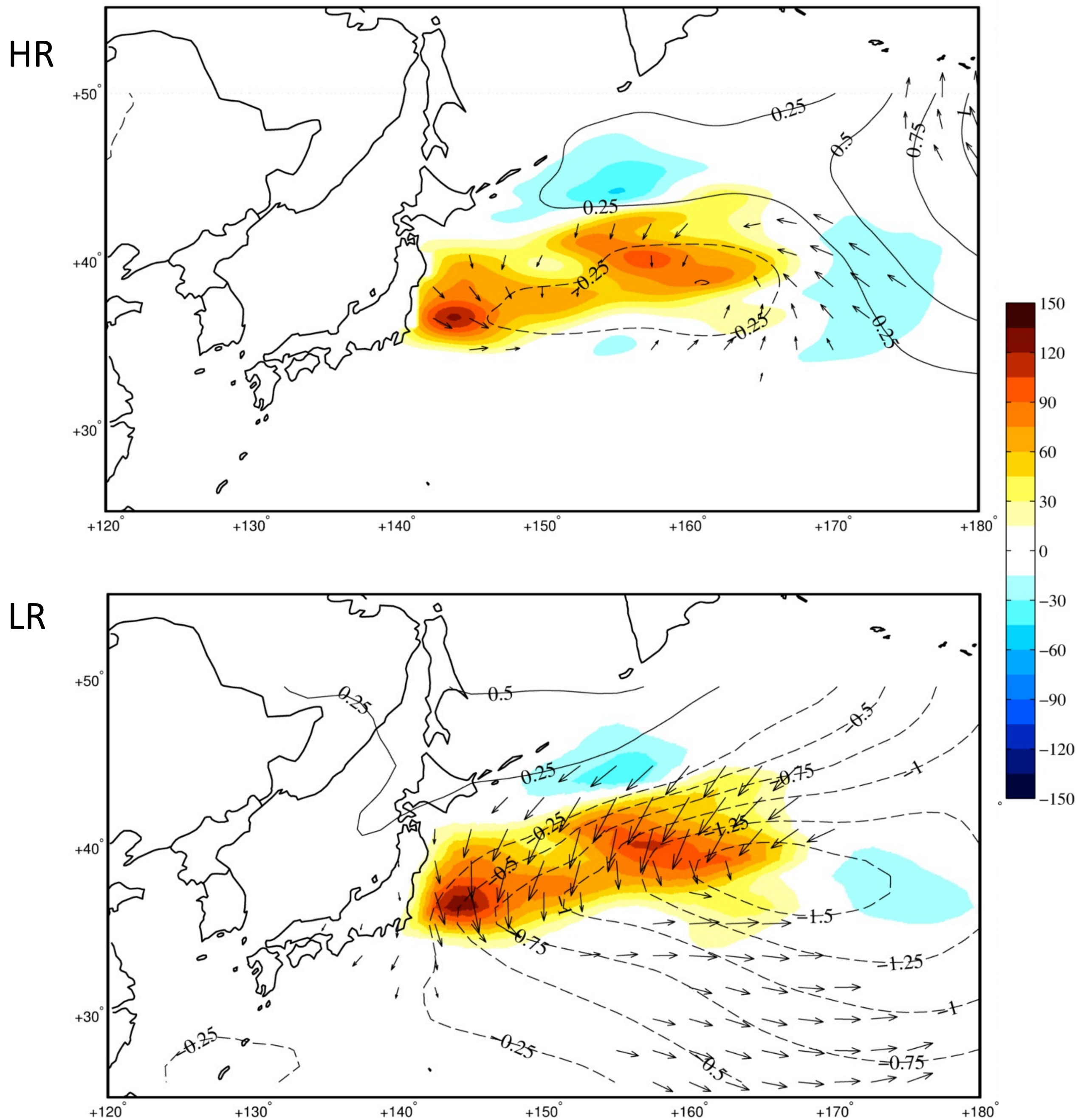
Oyashio Front Model Experiments: “Do we really need to use 0.25°”?

5.1.2013



LR: 1° CAM5 simulations
HR: 0.25° CAM5

ΔTurbulent (LH+SH) flux, color
ΔPSL, contour
Δ[u,v], vectors

$\Delta THF_{HR} = 0.9\ \Delta THF_{LR}$
$\Delta PSL_{HR} = 0.25\ \Delta PSL_{LR}$
$\Delta|U|_{HR} = 0.5\ \Delta\ |U|_{LR}$

LR ΔPSL appears ~4X **stronger** than observations (Tokinaga et al., 2009) and RCMs (Putrasahan et al, 2013). These studies show PSL changes of <=0.5hPa across the front.

Larger ΔPSL in LR creates stronger surface wind anomalies that cause an increase in THF.

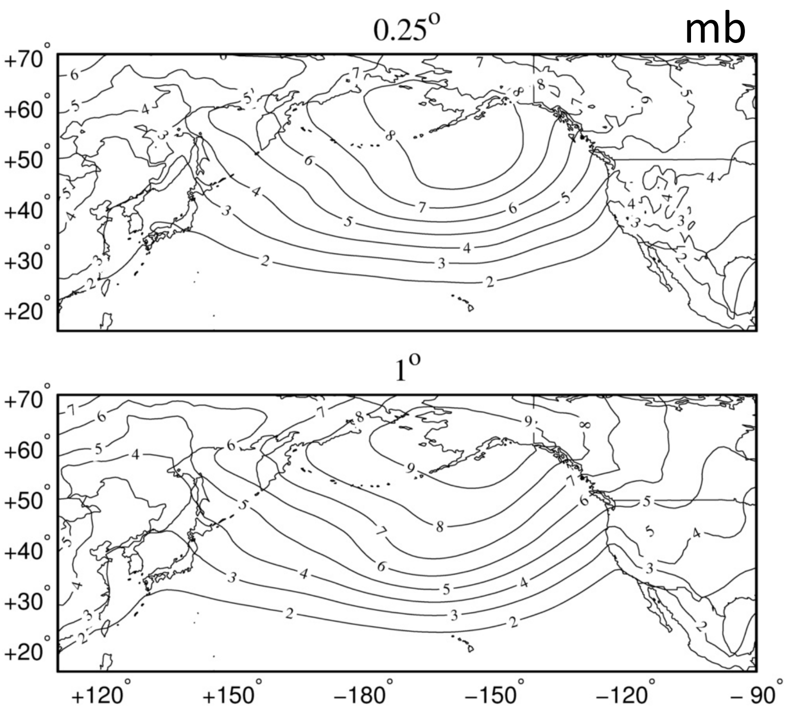
These differences may not appear all that large, but result in vastly different larger-scale outcomes…

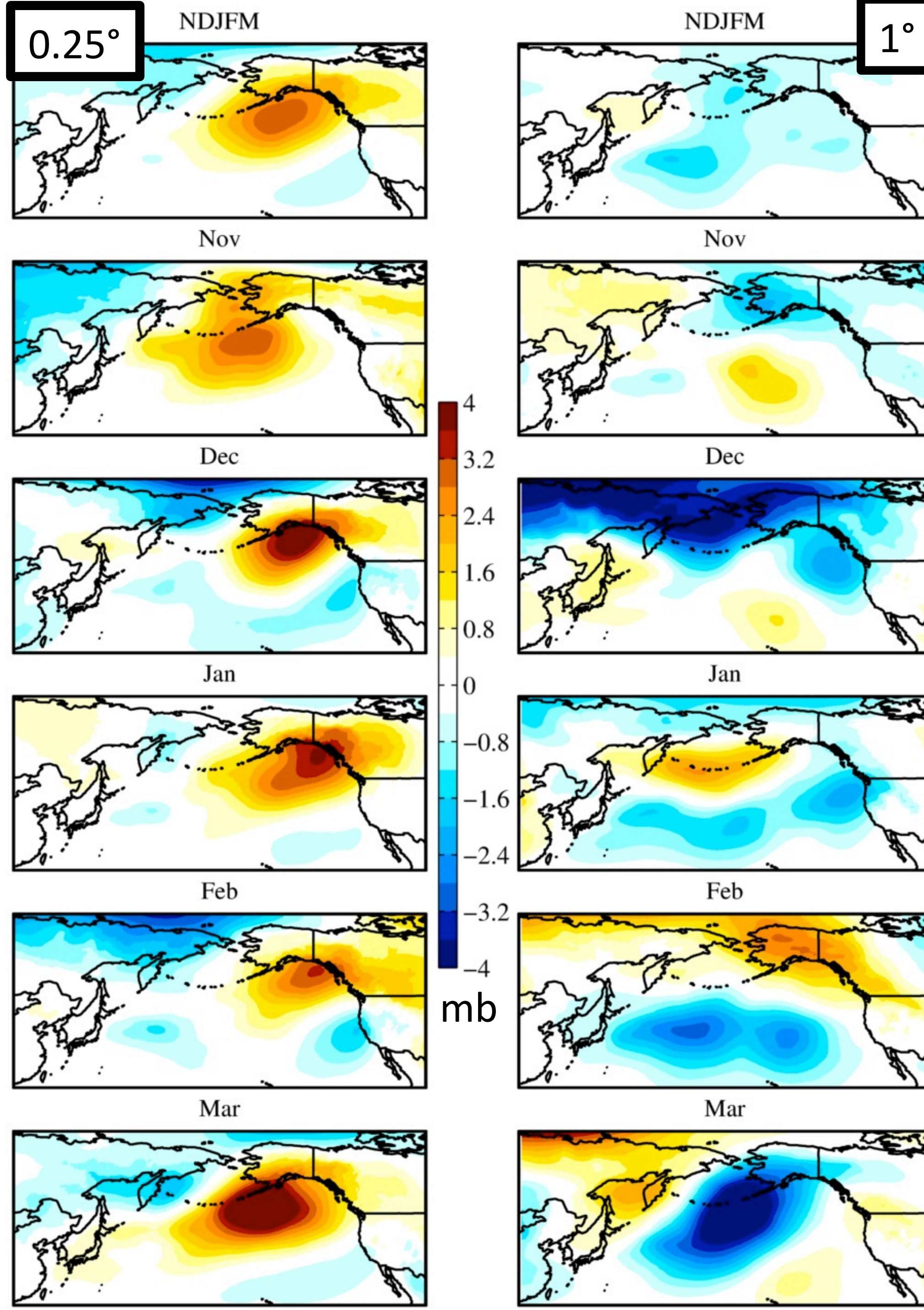
Comparison between 0.25° and 1° simulations

