Mechanism of Interannual variability of cross-equatorial heat transport (CEHT) of the Indian Ocean

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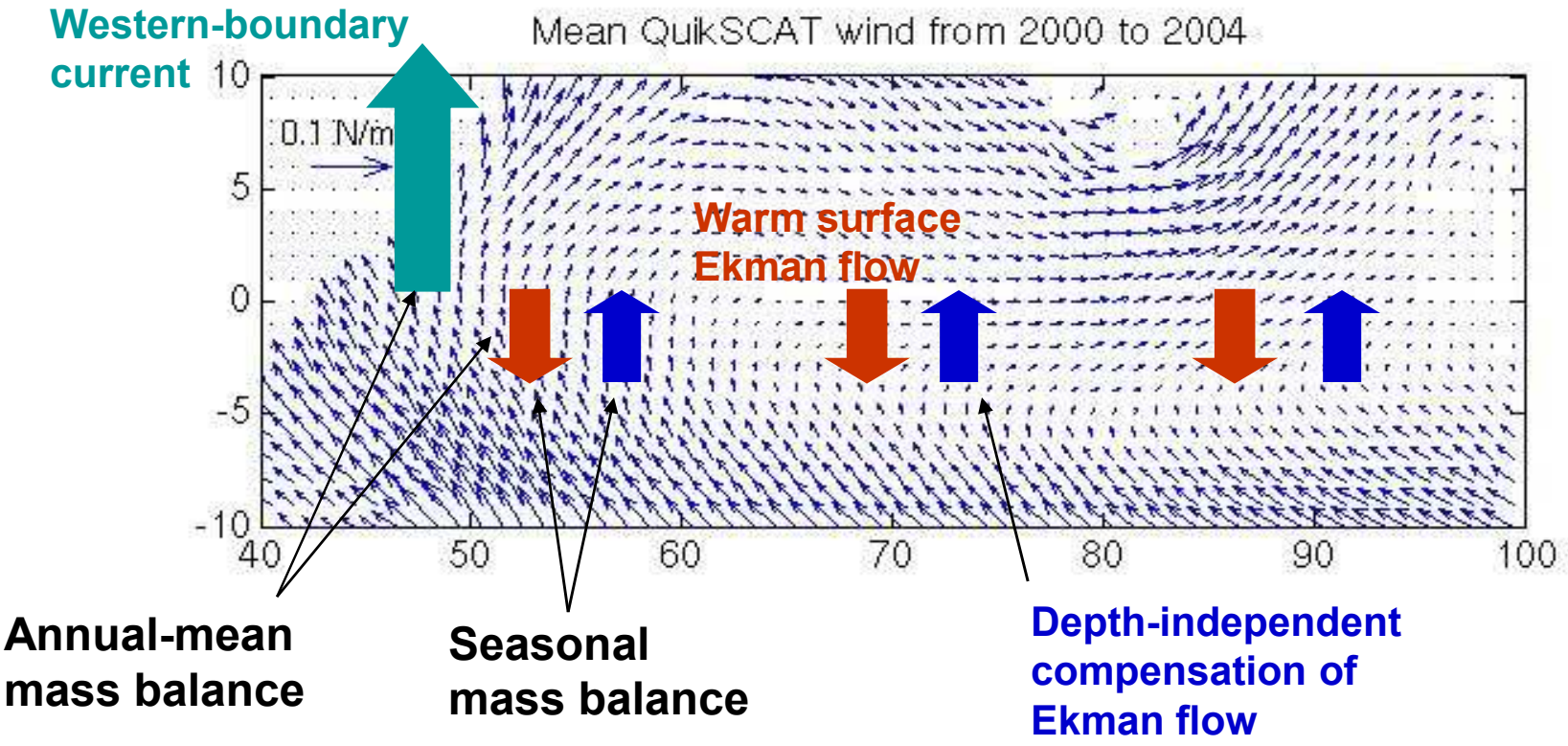
Q: Why Indian-Ocean CEHT?

