High Latitude Fluxes and Products: Gridded, time series

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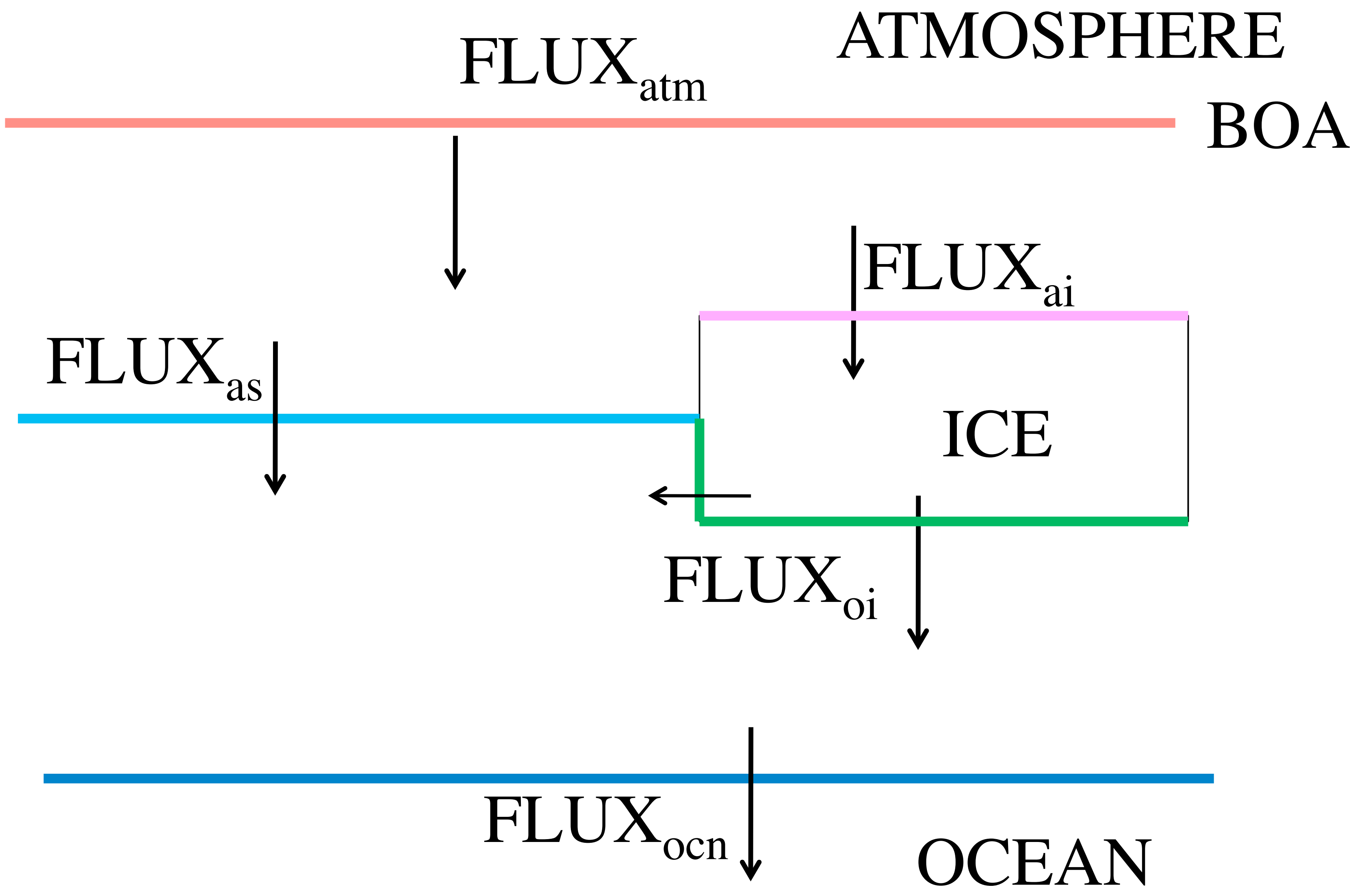
Why gridded flux time series ?

- **Forcing component models of the ocean, sea-ice, atmosphere and land**
- **Assessing flux errors in coupled climate simulations**
- **Estimating and understanding large scale (global) trends**
- **Investigating coupled feedbacks (clouds) and remote responses**

Challenges of sea-ice (snow) cover



Ocean Surfaces Fluxes

For a fractional sea-ice coverage, f_i, there are

air-sea $\{Q_{as}, F_{as}, \boldsymbol{\tau}_{as}\}$ and

ice-ocean $\{Q_{io}, F_{io}, \boldsymbol{\tau}_{io}\}$ fluxes

$$Q_{ocn} = f_o\ Q_{as} + f_i\ Q_{io} + Q_R$$

$$F_{ocn} = f_o\ F_{as} + f_i\ F_{io} + \text{Runoff}$$

$$\boldsymbol{\tau}_{ocn} = f_o\ \boldsymbol{\tau}_{as} + f_i\ \boldsymbol{\tau}_{io}$$

$$f_o = 1 - f_i$$

Air –Sea (Ice) Flux Components

$F_{as} = E(\text{evaporation}) + P_R(\text{rain}) + P_S(\text{snow})$

$Q_{as} = Q_S(\text{SW} \downarrow \uparrow) \rightarrow Q_I(\text{insolation})\ [1 - \alpha_s\ (\text{albedo})\ ]$

$+\ Q_L(\text{LW} \downarrow \uparrow) \rightarrow Q_A(\text{LW} \downarrow) - \varepsilon\ \sigma\ (\text{SST})^4$

$+\ Q_E(\text{latent}) \rightarrow E\ \Lambda(\text{latent heat of vaporization})$

$+\ Q_H(\text{sensible})$

$+\ Q_P(\text{heating/cooling of P to SST and snow melt})$

Known (not certain about much)

$\Delta \mathbf{U} = \mathbf{U}(h) - \mathbf{U}_o$ from satellites gives

$\boldsymbol{\tau}_{as}$,but neither $\boldsymbol{\tau}_{ai}$ nor $\boldsymbol{\tau}_{io}$, to within about 10%

