Intraseasonal SST oscillations in the Japan/East Sea

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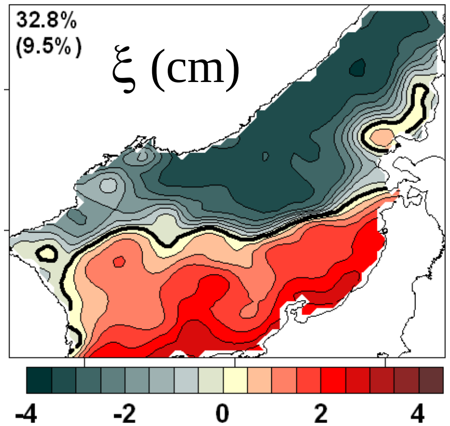
Variation of circulation strength and energetics of mesoscale motions in the Japan/East Sea

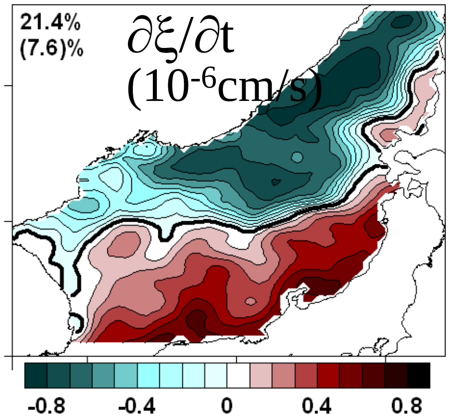
discussed at the PICES Annual Meetings, 2009-2011,
were based on sea level anomalies from satellite altimetry measurements.

Seasonal strength variation of the mean currents

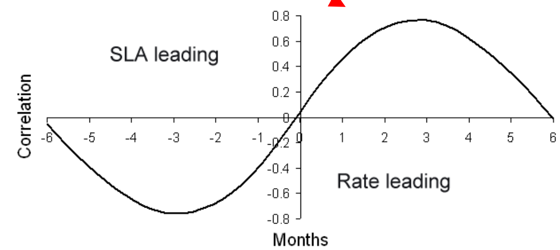
Sea level anomaly

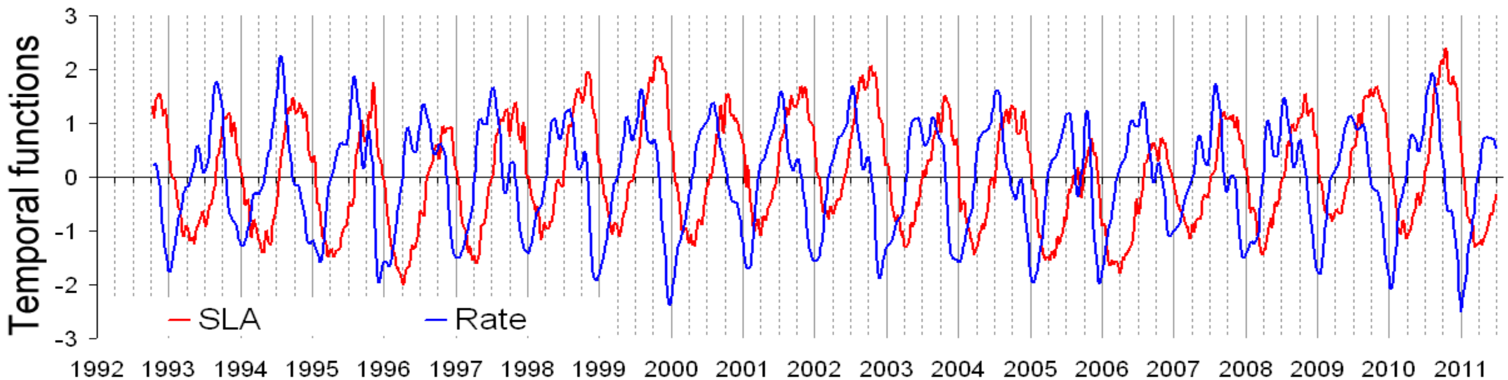


Sea level rate



Rate mode leads
SLA at 3-month lag



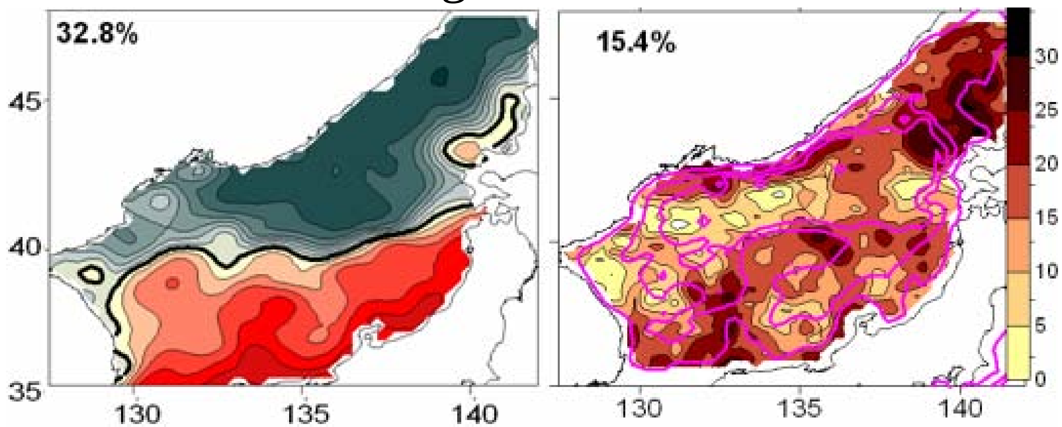


The meridional sea level gradient is sharpest in October and weakest in March.
Rate of the gradient change is 3 months ahead, with extremes in early July and late December.

