Air-Sea Surface Interactions: Emphasis on near-surface FLUXES

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- WHAT IS AN INTERFACIAL FLUX? Transfer of something between the fluids
- HOW? By molecular diffusion, turbulence, pressure-wave coherence, and bubbles/droplets
- MEASURE? In one fluid or the other
  - Direct measurement follows from fundamental definition
  - Turbulent Flux of x = <w'x'>, < > denotes average
  - W is vertical fluid motion
  - X is temperature, moisture, momentum, kinetic energy, aerosols, trace gases
- PARAMETERIZE?
  - Flux of x = Cx*Windspeed *(X_{sea}-X_{air})=Cx*U*DX
  - U, X_{sea}, X_{air} are system variables of each fluid
  - Cx the dreaded coefficient – contains all the information about the INTERFACE (including the fluxes themselves!!!)

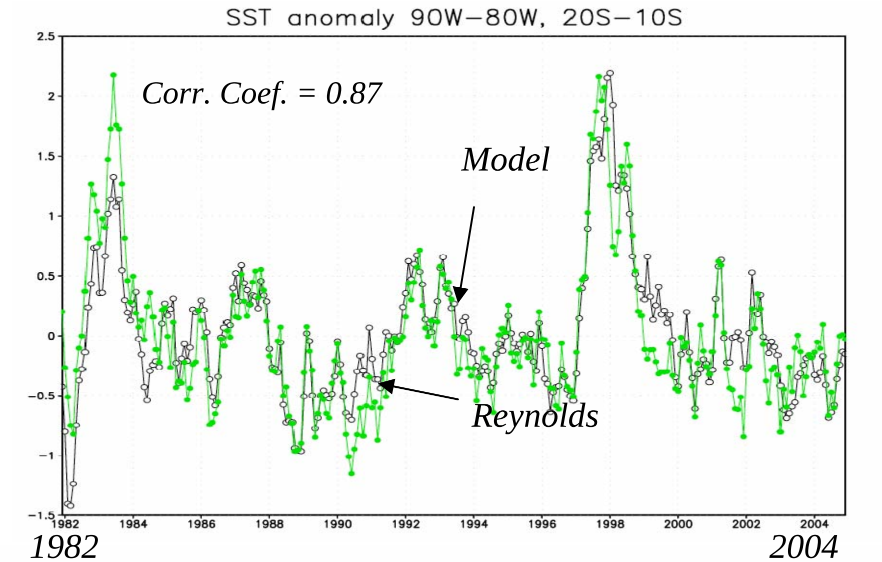
Air-Sea Surface Interactions:

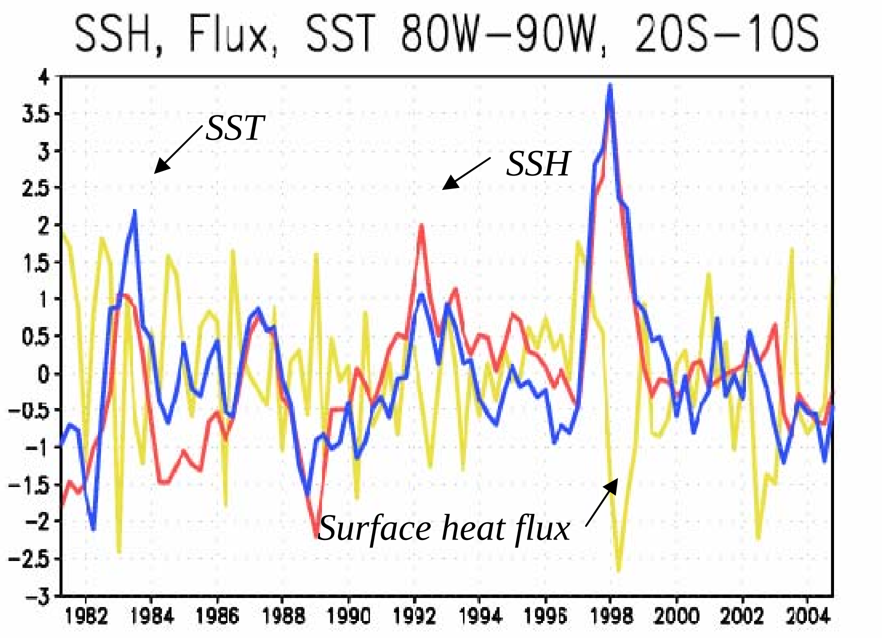
Physics of air-surface interactions
Examples of Coupling to Large Scale

