Air-Sea Coupled Modeling of Storms: Collaborative Research at ESRL

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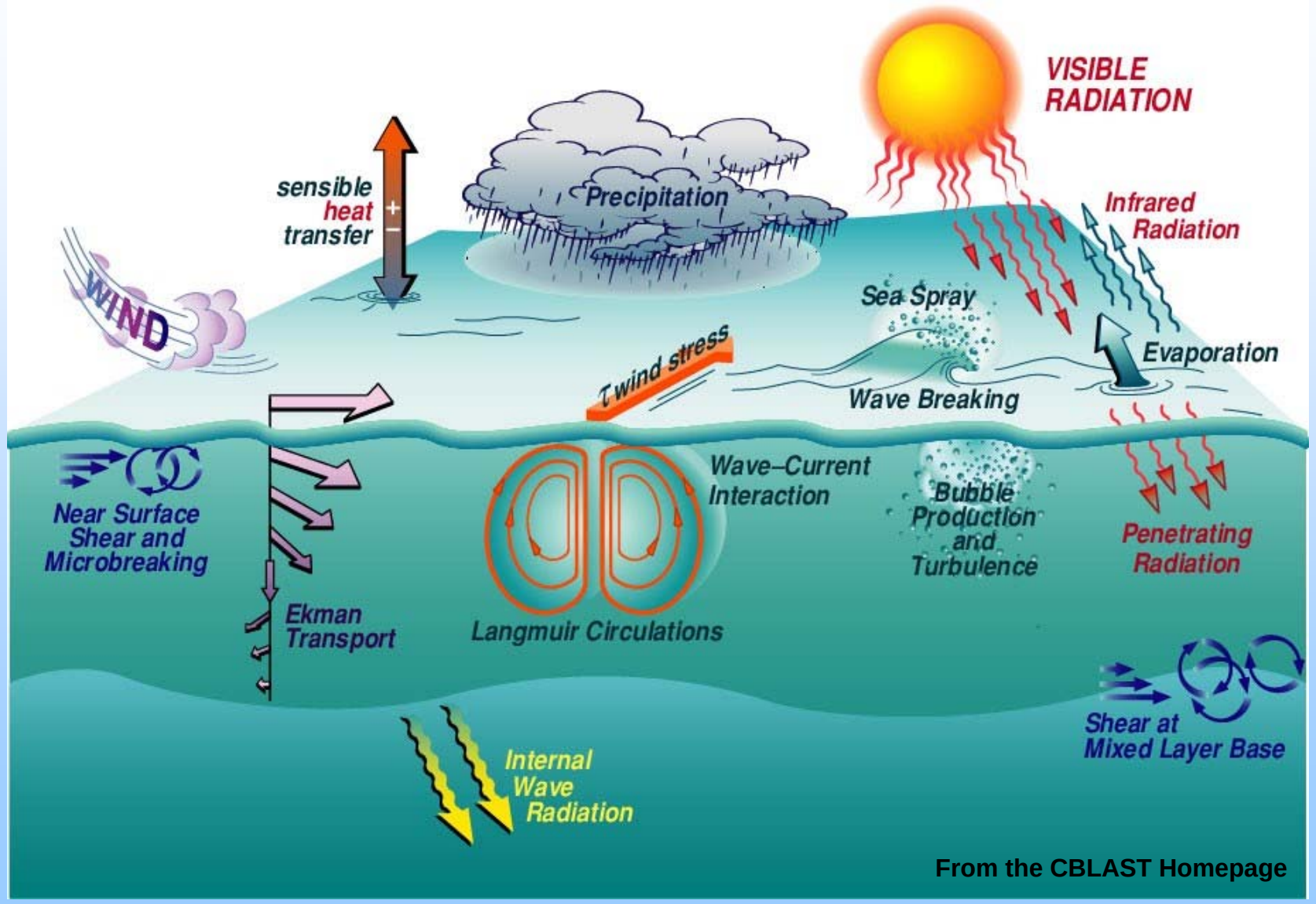
OUTLINE

