Correction of TOPEX/POSEIDON altimeter data for high frequency (2-20 days) barotropic motion in the East/Japan Sea

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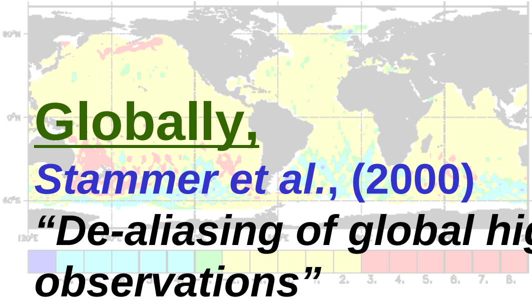
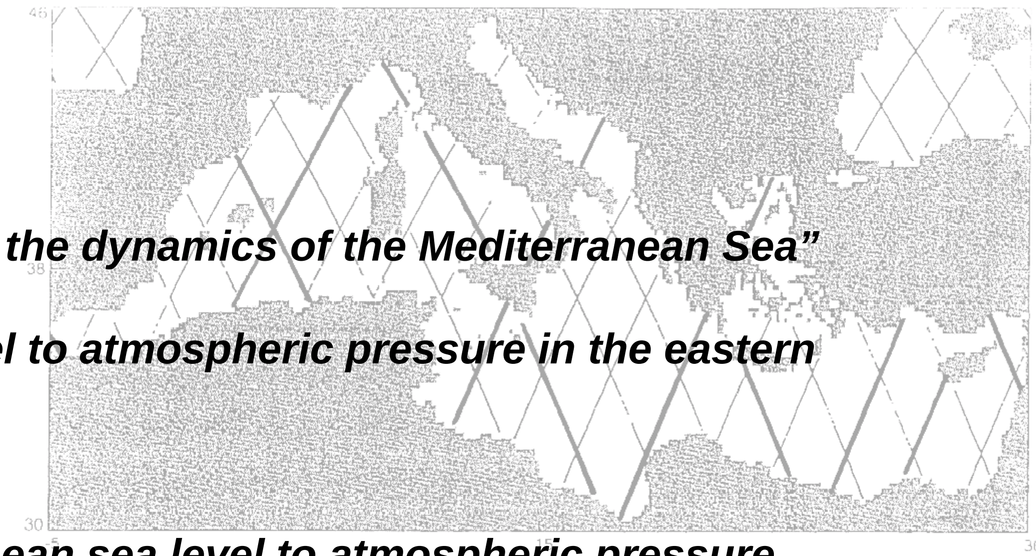
Introduction (Previous Studies)



Globally,

Stammer et al., (2000)

"De-aliasing of global high frequency barotropic motions in altimeter observations"



In a semi-enclosed sea,

Candela, J. (1991)

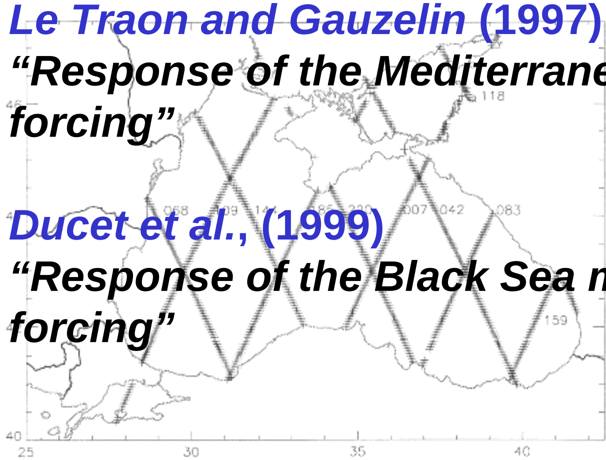
"The Gibraltar Strait and its role in the dynamics of the Mediterranean Sea"

Garrett and Majaess (1984)

"Nonisostatic response of sea level to atmospheric pressure in the eastern Mediterranean"

Le Traon and Gauzelin (1997)

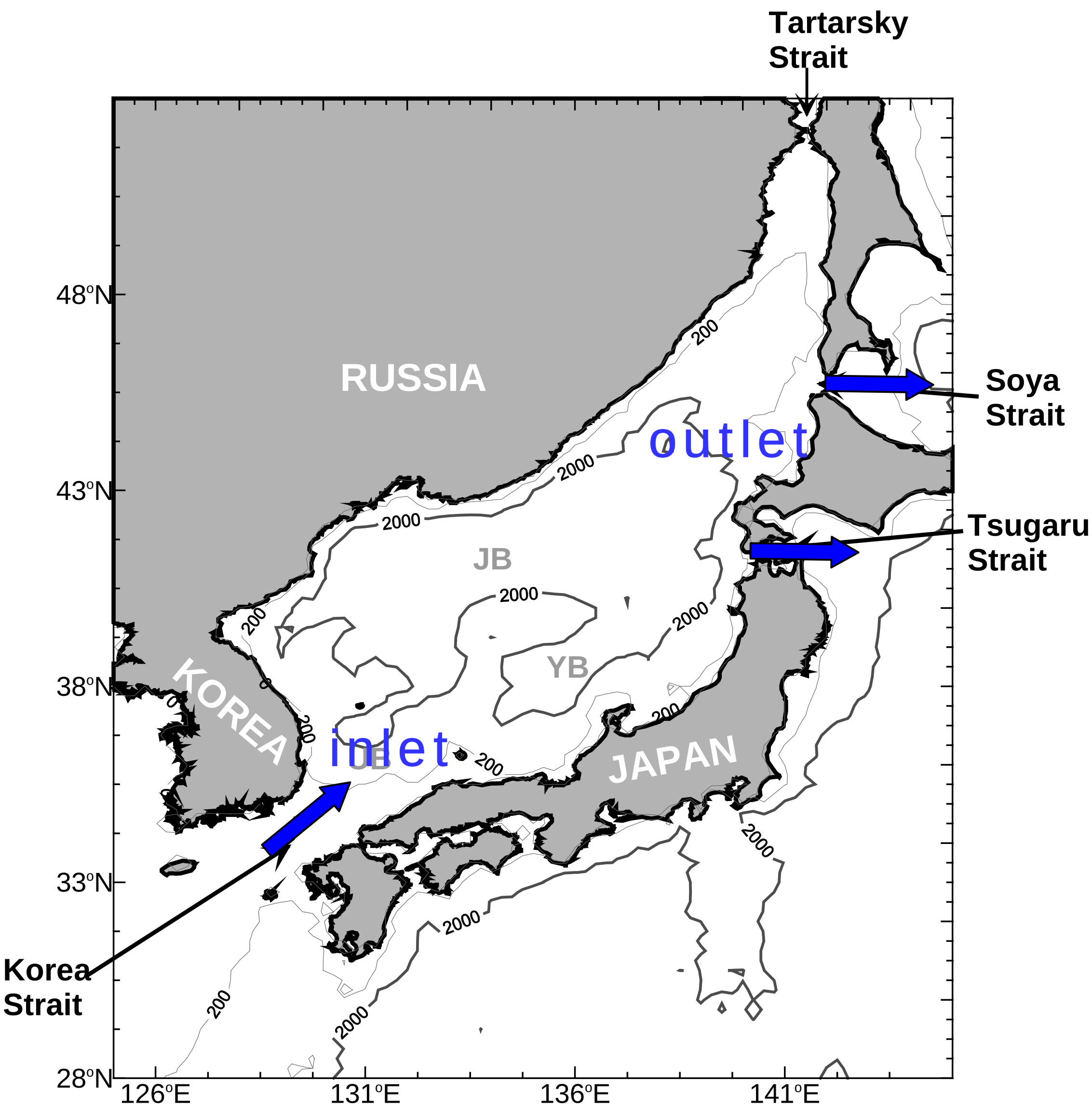
"Response of the Mediterranean mean sea level to atmospheric pressure forcing"



Ducet et al., (1999)

"Response of the Black Sea mean sea level to atmospheric pressure and wind forcing"

Introduction (East/Japan Sea)



