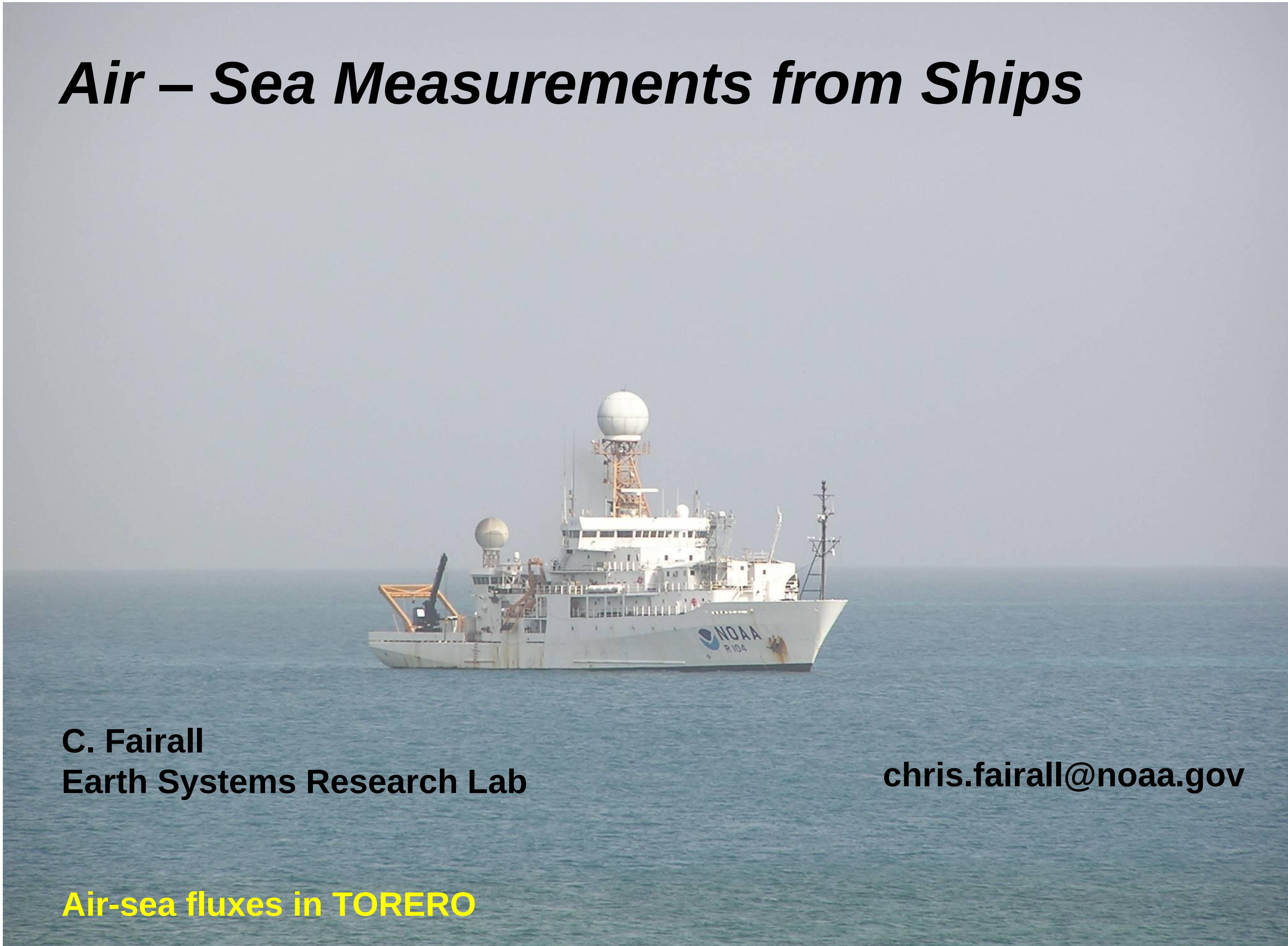
Air – Sea Measurements from Ships



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Air-sea fluxes in TORERO

Present Status of *Surface* Flux Parameterizations

Turbulent Fluxes: Bulk Parameterization

Mean correlation of turbulent variables represented in terms of mean flow variables – wind speed, surface-to-air variable difference

