Indian Ocean Subseasonal and Interannual SST Variability

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1. Historical analyses: What can we do with what we have?
2. Looking forward: What would we like to do, and what do we need to be able to do it?
    1. What time/space scales would we like to be able to resolve?

    (or…what's so special about a month?)

3. In Indian Ocean: sample (and even resolve) sub-seasonal timescales.

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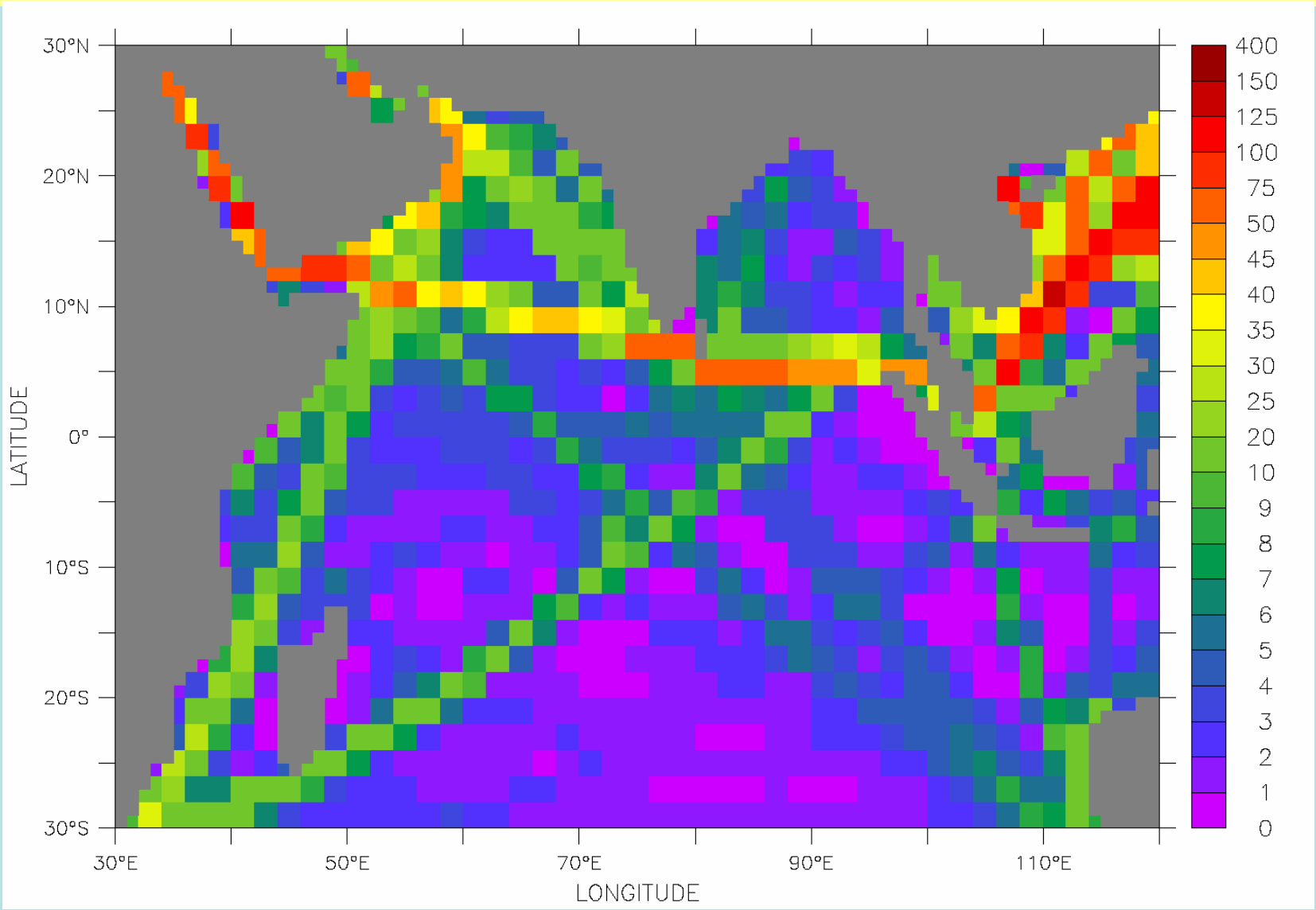
Historical Indian Ocean sampling is poor



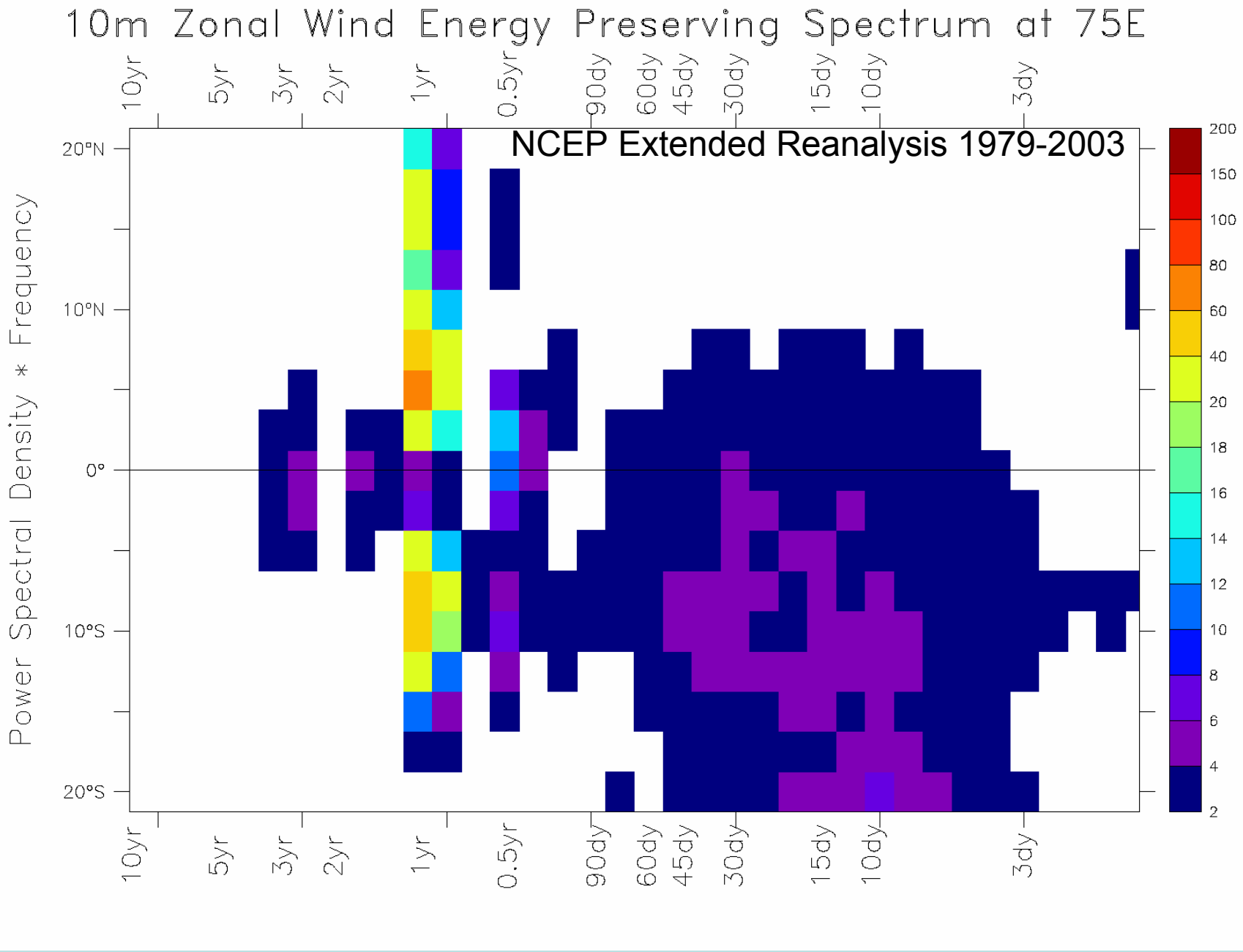
Average number COADS.v1 observations per month 1946-1993

Timescales of variability

- I.O. dominated by seasonal variability.
- Also considerable non-seasonal variability:
  - Sub-seasonal (more than just MJO).
  - Inter-annual (ENSO and more?)
  - Inter-decadal and/or trends?

    ~basinwide warming in last 40 years

    cooling in previous 40?



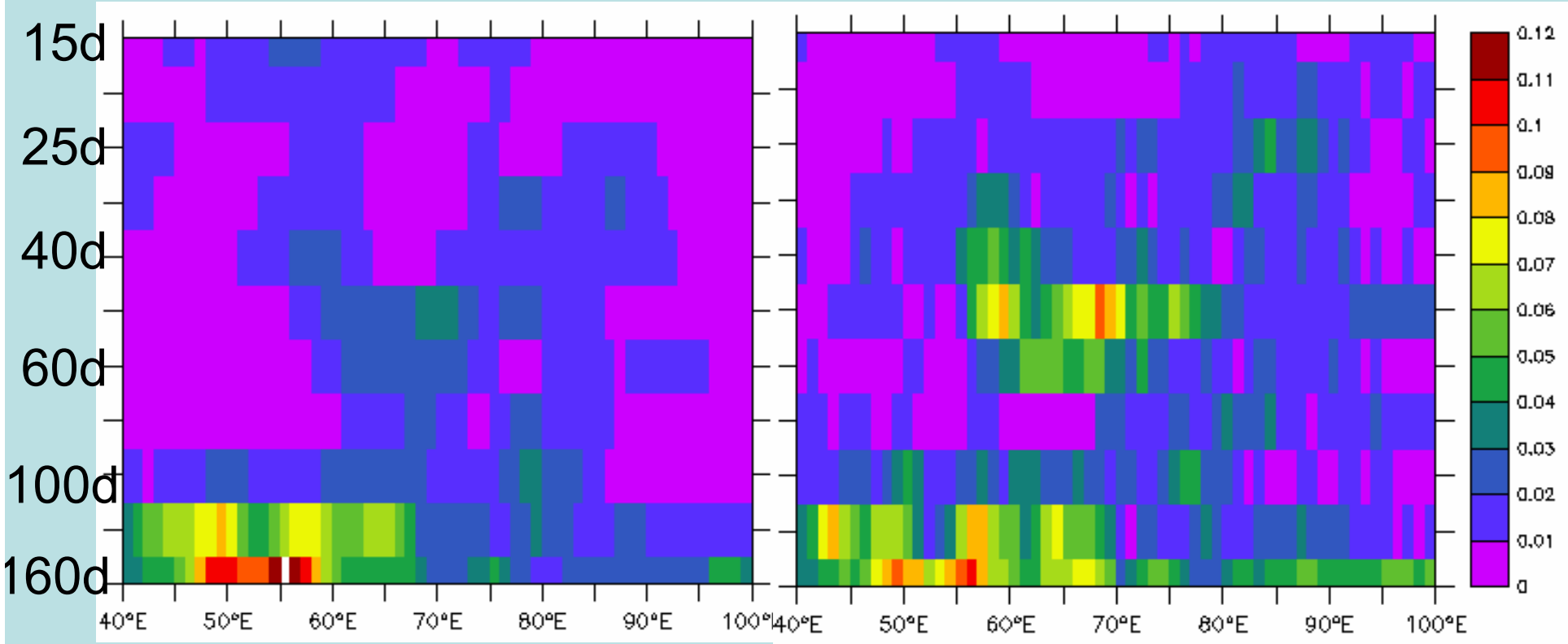
Indian Ocean non-seasonal dominated by sub-seasonal.

SST Energy along 5S in Indian Ocean

Strong 40-60 day energy associated with Nov-April eastward propagating MJO, swings O(1-2C).

Heat-fluxes not enough to explain changes.

(see Harrison and Vecchi 2001, GRL)



NCEP Weekly SST

TMI Weekly 1x1 SST

What's the big deal about sub-seasonal variability?

