Various Types of Latent Heating Structures and the role of Western Boundary Current over the Kuroshio-Oyashio Extension Region

Dong Wan “Lewis” Kim[1], Young-Oh Kwon[1], Claude Frankignoul[1,2], Clara Deser[3], Gokhan Danabasoglu[3], Adam Herrigton[3], Sunyong Kim[1]

[1] *Woods Hole Oceanographic Institution, USA*

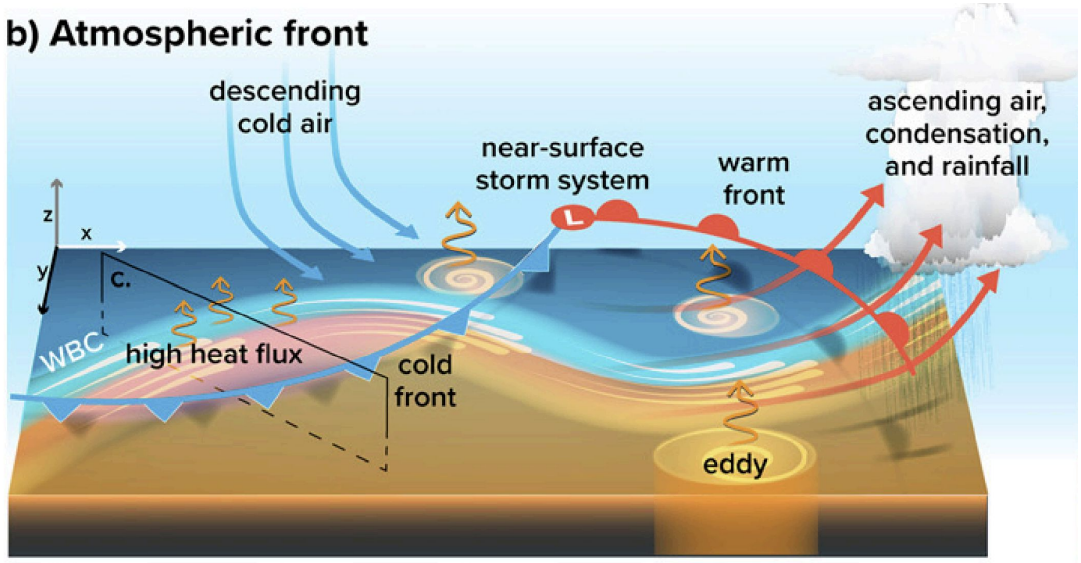
[2] *Sorbonne University, France*

[3] *US NSF National Center for Atmospheric Research, USA*

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Air-sea interaction and the role of SST anomaly

- How does SST interact with the atmospheric weather pattern over the western boundary current region?
  - Kuroshio-Oyashio Extension (KOE) region
  - Focus on the diabatic latent heating
    - Conduit for SST to impact atmosphere
    - Largescale condensational vs. convective heating
    - Model resolution dependent

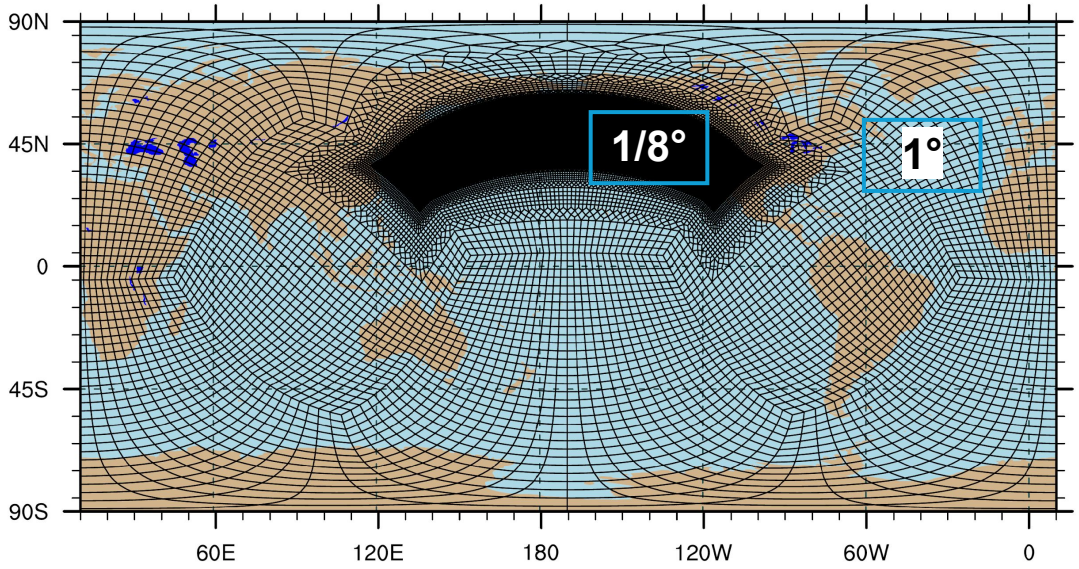


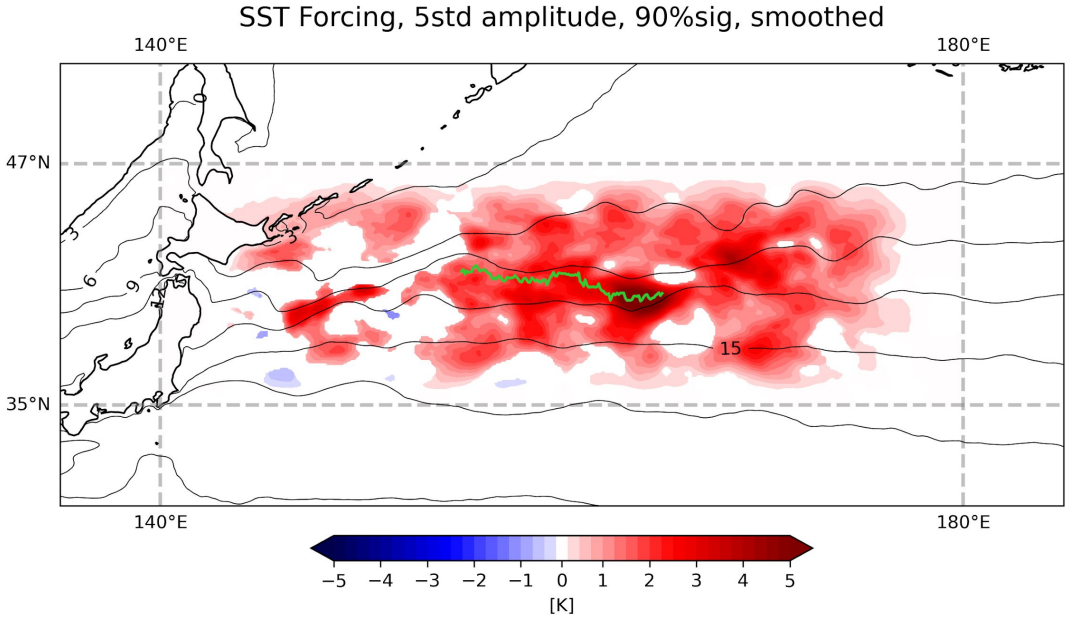
- Seo et. al. 2023

- Comprehensive understanding of the air-sea interaction will improve the predictability of the downstream weather pattern

