The Sensitivity of an Ocean Model's Architecture to the Latent Heat Transport in the Atmosphere

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PhD Case Studentship

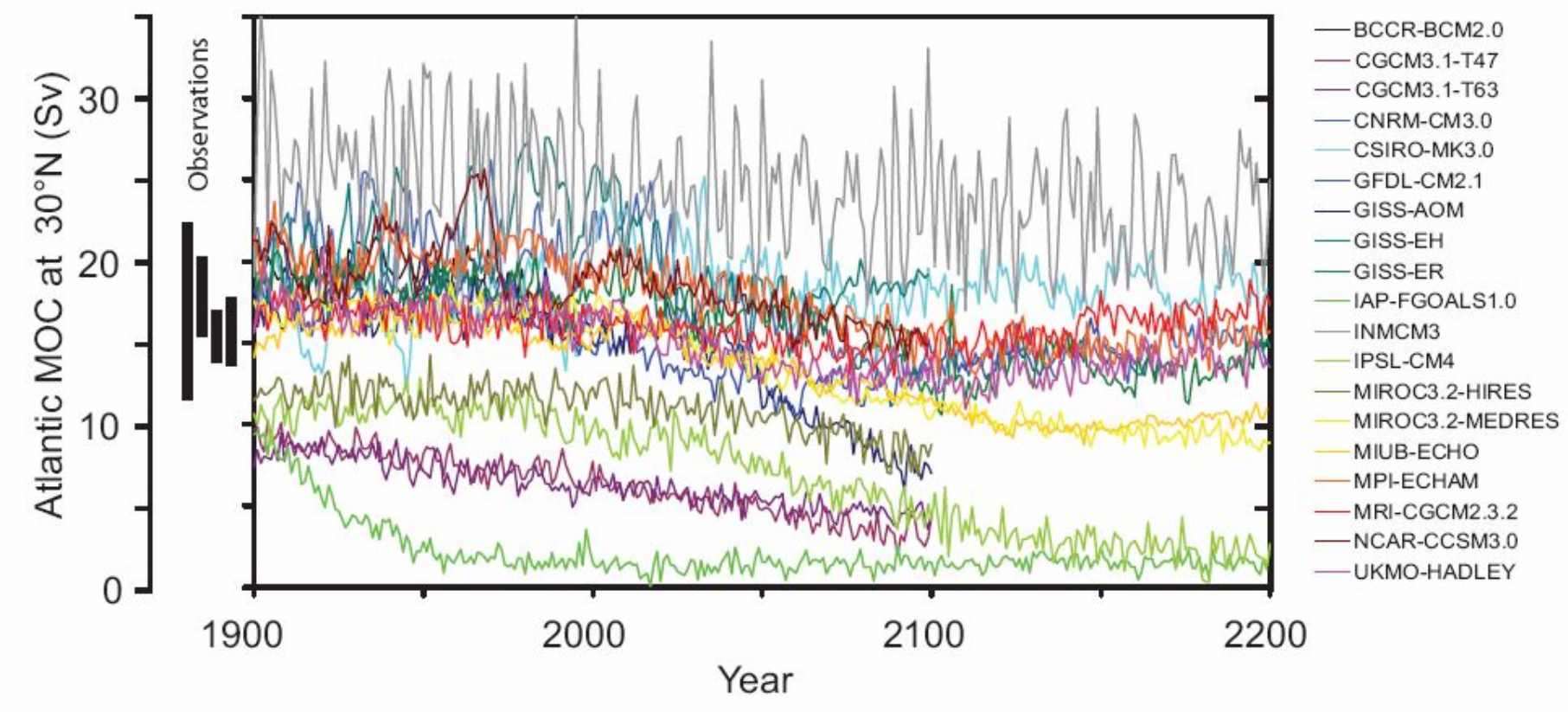
- Joint with National Oceanography Centre (NOC), Southampton, UK.
- Spend at least 3 months doing on-site research
- Present results from November and April visits

Talk Outline

- Motivation
- Constant Depth Vs. Constant Density
- Comparison of Models
- Effects on Ocean and Atmospheric Heat Transport
- Effects on Latent Heat Transport
- Brief Summary
- A little side project

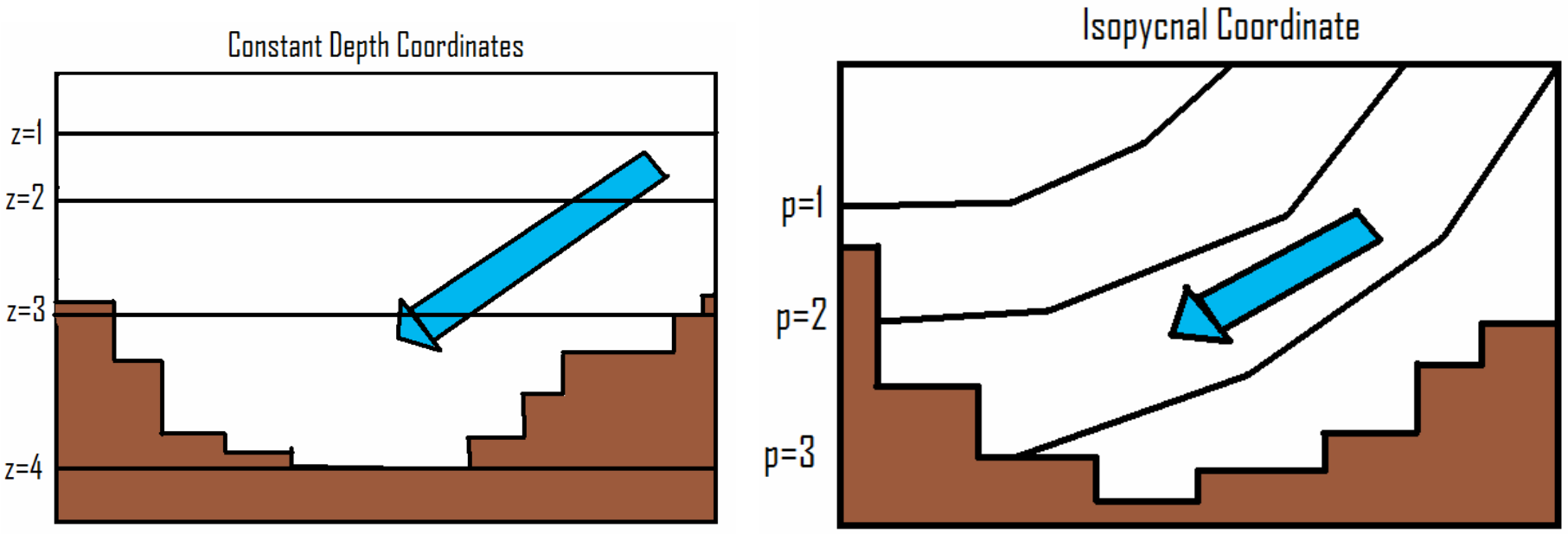
Motivation

Future predictions of AMOC strength from IPCC AR4



- Large uncertainties in model predictions
- Majority of models employ a z coordinate system in its ocean model
- Isopycnal ocean model may provide an alternative assessment

