Estimates of the interannual oceanic heat budget in the Gulf Stream and North Atlantic Current from four models

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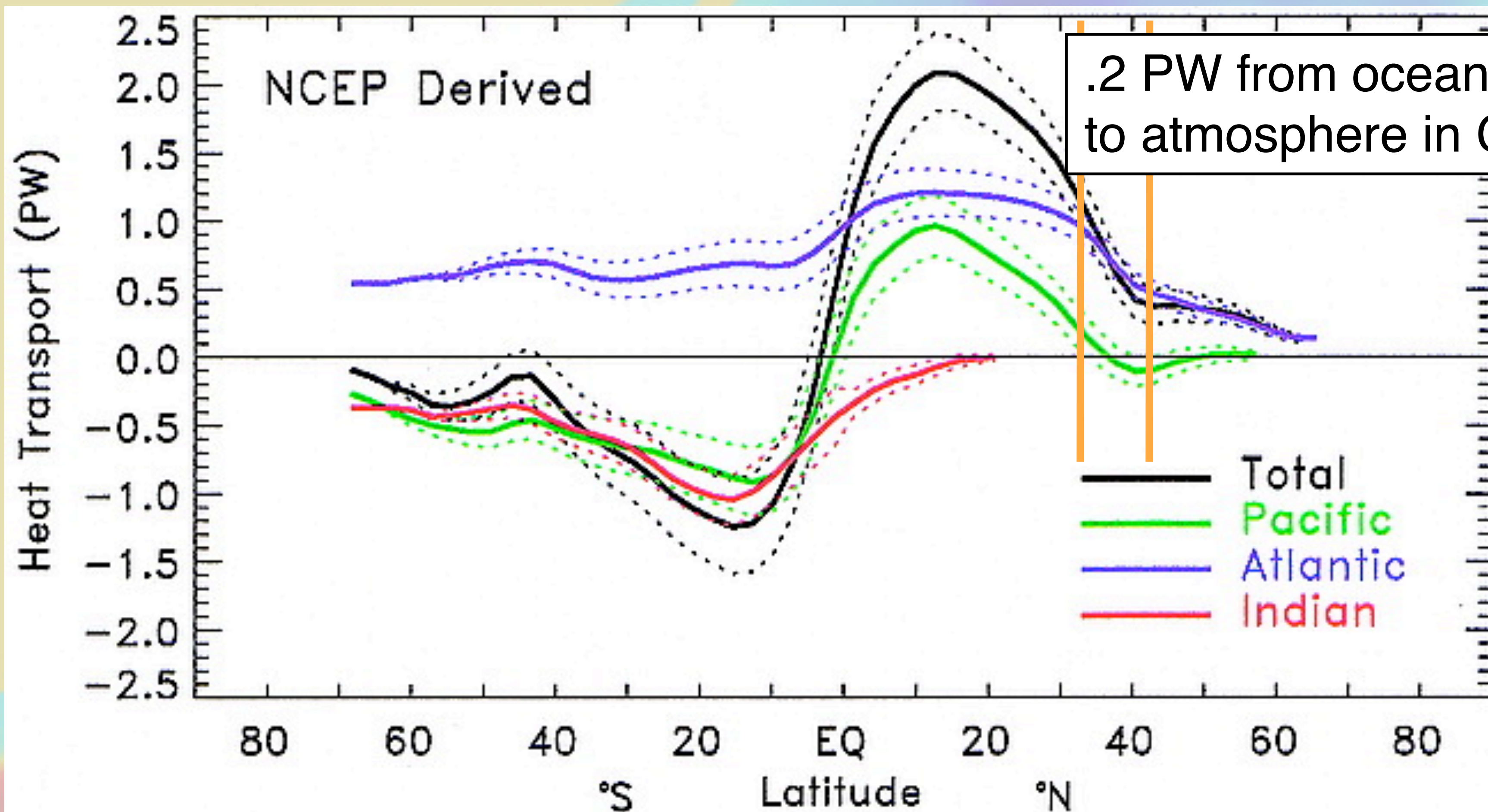
Heat Transport by the oceans



.2 PW from ocean to atmosphere in GS

Trenberth and Caron, J. Climate, 2001

Role of the GS and NAC in heat transport/storage

- What role does oceanic geostrophic advection play in GS and NAC heat budget on interannual time scales?
- How well can we estimate this?
- What processes control the the budget?
- What are the consequences for energy transport in climate system?

