Estimation of Wind Drift Current in the Soya Strait

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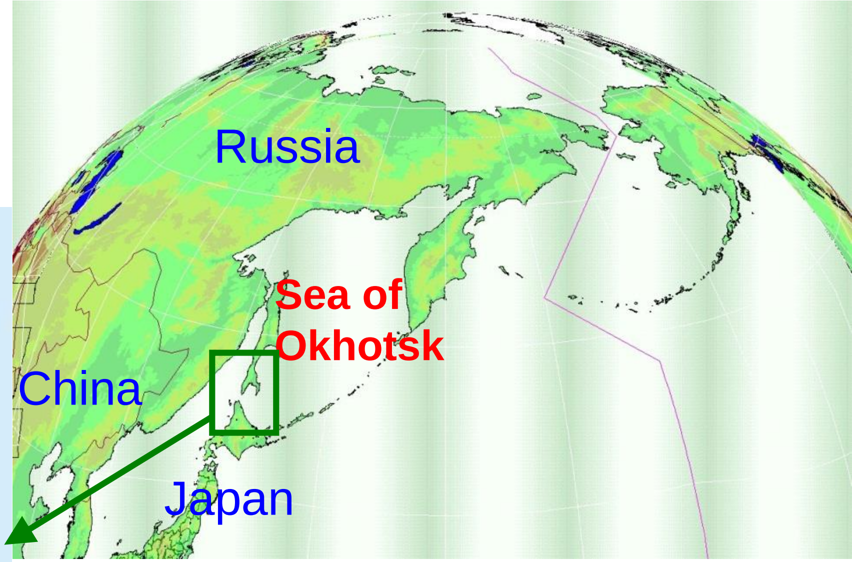
The Soya Strait

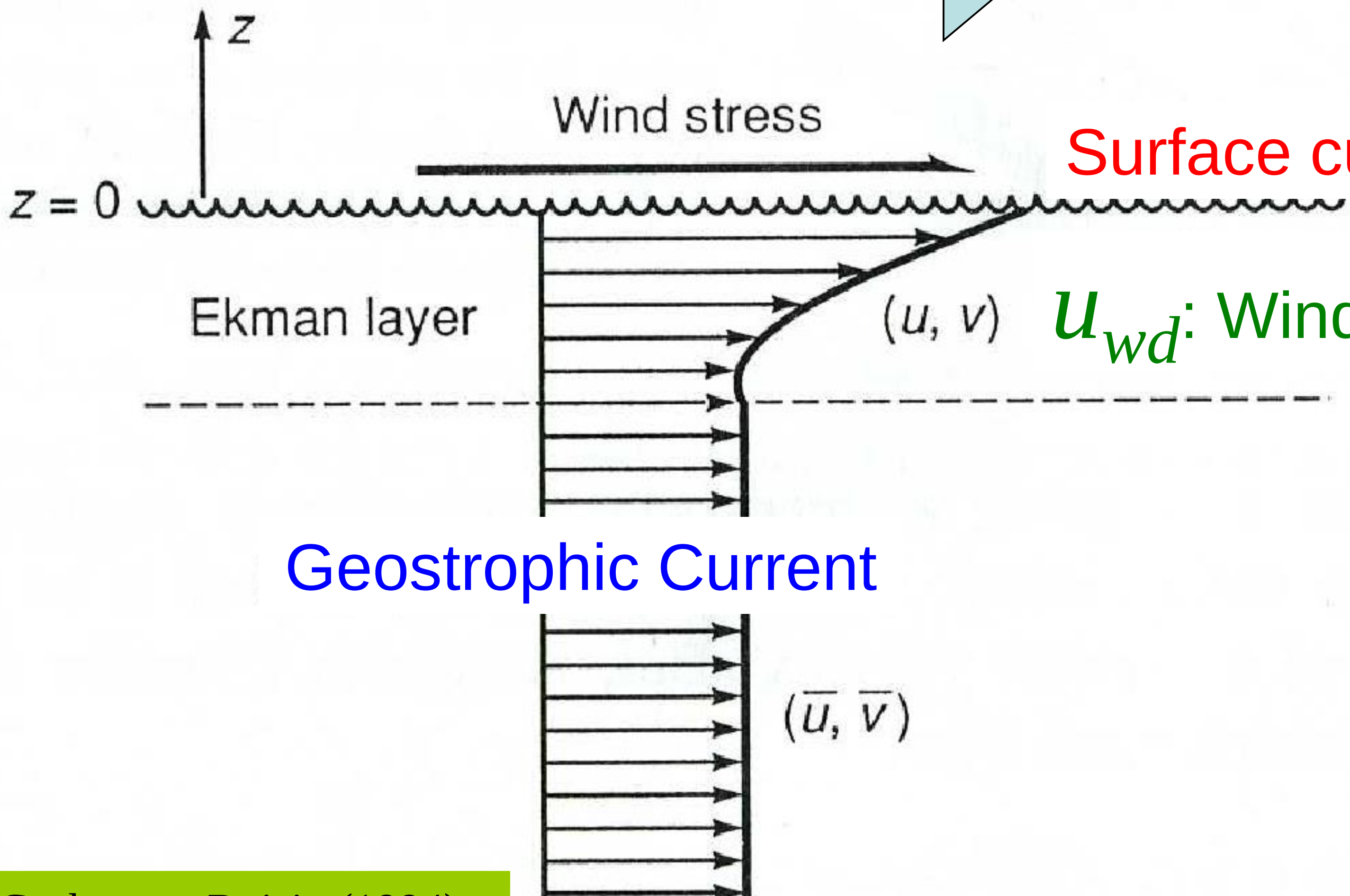


- Connection of Sea of Japan Sea and Sea of Okhotsk
- Soya warm current
- Fishery

Wind Drift Current

Wind

$$\boldsymbol{u}_s = \boldsymbol{u}_g + \boldsymbol{u}_{wd}$$



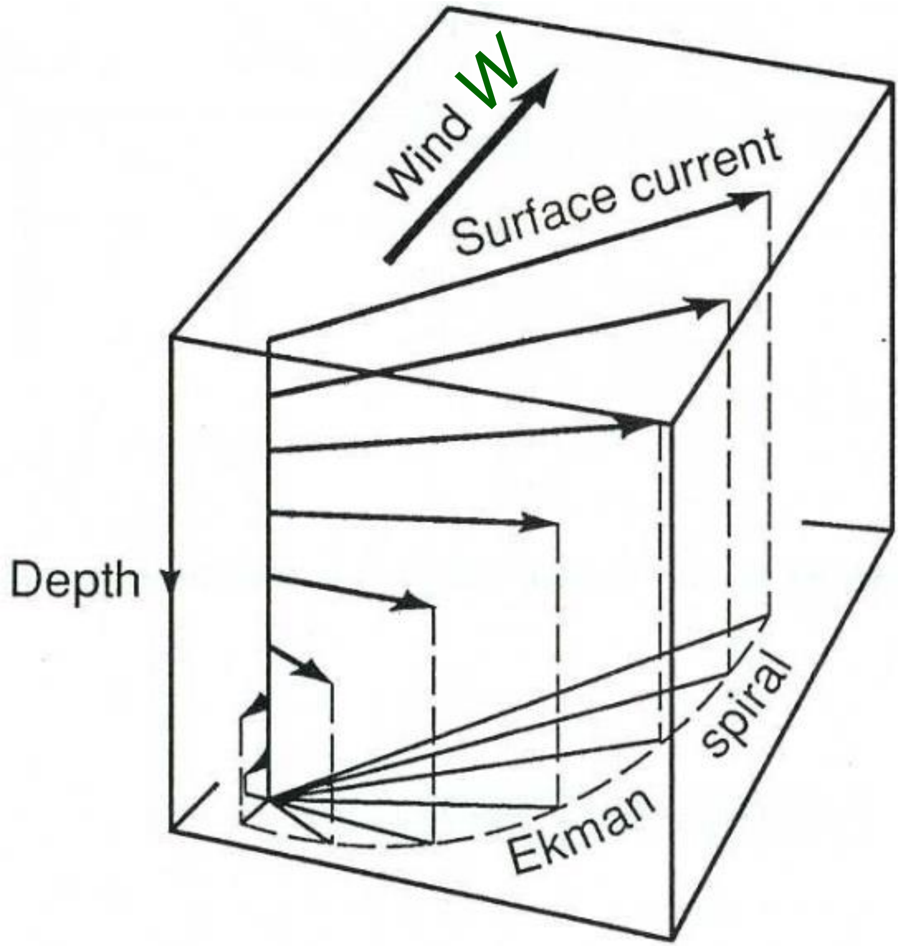
Surface current

$\boldsymbol{u}_{wd}$: Wind Drift Current

Geostrophic Current

Cushuman-Roisin (1994)

