Shipboard measurement of turbulent fluxes by eddy covariance technique in the Kuroshio Extension region

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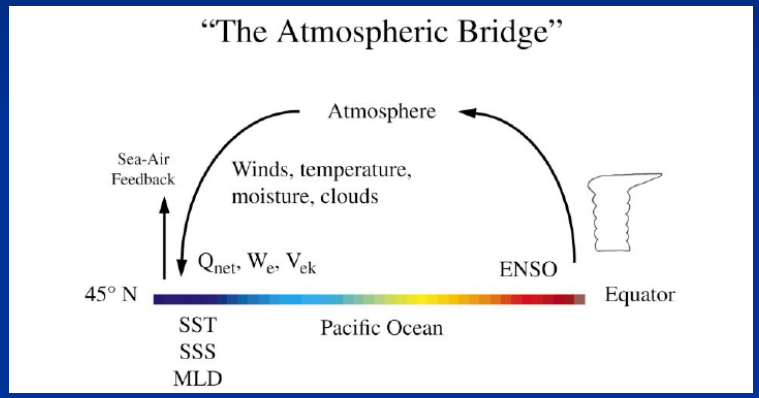
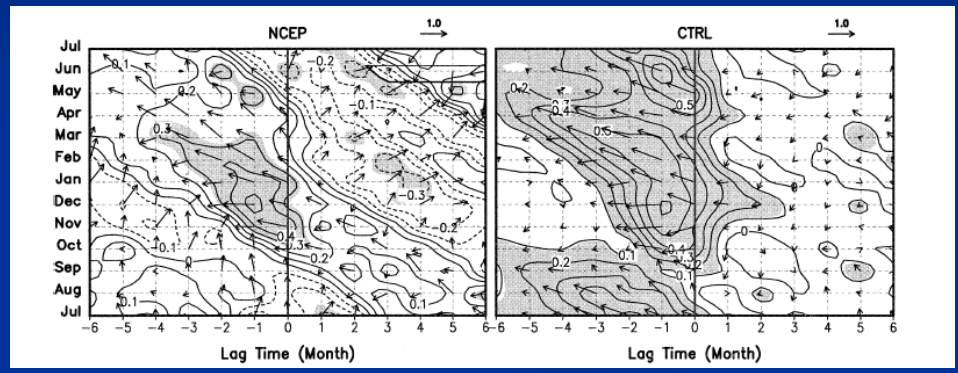
Atmospheric signal in the mid latitude

The atmospheric bridge



Pacific SST ⇒SLP in the NW America



Atmospheric bridge

- Lau and Nath (1994,1996)
- Alexandar et al.(2002)

Model studies

- Schneider and Cornuelle(2005)
- Newman (2006)
- Alexander et al. (2007)

Liu and Wu (2004)

- Lau et al. (2002)
- Liu and Wu (2004)
- Quan et al.(2006)
- Frankignoul and Sennechael (2007)
- Minobe et al.(2008) (GS)

Atm. circulation ⇒ SST variation in the NW Pacific

SLP⇔SST hypothesis ?

Ignored processes

SLP anomaly: proxy of the atmospheric anomalies

Divergence in the upper Part of the atmosphere / Advection

Evaporation (latent heat) Heating at the bottom (sensible heat)

Direct one dimensional effect ?