Experiment overview

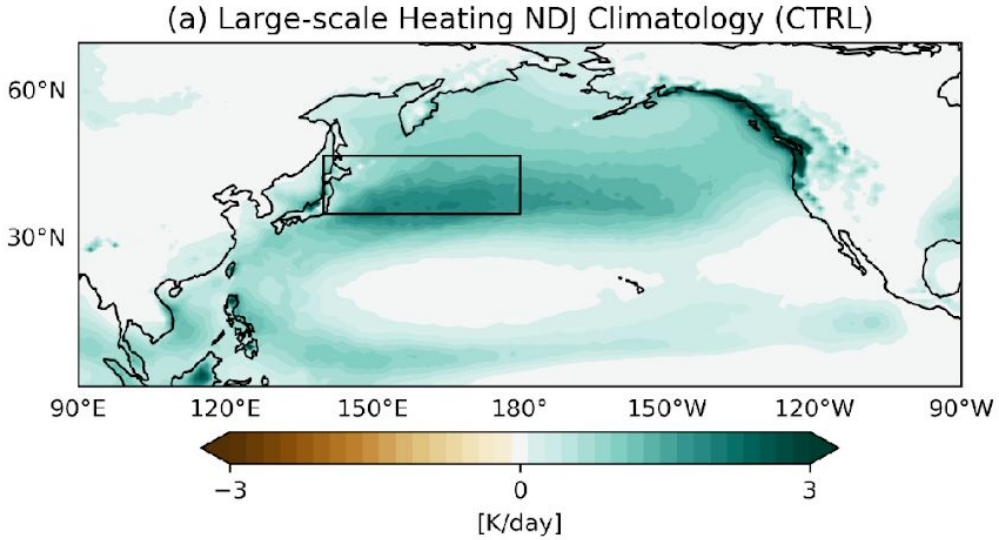
- Variable Resolution CAM6
  - **High resolution** over the target region
    - ~ 1/8deg North Pacific / ~1deg rest of globe
    - Effectively resolve moist process that are important for diabatic latent heating
  - **Simulation period** : Nov-Jan (3months)
    - 3-hourly output
  - **Initial Condition:** Nov 1st of ERA5
    - 1979-2021 (43 ensembles / 1 simulation set)
  - **Boundary condition**:
    - GLORYS12 reanalysis (1/12 deg)
    - *Control*: monthly climatology of SST/SIC
    - *Warm*: SST anomaly representing northward shift of the SST frontal system



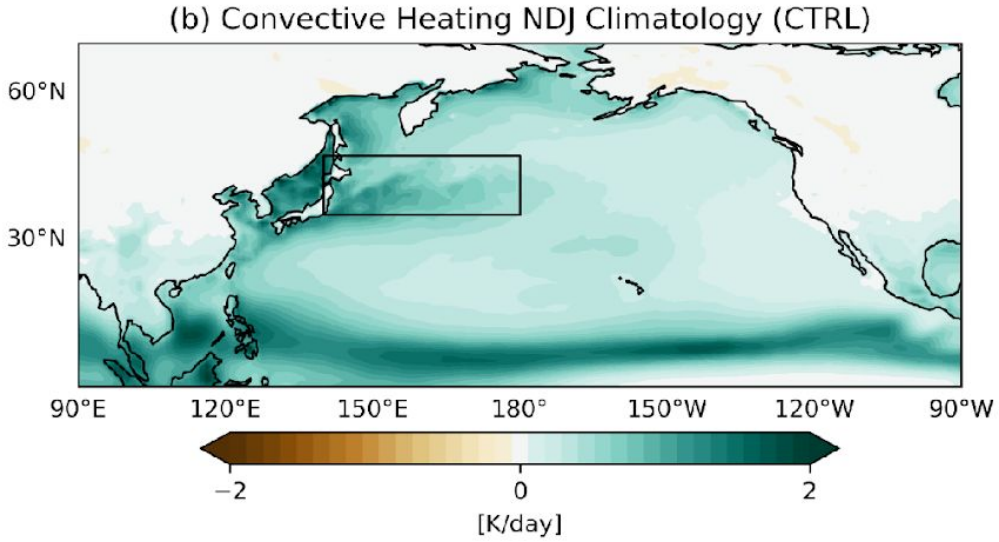


Weather timescale compos

- Heating index composite
  - Select days when two different latent heatings over the SST forcing region are enhanced
  - Diagnose the relevant weather patterns
  - From CTRL simulation
    - *Large-scale and convective heating occur together*
    - *Large-scale and convective heating occur alone*
  - From WARM simulation
    - Repeat the above procedure
    - Compare the composite difference to identify how SST anomaly plays a role

