Regional patterns of interannual sea level variability: Case of the Japan/East Sea

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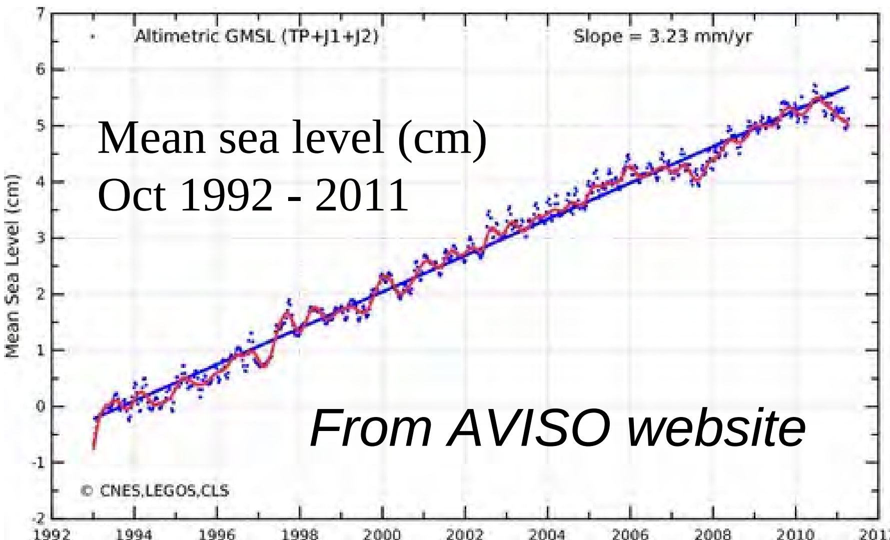
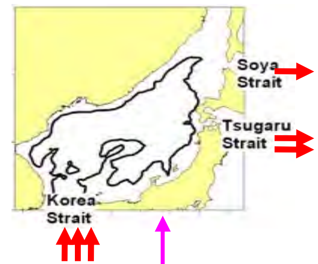
S1 - Climate variability versus anthropogenic impacts

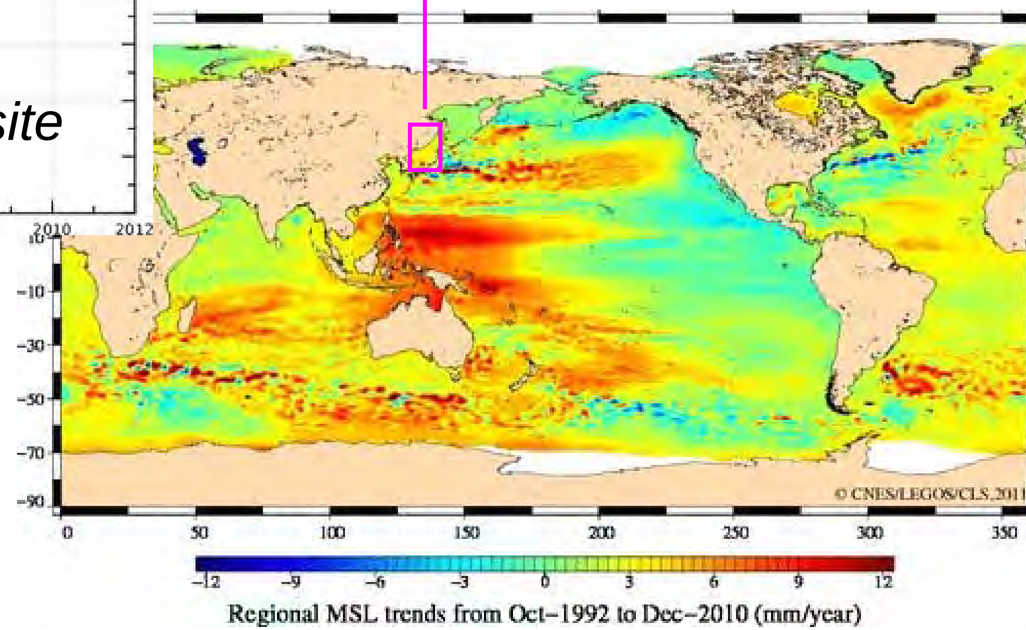
Introduction: global sea level from satellite altimetry



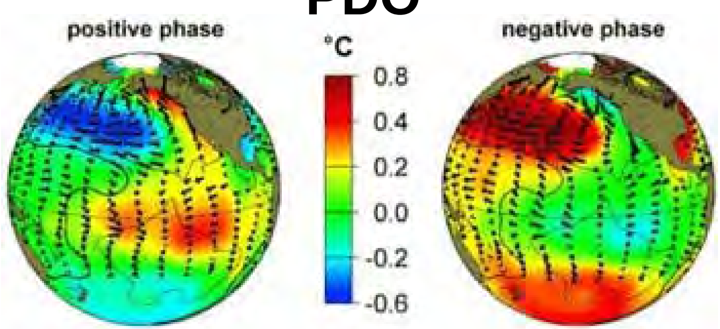


Regime of the Japan/East Sea is substantially forced by the throughflow

From AVISO website

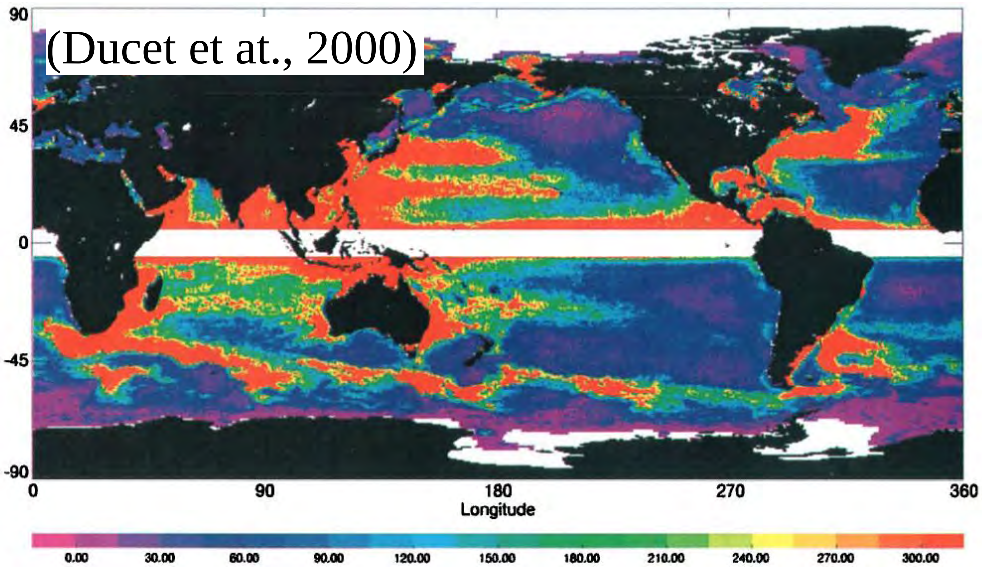


PDO



Spatial distribution of linear trends (since October 1992)

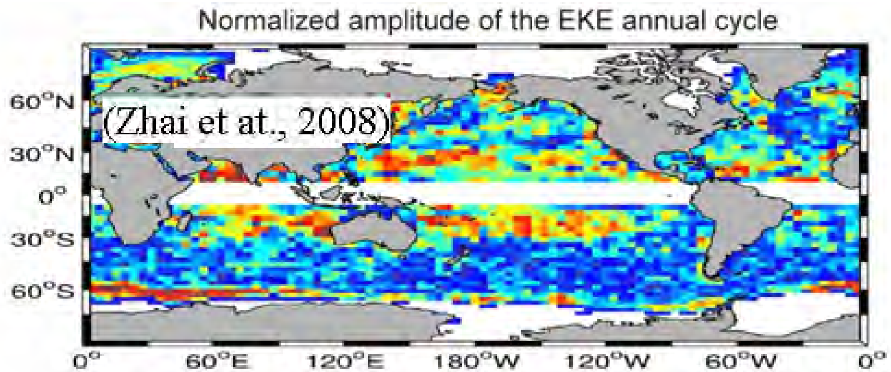
Introduction: synoptic energetics from satellite altimetry