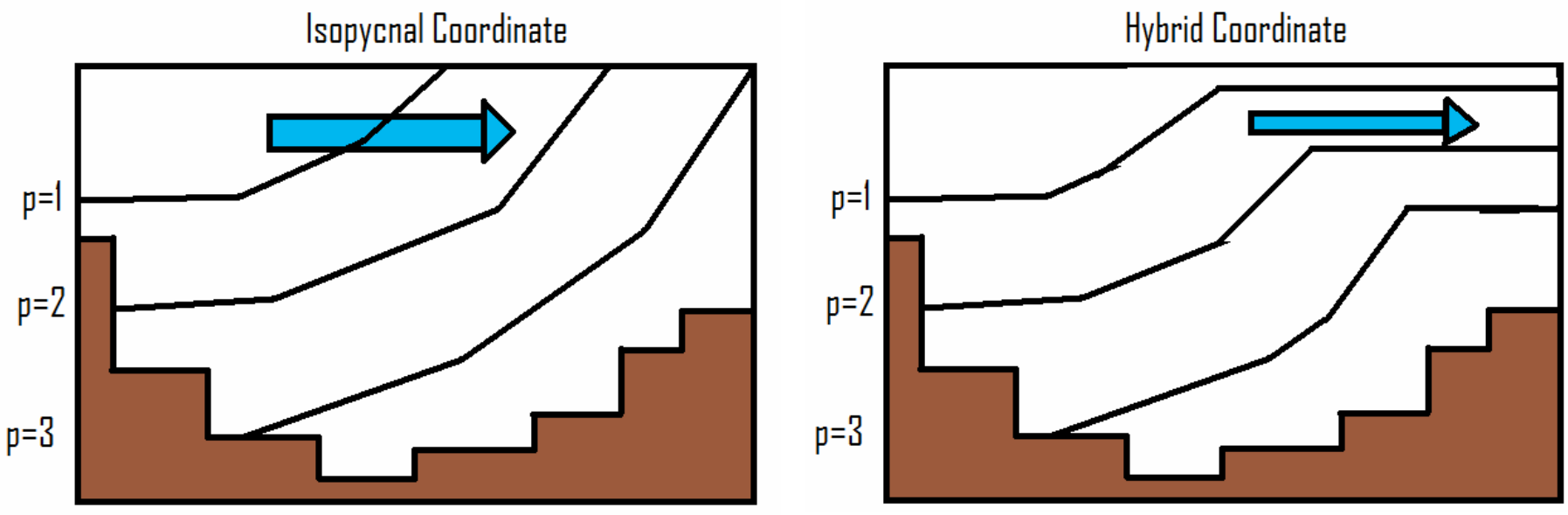
Comparing Depth Coordinates



- The interface between two layers produce spuriously high mixing when crossed

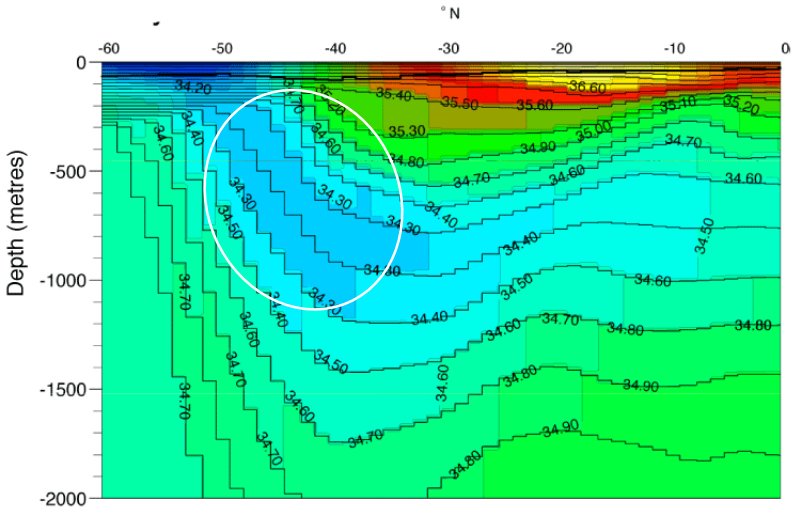
- In isopycnal (constant density) coordinates, water masses flow along layer boundaries thus eliminating this problem

The Hybrid Coordinate

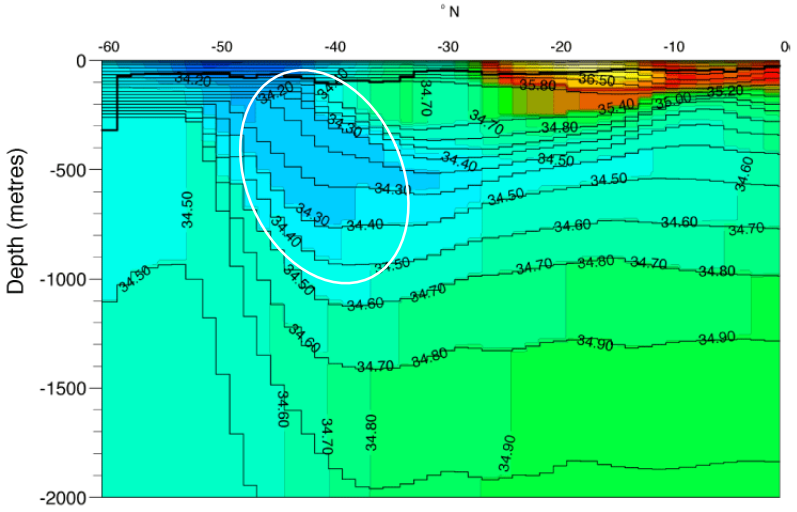


- For a purely isopycnal model, constant density surfaces outcrop at high latitudes causing poleward moving surface waters to cross isopleths
- Hybrid coordinate model uses constant z coordinates near surface and isopycnal coordinates within ocean interior
- **Hybrid coordinate model used in the Coupled Hadley-Isopycnic Model Experiment (CHIME)**

Representation of Antarctic Intermediate Water

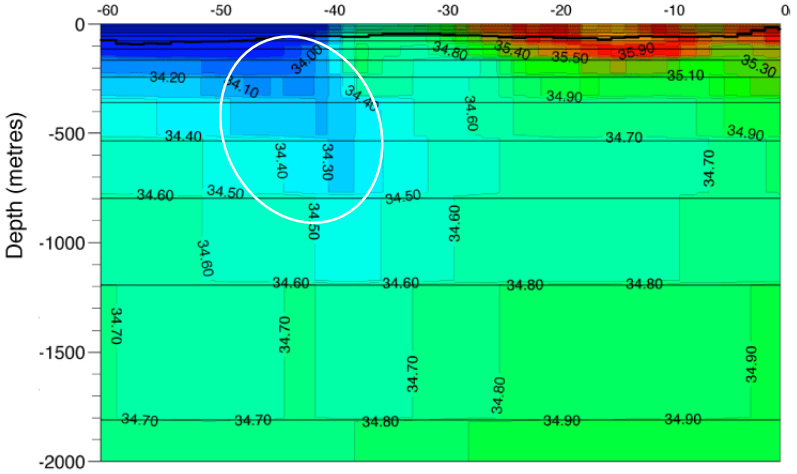


Salinity at 30° W at initialisation of CHIME



Salinity at 30° W at year 80 of CHIME

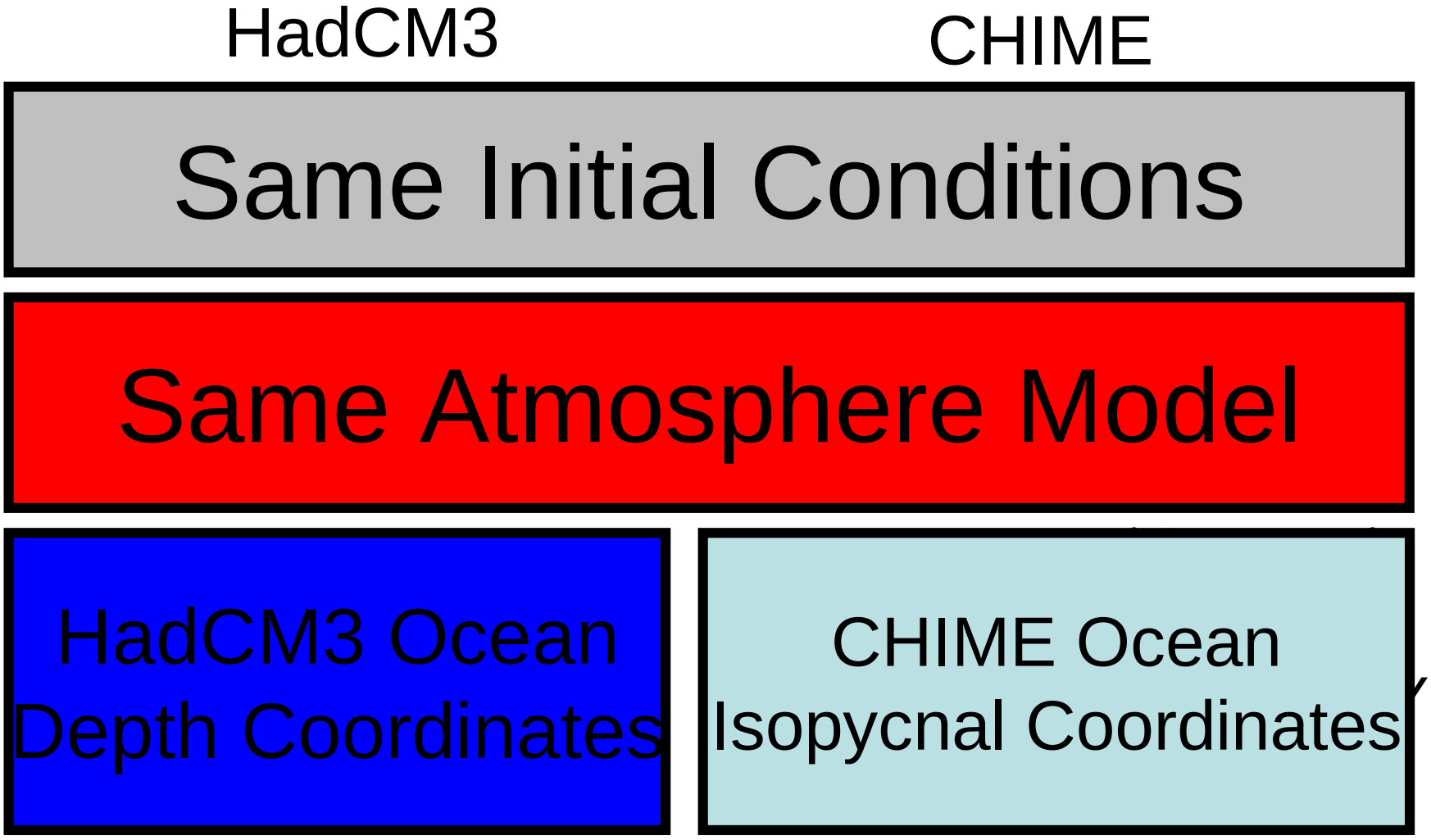
CHIME represents fresh tongue of AAIW realistically, and preserves it better than HadCM3, where it mixes with surrounding water masses within the first few decades.