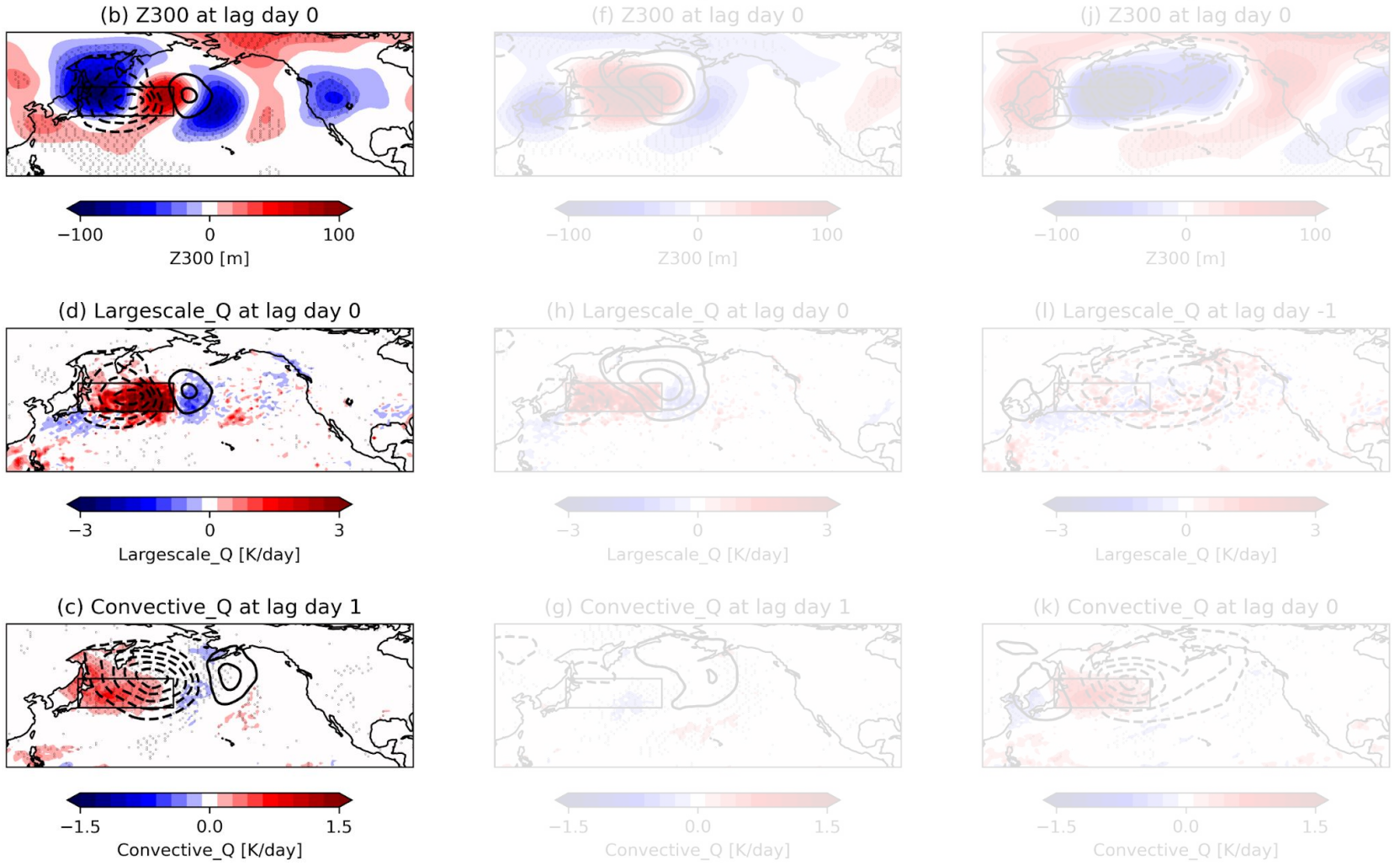


- Large-scale heating
  - Cloud macro, microphysics
- Convective heating
  - Shallow and deep convection
  - Boundary layer mixing



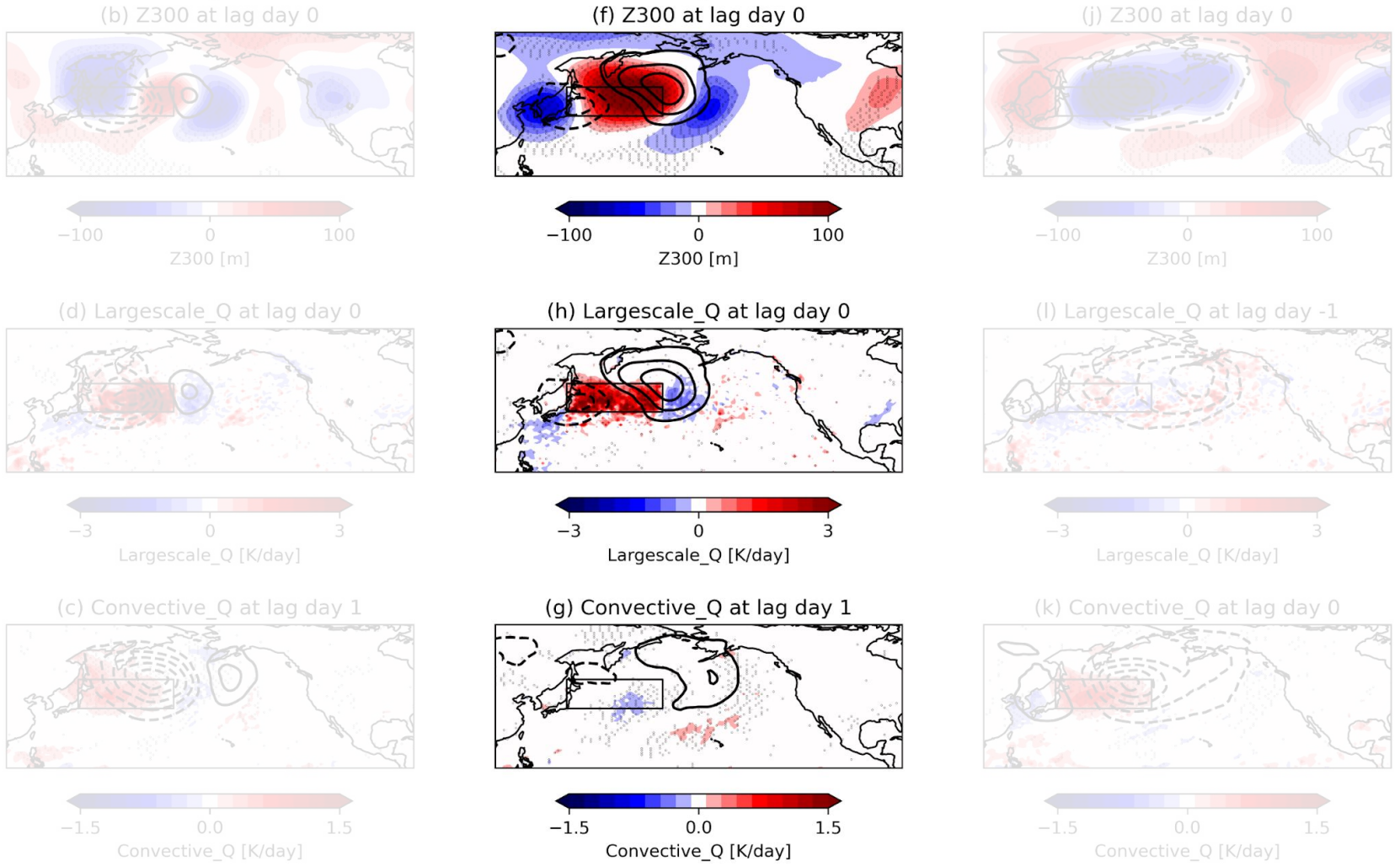
Composite structure (CTRL)

- Overlapping Largescale events:
  - Baroclinic circulation structure
  - Strong low-level cyclone
  - Extratropical cyclone-like structure
  - Large-scale heating on the warm-side of the cyclone
  - Convective heating on the cold side of the cyclone