MetFlux – Dominated by atmospheric turbulent xfer

GasFlux – Dominated by oceanic molecular xfer;
Enhanced by whitecap bubbles

$$Met\ Flux : \overline{w'x'} = C_x U (X_s - X_r) = C_x U \Delta X$$

$$Gas\ Flux : \overline{w'x'} = k_x \alpha_x \Delta X \qquad \alpha = sol.$$

$$Particles : F_{deposition} = -V_d(r)\overline{n(r)};$$

$$F_{source} = F(f_{whitecap}, U, u_*, wavebreaking, slope)$$

Met fluxes connected to gas fluxes

$$\tau = -\rho_a \overline{w'u'} = \rho_a u_*^2$$

$$k = \frac{u_*}{r_w + \alpha r_a}$$

$$r_w = [r_{wt}^{-1} + k_b / u_*]^{-1}$$

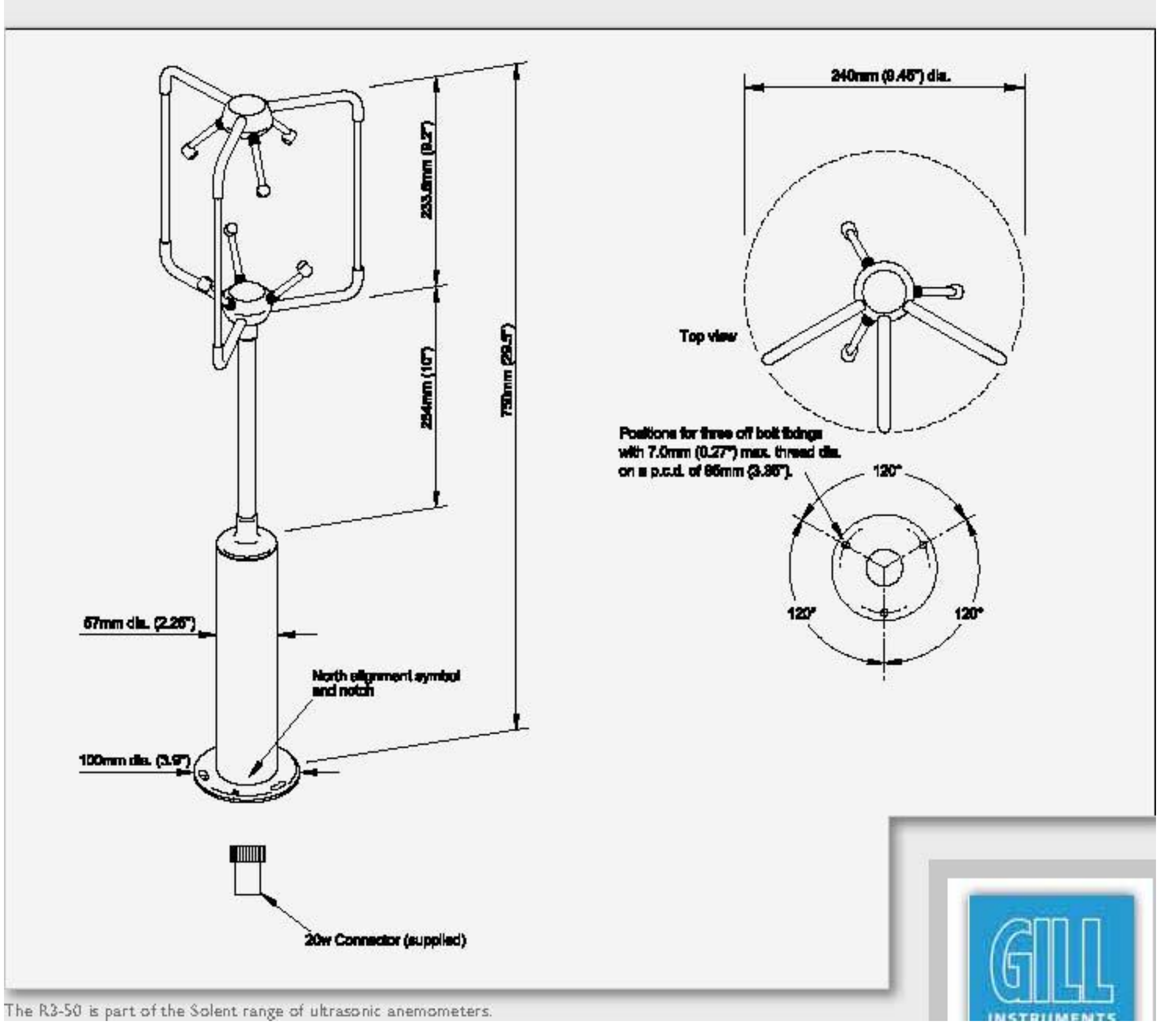
$$k(1 + \alpha r_a / r_w) = \frac{u_*}{r_w} = \frac{u_*}{r_{wt}} + k_b$$

