Progress and Issues in Simulating Boreal Summer Intraseasonal Variability

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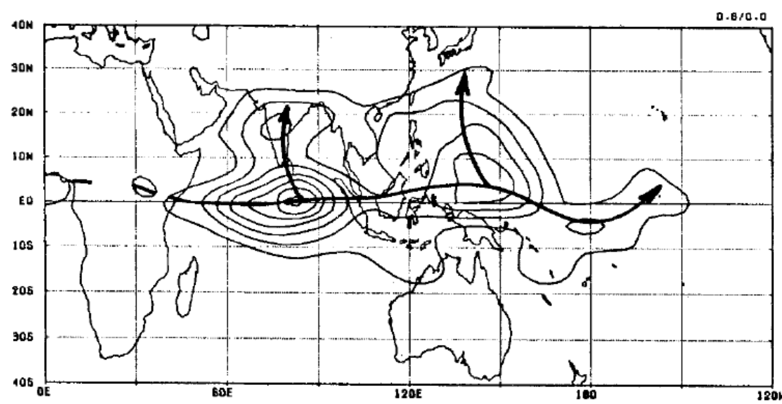

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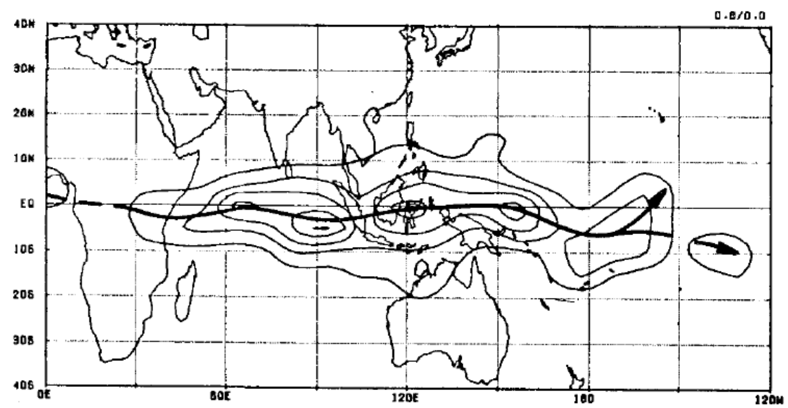
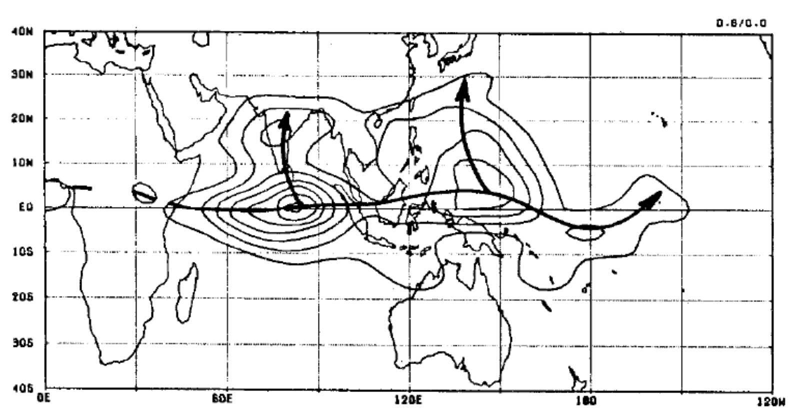
Outline

- **Background**
  - Characteristics of the BSISV (30-70 day variability)
- **Progress**
  - Improvement in the representation of the BSISV in GCMs
- **Issues**
  - Role of air-sea feedback in the northward propagation
- **Future Efforts**
  - Need for more in-depth process analysis of models to understand if improved BSISV representation is for the right reasons
  - Evolution of the variance structure changes during the course of the monsoon season
  - More attention and better understanding of the 10-30 day variability

Background: Patterns of BSISV over the monsoon domain

- Wang and Rui (1990, *Meteorol. Atmos. Phys*., 44, 43-61)
  - Eastward propagation dominates in boreal winter
  - Northward propagation present in boreal summer

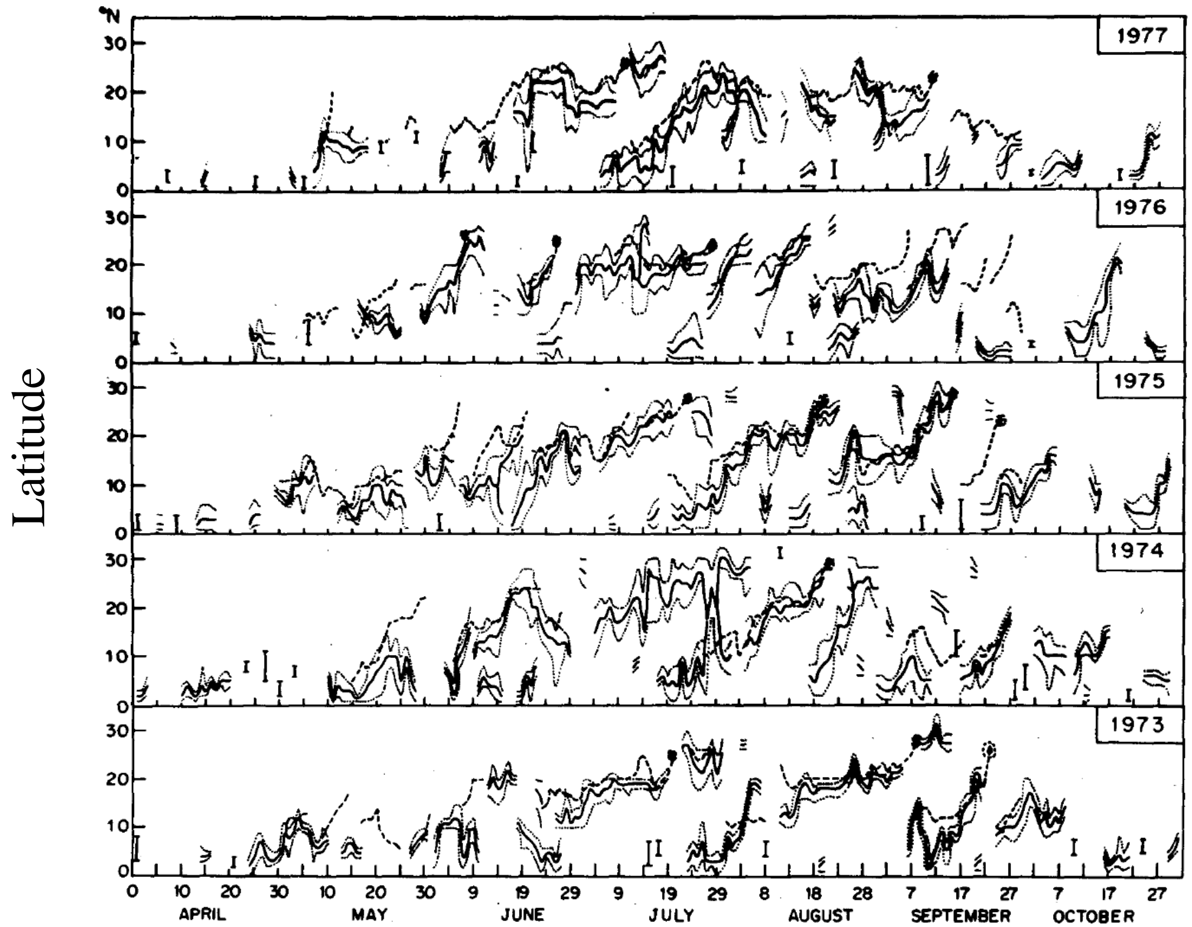




Lawrence and Webster (2002, *JAS*, 59, 1593-1606) used a longer record and determined that during boreal summer 78% of northward propagating events occurred in conjunction with eastward propagation.

BSISV: Discovery of northward propagation

- **Yasunari (1979, *J. Meteorol. Soc. Japan*, 57, 227-242)**
- **Yasunari (1980, *J. Meteorol. Soc. Japan*, 58, 225-229)**
- **Sikka and Gadgil (1980, *MWR*, 108, 1840-1853)**



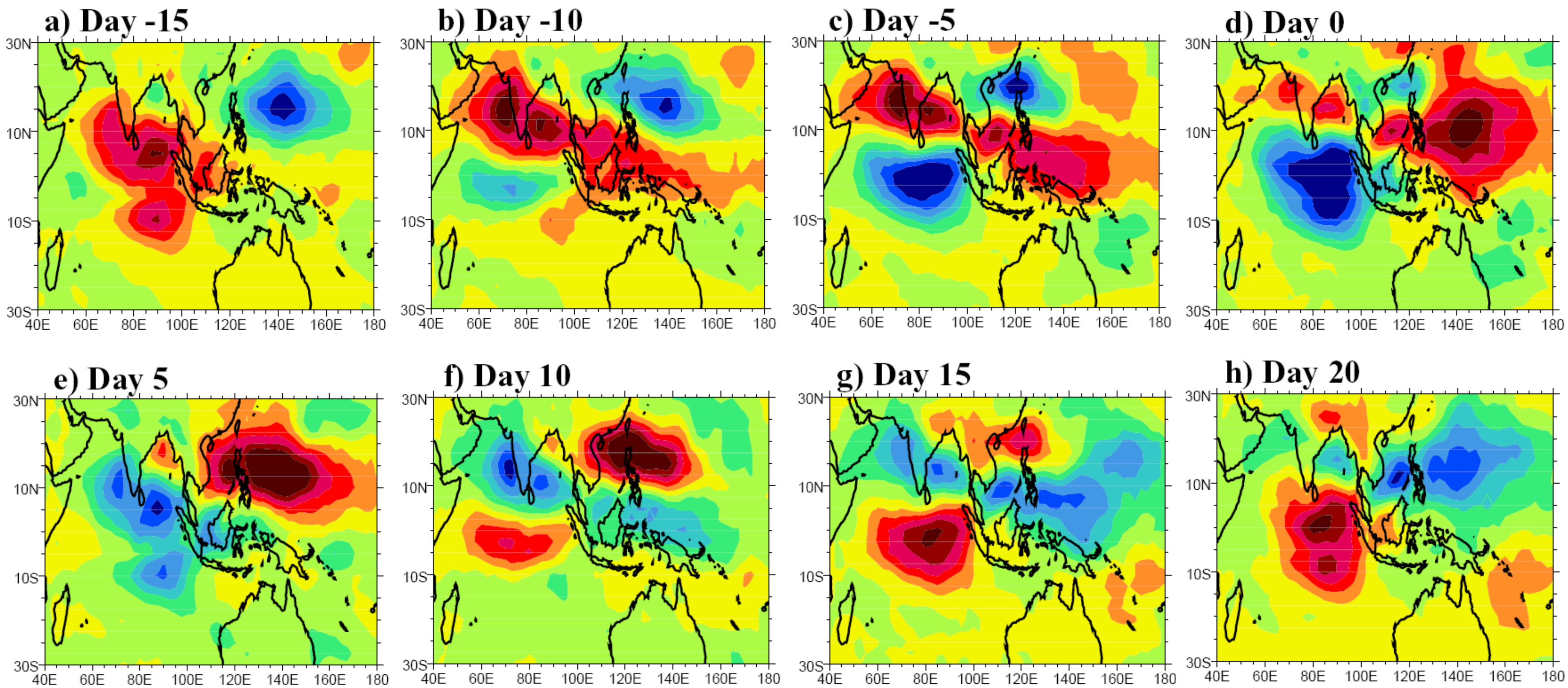
Time-latitude plots of the location and width of the maximum cloud zone at 90°E (after Sikka and Gadgil 1980)