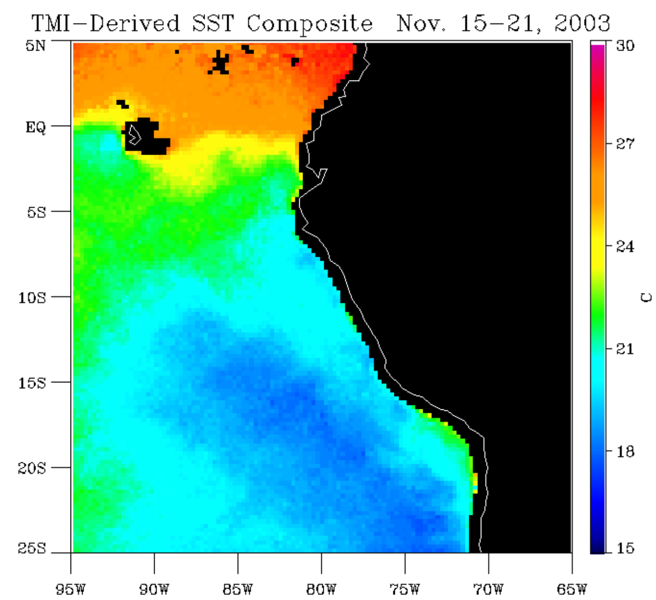
- Aerosols, cloud formation and transitions within the boundary layer
  - Oceanic direct production of Cloud Condensation Nuclei (CCN)
  - Indirect production of CCN (sea-air transfer of Dimethylsulfide-DMS)
- Effects of waves and sea spray on hurricanes
  - Sea spray parameterizations (drop source, heat fluxes)
  - Flux parameterizations in hurricane simulations
- Impact of the exchange of heat and gases over the ocean
  - Parameterizations of heat, momentum, gas transfer
  - Coupled Feedbacks

Upper ocean processes under stratus clouds in the SE Pacific

Ocean General Circulation Model (OGCM) Experiments







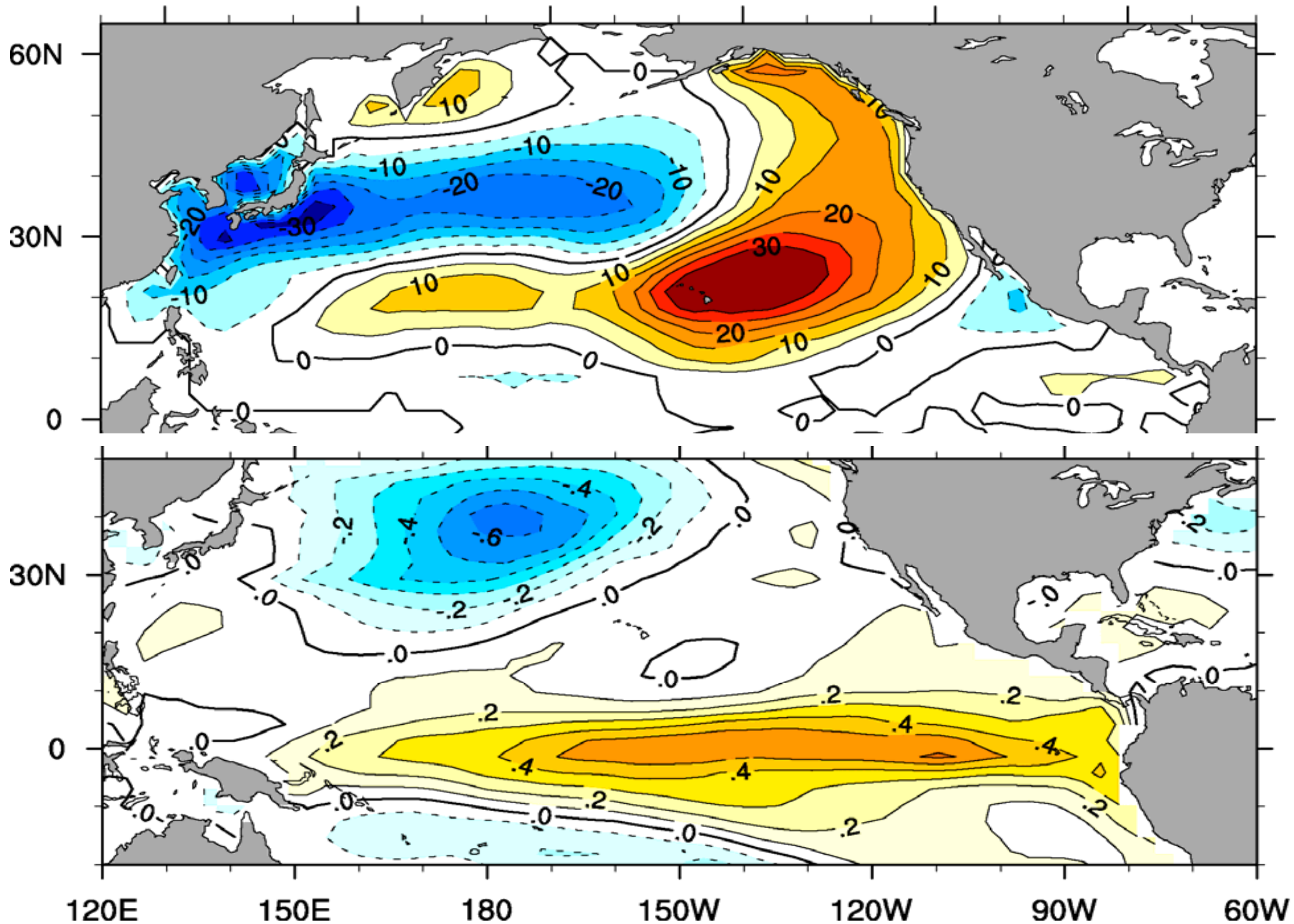
Using atmospheric reanalysis as driver, an OGCM is able to well simulate interannual variations of upper ocean and SST in the stratus cloud region.

