Air-sea energy fluxes with on-board eddy-covariance system during MISMO

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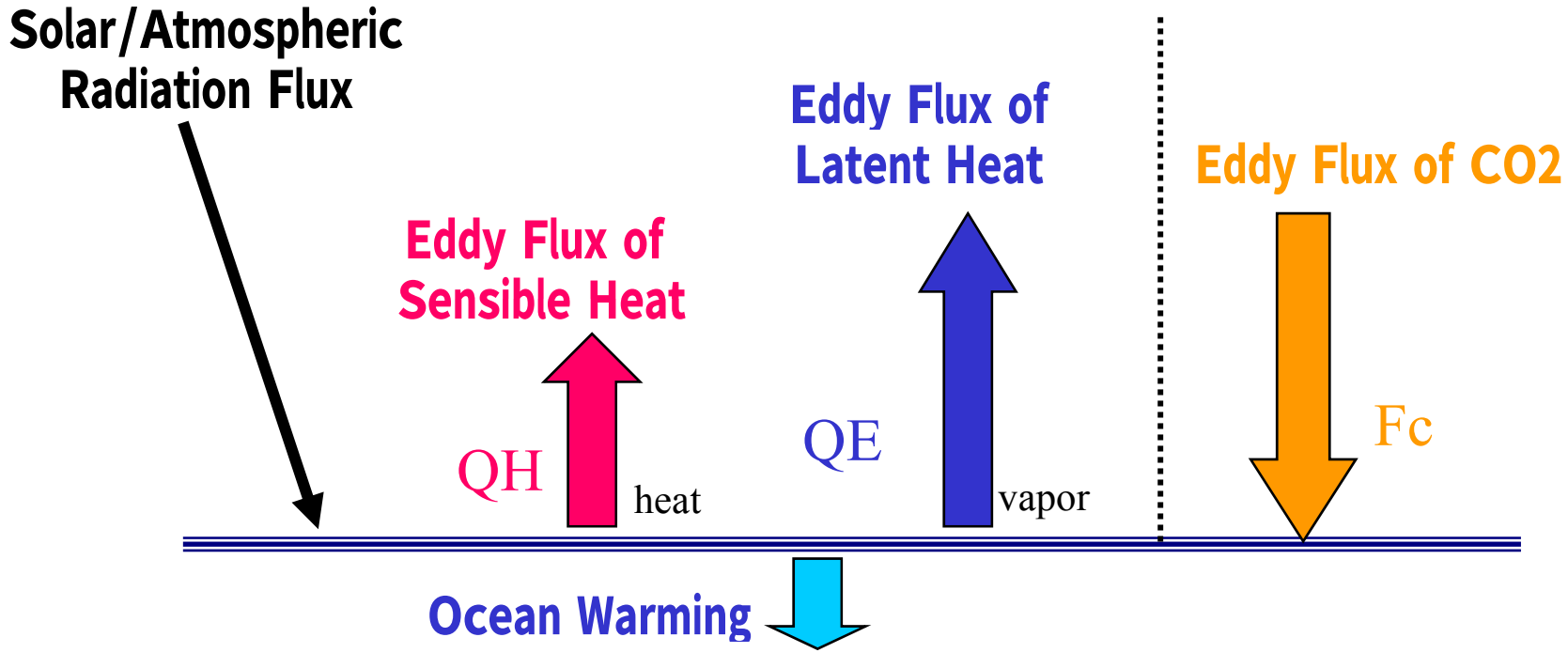
Sea Surface Heat(Energy)/Gas Exchanges



Bulk Method **Eddy−Covariance(Correlation) Method**

$$QH = \rho C_p C_H U (T_s - T) = \rho Cp \overline{w'T'}$$

$$QE = \rho L C_E U (q_S - q) = \rho L \overline{w'q'}$$

$$Fc = k\ s\ (C_{WATER} - C_{AIR}) = \overline{w'\rho_C'}$$

Eddy flux and Bulk flux with on-board data R/V MIRAI

- Eddy-covariance System
  (Takahashi et al. 2005)
- COARE Bulk Algorithm 3.0
  (Fairall et al,2003)

- Sea surface heat budget during MISMO

Application of eddy-covariance method to sea surface

Over land surface projects, eddy-covarinace method is accepted as in-situ real-time system

Difficulties over ocean

Moving platform---ship motion correction

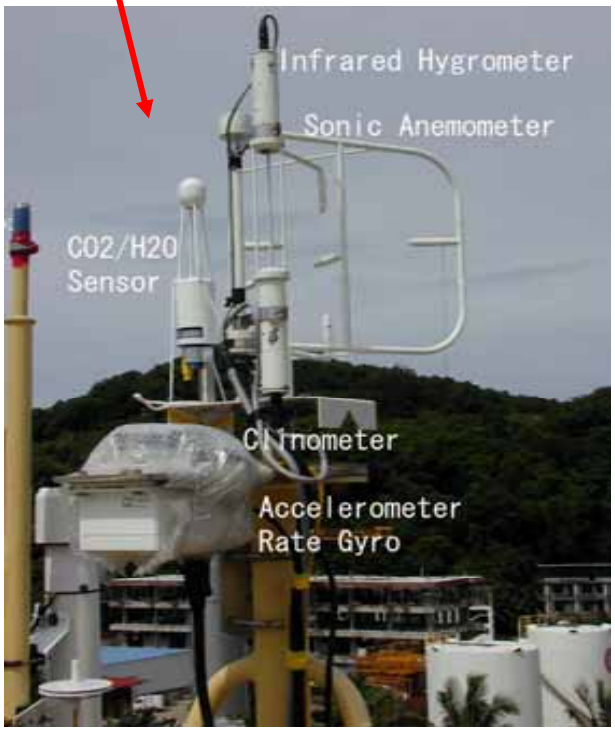
Flow distortion due to platform

Severe meteorological/oceanographic conditions

Eddy Flux System on R/V MIRAI

run against wind

dynamical and thermal effect



main chassis in the cabin

Installation, Flux Run

- Eddy flux system on the top of the foremast
- Steam up against the wind
- Keep the ship speed and heading

- To minimize the dynamic and thermal effect of the ship body

Ship motion correction for wind vector

Ship motion correction equation

$$V = T \cdot Vo + Vso$$

Coordinate Rotation

Dynamic Motion Correction

V : true wind(u,v,w)