Observed Characteristics of BSISV

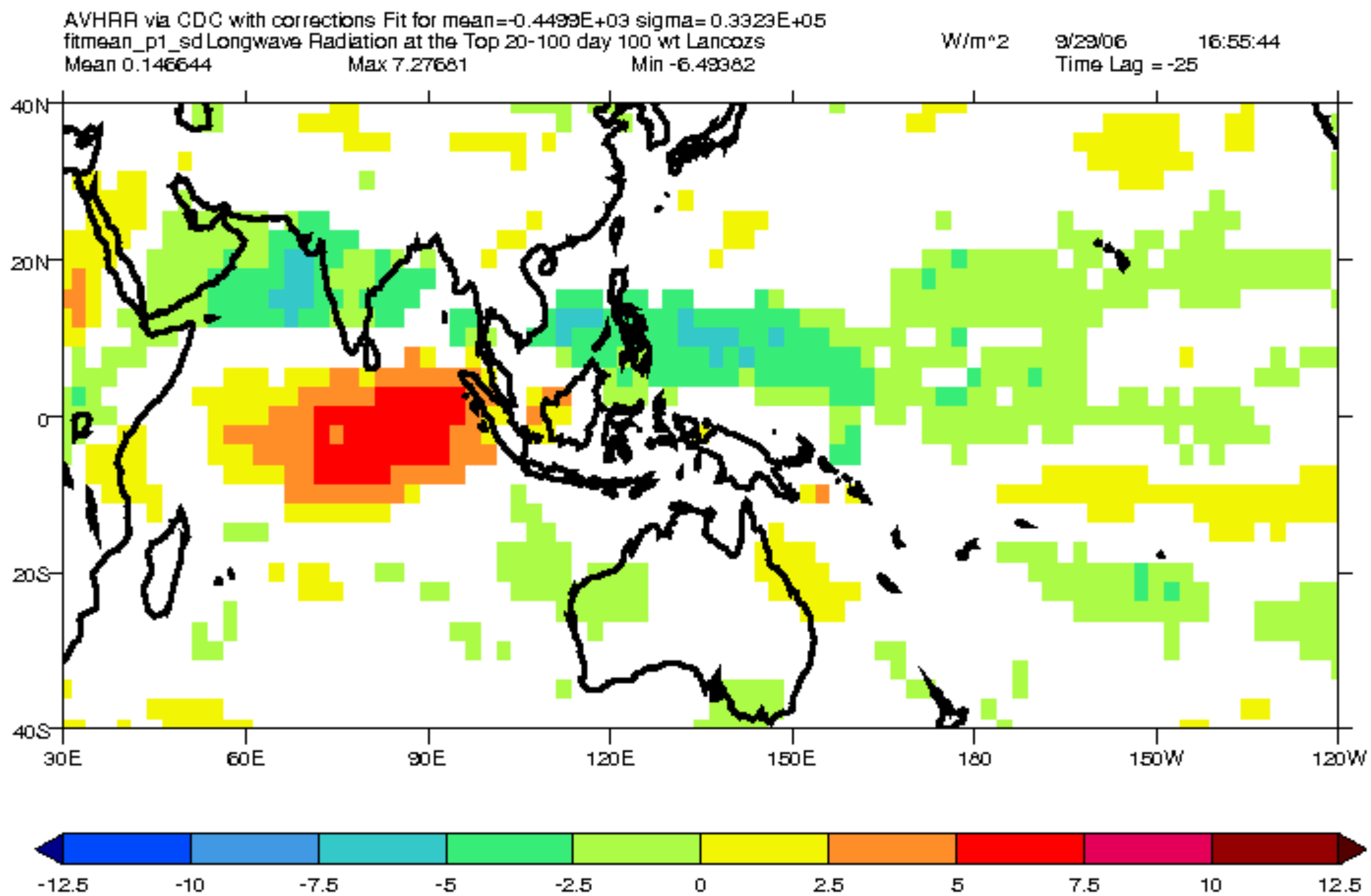
- Initiation in the western Equatorial Indian Ocean (60-70E)
  - (Wang, Webster, Teng 2005)
- Active/break ISM has 30-70-day cycles
  - Trapped in the eastern Hemisphere AAM region. Largest variability in the off-equatorial monsoon trough and EEIO(Ramamurthy 1969, Krishnamurti and Bhalme 1976, Krishnan et al. 2000, among others)
- NW-SE tilted rain band
  - The equatorial eastward propagating MJO tends to bifurcate poleward near Sumatra (Ferranti et al. 1997, Maloney and Hartmann 1998, Annamalai and Slingo 2001, Kemball-Cook and Wang 2001, Lawrence and Webster 2002, Waliser et al. 2003, Annamalai and Sperber 2005. Sperber and Annamalai 2008)
- Northward propagation in the Bay of Bengal
  - (Yasunari 1979, 1980, Sikka and Gadgil 1980, Krishnamurti and Subrahmanyam 1982, among others)
- Northwestward propagation in the WNP
  - (Nitta 1987)

BSISV: Cyclostationary EOF (CsEOF) using 20-100 day filtered AVHRR OLR (Wm^{-2})

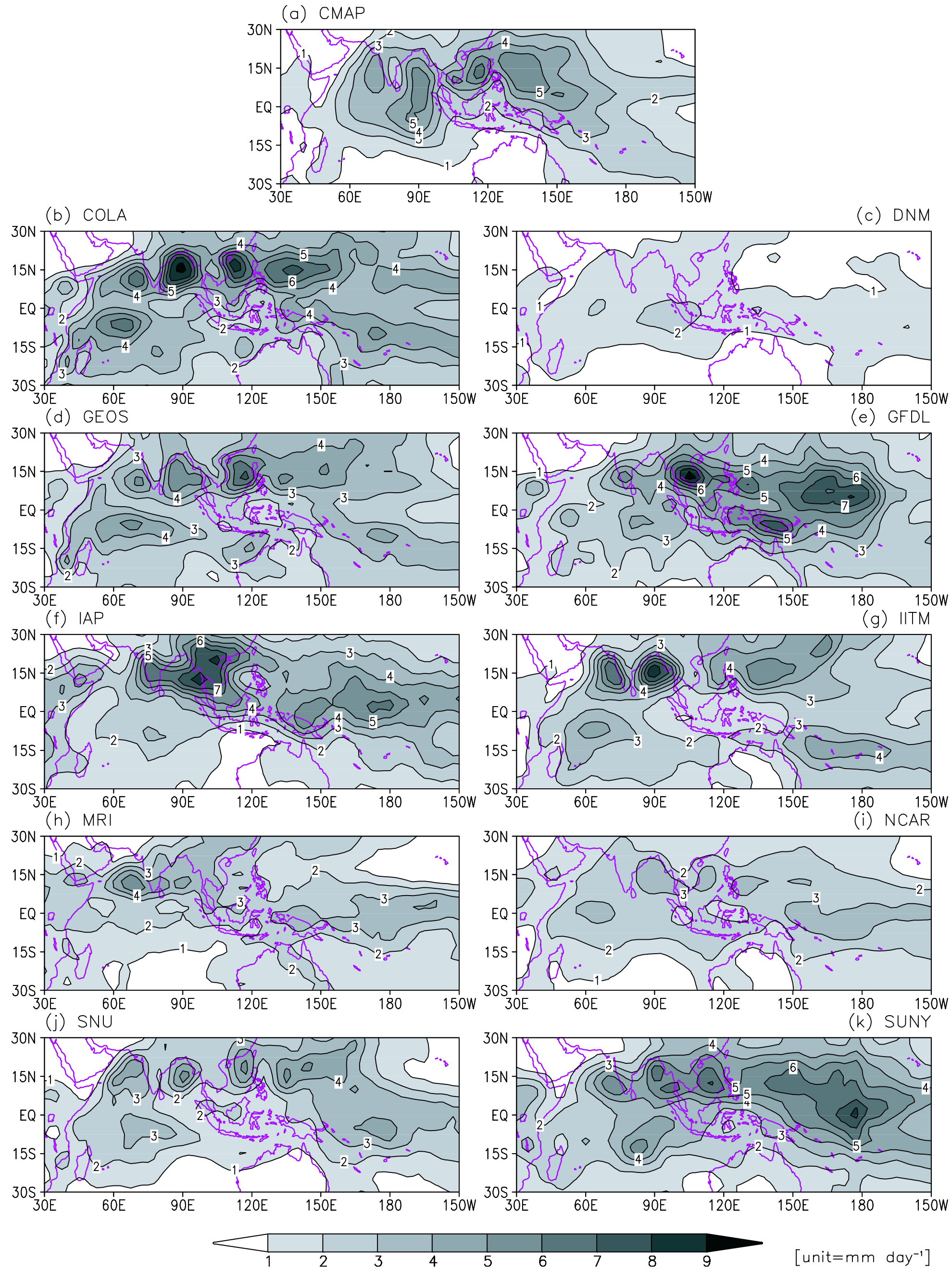
- **Eastward and northward propagating OLR anomalies (Annamalai and Sperber 2005, *JAS*, 2726-2748)**
  - **Mutually interactive system**



BSISV Life-Cycle: Animation of 20-100 day filtered OLR based on regression with PC-4 for lags -25 to 25 days



SD of 20-90 day filtered rainfall (mm/day) for May-Oct from the CMAP for 1979 to 1998 and for ten AGCMs (lower). In the case of the models, there were 20 summer seasons of data, i.e. ten members each consisting of two years. From Waliser et al. (2003).