Scatter in Southern Ocean Westerlies,
may reflect phase of AAO

C_{YX}
X = AAO

r_{YX} contoured at

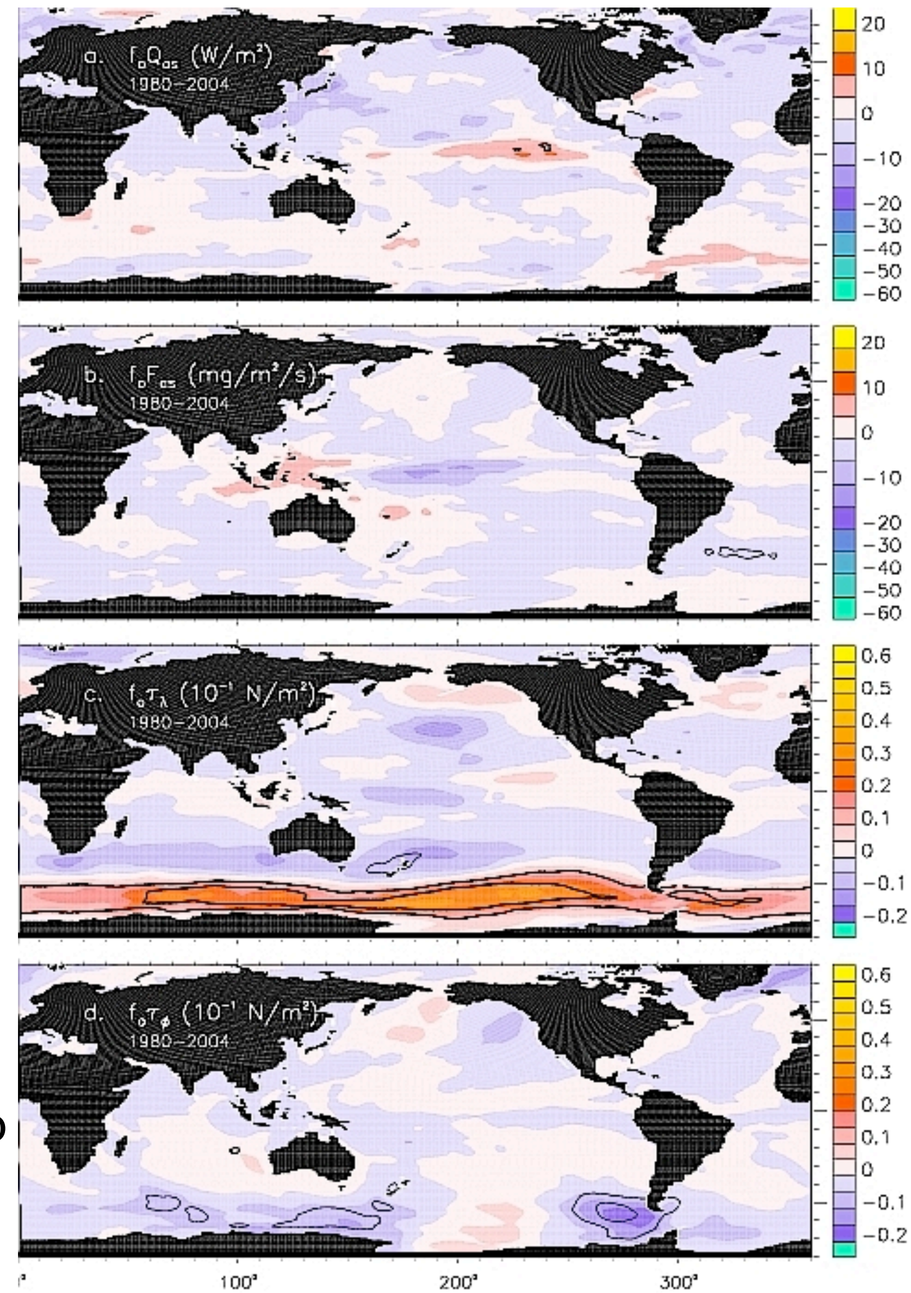
±.4, ±.6, ±.8

$f_o Q_{as}$

$f_o F_{as}$

$f_o \boldsymbol{\tau}_{\lambda}$

$f_o \boldsymbol{\tau}_{\phi}$



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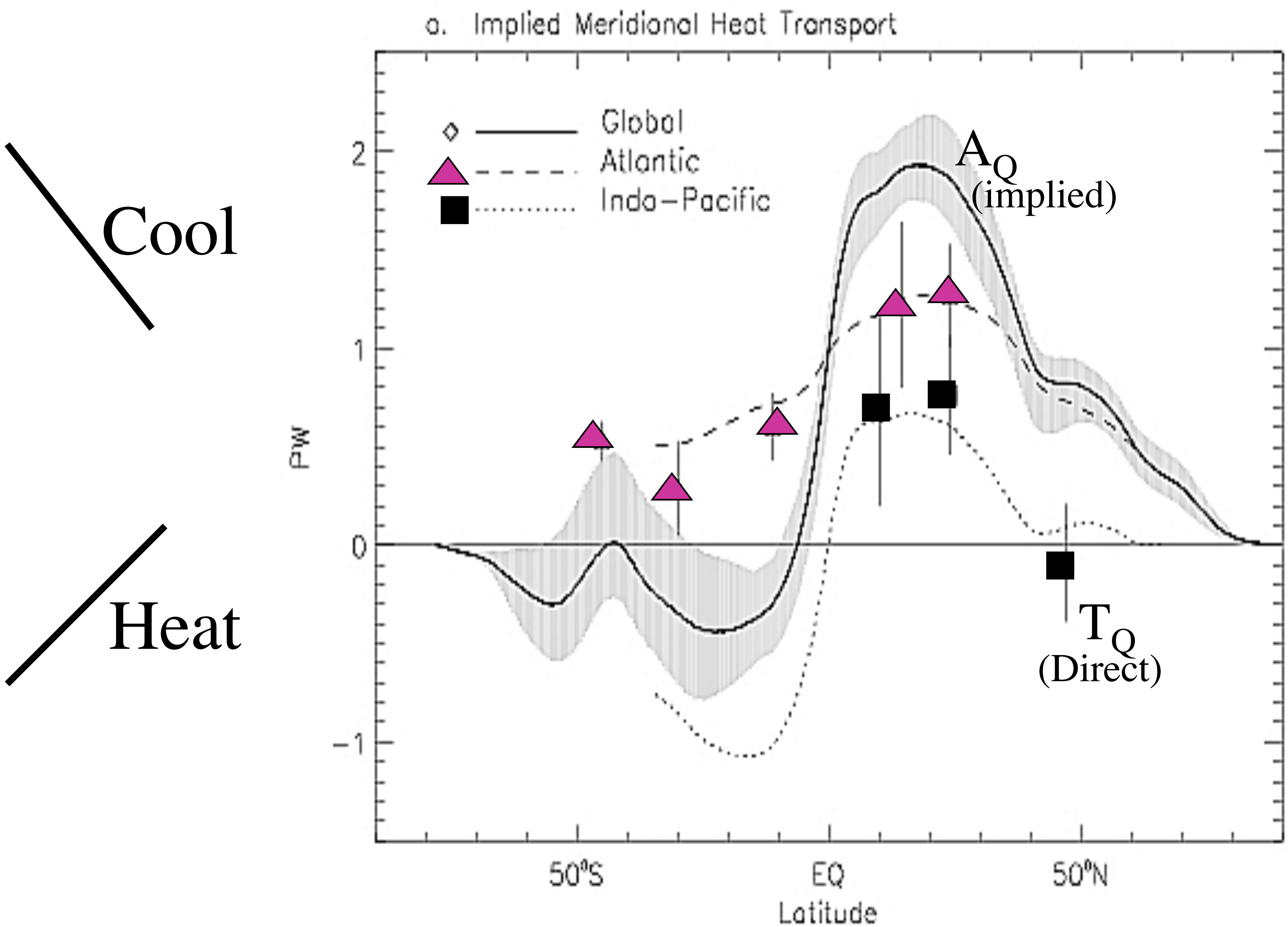
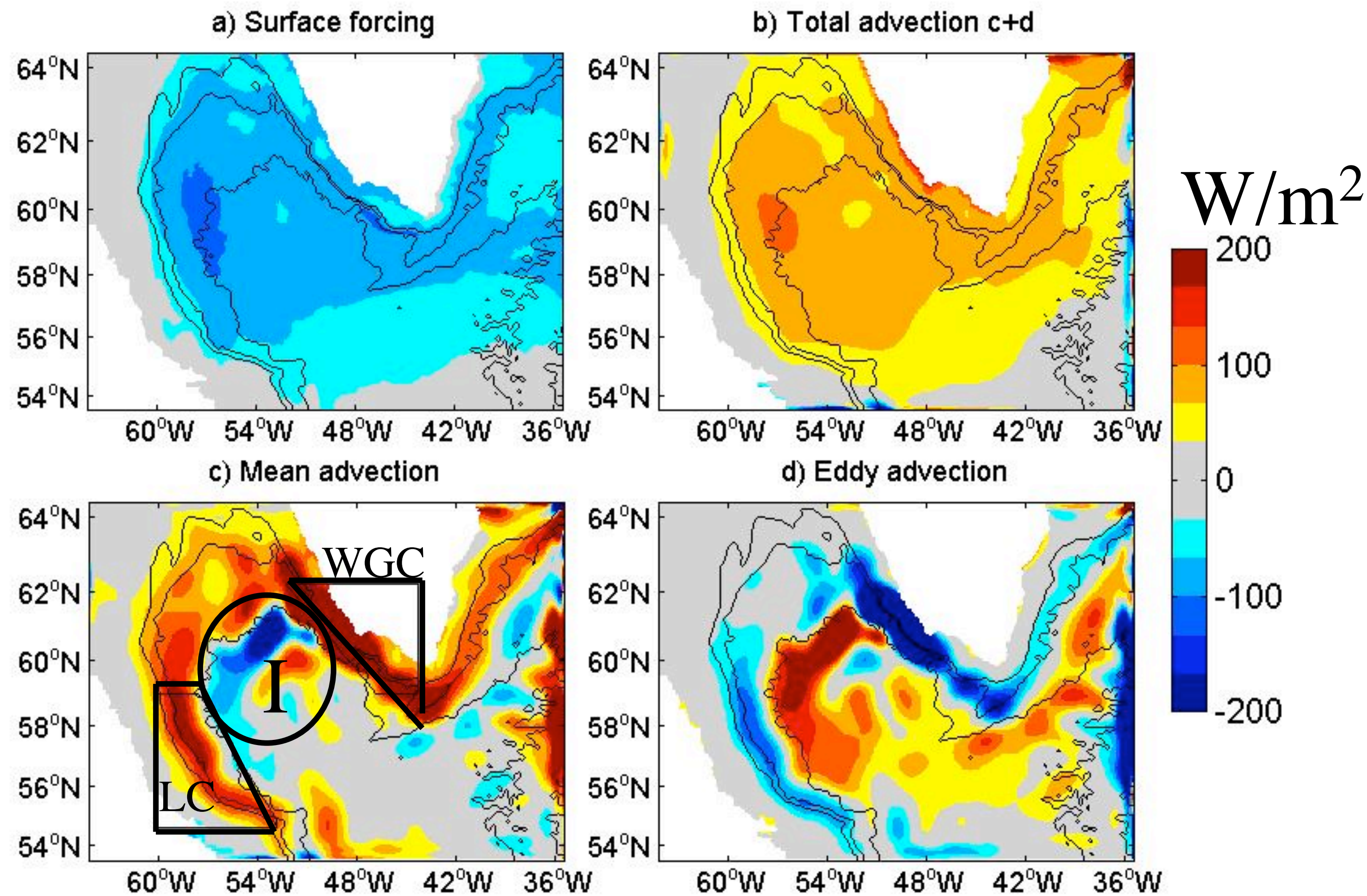
$$\langle Q_{ocn} \rangle = \langle f_o\, Q_{as} \rangle + \langle f_i\, Q_{oi} \rangle$$

$$< 2\ \mathrm{W/m^2} \sim 2\% \text{ of } Q_E$$

Northward heat transport (PW)



Depth Integrated Heat Budget : Labrador Sea



Lab Sea column heat Budget (W/m^2)

Region	Mean Advection	Eddy Advection	Surface Heat Flux	Residual
WGC	488	-412	-78	-2
LC	90	-36	-55	-1
Interior	-12	96	-79	4
Lab Sea	53	-1	-57	-5

