Decadal variability of the Kuroshio Extension jet and its relation to coastal sea level along Japan

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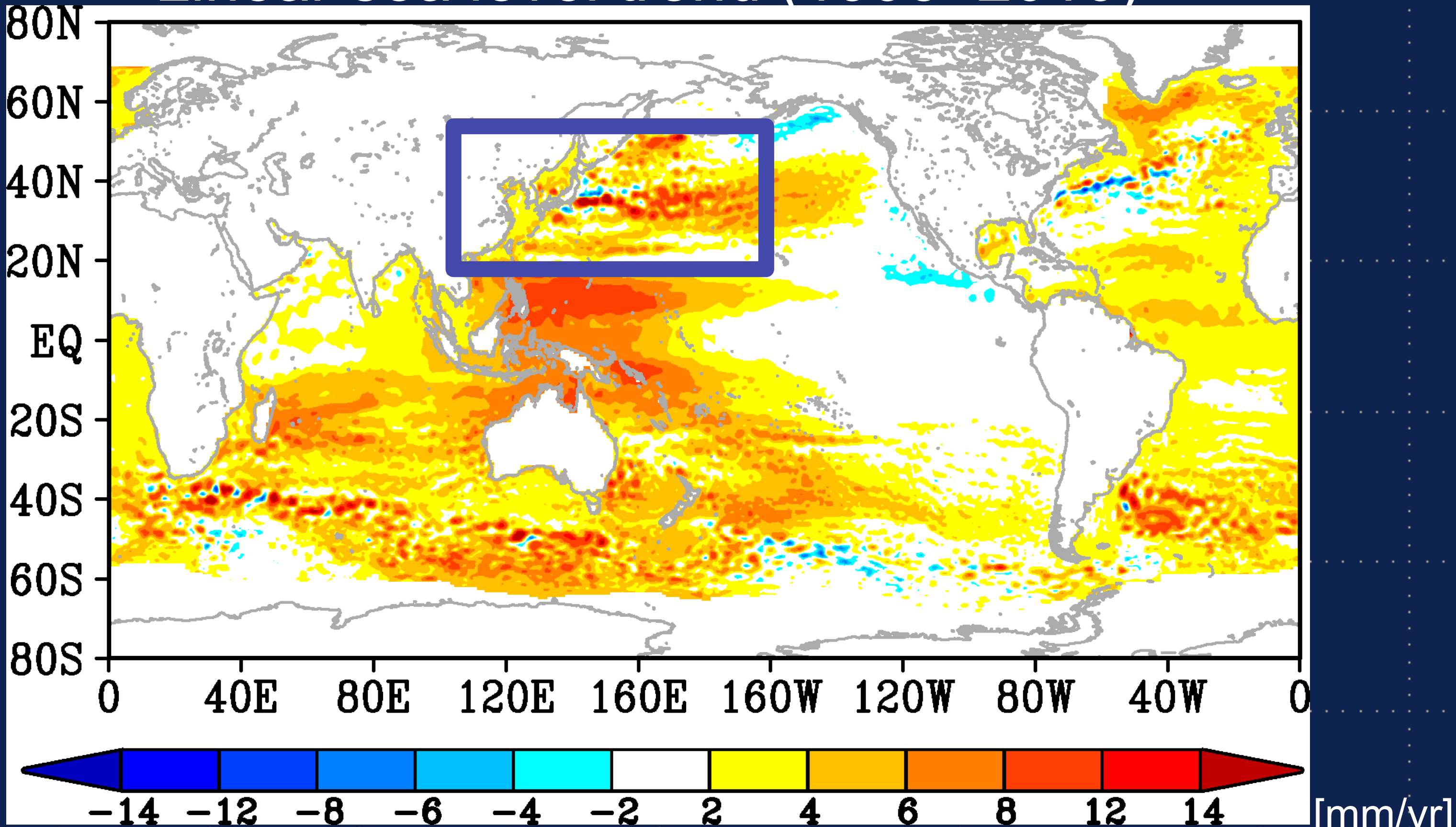
Sea Level Rise

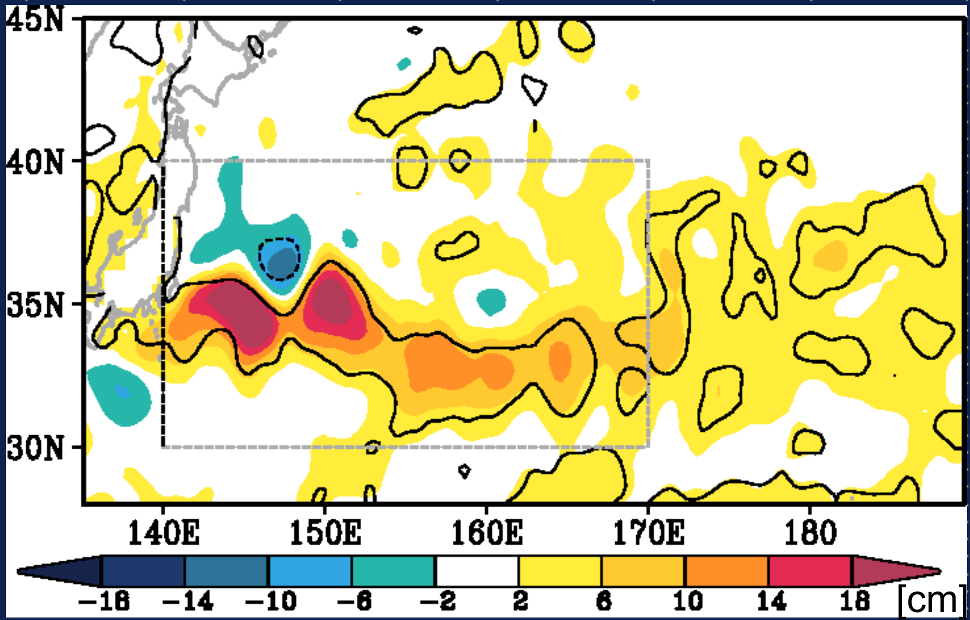
Linear sea level trend (1993–2010)

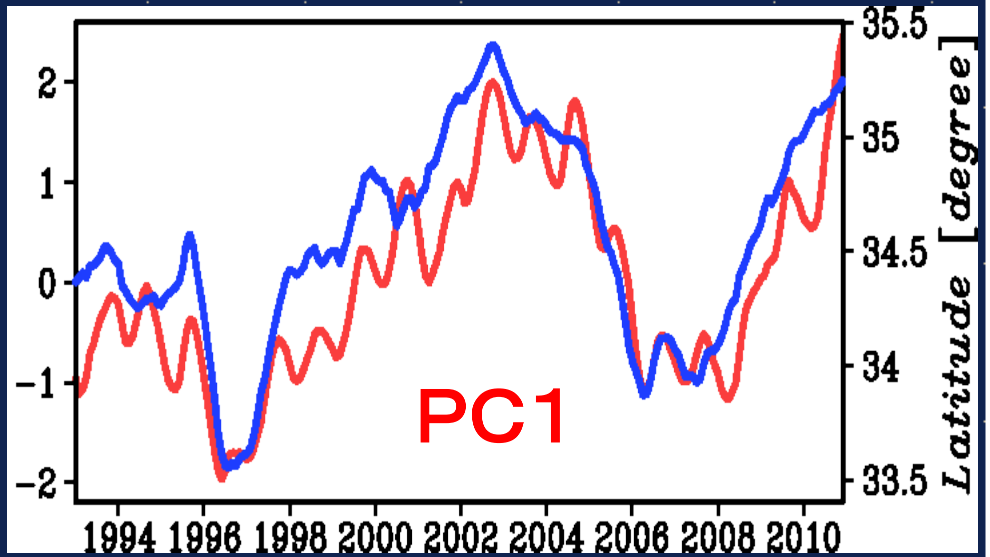


- The Kuroshio Extension (KE) is one of the regions where the prominent sea level rise occurs

