

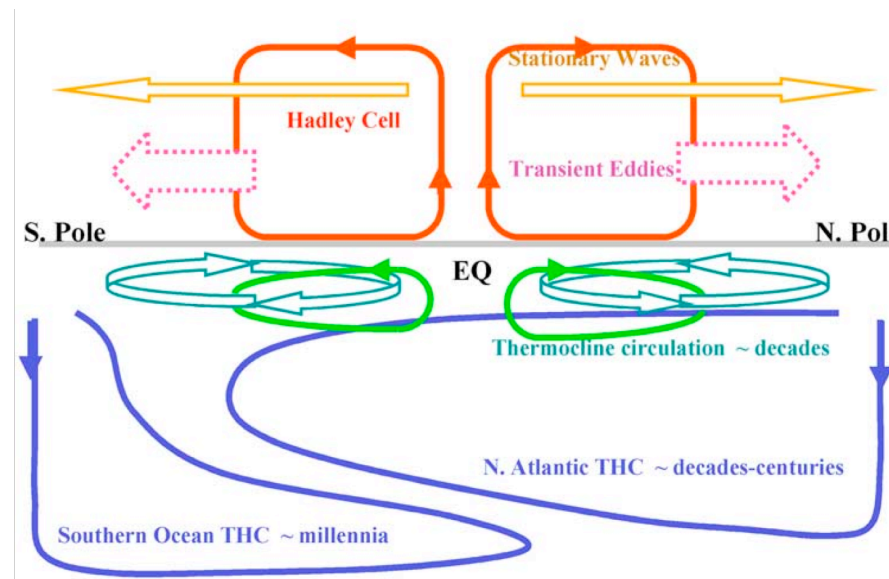
Aspects of the tropical-extratropical and interhemispheric interaction in sector AOGCM



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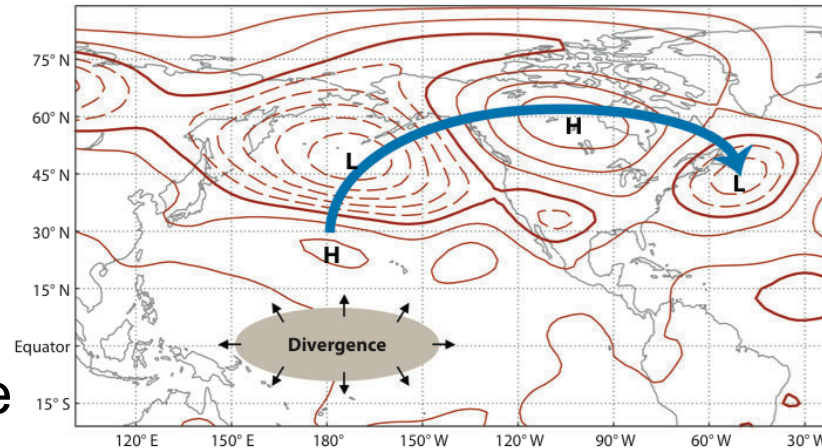


Liu, Z., and M. Alexander (2007), Rev. Geophys

Ocean's role? → Shape of tropical coastline and Drake Passage's depth could influence position of ITCZ !?

Motivation

Meridional teleconnections and transport of heat and water are crucial for climate



DJF 500mb response to 1986-87 El Nino
Chiang, J.C.H., (2009) Ann. Rev. Earth.

TROPICS $\xrightarrow{\text{ENSO, MJO}}$ **EXTRATROPICS**

Horel and Wallace (1981), Trenberth et al. (1998), Liu and Alexander (2007), ...

Here focus on: **EXTRATROPICS** \longrightarrow **TROPICS**
& INTERHEMISPHERIC INTERACTION

Chiang et al. (2003), Chiang and Bitz (2005), Chiang et al. (2008), Zhang and Delworth (2005), Broccoli et al. (2006), Timmermann et al. (2007), Kang et al. (2008), Kang et al. (2009), ...

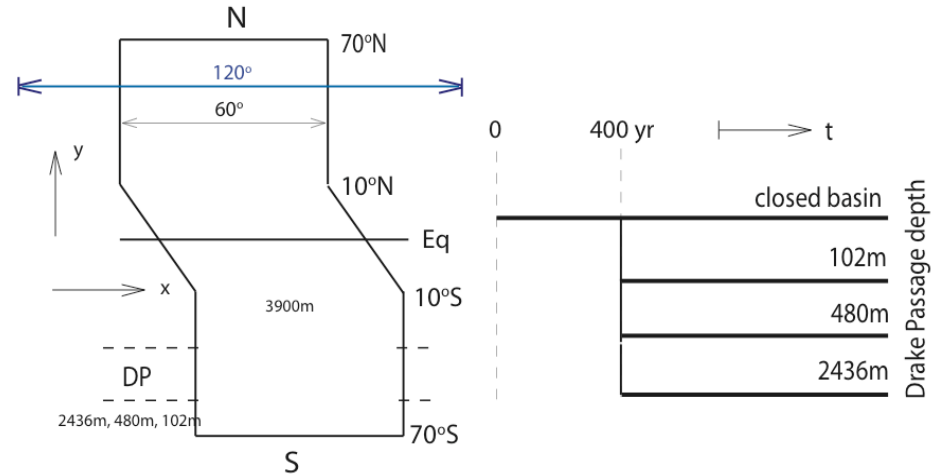
Paleoclimate evidence: Lea et al. (2003), Koutavas and Lynch-Stieglitz (2004), ...

ITCZ shifts toward (away from) the warmed (cooled) hemisphere

→ What is the potential role of ocean circulation and OHC?

Numerical setup

An intermediate complexity coupled climate model derived from GFDL CM2.0

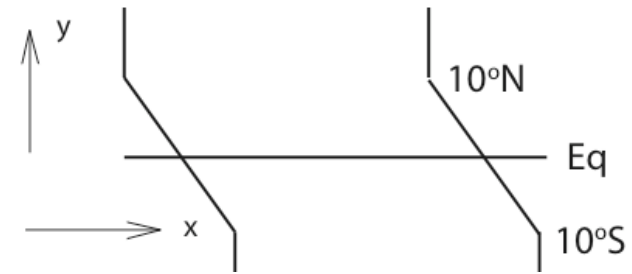


Key simplifications implemented in a modular manner:

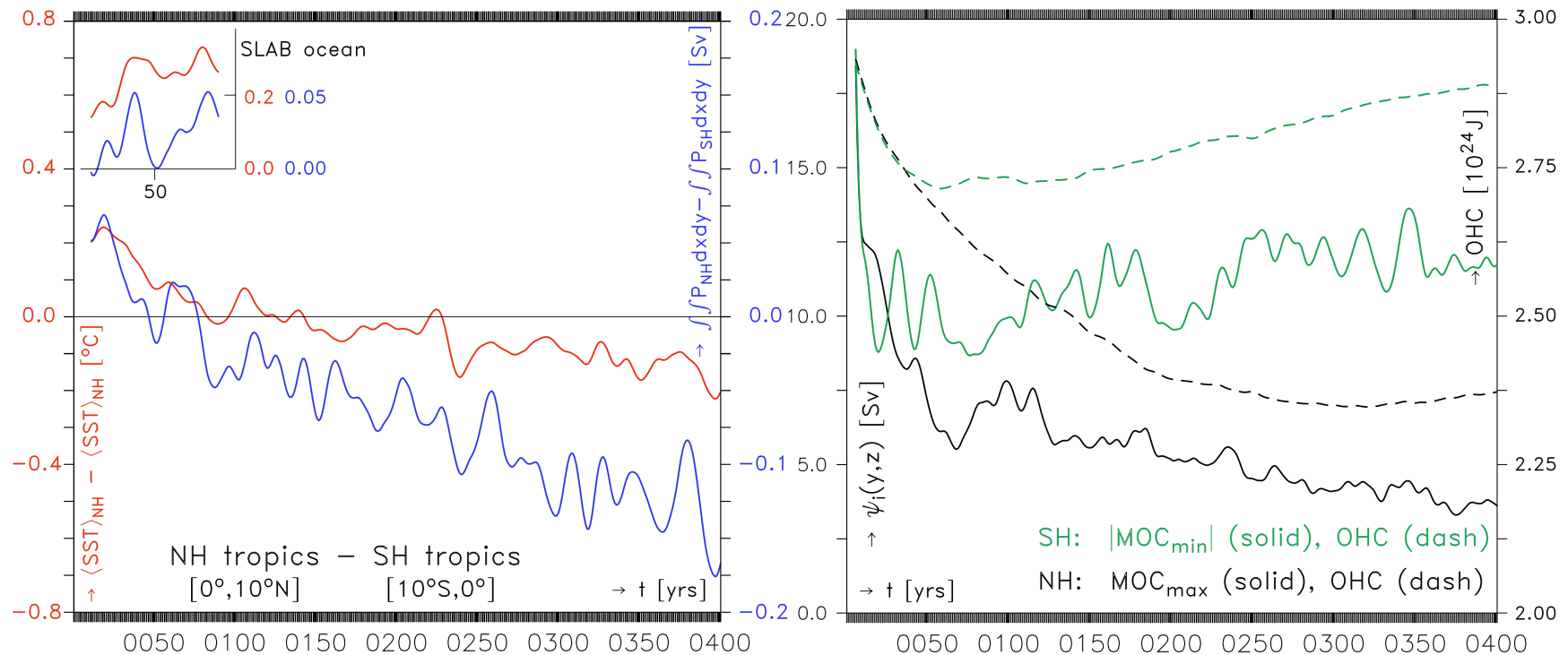
- 120° wide sector atmosphere over an ocean basin 60° wide
- MOM4.0 with 2°x2° horizontal resolution and 24 vertical levels
- B-grid moist atmospheric dynamical core with grey radiation scheme and no liquid water or clouds (3.75°x3° horizontal resolution and 7 vertical levels) – highly simplified physics parameterization
- SIS dynamic-thermodynamic sea-ice model
- Simplified bucket land model based on LM2.0
- Forcing: annual and zonal mean TOA SW flux