Common problems:

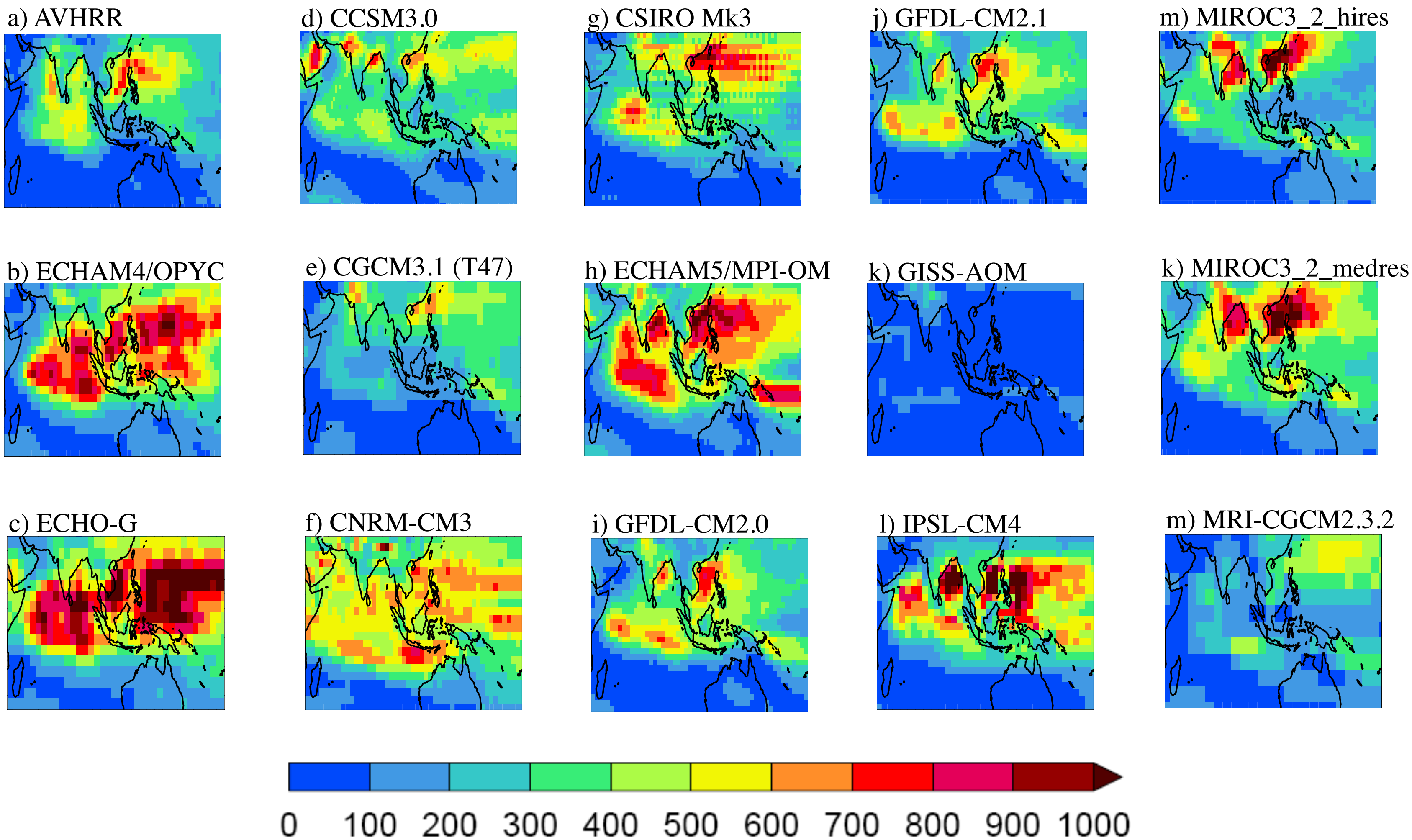
1. EIO activity center
2. Northward pathway in Bay of Bengal
3. Northwest pathway in the western North Pacific

Common strengths

1. Weakening over the MC
2. Off equatorial activity centers

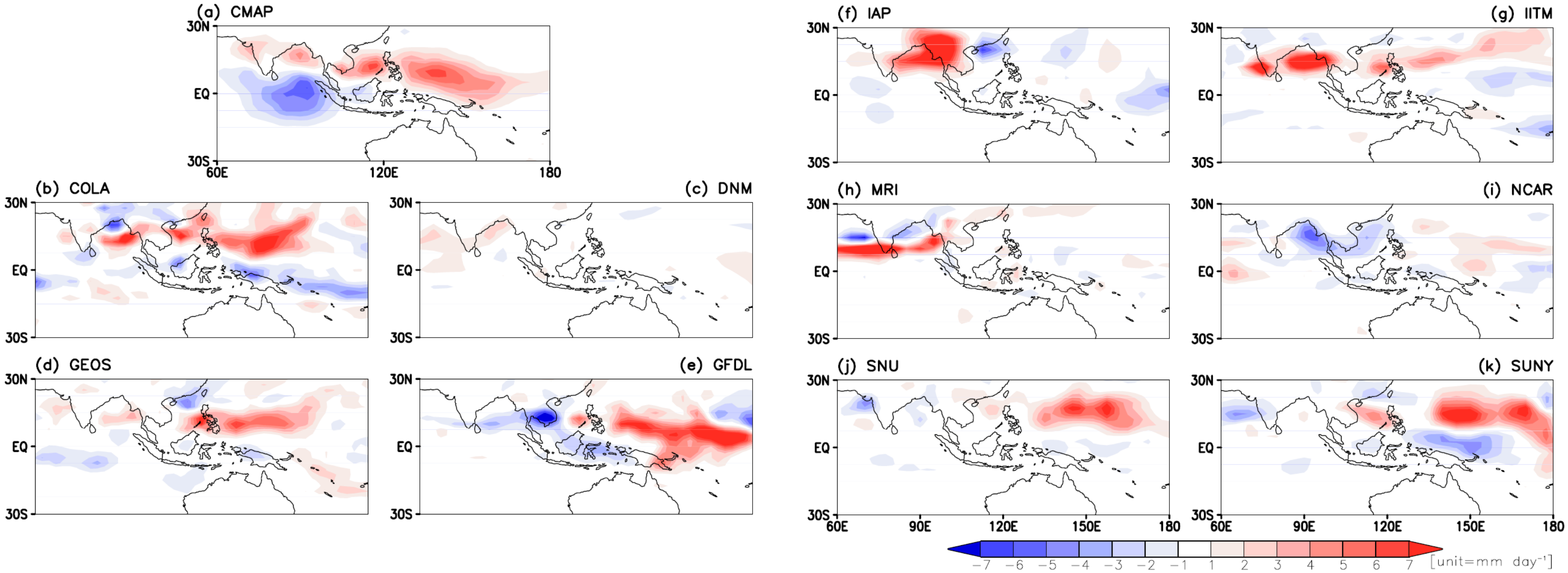
Boreal summer OLR: 20-100 day filtered variance $(Wm^{-2})^2$

- **In the models intraseasonal variance tends to be more localized, though in some cases it is too strong**