Four model estimates

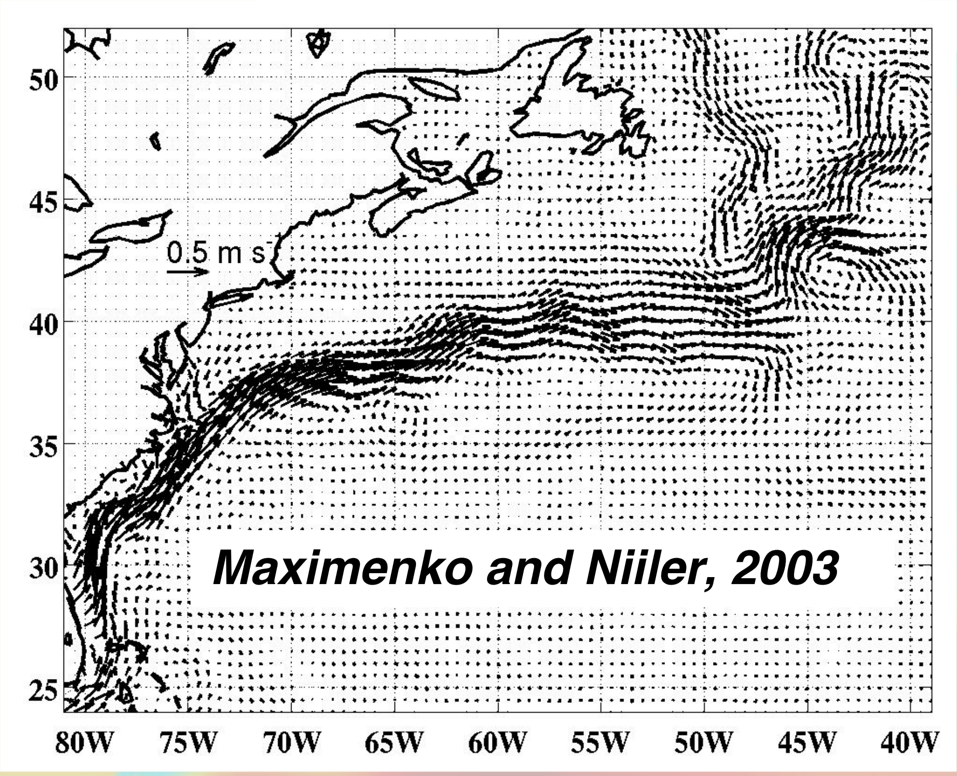
- **POP North Atlantic (Parallel Ocean Program)**
  - Daily NCEP forecast winds, prognostic
  - 1/10^{o} resolution, 21 day
  - Relaxation to climatology at northern (72N) and southern boundaries (20S)
- **Mercator North Atlantic**
  - Daily ECMWF ERA 40 winds
  - 1/3^{o} resolution, monthly
  - Nudges to in situ, SSH and SST
- **ECCO2 Global**
  - NCEP daily forcing
  - 18km resolution, monthly
  - Green's function assimilation
- **Diagnostic GS and NAC**
  - Daily NCEP/ISCCP forcing
  - 1^{o} by .5^{o}, 5 day
  - Velocity from SSH and prescribed vertical structure