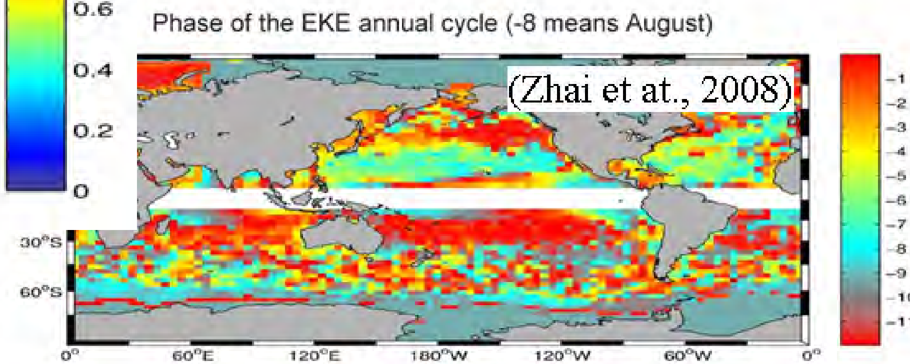


Geostrophic eddy kinetic energy

$E_m = (u'^2 + v'^2)/2$, where
$u' = -(g/f)\partial\eta/\partial y$, $v' = (g/f)\partial\eta/\partial x$,
η is altimetric sea level anomaly

Much less is done on interannual variability





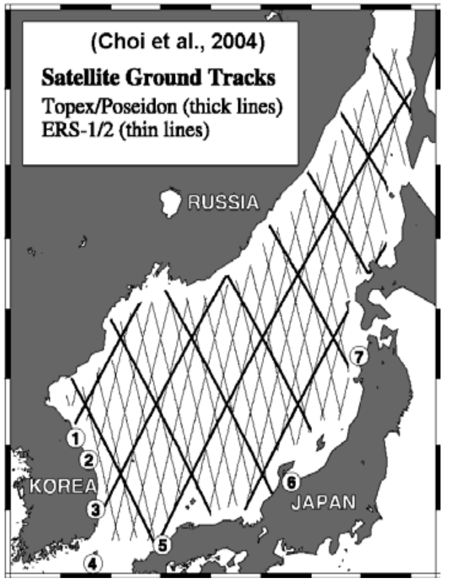
Purpose

To analyze interannual and, if possibly, decadal variability of sea level, circulation, and synoptic energetics in the Japan/East Sea using the whole available altimetric record.

Data

AVISO weekly reference 1/4°-gridded sea level anomalies, October 1992 - July 2011, 35.5°-48°N, 127.5°-142°E.

EKE = $(u'^2 + v'^2)/2$ where
$u' = -(g/f)\partial\eta/\partial y$, $v' = (g/f)\partial\eta/\partial x$, η - altimetric SLA → geostrophic & ergodic & spatial scales > 25 km.
(Noise level increased by differentiation.)



Filtering for noise removing, using Morler mother wavelet of the 6-th order, with the 20-week cut-off period. Similar results for the cut-off periods of 9 and 13 weeks but lower eigenvalues.

Interannual SLA and EKE ~ 1.3-year cut-off period.

Techniques of 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).

1) Covariances for computing eigenvectors → weaker signals can be lost.

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

2) Natural patterns are not necessarily orthogonal. However, orthogonality is intrinsic to EOF patterns.

3) Successive decompositions after the removal of contribution from a leading mode before every next step:

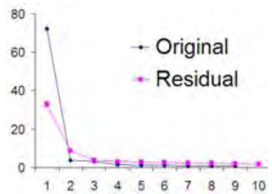
Residual sampling: $X_a(\mathbf{r}, t) = X(\mathbf{r}, t) - A_1(\mathbf{r})\cdot B_1(t) = \sum A'_k(\mathbf{r})\cdot B'_k(t)$.

Using correlations allows for new modes in successive decompositions, i.e. it is possible that $A'_k \neq A_{k+1}$ and $B'_k \neq B_{k+1}$ if natural modes are non-orthogonal.

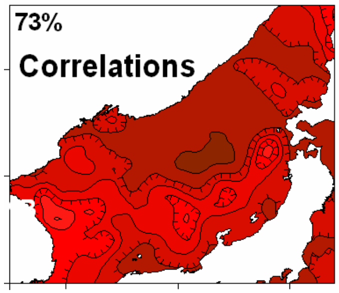
In contrast, using covariances would only result in successive removing of a leading mode, with $A'_k = A_{k+1}$ and $B'_k = B_{k+1}$.

Sea level and circulation strength in the Japan/East Sea

Interacting SLA modes in the Japan/East Sea

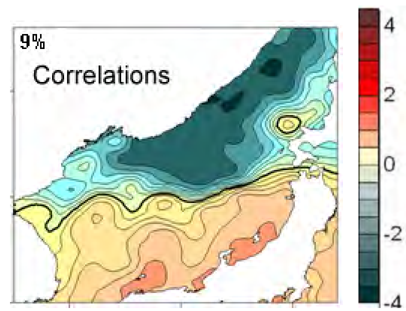


Synchronous Mode

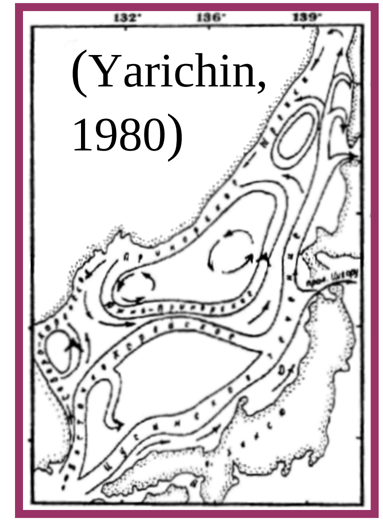


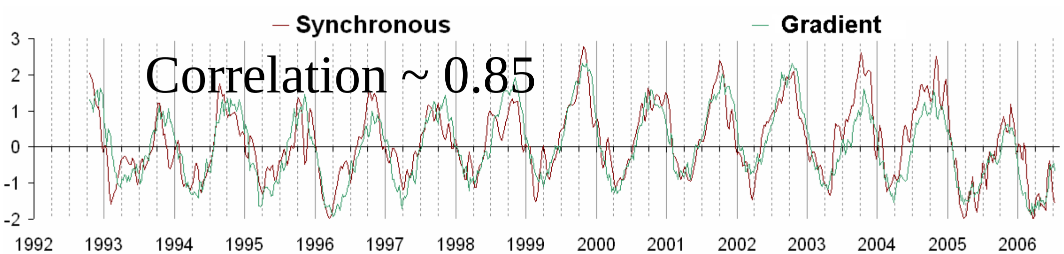
Original sampling

Gradient Mode



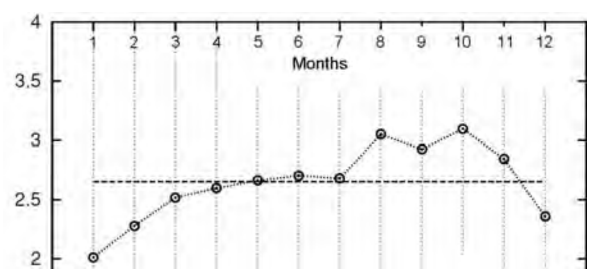
Residual sampling





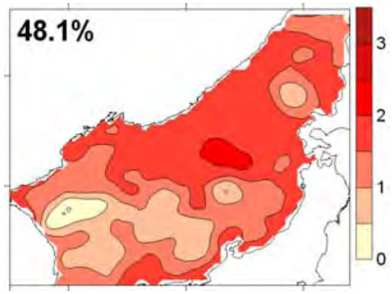
The sea level rise and meridional gradient sharpening (circulation strengthening) in the warm season and the reverse phase in the cold season.