Strong connections to weather over land:

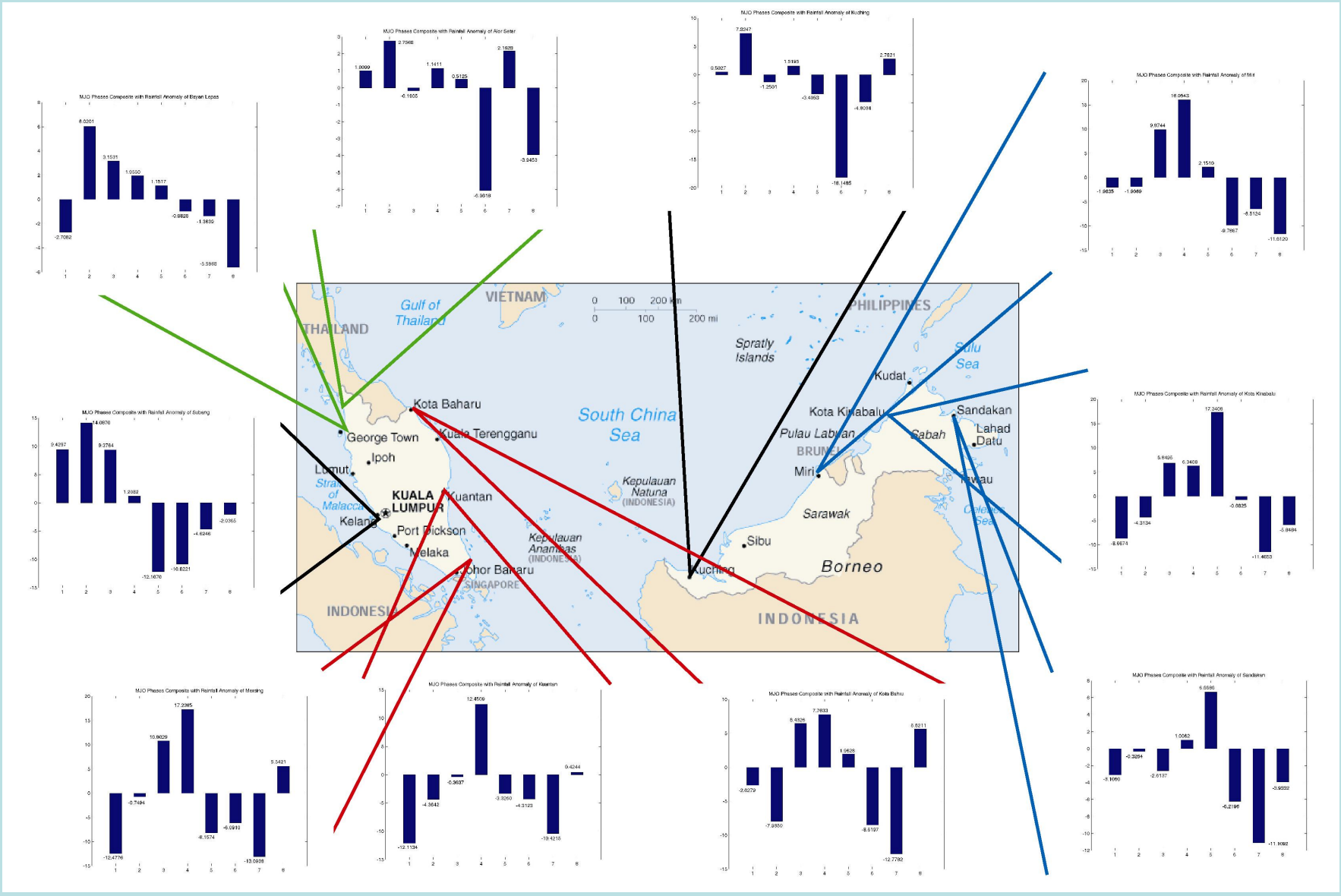
- MJO connects:
  - locally (tropical Indo-Pacific region)
  - remotely (western America, Eurasia and Arctic!)

  - Potential for improvement of >2 week forecasts…

  (Waliser *et al*. 2003)

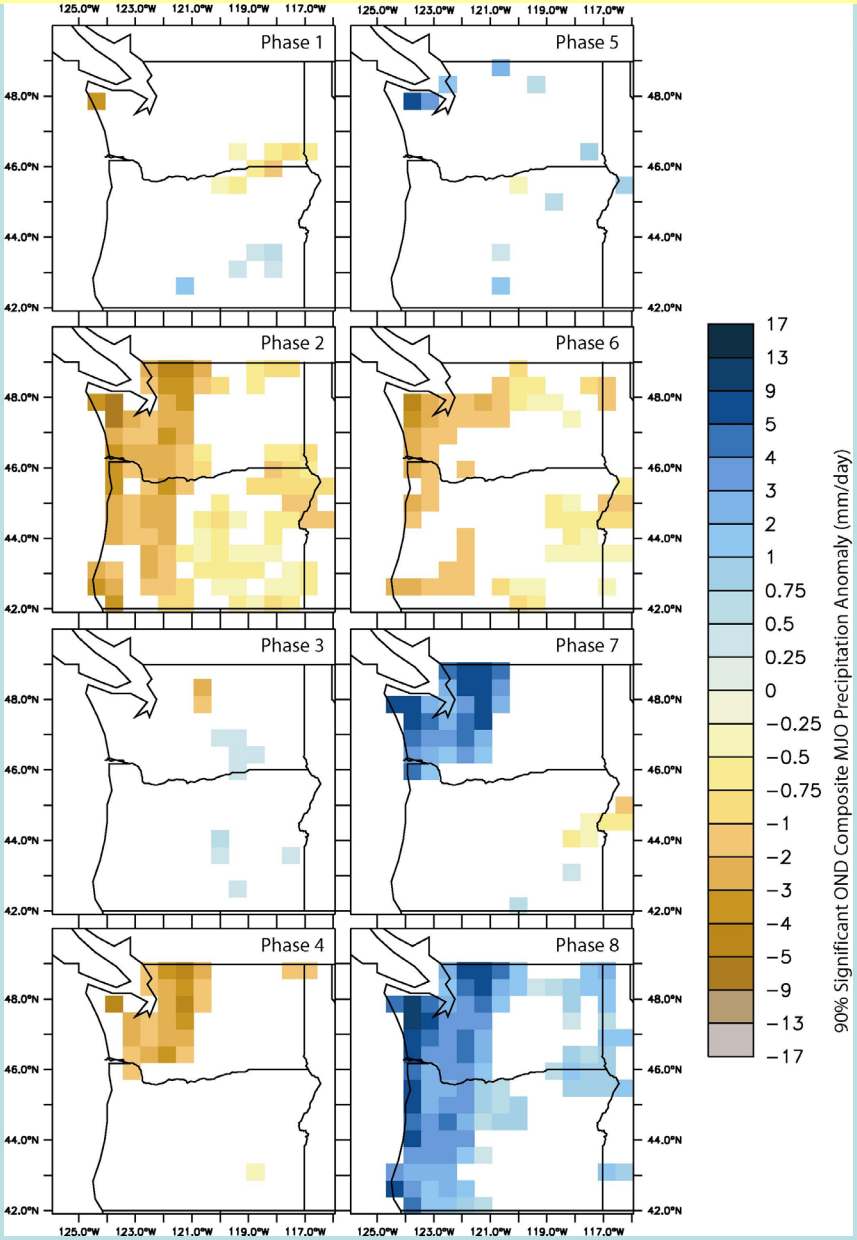
- Other sub-seasonal variability connects locally:
  - *e.g.* Monsoon breaks over India.

Malaysian Precipitation and MJO

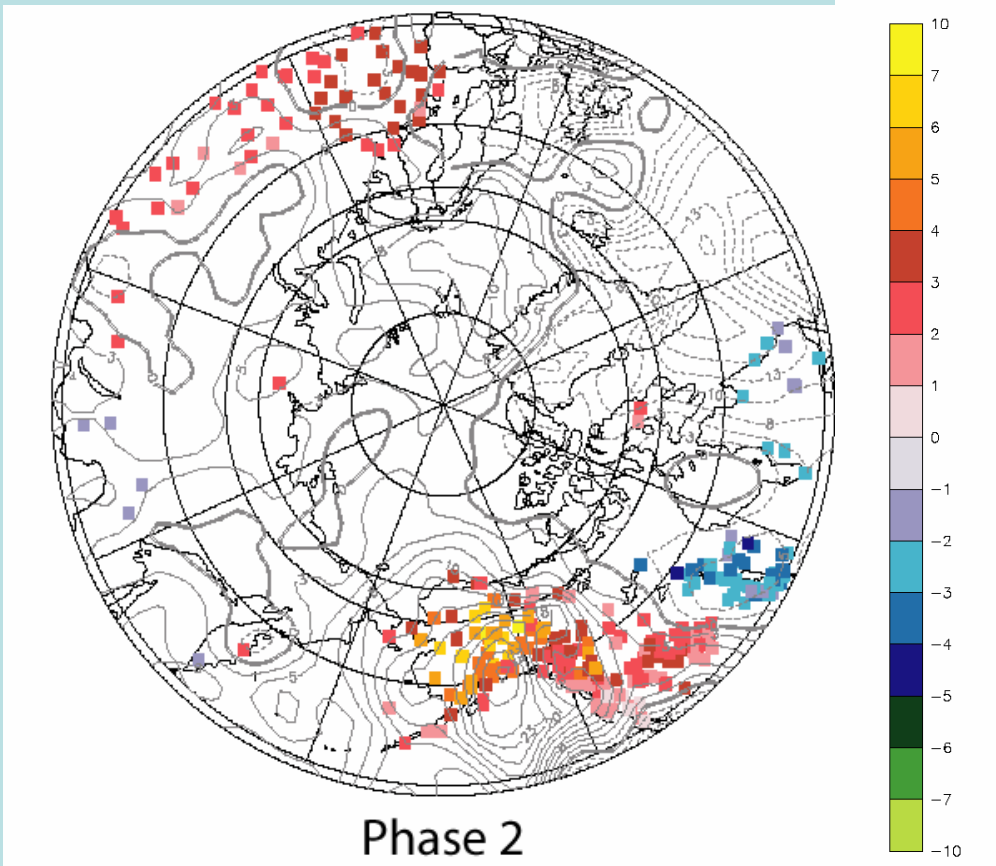


Chen, Tangang and Vecchi (2003)

Also remote…



Pacific NW of USA Precipitation and MJO (Bond and Vecchi, 2003, Wea. & Forecast.)



Global Arctic Air Temperature and MJO
(Vecchi and Bond, 2003, GRL)

The northward propagating summer ISO (25-30 day period)