***Lyu et al.* (2002)**
"Atmospheric pressure-forced subinertial variation in the transport through the Korea Strait"

***Park and Watts* (2003)**
"Response of Southwestern Japan/East Sea to atmospheric pressure"

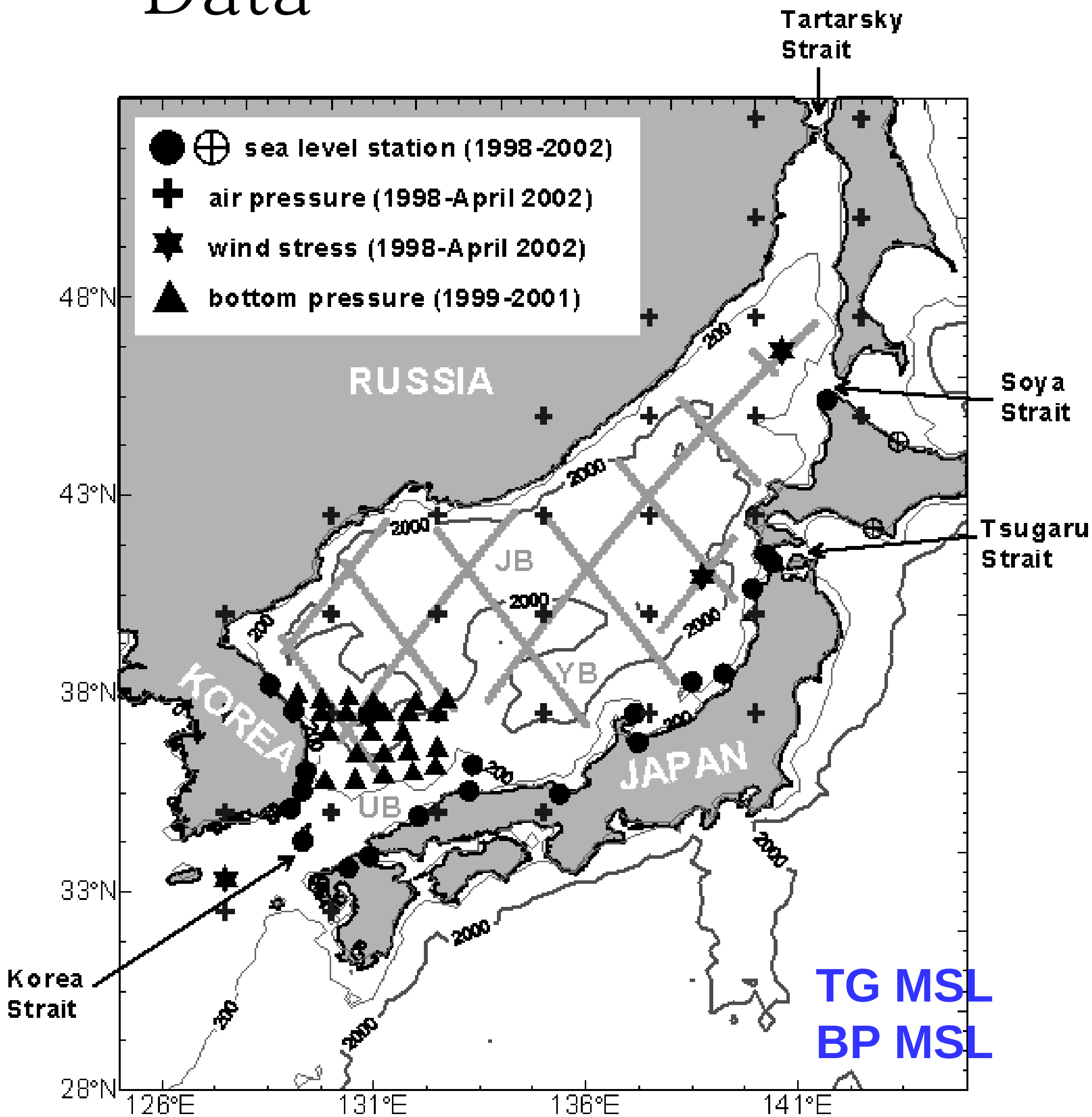
***Lyu* (2003)**
"Temporal variation of the transport from the cable voltage across the Korea Strait and its mechanism"

Objective

1. To understand high frequency MSL fluctuation effects on the T/P data in the East/Japan Sea

2. To provide an improved correction of the effects for the altimetry data with the Lyu model

Data



Tide gauge (TG)

Spatially averaged sea level measured at 24 sites around and outside the East/Japan Sea

T/P altimeter

JPL PO.DAAC (MGDR-B)
1998-2002 (cycle 180-375)
Deep (> 1000 m) region
11 tracks in a cycle
Standard correction [Le Traon and Gauzelin ,1997]
Ocean tides are eliminated using the aliased harmonics [Morimoto et al., 2000]

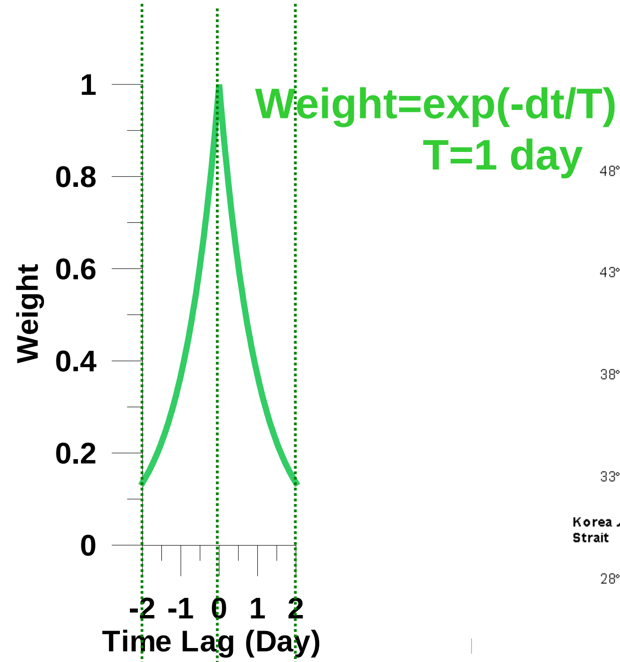
NCEP reanalyzed data

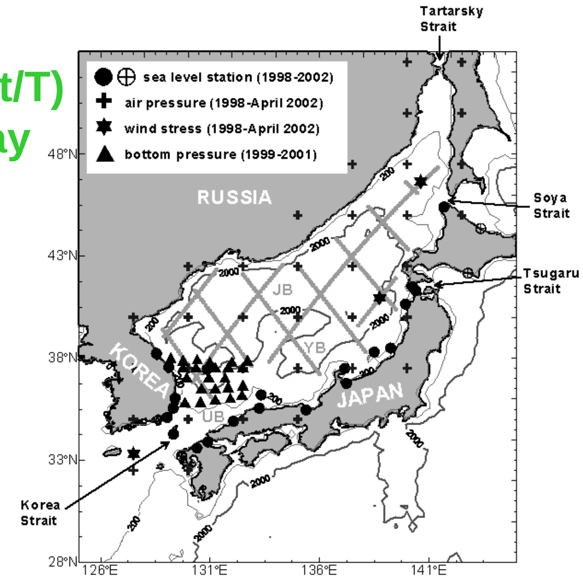
Spatially averaged air pressure
Wind stresses on the straits

