Indian Ocean Intraseasonal SST Variability During Boreal Summer

MJO Versus Submonthly Forcing and Processes

JGR - Oceans, under revision

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Outline:

1. Motivation/Importance
2. Background:
   - Goals & Procedure
   - Model
   - Data
3. Results
4. Summary & Conclusion

Motivation & Importance:

- Lack of current research (submonthly)/consensus (MJO)
- More knowledge about these processes is important:

Better Knowledge of SST Processes ➔ Improved Understanding of Air-Sea Interactions ➔ Better Indian Ocean modeling

  - Atmospheric feedback

- Benefit society in India
  - 80% rainfall during summer monsoon ➔ crops, flooding *(Webster & Hoyos, 2004)*

BBC News, 2005: http://news.bbc.co.uk/2/hi/south_asia/4733897.stm

Goals & Procedure:

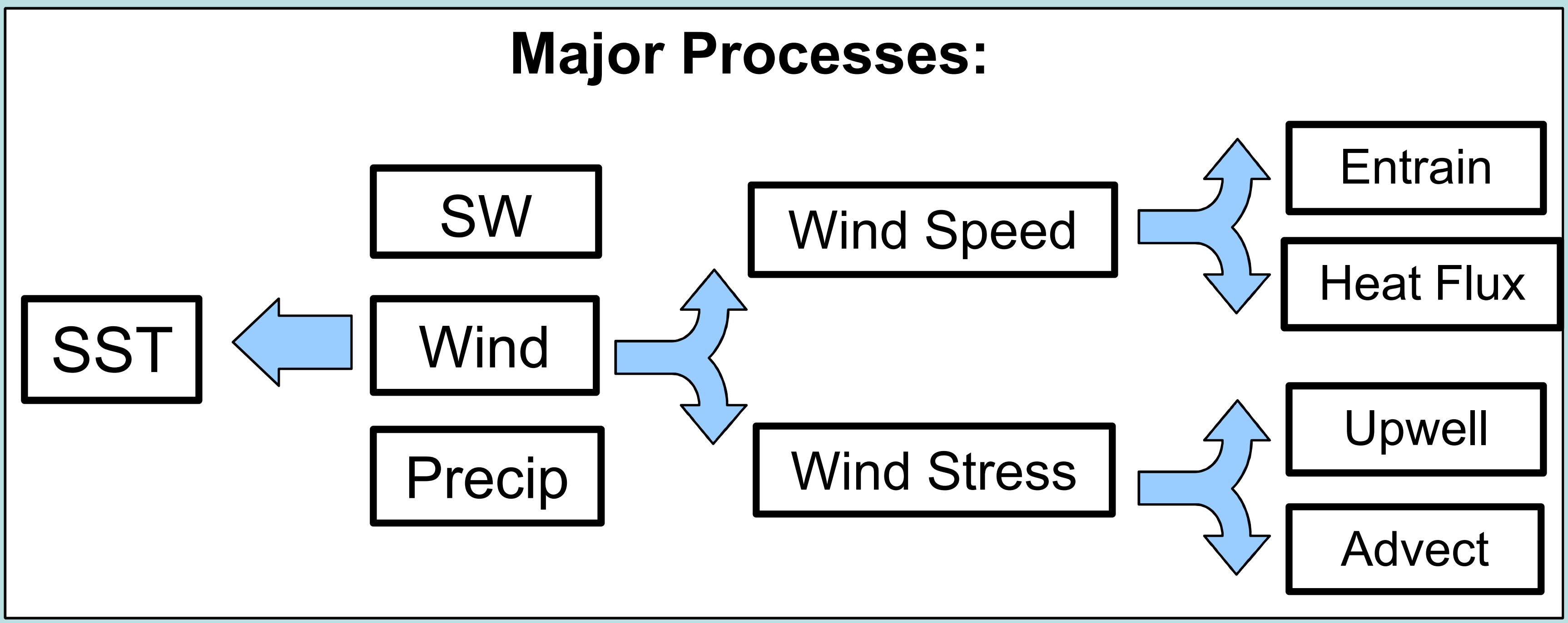
Use a model/observation experiment to:

1. Assess model validity – compare model SST with data
2. Study impact of submonthly & MJO events on SST

Use model runs to isolate processes that cause SST variability

Look at specific events & general timescales

If a process consistently dominates, then how & why?



The Model:

- HYbrid Coordinate Ocean Model (HYCOM)
  - OGCM with hybrid vertical coordinates, 18 layers
  - Vertical Mixing: K-Profile Parameterization (*Large et al. 1994*)
  - Configured for Indian Ocean, horiz resolution 0.5°x0.5°
  - Model runs from 1 January 1998-November 2004
- Use a hierarchy of model experiments to isolate processes

Experiment Number:	**Forcings used:**
MR	All 3-day mean fields: winds, air temp, humidity, fluxes, precipitation
EXP 1	Lowpassed 105 days
EXP 2	Lowpassed 30 days
EXP 3	Lowpassed wind stress
EXP 4	Lowpassed wind stress and speed
EXP 5	Lowpassed shortwave flux
EXP 6	Lowpassed precipitation

Difference Solution:	**Isolates Ocean Response To:**
MR-EXP1	Subseasonal ISOs
MR-EXP2	Submonthly ISOs
EXP2-EXP1	30-90 day MJO Events
MR-EXP3	ISO wind stress
MR-EXP4	ISO wind stress and speed
EXP3-EXP4	ISO wind speed
MR-EXP5	ISO shortwave flux
MR-EXP6	ISO precipitation

Data Used:

- For model forcing:
  - QuickSCAT 3-day winds & derived wind stress (*Tang & Liu*)
  - ISCCP net shortwave and longwave fluxes
  - CMAP precipitation
  - ERA-40 air temperature & specific humidity
  - Surface and latent heat fluxes from bulk formulas (*Kara et al. 2000*)
- For model-data comparisons & further study:
  - QuickSCAT 3-day 10 meter winds
  - NOAA Satellite-observed OLR
  - TRMM SST
  - ARGO & TRITON float data