Dominant sea level variability

Satellite 1st EOF mode



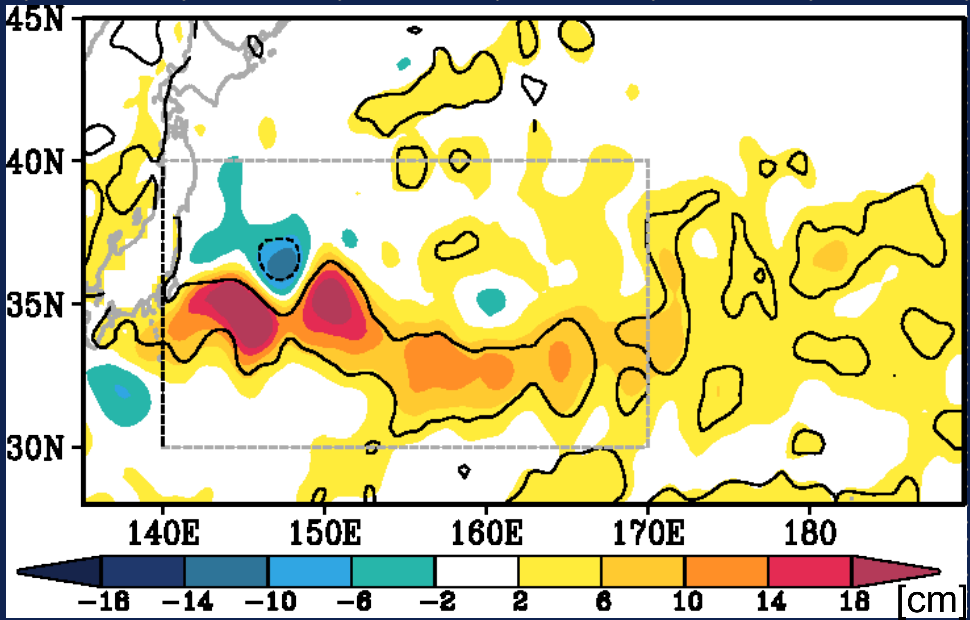


- The large sea level rise in the KE is attributed to meridional shifts of the KE jet on decadal timescales
- What is the mechanism for the narrow sea level variability?

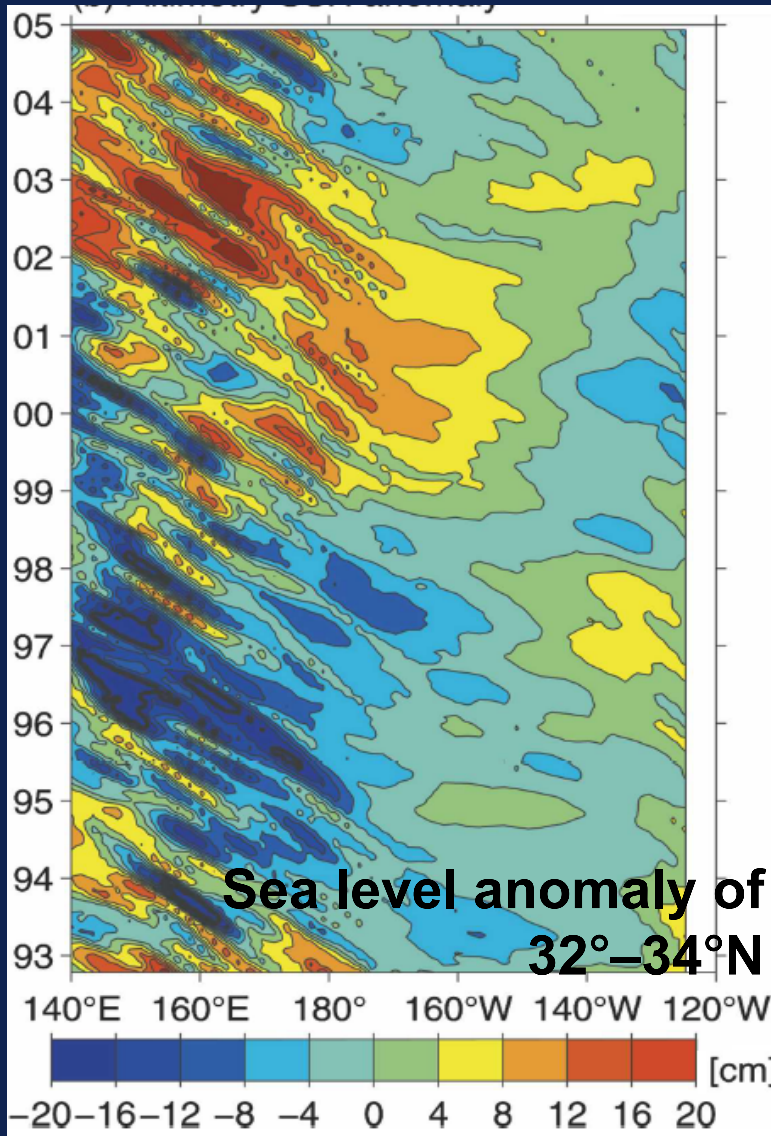
Sasaki et al. (2013, JPO)

Dominant sea level variability

Satellite 1st EOF mode

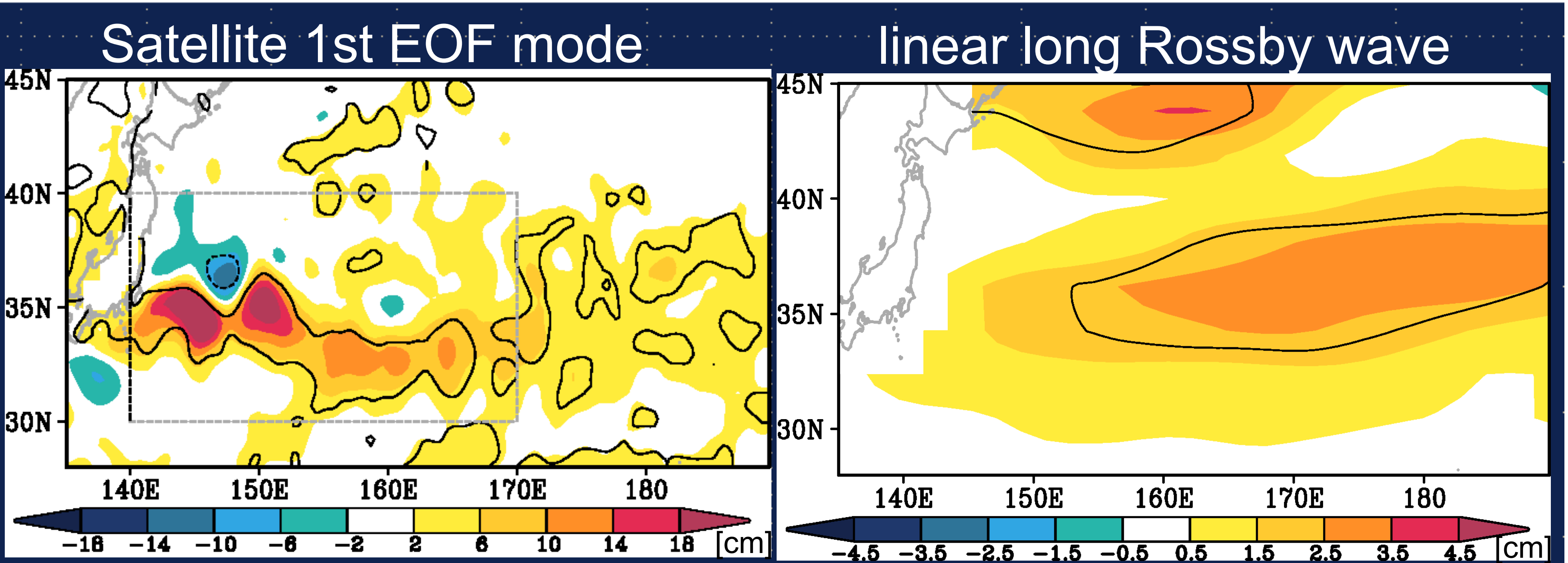


- A traditional mechanism is a linear long Rossby wave, but …



Qiu and Chen (2005)