Drift Parameter



$$\boldsymbol{u}_{wd} = \boldsymbol{u}_s - \boldsymbol{u}_g$$
$$= \boldsymbol{A}(\alpha, \theta)\boldsymbol{W}$$

$$A(\alpha,\theta) = \alpha \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$$

α: speed factor

θ: deflection angle

W: wind vector

$\boldsymbol{u}_s$: surface current

$\boldsymbol{u}_g$: geostrophic current

Cushuman-Roisin (1994)

How to calculate wind drift parameter

LSM

$$\min_{(\alpha,\theta)}[(\boldsymbol{u}_s - \boldsymbol{u}_g) - \boldsymbol{A}(\alpha,\theta)\boldsymbol{W}]$$

***Complex PCA/EOF**

$$(\alpha,\theta) \Leftarrow \begin{bmatrix} \boldsymbol{W}_{1st} \\ \boldsymbol{u}_{wd1st} \end{bmatrix} = CEOF\left(\begin{bmatrix} \boldsymbol{W} \\ \boldsymbol{u}_s - \boldsymbol{u}_g \end{bmatrix}\right)$$

- Surface current (HF radar data)
- Geostrophic current
  (ADCP data / Tide gauges data)
- Wind (JMA GPV/MSM)

* Kundu and Allen (1976)

CEOF Brief Introduction

$$W(U,V) = U + Vi$$

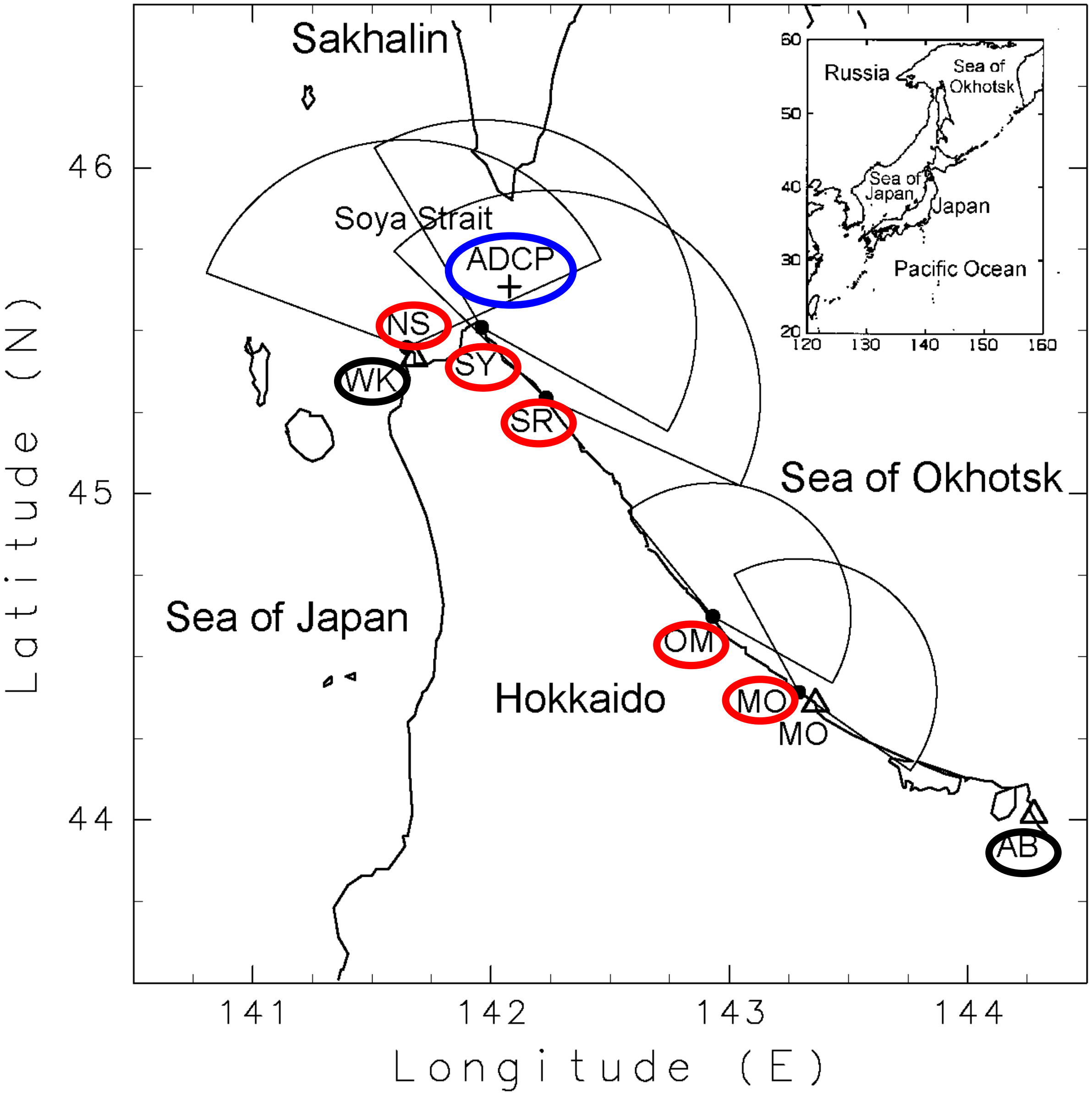
$$CEOF(W) = EOF(U + Vi)$$

$$\Downarrow$$

$$(U_{1st} + V_{1st} i)$$

Kundu and Allen (1976)

Observation



Long Term:

- HF Radars
- Tide Gauges
- Wind

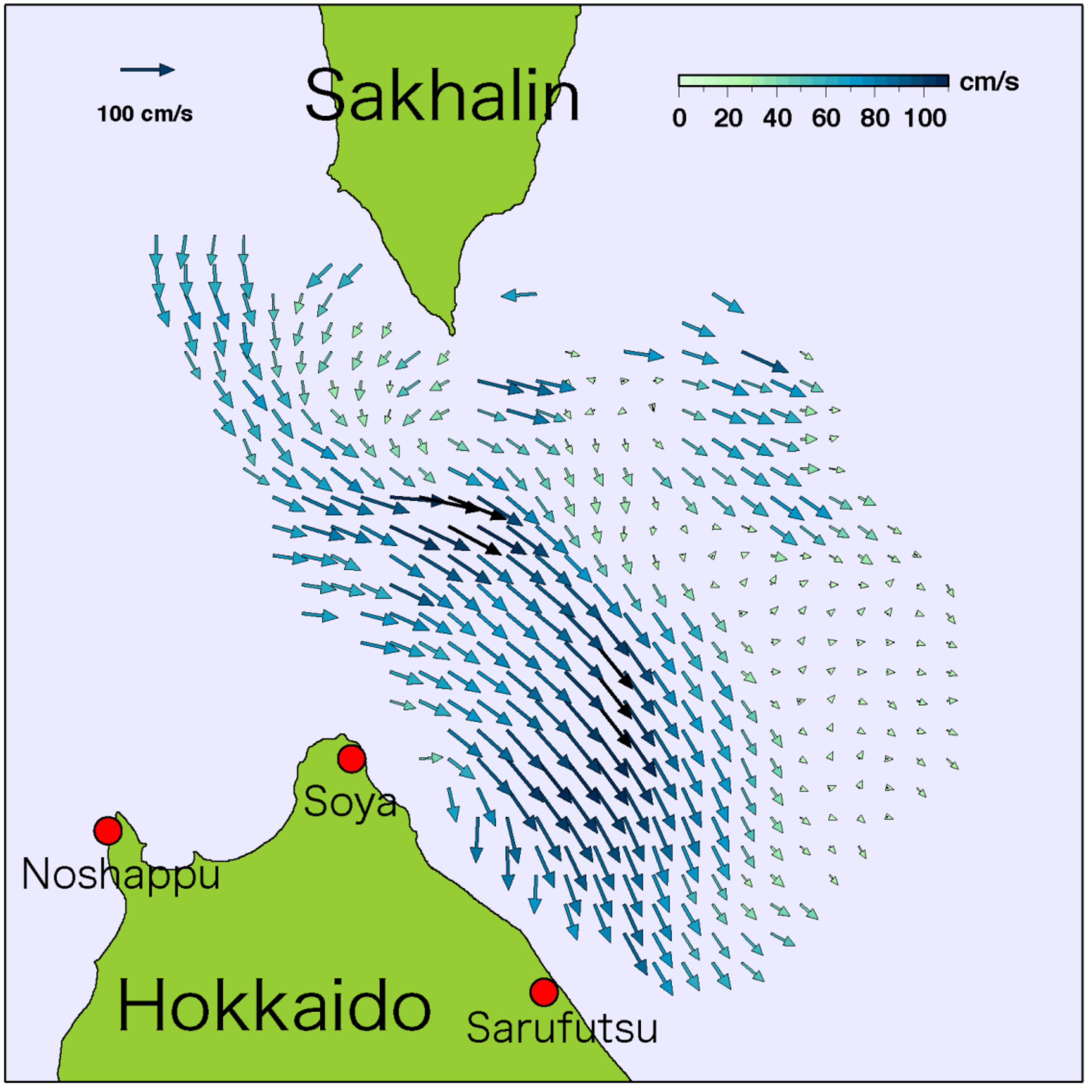
  (JMA GPV/MSM)