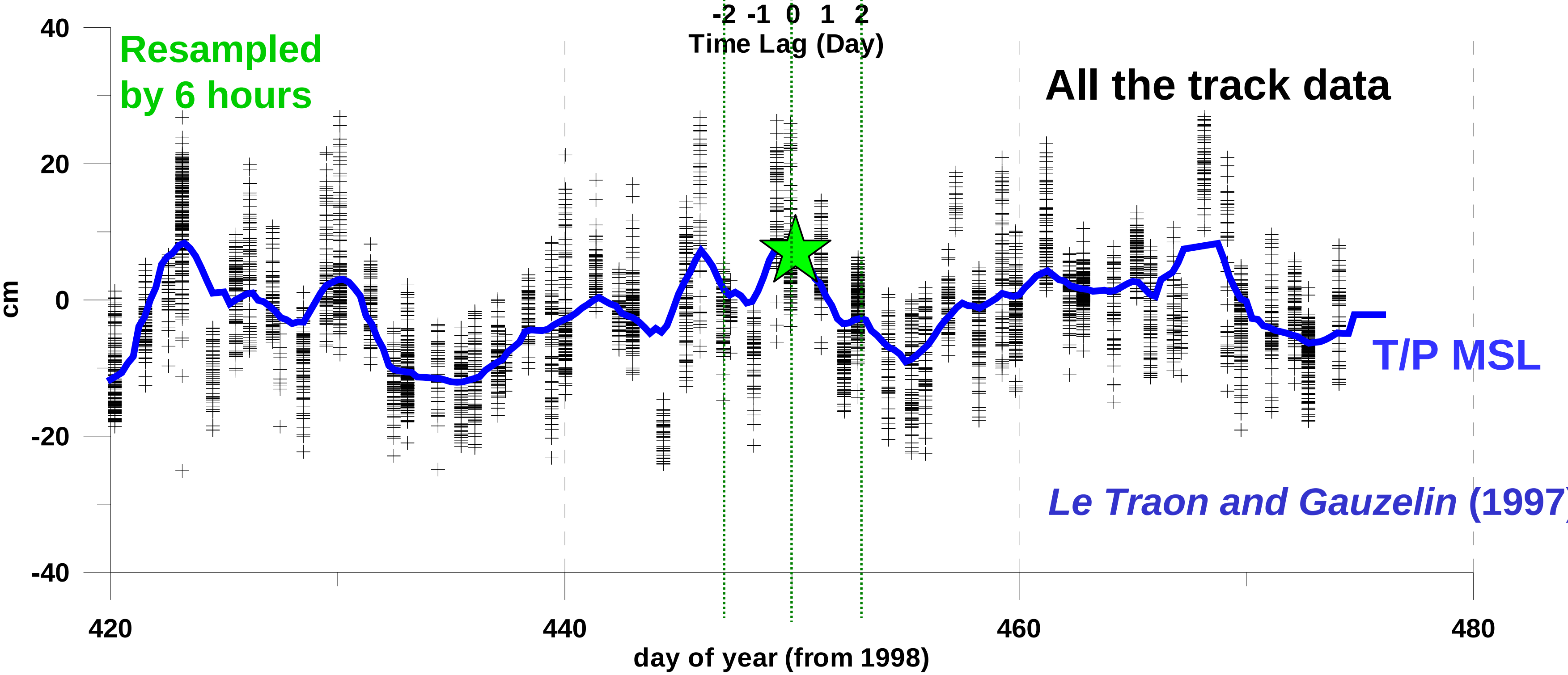
Bottom pressure (BP)

Spatially averaged bottom pressure measured at 23 sites in the Ulleung Basin

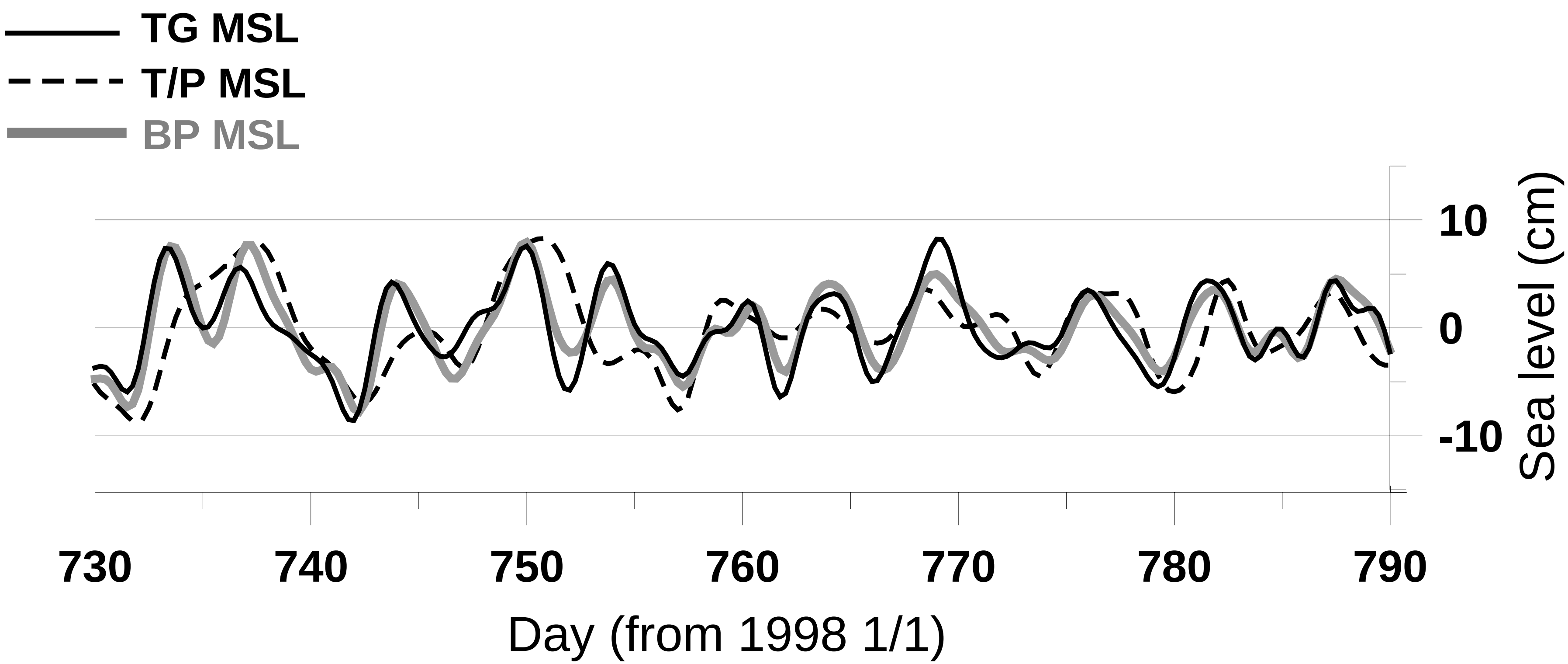
Data (T/P MSL)


Weight=exp(-dt/T)
T=1 day
Weight
1
0.8
0.6
0.4
0.2
0
-2 -1 0 1 2
Time Lag (Day)


Tartarsky Strait
sea level station (1998-2002)
air pressure (1998-April 2002)
wind stress (1998-April 2002)
bottom pressure (1999-2001)
RUSSIA
Soya Strait
Tsugaru Strait
JB
YB
UB
KOREA
JAPAN
Korea Strait
48°N
43°N
38°N
33°N
28°N
126°E
131°E
136°E
141°E

