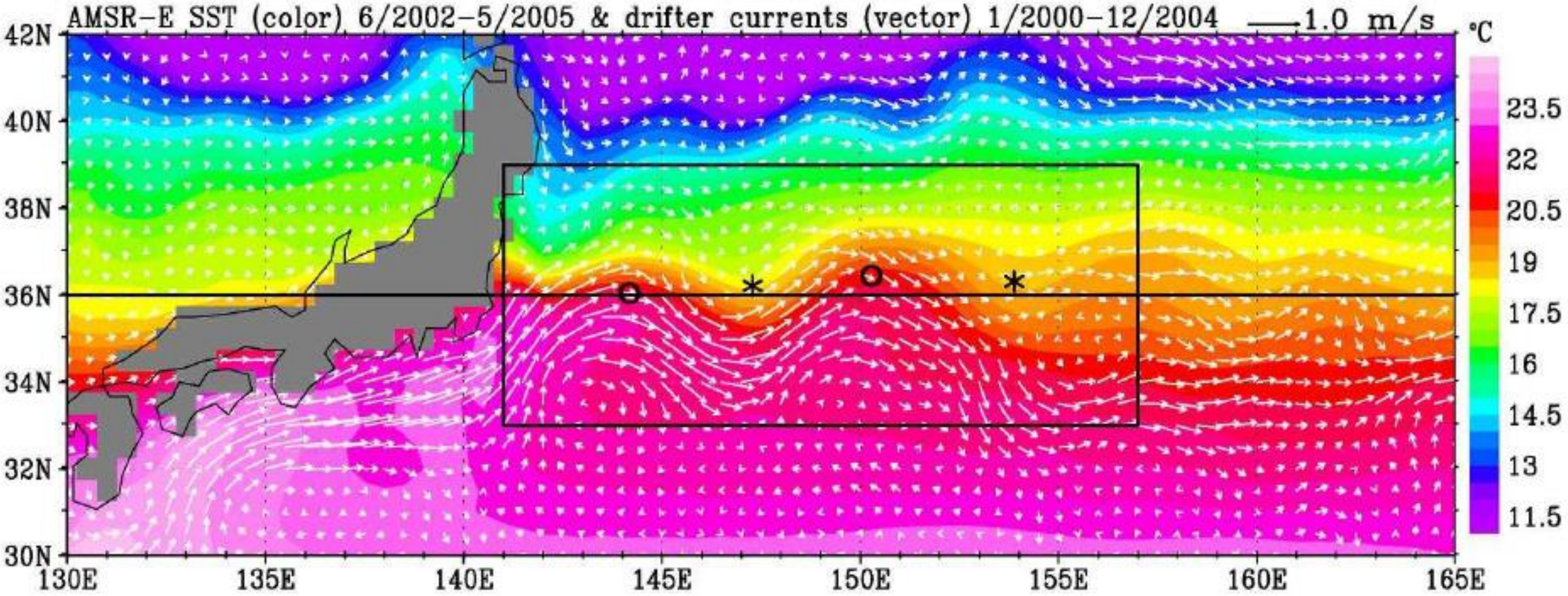
Observational evidence of frontal-scale atmospheric responses to Kuroshio Extension variability

Yi-Hui Wang and W. Timothy Liu

Jet Propulsion Laboratory, California Institute of Technology

AIRS Science Team Meeting 4/22/2015

Ocean has slow and frontal scale processes



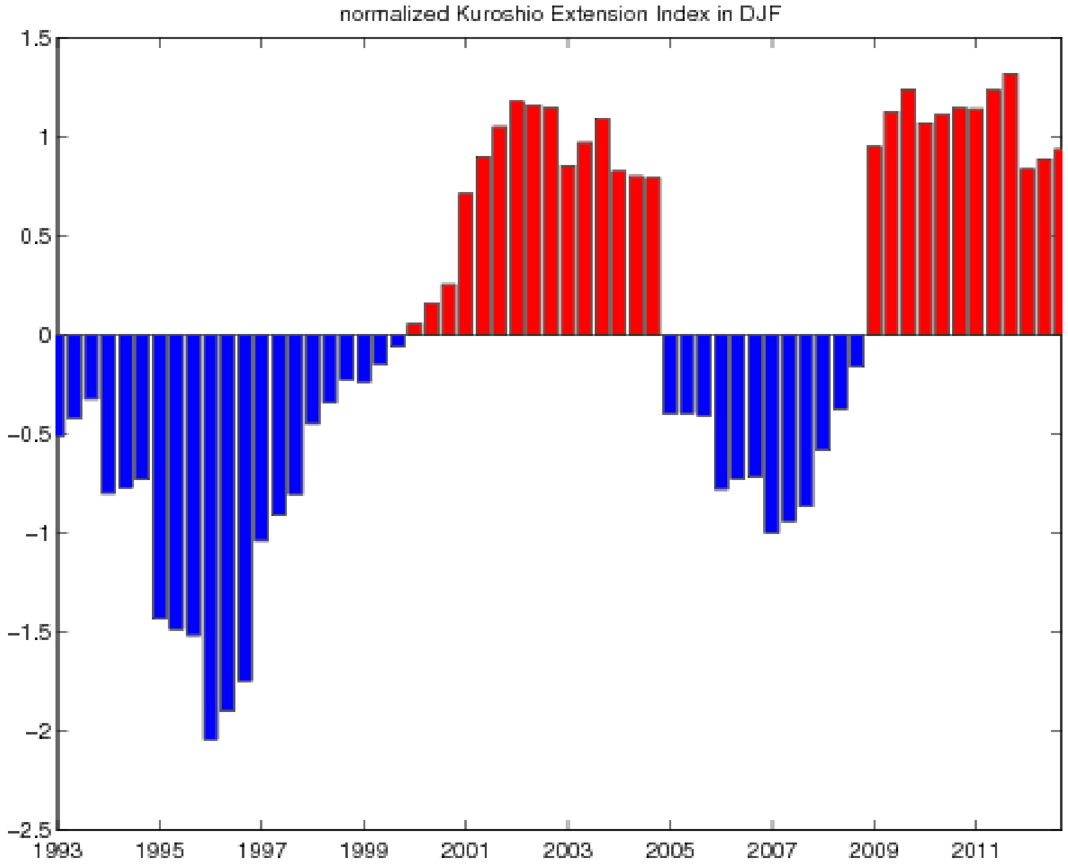
Liu and Xie (2008)

Semi-permanent meanders.
For the Kuroshio Extension (KE), interannual-to-decadal variability is pronounced in terms of its location and strength.
What is the imprint of KE variations on local atmosphere at low frequencies?

Kuroshio Extension (KE) index

- SSHA from AVISO averaged over the domain, 31-36°N and 140-165°E.
- Apply 13-month moving average.
- DJF of 1993-2012 (Dec in 1993-2012 and Jan-Feb in 1994-2013).
- Positive: strengthen eastward transport and migrate northward.
- Decadal variability.

- Normalized KE index

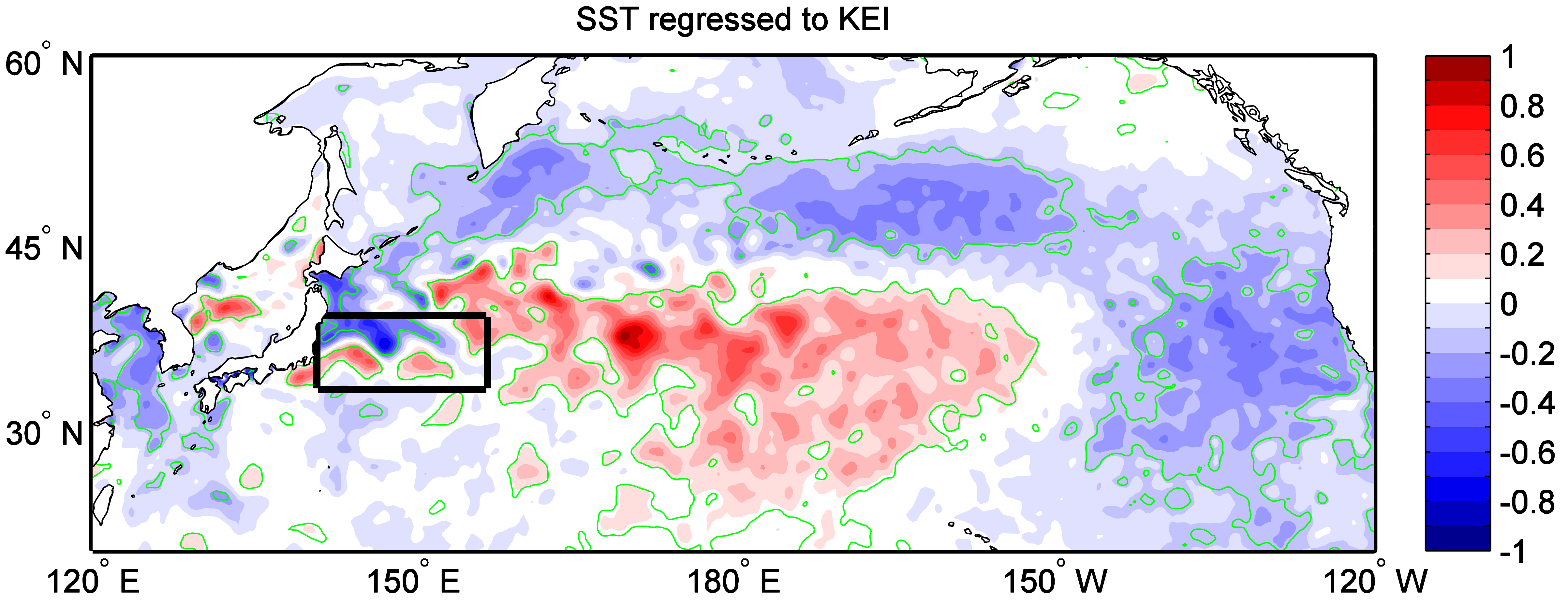


Data and methods used

- Data: monthly-mean in DJF
- 1) Satellite
  - TRMM 3B43 (50^oS-50^oN) surface precipitation, TRMM 3A12 (40^oS-40^oS) rain rate and latent heating rate (December 1998 to February 2013)
  - AIRS level 3 air temperature and geopotential height (December 2003 to February 2013)
- 2) Reanalysis
  - ERA-Interim: 10 m wind vectors, horizontal and vertical velocity, sea level pressure, air temperature and geopotential height
- Methods
  - Spatial filter: a running window with 10^olon x 2^olat
  - ENSO signal removal
  - Linear regression of the KE index onto climate variables pointwise