Closed basin

(without a circumpolar channel)

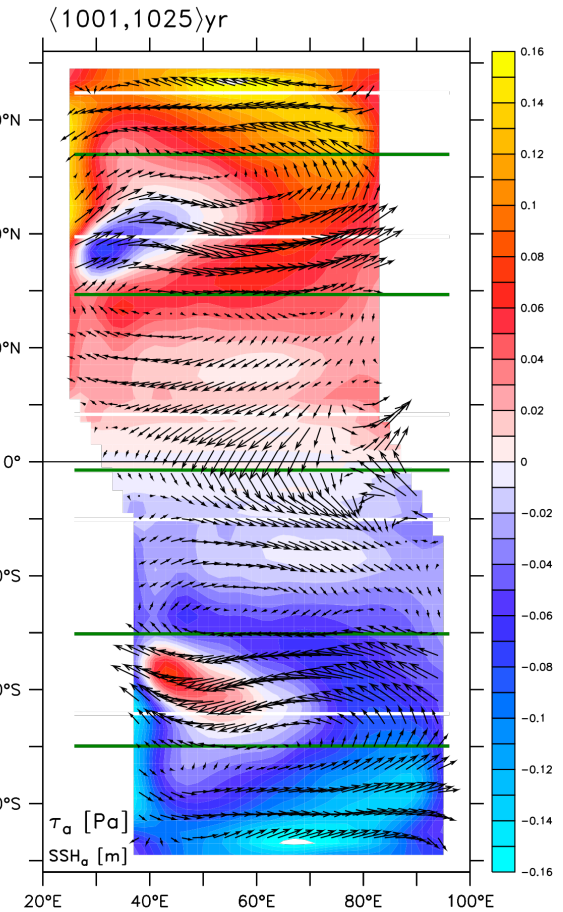
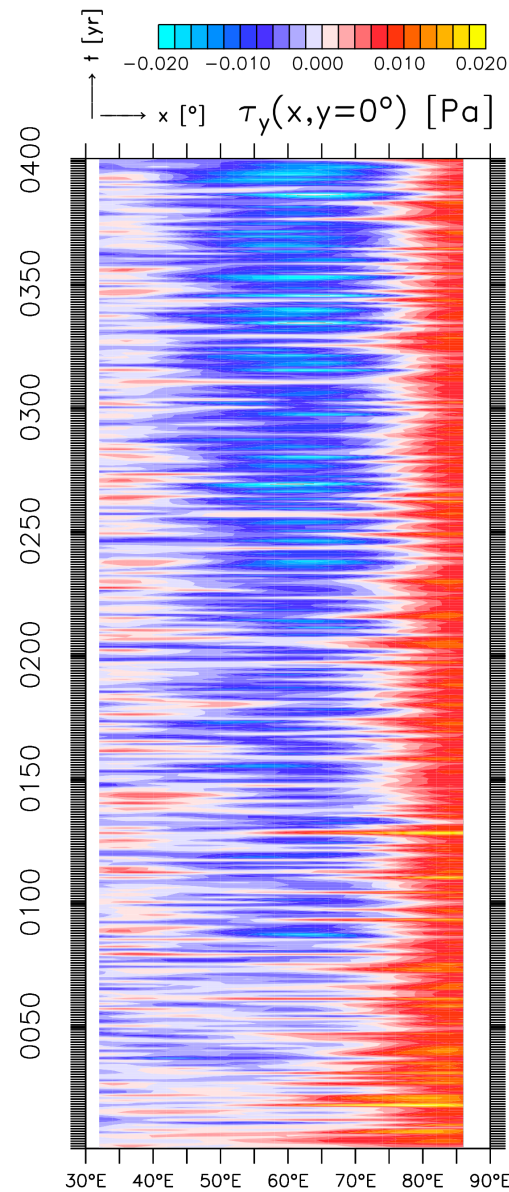
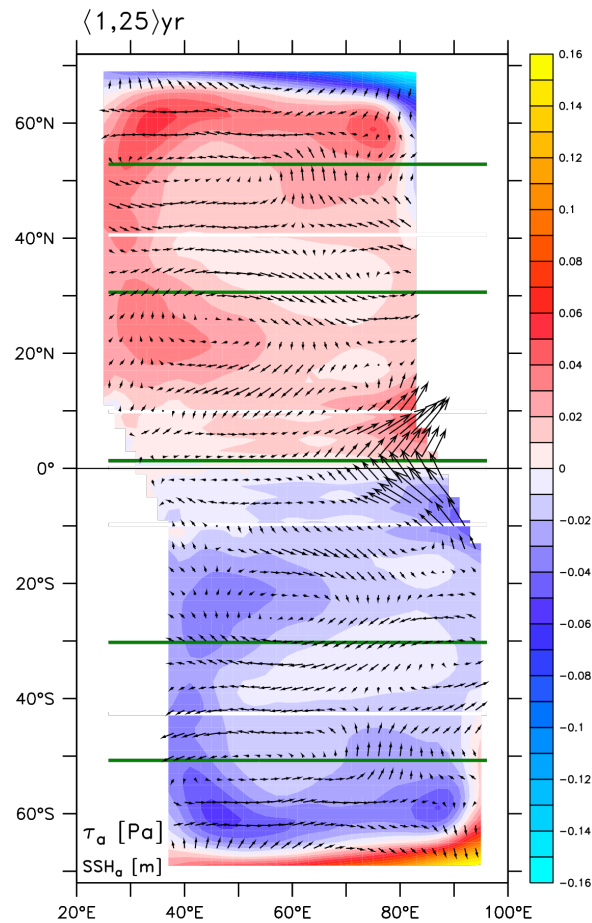


Localized meridional asymmetry in tropics (e.g. slanted coastline in east) can induce interhemispheric asymmetry in global climate



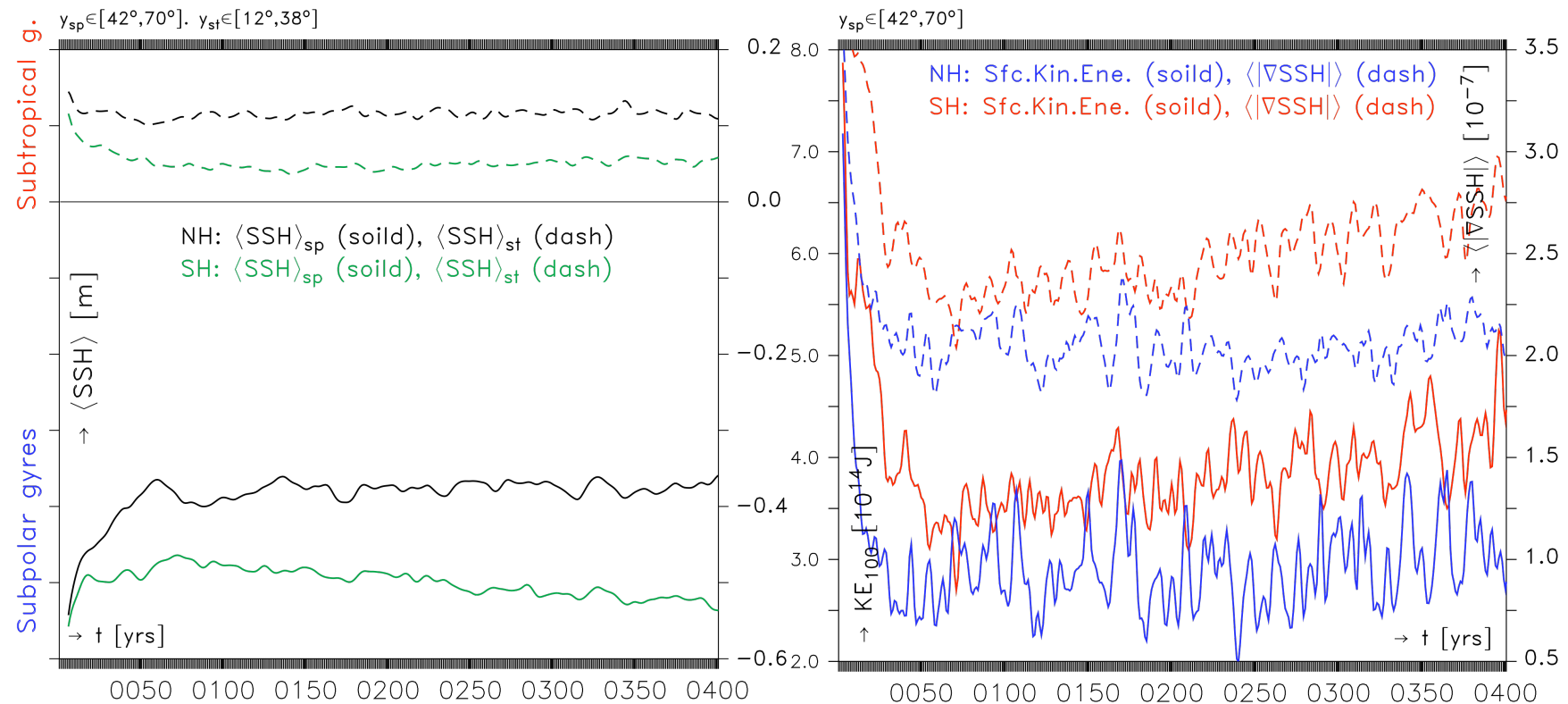
$$\begin{aligned} \text{e.g. } \eta(y) &= \eta_s(y) + \eta_a(y) \\ &= [\eta(y) + \eta(-y)]/2 \\ &\quad + [\eta(y) - \eta(-y)]/2 \end{aligned}$$

$$\begin{aligned} \eta_s(-y) &= \eta_s(y); \quad \eta_a(-y) = -\eta_a(y) \\ \text{SYMMETRIC} \quad & \text{ANTISYMMETRIC} \end{aligned}$$