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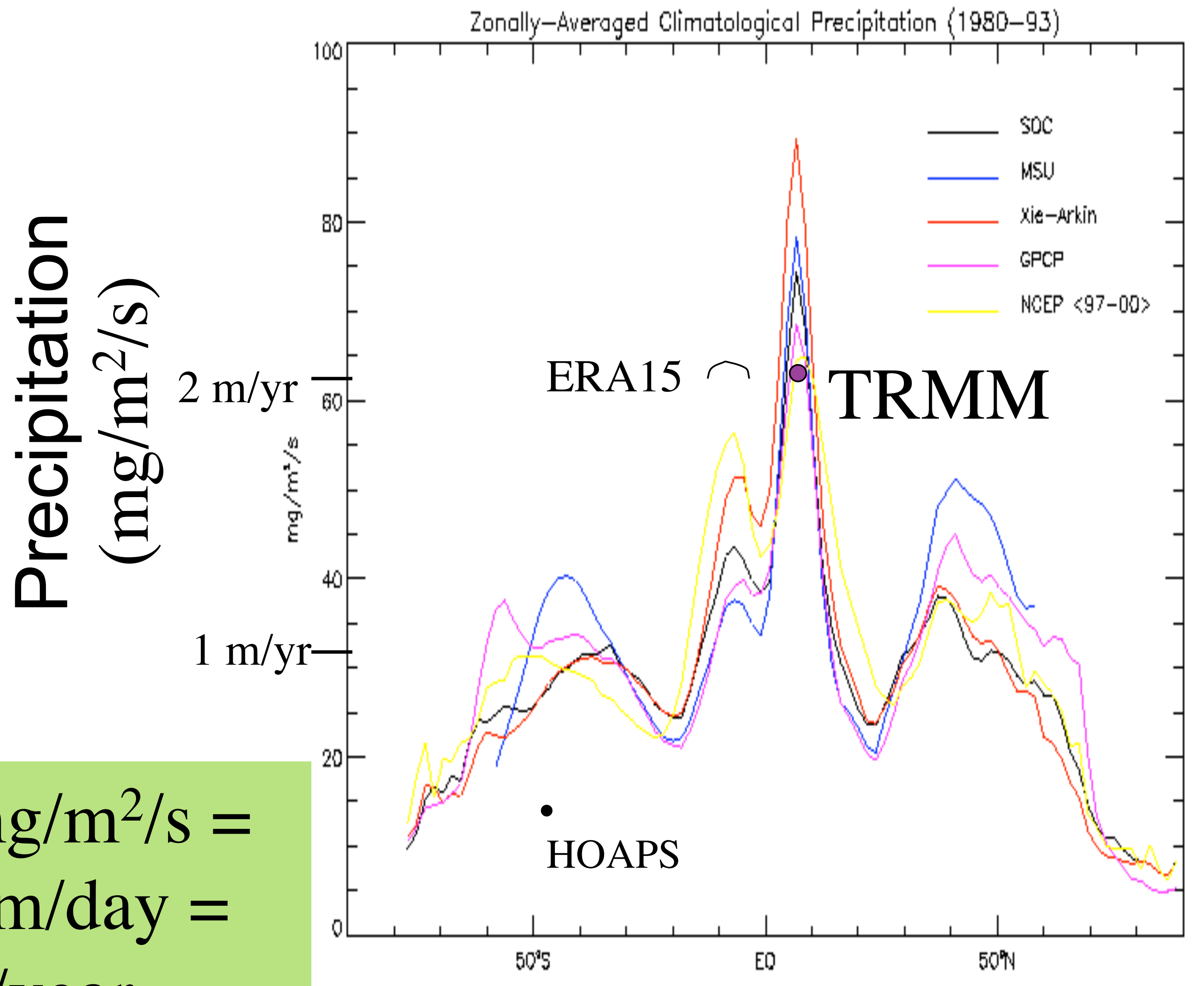
$< F_{ocn}$ - Runoff $> \sim .1\%$ of E

