Interhemispheric Asymmetry in Global Warming

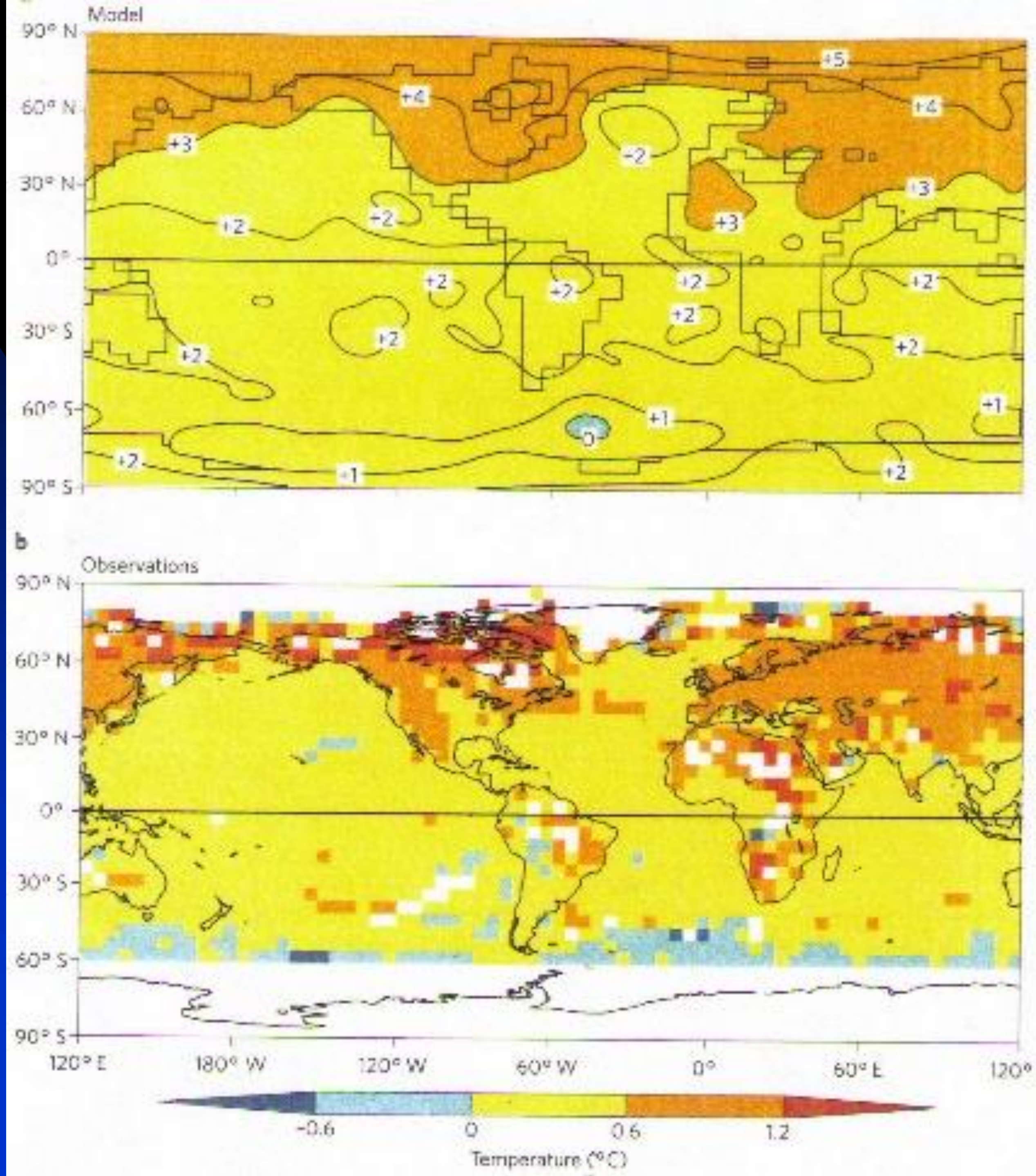
Stouffer, Manabe, and Bryan, Nature, 1989

Manabe et al., J. Climate, 1991, 1992

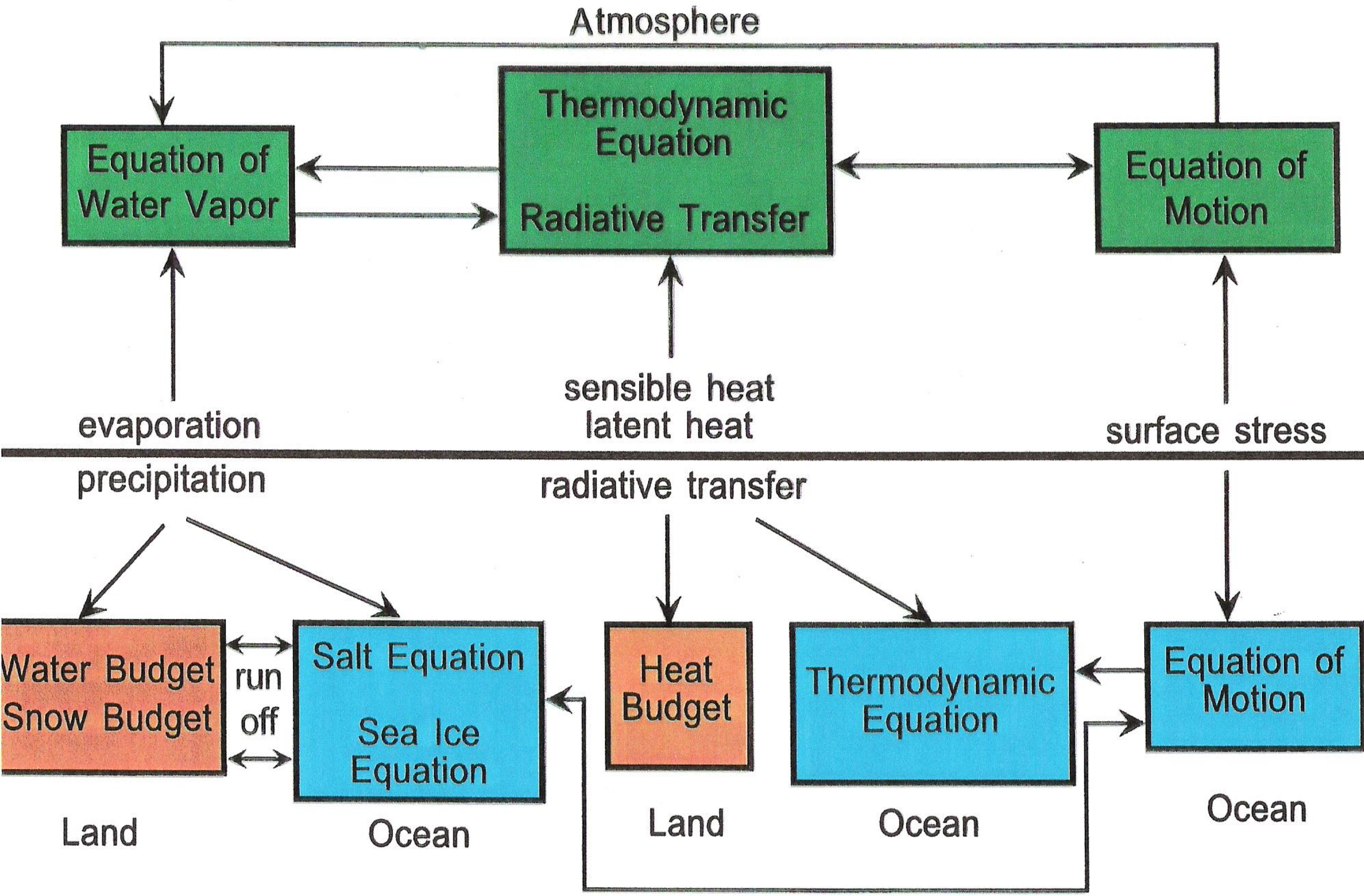
Stouffer & Manabe, Nature Climate Change, 2017

Simulated

Observed



Coupled Ocean-Atmosphere-Land Model



Coupled Atmosphere-Ocean-Land Model

with Simple Parameterizations
& Low Resolution

Atmospheric Component

- Spectral Transform GCM
- Moist Convective Adjustment

Oceanic Component

- Finite Difference GCM
- Simple Sea Ice Model

Land Component

- Bucket Model

*To initialize the coupled model, Flux Adjustment Method is used.

