Near-surface Meteorology, Surface Flux, and Cloud Observations

Chris Fairall

Weather and Climate Physics Branch
Physical Sciences Division
NOAA/ESRL
Boulder, Colorado

H. Zhang – NCDC

R. Weller/A. Plueddemann -WHOI

F. Bradley – CSIRO

S. DeSzoeke – Oregon SU

A. Beljaars - ECMWF

BIG PICTURE

Oceanic Near-Surface Observations

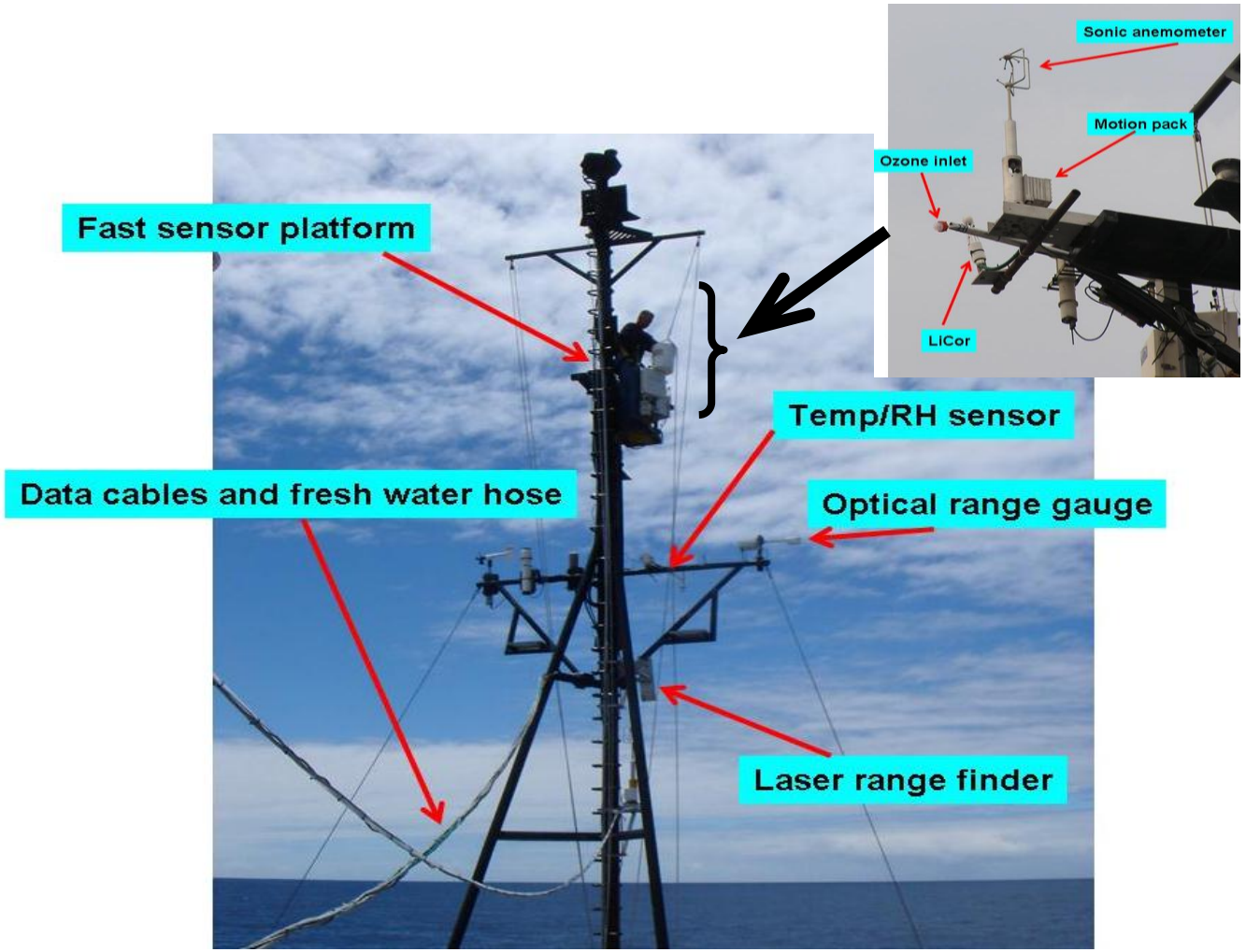
Gulev et al., *Surface energy and CO2 fluxes in the global ocean-atmosphere-ice system*. Plenary White Paper, OceanObs2009

- Satellite
  - J-Ofuro, HOAPS, EFREMER, Goddard
- Operational NWP
- Blended/Hybird
  - OAFlux (WHOI), CORE (NCAR), U. Wash.
- In situ
  - NOAA ESRL Ship-based (40 cruises)
  - SAMOS Archive of R/V (20 vessels)
  - Ocean Sites Archive flux buoys (20 sites)
  - Operational TAO/PIRATA/RAMA (200 sites)
  - VOS/VOSCLIM Volunteer vessels (declining numbers)

Objectives of ESRL Studies

- Local air-sea interaction in the Tropical cold tongue, stratus region, and ITCZ.
- Surface flux parameterizations - deep convection.
- Variability.
- Convective and stratus clouds and aerosols in cloud radiative forcing.
- Enhance value of buoy observations: intercalibration, atmospheric profiles, cloud properties, and spatial context.
- Operational NWP and satellite fluxes; flux products