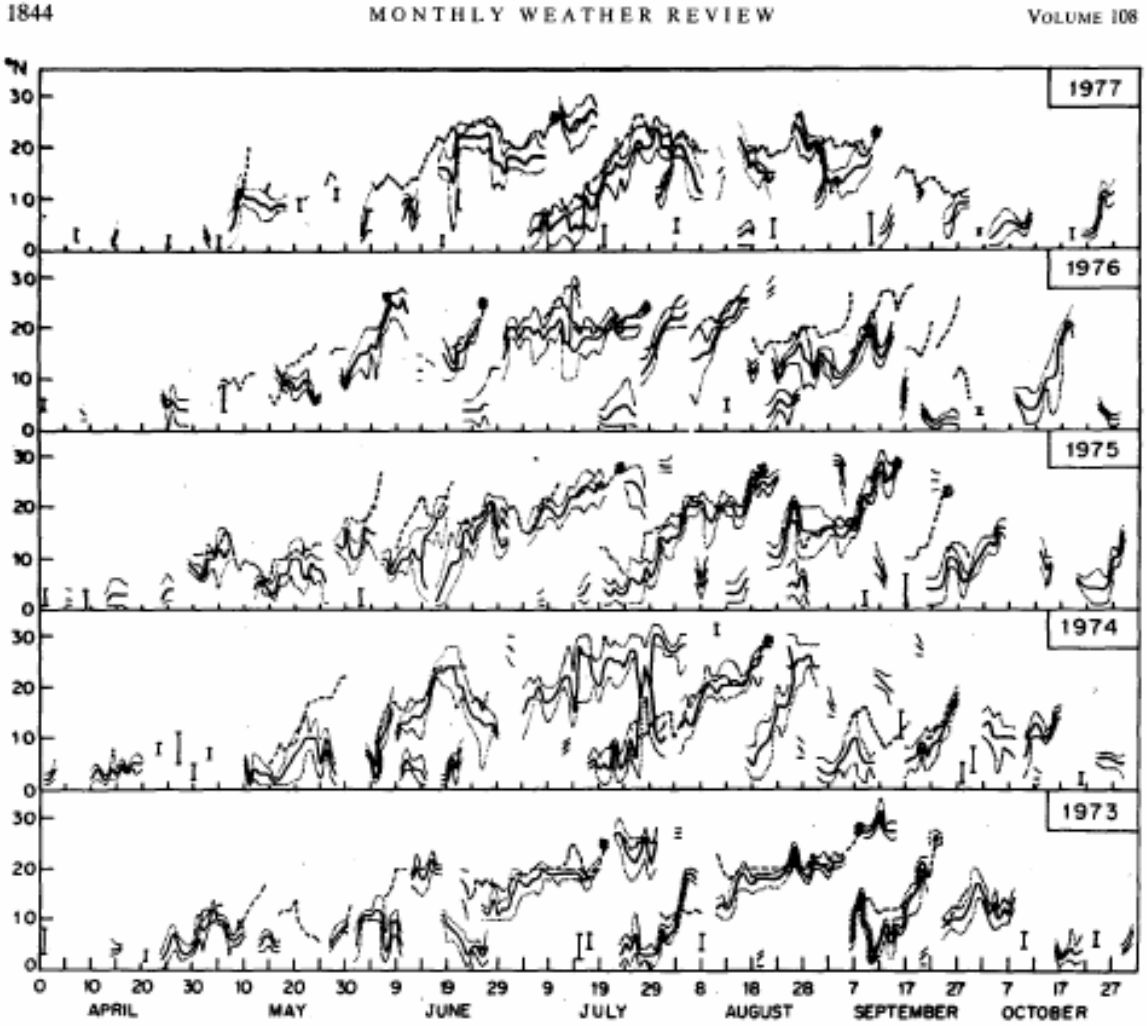
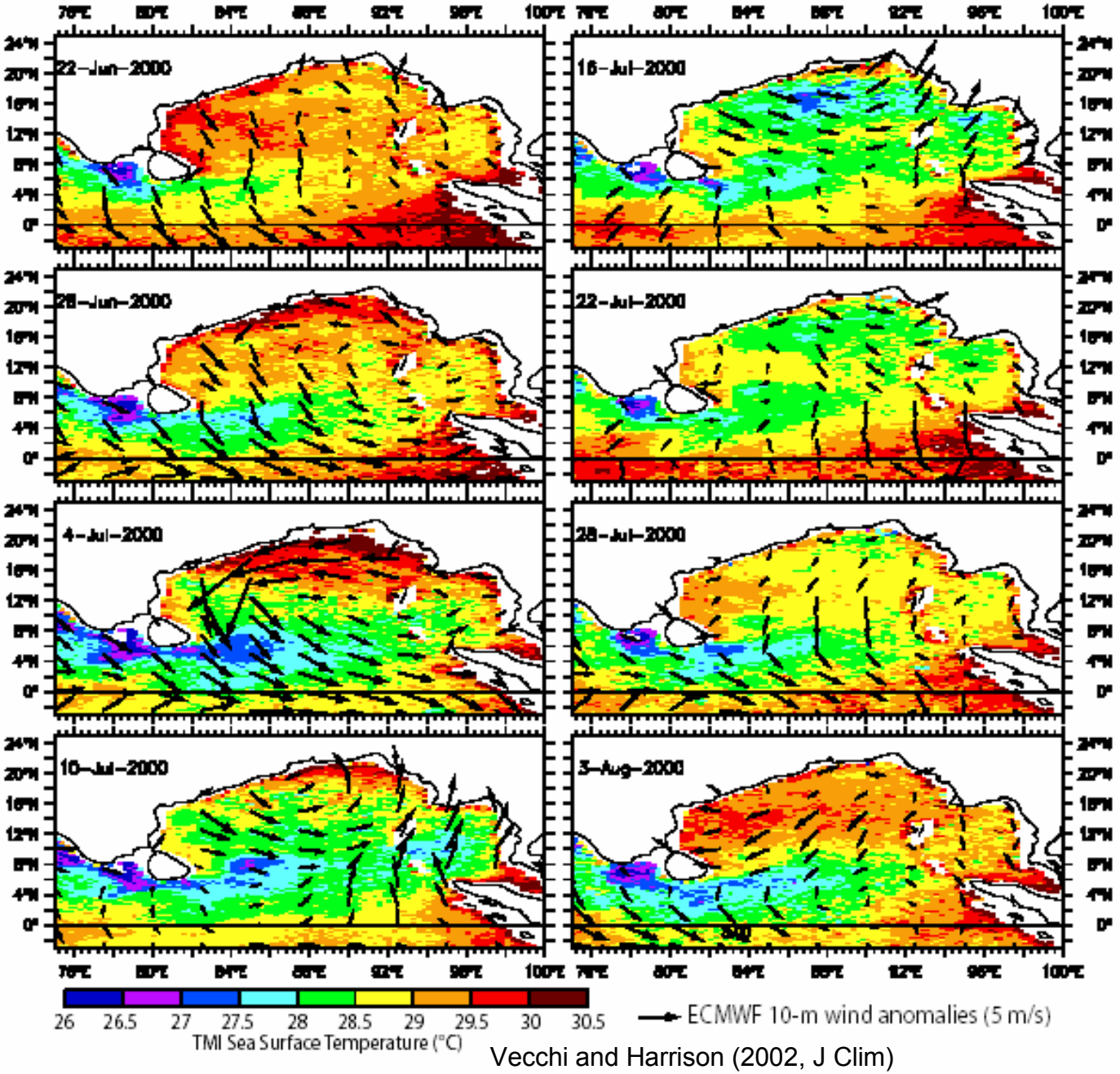


FIG. 4. Daily variation of the latitude of the axis of the MCZ (solid line); northern and southern limits (dotted line) of the MCZ; and the location of the 700 mb trough (dashed line) at 90°E during 1973–77.

Bay of Bengal dominated by northward propagating ISO in SW-monsoon.

Active and break monsoon periods.

From Sikka and Gadgil (1981)

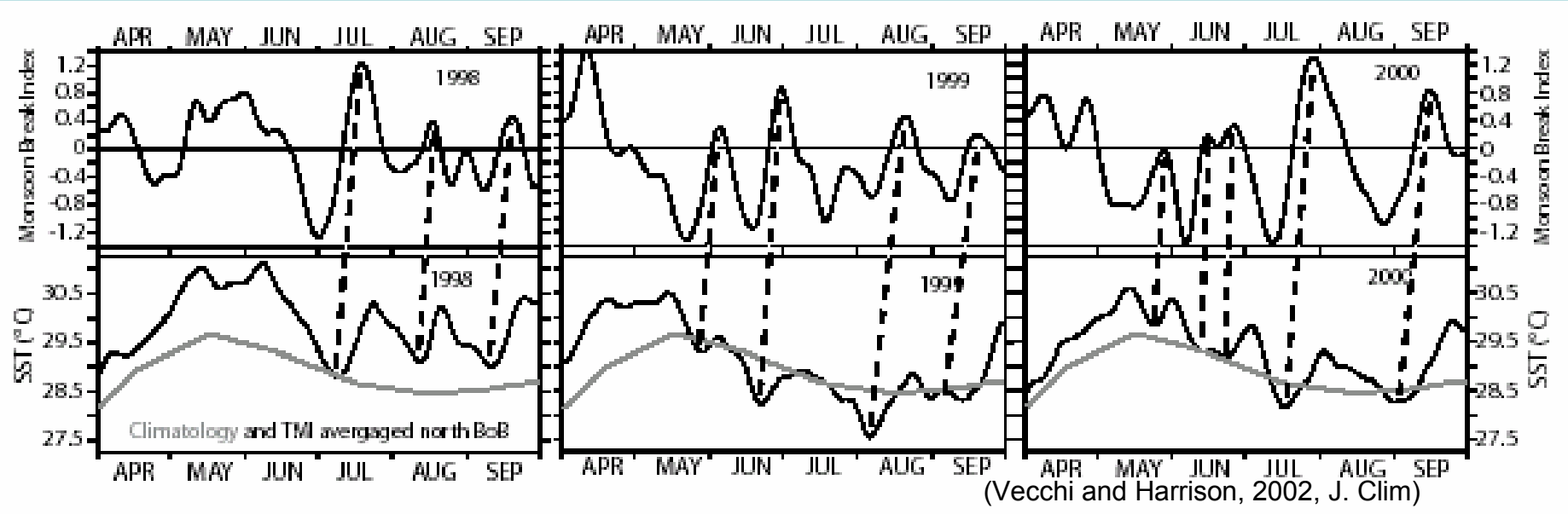


Vecchi and Harrison (2002, J Clim)

Bay of Bengal SST evolution during typical N-Prop ISO

Sub-seasonal SST variations in Bay of Bengal are damped (or absent) in NCEP-OI relative to buoy observations (*e.g.* Sengupta and Ravichadran 2001).

North Bay of Bengal SST Coherent with Monsoon Breaks



(Vecchi and Harrison, 2002, J. Clim)

Relationship holds for 2001-2003 as well.

Fu *et al.* (2003, J. Clim.) find similar variability in CGCM. Coupling modifies breaks.

Sub-seasonal -> interannual variability

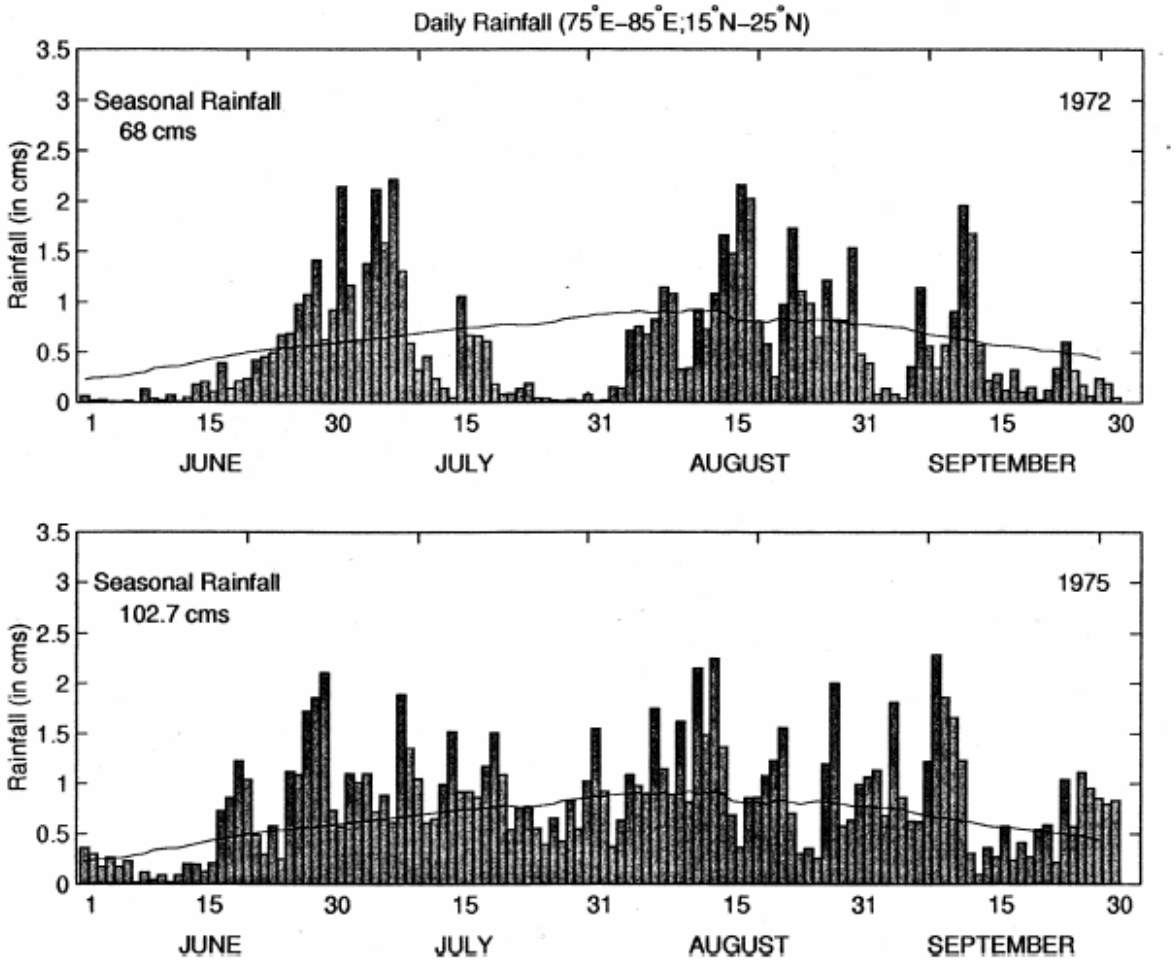


FIG. 3. Daily rainfall over central India during 1972 and 1975, which were deficit and excess monsoon rainfall years, respectively. In 1972, active and weak rain spells were well separated with the break during the last week of Jul and first week of Aug clearly seen, whereas in 1975, although there were days of heavy rainfall (active spell), there were no clear-cut breaks.