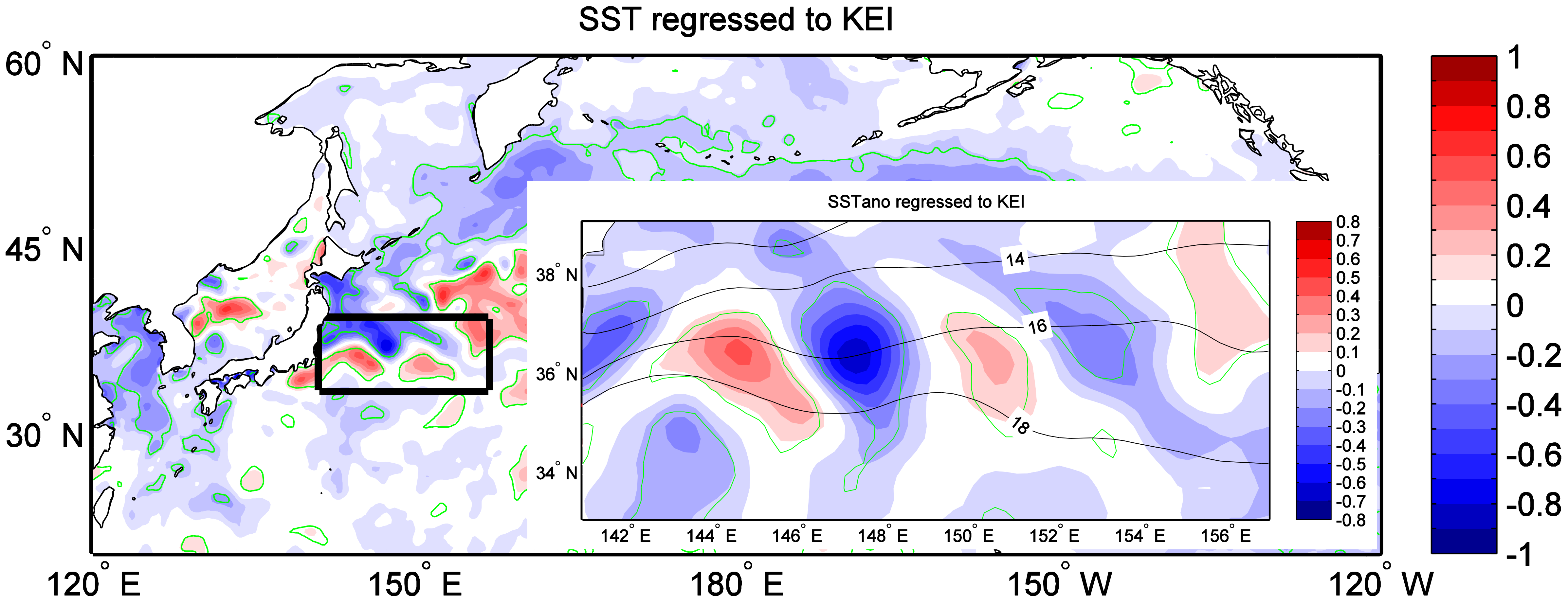
Manifestation of KE index on SST variability

- Basin scale

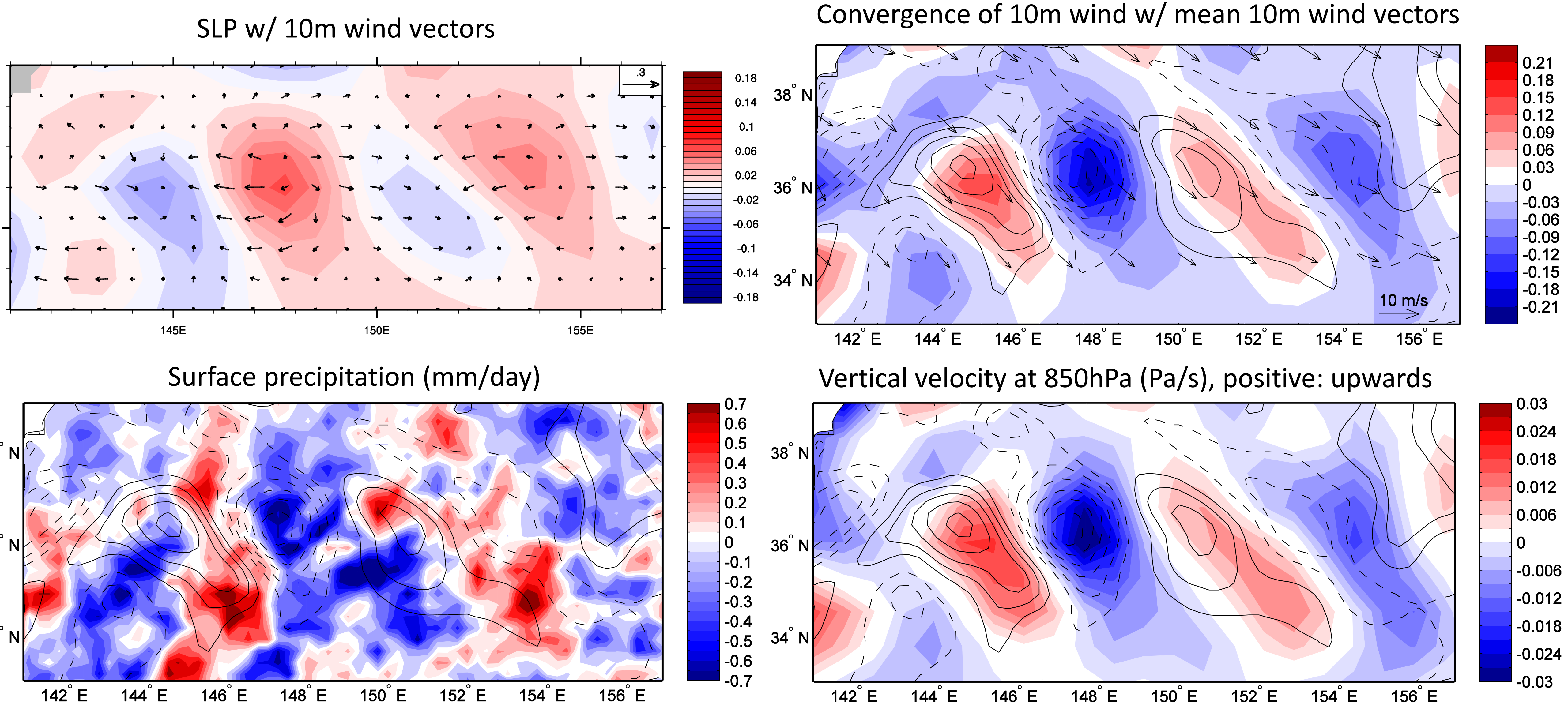


Manifestation of KE index on SST variability

- Frontal scale: warm SST anomaly – SST ridges; cold SST anomaly – SST troughs.