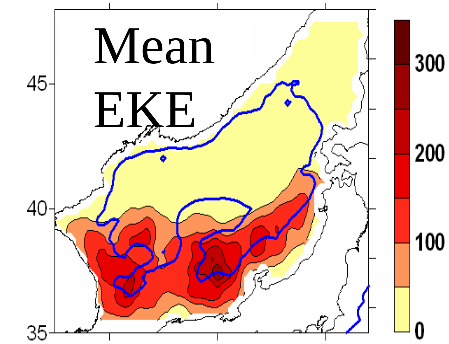
Mesoscale energetics: eddy kinetic energy (EKE)

Circulation strength

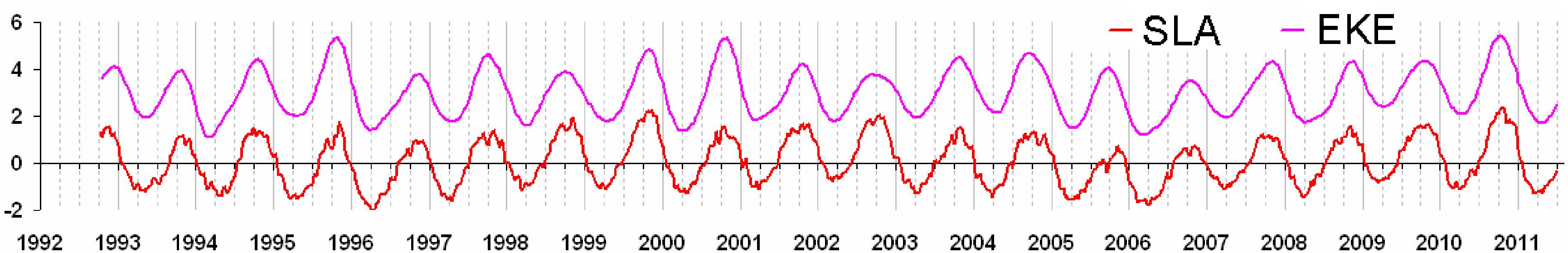
EKE



Contours: bathymetry



Correlation ~ 0.84.



EKE is highest in October – November and lowest March – April → same as seasonal variation of the circulation strength → shear instability is important.

EKE generation due to instability of the mean currents and interactions with bathymetry. Shear instability is important

Limitations

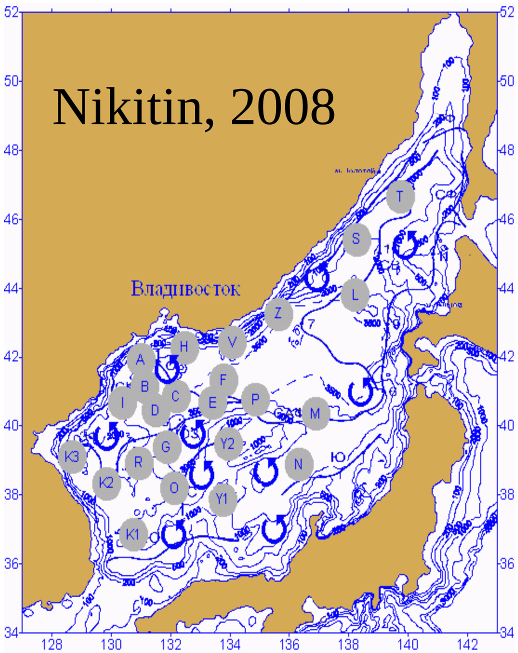
T/P - Jason period ~ 10 days.
ERS – EnviSAT period ~ 35 days.
Gtidded weekly data.
Low-frequency EKE with temporal scales > 2-4 months
(filtering necessary for noise removing).

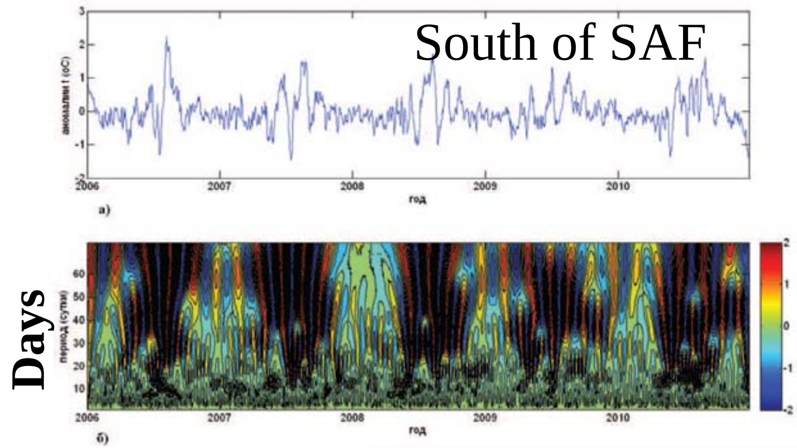
Life time of eddies in the northern Sea is from 1-2 weeks to 1-2 months
(Lobanov, Ladychenko, 2002-2012).

Better temporal resolution is needed.
It is provided by satellite infrared imagery –
daily SST data are available.

