Synchronous and asynchronous variability of the North Pacific western boundary currents: Kuroshio and Oyashio

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Background:

Almost of studies on variability of Oyashio focused on the variability of southern intrusion of Oyashio 1st Branch.

Transport variability

Barotrophic response (Sekine, 1988; Kono & Kawasaki, 1997)

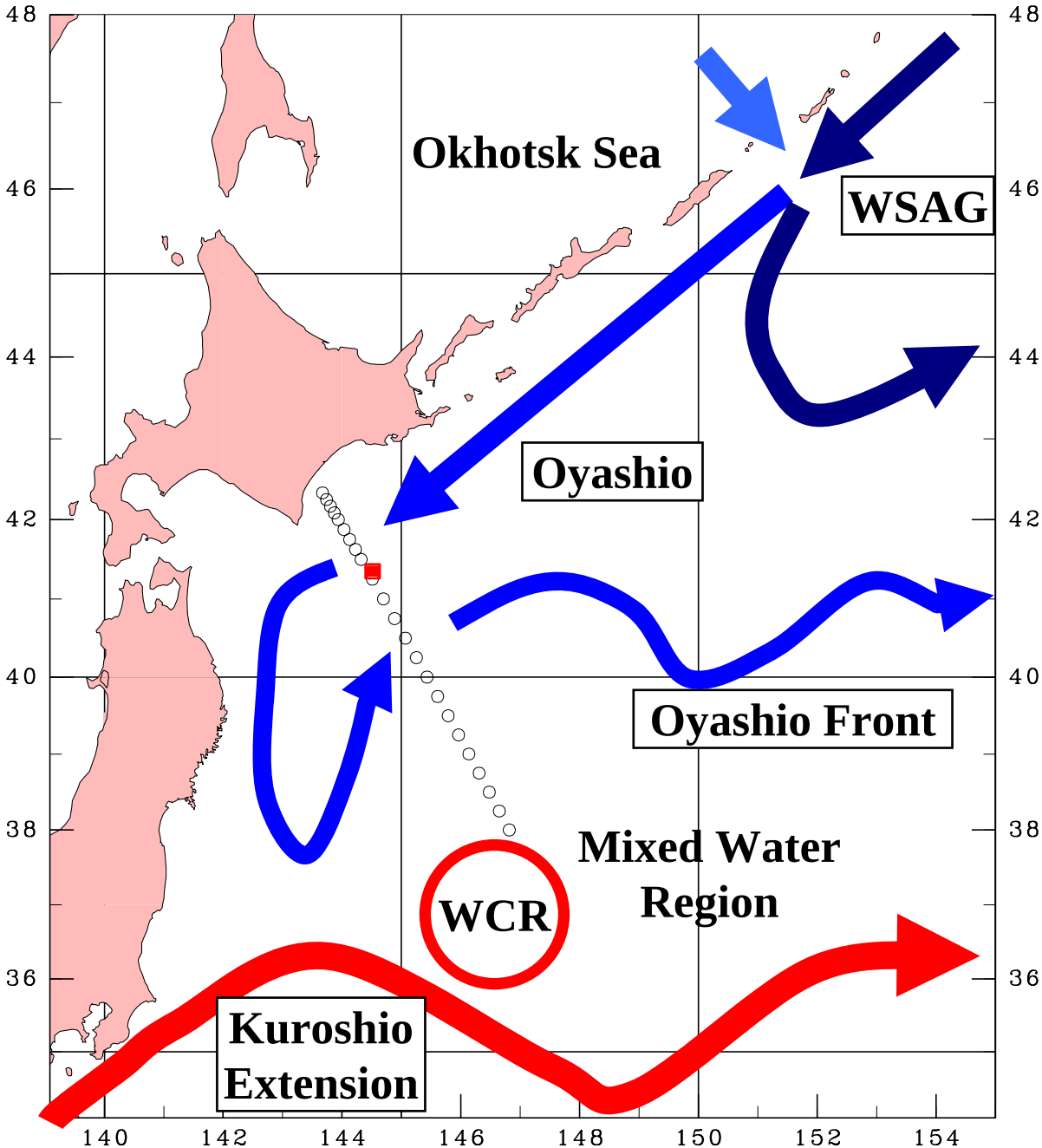
Velocity variability

Uehara et al. (1997): seasonal variability

Qiu(2002): the interannual changes are influenced by both barotropic and baroclinic response (with 6 years damping).

Tatebe & Yasuda (2005): baroclinic decadal response

Need direct observation of transport.



OICE：
Oyashio Intensive observation line off Cape E mo

set on T/P ground-track

repeat hydrographic survey & mooring 1997-2002

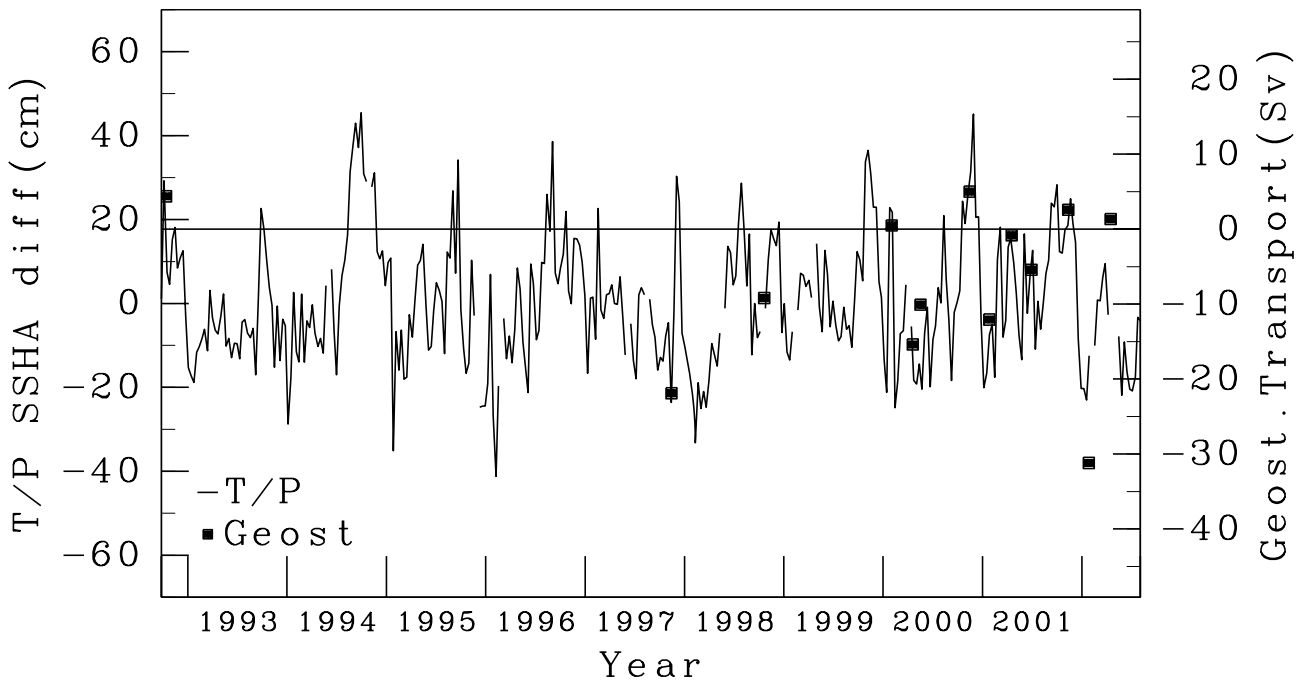
Ito et al. (2004)