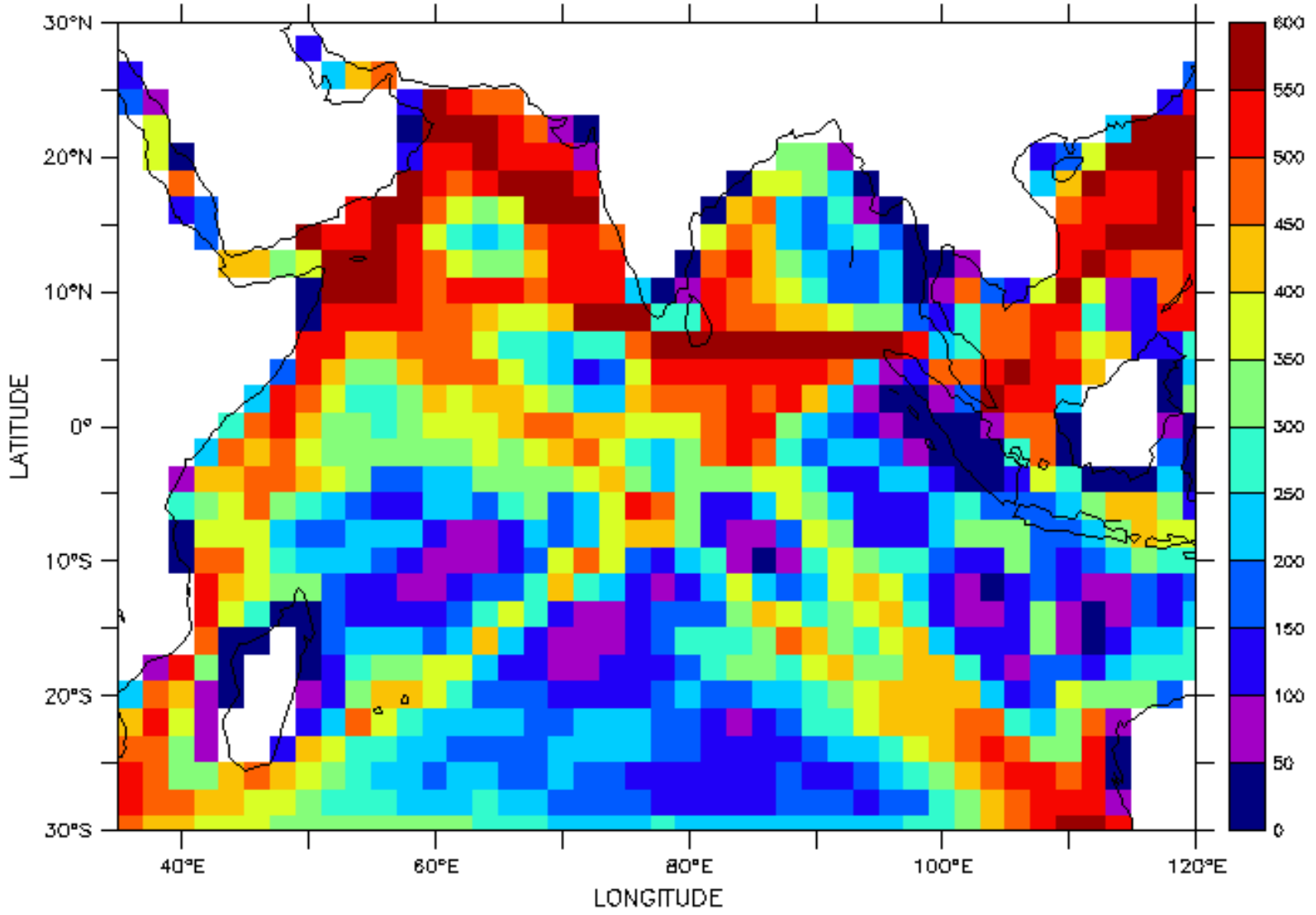
Over India, rainfall deficits over the SW-monsoon can result from changes in the strength/number of monsoon breaks.

Changes in sub-seasonal variability result in interannual variability.

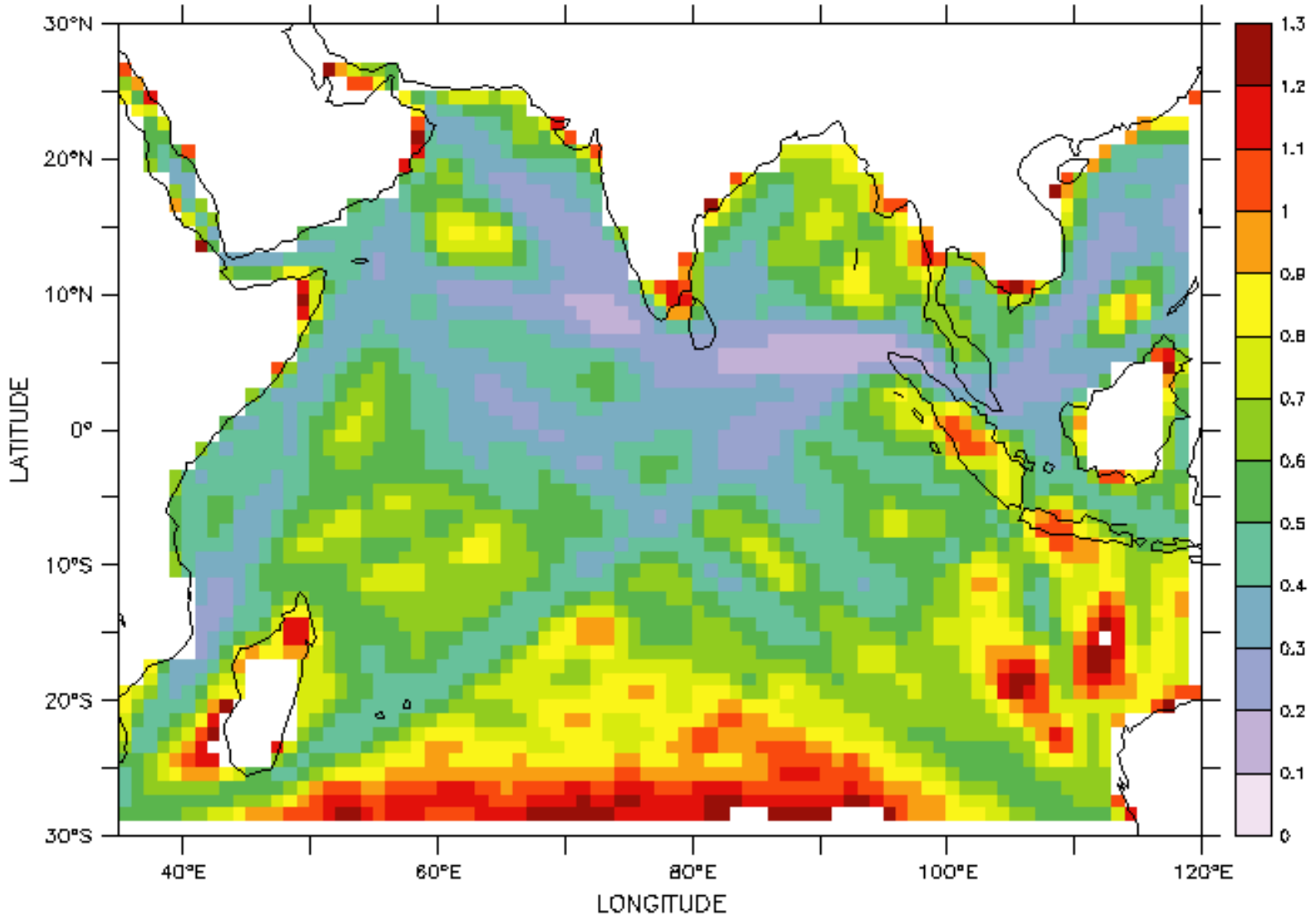
Figure from Bhat *et al.* (2001, BAMS; "BOBMEX: The Bay of Bengal Monsoon Experiment"