Initialization and time integration of the coupled model

- Time integration of the atmospheric component with realistic distribution of SST and sea ice

  →I = Interfacial fluxes of heat and water

- Time integration of the oceanic component with realistic distributions of SST, SSS and sea ice

  →II = Interfacial fluxes of heat and water

- Time integration of the coupled model with flux adjustment at the ocean-atmosphere interface

  Adjustment = II -I

Flux Adjustment

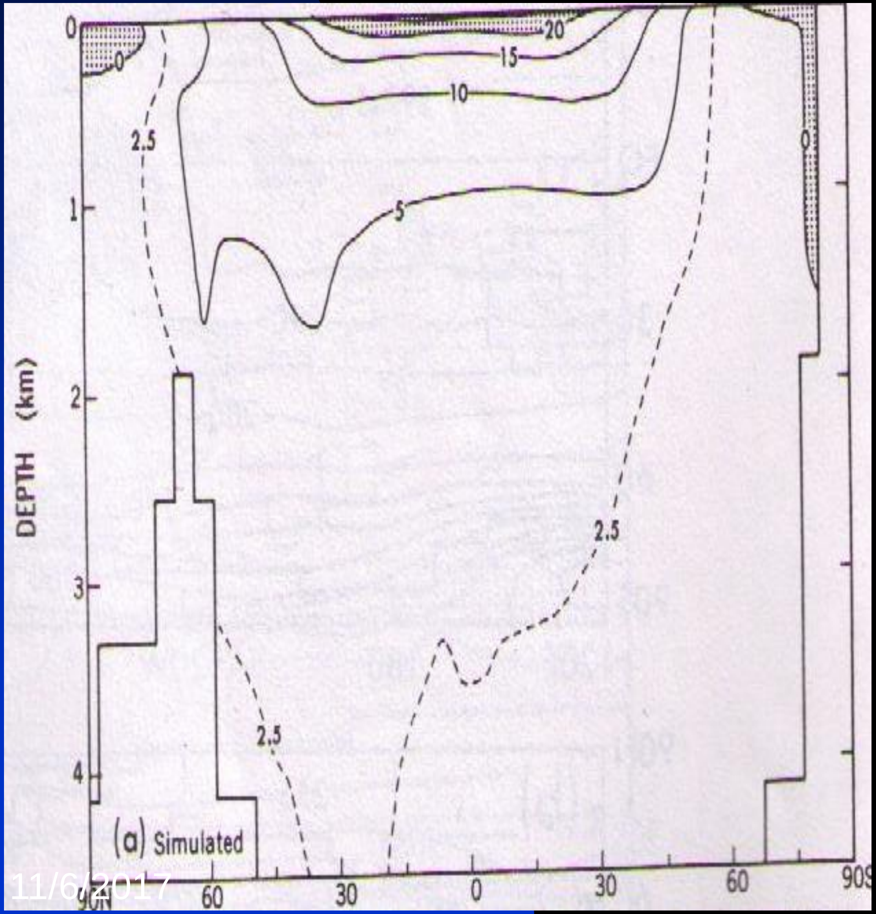
Owing to the flux adjustment, SST, SSS and sea ice thickness fluctuate around realistic values without systematic trends in the control experiment.

Flux Adjustment prevents harmful, initial drift of climate in a time-integration of a model.

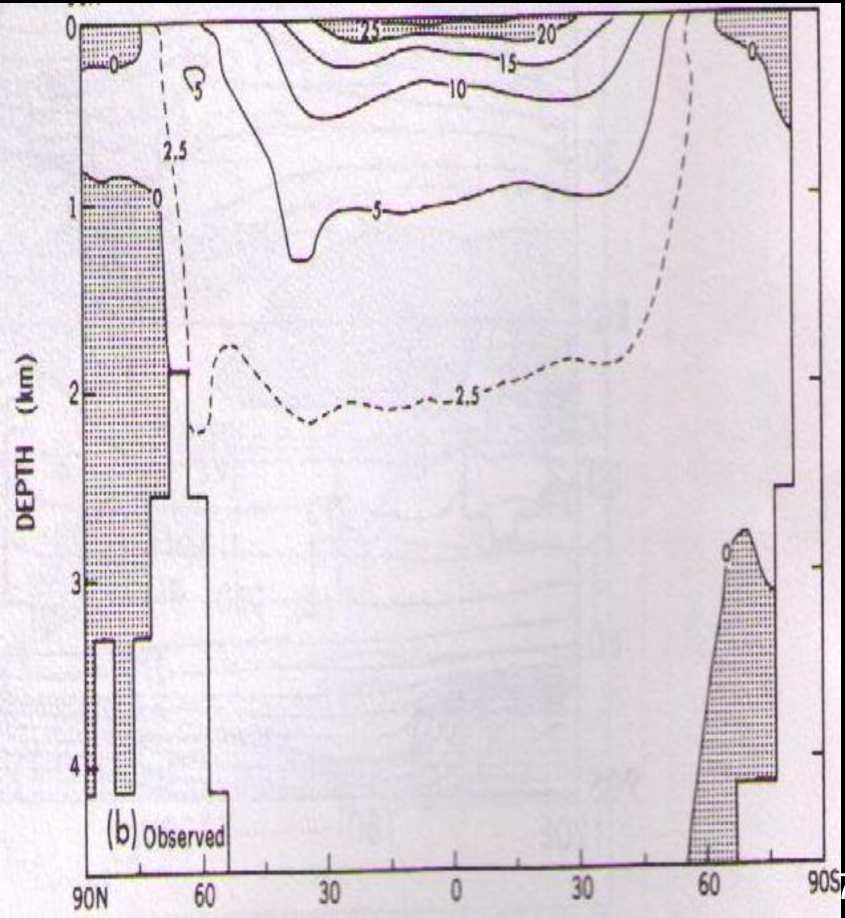
Because of realistic distributions of sea surface temperature and sea ice thickness, the model with flux adjustment is likely to have realistic sensitivity of climate.

Zonal Mean Temperature (°C)