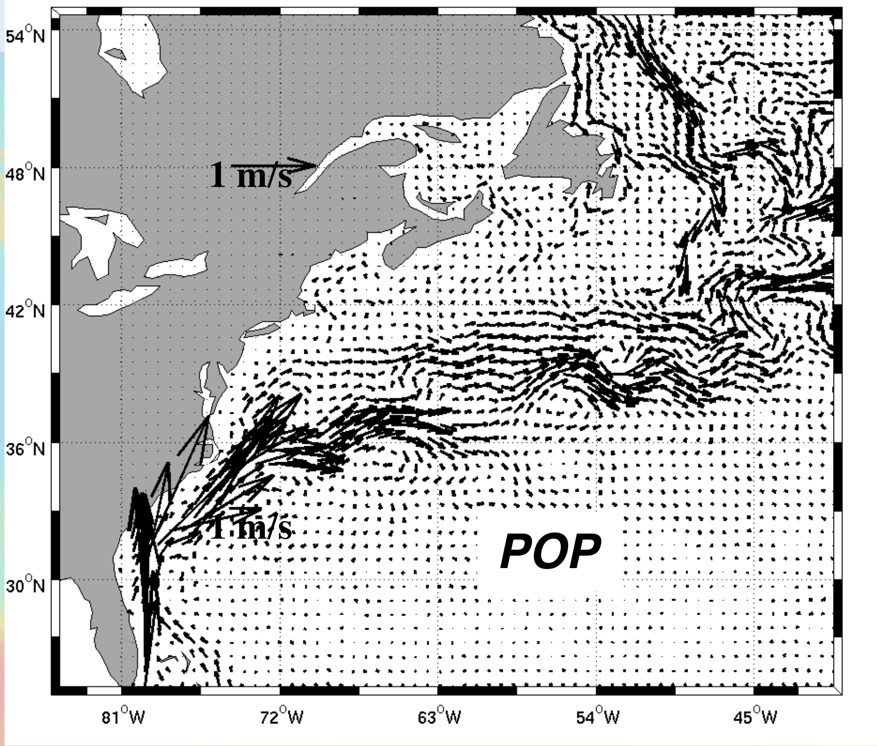
Observed SSH

Caveats for Estimates

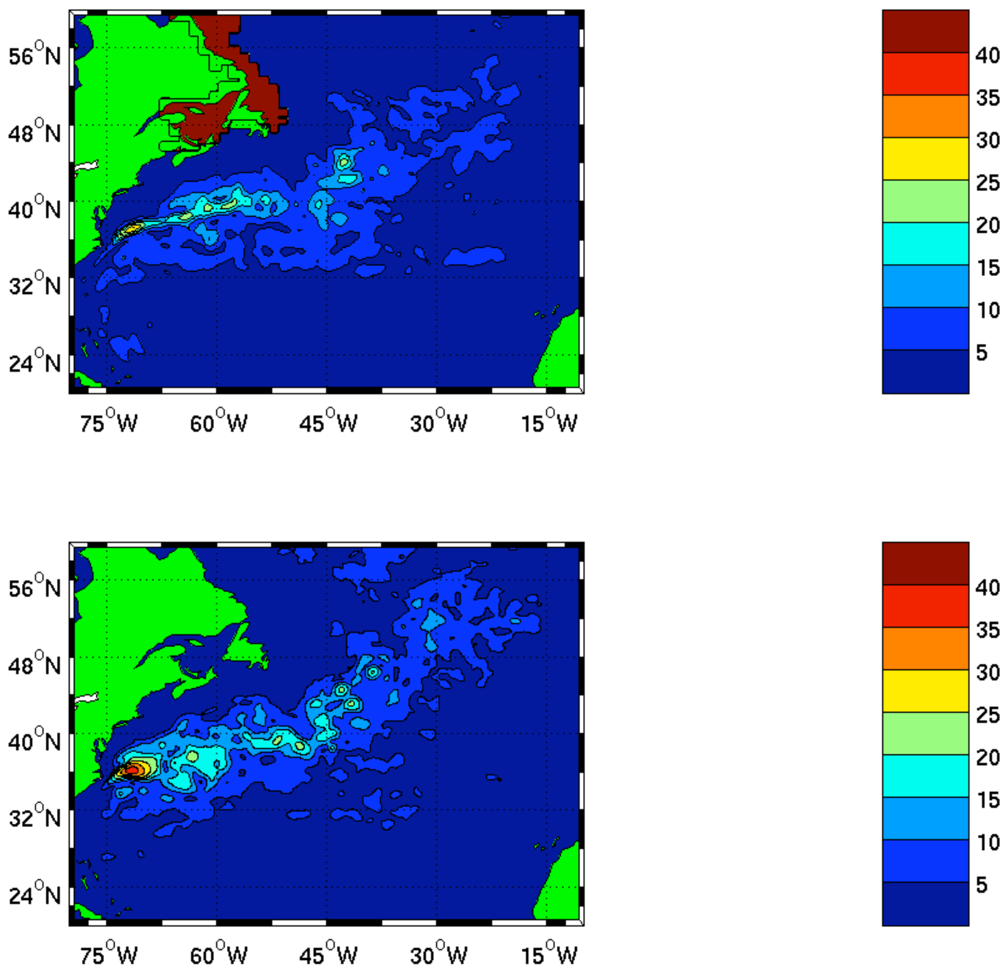
- **POP (Parallel Ocean Program) North Atlantic**
  - Fully eddy resolving
  - Interior fields and SSH not constrained by observations
  - Effective relaxation from surface buoyancy forcing
- **Mercator: North Atlantic**
  - Nudging causes agreement with observations despite low resolution
  - Interior sources of heat and salt, but surface forcing not adjusted
  - Output not from native grid: not volume conserving
- **ECCO2: Global**
  - State estimate consistent with ocean obs
  - Adjustment of surface forcing
  - Eddy permitting
- **Diagnostic (Dong and Kelly, 2004)**
  - Surface forcing not adjusted
  - Does not conserve volume
  - Not eddy resolving and vertical structure prescribed
  - Low frequency variability determined from SSH

Mean Surface Velocities well represented in all models





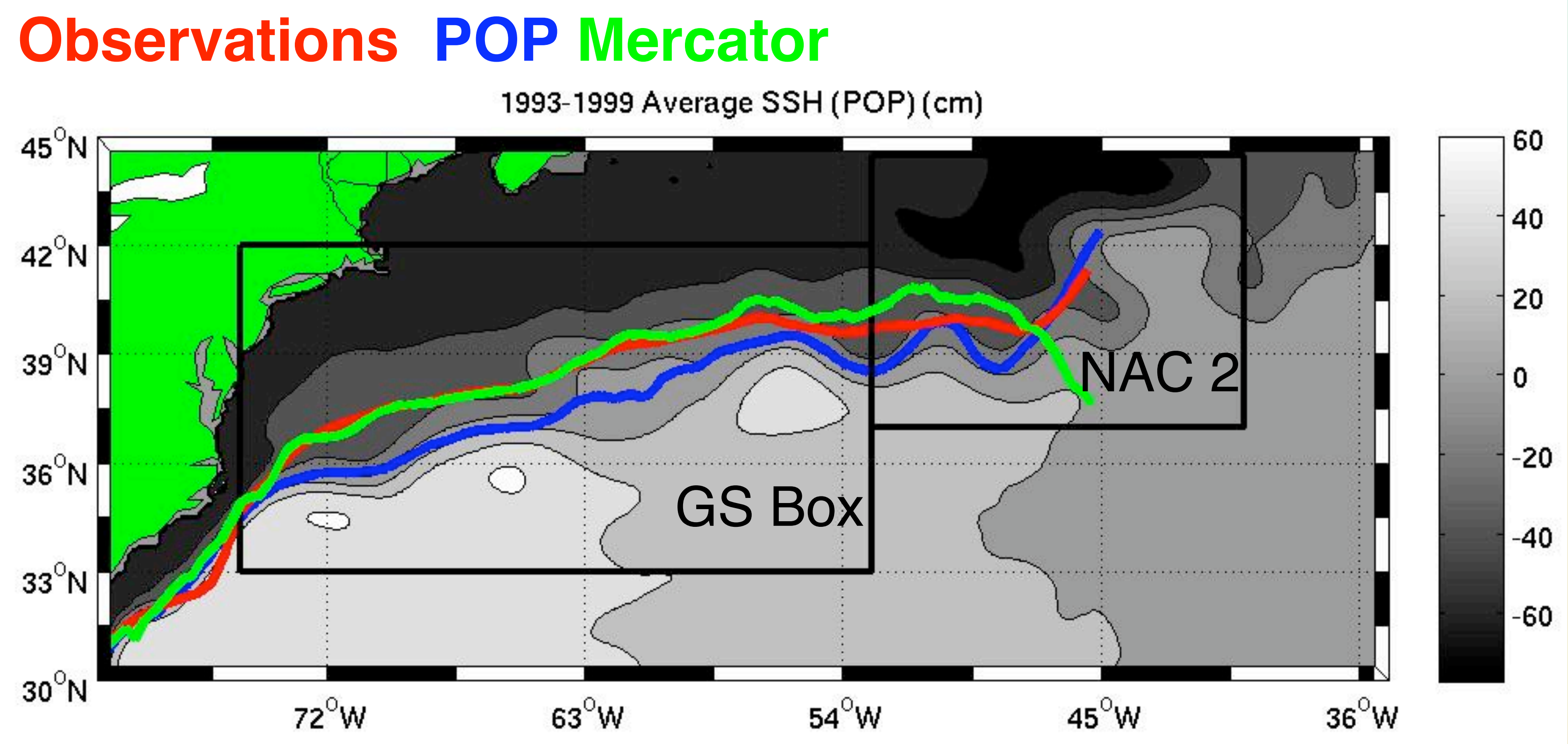
Interannual SSH variance: POP reproduces NW corner but too much variance upstream