Results: Observations

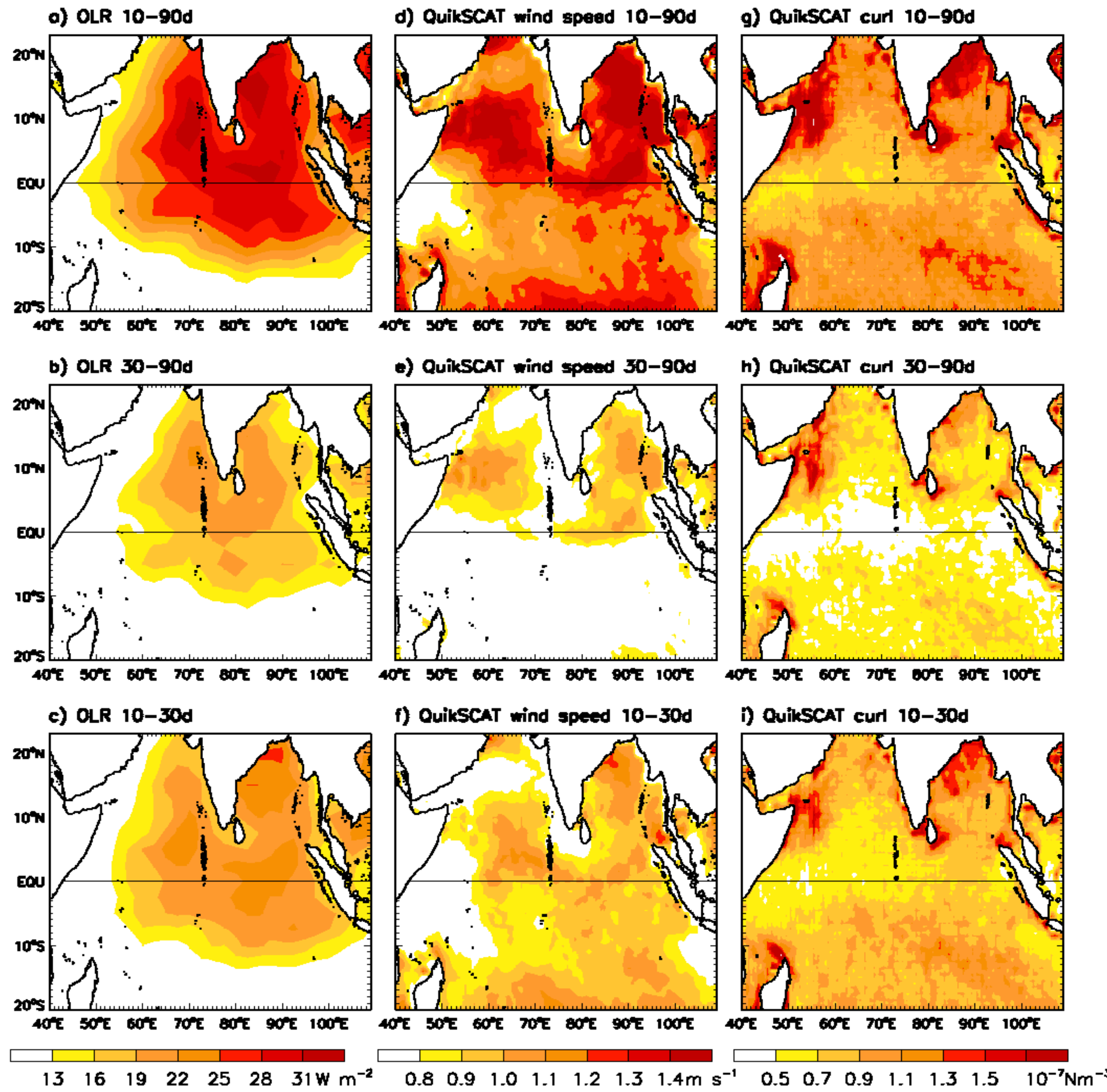
STD: Summers 1999-2003

OLR | Wind speed | Wind stress curl

10-90d

30-90d

10-30d



Results: Model Validity

SST STD, 1999-2003

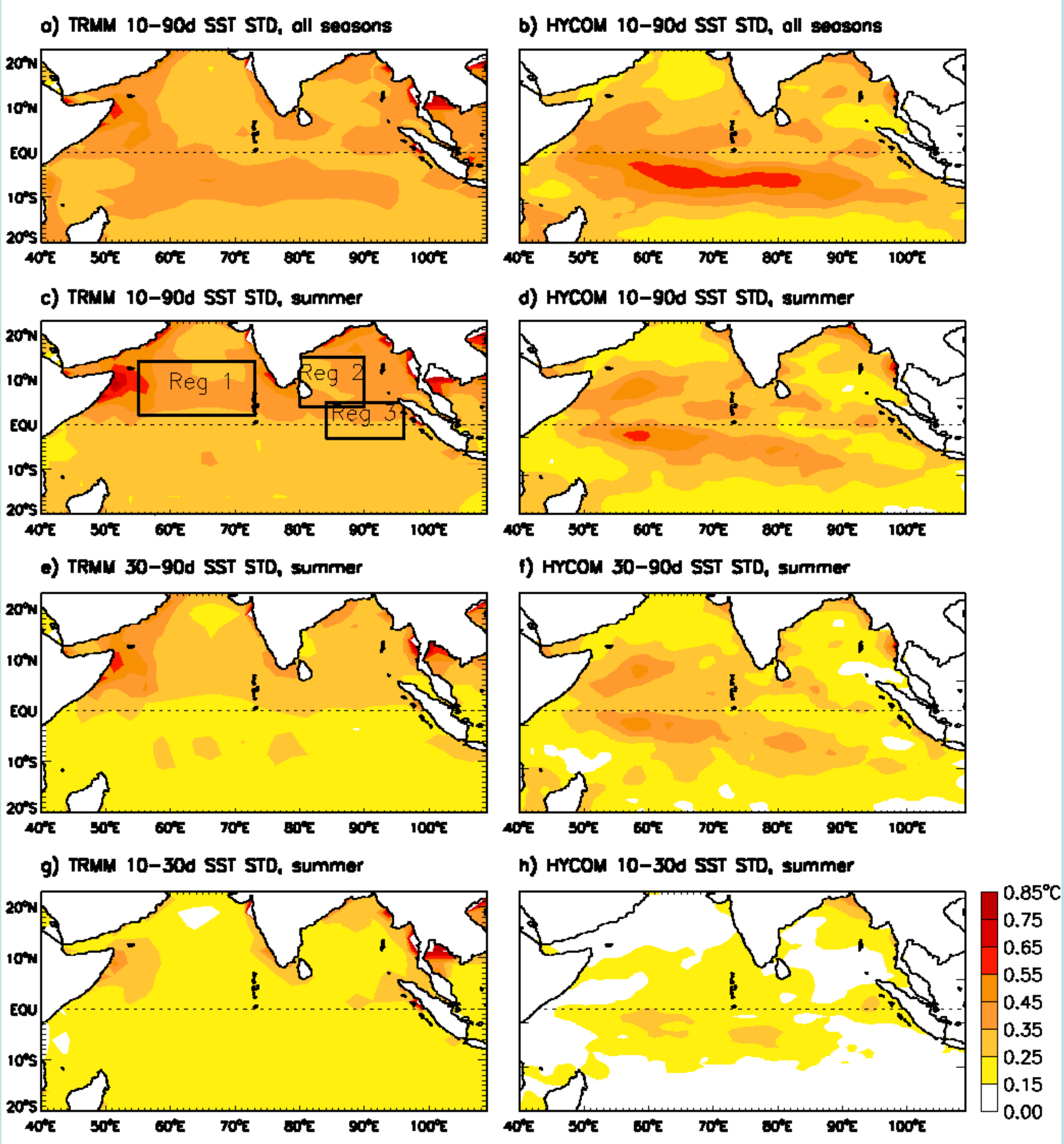
TRMM SST STD HYCOM SST STD

10-90d, all seasons

10-90d, summer

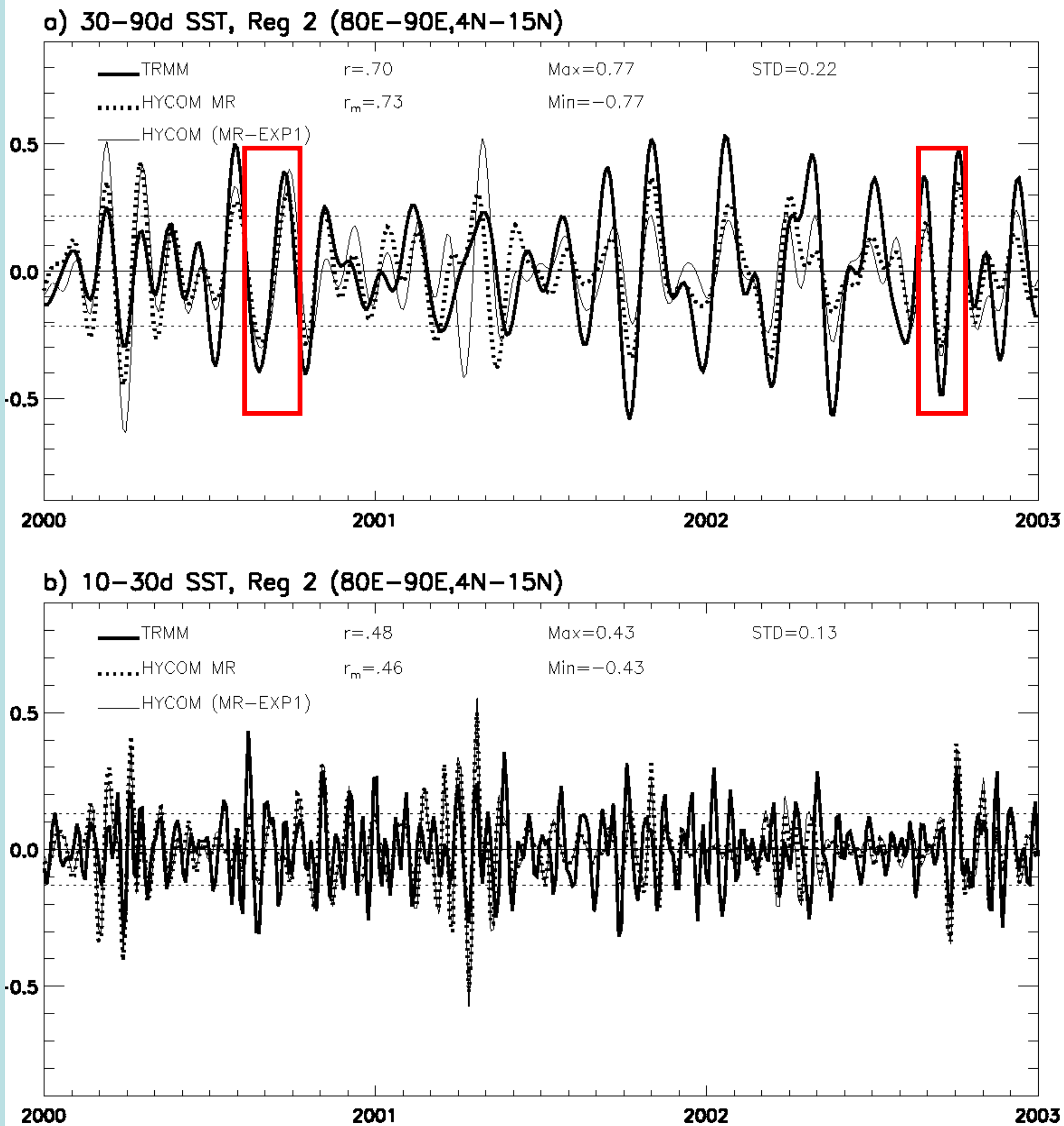
30-90d, summer

10-30d, summer