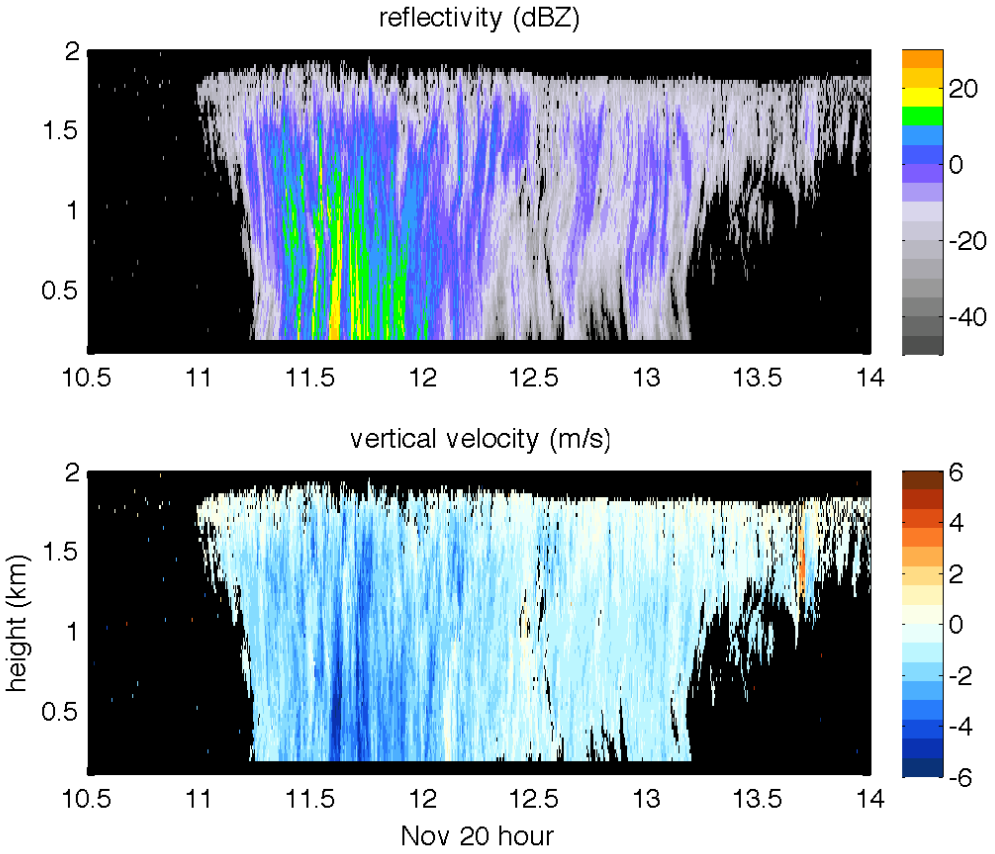
Flux Instrumentation and measurements



A New Motion-Stabilized W-band (94-GHz) Cloud Radar for Observations of Marine Boundary-Layer Clouds

Lidar ceilometer

Microwave LWP



Example 1

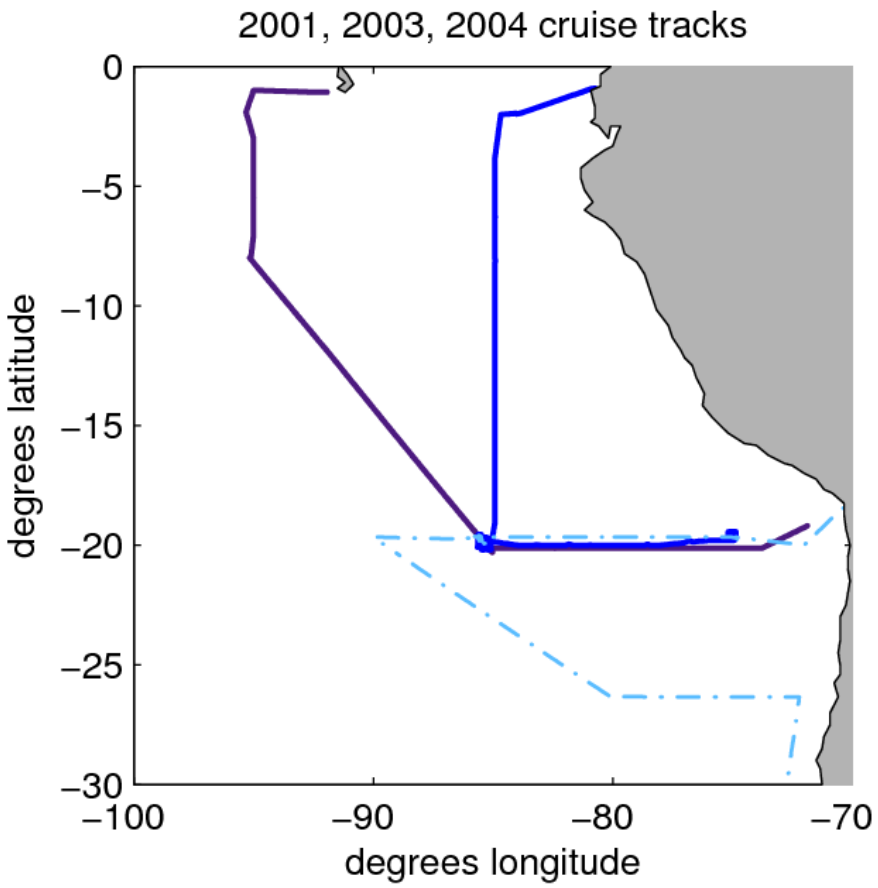
Comparisons of Ship and Buoy Surface Flux Data with Data Products and Climate Models

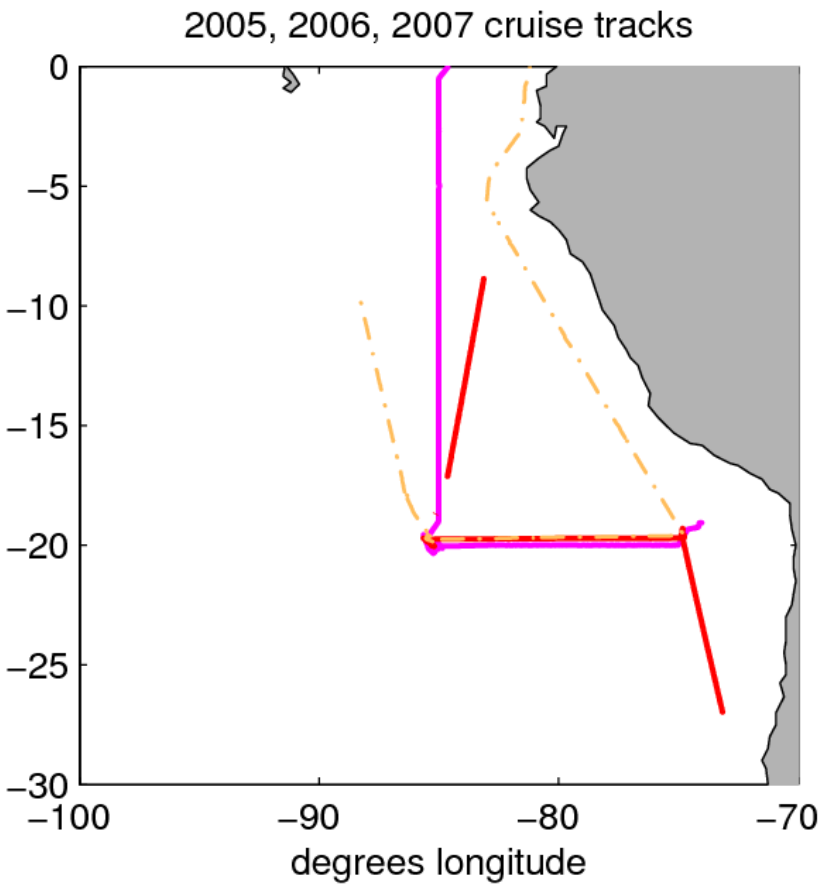
Stratus Synthesis of NOAA ship observations

