Preliminary Analysis of Wintertime Diabatic Heating Biases in UFS Prototype-P8

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Why Diabatic Heating?

- Subseasonal to seasonal predictability is largely due to the influence of slowly-varying boundary conditions
  - ENSO, other SST anomalies, soil moisture, etc.
- Direct influence of these surface anomalies on the atmosphere is limited and local
- Remote influence is communicated via the upper atmosphere through diabatic heating anomalies
  - E.g. Teleconnections or ‘atmospheric bridge’
- Diabatic heating is very difficult to observe directly
  - E.g., satellite measurements of condensation
  - Generally includes large observational uncertainties

- However, the diabatic heating field can be estimated through fundamental thermodynamics in conjunction with modern assessments of the full 3-dimensional state of the atmosphere

$$\frac{\partial \Theta}{\partial t} + \vec{u} \cdot \vec{\nabla} \Theta + \omega \frac{\partial \Theta}{\partial p} = \frac{1}{C_p} \left(\frac{p_0}{p} \right)^{\kappa} Q$$

Where $\theta = T \left(\frac{p_0}{p} \right)^{\kappa}$ is the potential temperature and = *dp/dt* (material derivative of pressure *p*)

<u>The left hand side can be evaluated every 6 hours from modern reanalyses to obtain 6-hourly estimates of at many pressure levels!</u>

Diabatic Heating Bias in UFS Prototype-P8

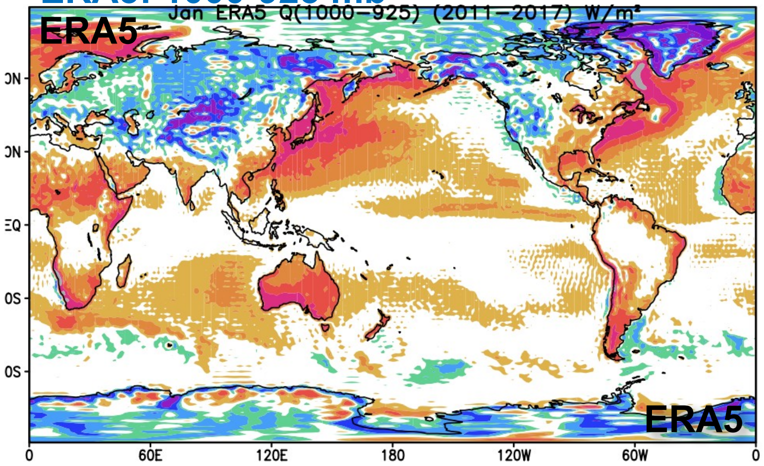
- Monthly mean diabatic heating diagnosed from January 01 starts for 2012-2018
  - Data obtained from https://registry.opendata.aws/noaa-ufs-s2s

- Assessed relative to monthly mean diabatic heating diagnosed from ERA5 for same dates

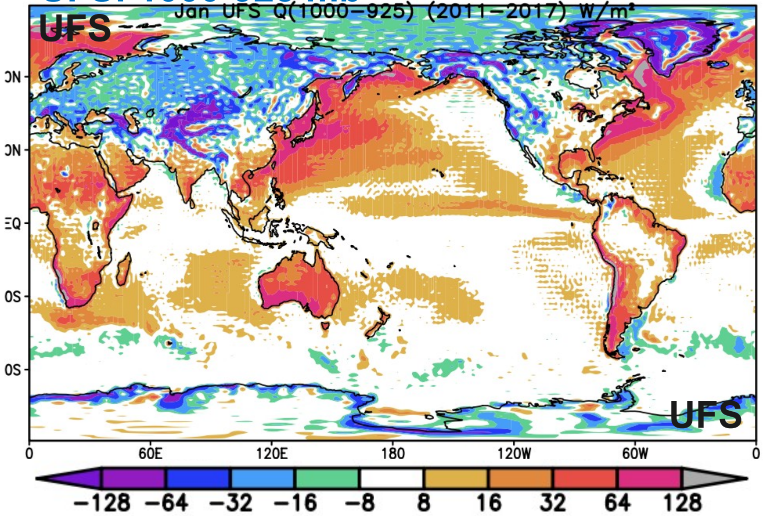
- Heating integrated over 9 layers
  - 1000-925; 925-850; 850-750; 750-650; 650-550; 550-450; 450-350; 350-200; 200-50
  - All results in units of W/m**2