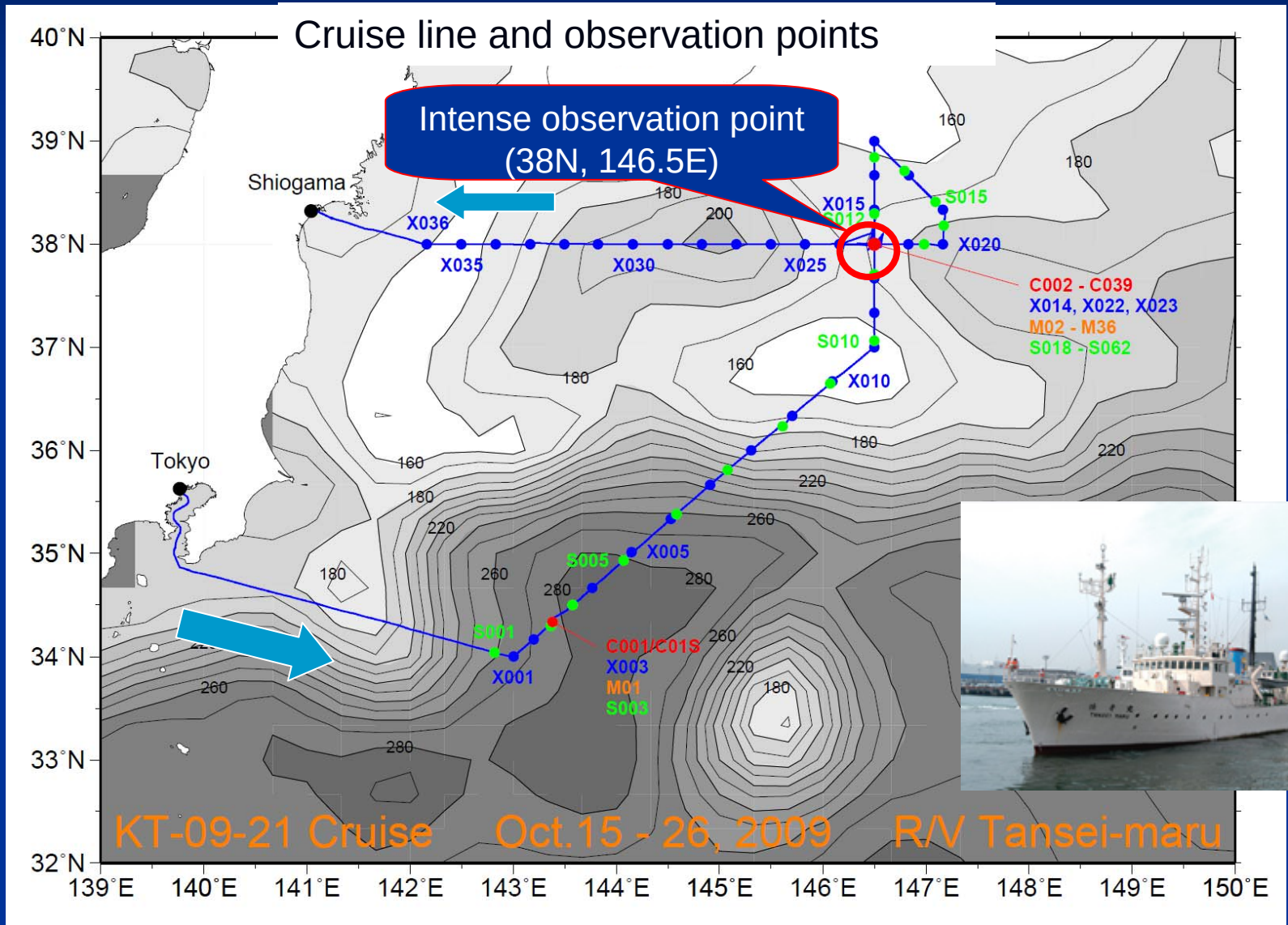
strengths
occurrences

Storm track:
synoptic scale disturbance
Baroclinic instability

Effect of the surface heat fluxes

SST anomaly

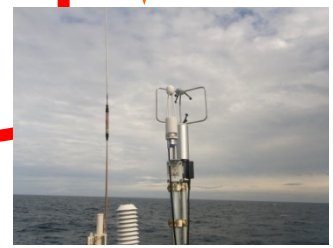
KT0921 air-sea interaction measurement by R/V Tansei maru (PI N. Iwasaka)