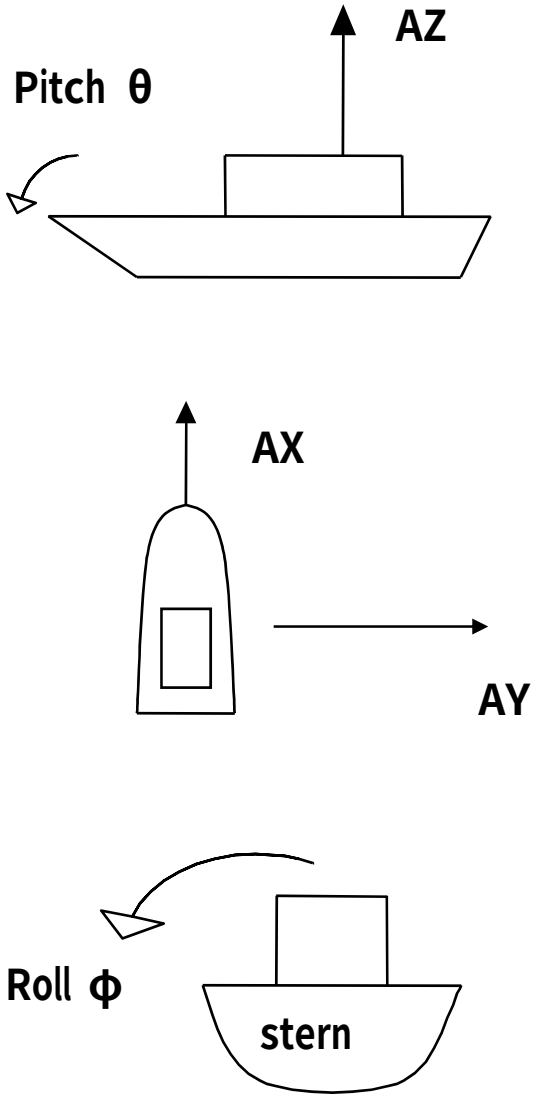
Vo : observed wind (uo,vo,wo)

$$T = \begin{pmatrix} \cos\theta & 0 & \sin\theta\cos\phi \\ 0 & \cos\theta & -\sin\theta \\ -\sin\theta & \cos\theta\sin\phi & \cos\theta\sin\phi \end{pmatrix}$$