***Sub-seasonal variability**

***Air-sea feedback** processes (coupled model experiments)

Seasonal Footprint Mechanism: Extratropical El Niño Trigger

- **Hypothesis: N Pacific atmospheric variability in winter is a TRIGGER**
- Surface Heat Flux → Subtropical SSTs in spring/summer → Westerly Wind on the Equator →Kelvin waves →ENSO
- **Test hypothesis** by adding heat flux forcing only in winter to a coupled atmosphere-ocean model



Heat Flux Forcing (Wm^{-2}) NDJFM(0)

SST Response NDJ (1)

Perspective on Surface Flux Parameterizations

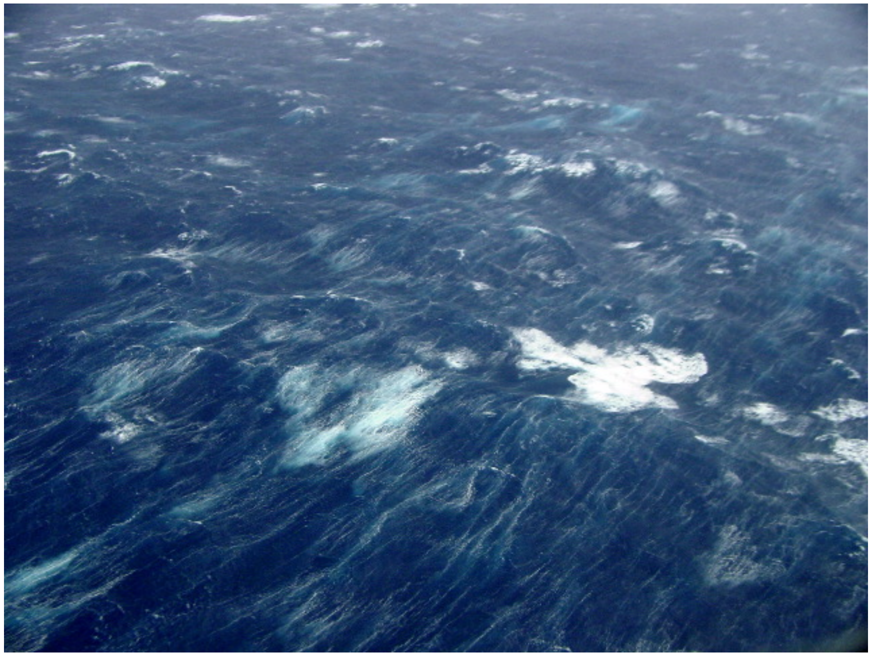
$$Flux = Coefficient * Windspeed * [X_{seasurface} - X_{air}]$$

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

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

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

Cx; $k_x = C_{gas} * U$; $V_d = C_{aerosol} * U$ Describes the Interface



Do you believe in miracles?