Short Term: (22 months)

- ADCP

  (Bottom mounted)

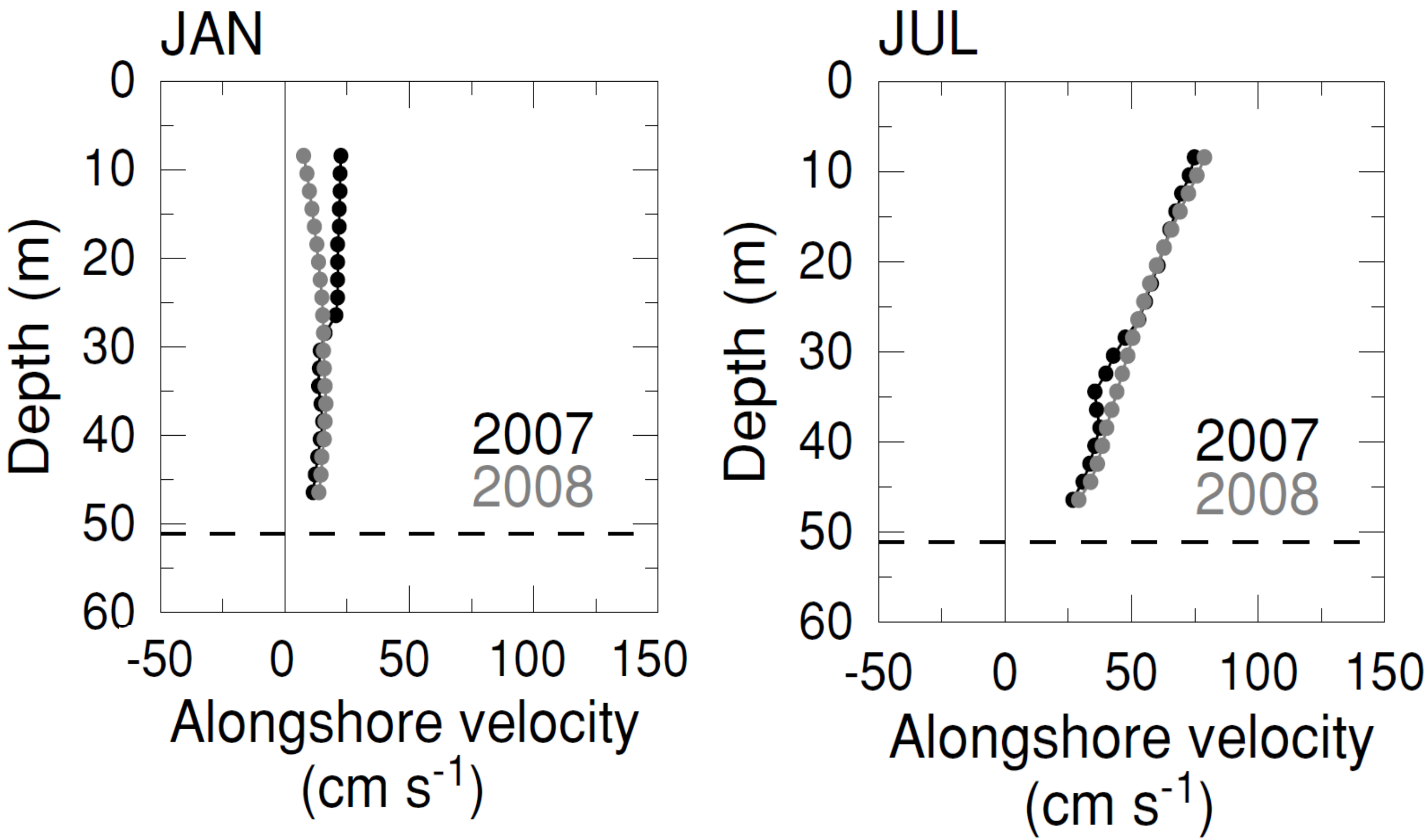
Example of HF Radar Snapshot



17h20m (JST)
3 Aug 2003

http://wwwoc.lowtem.hokudai.ac.jp/hf-radar/index.html

Example of ADCP vertical profiles



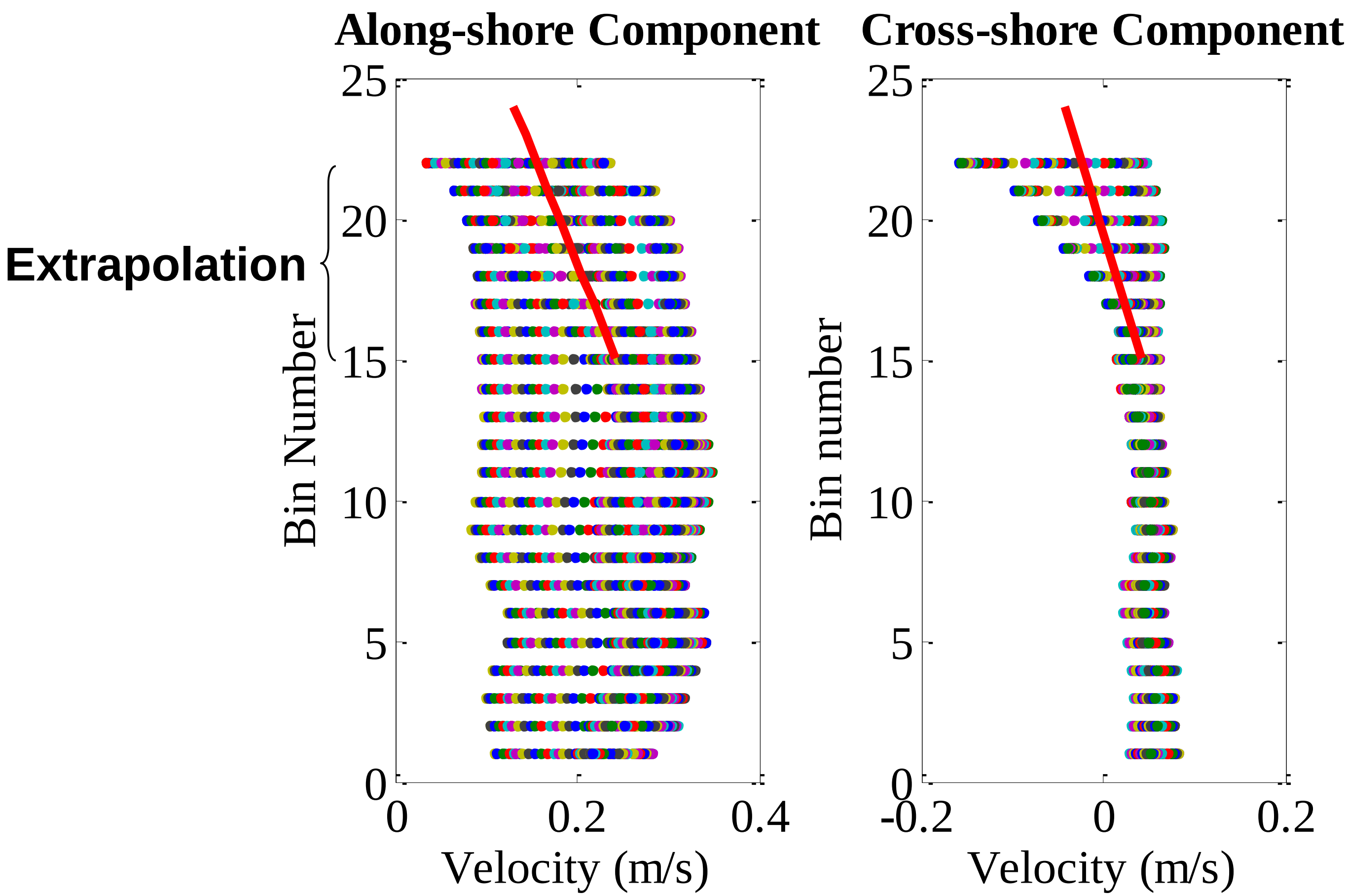
Monthly-mean of alongshore velocity observed by ADCP.