BSISV: The tilted rainband

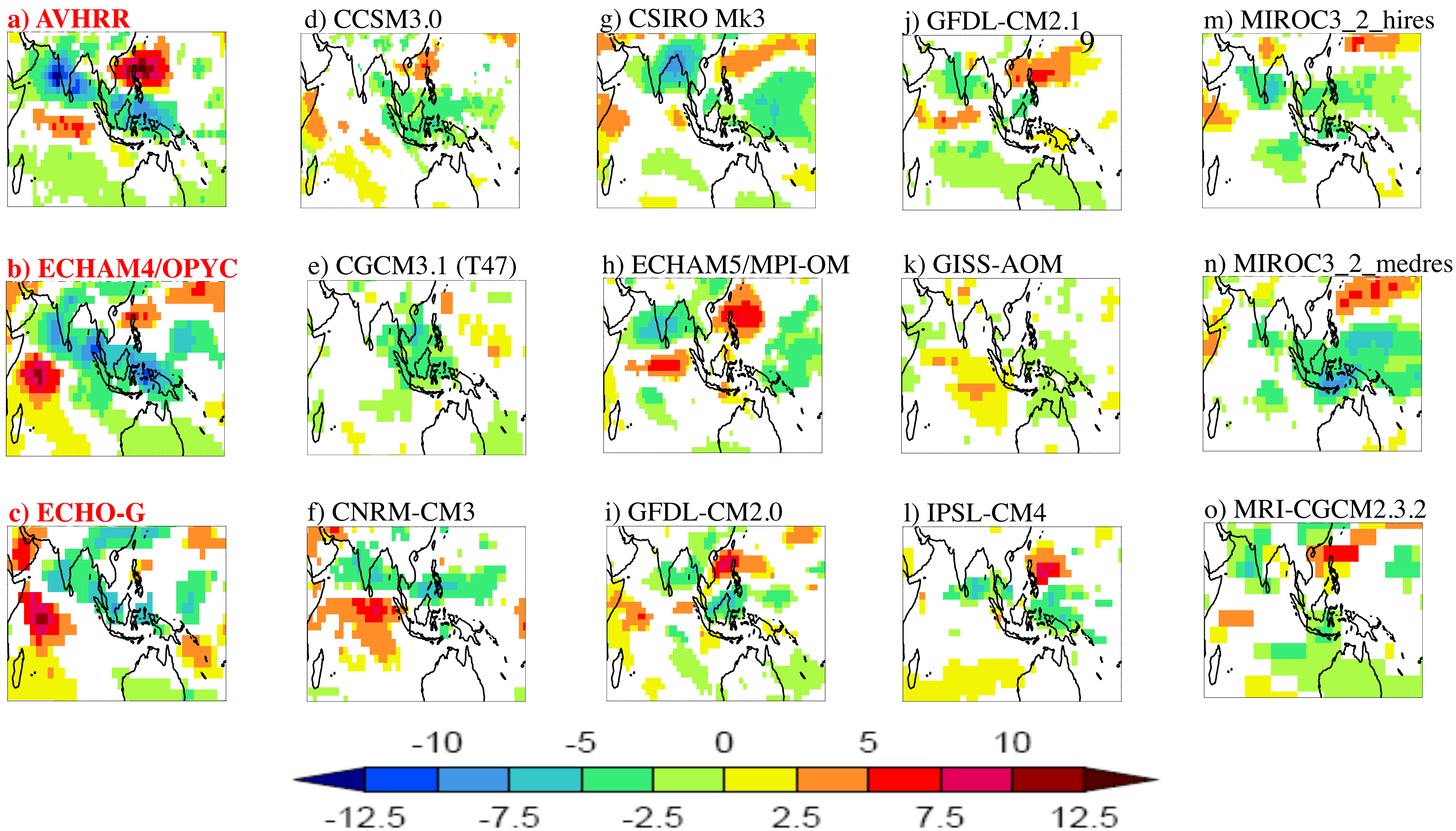
- **CLIVAR AAM experiments, 1997/98; 10 member ensembles; weekly SST prescribed**
- **Typically, AGCMs poorly represent the BSISV tilted rainband (Waliser et al. 2003, *Clim. Dynam*., 21, 423-446)**



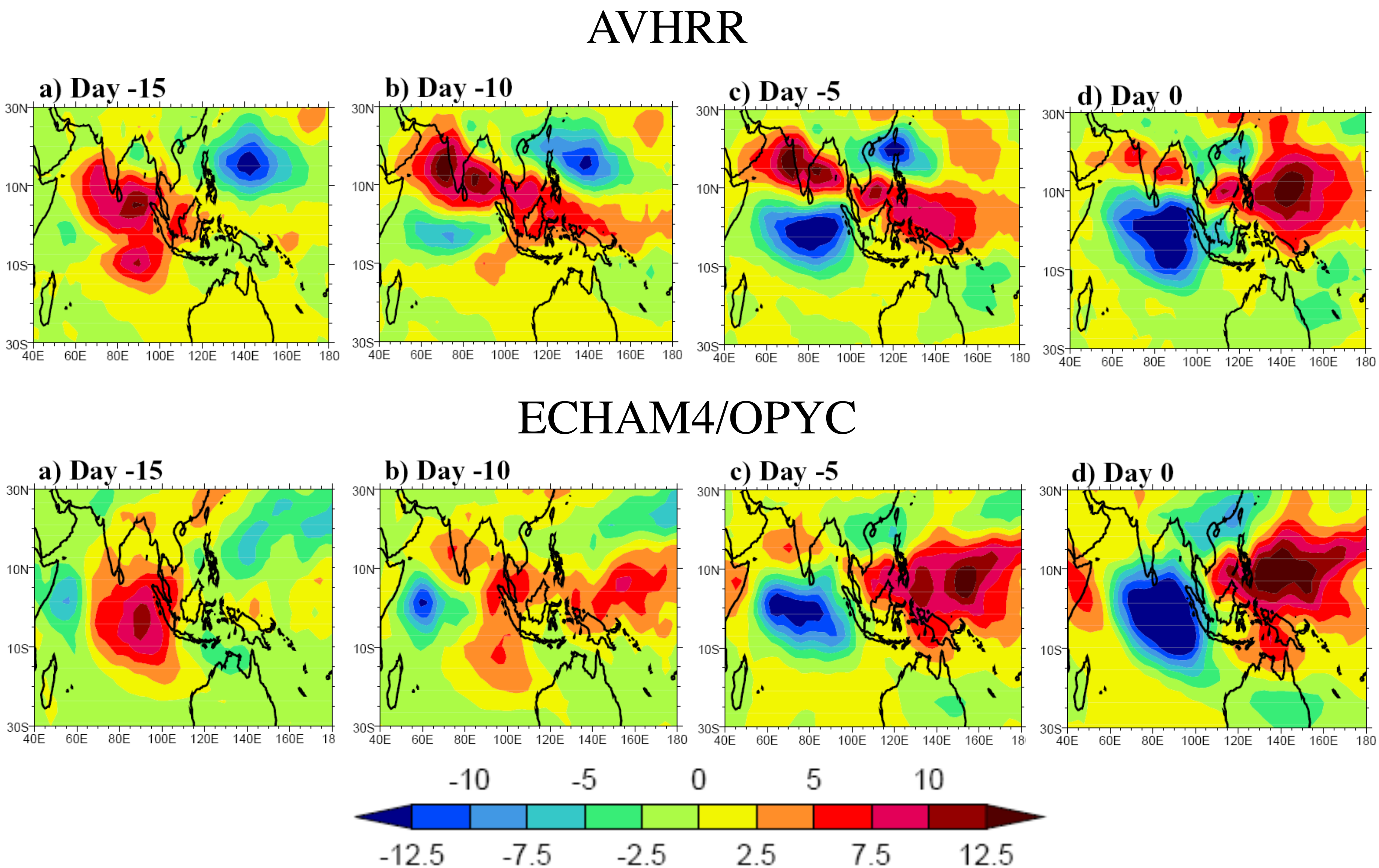
Figures kindly provided by D. Waliser

BSISV: PC4 regression with 20-100 day filtered OLR (Wm^{-2}; best fit to AVHRR Day 10 CsEOF using pattern correlation)

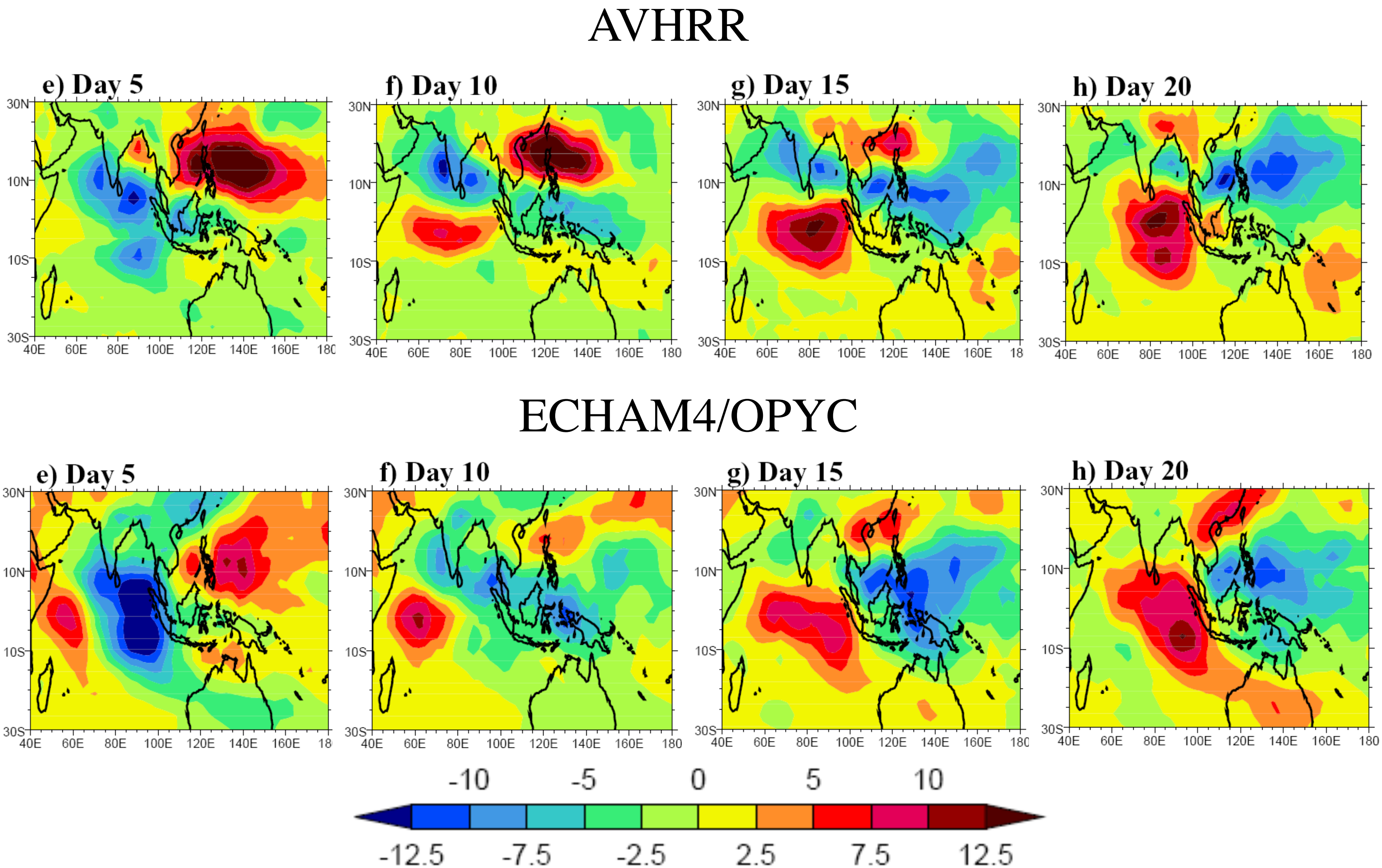
- Compared to the GCMs analyzed by Waliser et al. (2003) the newer coupled models are better at representing the BSISV (Sperber and Annamalai 2008)