Oyashio geostrophic transport and SSHA difference

Linear regression

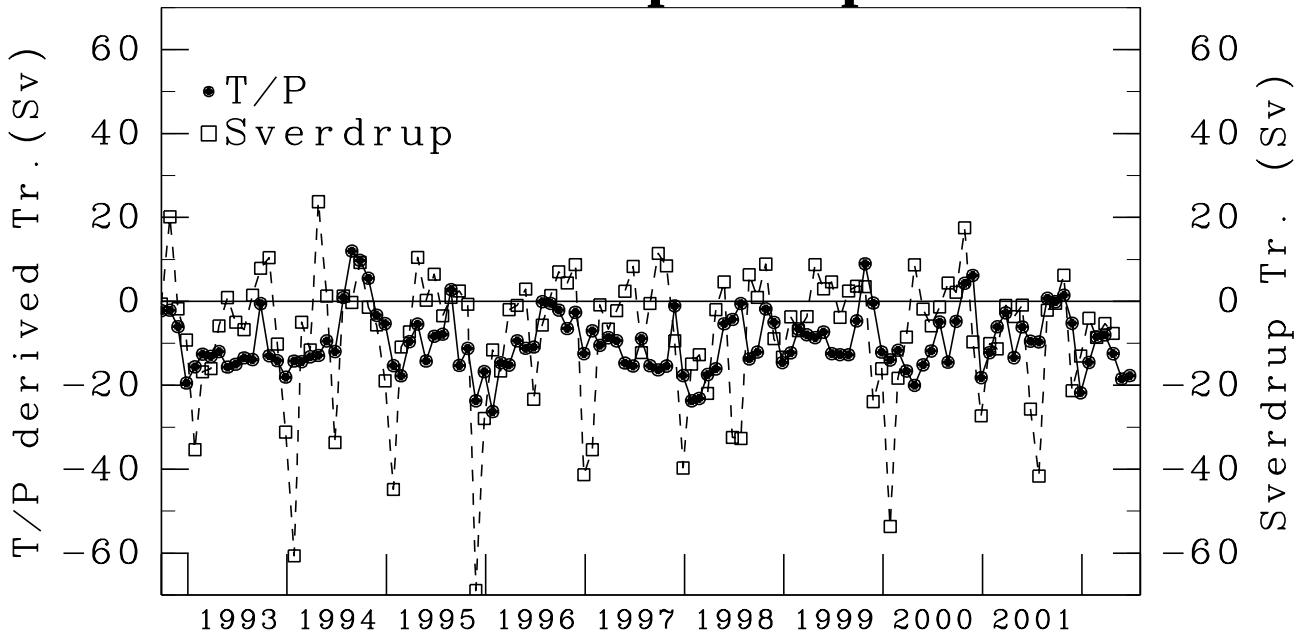
$$Tr = 0.539 \times \Delta D_{T/P} - 9.46$$

R=0.93



Ito et al. (2004)

Oyashio transport (SSHA derived) and Sverdrup transport



Oyashio transport

derive from SSHA difference between 39.5 - 42.0 N using linear regression equation to 3000db-ref. geostrophic transport

monthly mean

Sverdrup transport

calculated from NCEP monthly wind data

between 40 - 42.5 N

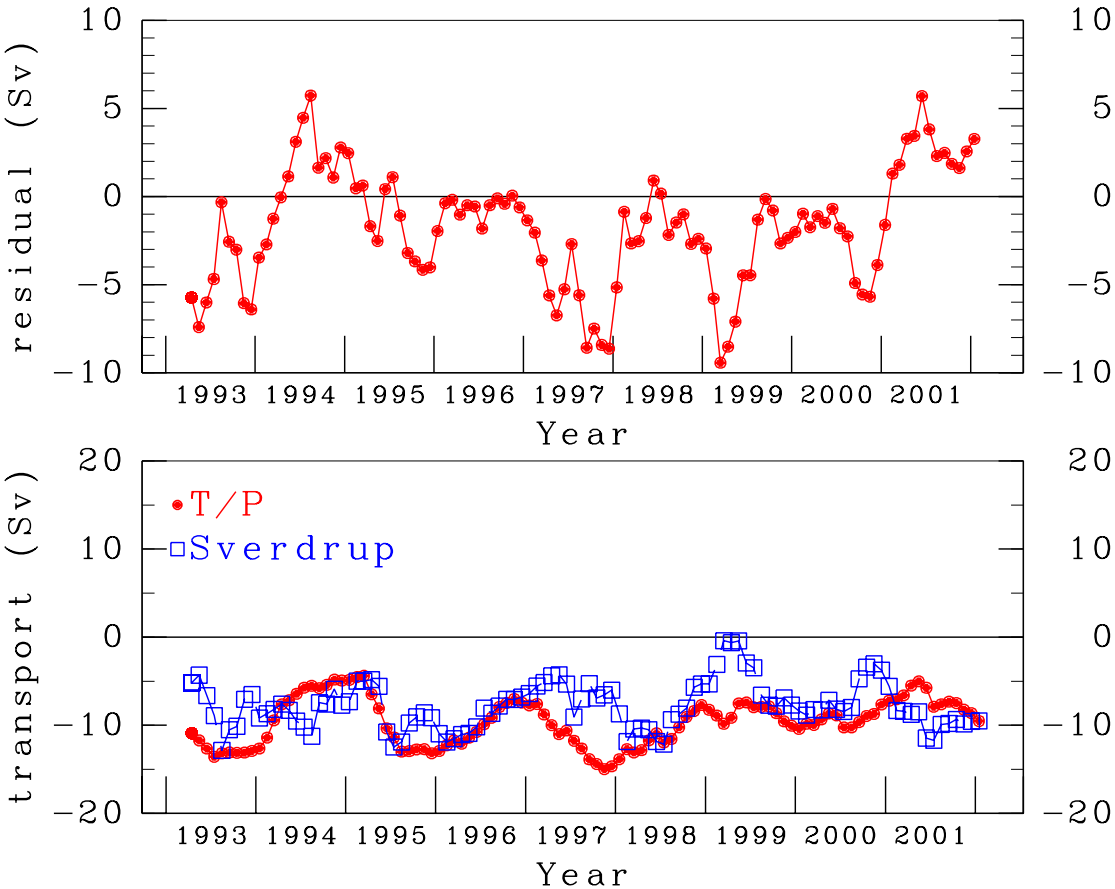
integrated from the Emperor Sea Mount

relative good correspondence with seasonal variability

no good correspondence with transport variability itself

residual between Oyashio transport (SSHA derived) on OICE and Sverdrup transport

13 month running mean



Ito et al. (2004)