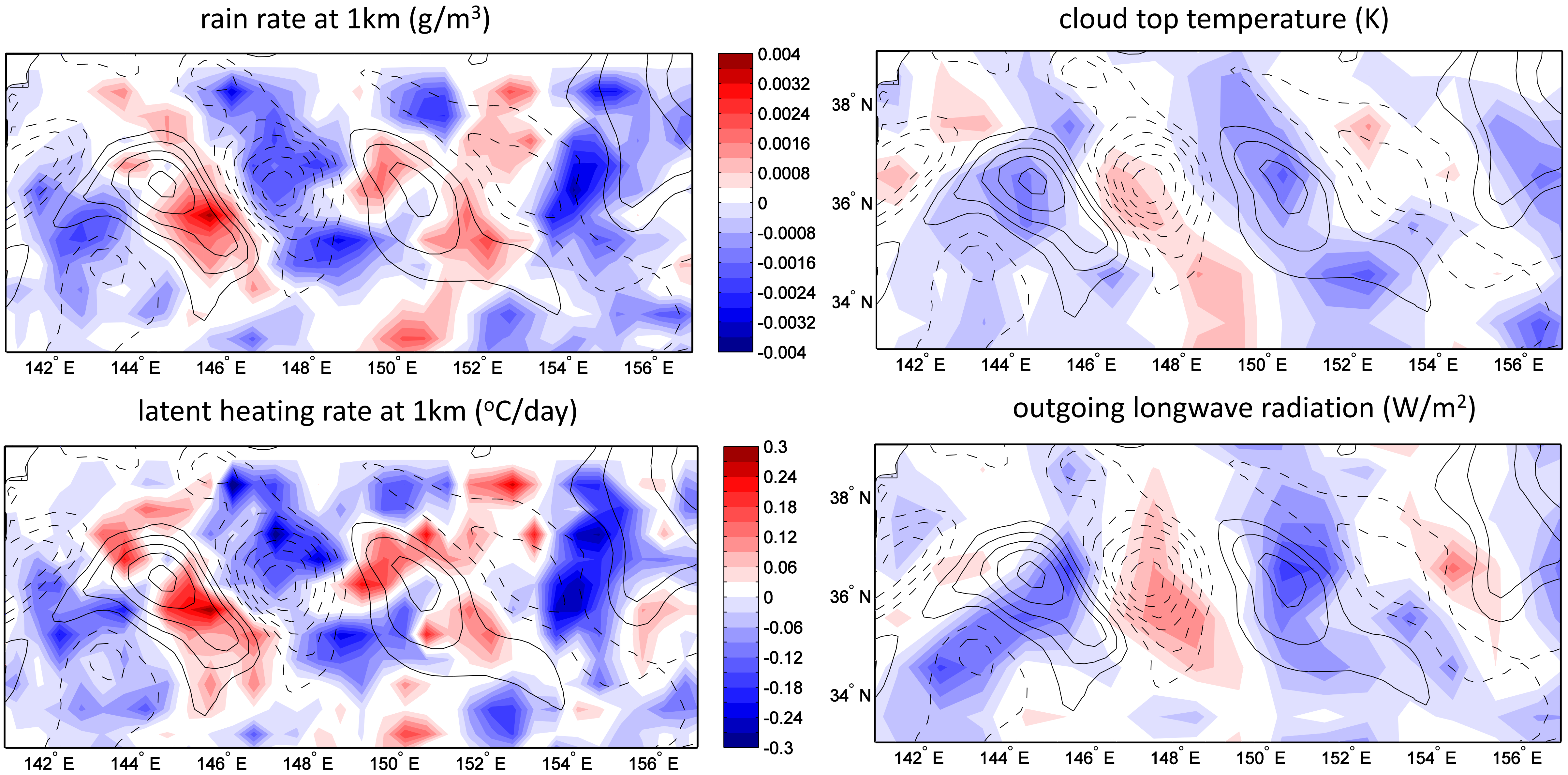
Atmospheric response



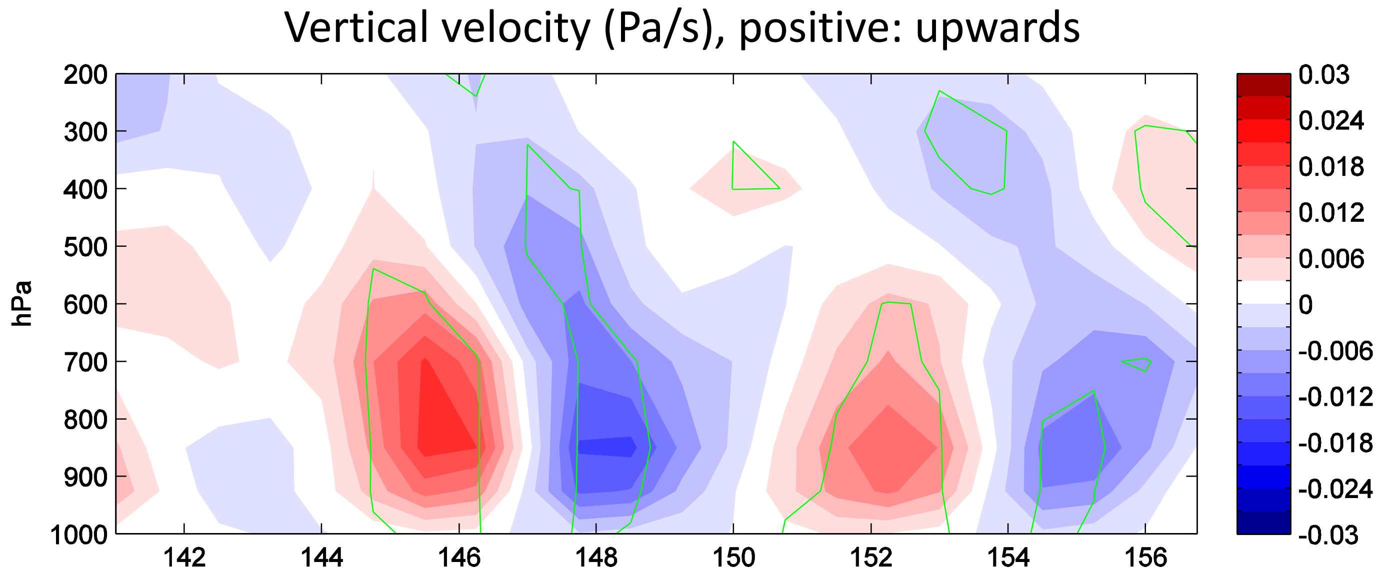
Displacement may be linked to the advection effect of background flows.

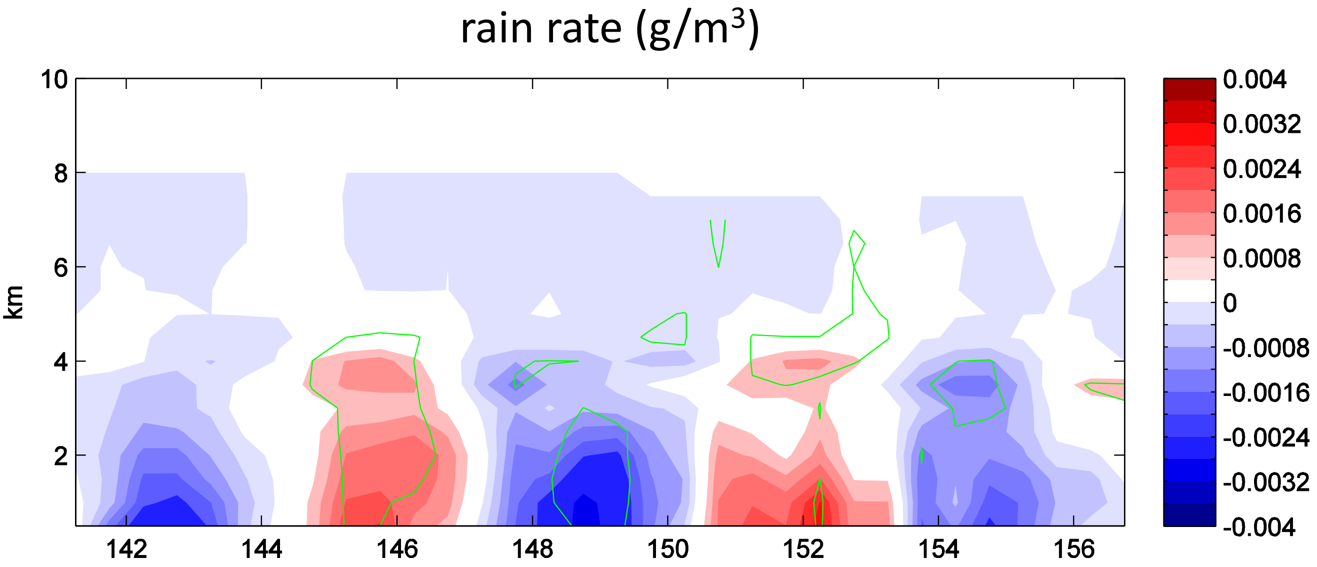
Pressure adjustment mechanism: KE-induced SST-> pressure-> surface convergence-> vertical motion-> precipitation

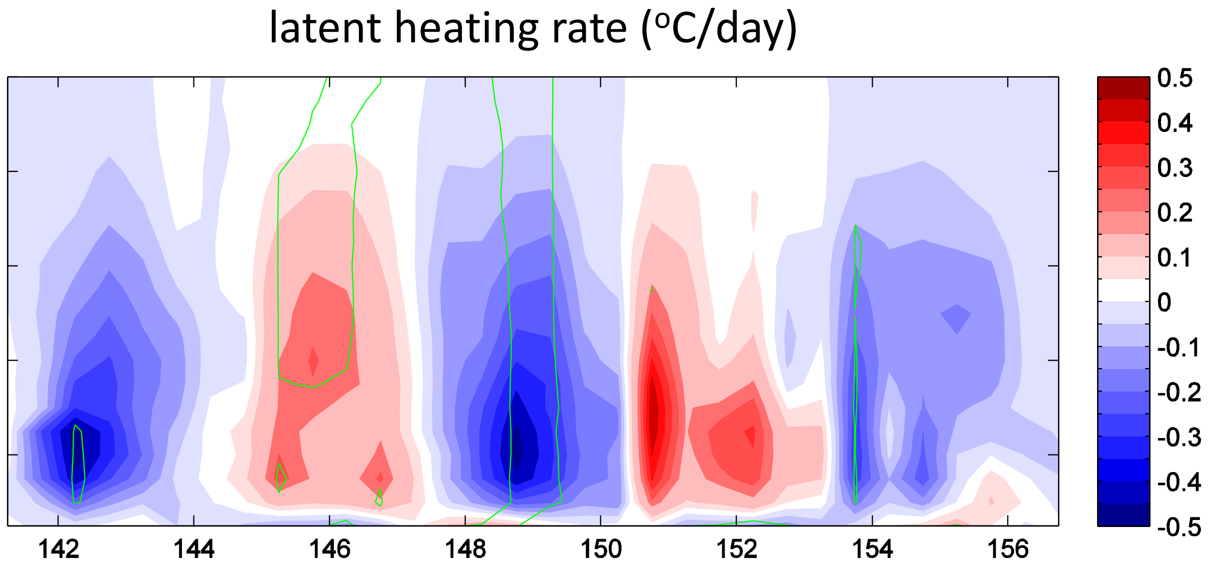
Atmospheric response



Atmospheric response
Vertical profiles along 35°N

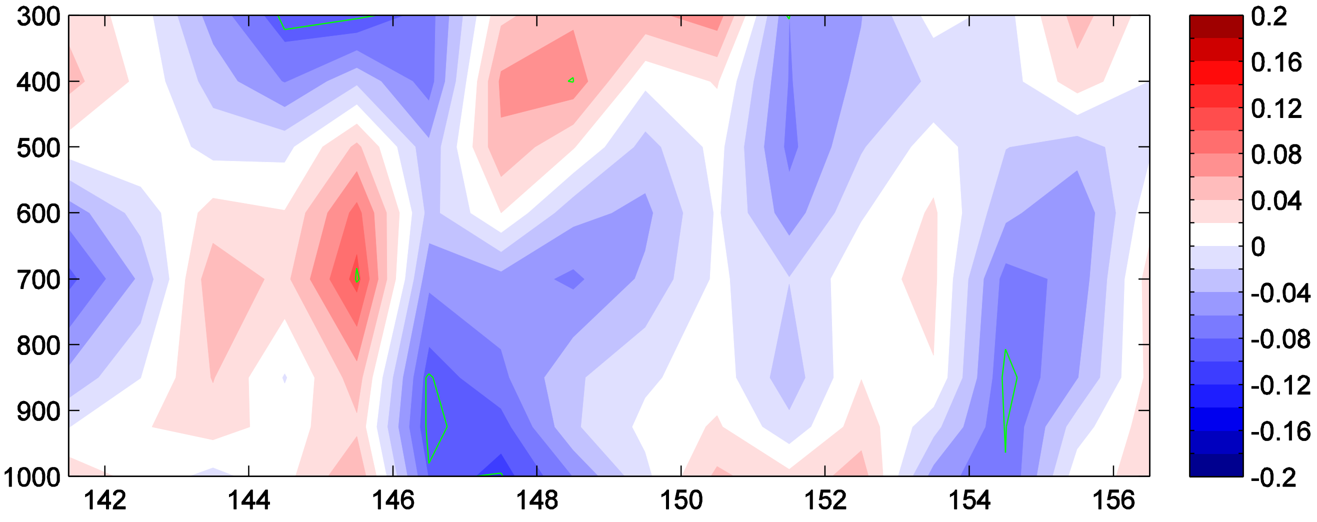




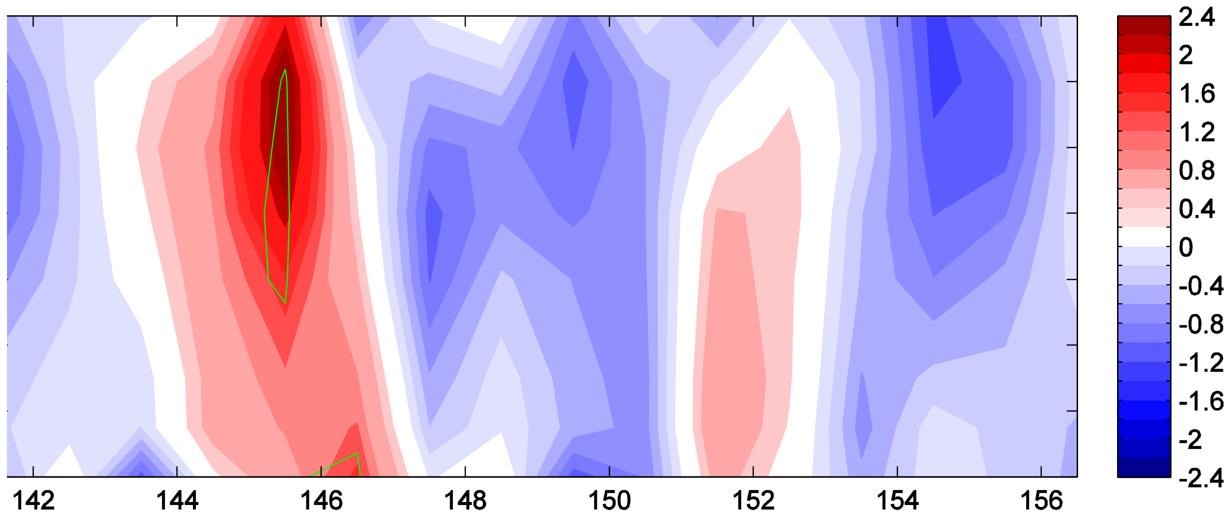


Atmospheric response
Vertical profiles along 35.5°N

AIRS-derived air temperature (K)