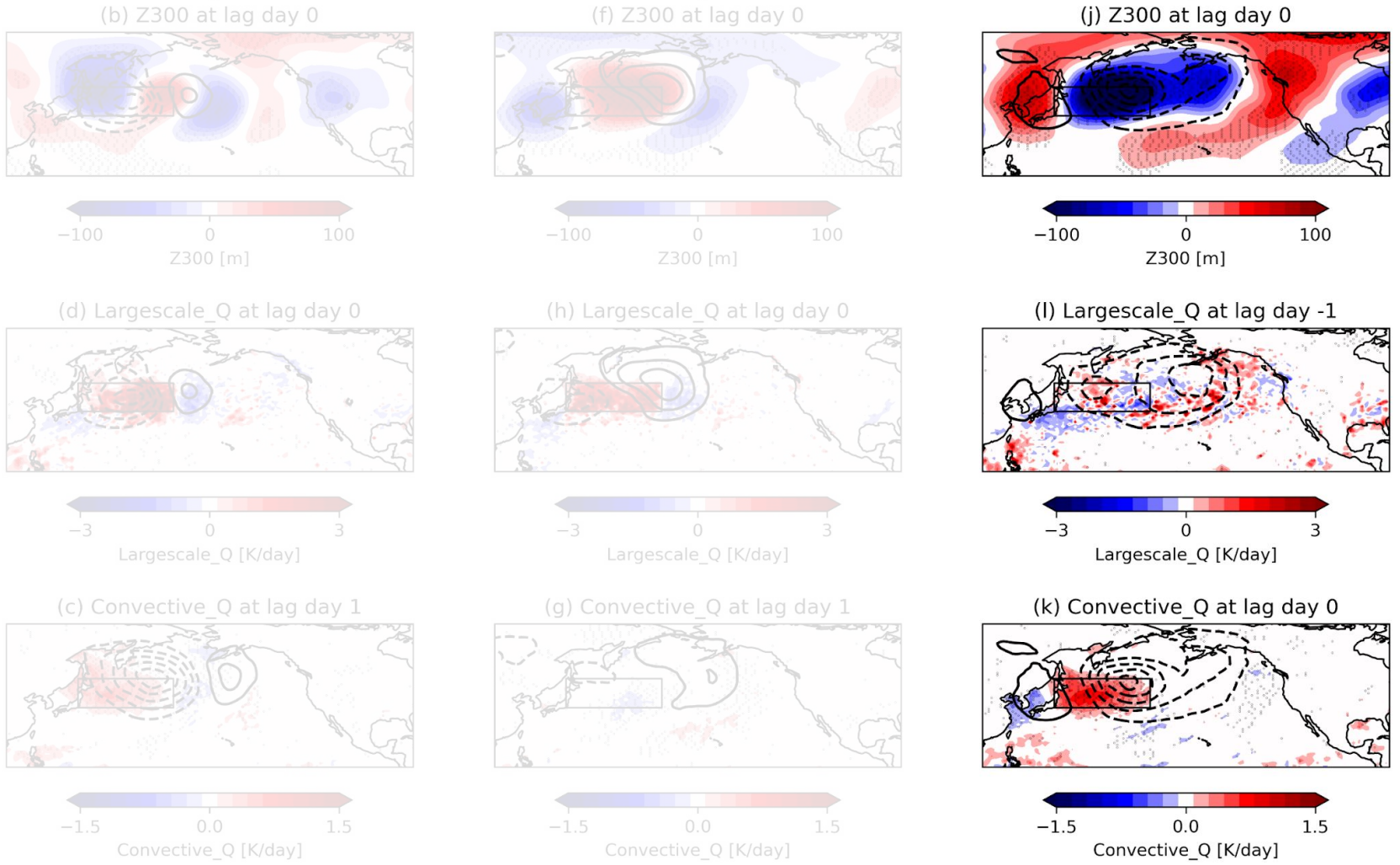
Composite structure (CTRL)

- Large-scale heating-only event
  - Baroclinic, but anticyclonic circulation
  - Large-scale heating with southerly moist wind
  - No low-level cyclone development
  - No convective heating



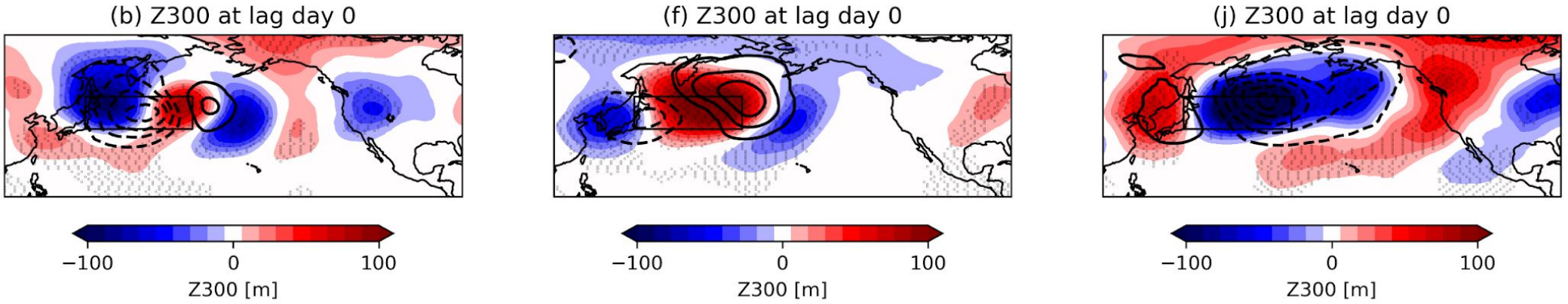
Composite structure (CTRL)

- Convective heating-only events
  - Barotropic cyclonic circulation
  - Large-scale heating is spread into the North Pacific
  - Convective heating enhancement following the northerly wind of the cyclonic circulation



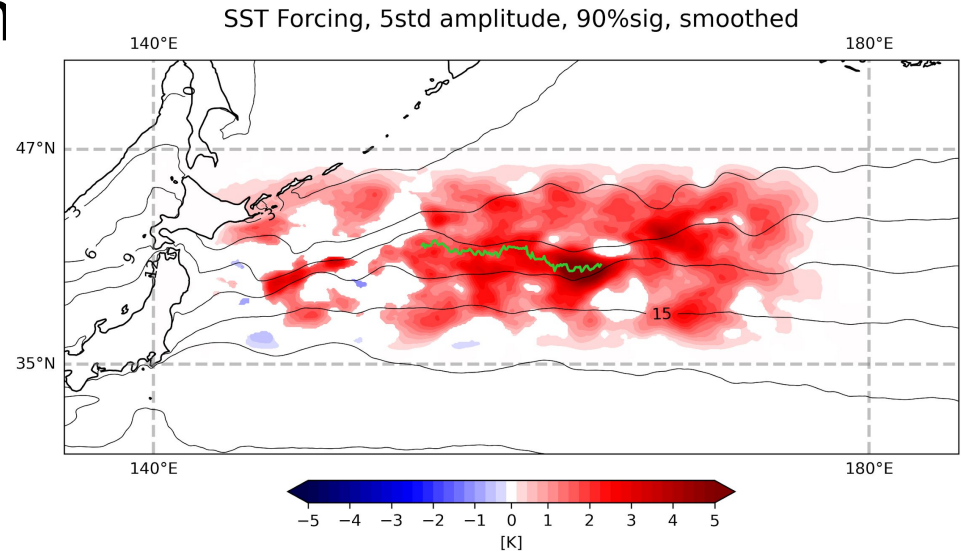
CTRL summary

- Three different synoptic weather patterns that induces strong latent heating enhancement over the western boundary current region
- Latent heating enhancement depends on the circulation structure



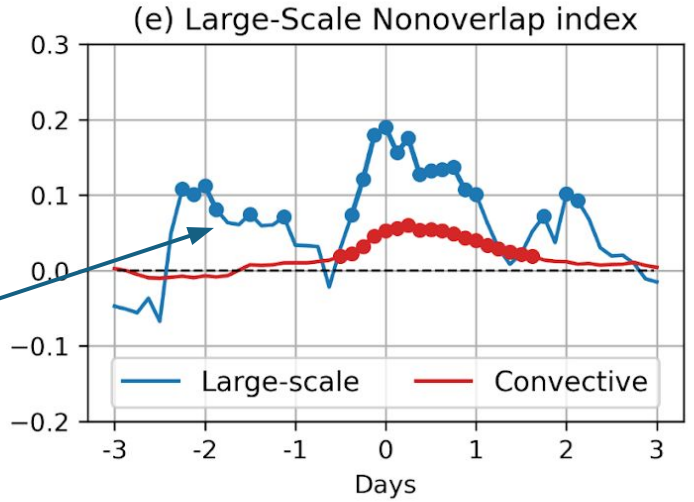
CTRL summary

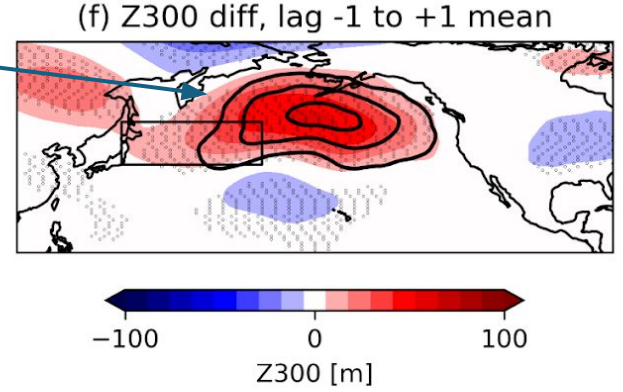
- Three different synoptic weather patterns that induces strong latent heating enhancement over the western boundary current region
- Latent heating enhancement depends on the circulation structure
- How would they respond to the SST an