Turbulent fluxes (direct covariance)

Latent heat	$\rho L_v \langle w'q' \rangle$	**[W/m^2]**
Sensible heat	$\rho C_p \langle w'T' \rangle$	**[W/m^2]**
Momentum	$\rho \langle u'w' \rangle$	**[N/m^2]**
Gas (etc)	$\langle w'c' \rangle$	

Instruments:

- **Sonic anemometer (wind, temperature)**
- **Infrared gas analyzer (humidity, CO2, etc)**
- **Motion (roll, pitch, yaw, heave, surge, sway)**
- **GPS/Compass/Doppler speed**



L = path length
t = time of flight
c = speed of sound
v = wind velocity
T = temperature
T_s = “virtual” temp
p = pressure
e = water vapor pressure

$t_1 = L / (c + v)$; $t_2 = L / (c - v)$;

$v = 0.5\, L\, (1/t_1 – 1/t_2)$; $c = 0.5\, L\, (1/t_1 + 1/t_2)$;

$T_s = c^2 / 403$; $T = T_s / (1 + 0.32\, e / p)$

Infrared Gas Analyzer (IRGA)

Absorptance of a *particular* gas

$\alpha = 1 - A / A_o$

A = power received at absorbing wavelength

A_o = power received at non-absorbing wavelength

$\rho = P_e\, f(\alpha / P_e)$ [mol m^{-3}] number density

$\rho = P_e\, f([1 - z\, A / A_o]\, S / P_e)$; P_e is equivalent pressure

S is ‘span’

Channels available for water vapor and CO_2

Wind Stress

Ƭ = ρ <u'w'> + ρ <v'w'>
streamwise transverse wave stress

Um = <u> + u' +uship
Vm = <v> + v' +vship
Wm= <w> + w' +wship

Wind stress (momentum flux) drives currents and waves, thus driving heat transport in the ocean.