Observed

POP

Analysis region, focus on GS and NAC



Heat Budget

Calculate contribution to heat content from Horizontal advection and surface heat flux (integrating to the bottom and to 800m)

- –Average over boxes (given in Watts/m^2)
- –Remove seasonal cycle
- –Low pass for interannual signal
- –Positive indicates heating

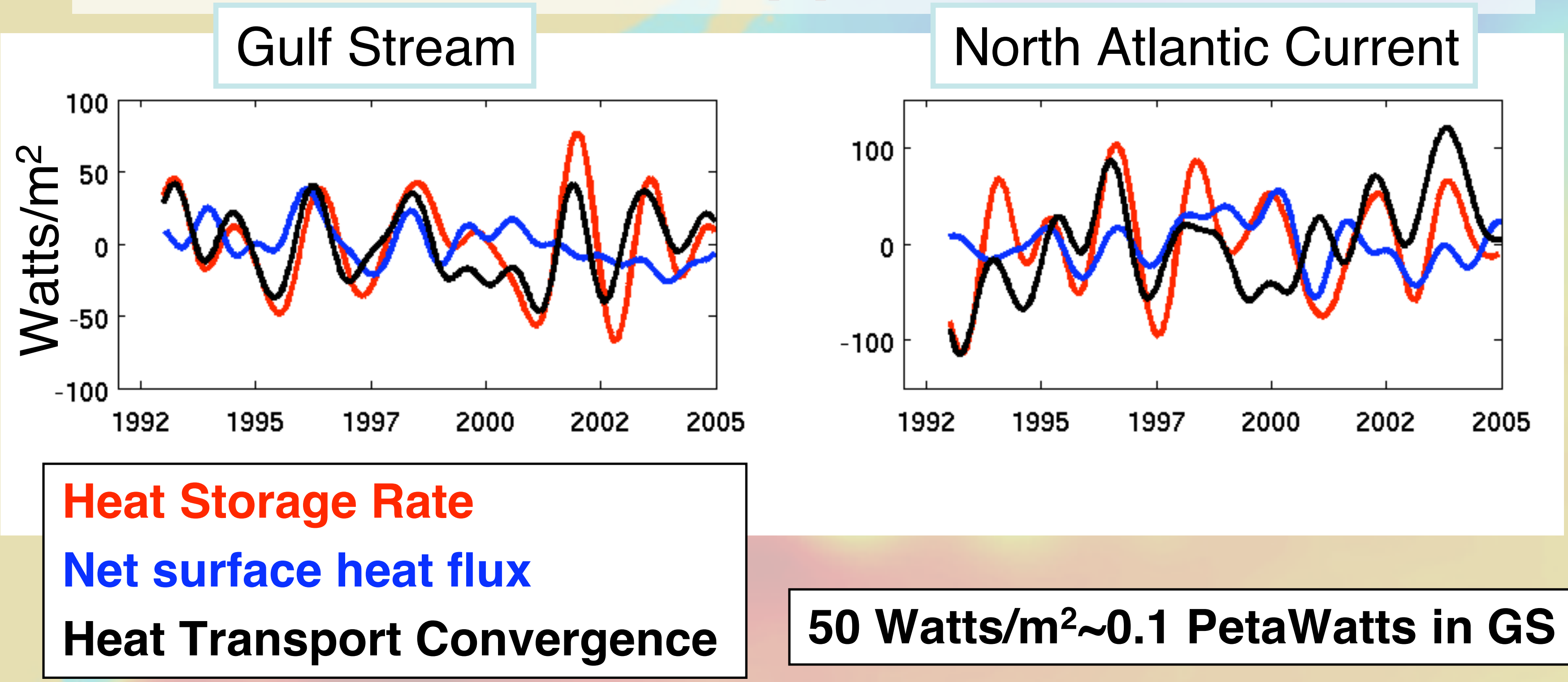
Heat storage rate=

Horizontal Heat transport convergence

+vertical heat transport convergence

+surface heat flux

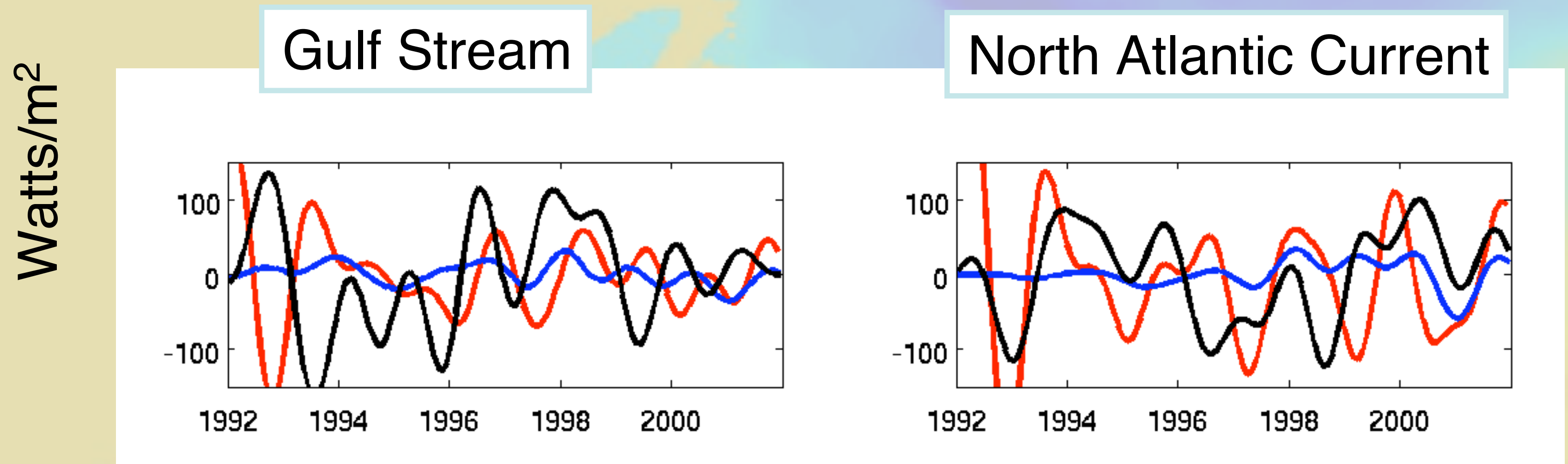
Diagnostic: heat transport convergence dominates heat storage rate in upper 800m