BSISV Life-Cycle: PC4 regression with 20-100 day filtered OLR (Wm^{-2}) (1)



BSISV Life-Cycle: PC4 regression with 20-100 day filtered OLR (Wm^{-2}) (2)



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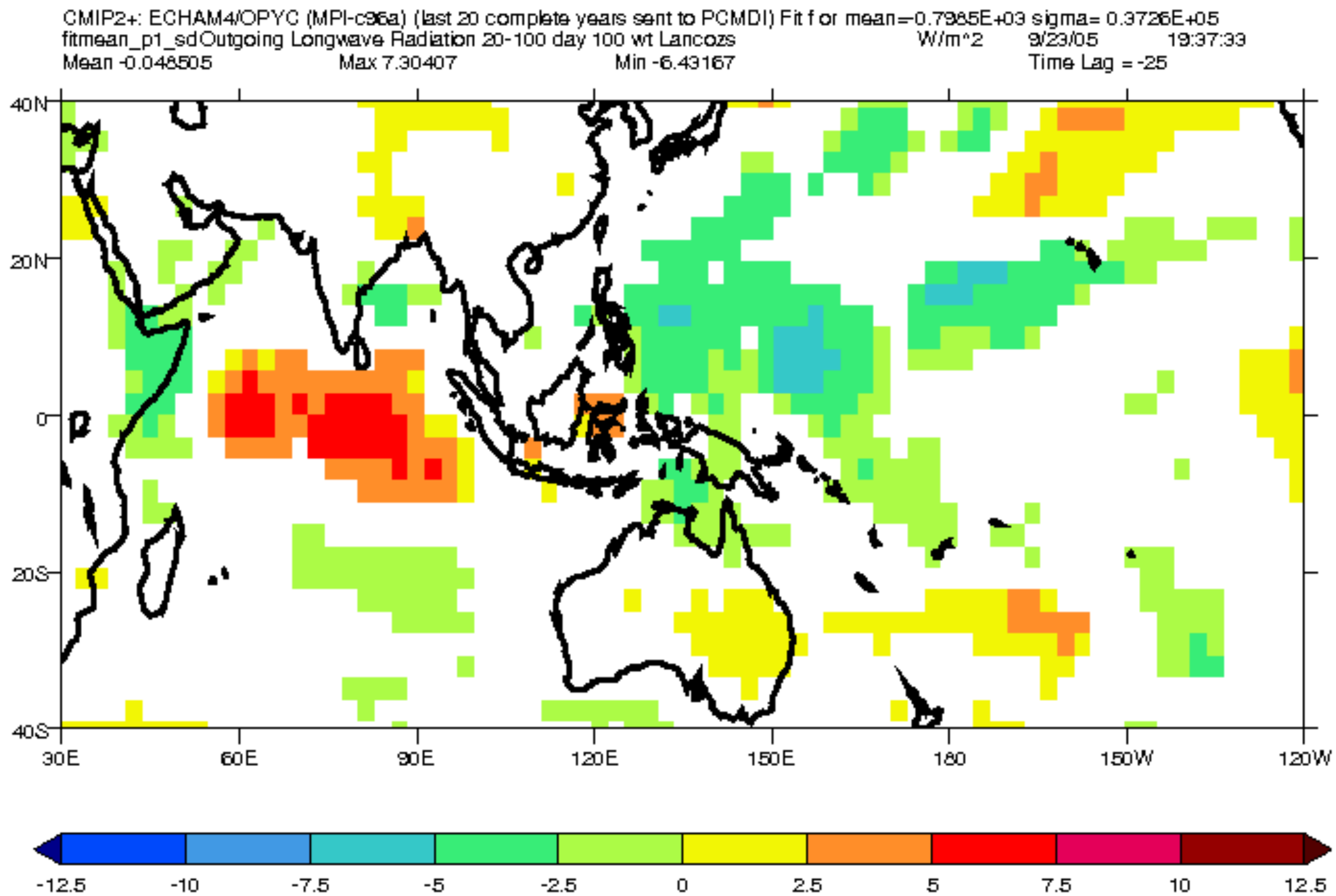
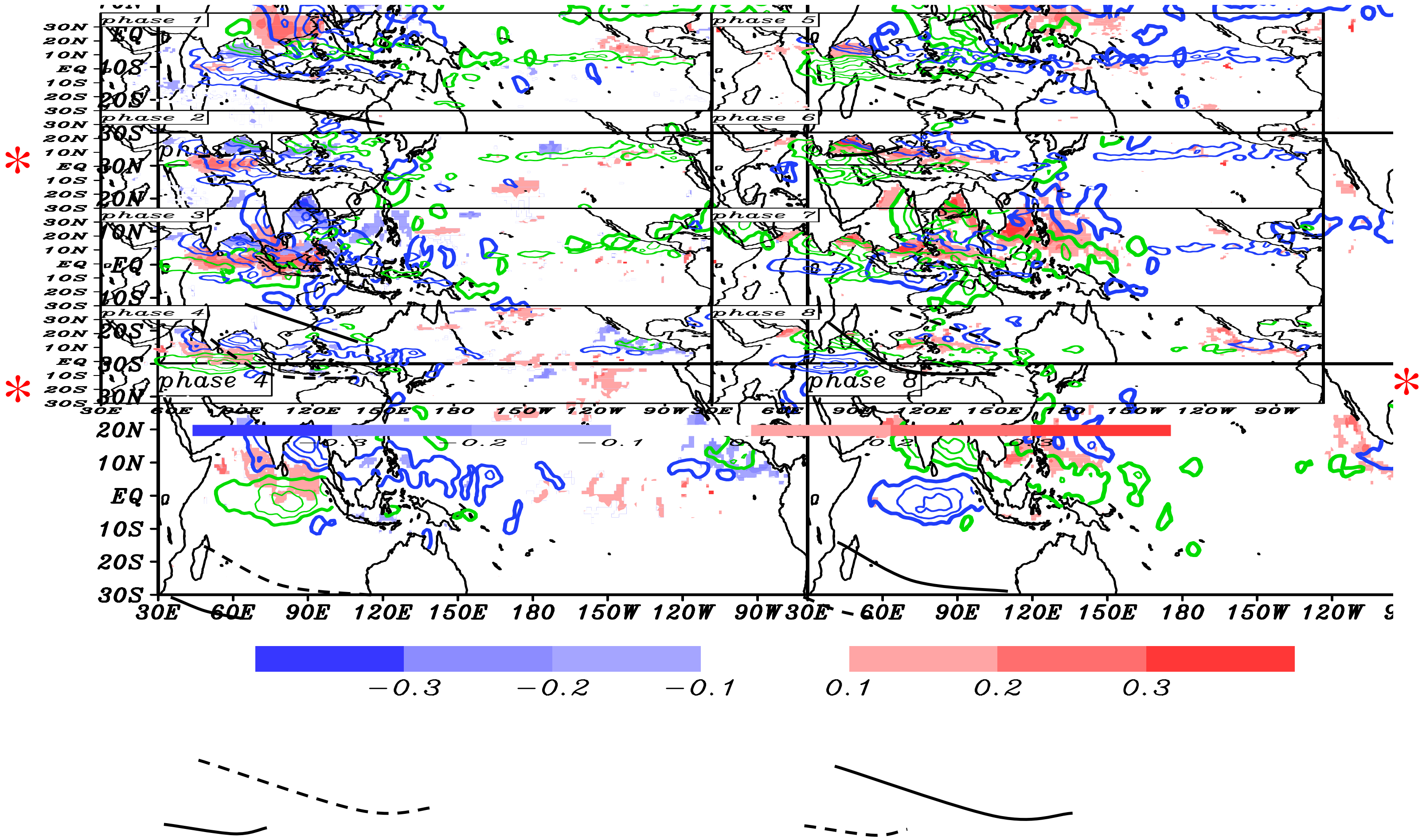
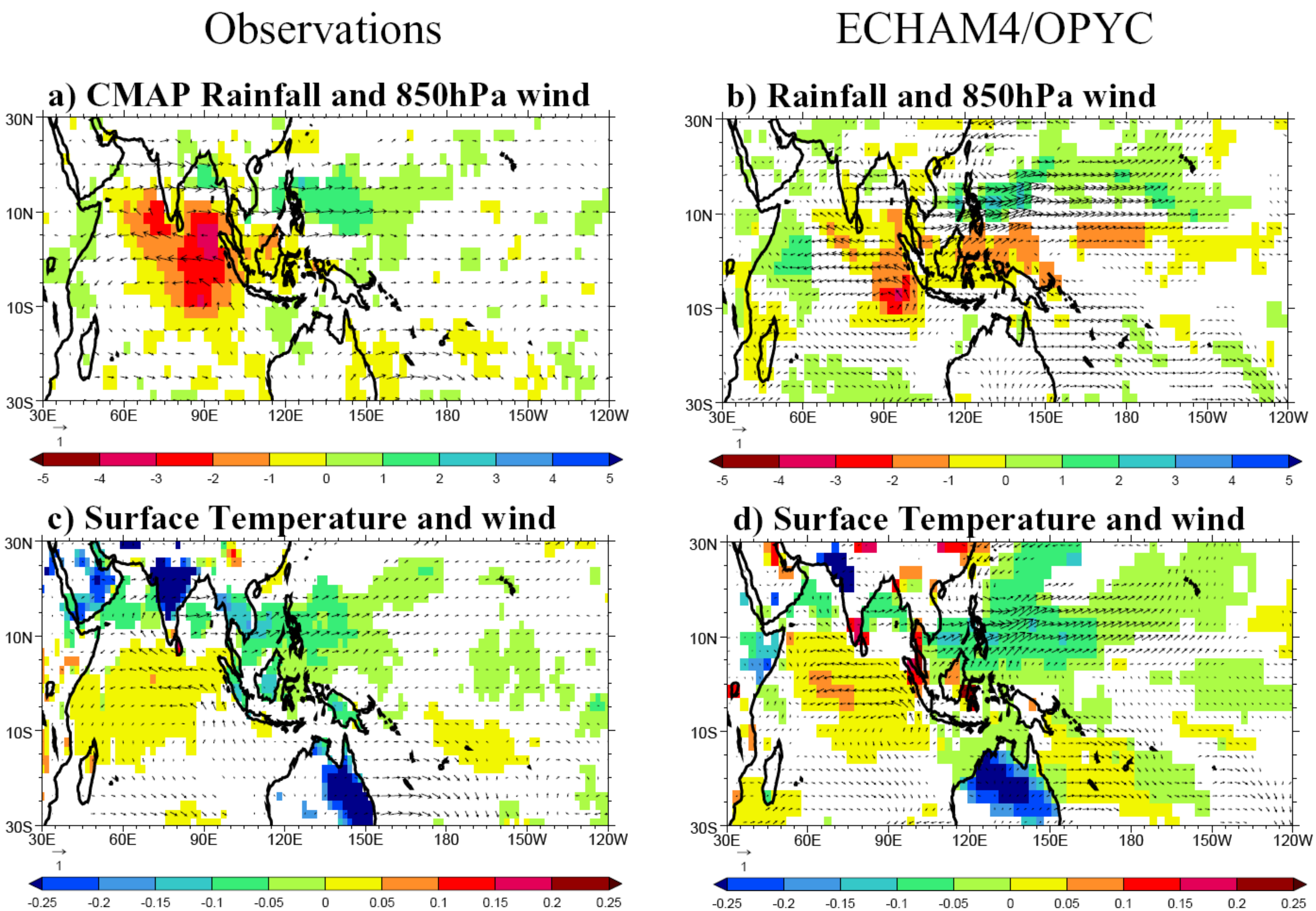


