Estimation of Satellite-derived turbulent heat flux and use of in-situ observation

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Contents

- *Overview of Satellite-derived turbulent heat flux*
- *Use of high-resolution in-situ observation*

How to estimate turbulent heat flux

directly method
bulk method

How to estimate turbulent heat flux

Direct method (ex. Eddy correlation)

$$LHF = \rho\, L\, [w'q'] \qquad SHF = \rho\, Cp\, [w'T']$$

Most accurate flux

Hard Observation

Bulk method

$$LHF = \rho\, L\, Ce\, U\, (qs - q)$$

$$SHF = \rho\, Cp\, Ch\, U\, (Ts - T)$$

Easy observation

Uncertainty of bulk coef.

LHF: Latent Heat Flux
SHF: Sensible Heat Flux
w: vertical wind speed
U: scalar horizontal wind
q: air specific humidity
T: air temperature
qs: saturate specific
Ts: sea surface temperature
ρ : air density
L : latent heat of water
Cp : specific heat of air
Ce: bulk transfer coef. for LHF
Ch: bulk transfer coef. for SHF

How to estimate turbulent heat flux

Direct flux measurement（Eddy correlation)

We can not apply "Eddy correlation method" for satellite observation.

Most accurate flux

Hard Observation

Bulk method

$$LHF = \rho\ L\ Ce\ U\ (qs - q)$$

$$SHF = \rho\ Cp\ Ch\ U\ (Ts - T)$$

Easy observation

Uncertainty of bulk coef.

LHF: Latent Heat Flux
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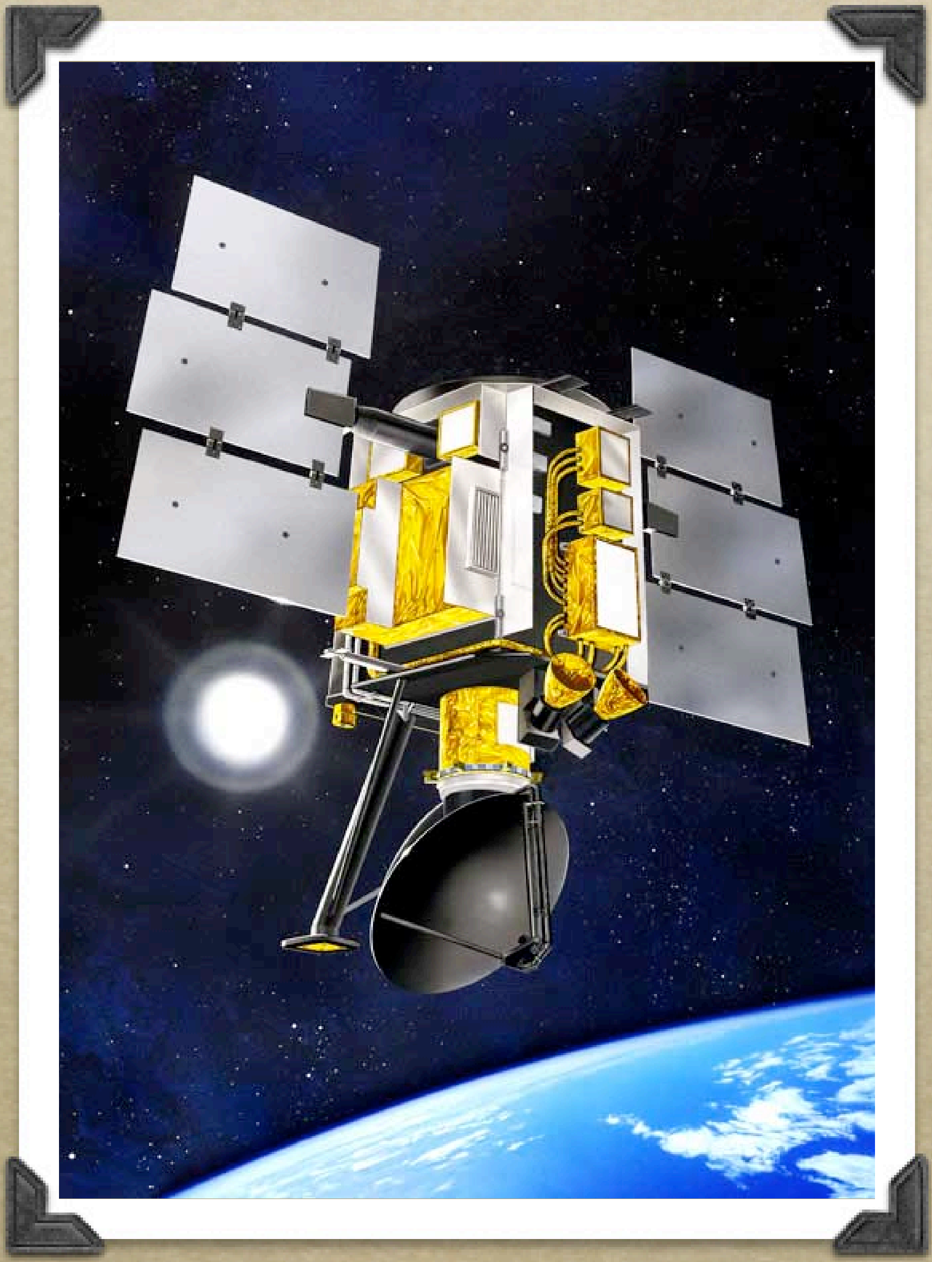
How to estimate bulk parameters

Microwave Radiometer
Microwave Scatterometer
Infrared Radiometer



Estimation of bulk parameters

U: Wind Speed

Microwave radiometer (SSMI, AMSR, TMI...etc)
Microwave scatterometer (QuikSCAT, ERS)

q: Specific humidity

Microwave radiometer (SSMI, AMSR-E, TMI...etc)

Ts (qs): Sea surface temperature

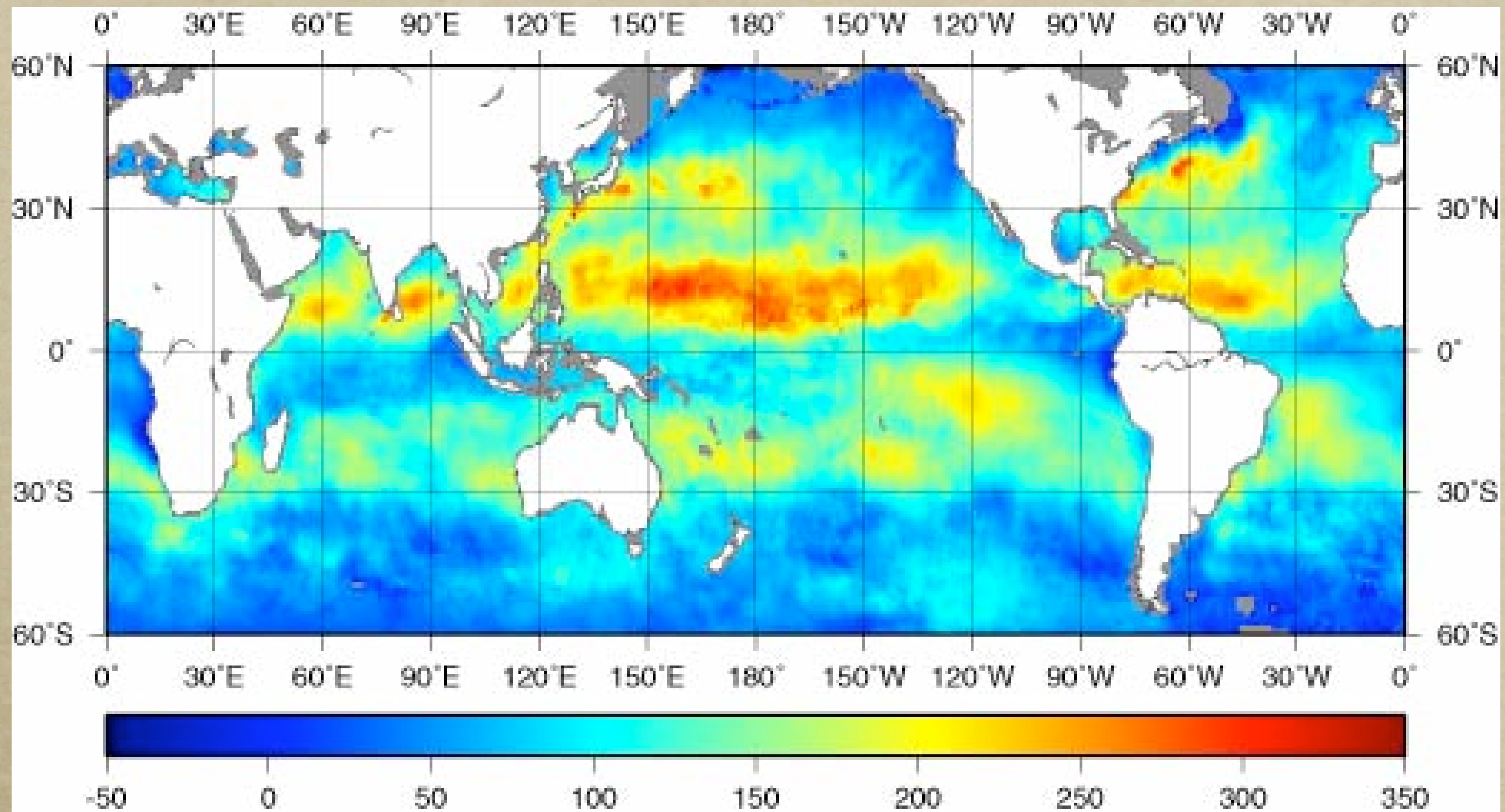
Infrared radiometer (AVHRR)
Microwave radiometer (SSMI, AMSR-E, TMI...etc)

Various satellite-derived turbulent heat flux

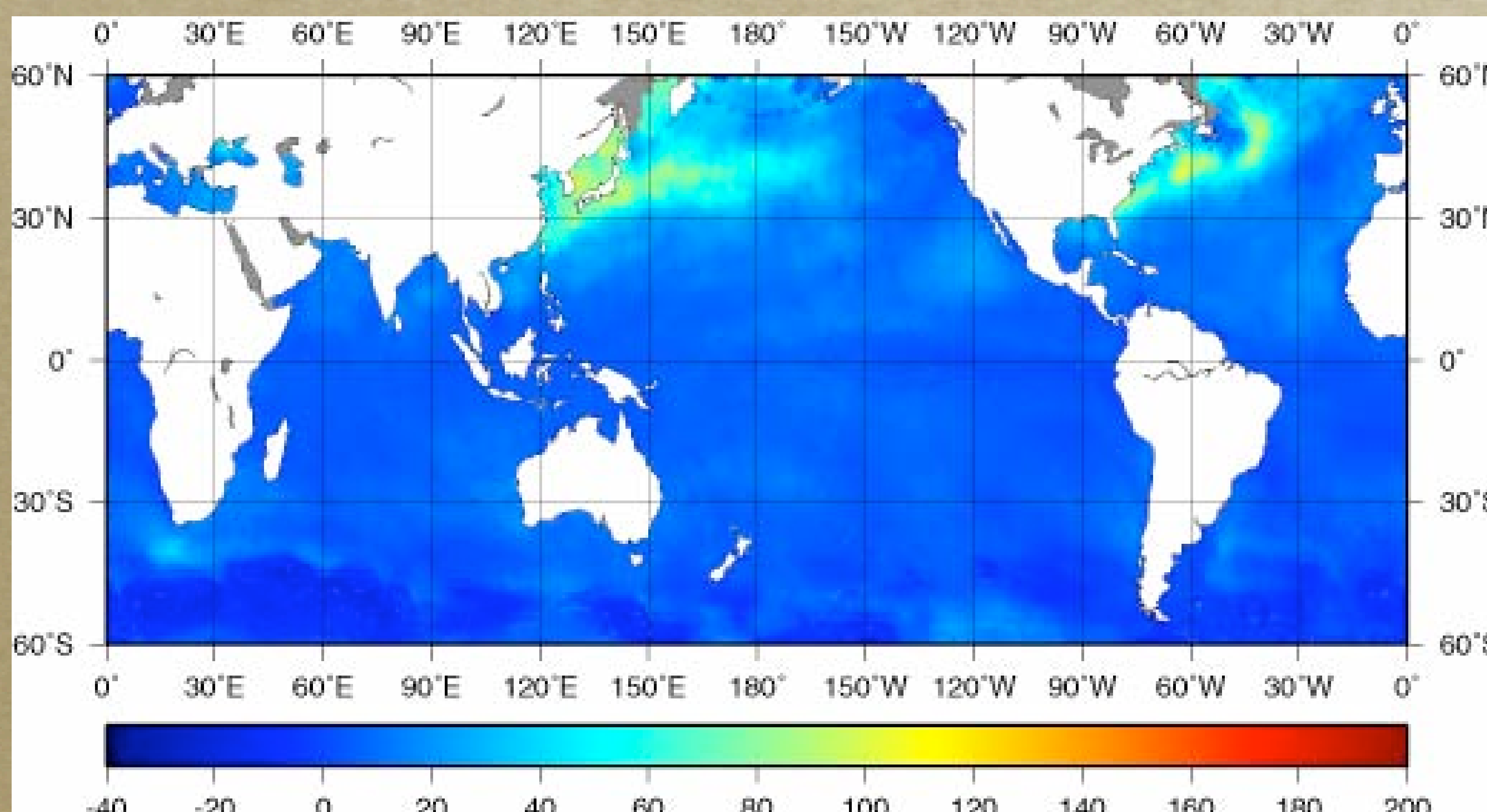
Data Sets	Grid size		Availability
	Spatial	Temporal	
GSSTF2	1 deg.	Daily	1988-2000
HOAPS2	0.25 deg.	Daily	1988-2000
J-OFURO	1 deg.	3 days	1992-2000