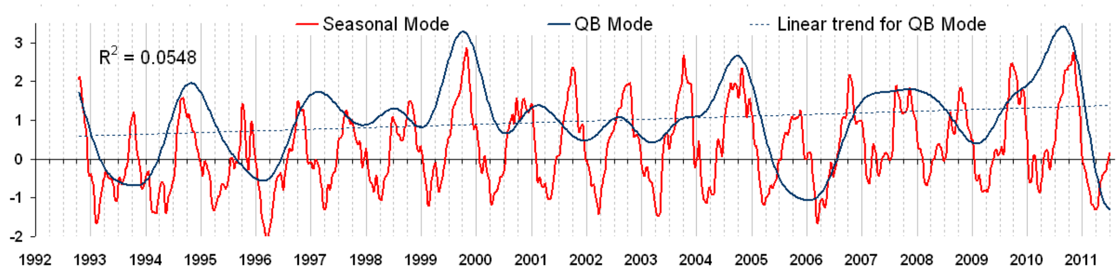
Transport
in the Korea Strait
(Fukudome et al., 2010)



Seasonal extremes of the Synchronous and Gradient Modes in October and March.

Quasi-biennial Synchronous Mode
(from low-pass filtered SLA)



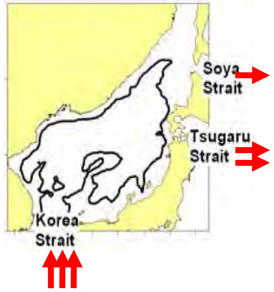


No statistically significant linear trend.

QB and decadal variability.

SLA caused by the volume imbalance.

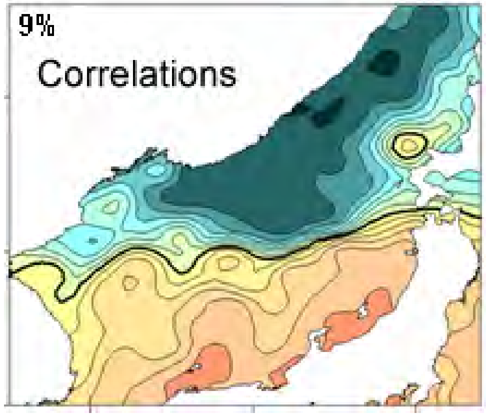
Imbalance of transports through the straits: SLA of 0.5-3 cm correspond to 0.4-2% of volume imbalance.



Stronger anomalies in 1999, 2004-2005, 2010 (decadal variability).

Indirect forcing from the atmospheric QBO (Baldwin et al., 2001)?

No interannual counterpart of the Gradient Mode

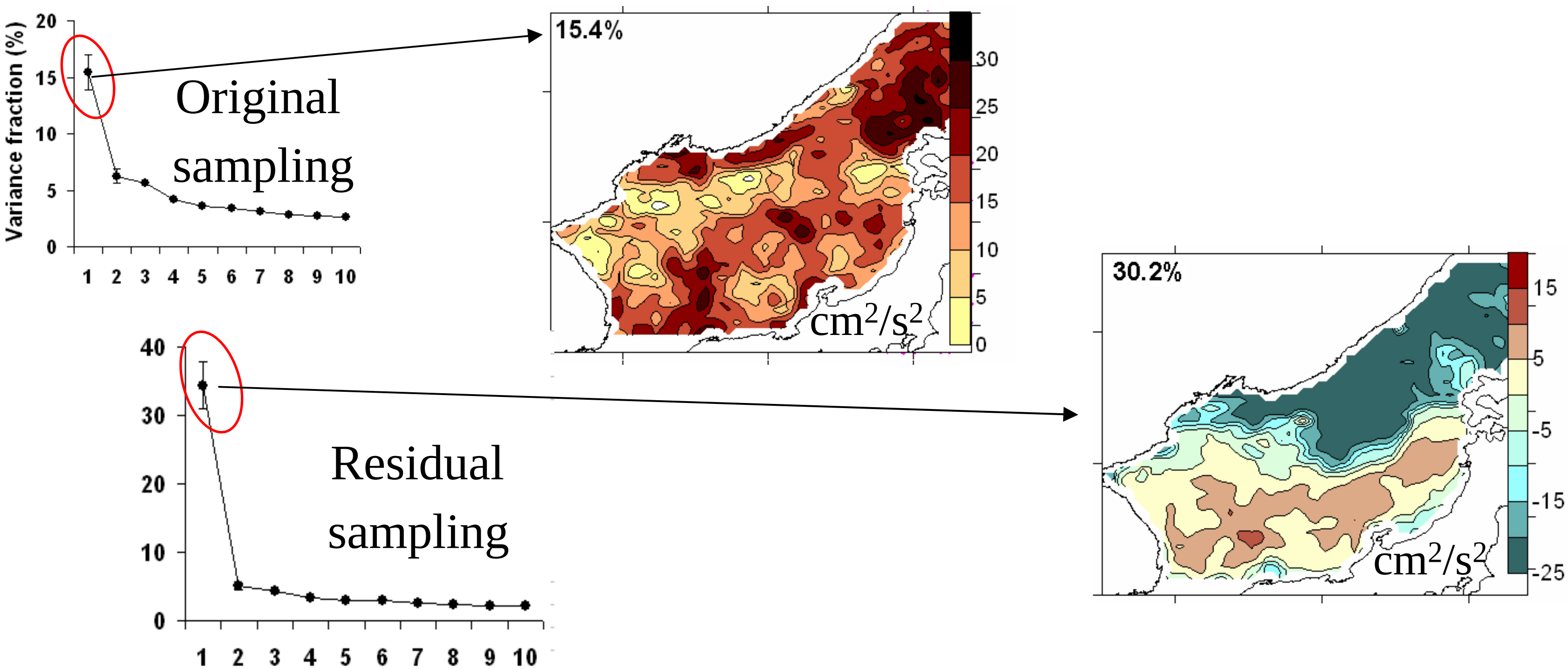


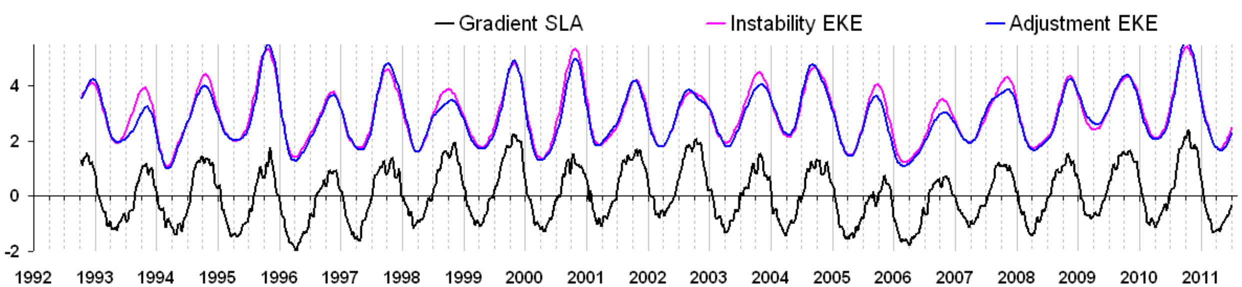
Only seasonal!

