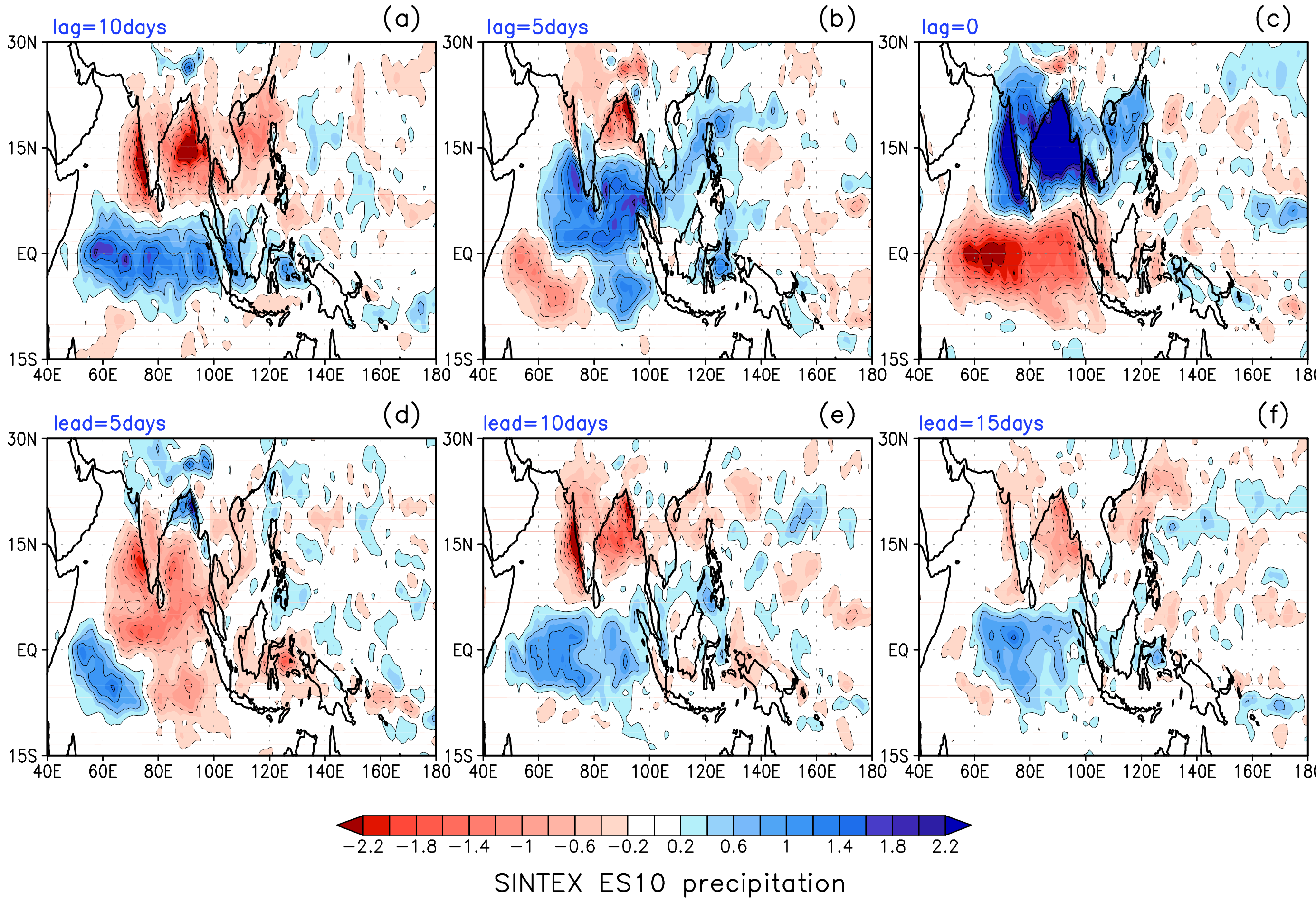
- ✓ Warm SST and Convection over EIO, intensifies TCZ.
- ✓ Ascending motion over EIO and descending motion and clear sky over MT.
- ✓ Cyclonic ζ and associated BLMC is maximum north of max: convection.
- ✓ Convection moves northward.