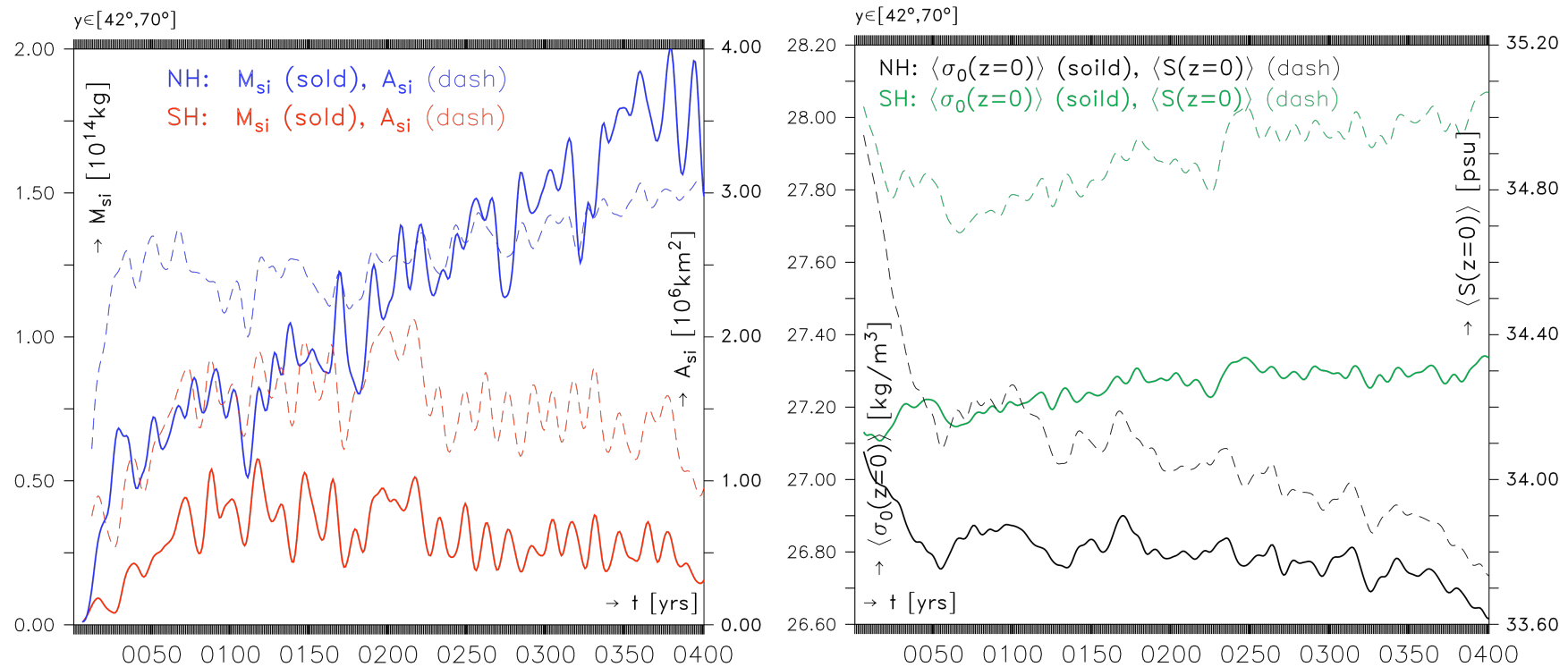


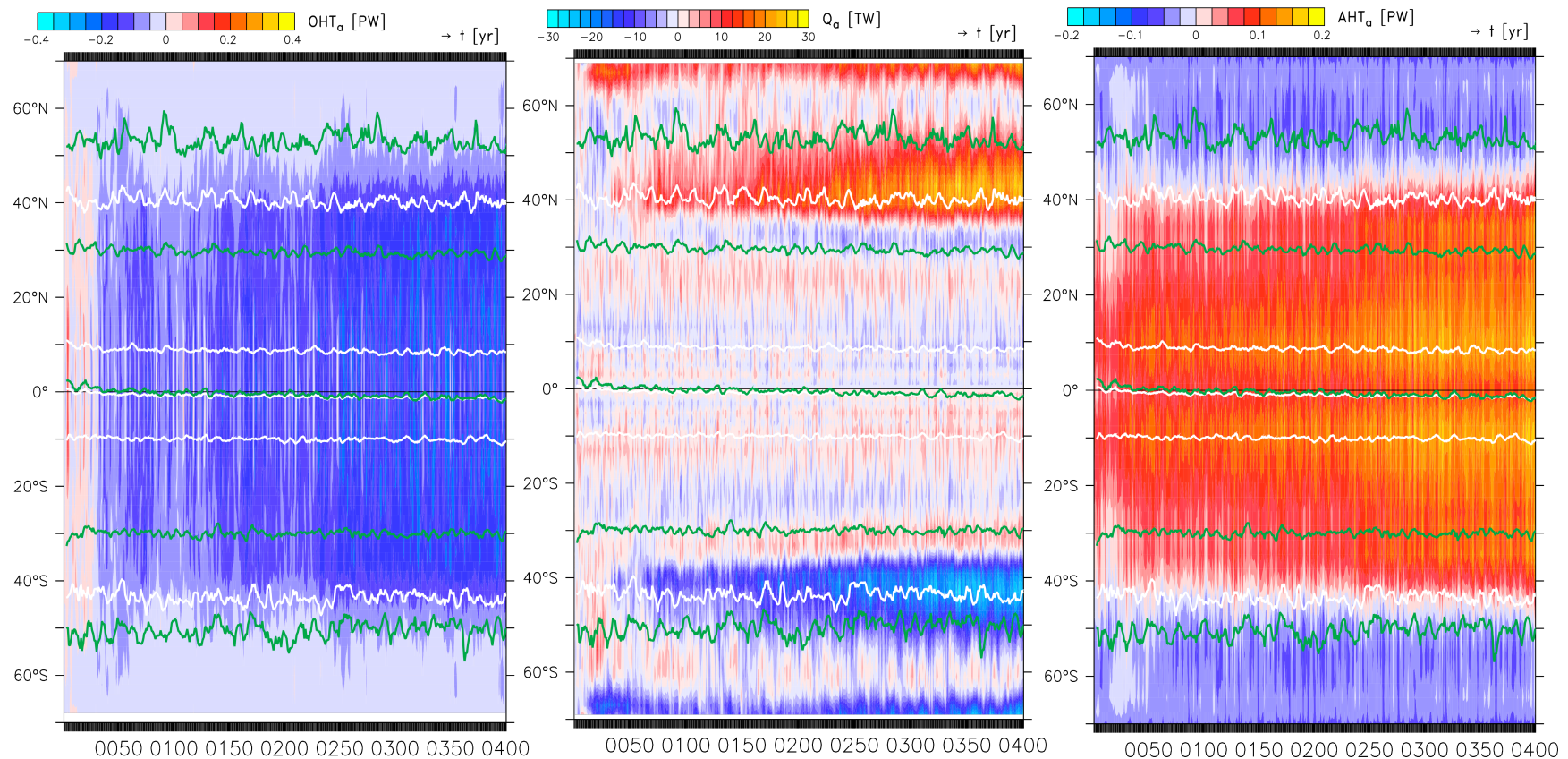
In tropics anomalous southerly wind along eastern boundary persists.