Fukamachi *et al.*(2010)

Geostrophic Current Estimation (Method 1)

LSM 1

Complex PCA/EOF

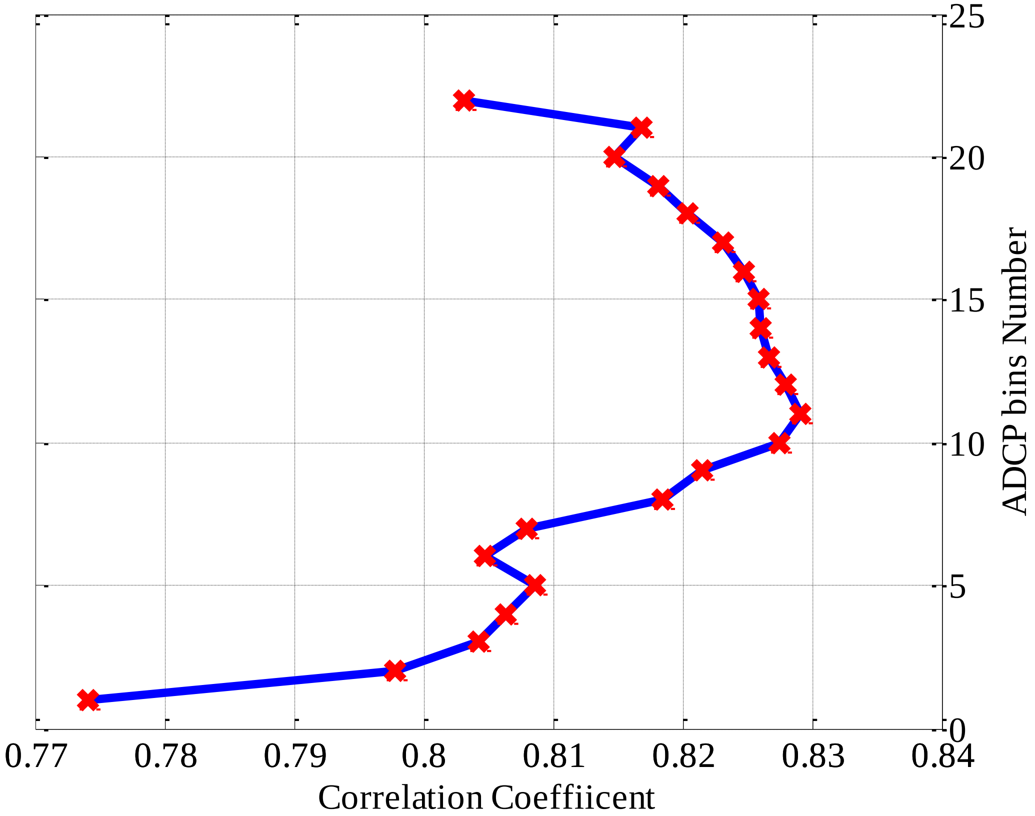


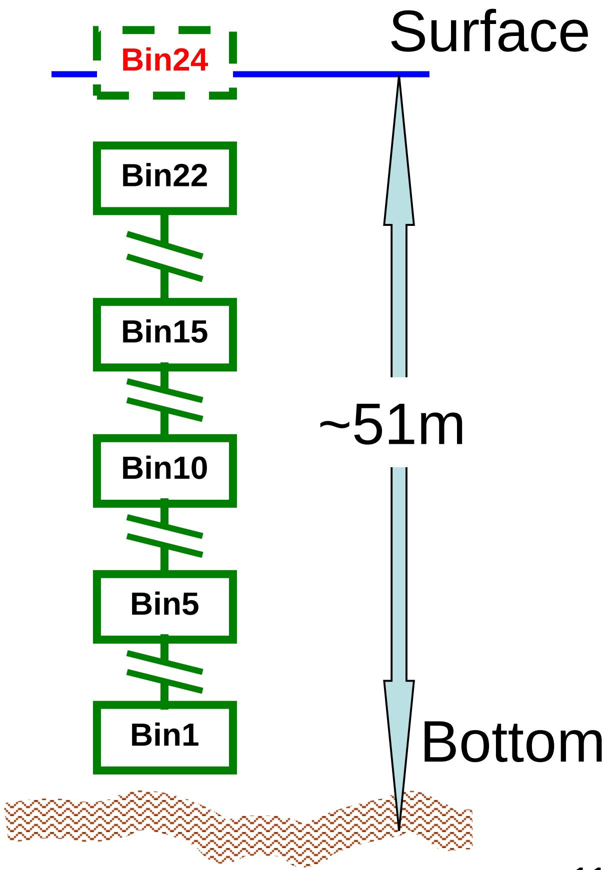
Dec. 23 2007 ~ Dec. 27 2007

5-day geostrophic current estimation from ADCP

Sea Level Difference vs. Along-shore Current

Correlation Coefficient between Sea Level Difference (SLD) and alongshore velocities of ADCP bins.





Alongshore velocities correspond well with sea level difference.

Geostrophic Current Estimation (Method 2)

LSM 2

~~**Complex PCA/EOF**~~

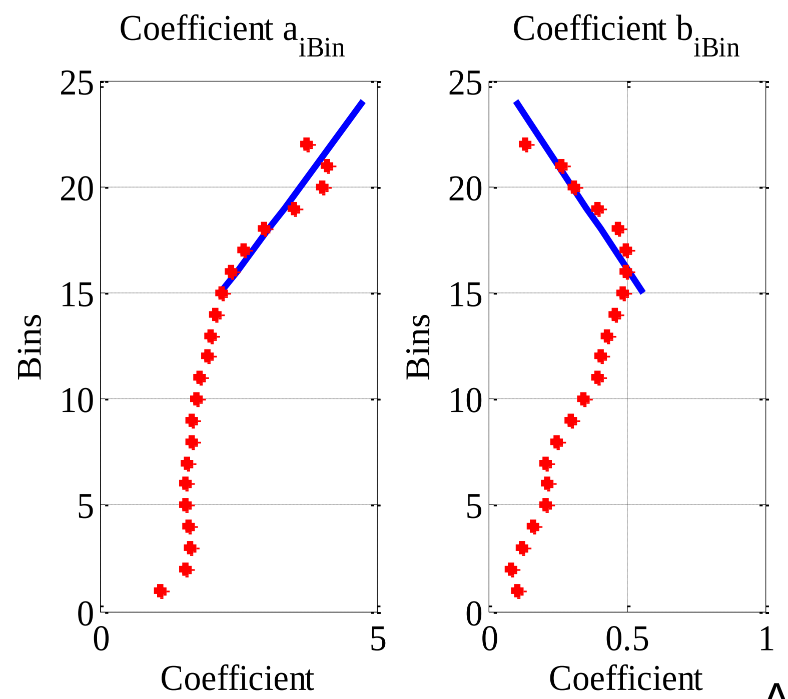
$$u_g = a_{Bin24}\Delta\eta + b_{Bin24}$$

$$u_{iBin} = a_{iBin}\Delta\eta + b_{iBin}$$

$$u_{Bin22} = a_{Bin22}\Delta\eta + b_{Bin22}$$

$$u_{Bin18} = a_{Bin18}\Delta\eta + b_{Bin18}$$

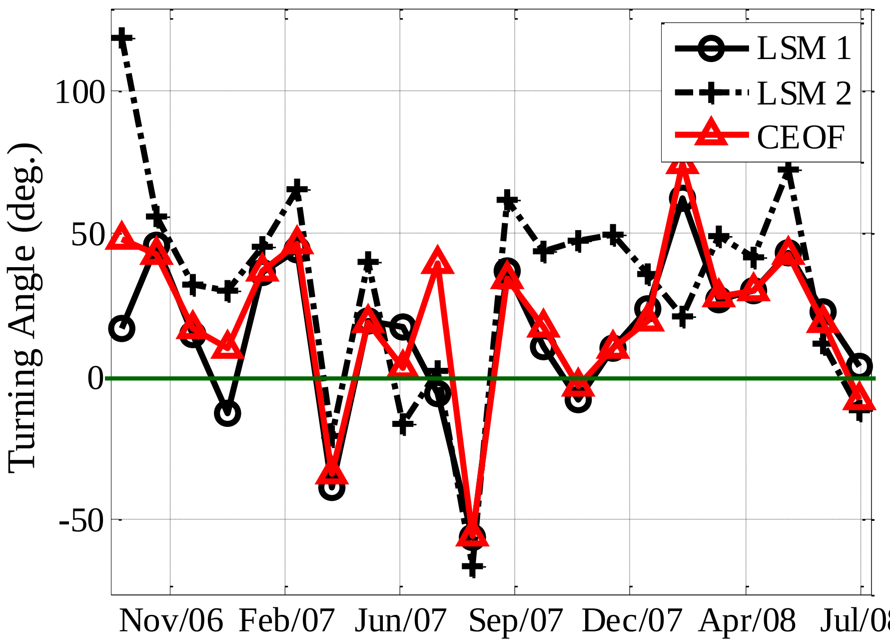
$$u_{Bin15} = a_{Bin15}\Delta\eta + b_{Bin15}$$