Stratification as a stabilizing factor: interannual oscillations are too weak.

Synoptic energetics in the Japan/East Sea

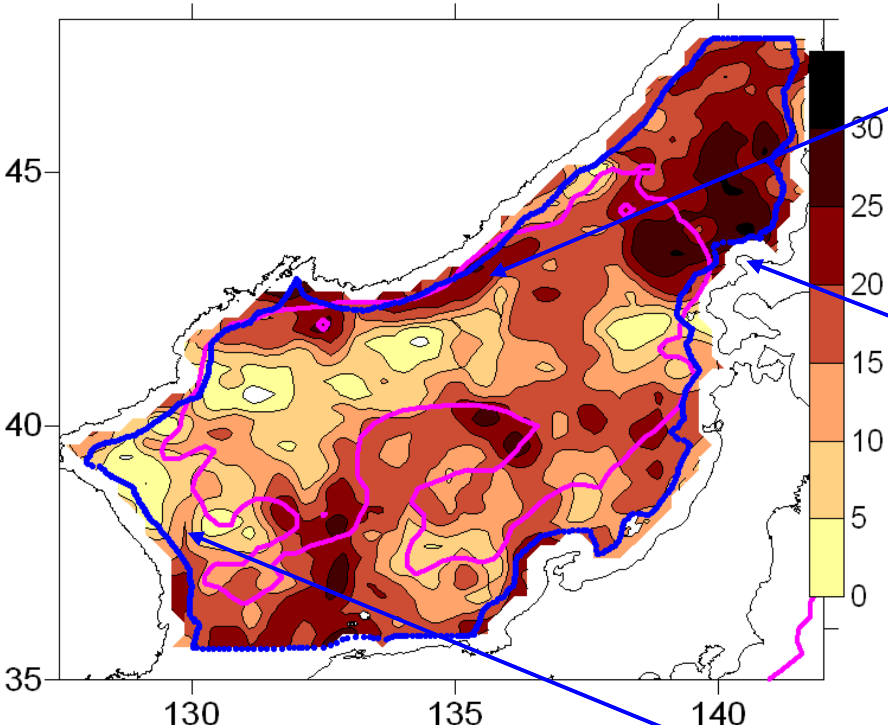
Leading EKE modes
(the same from the original and residual SLA)





Correlation with the SLA Gradient Mode Mode ~ 0.84.

Instability of mean currents

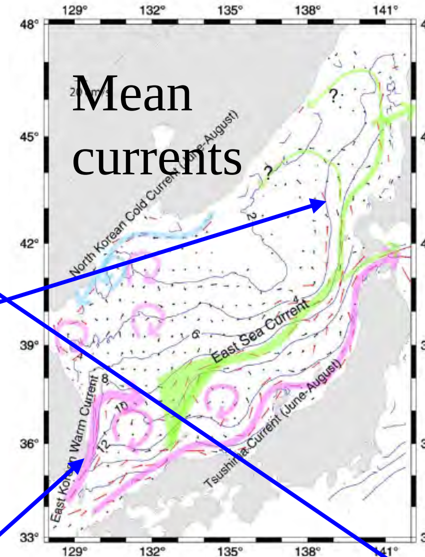


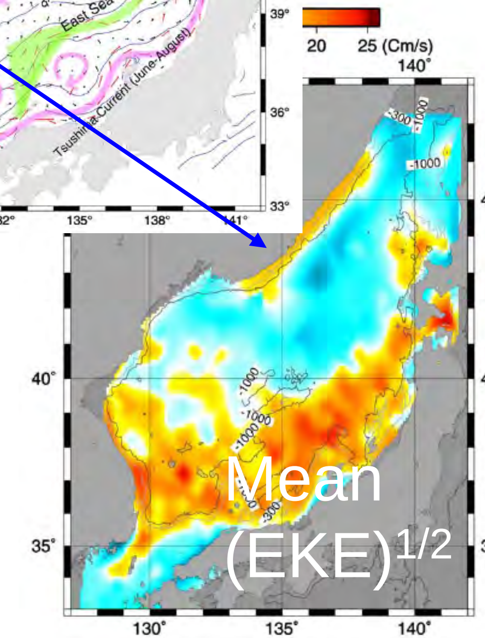
Primorye Current

TWC branching off Hokkaido

EKWC and EKWC Extension

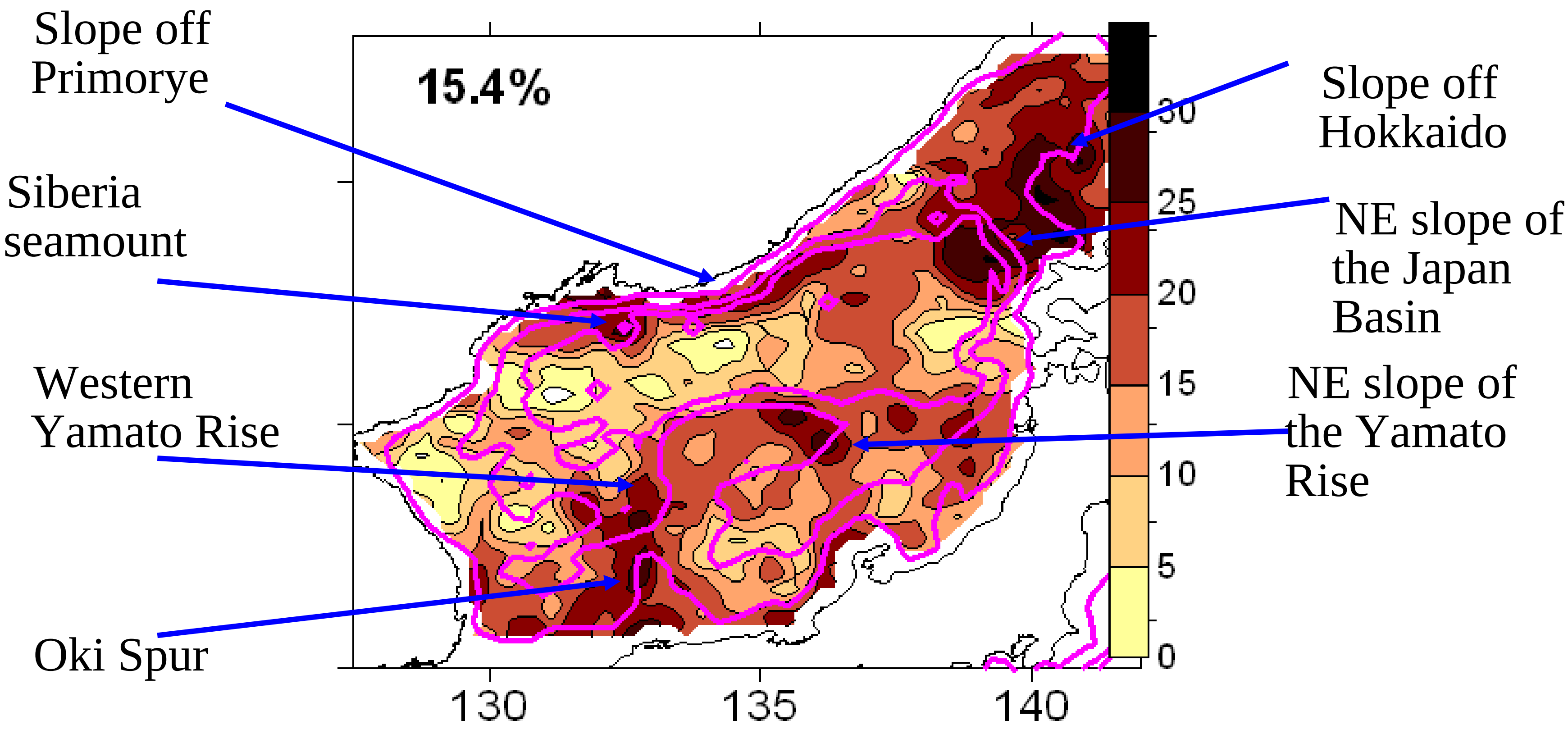
From surface drifters





(Lee and Niiler, 2005)