Observation at 38N, 146.5E
October 18-23

Radiosonde

Eddy covariance flux measurement mobile system



Ceilometer

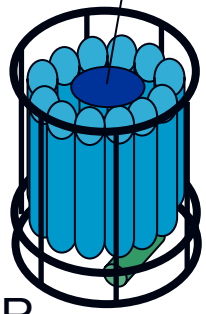
Pyranometer

R/V Tansei-maru

ADCP

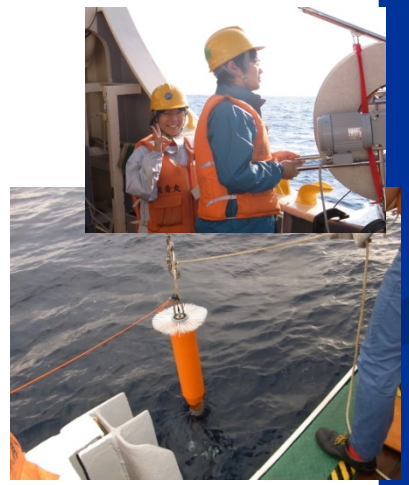
CTDO2

NISKIN SAMPLER

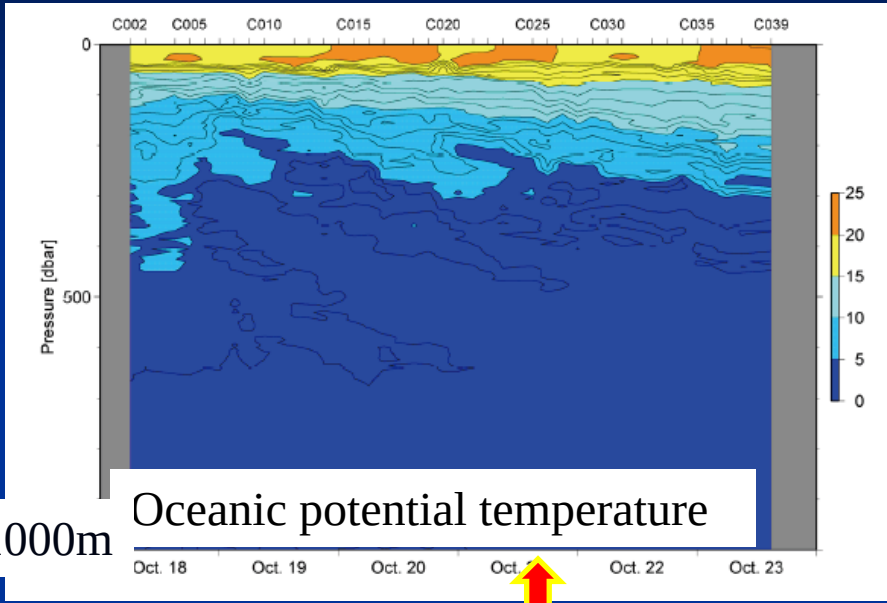


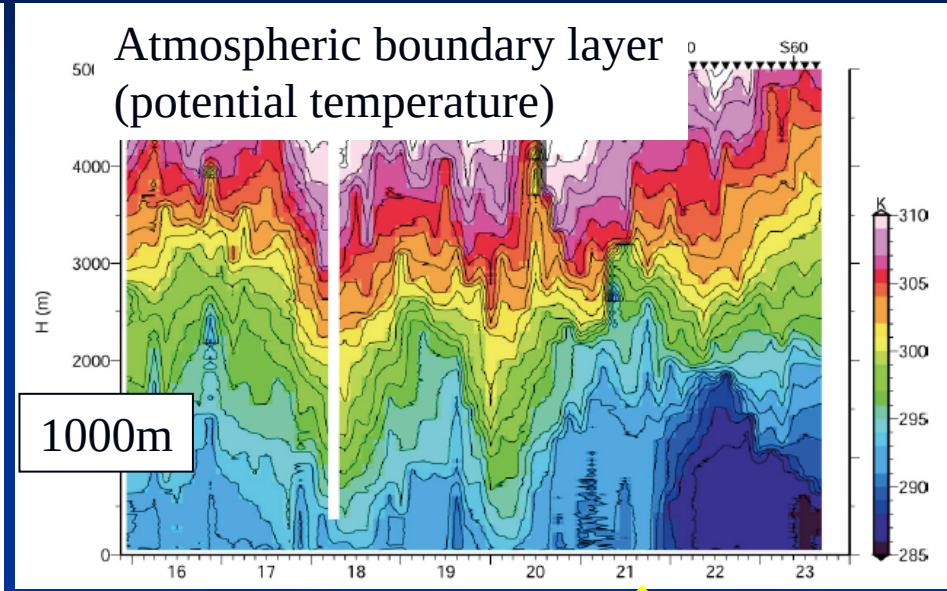
LADCP

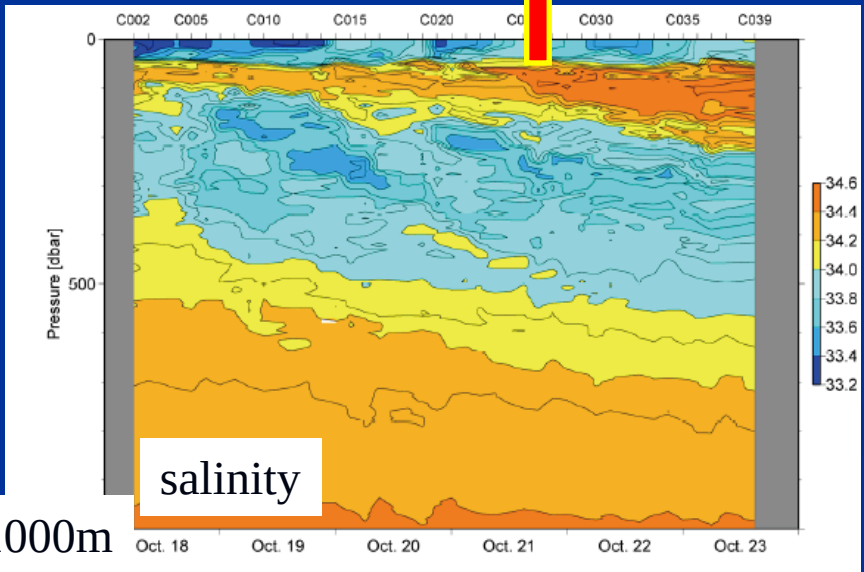
Microstructure profiler



The ocean and the atmospheric mixed layer during KT0921





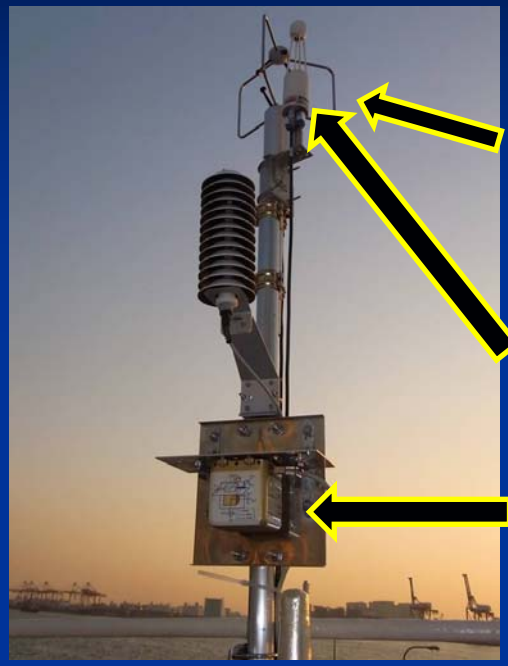


Warm condition

Cold condition

- Oceanic mixed layer is being formed.
- Mean wind direction changed from southerly to northerly on 21, Oct.
- Notable synoptic scale disturbance

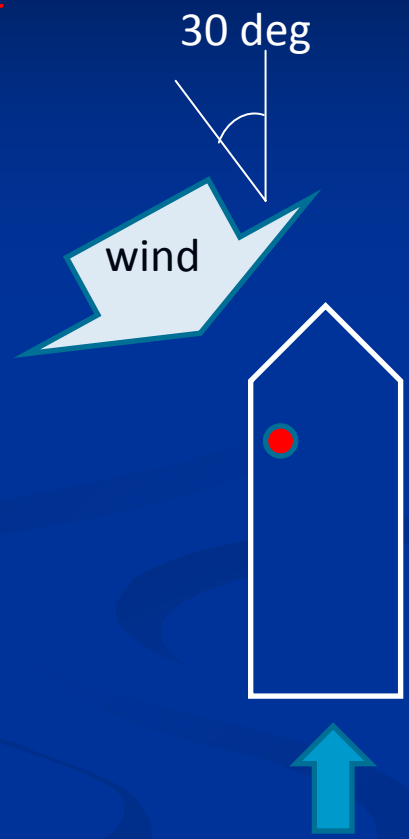
Mobile eddy covariance system and the dedicated one hour for the flux measurement



- 10 Hz measurement
- Sonic anemometer (virtual temperature, U, V, W wind components)
- LICOR-7500 (humidity and CO2)
- Accelerometer computing the platform motion (inclination, wind speed correction)
- DGPS gyro compass

Direct measurement of

$$\overline{\rho u'w'}, \quad \overline{\rho q'w'}, \quad C_p\overline{\rho T'w'}$$



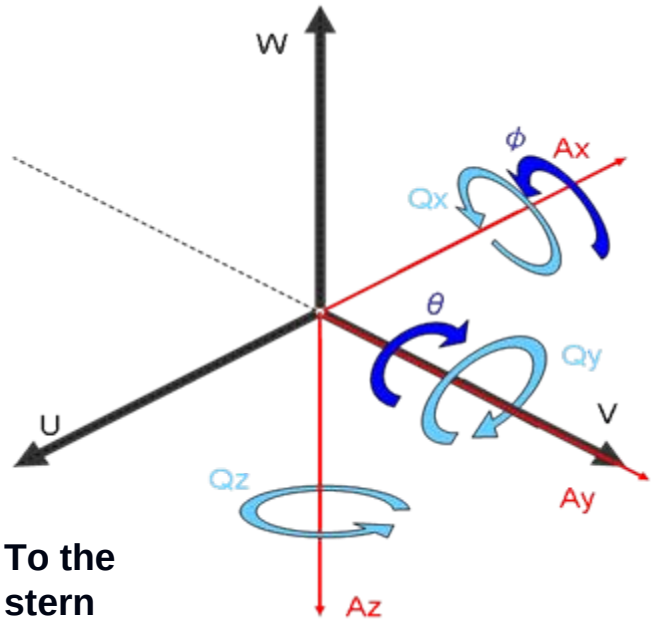
Steering the ship into near upwind to minimize the disturbance due to the ship body from 21:00 .

The eddy covariance technique to estimate turbulent fluxes

- Removal of the shipboard motion from observed (u,v,w)
  - Inclination of the anemometer
  - Pseudo wind caused by the shipboard motion

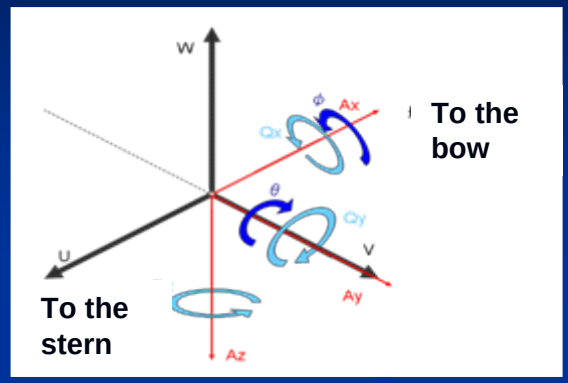
- Mobile eddy covariance system for the moving platform
  - Sonic anemometer
  - Integration of the angular velocity
    ⇨ inclination of the ship (anemometer)
  - Inclinometer is sometimes inaccurate under the strong motion
  - Integration of the 3 dimensional acceleration
    ⇨ the motion of the anemometer

Pitching angle and rolling angle are determined.