50 Watts/m^2~0.1 PetaWatts in GS

Net volume transport convergence of a few Sverdrups
Heat budget does not close: vertical processes and volume changes
Dong and Kelly (2004)

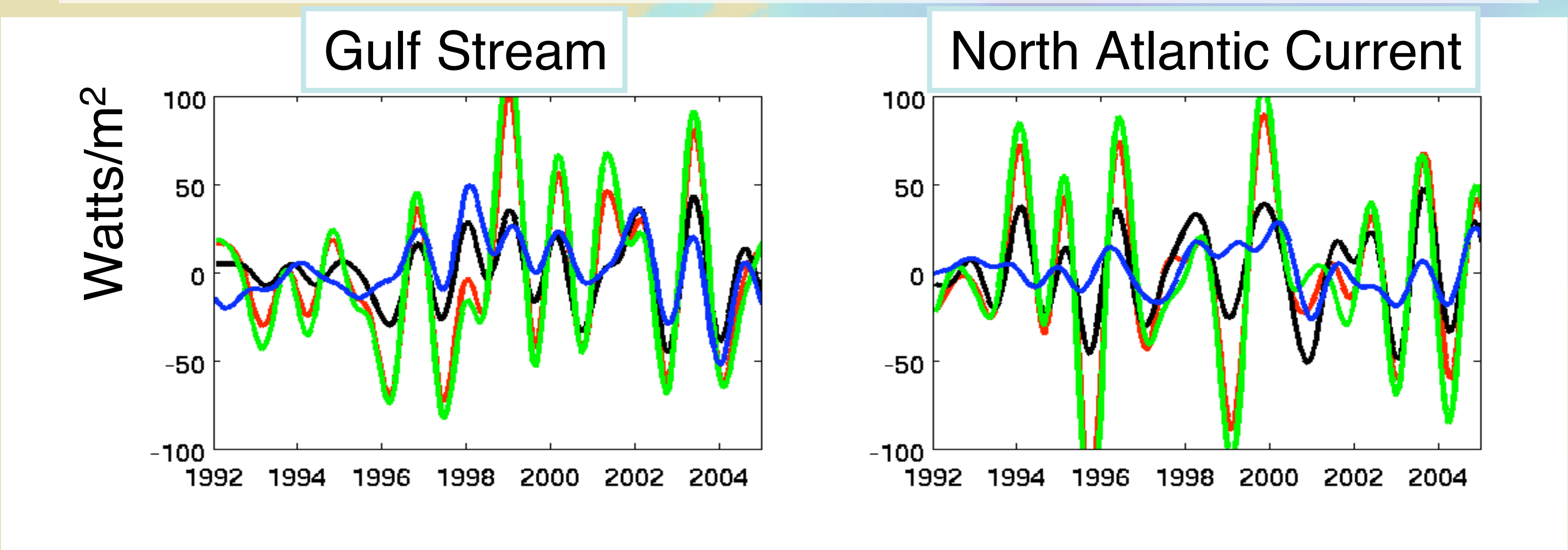
Mercator top to bottom heat budget: nudging throughout heat budget not closed



Heat storage rate
Net surface heat flux
Heat Transport Convergence

Model output not on native grid: volume not conserved (~5 Sv)
Heat transport convergence dominates similar to diagnostic model

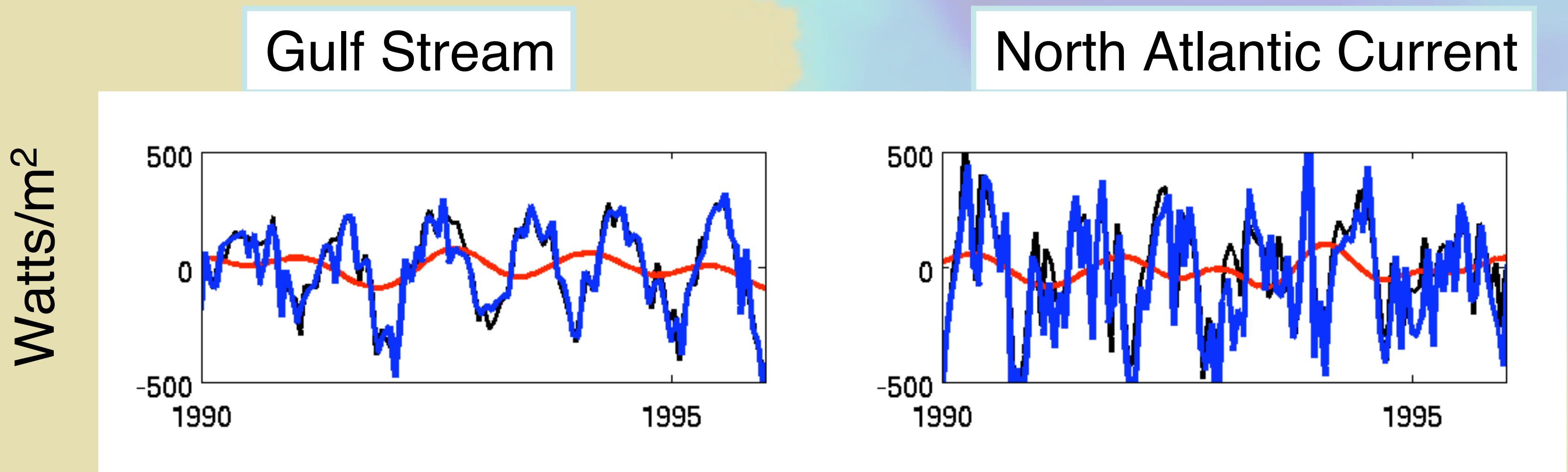
ECCO2: 85% of interannual heat storage rate in the upper 800 m (also for Mercator)