Salinity at 30° W at year 80 of HadCM3

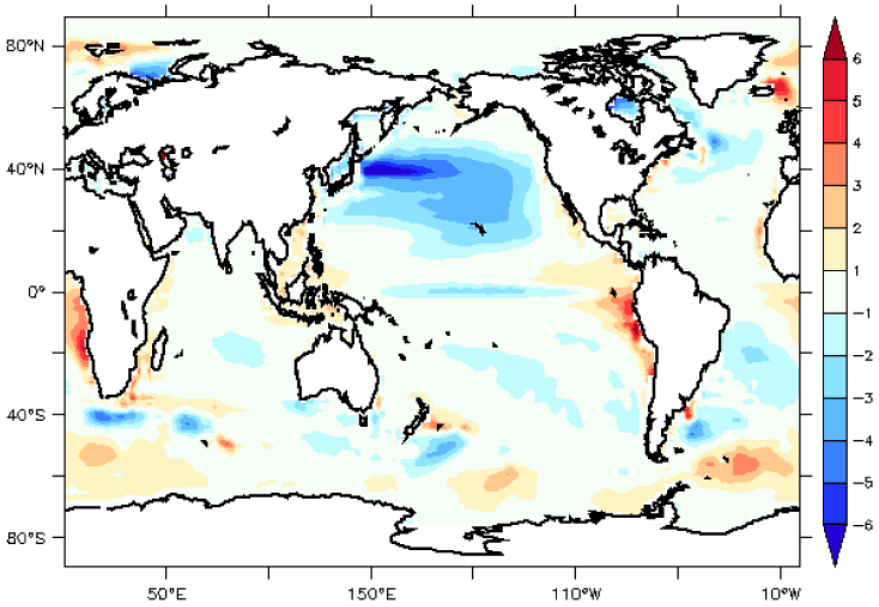
With permission from Alex Megann

Comparisons of the Models

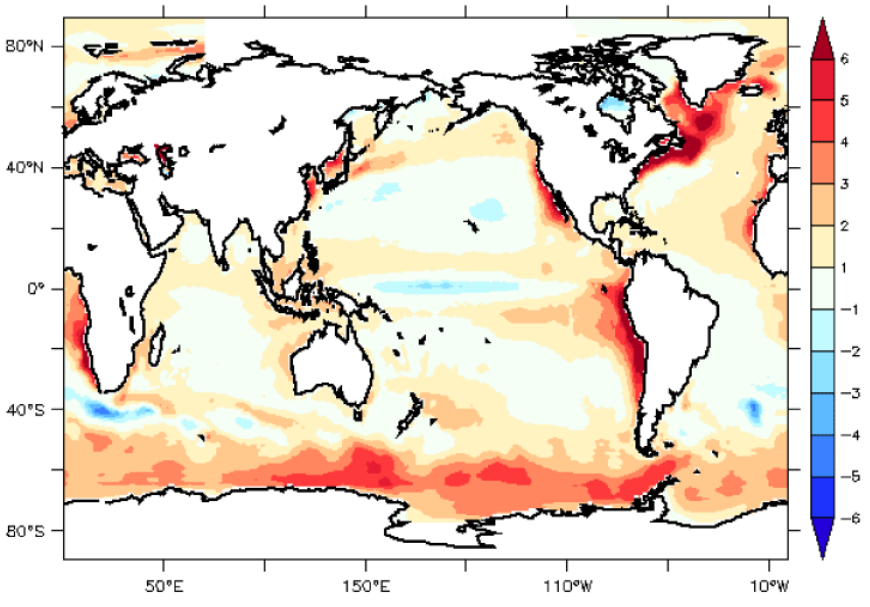


Sea Surface Temperature (SST) Drifts

Mean SST years 80-120 minus NOCS SST climatology, Control Runs



HadCM3



CHIME

• General impression that CHIME is too warm at surface, heat not being taken up by ocean as rapidly as in HadCM3, possibly less mixing.

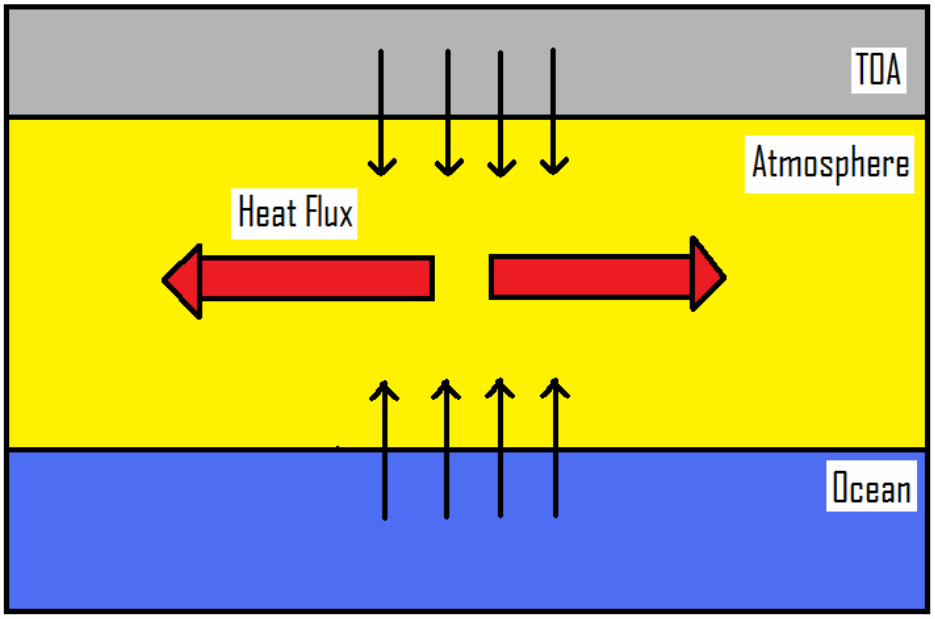
With permission from Alex Megann

Question 1?

How does this new coordinate system affect the transport of heat?

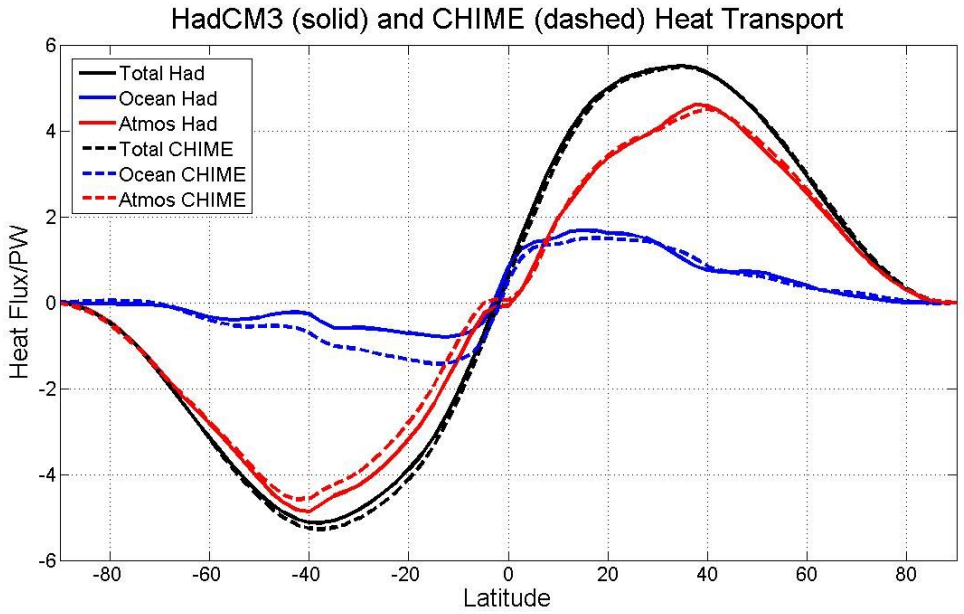
Computing Heat Transport

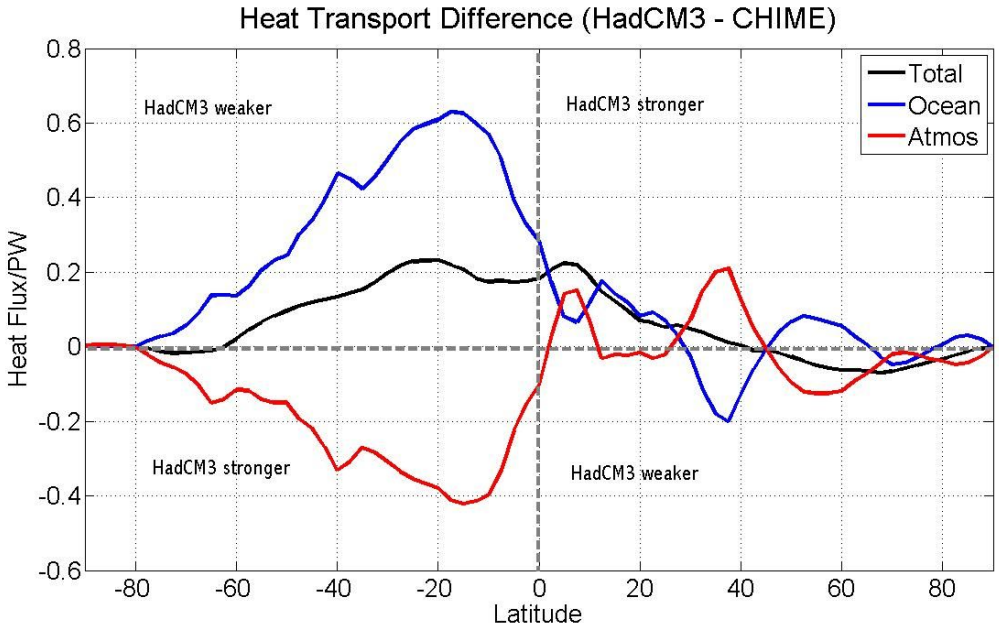
- Total Heat Transport is calculated from the net radiation flux at the TOA
- Atmospheric Heat Transport calculated from the balance of flux from TOA and surface
- Ocean Heat Transport calculated as a residual



Comparison of Heat Transports for HadCM3 and CHIME

- Total Heat Transport similar across models
- Ocean heat Transport different in CHIME
- Atmosphere must compensate (Bjerknes Compensation)
- How?