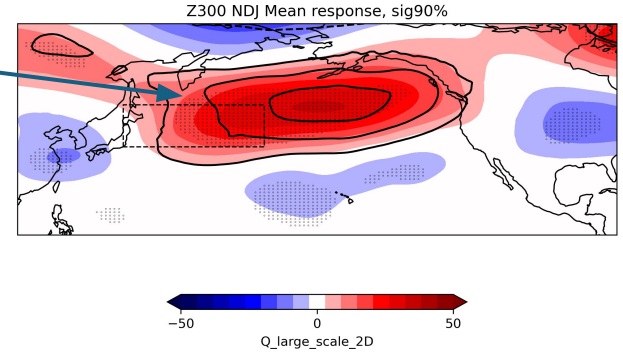


Response to the SST forcing

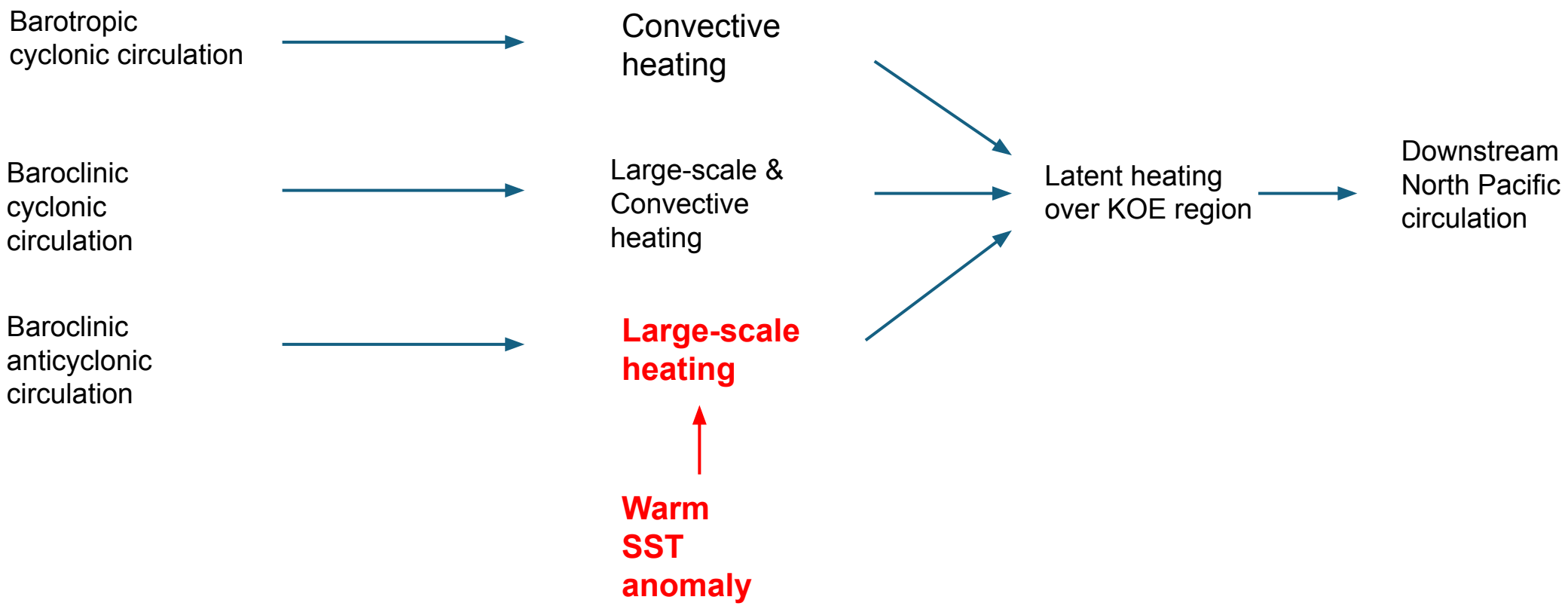
- Large-scale heating-only case
  - SST likely provided more moisture and updraft that leads to enhancement of latent heating
  - Enhancement of anticyclonic circulation
  - Enhanced latent heating -> important factor for maintenance of blocking-like anticyclone (Pfahl et al. 2015)
- Resemblance to the seasonal mean response pattern
  - Seasonal mean response to the SST forcing: prominent North Pacific anticyclone
  - Changes in a particular weather system -> influences seasonal mean response
  - Other latent heating event didn't much change with the SST







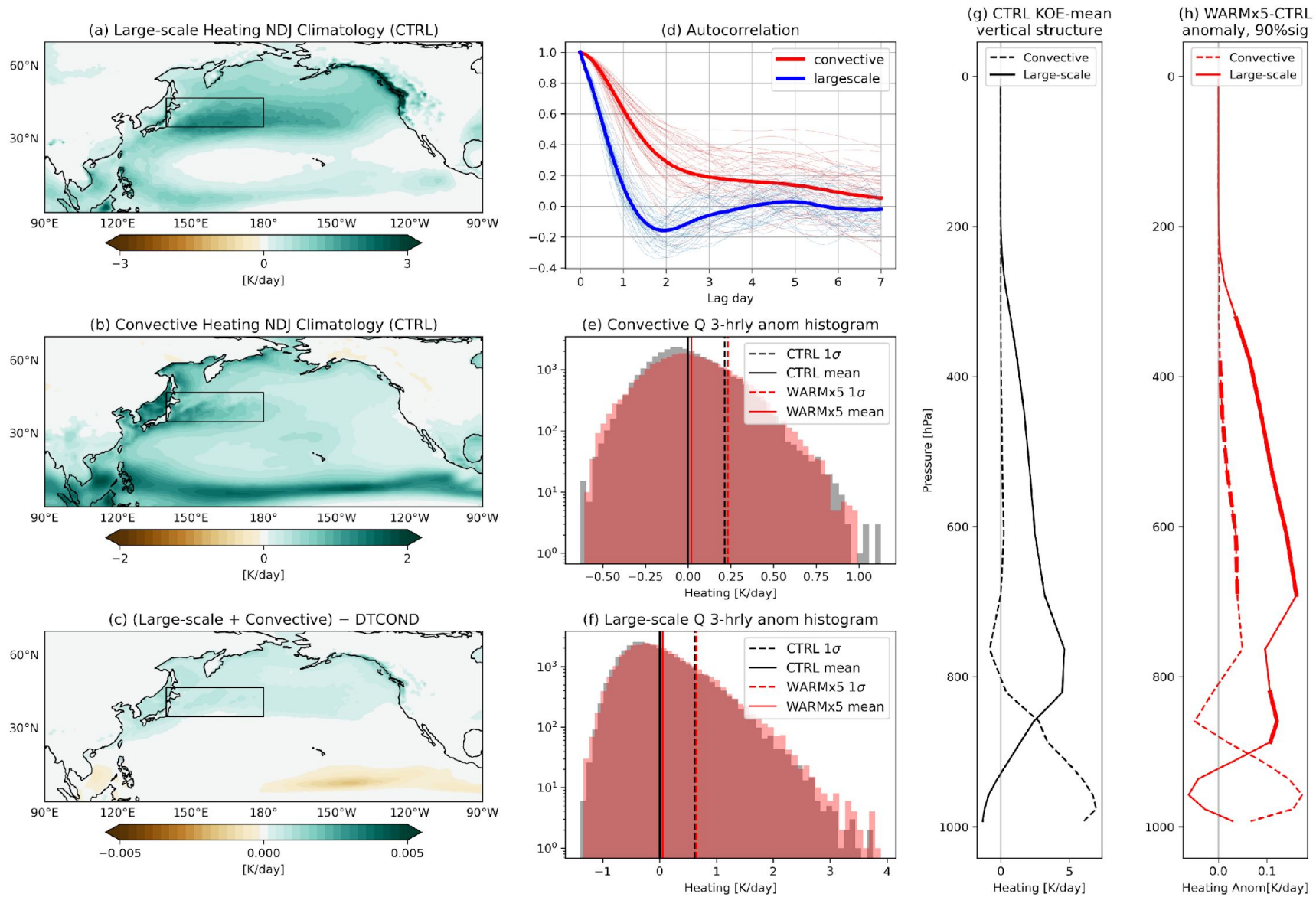
Summary from the structure of two events