J-OFURO Turbulent Heat Flux (1992.01)

LHF (W/m^2)



SHF (W/m^2)



Various surface turbulent heat flux data sets

In-situ observation

daSilva, SOC

AGCM and data assimilation

NCEP/NCAR Reanalysis (NRA)
ECMWF Reanalysis (ERA)
Japanese Reanalysis (JRA25)

Others

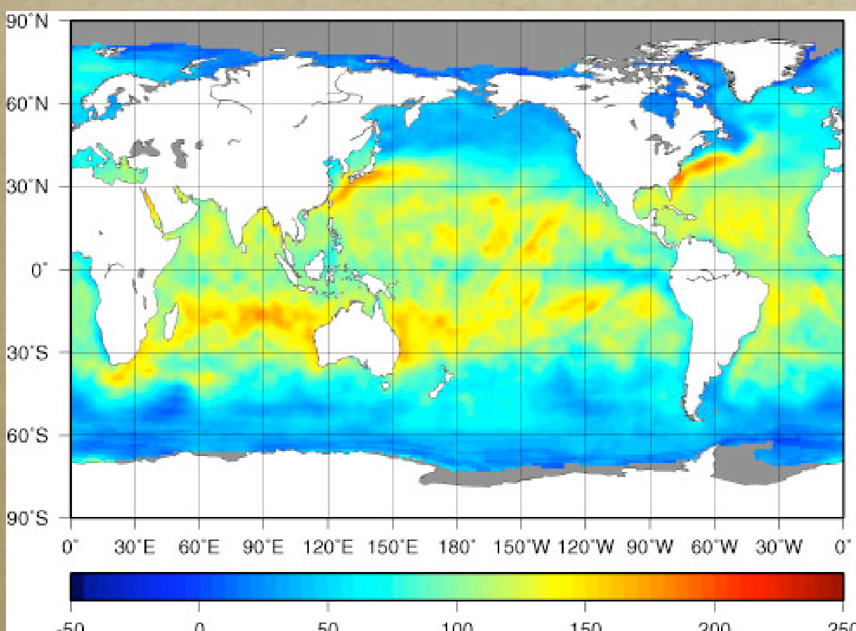
WHOI OAFlux (Yu et al. 2004)

Various global turbulent heat flux

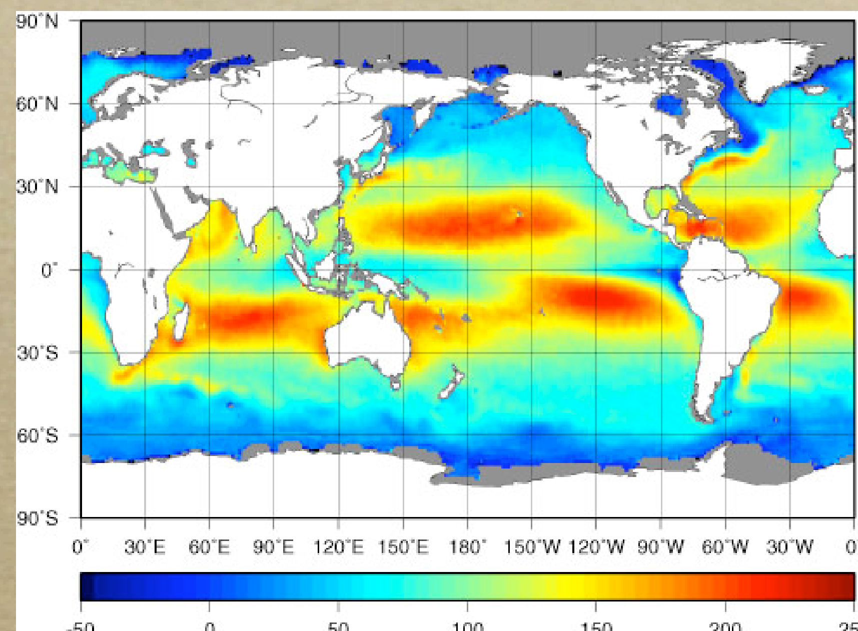
Data Sets	Souurce	Grid size		Availability
		Spatial	Temporal	
DaSilva	in situ	1 deg.	Monthly	1945-1993
SOC				1980-1993
NRA1	Reanalysis	T62 gaussian	6 hourly	1948-2003
NRA2				1948-2003
ERA15		1.125 deg.		1979-1993
ERA40				1979-2001
GSSTF1	Satellite	1 deg.	Daily	1988-2000
GSSTF2				1988-2000
HOAPS1		0.5 deg		1992-1998
HOAPS2		0.25 deg.		1992-2001
J-OFURO		1 deg.	3 days	1992-2000

Inter-comparison

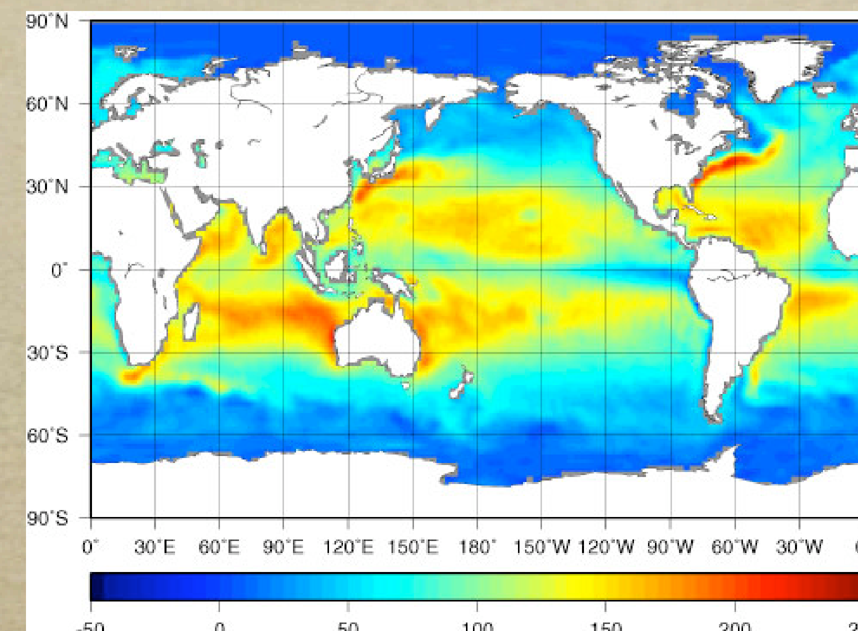
SOC(in-situ)



J-OFURO (satellite)

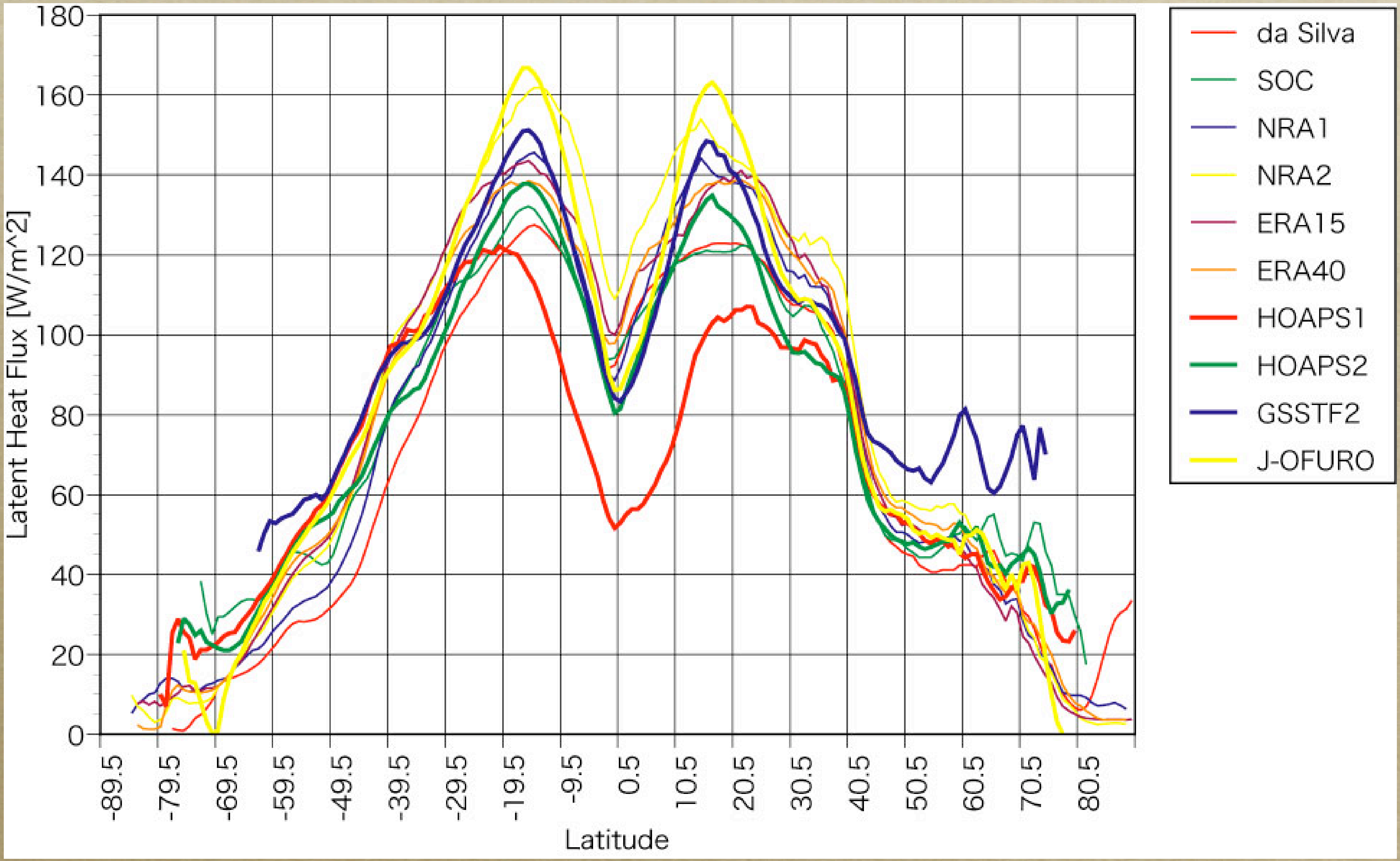


NRA1 (reanalysis)