Diabatic Heating Comparison

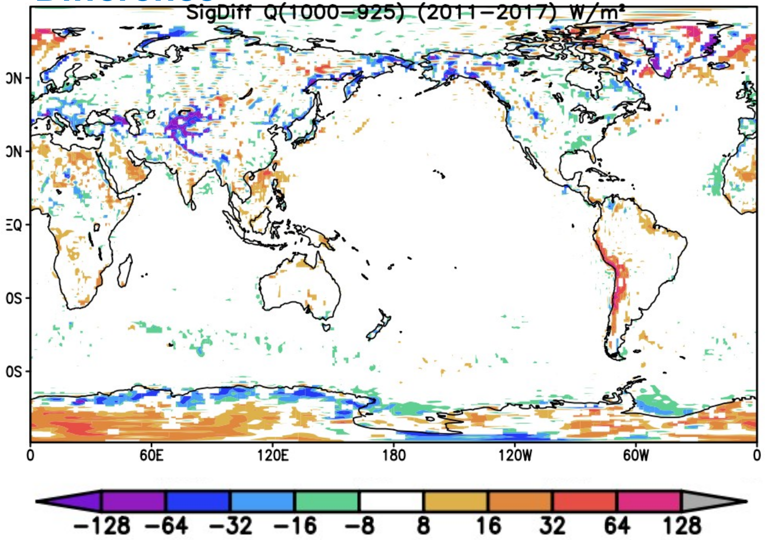
ERA5: 1000-925 mb



UFS: 1000-925 mb



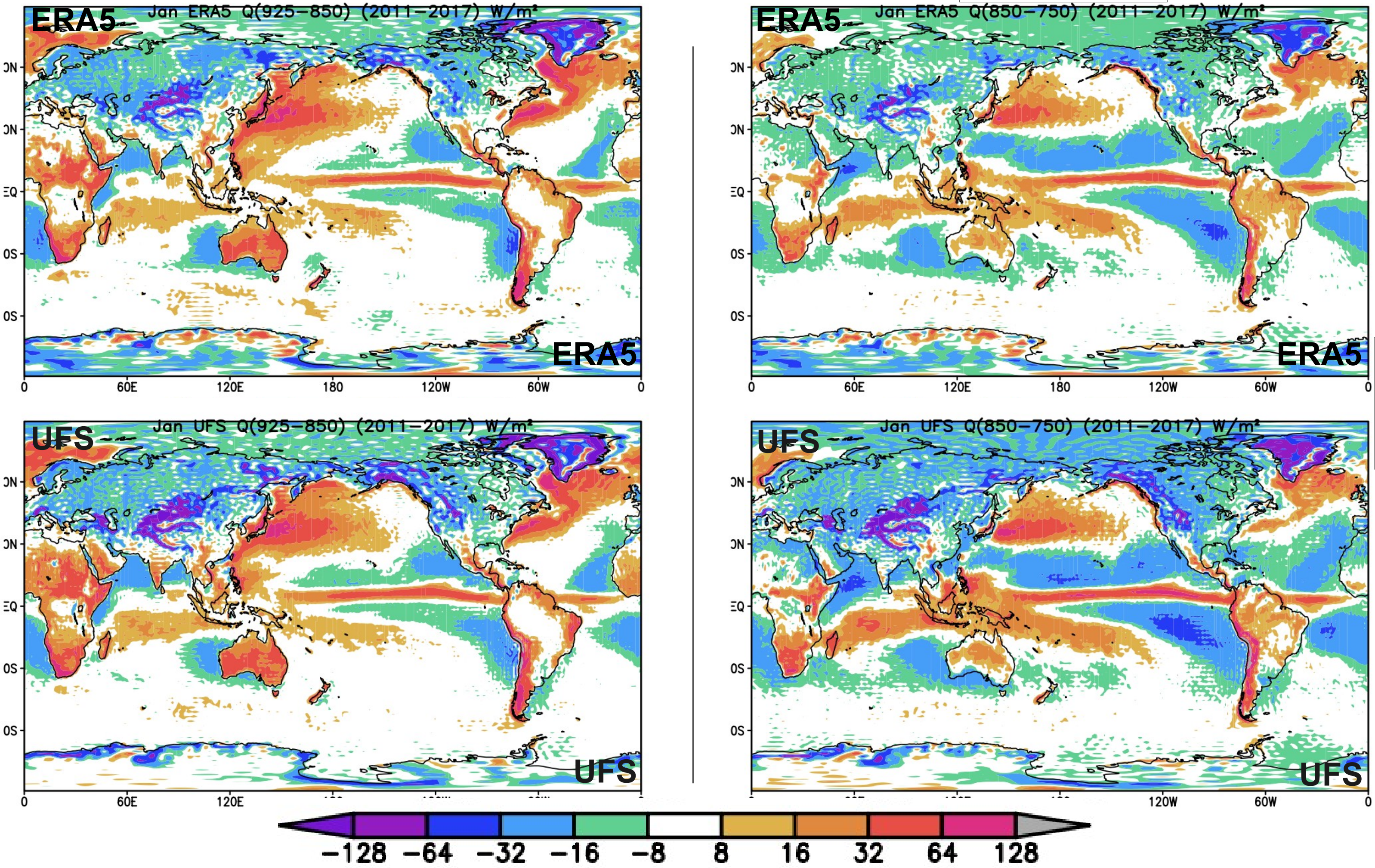
Difference



Close agreement at lowest levels