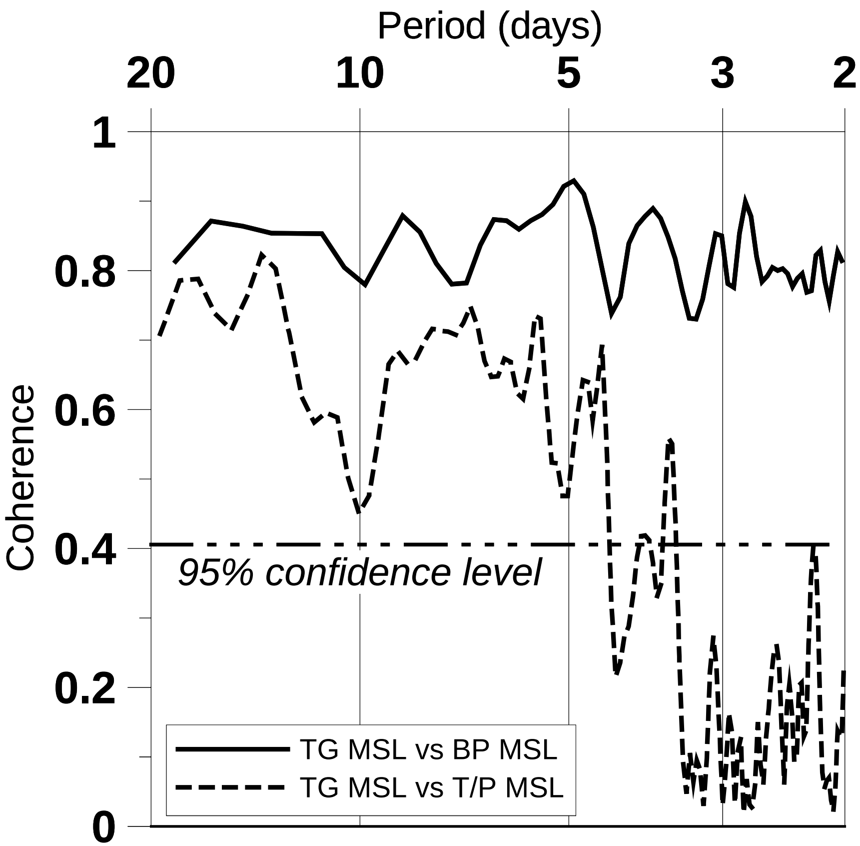

Resampled by 6 hours
All the track data
T/P MSL
Le Traon and Gauzelin (1997)
cm
40
20
0
-20
-40
420
440
460
480
day of year (from 1998)

Results (Time Series Analysis)

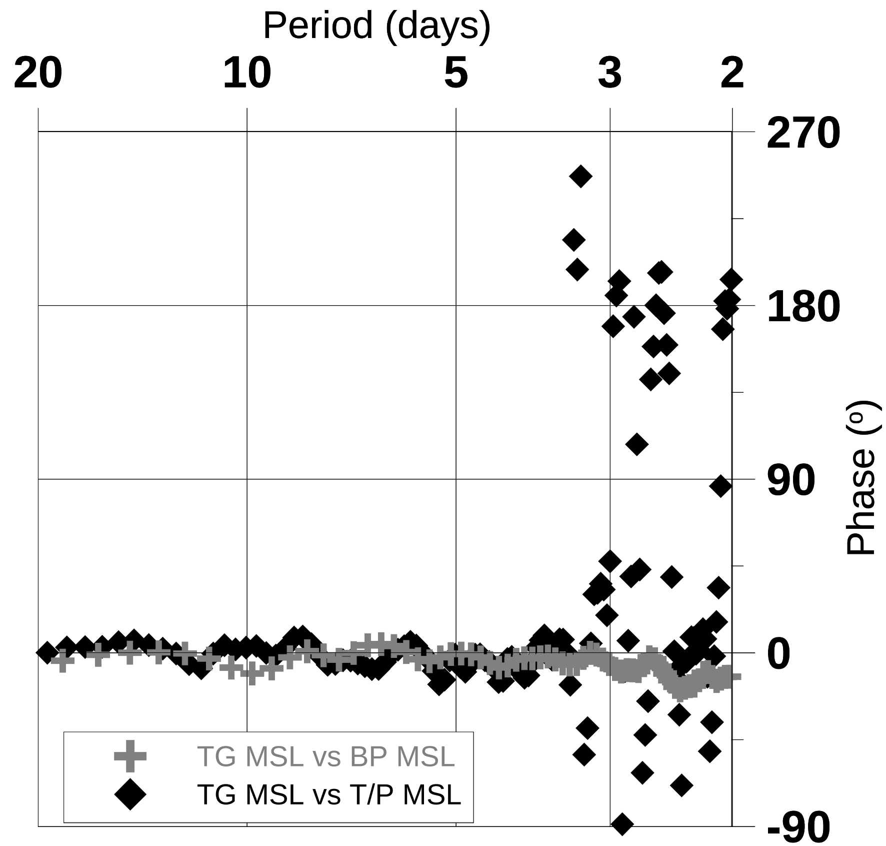


Results (Cross-spectrum Analysis)

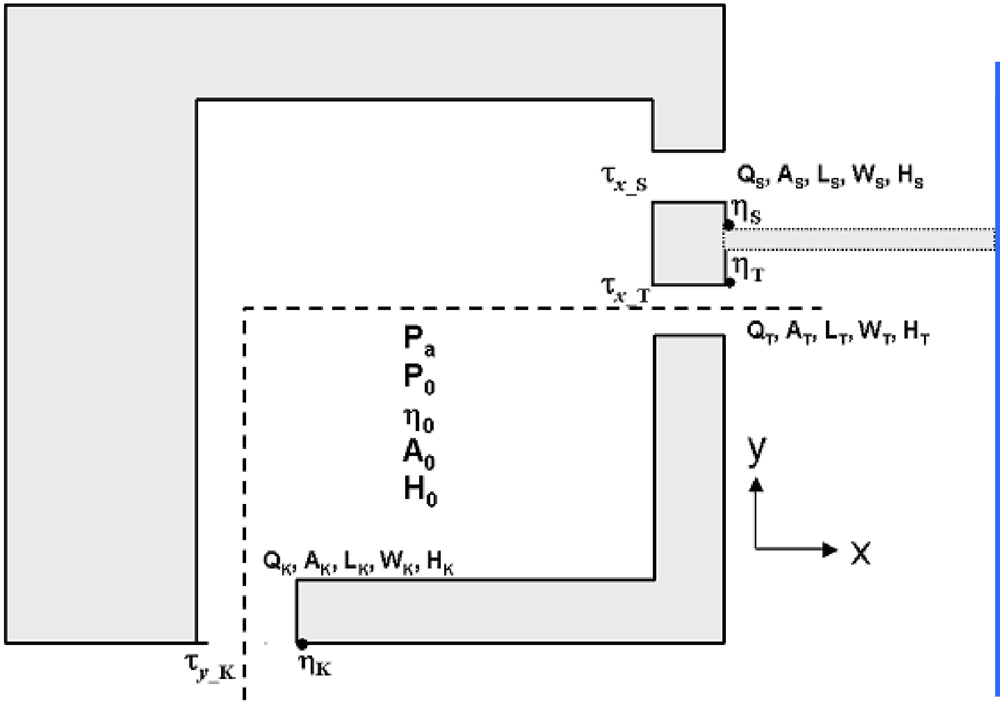
Coherence



Phase



Application of Lyu model (1)



Lyu model equations

$$\frac{\partial Q_{K,T,S}}{\partial t} = -\frac{A_{K,T,S}}{\rho}\left(\frac{\partial P}{\partial x}, \frac{\partial P}{\partial y}\right) + \frac{A_{K,T,S}}{\rho H_{K,T,S}}\tau_{K,T,S} - \lambda_{K,T,S} Q_{K,T,S}$$

$$A_0 \frac{\partial \eta_0}{\partial t} = Q_K - Q_T - Q_S,$$

$$P_0 = P_a + \rho g \eta_0$$

Lyu et al. **(2002)**
Lyu **(2003)**

Application of Lyu model (2)