Mean fields of latent heat flux during 1992-93

Inter-comparison



Zonally averaged latent heat flux for mean fields during 1992-93

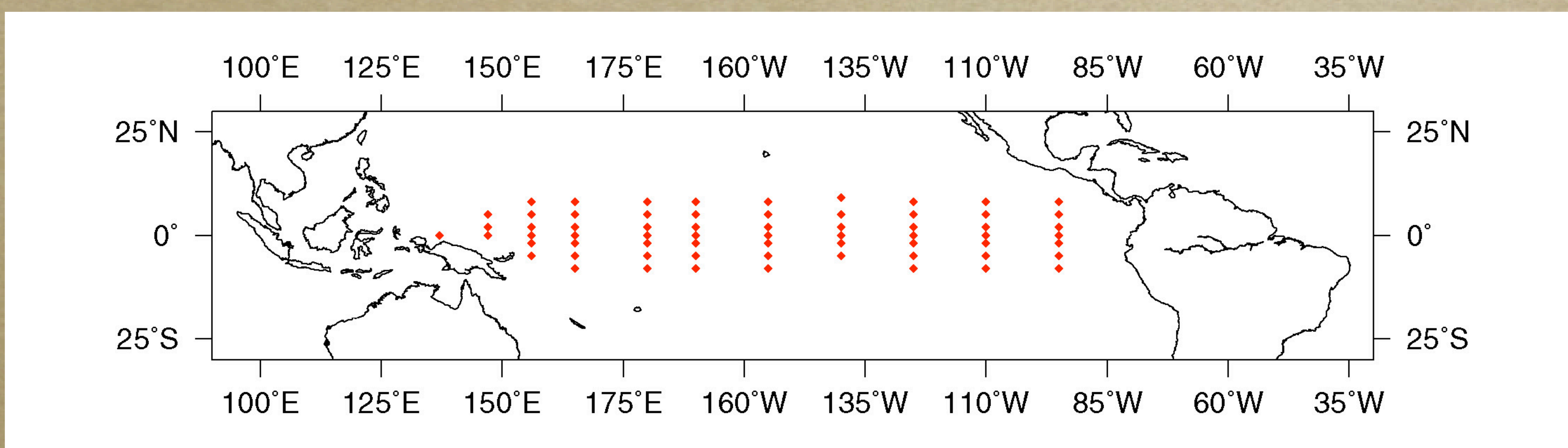
Accuracy

Comparison with moored buoy

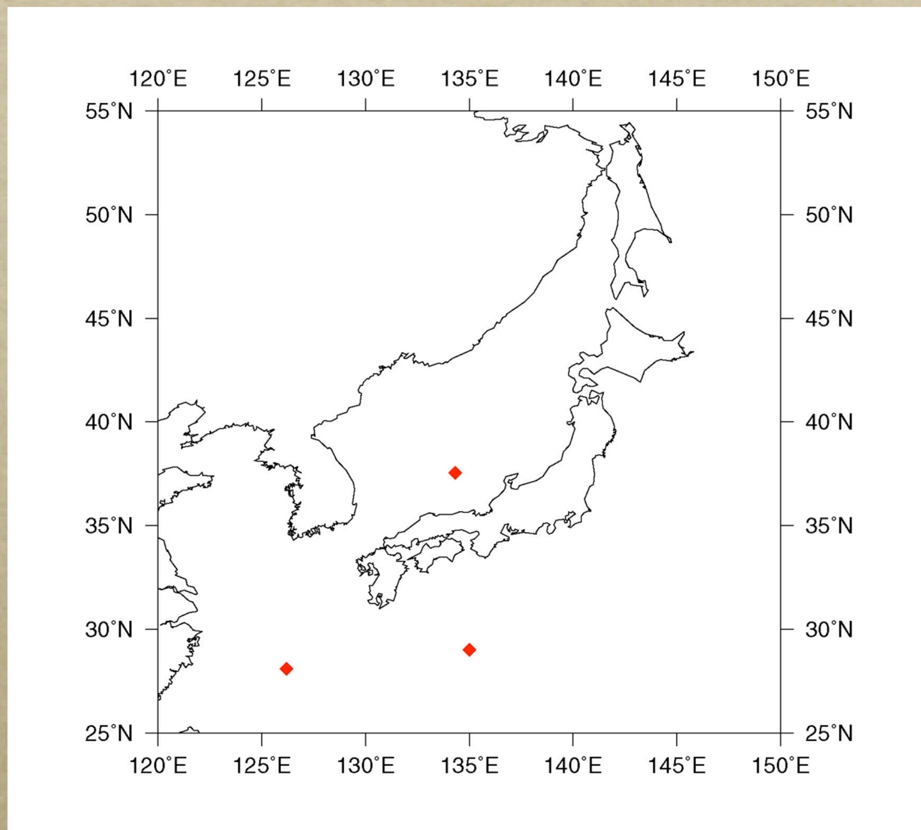
TAO/TRITON Buoys

65 buoys
every hour, 1992-2000
Wind Speed, Relative Humidity, SST

3 days mean
turbulent heat flux



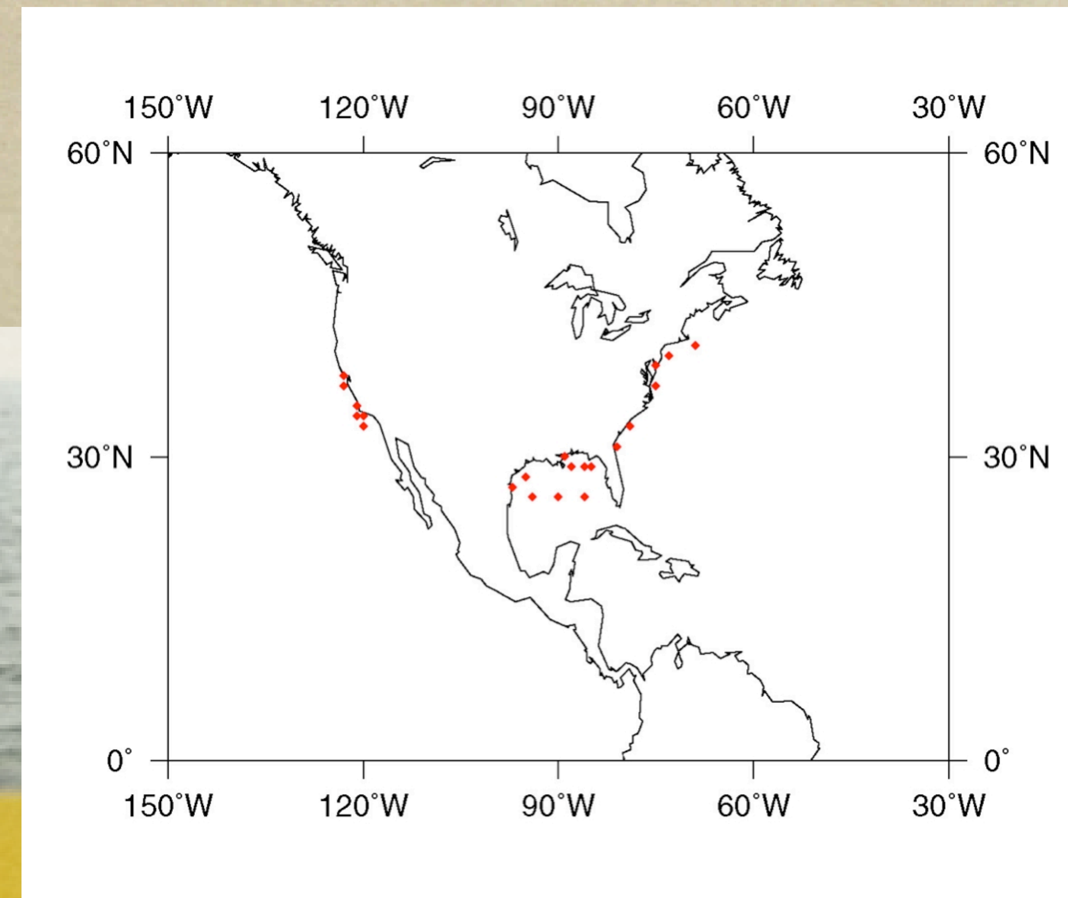
<u>JMA Buoys</u>

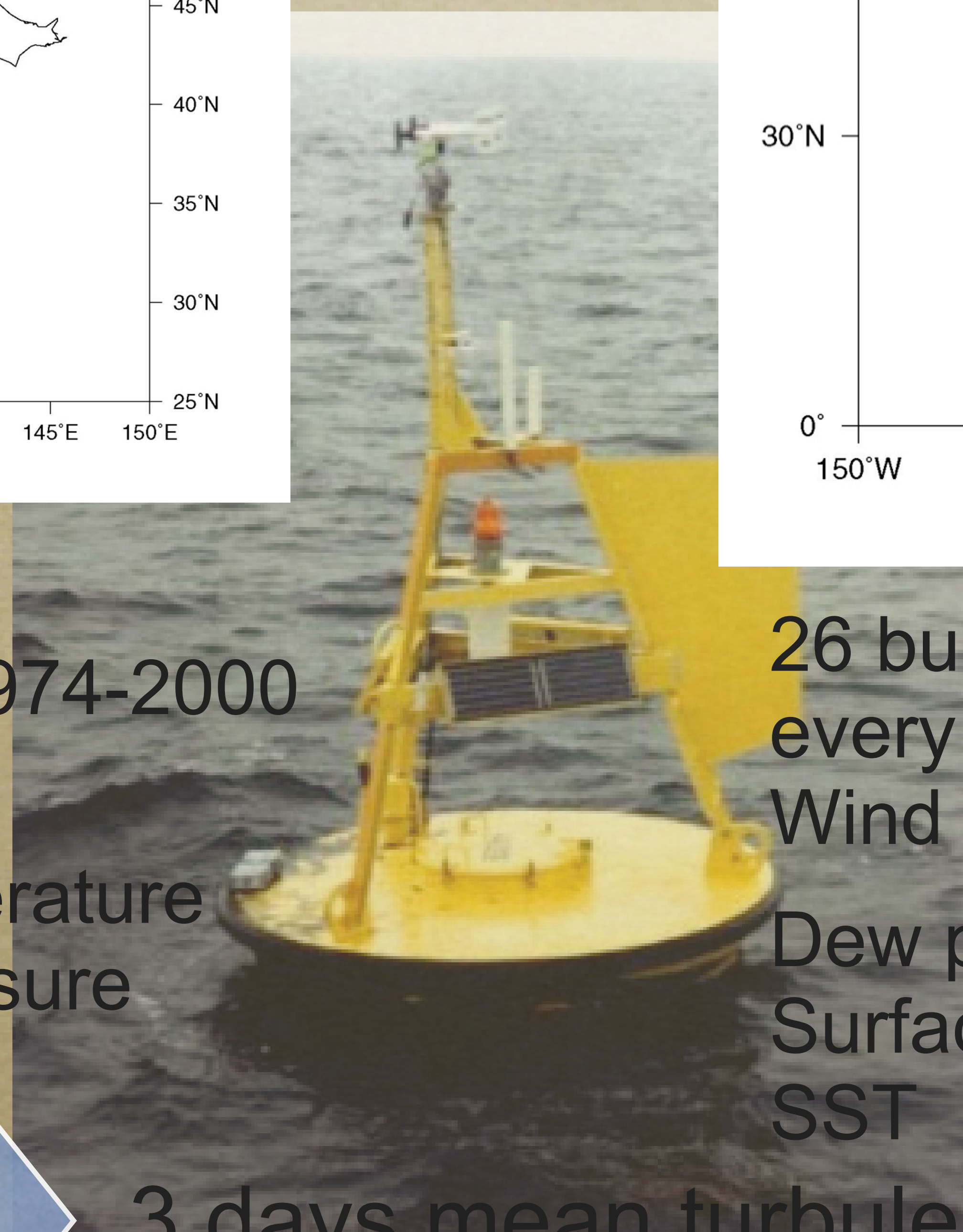


3 buoys
every 3 hours, 1974-2000

Wind Speed
Dew point temperature
Surface Air Pressure
SST

<u>NDBC Buoys</u>



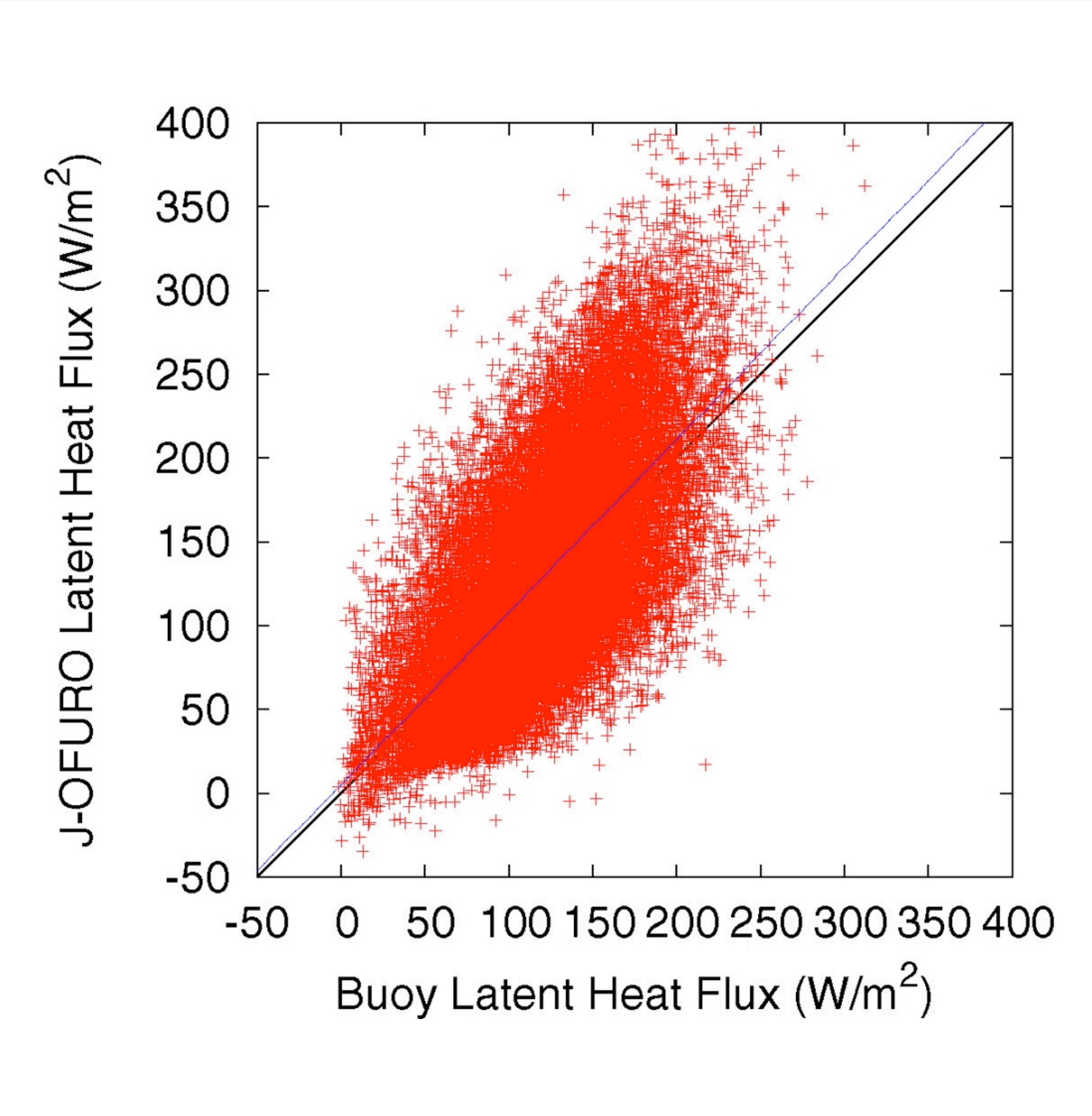


26 buoys
every hour, 1992-2000
Wind Speed,

Dew point temperature,
Surface Air Pressure,
SST