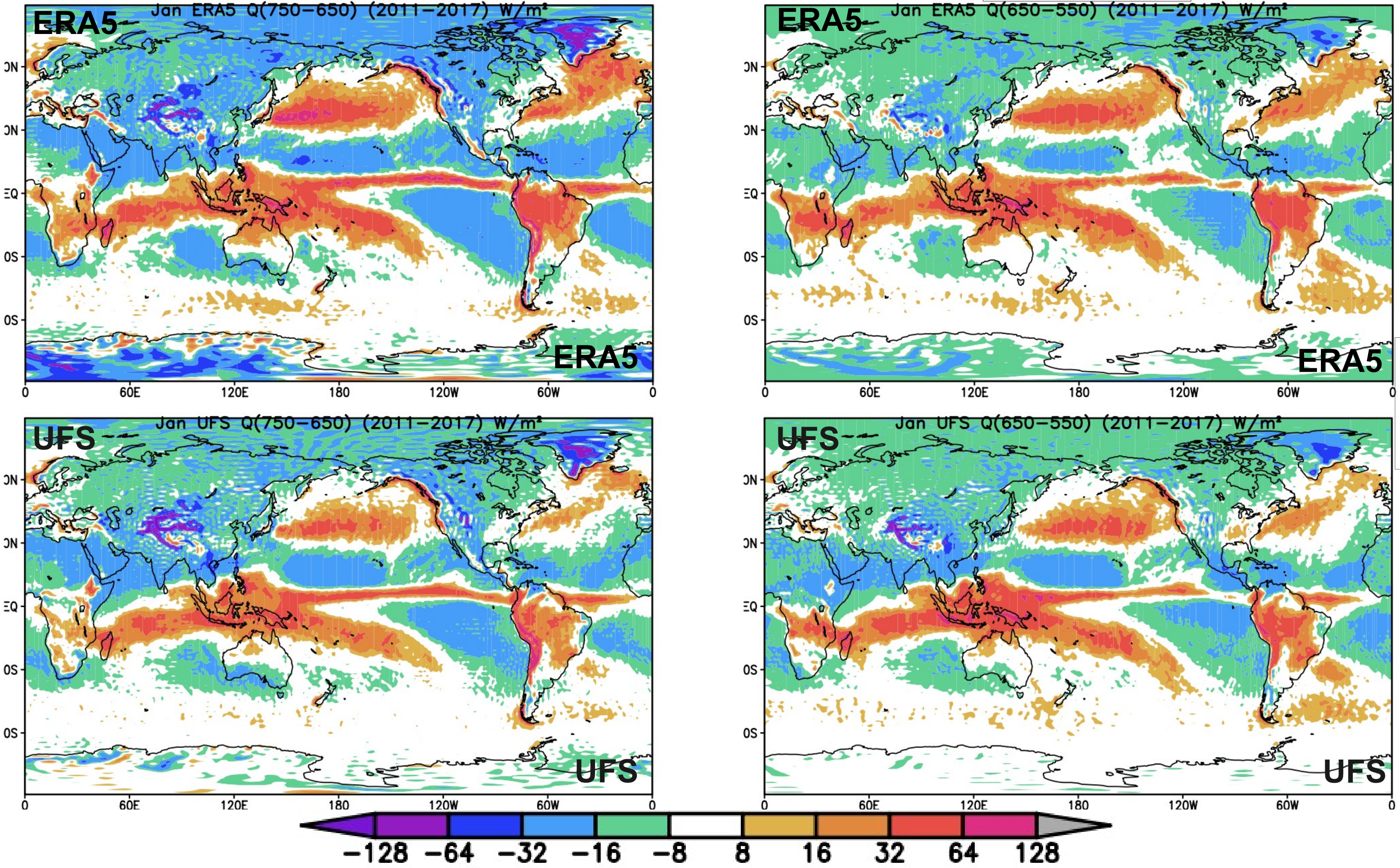
925-850 mb

850-750 mb



Close agreement maintained

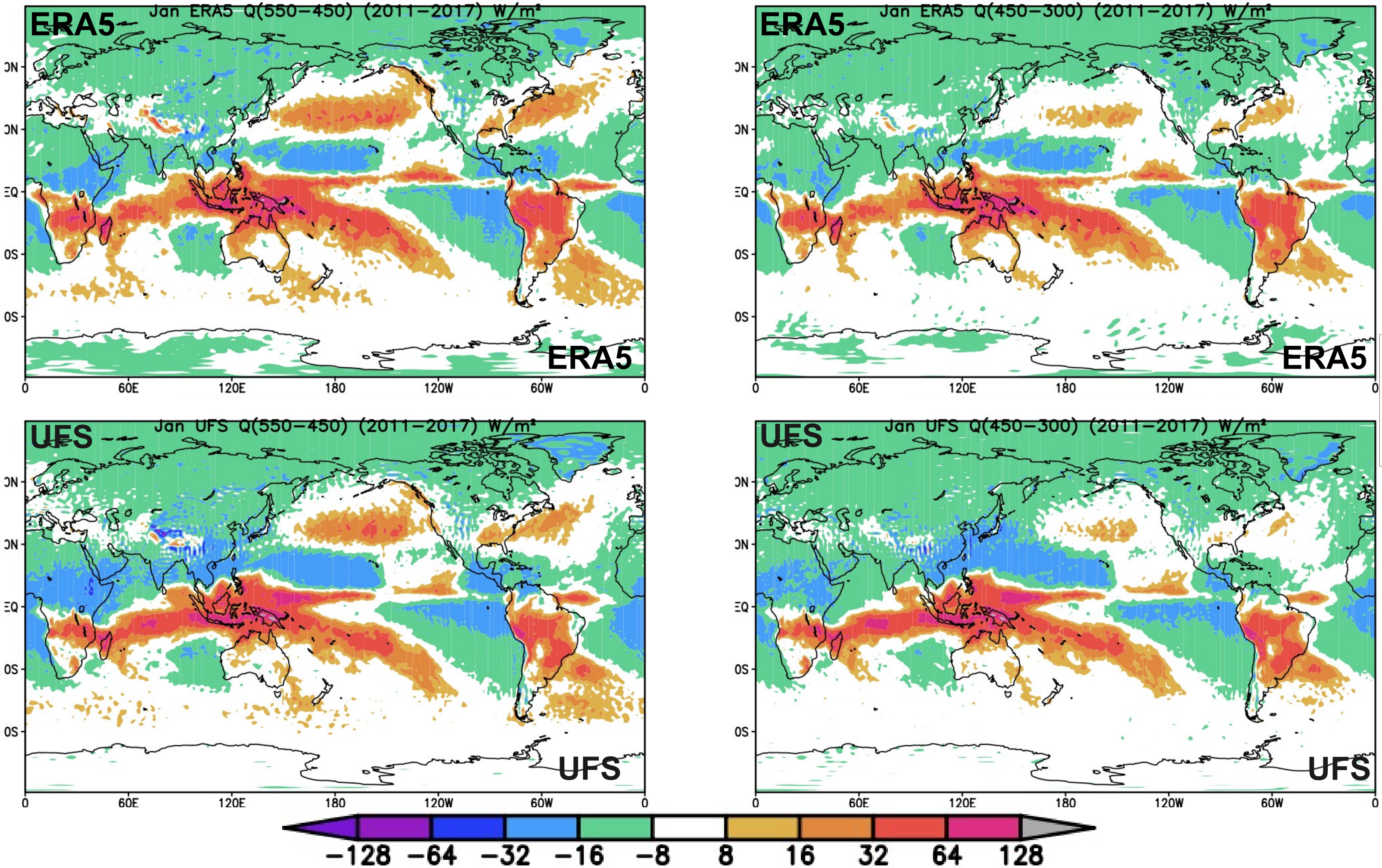
750-650 mb | **650-550 mb**



Close agreement maintained