residual between Oyashio transport and barotropic response

amplitude : 10 Sv

same order as barotropic response

1994-1996 : lower than BT

1997-2000 : higher than BT

2001- : lower than BT

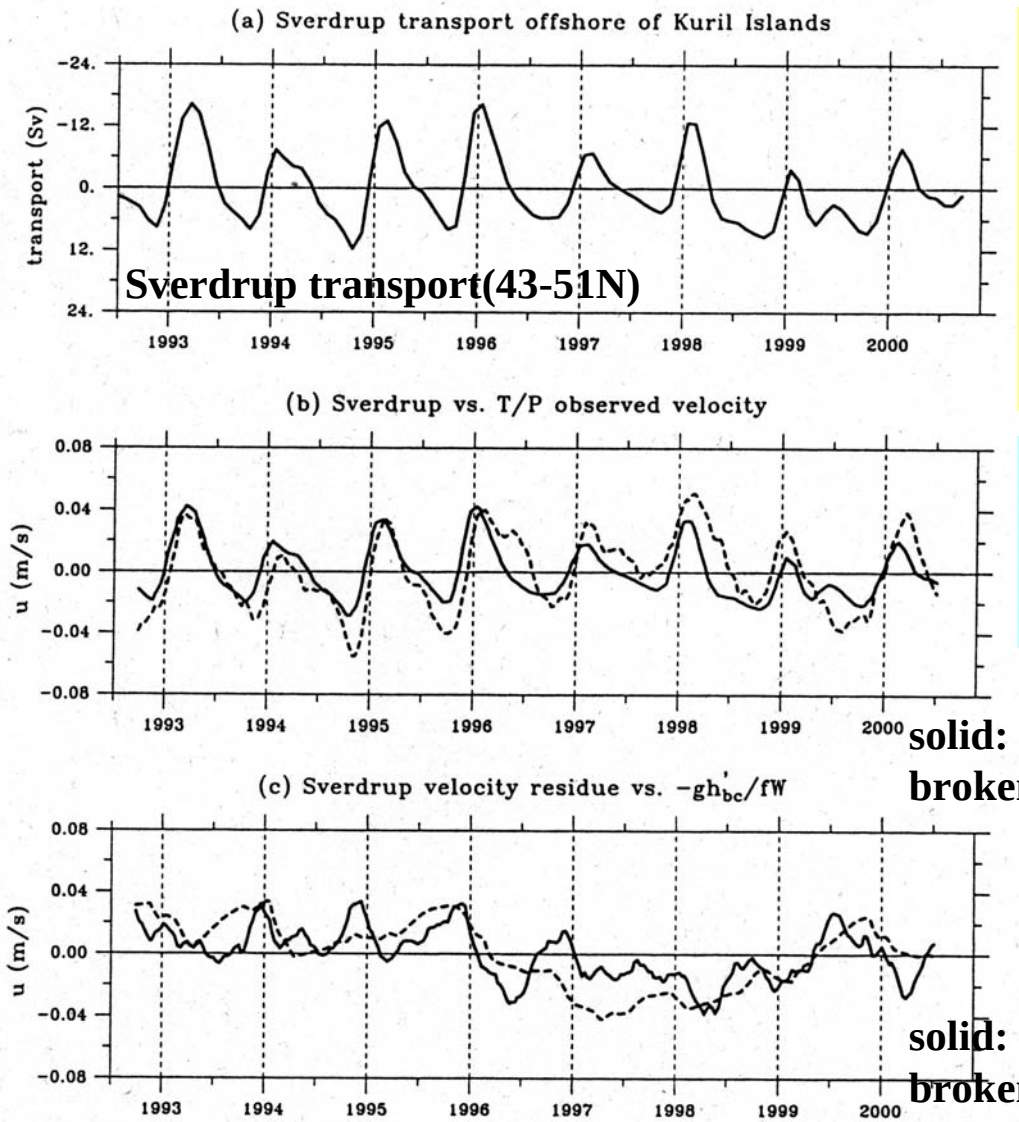
could be explained by baroclinic response with 1 year lag

Qiu (2002)

1993-1995 : reduce by BC

1996-1999 : enhanced by BC

barotropic and baroclinic response : Qiu (2002)



barotropic response

good agreement with SSHA derived surface velocity in seasonal variability

residual : 1993-1995 reduced

: 1996-1999 increased

baroclinic with damping

$$\frac{\partial h_{bc}}{\partial t} - \frac{\beta g' H_e}{f_0^2}\frac{\partial h_{bc}}{\partial x} = -\frac{g' H_e^2 \nabla \times \tau}{\rho_0 g f_0 H_1^2} - \varepsilon h_{bc}$$

solid: scaled Sverdrup transport(43-51N)

broken: EKC/Oyashio surface velocity anomaly (T/P) (43-51N)

solid: residual of (b)

broken: baroclinic response with damping

70 days low-passed filter

Qiu (2002)

Conclusion for Oyashio transport

interannual variability of Oyashio transport (Ito et al., 2004)

annual mean transport: -9.46 Sv

between -30 and 15 Sv (3000 db ref. case)

basically corresponds with Sverdrup transport in seasonal time scale

baroclinic response contributes to interannual time scale as same as the barotropic one

this is consistent with Qiu (2002) with one year lag

Question

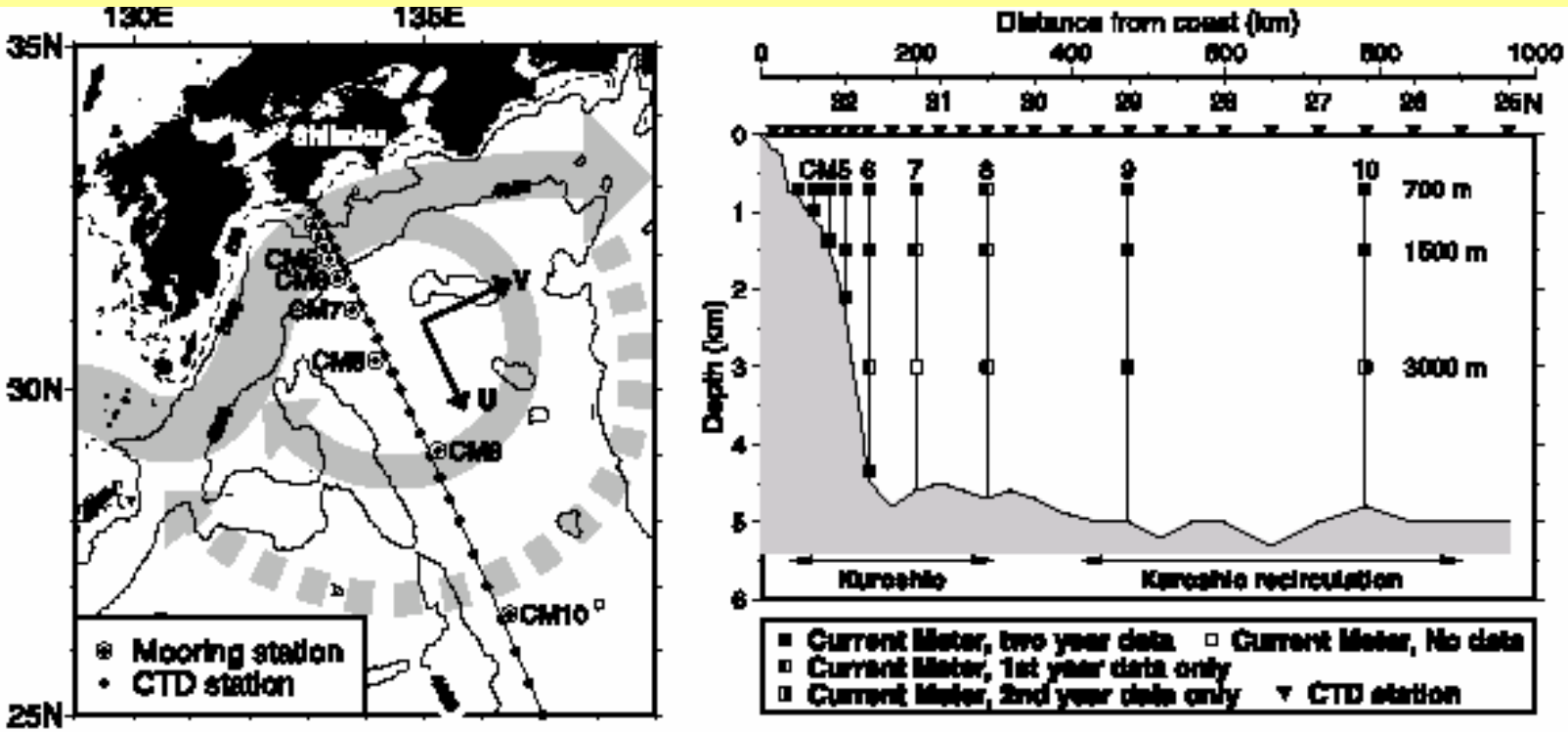
If the batotropic response also appears in the subtropical, synchronicity between Oyashio and Kuroshio may be found.

ASUKA (Affiliated Surveys of the Kuroshio off Cape Ashizuri)

A repeated observations line along ground track T/P were also conducted to estimate Kuroshio transport.

