Wind-driven and intrinsic interannual variability in the Kuroshio Extension jet and its eddy activities

Masami Nonaka
Hideharu Sasaki
(APL, JAMSTEC)

and

Niklas Schneider
(IPRC, Univ. of Hawaii)

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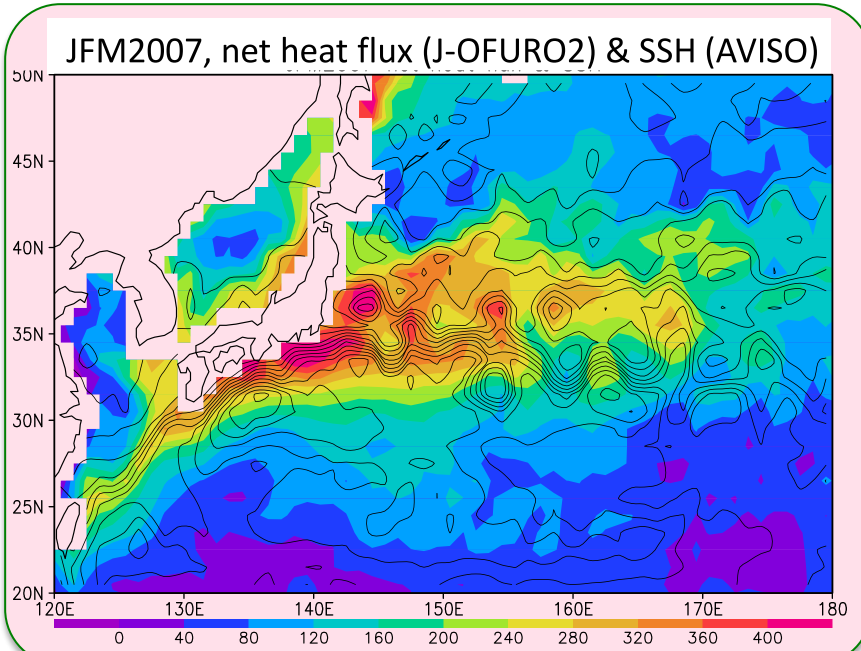
Importance of the Kuroshio Extension (KE)



Kuroshio Extension (KE) is important for climate due to its huge amount of heat transport, and strong SST frontal zone associated with it. Its importance has been investigated, for example, by Qiu et al. (2007).

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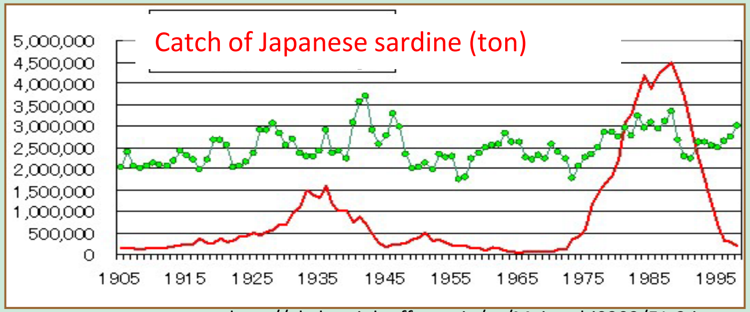
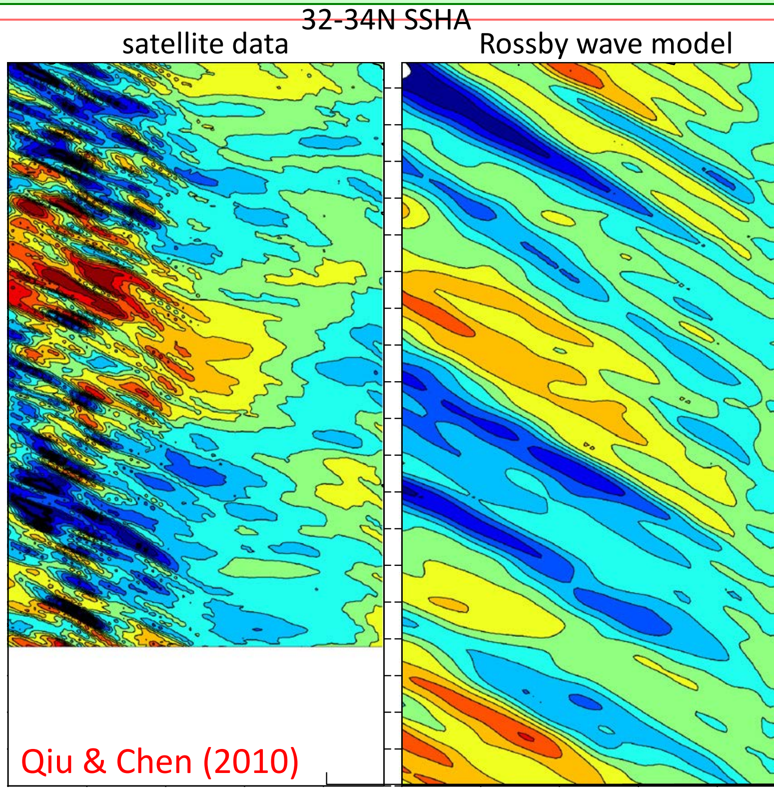


http://abchan.job.affrc.go.jp/pr/Maiwashi0302/F1-3.jpg

Also, KE is important for marine ecosystem. For example, Nishikawa and Yasuda (2011) suggest importance of variability in the Kuroshio and upstream KE jet speed for natural mortality of Japanese sardine especially around 1990, when number of Japanese sardine drastically reduced.

Because of these importance, we investigate variability of KE jet.

Mechanisms of variability in the KE jet: forced variability

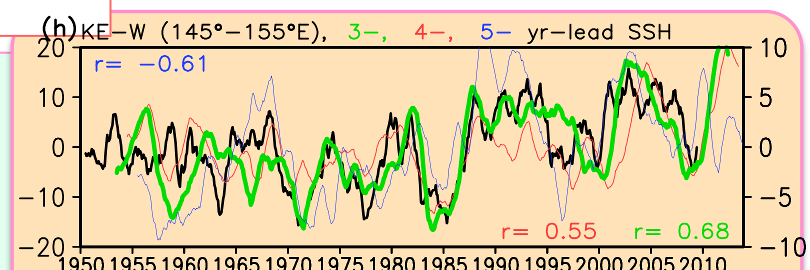


in (32-38N, 141-153E)

On the one hand, …

For interannual variability in KE, importance of propagation of Rossby waves driven by wind variability in the central/eastern NP has been shown based on satellite observed SSH.

Through westward propagation of Rossby waves across the basin, predictability with several years lead time for SST in the broad Kuroshio-Oyashio Extension region (Schneider & Miller 2001), and the KE jet speed (Nonaka et al. 2012) have been suggested.