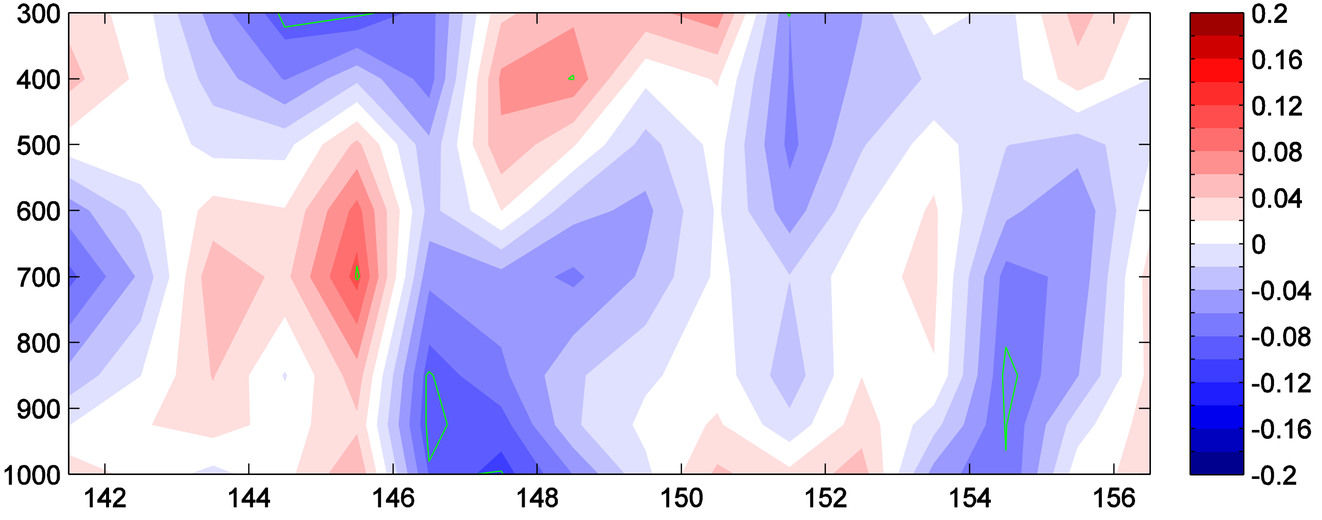


AIRS-derived geopotential height (m)

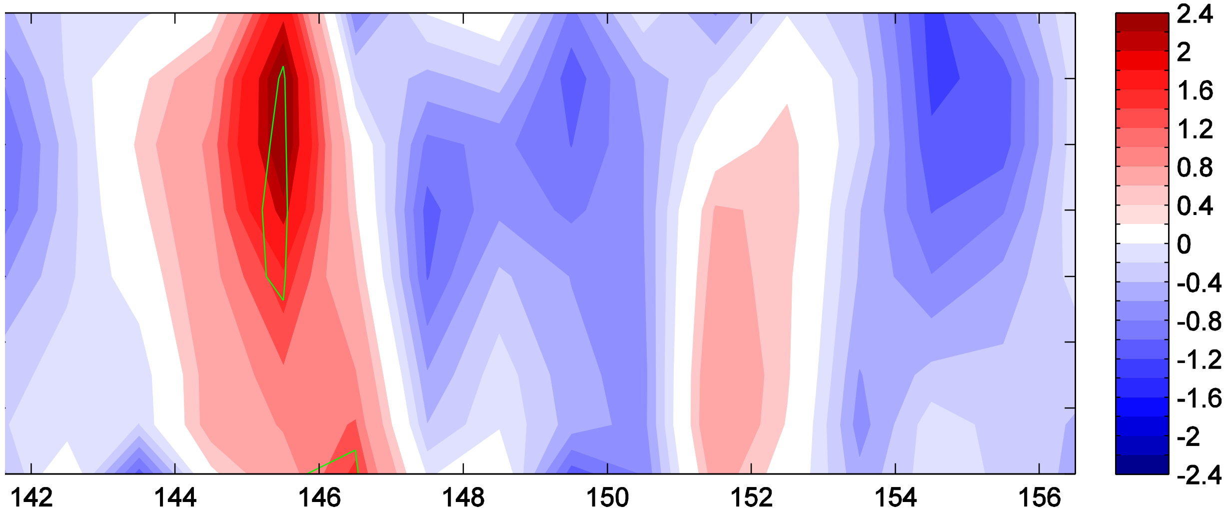


Atmospheric response
Vertical profiles along 35.5^{o}N

AIRS-derived air temperature (K)



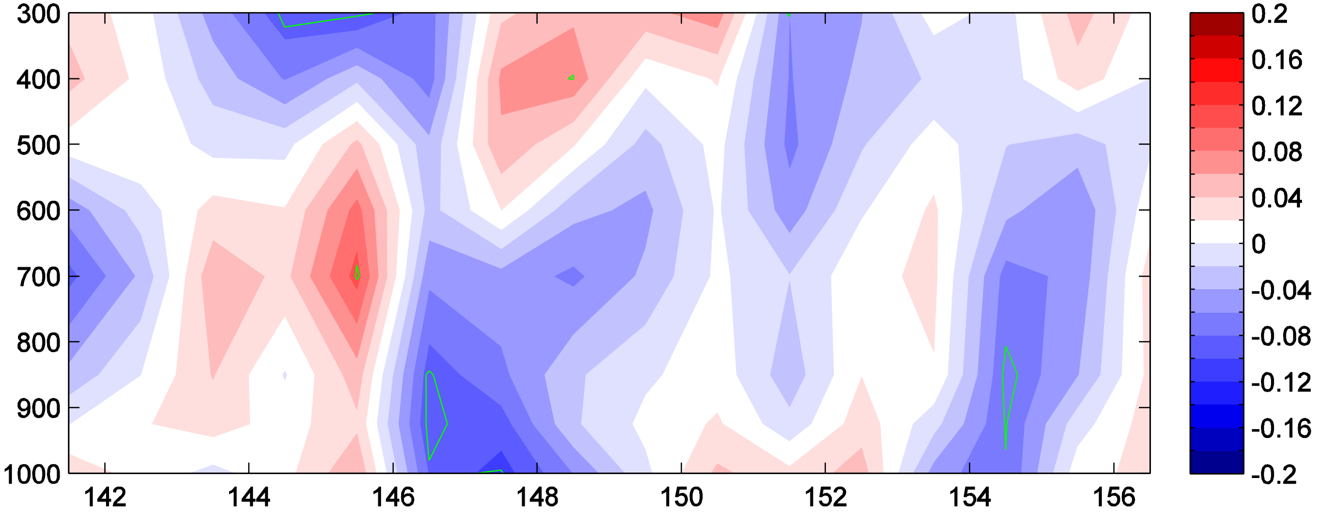
AIRS-derived geopotential height (m)



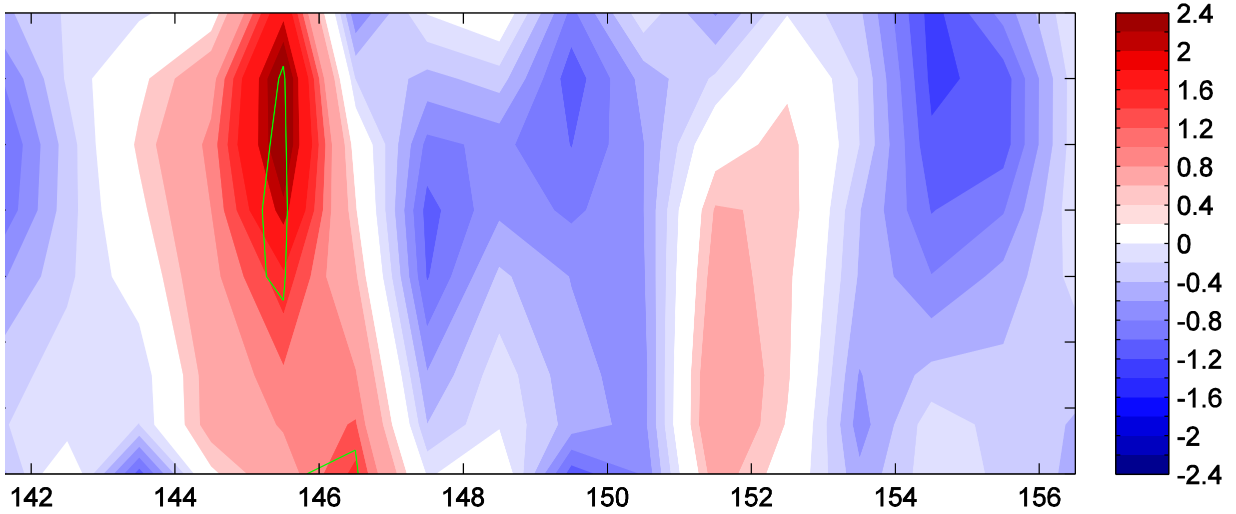
- Consistent imprints of the KE variations on the local atmosphere.
- The effect of the KE variations penetrates towards the free atmosphere is observed by the TRMM and AIRS data, which implies a potential pathway to influence the large-scale atmospheric circulation.