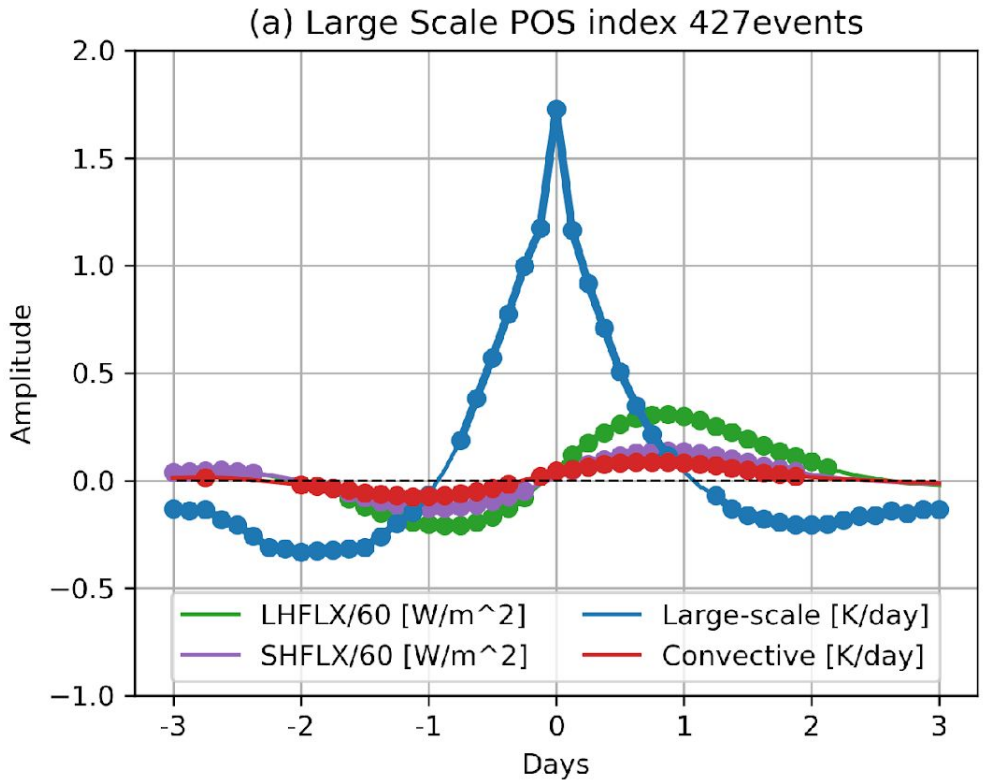


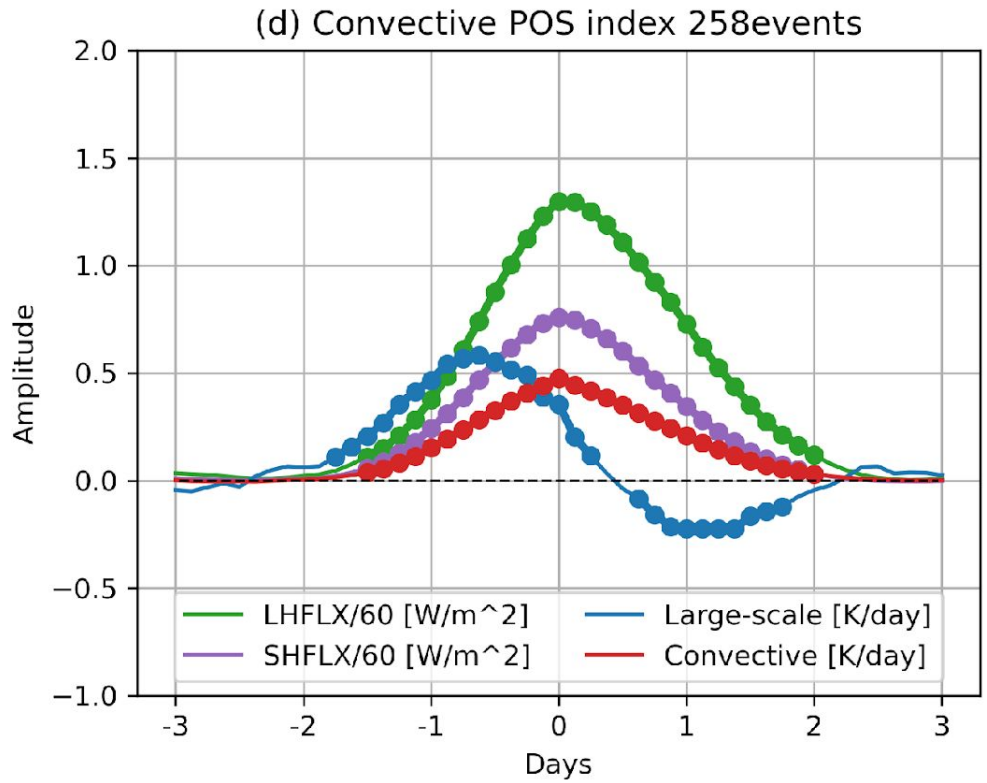
- Different types of weather event over the North Pacific western boundary current region
- Each pattern responds differently with underlying SST anomaly forcing
- Identifying dynamically important synoptic weather patterns help to understand complicated climate response to the SST anomaly