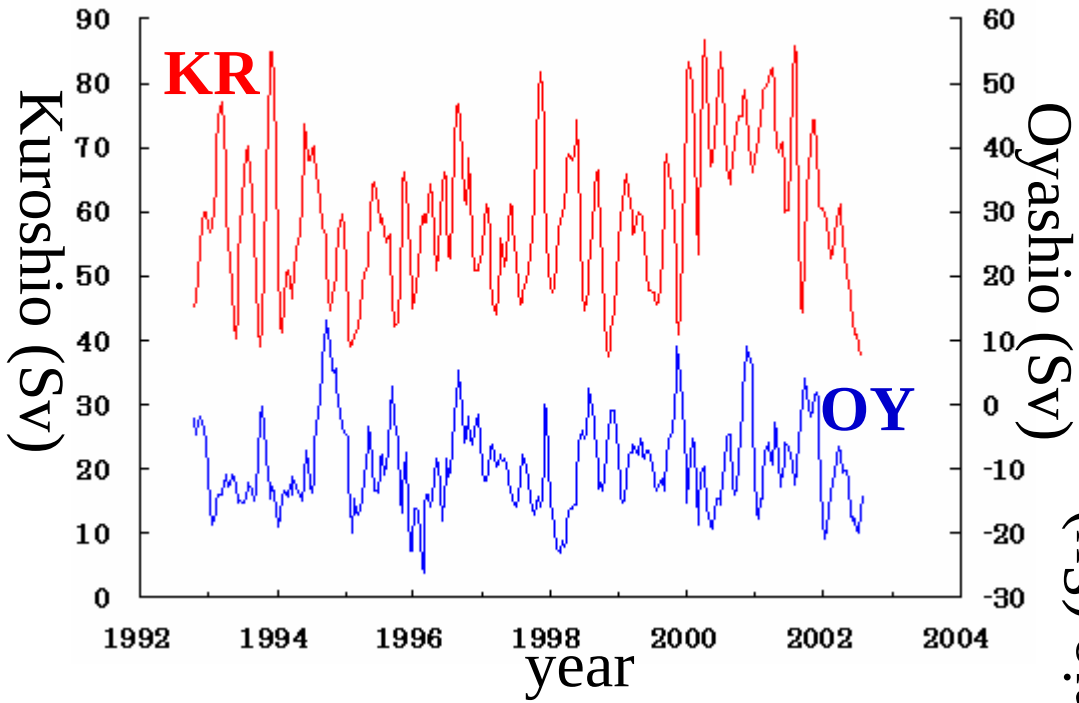
Imawaki et al. (2001), Umatani et al. (2001)

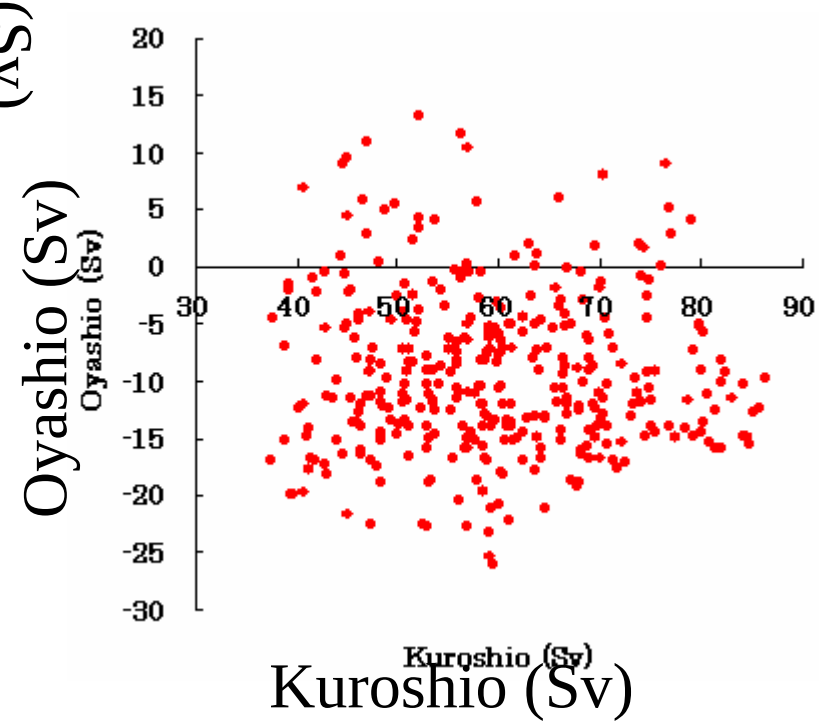
carried out 1993-1995



Kashima et al. (2003)

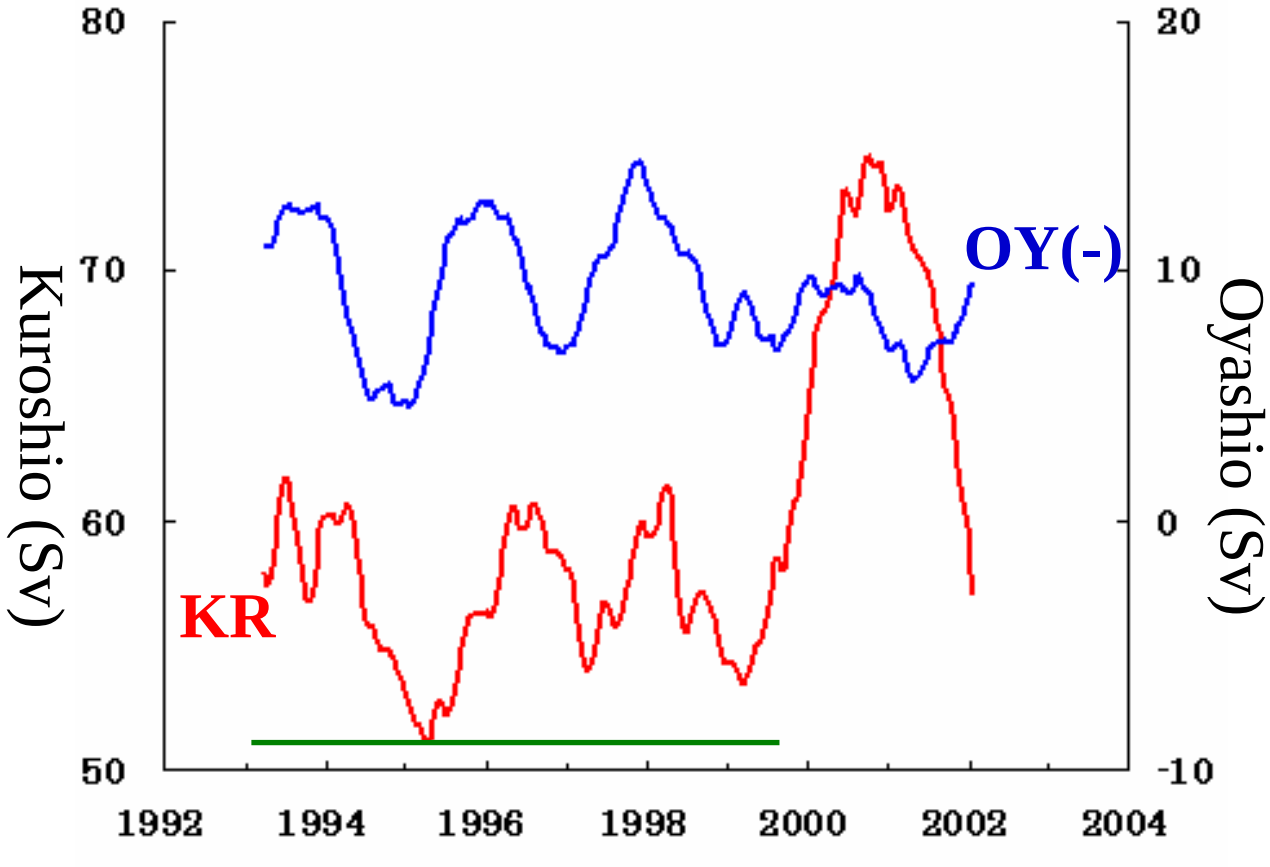
Kuroshio vs Oyashio (transport)





Monthly Oyashio & Kuroshio transport seems to fluctuate independently.