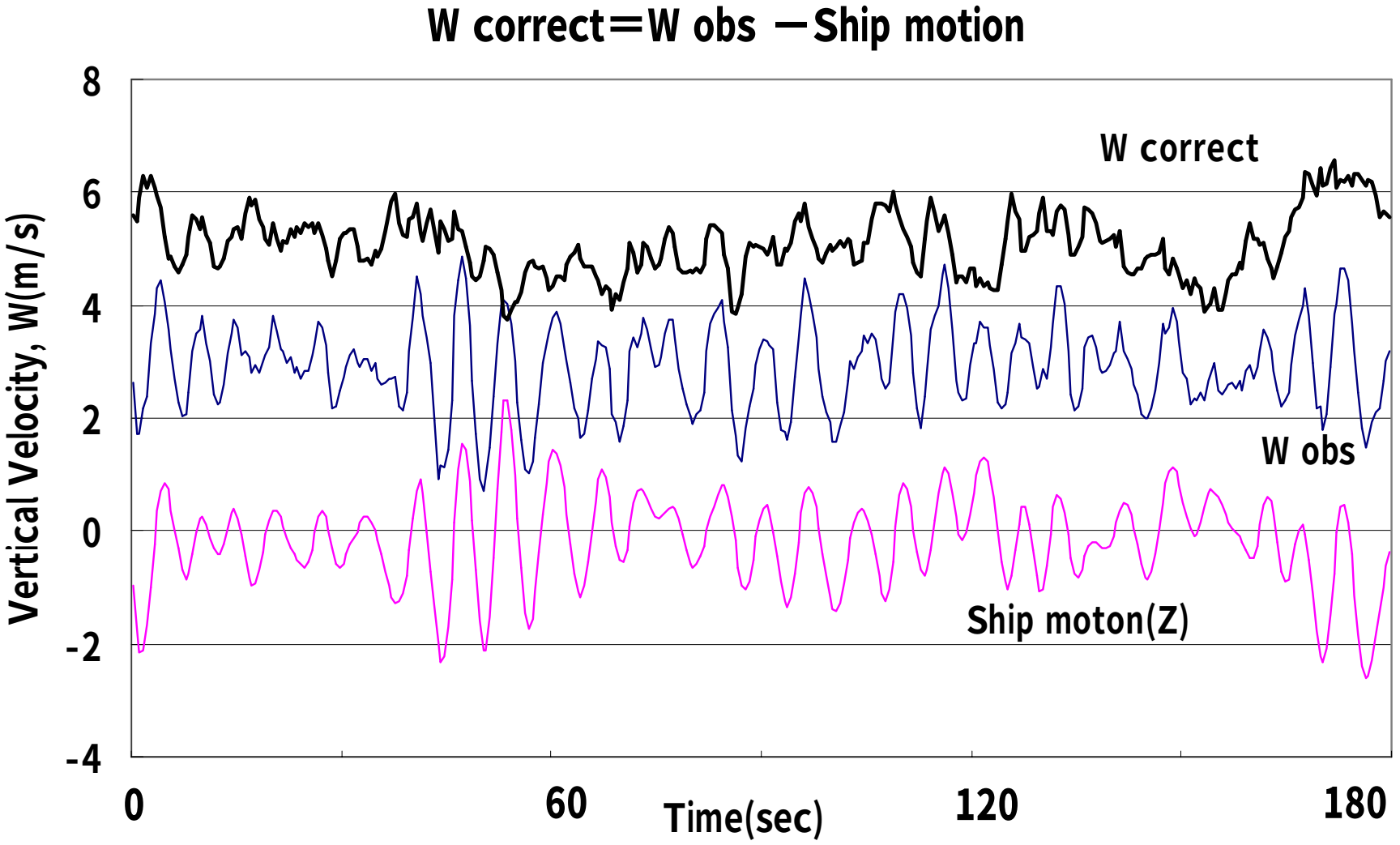
$$Vso = \int A\,dt$$

Time integration

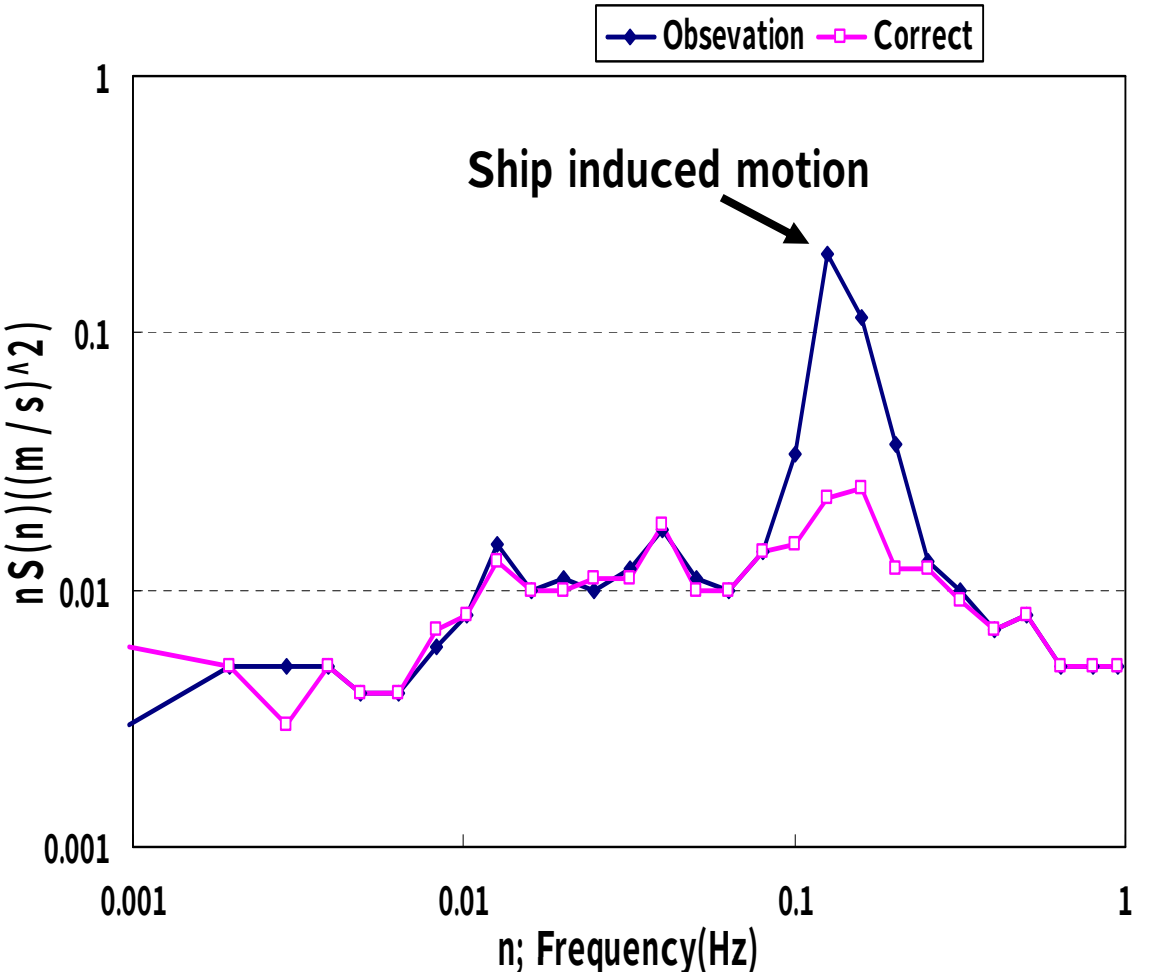
A : 3-axis accelerations



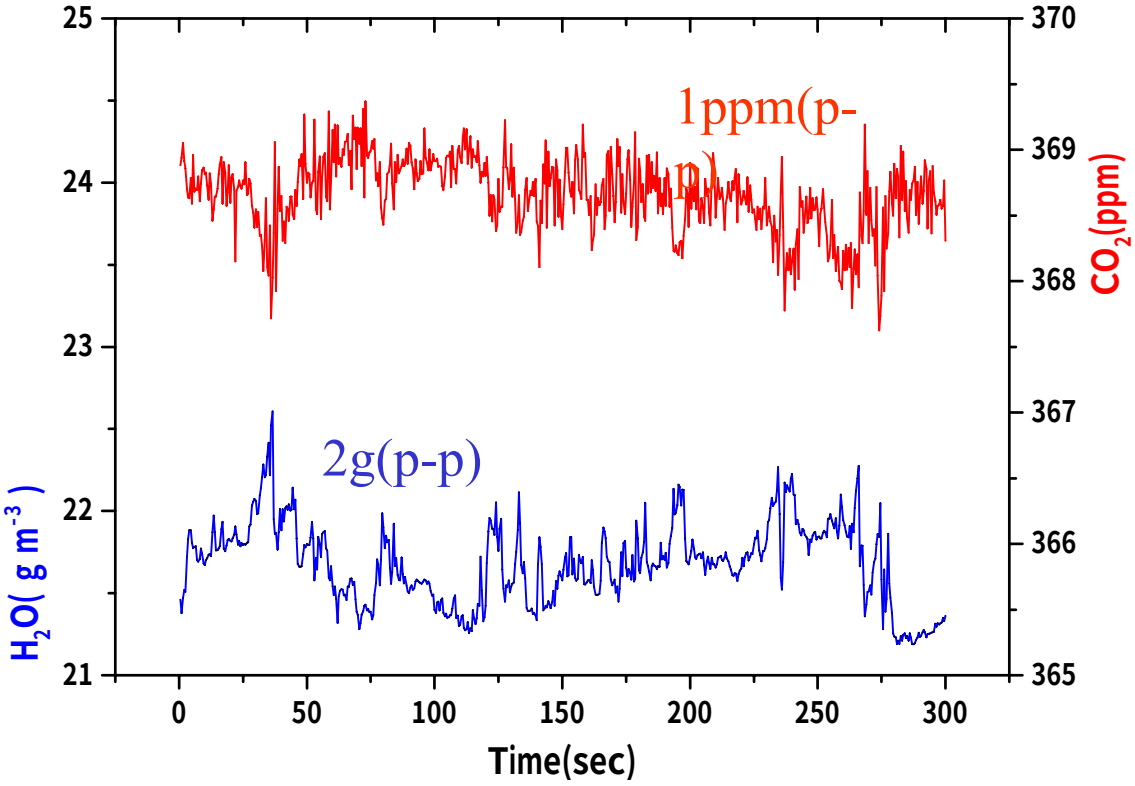
ship motion correction(time series)



Ship motion correction(Power Spectrum of w)