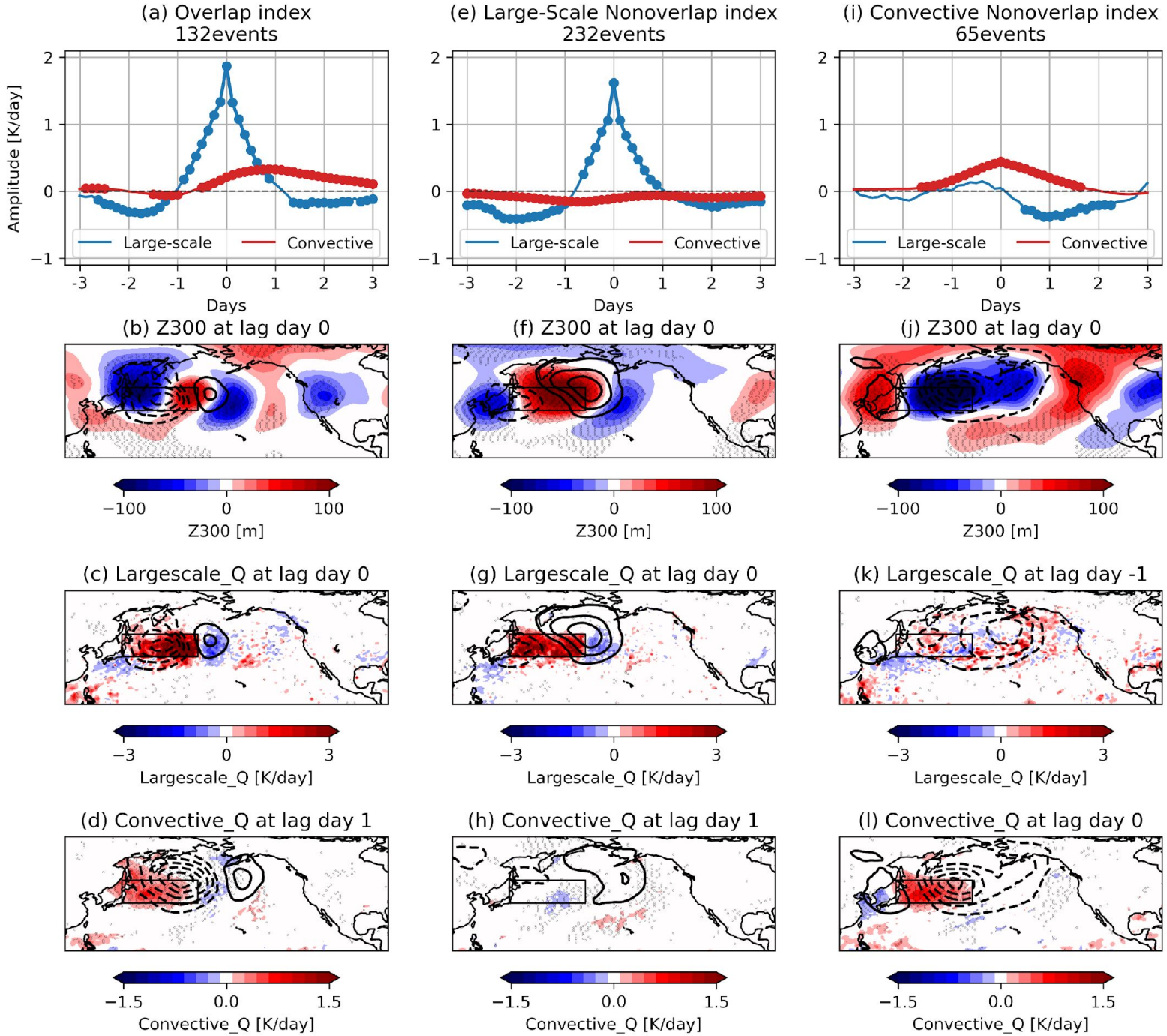
END

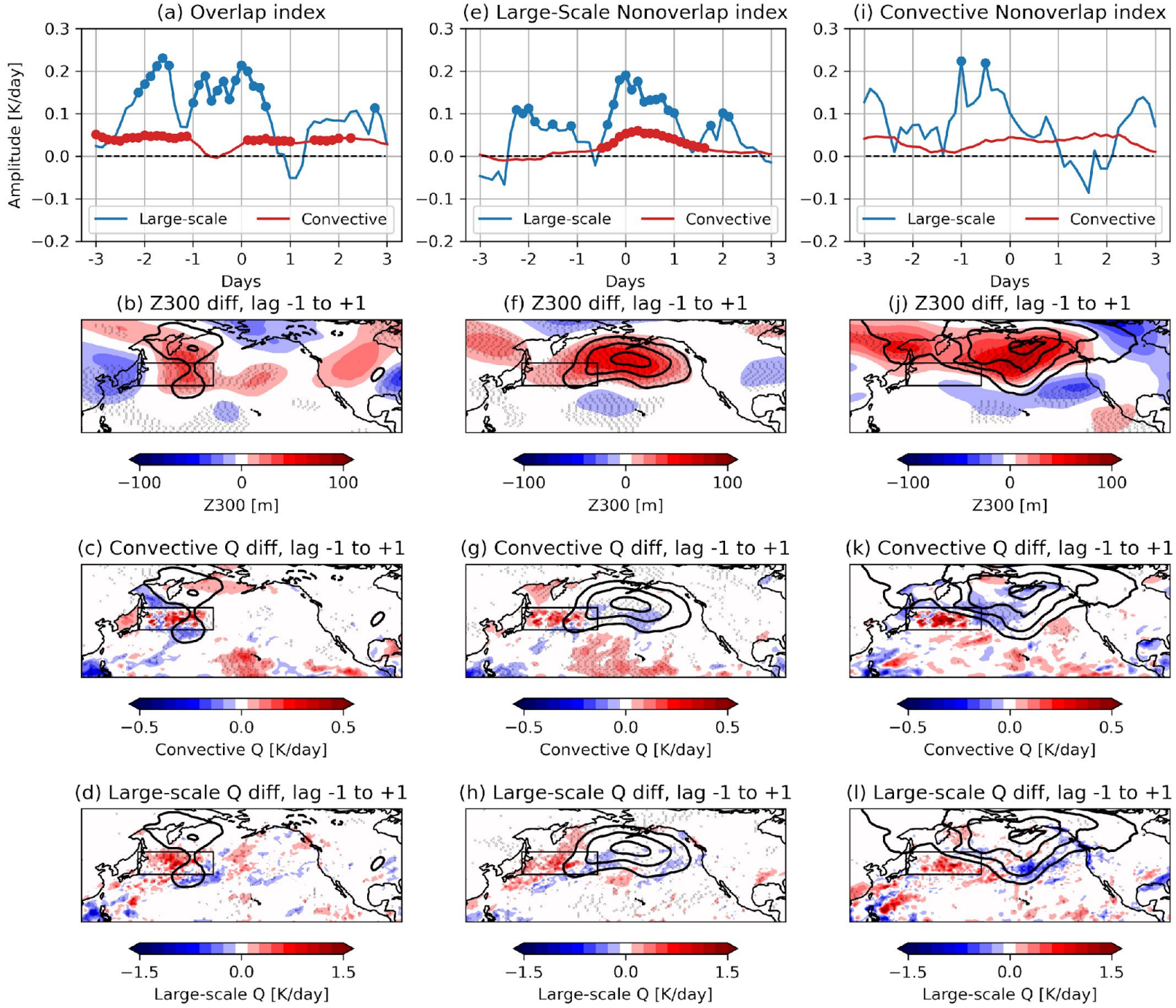
Supplementary figures

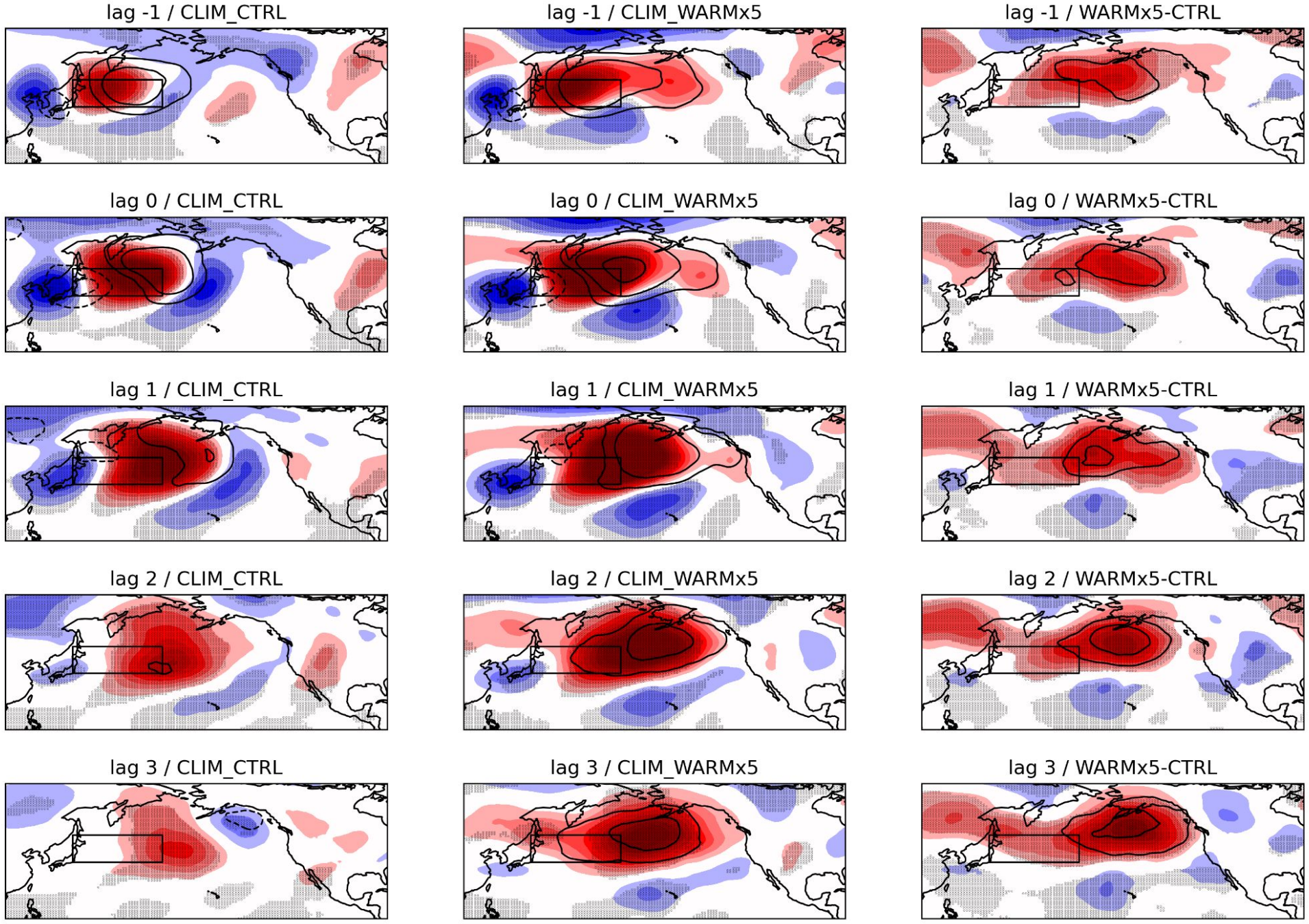

(a) Large-scale Heating NDJ Climatology (CTRL)
60°N
30°N
90°E
120°E
150°E
180°
150°W
120°W
90°W
−3
0
3
[K/day]
(b) Convective Heating NDJ Climatology (CTRL)
−2
2
(c) (Large-scale + Convective) − DTCOND
−0.005
0.000
0.005
(d) Autocorrelation
convective
largescale
Lag day
(e) Convective Q 3-hrly anom histogram
CTRL 1σ
CTRL mean
WARMx5 1σ
WARMx5 mean
Heating [K/day]
(f) Large-scale Q 3-hrly anom histogram
(g) CTRL KOE-mean vertical structure
Convective
Large-scale
Pressure [hPa]
(h) WARMx5-CTRL anomaly, 90%sig
Heating Anom[K/day]


(a) Large Scale POS index 427events
Amplitude
Days
LHFLX/60 [W/m^2]
SHFLX/60 [W/m^2]
Large-scale [K/day]
Convective [K/day]


(d) Convective POS index 258events
Amplitude
Days
LHFLX/60 [W/m^2]
SHFLX/60 [W/m^2]
Large-scale [K/day]
Convective [K/day]


(a) Overlap index
132events
(e) Large-Scale Nonoverlap index
232events
(i) Convective Nonoverlap index
65events
Amplitude [K/day]
Large-scale
Convective