Why Convection Moves Northward ?

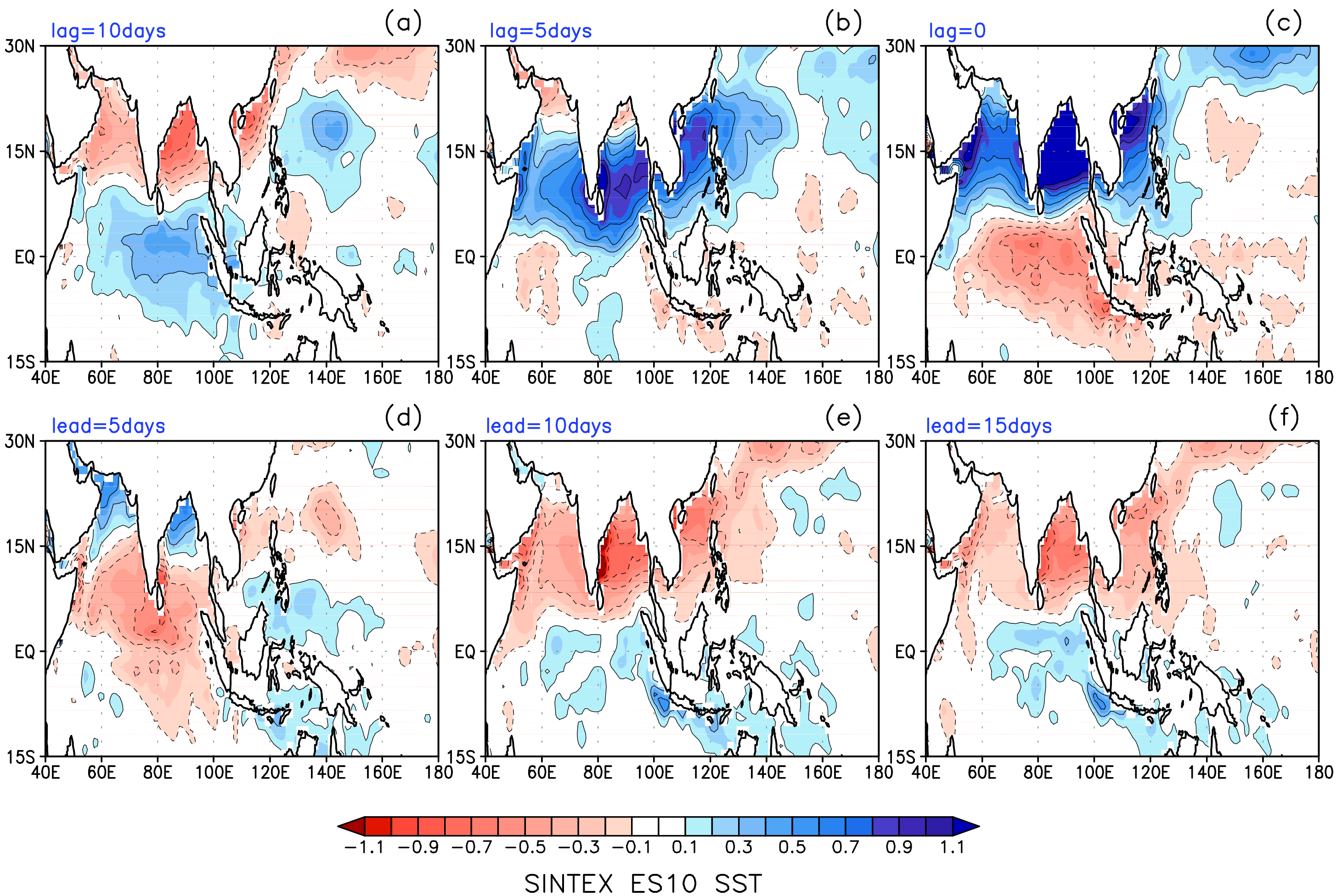
- ✓ Convection moves to foothills of Himalayas.
- ✓ Clear conditions over EIO also moves northward.
- ✓ Decrease in subsidence, continued clear sky conditions, raises SST as net heat flux at surface becomes positive, causing convection to break-out.
- ✓ Convection builds up to become maximum in another 10 days.