Thermal contrasts from satellite infrared imagery

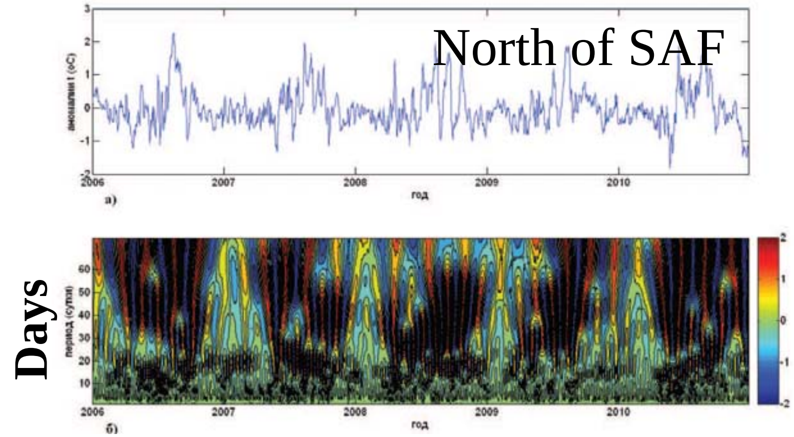
Frequent positions of mesoscale eddies





Periods of 20-60 days

(Zero is green)



Eddy tracking, estimations of eddy sizes, life times, etc…

Wavelet transform of anomalies from daily mean SST for 2006-2010 averaged south and north of the Subpolar Front: stronger oscillations in the warm season (Belonenko, Bloshkina, 2012).

Purpose

Detailed analysis of intraseasonal SST variability, estimation of time scales and its relationships with the circulation in the Japan/East Sea

Data

Daily 1/4°-gridded SST from Japan Meteorological Agency,
from October 1993 onwards.

Area: 35.5°- 48°N, 127.5°-142°E

Band-pass filtering, periods retained from **2 weeks through 4 months**:
for noise removing (less than 2 weeks) and
removing variability from semiannual to longer scales.

Scale range consistent with life times of with mesoscale eddies.

Wavelet transform using Morler mother wavelet of the 6-th order
is applied for filtering and time scale detection.

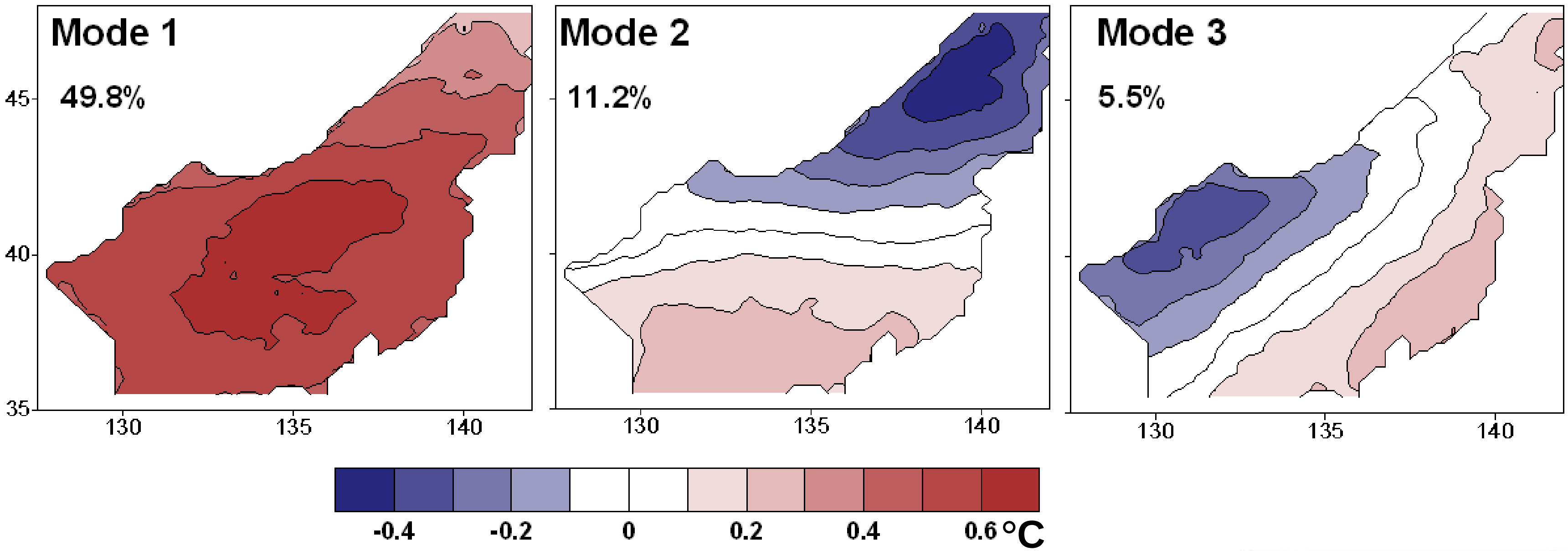
EOF analysis

EOF analysis: a set of orthogonal patterns focused on areas of large variance: $X(\mathbf{r}, t) = \sum A_k(\mathbf{r})\cdot B_k(t)$, where $X(\mathbf{r}, t)$ is original signal, $A_k(\mathbf{r})$ is eigenvector, $B_k(t)$ is principal component (PC).

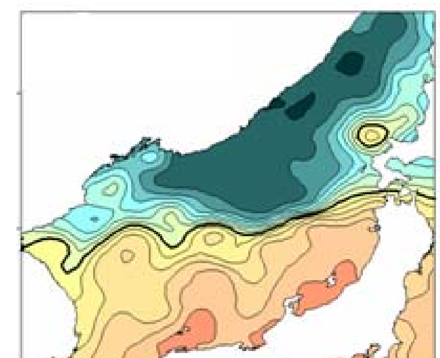
Covariances for computing eigenvectors → weaker signals can be lost.

Correlations (normalized X) → detection of small amplitude anomalies.