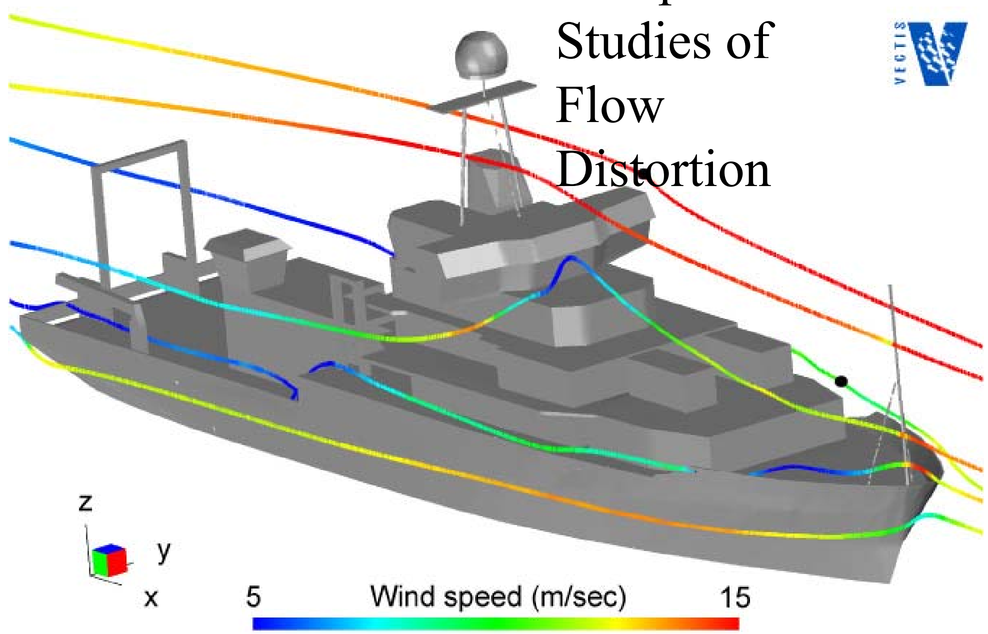
Progress In Flux Parameterization

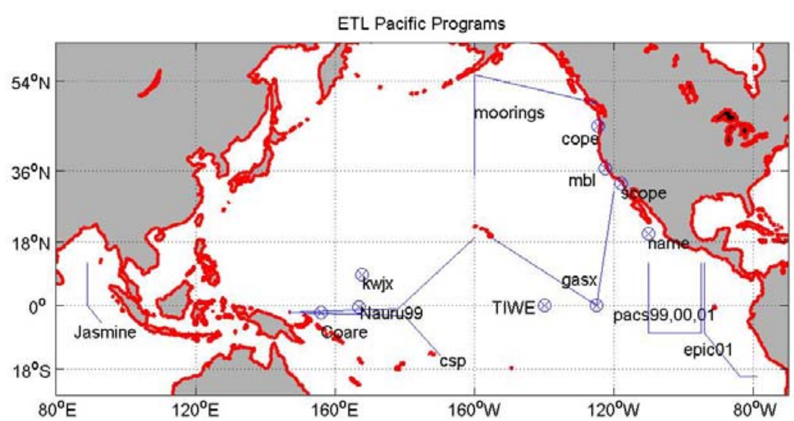
- Breakthroughs in Observing Technology
  - Sensors and computers
  - Ship motion and flow distortion corrections
- Breakthroughs in Physically-Based parameterization
  - One or two levels deeper in fundamental physics
  - Fundamental process variables
    - Droplet flux ~ $U^{3.4}$
    - Droplet flux ~ Whitecap Fraction
    - Droplet flux ~ Wave Energy Dissipation (from wave model)
- Results
  - Vastly expanded high quality database
  - NOAA COARE flux algorithm (s)