Inclination of the platform (anemometer)

$$\begin{pmatrix} \cos\theta & -\sin\theta\sin\phi & -\sin\theta\cos\phi \\ 0 & \cos\phi & -\sin\phi \\ \sin\theta & \cos\theta\sin\phi & \cos\theta\cos\phi \end{pmatrix} \begin{pmatrix} u_{anemo} \\ v_{anemo} \\ w_{anemo} \end{pmatrix}$$



θ :pitching angle, ϕ : rolling angle

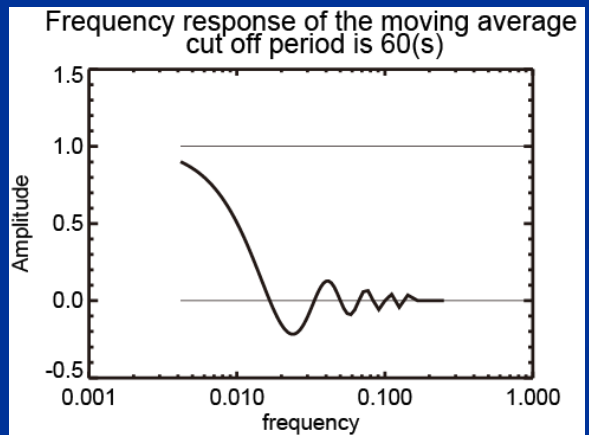
$$\theta = \sum q_x \Delta T + \Phi_x$$

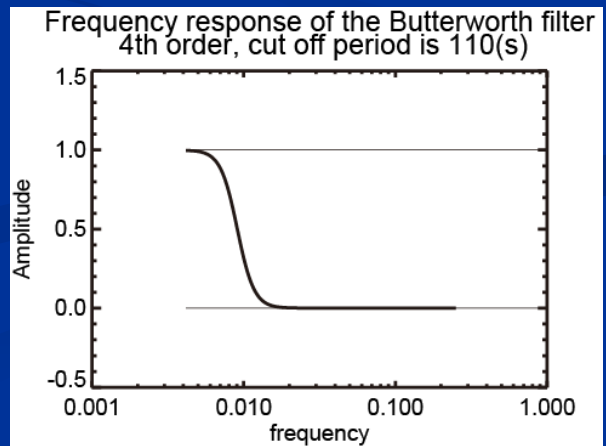
$$\phi = \sum q_y \Delta T + \Phi_y$$

Mean attitude of the ship from the mean angle derived by the accelerometer

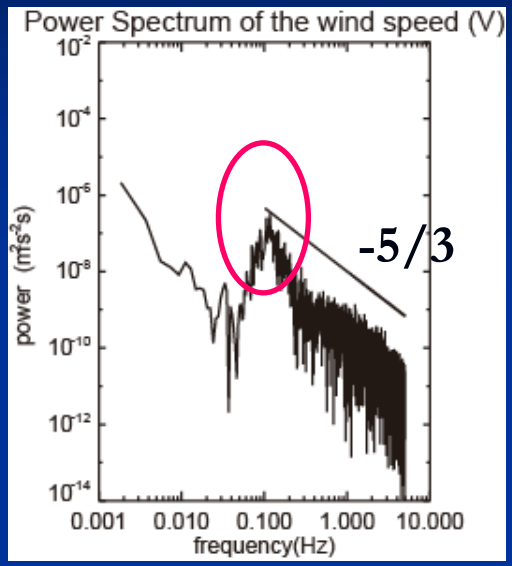
High-pass filtered accumulation of the angular velocity

Raw – low-pass filter

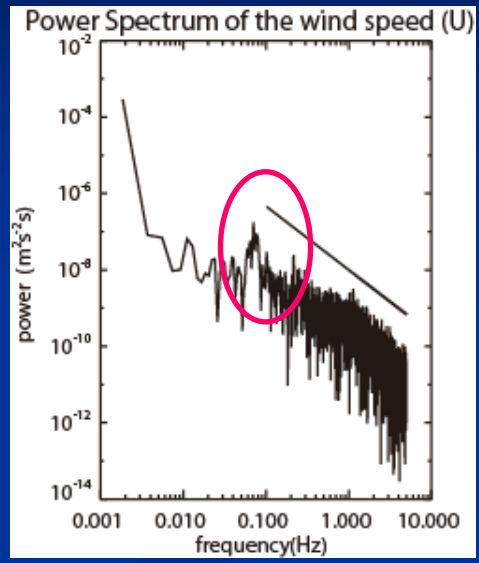




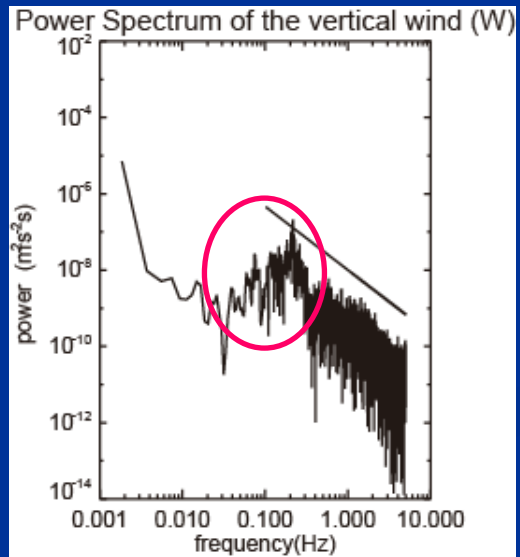
Wind measurement: Contamination caused by the ship motion