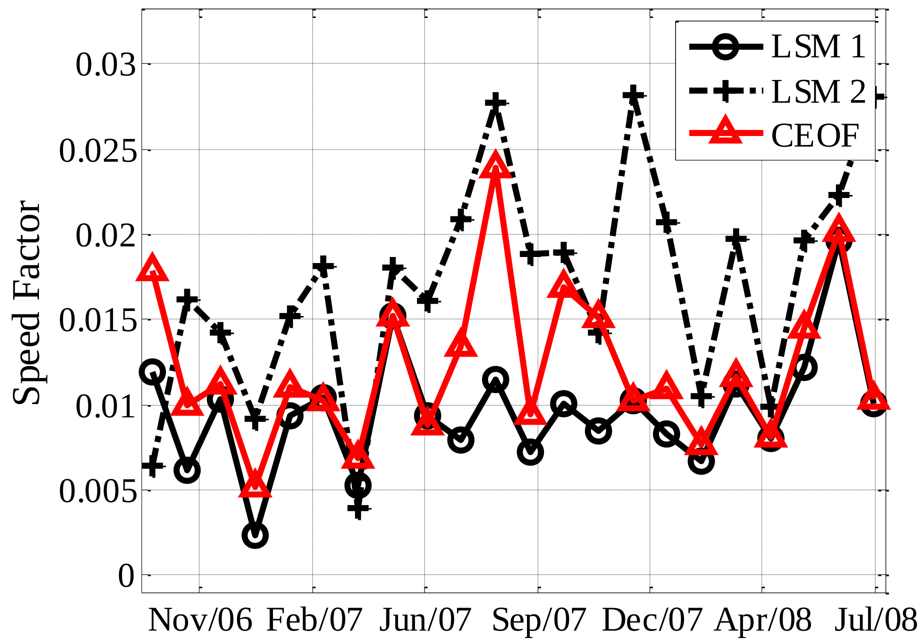


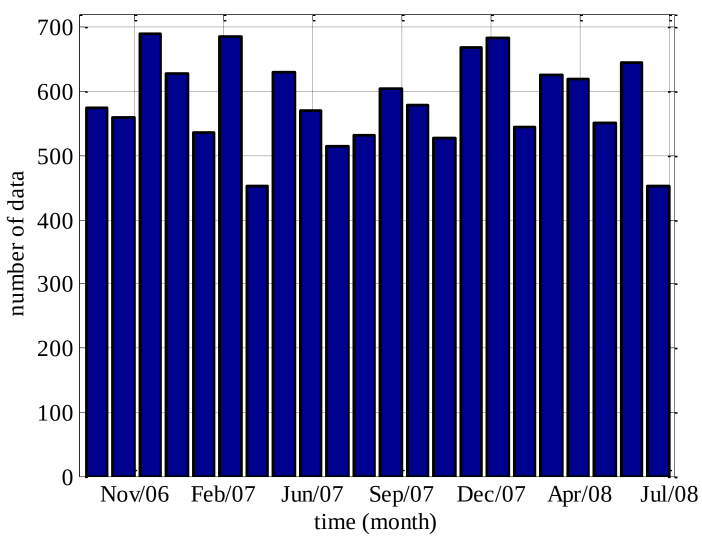
Aug. 2007

Geostrophic current estimated from Sea Level Difference Coefficient

Monthly-Mean Drift Parameters







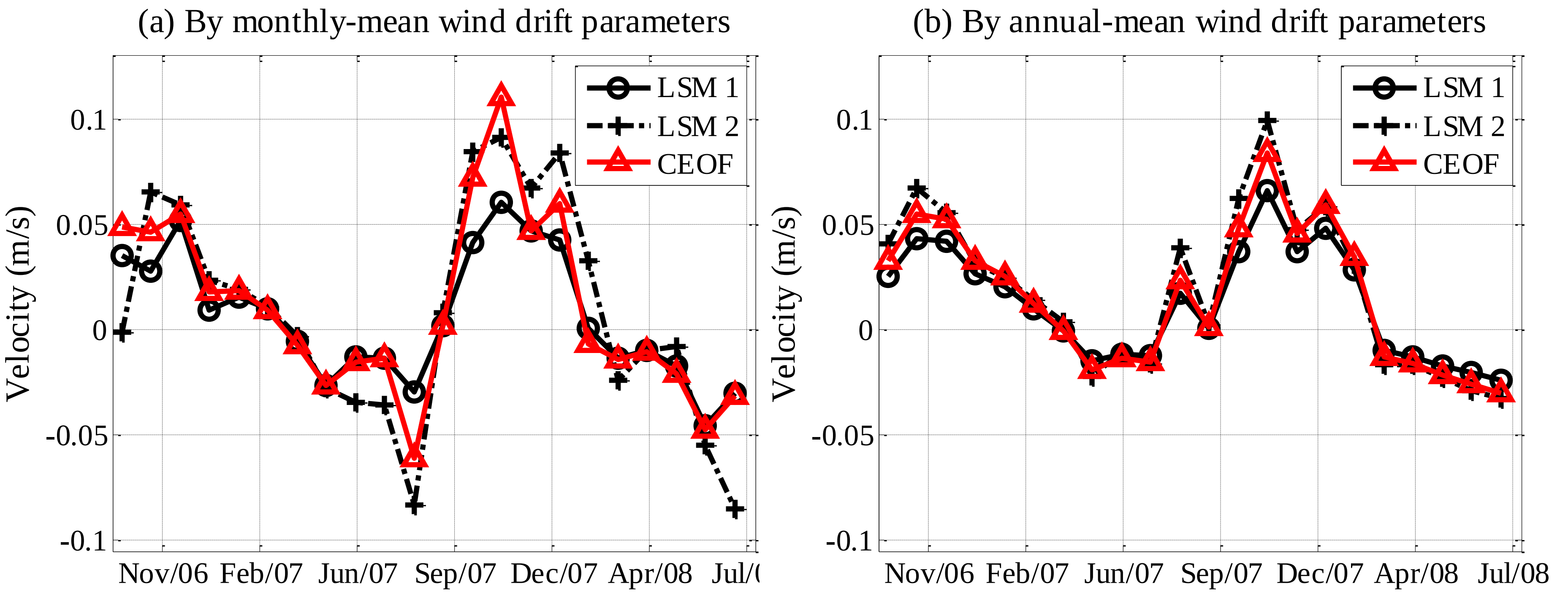
The drift parameters are roughly similar.

Annual-Mean Drift Parameter

		α ($\times 10^{-2}$)	θ (deg.)
Value	LSM1	0.87	18
	LSM2	1.39	34
	CEOF	**1.10**	**21**
RMSE	LSM1	1.64	78
	LSM2	2.60	77
	CEOF	1.93	98

Root-Mean-Square error with daily drift parameters

Wind Drift Current Estimation



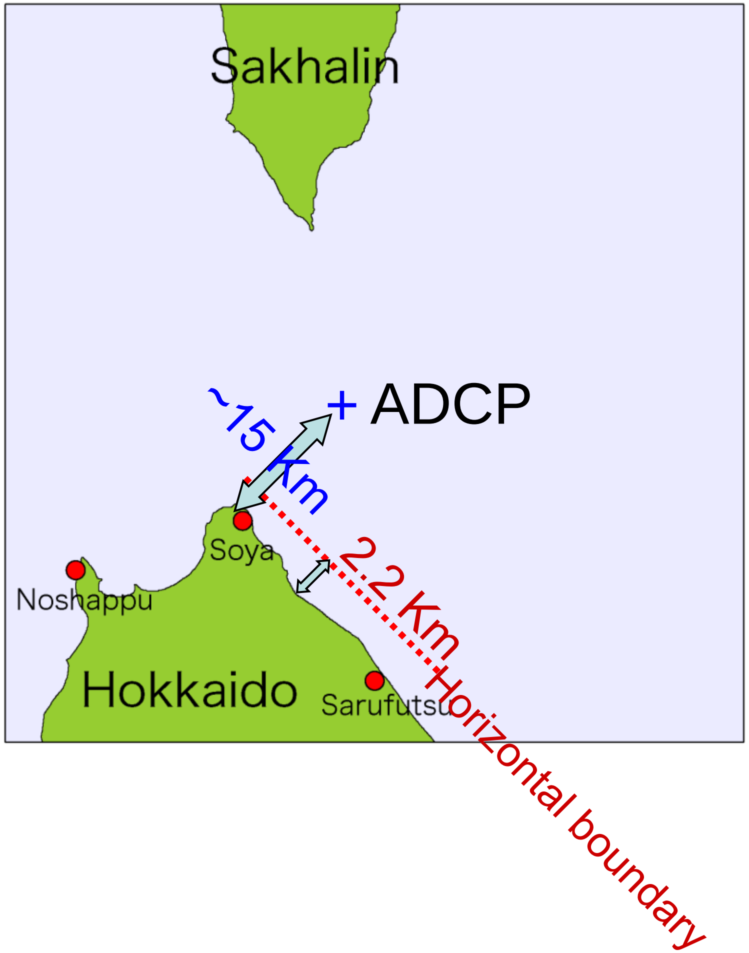
The wind drift current is strong in winter, but weak in summer.