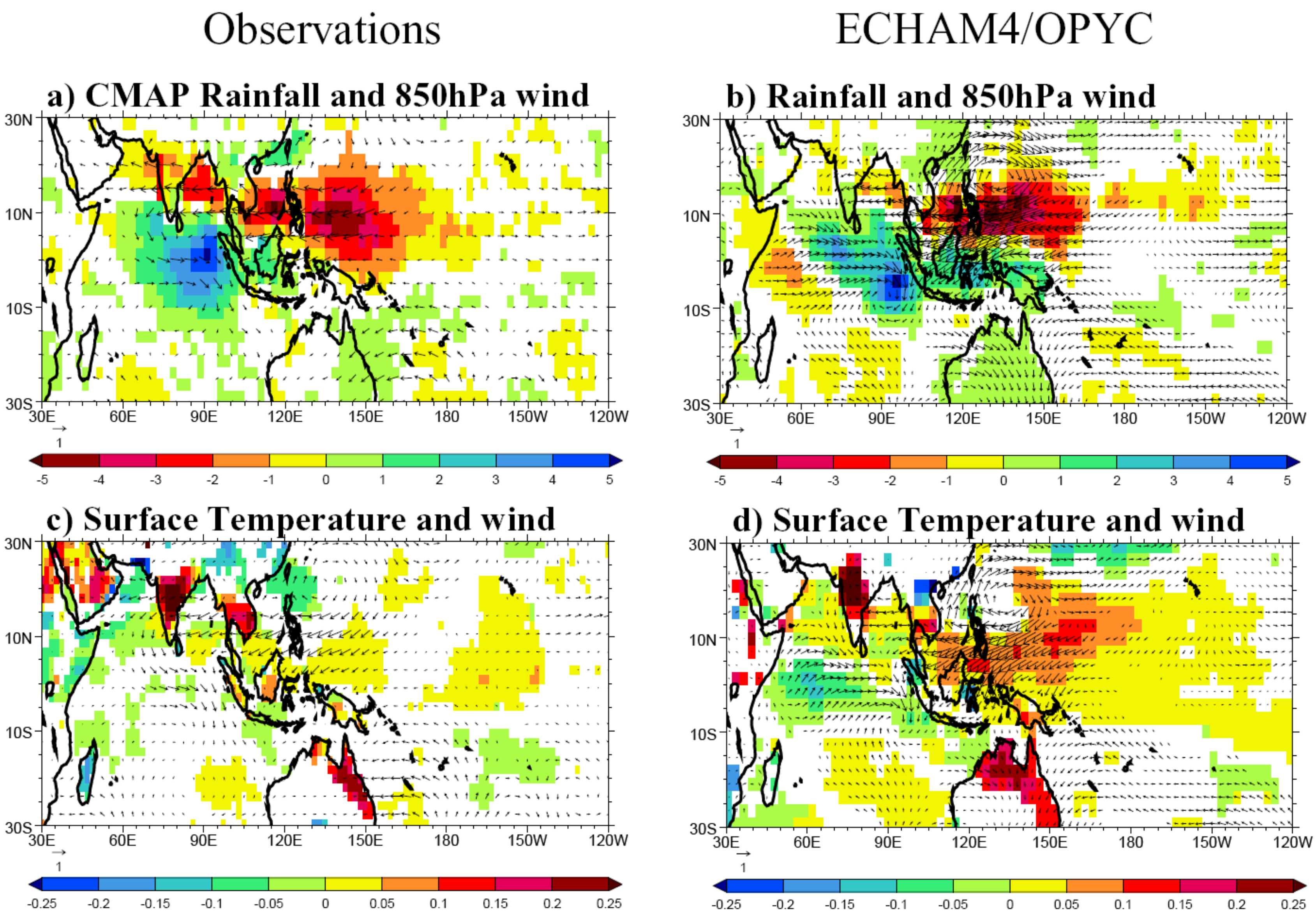
Composite life cycle of ISO TRMM rain rate (contour; green above normal rainfall) & SST (shading)



Onset of Convection in the Western Indian Ocean (Day -15 AS(2005), Phase 2 TRMM)

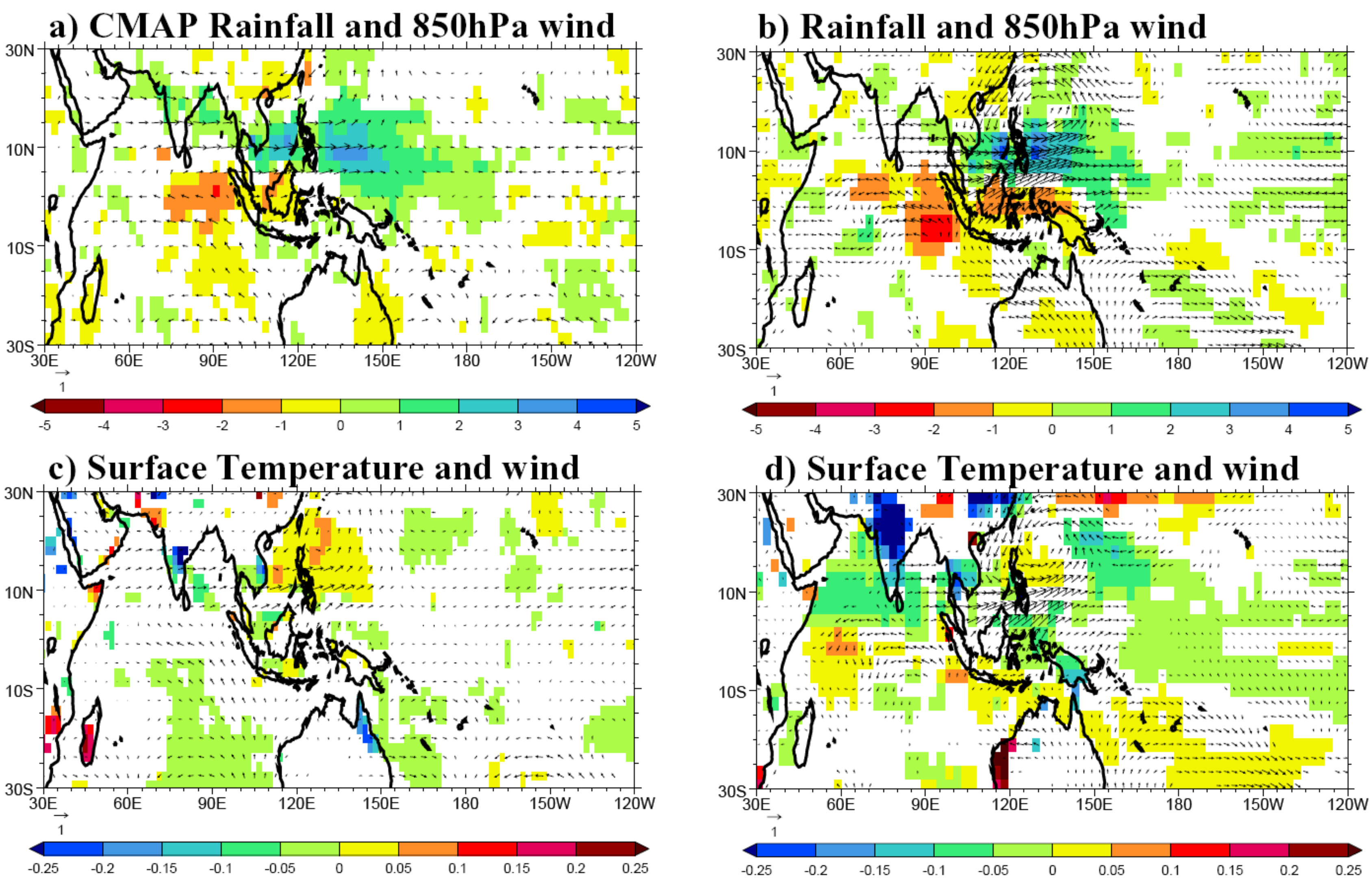


Northward Propagation of Convection (Day 0 AS(2005), Phase 6 TRMM)