Atmospheric response
Vertical profiles along 35.5°N

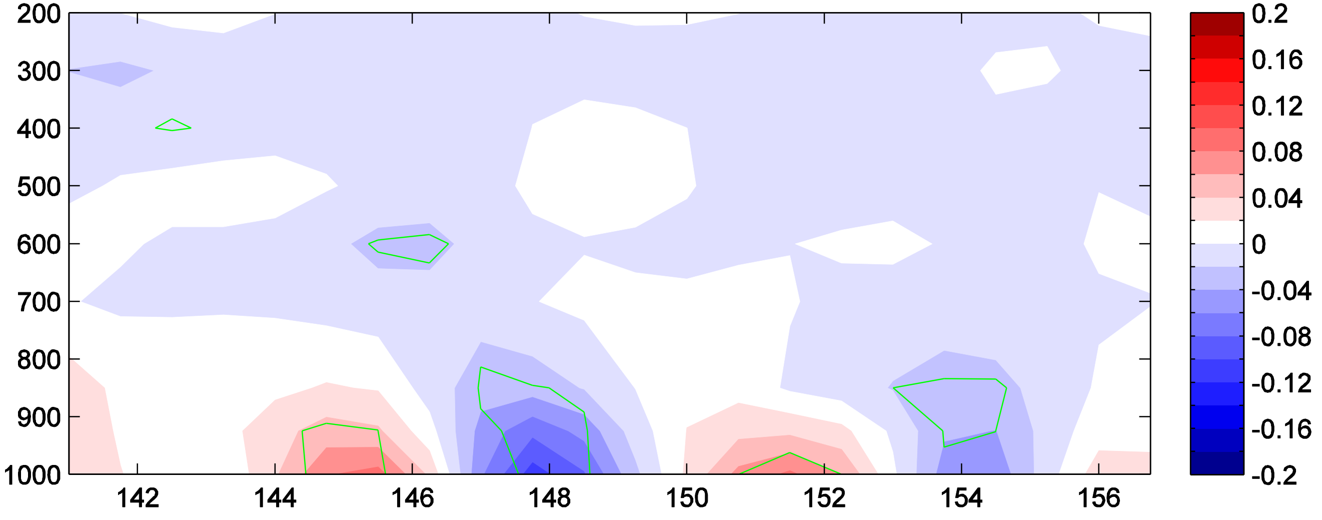
AIRS-derived air temperature (K)



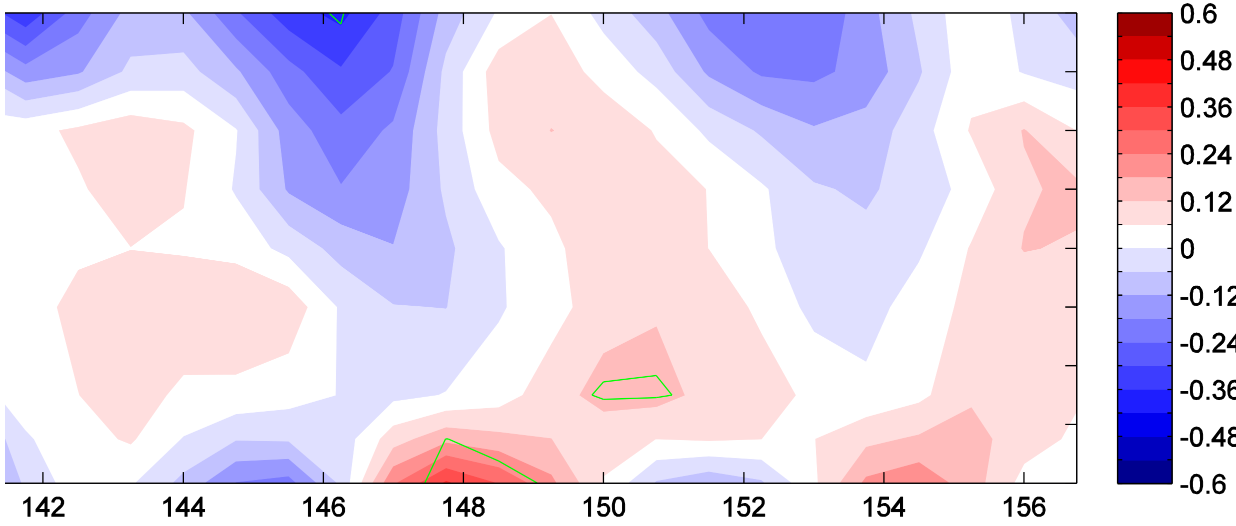
AIRS-derived geopotential height (m)



ERAi-derived air temperature (K)

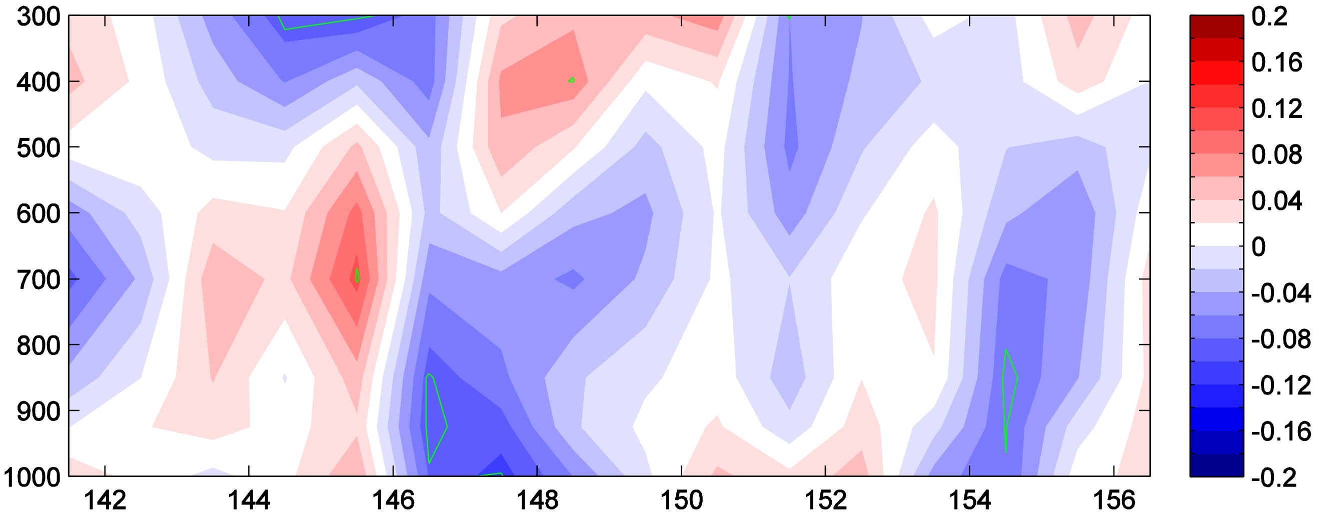


ERAi-derived geopotential height (m)

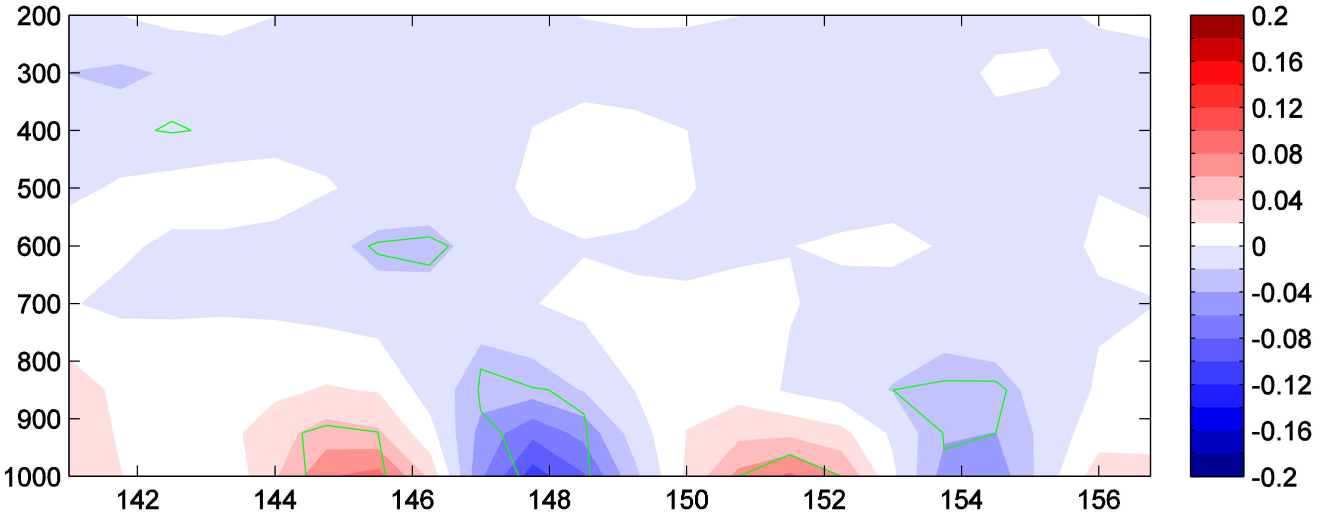


Compare AIRS and ERA-Interim air temperature

AIRS-derived air temperature (K)



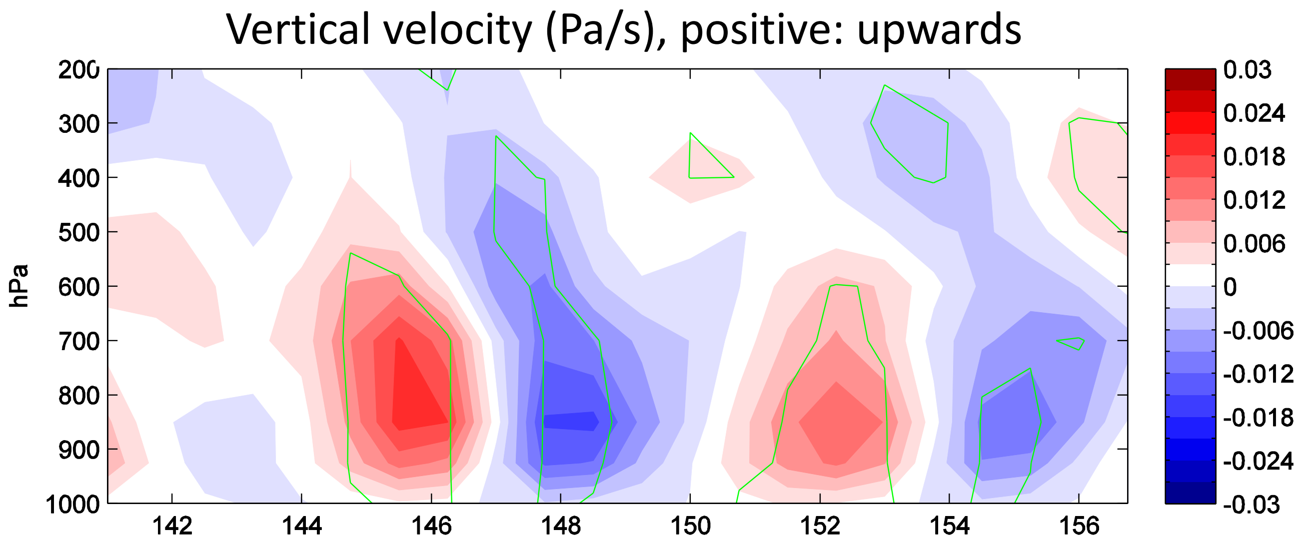
ERAi-derived air temperature (K)