Results: Model Validity

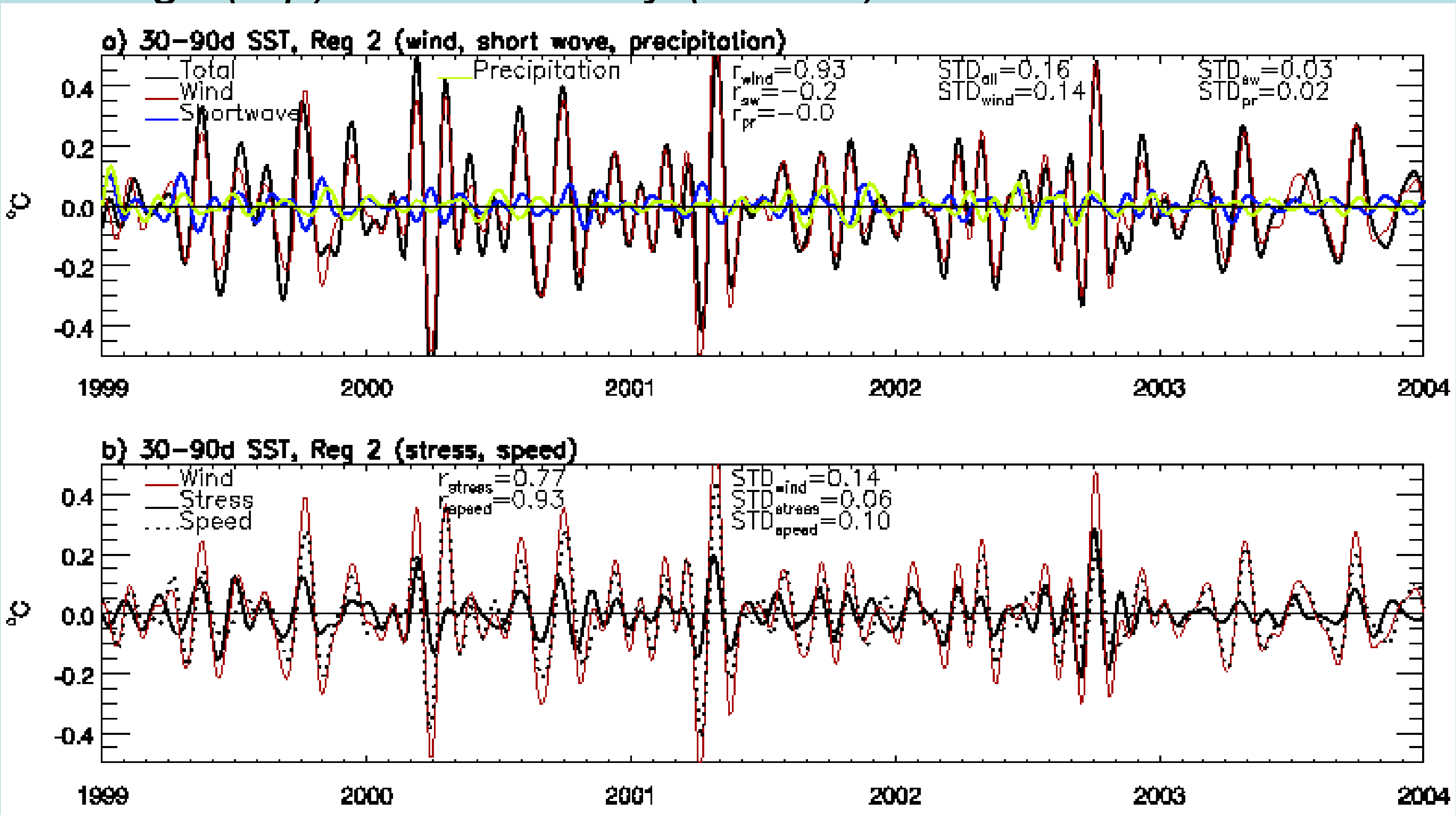
Time series of 30-90 & 10-30 day SST averaged over region 2 (the BOB) from 2000-2003



Thick line - observed SST
Dotted line - modeled SST

Results: General Processes

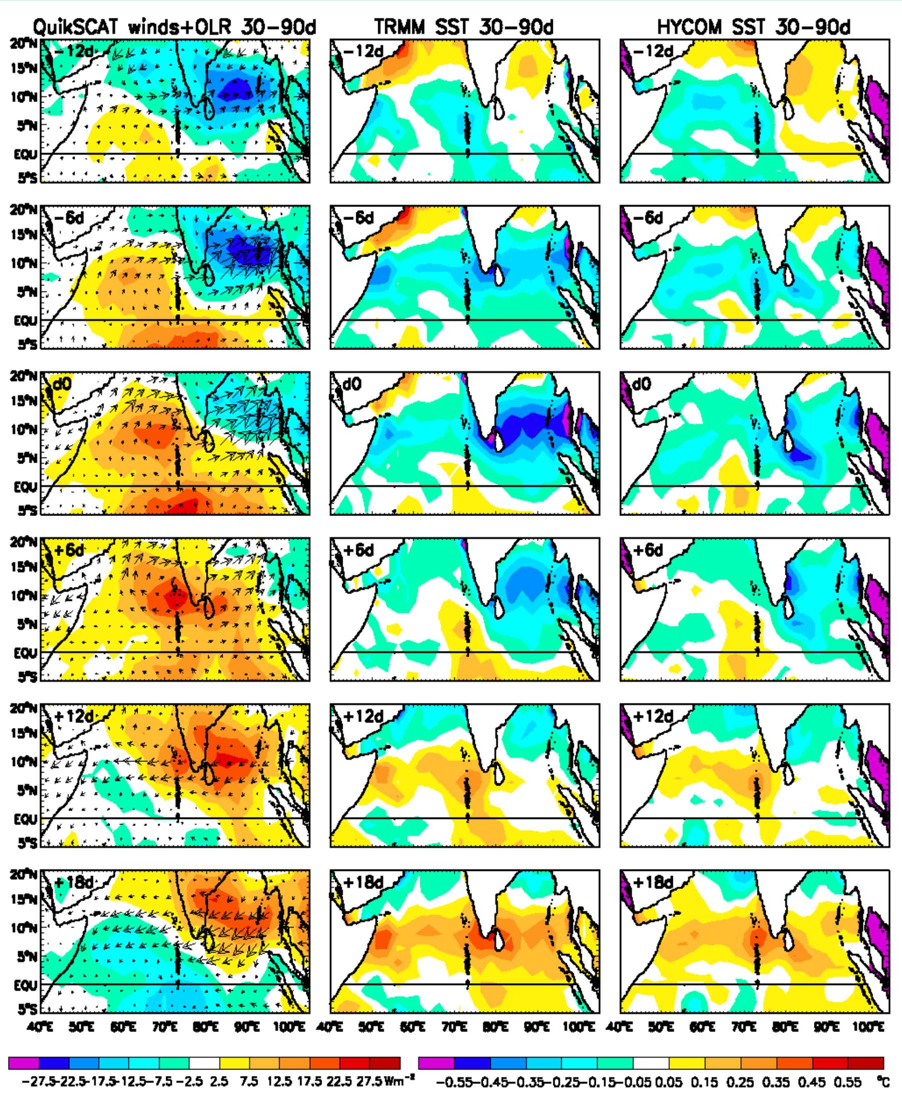
Time series of 30-90d SST from forcings in BOB from 1999-2004
All forcings (top) and wind only (bottom).