Lyu model solutions

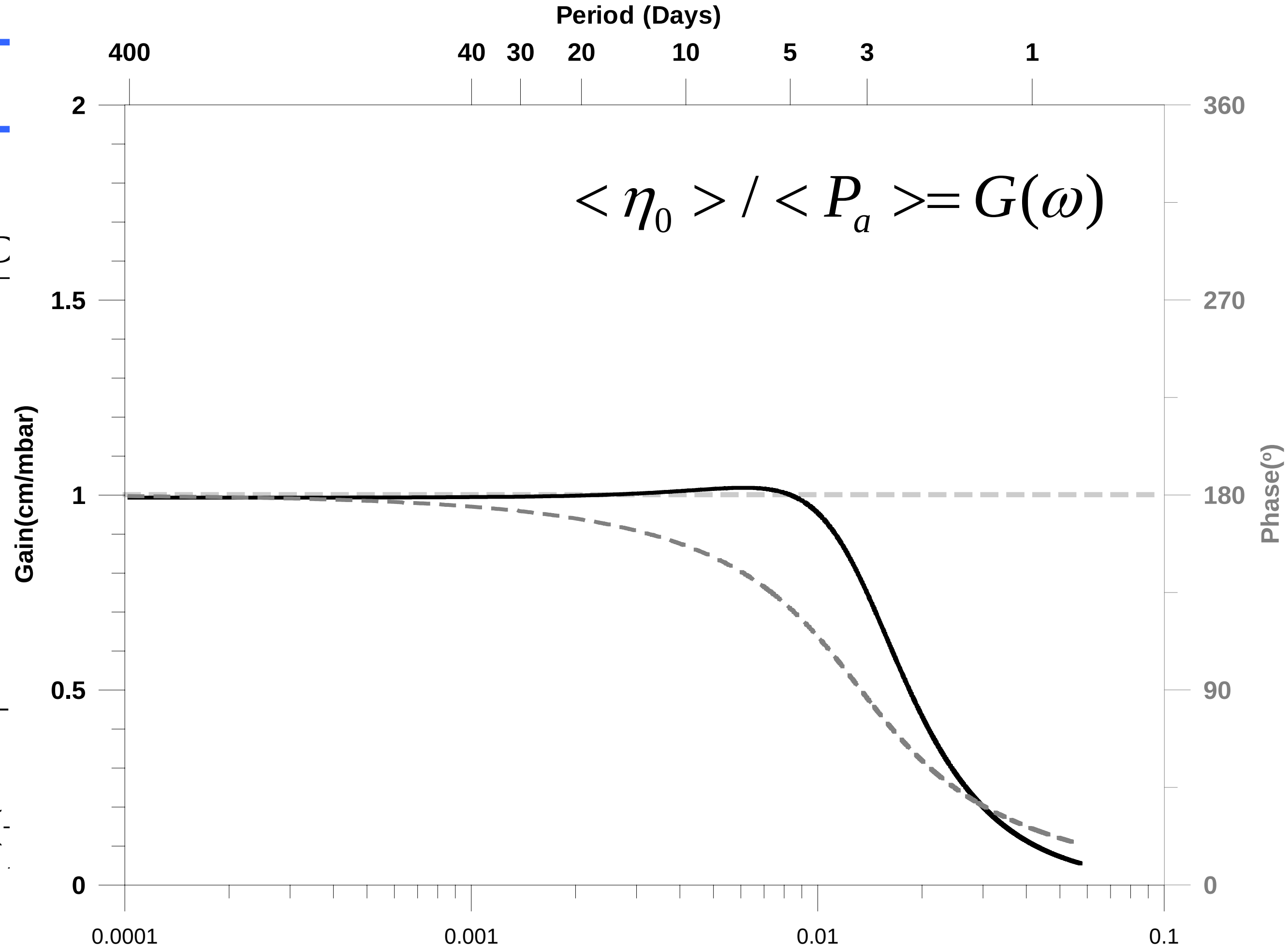
$$\eta_0 = \frac{[\{D_r(Q_{Ki} - Q_{Ti} - Q_{Si}) - D}{}$$