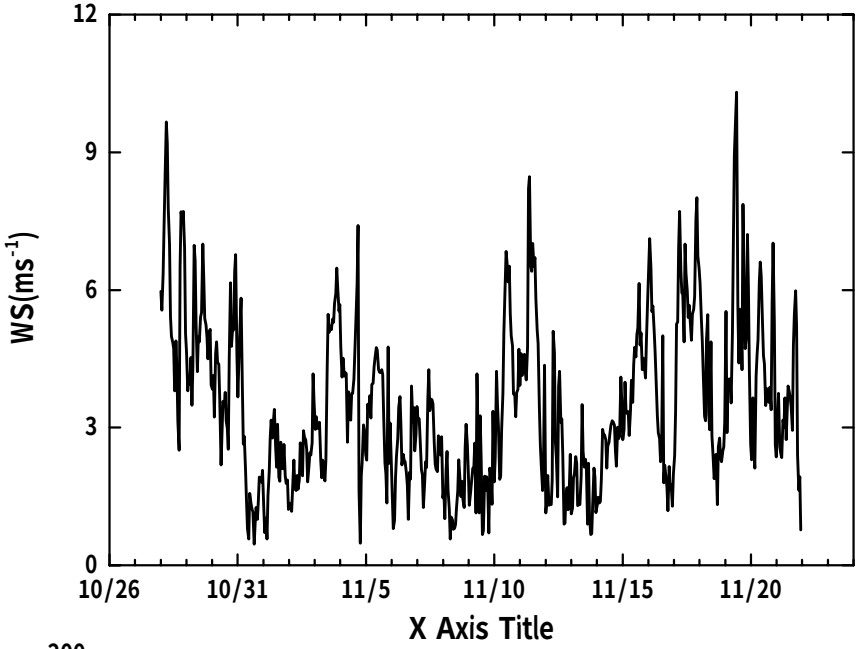


ship motion period of 10s

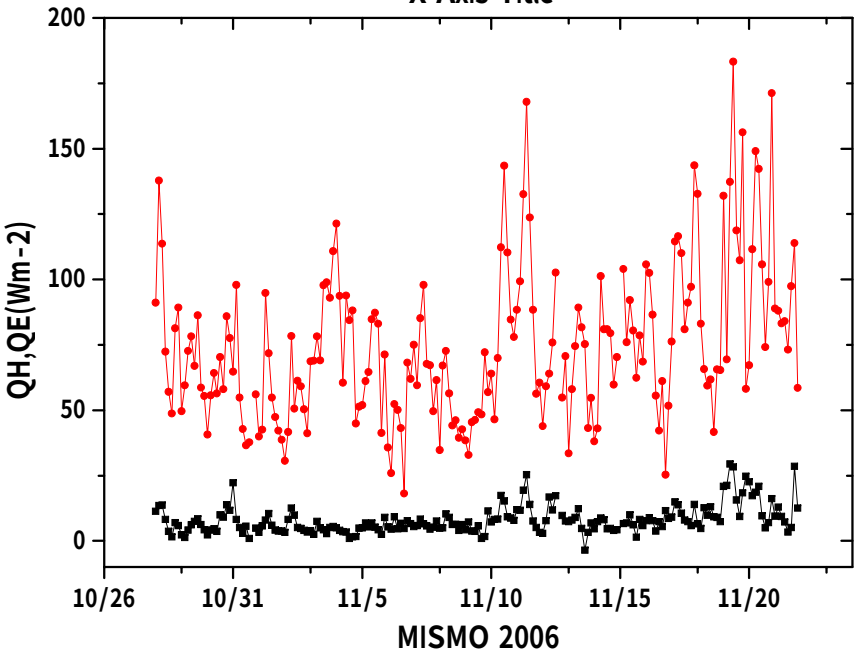


Open-path CO_2 analyzer(LI-7500) mounted on R/V MIRAI

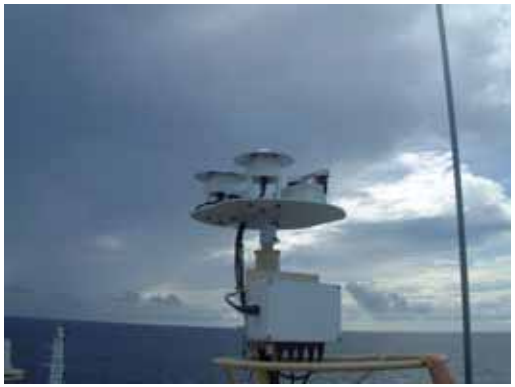
Wind speed



Eddy fluxes
QH,QE



Bulk Flux Algorithm



- ***INPUT***

  MIRAI SOAR data

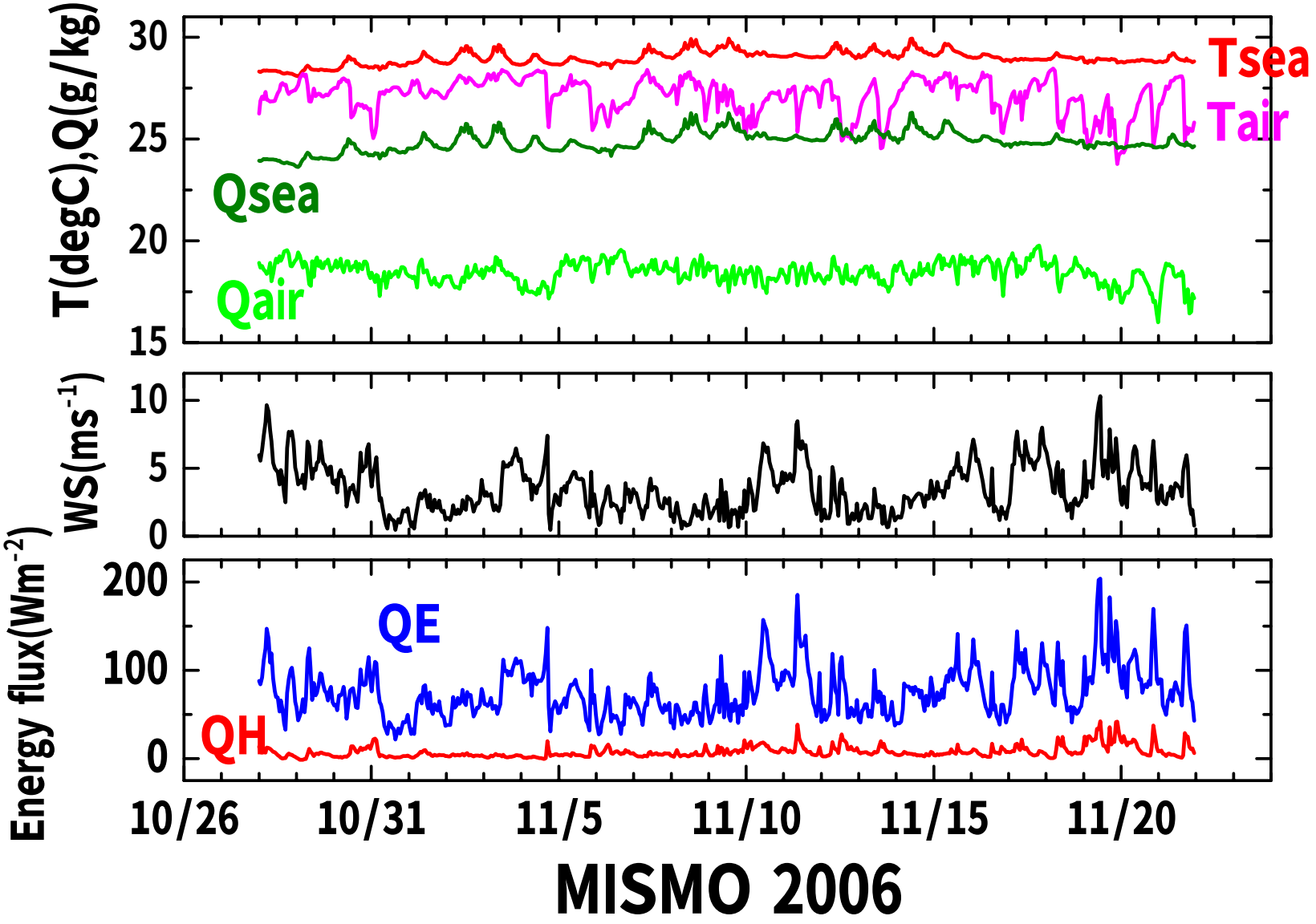