Sampling Issues

Historical IO data coverage sparse

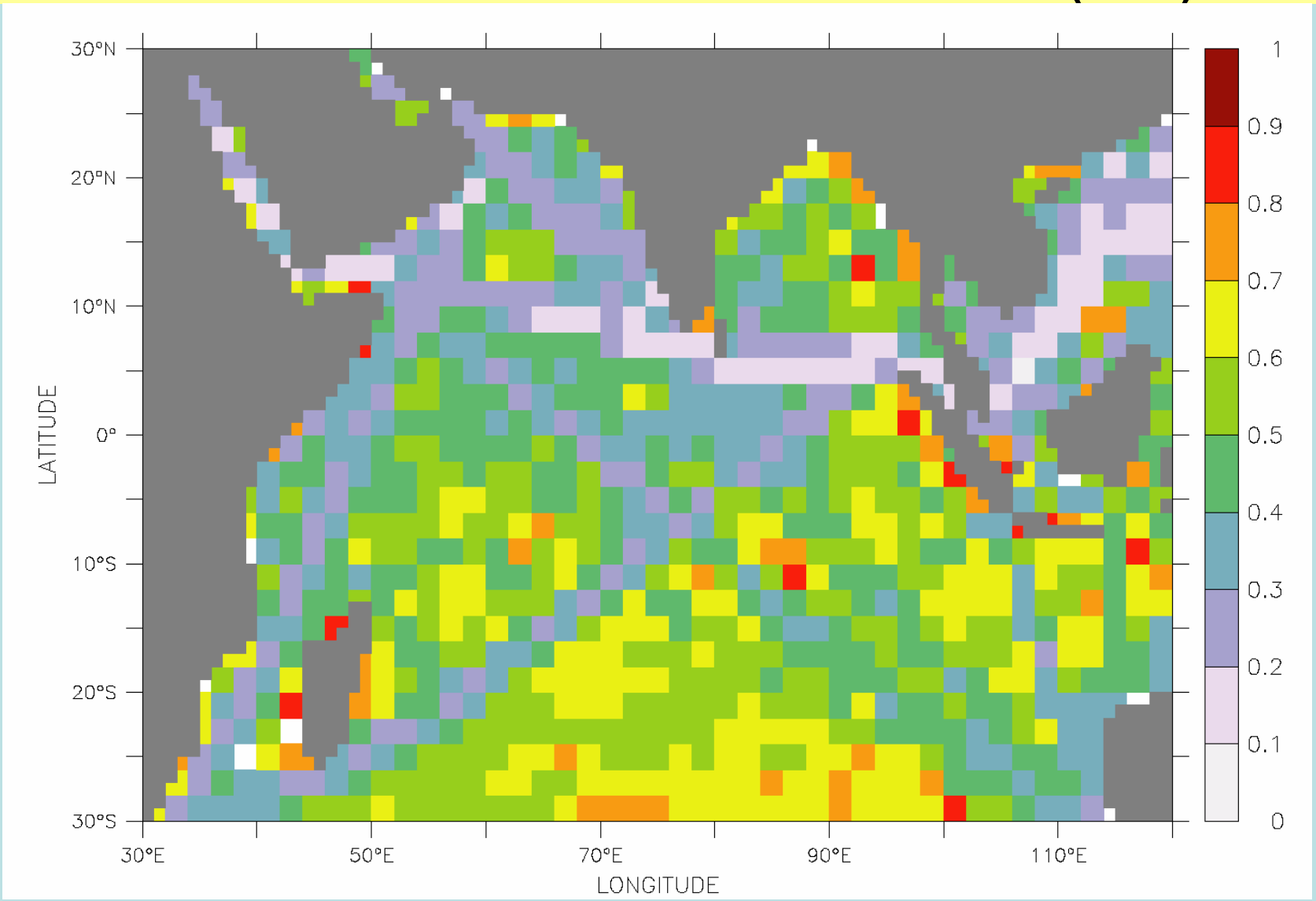


Conspicuous pattern…



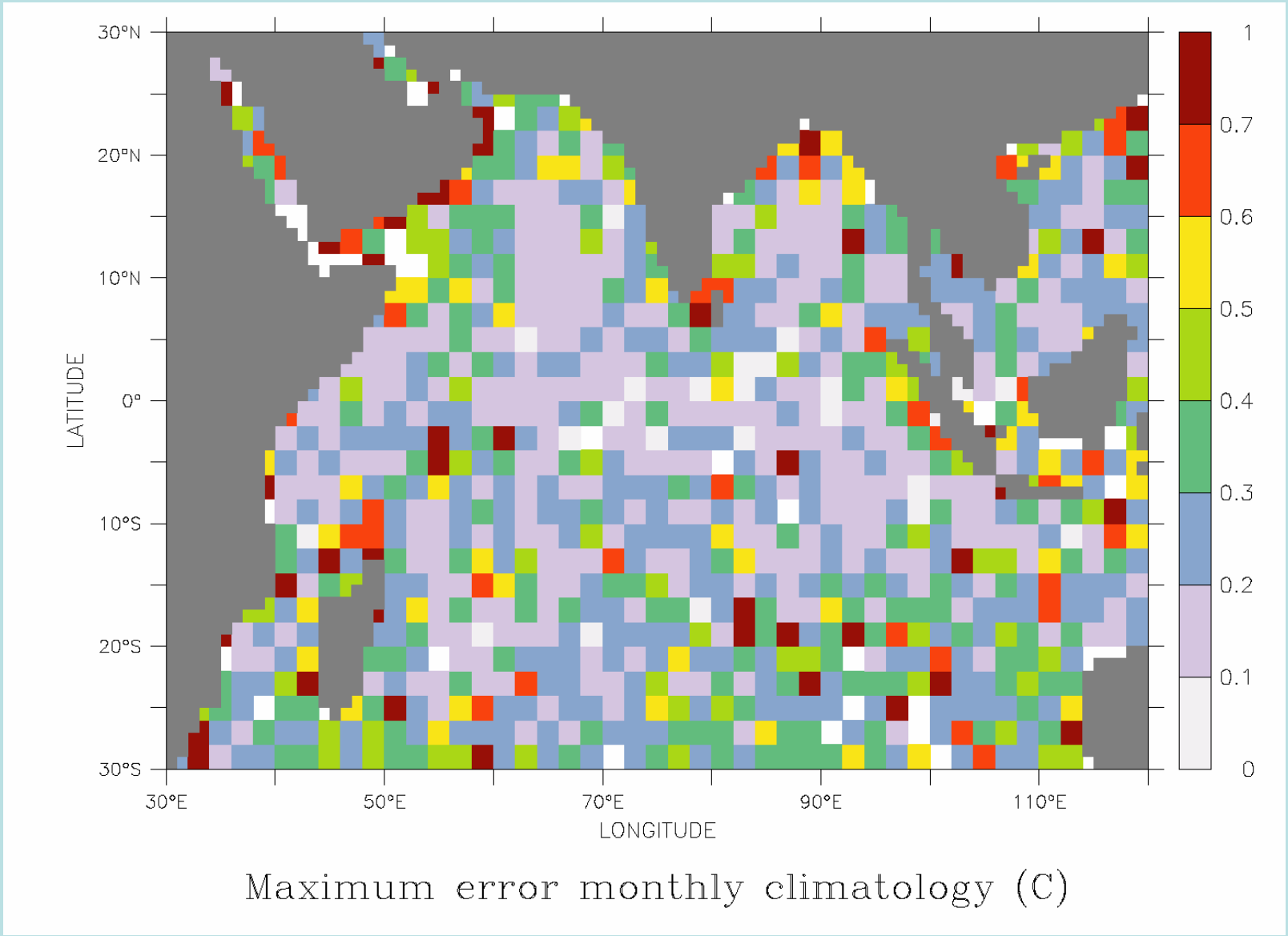
Variance of SSTA from COADS

Sub-sample Year 2000 TMI SST data with statistics of 1946-1993 COADS (v.1)



Standard deviation of sub-sampled SST Anomalies

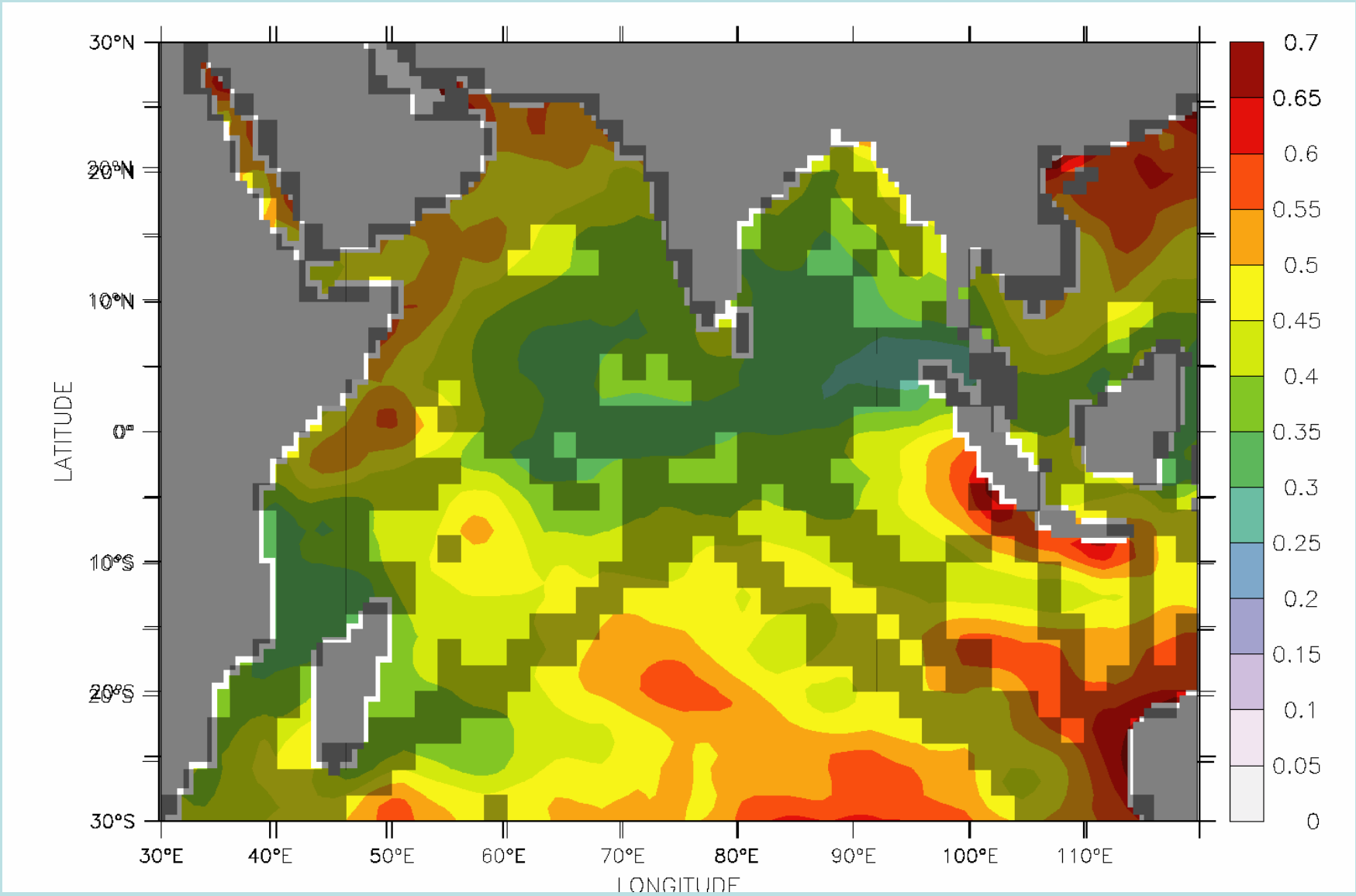
Can result in mis-estimates of climatology



Even if sub-seasonal variability were unimportant

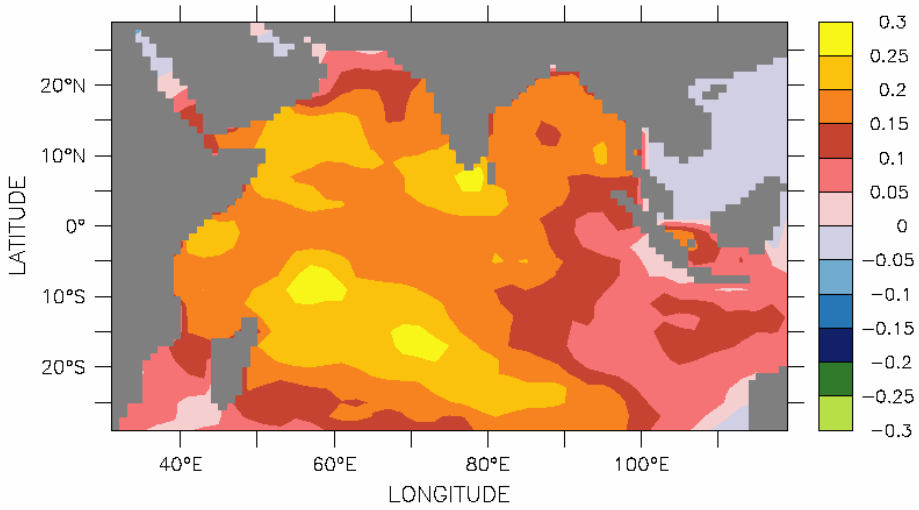
- We need to better sample southern IO.
- Data hole is maximum in NCEP-OI variability. (And of EOFs of NCEP-OI)
- Southern IO interannual variability not necessarily all spurious.