- ⇒ initiates poleward +/- Kelvin coastal waves in NH/SH
- ⇒ emit westward +/- Rossby waves in NH/SH basin interior
- ⇒ \uparrow / \downarrow SSH in NH/SH, and $\downarrow / \uparrow |\nabla \text{SSH}|$ in NH/SH subpolar gyre
- ⇒ decrease/increases surface U and KE of NH/SH subpolar gyre



- ⇒ ocean stress on sea ice is weaker/stronger in NH/SH
- ⇒ sea-ice area and mass are bigger/smaller in NH/SH
- ⇒ surface salinity and density are smaller/bigger in NH/SH
- subpolar gyre ⇒ deep water production decreases/increases in NH/SH ⇒ anomalous southward ocean heat transport





Anomalous Ocean
Heat Transport

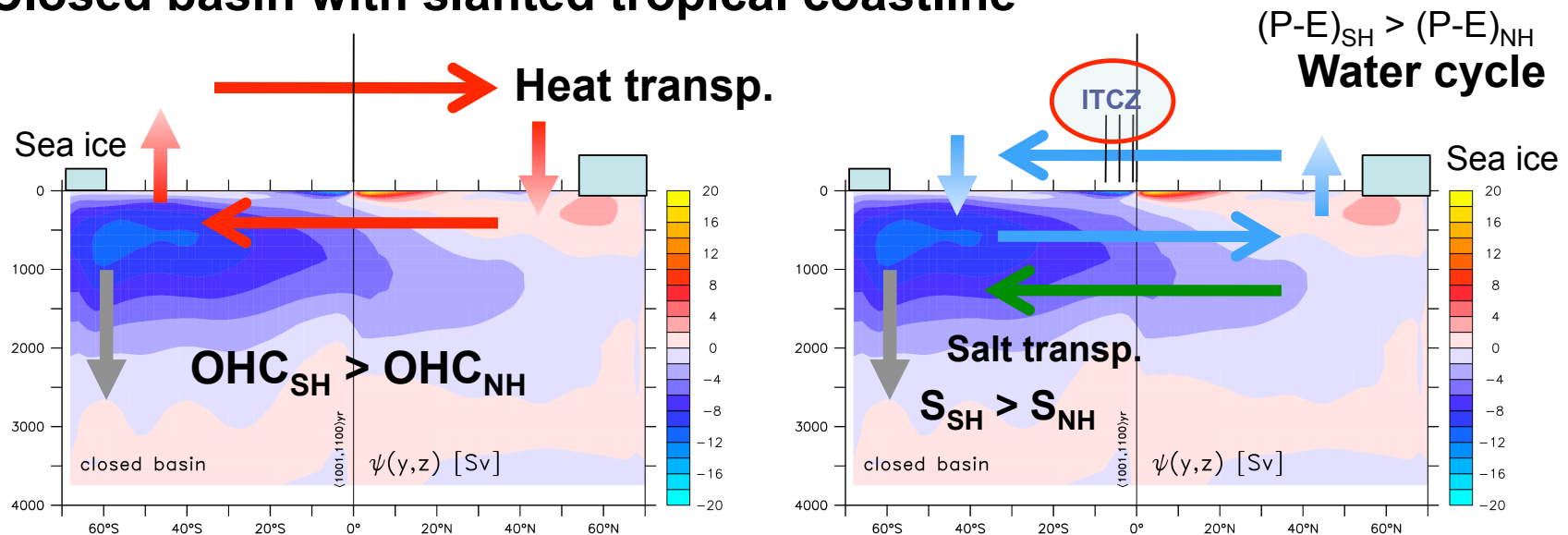
Anomalous ($\int dx$)
Surface Heat Flux

Anomalous Atmos.
Heat Transport

⇒ ocean heat content is smaller/bigger in the NH/SH

⇒ anom. southward salt/freshwater transport in ocean/atmos.

Closed basin with slanted tropical coastline



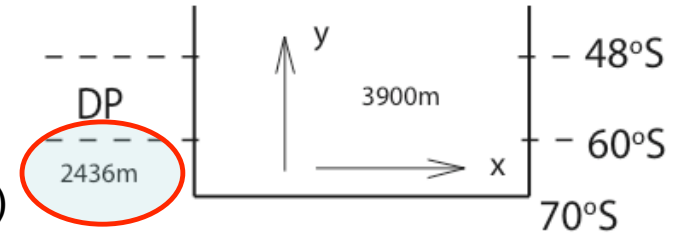
- Tropical geometric asymmetry (westward slanted coastline)
 \Rightarrow poleward perturbations via atmospheric (fast) and oceanic (slow, prevails) pathways \Rightarrow climate interhemispheric asymmetry

Δ deep water formation \Rightarrow gradual Δ mode water formation that is associated with the key part of surface heat flux anomaly

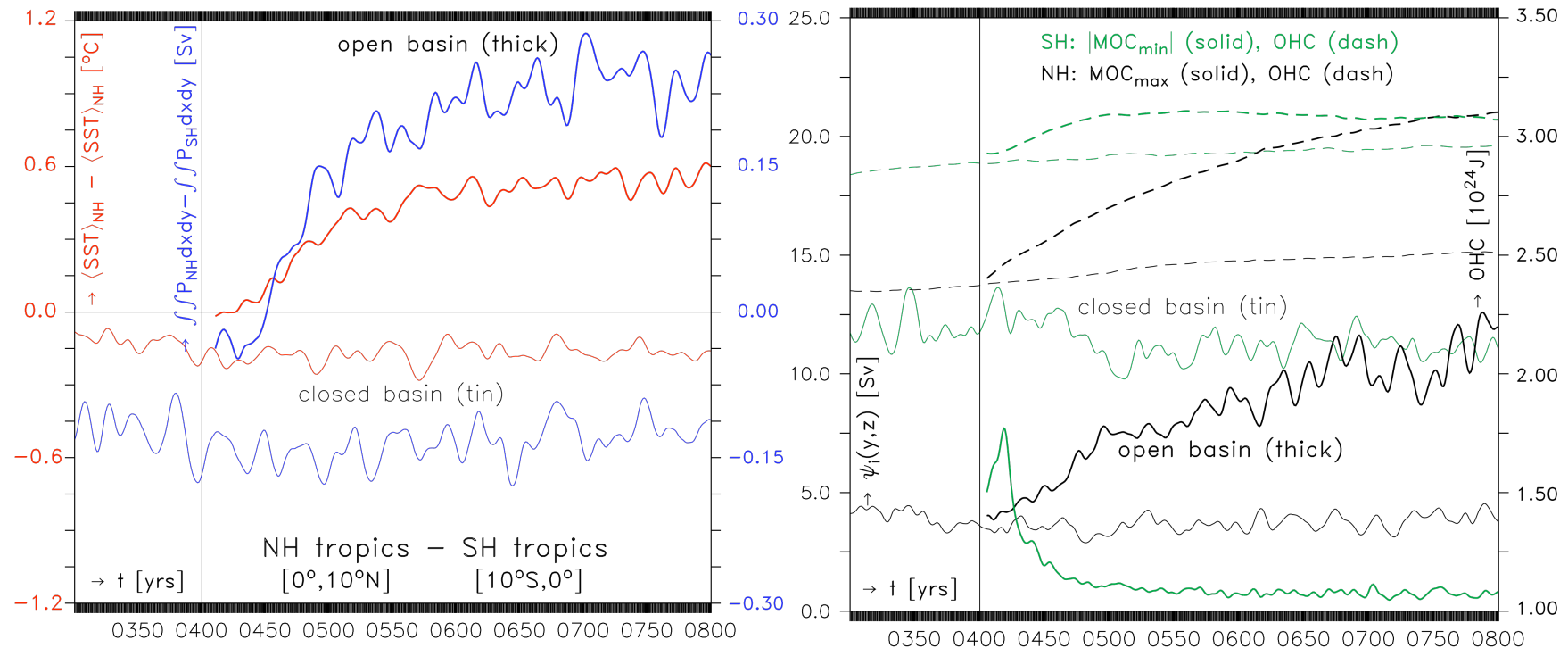
- Anomalous northward AHT across equator leads to southward shift of Hadley cells and ITCZ

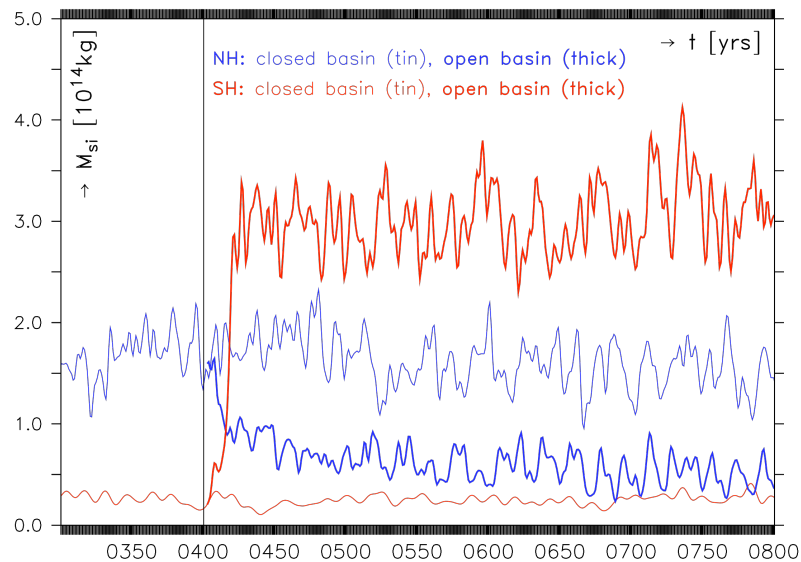
Open basin

(sudden opening of an idealized Drake Passage)