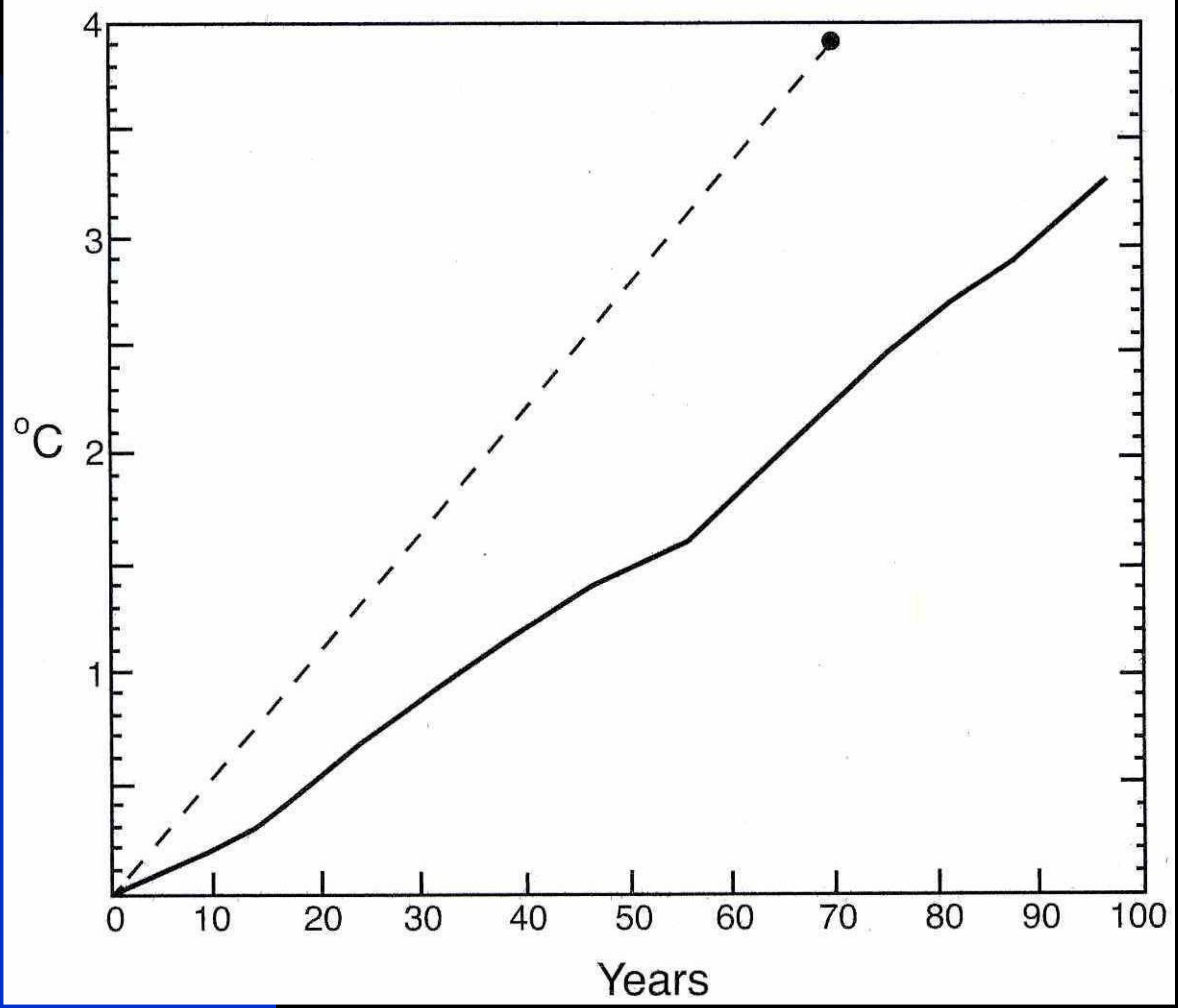
Simulated



Observed



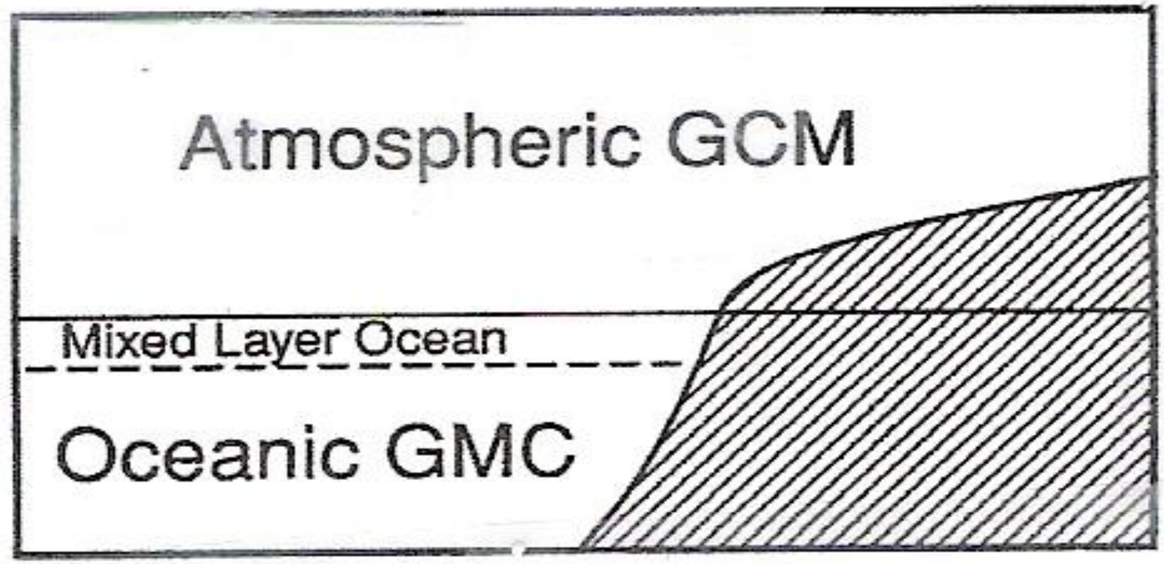
Change in Global Mean Surface Temperature (°C)