Heat storage rate (800 m)
Heat storage rate (100 m)
Heat Storage Rate (bottom)
Net surface heat flux

Heat budget closed (vertical + horizontal convergence as residual)

POP: heat budget to bottom closes



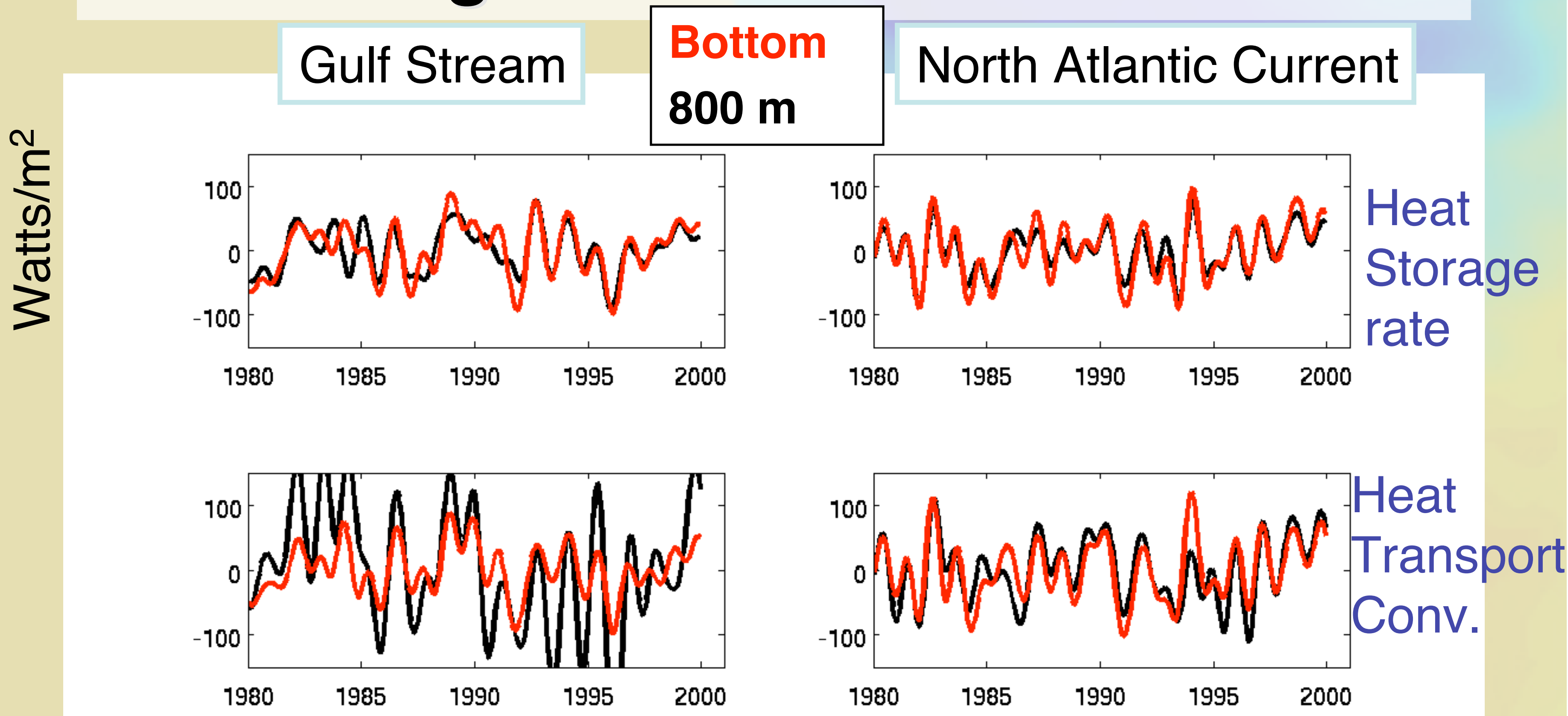
Interannual heat storage rate

Heat storage rate

Horizontal Heat Transport