  WS, Tair, RH,intake SST, SR,LR,rain

- ***OUTPUT***

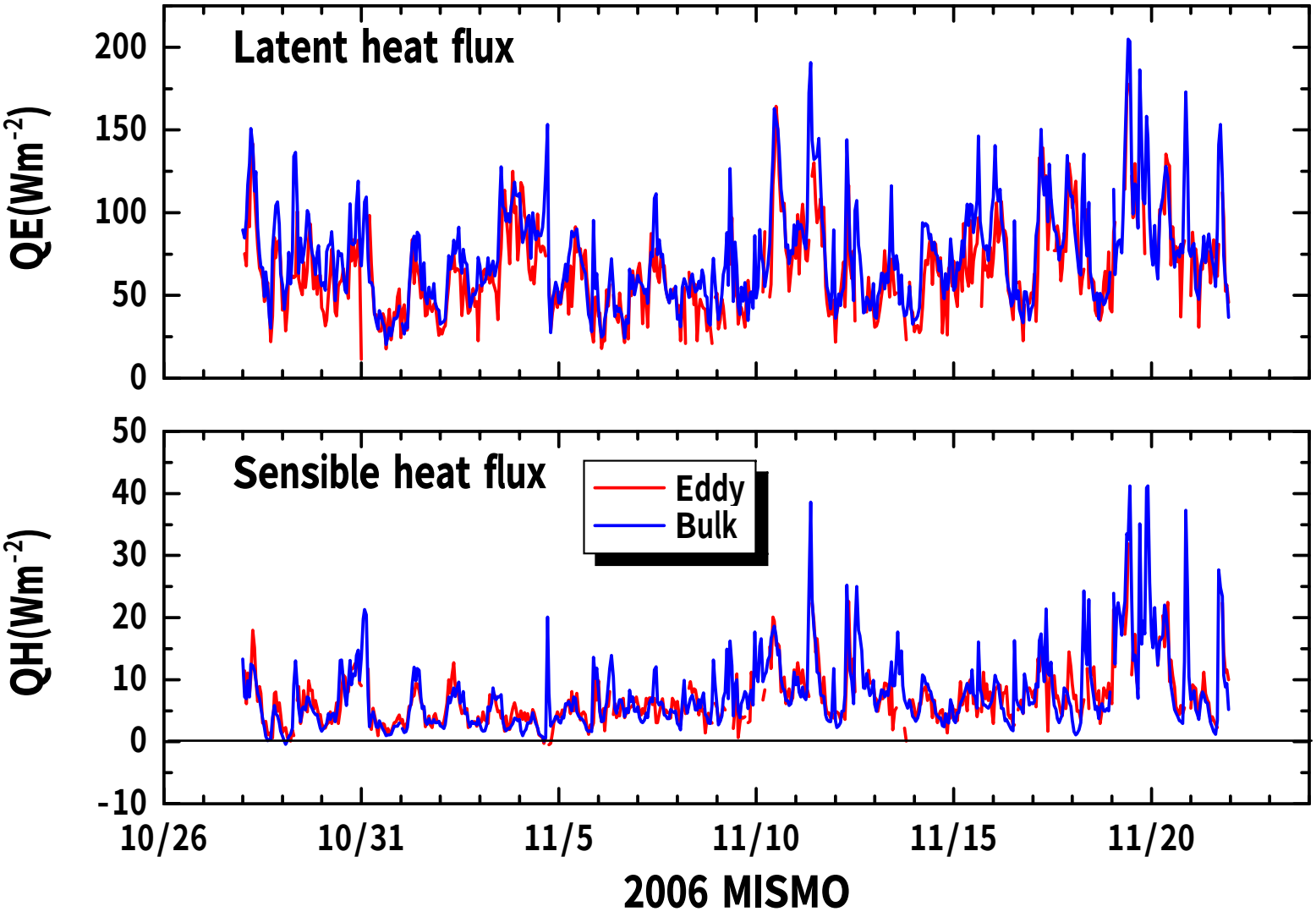
  flux: momentum, sensible heat, latent heat

  SSST (Sea surface Skin Temperature) including surface warming & cooling

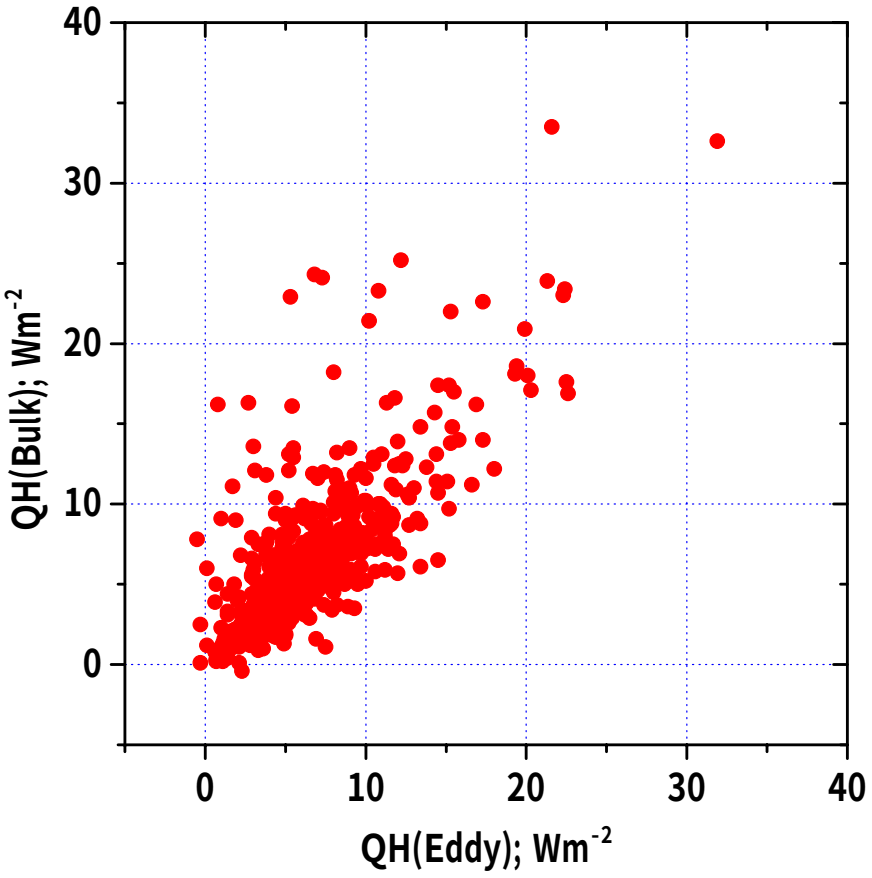
Bulk parameters & fluxes



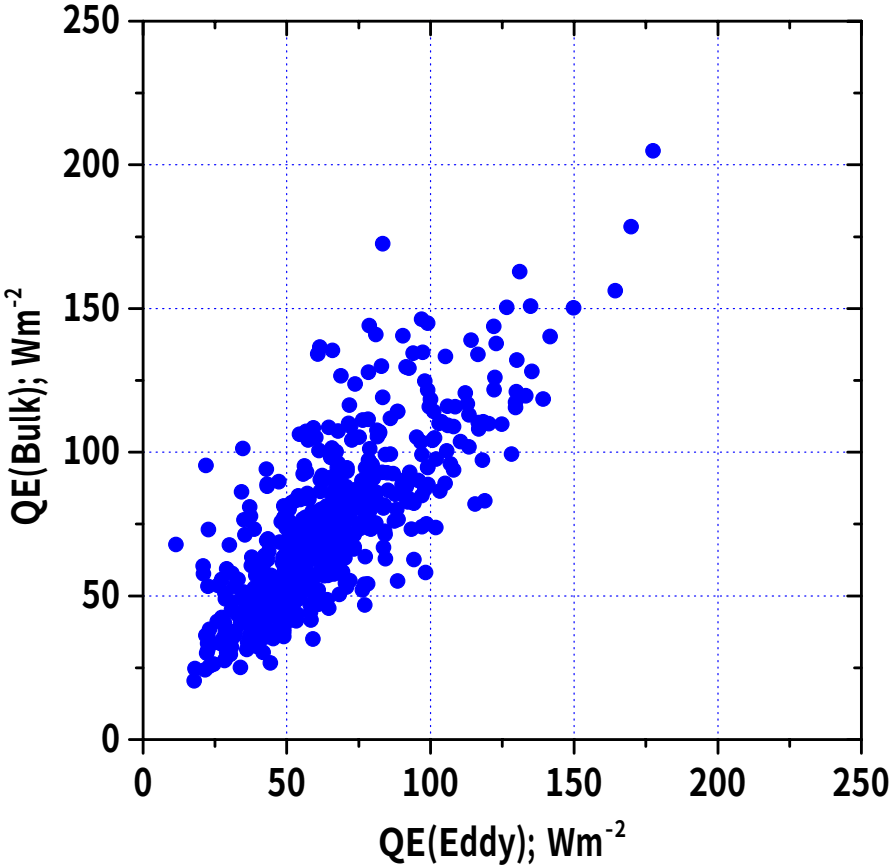
Eddy/Bulk Fluxes (Time series)