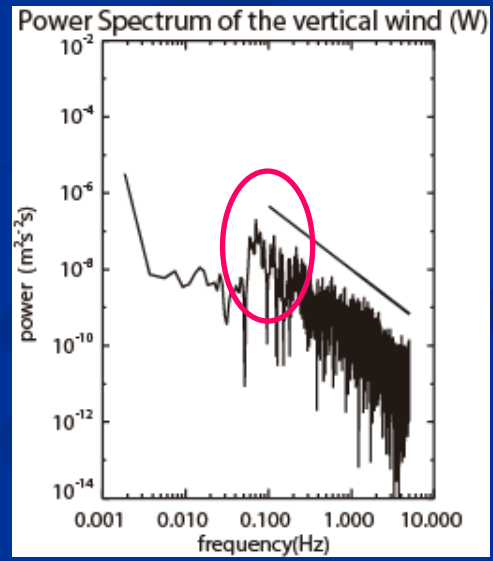
Horizontal wind power spectrum



Ship movement effect around 10 s period oscillation

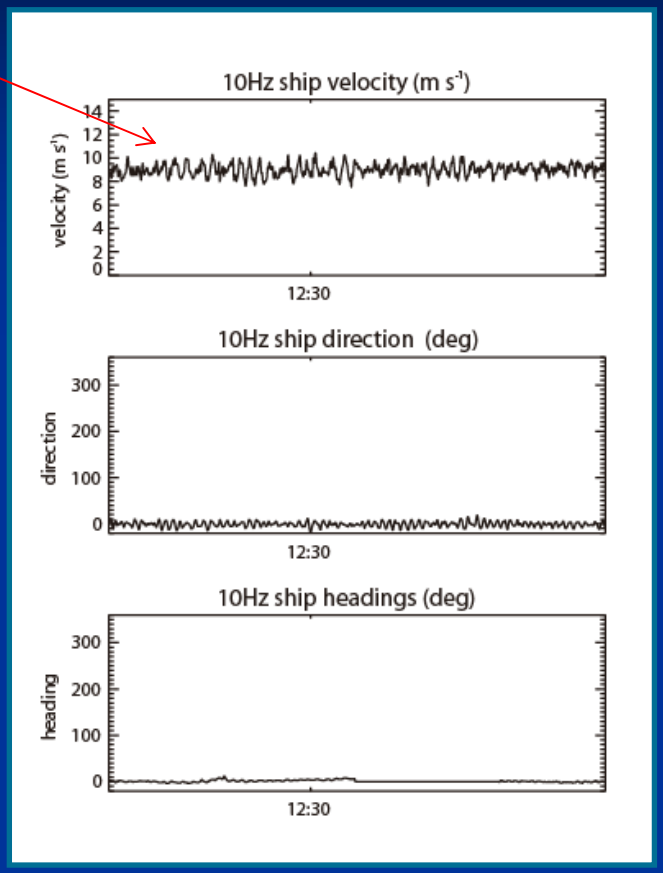


Vertical wind power spectrum



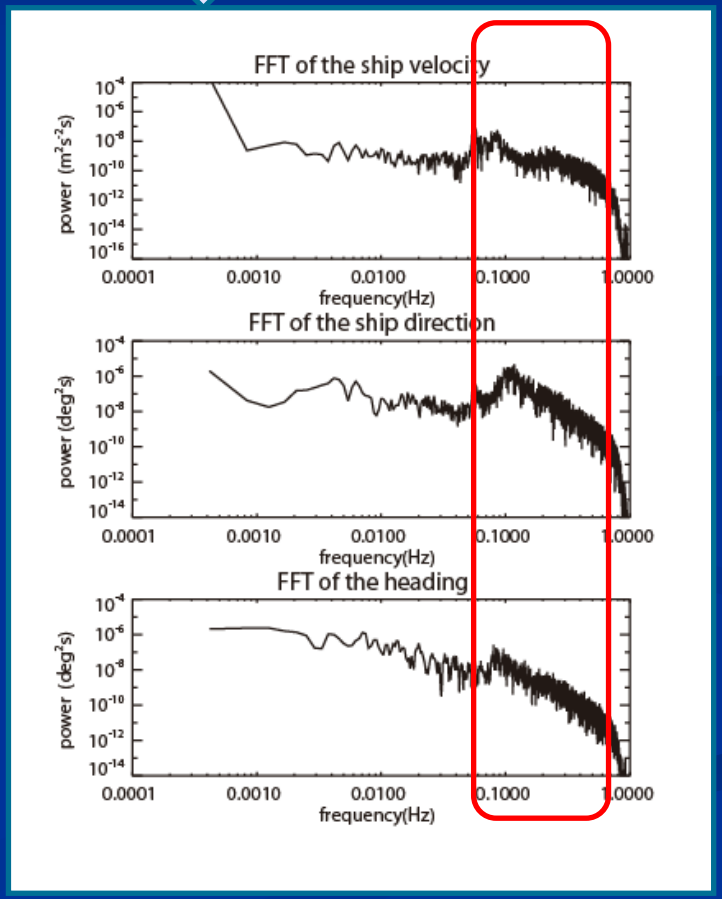
Ship velocity variations
(ignored in the standard technique)