Interactions with bathymetry



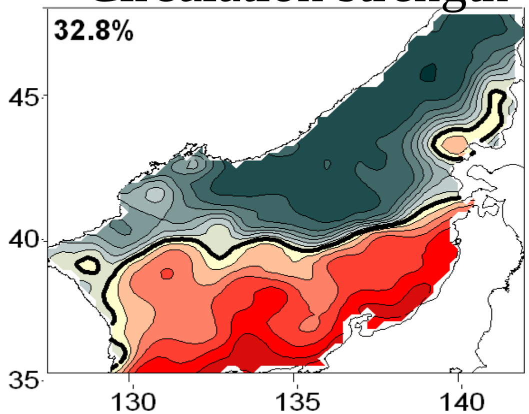
The 500, 2000, and 3000 m isobaths

EKE generated by hydrodynamic instability

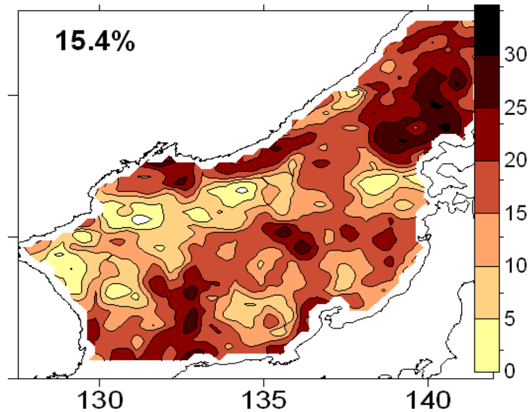
Baroclinic instability is usually considered.

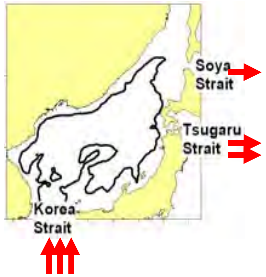
Shear instability

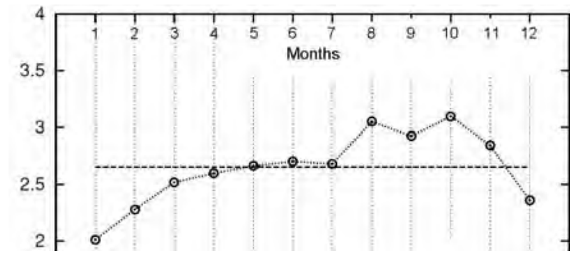
Circulation strength

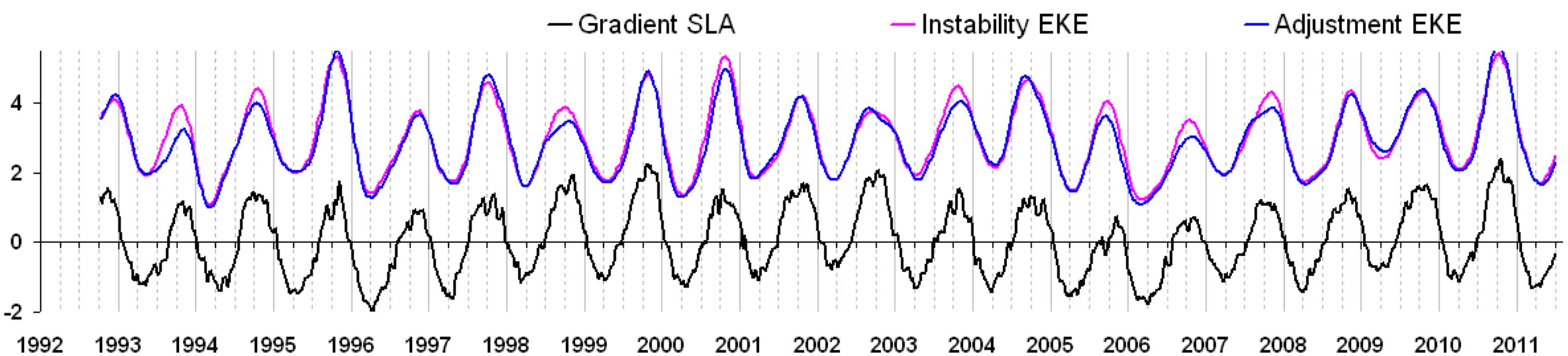


EKE









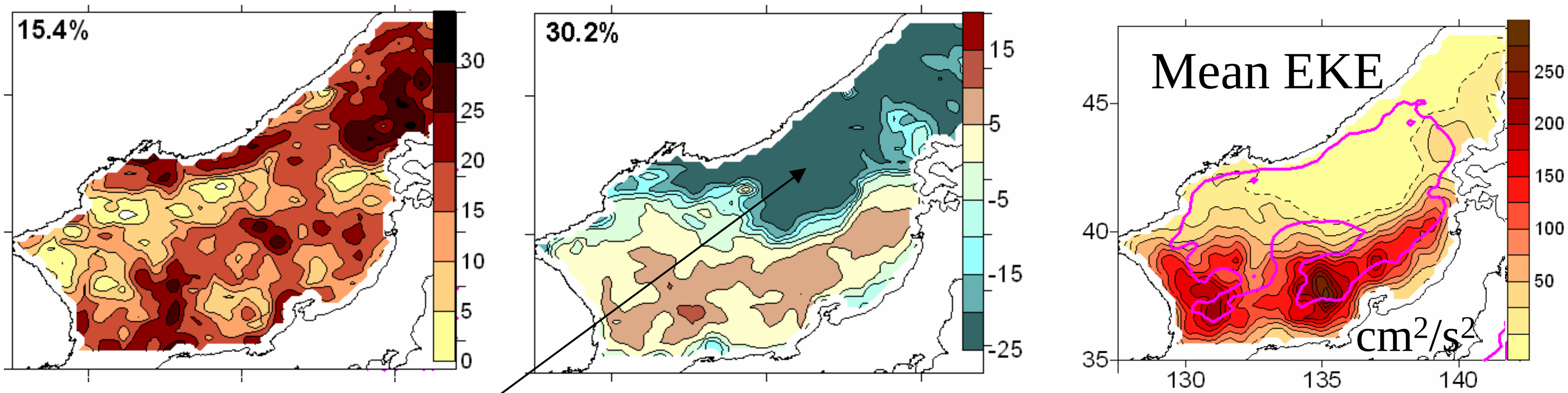
Seasonal variation of the circulation strength and EKE are the same → instability increase due to the increased current shear.