3 days mean turbulent heat flux

Accuracy of satellite derived LHF



J-OFURO vs Buoy

1992-2000
3 days mean

Bias	-8.54 W/m^2
RMS	49.43 W/m^2
RMSR	48.69 W/m^2
Corr.	*0.68*

Kuroshio Extension Observation buoy

NOAA PMEL

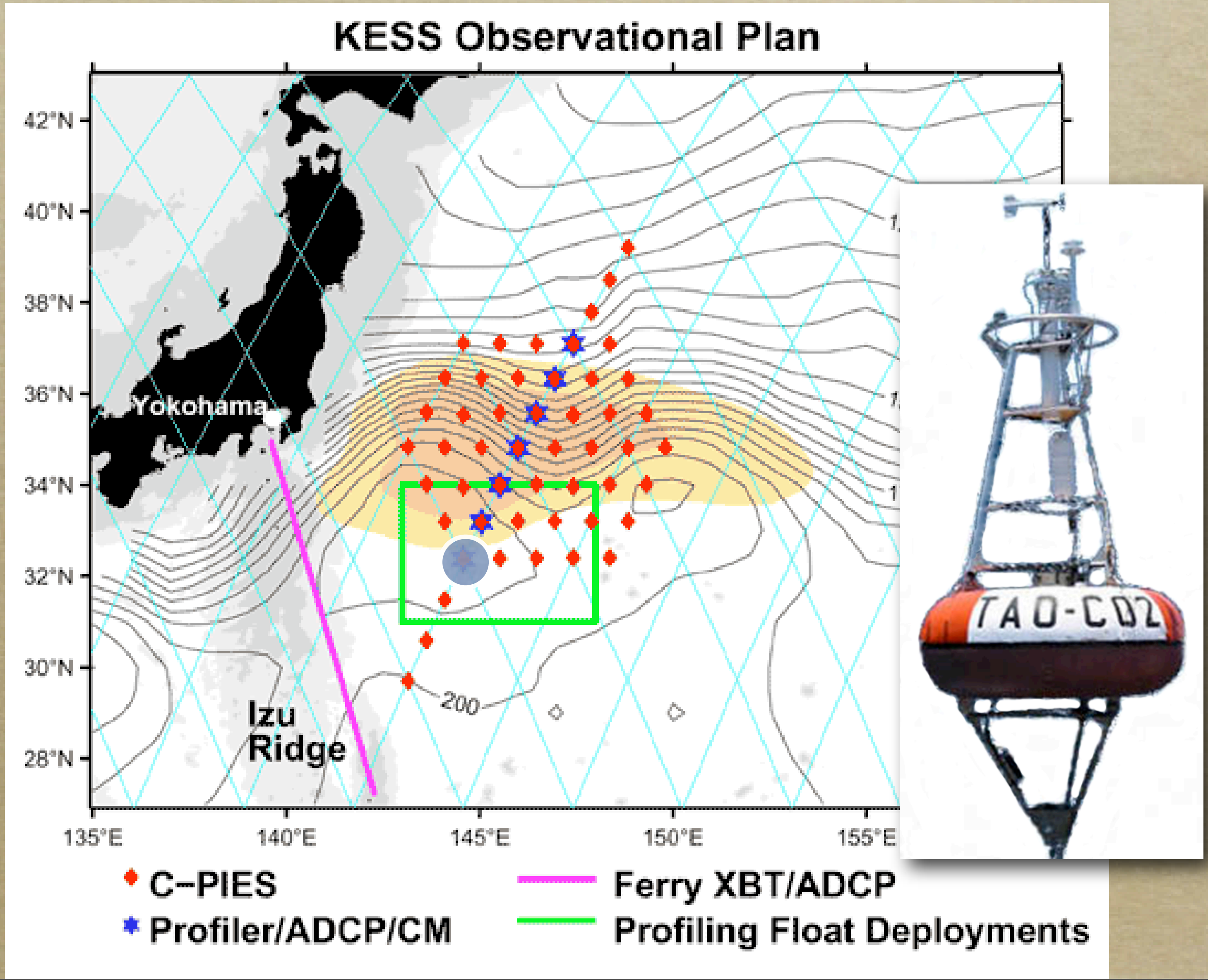
Location: 144.5E, 32.3N

2004.06.17～2005.10.xx

Surface Meteorological Parameters

Ts, Ta, RH, U, V

10 min average



Comparison with buoy flux during 2004

Pre-extended J-OFURO LHF

2004 (1year)

COARE 3.0 , Qa from Bentamy's mthod

vs

KEO buoy

KEO : 144.5E, 32.3N

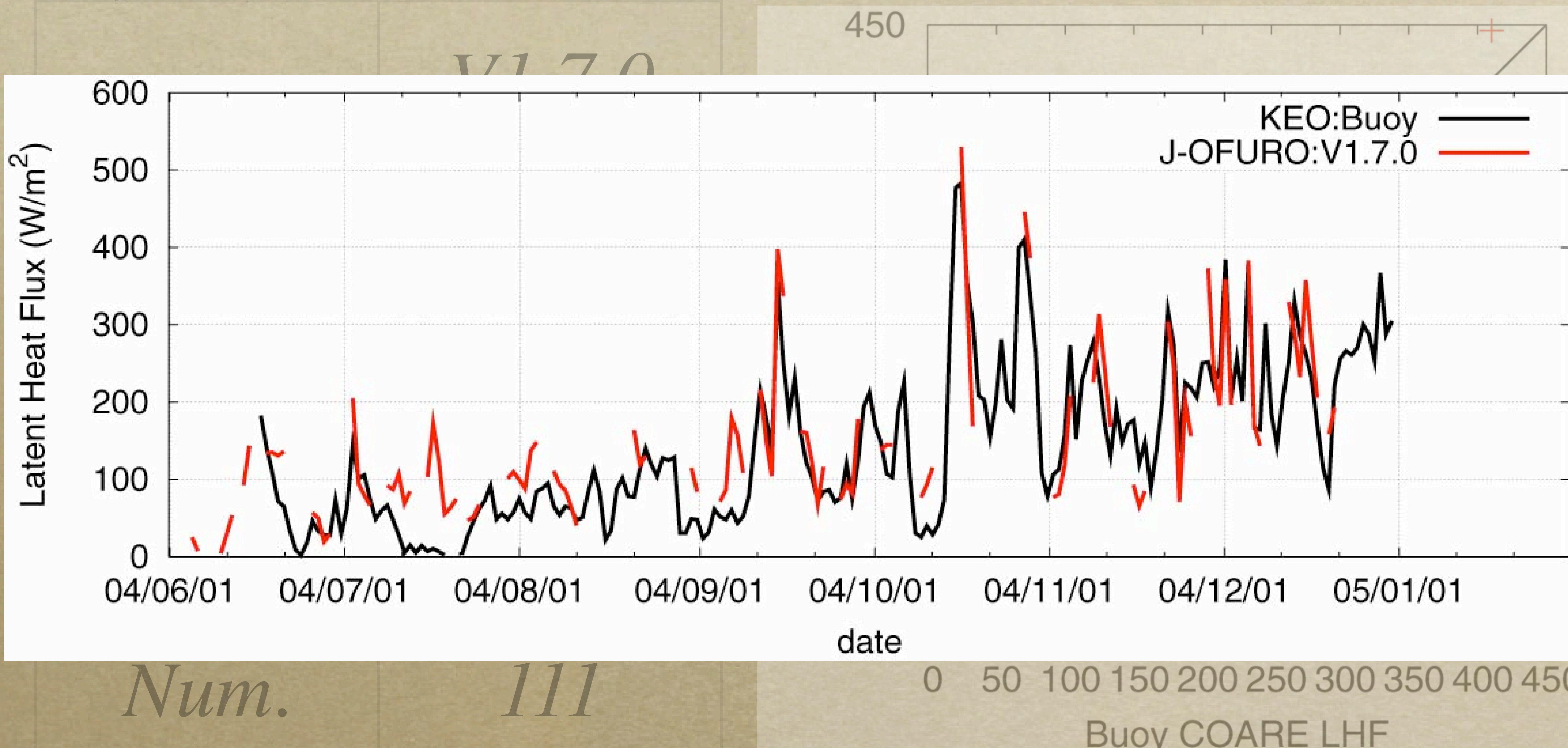
2004.06.17-12.31, 6 monts

TAO array: (50 buoys)

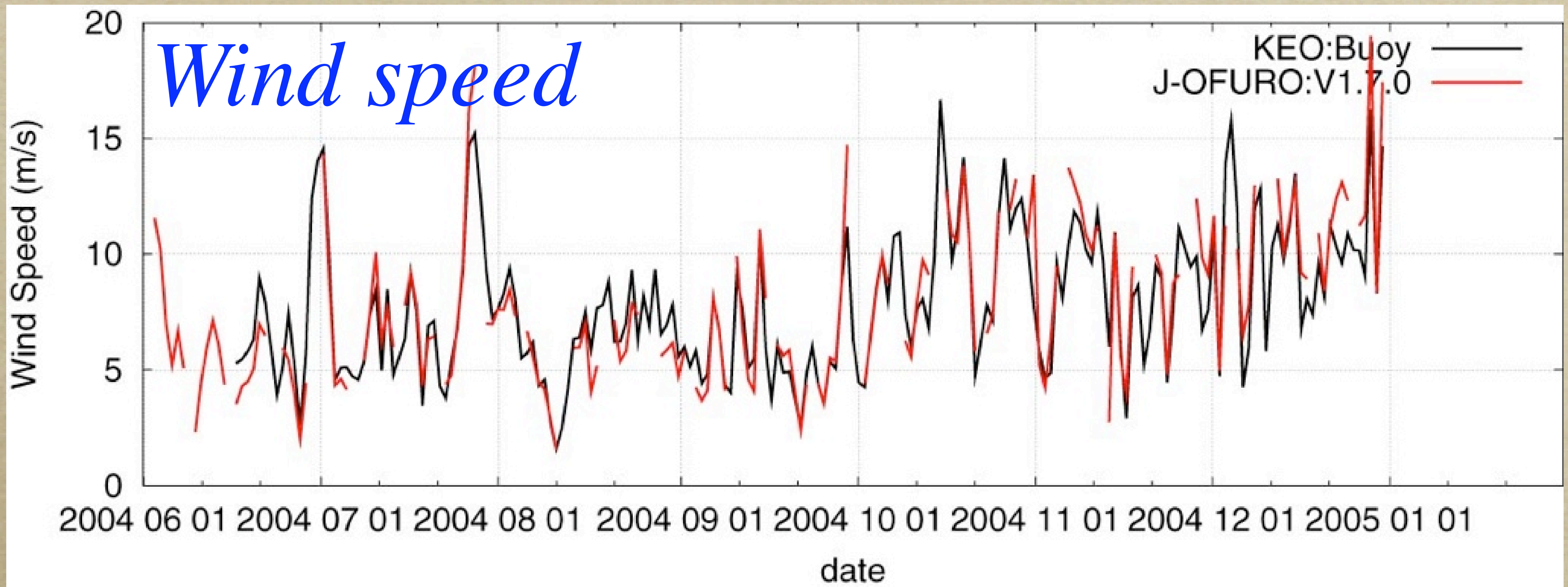
High resolution data (10min average) →*Daily mean*→ *LHF by COARE 3.0 without WL and CS*