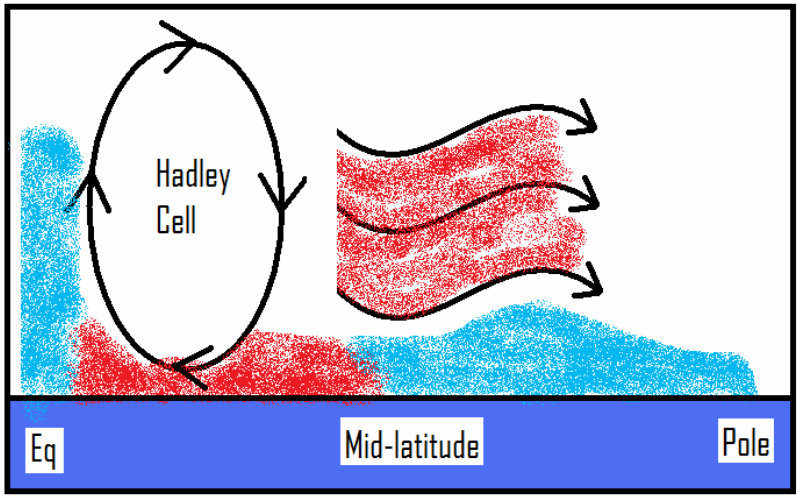


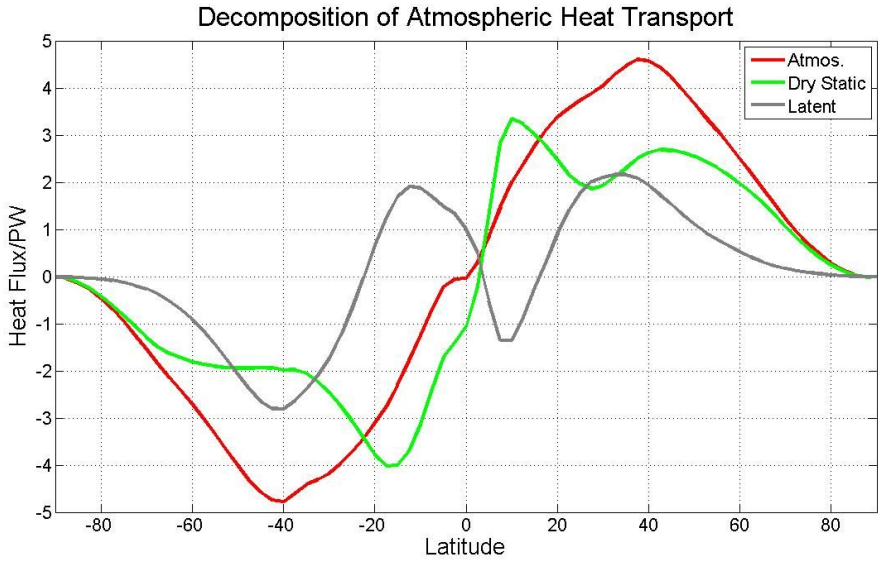


Question 2?

If [heat transport] changes in the ocean are compensated by changes in the atmosphere, how will this affect the transport of latent heat?