550-450 mb

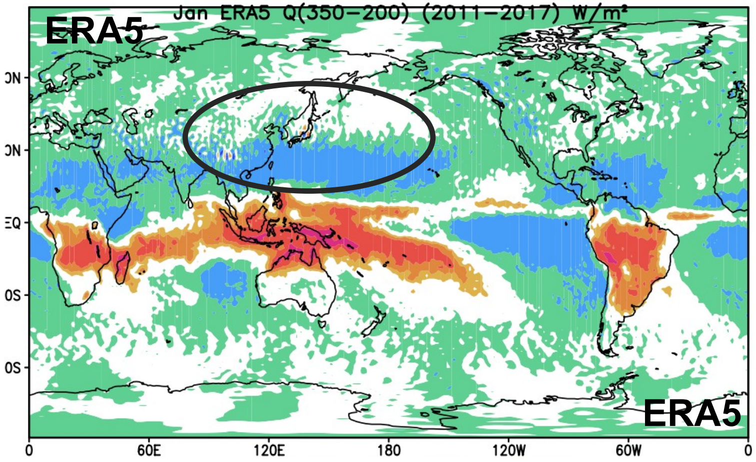
450-300 mb

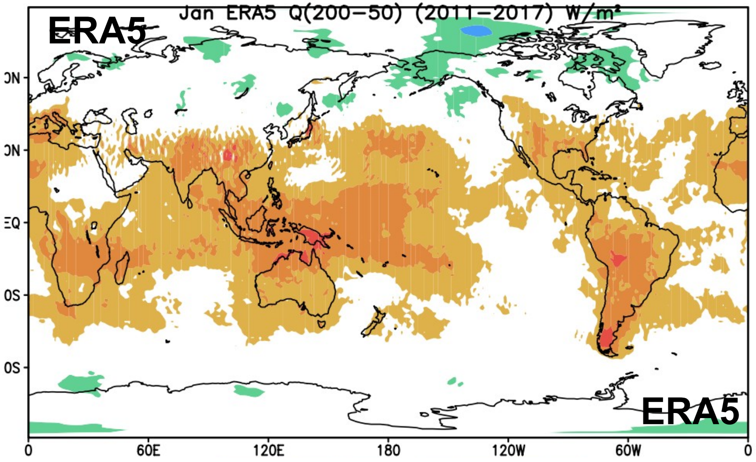


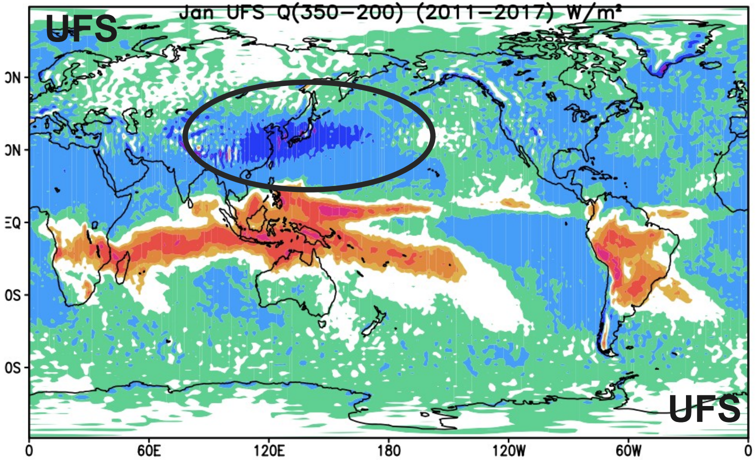
Close agreement maintained