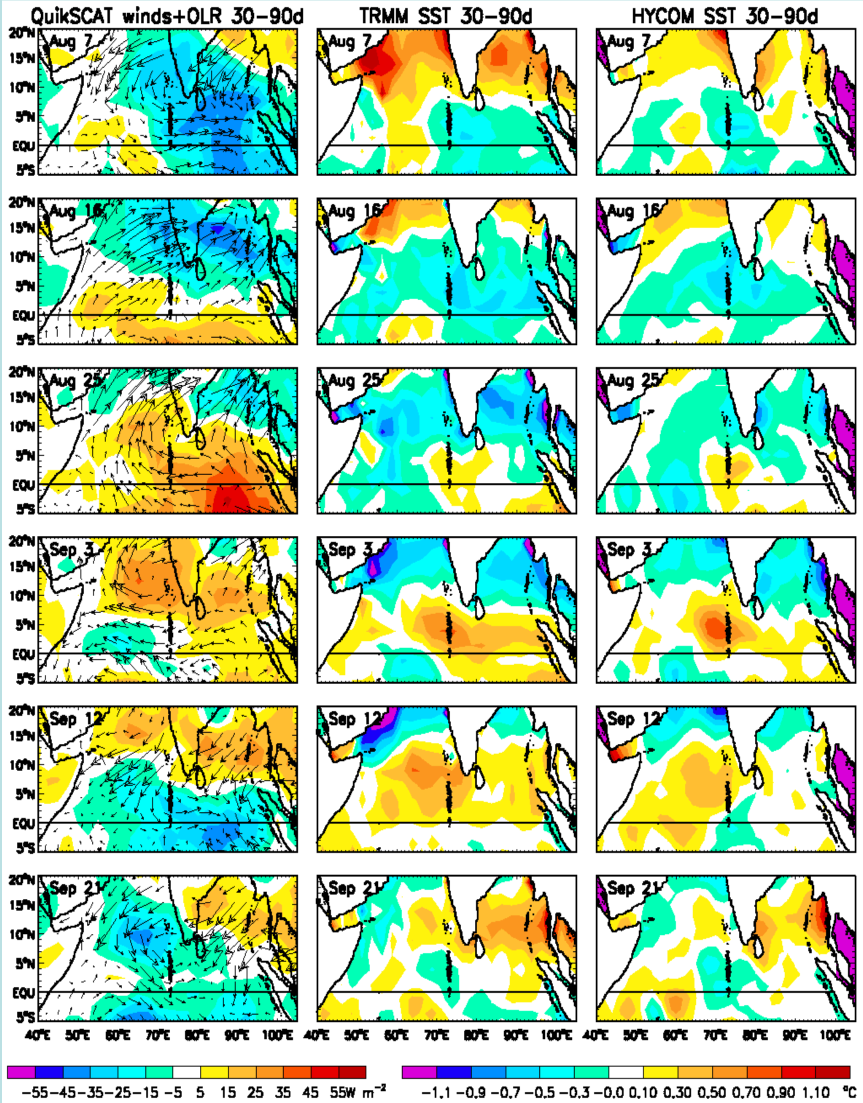


Results are similar in Regions 1 and 2 on both MJO & submonthly timescales.

Results: Composite vs. Specific MJO Event

Composite event (left) underestimates the MJO SST extremes seen in the specific strong event (right). Color scales for composite event are ½ those for the specific event.





Results: Specific MJO Event

Processes on Peak and End Days of 30-90d Event

Peak Day

End Day

All Forcings

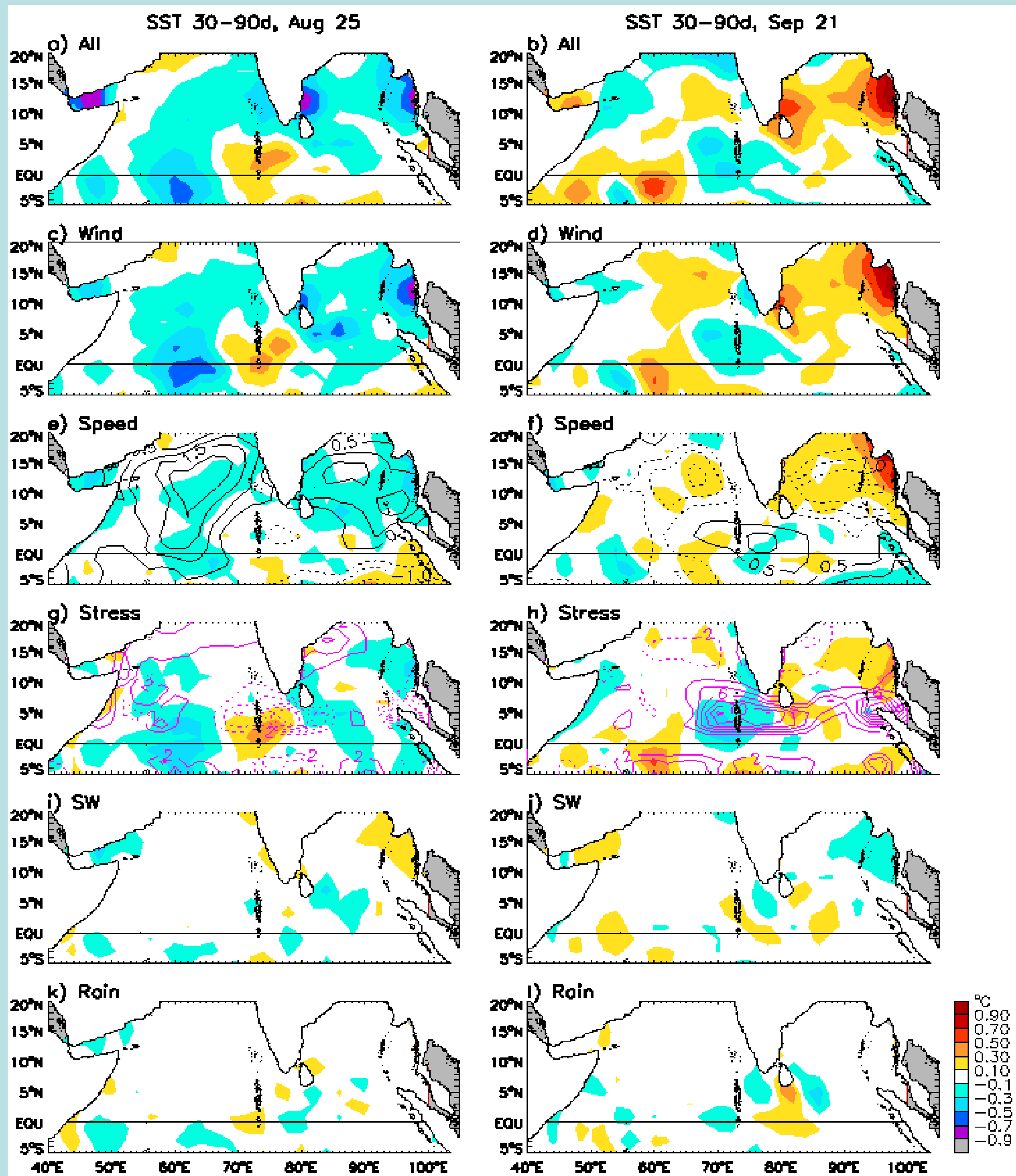
Wind Only

Speed Only

Stress Only

SW Only

Precip Only



Why is wind speed stronger than wind stress in the BOB?