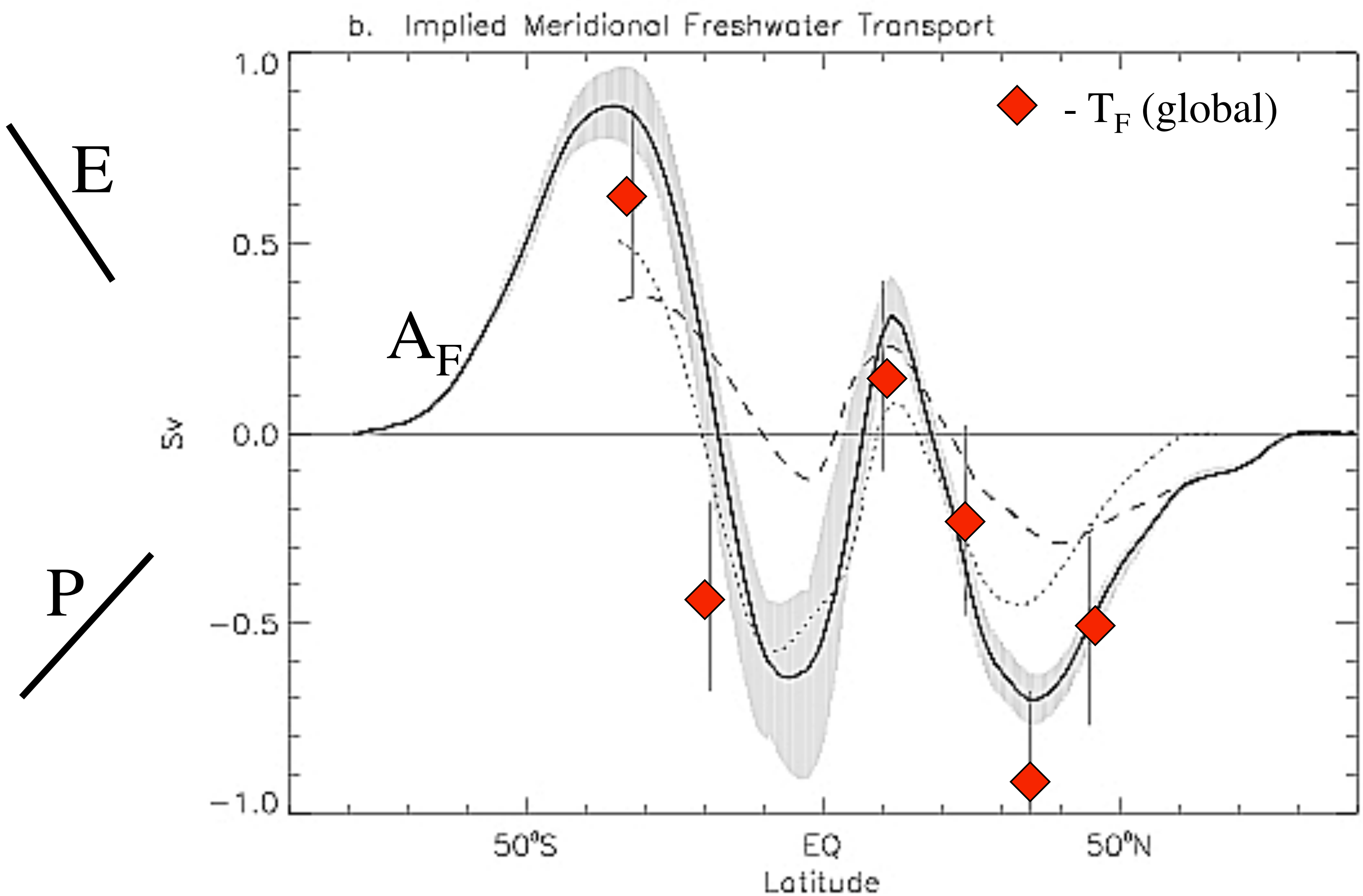
BIG PROBLEM



100 mg/m^2/s =
8.6 mm/day =
3.1 m/year

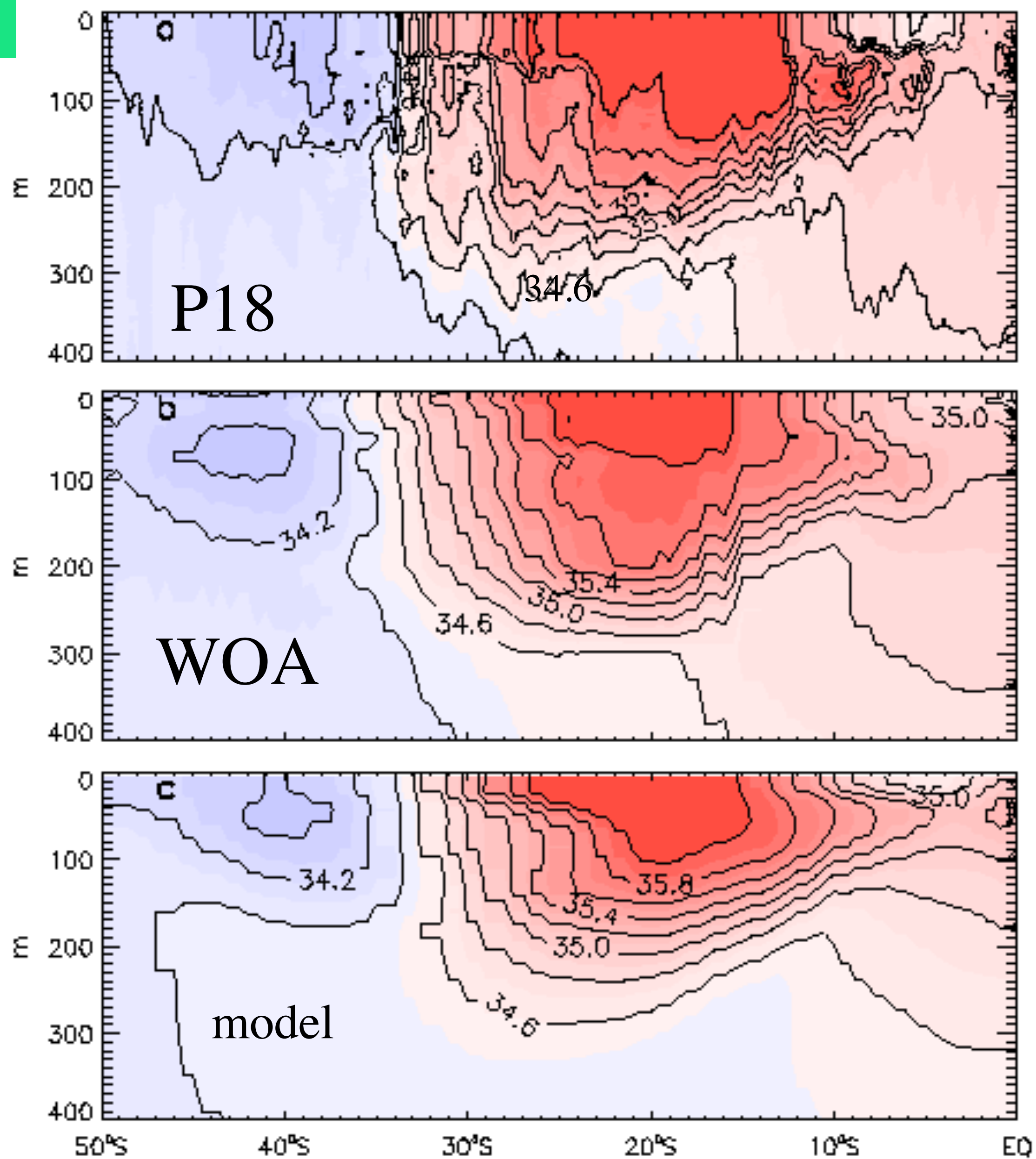
Figure 4: Zonally averaged climatological ocean precipitation from various sources,as described in Large and Yeager (2008).

Northward freshwater transport (Sv)



OGCM Fidelity

S



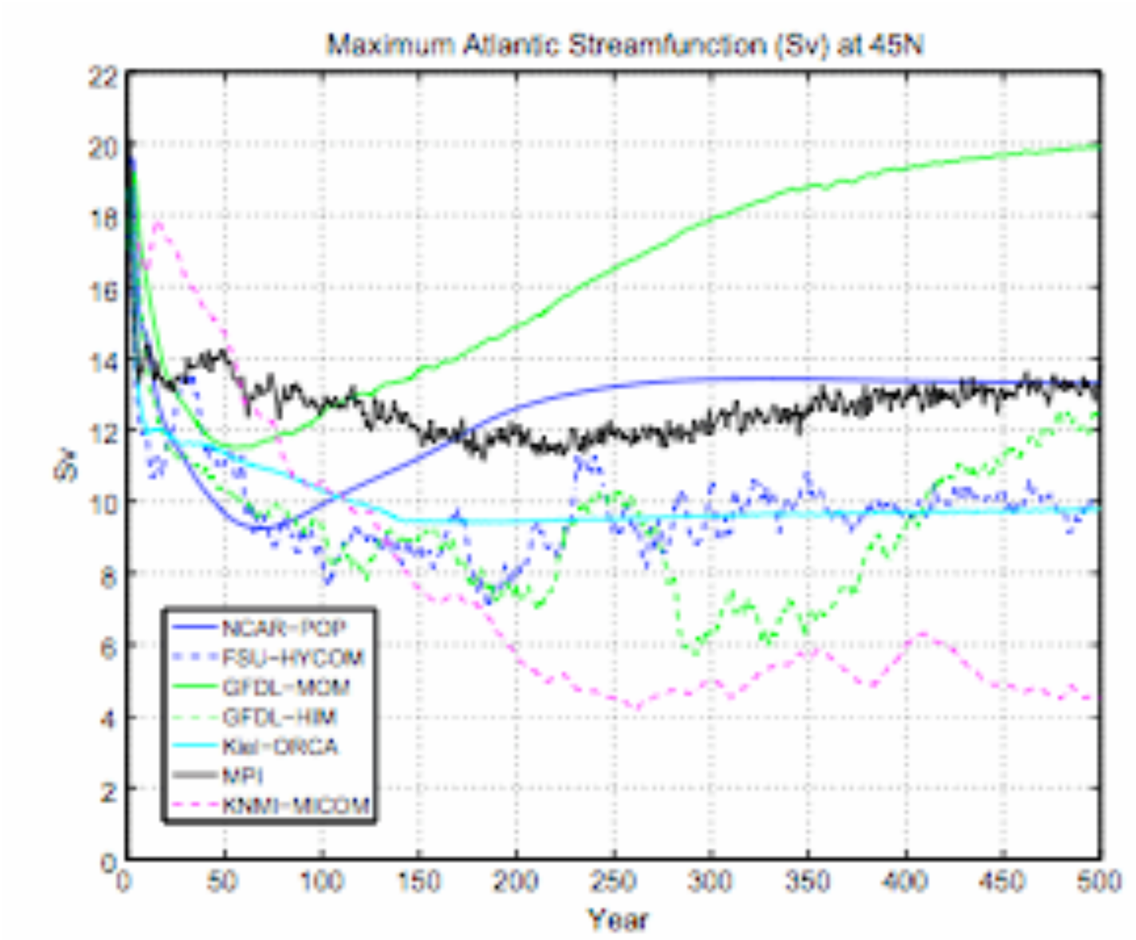
March model salinity unstable &comparable to WOCE (P18) and WOA98