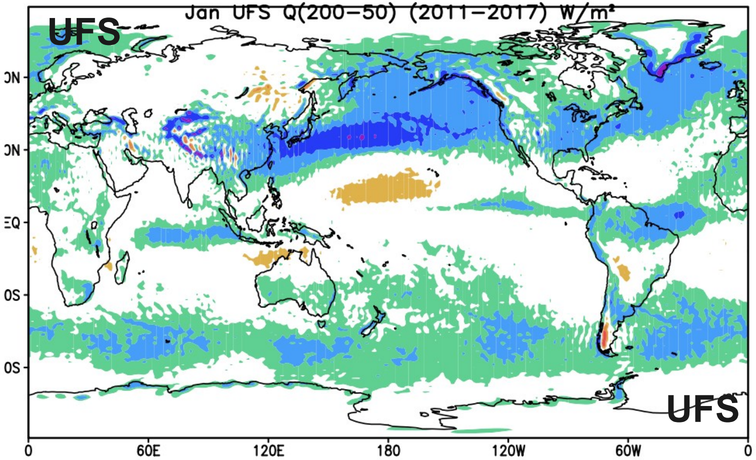
350-200 mb

200-50 mb



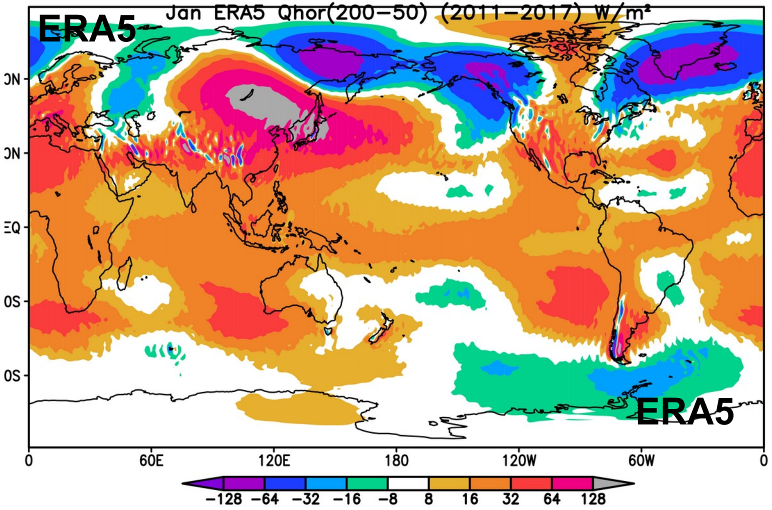


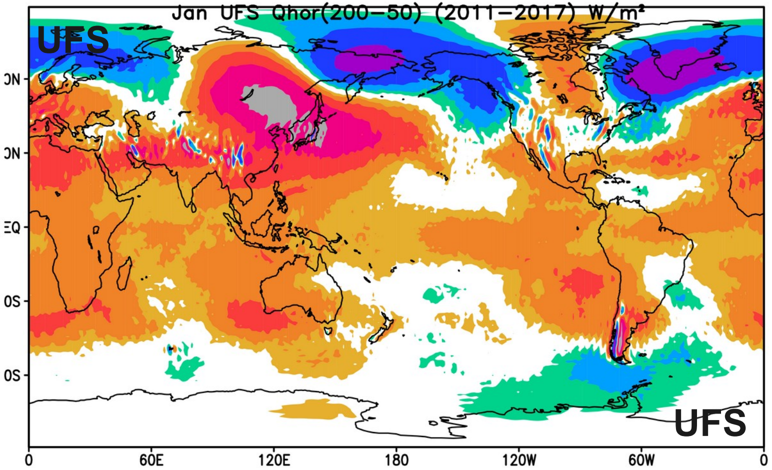




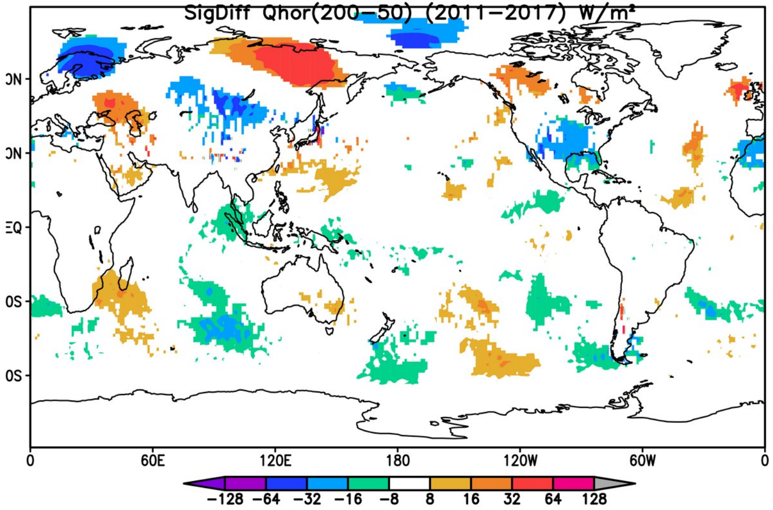