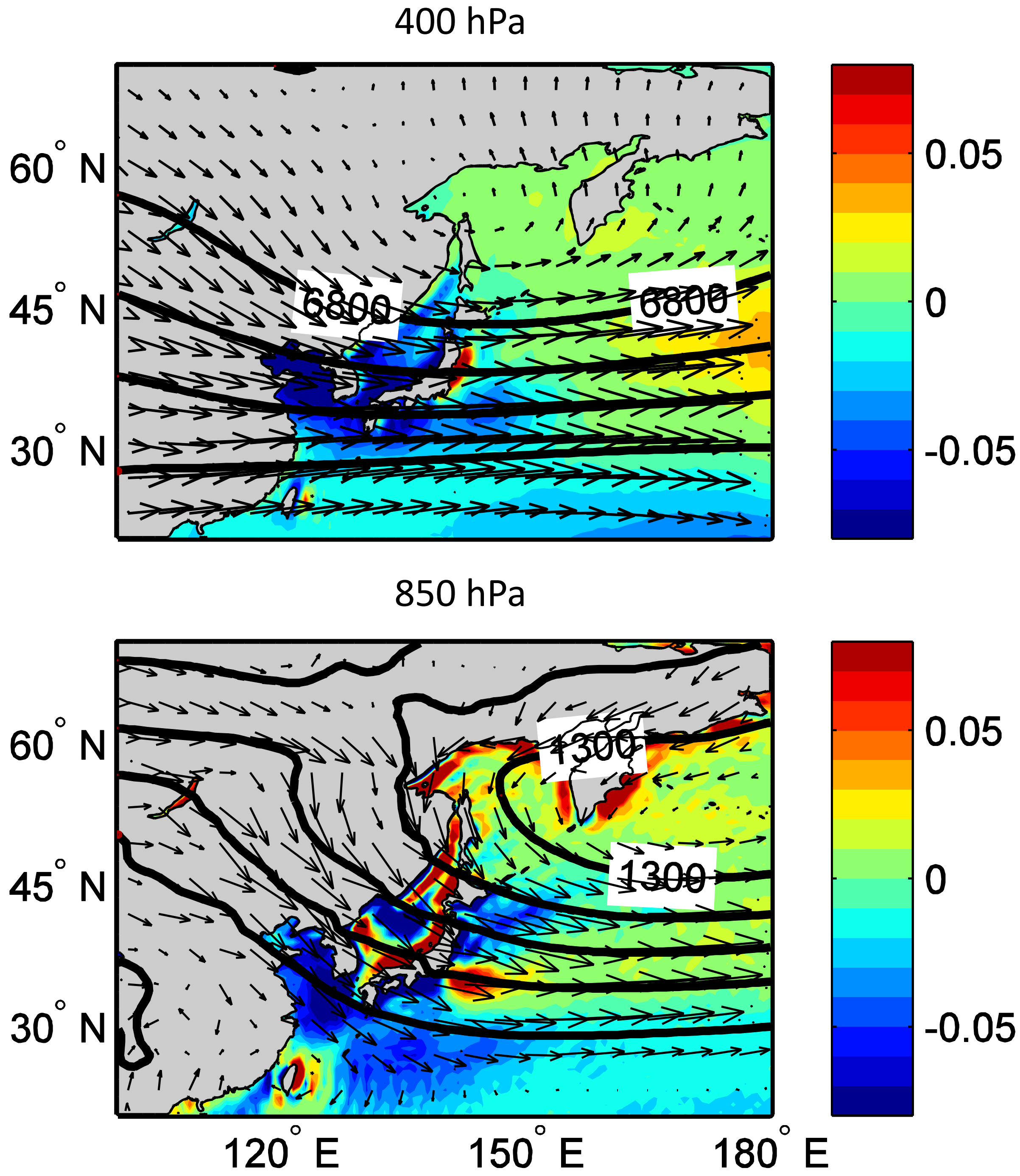


- AIRS:
  - The observing conditions in the absence of optically thick clouds.
  - Incomplete diurnal cycle.
- ERAi:
  - Fewer constraints in the upper troposphere.
  - Responses are subject to prescribed SSTs.

Modeling bias in the vertical penetrating effect of small-scale ocean processes?

Why is there a tilted structure?

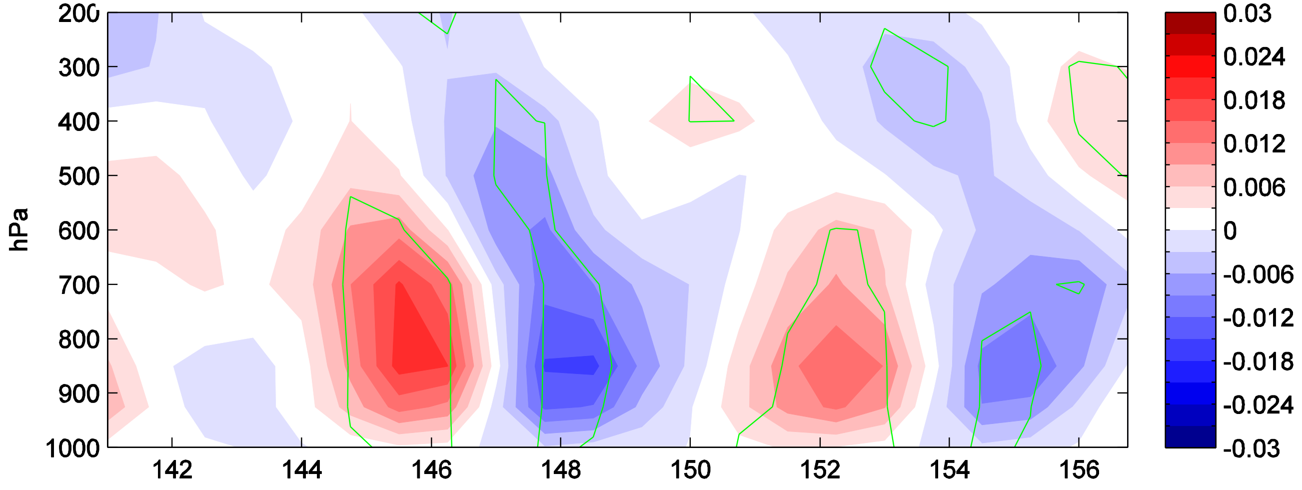




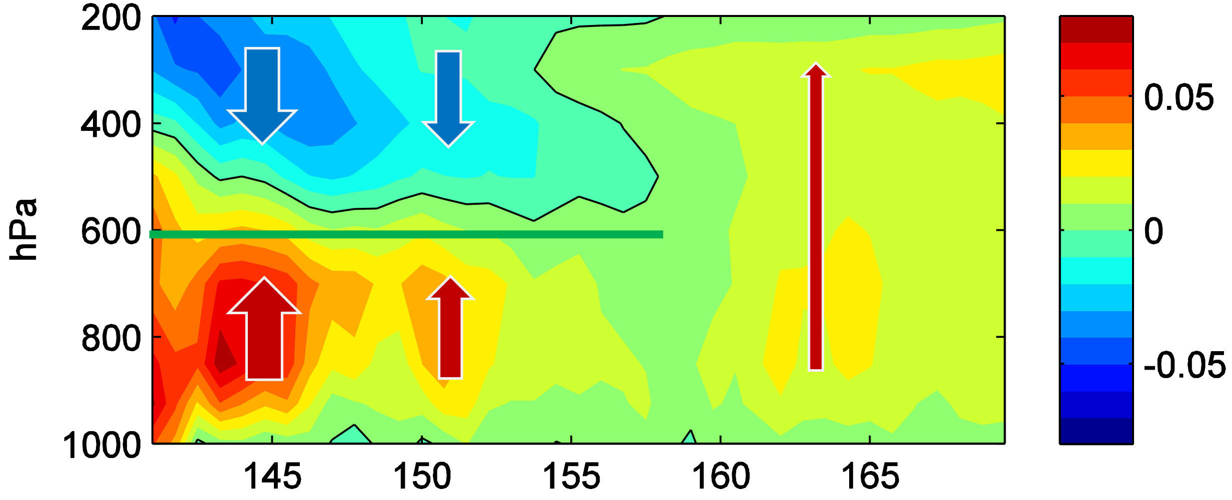
Mean for DJF of 1993-2012
Shading: vertical velocity (Pa/s)
Contours: geopotential height (m)
Wind vectors

Why is there a tilted structure?

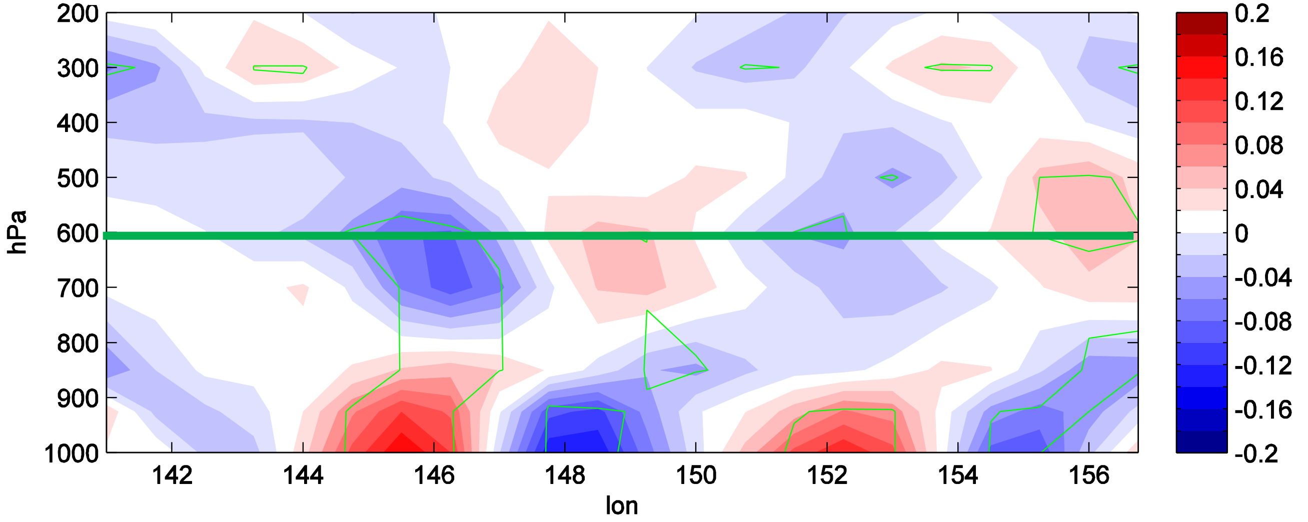
Vertical velocity (Pa/s), positive: upwards