Coordinated Ocean Research Experiments (CORE) :

Hypothesis : With similar forcing, different coupled ocean-ice models will give similar solutions.

FALSE !!!

CORE : AMOC



Maximum Atlantic Streamfunction (Sv) at 45N
Sv
Year
0
2
4
6
8
10
12
14
16
18
20
22
0
50
100
150
200
250
300
350
400
450
500
NCAR−POP
FSU−HYCOM
GFDL−MOM
GFDL−HIM
Kiel−ORCA
MPI
KNMI−MICOM

Coordinated Ocean Research Experiments (CORE) :

$$F_{ocn} = f_o F_{as} + f_i F_{io} + \text{Runoff} + \underline{\mathbf{F}_{\mathbf{r}}}$$

$$\mathbf{F}_{\mathbf{r}} = V_p [S(1) - SSS_{obs}] \cdot \{ f_o; 1\text{-}H(f_i); (f_o+f_i) \}$$

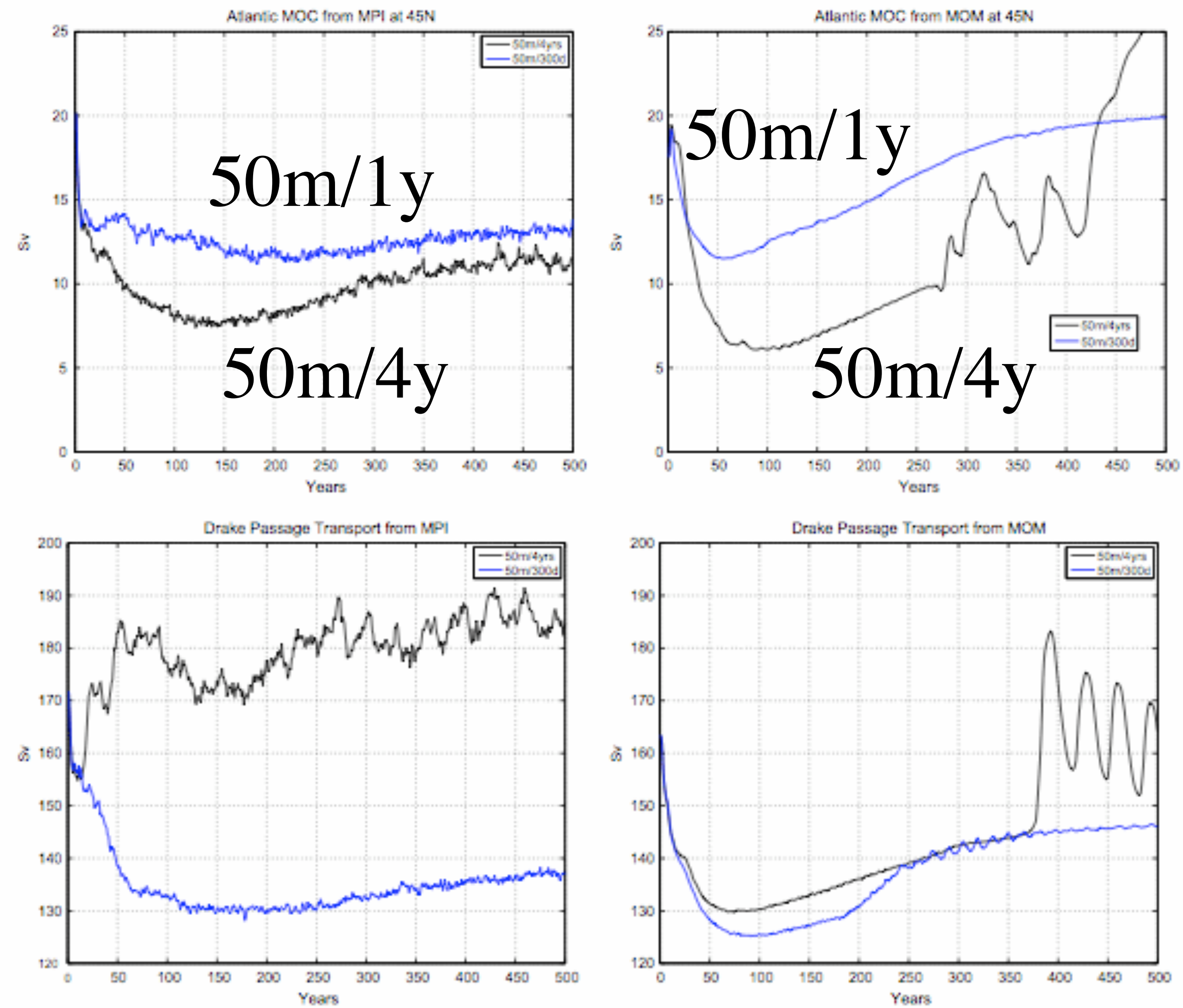
$$Vp = \{ 0 ; 50m/4y ; 50m/1y ; 50m/30d \}$$