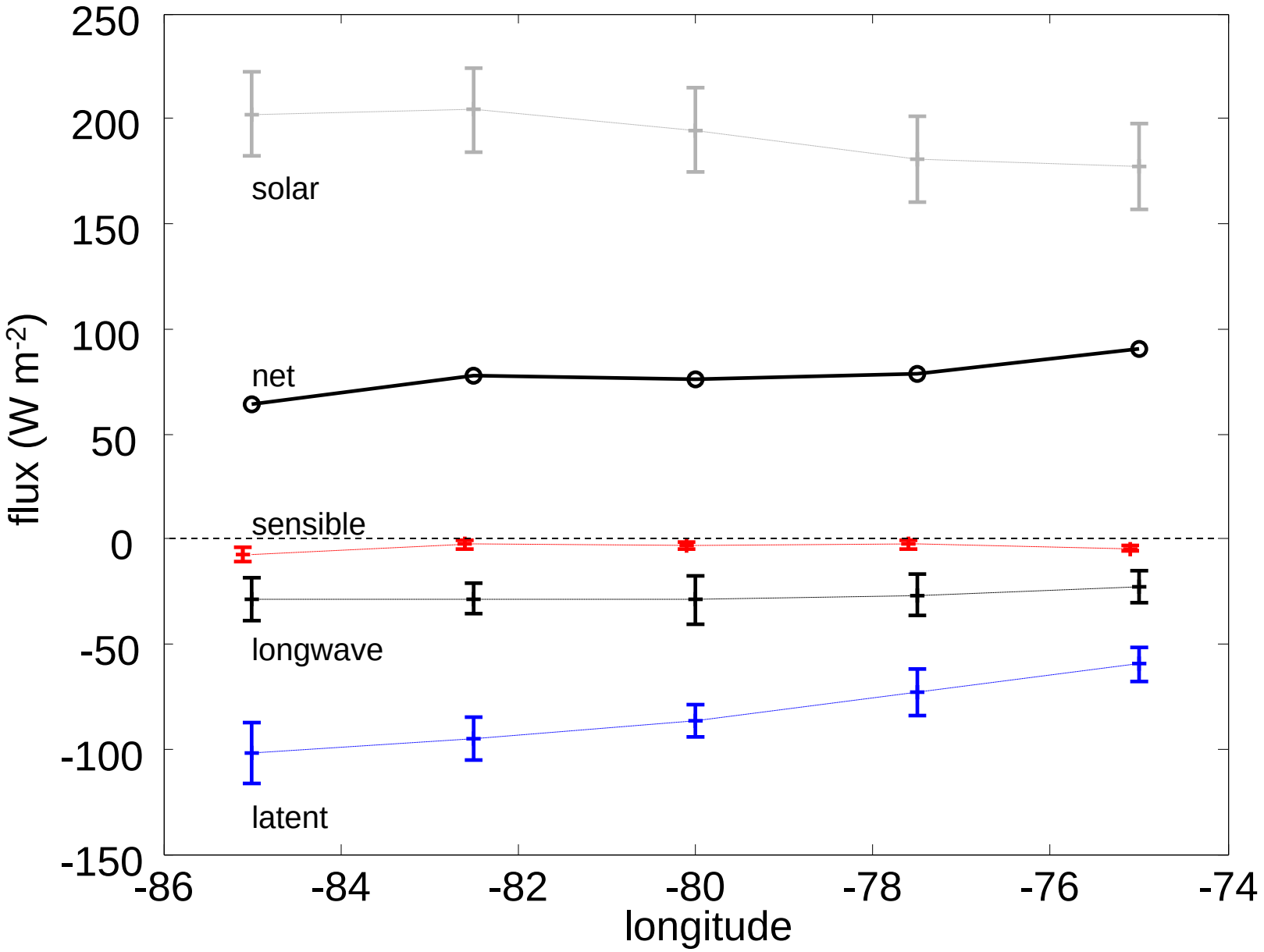
http://www.esrl.noaa.gov/psd/psd3/synthesis

- Fall 2001, 2003-2009 (8 years) 20˚S, 75-85˚W.
- Measurements:
  - Surface meteorology
  - Turbulent and radiative fluxes
  - Cloud vertical structure: top, base, and LCL.
  - Rawinsonde profiles
  - Column water vapor and liquid water path
  - Aerosols
- Assess model and analysis fluxes from ground.
- VOCALS 2008 (2 cruises) to be added soon