Spatial patterns: intraseasonal SST variability in the entire Japan Sea

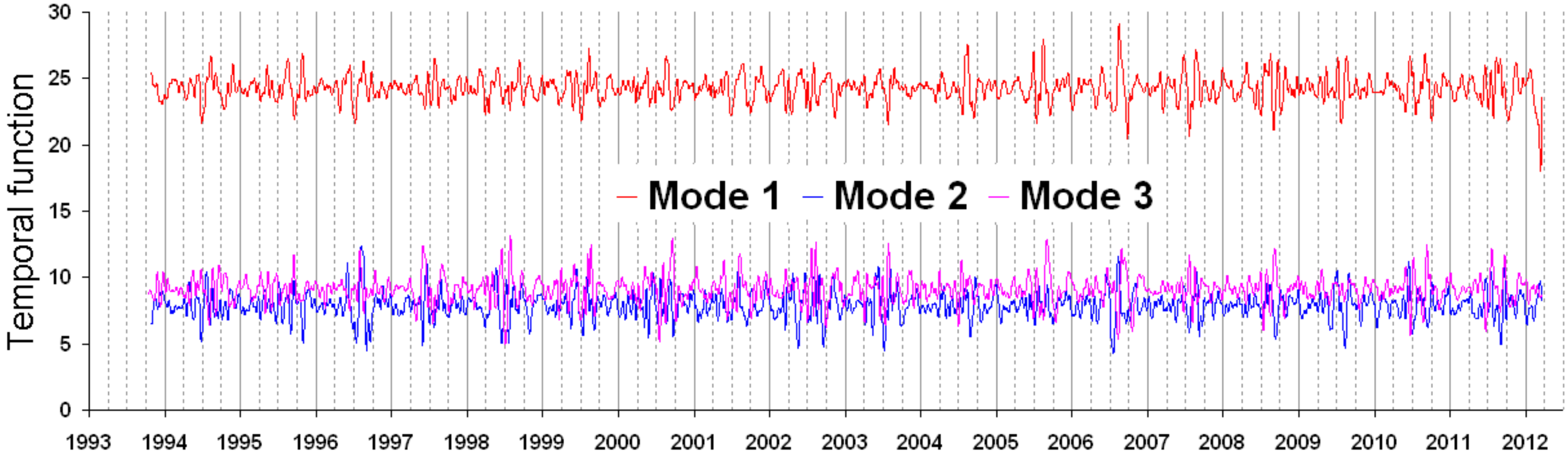


Diffuse spatial patterns: succession of 2D harmonic functions.
Mode 1: SST anomalies in the entire Sea.
Mode 2: lower/higher SST in the northern/southern sea (stronger northward of 44°N).
Mode 3: lower/higher SST in the western/eastern Sea (stronger in the NW area off the south Primorye and North Korea).



SLA gradient

Temporal patterns: large means, small oscillations strengthening in the warm season



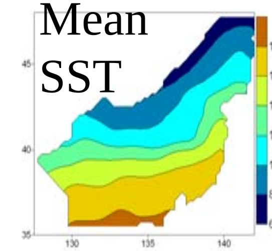
Mean contribution

Mode 1 (in the central sea): 13.3°C.

Mode 2 (northward of 44°N): -2.0°C.

Mode 3 (off the south Primorye and North Korea): -1.8°C.

Mean SST

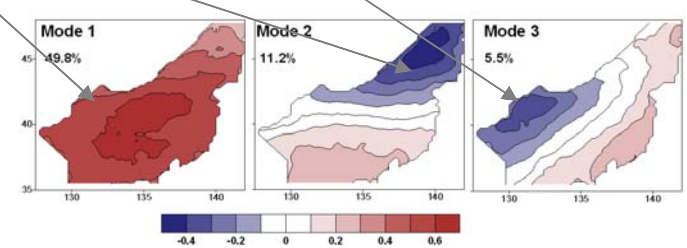


Mean SST anomaly (absolute value)

Mode 1: 0.4°C (3% of mean value)

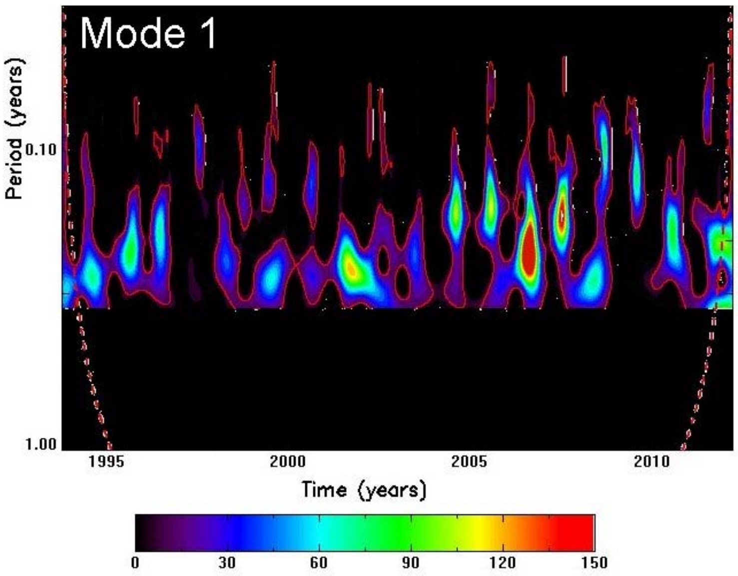
Mode 2: 0.2°C (10% of mean value)