Dominant sea level variability



- A linear long Rossby wave does not show narrow sea level variability around the KE jet

⇒ Another dynamic framework is necessary

Purposes

- We propose new mechanism for the decadal variability in the KE and clarify the extent to which this mechanism can explain

- We show responses to the meridional shift of the KE jet
  - stable/unstable modes
  - sea level change along the Japan coast

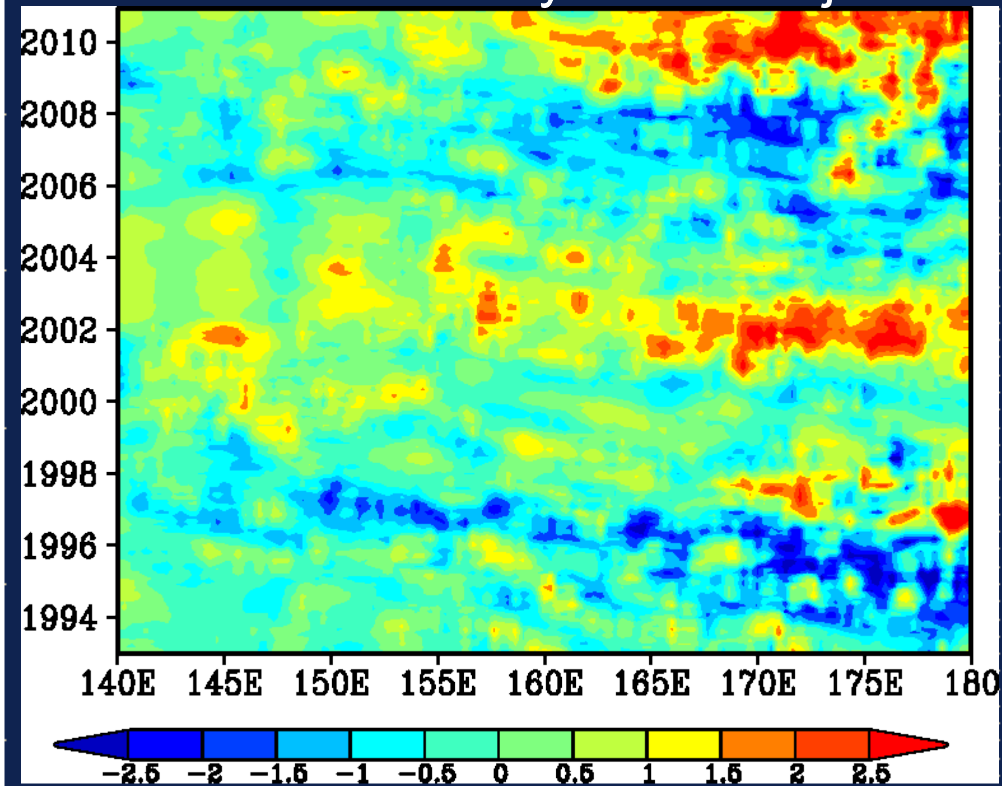
New mechanism

- In the traditional linear Rossby wave theory, the equations are linearized in Eulerian coordinates
- The equations in the natural coordinates are scaled and linearized for decadal variability in the KE, following Cushman-Roisin et al. (1993)
- The resultant equations show:
  1. A meridional structure of the jet is frozen in time
  2. Meridional shifts of the jet axis propagate westward
     - ➢This wave is referred to as a jet-trapped Rossby wave

Sasaki et al. (2011, JPO; 2013, JPO)

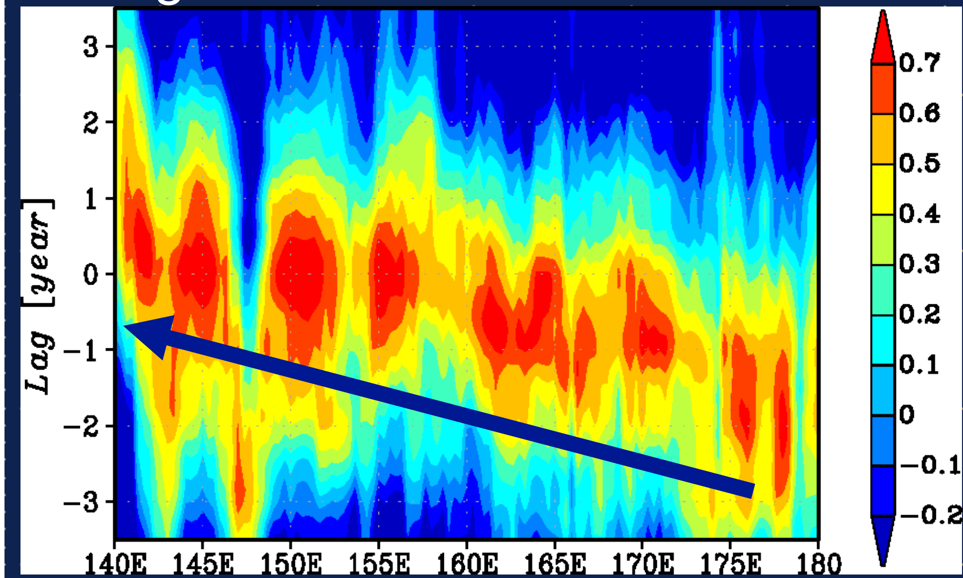
Propagating signals

Latitude anomaly of the KE jet



[degree]