Sensitivity

Model A Model B

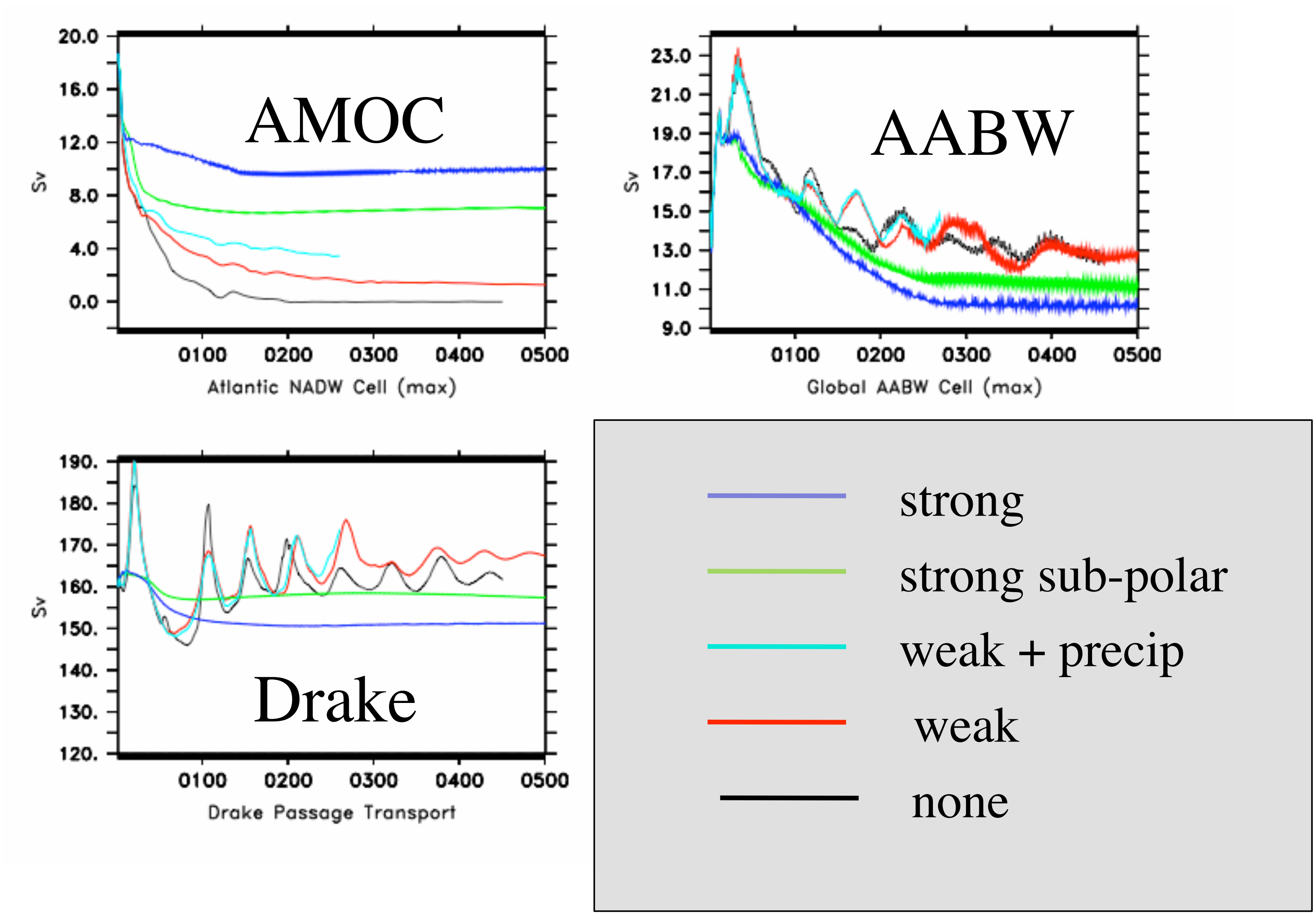
AMOC

Drake Passage



Sensitivity

Model C



Bulk turbulent fluxes :

$$E = \rho \quad C_E(h) \quad |\Delta \mathbf{U}(h)| \quad [\, q(h) - q_{sat}(SST)]$$

$$Q_H = \rho\, C_p \quad C_H(h) \quad |\Delta \mathbf{U}(h)| \quad [\, \theta(h) \; - \; (SST)\,]$$

$$\boldsymbol{\tau}_{as} = \rho \quad C_D(h) \quad |\Delta \mathbf{U}(h)| \quad \Delta \mathbf{U}(h)$$

$\mathbf{U}(h)$, wind velocity at z = h (10m)