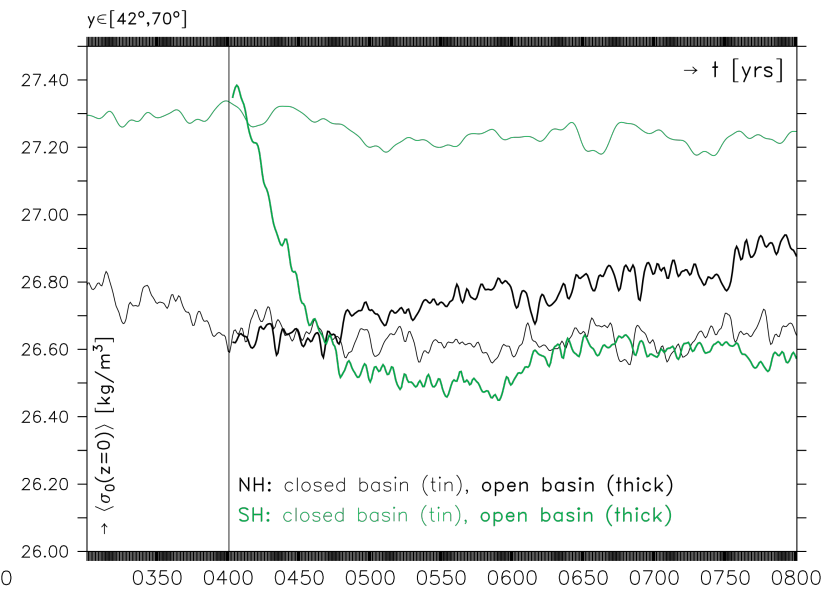
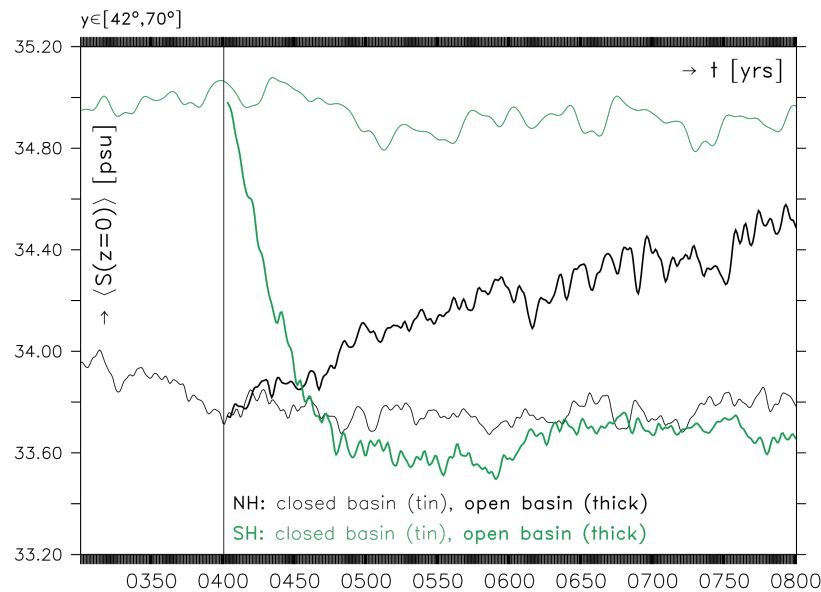
Subpolar circumpolar channel in MOC dominant hemisphere can reverse global climate interhemispheric asymmetry

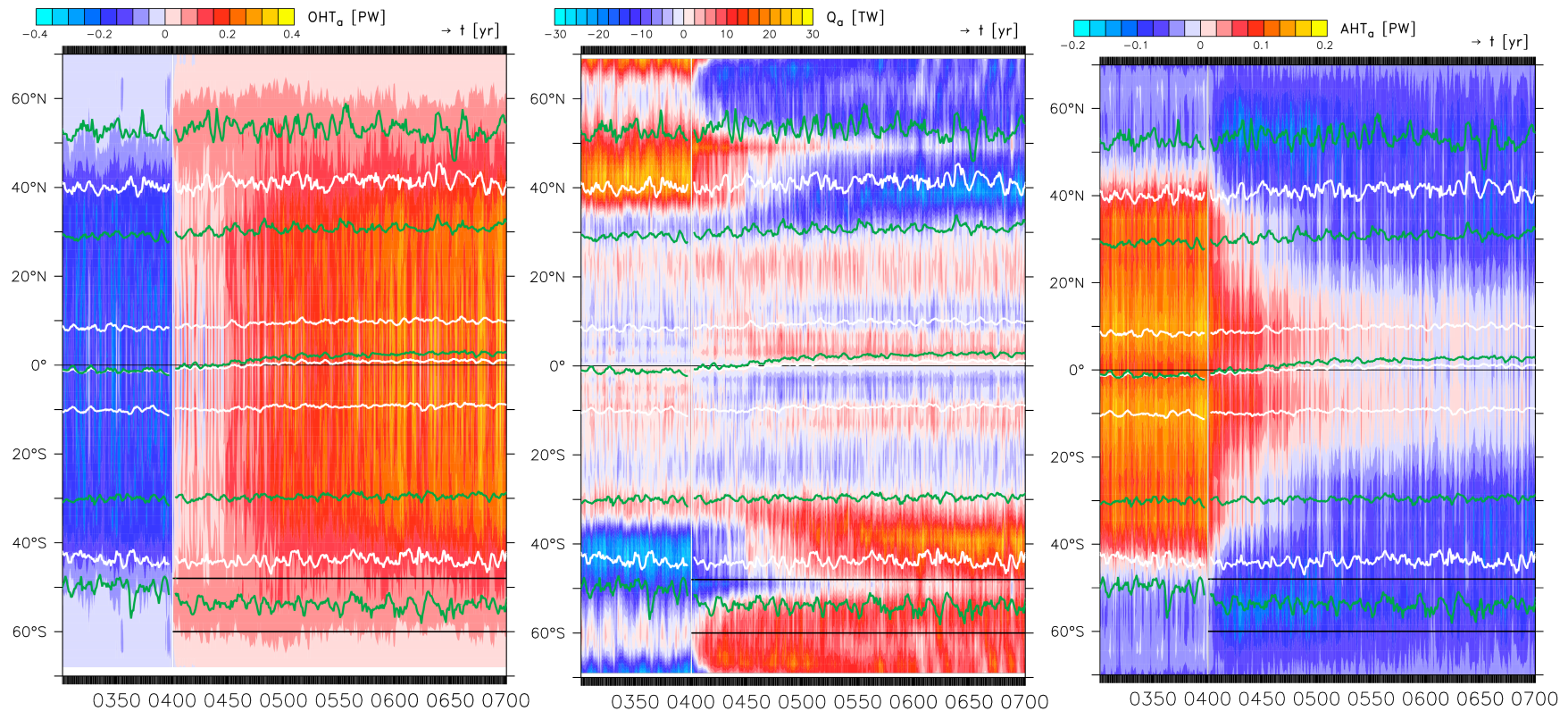




Sudden opening of Drake Passage:

- ⇒ w_{Ek} can bring deep cold water to surface and circumpolar current reduces MLD and southward OHT
- ⇒ SH sea ice grows
- ⇒ SH surface salinity and density decrease ⇒ SH MOC decreases