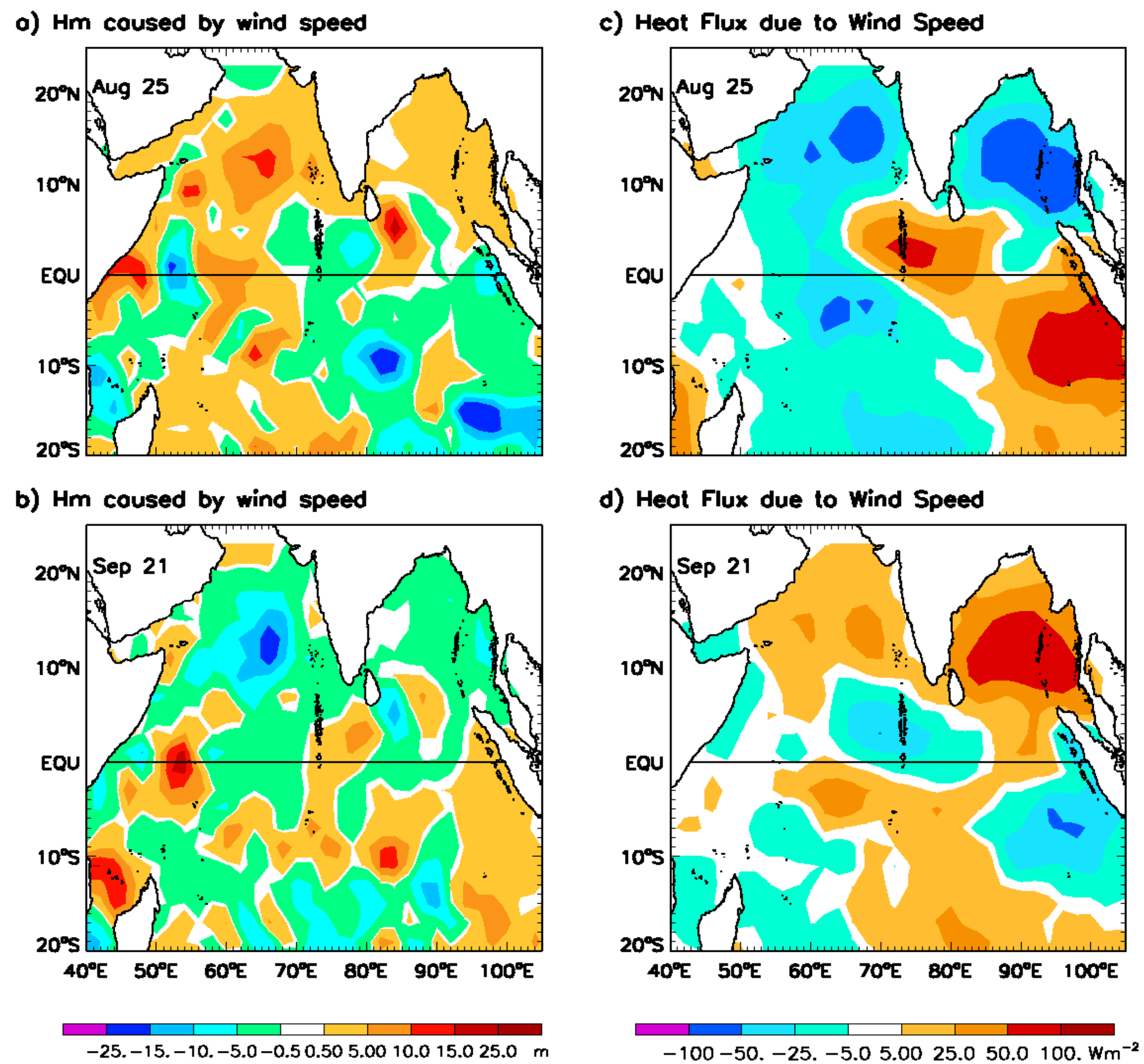
Turbulent Heat Flux!

Hmix due to Wind Speed (Entrainment)

Heat Flux due to Wind Speed (Turbulent Heat Flux)