A: It regulates oceanic heat content directly & affect air-sea interaction indirectly; implications to climate variability (monsoon, zonal-dipole mode, biennial oscillation, etc.).

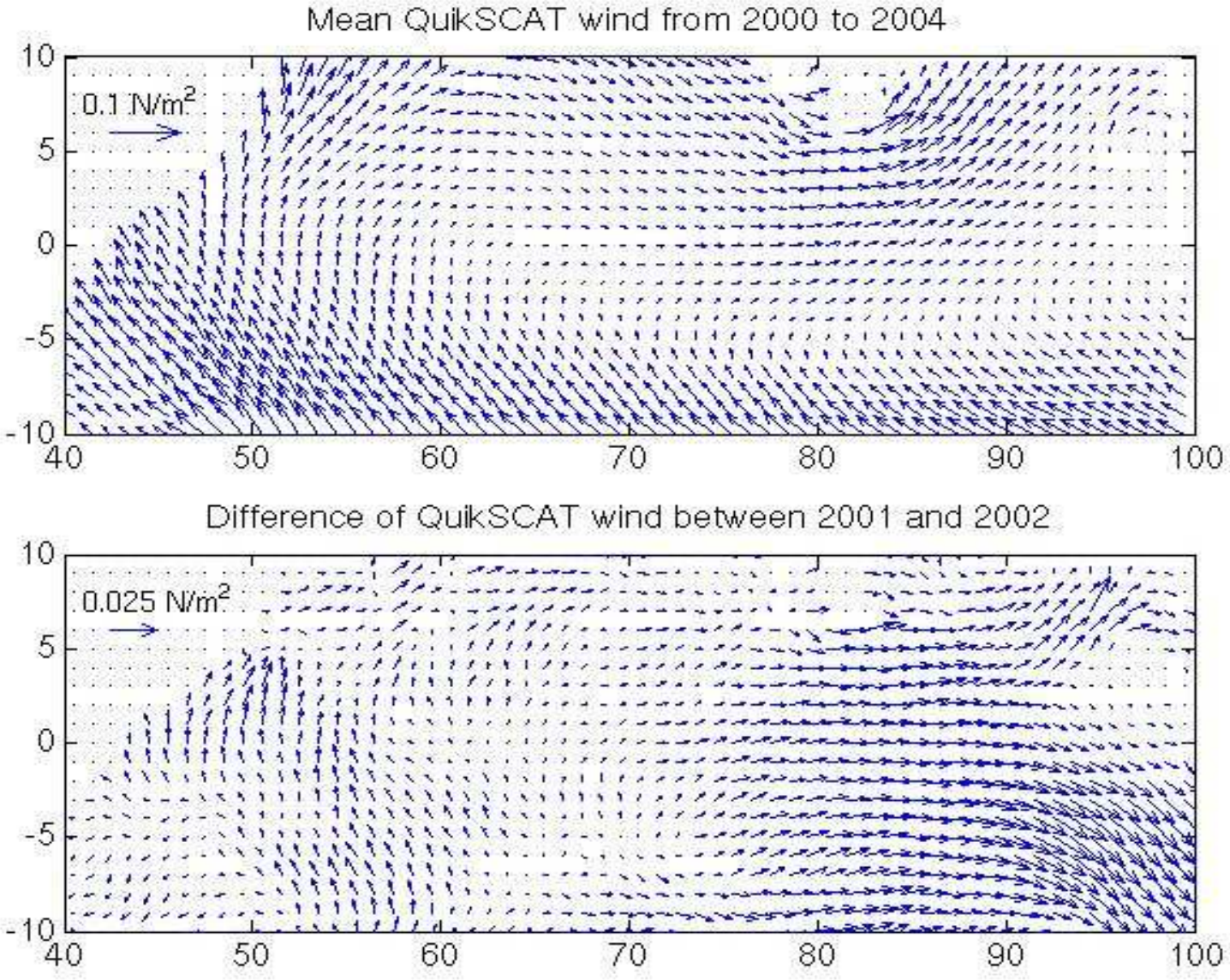
Q: Why interannual?