(Right) The NDJFM and month by month mean difference in SLP.

Observations aside, the 0.25° is relatively self-consistent across different months. The 1° is not.

(Below) σ_{SLP} during NDJFM is about 10% higher in the 1° simulation





Simplest hypothesis: The large-scale circulation differences between the HR and LR could be the result of a stronger anomalous vertical frontal circulation that should be present in sharper HR front.

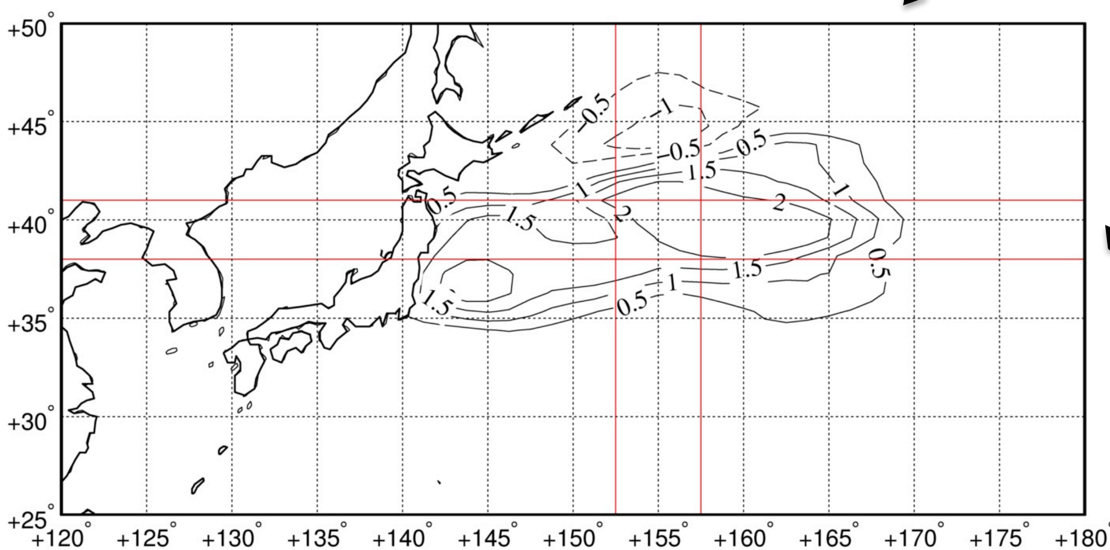
Investigate the frontal circulation…

LR & HR comparison: Frontal circulation

First, inspect any differences in the "mean" state using cross-front and along-front vertical motion (ω) and total diabatic heating (Q_{DIAB}) x-sections from the 0.25° and 1° warm simulations averaged over **DJF** using monthly-mean data. Second, compare difference between WARM-COLD.

Across-front (zonal average)

ΔSST



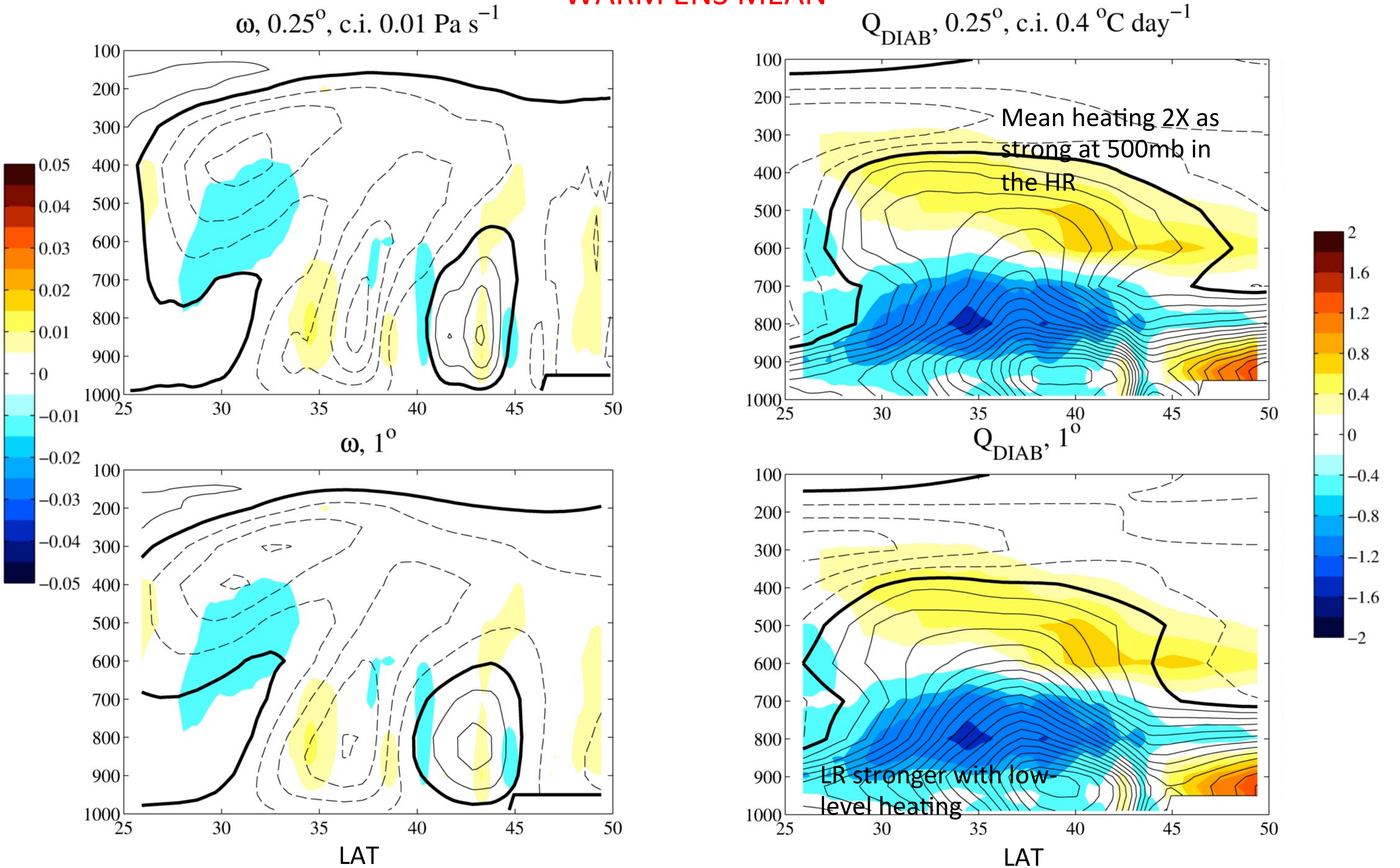
Along-front (meridional average)

Slides 6 & 9 compare the mean state of the warm LR and HR simulations. Contours show the mean, colors show the mean difference between LR and HR (LR was interpolated onto HR grid)