Affection of coastline on drift parameter

The horizontal boundary layer width*:

$$\delta_H = \left(\frac{2A_H}{f} \frac{D}{\delta_E} \right)^{1/2} \approx 2.2km$$

$$A_H = 200m^2 s^{-1},\ D \approx 50m$$



The horizontal boundary layer effect on the wind drift current can be neglected.

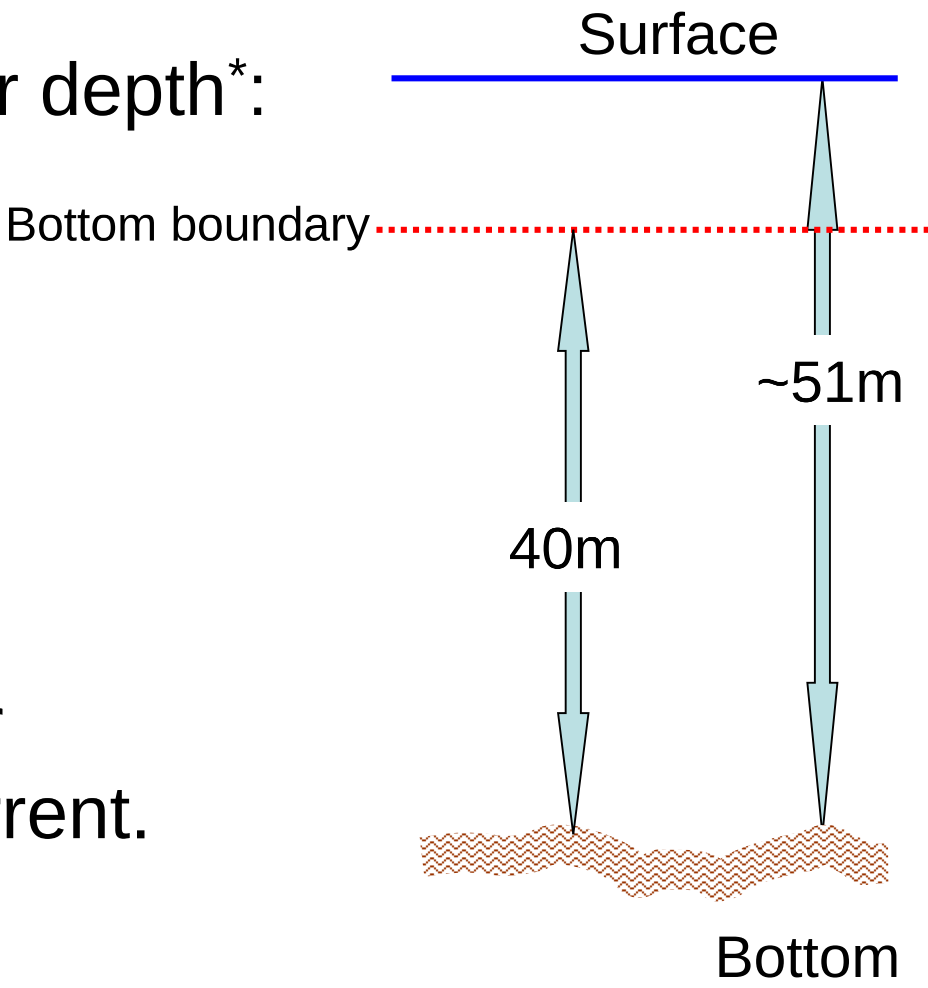
* Yoshikawa and Masuda (2009); Pedlosky (1987)

Affection of bottom on drift parameter

The bottom boundary layer depth*:

$$\delta_E = 0.4\frac{U_*}{f} \approx 40m$$

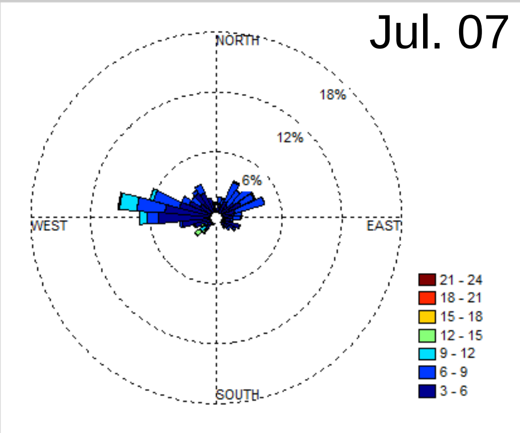
$$U_* \approx 10^{-2} ms^{-1},\ f \approx 1\times10^{-4} s^{-1}$$

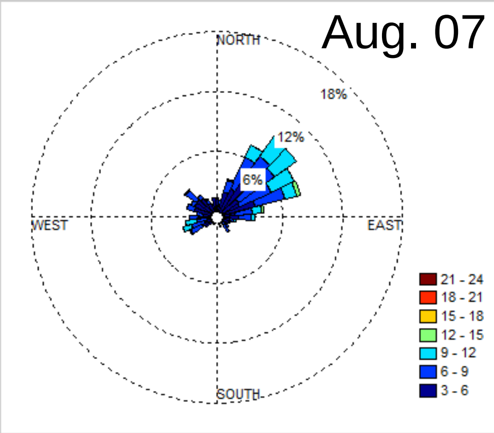


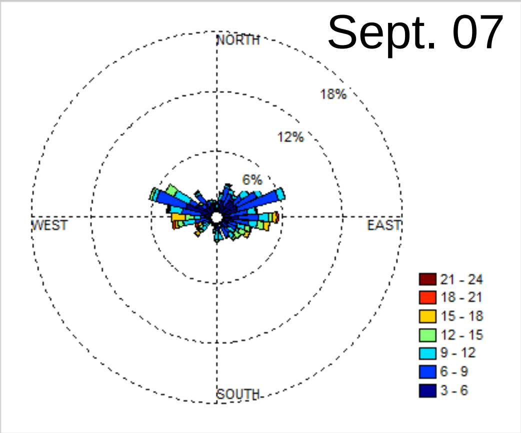
The bottom boundary layer affects on the wind drift current.

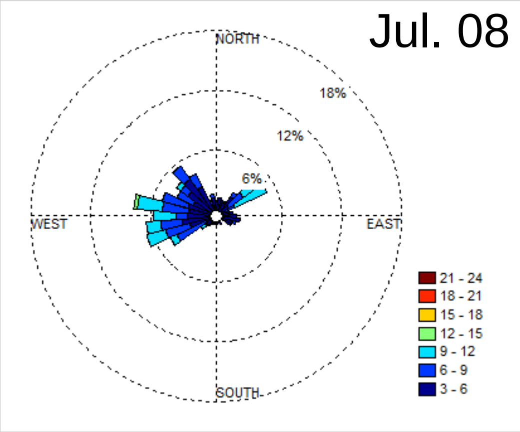
* Yoshikawa and Masuda (2009); Cushuman-Roisin (1994)