Mean-state vertical velocity along 35N

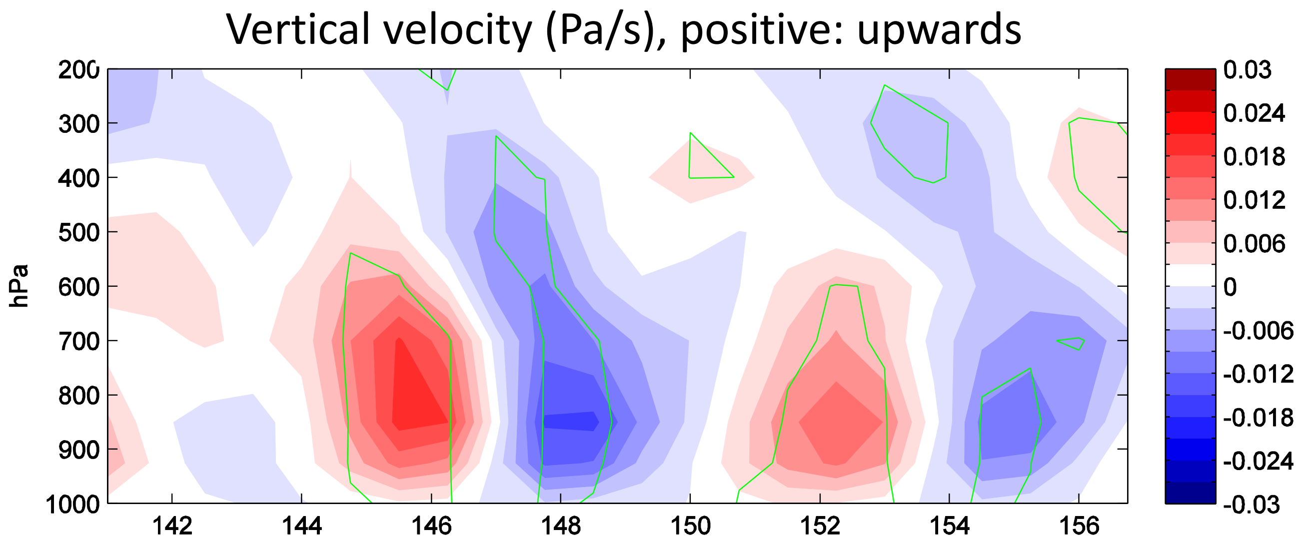


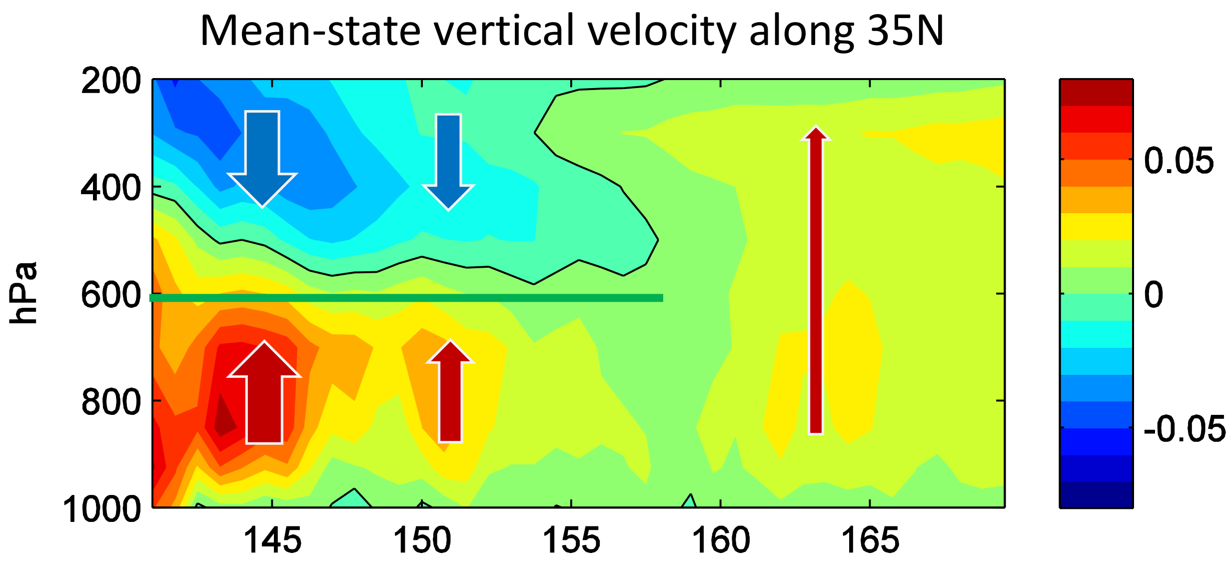
Horizontal convergence (1/s), positive: convergence

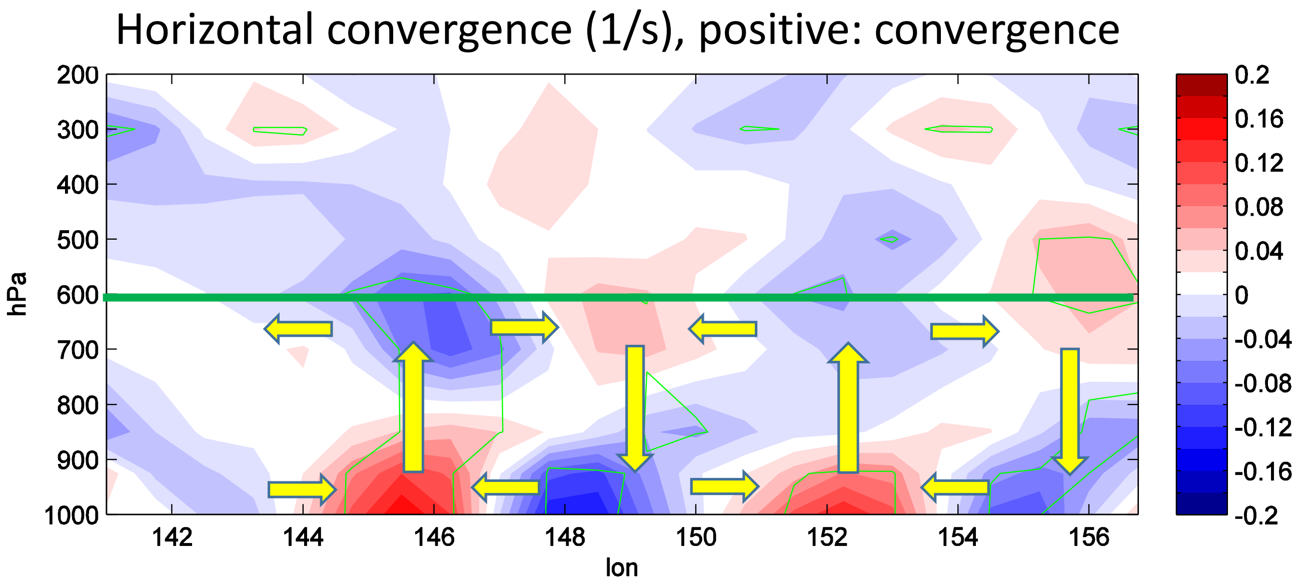


- The mean state of vertical velocity appears to act like a cap.

Why is there a tilted structure?



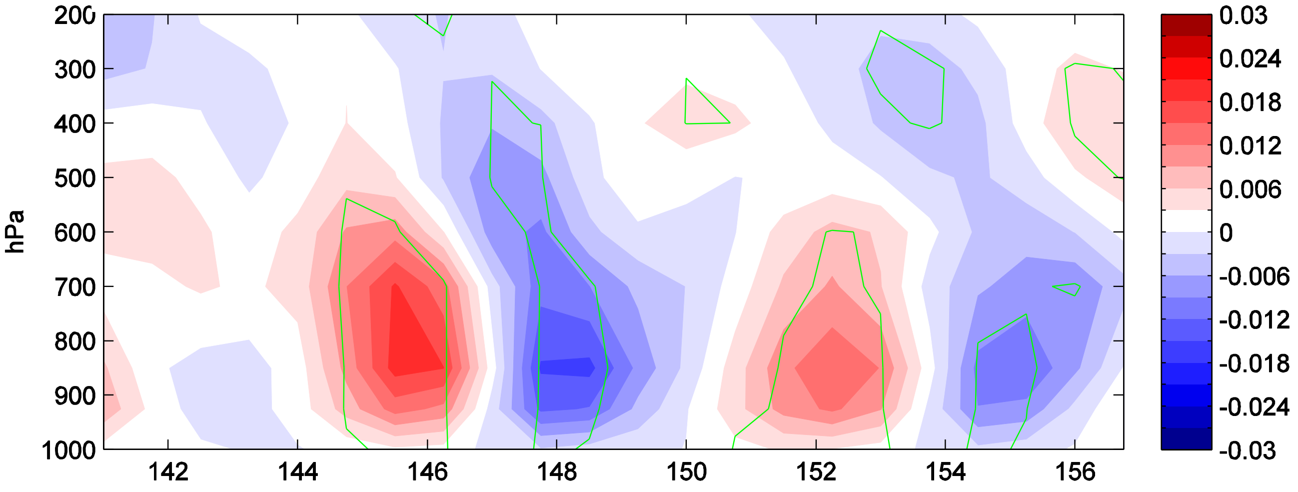




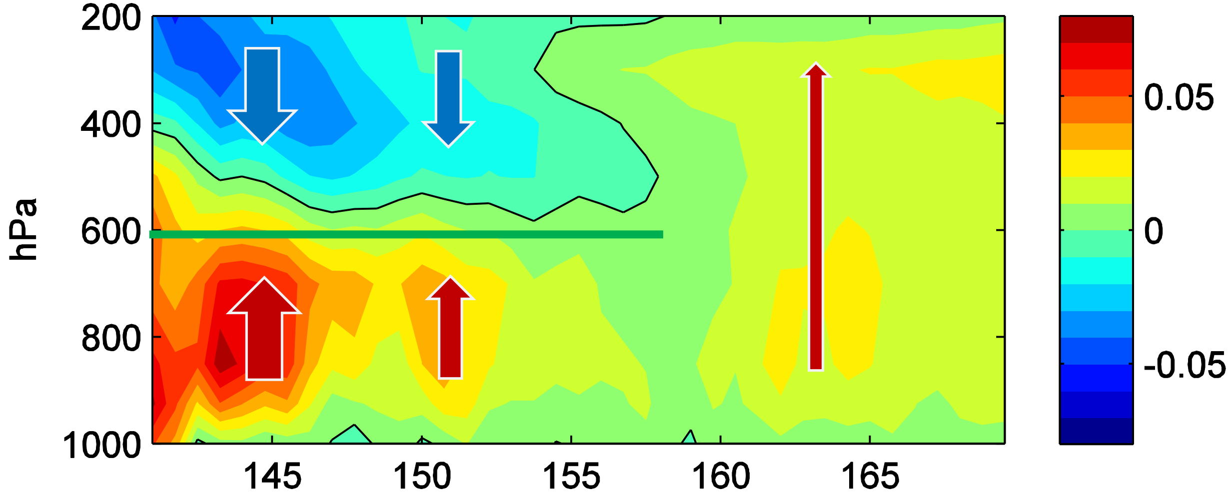
- The mean state of vertical velocity appears to act like a cap.
- To balance air motion from the surface, air motion changes in the middle- and upper- troposphere.

Why is there a tilted structure?