1 - 2 m/s fluctuations

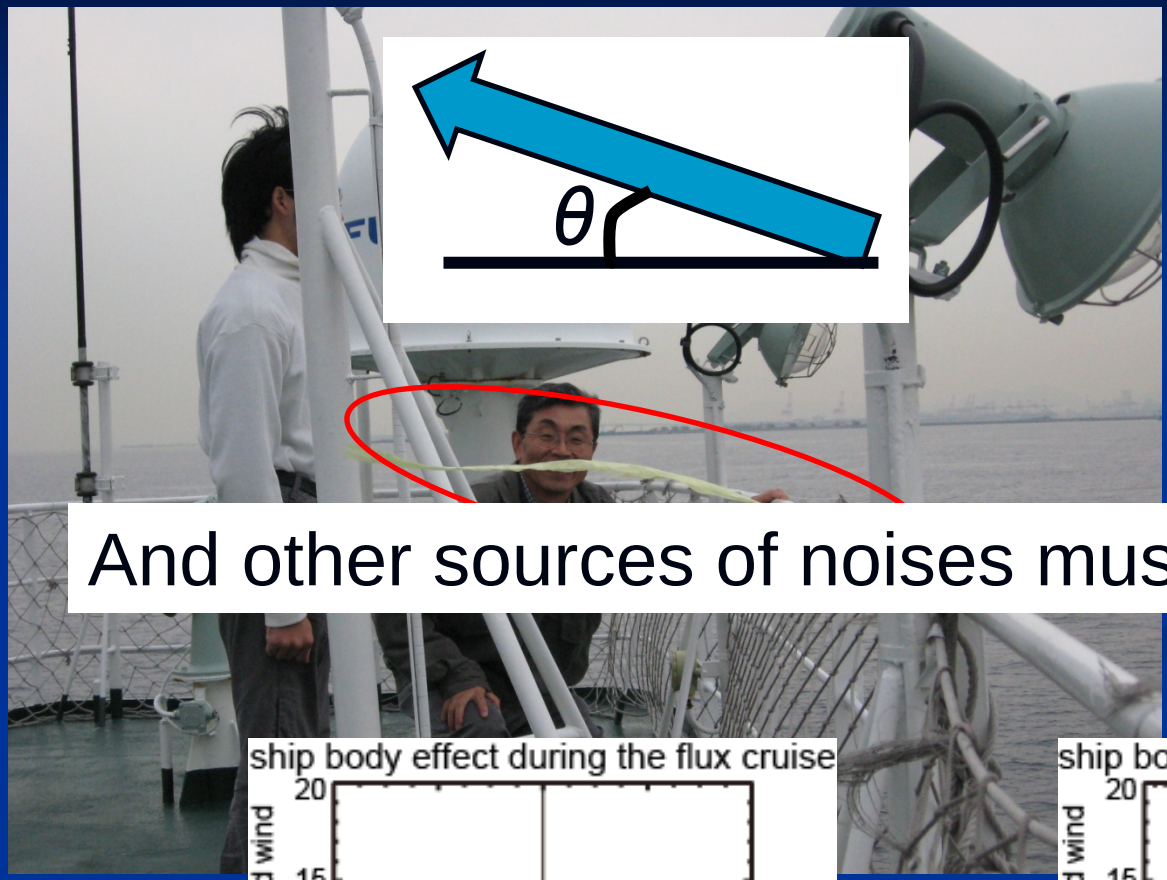


10 minutes

Oscillation at around 0.1 Hz

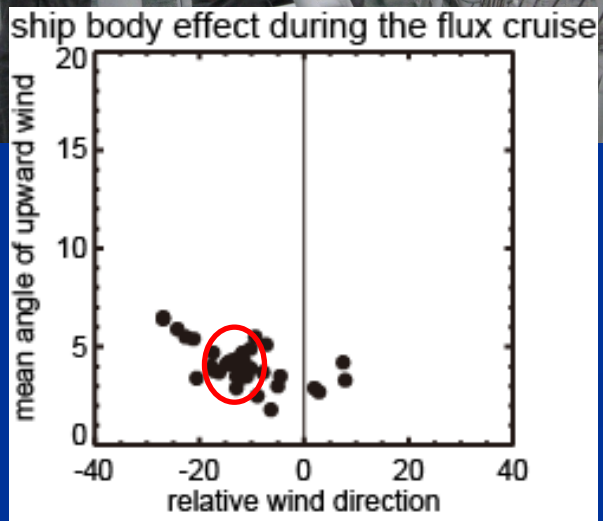


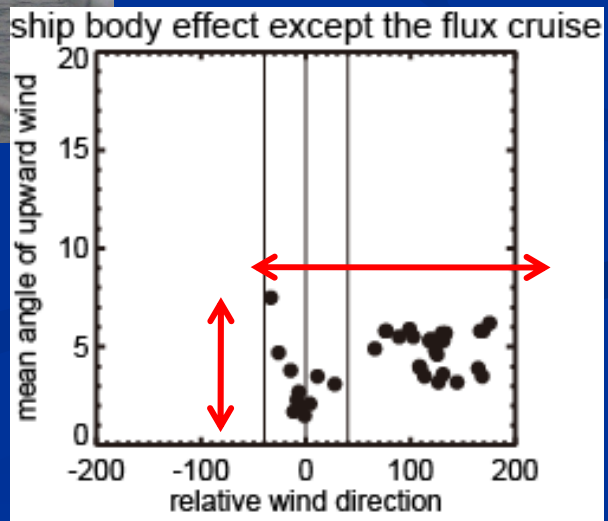
Ship body effect (tilt correction)



Winds from the bow

And other sources of noises must be considered.

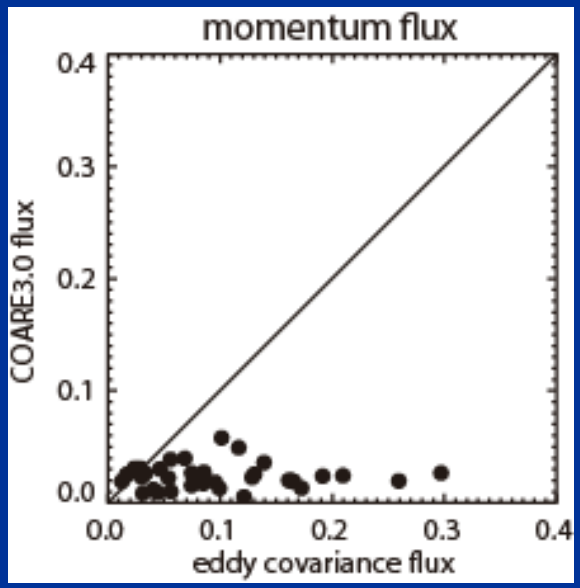


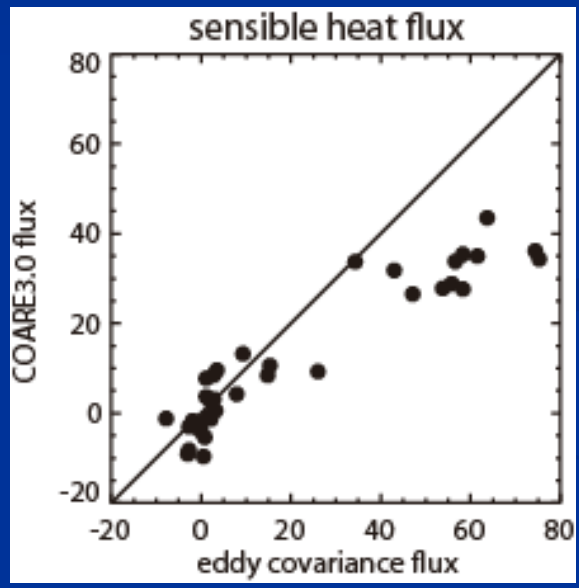


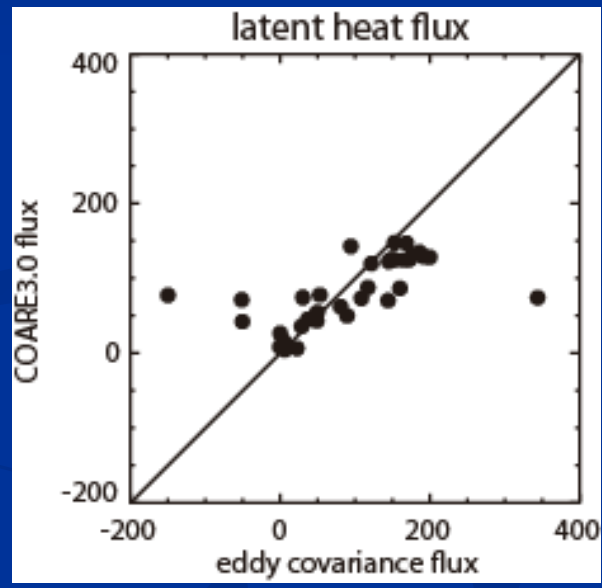
Bulk – eddy covariance fluxes comparison