Measurement Technology

Fast Ozone Sensor

Computer Studies of Flow Distortion

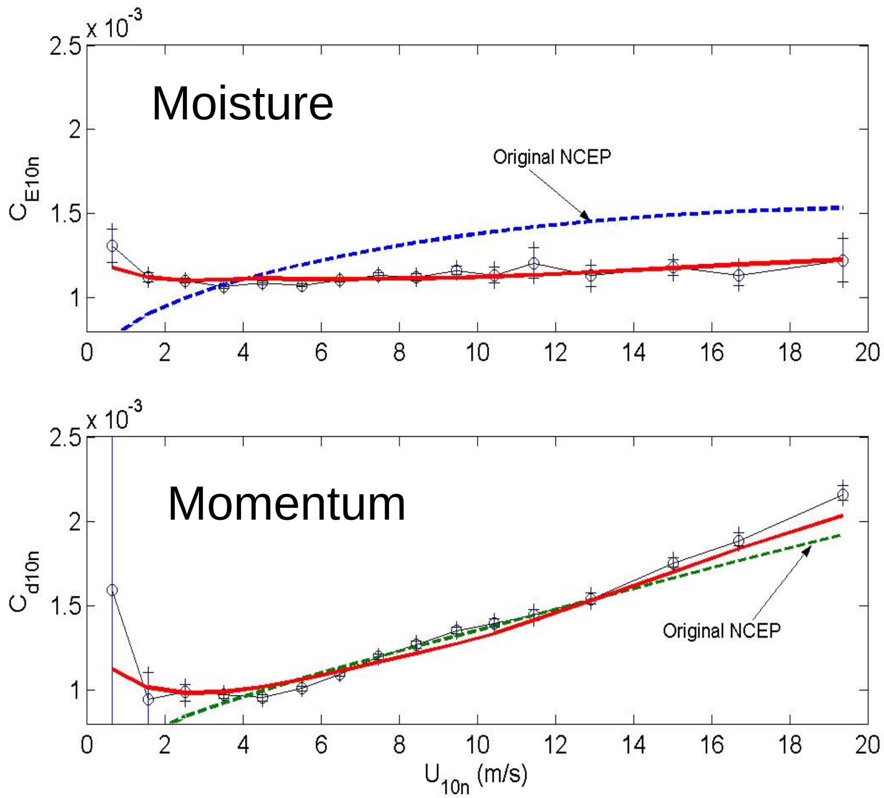


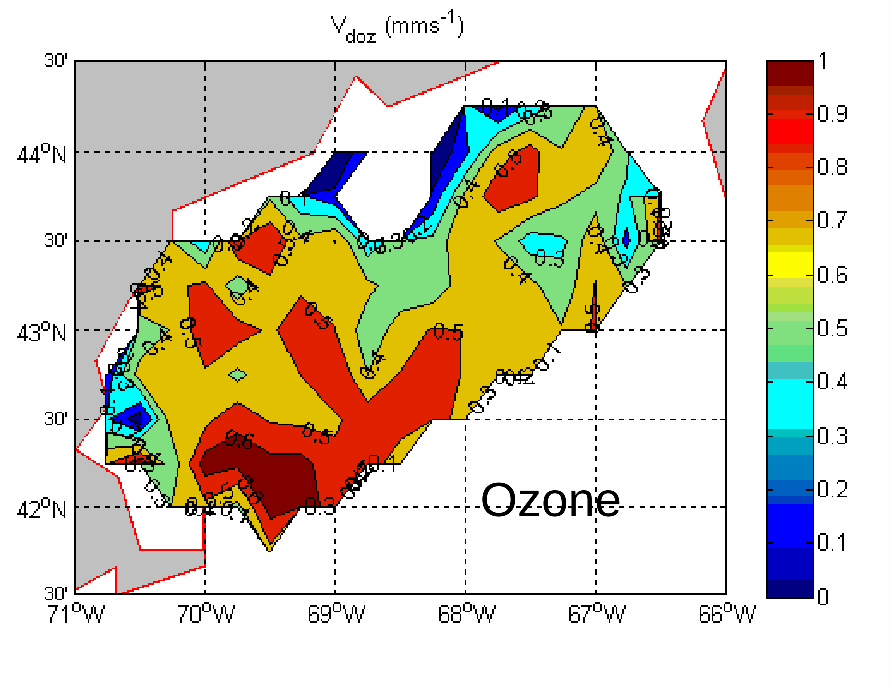


PSD Cruises 1992-2001

Turbulent Flux Sensors

NOAA COARE Air-Sea Flux Parameterization: One Structure - All Variables

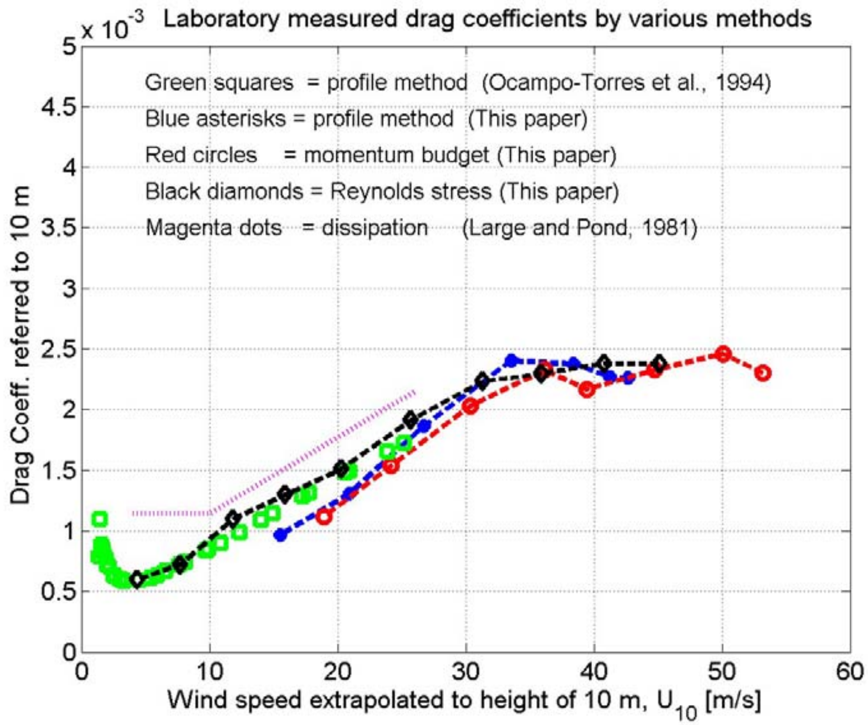




Air-Sea transfer coefficients as a function of wind speed: l**atent heat flux** (upper panel) and **momentum flux** (lower panel). The red line is the COARE algorithm version 3.0.

Contour map of NOAA COARE **Ozone** deposition velocity from the New England Air Quality Study field program (2004)

Transition in Fluxes at High Wind Speeds: Droplet Effects?



Hypothesized Droplet Effects

•Increase or decrease sensible heat and stress

•Increase latent heat flux

•Increase or decrease gas transfer

•Increase hair loss (too much combing)