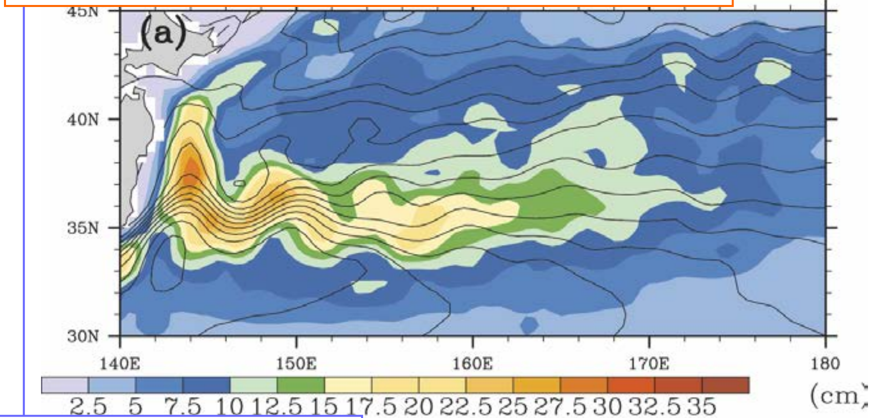


KE jet speed in [145° -155° E] (black) and 3-yr-lead SSHAs in [30° -34° N, 170° E-175° W] (green). 13-month running mean is applied.

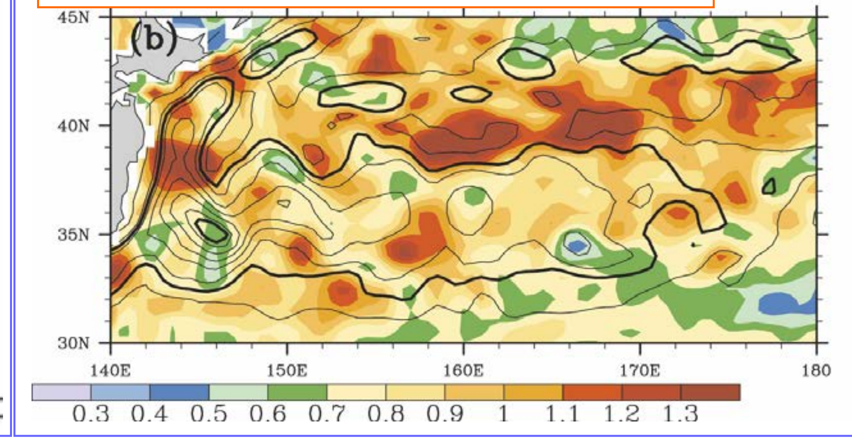
Mechanisms of variability in the KE jet: intrinsic variability

On the other hand, KE jet can have variability generated by internal oceanic dynamics, which is by nature unpredictable (c.f., Pierini 2006; Taguchi et al. 2007, among otehrs).

SSH std. in OFES climatological run



SSH std. climatological / hindcast



Taguchi et al. (2007)

- In the western boundary regions, it has been known that oceanic internal dynamics can induce intrinsic variability based on idealized models.

- Even in realistic OGCMs, it is known that substantial interannual variability is found in the integration driven by atmospheric forcing *without interannual variability* (e.g., Taguchi et al. 2007).

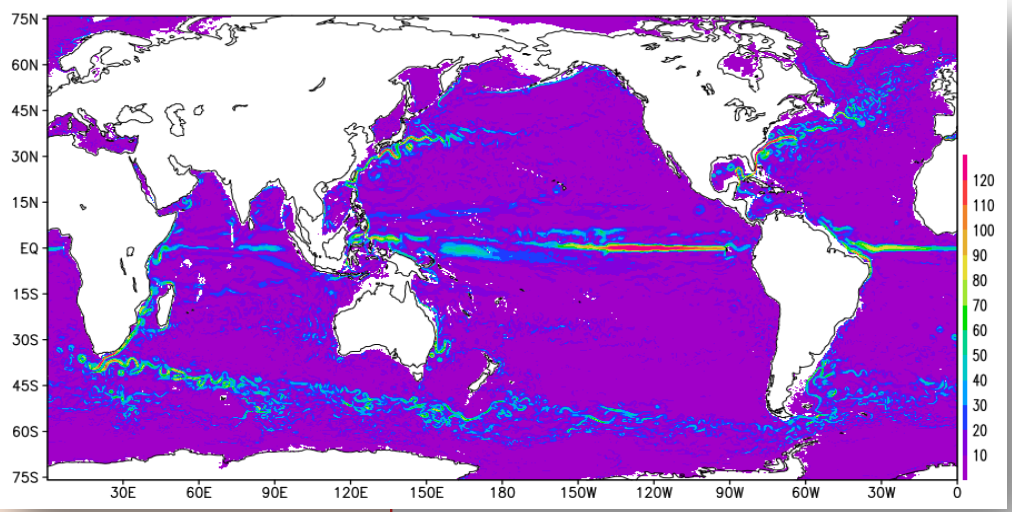
Climatological run: Driven by *long-term mean* atmosphere w/o interannual variability
Hindcast run: Driven by *observed* (reanalysis) atmosphere w/ interannual variability

Purposes

- Examine if there are significant intrinsic variability in the Kuroshio Extension jet even if the ocean is driven *interannually varying* atmospheric forcing.
- Estimate its amplitude and compere with that of wind-driven variability.
- Examine if there are deterministic (wind-driven) component in eddy activity in the Kuroshio Extension region.

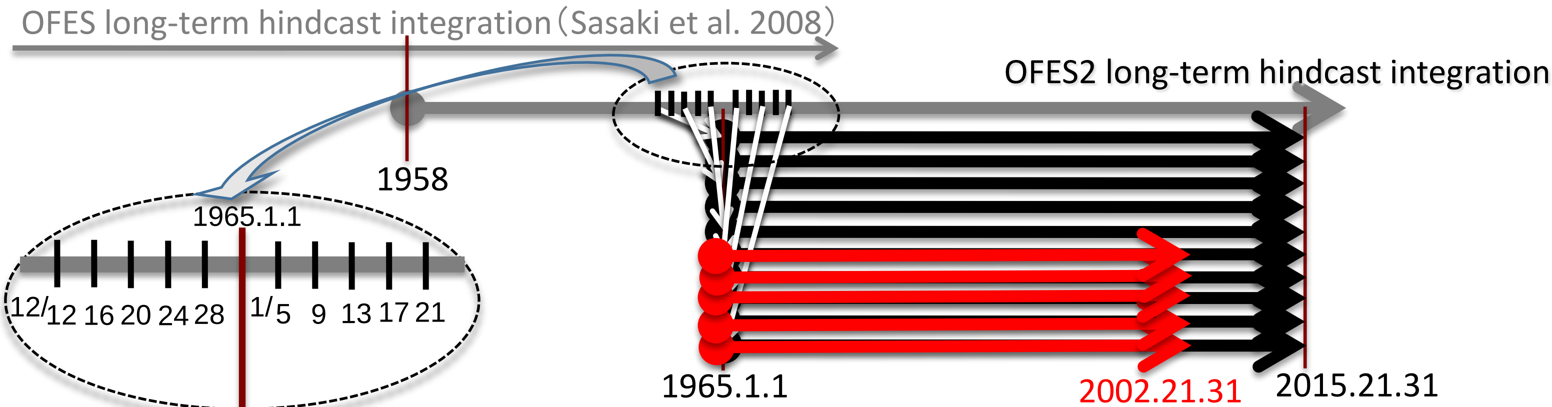
- Wile it is also investigated in our previous study (Nonaka et al. 2016), its experiment was limited, and difficult to conduct quantitative study.