Decomposition of Atmospheric Heat Transport

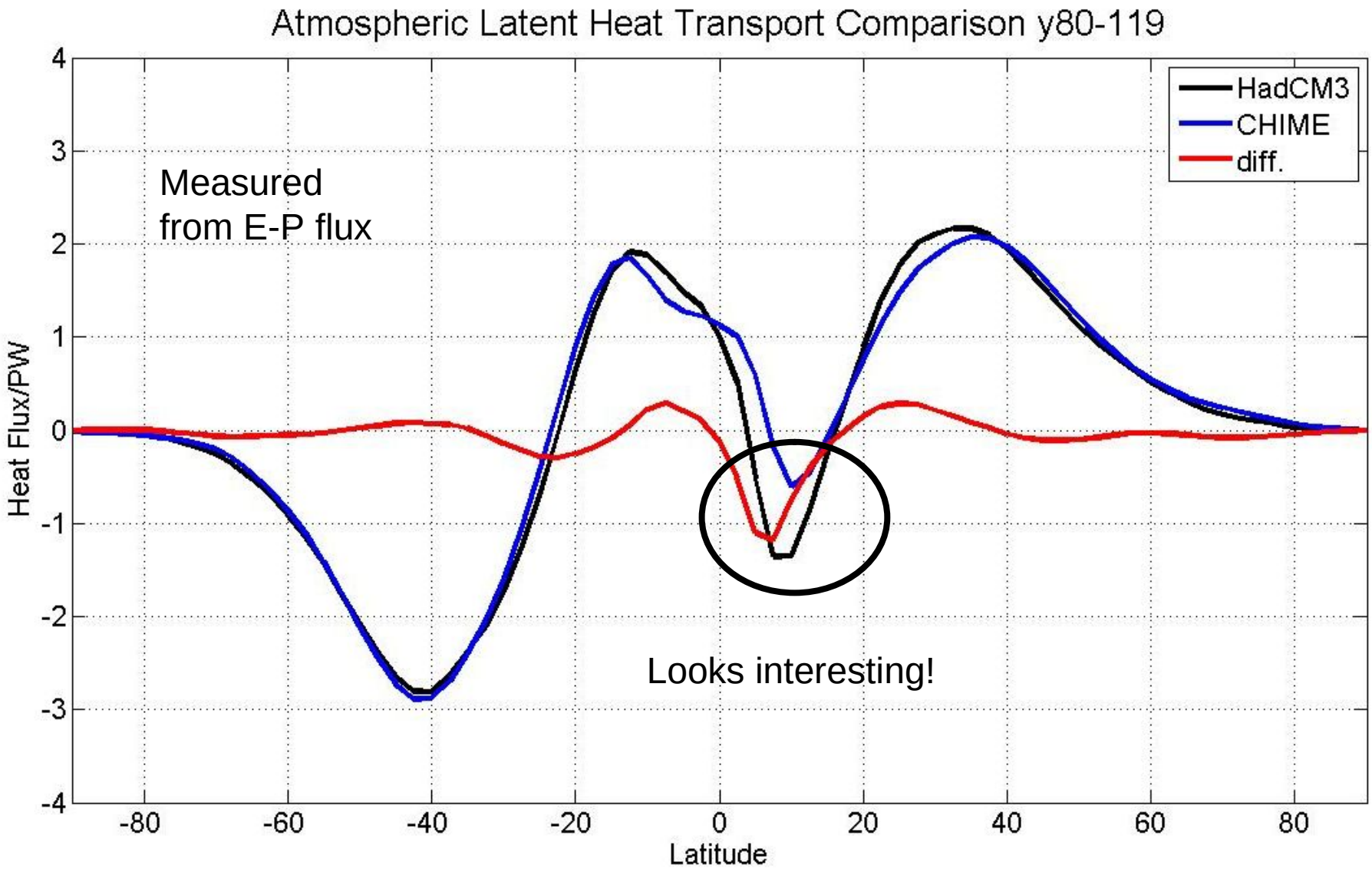


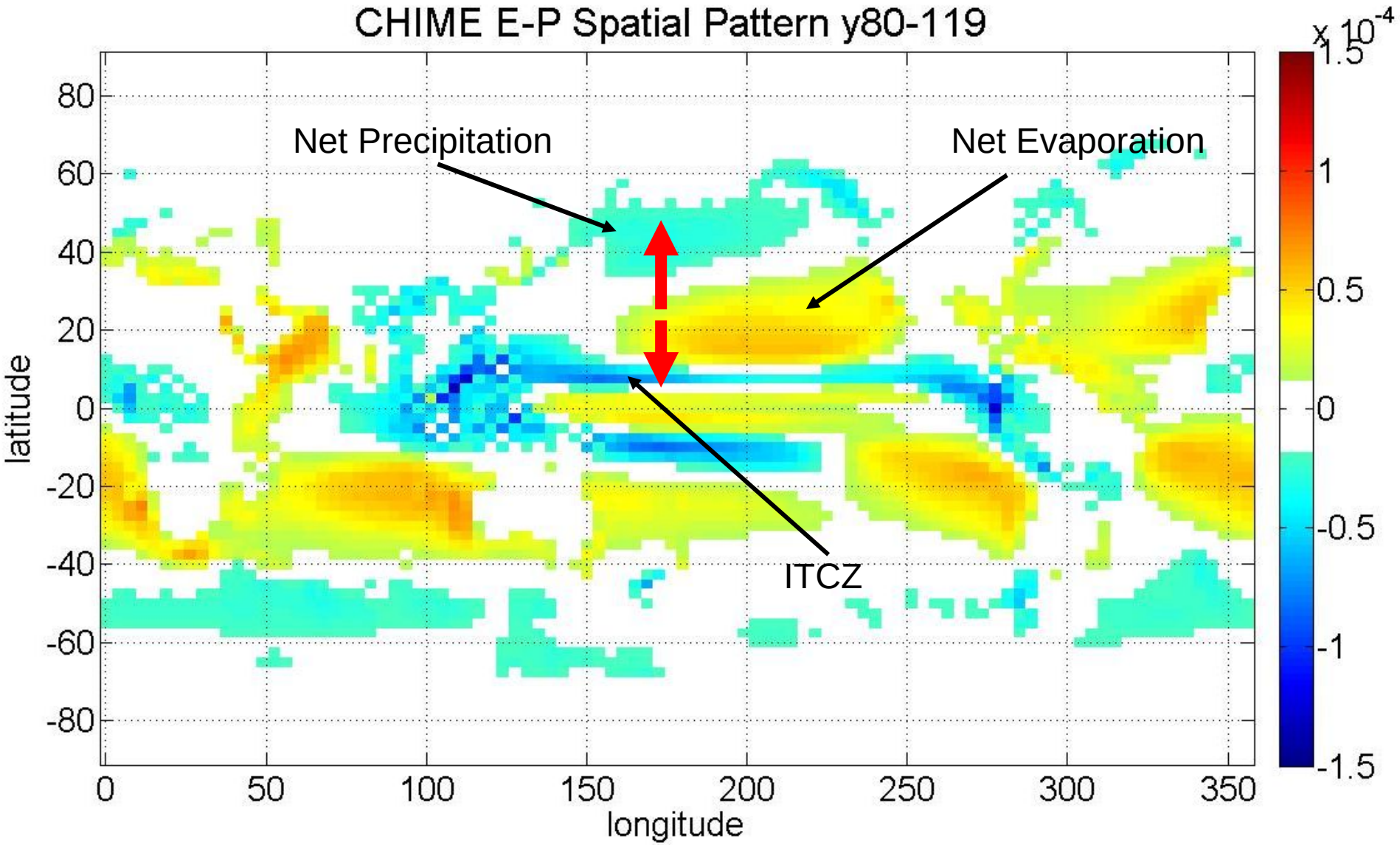


- Opposing directions of latent and Dry Static energy at low latitudes suppress atmospheric heat transport – Ocean is main conveyor of heat in this region
- Baroclinic instabilities within the atmosphere at mid-latitudes are the main conveyors of heat

$$H_a = l_v q + c_p T_a + gz$$

Latent Dry Static


Atmospheric Latent Heat Transport Comparison y80-119
HadCM3
CHIME
diff.
Measured
from E-P flux
Looks interesting!
Heat Flux/PW
Latitude
4
3
2
1
0
-1
-2
-3
-4
-80
-60
-40
-20
0
20
40
60
80


CHIME E-P Spatial Pattern y80-119
Net Precipitation
Net Evaporation
ITCZ
latitude
longitude
80
60
40
20
0
-20
-40
-60
-80
0
50
100
150
200
250
300
350
x 10^-4
1.5
1
0.5
0
-0.5
-1
-1.5

Simple Maths Toolkit

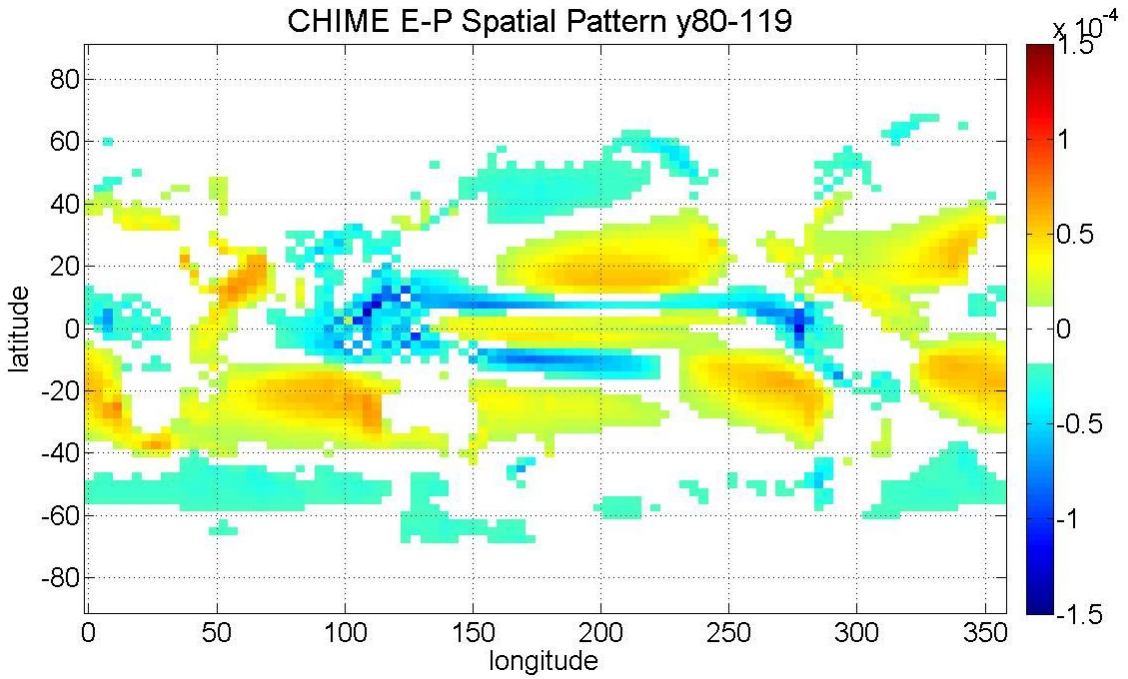
$$\Psi_{CHI} = \Psi_{Had} + \Psi_{res}$$

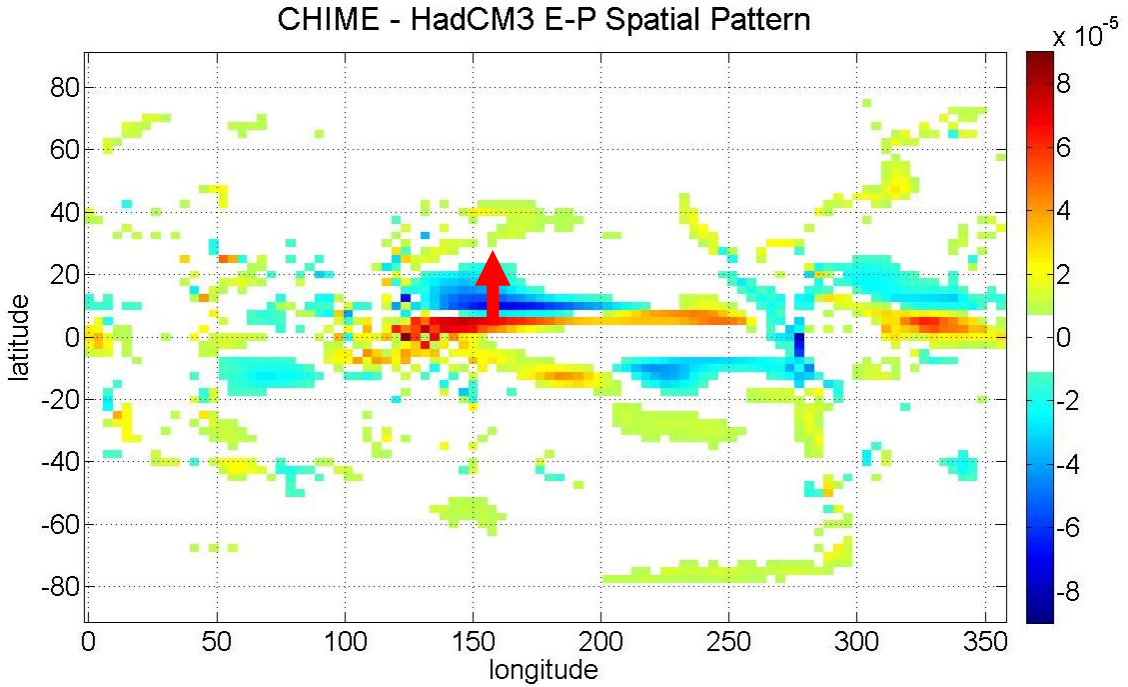
- Ψ is any variable i.e. SST, q, wind velocity

$$\Psi_{res} = \Psi_{CHI} - \Psi_{Had}$$

E-P Spatial Patterns

- CHIME has weaker E-P spatial distribution for the Northern Hemisphere Tropics





What does this mean?