Heat Fluxes

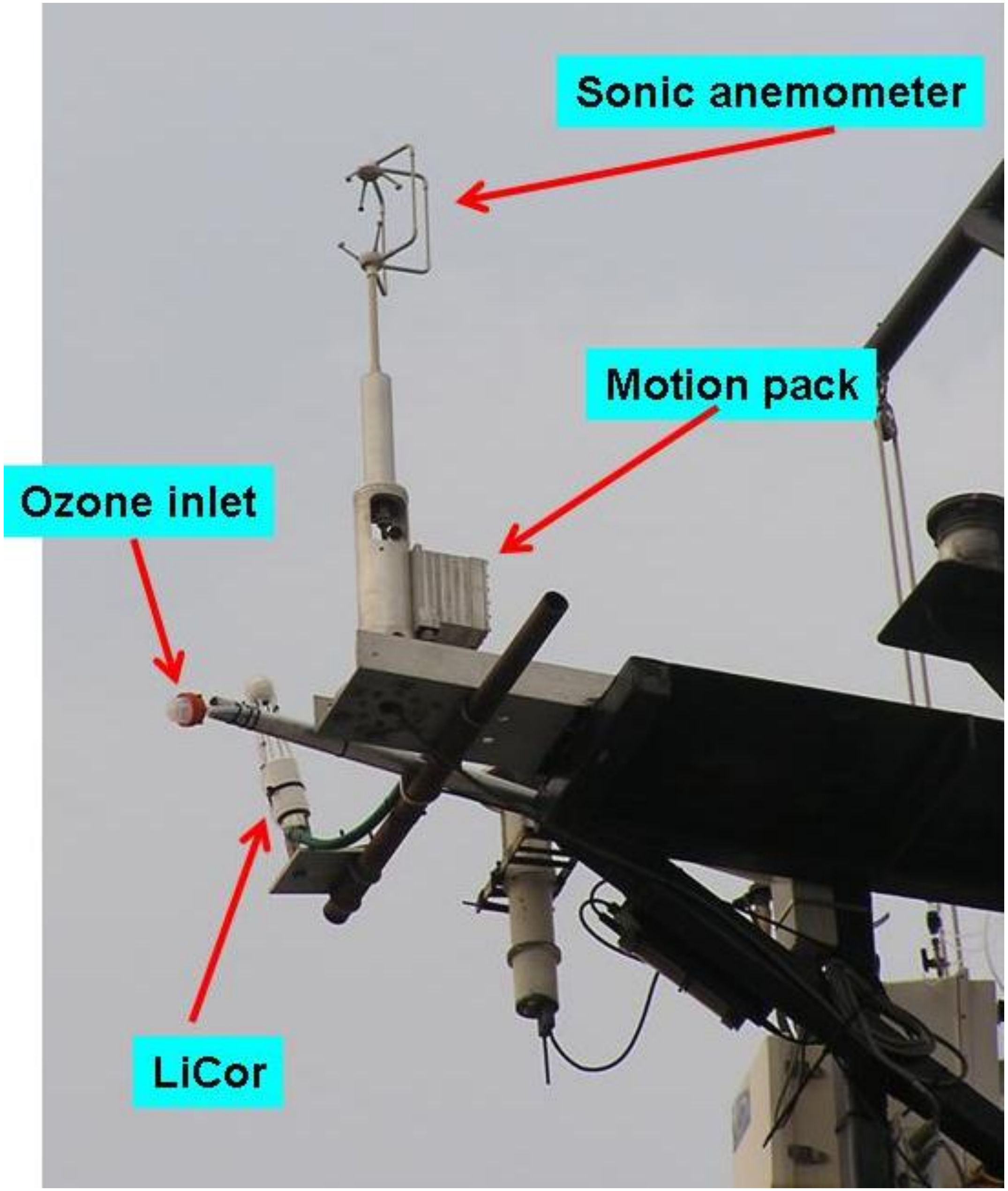
$H_s = \rho C_p \langle w'\theta' \rangle$ **Sensible heat flux**

$H_L = \rho L_v \langle w'q' \rangle$ **Latent heat flux**

$\mathbf{T} = \langle \Theta \rangle + \theta'$

$\mathbf{Q} = \langle q \rangle + q'$

Heat transfer between the sea surface and atmosphere is another primary driver of ocean circulation



NOAA/ESRL Turbulent Flux System

Energy Budget

$$Q_{NET} = Q_S\uparrow + Q_S\downarrow + Q_L\uparrow + Q_L\downarrow + H_S + H_L$$