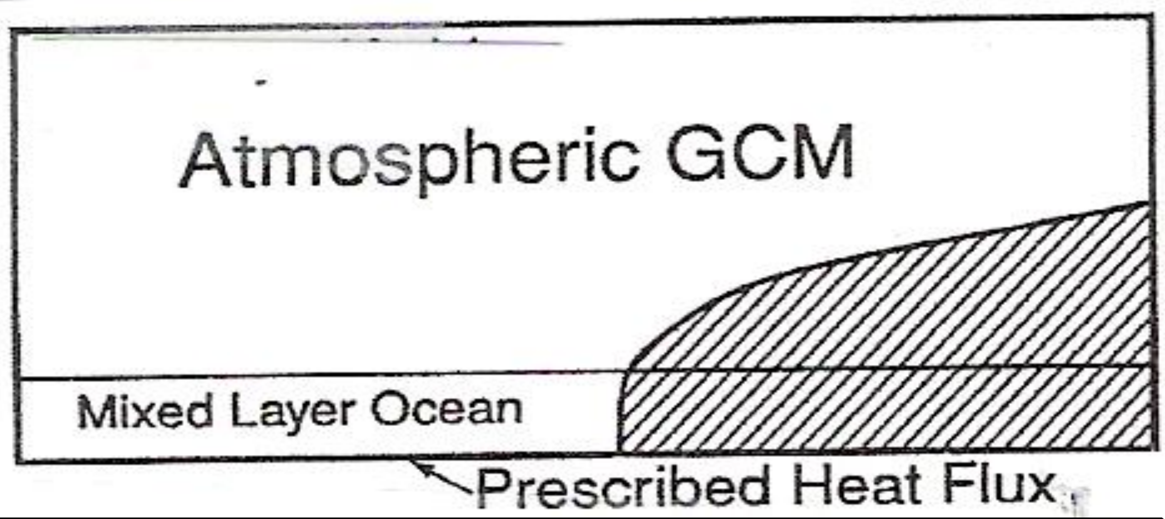
Flux Adj.→

Q-Flux→

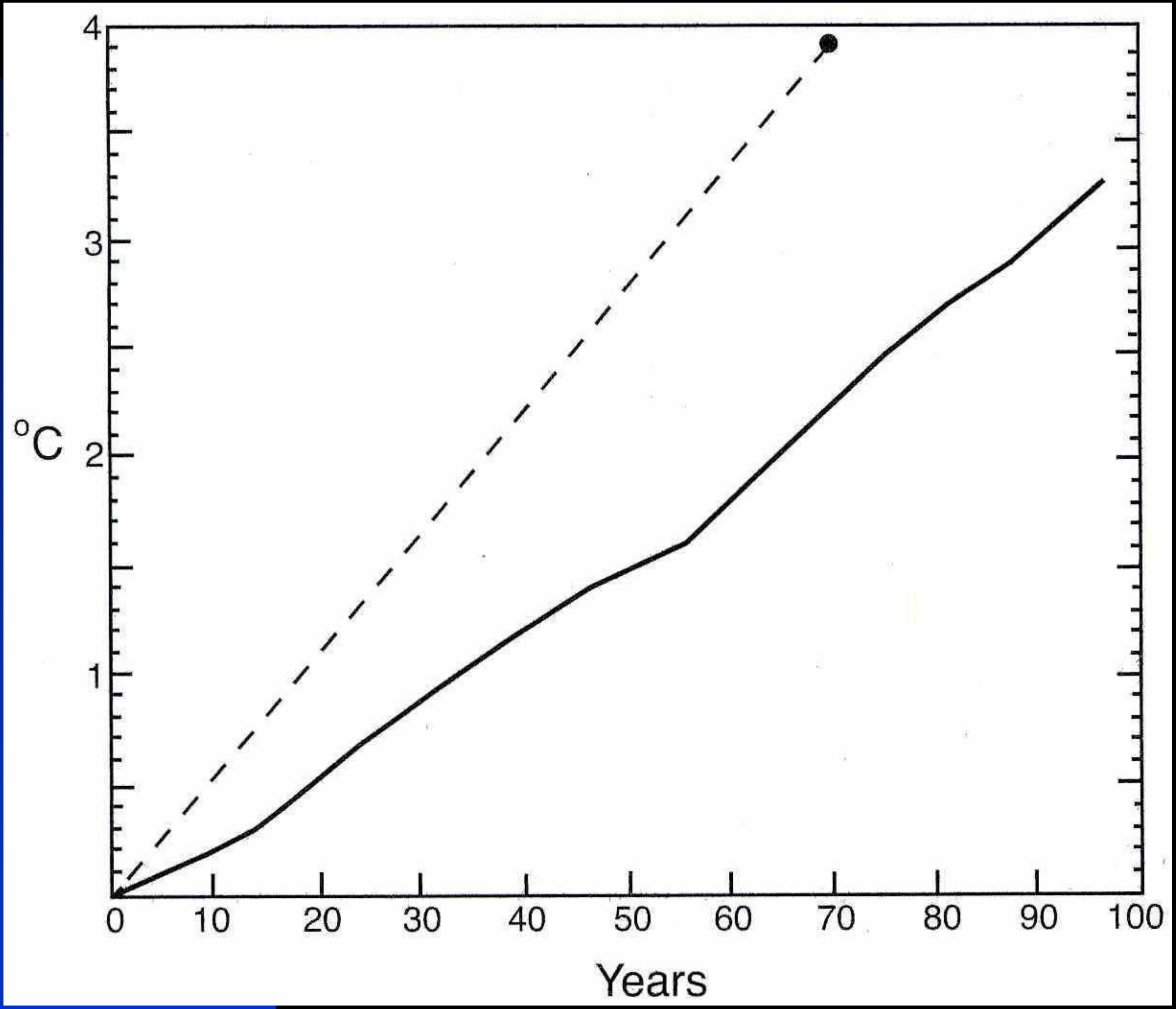
Coupled Ocean Atmosphere Model



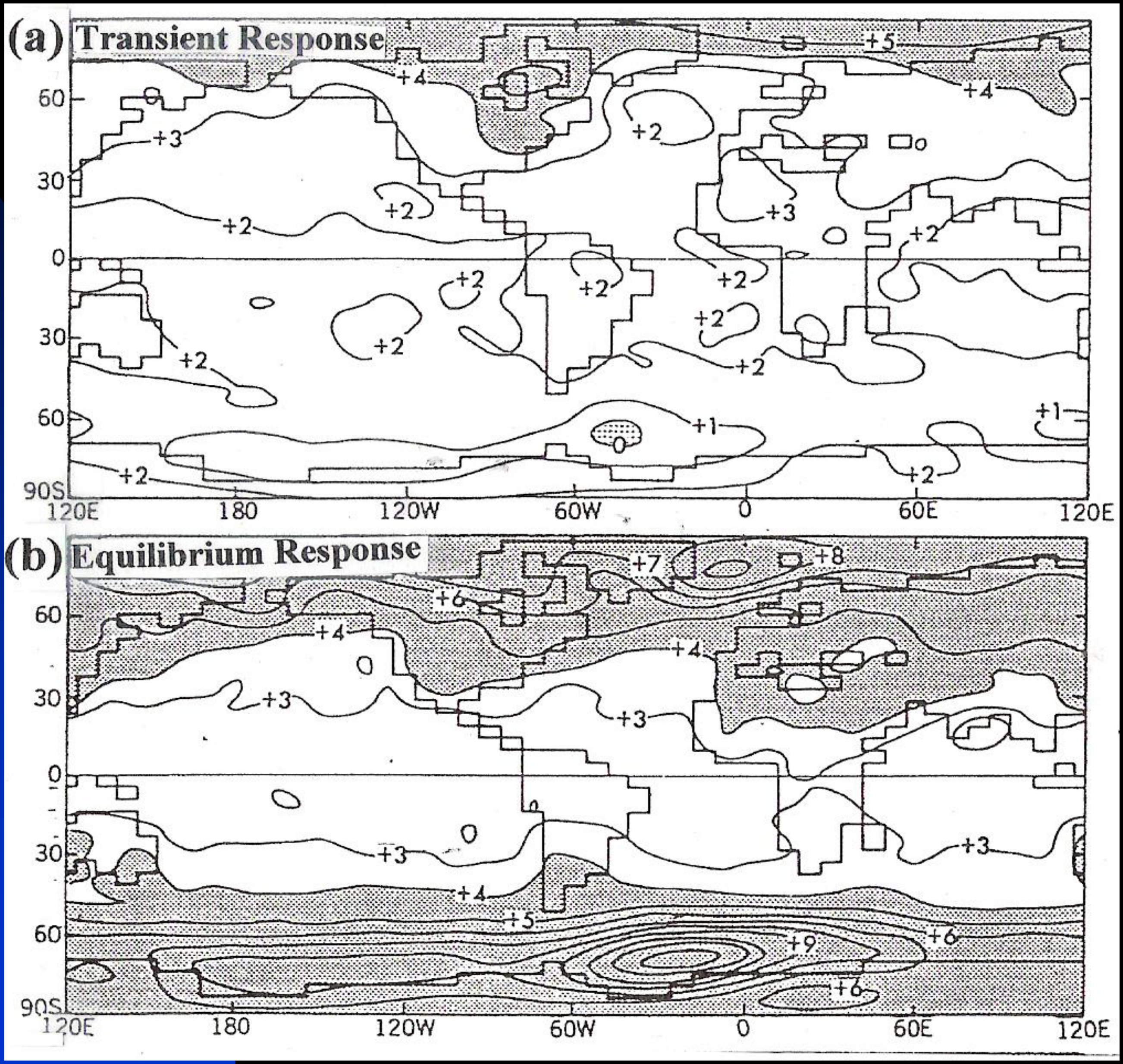
Coupled Mixed Layer Ocean Model