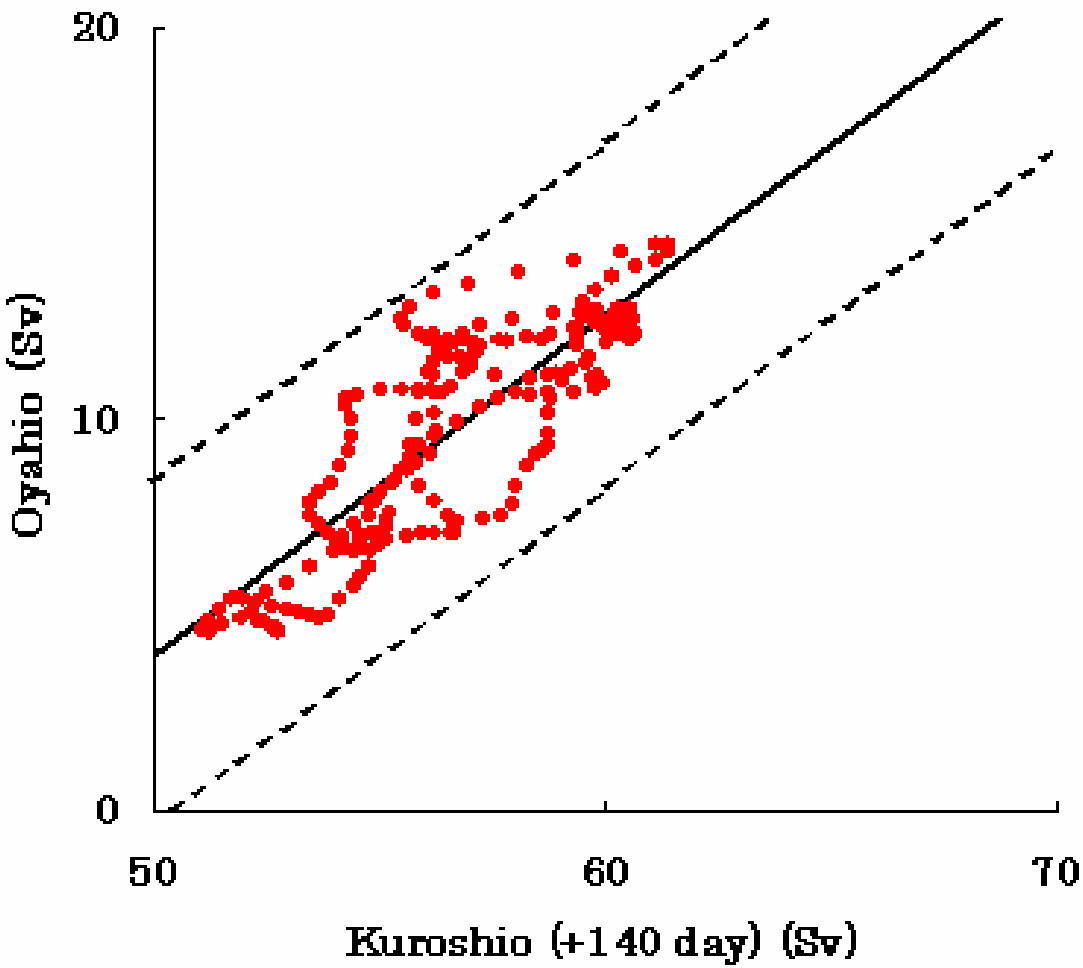
Kuroshio vs Oyashio(-) (transport)
13 month running mean



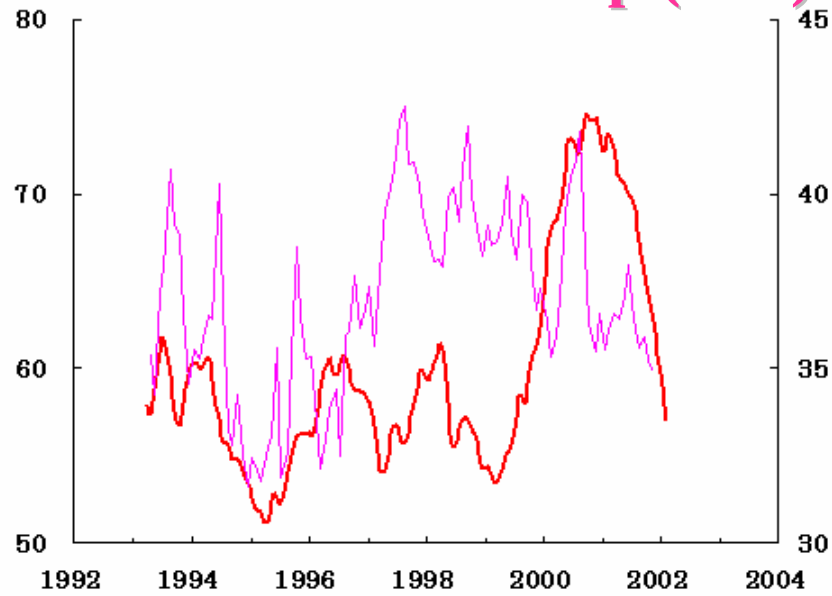
Low frequency variations are synchronized between Oyashio & Kuroshio transport.

Especially during 1993.4.1-1999.5.31
R=0.84
with 140 days lag
(Oyashio advanced)

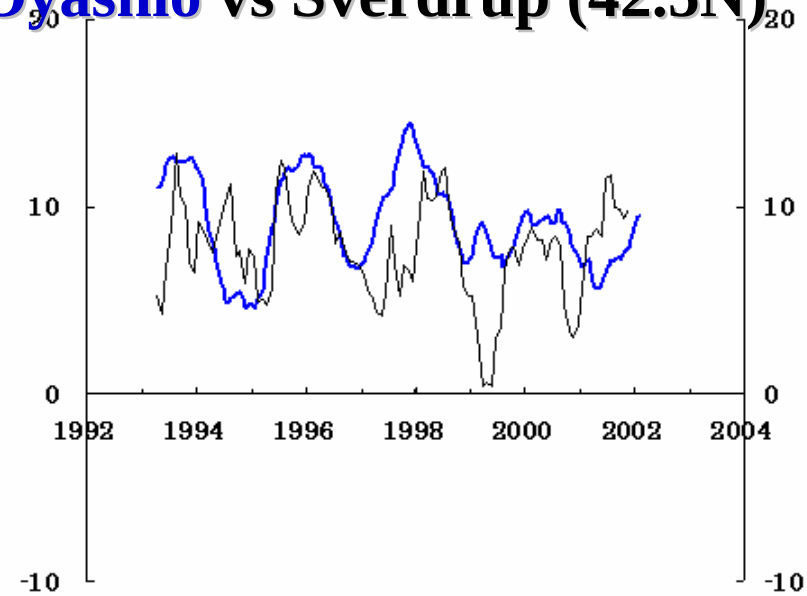
Kuroshio vs Oyashio(-) (transport)
13 month running mean
With 140 days lag (Oyashio advanced)