$\theta(h)$, potential temperature at z=h

$q(h)$, specific humidity at z=h

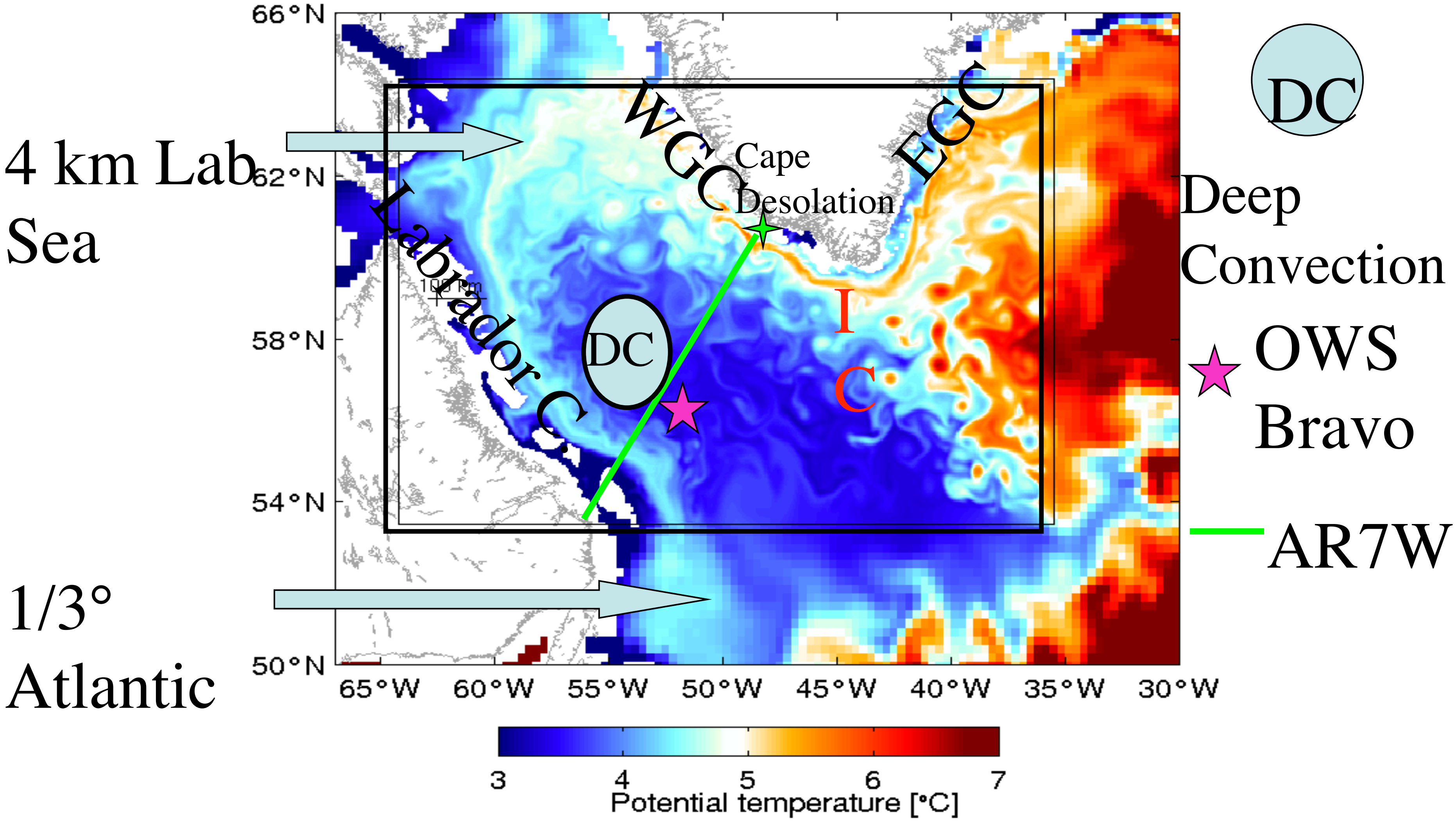
ρ , air density

SST, sea surface temperature

$\mathbf{U}_o$, sea surface current

$\Delta \mathbf{U} = \mathbf{U}(h) - \mathbf{U}_o$, Surface Vector Wind (satellite)

Labrador Sea, T(182m), Year 10



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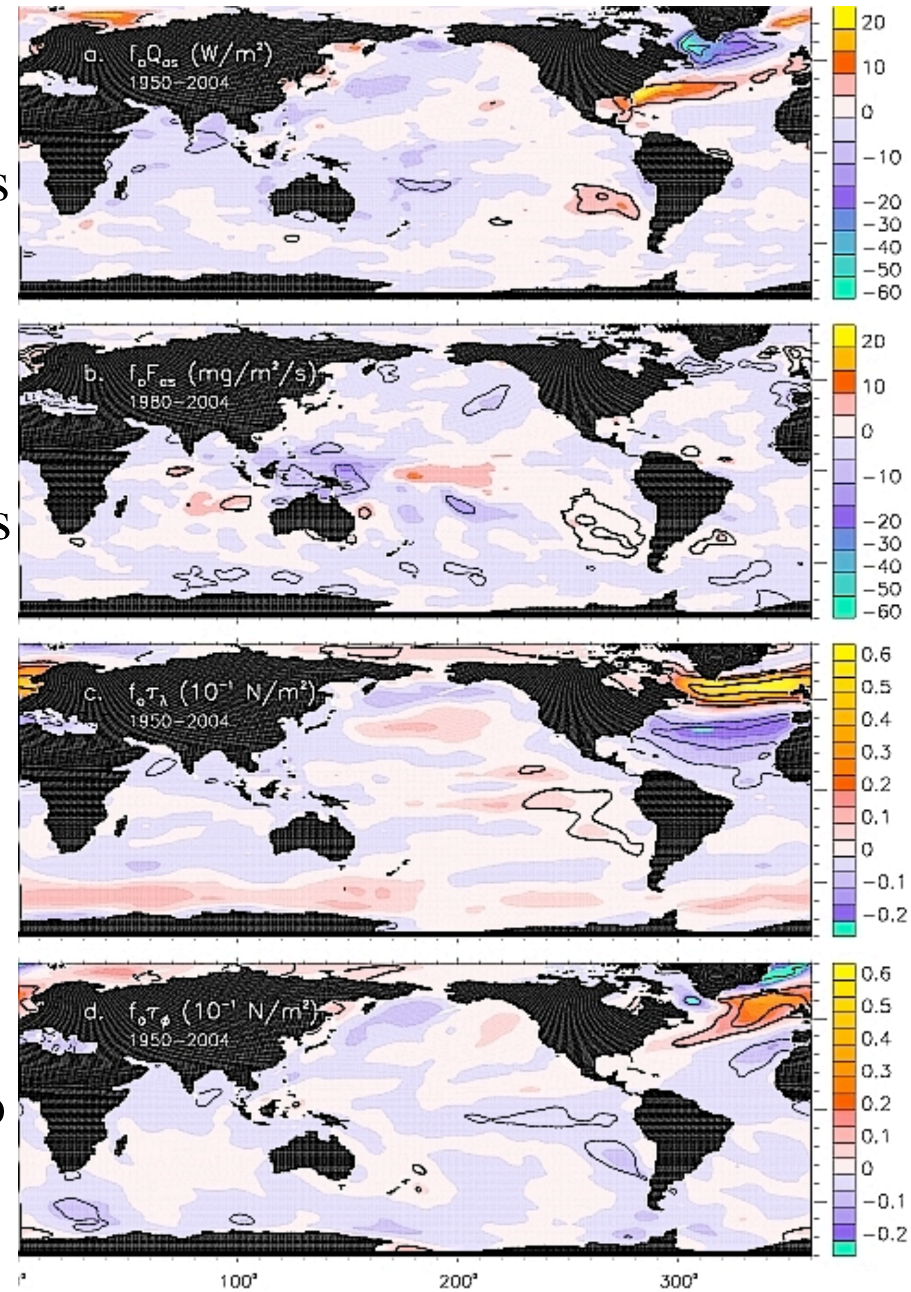

e.g Ocean (Ice) surface fluxes

Q_{ocn}, the net surface heat flux **into** the ocean

F_{ocn}, the net freshwater flux **into** the ocean

$\boldsymbol{\tau}_{ocn} = (\tau_\lambda, \tau_\phi)_{ocn}$, the horizontal stress, or momentum flux vector **into** the ocean (zonal, +ve east, meridional, +ve north)

All these fluxes are highly variable in time (weather, seasonal cycle) and space (tropics to high latitudes), with much less interannual (decadal) variability and small trends;

AMOC