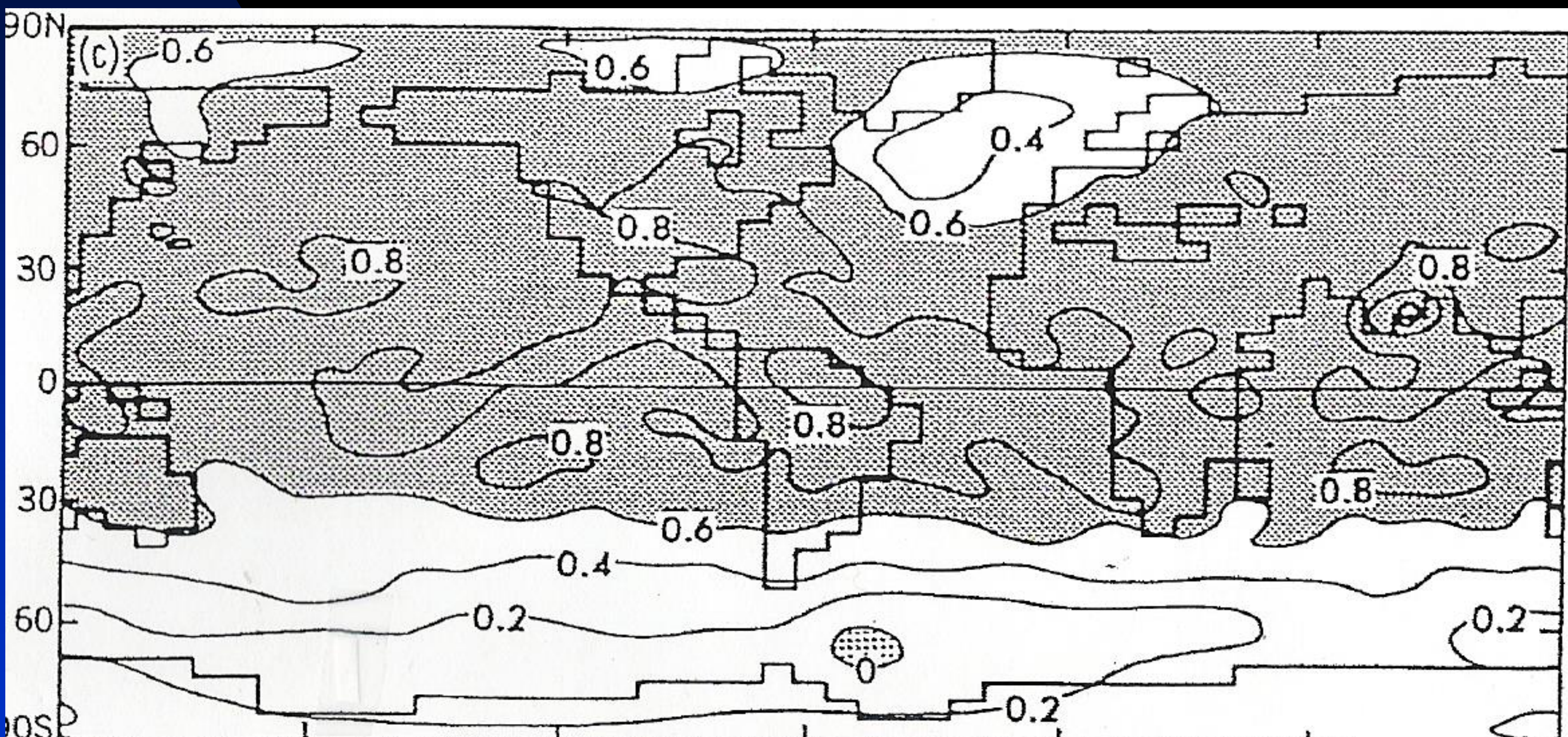
Change in Global Mean Surface Temperature (°C)



Change in Surface Air Temperature, °C

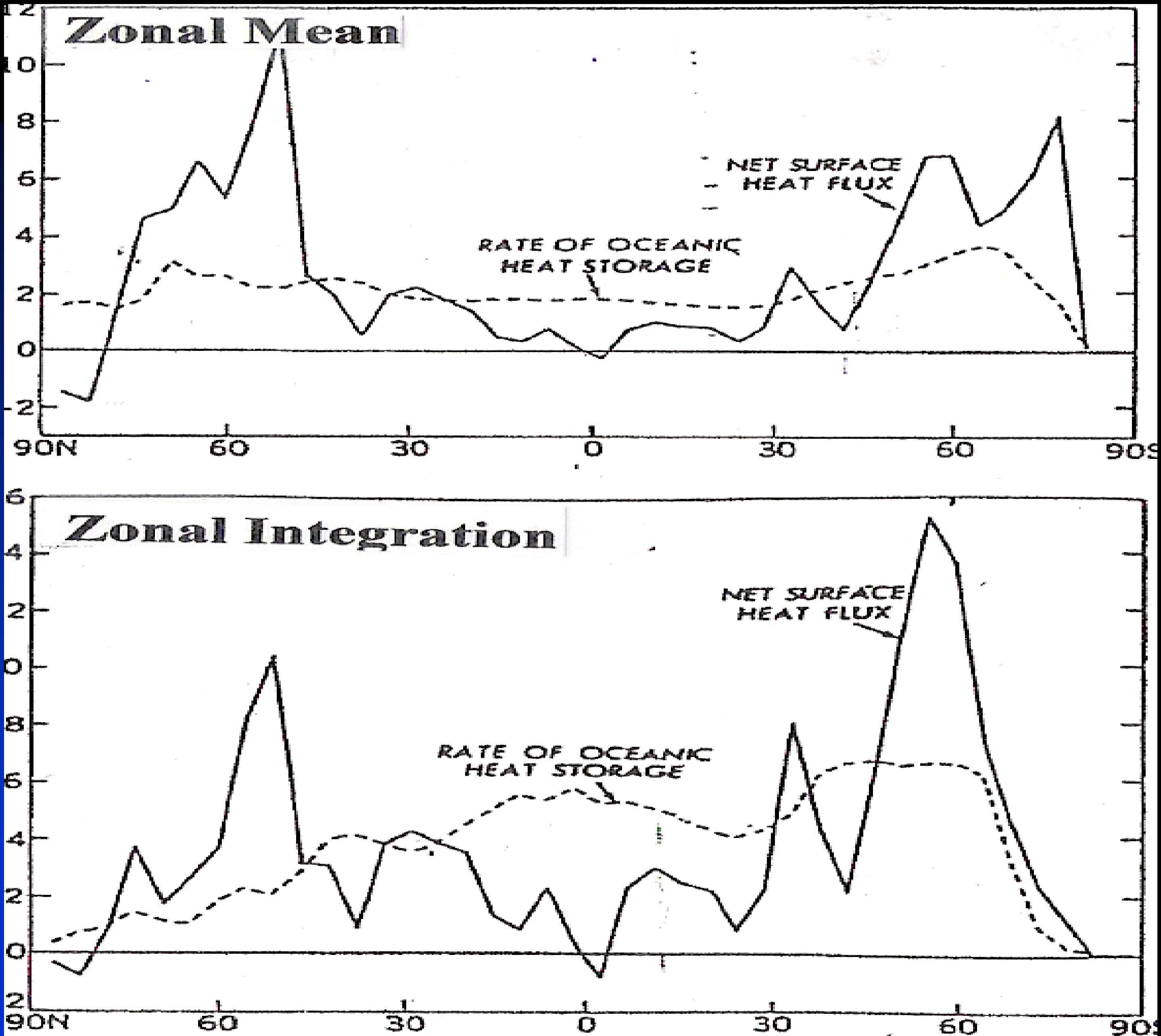


(Transient Response) / (Equilibrium Response)