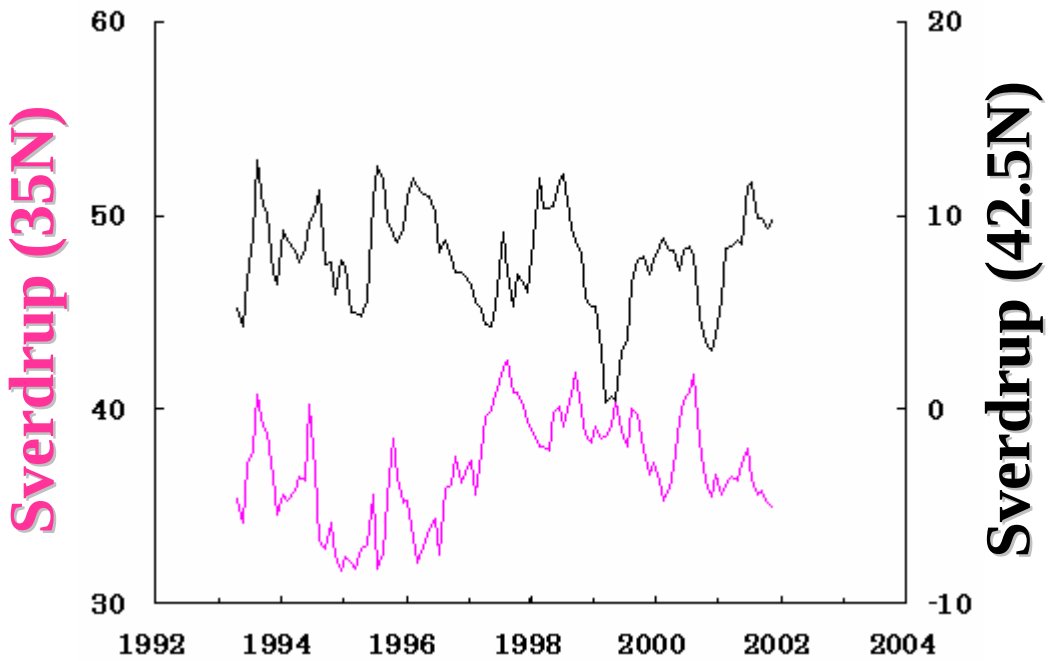


Kuroshio vs Sverdrup (35N)



Oyashio vs Sverdrup (42.5N)

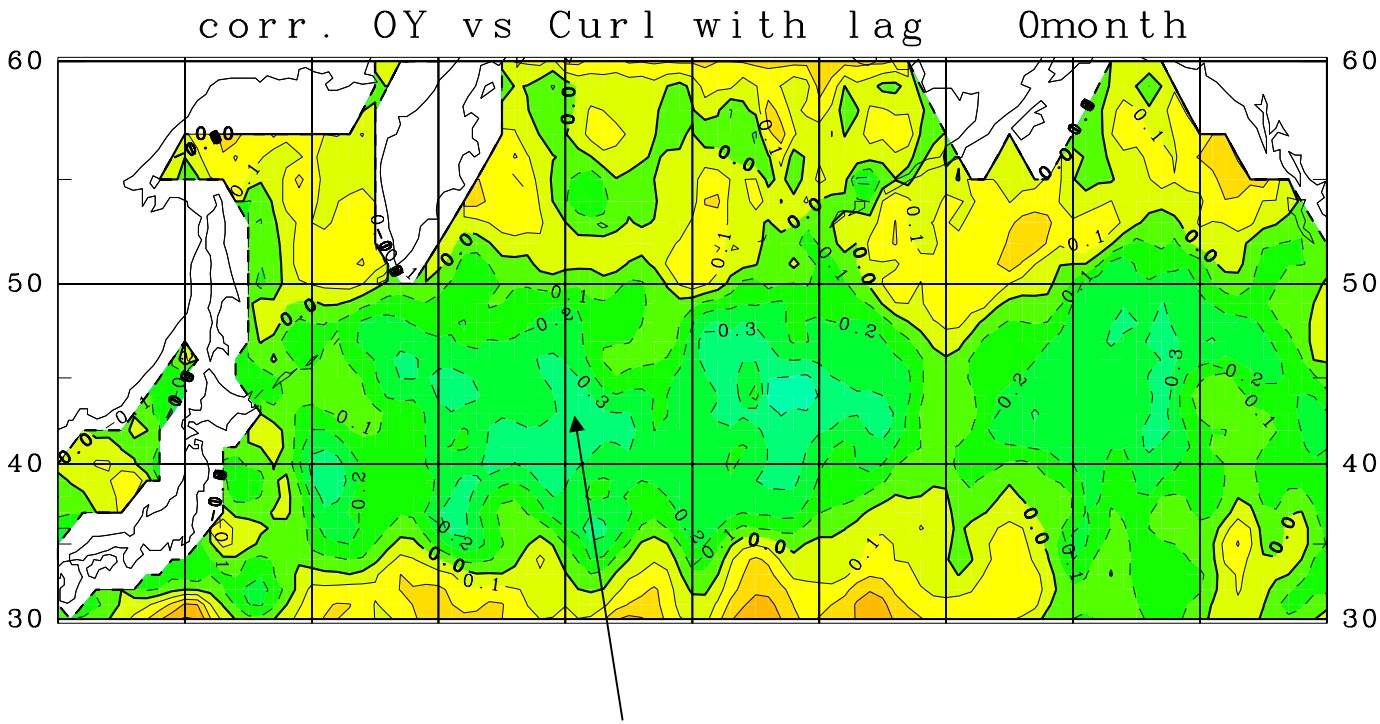




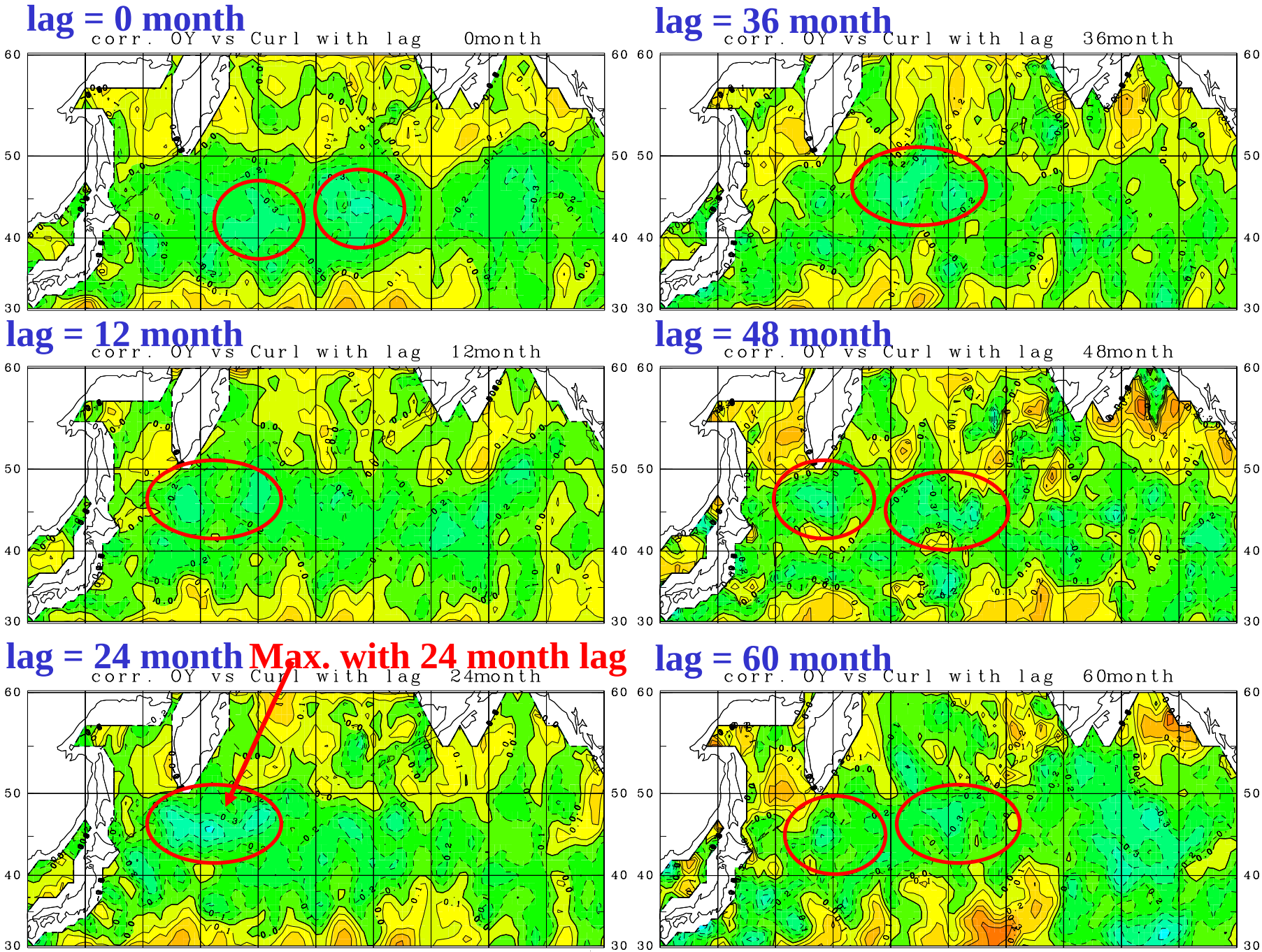
Oyashio shows relatively good correspondence to Sverdrup transport.