Large differences at upper levels

Horizontal Advection Component





Difference

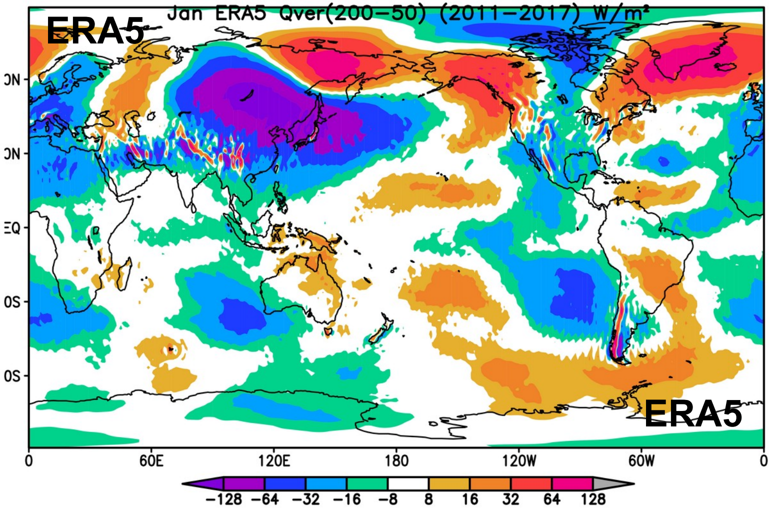


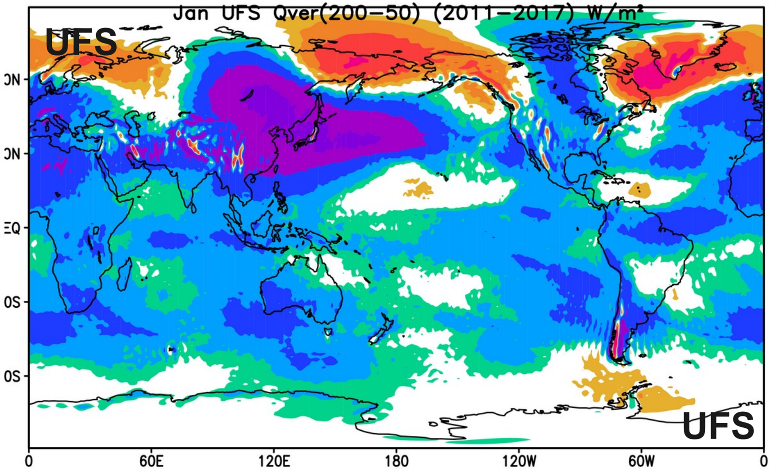
Contribution from Horizontal Advection Only

$$Q = c_p \left(\frac{p}{p_0}\right)^{\kappa}\left(\frac{\partial \theta}{\partial t} + \vec{u}\cdot\vec{\nabla}\theta + \omega\frac{\partial \theta}{\partial p}\right)$$