Synchronized barotropic and baroclinic instability as a possible cause of the very intense mesoscale dynamics in the Japan Sea

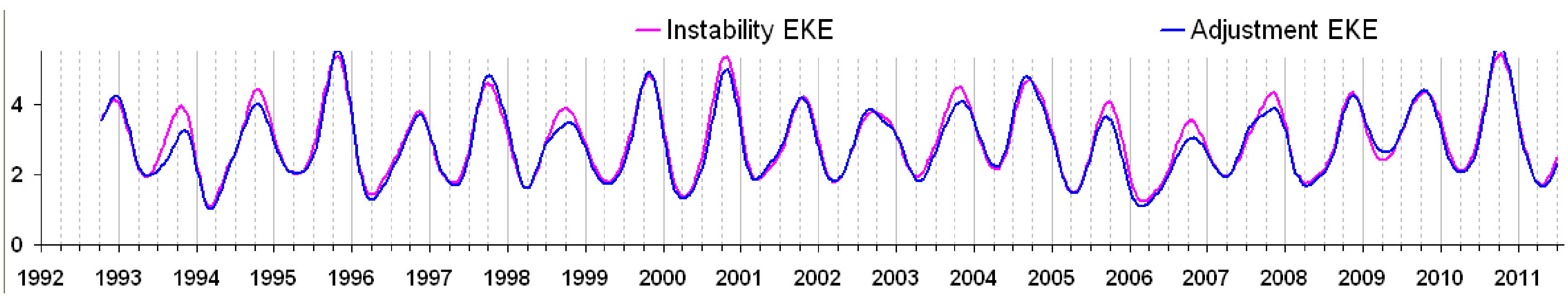
Adjustment mode: adjustment to the mean EKE

Original sampling
Instability Mode

Residual sampling
Adjustment Mode

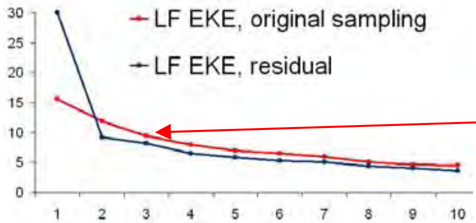


Uniform northern core

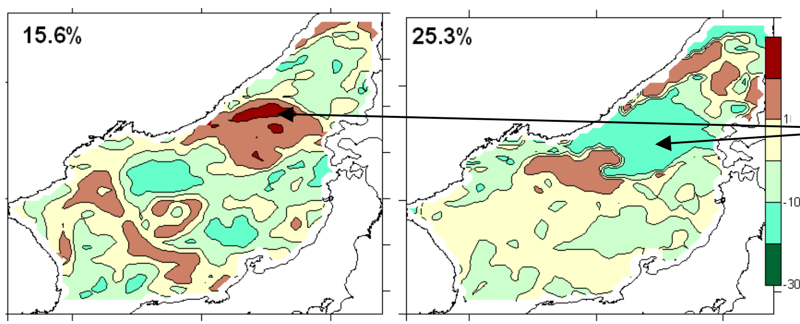


Correlation ~ 0.98

EKE: weak interannual variability:
the only strong event in fall 2003



Degenerate eigenspectrum from the original sampling

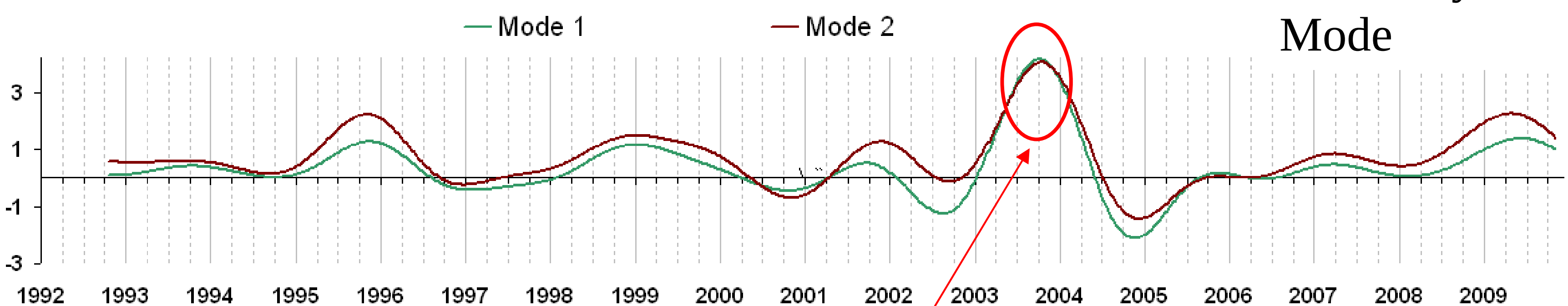


Off Primorye (Russian) coast

Original sampling

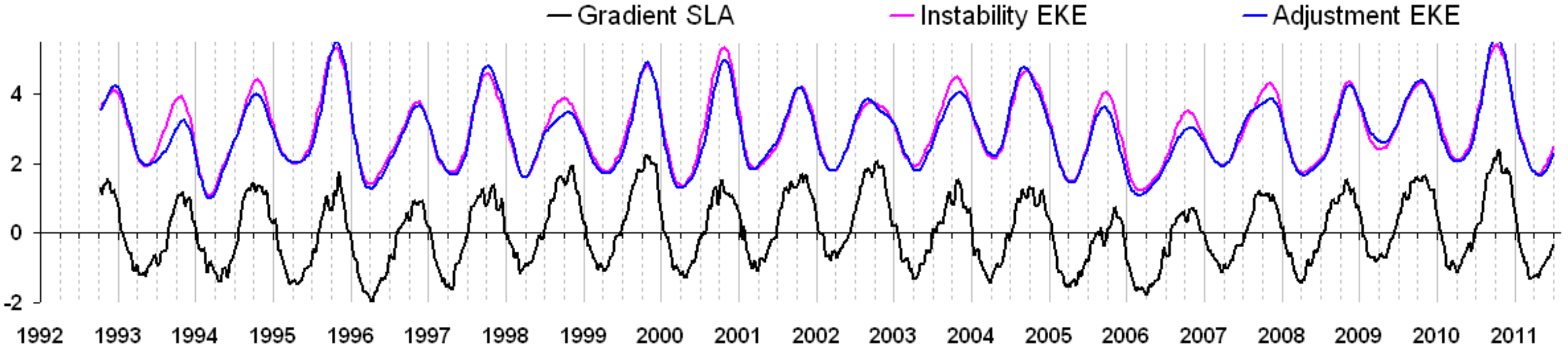
Residual sampling

No interannual SLA Gradient Mode or EKE Instability Mode



Anomalous warm conditions off the Primorye coast in fall 2003 (Vanin, 2004)

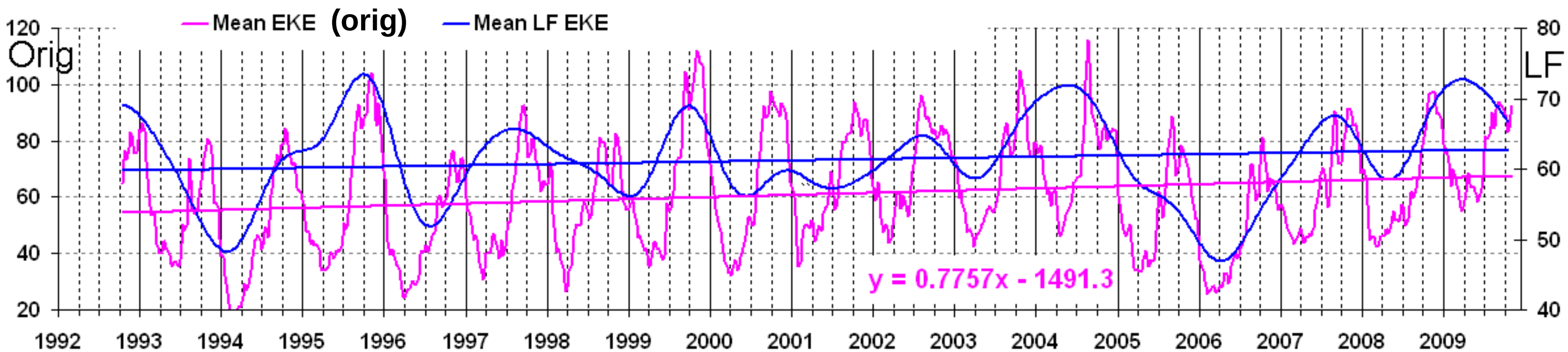
No interannual counterpart of the EKE Instability Mode or SLA Gradient Mode