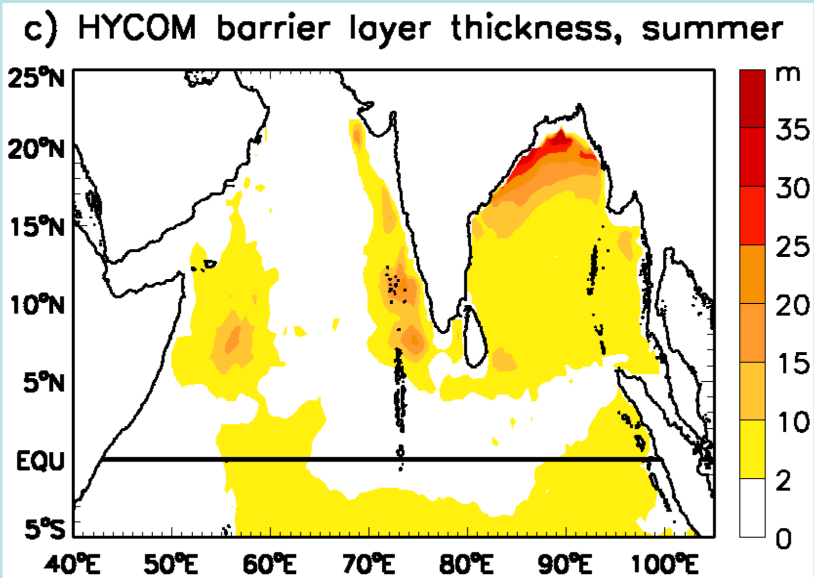
Peak

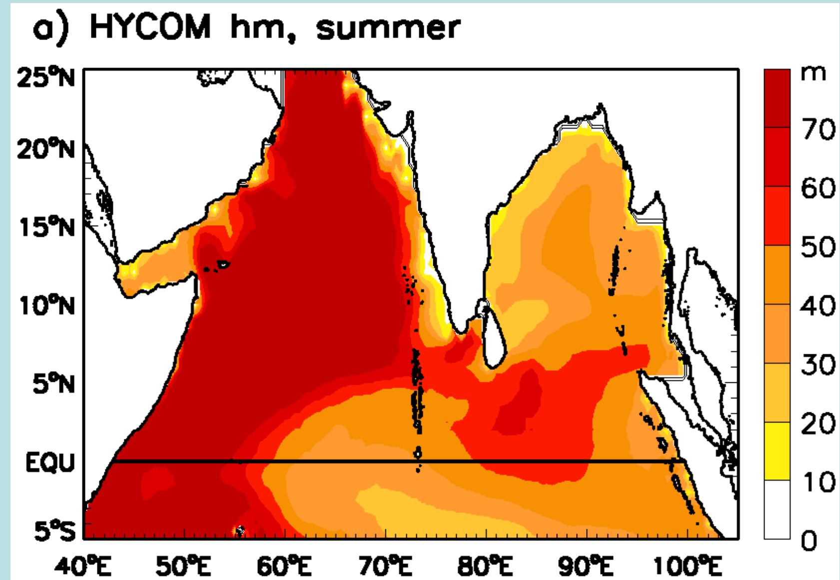
End

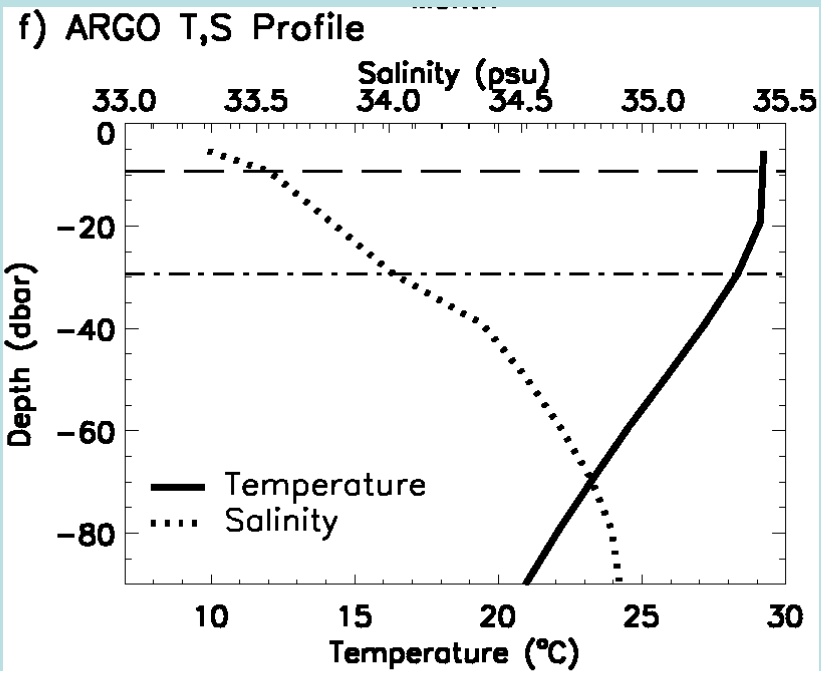


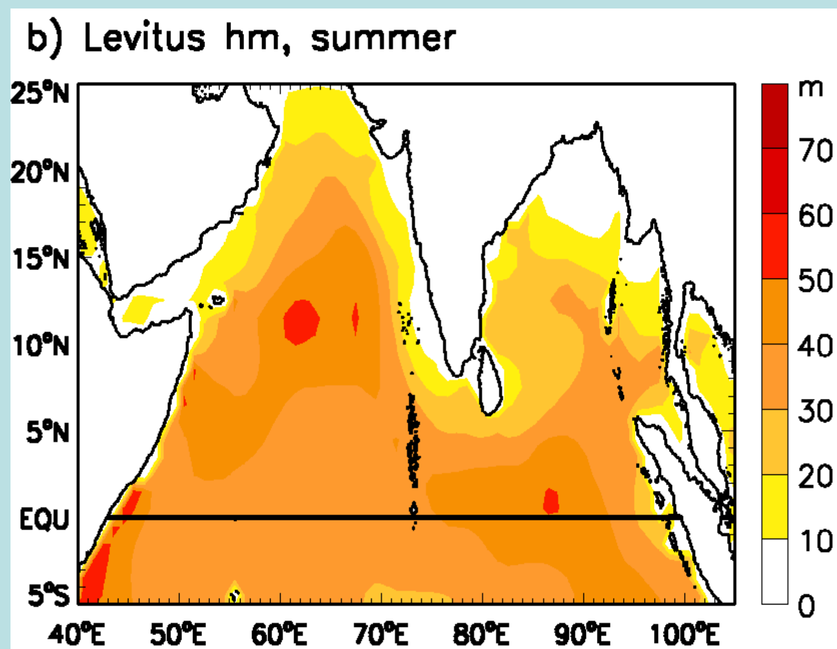
Why turbulent fluxes in the BOB?

Barrier layer & Thin mixed layer









Summary & Conclusions:

- MJO composite can average out details
- Effects of Wind >> SW, Precipitation
  - Agrees with winter events (*Han et al* 2007) and with *Waliser et al* (2004) study of canonical summer ISOs