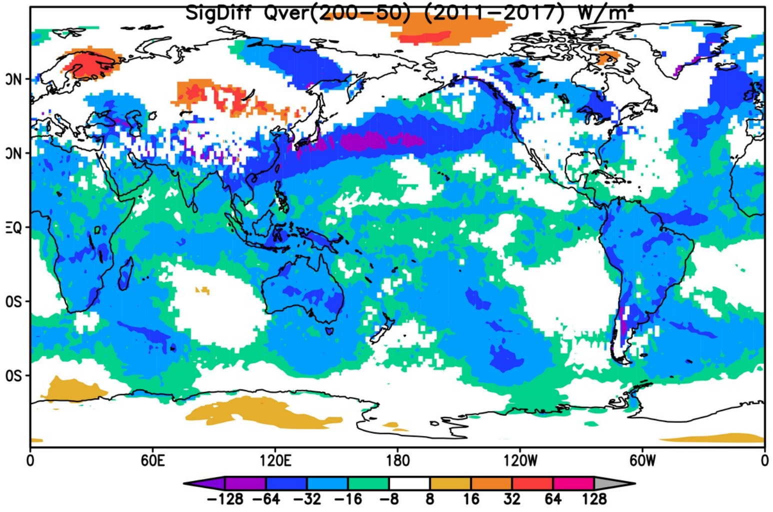
Minimal differences

Vertical Advection Component





Difference



Contribution from Vertical Advection Only

$$Q = c_p \left(\frac{p}{p_0}\right)^{\kappa} \left(\frac{\partial \theta}{\partial t} + \vec{u}\cdot\vec{\nabla}\theta + \omega\frac{\partial \theta}{\partial p}\right)$$

Majority of the differences

Conclusions

- Diagnosed diabatic heating closely matches ERA5 through most of the troposphere
  - Significantly too negative in the Northern Hemisphere January storm-track regions
  - Largest differences in the upper troposphere to lower stratosphere (200 – 50 hPa)

- Time average vertical advection term is responsible for this difference
  - Minimal differences in horizontal advection term
  - Mean static stability in this region is too low?
  - Dynamics of transients above the main storm track are faulty?

- Ongoing work
  - Further decomposition of vertical term
    - Requires longer runs than the 35 day Prototype runs
    - Analyzing seasonal runs performed on Frontera now
  - Impact of correcting bias on model fidelity and skill

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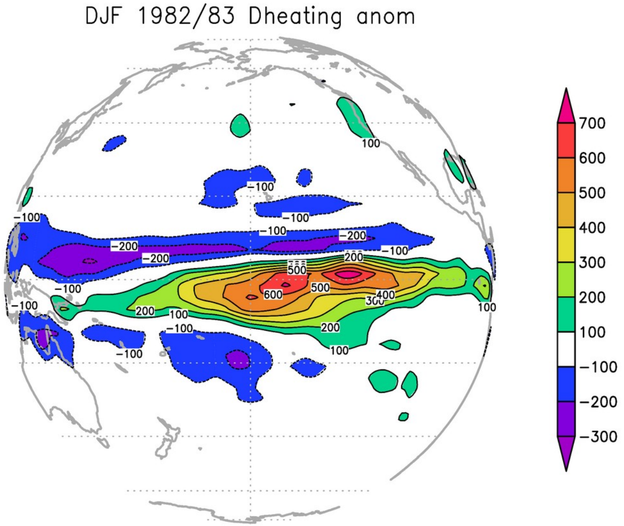
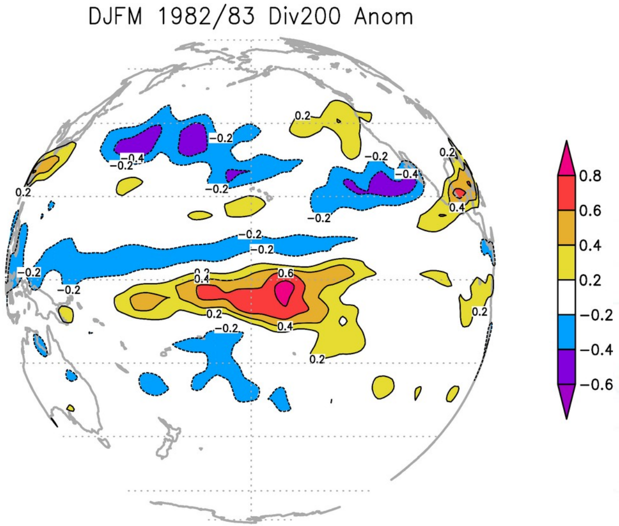
Additional Material

Example: Seasonal response to seasonal heating
Heating and divergence for the 1982/83 El Niño





DJF vertically integrated heating anomaly calculated from the residual method is collocated with the 200hPa divergence anomaly, as we would expect

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