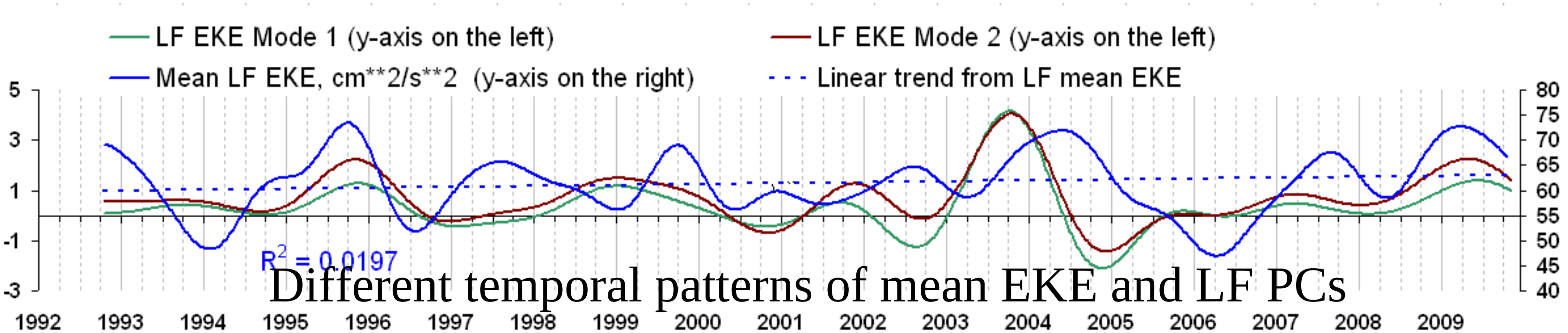


Interannual variability only in intensity of the seasonal SLA and EKE modes.

Mean EKE – QB variability

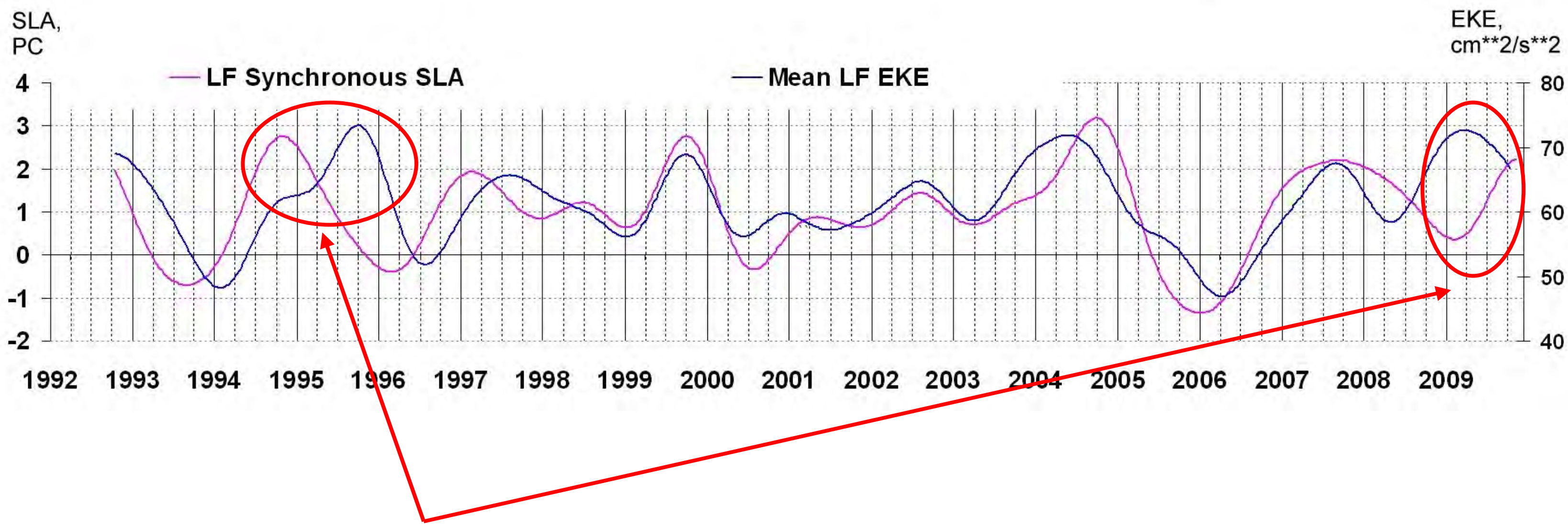
Mean EKE: 0.9 cm^2/s^2 per year for 1993-2007 (Son et al., 2011),
~0.8 cm^2/s^2 per year for 1993-2009





Different temporal patterns of mean EKE and LF PCs

SLA and EKE

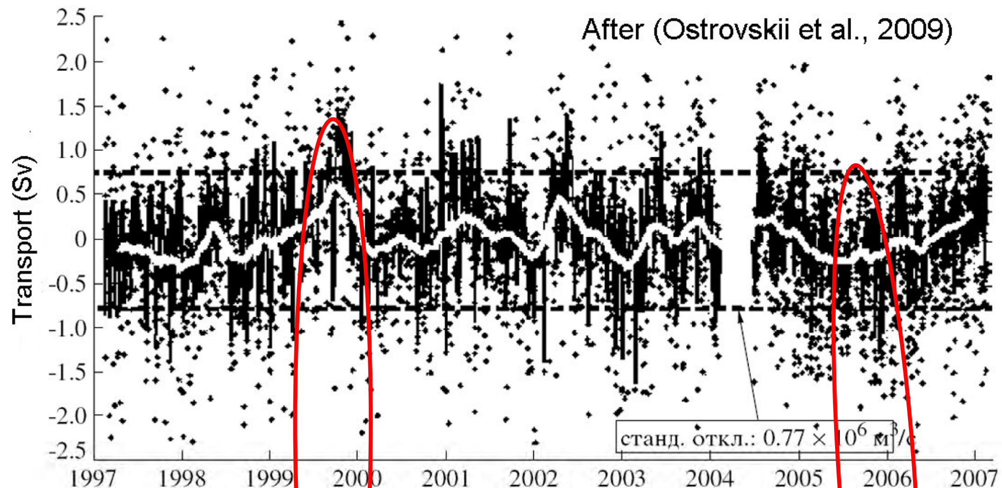


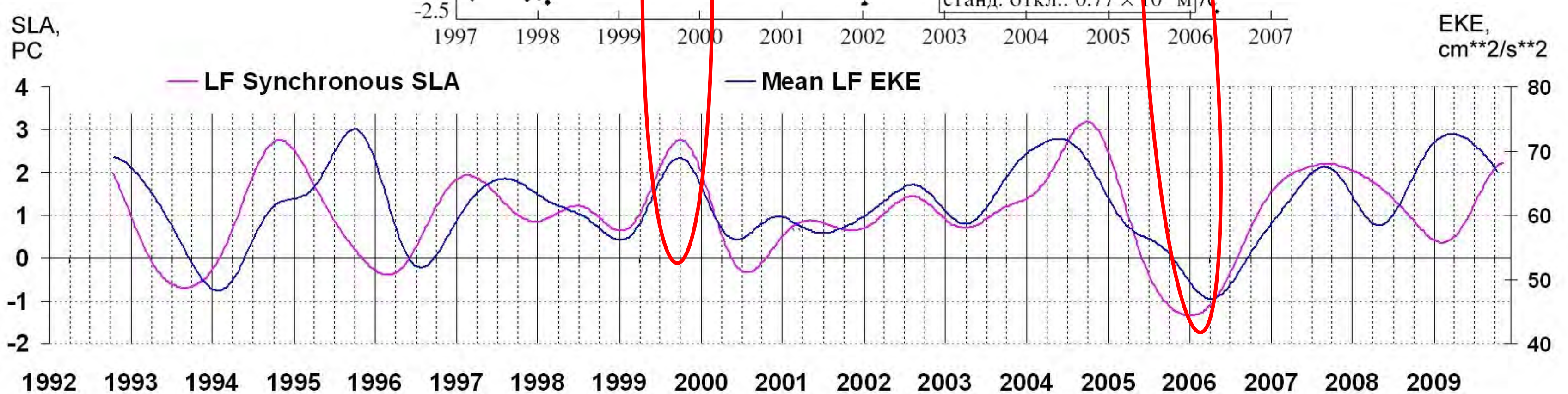
Close resemblance of low-frequency SLA and mean EKE, although with some discrepancies.