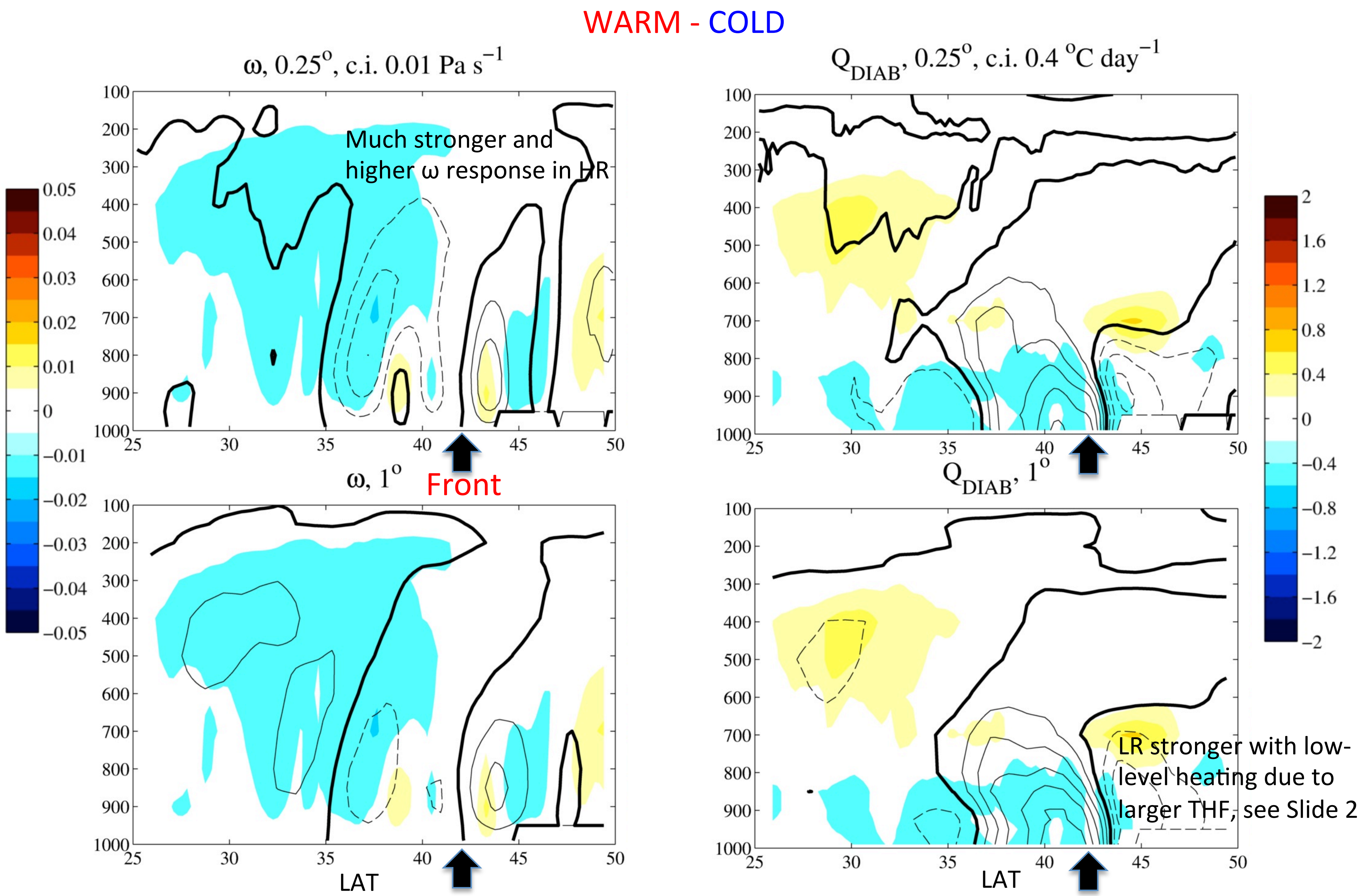
Slides 7 & 10 compare the mean difference (warm-cold) for the LR and HR simulations. Contours show the mean difference, colors shows the difference of the mean difference: $(W\text{-}C)|_{HR} - (W\text{-}C)|_{LR}$