West Pacific Convection and Onset of Monsoon Break Over India (Day 20 AS(2005), Phase 1 TRMM)

Observations ECHAM4/OPYC



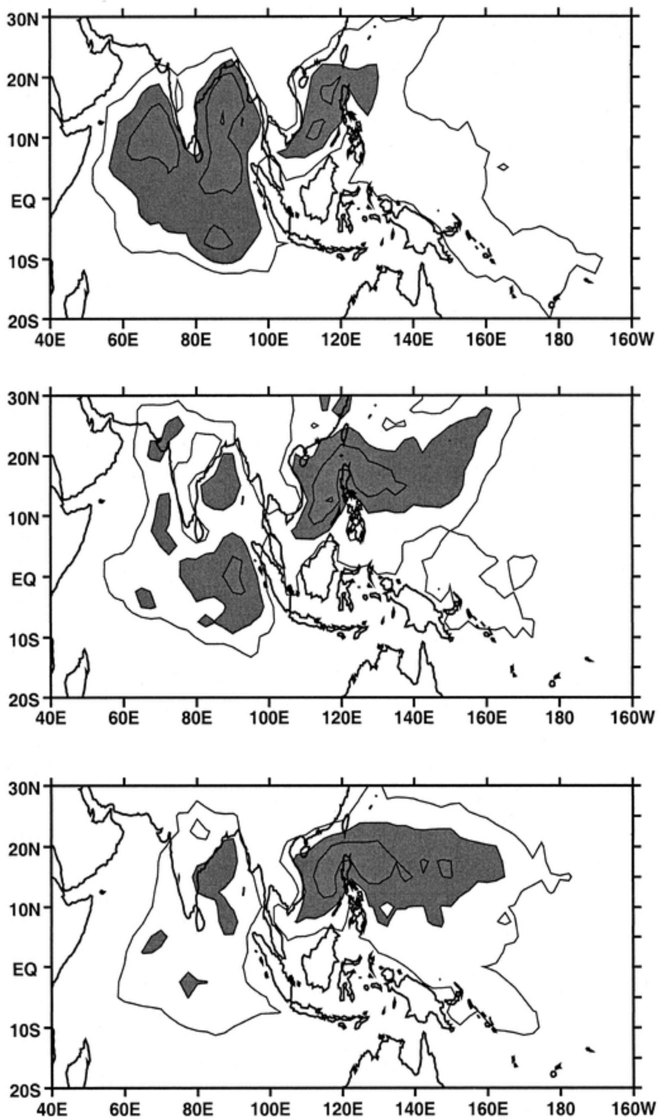
Subseasonal variation of BSISV

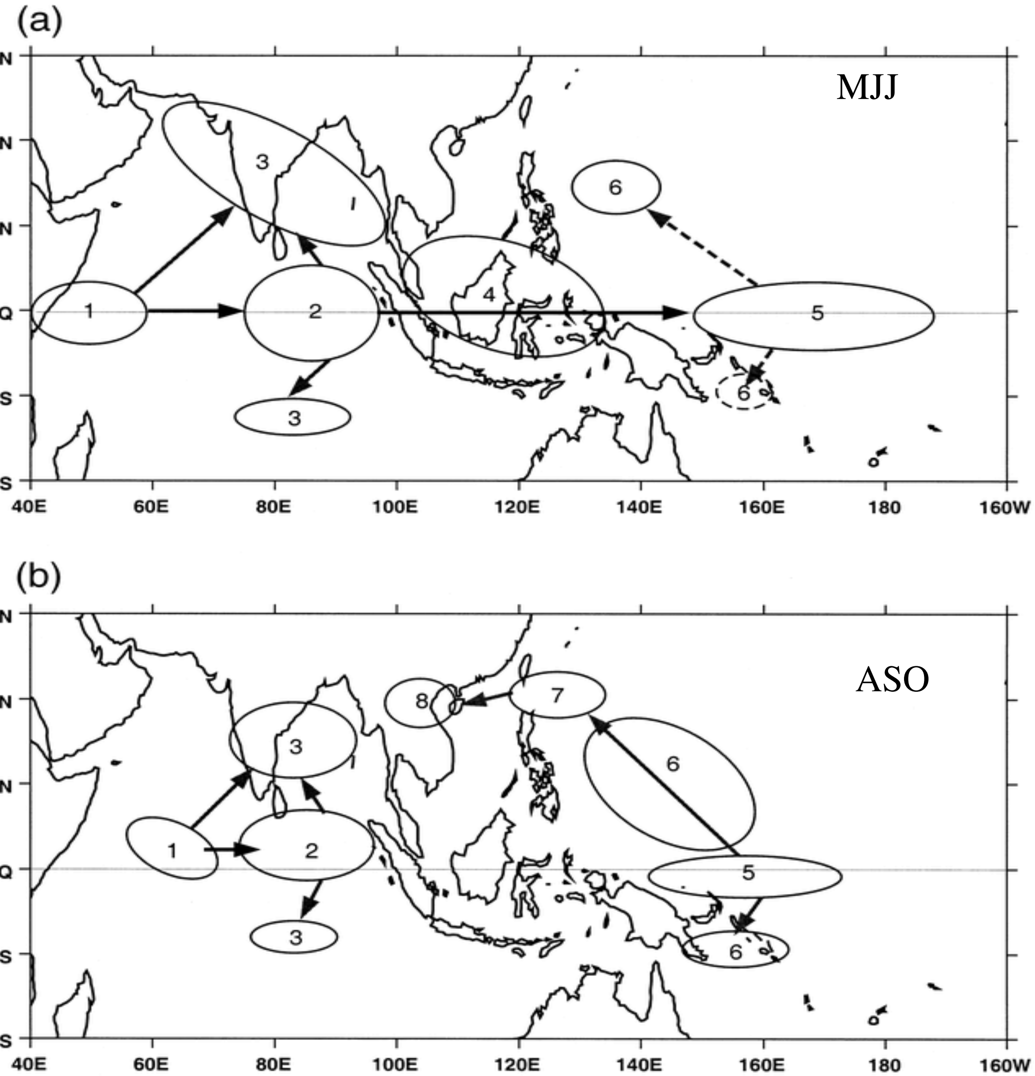
IS Variance-OLR | Propagation pattern

MJ

July

ASO





Kemball-Cook and Wang 2001

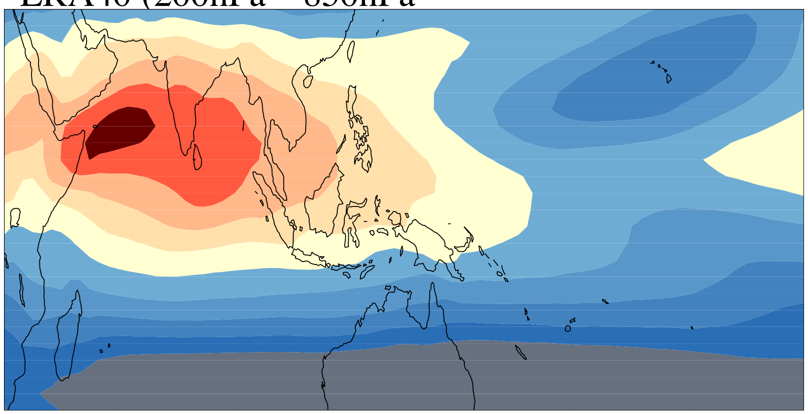
Progress Summary

- **All of the CMIP3 models exhibit success at simulating the equatorial eastward propagation over the Indian Ocean**
  - **This appears to be related to accurate time-mean SST (especially its gradient) and low-level moisture, despite differences in simulating the locations of the three main BSISV heat sources**
- **Eastward extension of the convective anomalies over the Maritime Continent is a necessary, but not sufficient condition for the generation of northward propagation near India on 30-90 day time scale**
  - **It appears that equatorial convective anomalies must be of sufficient amplitude to excite the northward propagation, and time-mean easterly shear needs to be present**
  - **When the equatorial eastward extension of convective anomalies is not present, the tendency is for off-equatorial westerlies to penetrate further to the west than observed**
- **Models need to be assessed more rigorously and in a consistent fashion**
  - **Replicate seasonality of BSISV variance**
  - **Uniform diagnostic approach**

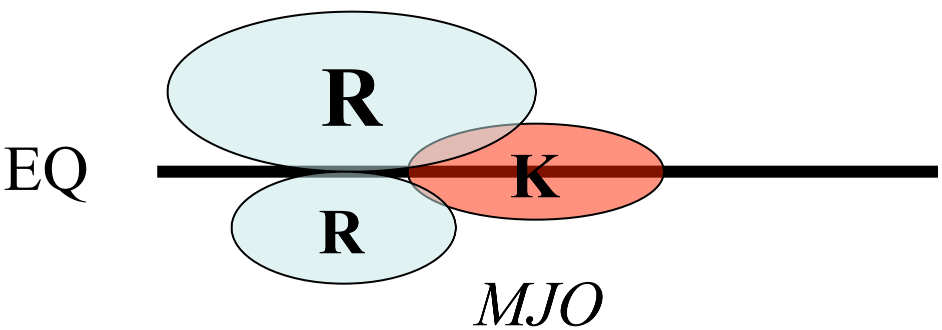
Issue: What mechanisms drive the northward propagation of convection during the BSISV?