Net at the surface
Shortwave up/down (albedo)
Longwave up/down
Sensible turbulent heat flux
Latent turbulent heat flux

$$Q_L\uparrow = \varepsilon\text{missivity}(\sigma T^4 - Q_L\downarrow) \quad Q_S\uparrow = \text{albedo}(Q_S\downarrow)$$

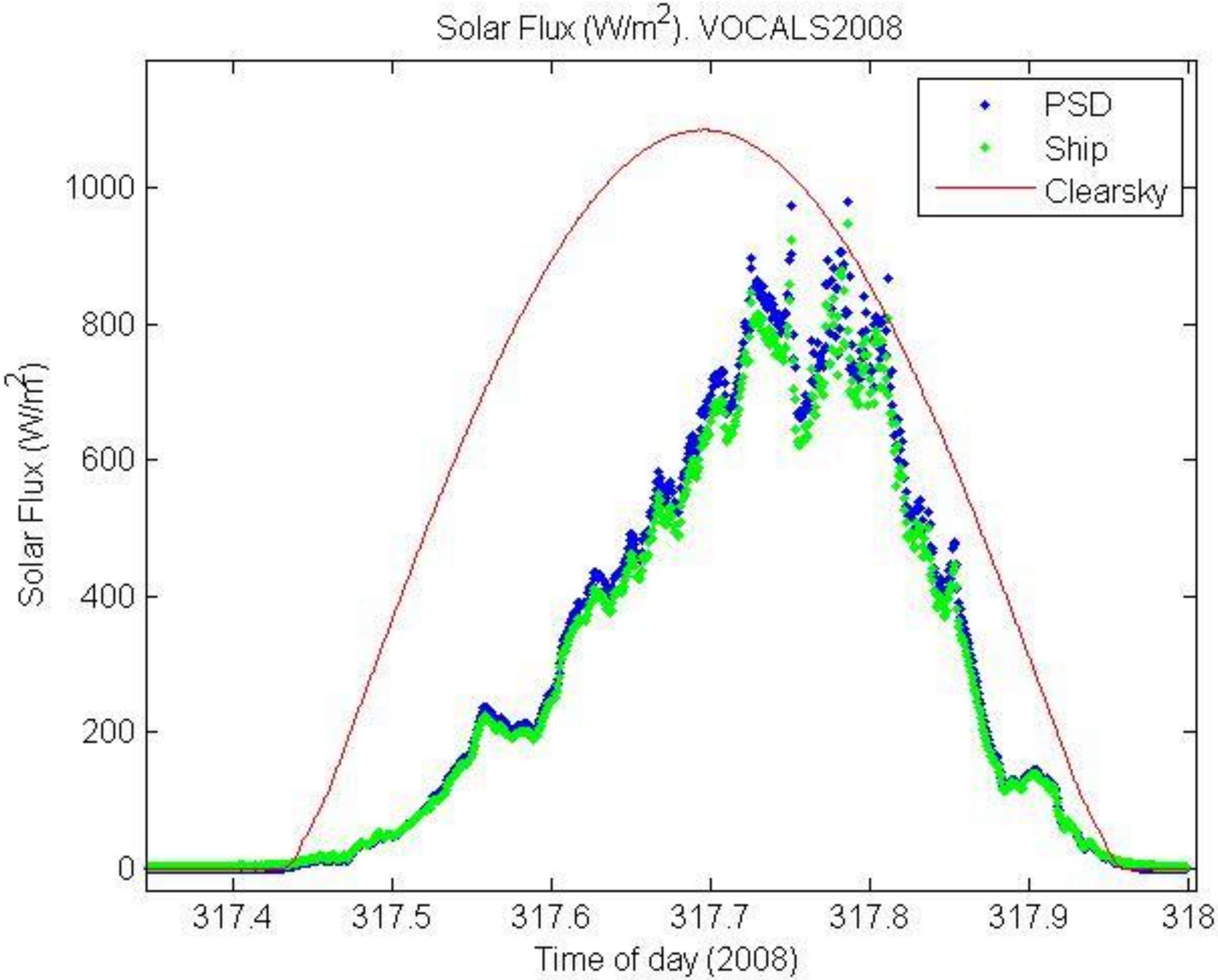
Radiative fluxes

Downwelling solar
Downwelling IR