LR & HR mean comparison: Across Front

WARM ENS MEAN

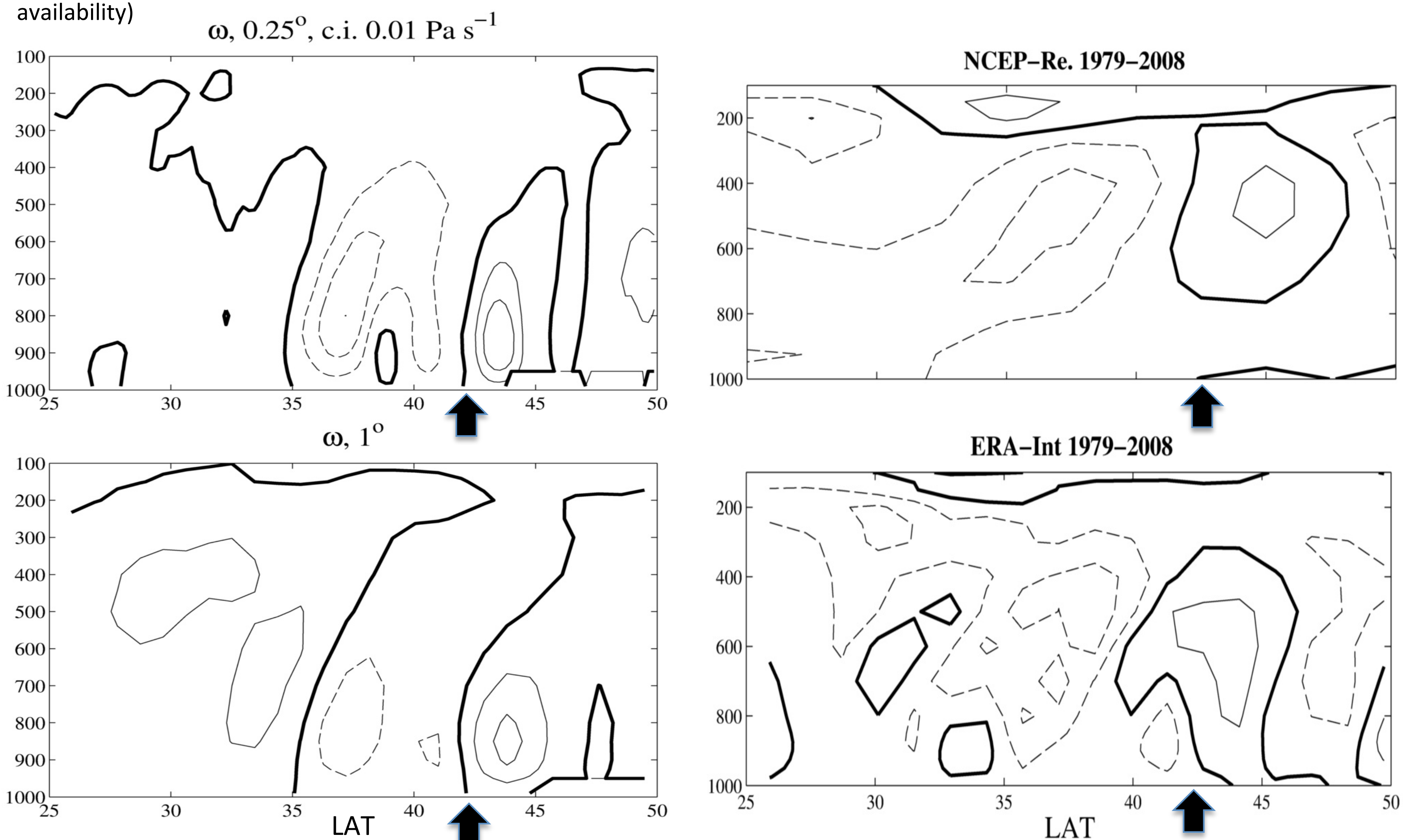


LR & HR mean difference comparison: Across Front



Comparison with observations: across front

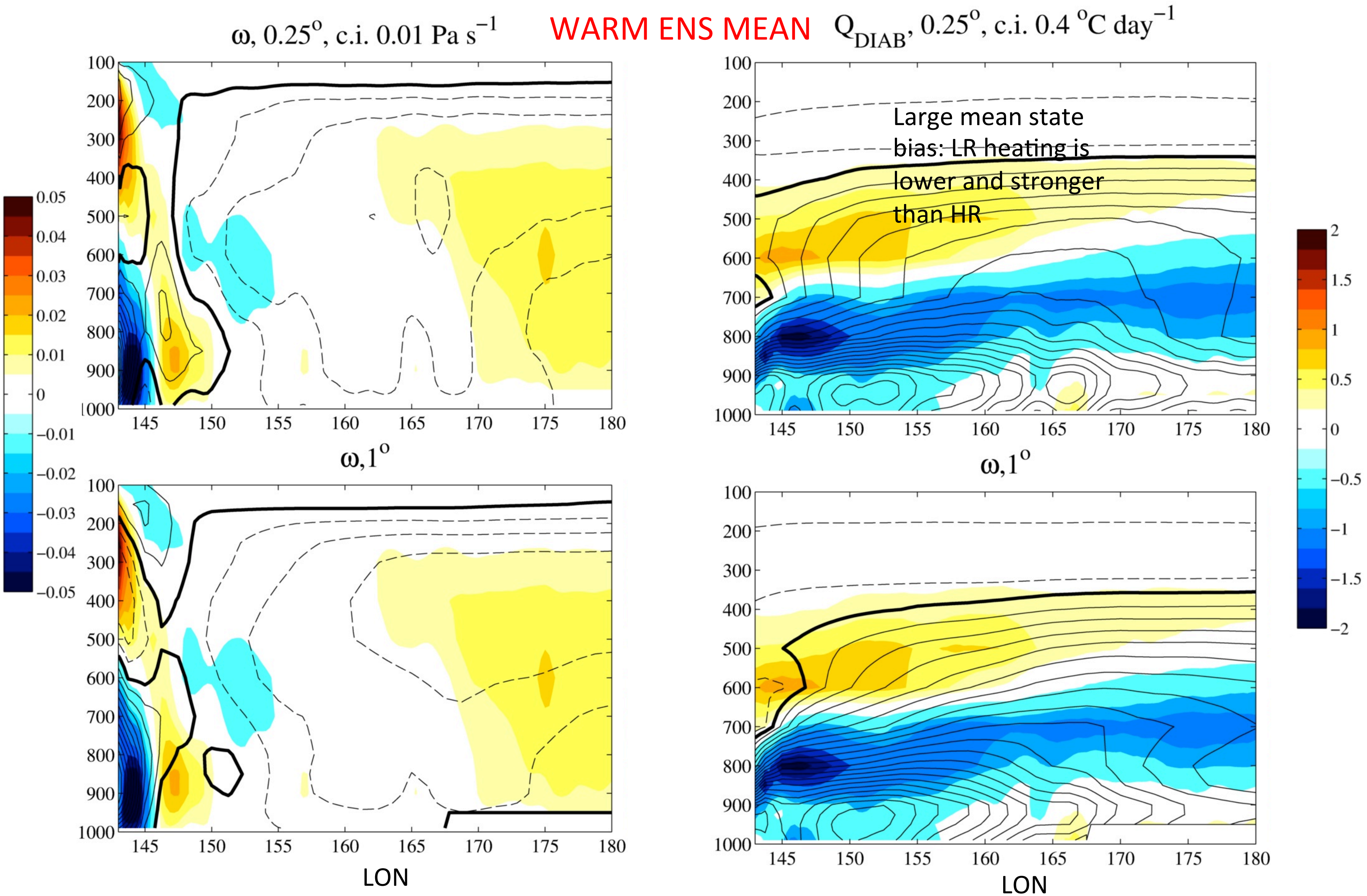
Regress extended OEI onto monthly averaged ω using [T63] NCEP-Reanalysis and [T85] ERA-Int over 1979-2008 (period of ERA-Int availability)



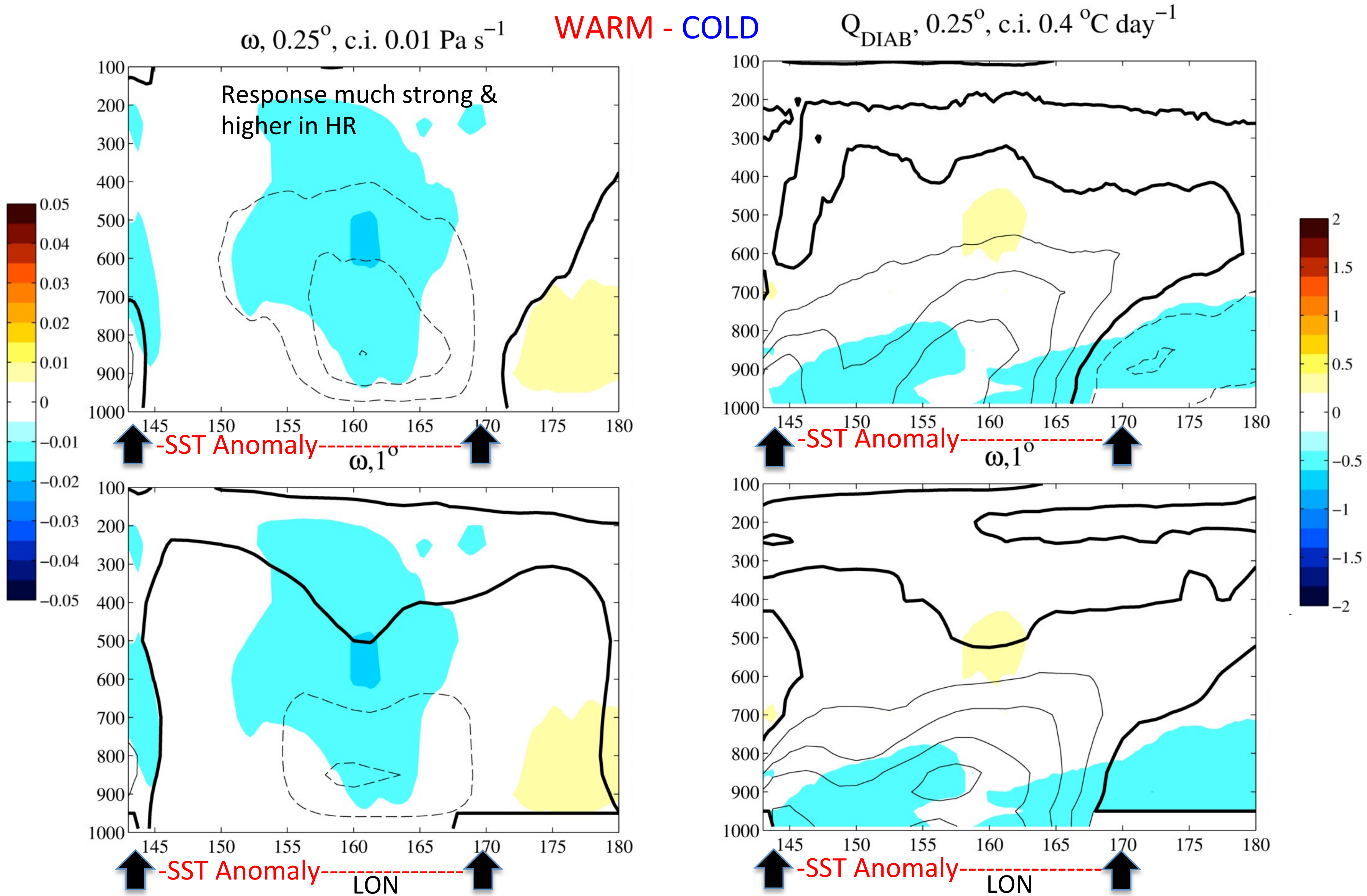
- Suggests 1° CAM strongly underestimates vertical circulation strength and depth.

- Suggests ERA-Int may be a superior tool for observational comparison. Need to investigate other high-res datasets…