Stratus cruise tracks

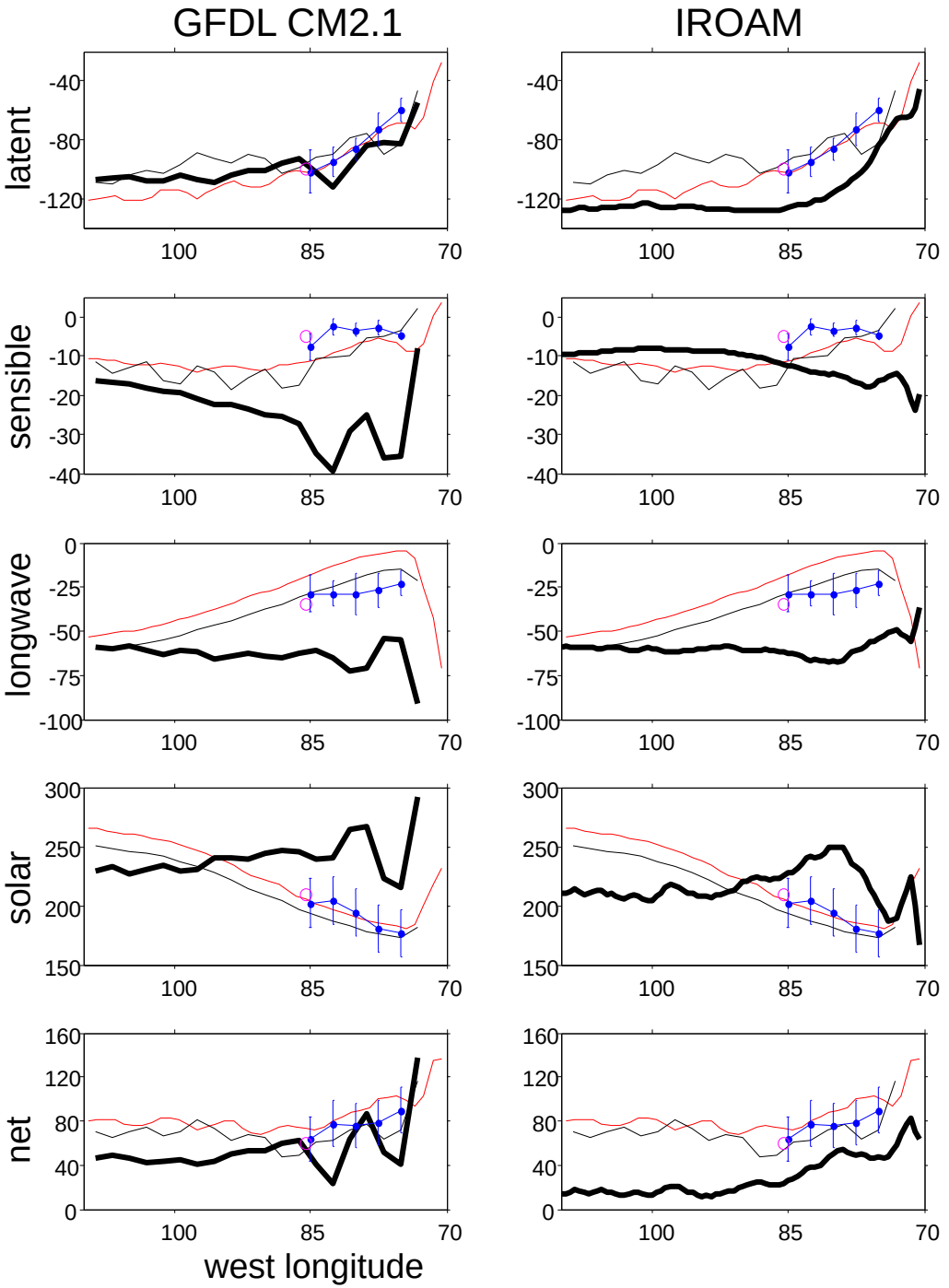




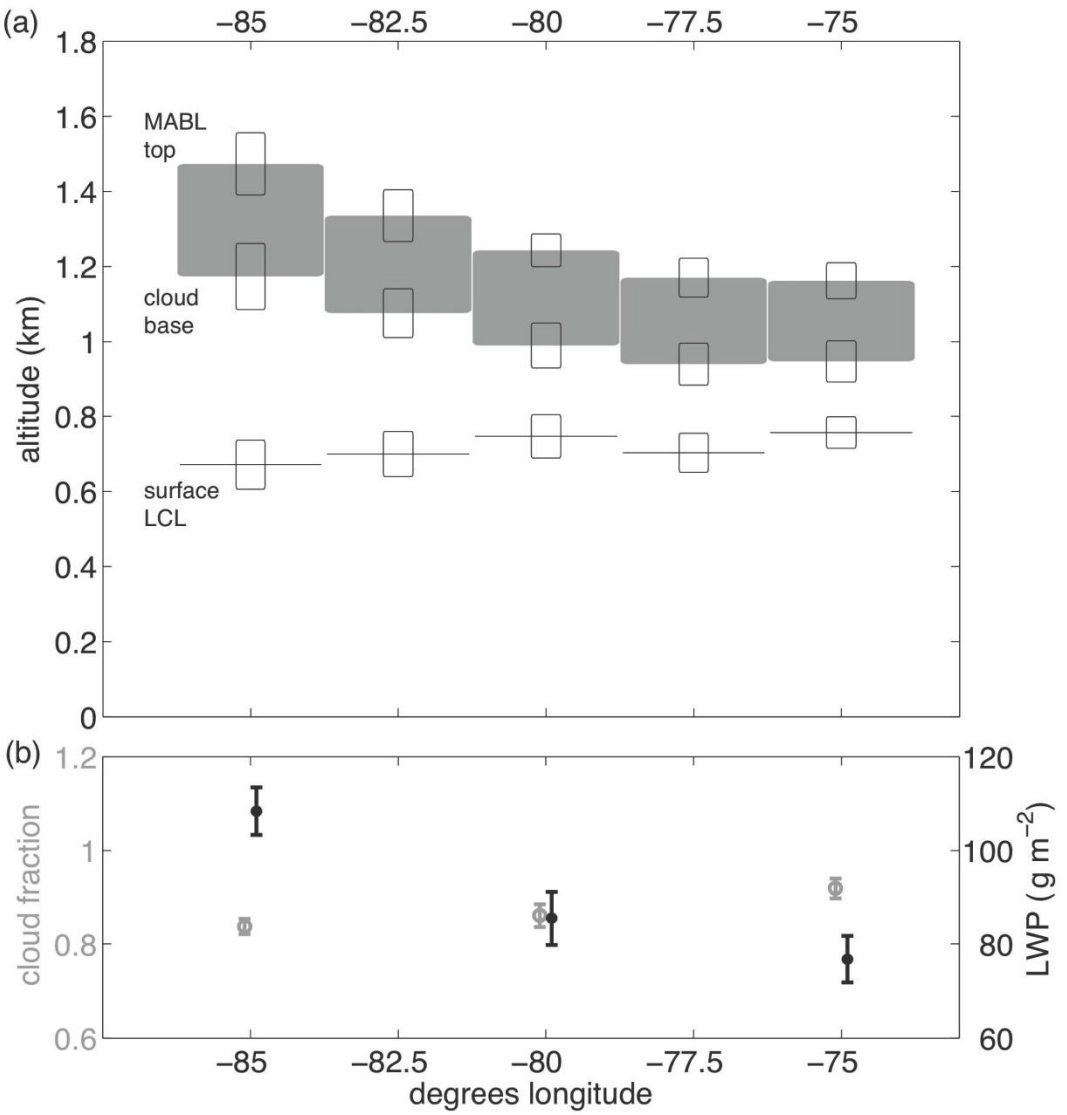

20˚S surface heat budget
250
200
150
100
50
0
-50
-100
-150
flux (W m-2)
solar
net
sensible
longwave
latent
-86
-84
-82
-80
-78
-76
-74
longitude

October heat fluxes at 20˚S:

assess analyses and models

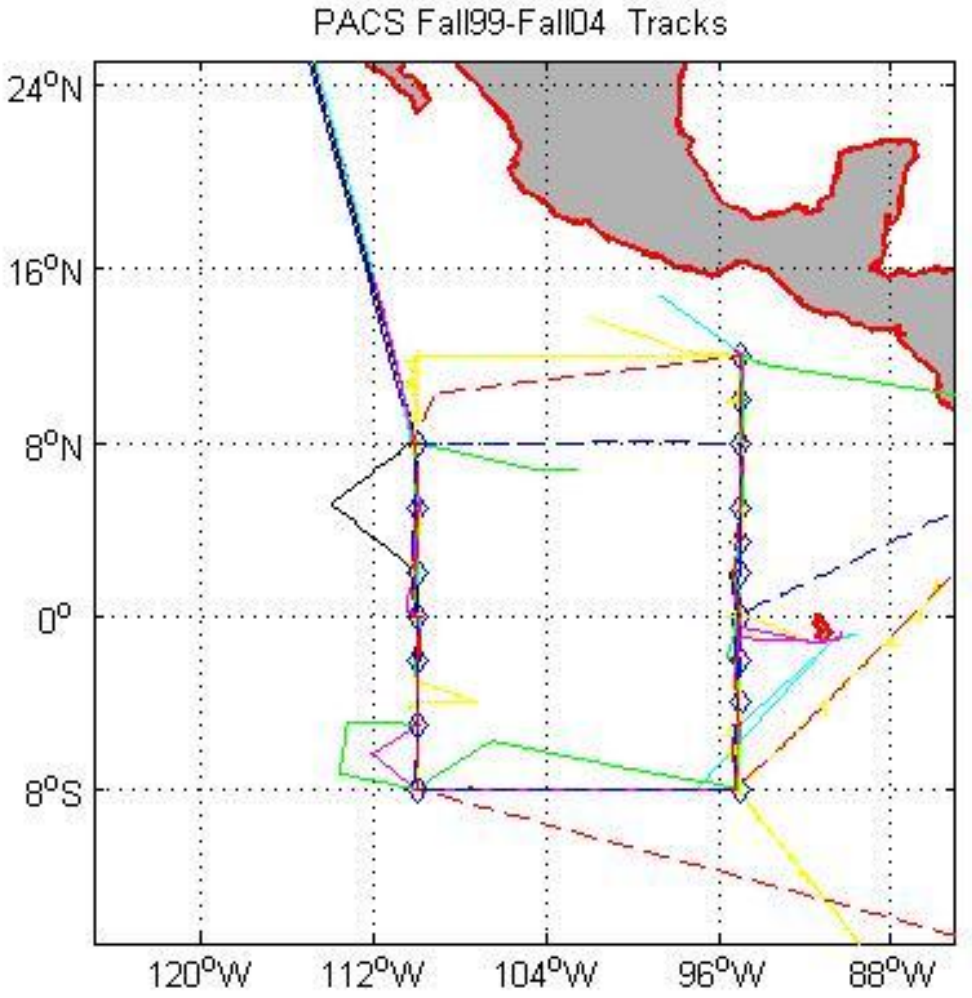


Cloud Properties on 20 S



PACS cruise tracks

9 PACS Cruises Conducted Before Stratus Cruises



Global/Regional Flux Products

- Re-analaysis products
- Blended products (WHOI, CORE)
- SURFA http://www.ncdc.noaa.gov/oa/rsad/air-sea/surfa.html

The SURFA (Surface Flux Analysis) project is a WCRP initiative promoted by the WCRP Working Groups on Surface Fluxes, Numerical Experimentation, Observation & Assimilation Panel, Ocean Observation Panel for Climate, etc.

EXAMPLE 2

Ship-Based Synthesis Data Compared with SURFA at WHOI Stratus Buoy 20 S 85 W

The simplest index of cloud effects on the surface energy budget: Focus on the Clouds

- Cloud forcing is the difference in the observed *mean* radiative flux versus what the flux would be in the absence of clouds (clear sky model)

$$CF_x = < R_x > - < R_{x0} >$$

- A related variable that is often used is the *maximum* cloud forcing, which is the conditional change in the flux when a *cloud is actually* present:

$$MCF_x = < R_{x1} > - < R_{x0} > \approx CF_x / f$$

- Uses simple measurements that can be made accurately

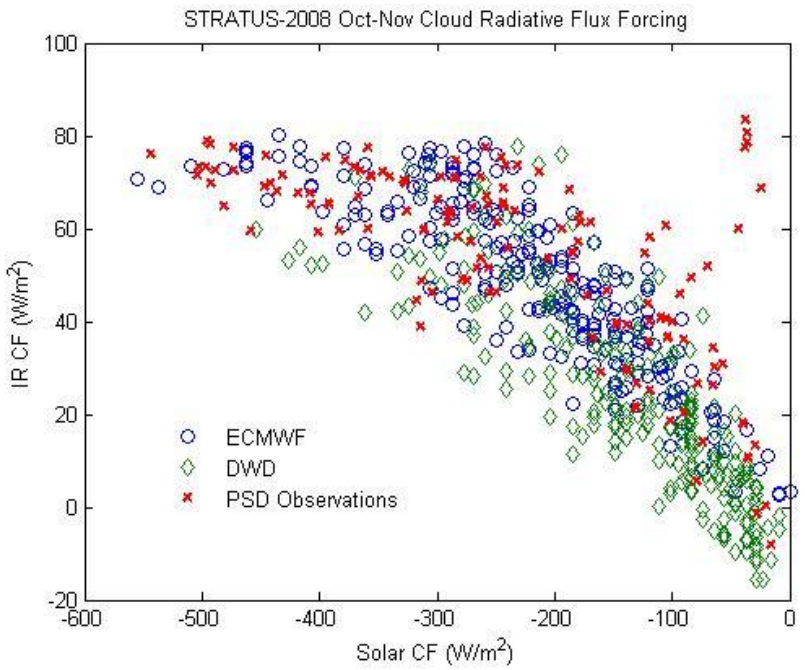
R=radiative flux; subscript x=s, solar or l, longwave

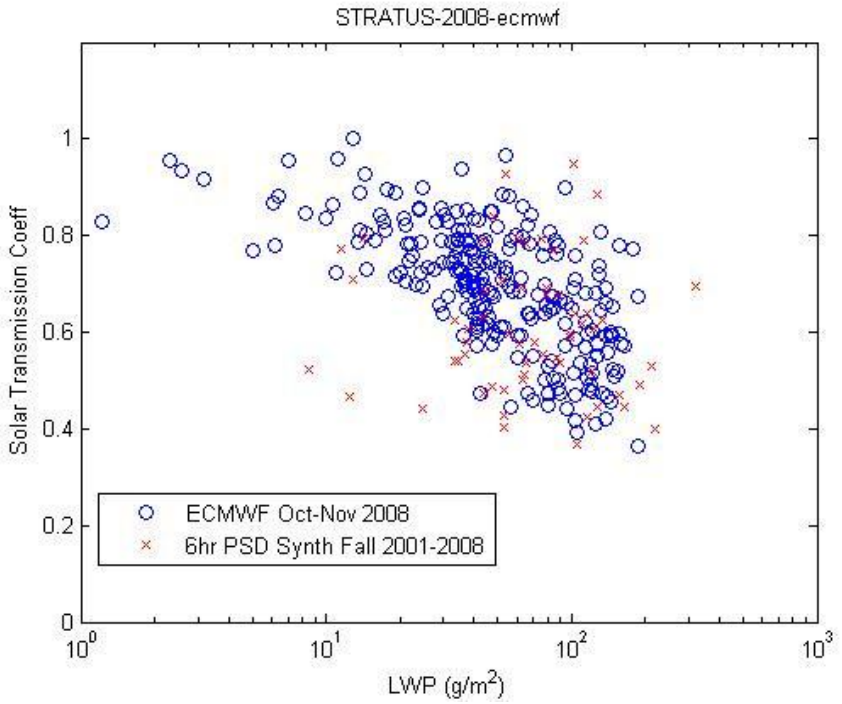
0 implies flux in the absence of clouds (model computation)

f is the cloud fraction

Basic Bulk Cloud-Radiative Properties

(o – ECMWF, Diamond – DWD, x – observed)