- ✓ Active monsoon, convection over MT.
- ✓ Clear sky over EIO.
- ✓ Anticyclonic ζ and subsidence over EIO.
- ✓ BLMC north of convection.

A schematic representation of the evolution and northward propagation of the meridional circulation associated with the 30-60 day mode in the meridional plane. The thin arrows indicate anomalous Hadley circulation. The thick vertical arrow indicates the location of the center of the boundary layer moisture convergence, while the thick horizontal arrow indicates the direction of poleward motion of the cloud band. The thin solid (dotted) line indicates the phase of the relative vorticity at 850 hPa (divergence at 925 hPa) with positive (negative) phase being above (below) the base line. The location of clear sky conditions is shown by the sun-like symbol.

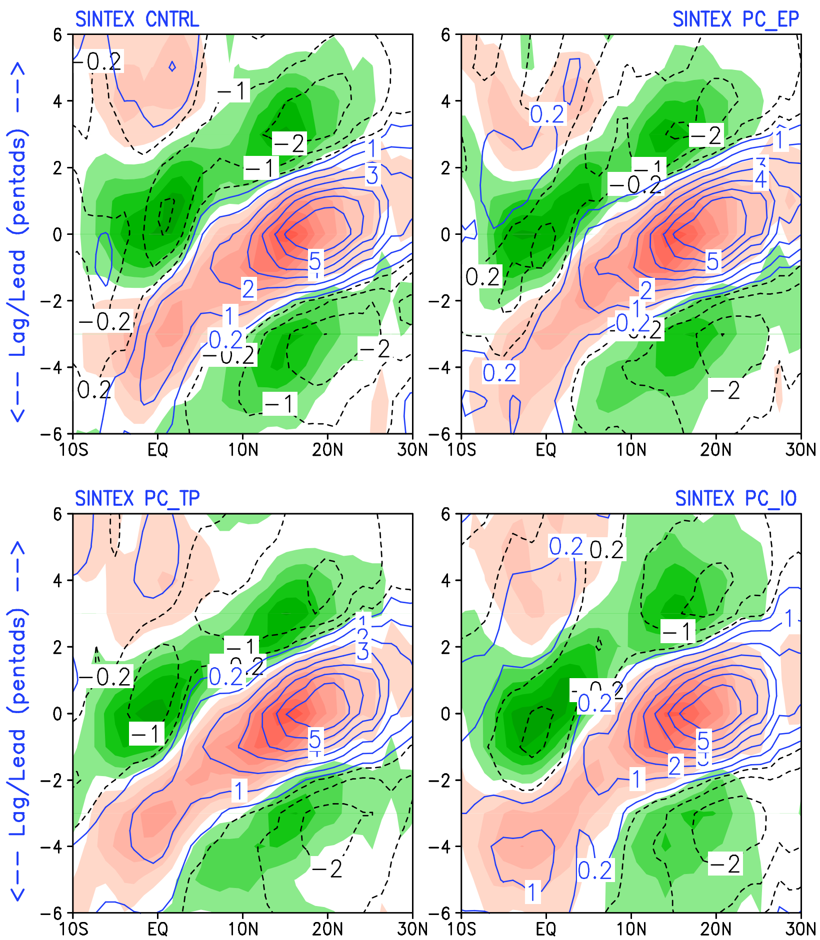


lag=10days
(a)
lag=5days
(b)
lag=0
(c)
lead=5days
(d)
lead=10days
(e)
lead=15days
(f)
30N
15N
EQ
15S
40E 60E 80E 100E 120E 140E 160E 180
−2.2 −1.8 −1.4 −1 −0.6 −0.2 0.2 0.6 1 1.4 1.8 2.2
SINTEX ES10 precipitation