Convergence + net
surface heat flux

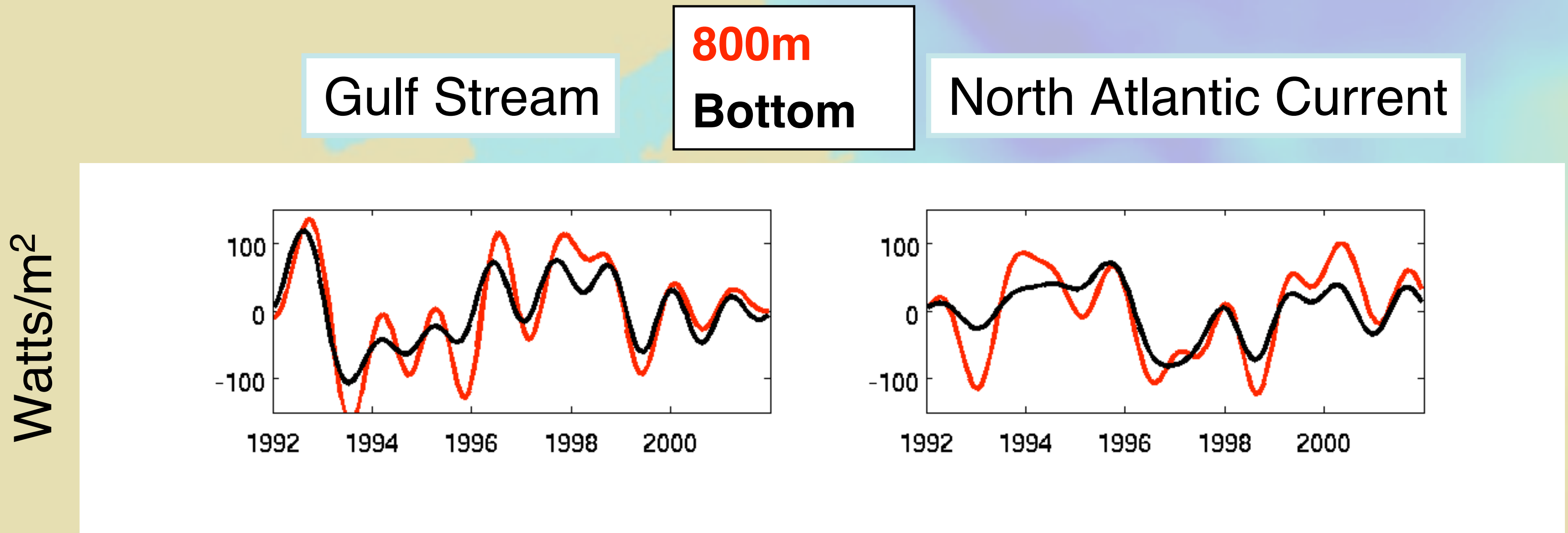
Volume conservation to within ~0.1 Sv

POP: heat storage rate and transport convergence to bottom vs 800 m



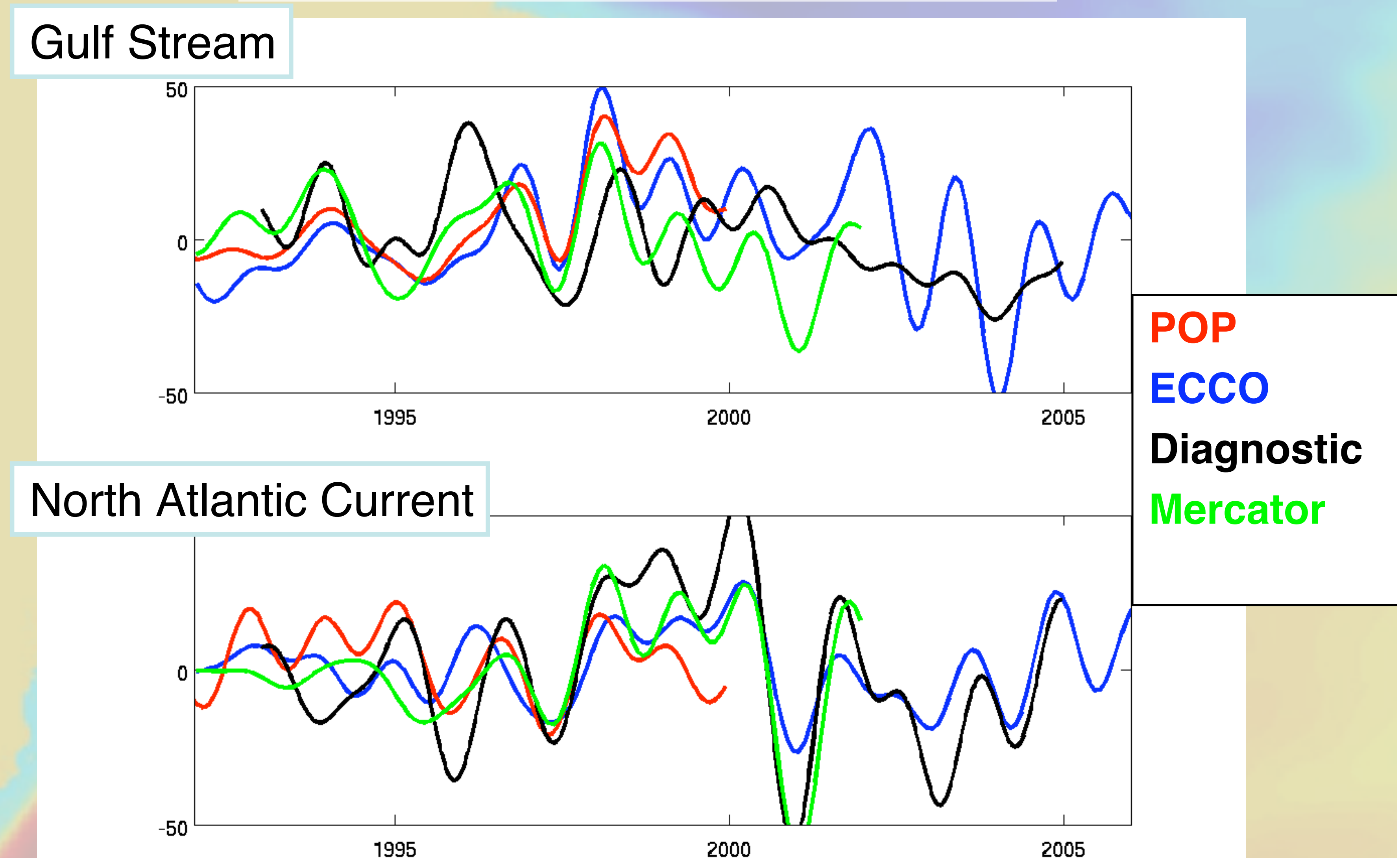
Gulf Stream horizontal transport convergence balanced by vertical divergence, NAC vertical motions small