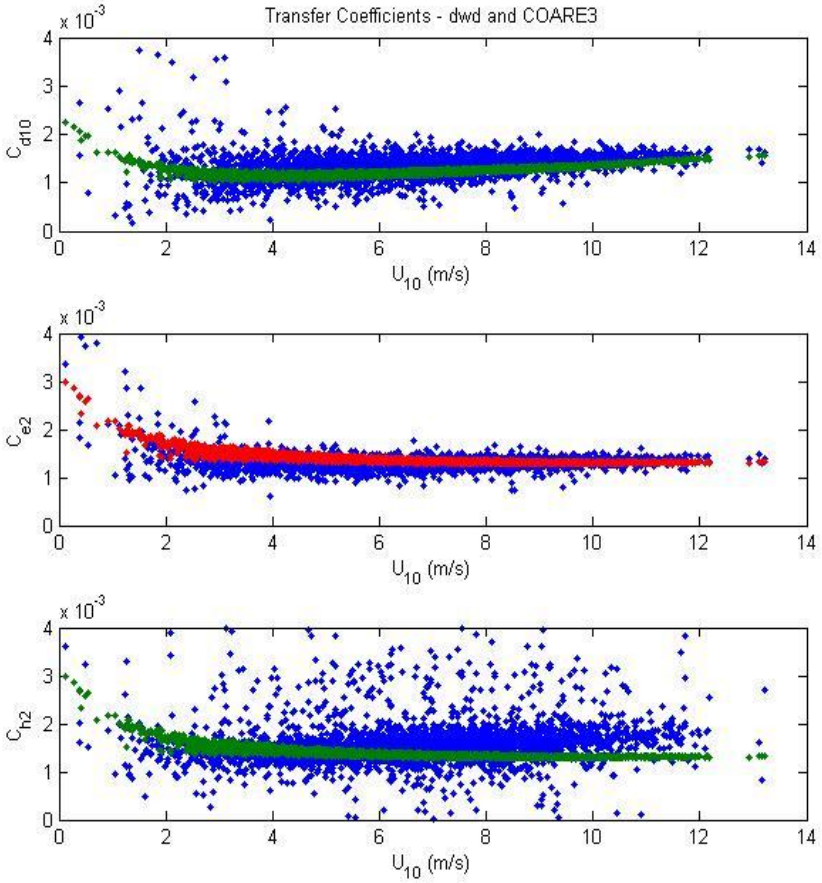


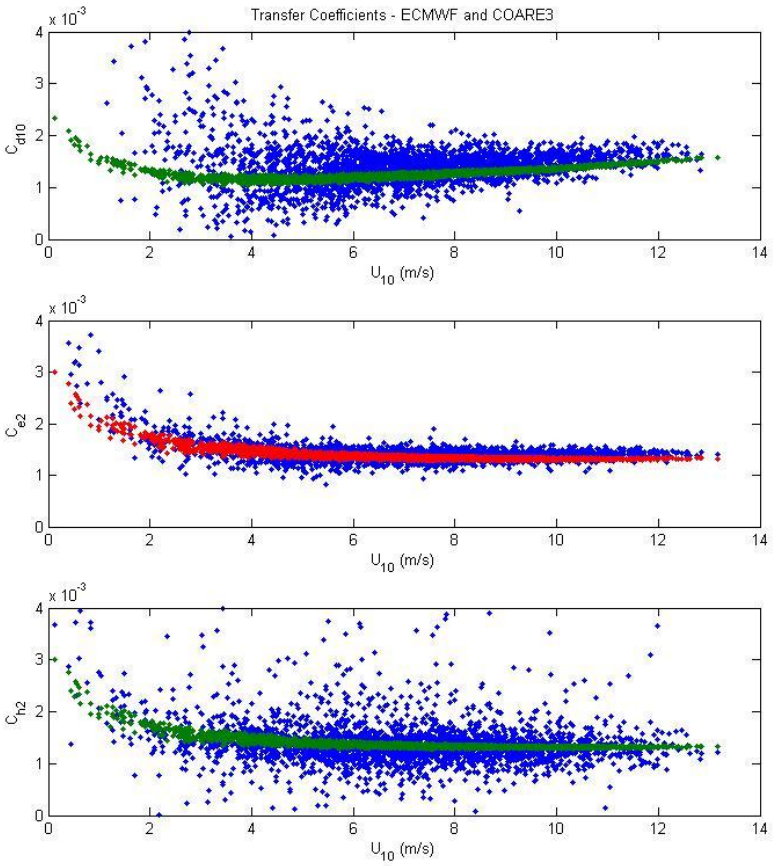
Cloud radiative forcing phase diagram – IR cloud forcing vs Solar cloud forcing during daytime.
CF defined as Mean radiative flux – Clear Sky flux
CF=0 in the absence of clouds

Cloud solar radiative flux transmission coefficient as a function of column Liquid Water Path.
Tr=Mean Flux/Clear sky flux
Tr=1 in the absence of clouds

Comparisons of Turbulent Parameterizations

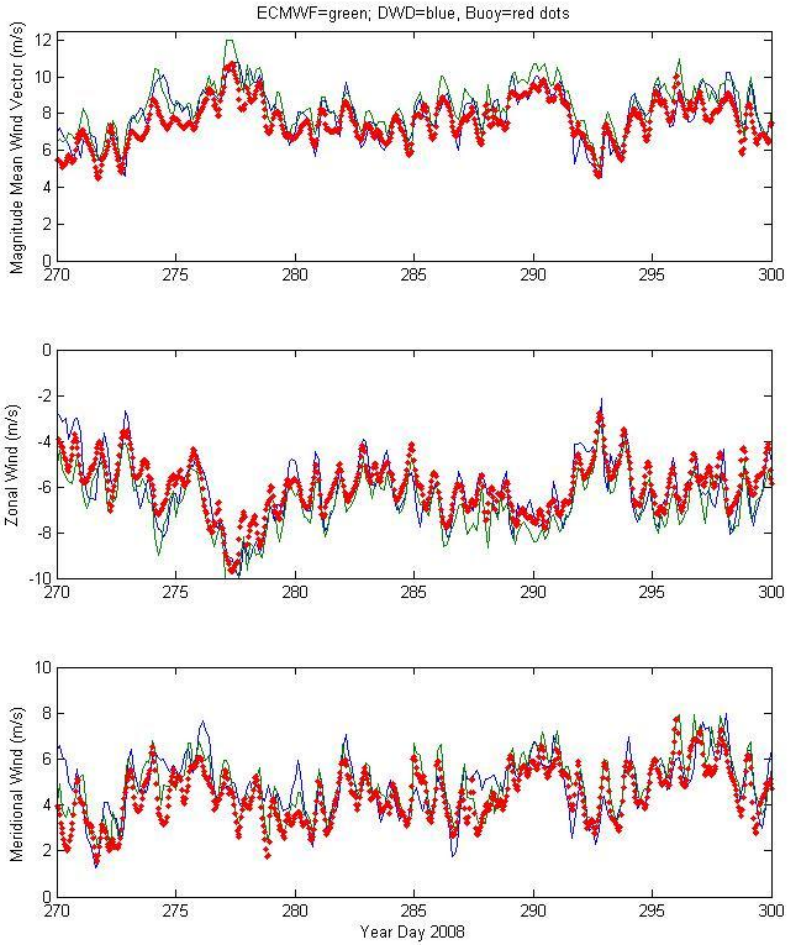
- SURFA near-surface meteorology re-run with COARE3.0 flux model. Fluxes and Transfer Coefficients compared with ECMWF