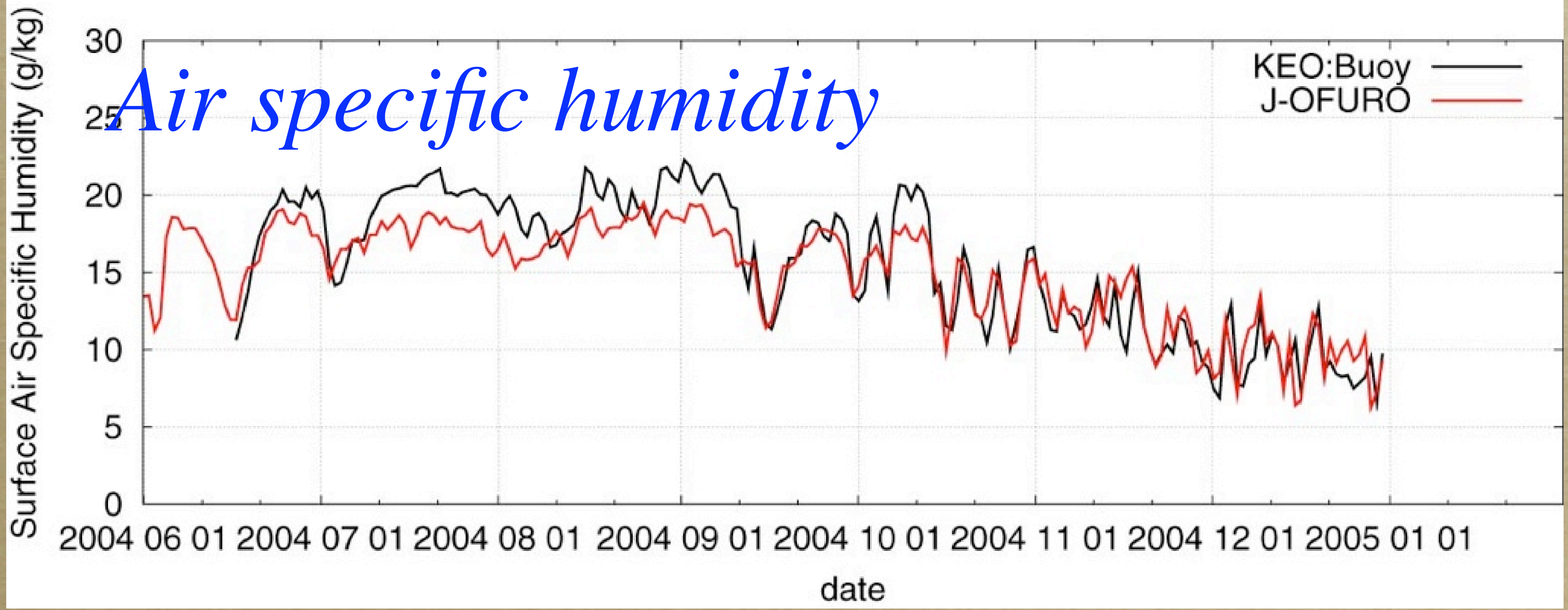
Comparison with KEO buoy flux

	V1.7.0
Num.	111

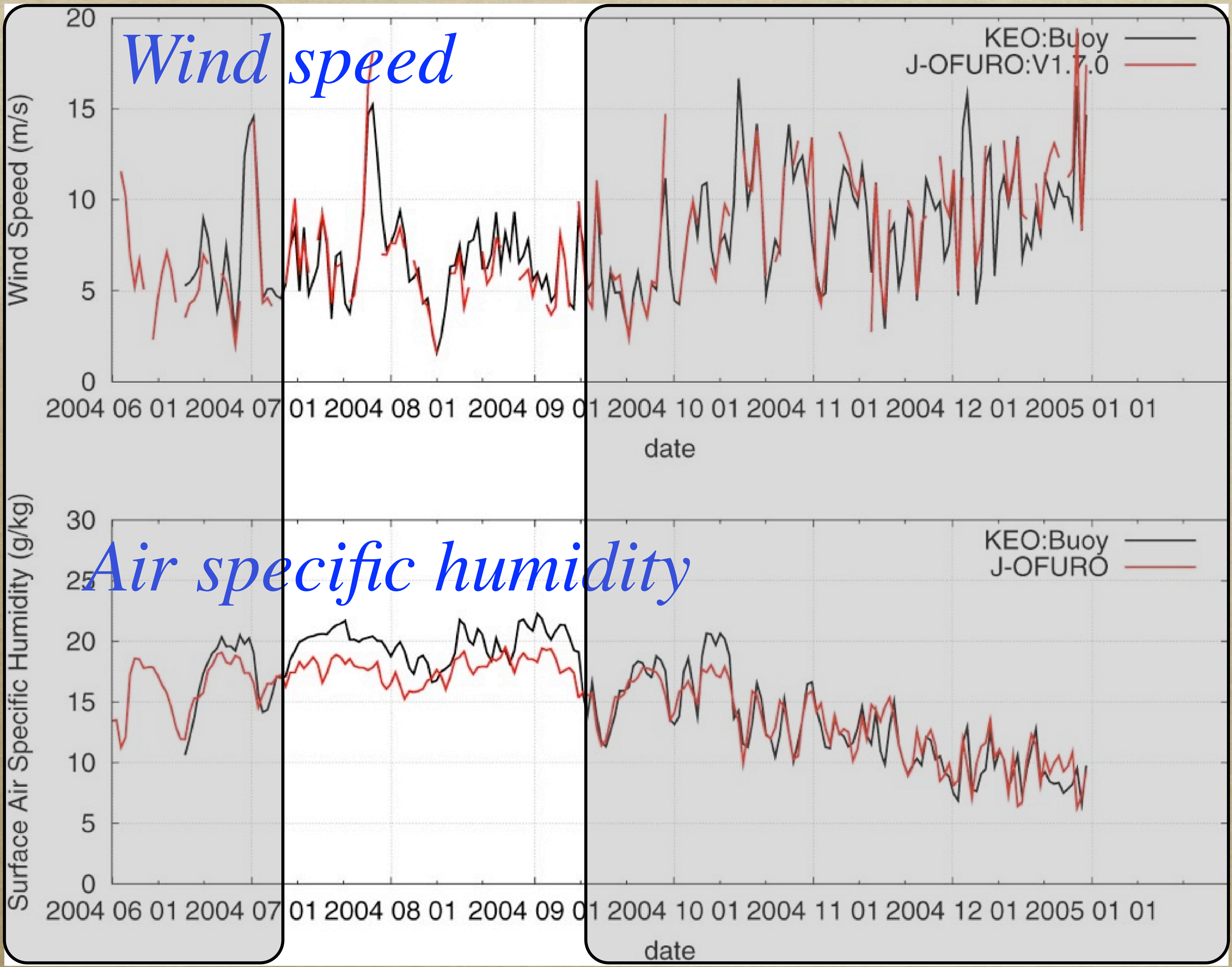


Comparison of W and Qa with KEO buoy





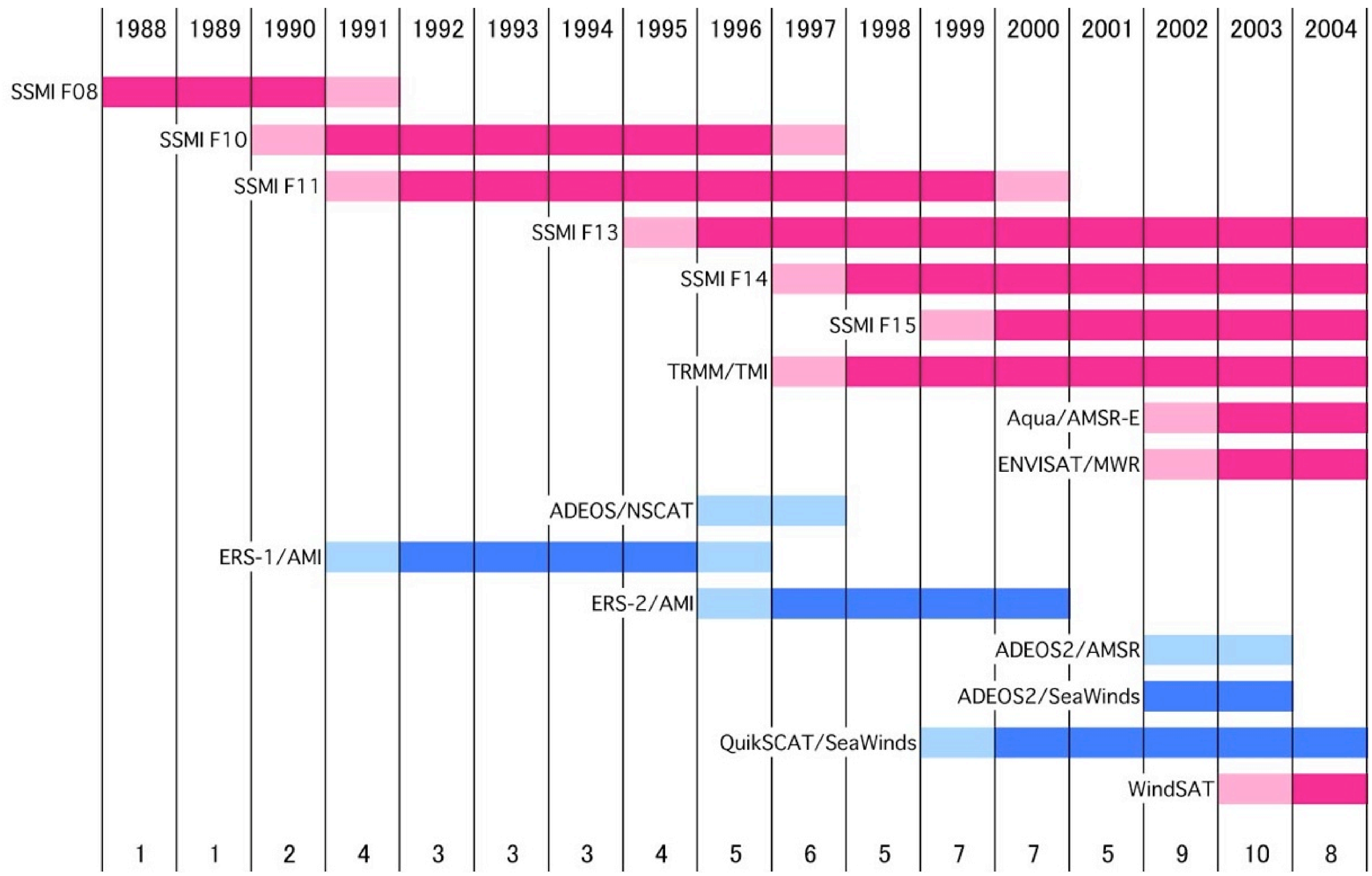
Comparison of W and Qa with KEO buoy



Future developments

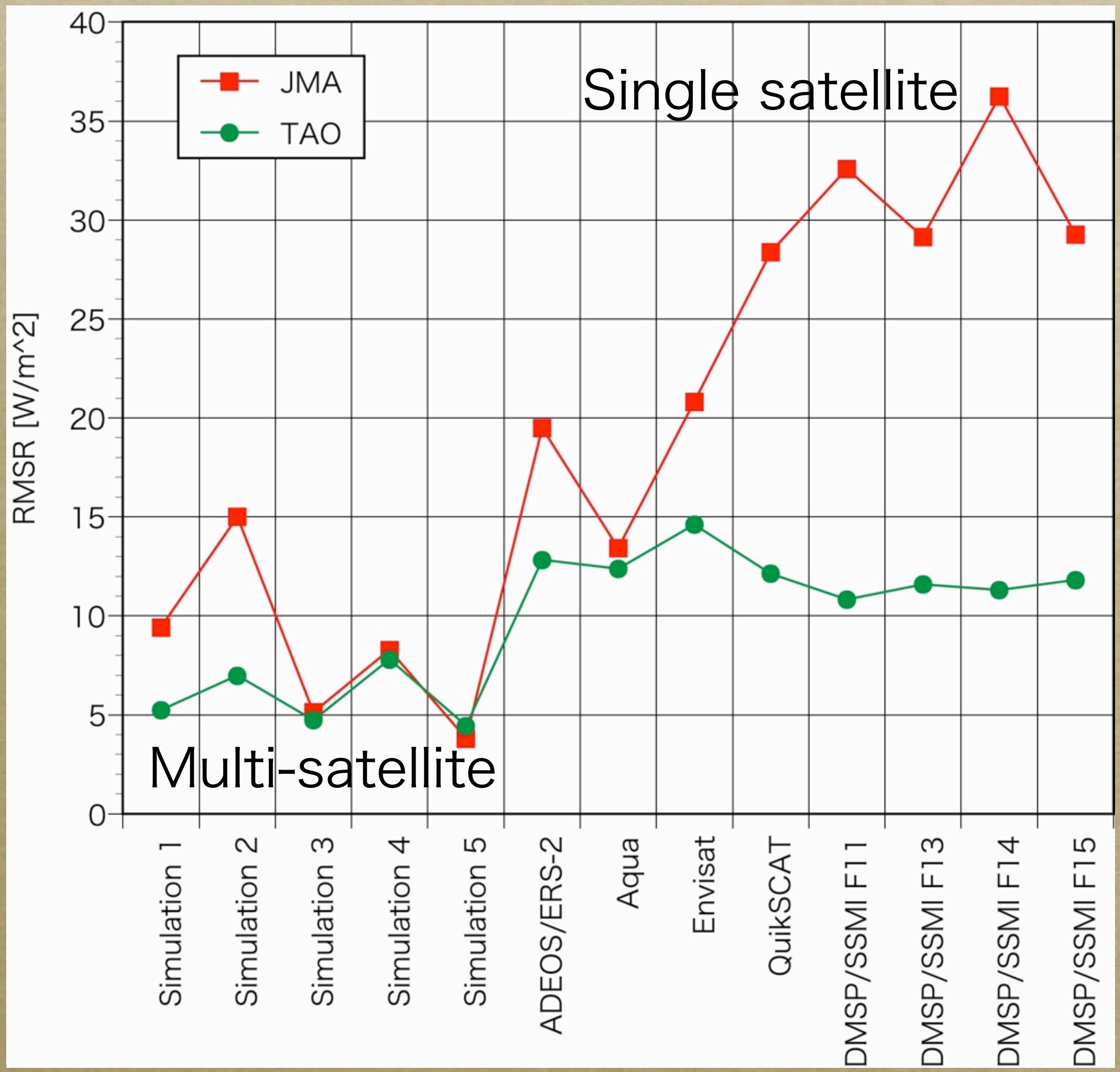
- *Use of multi-satellite*
- *Merged/hybrid product*
  - *Yu et al. (2005)WHOI OAFlux*
  - *Jiang et al.(2005)*