- Less Latent Heat transport for Tropical Northern Hemisphere
- Reduced E-P Spatial Pattern
- Must look at Northern Hemisphere Hadley Cell

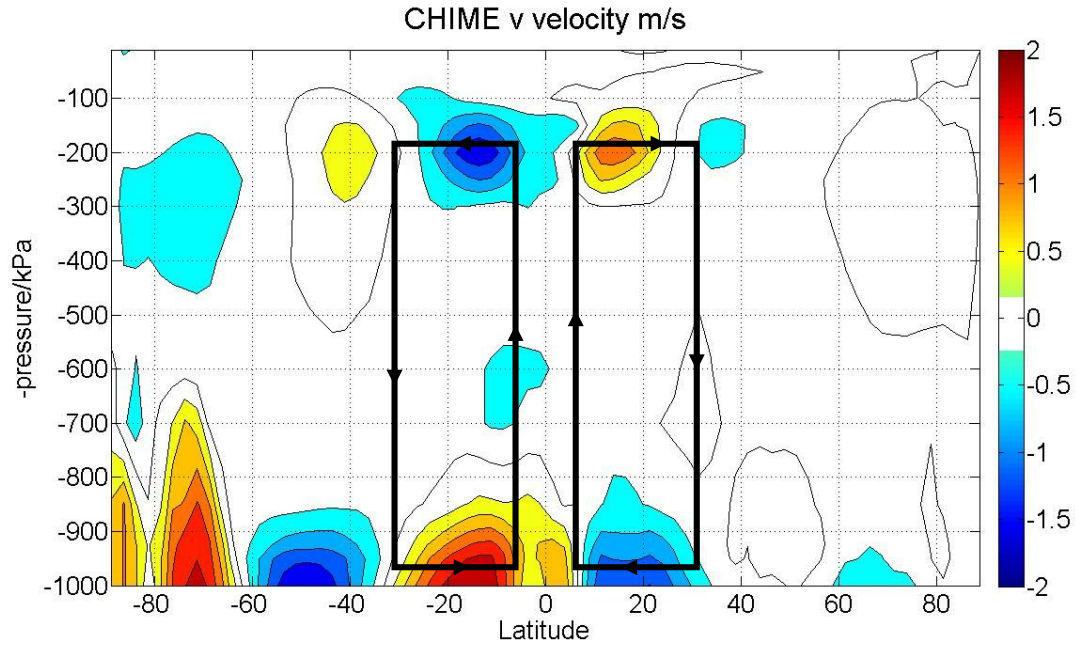
- Analyse Meridional Wind Velocity to look at M
- Analyse specific humidity q

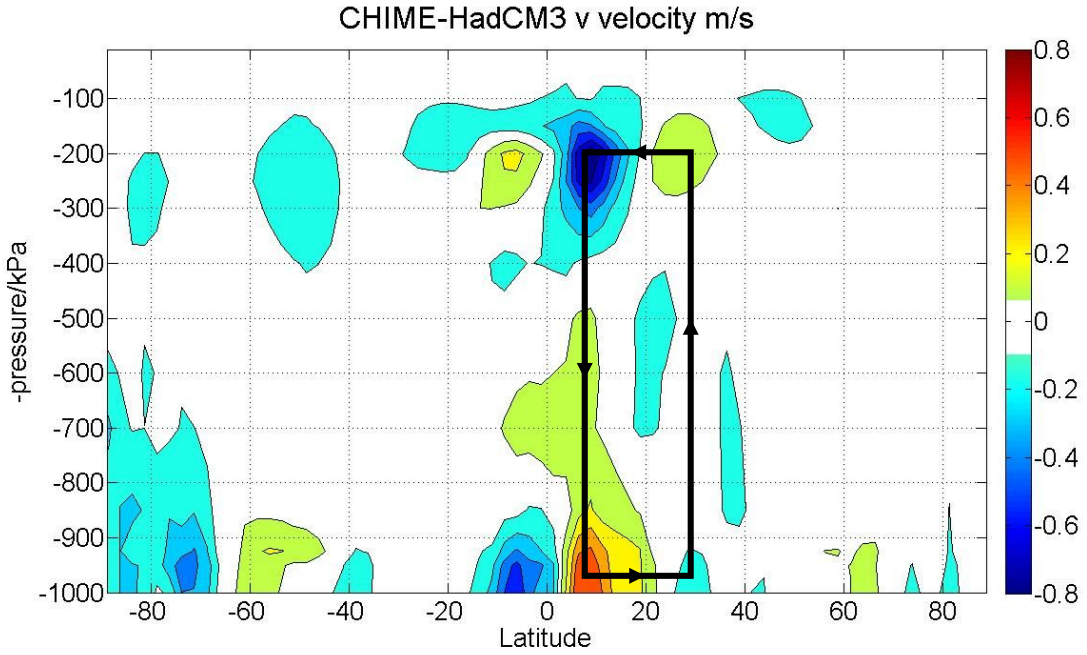
$$F = M \times q$$

Freshwater Transport	Atm. Mass Transport	Specific humidity

Meridional Velocity Comparison

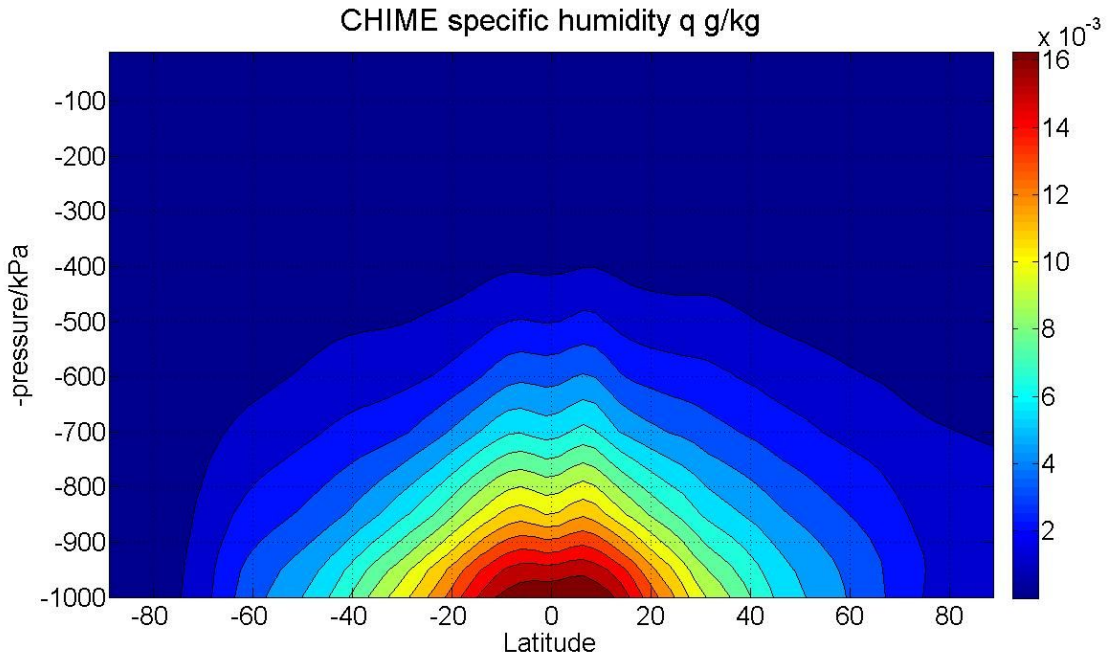
- CHIME has weaker mass transport in Northern Hemisphere Hadley Cell

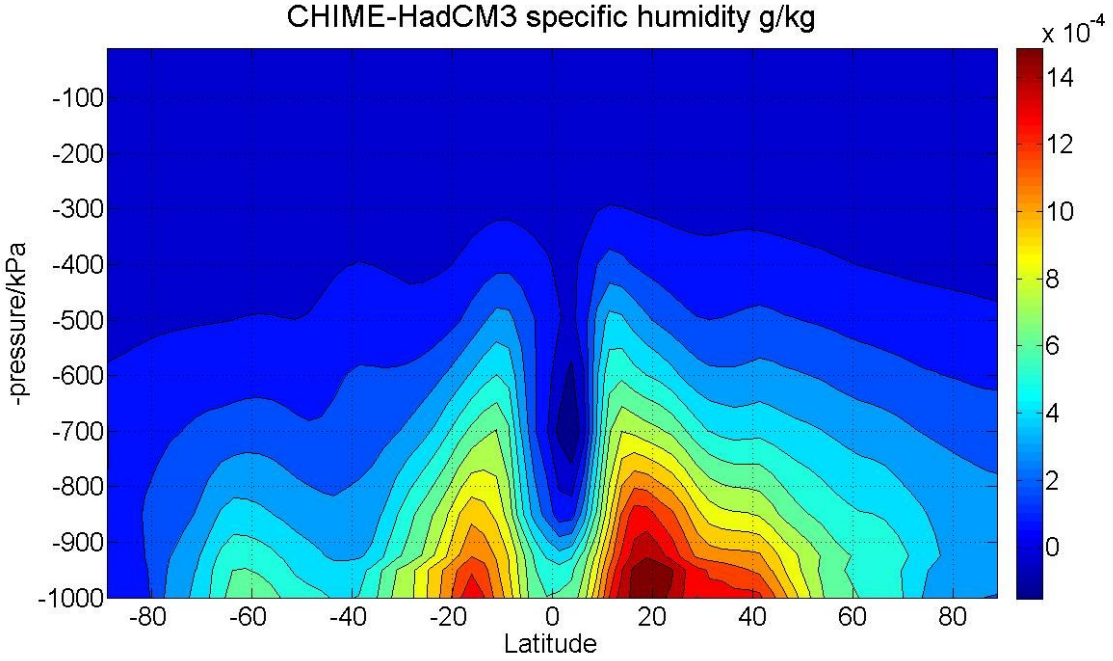




Specific Humidity Comparison

- CHIME has larger values of specific humidity due to a warmer surface temperature