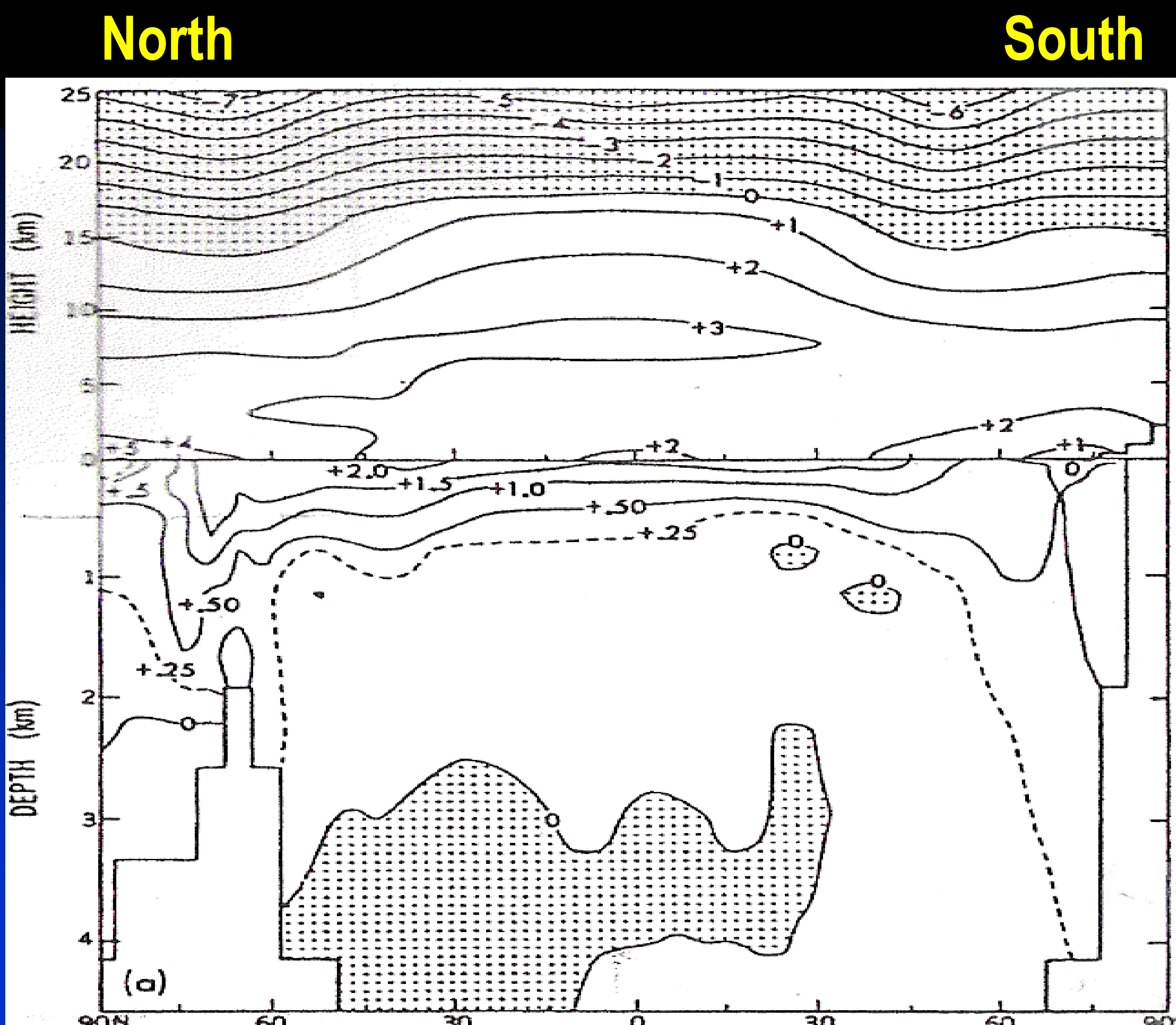


Change in the Rate of Oceanic Heat Uptake

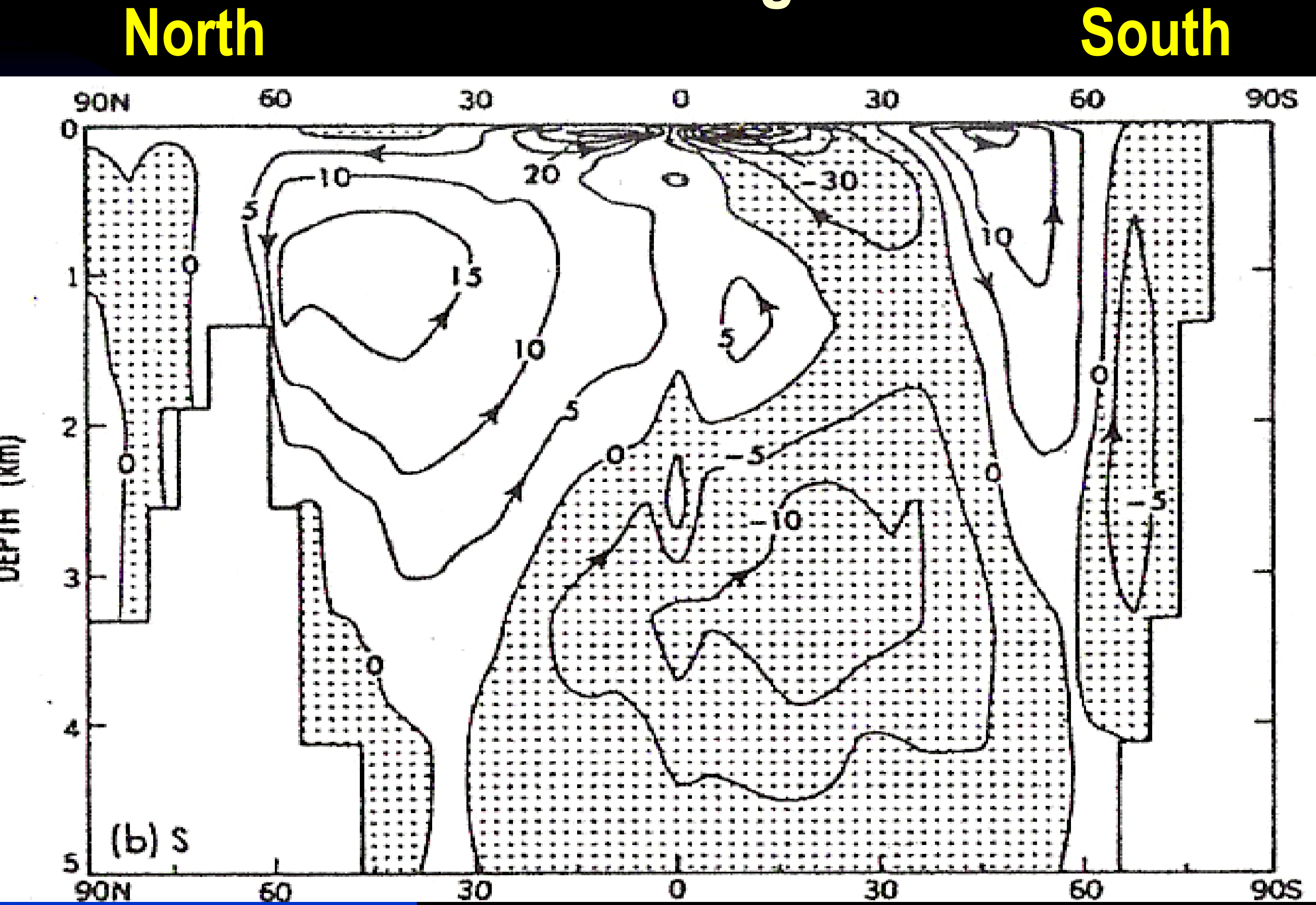
North **South**



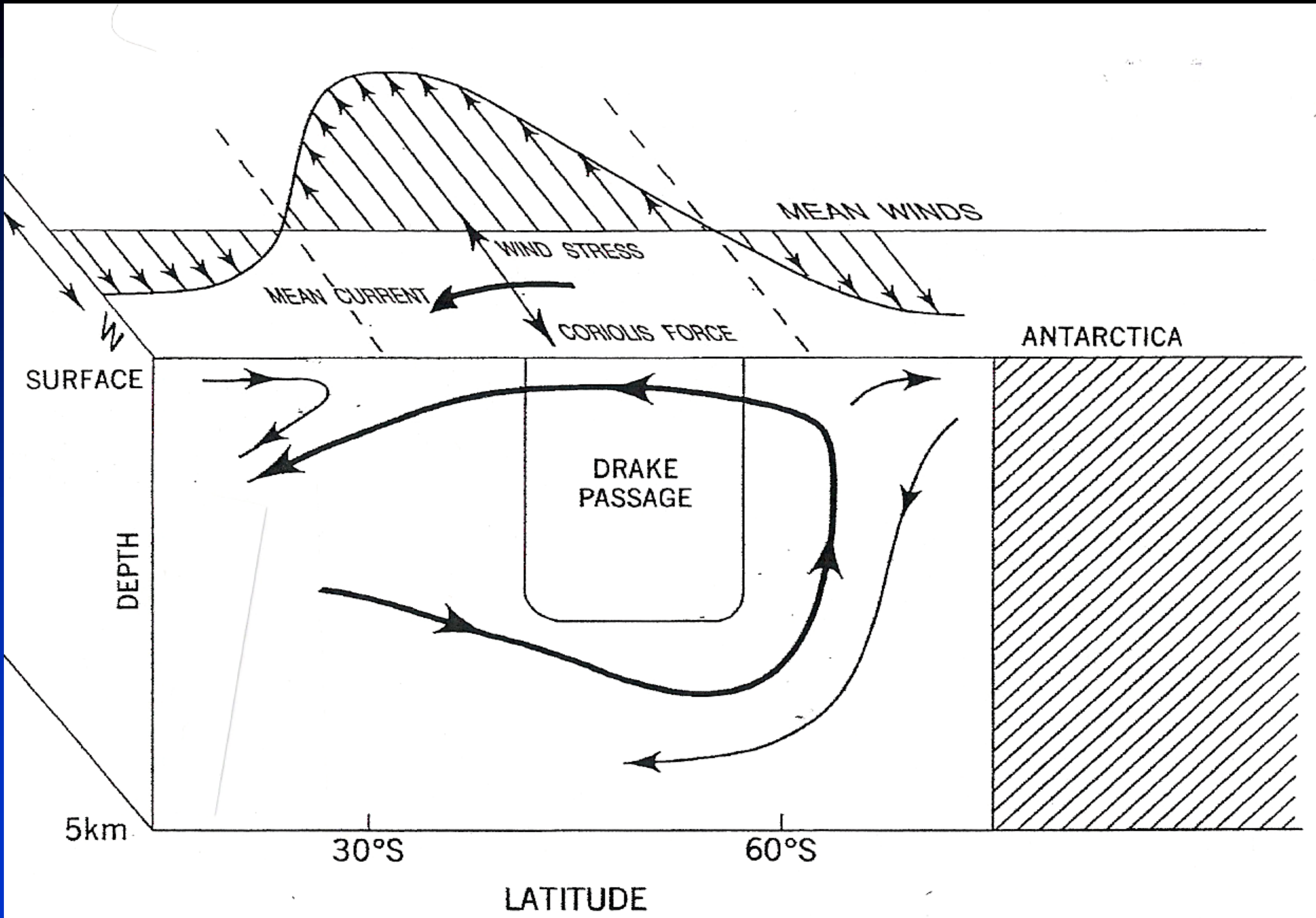
Zonal Mean Temperature Change, °C



Meridional Overturning Circulation



MOC in Circumpolar Ocean, Held, 1993



Eddy-induced overturning circulation

- Donabasoglu, McWilliams, and Gent, 1994: *Science,*