Bulk flux algorithm: COARE 3.0 (night condition)

Eddy covariance flux (standard version)







-0.3 ± 0.6 N/m^2 -9.4 ± 12.8 W/m^2 1.9 ± 97.7 W/m^2

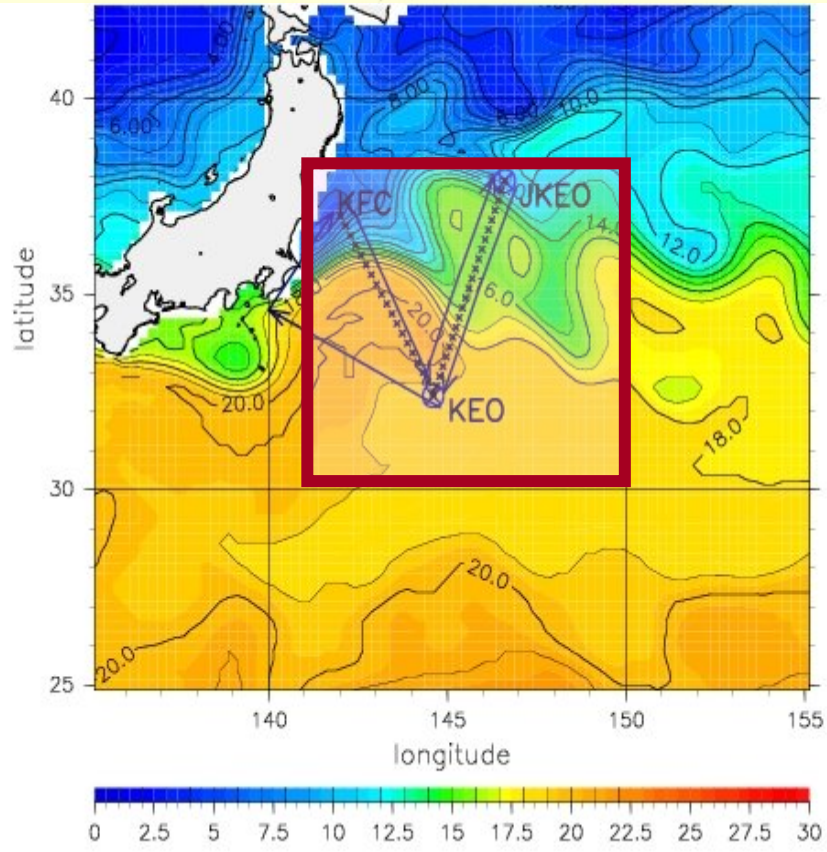
There is space for improvement on the standard technique of the removal of the contamination caused by the moving platform

Cruise by R/V Hakuho-Maru (Feb. 25 – Mar. 23, 2011)

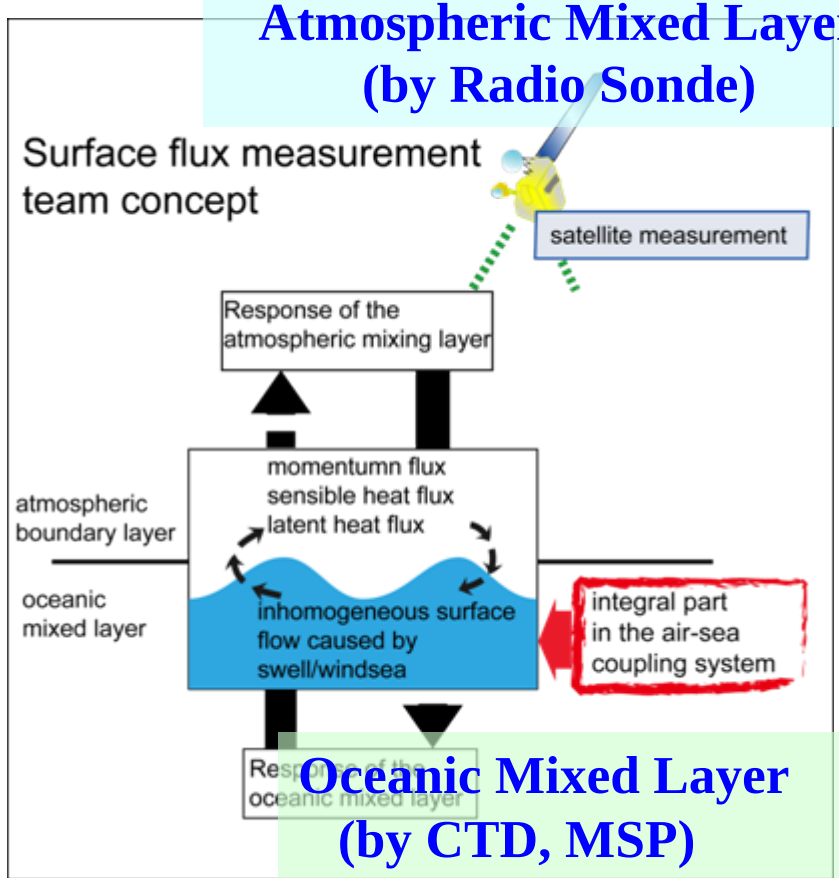
The ocean-atmosphere interaction in the Kuroshio Extension region

PI K. Kutsuwada (Tokai Univ.)

Observation Region (*tentative*)



Atmospheric Mixed Layer (by Radio Sonde)



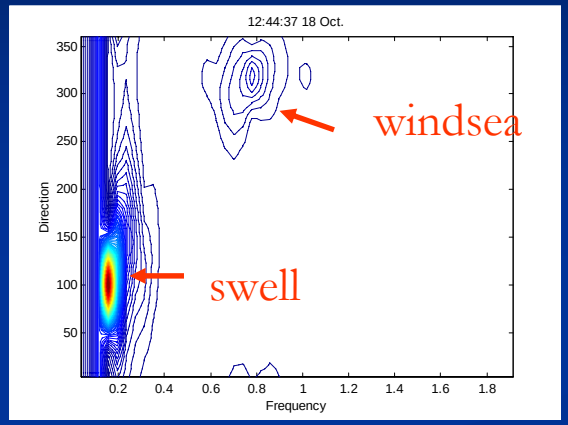
Oceanic Mixed Layer (by CTD, MSP)

Swell and windsea measurement during the cruise by R/V Hakuho-maru in the next winter