Quasi global hindcast simulations at horizontal resolution of 0.1°: OGCM for the Earth Simulator ver. 2 (OFES2)



Domain	76S-76N
Resolution	1/10°
Vertical Level	105 (7,500m)
Topography	ETOPO1
Mixing Scheme	Noh and Kim(1999)
Sea Ice	Sea Ice model (Komori et al., 2005)
Tidal Mixing	Parameterization (St. Laurent et al., 2002)
Marginal Sea Restoring	Restoring(Mediterranean sea, Red Sea, Persian Gulf)
Forcings	**3houly JRA55 (1958-present)**
Initial Condition	OFES TS in Jan 1958 without motion
Outputs	Monthly, Daily Mean

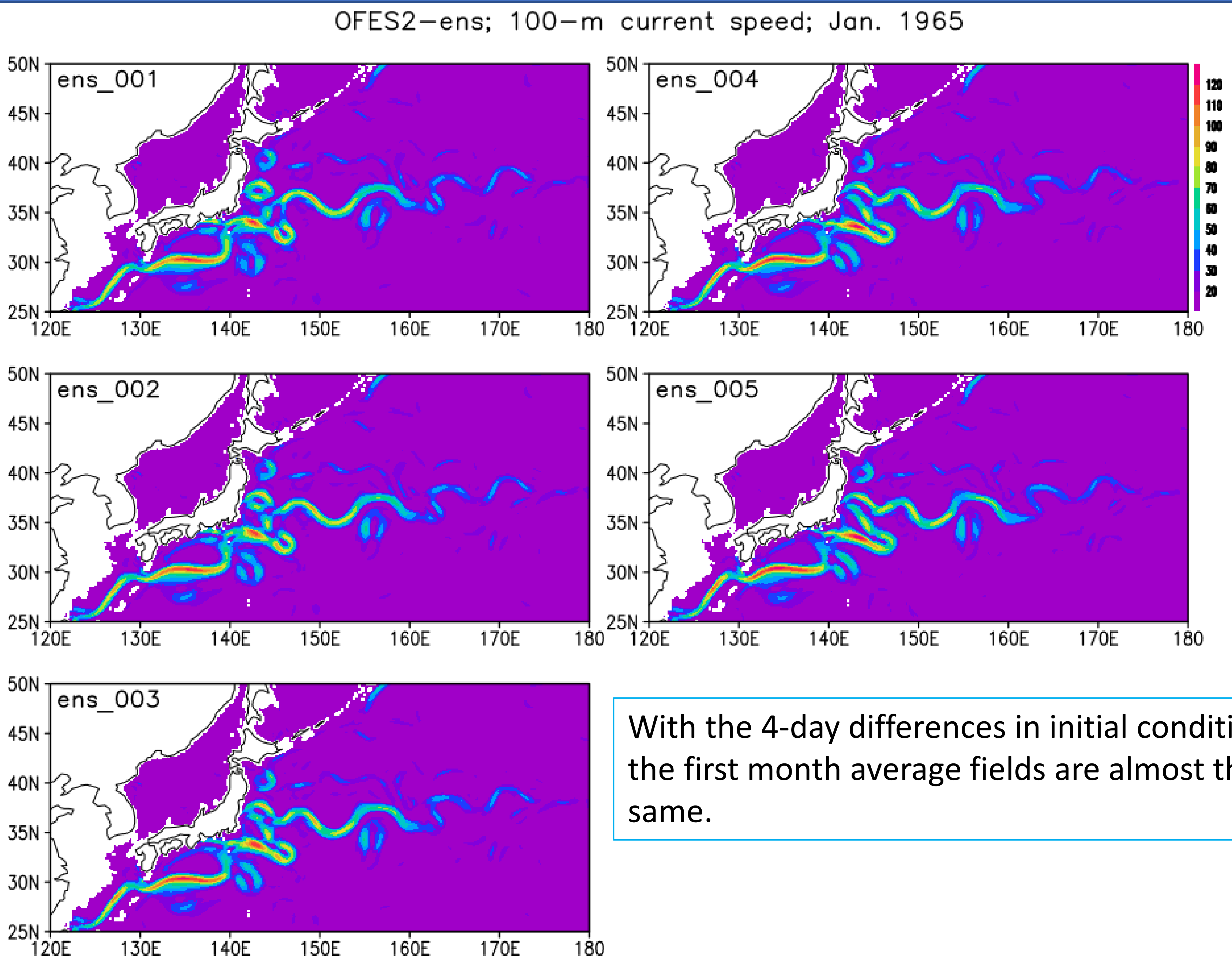
OFES2 ensemble (on-going project)



10-member long-term ensemble integration: Jan. 1st, 1965〜Dec. 31st, 2015（51 years）
Initial condition：Obtained from OFES2 long-term integration on Dec. 12th, 16th, 20th, 24th, 28, 1964, and Jan. 5th, 9th, 13th, 17st, 21st, 1965 (4-days differences). Driven by the identical atmospheric forcing of JRA-55'.

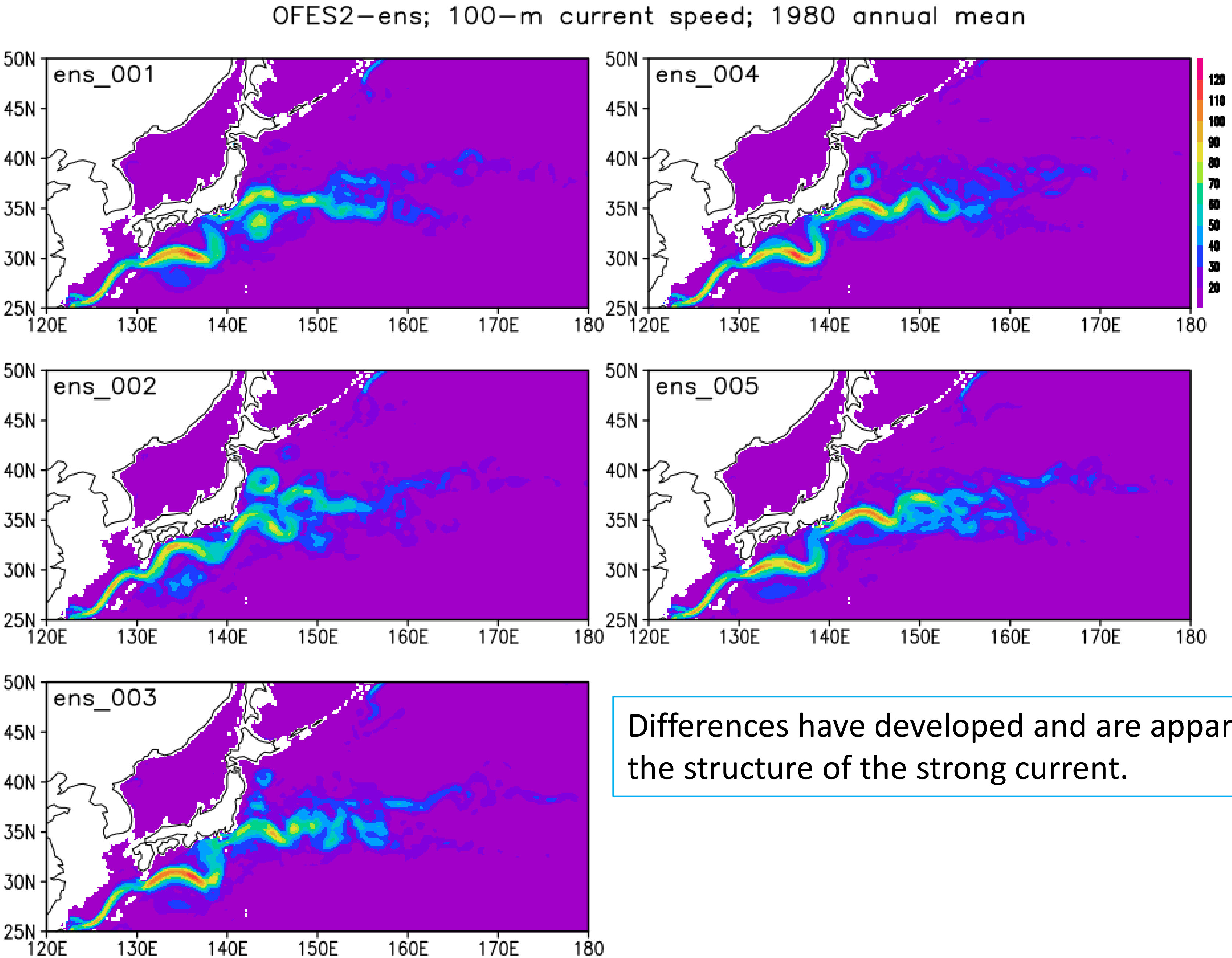
- 5 member ensemble integration has been integrated for 33 years (1965-2002) with slightly different I.C. of Jan. 5th, 9th, 13th, 17th, and 21st, 1965, and identical atmospheric forcing.
- We plan to conduct 10 member 51-year integrations.