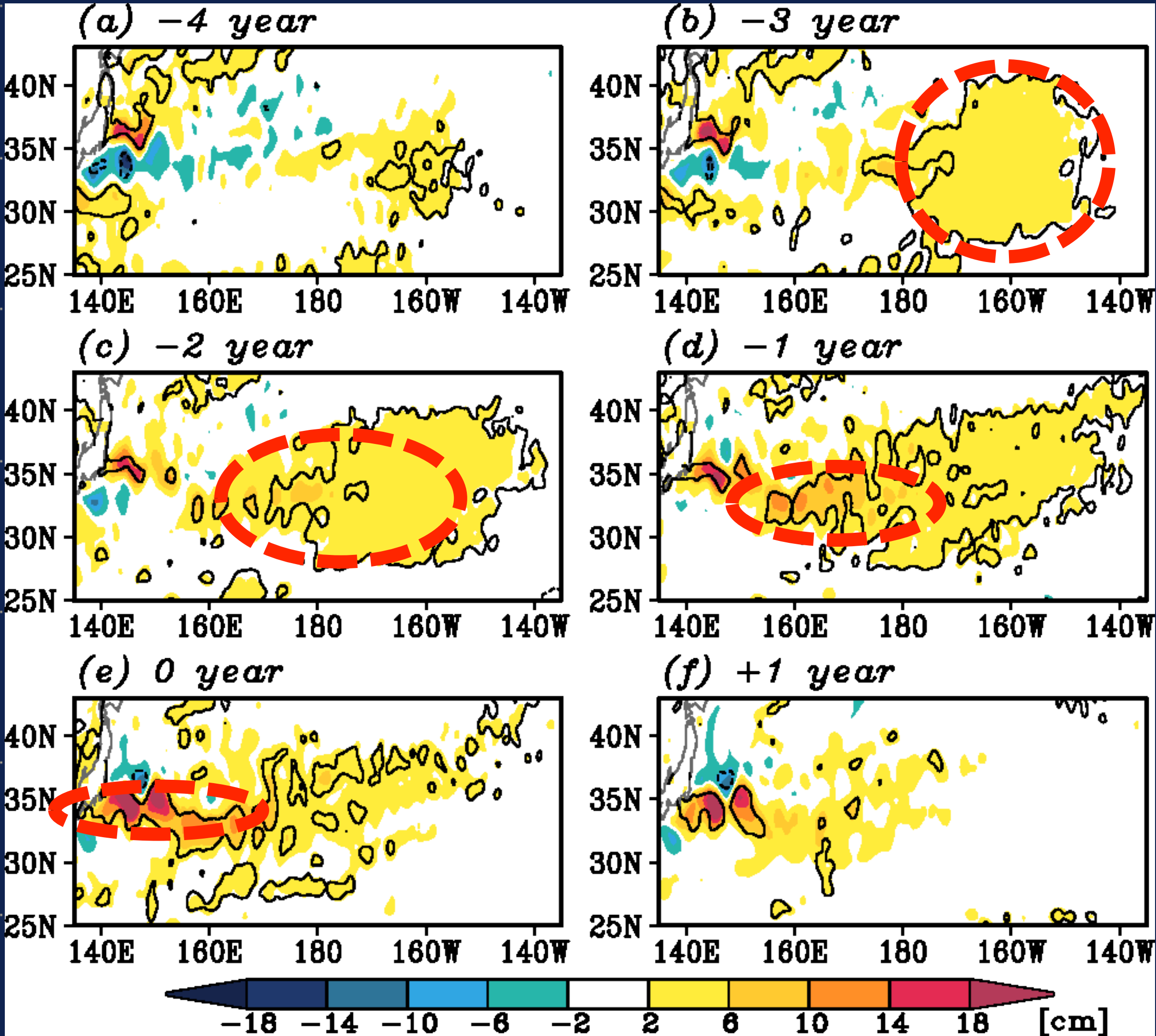
Lag-corr of the latitude onto PC1



- Meridional shifts of the KE jet propagate westward, consistent with the jet-trapped Rossby wave

Sasaki et al. (2013, JPO)

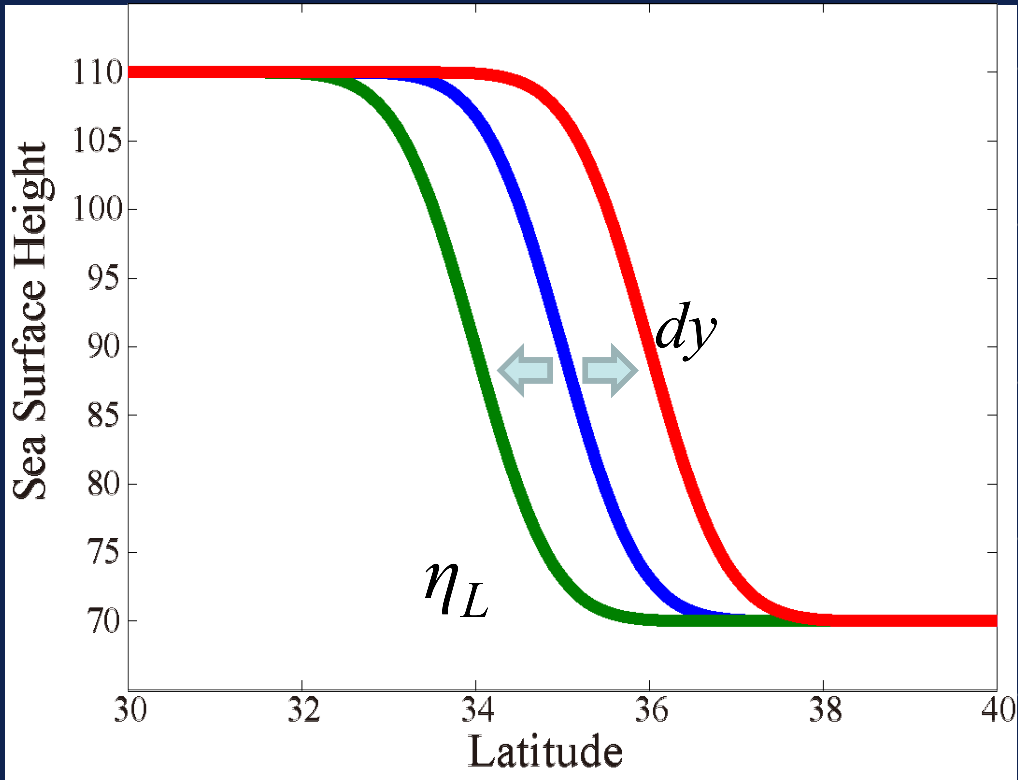
Propagating signals



- The meridional scale gradually narrows, and the amplitude gradually increases probably due to PV conservation

Sasaki et al. (2013, JPO)

Reconstructed sea level variability

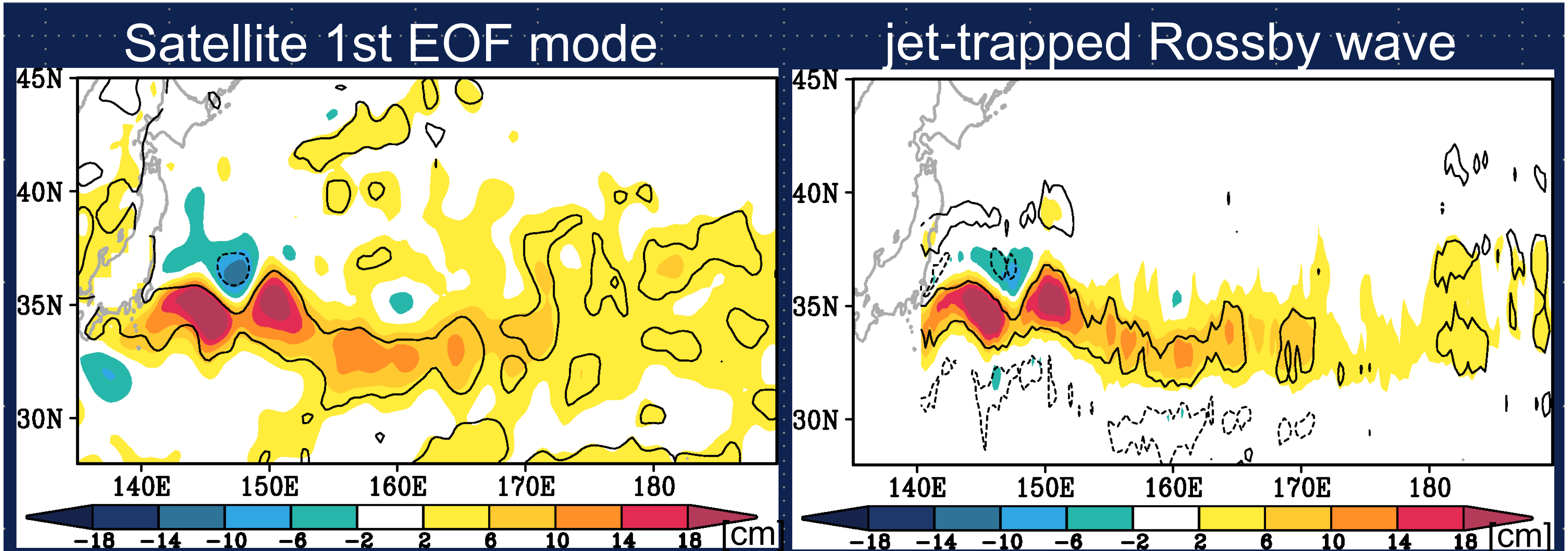


$$\eta(x,y,t) = \eta_L\left[x, y_0 + dy(x,t)\right]$$

- *dy* is given by the observational values

Sasaki et al. (2013, JPO)