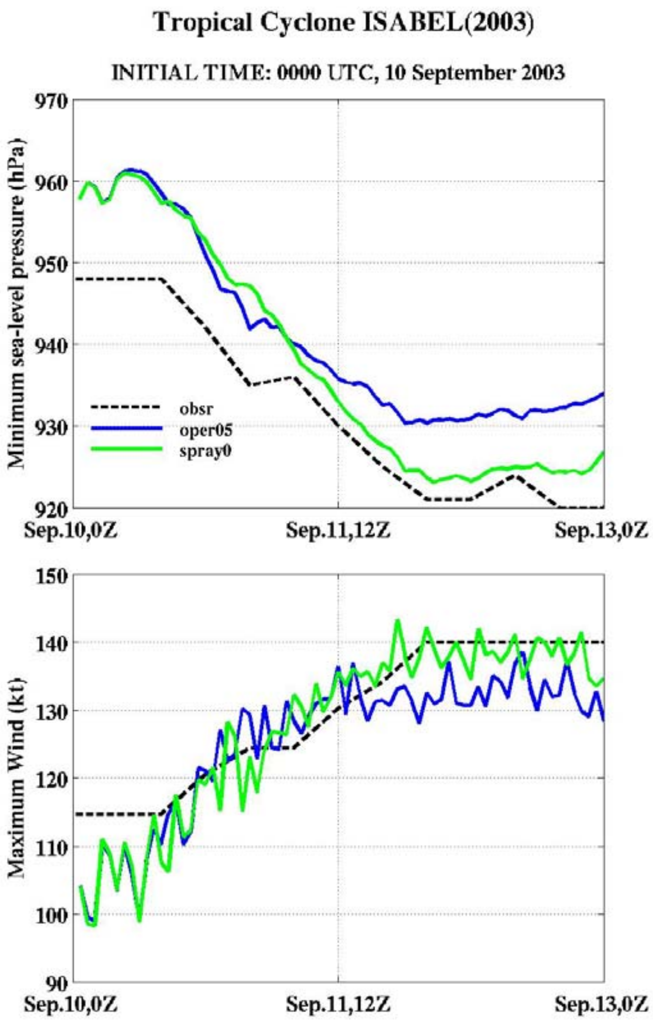
USATODAY.com

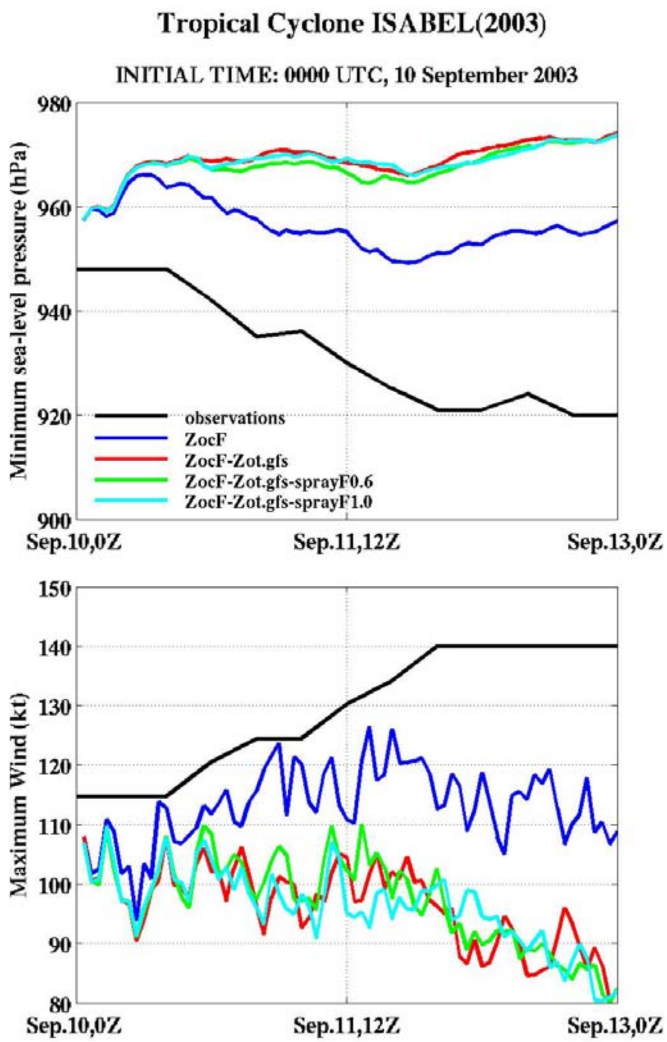
Sea spray whips winds to hurricane strength

By Michelle Lefort, USA TODAY

Posted 7/31/2005. In a study out last week, researchers from the University of California, Berkeley, and a Russian colleague argue that sea *spray kicked up by storms actually has a lubricating effect* that helps accelerate wind. Chorin says that sea spray reduces turbulence — chaotic fluctuations in wind velocity and direction — like a comb through unruly hair.

Simulation with GFDL Operational Model: Isabel





GFDL Model OLD surface fluxes: Wind and without **sea spray**

GFDL Model, **NEW&IMPROVED** surface fluxes: with and without **sea spray**

Where is the Action in Surface Fluxes?

- General: high wind speeds; Coastal
- Gas transfer: General theory for all gases, bubbles, direct measurements
- Linking to fundamental variables (waves, energy transfers, bubbles, spray)
- Near-surface observations in hurricanes
- Transition observationally based parameterizations to Operations (WRF, CFS, …)

Some Exciting New Developments at ESRL

- Hurricanes
  - New observing systems (P-3 W-band radar, buoy turbulence/spray, UAS?)
  - Cooperation with EMC on *Hurricane* Weather Research Forecasting Model
- Gas Fluxes
  - Big NOAA programs – Health of Atmosphere, Carbon Cycle
  - Great linkages with Universities (NSF programs)
- Observation-Model synthesis project SURFA (ESRL, PMEL, NCDC)
  - Matching NWP global surface fluxes with routine flux observations
  - IOCADS, BSRN, TAO, …

SPECIAL BONUS SLIDE: Droplet Contribution to Gas Transfer?

*Area effect: At high winds droplet area becomes comparable to ocean area

*Concentration effect: As droplets evaporate, concentration of trace gas in the droplet increases (DX gets bigger) 8 times at RH=80%

*Droplets effects could reverse direction of flux