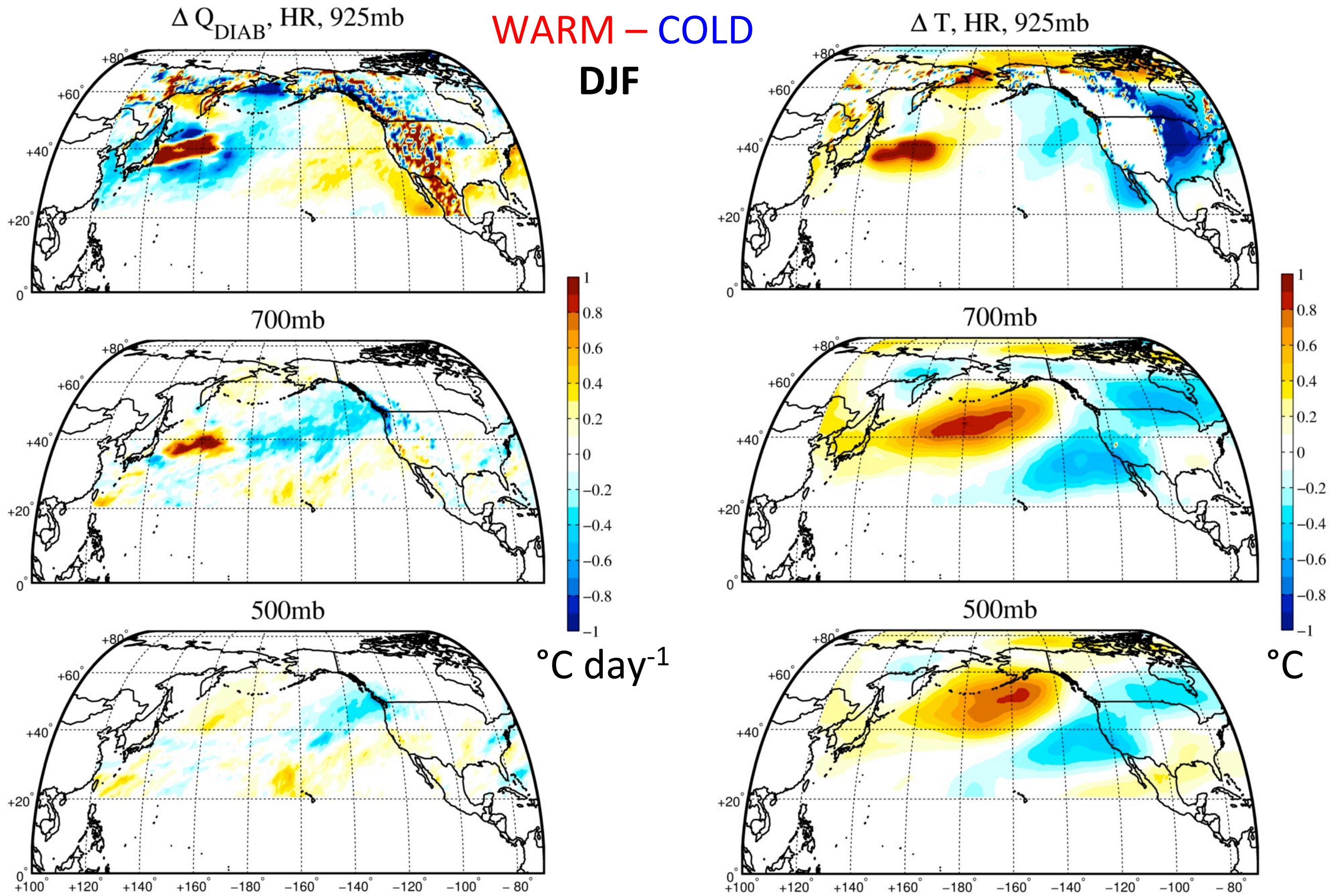
LR & HR mean comparison: Along Front



LR & HR mean difference comparison: Along Front



Q_{DIAB} response is very strong, what about air temperature?



Q_{DIAB} is only directly responsible for the local, low-level warming. A thermodynamic budget will reveal the processes responsible for the downstream warming.

Thermo budget: intro

$$\bar{u}\frac{\partial \bar{T}}{\partial x} + \bar{v}\frac{\partial \bar{T}}{\partial y} + \frac{\partial}{\partial x}\overline{u'T'} + \frac{\partial}{\partial y}\overline{v'T'} + \left[\frac{\kappa}{p}\overline{\omega}\overline{T} - \overline{\omega}\frac{\partial \bar{T}}{\partial p}\right] + \left[\frac{\kappa}{p}\overline{\omega'T'} - \frac{\partial \overline{\omega'T'}}{\partial p}\right] = \overline{Q}\{+RES\}$$

A B C D E F G H

METHODOLOGY – PART 1

- Herein, the focus on the equilibrated response. In fact, the DJF mean temperature response (shown in previous slide) is representative of Dec, Jan & Feb individually (not shown)
- Define $X = \overline{X} + X'$ where (‘) denotes a deviation from each warm and cold ensemble’s *overall* mean for that month (i.e. not mean of each warm ensemble). Calculate the balance of terms separately for warm and cold ensemble means for each month. Take the average across DJF. Look at the term-by-term difference.
- The null hypothesis is the mean climate is different between the warm and cold [i.e. if that were not the case, we would use Xbar = ½(Xw+Xc)]
- Eddy terms are estimated using monthly average data, e.g. $\overline{v'T'} = \overline{vT} - \bar{v}\bar{T}$
- Residual confirmed to be <=5% of Q_{DIAB}
- Follow similar logic as before: first compare the HR and LR warm means (slides 13-16), then compare the difference between $(W\text{-}C)|_{HR}$ and $(W\text{-}C)|_{LR}$ (slides 17-19)

Thermo budget: mean (850mb)

Term by term analysis for the HR **warm** ensembles averaged over DJF

Negligible, <5% of Q_{DIAB}, not shown hereafter

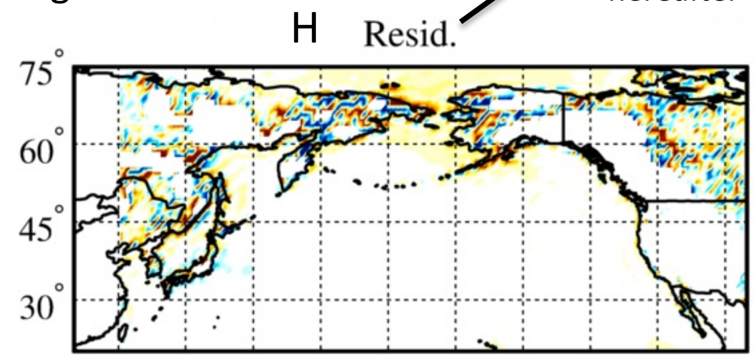
A+B: net *mean* horizontal heat transport

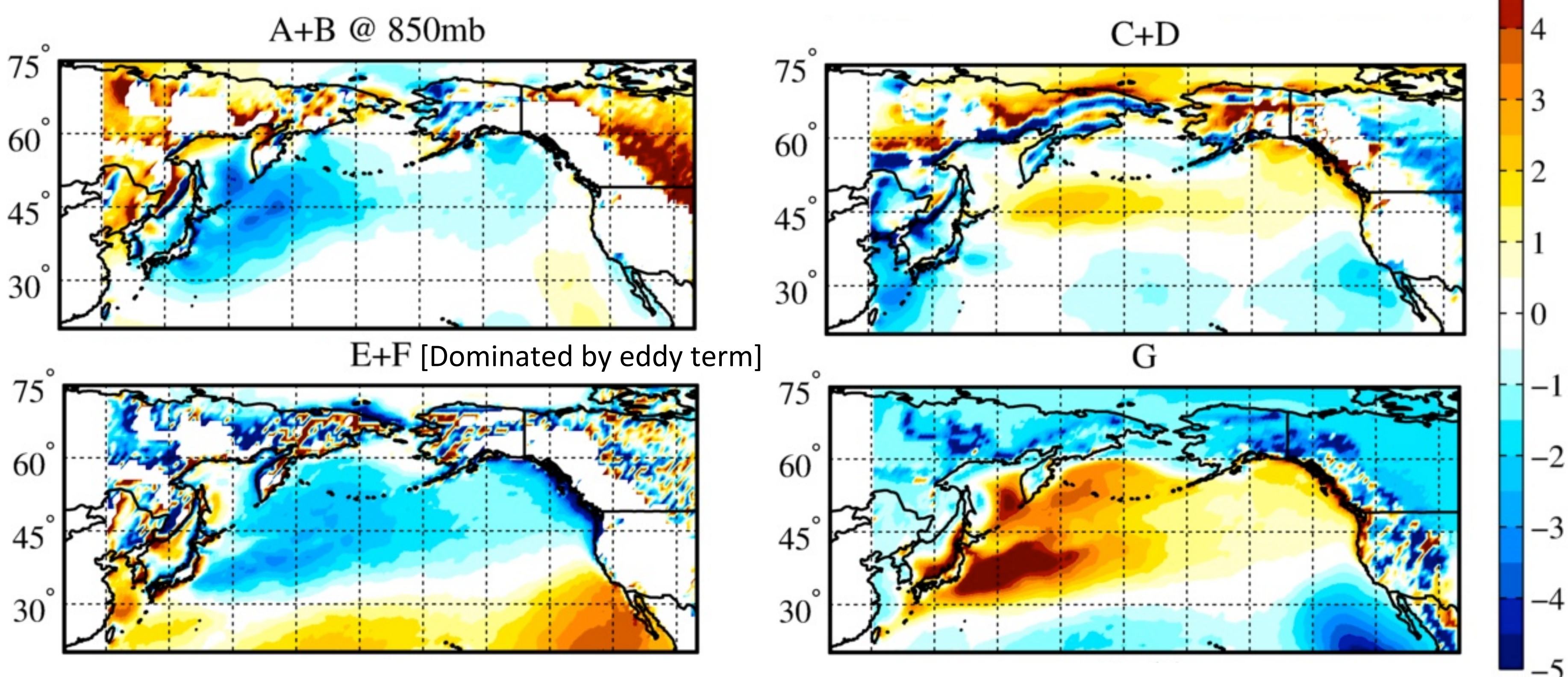
C+D: net *eddy* horizontal heat transport