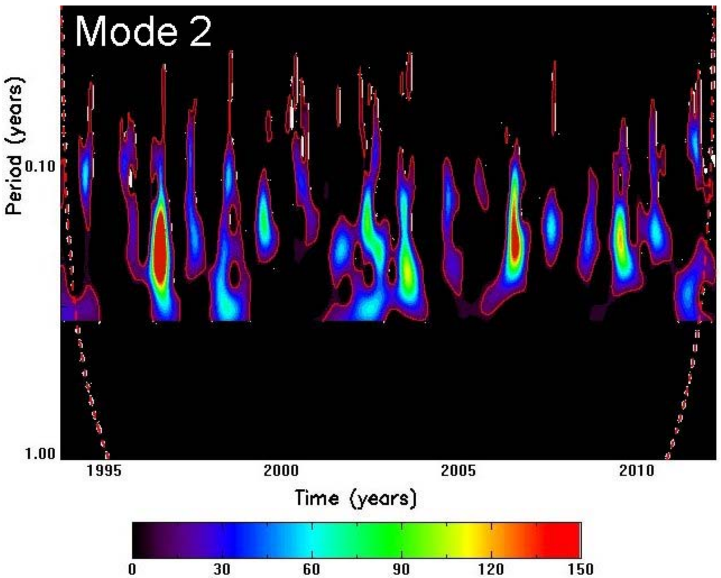
Mode 3: 0.2°C (10% of mean value)

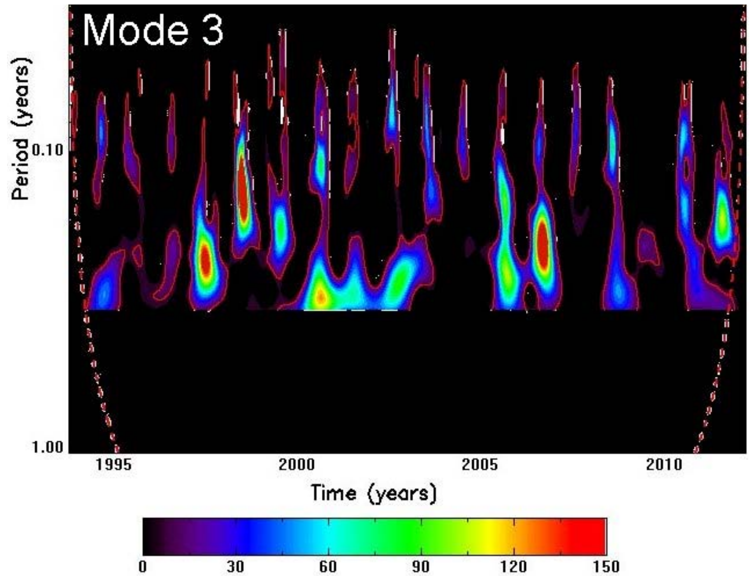


Temporal functions: characteristic time scales

Power ($|A|^2$)





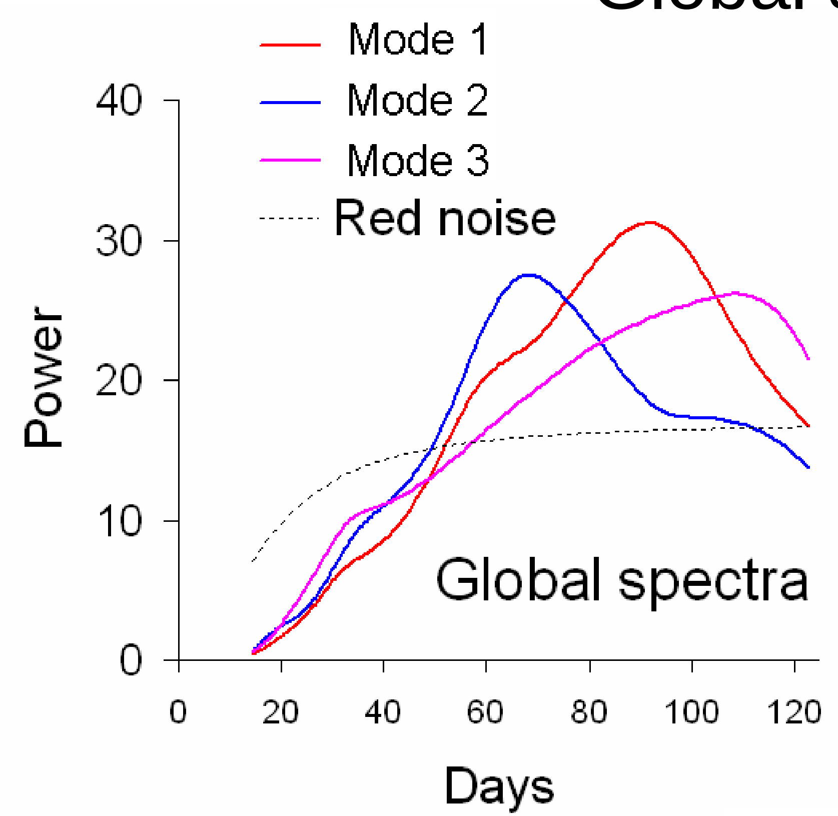


Periods 60-120 days

Strengthening in the warm season, interannual variability.

Stretched along the period (y) axis, even if the Morlet mother wavelet is used, with better resolution along the time (x) axis.