Correlated at 0.54 for the whole record and at 0.61 from mid 1996 through early 2008.

Relationship with transport in the Korea Strait

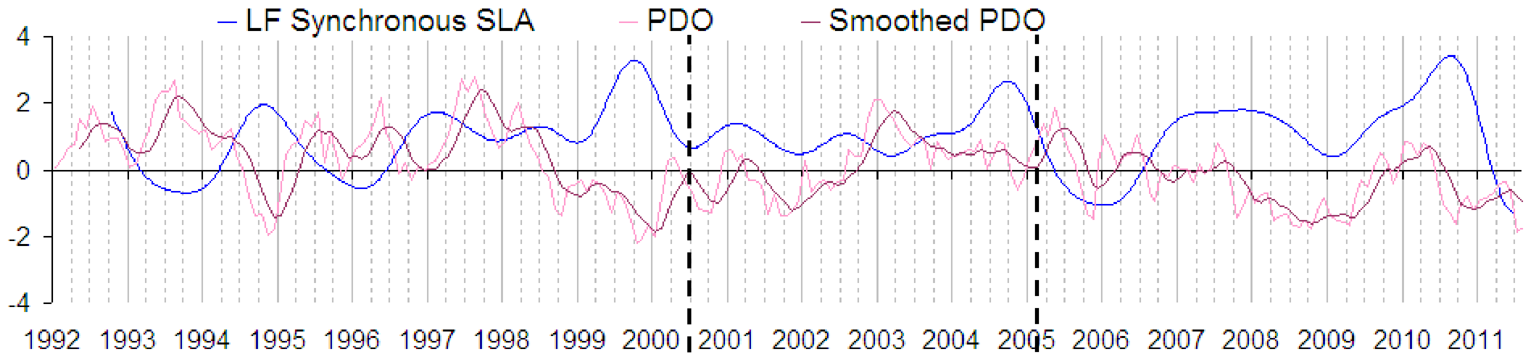
From ADCP mounted onboard of *Camelia* Ferry





Considerable sea level rise in 1999 and decline in July 2005 through June 2006 corresponds to the transport in the Korea Strait being largest (smallest) in 1999 (2005) (Ostrovskii et al., 2009).

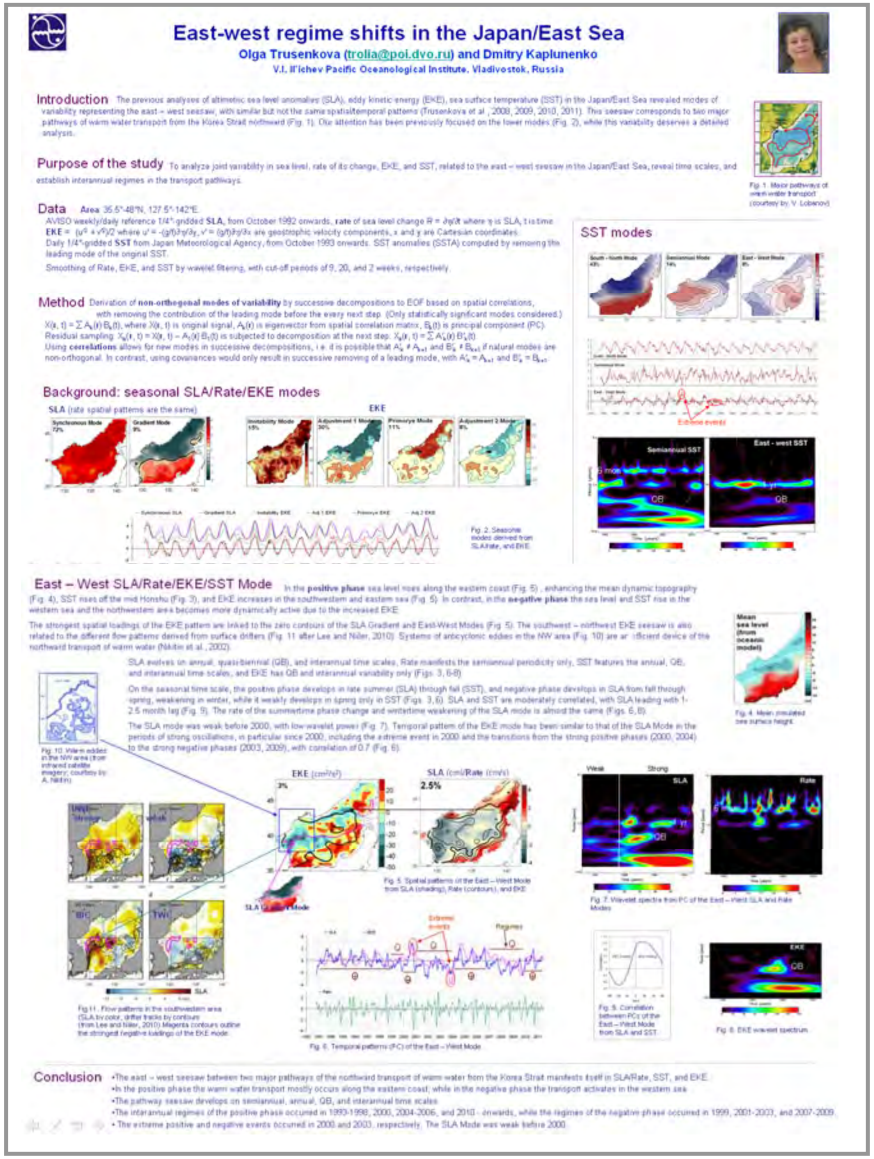
Changing linkage with PDO



Out of phase In phase

Positive SLA with negative PDO explained by transport variations in the Korea Strait (Gordon and Giulivi, 2004)

Interannual regimes of the east - west seesaw in SLA, EKE, and SST (S9 poster)



Conclusion

- Neither sea level nor eddy kinetic energy in the Japan/East Sea reveal linear trends for the last two decades but rather they manifest oscillatory patterns.
- Sea level and mean EKE manifest QB and decadal variability.
- The Synchronous and Gradient Modes of sea level are coupled on the annual time scale, manifesting the same seasonal variation.
- The SLA Gradient Mode and Instability EKE Modes manifest the same seasonal variation, implying that shear instability is important for the EKE generation.
- There are no interannual counterparts of either SLA Gradient Mode or EKE Instability mode.
- Weak interannual variability of EKE can be attributed to the stability of the meridional sea level gradient, i.e. of the intensity of mean currents (on interannual time scale).
- Interannual variability of the mean EKE is due to the subtropical (southern) area and seems to be related to the transport variations in the Korea Strait.


Thank you!