Reconstructed sea level variability

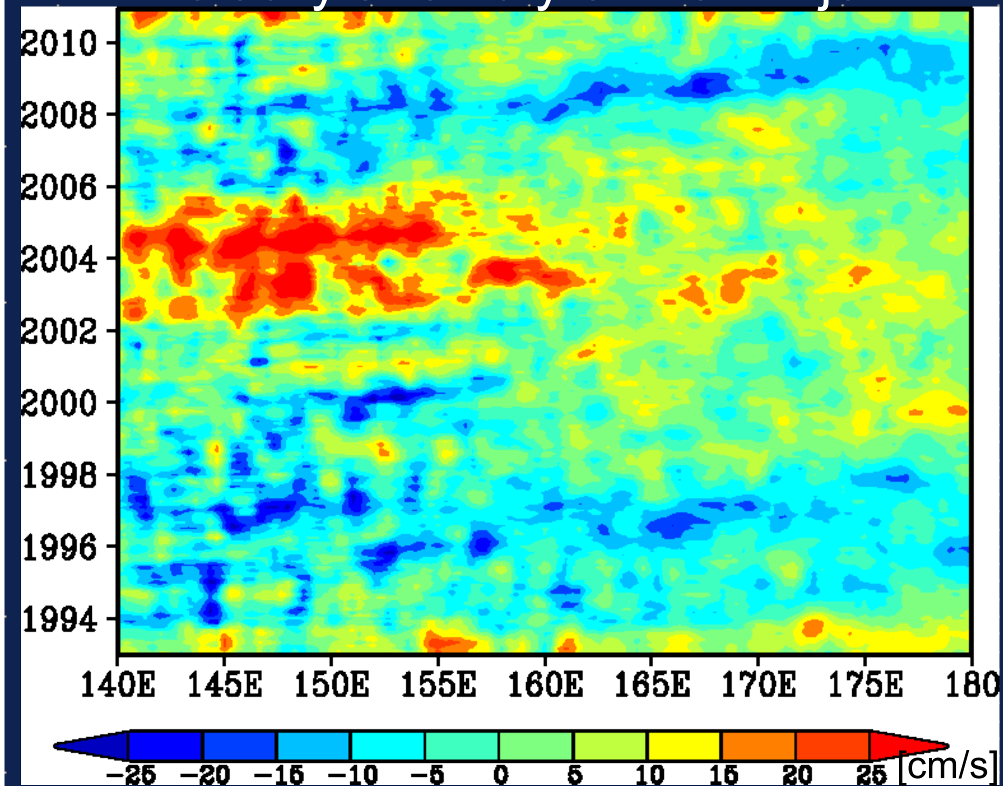


- The meridional position, amplitude and meridional scale of the reconstructed SLAs well correspond to the observation

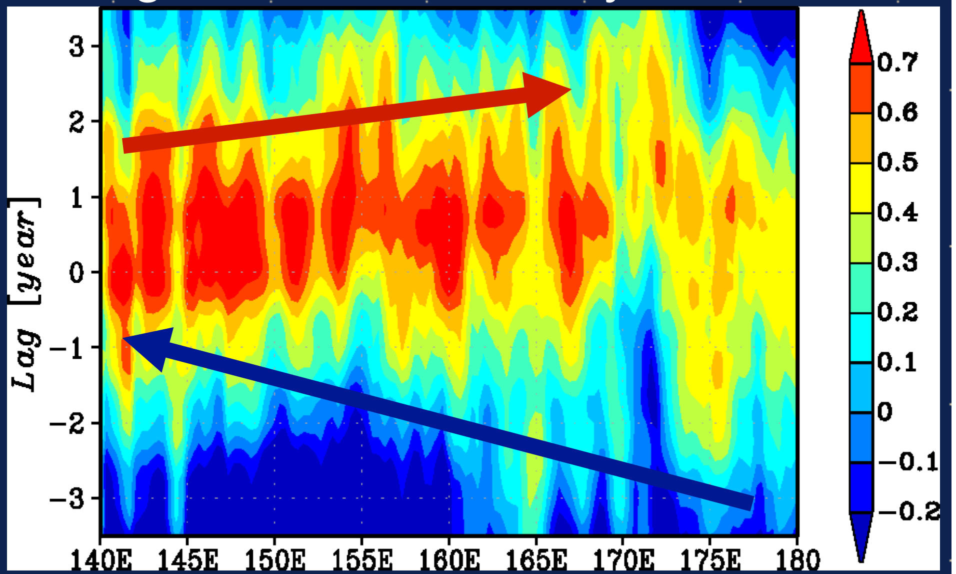
Sasaki et al. (2013, JPO)

Response of the strength of the jet

Velocity anomaly of the KE jet



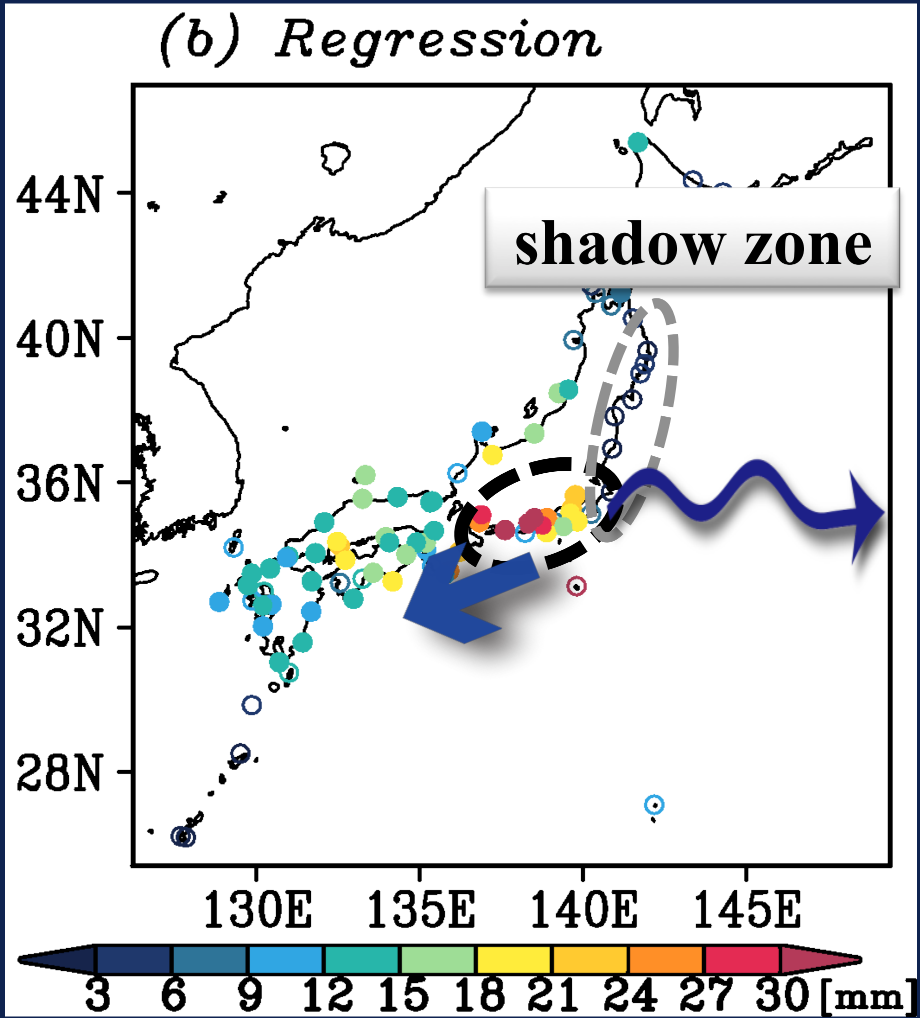
Lag-corr of the velocity onto PC1



- Velocity changes of the KE jet propagate eastward in response to the incoming jet-trapped Rossby waves
- Velocity changes of the KE jet are negatively correlated with the number of pinch-off rings