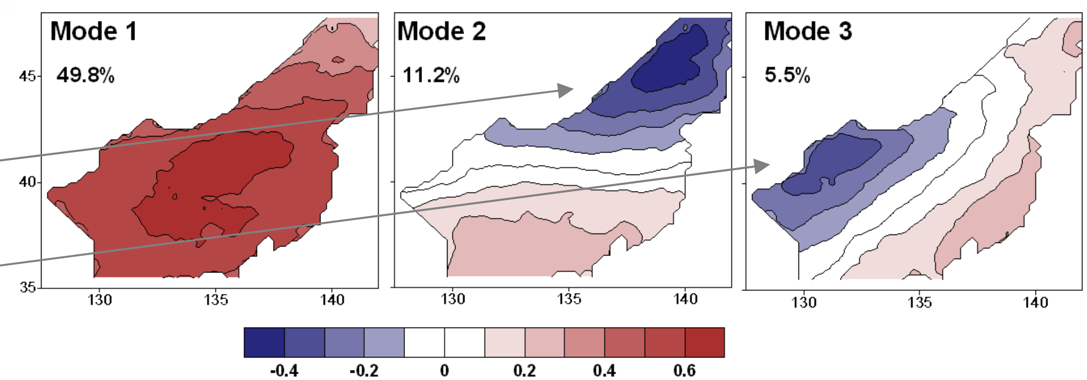
Global spectra: mean time scales



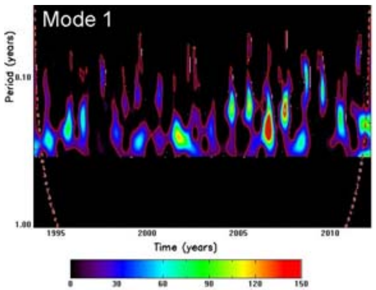
Max power:
Mode 1: 90 days
Mode 2: 65-70 days
Mode 3: 105-110 days