NCEP-OI SSTA variability patterns

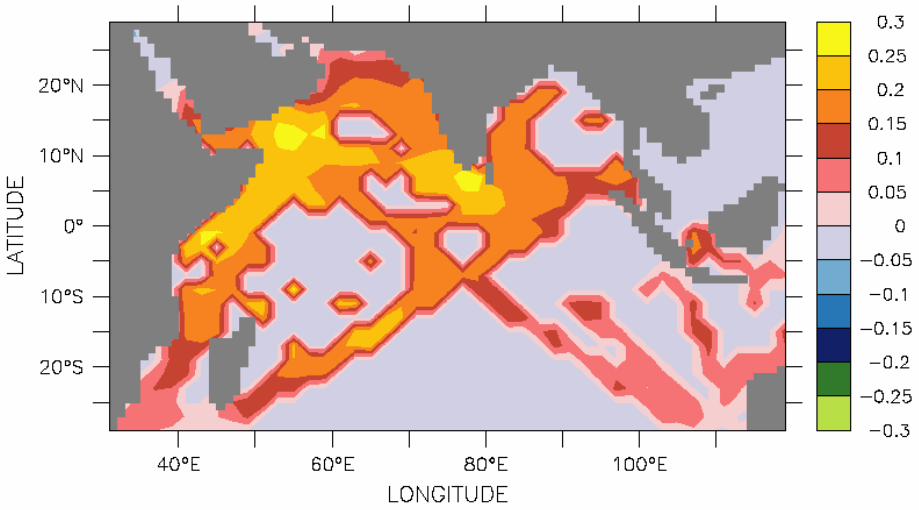


Stdv of NCEP-OI SSTA (1982-2003)

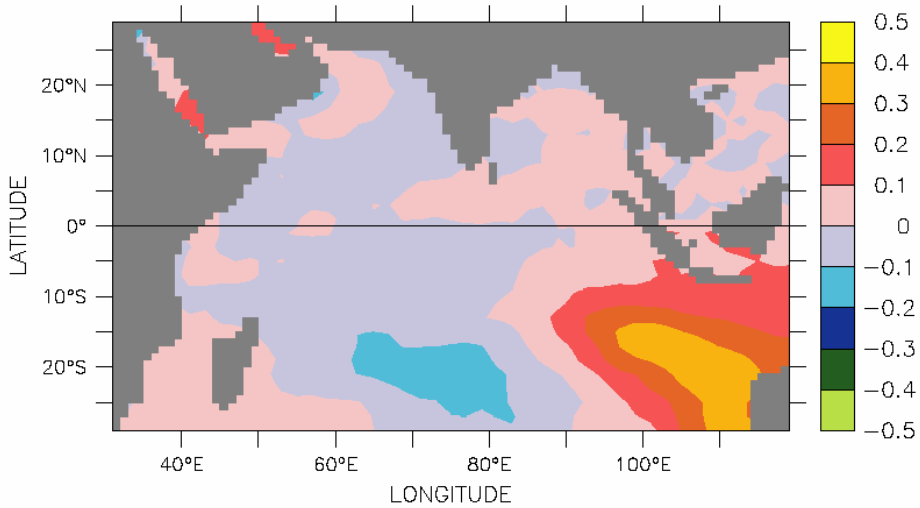
EOFs of NCEP OI 12-mo smooted SSTA



EOF 1 of all data



EOF 1 of heavy sampling



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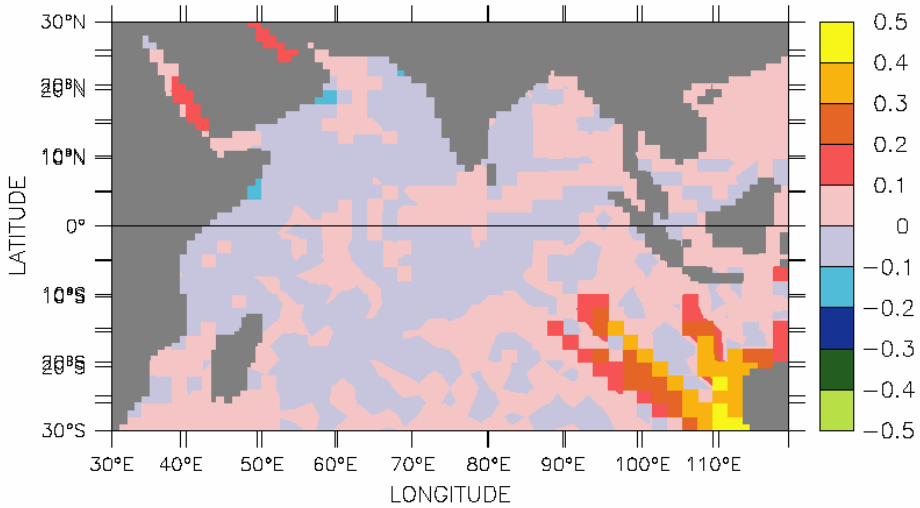
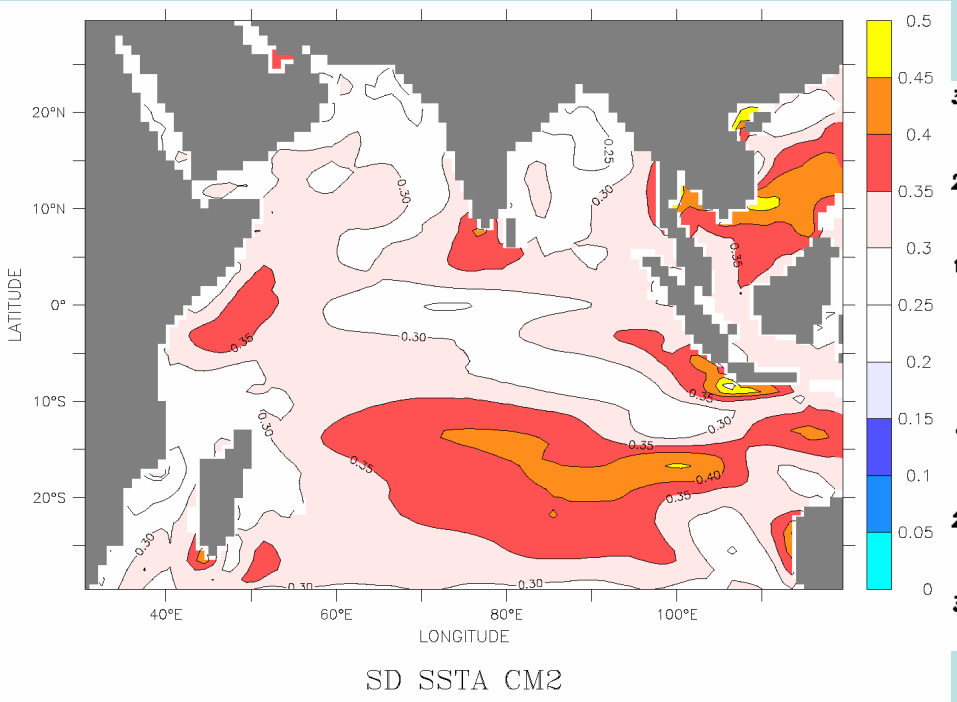
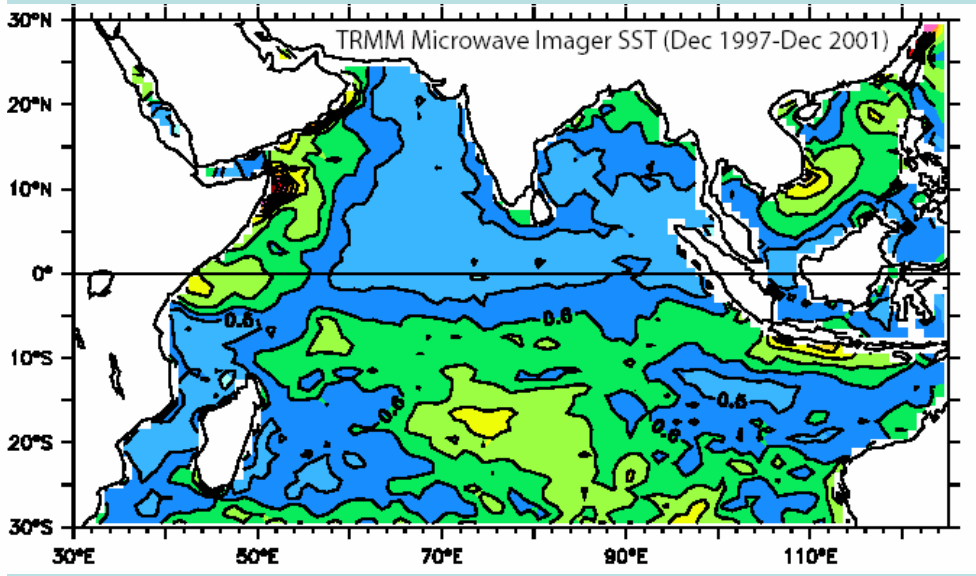


EOF 2 of heavy sampling

Southern IO variability not necessarily spurious…



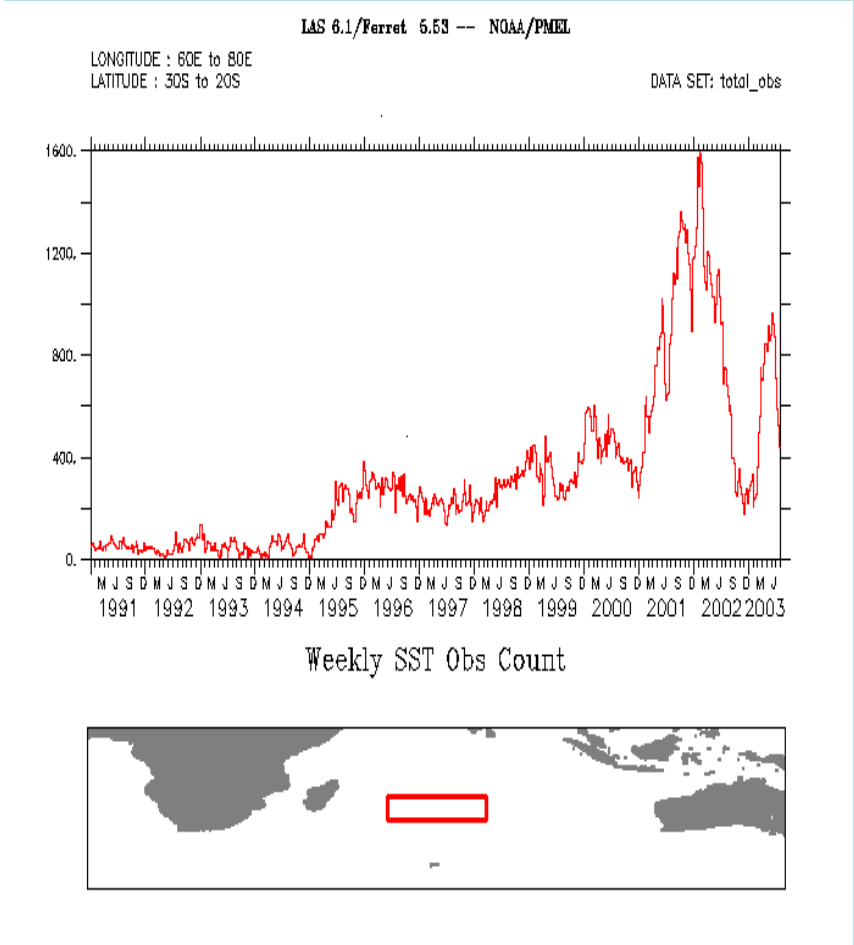


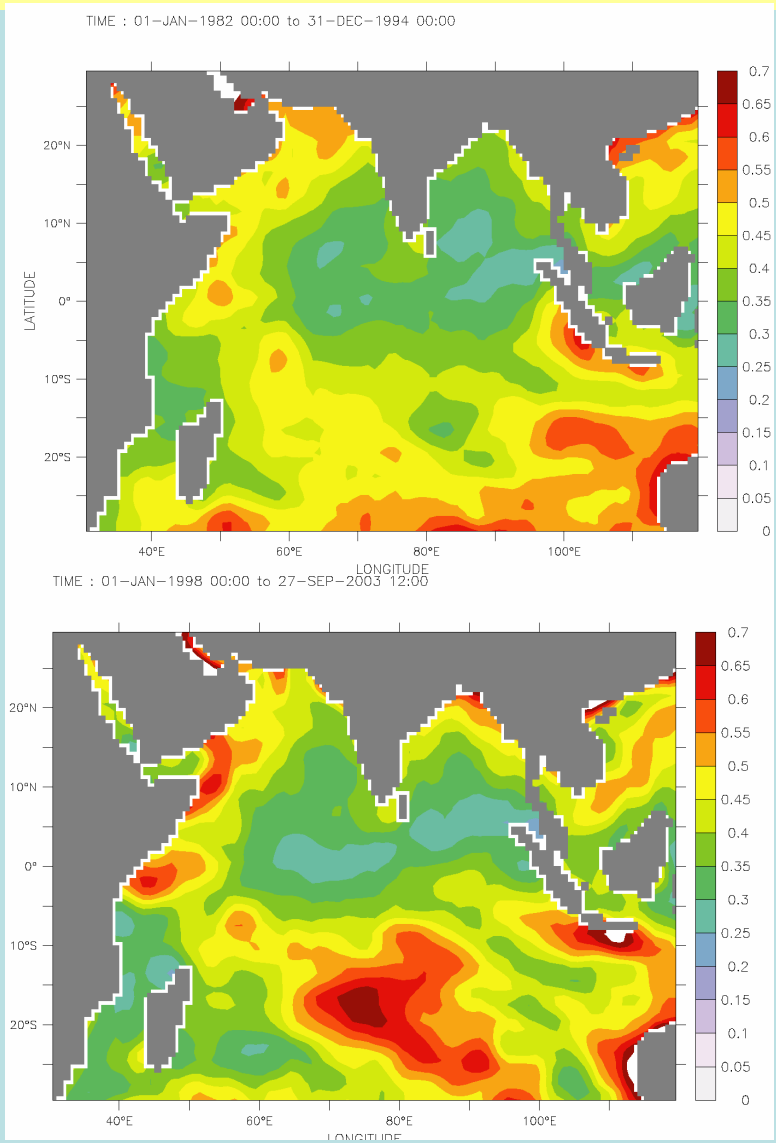
GFDL coupled GCM
100-year run.