Anomalous Ocean
Heat Transport

Anomalous ($\int dx$)
Surface Heat Flux

Anomalous Atmos.
Heat Transport

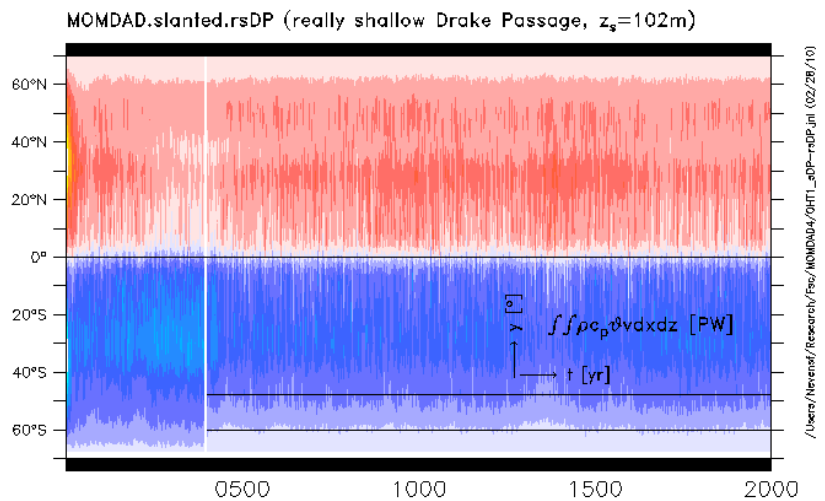
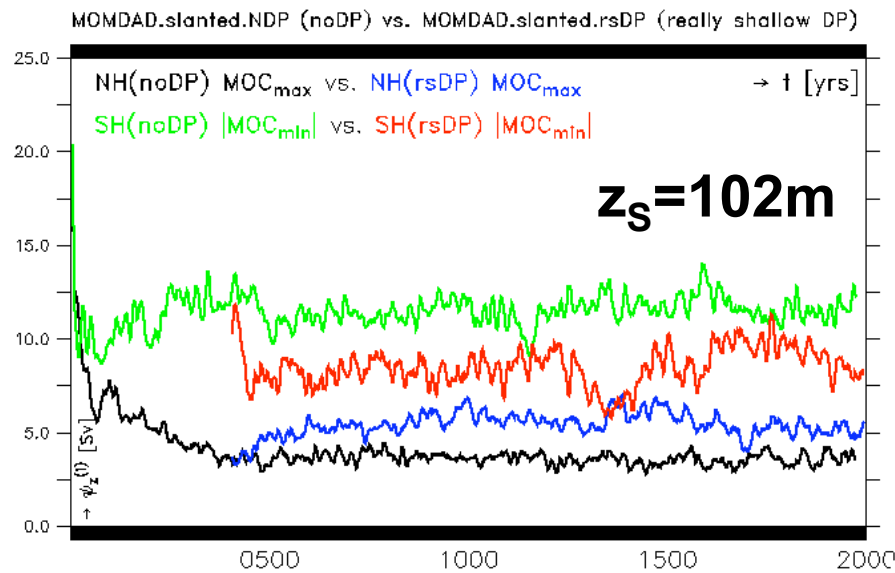
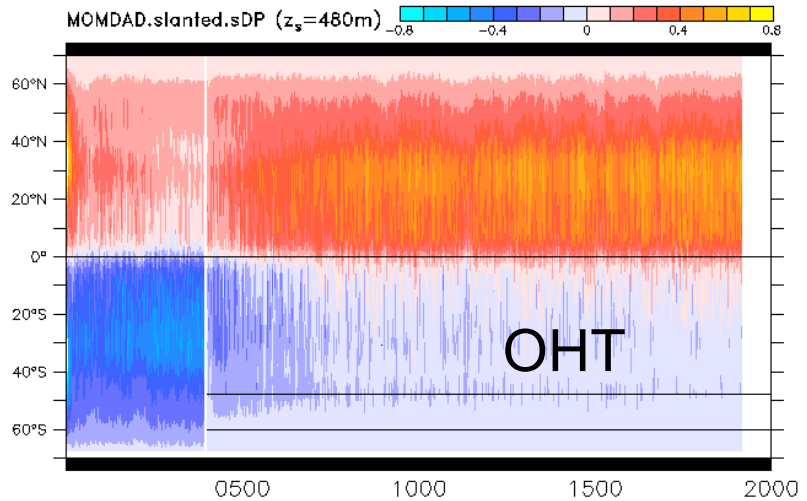
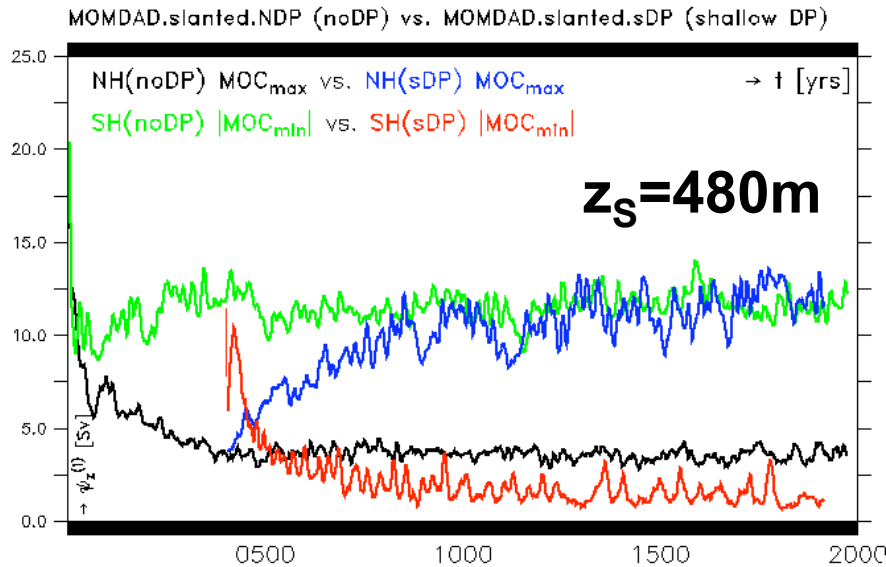
⇒ NH ocean heat content is increasing

$z_s=2436\text{m}$

⇒ anom. northward salt/freshwater transport in ocean/atmos.

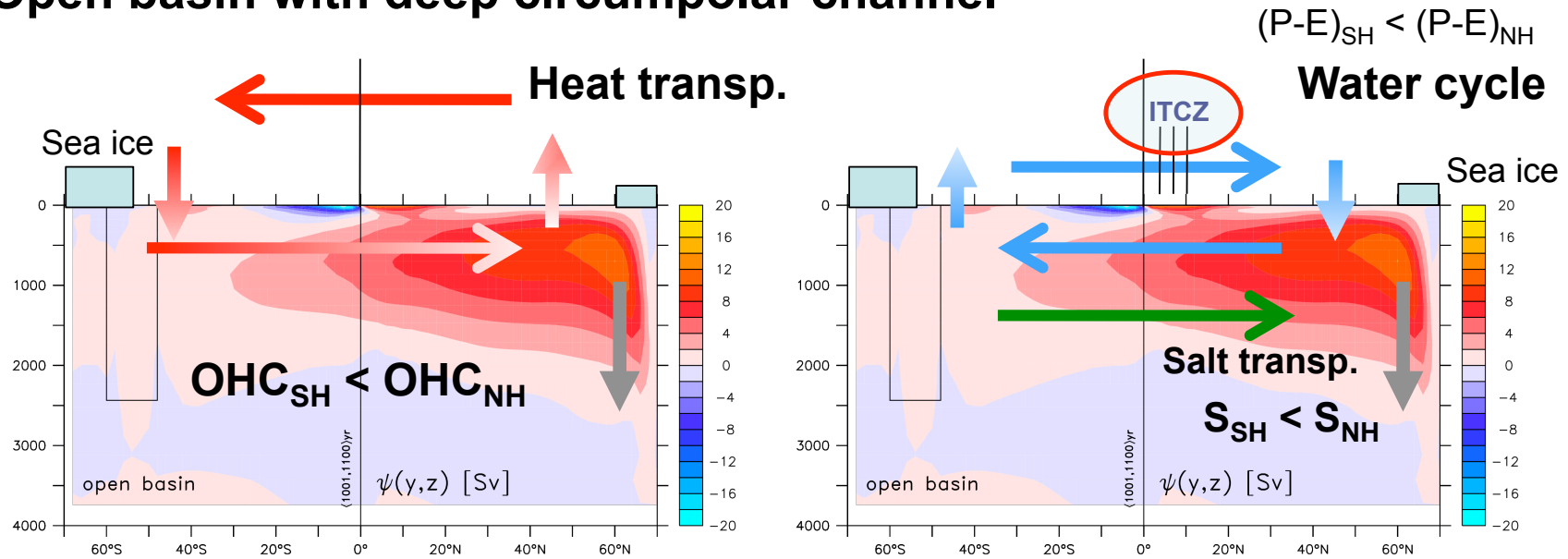
Δ deep water export leads Δ mode water

DP still deep enough to reverse interhemispheric asymmetry

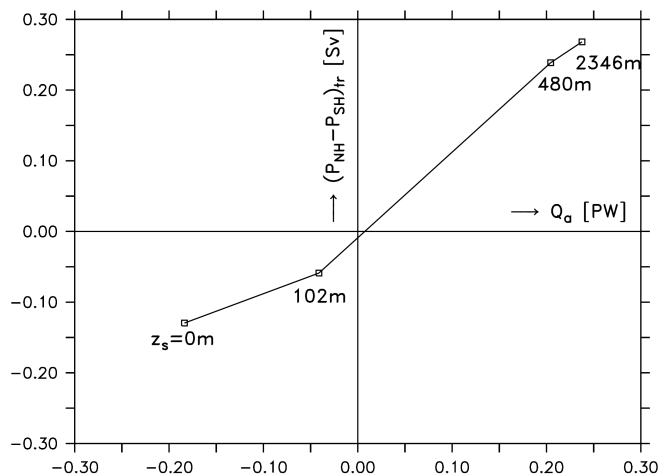


DP not deep enough to reverse asymmetry

Open basin with deep circumpolar channel



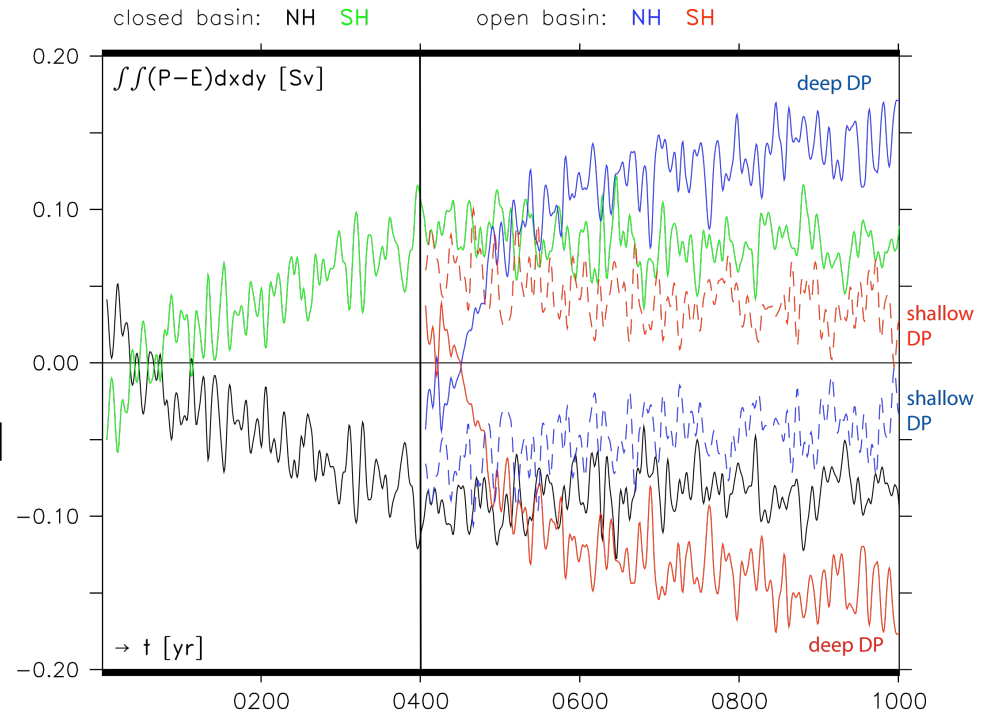
- Opening of a sufficiently deep subpolar circumpolar channel (SH)
 \Rightarrow modifies tropical circulation and ITCZ (shifts to the NH)