Sasaki et al. (2013, JPO, 2015, JO)

Response of the coastal sea level



- Northward shifts of the KE jet are accompanied by coastal sea level rise
- The coastal sea level change shows large spatial contrast due to the jet-trapped nature of the incoming signals

Sasaki et al. (2014, JGR)

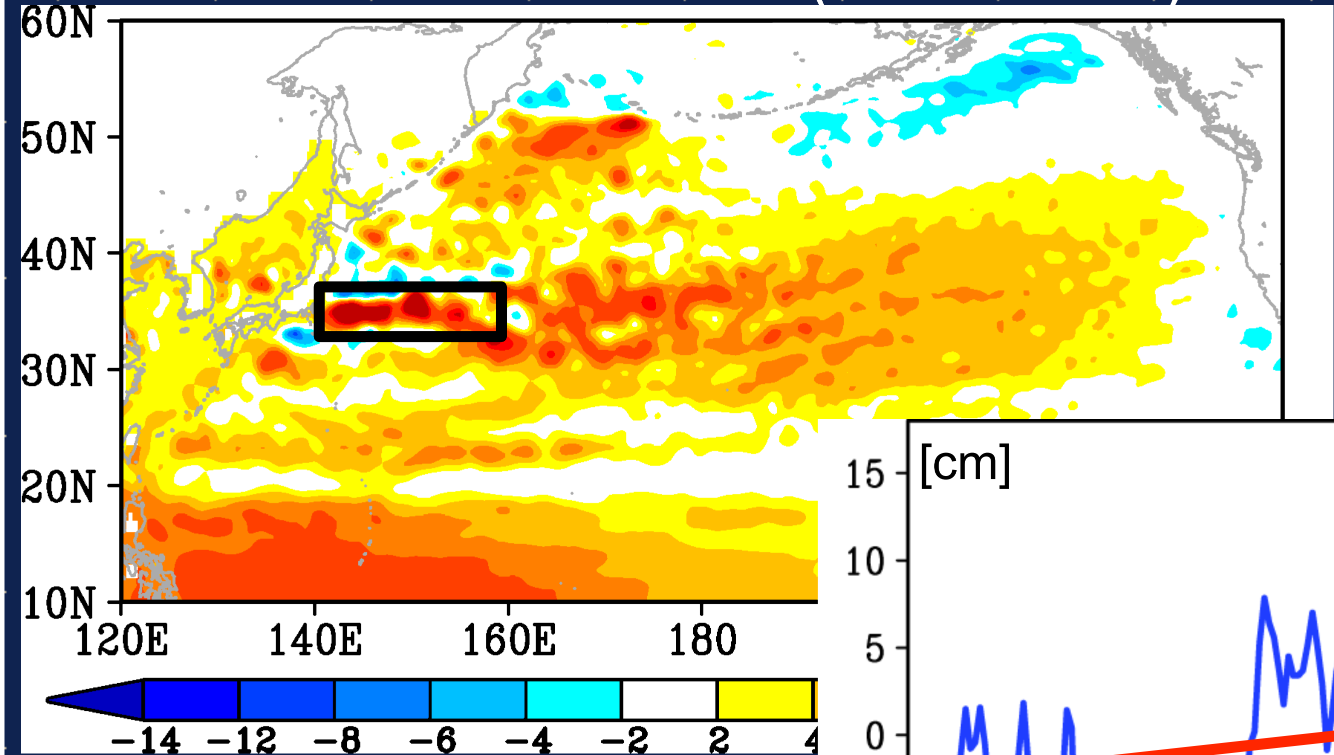
Conclusion

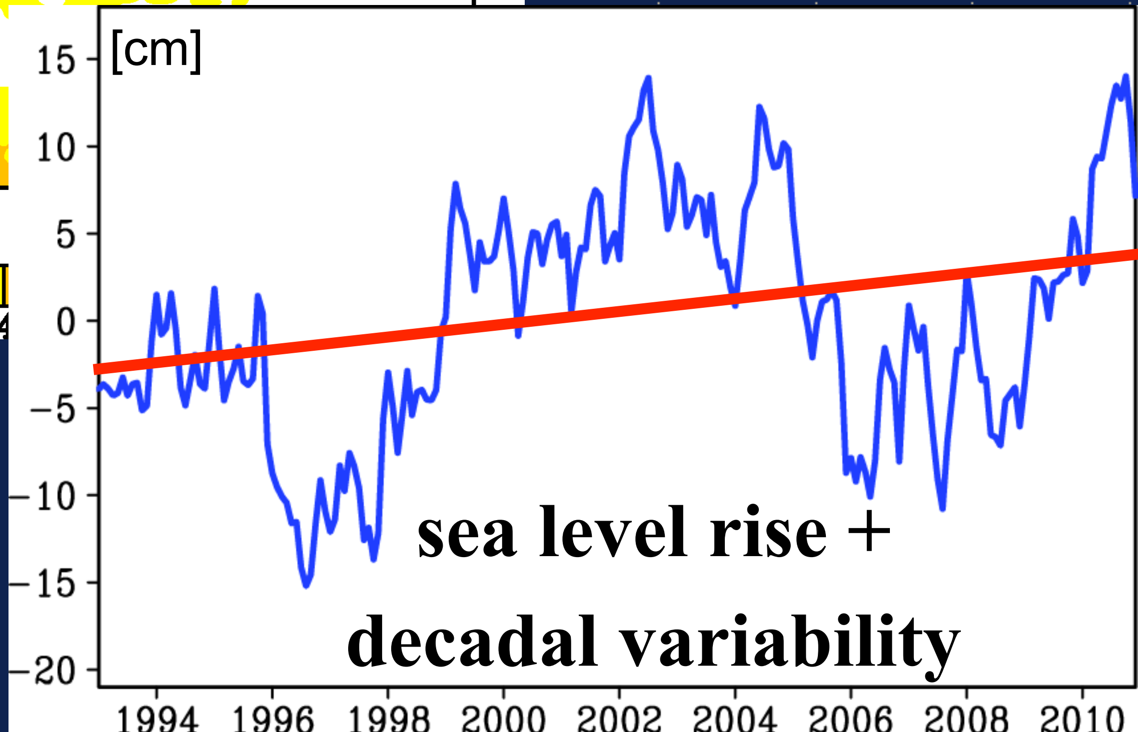
- The jet-trapped Rossby wave can explain the decadal variability of the KE jet
  - Jet-trapped Rossby waves play an important role in the transitions between stable/unstable modes
  - Jet-trapped Rossby waves induce spatial contrast of sea level change along the Japan coast

Sasaki et al. (2011, JPO; 2013, JPO; 2014, JGR; 2015, JO)