Bulk/Eddy Fluxes (scatter)

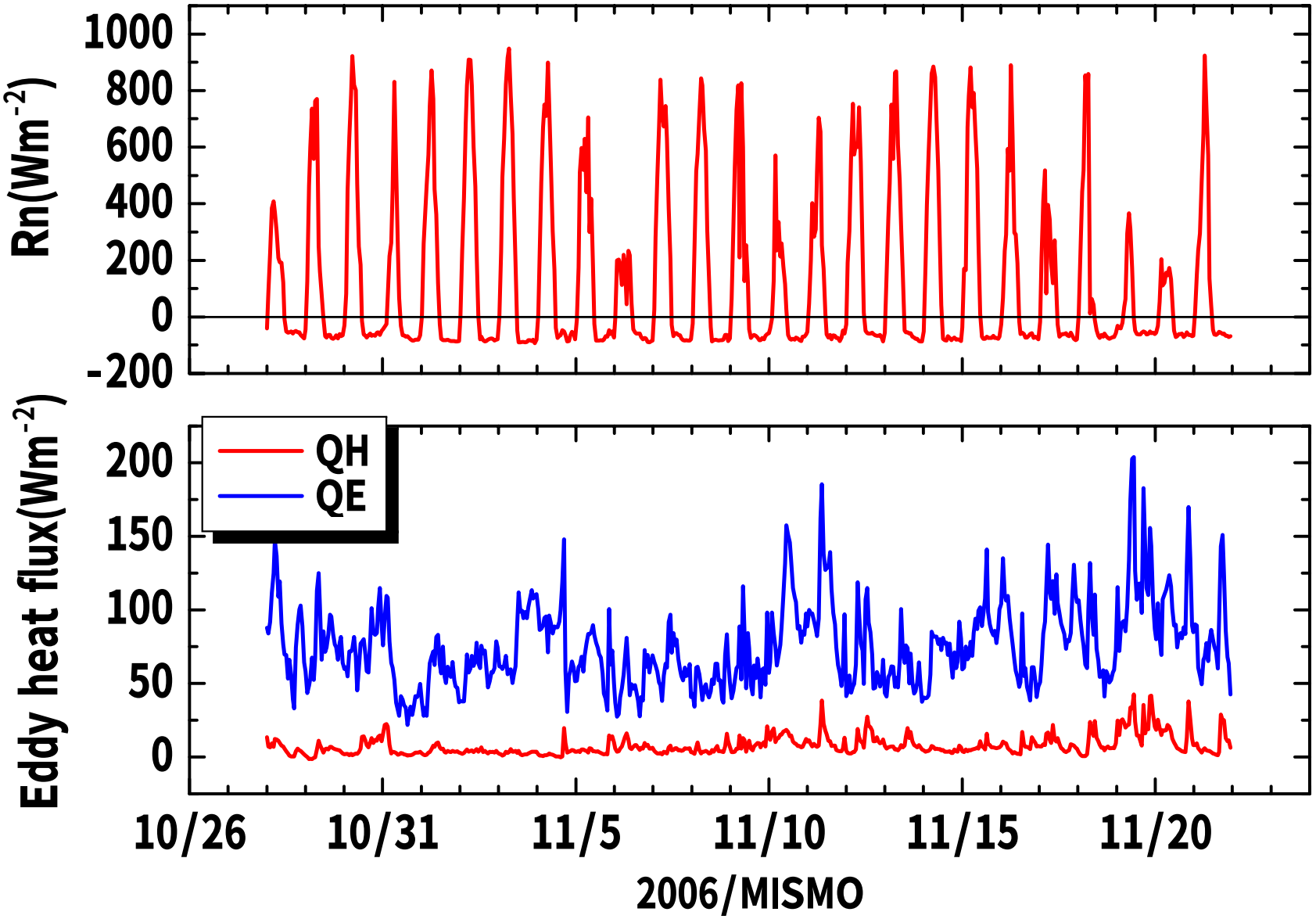


Sensible Heat Flux

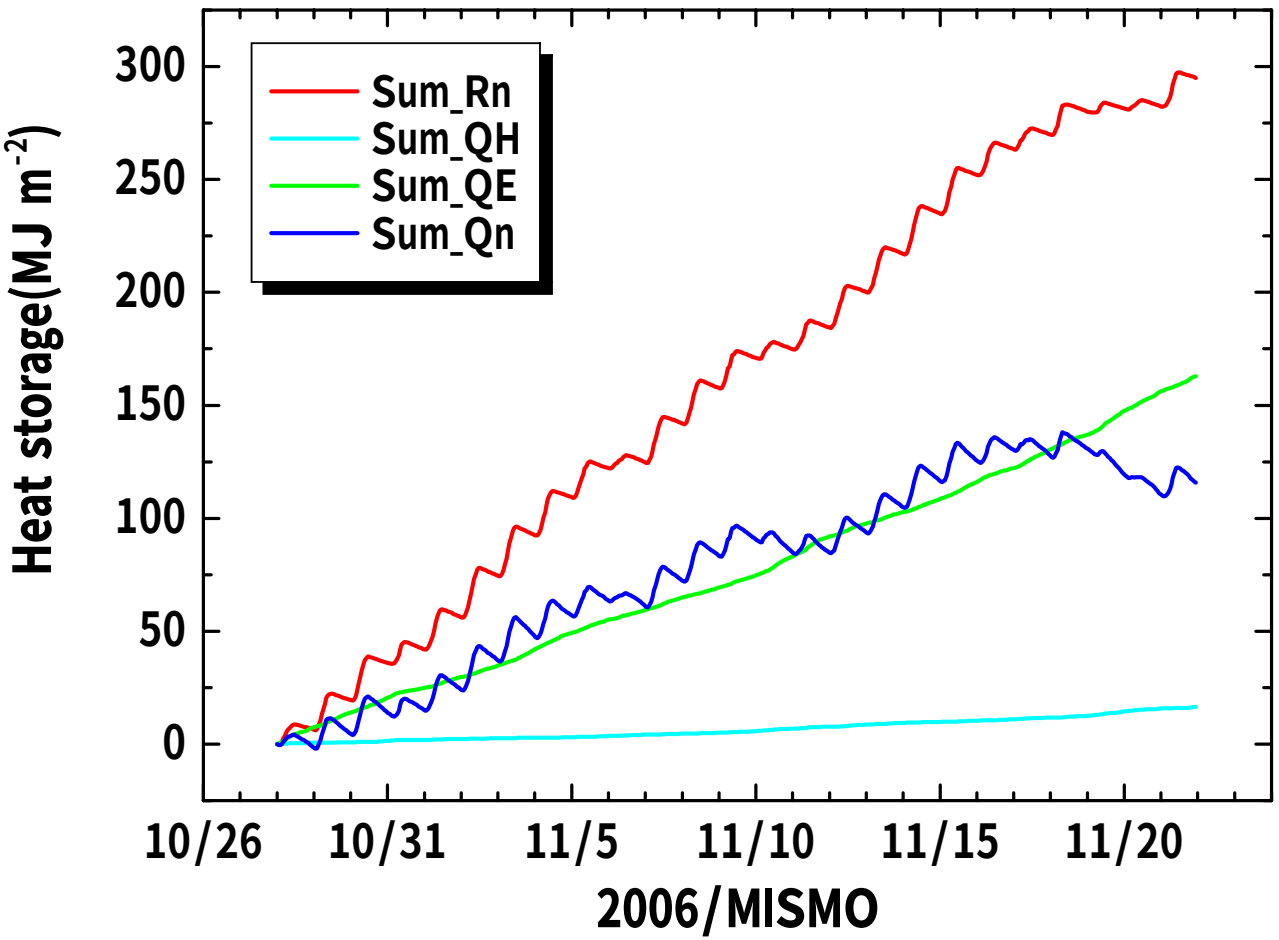


Latent Heat Flux

Sea surface heat budget



Integrated Heat Flux
Qn=Rn-QH-QE

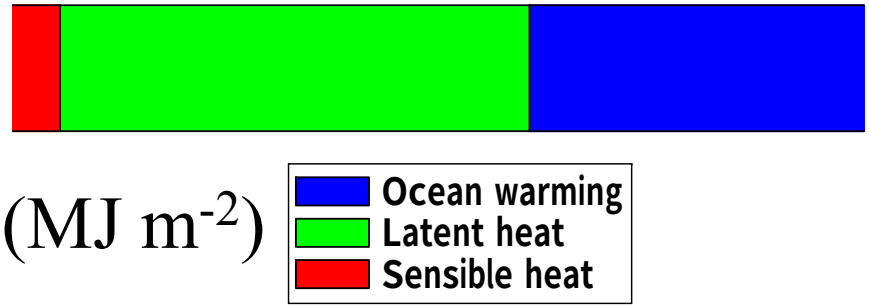


- ∑Qn
- 0.35C Tup through 100m mixing layer