$$Q_{(K,T,S)} = Q_{(Kr,Tr,Sr)} + Q_{(Ki,Ti,Si)}$$

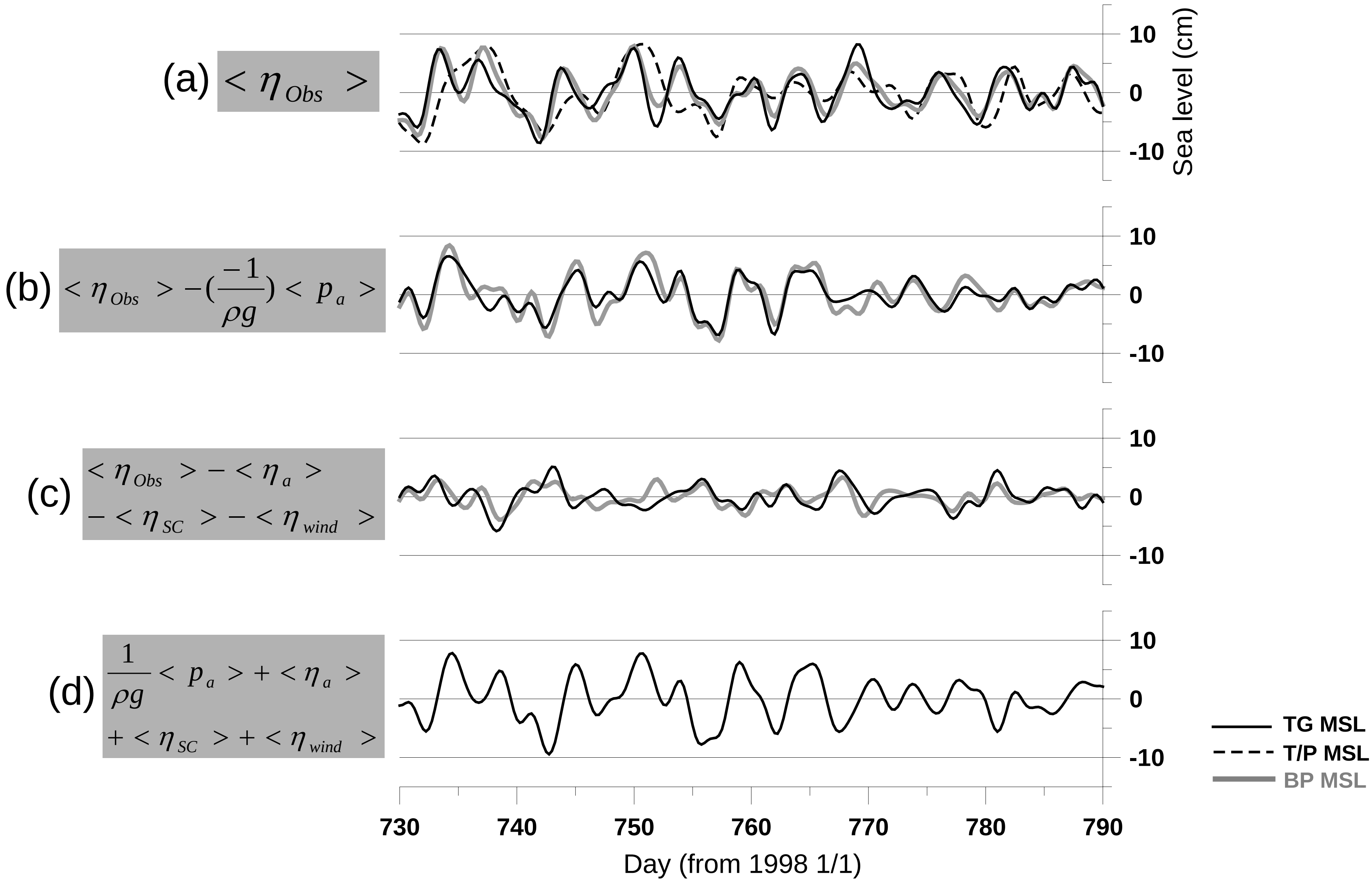
$$D = D_r + iD_i$$

$$= [-\omega^2\{\omega^4 - (\frac{gA_K}{AL_K} + \frac{gA_T}{AL_T} +$$

$$+ i[\omega^3\{(\lambda_K + \lambda_T + \lambda_S)\omega^2 - ($$

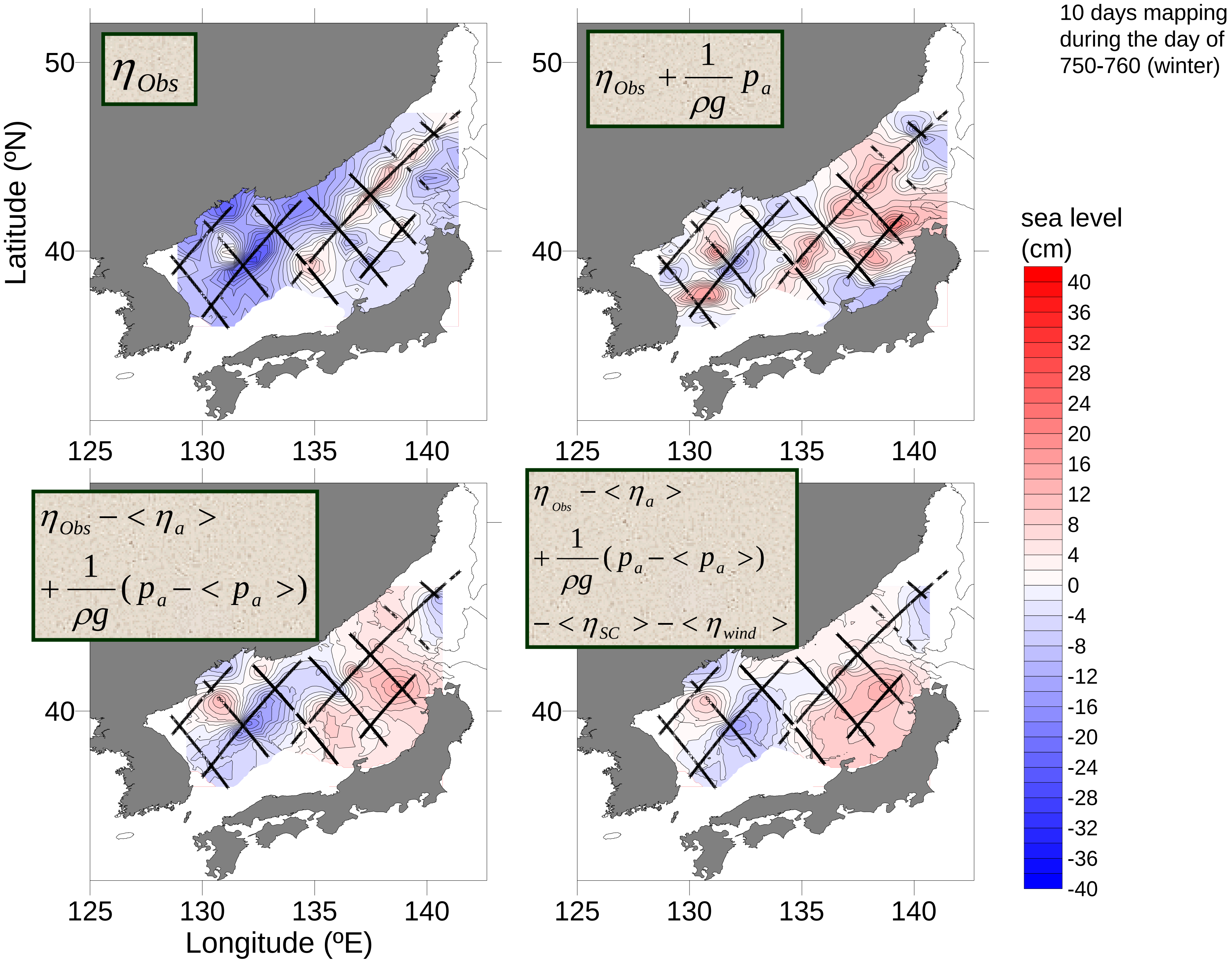


Lyu model Impact (Time Series)



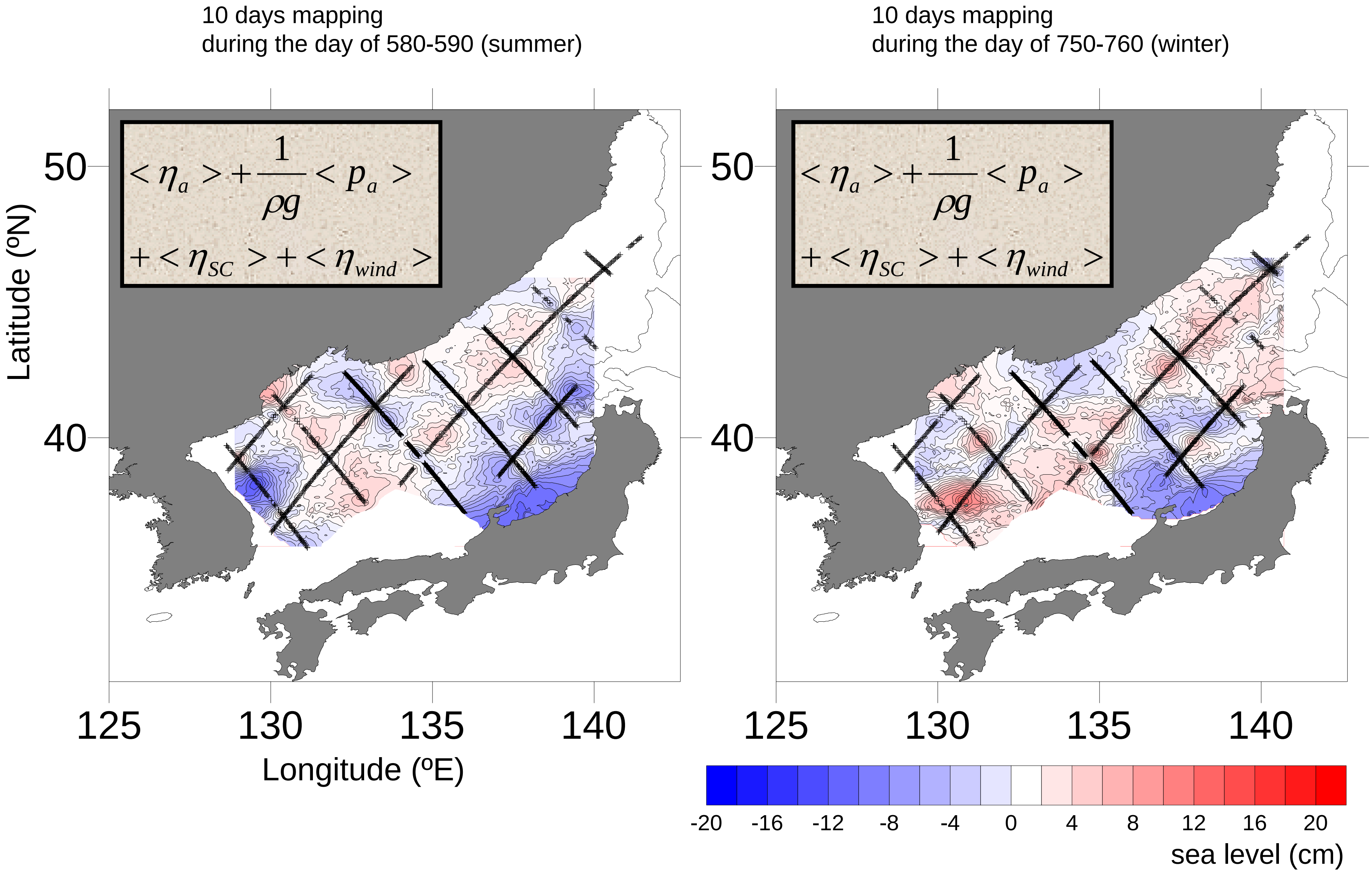
Lyu model Impact (Table)

	Variance (cm^2) TG MSL	Variance (cm^2) BP MSL
1. $< \eta_{Obs} >$	19.0	21.2
2. $< \eta_a >$	13.2	
3. $(-1/\rho g) < p_a >$	14.2	
4. $< \eta_a >$ - $(-1/\rho g) < p_a >$	7.7	
5. $< \eta_{Obs} >$ - $(-1/\rho g) < p_a >$	11.1	11.0
6. $< \eta_{Obs} >$ - $< \eta_a >$	9.2	9.6
7. $< \eta_{Obs} >$ - $< \eta_a >$ - $< \eta_{SC} >$	6.7	4.9
8. $< \eta_{Obs} >$ - $< \eta_a >$ - $< \eta_{SC} >$ - $< \eta_{wind} >$	5.7	3.9
9. $< \eta_a >$ + $< \eta_{SC} >$ + $< \eta_{wind} >$ - $(-1/\rho g) < p_a >$	12.3	