- Effects of Wind Speed ~ Wind Stress in East Eq IO
- Effects of Wind Speed > Wind Stress in the BOB & AS
  - Less so during submonthly events
- Turbulent Heat Flux > Entrainment in the BOB
  - Barrier Layer, Shallow mixed layer

Thank you! Any Questions?

Begin Bonus Slides…

Spectral Analysis: Qscat vs. ERA40

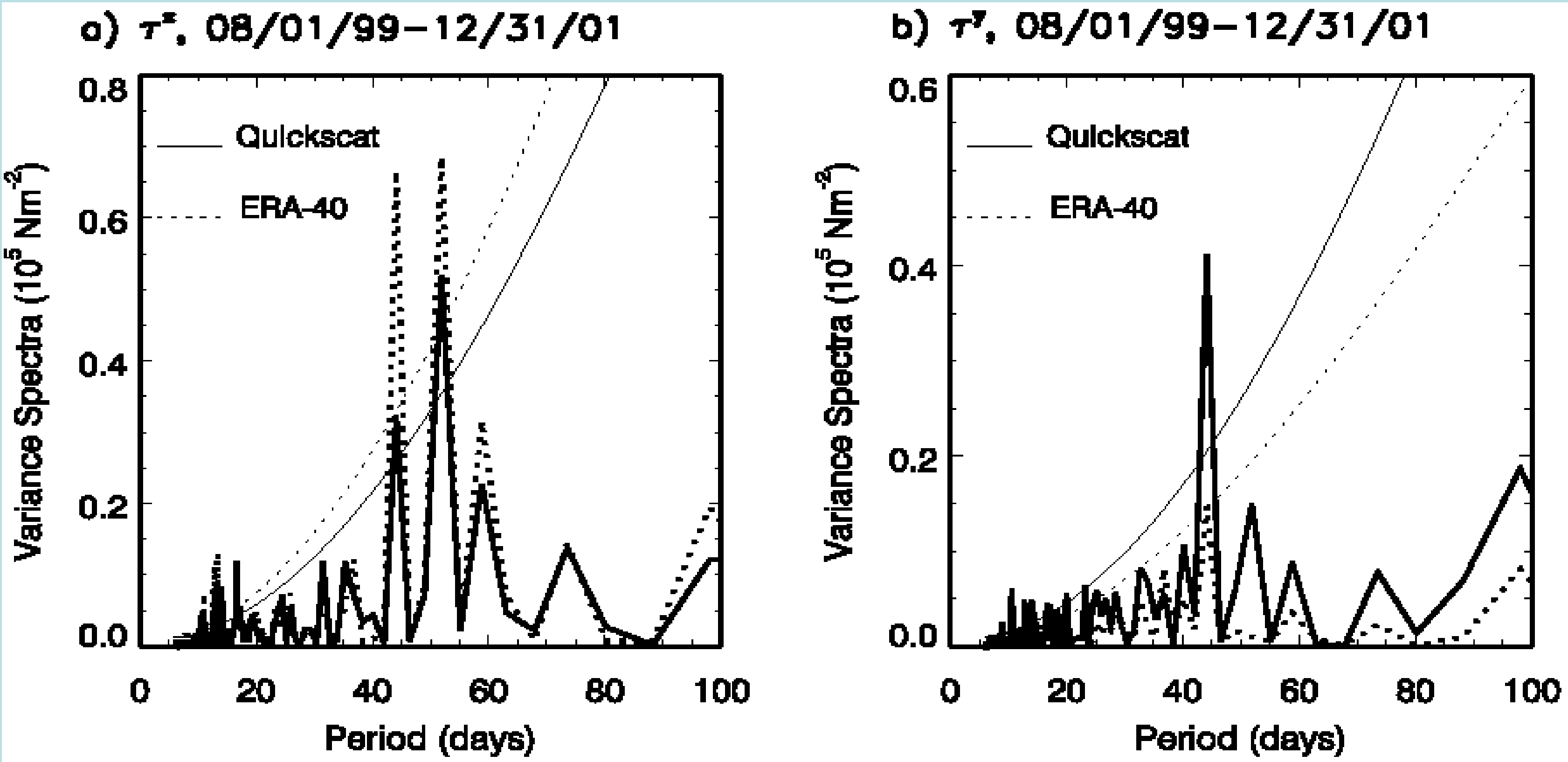
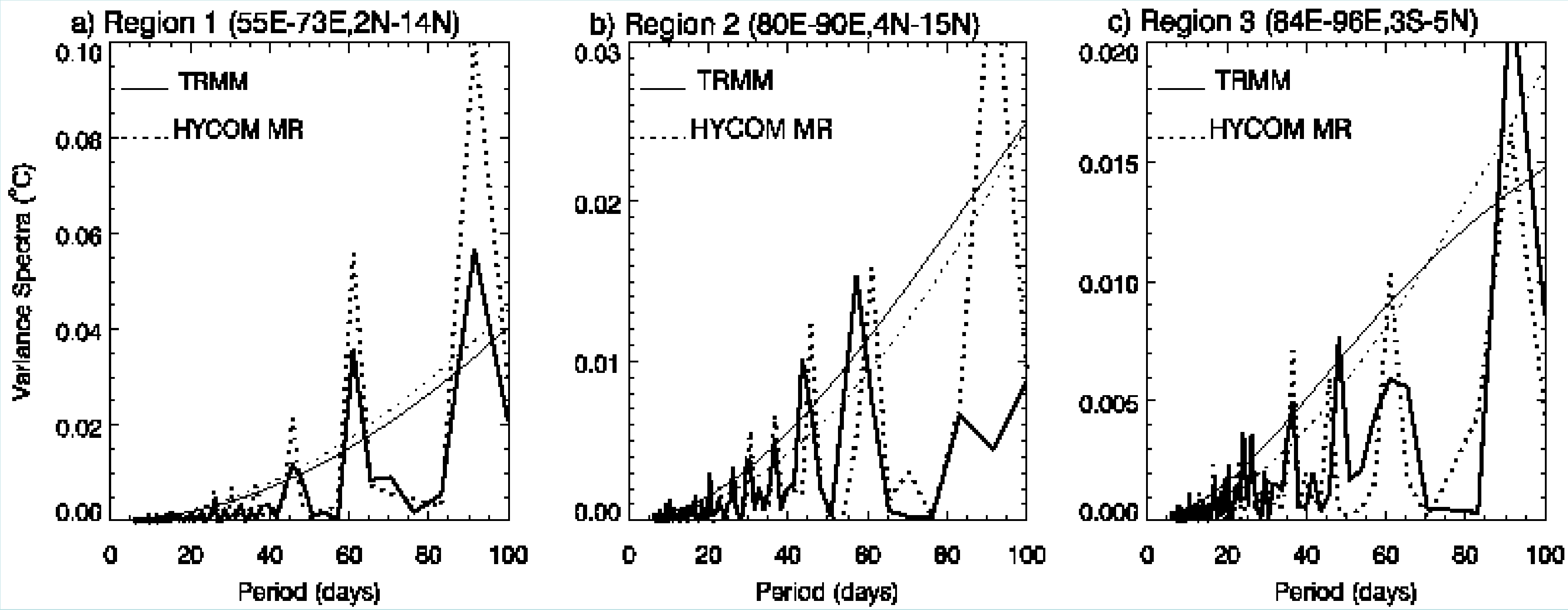