TRMM Microwave imager

Figure from Tony Rosati

More observations in southern IO recently





Stdv 1982-1994

Stdv 1998-2003

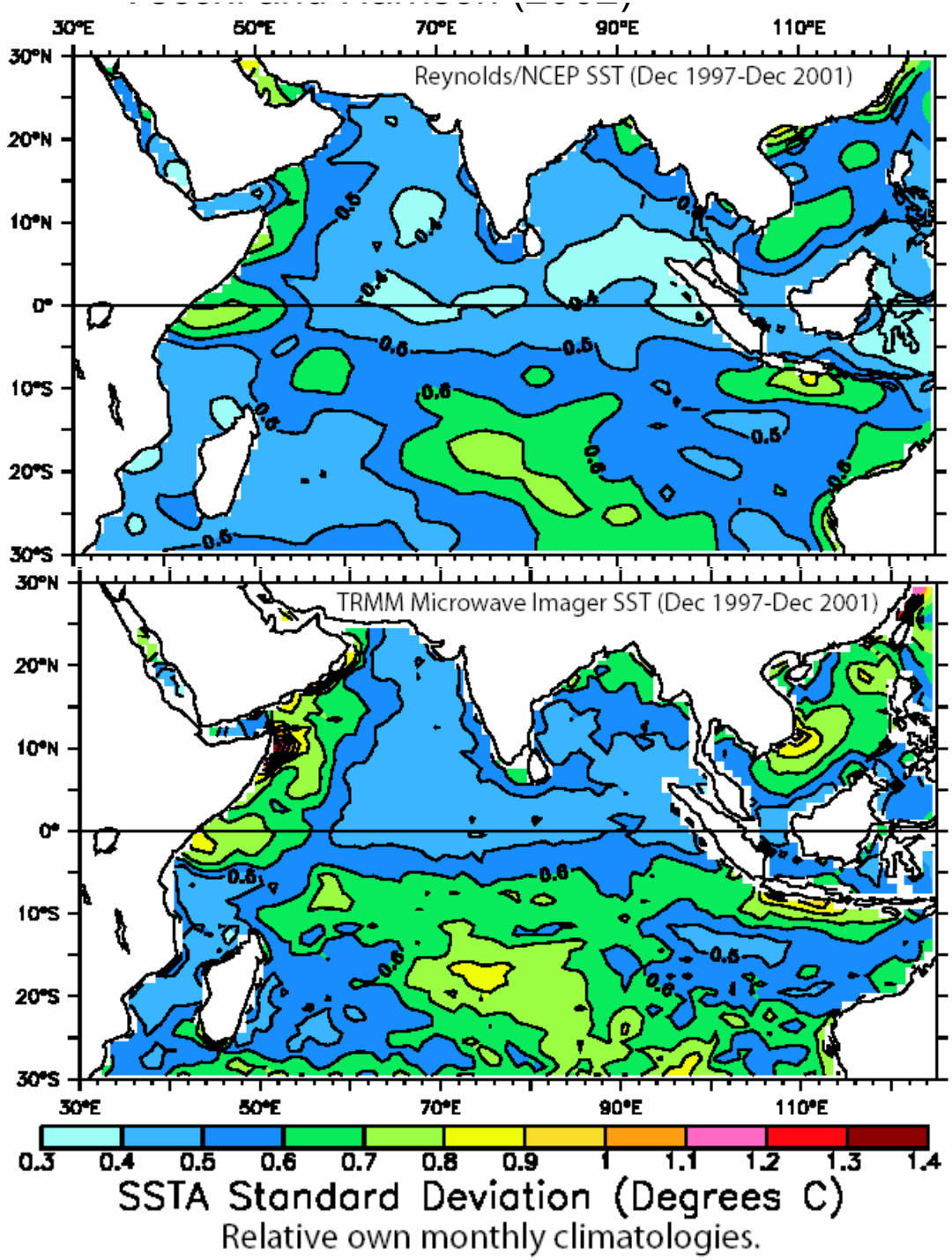
Is change in location of max. variance real?

Summary

- Sub-seasonal variability is prominent in IO.
  - impacts humanity (worldwide).
  - Could alias estimates of longer timescales.

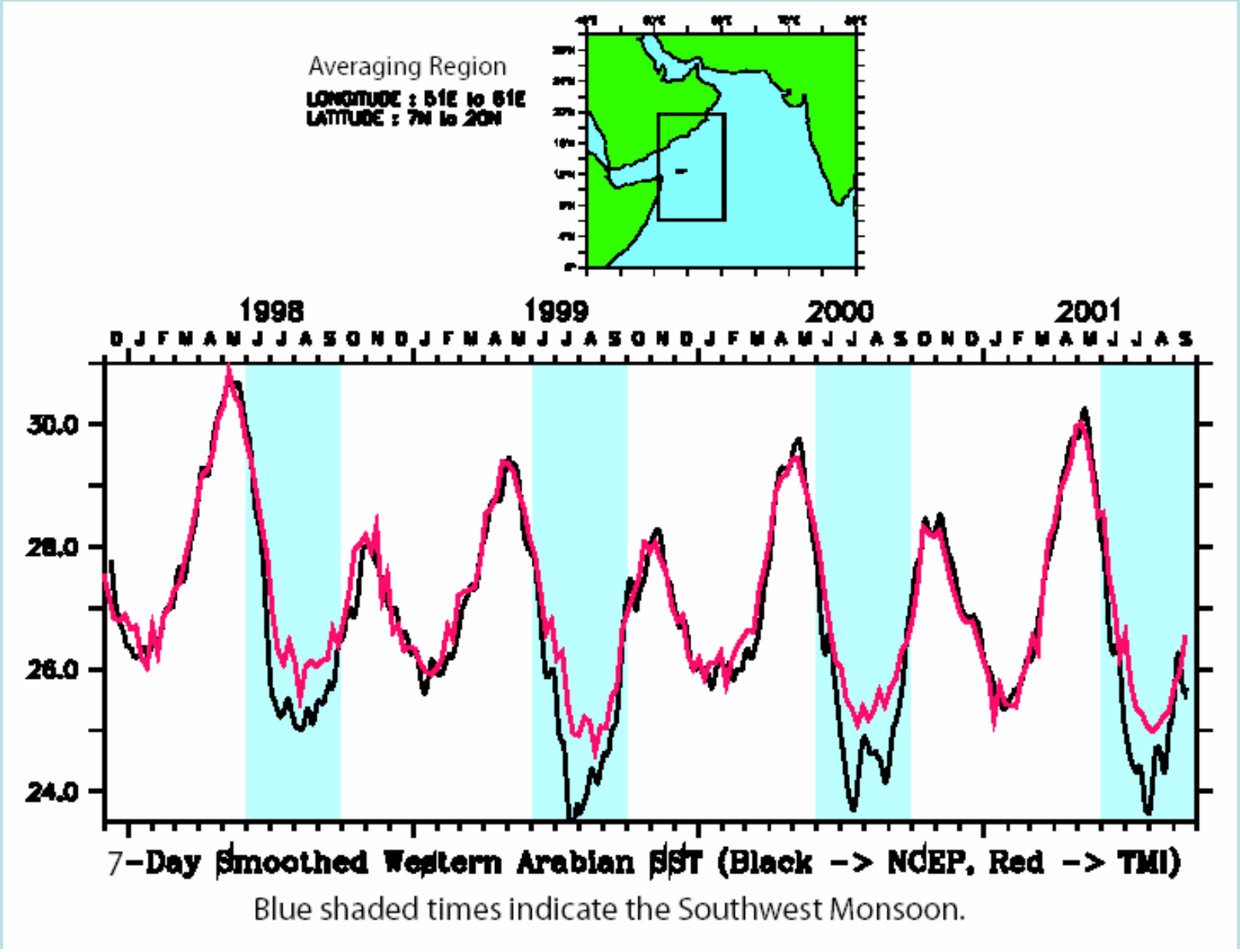
- Historical *in situ* sampling not adequate for:
  - sub-seasonal in IO.
  - southern IO SSTA.

As we look forward we should aim to develop a system that can adequately sample both.



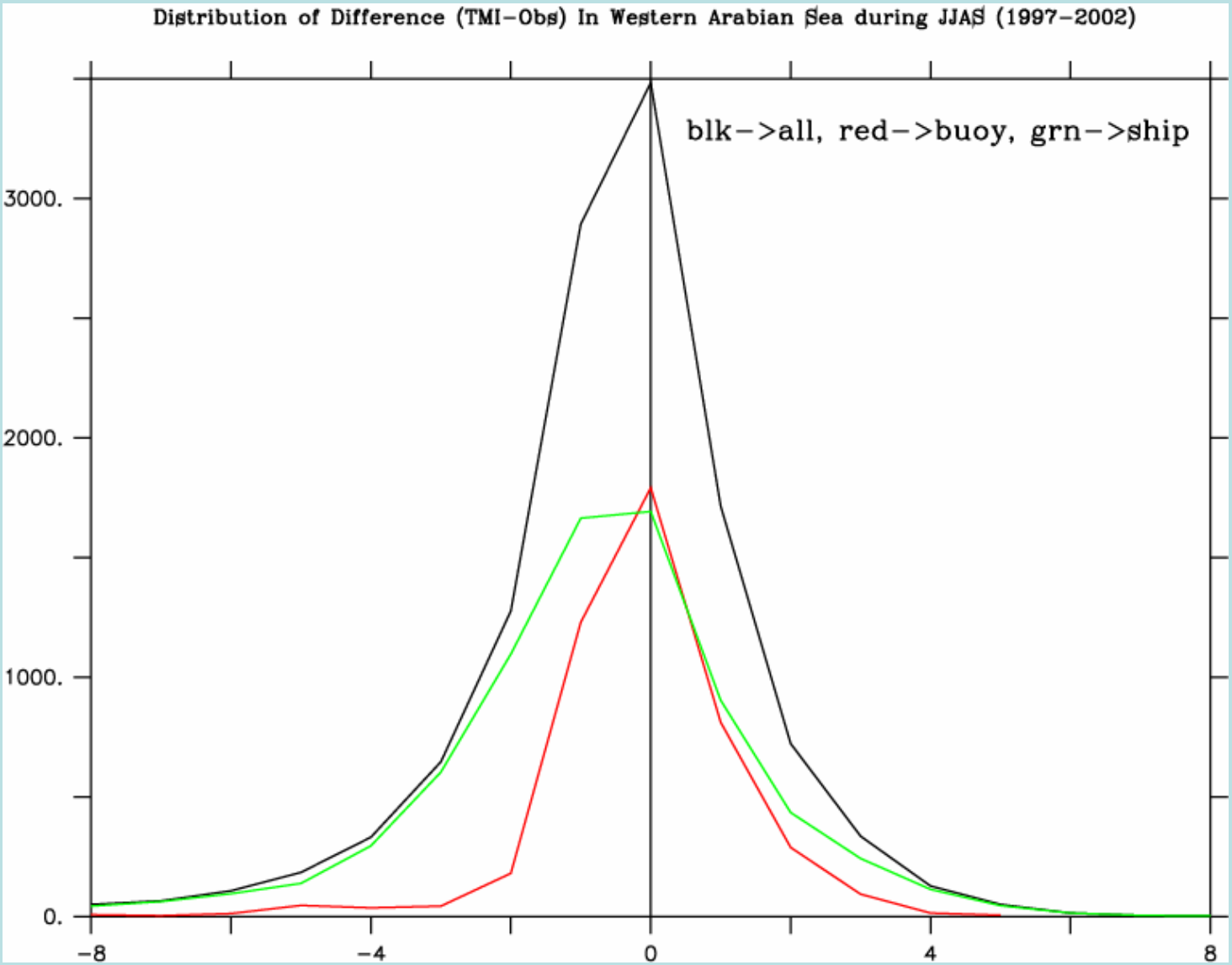
SSTA Variability in Western Arabian Sea much larger in TMI….