- ∑QE
- 64mm water
- 3mm/day Evaporation

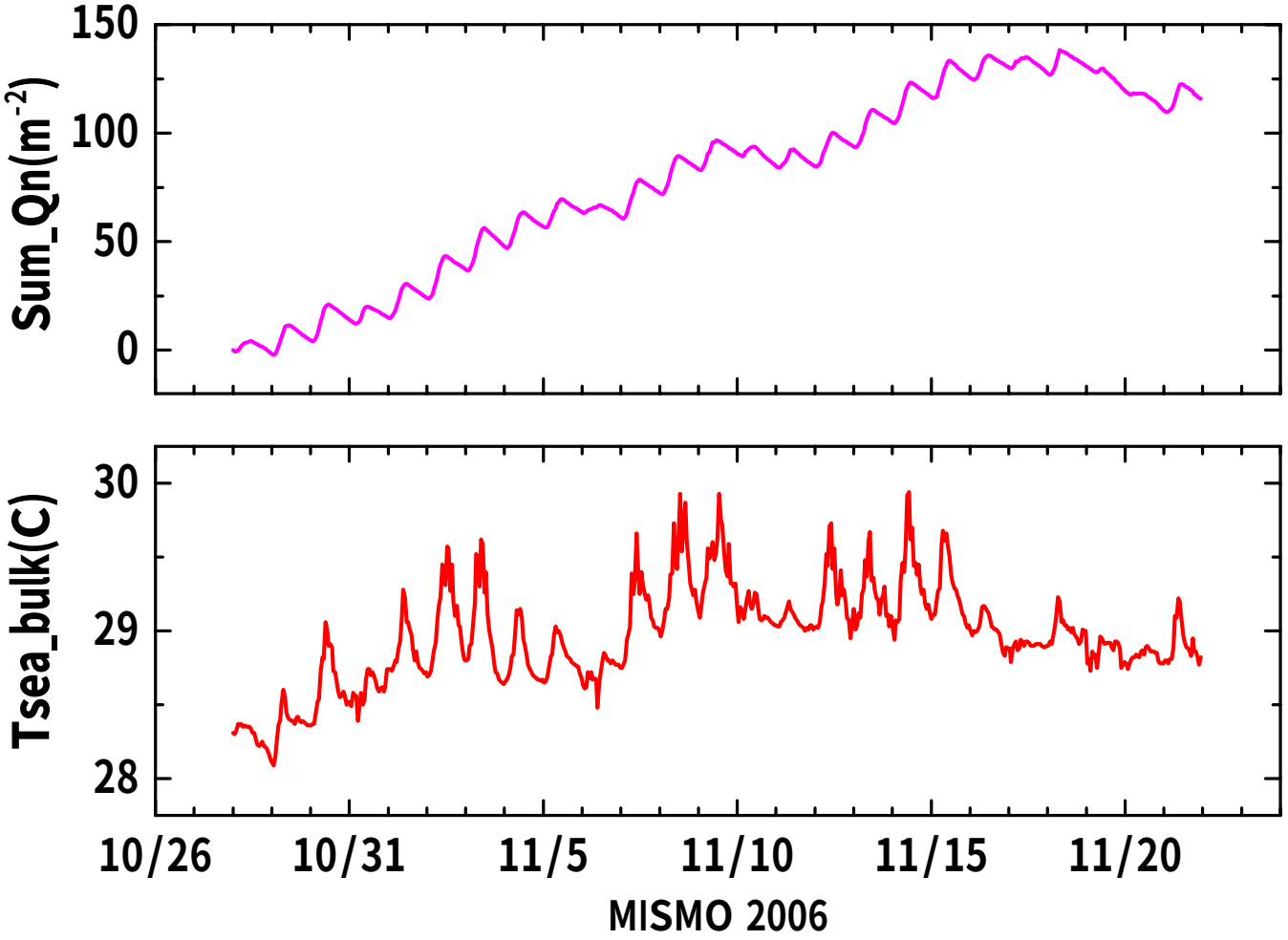
Sea Surface Heat Budget

- Net radiation;Rn
- Surface eddy/bulk fluxes;QH,QE
- Net ocean warming;Qn

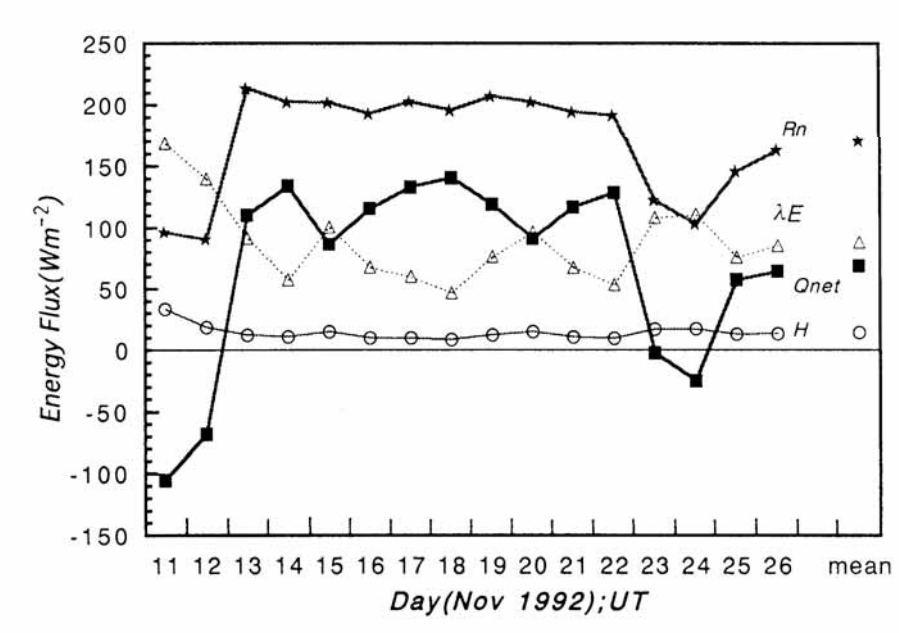
- Rn =QH + QE + Qn
- 294 =16 + 163 + 116 (MJ m^{-2})
- 100%=6% + 55% + 39%