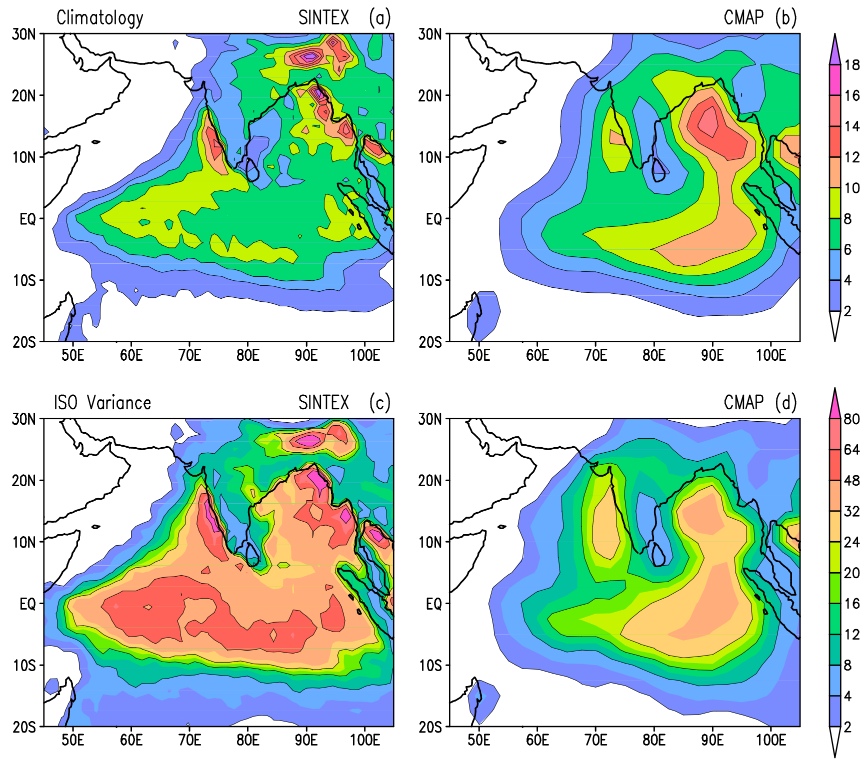
lag=10days
(a)
lag=5days
(b)
lag=0
(c)
lead=5days
(d)
lead=10days
(e)
lead=15days
(f)
30N
15N
EQ
15S
40E 60E 80E 100E 120E 140E 160E 180
−1.1 −0.9 −0.7 −0.5 −0.3 −0.1 0.1 0.3 0.5 0.7 0.9 1.1
SINTEX ES10 SST

Poleward Propagating MJO in the Indian Ocean



- Shading: Precipitation
- Contour: Boundary layer moisture convergence $\nabla . q\vec{U}$

SINTEX-F1 Monsoon Climatology



CGCMs	No:	CGCMs	No:
gfdl_cm2_1	2	miroc3_2_medres	14
ingv_echam4	3	inmcm3_0	15
mpi_echam5	4	miroc3_2_hires	16
mri_cgcm2_3_2a	5	ncar_pcm1	17
iap_fgoals1_0_g	6	csiro_mk3_5	18
gfdl_cm2_0	7	csiro_mk3_0	19
cccma_cgcm3_t47	8	ncar_ccsm3_0	20
cccma_cgcm3_1_t63	9	ipsl_cm4	21
miub_echo_g	10	giss_model_e_r	22
cnrm_cm3	11	giss_model_e_h	23
giss_aom	12	bcc_cm1	24
bccr_bcm2	13	SINTEX	25