Brief Summary

- CHIME N. Hem. Hadley Cell transports less latent heat

$$F = M \times q$$

- Strength of Meridional Winds v

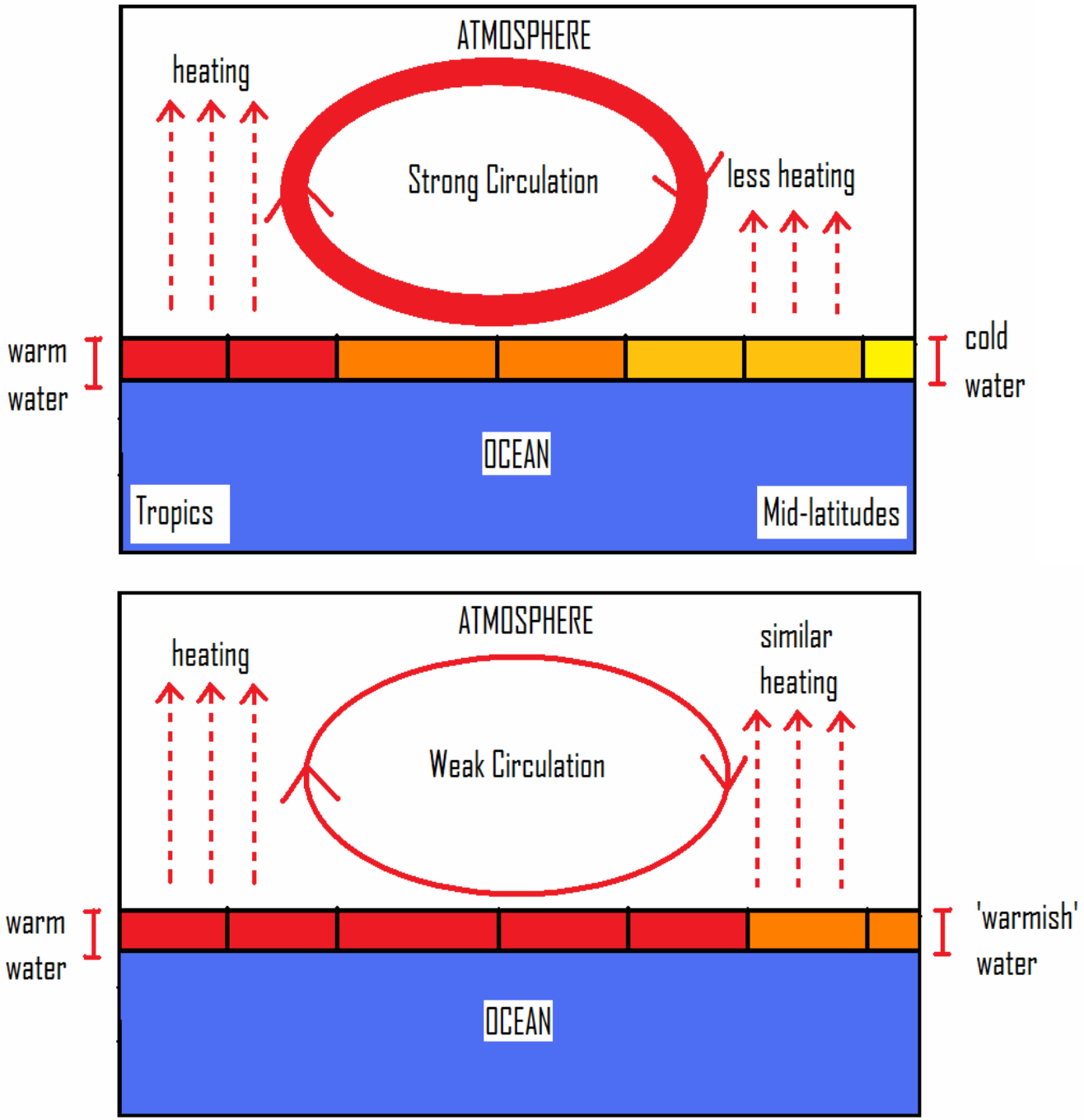
  CHIME:HadCM3 ~ 2:3

- Specific Humidity q

  CHIME:HadCM3 ~ 11:10

- **Reduction in latent heat transport is due to the decrease in mass transport of Hadley Cell**

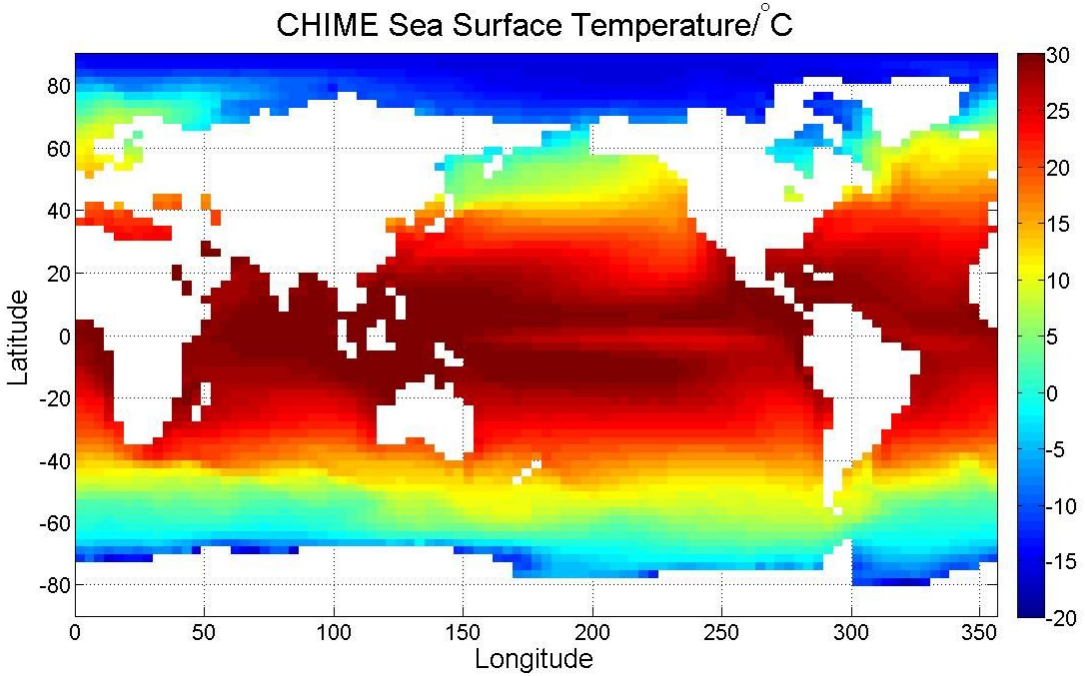
The Importance of the Temperature Gradient