(nearly) Initial conditions in the Kuroshio Extension region



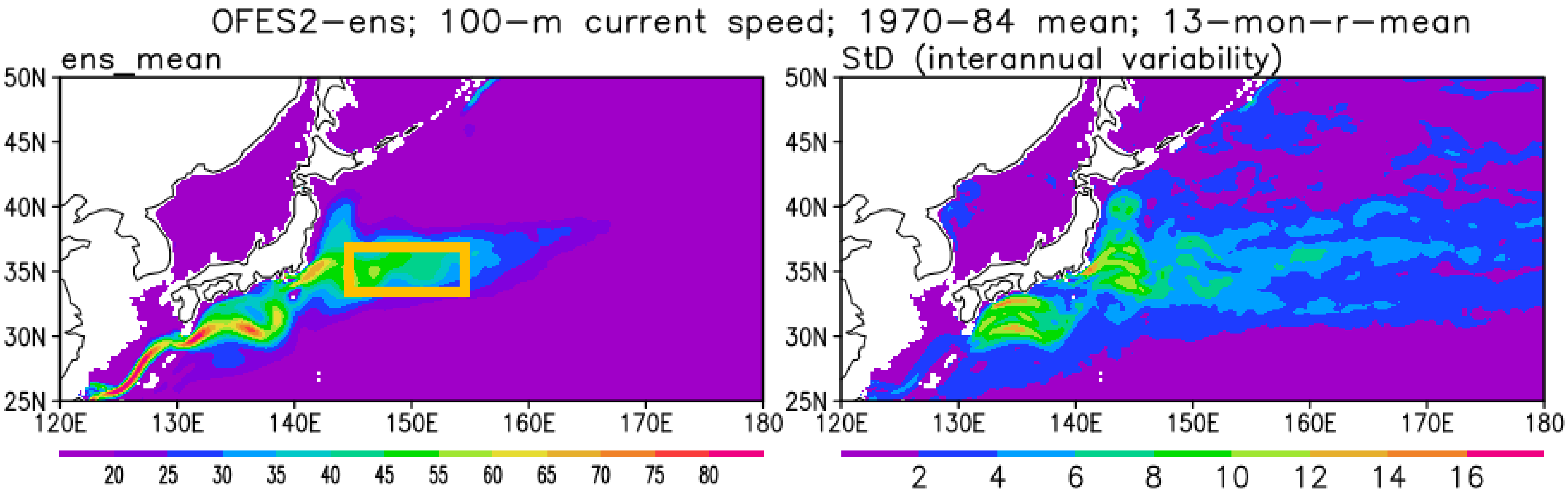
With the 4-day differences in initial conditions, the first month average fields are almost the same.

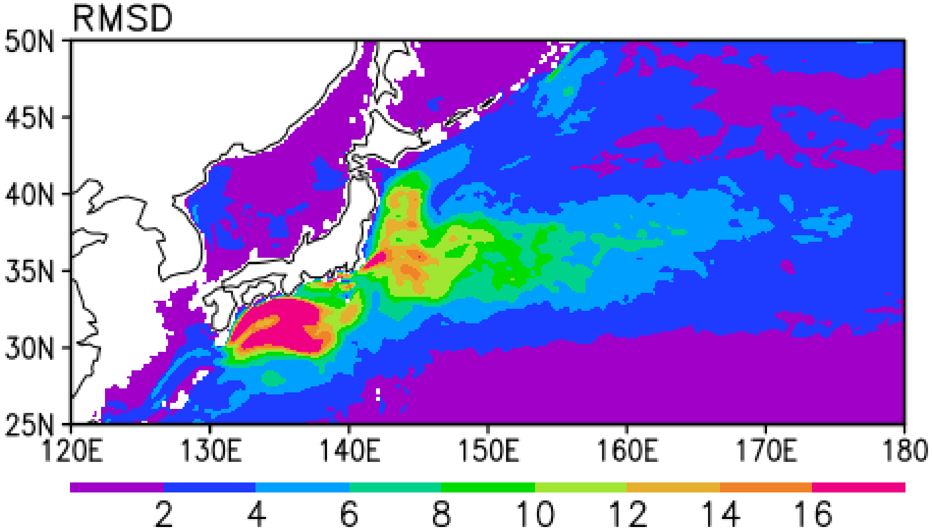
Annual mean in 1980 in the Kuroshio Extension region



Differences have developed and are apparent in the structure of the strong current.

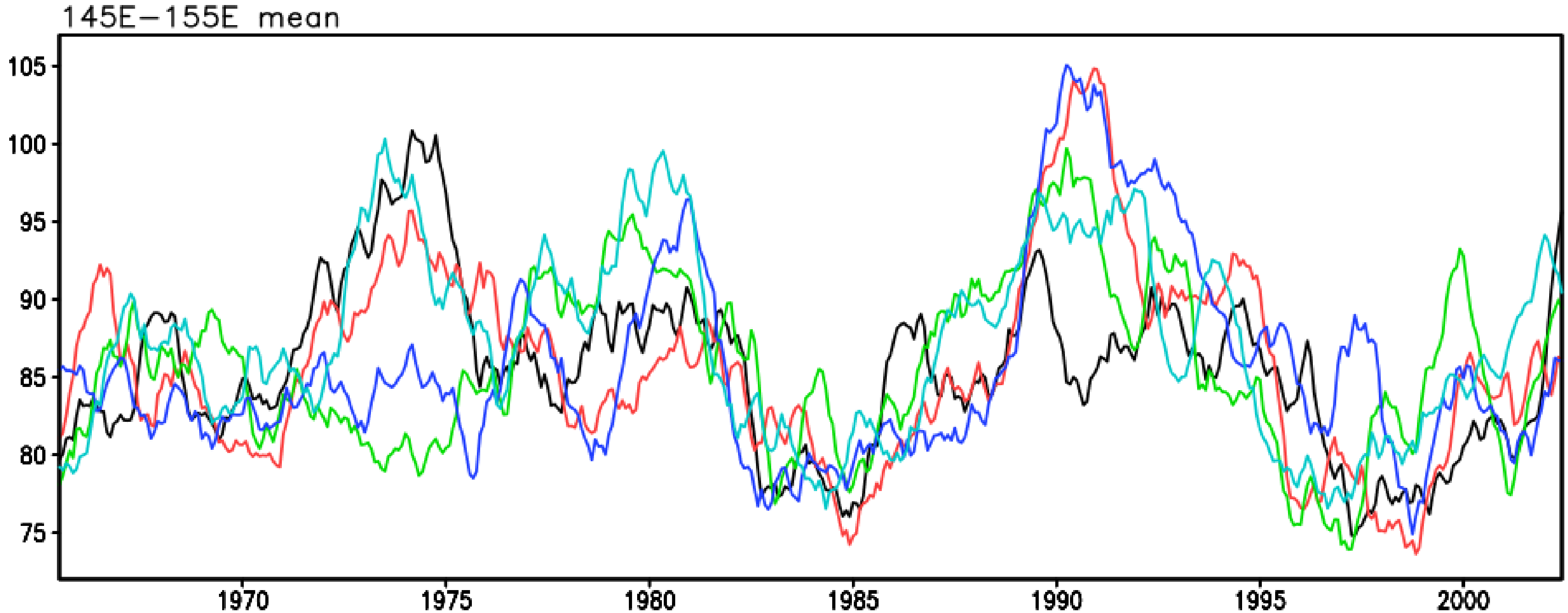
Interannual variability and RMSD in the western North Pacific