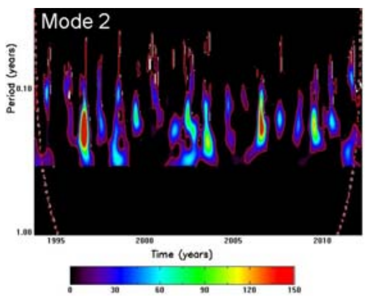
Shorter-lived structures

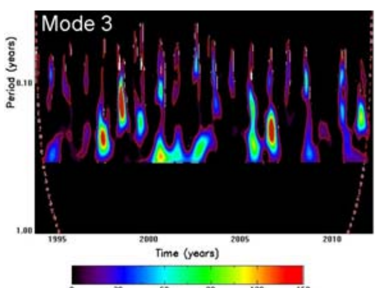
Longer-lived structures

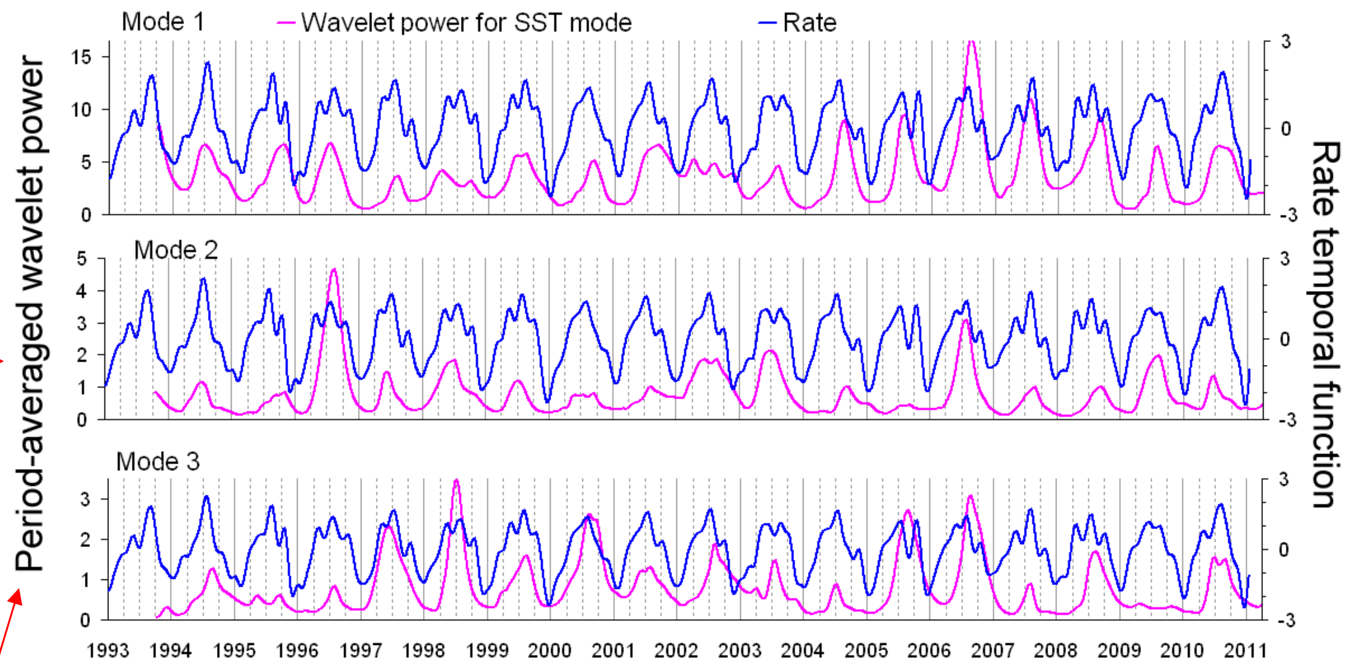


Period-averaged wavelet power for SST vs. Rate







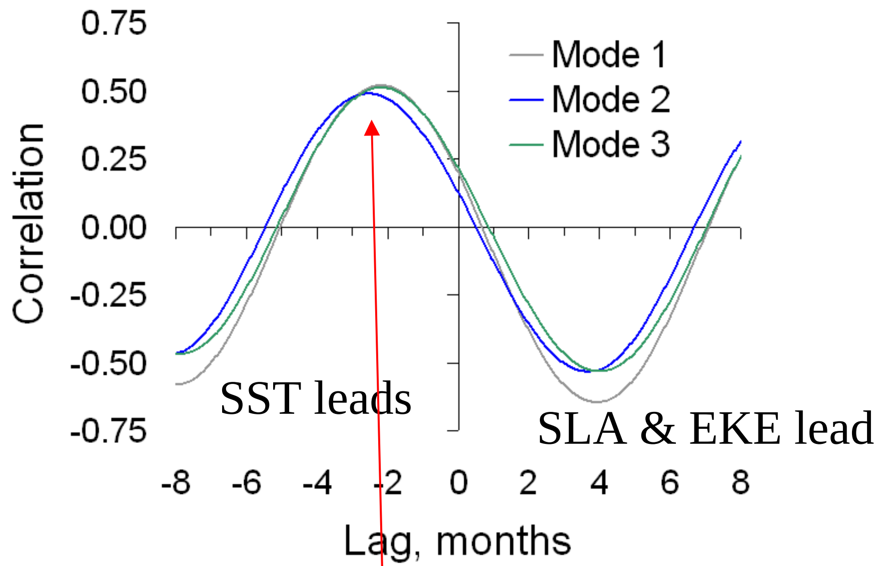


Rate of sea level change is highest 3 months before the mean currents are strongest and EKE largest.

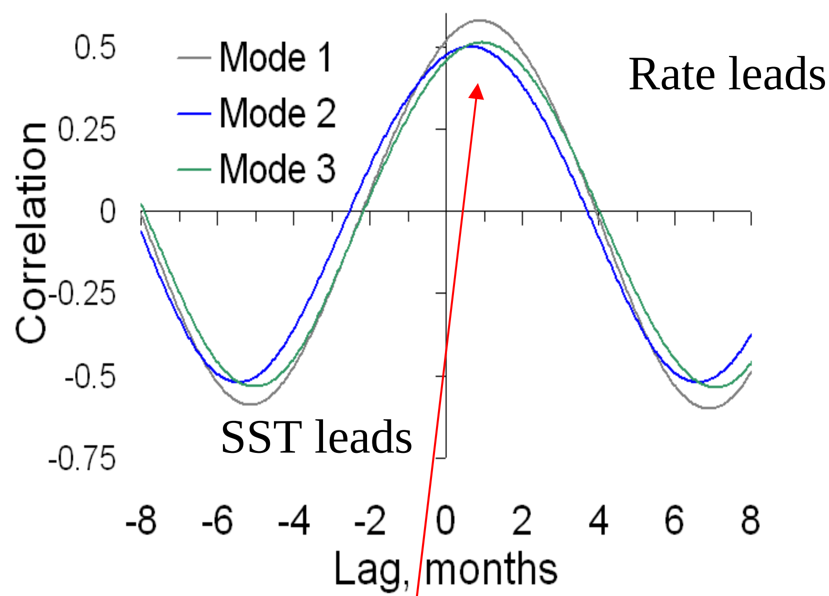
Intraseasonal SST oscillations are strongest during the period of the mean currents strengthening and EKE increase.