A: Previous studies – annual mean & seasonal cycle; lack of understanding of interannual variation.

Wind, meridional mass balance, & heat transport for annual mean and seasonal cycle



Patterns of interannual wind change very different from the anti-symmetric pattern of annual mean and seasonal anomaly, suggesting different mass balance & heat transport mechanism.



Science questions for interannual variability

- Is heat transport $\overline{V}\overline{T}'$ primarily due to $\overline{V}\overline{T}'$ or $V'\overline{T}$?
- Is V' mostly Ekman? Does geostrophic flow near western boundary play any role?
- Relative roles of wind vs. buoyancy forcing
- Regional contribution by forcing
- Effect of forcing at different lead time (lagged oceanic response?)

Approach

• Scatterometer wind + OGCM & its adjoint for diagnostics & sensitivity analysis: decipher variability of CEHT and relation to wind forcing.

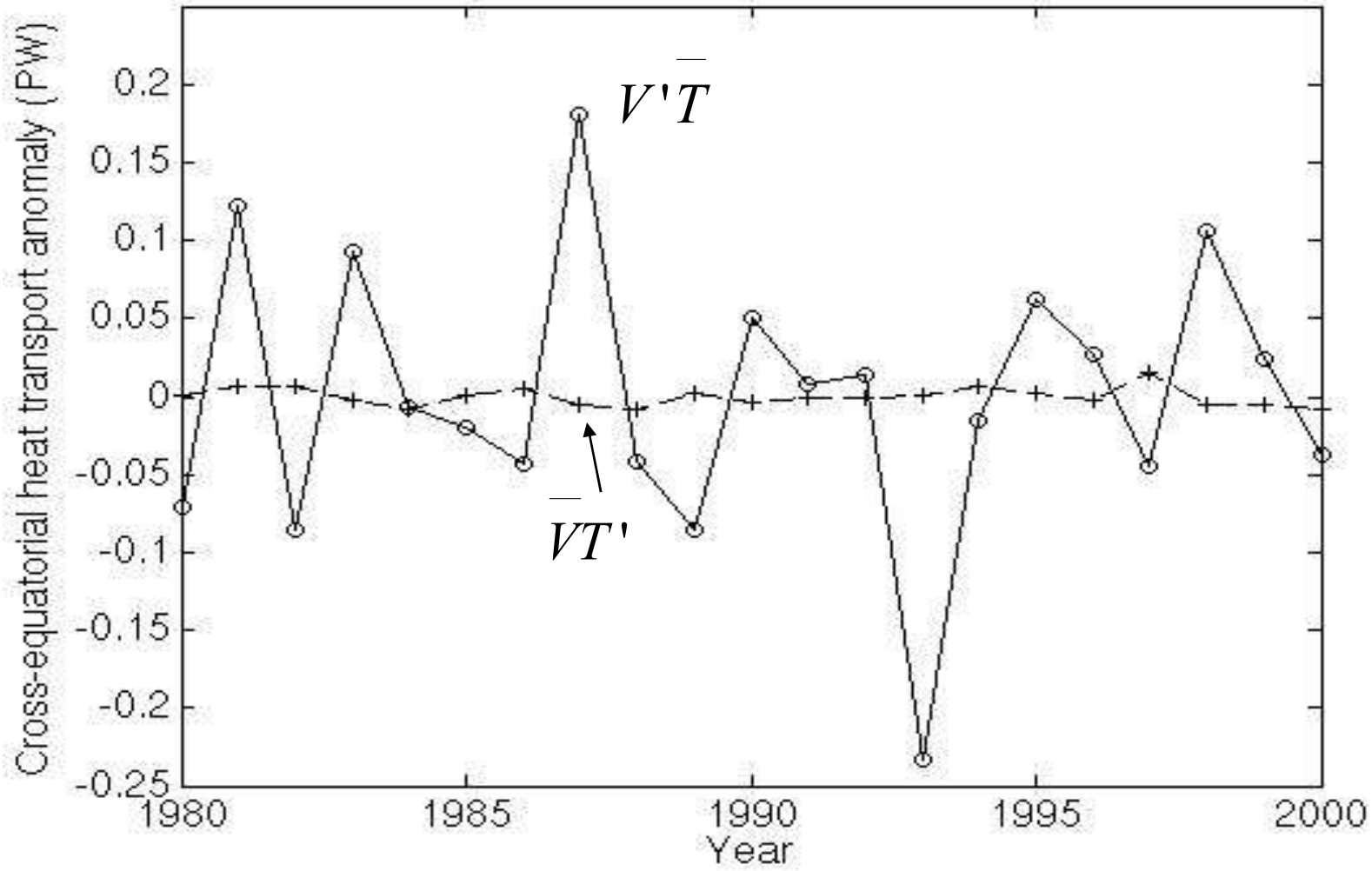
• OGCM: Near-global MITGCM, 1°x(0.3-1)°, 46 levels, dz=10-400 m, advanced mixing schemes (KPP & GM).