Spread among the ensemble members are similar or larger than interannual variability in the ensemble mean.

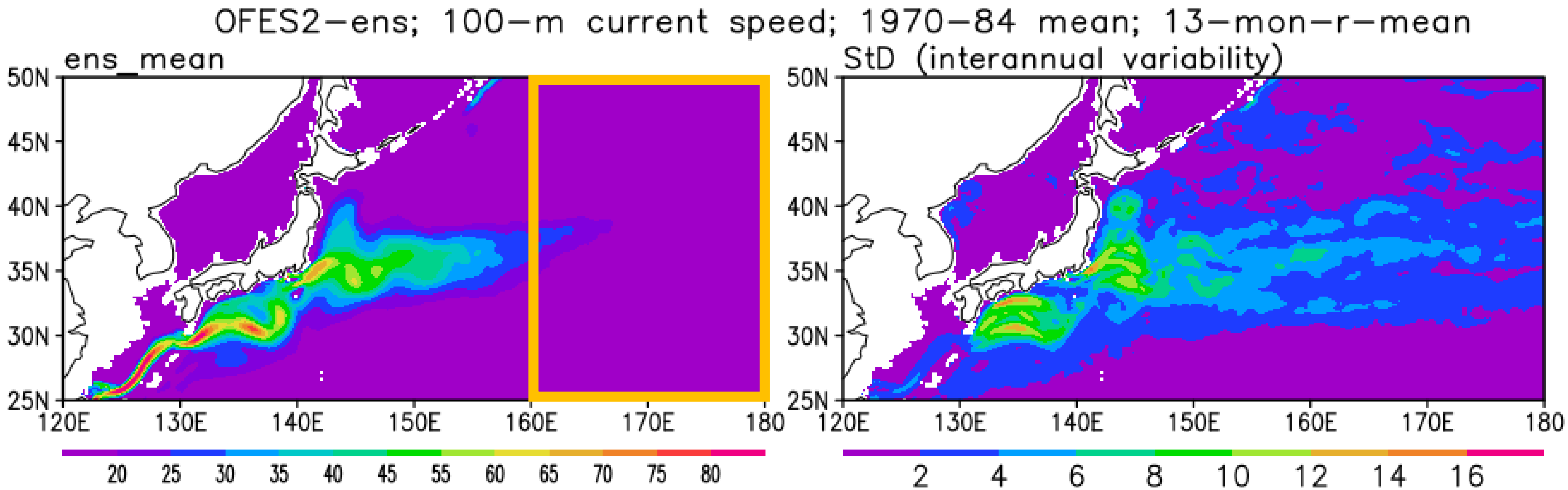
Time series of the KE jet speed (100-m depth, 145-155E mean)

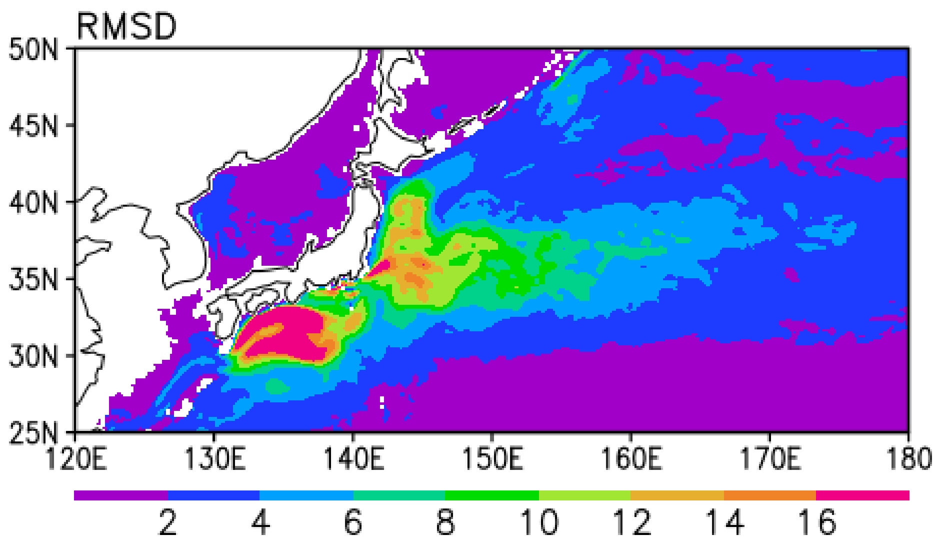


Time series of the 100-m depth KE jet speed on its axis in each ensemble member. Zonally averaged over 145~155E. The KE axis is defined as the grid point at the highest current speed between 30~40N.

- Interannual variability in the KE jet speed has substantial difference among the ensemble members, although decadal tendency is similar.
- Variance of the intrinsic variability is similar to that of the wind-driven variability. It limits potential predictability.