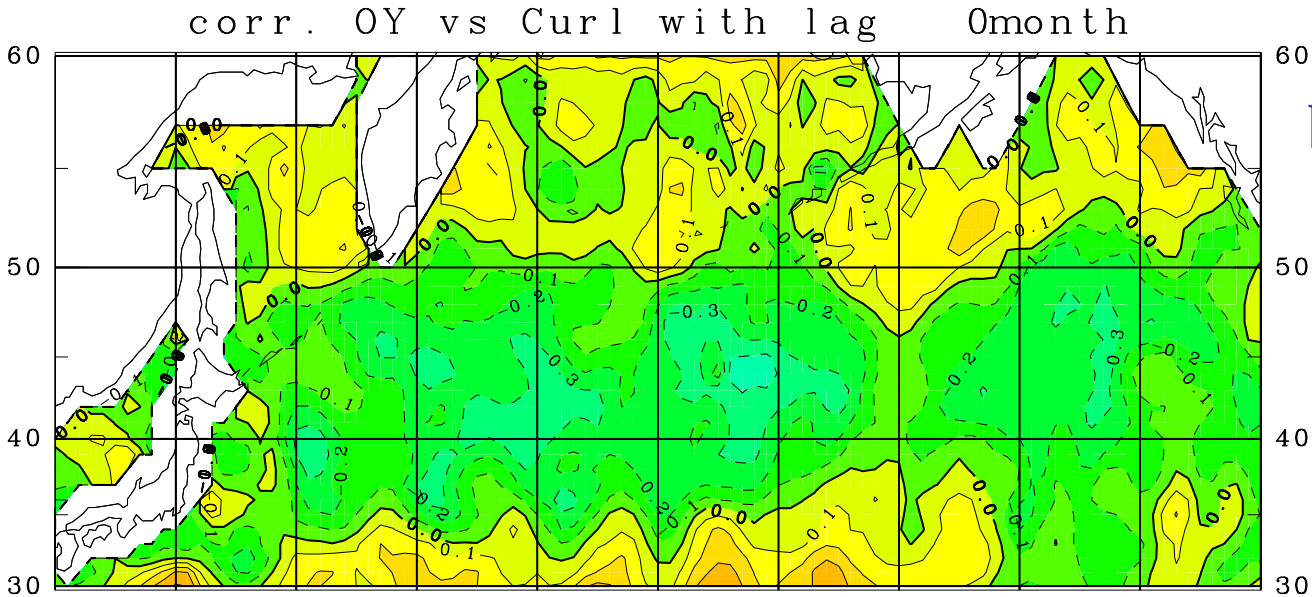
Sverdrup transport in both latitude do not show any synchronicity.

Correlation between Oyashio transport and curl τ/β

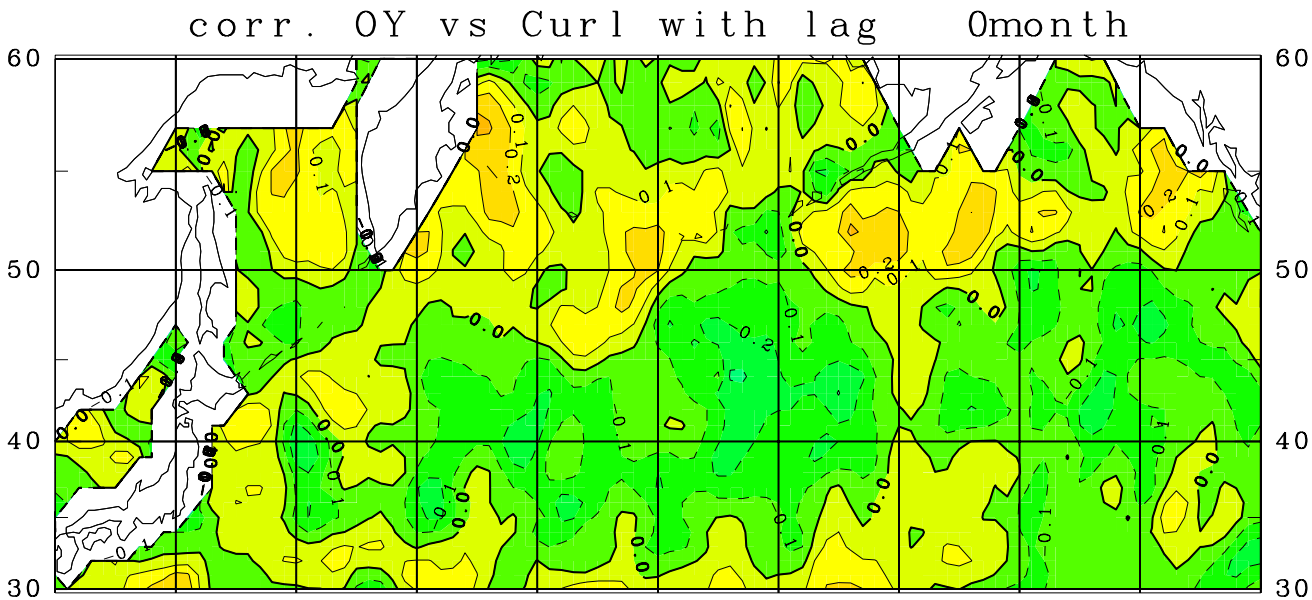


Emperor Sea Mounts


lag = 0 month
corr. OY vs Curl with lag 0month
lag = 36 month
corr. OY vs Curl with lag 36month
lag = 12 month
corr. OY vs Curl with lag 12month
lag = 48 month
corr. OY vs Curl with lag 48month
lag = 24 month
Max. with 24 month lag
corr. OY vs Curl with lag 24month
lag = 60 month
corr. OY vs Curl with lag 60month
60
50
40
30