10 days mapping
during the day of
750-760 (winter)
η_{Obs}
$\eta_{Obs} + \frac{1}{\rho g} p_a$
$\eta_{Obs} - <\eta_a> + \frac{1}{\rho g}(p_a - <p_a>)$
$\eta_{Obs} - <\eta_a> + \frac{1}{\rho g}(p_a - <p_a>) - <\eta_{SC}> - <\eta_{wind}>$
Latitude (ºN)
Longitude (ºE)
50
40
125
130
135
140
sea level
(cm)
40
36
32
28
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
-28
-32
-36
-40

10 Day Contour Map (Difference)



Conclusion

- The Lyu (analytic) model
➔ significantly improved correction of high-frequency (2-20 days) sea level fluctuation effects on satellite altimeter data, compared to the standard IB correction

- Rms difference of 3-4 cm between the model and IB corrections with maximum difference of up to 10 cm
➔ the impact on the two-dimensional mapping of SSH is substantial

- Most (70-80%) of the high frequency variances in the TG MSL and BP MSL
➔ explained by the Lyu model

- Trackiness in the 10 day T/P maps of SSH with no correction or only with IB correction
➔ significantly improved with the model correction

Thank You !

Discussion

- Not used T/P MSL in the East Sea

- TG data limitation in representing East Sea MSL (coastal effects or errors due to unevenly distributed TG stations)

- BP MSL measured only in the Ulleung Basin, not the entire East Sea (comparison between Ulleung Basin mean bottom pressure and East Sea mean bottom pressure)

- Lyu model limitation

- Some cycles for which the model correction does no better than the IB correction in reducing the high frequency fluctuations

- Tidal errors

Future Studies

<u>Numerical model</u>

➔ complex bathymetry of the straits and the three (Japan, Yamato, and Ulleung) basins in the East Sea
➔ baroclinic part of the fluctuations
➔ variations of the internal structures inside the East Sea
➔ roles of external forcings from the East China Sea, Yellow Sea, Okhotsk Sea, and Northeastern Pacific.

<u>Merging multiple-satellite altimeter mission</u>
(T/P+ERS+ENVISAT+Jason-1)

➔ significant improvement for spatial mapping. ***[Le Traon and Gauzelin, 2000]***

Formulation (Sea level decomposition)

Subsurface pressure

$$p = \rho g \eta_{Obs} + p_a = \rho g \eta_{Obs} + < p_a > + (p_a - < p_a >)$$
$$= \rho g \eta'$$

Adjusted sea level

$$\eta' = \{\eta_{Obs} + \frac{1}{\rho g} < p_a > + \frac{1}{\rho g}(p_a - < p_a >)\}$$
$$= \{< \eta_a > + \frac{1}{\rho g} < p_a >\} + < \eta_{SC} > + < \eta_{wind} > + \eta_{residual}$$