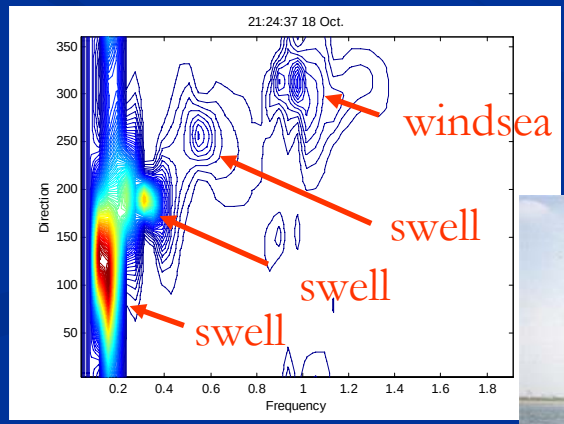
GPS Wave follower buoy:
(developed by JAXA
and Zenilite buoy co.ltd)

We hope to obtain…

Swell against the windsea



Swells come from different directions

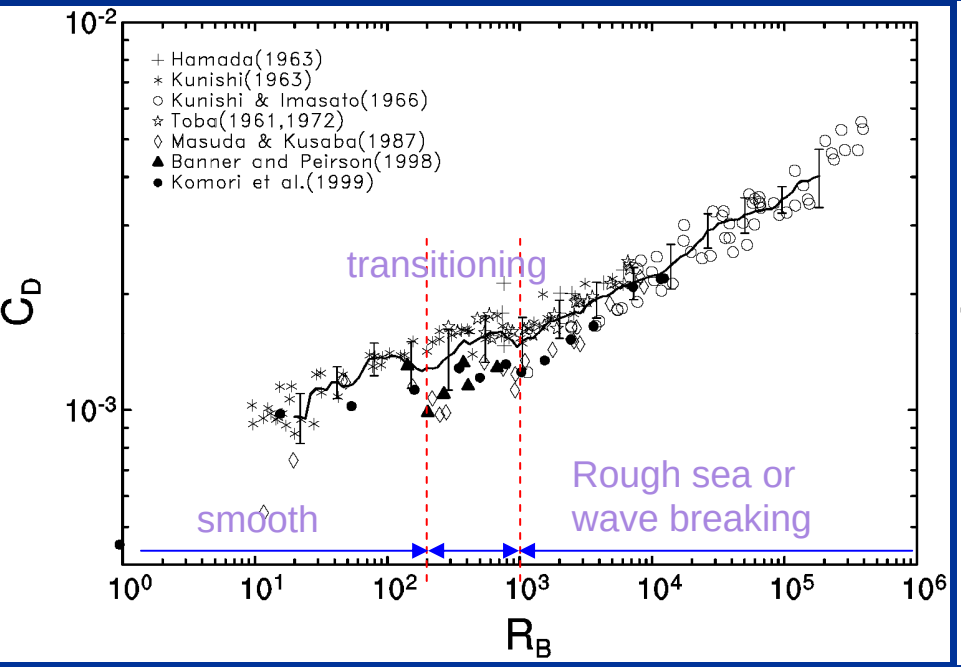


(Suzuki et al. 2002)

The relationship between the drag coefficient and the Reynolds number（Toba et al., 2006)

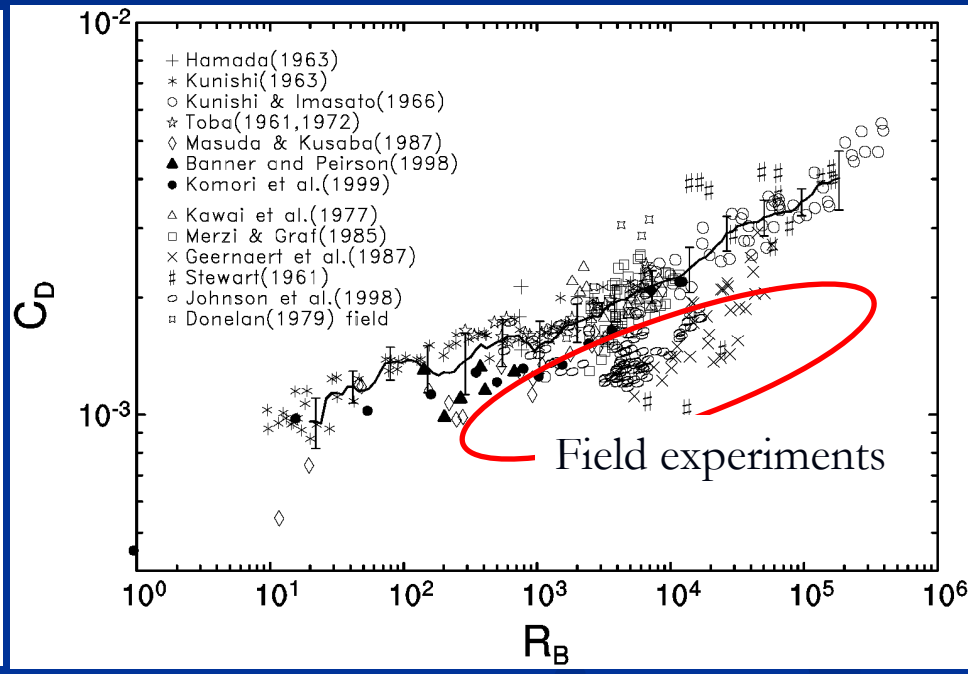
$$R_B = \frac{u_*^2}{\nu \sigma_p}$$

Indoor experiment



Basically in good relationship

Indoor + field experiment



Data in field experiments largely deviate from the indoor experiments

Suggesting the influence of the swell

Summary

■Eddy covariance technique to measure the turbulent heat flux on the moving platform was tried in the late fall in the Kuroshio Extension region (KT0921)

■There is space for improvement on the eddy covariance technique (ship body effect, trend or long term period oscillation removal, etc.)

■ We are planning the next cruise by R/V Hakuho-maru in the next winter in the Kuroshio Extension region. The coordinated observation of the ABL-sea surface flux-Ocean mixed layer coupling system will be made.

■The swell and windsea measurement is planned to understand the influence of the surface current on the bulk parameterization.

A voluntary air-sea interaction measurement group in Japan

- Head : M. Kubota (Tokai Univ)
- ABL: Y. Tanimoto, (Hokkaido Univ), F. Kobashi (Tokyo Univ. of Marine Sci. and Tech)
- Air-sea flux: K. Kutsuwada (Tokai Univ.), M. Konda (Kyoto Univ.)
- Ocean ML: N. Iwasaka (Tokyo Univ. of Marine Sci. and Tech), K. Uehara (Tokai Univ)