- **Two mechanisms have received the most attention over the past decade**
  1) Kelvin wave/Rossby wave interaction- Easterly windshear is a necessary condition for the emanation of Rossby waves

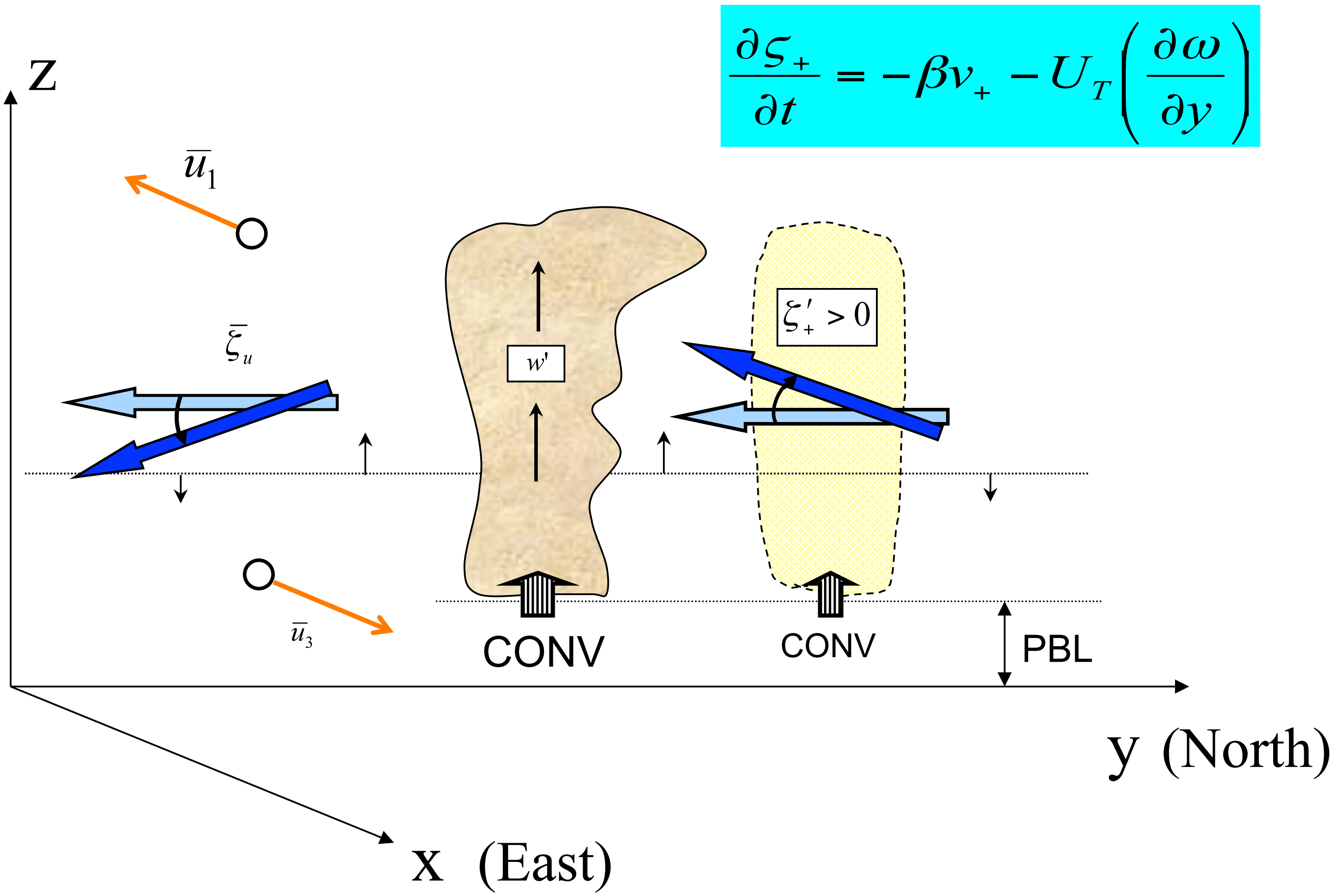
ERA40 (200hPa – 850hPa



Lau and Peng (1990, *JAS*, 47, 1443-1462)
Wang and Xie (1997, *JAS*, 54, 72-86)



Figures kindly provided by H. Annamalai



An atmospheric internal dynamic mechanism for northward propagation: monsoon easterly vertical shear provides a vorticity source, which, upon being twisted by the north-south varying vertical motion field associated with the moist Rossby waves, generates positive vorticity north of the convection, creating boundary layer moisture convergence that favors northward movement of the enhanced rainfall.

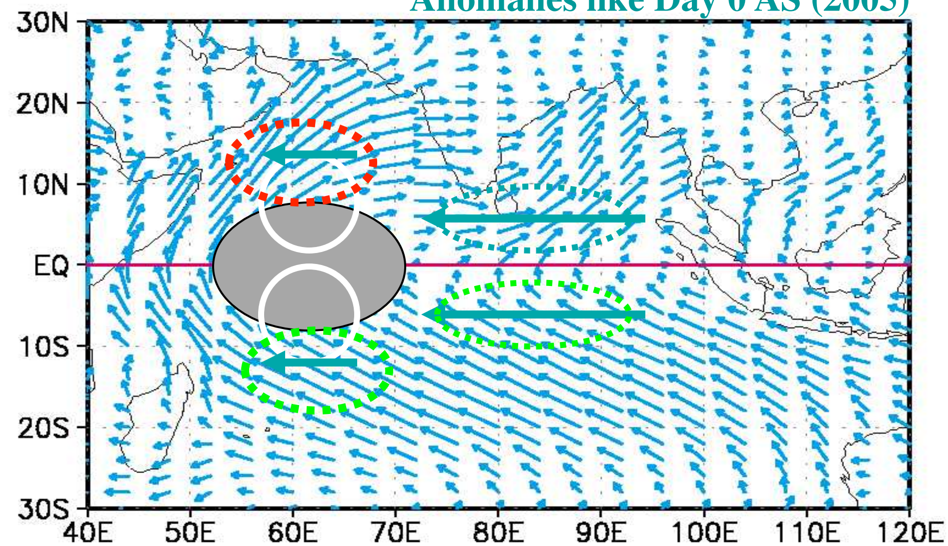
Issue: What determines the northward propagation of convection during the BSISV?

- **Two mechanisms have received the most attention over the past decade**

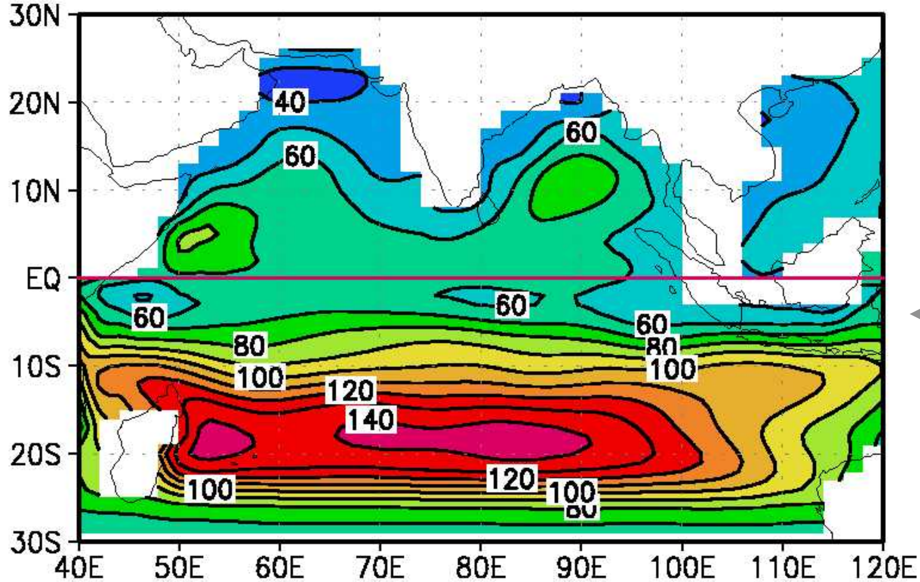
  2) Air-sea interaction-forces or feedbacks to promote northward propagation of convection through modulation of surface fluxes

Surface Wind & Latent Heat Flux

Anomalies like Day 0 AS (2005)



Mixed-layer Depth



Issue: What determines the northward propagation of convection during the BSISV?

- **There is confusion over the relative roles of internal dynamics vs. coupled processes in promoting the northward propagation**
  - Kelvin wave/Rossby wave interaction- Easterly windshear is a necessary condition, providing an environment favorable for the emanation of Rossby waves
    - Simple and complex GCM's produce northward propagation when easterly shear is evident (e.g., Lau and Peng 1990, Wang and Xie 1997, Kemball-Cook et al. 2002, Annamalai and Sperber 2005)
  - Air-sea interaction-forces or feedbacks to promote northward propagation of convection
    - Ajayamohan et al. (2010) Not necessary, internal dynamics sufficient
      - ➢ Suggested that overly strong BSISV/MJO variance in model may have dominated over the need for air-sea interaction/feedback for propagation
    - Kemball-Cook et al. (2002): promotes increased convergence into +SST anomaly ahead of deep convection for propagation
    - Rajendran and Kitoh (2006): Intrinsic dynamical mode, but coupling improves signal, with low-level moisture convergence important for propagation
    - Fu et al. (2003): SST feedback important, otherwise northward propagation weak; northward propagation linked to local SST rather than equatorial MJO, Kelvin wave/Rossby wave dynamics don't play a major role
    - W. Wang et al. (2009): Necessary, internal dynamics not sufficient

Issue: Role of air-sea interaction/feedback?

- **Findings**
  - A-O interaction enhances ISO variability (Flateau 1997, Wang and Xie 1998, Waliser et al. 1999,…)
  - AGCM (AMIP run) failed to simulate correct SST-Precipitation relationship: in phase in the AGCM models but 90 degrees out of phase in reality. (Wu et al. 2002)
  - CGCM and AGCM alone yield fundamentally different ISO solution, coupling leads to realistic SST-precipitation relationship (Fu et al. 2003).
  - Coupling between atmosphere and ocean add predictability to boreal summer ISO (Fu et al. 2006)
- **Questions**
  - How does ocean intraseasonal variability feedback to atmospheric ISO?
  - What are precise relationships between the SST and surface heat fluxes?
  - What are the relative roles of entrainment, upwelling, and advection in controlling SST ISV? To what extent are these processes dependent on atmospheric forcing? (or do ocean processes add noise to ISO?)
  - What is the role of land-surface processes in destabilizing the atmosphere to promote northward propagation (Webster 1983)?