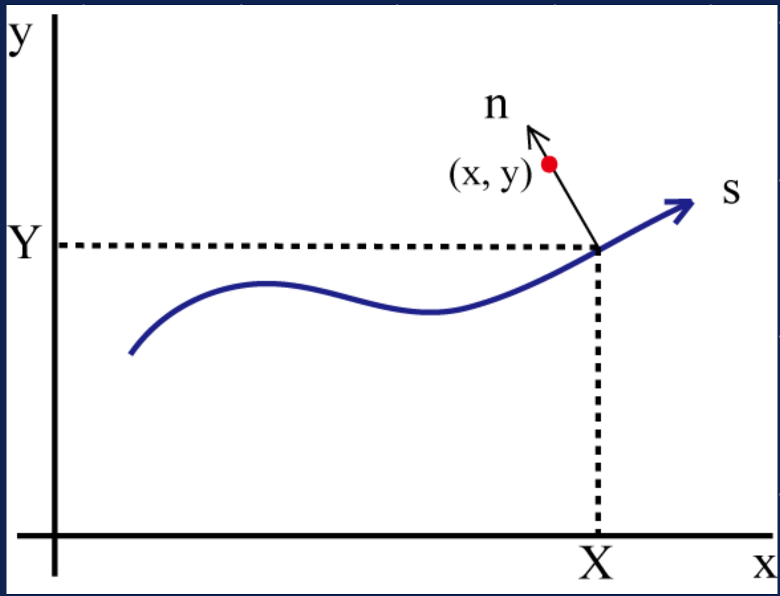
Sea Level Rise in the North Pacific

Linear sea level trend (1993–2010)





A jet-trapped Rossby wave



s: the distance along the jet

n: the distance from the arbitrary point (x, y) to the nearest jet

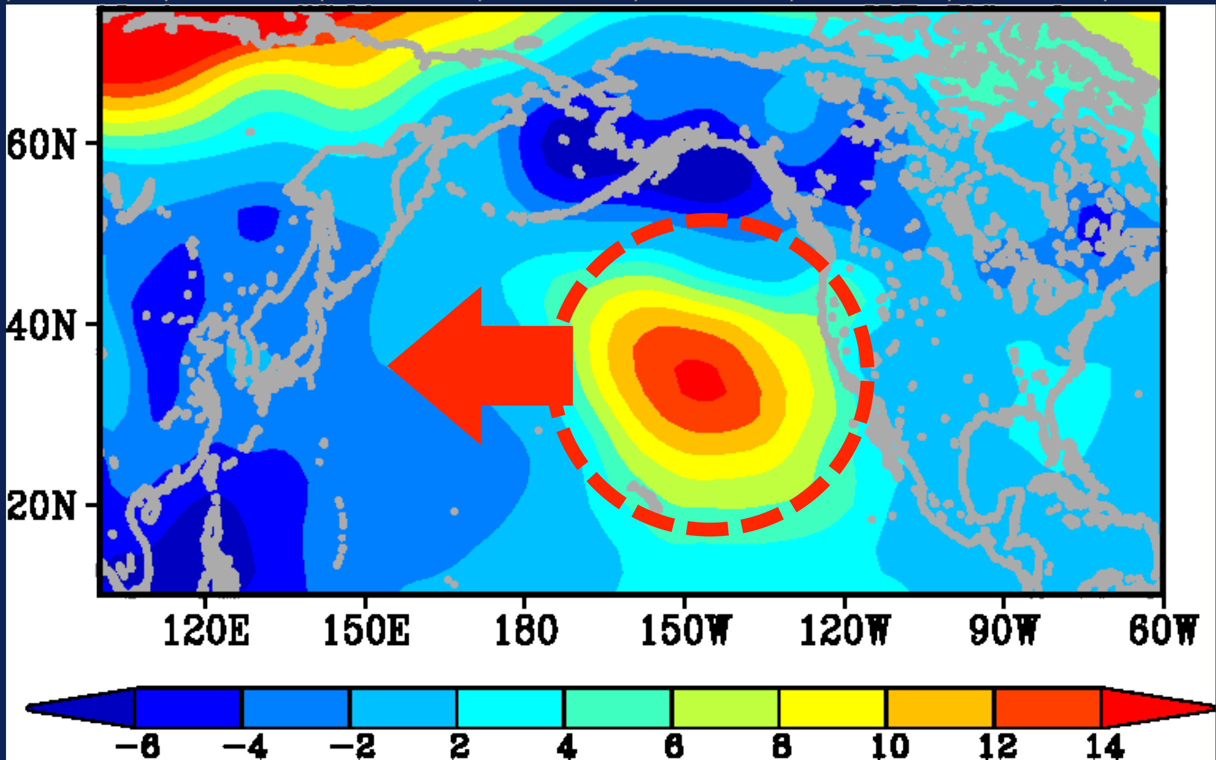
X, Y: the point on the jet

- The thin-jet theory (Cushman-Roisin et al. 1993) is modified for the decadal variability of the KE jet
- Meridional shifts of the KE jet propagate westward
- We refer to as a jet-trapped Rossby wave

Sasaki and Schneider (2011, JPO)

Atmospheric fluctuations

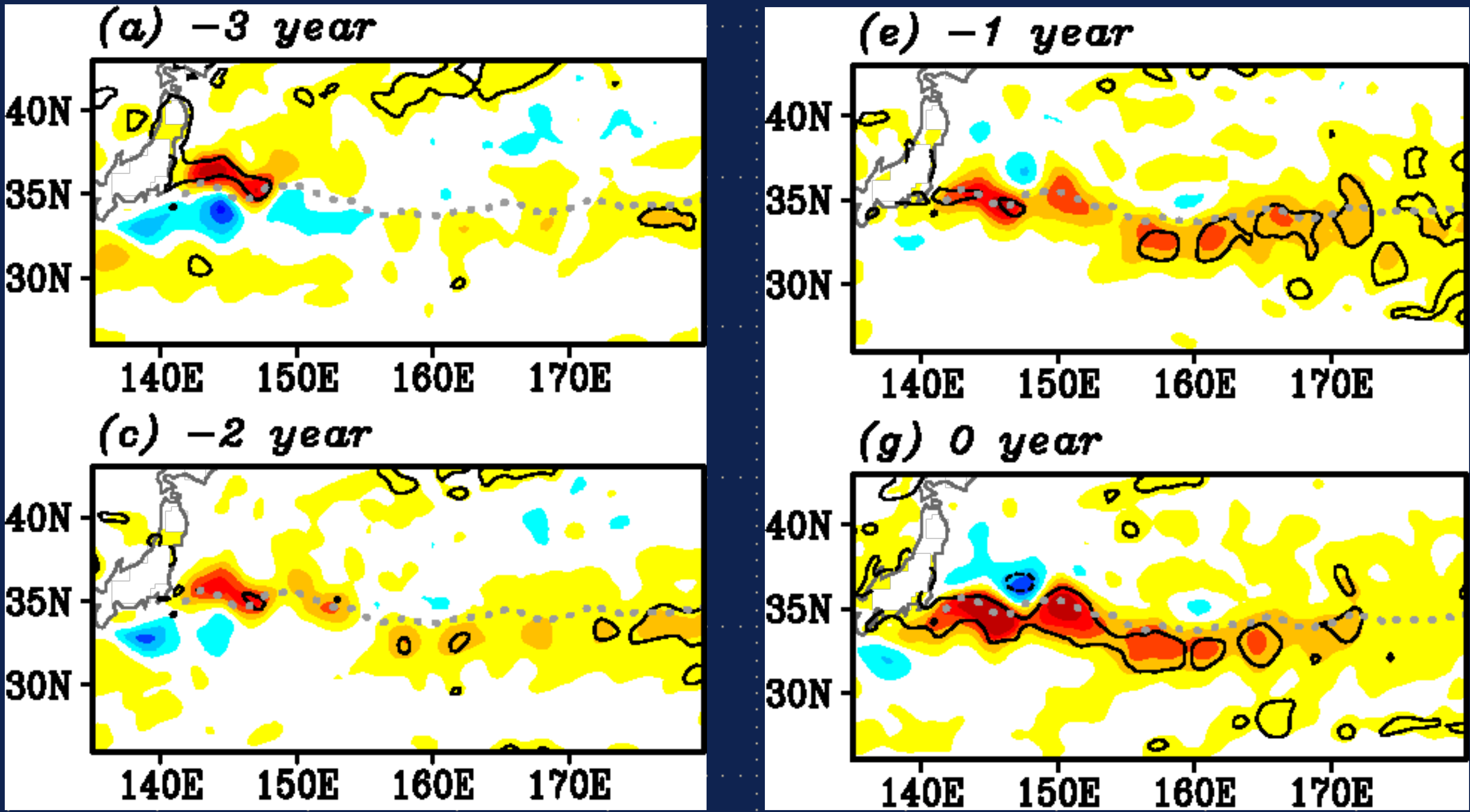
Z1000 anomalies (3-yr leading)