Data availability of satellite-derived wind speed and surface air specific humidity

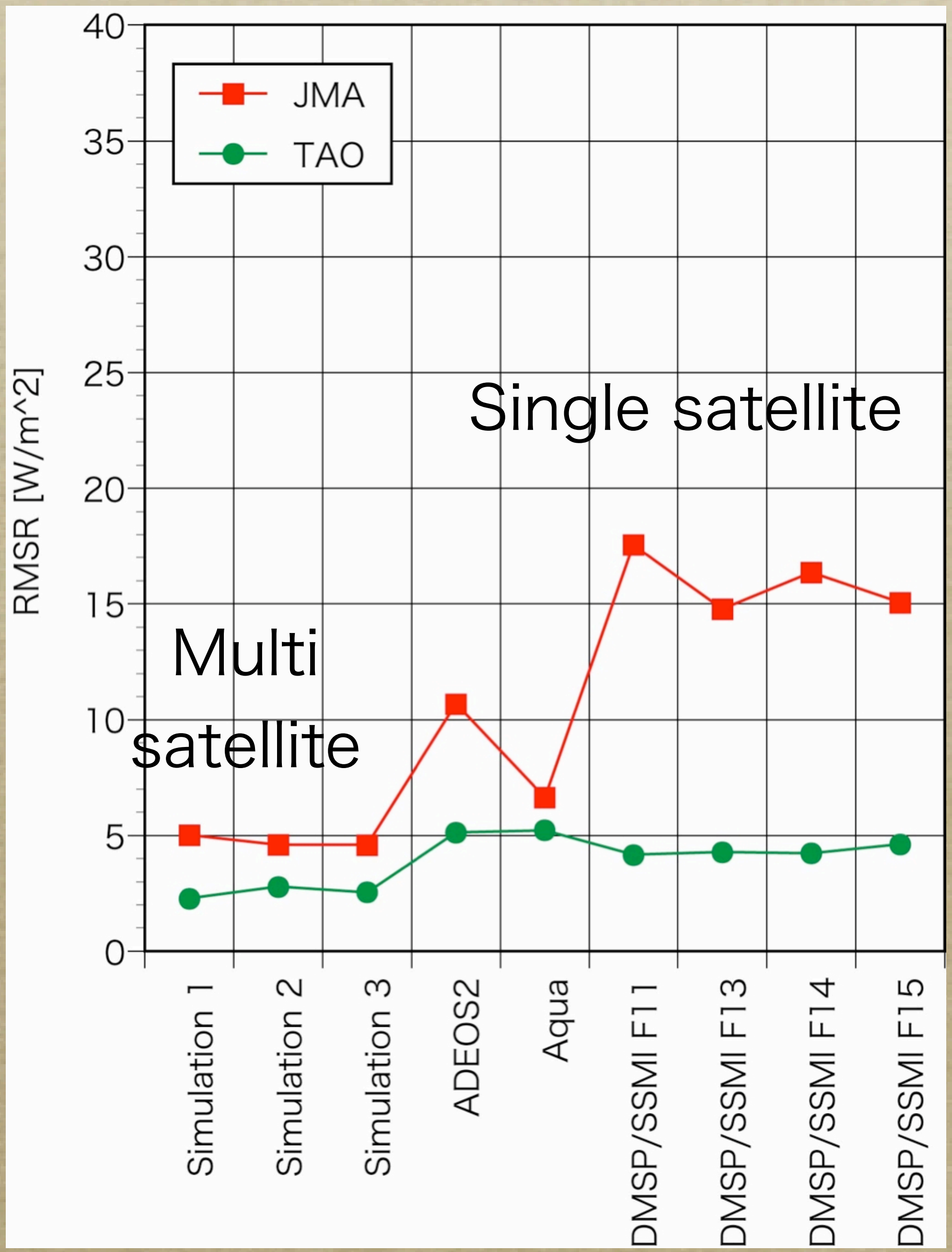


Simulation of multi-satellite

Impact for wind speed on LHF
RMS (W/m^2)



Impact for specific humidity on LHF
RMS (W/m^2)



Use of high-resolution in-situ observation

Use of high-resolution in-situ observation

In-situ data

SAMOS data

moored buoy data

- *Evaluation of satellite-derived parameters*
- *Improved estimation of global parameters*

Estimation of sampling error

Developing merged product

Kuroshio Extension Observation buoy

NOAA PMEL

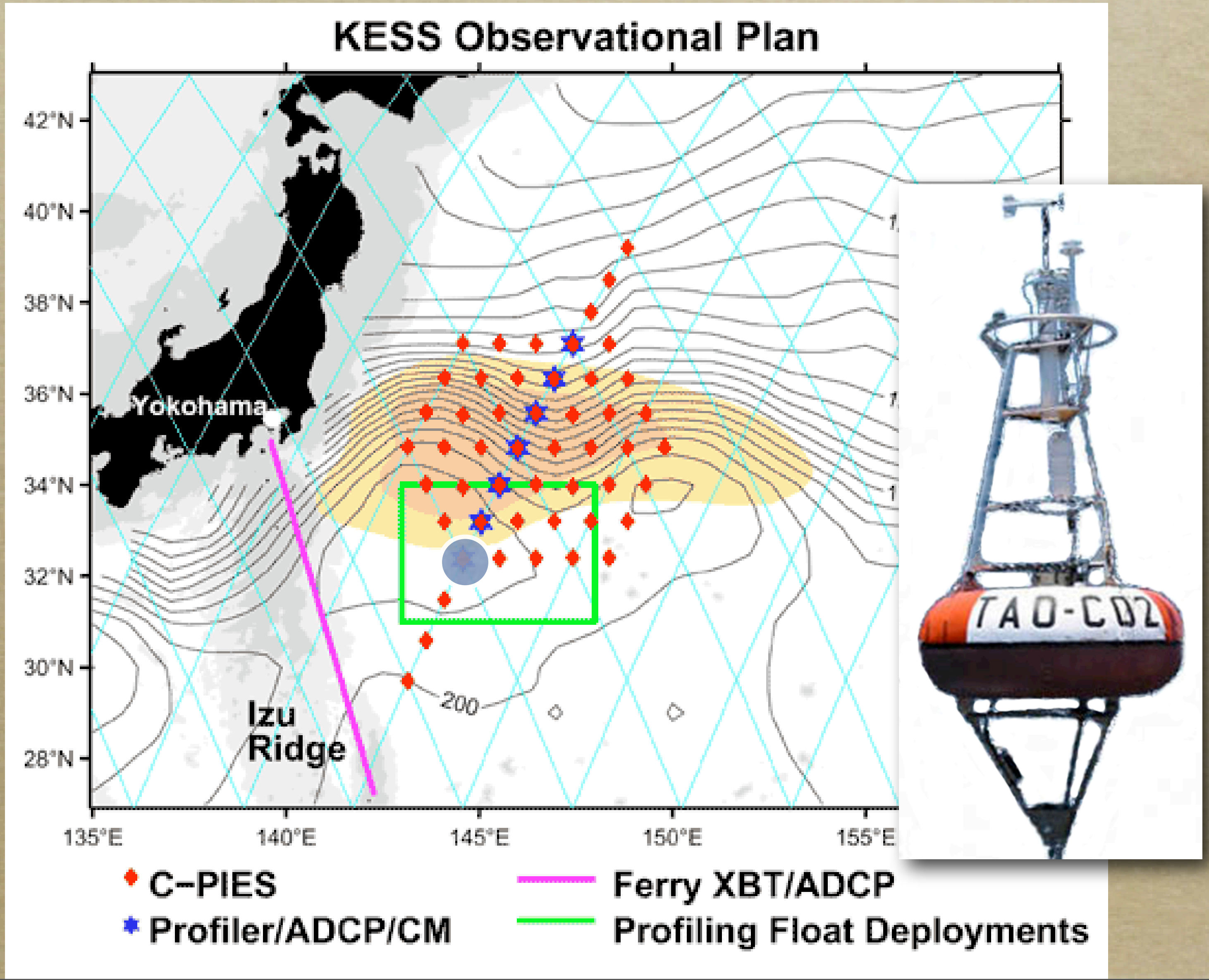
Location: 144.5E, 32.3N

2004.06.17～2005.11.09

10 min averaged
Surface Meteorological Parameters

Ts, Ta, RH, U, V

Radiation, precipitation



Japanese KEO (J-KEO) buoy

JAMSTEC/IORGC and NOAA PMEL

Location: 144°51'E, 32°21'N

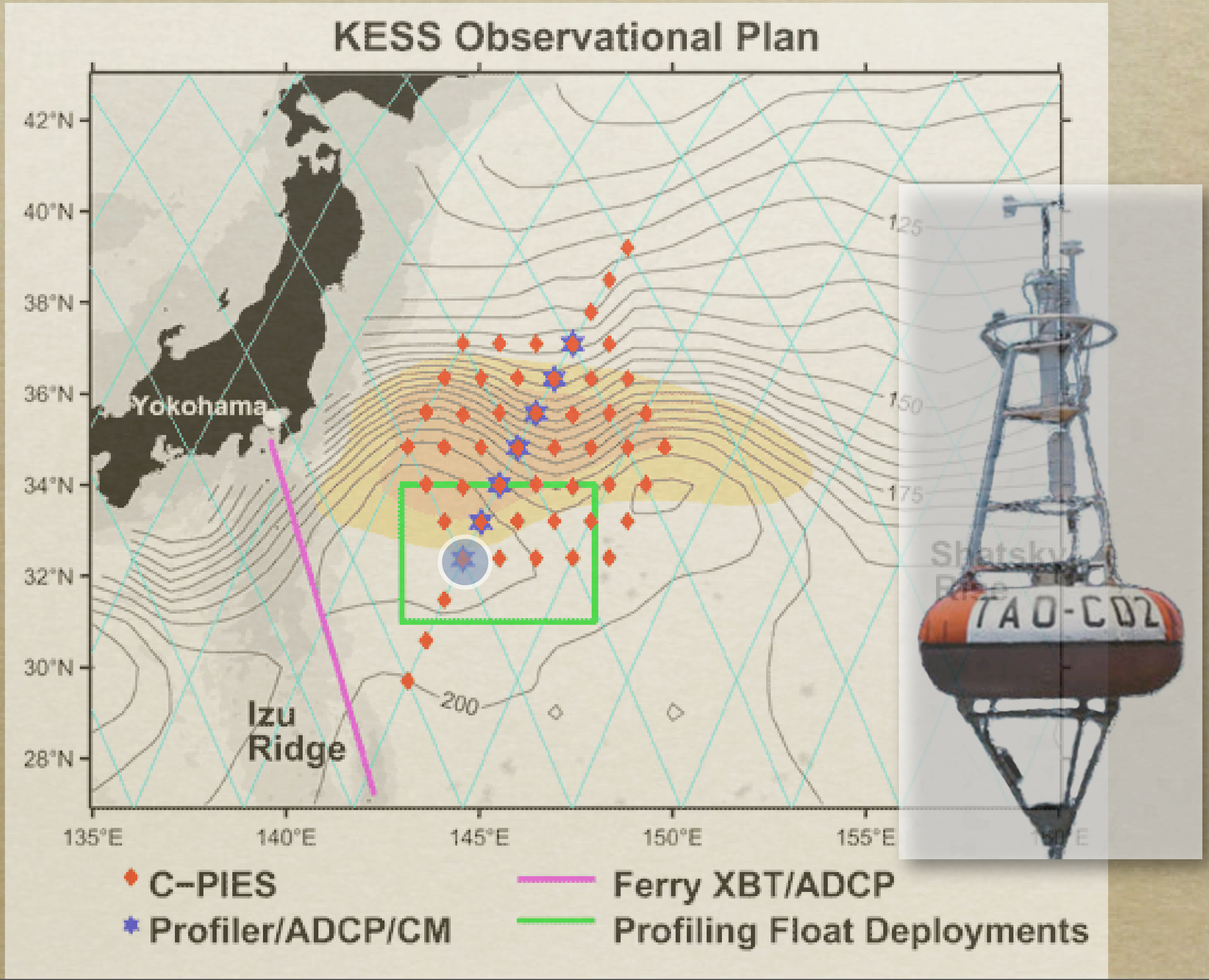
(close to KEO ~25km)