"Eddy-induced circulation in their model flows in the opposite direction from wind-driven circulation, i.e., Deacon Cell, yielding practically no residual circulation."

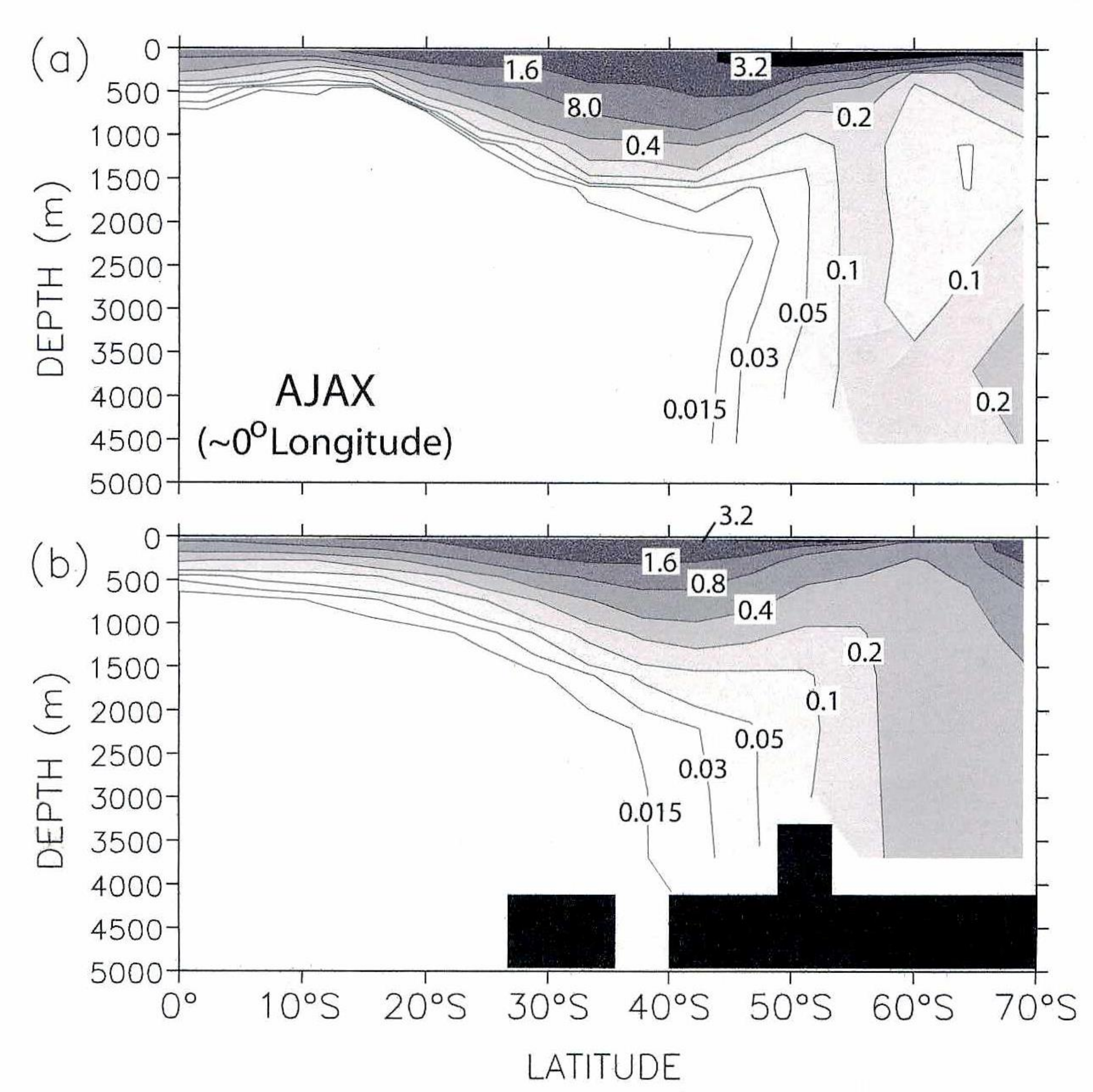
- Henning and Vallis, 2005: *J. Phys. Oceanography,*

"Eddy-induced circulation may not be strong enough to balance the wind-driven circulation."