Correlations: SST wavelet power vs. SLA and Rate

SST power vs. sea level anomaly



SST power vs. sea level rate

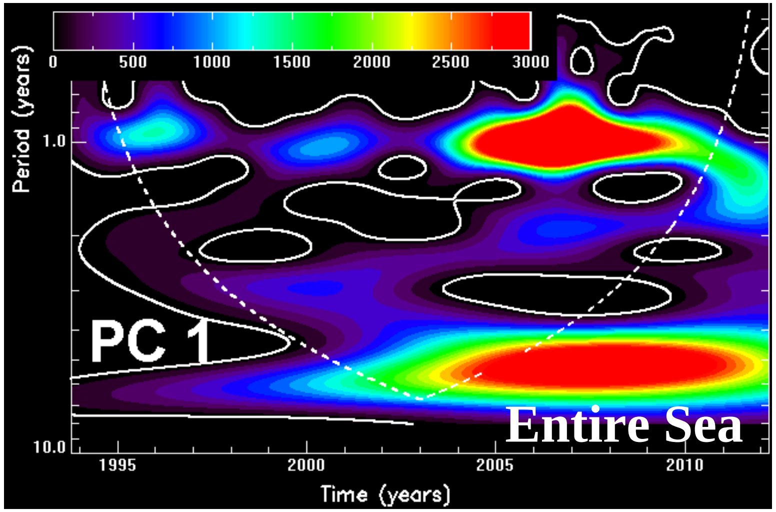


SST power leads SLA & EKE at 2-month lag

Rate leads SST power at 1-month lag

Rate leads SLA & EKE by 3-months

Time scales of the SST wavelet power



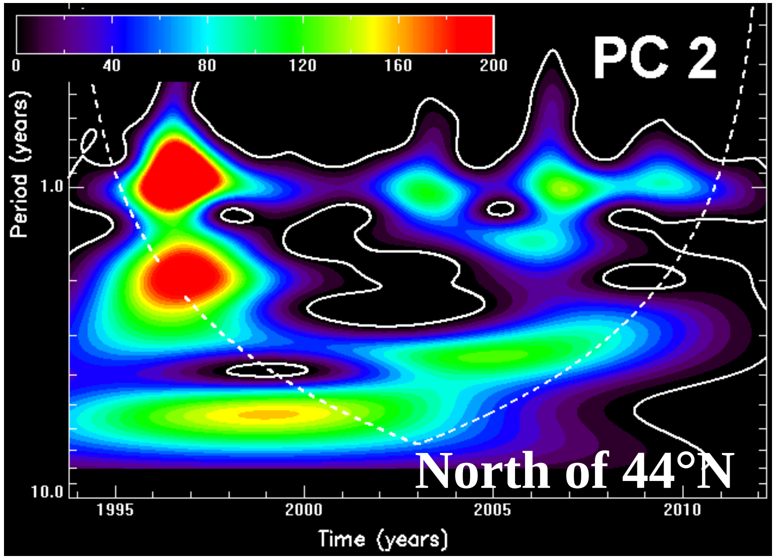
Wavelet power of the wavelet power

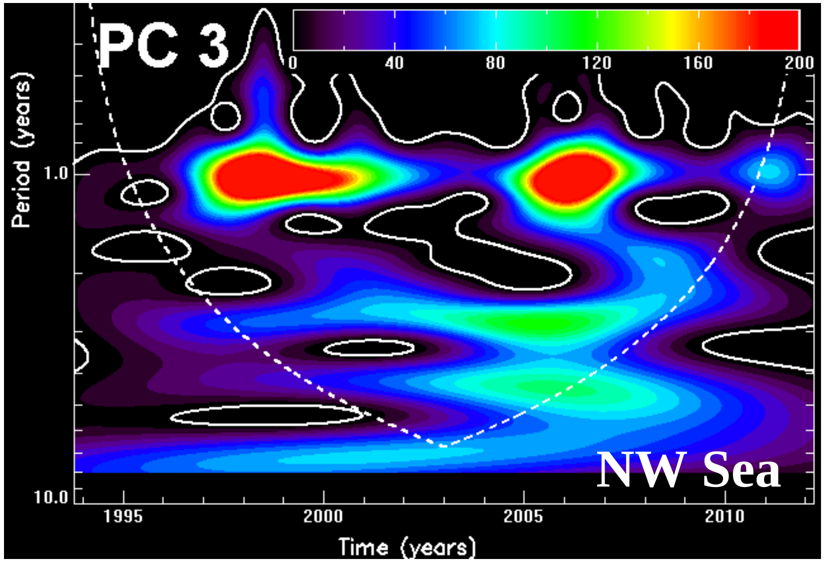
Weak oscillations: early 2000s

Annual

Quasi-biennial:
Mode 1: shifting from 3 to 2 years in 2002-2004
Mode 3: strengthening since 2003

Interannual:
Mode 2: 3-4 yrs since 2003
Mode 3: 4-5 yrs, strengthening since 2002





Conclusion

•Intraseasonal SST oscillations in the Japan/East Sea intensify in the warm season and are strongest in mid summer when the mean currents are still strengthening and EKE increasing.

•Mean time scales of intraseasonal SST oscillations are 90 days in the entire Sea, 65-70 days in the northern Sea, and 105-110 days in the NW area off the southern Primorye – North Korea.

•The strength of SST oscillations manifests strong interannual variability on the quasi-biennial and 3-5 yrs time scales.

•The intraseasonal SST oscillations were weak in early 2000s.

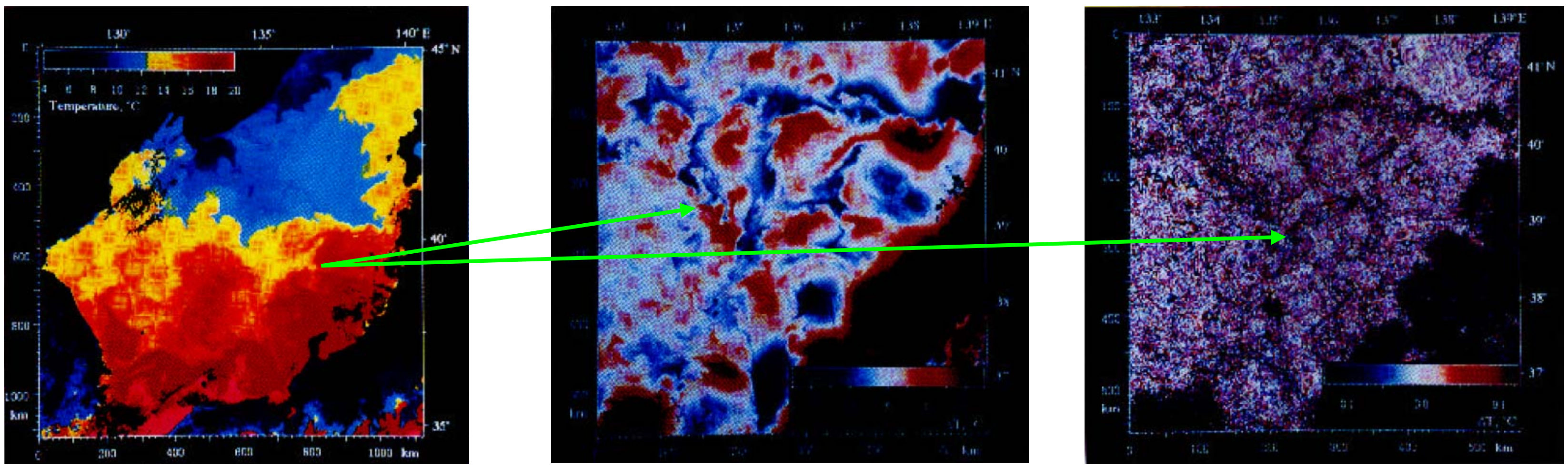
Concluding remarks

Periods 90-110 days are consistent with life-times of mesoscale eddies.

Structure sizes > 25 km (SST grid size) – but can be averaged manifestations of sub-mesoscale structures → diffuse spatial patterns.

(Ostrovskii, 1995) – signatures of stirring and mixing at the surface (in fall 1993 and spring 1994).

Original Mesoscale Sub-mesoscale



Infrared image in fall 1993 and its fragments low-pass filtered by 2D wavelet transform. Structure sizes < 30 km. Evidence of the 3D turbulence from the spectral power (Ostrovskii, 1995).

THANK YOU!