Start from January or February 2007

10 min averaged Surface Meteorological Parameters

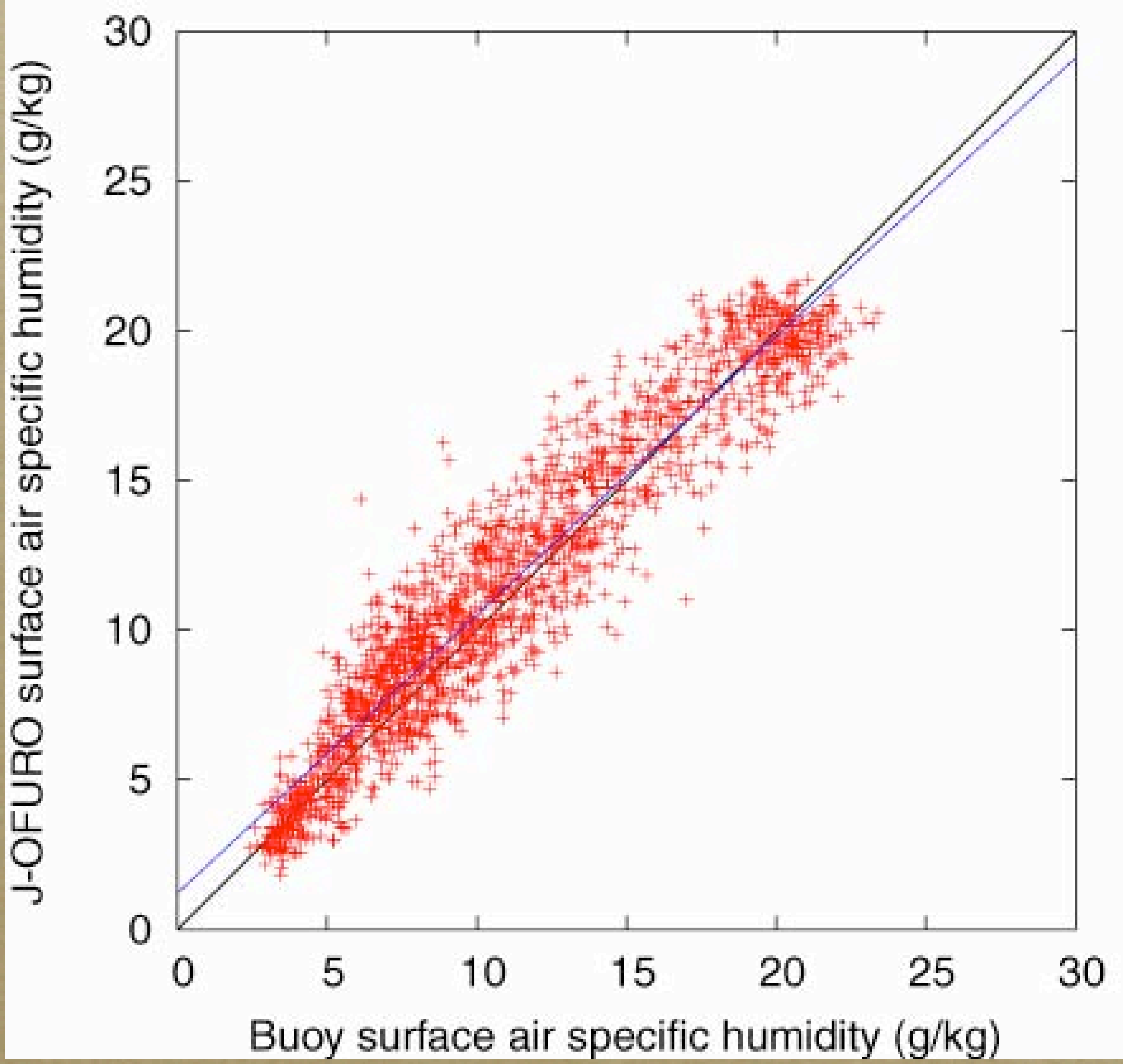
Ts, Ta, RH, U, V

Radiation, precipitation

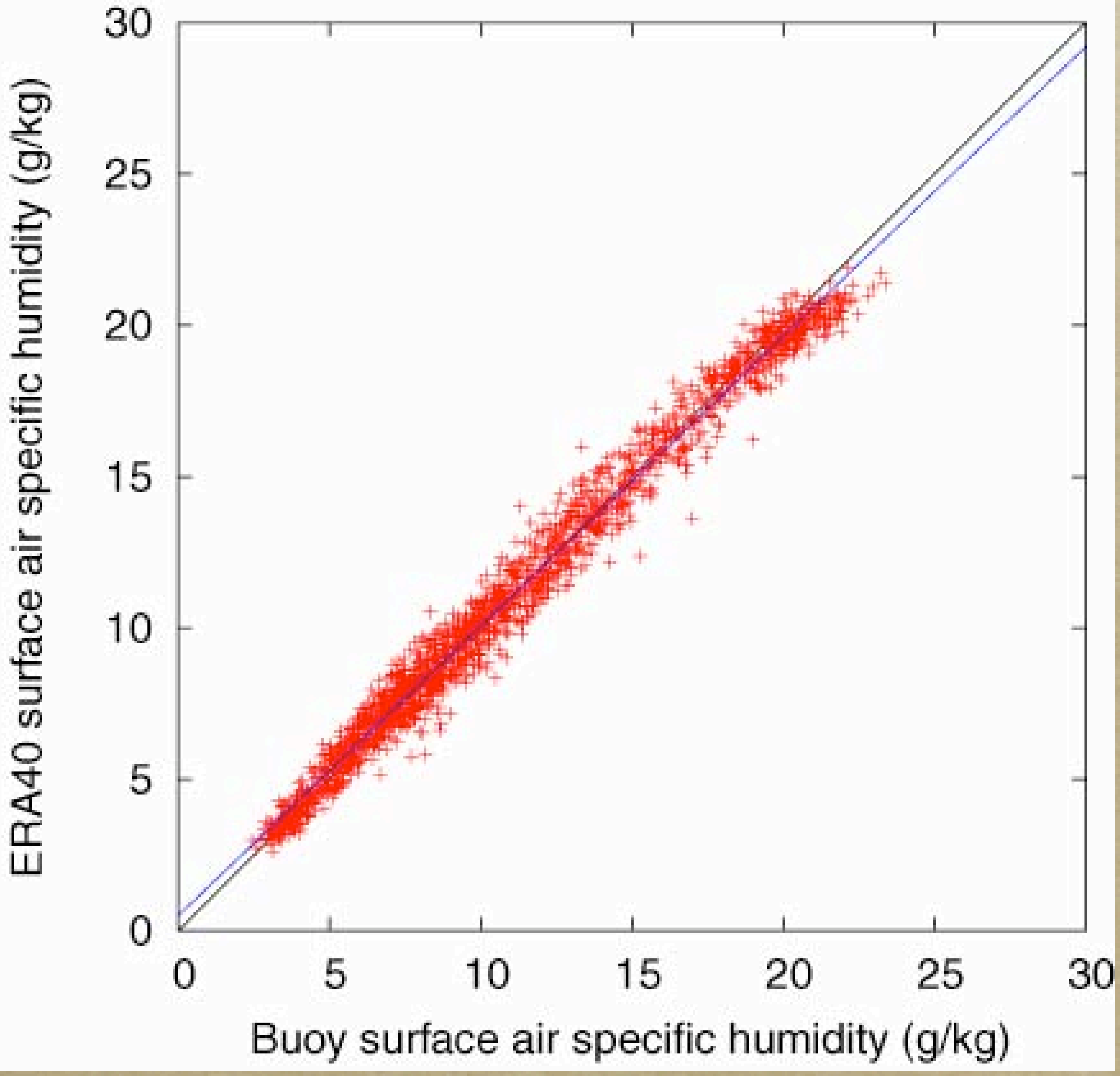


Comparison of daily mean Qa with JMA buoy

J-OFURO Qa

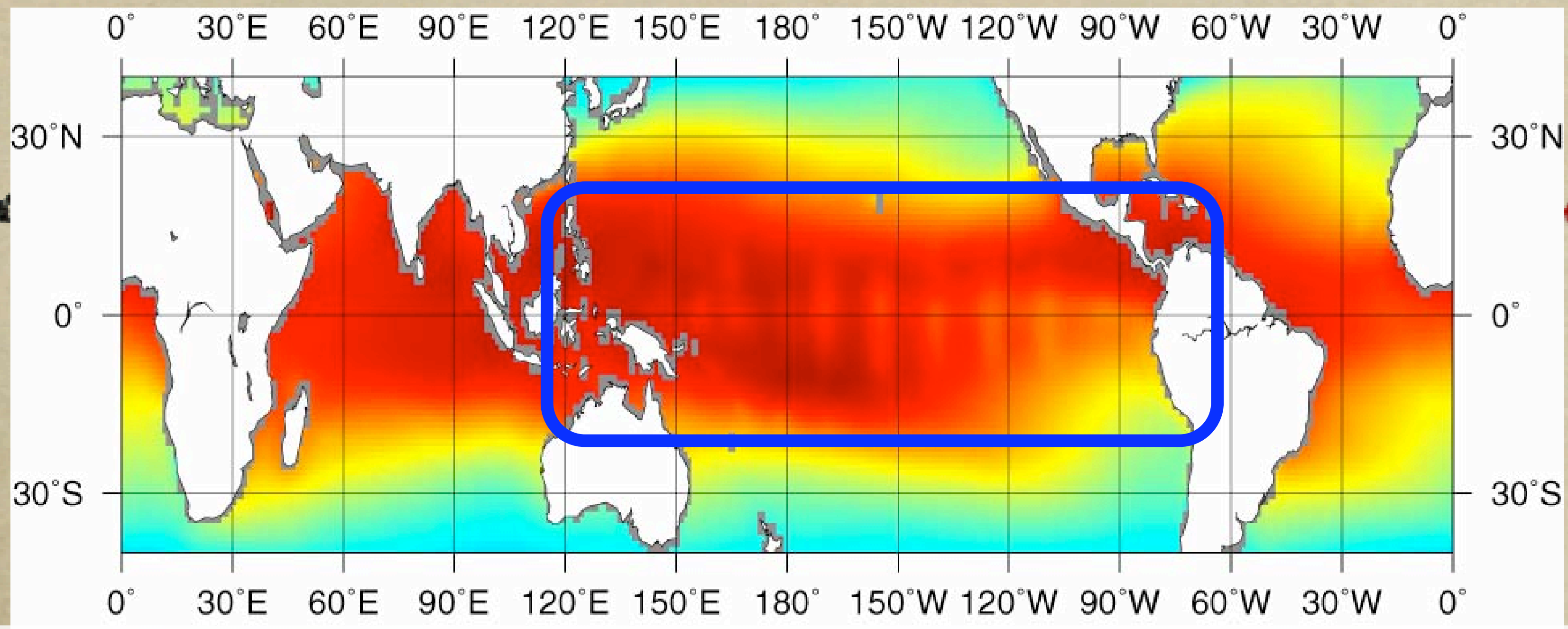


ERA40 Qa