Days
(b) Z300 at lag day 0
(f) Z300 at lag day 0
(j) Z300 at lag day 0
Z300 [m]
(c) Largescale_Q at lag day 0
(g) Largescale_Q at lag day 0
(k) Largescale_Q at lag day -1
Largescale_Q [K/day]
(d) Convective_Q at lag day 1
(h) Convective_Q at lag day 1
(l) Convective_Q at lag day 0
Convective_Q [K/day]


(a) Overlap index
(e) Large-Scale Nonoverlap index
(i) Convective Nonoverlap index
Amplitude [K/day]
Days
Large-scale
Convective
(b) Z300 diff, lag -1 to +1
(f) Z300 diff, lag -1 to +1
(j) Z300 diff, lag -1 to +1
Z300 [m]
(c) Convective Q diff, lag -1 to +1
(g) Convective Q diff, lag -1 to +1
(k) Convective Q diff, lag -1 to +1
Convective Q [K/day]
(d) Large-scale Q diff, lag -1 to +1
(h) Large-scale Q diff, lag -1 to +1
(l) Large-scale Q diff, lag -1 to +1
Large-scale Q [K/day]


lag -1 / CLIM_CTRL
lag -1 / CLIM_WARMx5
lag -1 / WARMx5-CTRL
lag 0 / CLIM_CTRL
lag 0 / CLIM_WARMx5
lag 0 / WARMx5-CTRL
lag 1 / CLIM_CTRL
lag 1 / CLIM_WARMx5
lag 1 / WARMx5-CTRL
lag 2 / CLIM_CTRL
lag 2 / CLIM_WARMx5
lag 2 / WARMx5-CTRL
lag 3 / CLIM_CTRL
lag 3 / CLIM_WARMx5
lag 3 / WARMx5-CTRL