• Adjoint of OGCM: computes sensitivity of CEHT to different forcings at different lead times over every grid of the entire (global) model domain.

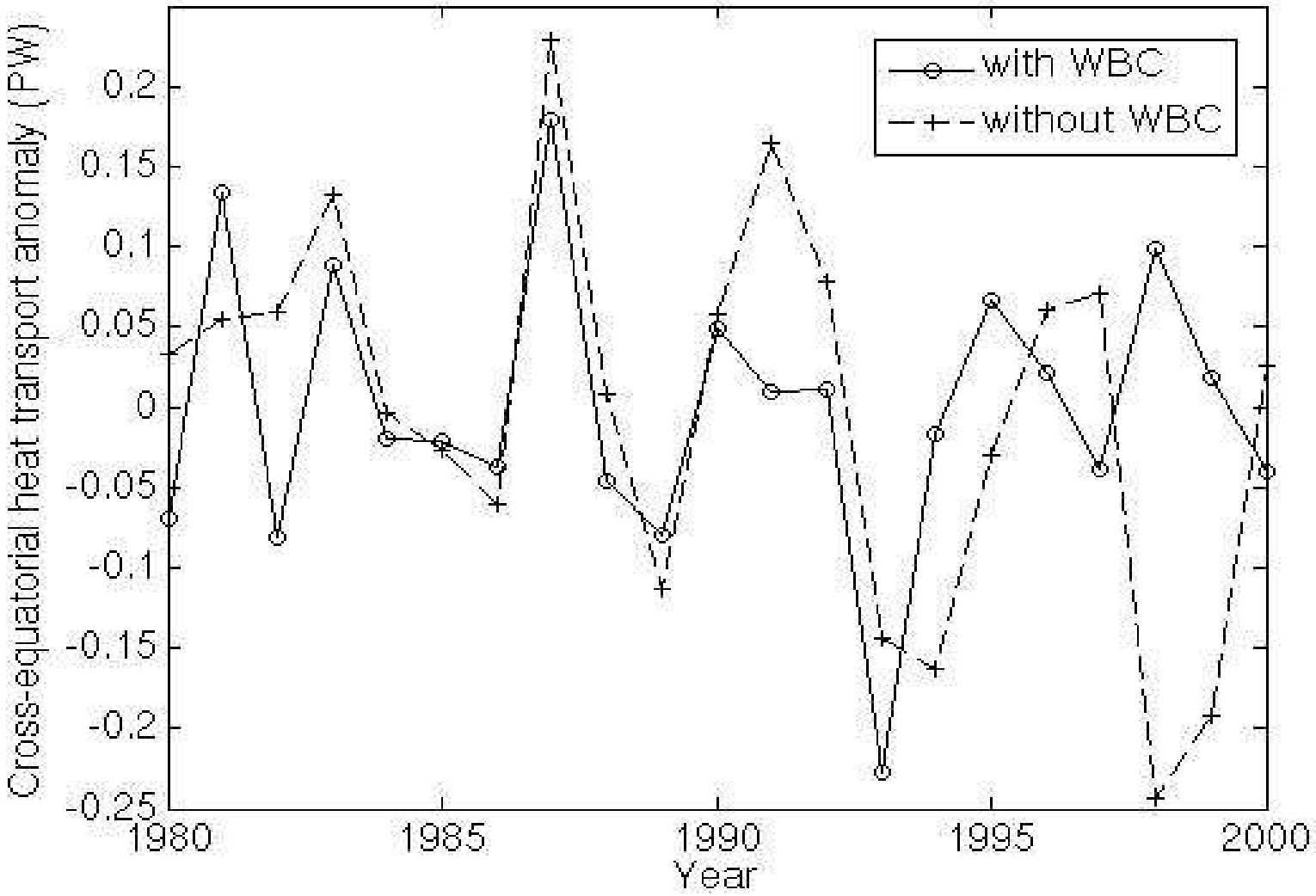
Preliminary results of model simulation & sensitivity using NCEP forcing