Figure 2: (a) Variance spectra of zonal wind stress τ^x, for QuickSCAT observations (thick solid line) and scaled ERA-40 reanalysis (thick dashed line) from 1 August 1999 – 31 December 2001, averaged over the western BOB (80-90°E, 4-15°N). The thin solid/dashed lines show the 90% significance level for each. (b) Same as Figure 2a, but for meridional wind stress τ^y. Units are Nm^{-2}.

Results - Model Validity:

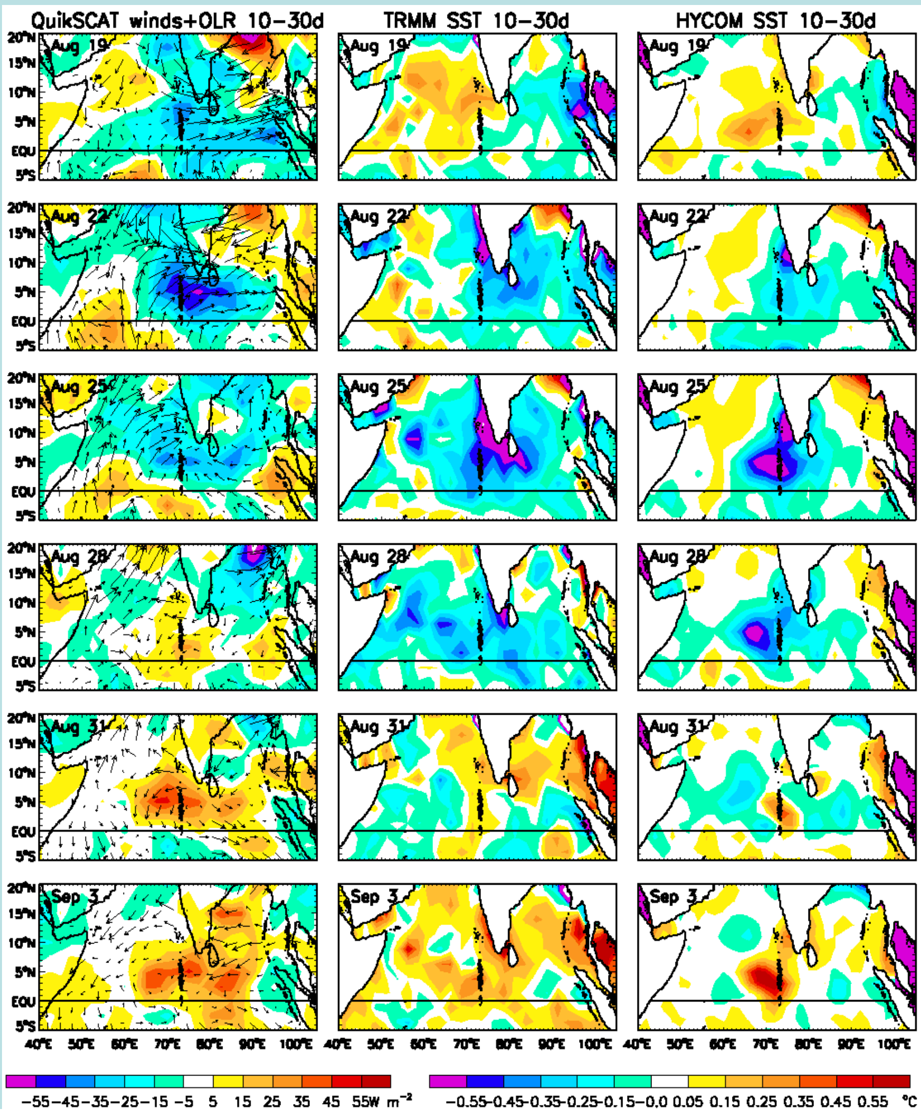


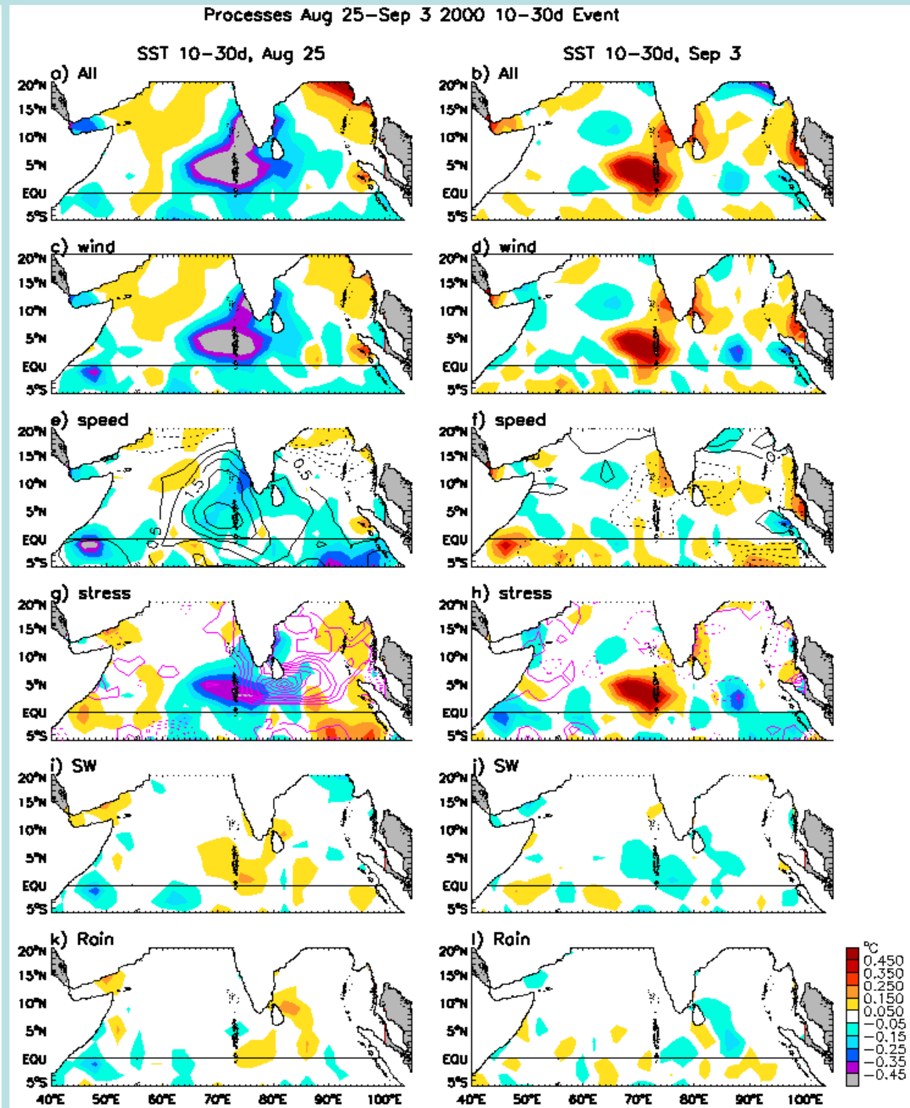
Region 1 Region 2 Region 3

Spectral Analysis of TRMM (solid line) vs. HYCOM MR (dashed line) SSTs, averaged over summers from 1999-2003, in the 3 regions of interest. Thin line is 90% confidence level for each.

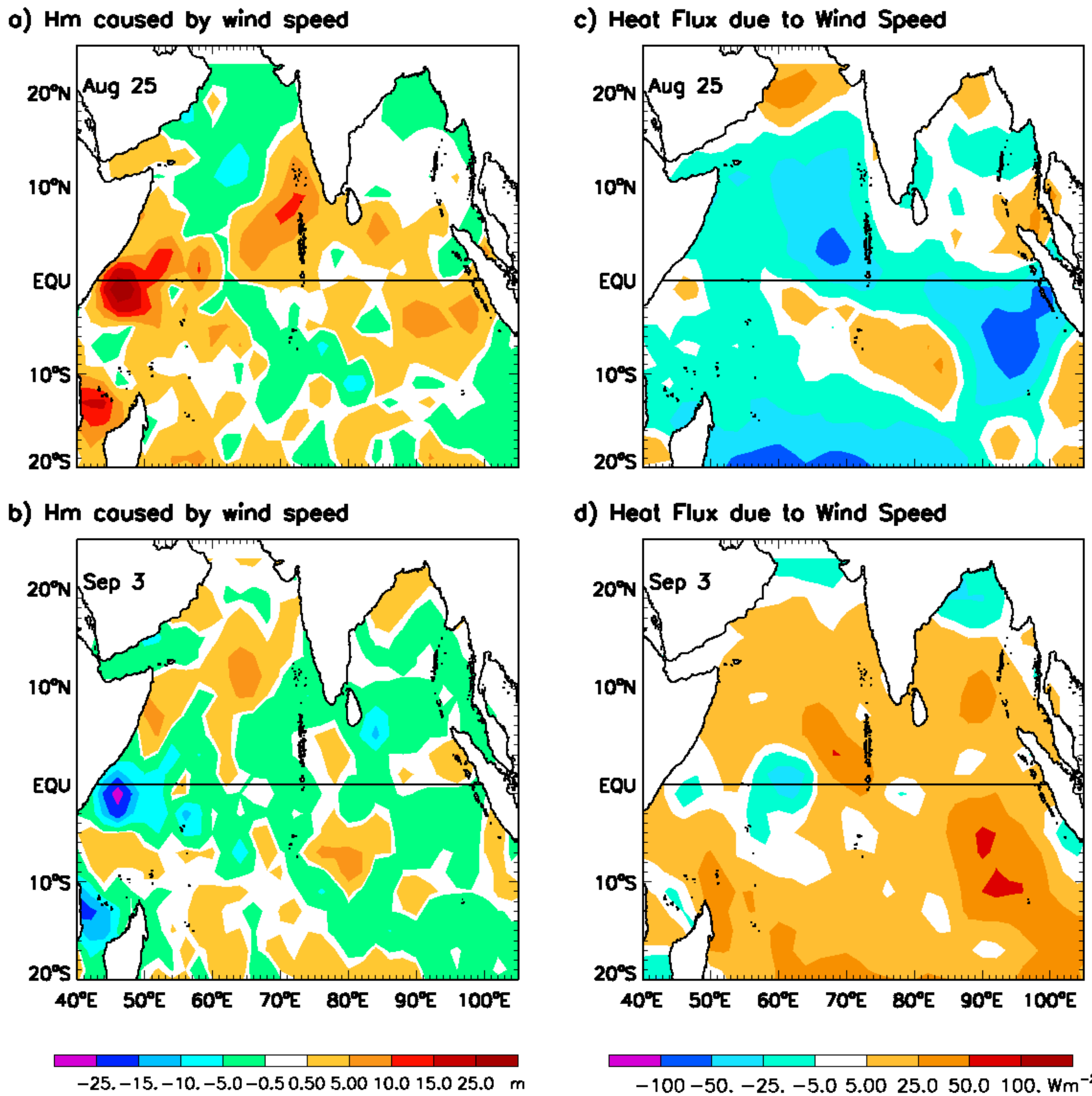
Results – Submonthly Event:

- Wind speed & stress effects are closer in magnitude in all regions
  - Speed still slightly stronger than stress in the Arabian Sea and BOB





Hmix & Turb Flux Due to Wind Speed, Submonthly Event



Wind stress and horizontal advection equations:

- QuickSCAT-derived wind stress:
  - Have wind speed **|V|** and direction θ
  - Wind vectors **V**=(u,v) are u=|**V**|cosθ & v=|**V**|sinθ
  - Then, wind stress (τ) is: $\vec{\tau} = \rho_a C_D |\mathbf{V}|\mathbf{V}$
    $\vec{\tau} = \tau_x + \tau_y$
- Wind stress curl is: $$curl(\vec{\tau}) = \frac{\partial}{\partial x}(\tau_y) - \frac{\partial}{\partial y}(\tau_x)$$
- And Ekman pumping velocity (w_E) is: $$w_E = \frac{\partial}{\partial x}(\frac{\tau^y}{f}) - \frac{\partial}{\partial y}(\frac{\tau^x}{f})$$
- Horizontal advection due to wind stress is calculated with:

$$\Delta T = -[u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} - (\overline{u}\frac{\partial \overline{T}}{\partial x} + \overline{v}\frac{\partial \overline{T}}{\partial y})]\Delta t$$

  - Where u, v, & T are zonal and merid currents & SST from MR and overbars indicate fields from EXP3