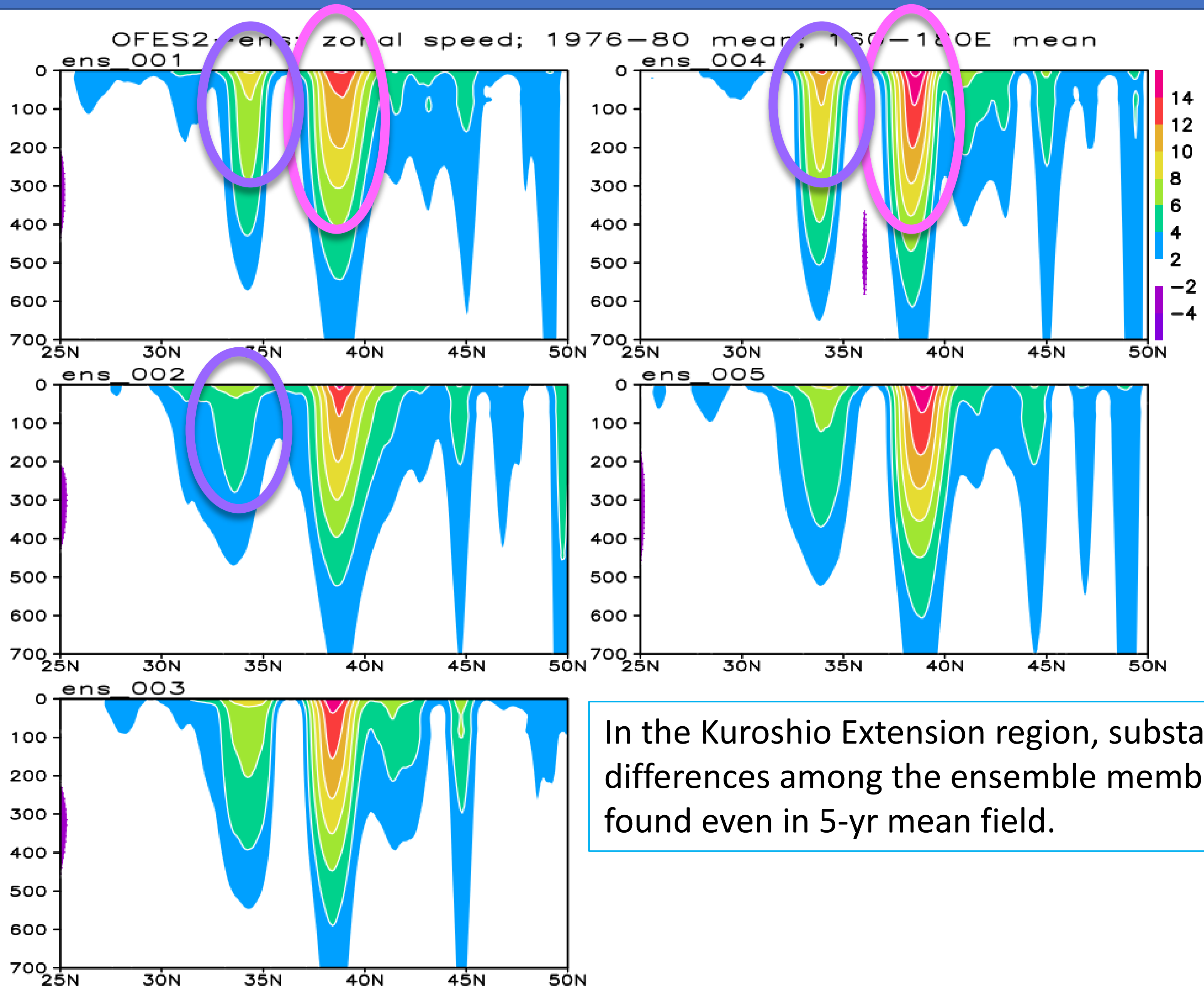
Interannual variability and RMSD in the western North Pacific





Spread among the ensemble members are similar or larger than interannual variability in the ensemble mean.

Differences in 5-yr mean, 160-180E mean zonal current speed

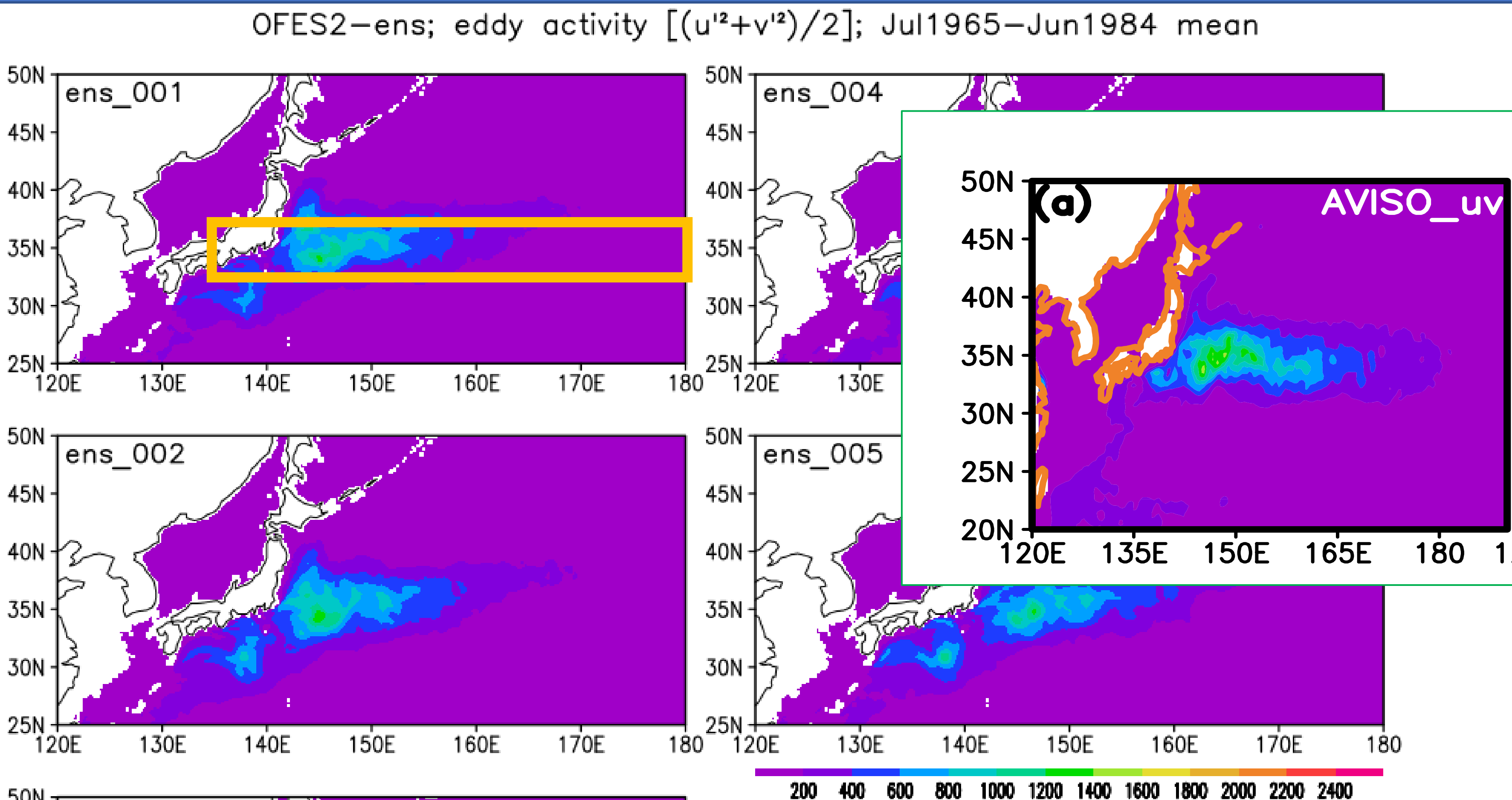


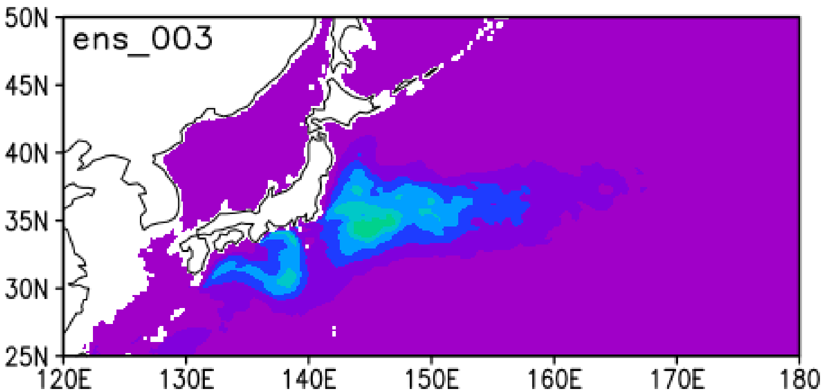
In the Kuroshio Extension region, substantial differences among the ensemble members are found even in 5-yr mean field.