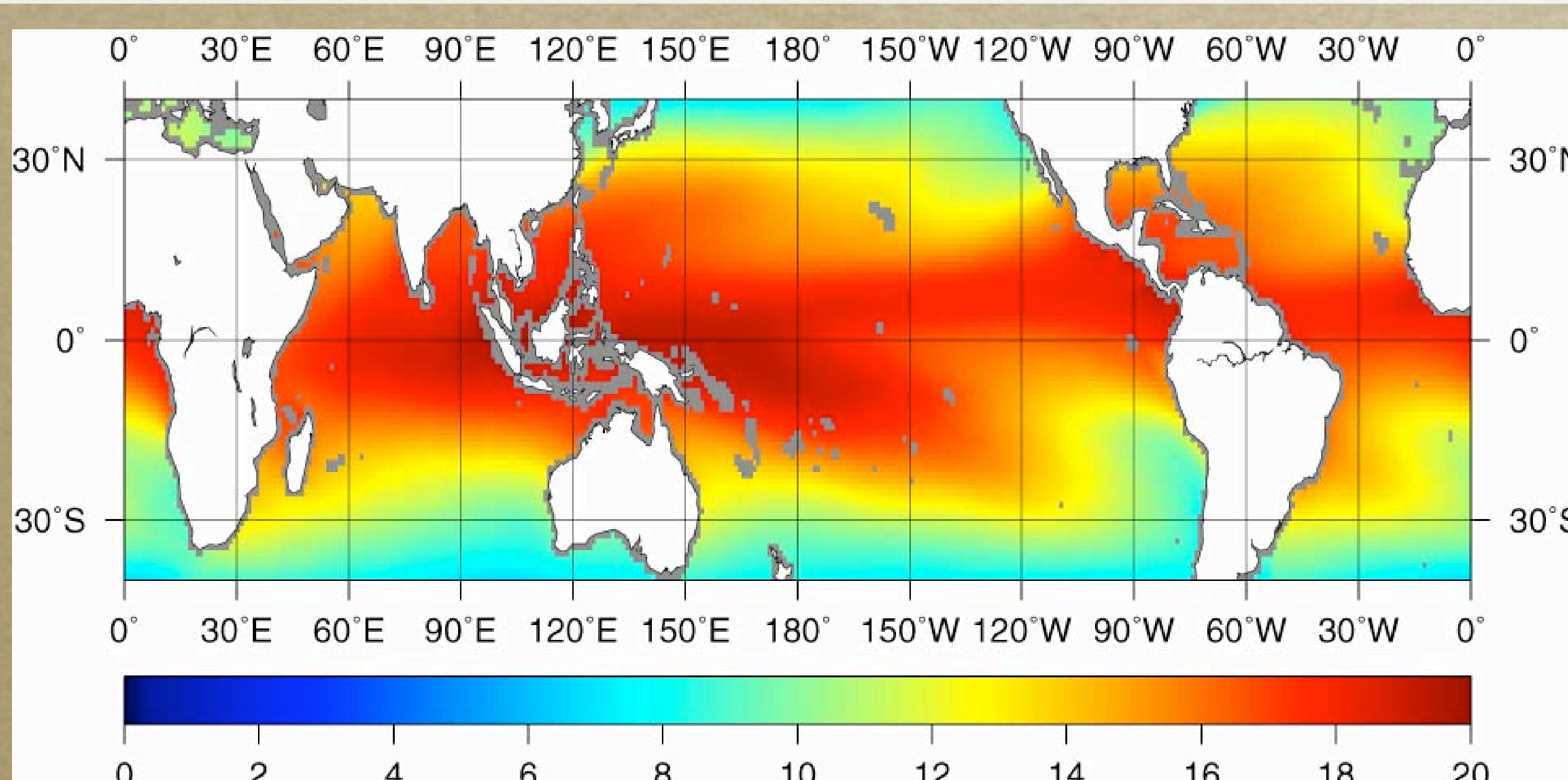
Spatial distribution of Qa

ERA40



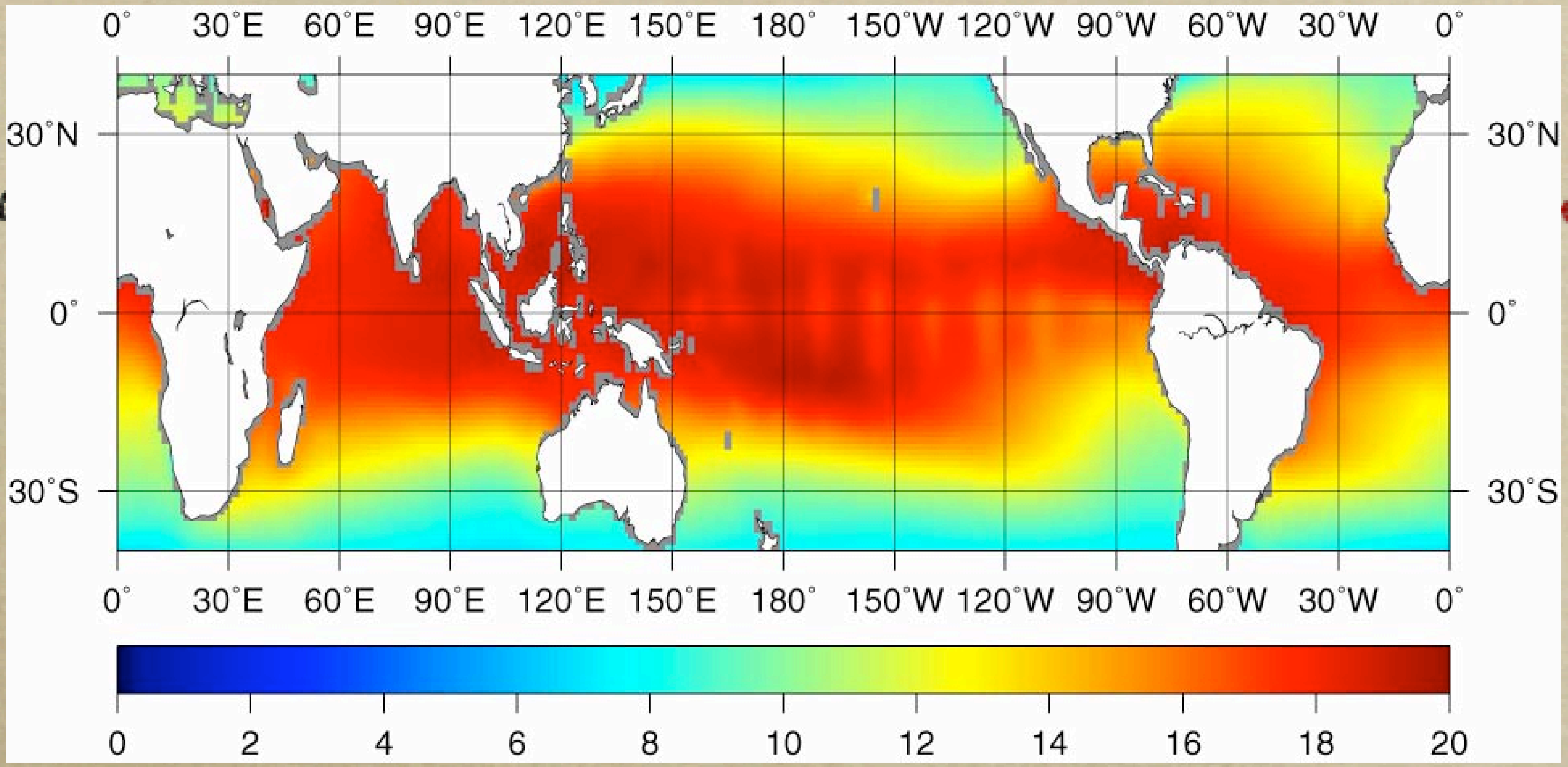
ERA40 Qa is quite inhomogeneous!!

Satellite

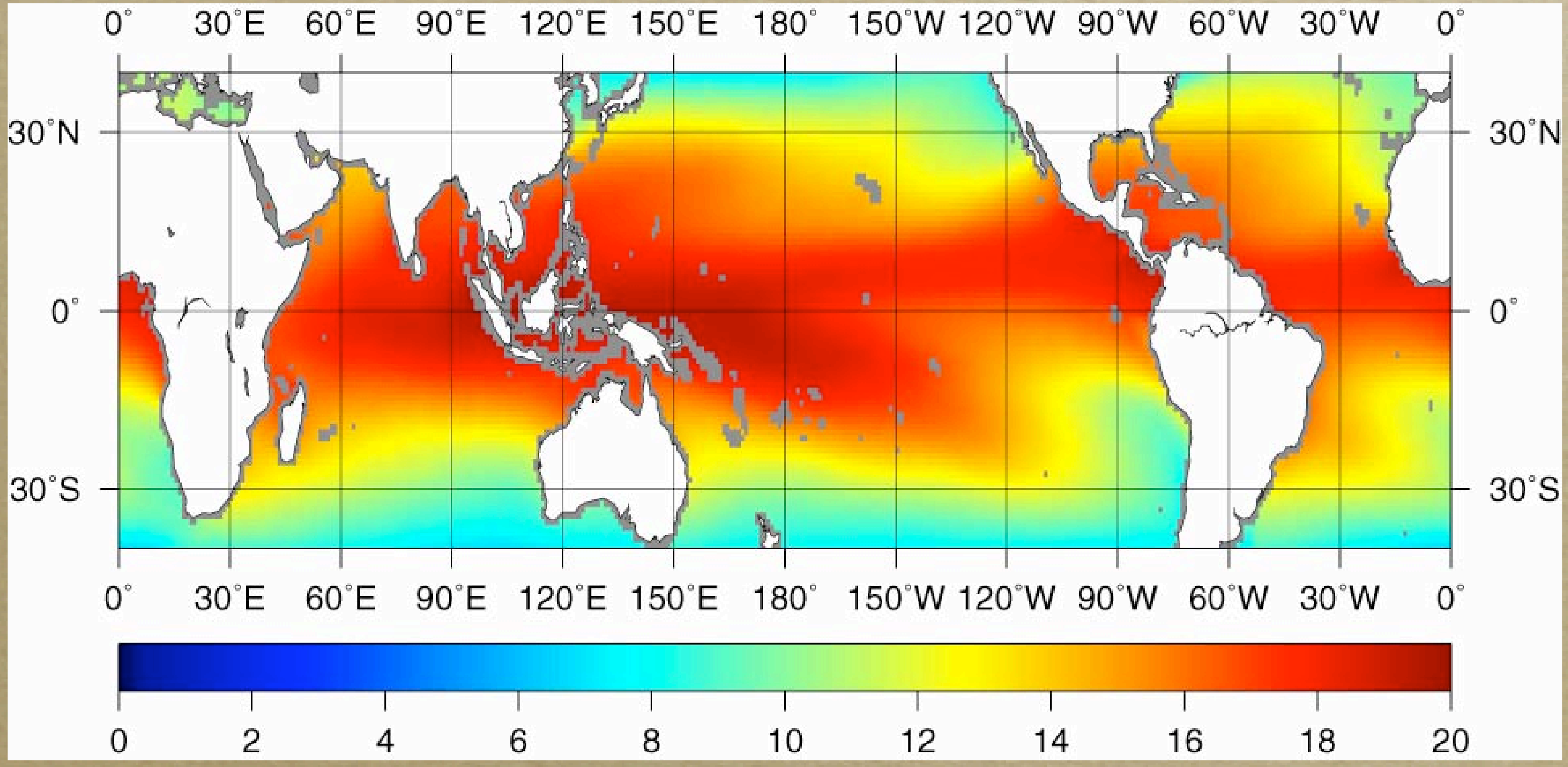


ERA40 Qa is inhomegenious!!

ERA40



Satellite



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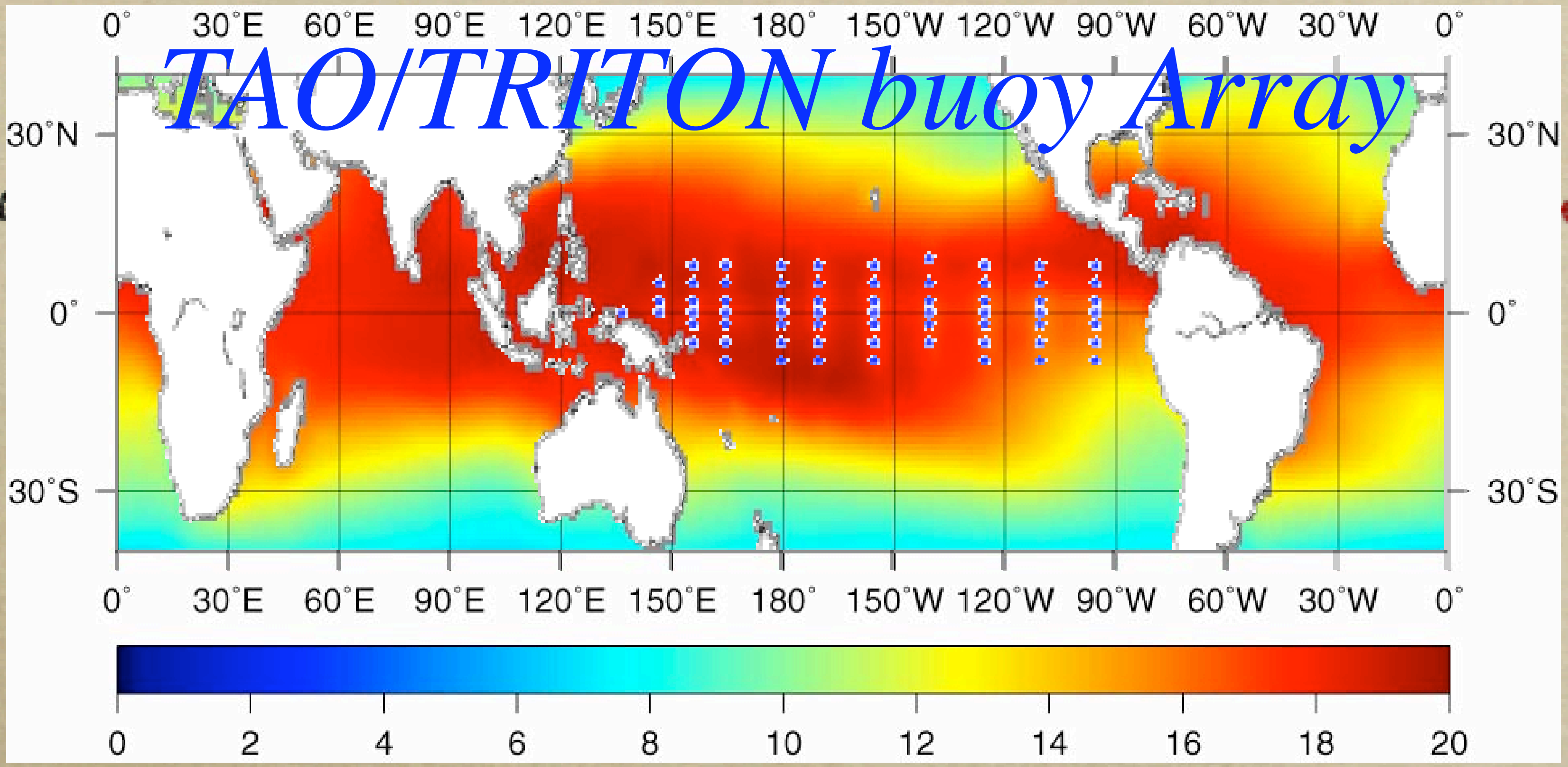

Satellite