….And seasonal variability differs as well.

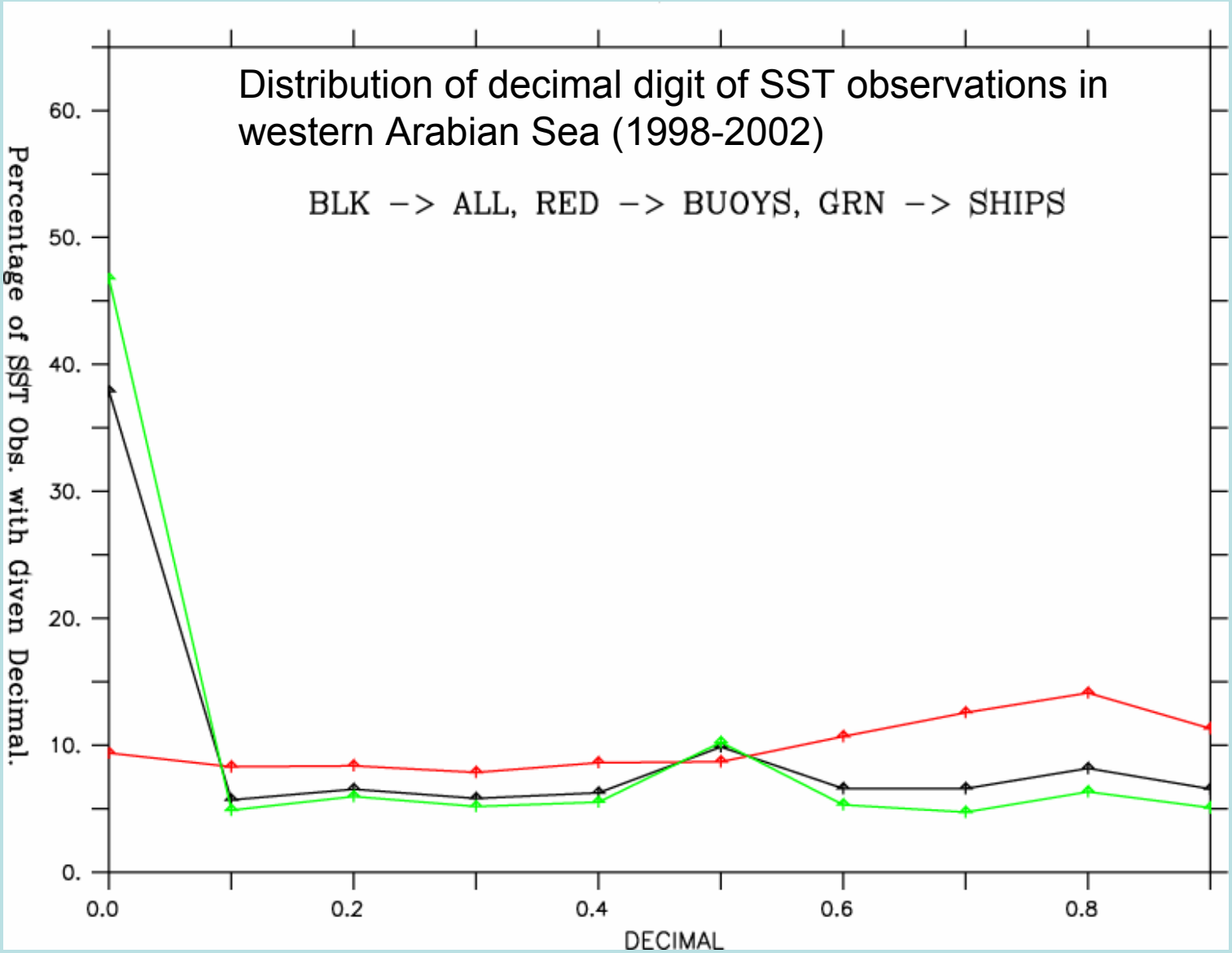


Blue shaded times indicate the Southwest Monsoon.

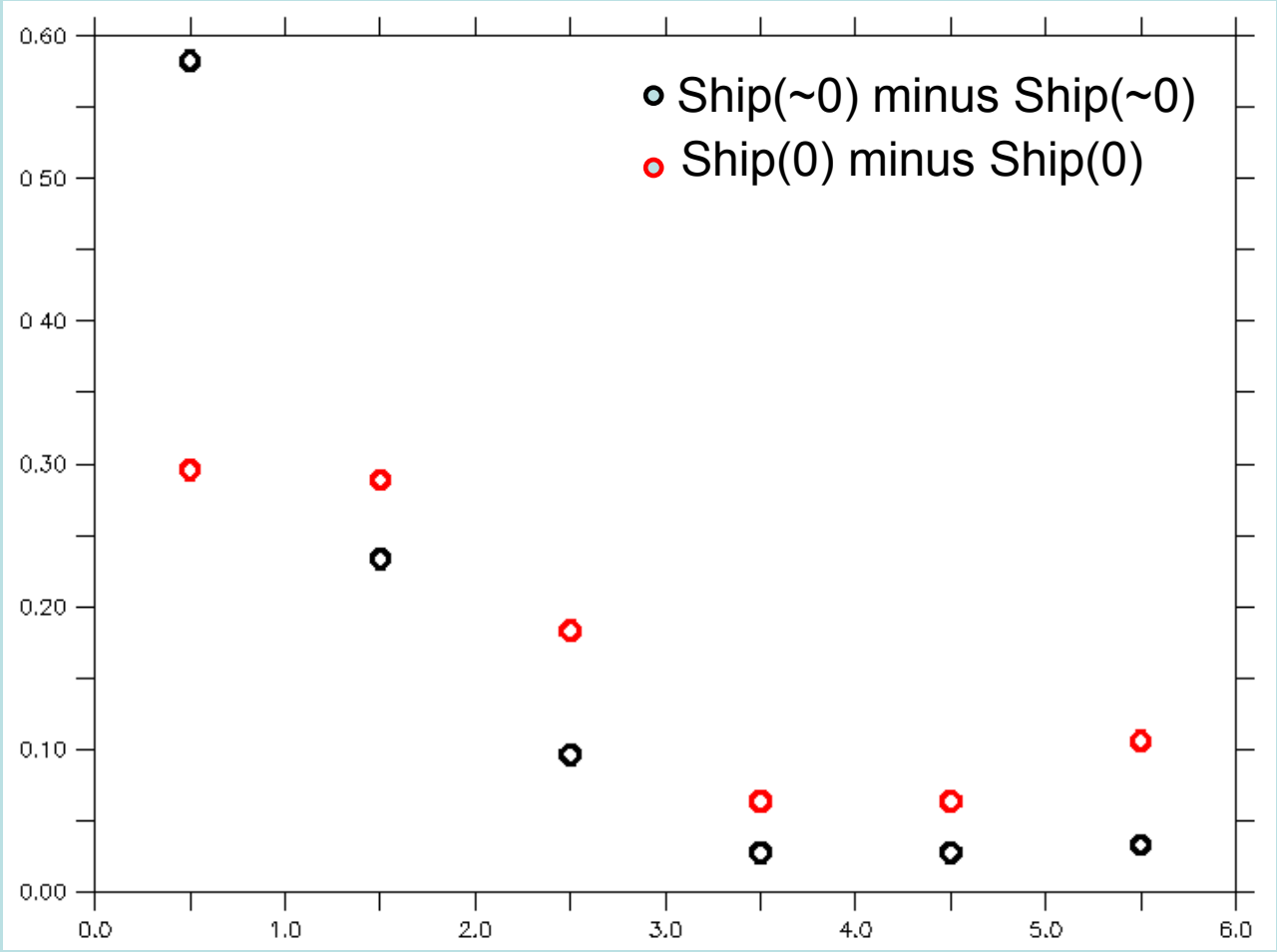
Buoys agree more with TMI than do ships



Disproportionate amount of SST obs. end in ".0"



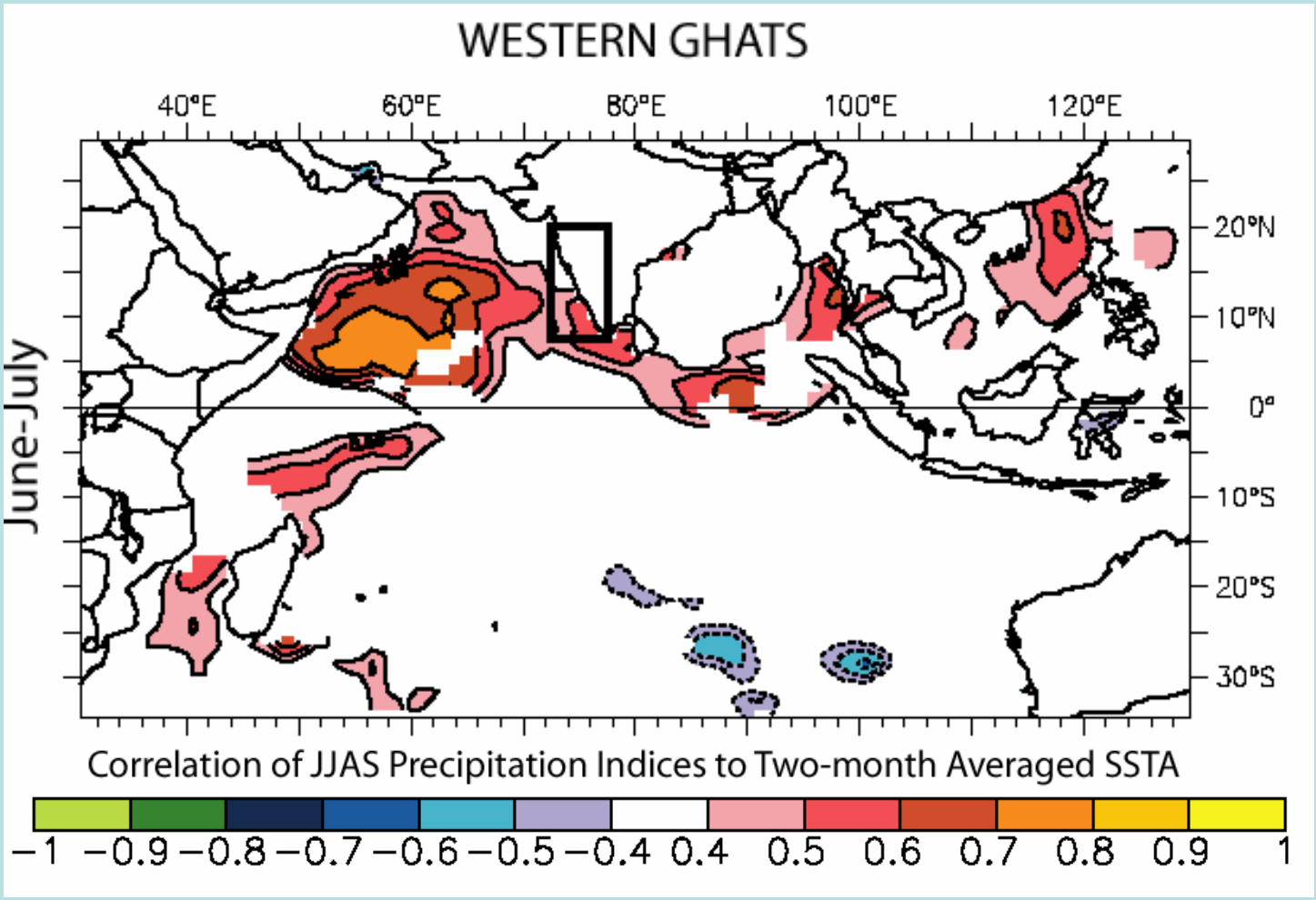
Ship obs. ending in ".0" 'worse' than those not ending in ".0"



~60% of ship observations not ending in ".0" are within 1C of neighbors.

70% of ship observations ending in ".0" are more than 1C away from neighbors!

Interannual SST connections to regional Indian Rainfall



Based on Reynolds SST.

Strong regional rainfall connections to Western Arabian SSTA.