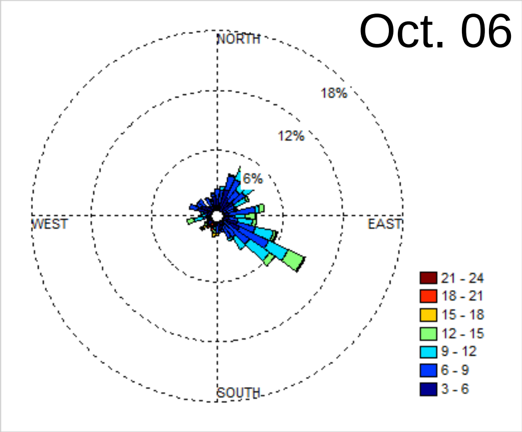
Wind in Summer

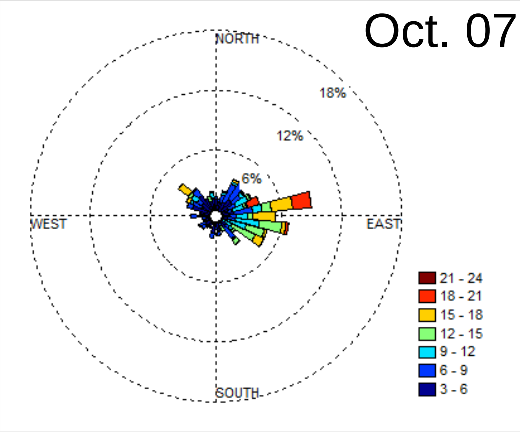






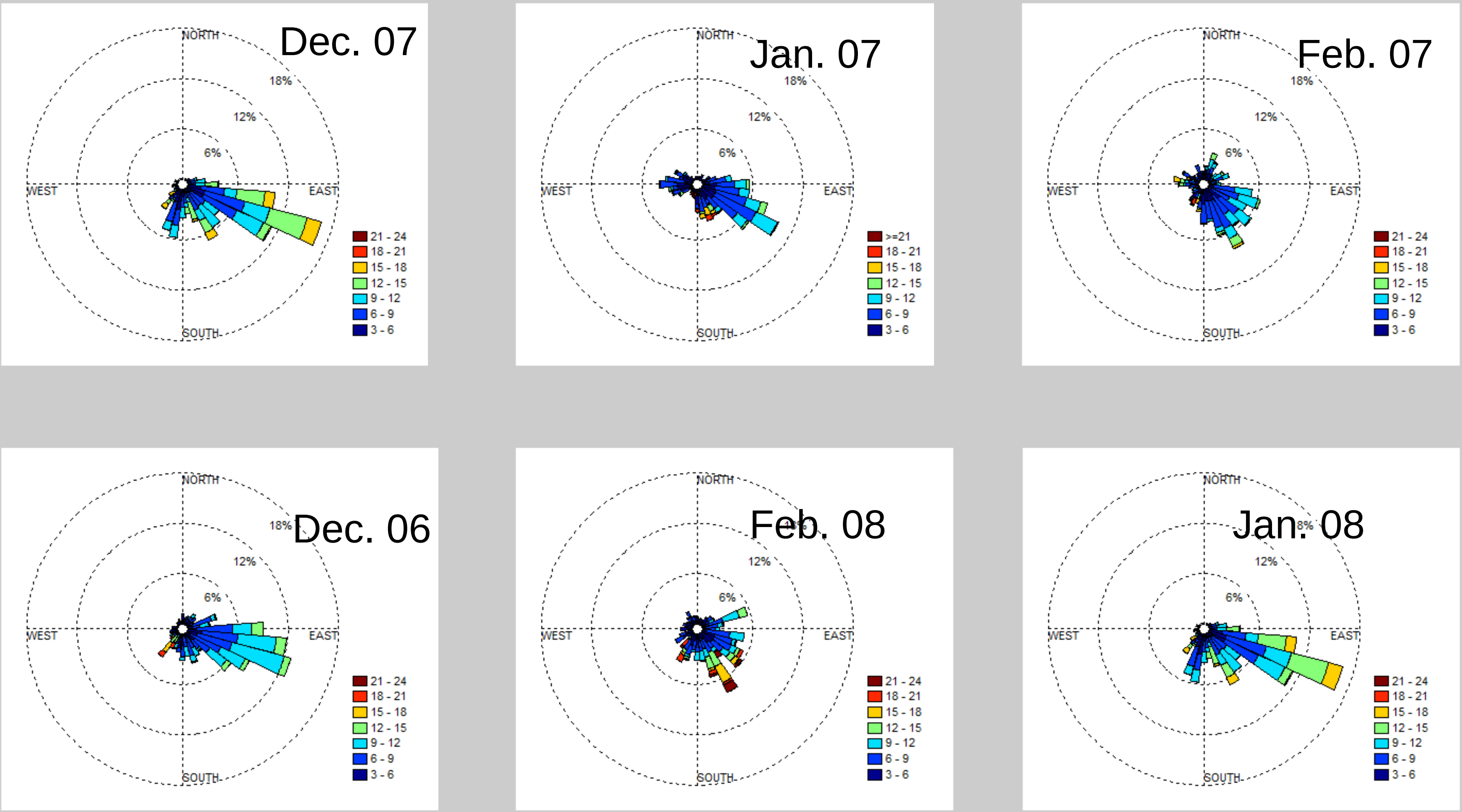






The wind is weak, and its direction is unstable.

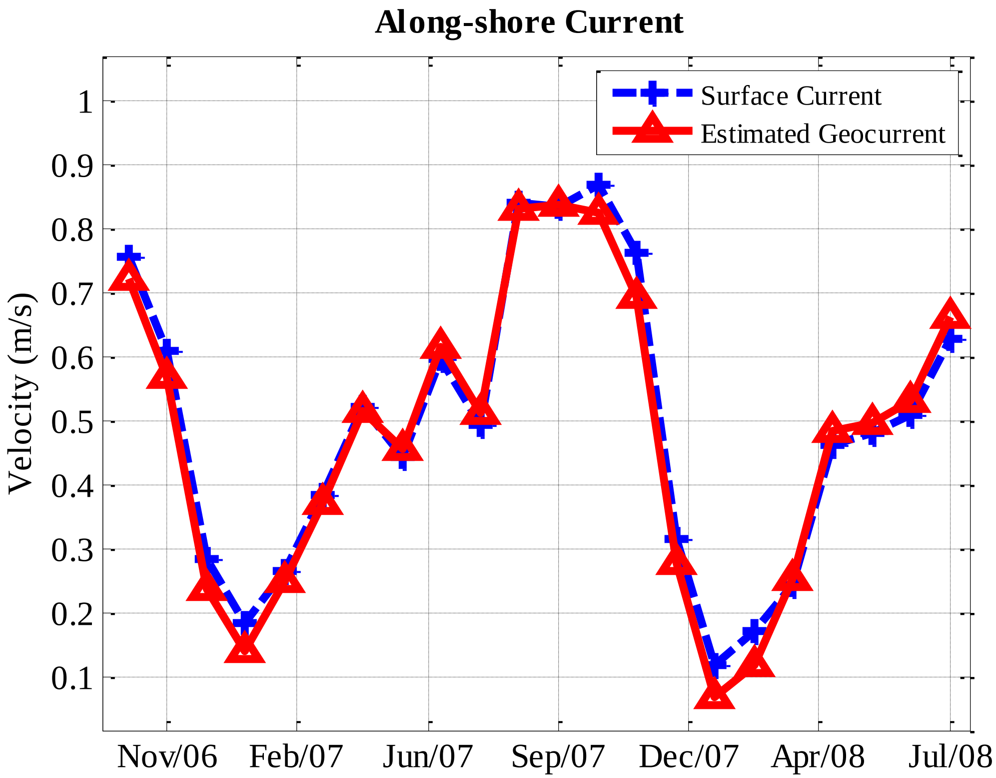
Wind in Winter



The wind is strong, and its direction is stable.

Evaluation

$$\hat{u}_g = u_s - A(\hat{\alpha},\hat{\theta})W$$



Along-shore current vs. sea level difference

	HF	LSM 1		LSM 2		CEOF	
Correlation	u_s	Monthly	**Mean**	Monthly	**Mean**	Monthly	**Mean**
	0.710	0.757	**0.759**	0.785	**0.774**	0.763	**0.768**

Summary

- Wind drift parameters calculated from 3 methods are roughly similar.
- Annual-mean wind drift parameters are a simple and effective way to estimate wind drift current.
- Wind drift current estimation is more obvious in winter, but weak in summer.

Main reference

- Yoshikawa, Y. and A. Masuda (2009): Seasonal variations in the speed factor and deflection angle of the wind-driven surface flow in the Tsushima Strait. J. Geophys. Res. Oceans, 114, C12022, doi:10.1029/2009JC005632.
- Cushuman-Roisin, B. (1994), Introduction to Geophysical Fluid Dynamics, 320 pp., Prentice-Hall, Englewood Cliffs, N. J.
- Fukamachi, Y., K. I. Ohshima, N. Ebuchi, T. Bando, K. Ono, and M. Sano (2010): Volume Transport in the Soya Strait during 2006-2008, *Journal of Oceanography*, *66*, 685-696.
- Kundu, P. K., and J. S. Allen (1976), Some three-dimensional characteristics of low-frequency current fluctuations near the Oregon coast, J. Phys. Oceanogr., 6, 181– 199.
- Pedlosky, J. (1987), Geophysical Fluid Dynamics, 2nd ed., 710 pp., Springer, New York.
- Yoshikawa, Y., et al. A surface velocity spiral observed with ADCP and HF radar in the Tsushima Strait. Journal of Geophysical Research: Oceans (1978–2012) 112.C6 (2007).