Mercator: heat transport convergence to bottom vs 800 m



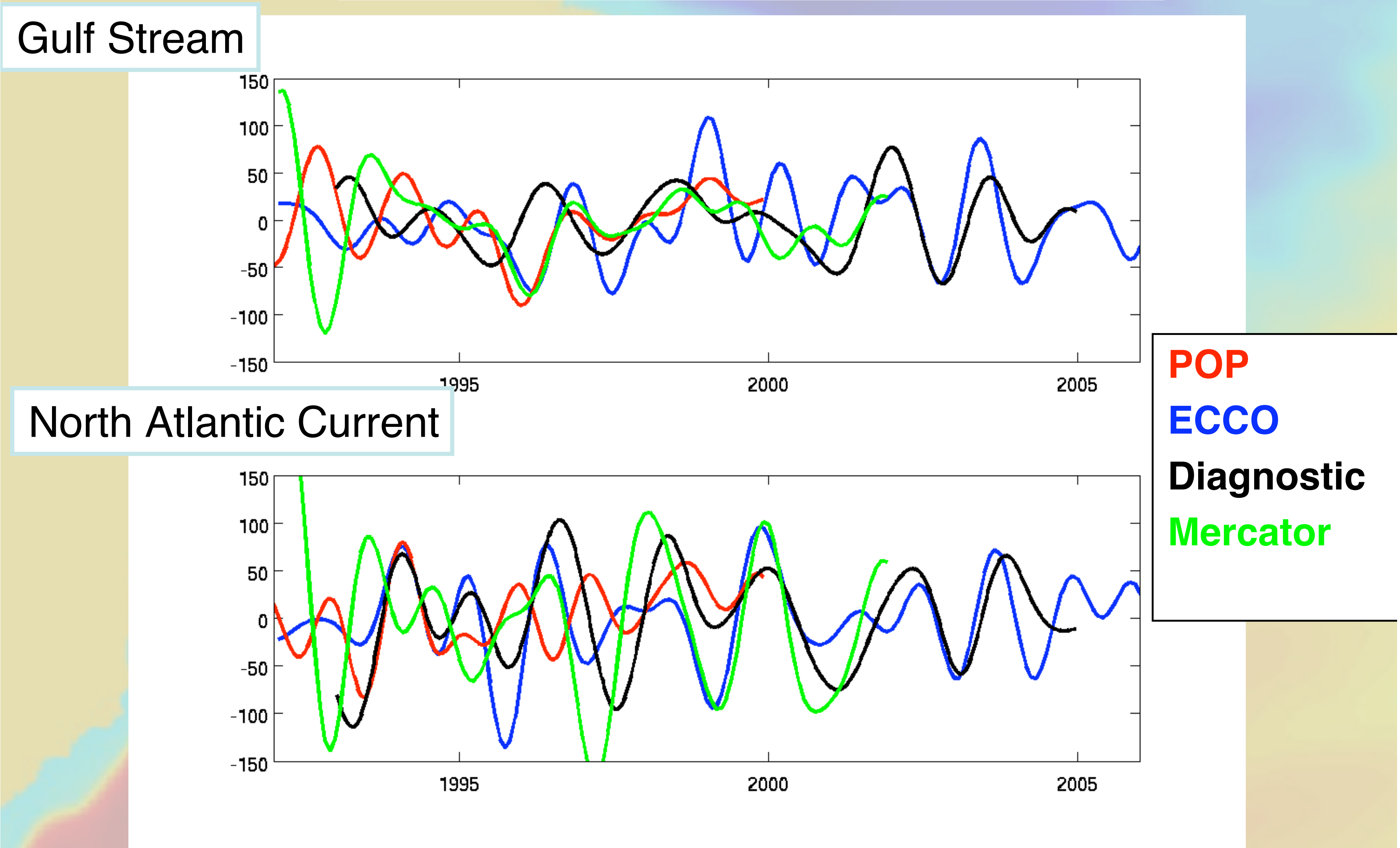
Mercator vertical divergences much smaller than in POP

Net surface heat flux



Surface fluxes differ by 20-40 Watts/m^2 especially in NAC

Heat storage rate: 800m



Variability 50-100 Watts/m2 with little agreement

Conclusions

Mean heat transport convergence about 0.2 PetaWatts in GS with interannual variability in surface fluxes large fraction of mean (NCEP Qnet)

In models that realistically represent the mean GS and NAC:

Interannual heat storage rate at 800m represents about 85% of total heat storage (all models)

Ocean heat storage is controlled by oceanic advection with storage rates 0.2 to 0.3 PetaWatts (all models)

Conclusions

Little agreement in heat storage rate despite use of SSH observations (Diagnostic, ECCO2, Mercator)

Large non-seasonal variability and lack of agreement indicates that eddies/intrinsic ocean variability important in heat budget in both GS and NAC (POP vs. ECCO2)

In GS, vertical heaving balances much of horizontal heat transport convergence at 800m, although phasing of 800m heat transport convergence is the same as that integrated to bottom (POP)

Conserving assimilation scheme important for heat budget studies and model output needed on native grid (Mercator vs. ECCO2)

On interannual times scales, storage by ocean in GS and NAC should be included in analysis of meridional energy transports of the climate system (all models)

Next steps

Is the heat transport convergence dominated by T’ or U’? (POP)

Can heat transport convergence be linked to strength of GS, to the NAO? (all models)

Can heat storage rate be linked to mode water? (POP)