- to be re-evaluated using scatterometer wind

Interannual variability of CEHT mostly due to fluctuating flow instead of fluctuating temperature



Western-boundary current plays a significant role

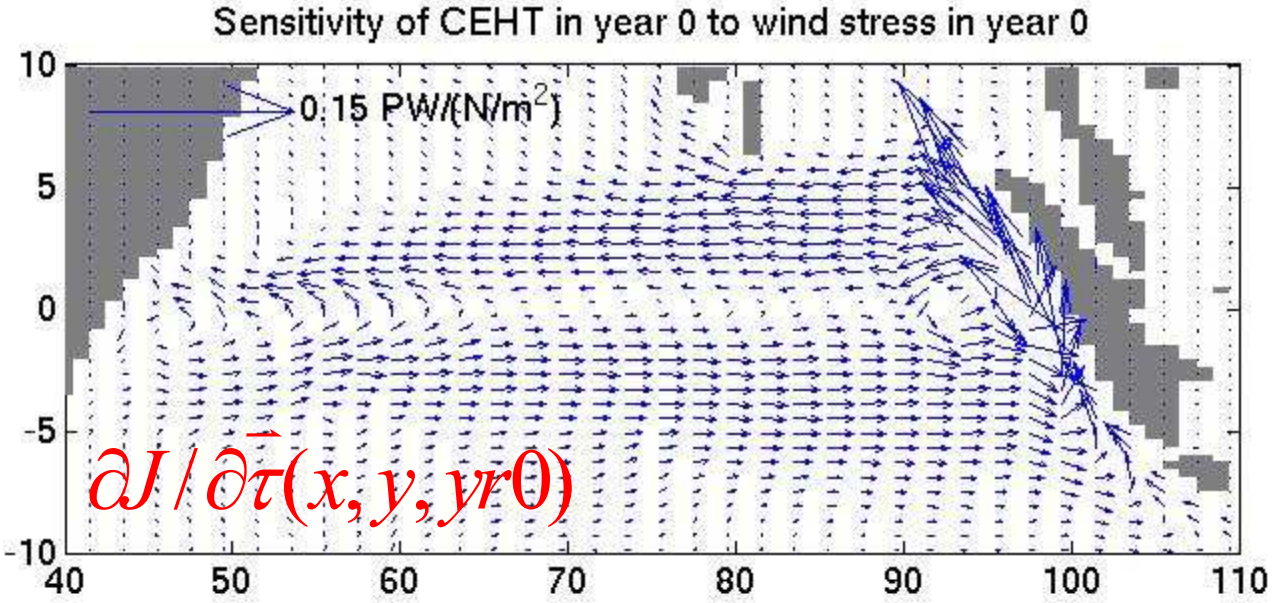


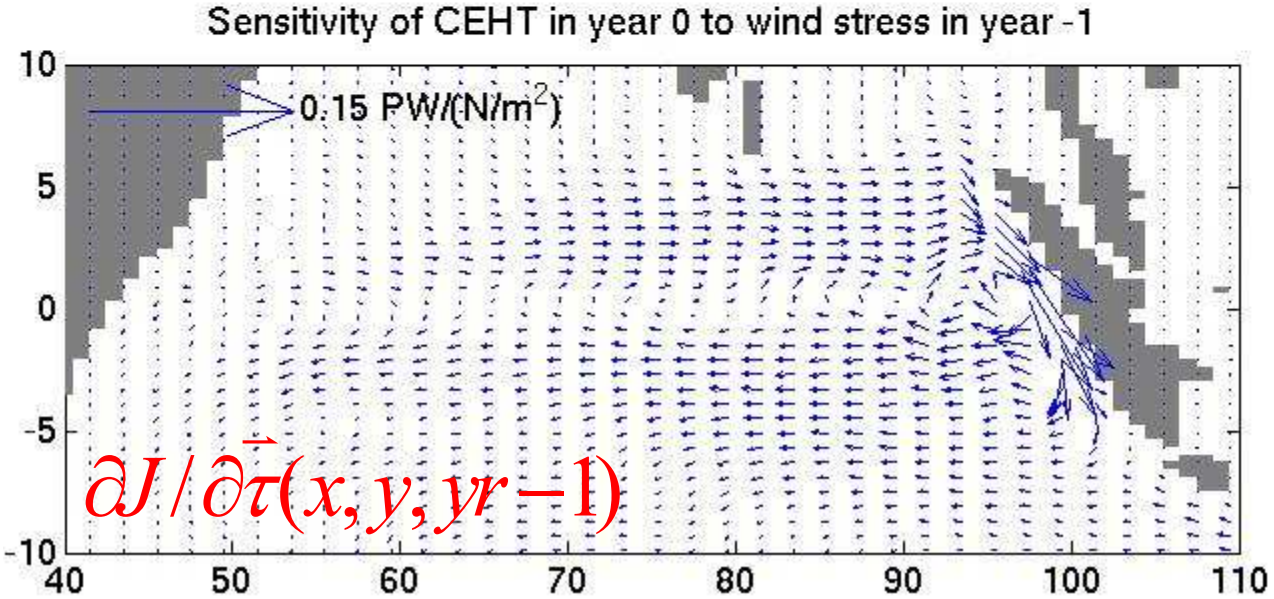
Example of adjoint sensitivity analysis

Opposite signs of sensitivity to wind in year 0 and -1:

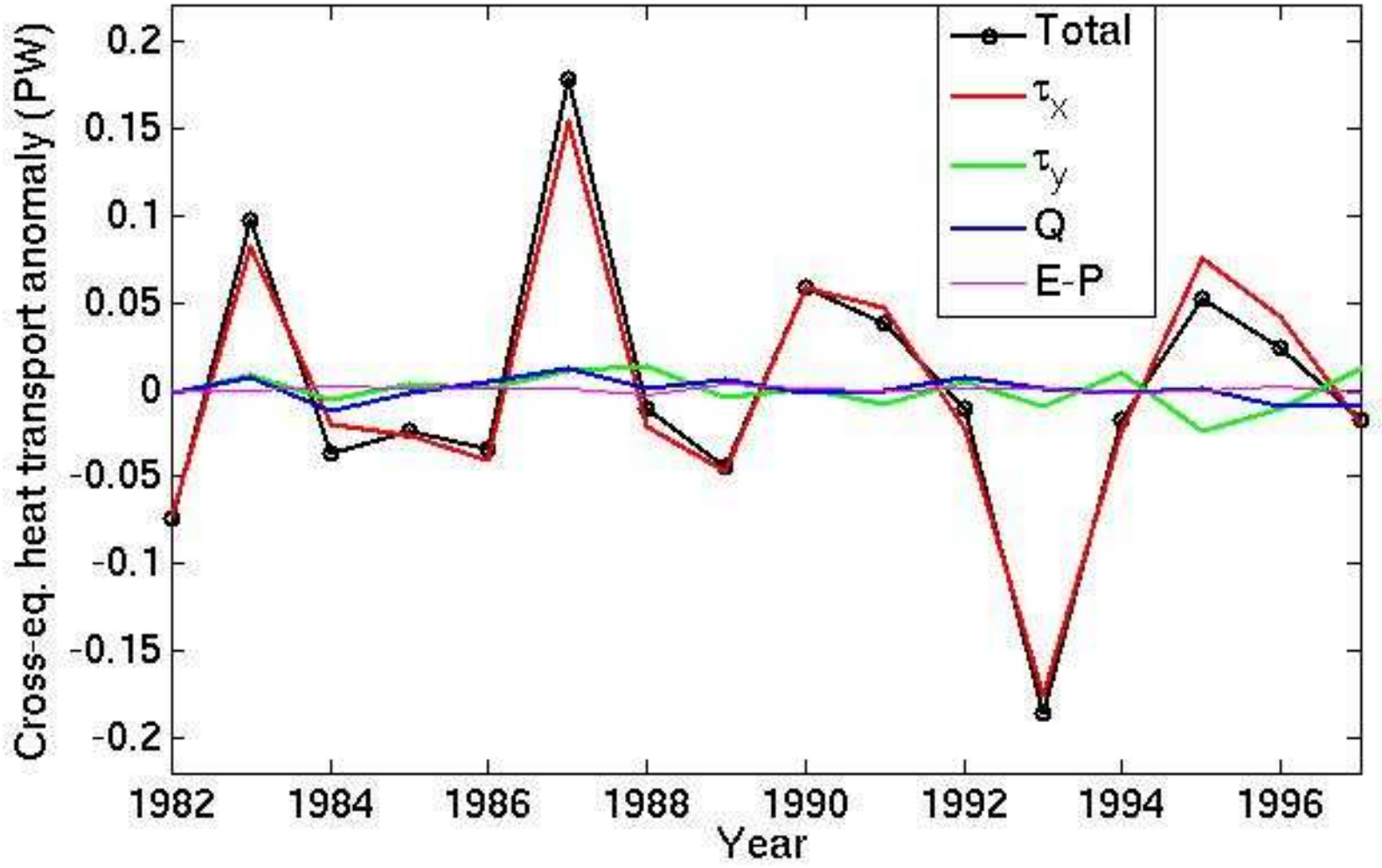
lagged response of WBC to wind (associated with Rossby waves);

- different mass balance in response to current & prior year wind;
- implication to biennial oscillation.