- Atmospheric fluctuations over the eastern North Pacific likely force the decadal variability in KE

Sasaki et al. (2013, JPO)

Propagating signals



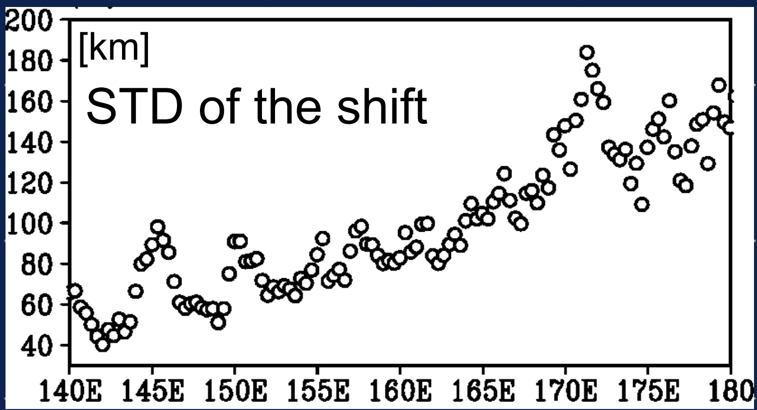
- The KE jet acts as a waveguide of the propagation signals, consistent with the jet-trapped Rossby wave

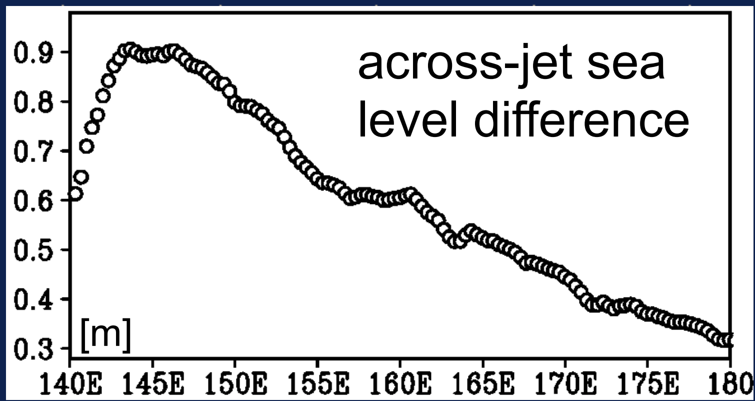
Sasaki et al. (2013, JPO)

Reconstruction of SLAs

$$\eta(x,y,t) = \eta_L\left[x, y_0 + dy(x,t)\right]$$

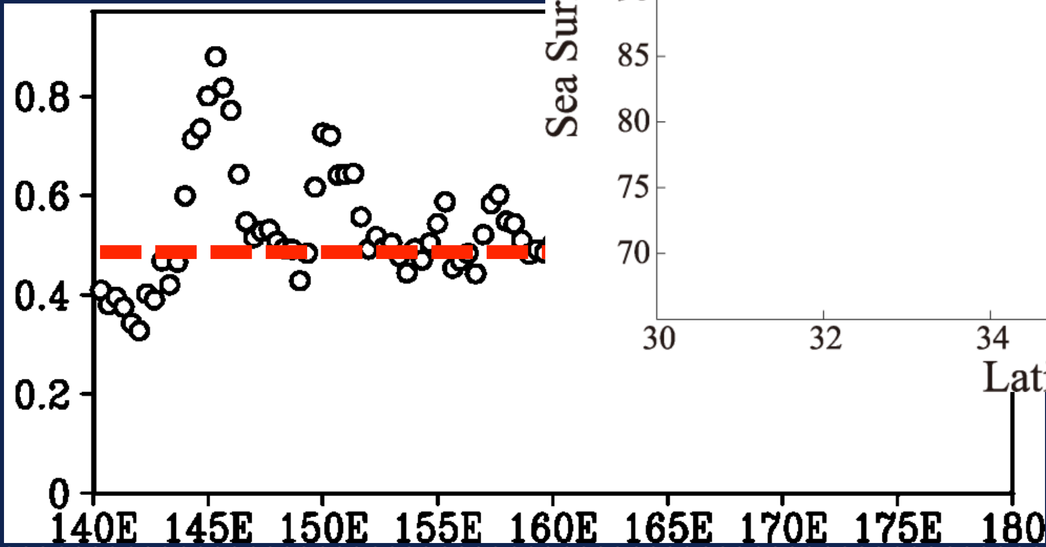
- The change of the meridional scale of SLAs is likely related to the change of the amplitude of the jet shift *dy*
- The increase of the amplitude of SLAs from east to west results from the increase of the across-jet sea level difference

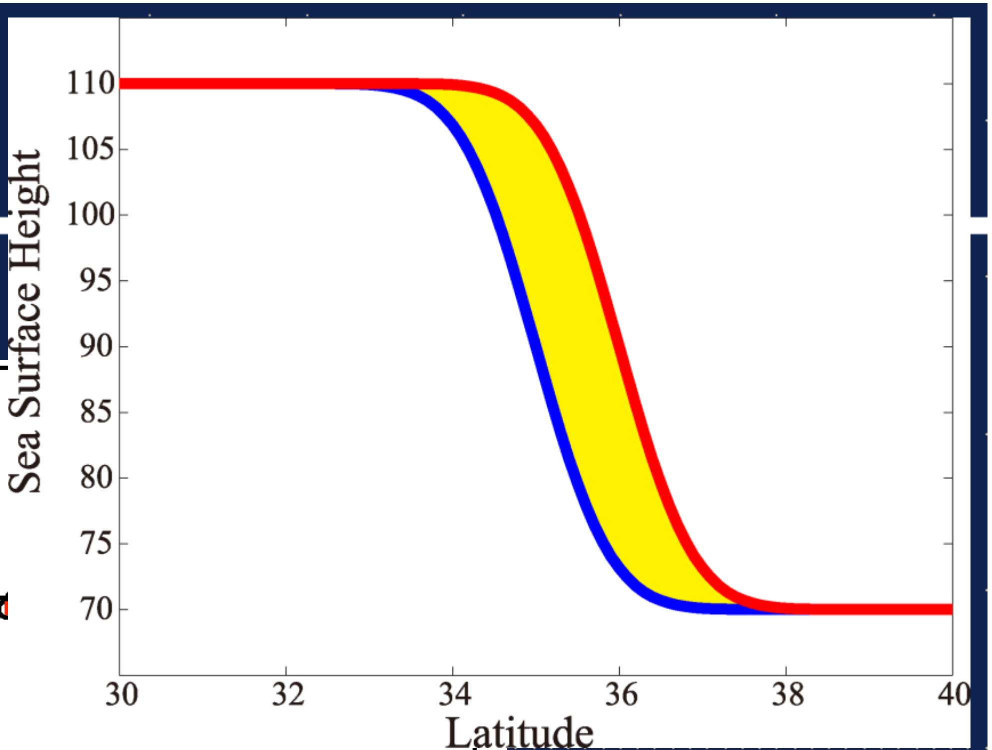




Sasaki et al. (2013, JPO)

Discussion





- The product of the amplitude of the jet shift and the across-jet sea level difference is roughly constant at each longitude
- Because this product corresponds to a volume (or QG PV) anomaly associated with the shift of the jet, the propagating signals may conserve their QG PV anomaly at each longitude

Sasaki et al. (2013, JPO)