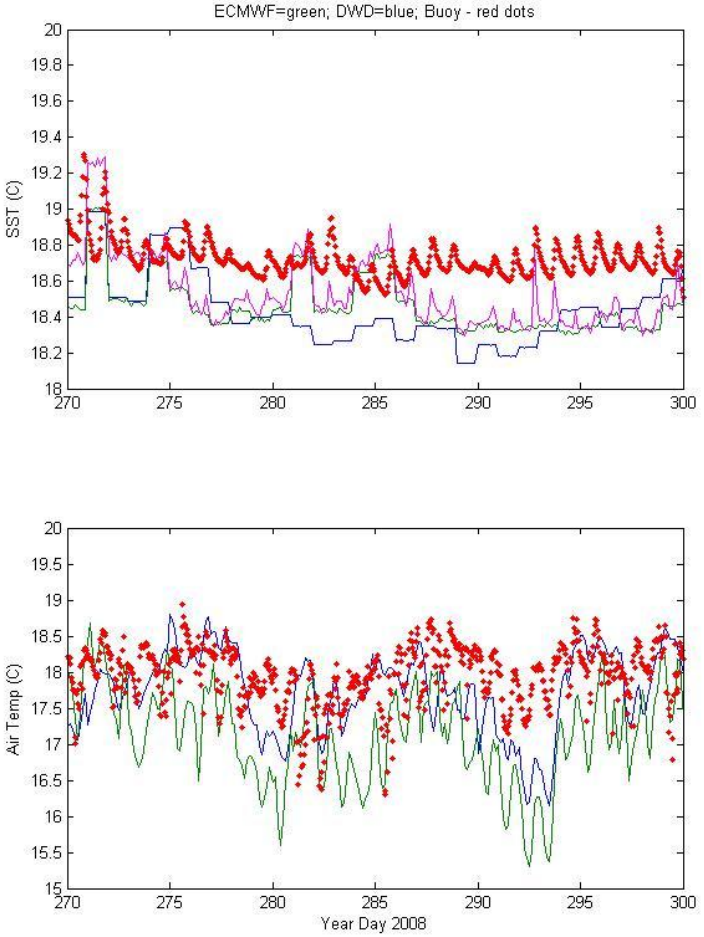


Transfer coefficients for momentum (Cd), sensible heat (Ch), and latent heat (Ce). Blue dots = DWD (left) or ECMWF (right); red/green dots are COARE3.0.

Wind and Temperature Comparisons



Comparison of 10-m wind speeds for Oct 2008: Upper panel – speed; middle – zonal wind; lower – meridional wind. ECMWF – green; DWD – blue; Buoy – red dots.



Comparison of temperatures for Oct 2008: Upper panel – SST; lower – 10-m air temperature. ECMWF – green; ECMWF+warm layer – magenta; DWD – blue; Buoy – red dots.

Simple Comparison of Mean Met & Fluxes

Table 1. Comparison of Mean Near-Surface Meteorological Variables and Cloud Properties. U, Ta, and qa computed at 10-m height for yearday>270 and yearday<330 . *The second row is for yearday>260 and yearday<300.

Var	Ts	Ta	qsea	qa	U	PW	LWP	Cloud f	N
Unit	C	C	g/kg	g/kg	m/s	Cm	g/m^2		
PSD 2001-07	18.6	17.7	13.1	9.2	6.8	1.65	116	0.87	296
ECMWF 2008	18.4 18.4*	17.2 16.8	12.8 12.8	8.9 8.6	8.1 8.1	1.38	74	0.73	479
DWD 2008	18.6 18.4*	17.8 17.4	13.0 12.8	8.6 8.5	7.6 7.8	1.55	45	0.45	479
WHOI Buoy 08	18.7*	17.7	13.1	8.9	8.0	—	—	0.83	969

Table 2. Comparison of Mean Fluxes for yearday>270 and yearday<330 . *The second row is for yearday>260 and yearday<300.

Var	Hs	Hl	Rns	Rnl	Rnet
Unit	W/m^2	W/m^2	W/m^2	W/m^2	W/m^2
PSD 2001-07	-6	-95	208	-36	72
ECMWF 2008	-14 -17*	-117 -127	270 251	-49 -48	90 59
DWD 2008	-9 -11*	-113 -117	309 302	-68 -74	118 99
WHOI Buoy 2008	-10*	-117	217	-44	45

Both models produce too much solar flux, which is PARTLY balanced by higher turbulent and IR radiative fluxes. This requires cooler, drier surface layer. Higher solar flux appears to be associated with lower cloud fraction and slightly lower LWP in clouds when they are present.

Planned SURFA Study:

SURFA Operational Models from ECMWF, JMA, and DWD

- STRATUS/DART 2 buoys, Chilean coast 8 PSD
- NTAS N. Atlantic Trade wind 1 PSD*
- WHOTS Hawaii 1 PSD*
- KEO Kuroshio Extension
- PAPA NW Pacific
  - *Annual PSD cruises planned for next 5 years

Observations of Air-sea Interaction in the Northeast Tropical Atlantic

C.W. Fairall, L. Bariteau, S. Pezoa, D. Wolfe
NOAA/ Earth System Research Laboratory, Physical Science Division & CIRES