Eddy activities

in the Kuroshio Extension region

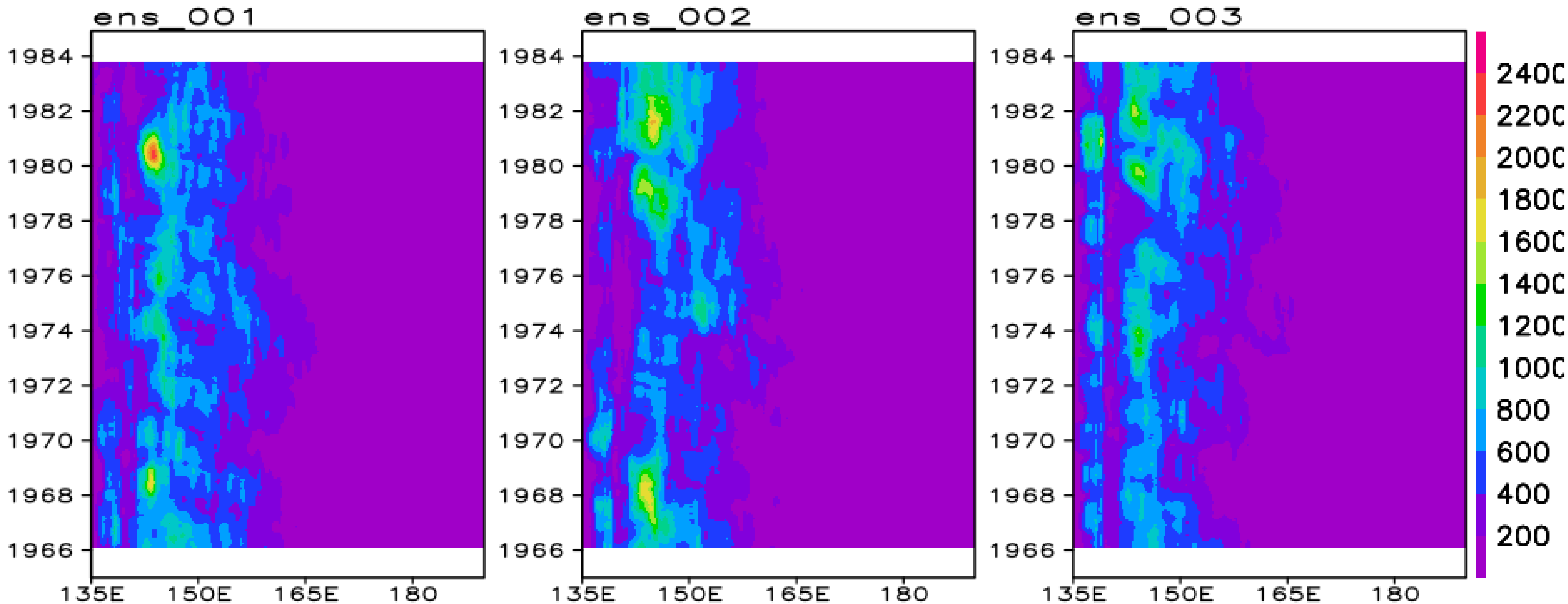
Long-term mean in eddy activities

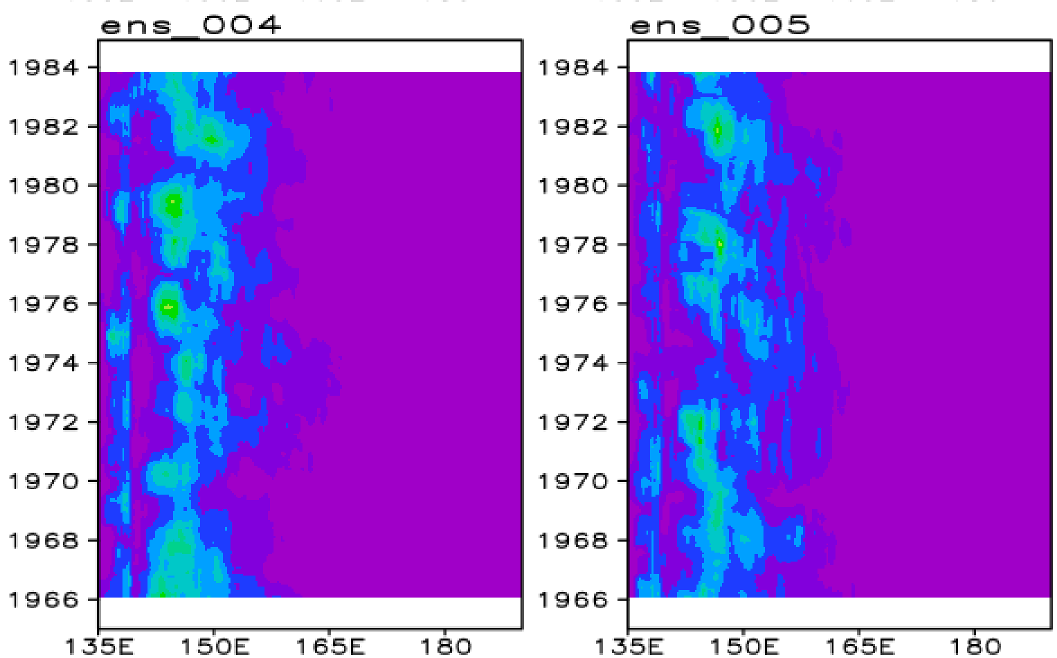




Eddies are active along the Kuroshio and its extension.
Compared to that estimated from satellite observed SSH, the model underestimate slightly.