- Morrison and Hoggs, 2013: J. Phys. Oceanography,

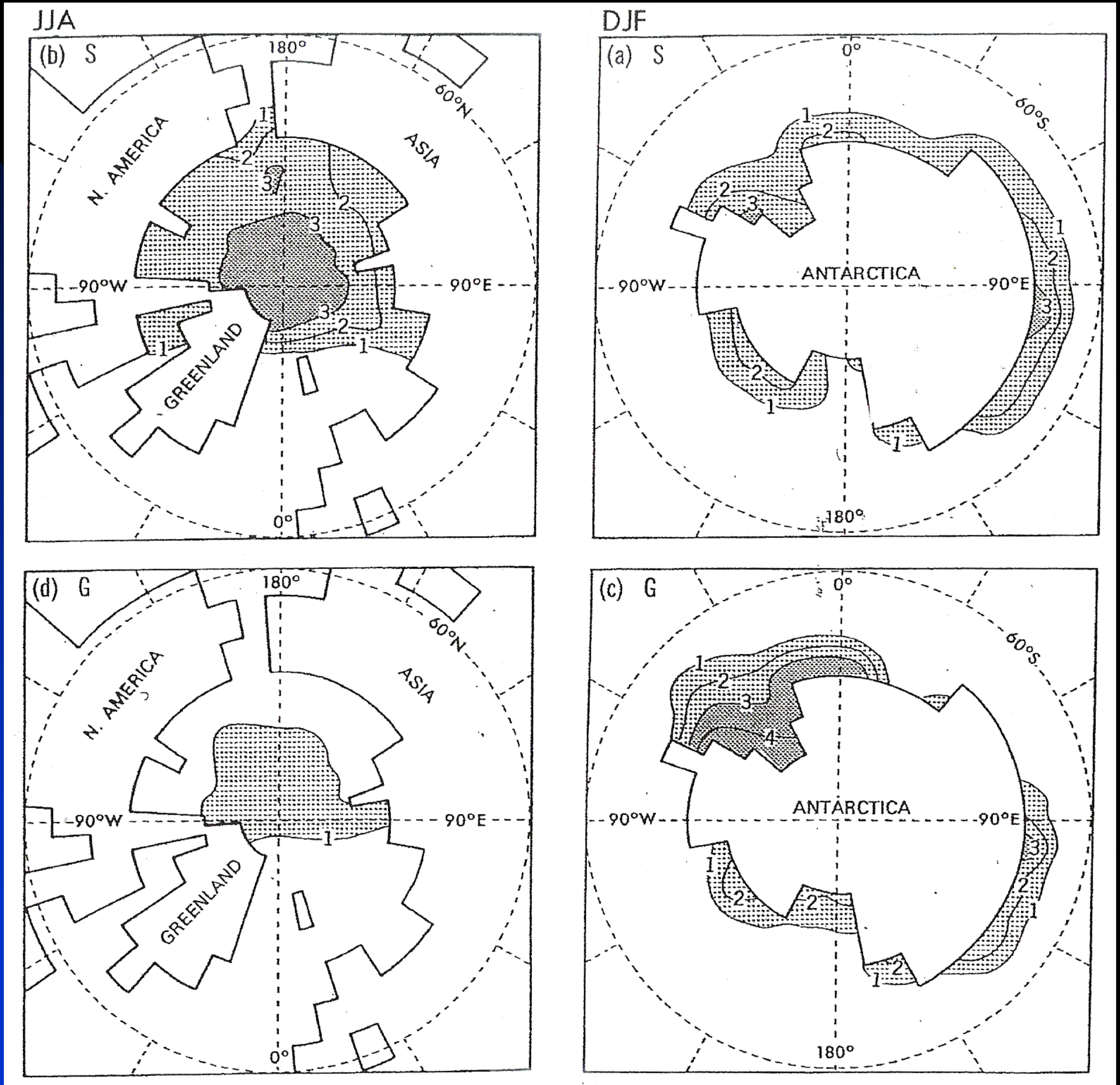
"Using an 'eddy-resolving' coupled model, Morrison and Hoggs (2013) found that the residual flow is about 60% of the wind-driven circulation.

Simulation of CFC, Dixon, Bullister et al., 1996

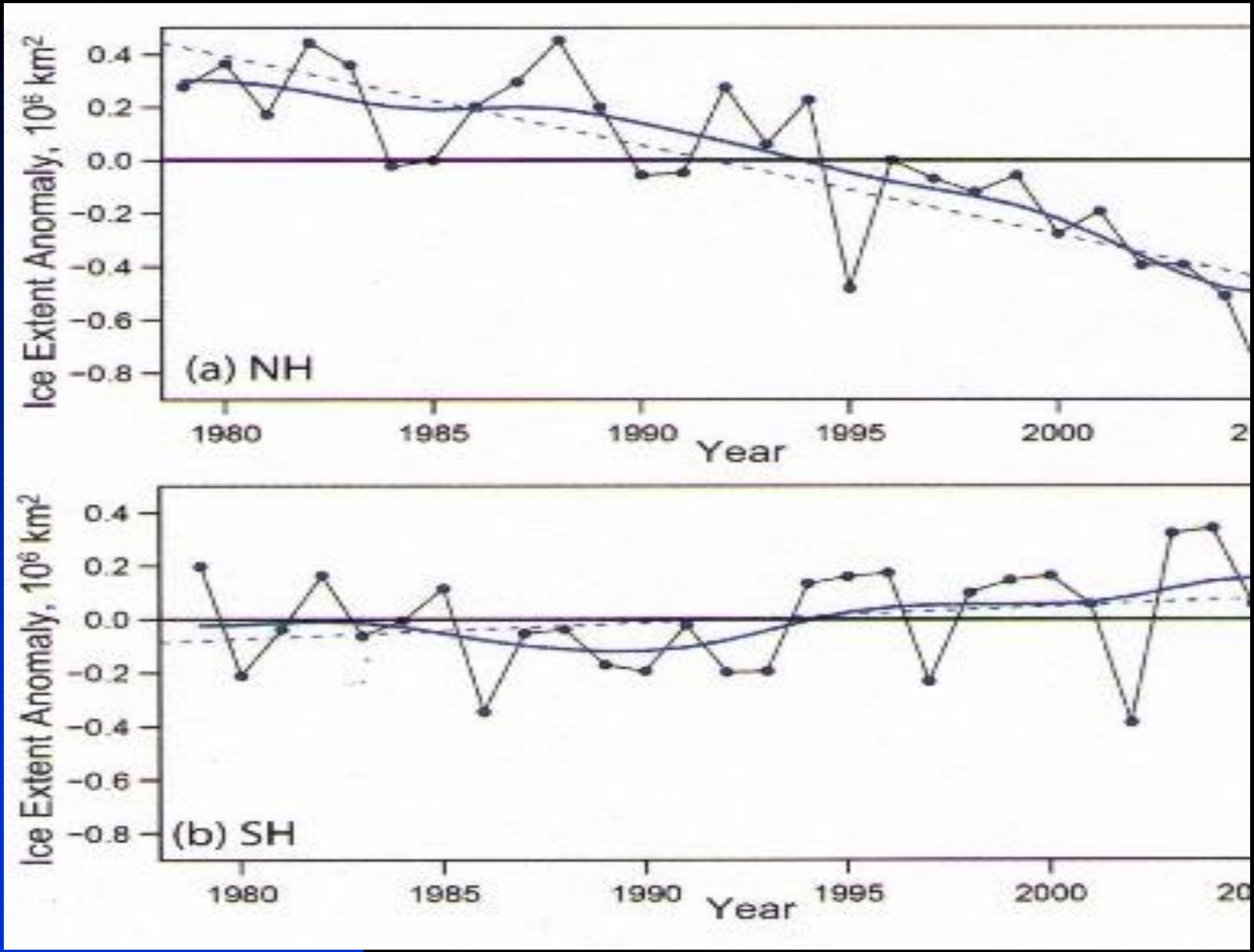


Sea Ice Thickness (m) in Summer

Arctic Ocean, JJA / Antarctic Ocean, DJF



Area Coverage of Annual Mean Sea Ice



Conclusion

Deep convective mixing of heat is mainly responsible for the absence of warming at oceanic surface poleward of 50°S in the Southern Ocean.

Speculation

Southern Ocean may played a critically important role in the formation of deep water with near-freezing temperature and sequestration of huge amount of carbon at the Last Glacial Maximum.

→Reduction of atmospheric CO_2.

(See Stephens & Keeling, 2000, Nature)

Concluding Remarks

Flux Adjustment is a very powerful tool not only for predicting climate change but also for estimating the sensitivity of climate.

It could **complement** tuning as the complexity of parameterization continues to increase in future.

End of Presentation

Atlantic M.O.C.

60N

80S