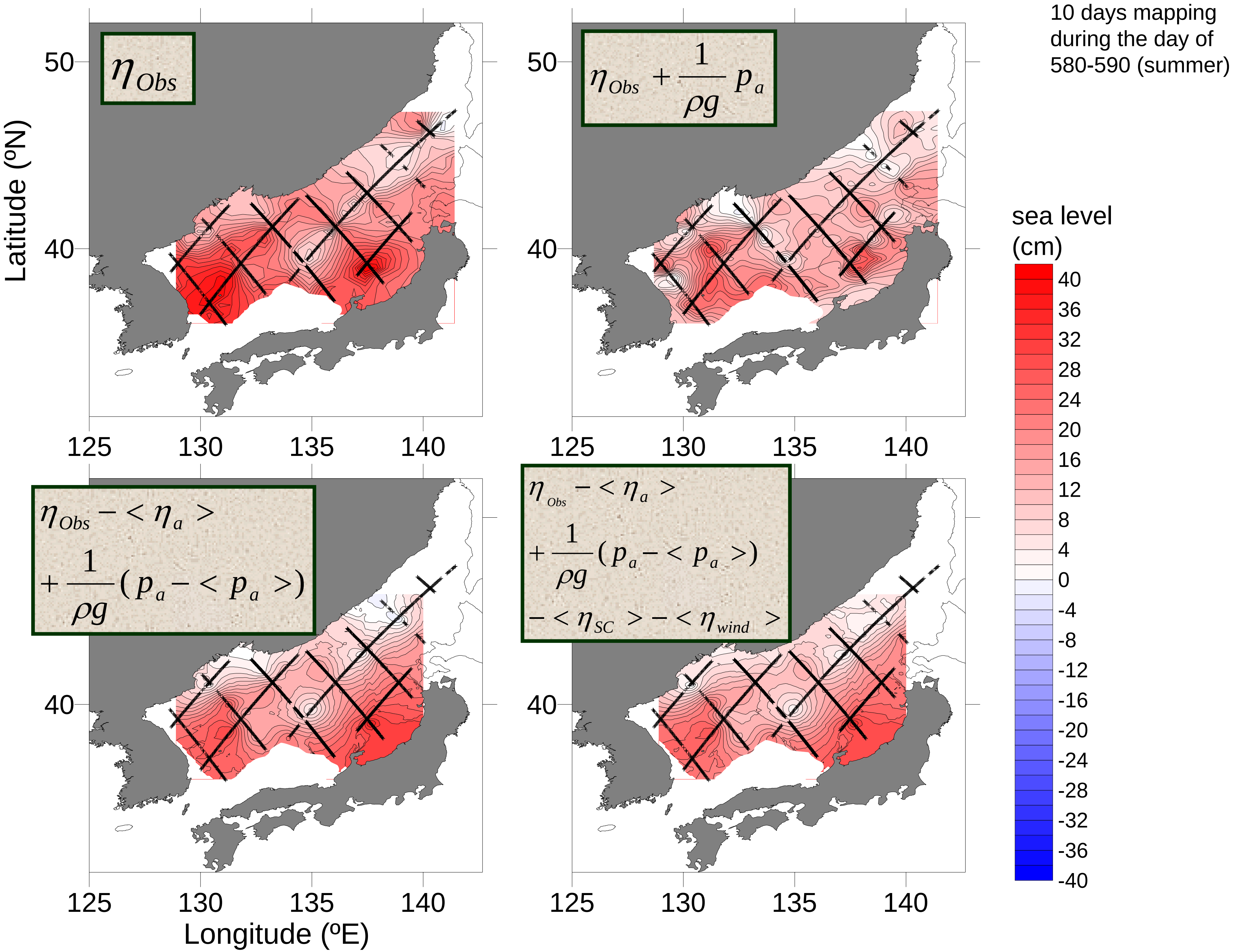
Observed sea level

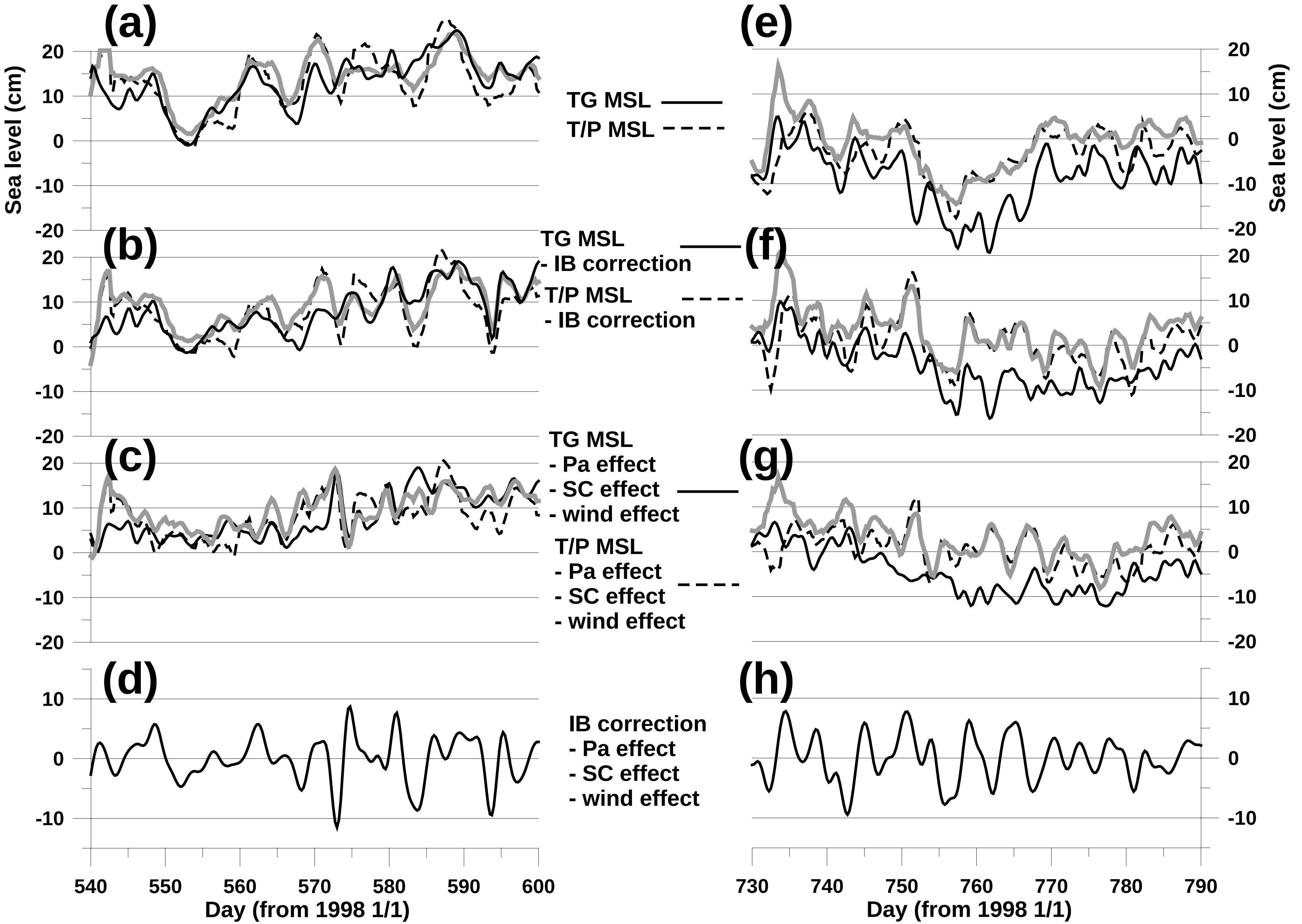
$$\eta_{Obs} = < \eta_a > - \frac{1}{\rho g}(p_a - < p_a >) + < \eta_{SC} > + < \eta_{wind} > + \eta_{residual}$$

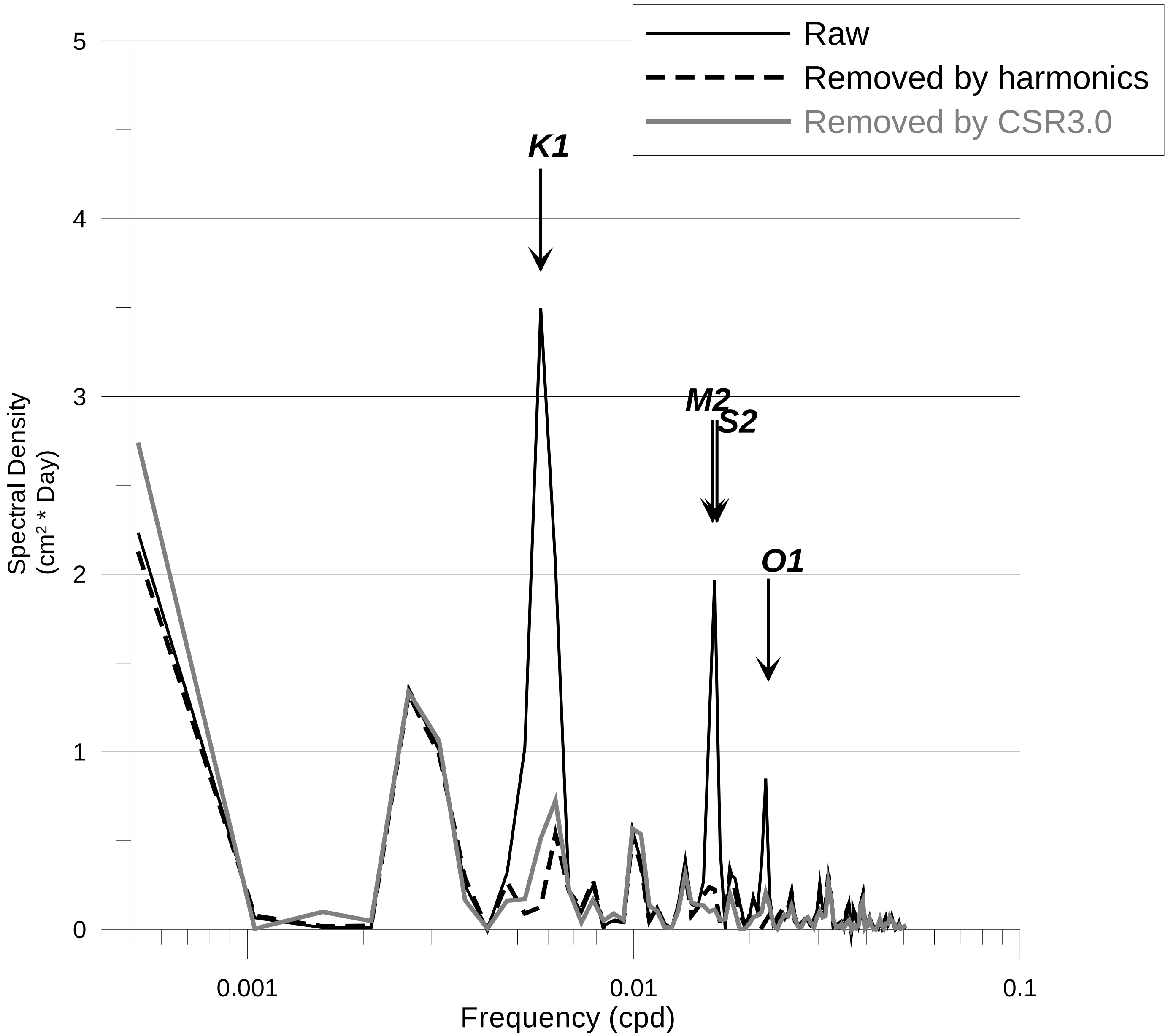
Model output

Observed MSL

$$< \eta_{Obs} > = < \eta_a > + < \eta_{SC} > + < \eta_{wind} > + < \eta_{residual} >$$


10 days mapping during the day of 580-590 (summer)
η_{Obs}
$\eta_{Obs} + \frac{1}{\rho g} p_a$
$\eta_{Obs} - <\eta_a> + \frac{1}{\rho g}(p_a - <p_a>)$
$\eta_{Obs} - <\eta_a> + \frac{1}{\rho g}(p_a - <p_a>) - <\eta_{SC}> - <\eta_{wind}>$
Latitude (ºN)
Longitude (ºE)
50
40
125
130
135
140
sea level (cm)
40
36
32
28
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
-28
-32
-36
-40


(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
Sea level (cm)
TG MSL
T/P MSL
TG MSL
- IB correction
T/P MSL
- IB correction
TG MSL
- Pa effect
- SC effect
- wind effect
T/P MSL
- Pa effect
- SC effect
- wind effect
IB correction
- Pa effect
- SC effect
- wind effect
Day (from 1998 1/1)
Day (from 1998 1/1)


Raw
Removed by harmonics
Removed by CSR3.0
K1
M2
S2
O1
Spectral Density
(cm² * Day)
5
4
3
2
1
0
0.001
0.01
0.1
Frequency (cpd)