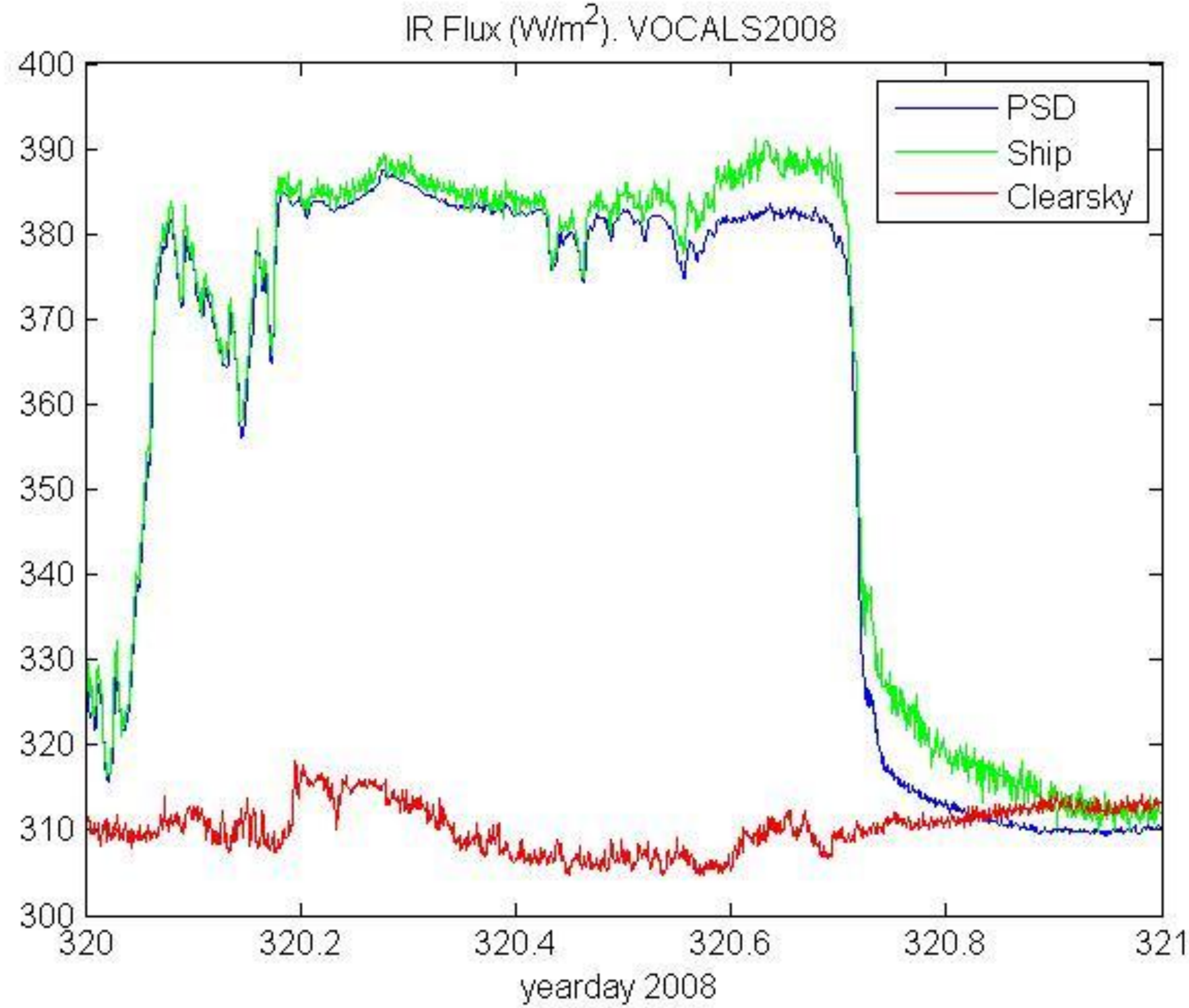
Instruments

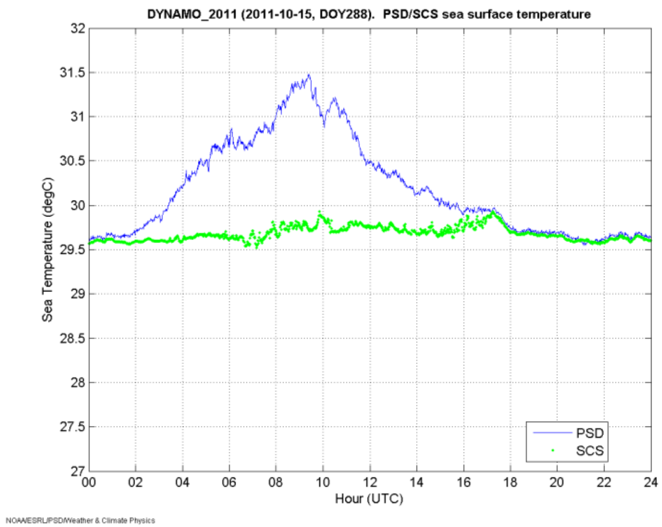
Pyrgeometer (PIR)

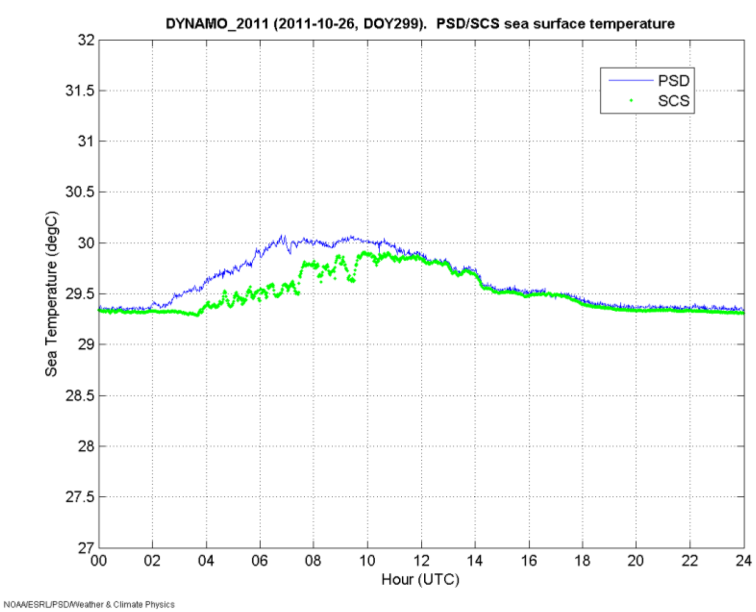
Pyranometer (PIR)