Cruises made on Ron Brown 2006-08

Cruise track: 2006

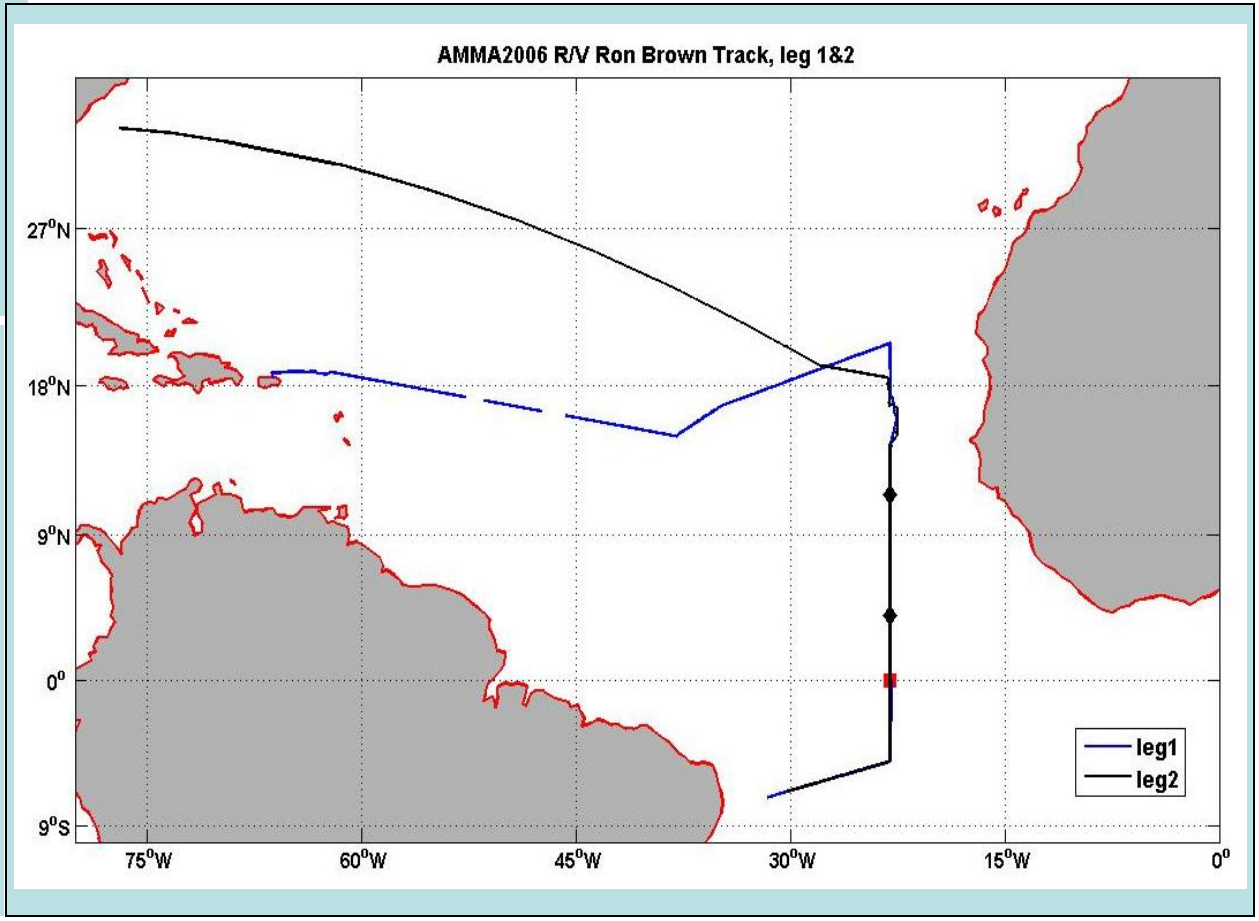
Two Legs:

- San Juan to Recife (May 27-June 18)

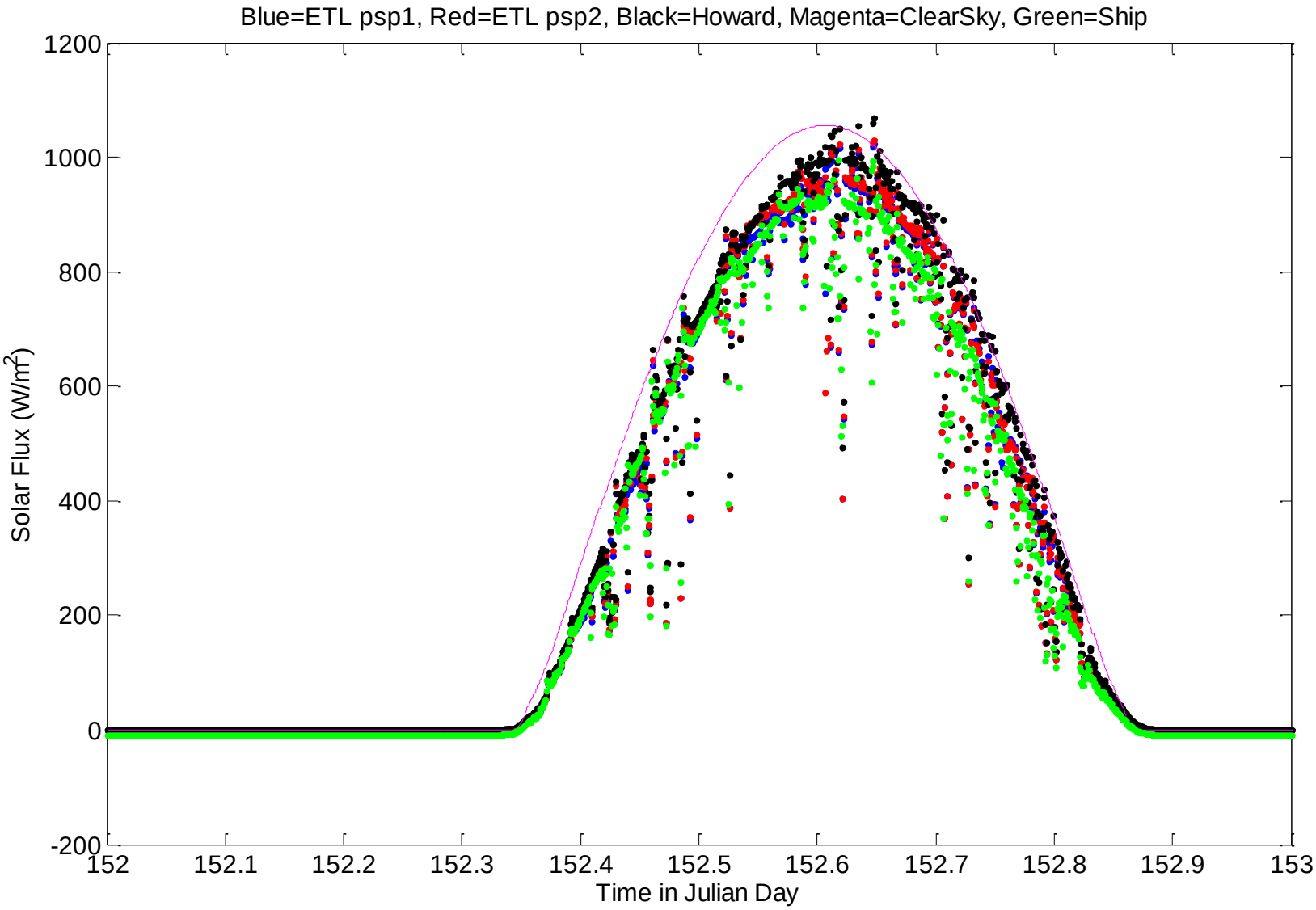
-Recife to Charleston (June 22-July 16)

Objectives:

- to collect a suite of oceanographic and meteorological observations in the northeast Tropical Atlantic
- to deploy two new moorings as a northeast extension of the PIRATA array (23°W at 4°N and 11.5°N)
- to service an existing mooring at 0º, 23ºW



Solar Clear Sky Model: Tuning the Aerosol Optical Thickness



Surface Radiative Flux Forcing for AMMA-2006