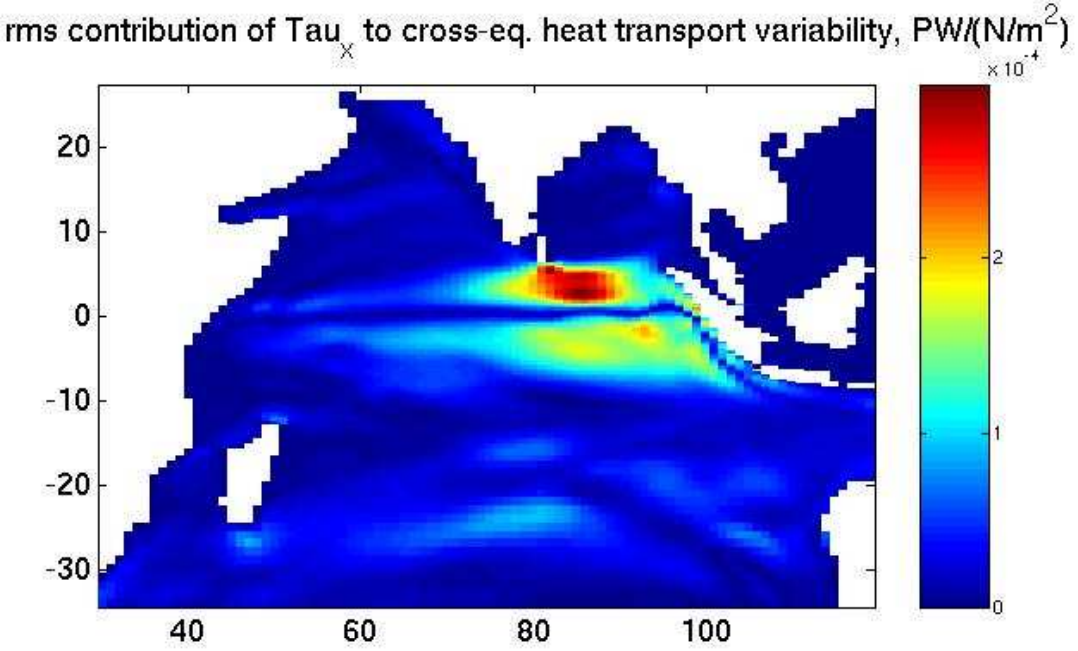




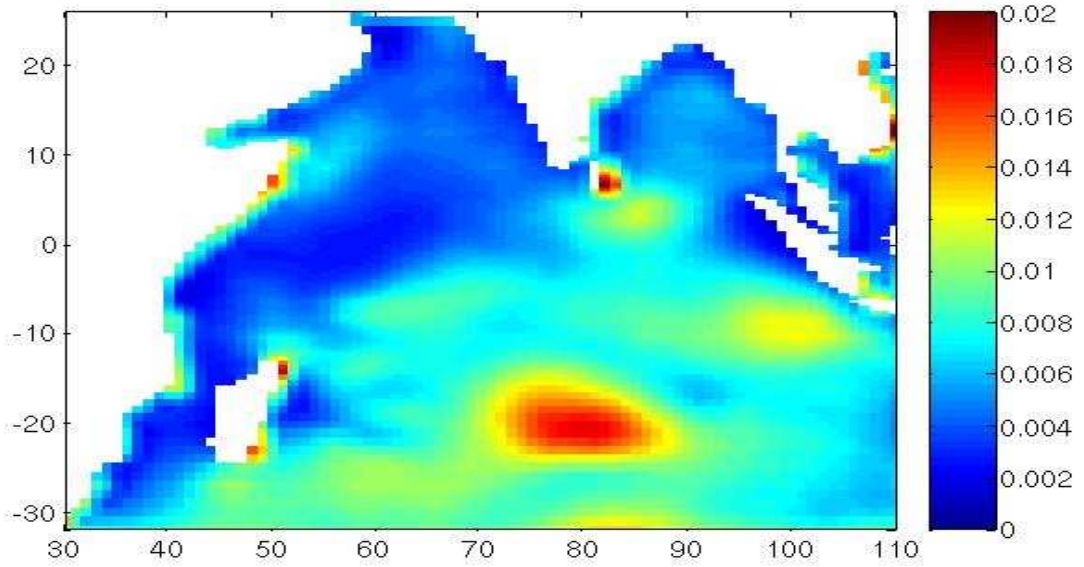
Projecting forcing anomalies to sensitivity functions to estimate contributions by different forcing: τx effect most important



Regional contribution of zonal wind to interannual variation of CEHT



Interannual standard deviation of NCEP zonal wind (N/m^2)



Summary

Scatterometer wind (ERS+QSCAT, 1991-present) will be used along with an OGCM & its adjoint to study mechanism of interannual variation of cross-equatorial heat transport of the Indian Ocean.

Preliminary results based on 1980-2000 NCEP forcing:

- Effect of fluctuating meridional flow >> that of fluctuating temperature.
- WBC plays a significant role.
- Contribution by zonal wind >> those by other forcing.
- Off-equatorial wind most important (!)
- Sensitivity of CEHT to wind stress reveals patterns that highlight interesting physical processes (another talk).

Indian-Ocean trade wind: weakening 1992-2000 & rebound in recent years: implications to heat transport