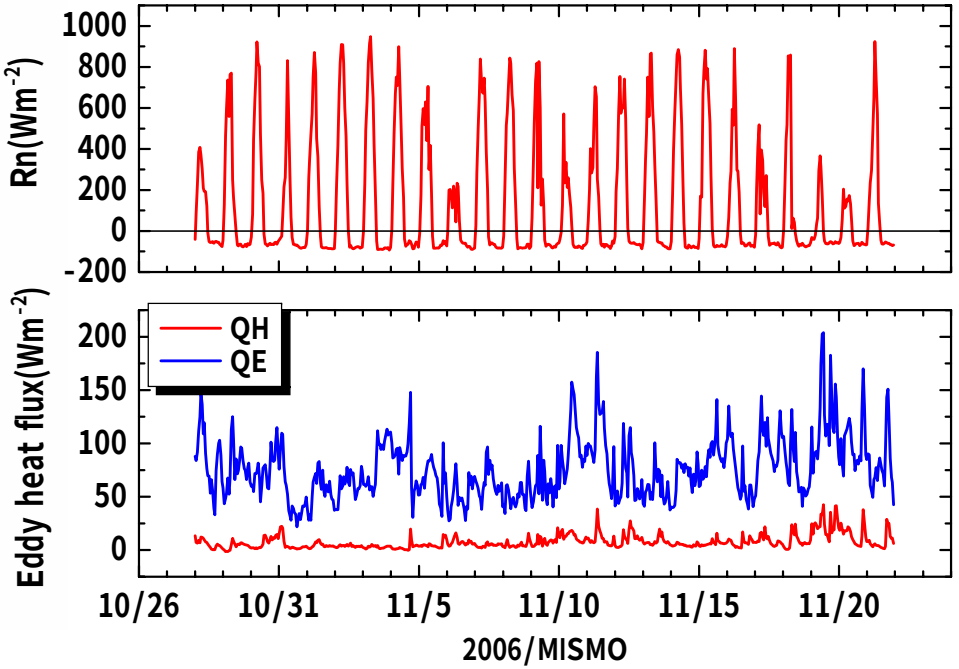


Ocean Warming



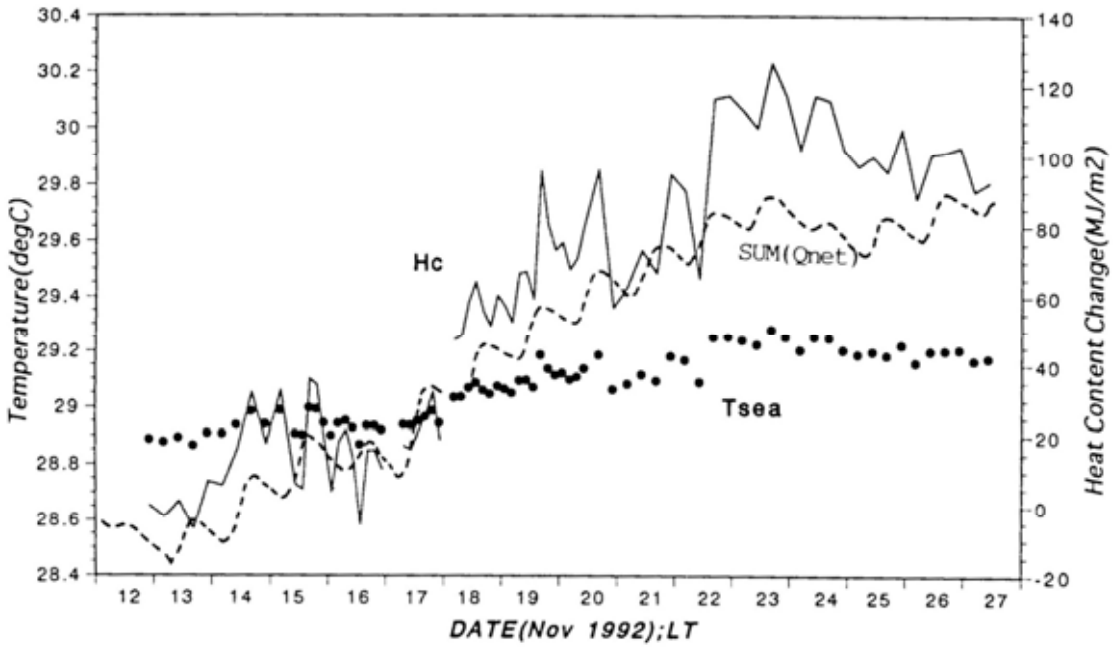
TOGA-COARE MISMO

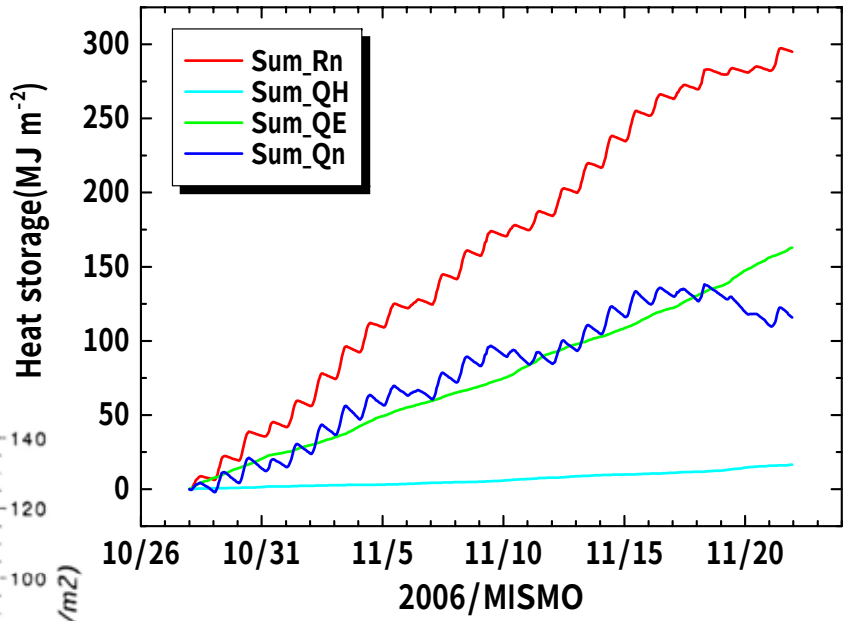




TOGA-COARE MISMO

14days





25days

Summary

Air-sea energy fluxes with on-board eddy-covariance system during MISMO

- On-board eddy-covariance measurement
- Bulk flux / Eddy flux
- Surface heat budget
- Ocean Warming
- Contrast between TOGA-COARE