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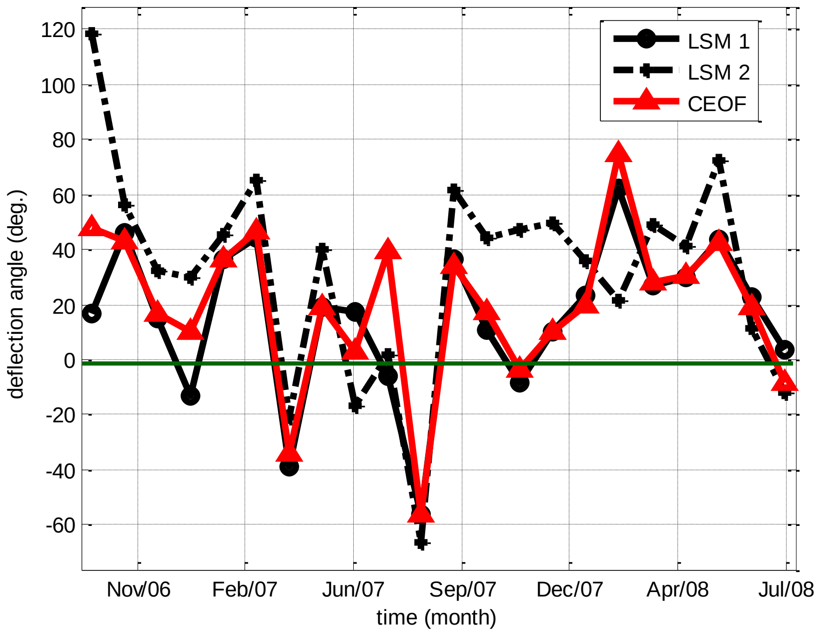
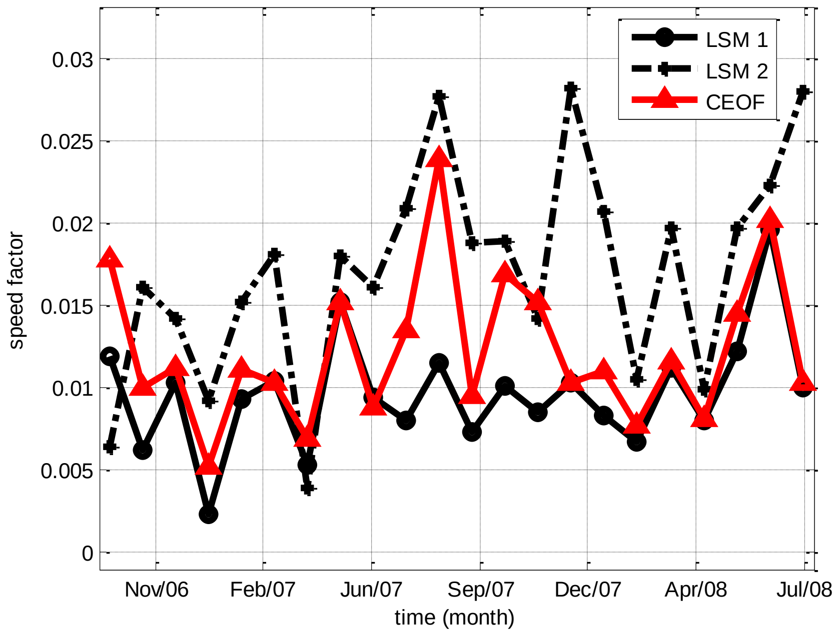
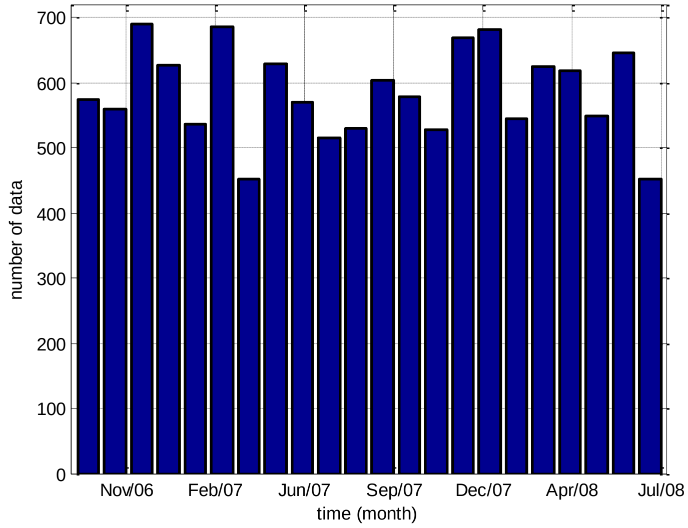
Thank you for your Attention

Back Up

Monthly Drift Parameters







CEOF is a better way to estimate wind drift parameter.

Annual-Mean Drift Parameter

		α ($\times 10^{-2}$)	θ (deg.)
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	CEOF	**1.10**	**21**
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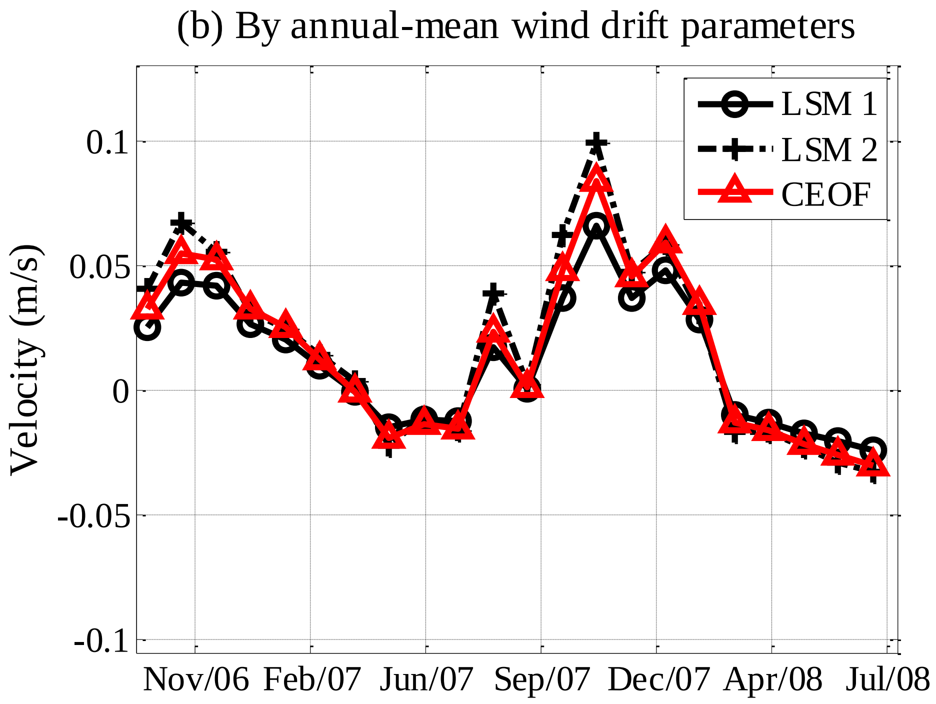

Root-Mean-Square error with daily drift parameters

LSM 2

LSM1

$$(\alpha,\theta) \Leftarrow \min_{(\alpha,\theta)}(u_{err}) = \min_{(\alpha,\theta)}((u_s - u_g) - (\alpha\cos(\theta$$

$$(u_{err}, v_{err}) = (\boldsymbol{u}_s - \boldsymbol{u}_g) - \boldsymbol{A}(\alpha,\theta)\boldsymbol{W}$$

* Kundu and Allen (1976)

LSM 2

$$(\alpha,\theta) \Leftarrow \min_{(\alpha,\theta)}(u_{err})$$

$$(u_{err}, v_{err}) = (\boldsymbol{u}_s - \boldsymbol{u}_g) - \boldsymbol{A}(\alpha,\theta)\boldsymbol{W}$$

* Kundu and Allen (1976)

LSM1 & CEOF

LSM1 $$(\alpha,\theta) \Leftarrow \min_{(\alpha,\theta)}[(u_{err}, v_{err})]$$

$$(u_{err}, v_{err}) = (\boldsymbol{u}_s - \boldsymbol{u}_g) - \boldsymbol{A}(\alpha,\theta)\boldsymbol{W}$$

***CEOF** $$(\alpha,\theta) \Leftarrow \begin{bmatrix} \boldsymbol{W}_{1st} \\ \boldsymbol{u}_{wd1st} \end{bmatrix} = CEOF\left(\begin{bmatrix} \boldsymbol{W} \\ \boldsymbol{u}_s - \boldsymbol{u}_g \end{bmatrix}\right)$$

$$W = U + V * i$$

* Kundu and Allen (1976)