E+F: net vertical transport (mean + eddy)

G: Net diabatic heating

H: Residual

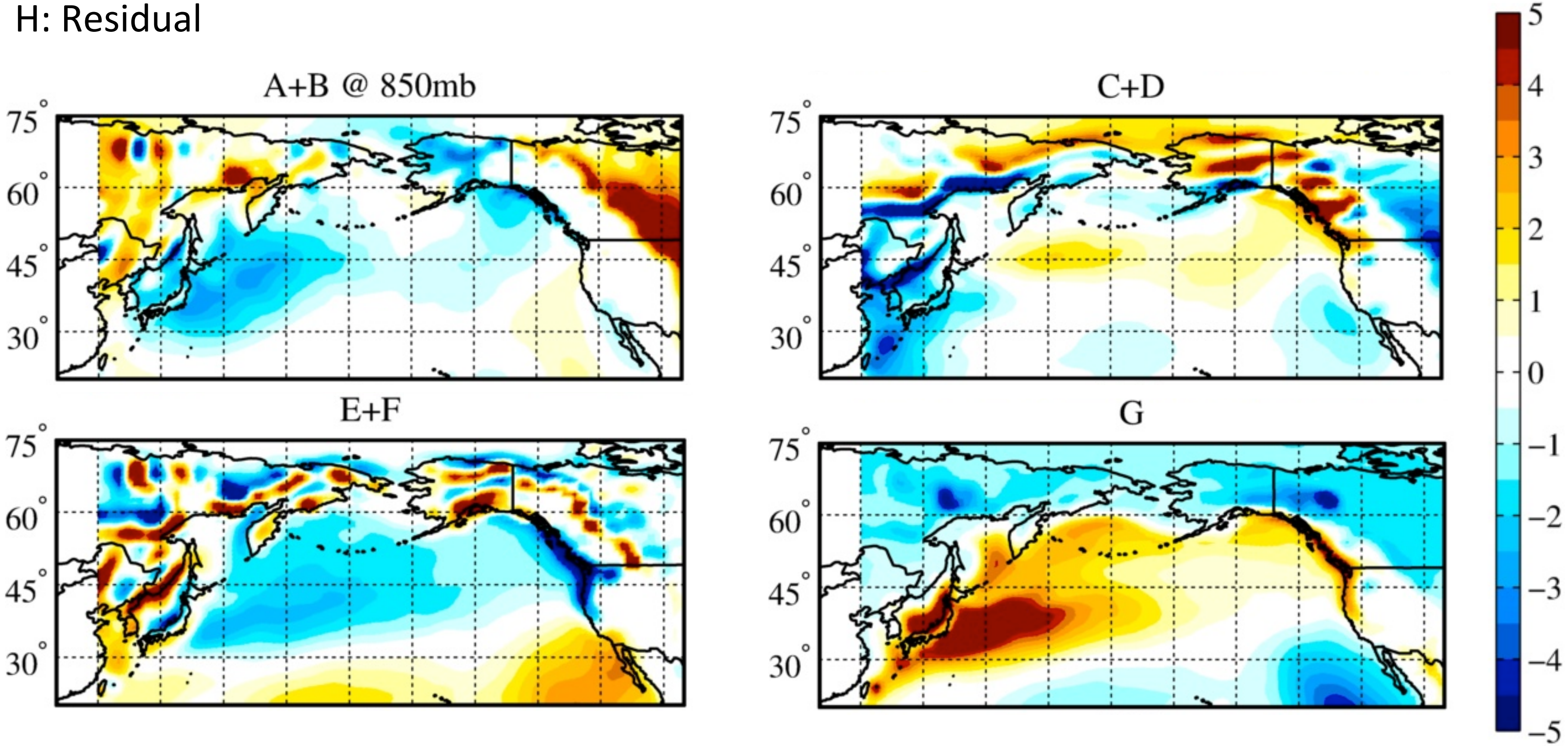




Thermo budget: mean (850mb)

Term by term analysis for the LR **warm** ensembles averaged over DJF

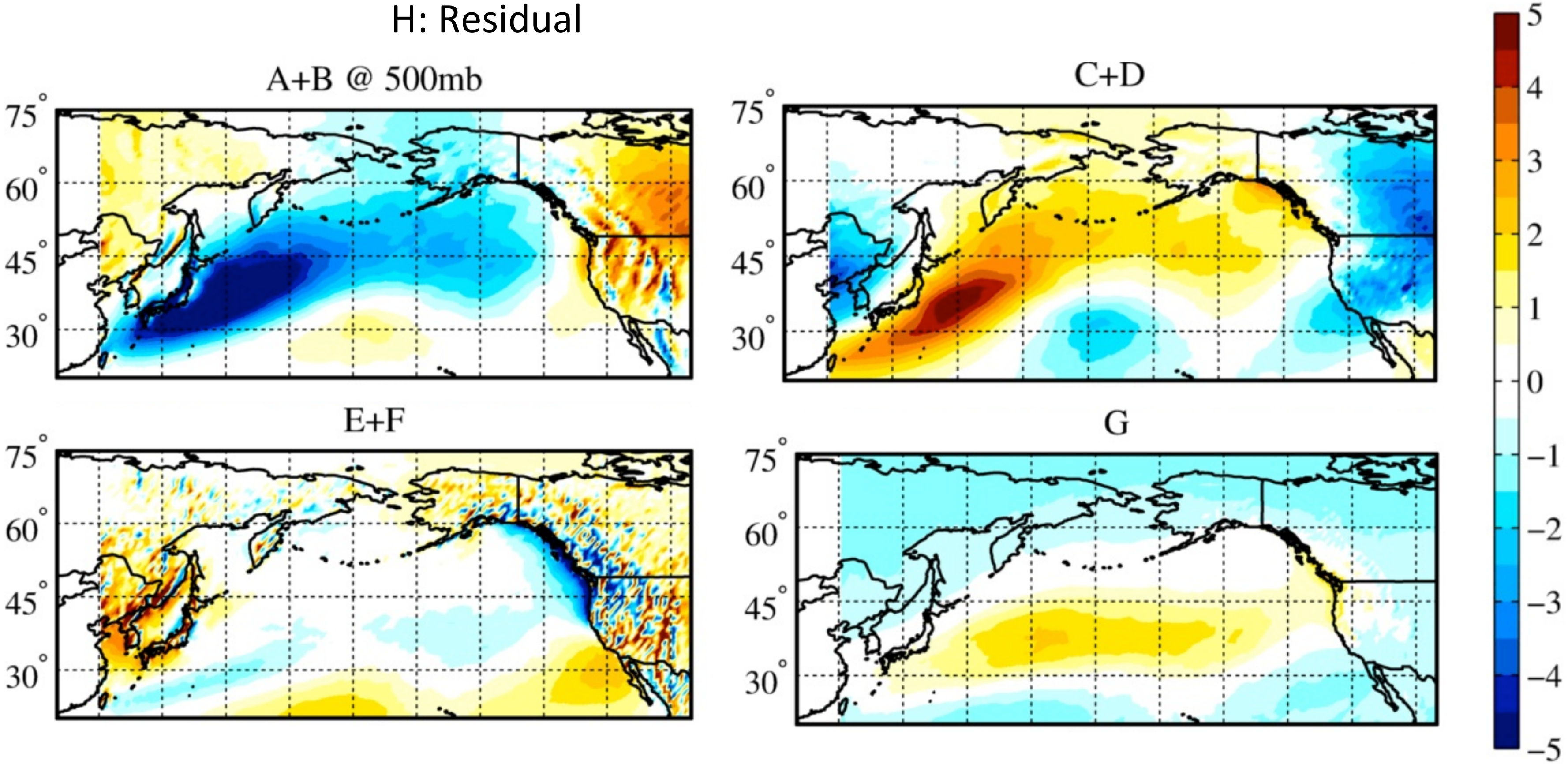
A+B: net *mean* horizontal heat transport
C+D: net *eddy* horizontal heat transport
E+F: net vertical transport (mean + eddy)
G: Net diabatic heating
H: Residual



Thermo budget: mean (500mb)

Term by term analysis for the HR **warm** ensembles averaged over DJF

A+B: net *mean* horizontal heat transport
C+D: net *eddy* horizontal heat transport
E+F: net vertical transport (mean + eddy)
G: Net diabatic heating
H: Residual



Thermo budget: mean (500mb)