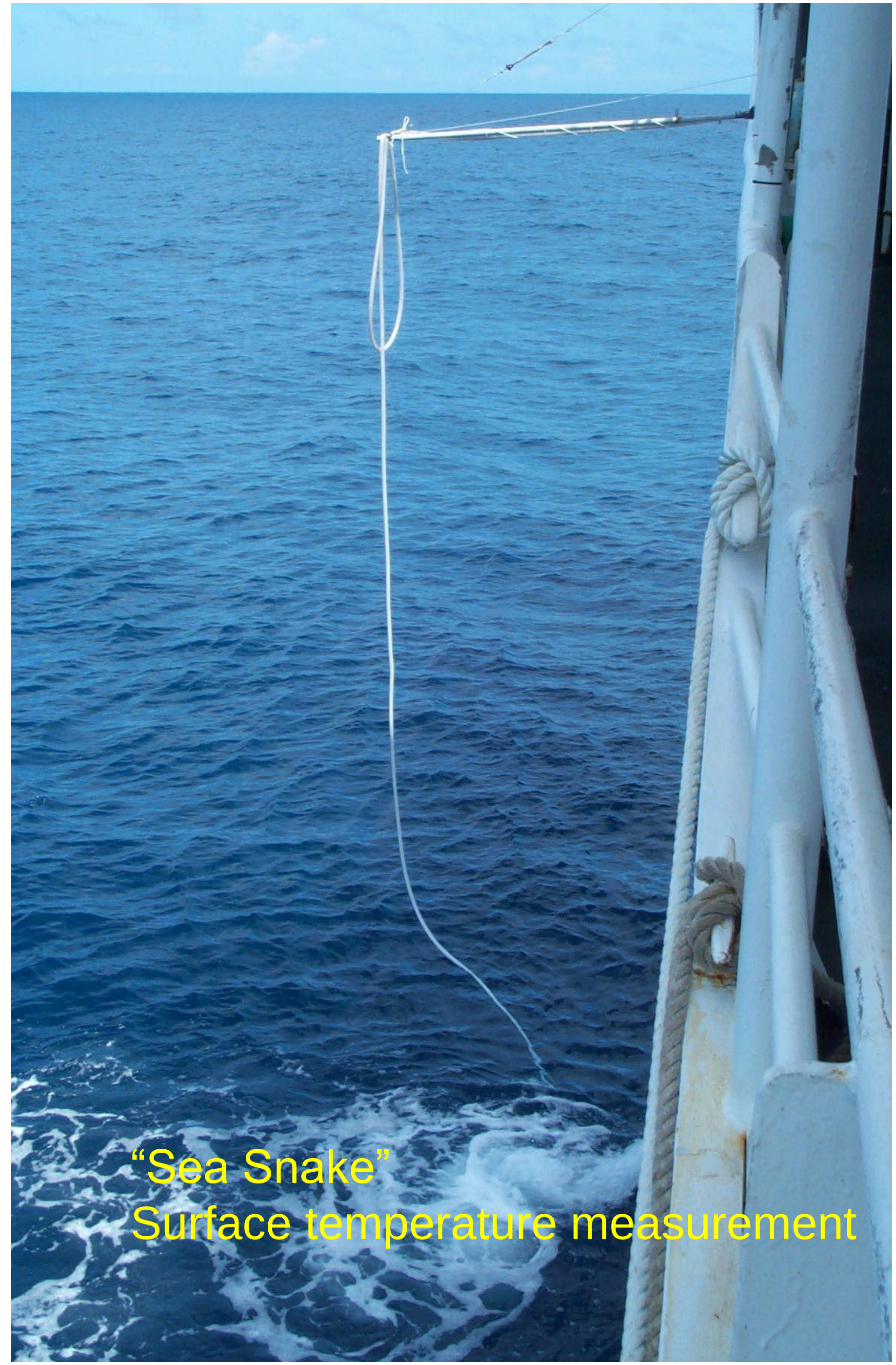


Solar Flux (W/m2). VOCALS2008
PSD
Ship
Clearsky
Solar Flux (W/m2)
1000
800
600
400
200
0
317.4
317.5
317.6
317.7
317.8
317.9
318
Time of day (2008)


IR Flux (W/m2). VOCALS2008
PSD
Ship
Clearsky
400
390
380
370
360
350
340
330
320
310
300
320
320.2
320.4
320.6
320.8
321
yearday 2008


DYNAMO_2011 (2011-10-15, DOY288). PSD/SCS sea surface temperature
Sea Temperature (degC)
Hour (UTC)
PSD
SCS
NOAA/ESRL/PSD/Weather & Climate Physics


DYNAMO_2011 (2011-10-26, DOY299). PSD/SCS sea surface temperature
Sea Temperature (degC)
Hour (UTC)
PSD
SCS
NOAA/ESRL/PSD/Weather & Climate Physics


"Sea Snake"
Surface temperature measurement

PSD foremast on Hai'alikai