- Magnitude and sign of extratropical surface flux anomalies Q_a depend on depth of a circumpolar channel in MOC dominant hemisphere \Rightarrow tropical atmos. respond to change in anomalous AHT across the equator controlled by Q_a

Conclusions

- Specific geometric/tectonic interhemispheric asymmetries in tropics (slanted coastline → **ITCZ in SH**) and extratropics (circumpolar channel → **ITCZ in NH**) can cause climate asymmetries



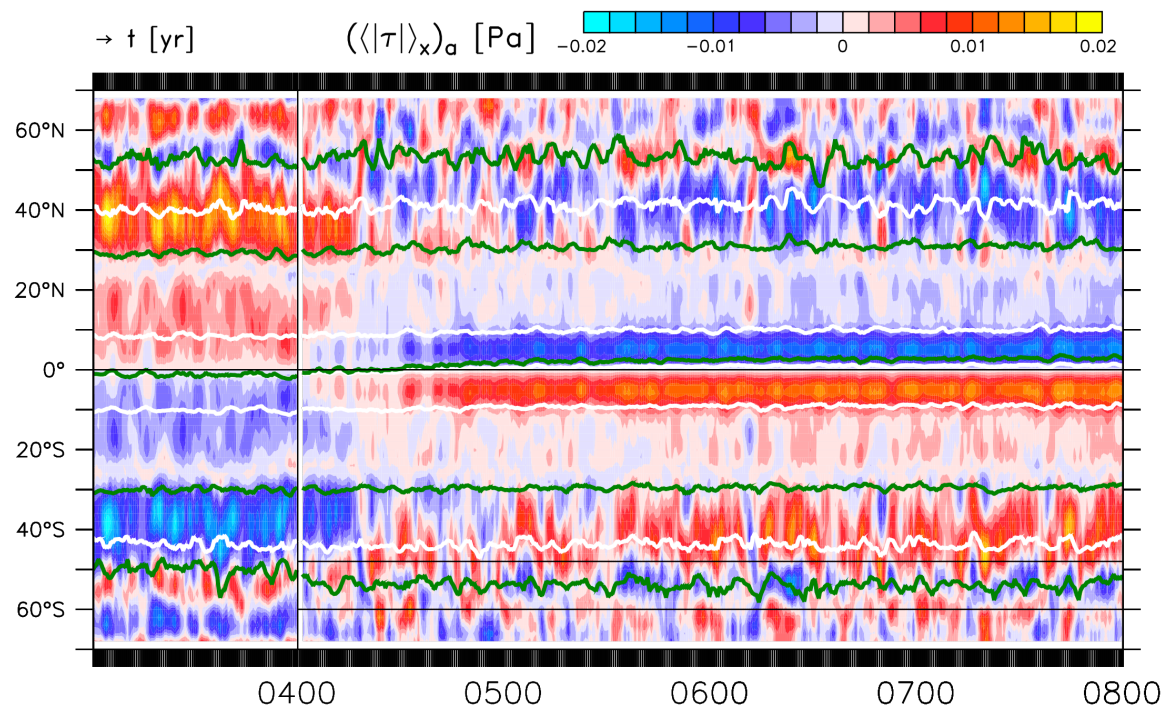
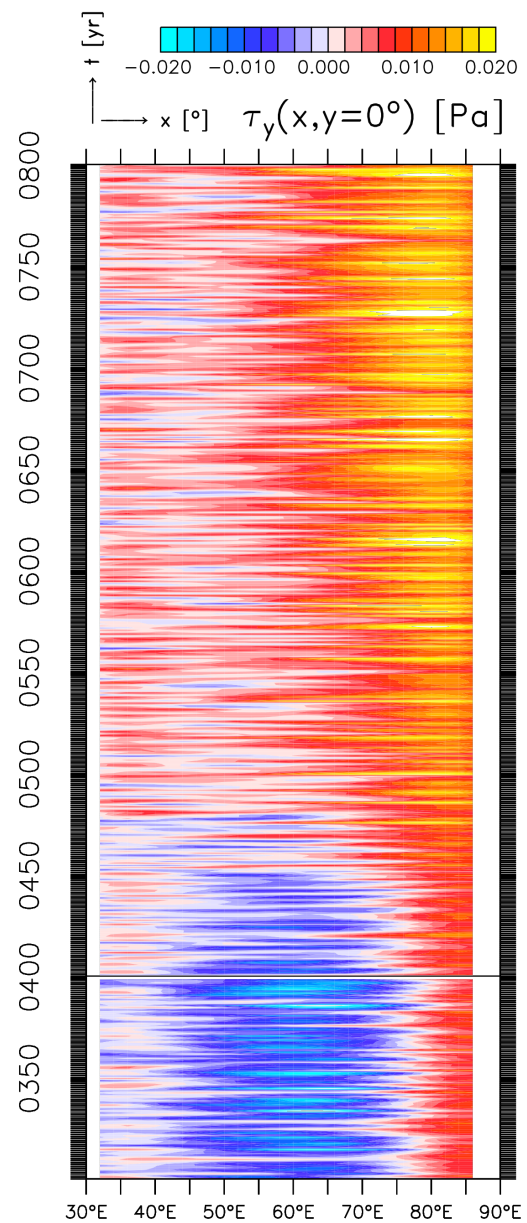
- Tropical-extratropical interaction via atmospheric and oceanic pathways is intertwined with interhemispheric interaction
- Interhemispheric sea-ice difference, influenced by the ocean circulation, can be important element for generation of global and tropical asymmetries in coupled system
- Tectonically induced asymmetries in deep MOC, mode water formation and OHT can substantially influence position of ITCZ