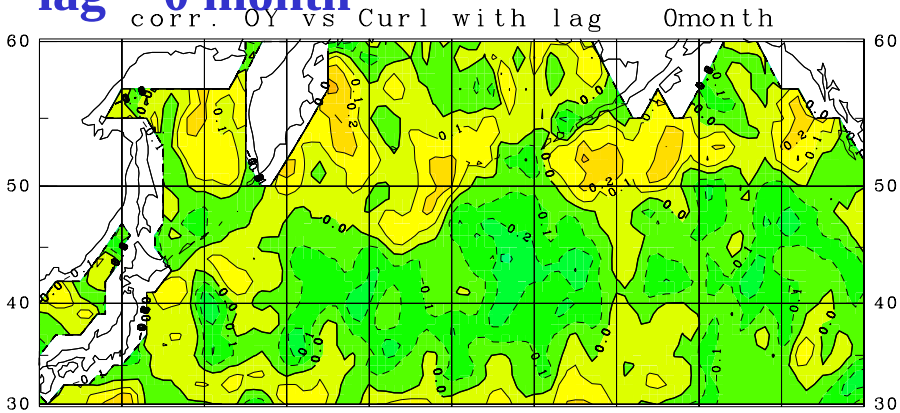
Correlation between Oyashio transport and curl τ/β (monthly data)



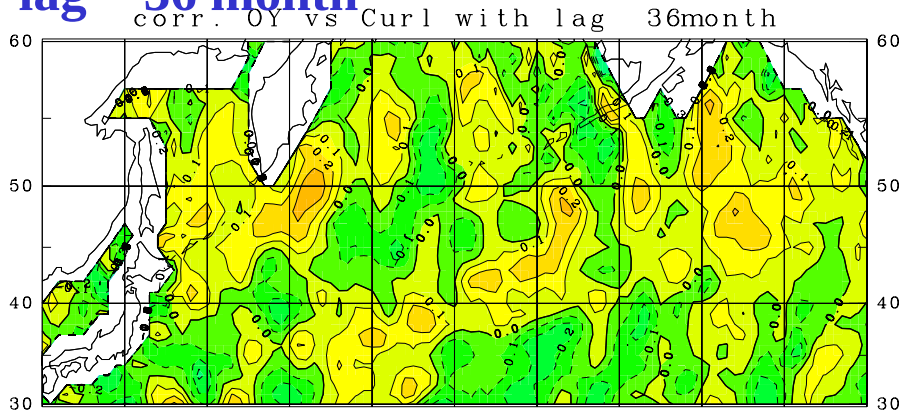
Correlation between Oyashio transport and curl τ/β (anomaly data)

Correlation decreased.

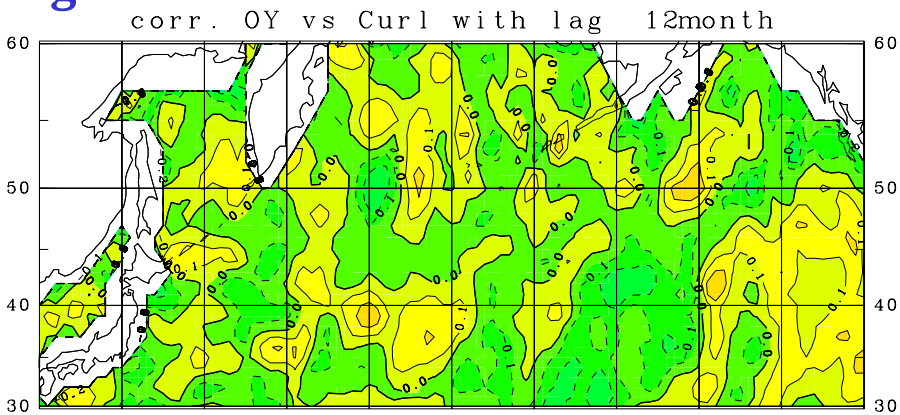
lag = 0 month



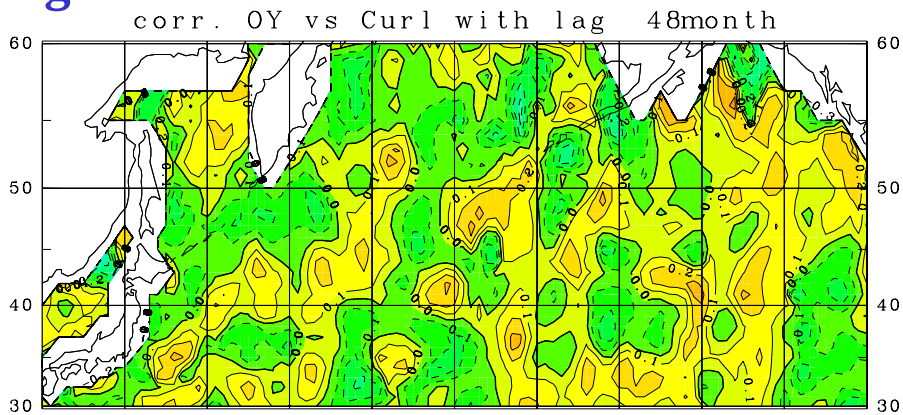
lag = 36 month



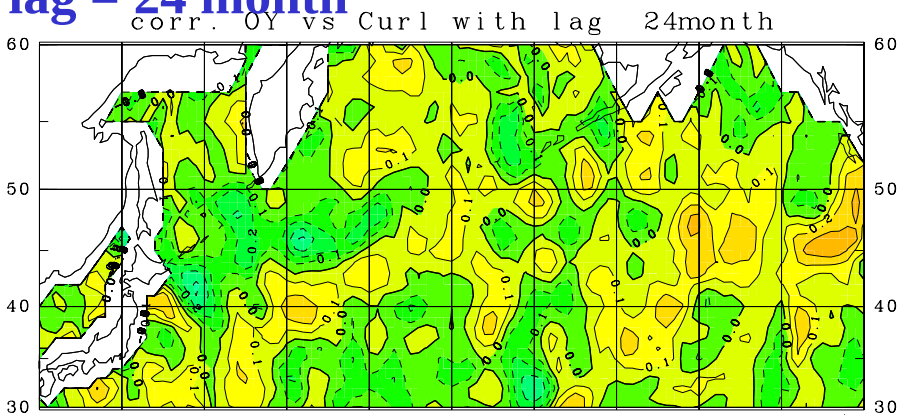
lag = 12 month



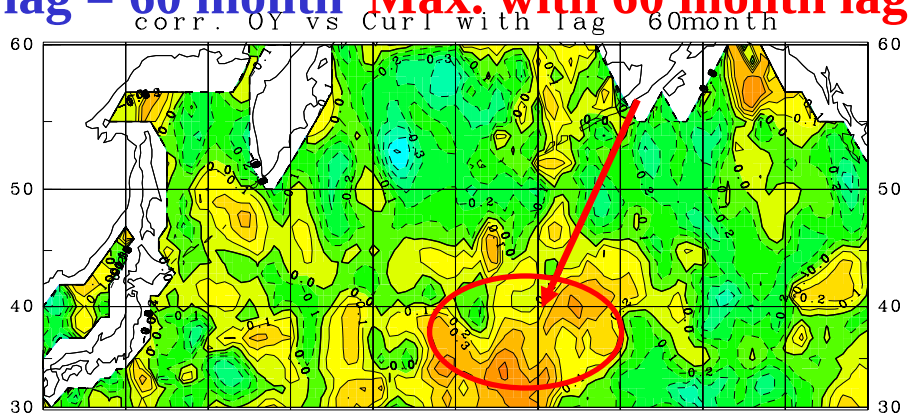
lag = 48 month



lag = 24 month



lag = 60 month **Max. with 60 month lag**



Conclusion

Oyashio transport

baroclinic response contributes to interannual time scale as same as the barotropic one (Ito et al. 2004)

Seasonal time scale

correlate with wind stress curl (max. with 2 year lag)

Interannual time scale

correlate with wind stress curl anomaly in subtropical with 5 years lag

Oyashio and Kuroshio

@synchronized with several month lag.

@especially during 1993.4.1-1999.5.31, R=0.84 with 140 days lag (Oyashio advanced)

@Sverdrup transport at both latitude do not show synchronicity in this time scale.

@The reason is still unclear (hint: Central Pacific???).