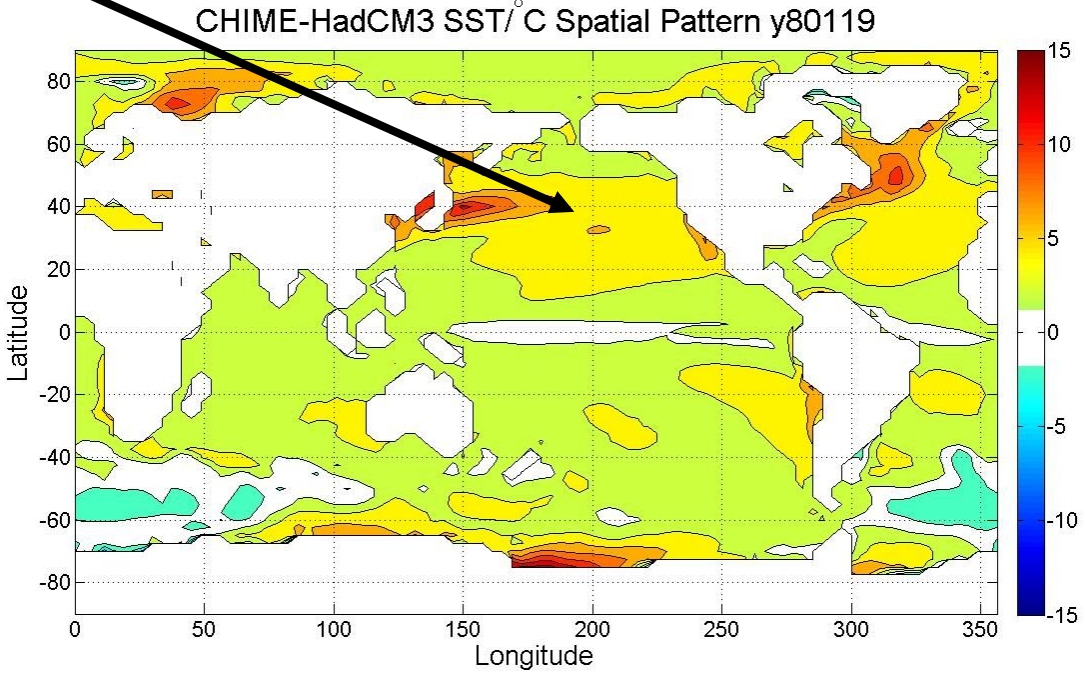


-CHIME has a warmer Sea Surface Temperature

Warmer mid-latitudes

Reduced temperature gradient leading to a reduction in meridional winds

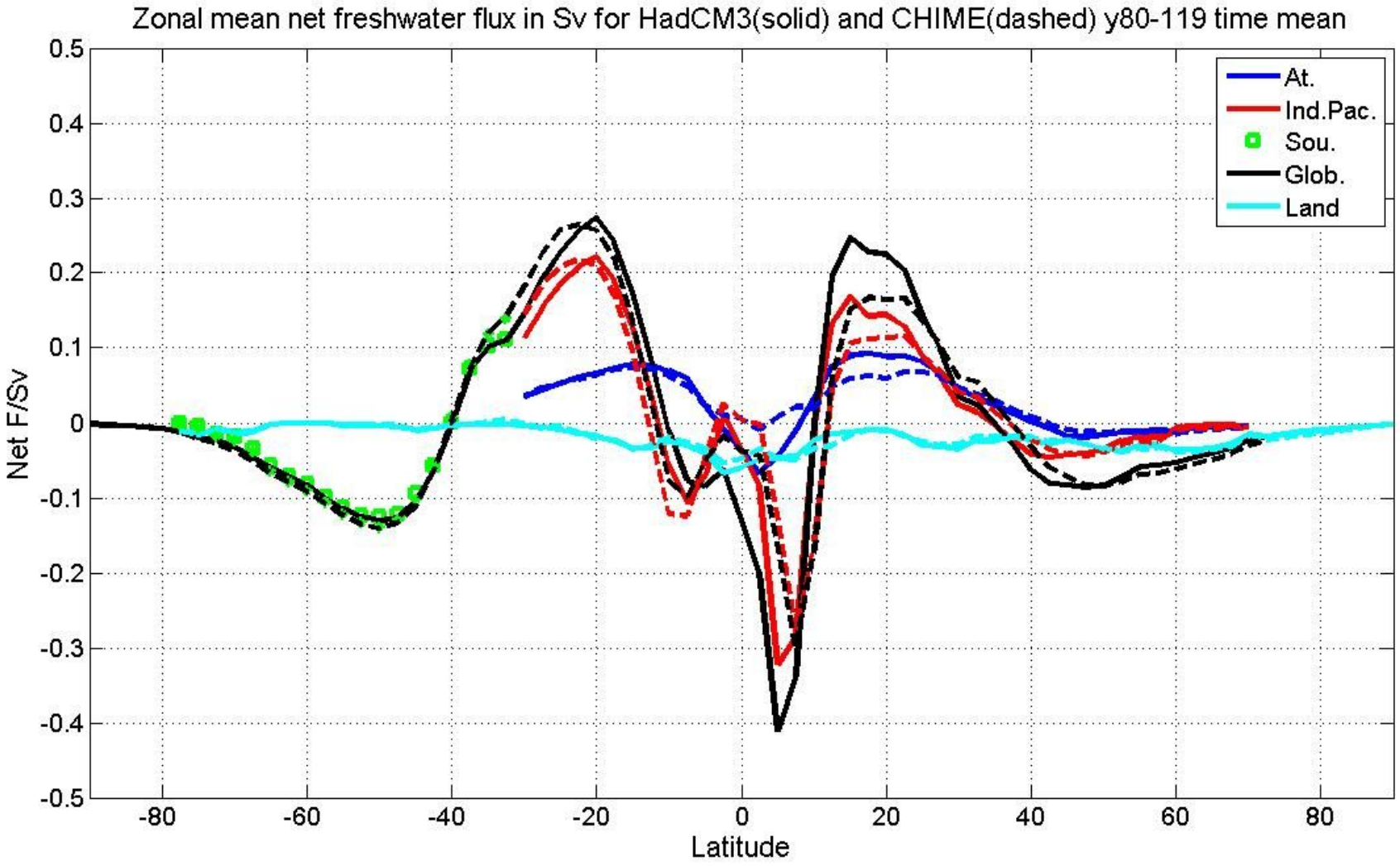




Main Summary

- Compared the latent heat transport between HadCM3 (constant depth) and CHIME (constant density)
- CHIME has weaker E-P spatial pattern in Northern Hemisphere Tropics
- Hadley Cell is weaker due to a reduction in Mass transport, even though humidity increases
- Reduction in winds are due to a reduced temperature gradient in zonal SSTs
- **All predominantly due to the ocean coordinate system**

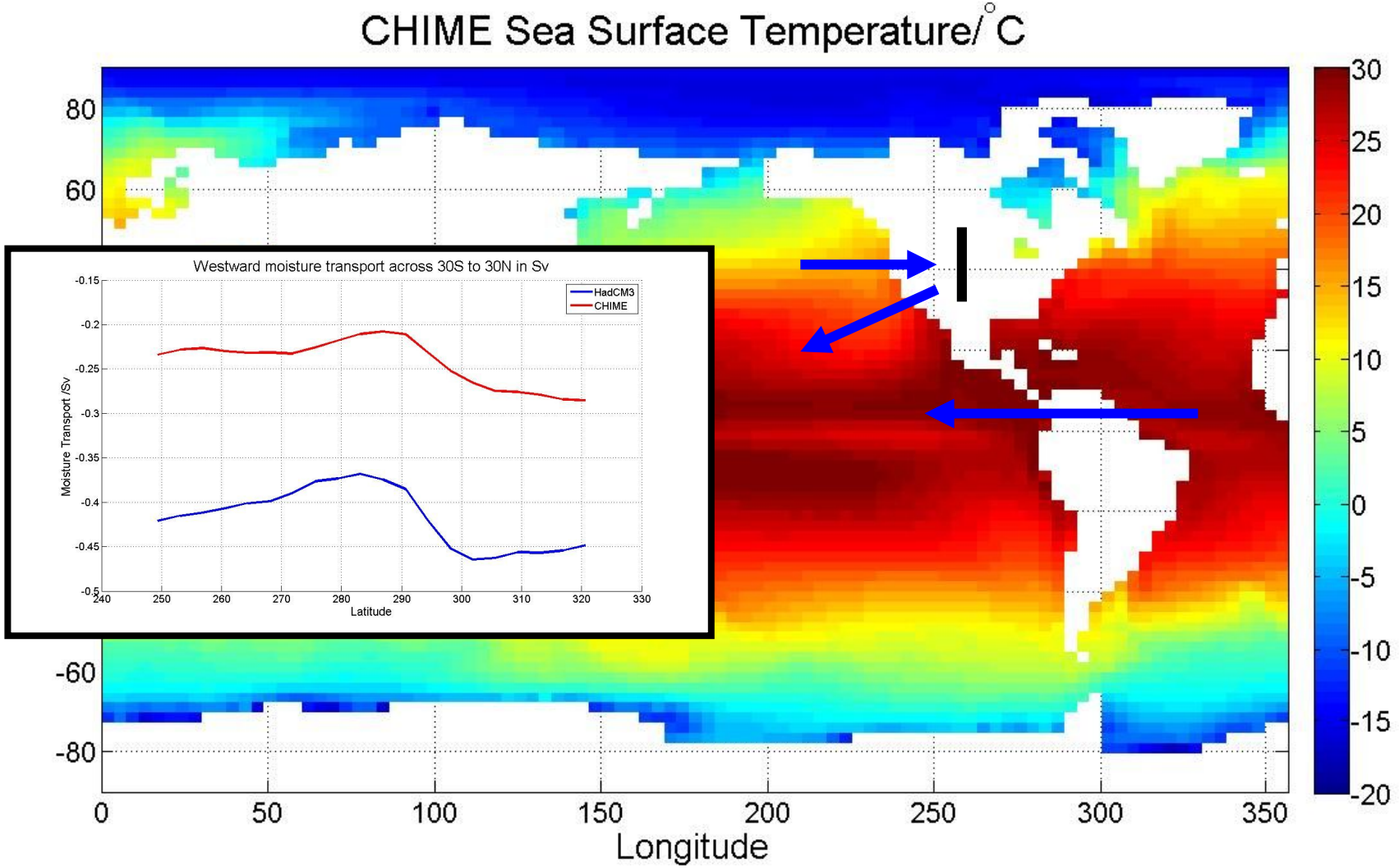
A little side project


Zonal mean net freshwater flux in Sv for HadCM3(solid) and CHIME(dashed) y80-119 time mean
Net F/Sv
Latitude
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-80
-60
-40
-20
0
20
40
60
80
At.
Ind.Pac.
Sou.
Glob.
Land

Net E-P vertical flux in Sv into each Ocean Basin

	Atlantic	Ind.Pac.	South.	Land
HadCM3	+1.11	+0.91	-0.75	-1.28
CHIME	+1.15	+0.86	-0.76	-1.25
CHI-Had	+0.04	-0.05	-0.01	+0.03
“CHIME has….”	More evap.	Less evap.	More precip.	More precip.

Possible Mechanism?



Thank you

Questions?