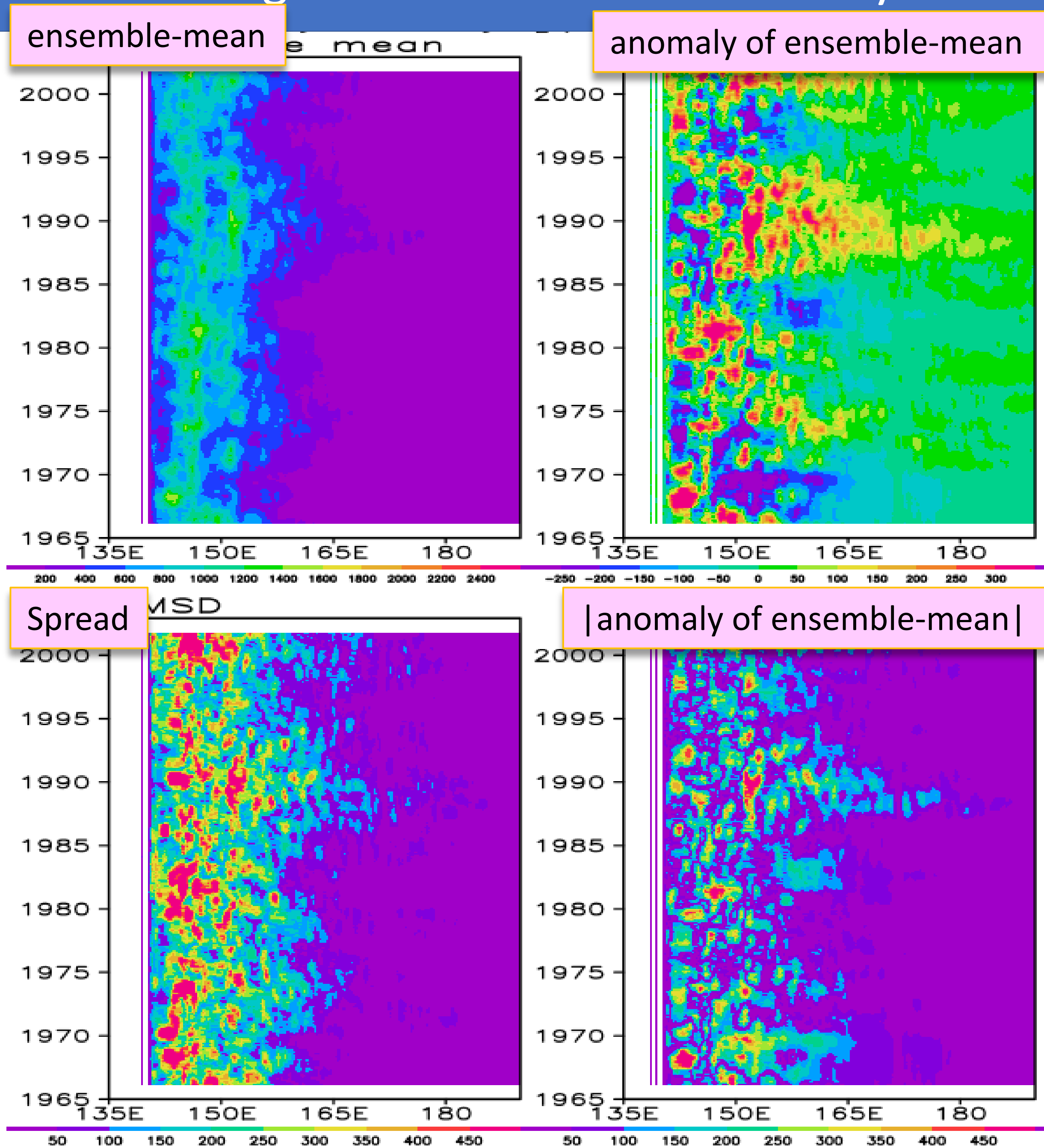
Longitude-time sections of eddy activities (32-37N mean)





Eddy activities have substantial interannual variability.
In some years, eddies are very weak in the upstream region as shown in the SSH satellite observations (Qiu and Chen 2005).

Longitude-time sections of eddy activities (32-37N mean)

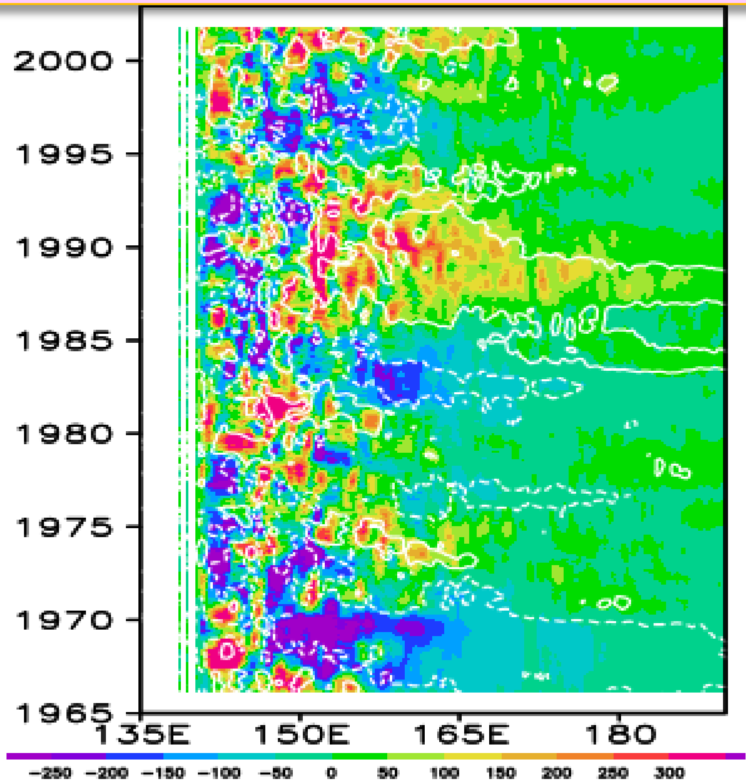


Spreads of eddy activities among the ensemble members are larger than the interannual variability in the ensemble mean, especially in the upstream region.

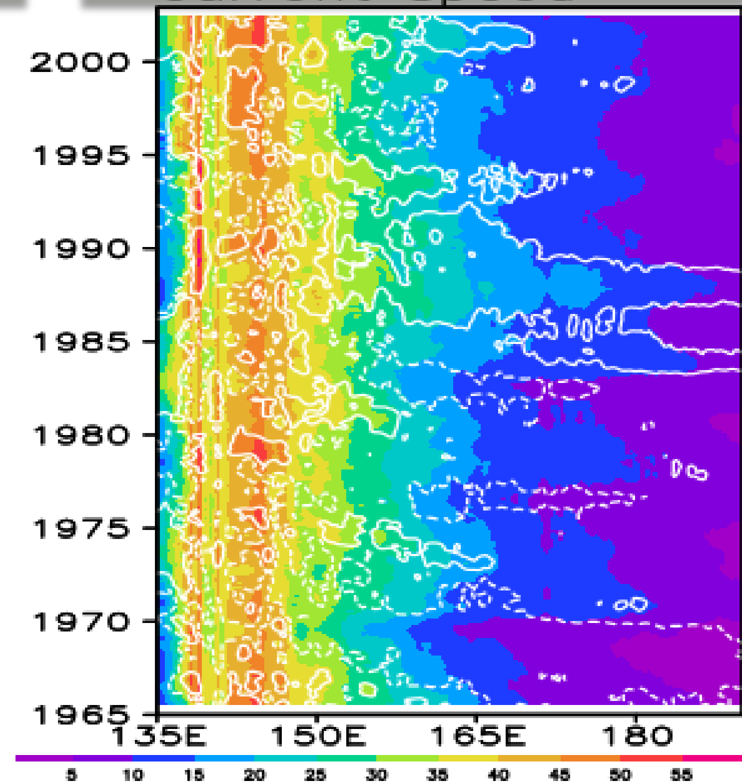
Interannual variability in the ensemble mean suggests westward propagating signal.

Longitude-time sections of eddy activities (32-37N mean)

ensemble-mean eddy-activity anomaly



ensemble-mean current-speed & anomaly



Comparing to the ensemble-mean current-speed, high (low) ensemble-mean eddy-activity tends to be associated with high (low) current speed of the Kuroshio Extension.

While mechanisms need to be investigated further, eddy-activity in the Kuroshio Extension region has some predictable signal that varies associated with current speed.

Summary

- Ensemble integration of an eddy-resolving OGCM has been conducted to investigate oceanic intrinsic variability under interannually varying forcing.
- Even on interannual time scale, intrinsic variability (and thus uncertainty) is similar to or larger than the wind-driven variability in the western boundary current regions.
- (In contrast, uncertainty is limited in the tropical oceans.)
- In the Kuroshio Extension region, part of interannual variability in eddy activity can be wind-driven and propagates westward associated with current speed anomalies.