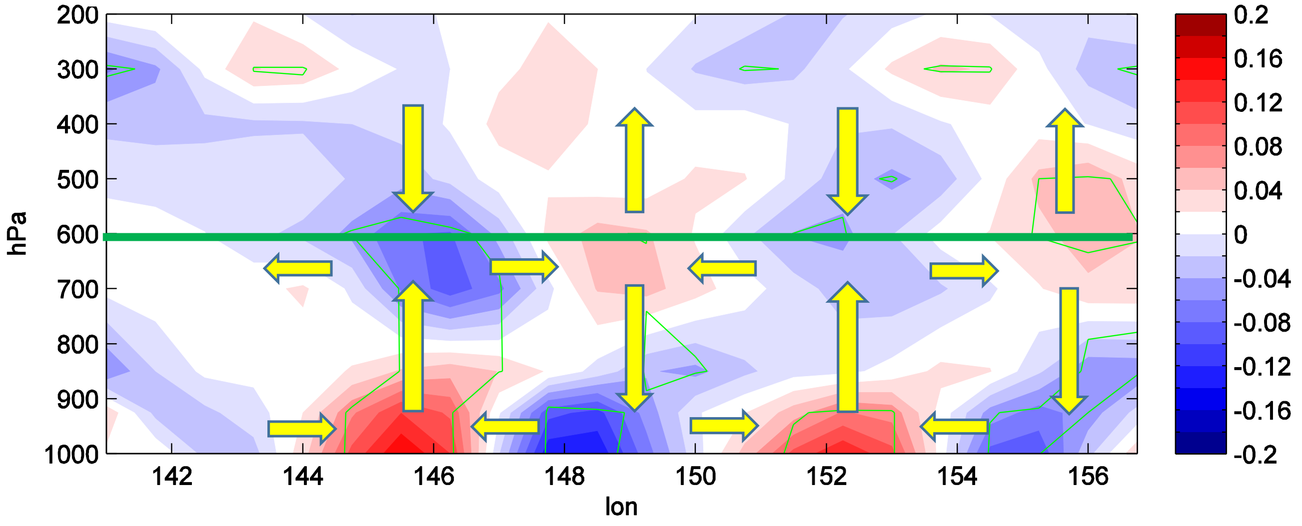
Vertical velocity (Pa/s), positive: upwards



Mean-state vertical velocity along 35N



Horizontal convergence (1/s), positive: convergence



- The mean state of vertical velocity appears to act like a cap.
- To balance air motion from the surface, air motion changes in the middle- and upper- troposphere.

Summary

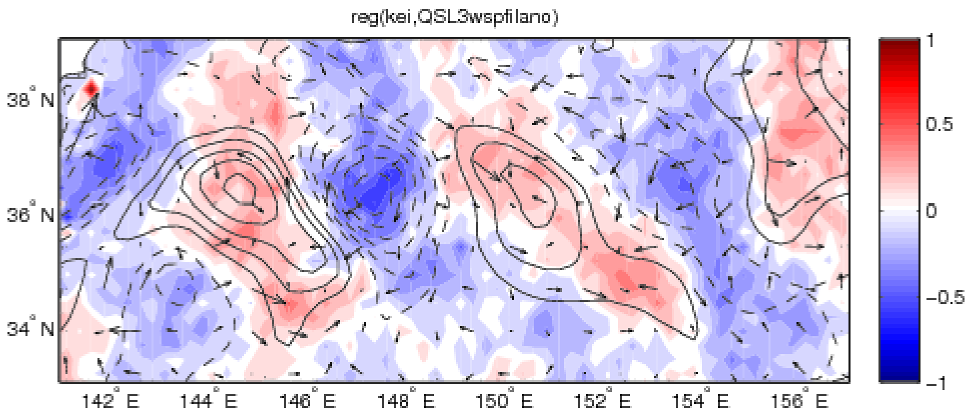
- Consistent local atmospheric responses to KE variations at low frequencies are found.

- Vertical penetrating effects of KE variations are present in the satellite-based observations.

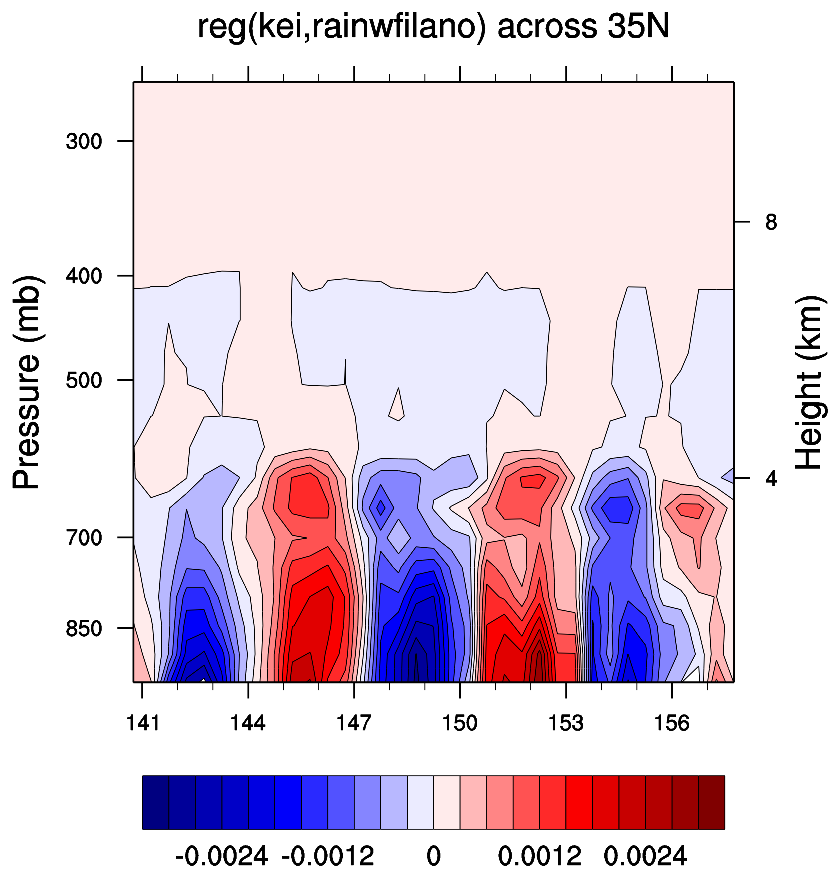
- Discrepancies between the AIRS and ERA-Interim data suggest the imperfect interpretation of atmospheric responses to small-scale ocean processes in numerical models.

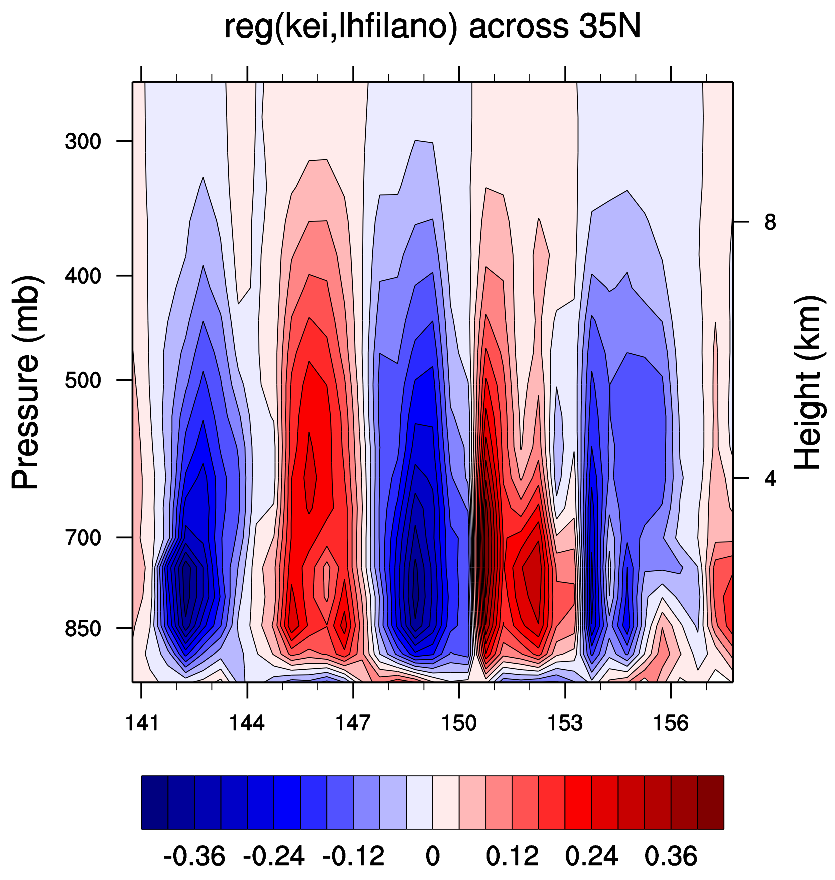
- Vertical tilted responses may be linked to the background flow effect.

Back-up slides



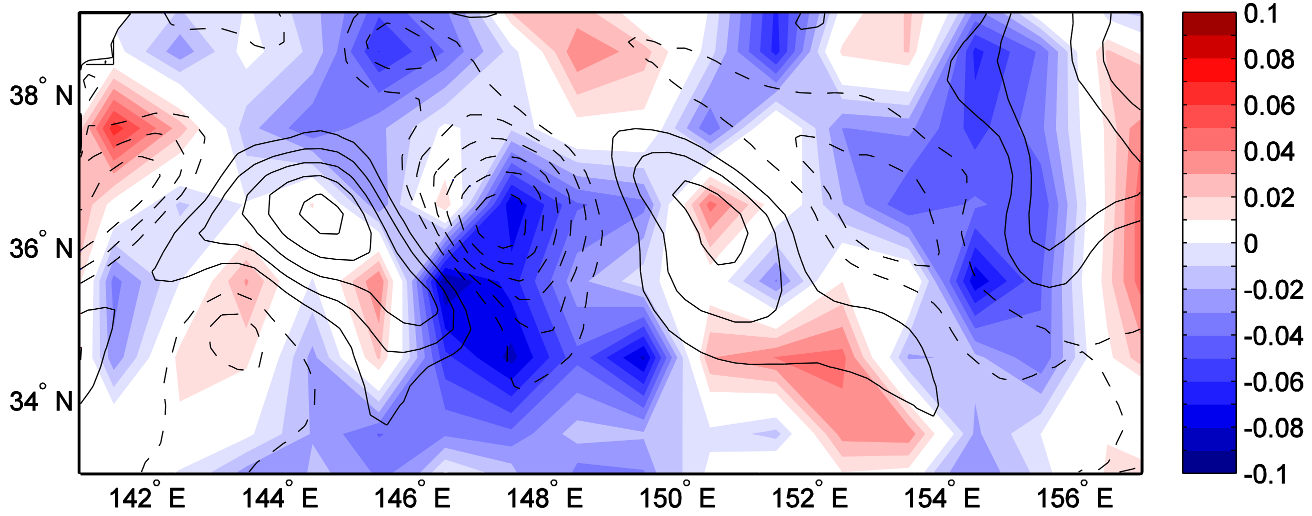
Approximate pressure converted from height





Atmospheric response

AIRS-derived air temperature at 850hPa (K)



AIRS-derived geopotential height at 850hPa (K)