Term by term analysis for the LR **warm** ensembles averaged over DJF

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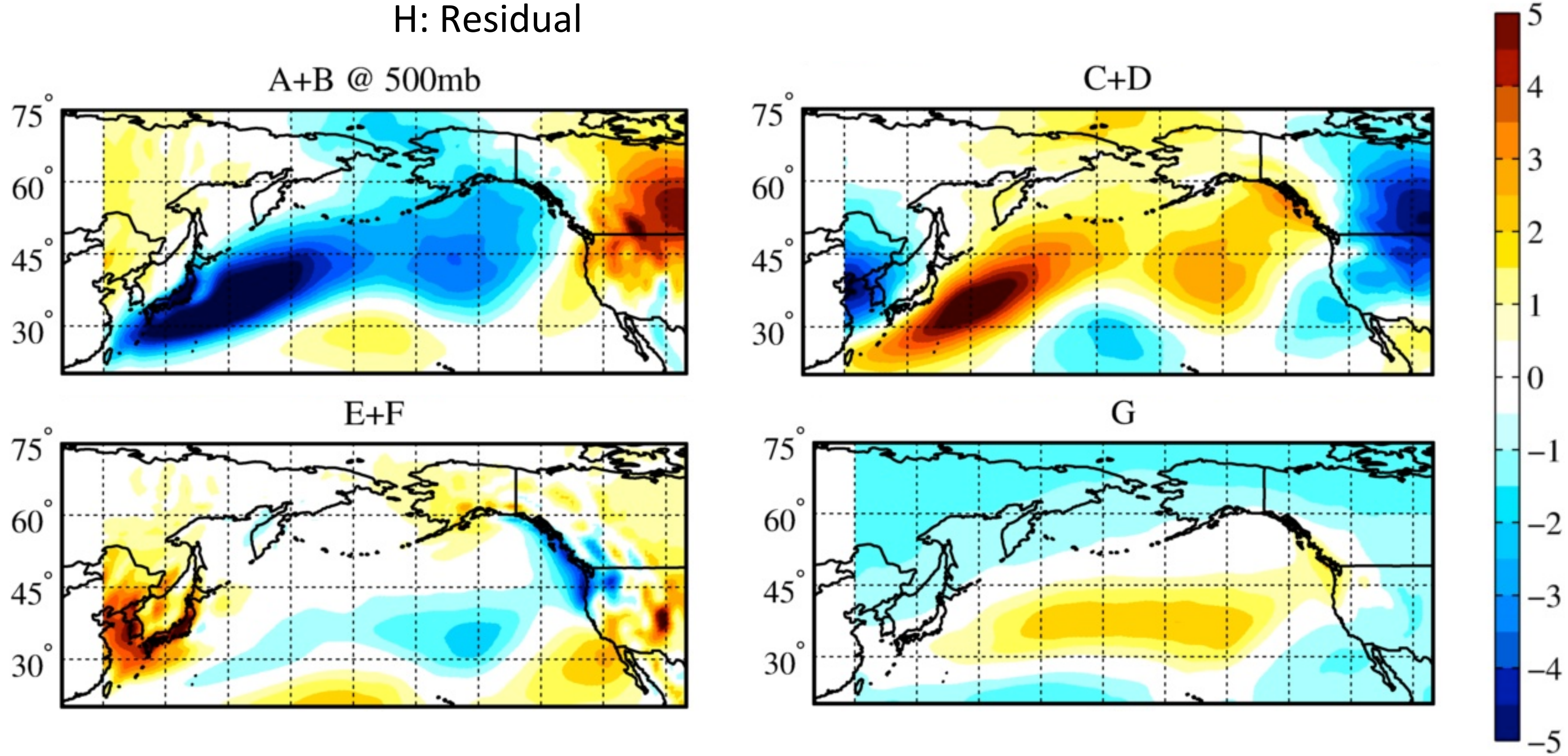
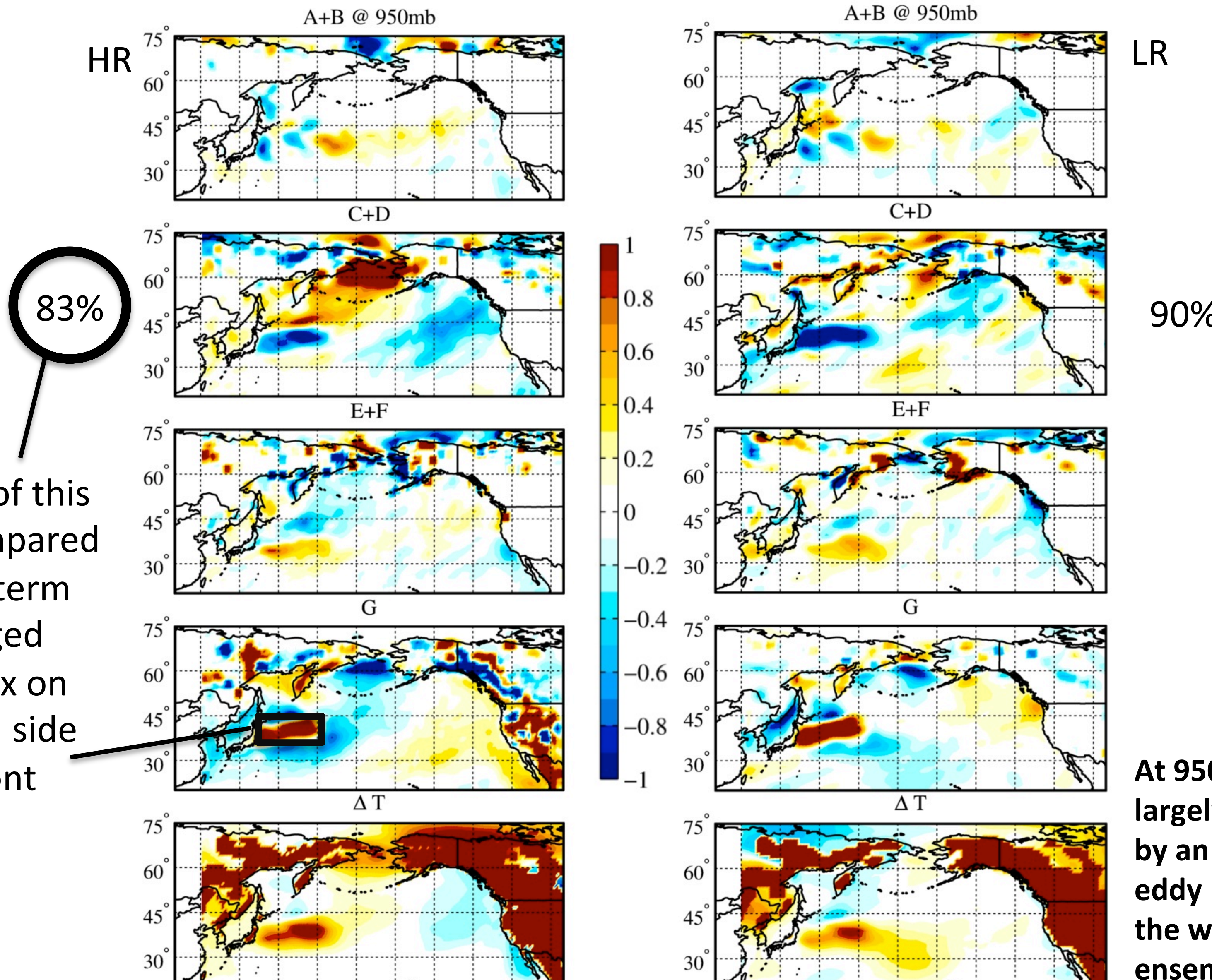


Thermo budget: mean difference (950mb)



Fraction of this term compared to Q_{DIAB} (term G) averaged over a box on the south side of SST front