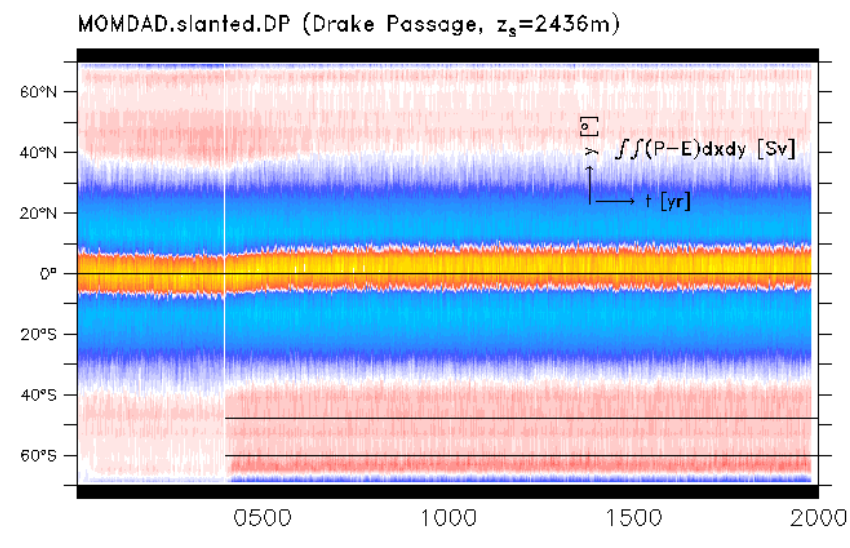
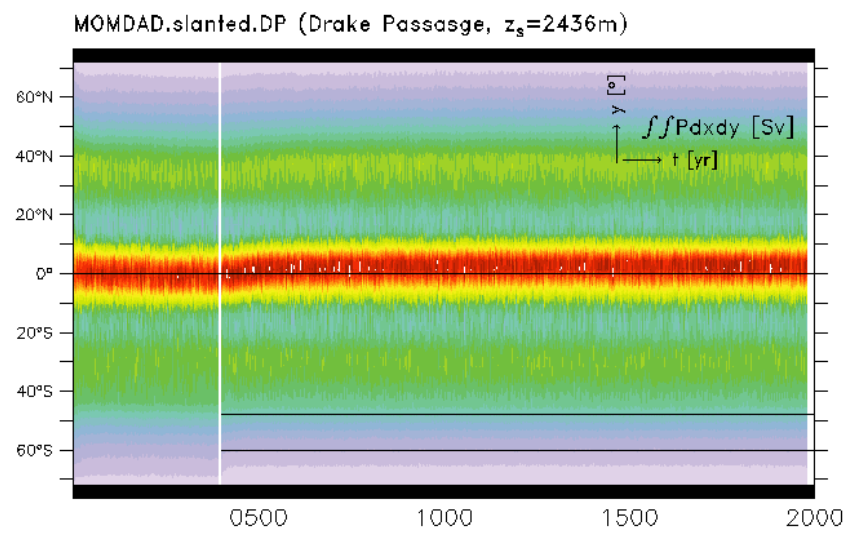
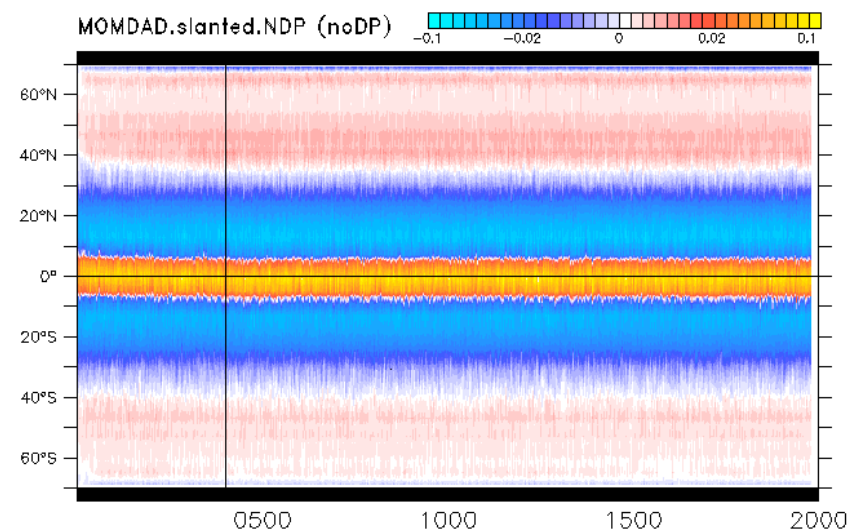
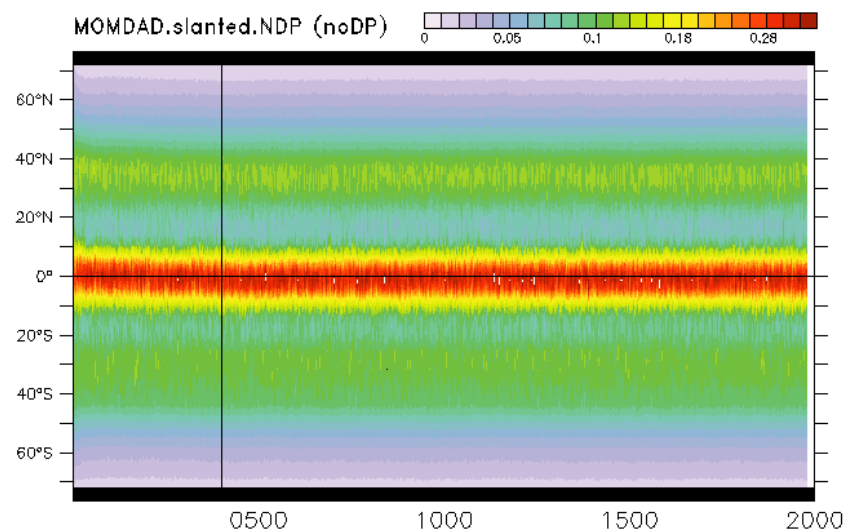


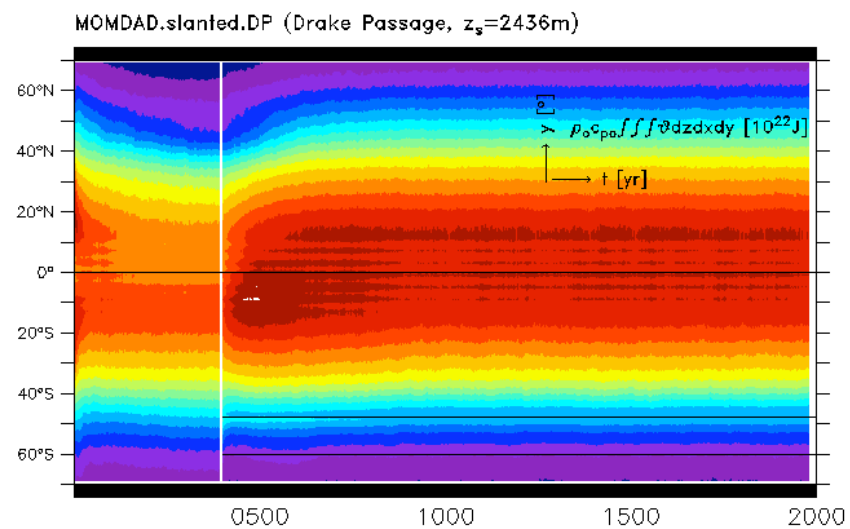
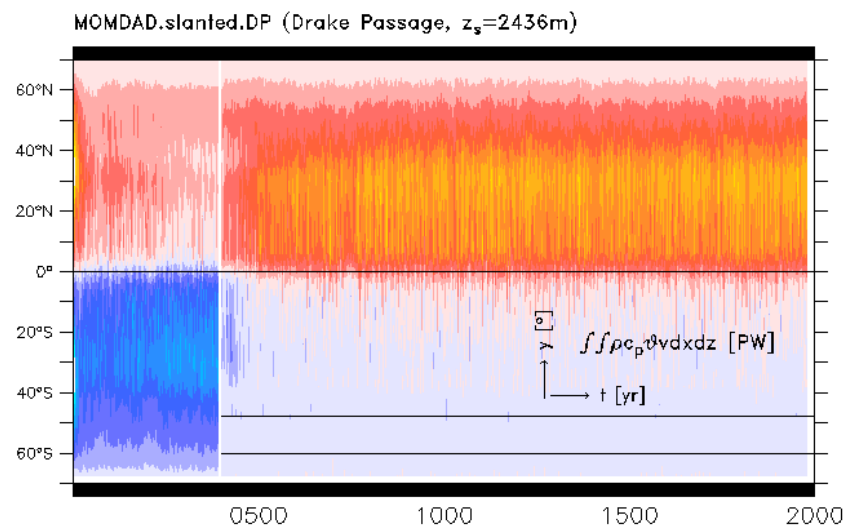
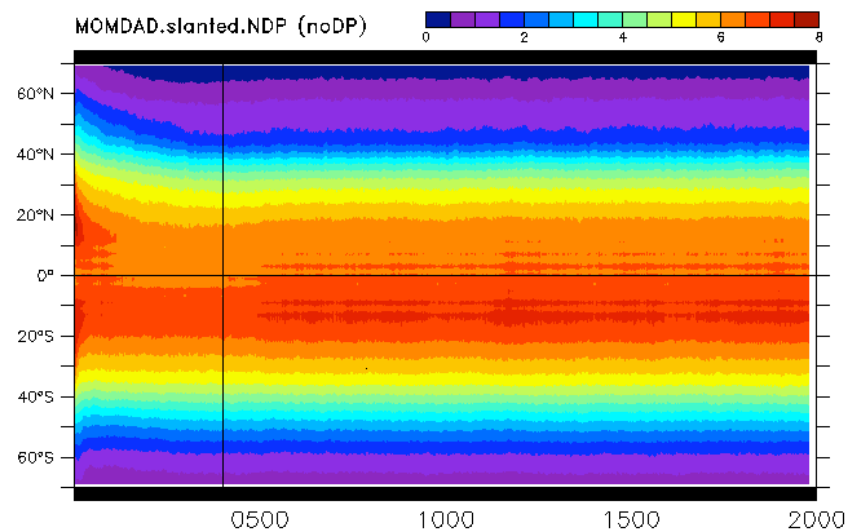
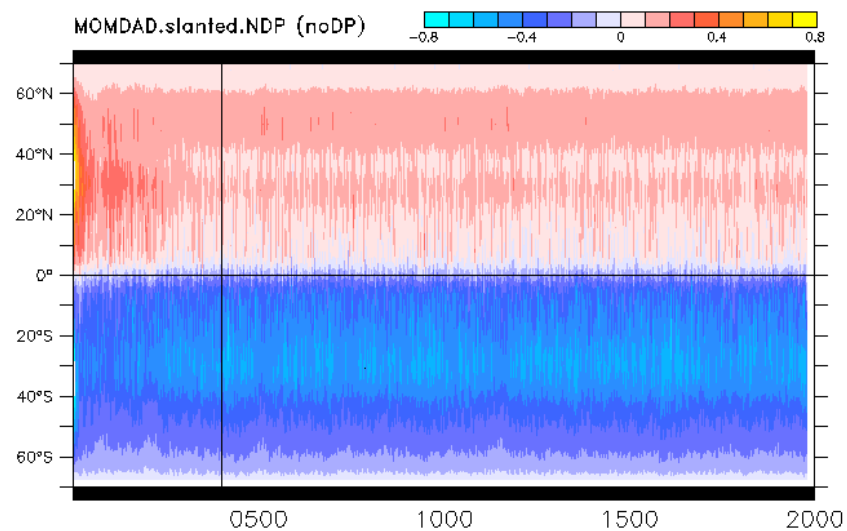
Mahalo

To follow: two-basin configuration, clouds, ...

stay tuned for more results ...







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