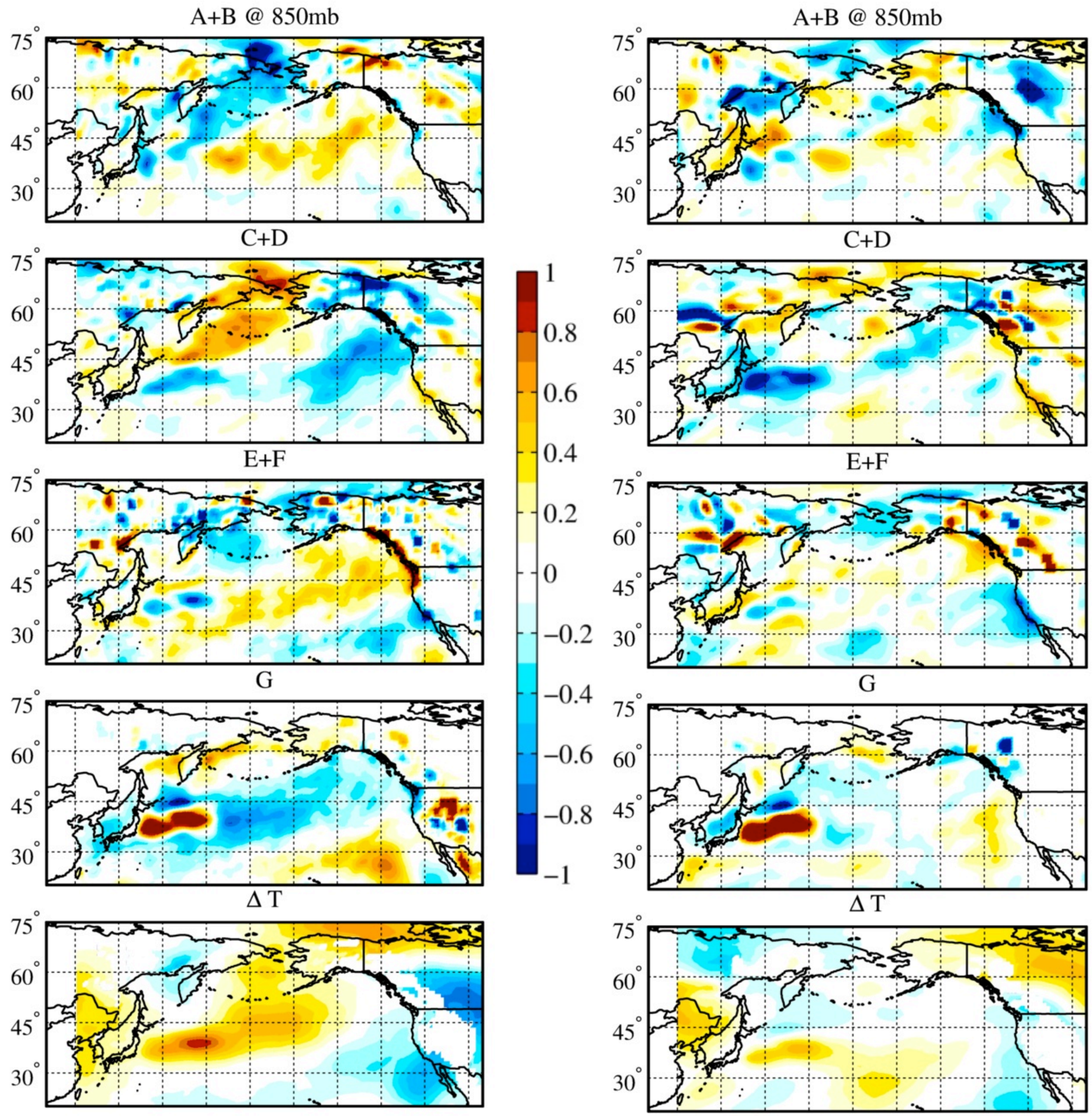
At 950mb, Q_{DIAB} is largely balanced by an increase in eddy heat flux in the warm ensembles

Thermo budget: mean difference (850mb)

HR

46%

39%



LR

71%

16%

At 850mb, Q_{DIAB} is now balanced by a combination of upward heat flux (E+F) and horizontal eddy heat flux (C+D). LR puts much more emphasis on horizontal eddy heat transport

Thermo budget: mean difference (700mb)

HR

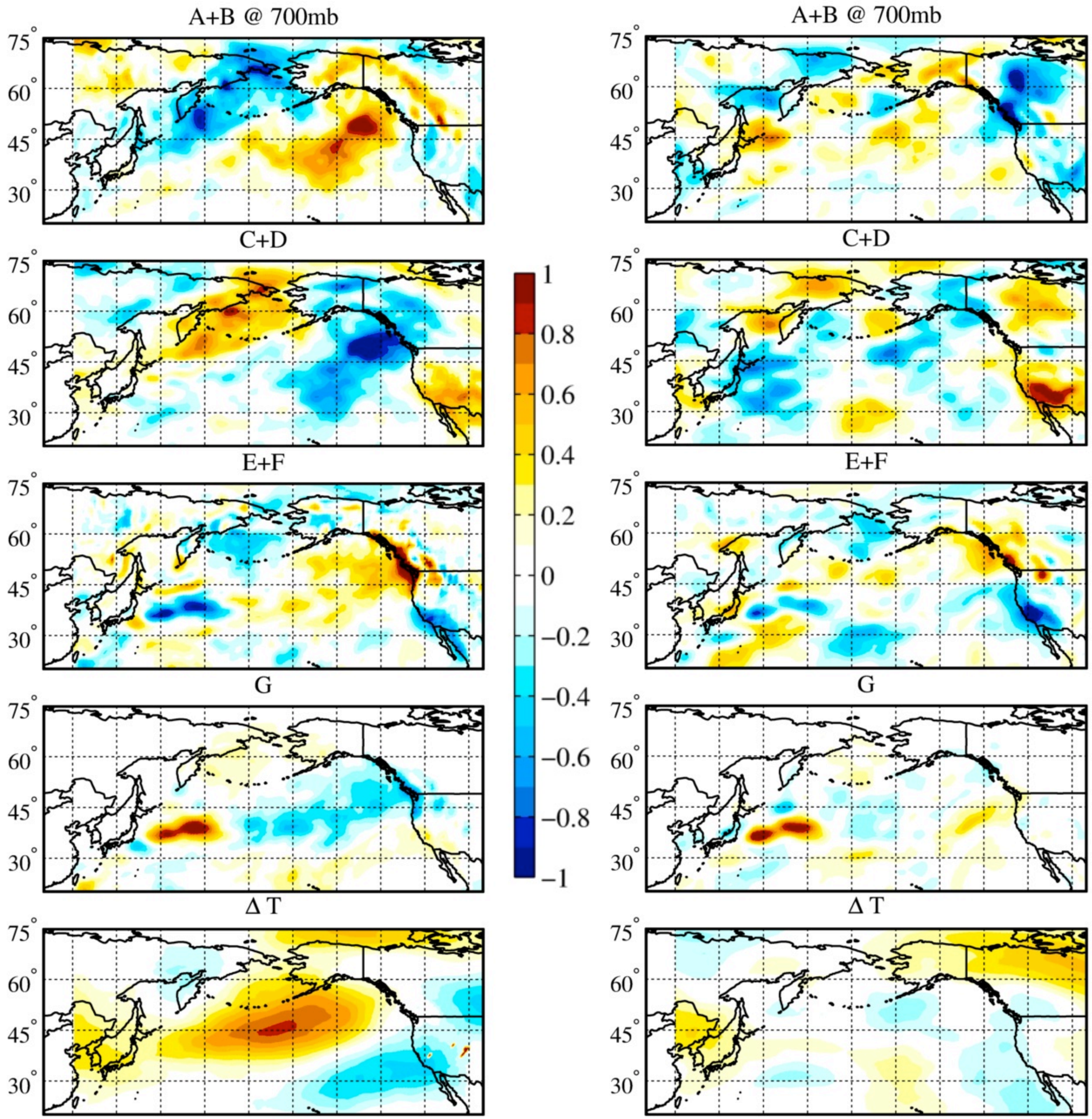
LR

<1%

59%

88%

53%



At 700mb, very large discrepancy in how Q_{DIAB} is balanced. LR continues to favor horizontal eddy transport. HR suggests vertical heat transport.

Conclusions

- The 0.25° version of CAM5 shows several clear advantages over the 1°, despite its large computational costs (~32X more than 1°):
  - More realistic depiction of low-level horizontal circulation (1° too deep with [-] SLP over warm SST). This causes the 1° to have a *larger* ΔTHF by 10%.
  - Significantly higher and stronger (50%) vertical motion over immediate frontal region
    - But even the 0.25°CAM5 may be underestimating ω compared to obs. (slide 8, Minobe et al., 2010)
- A thermodynamic budget reveals the implications of a stronger vertical frontal circulation:
  - Away from the surface, diabatic heating is largely balanced by horizontal eddy transport in the 1°, meanwhile it is balanced largely by vertical motion in the 0.25°
    - {SPLIT into v'T', u'T', etc.}
- Important implication since past studies suggest remote atmospheric forcing is more "efficient" when originates higher in the atmosphere (the ENSO atmospheric bridge; Hoskins and Karoly, 1981)

?'s still remaining

- Are the differences due to the higher-res SST field or the higher-res CAM5 atmospheric dynamics?
  - Shorten time-step in 1° from 30 min to 15 min
  - Investigate 0.25° AMIP simulation with effectively 1° SST (quick analysis shows that SLP response is also overestimated, though attribution is more difficult)
  - Using PUMA can show sensitivity to diabatic heating vertical depth (still working on getting this going at T85 resolution)
- Downstream response
  - Is the anomalous eqBT anticyclone the result of fewer storms? Weaker storms? More blocking? Look at daily or 3-hourly SLP distributions.

Oyashio Front Model Experiments:
“Do we really need to use 0.25°”?
YES