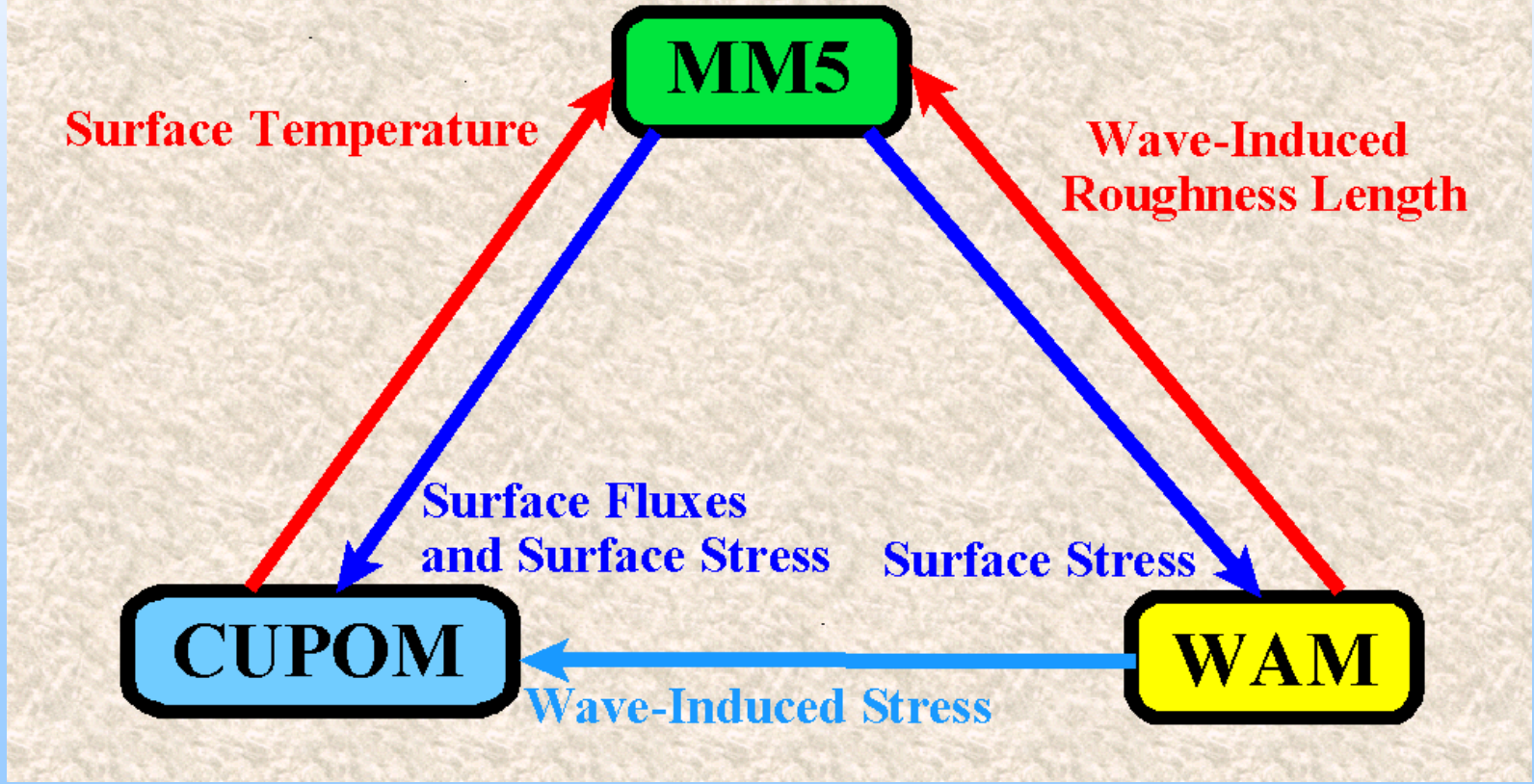
- Air-sea coupled modeling at high winds: a research subject
- ESRL regional air-sea coupled model for storm simulations
- Challenges of air-sea coupled modeling
- Future potential in research

Air-Sea Interaction: Multi-Scale Processes



Components of the ESRL Coupled Air-Sea Modeling System

Bao, J.-W., J. M. Wilczak, J.-K. Choi, and L. H. Kantha, 2000: Numerical Simulations of Air-Sea Interaction under high Wind Conditions Using a Coupled Model: A Study of Hurricane Development. *Mon. Wea Rev.*, **128**, 2190-2210.



Air-Sea Interaction at High Winds: Issues to Address

- Anomalous oceanic mixing associated with El Nino and landfalling winter storms
- Air-Sea fluxes and hurricane intensity
  - Role of sea-spray on sensible and latent heat fluxes

Surface Flux Parameterizations

$$Met\ Flux : < w' x' > = C_x U (X_s - X_r) = C_x U \Delta X$$

- U, X_s, and X_r are the surface wind, and the property x in the ocean and air
- C_x is the key to the parameterization – contains all the information about the INTERFACE (including the fluxes themselves!!!)

C_d -- drag coefficient **C_k -- heat exchange coefficient**

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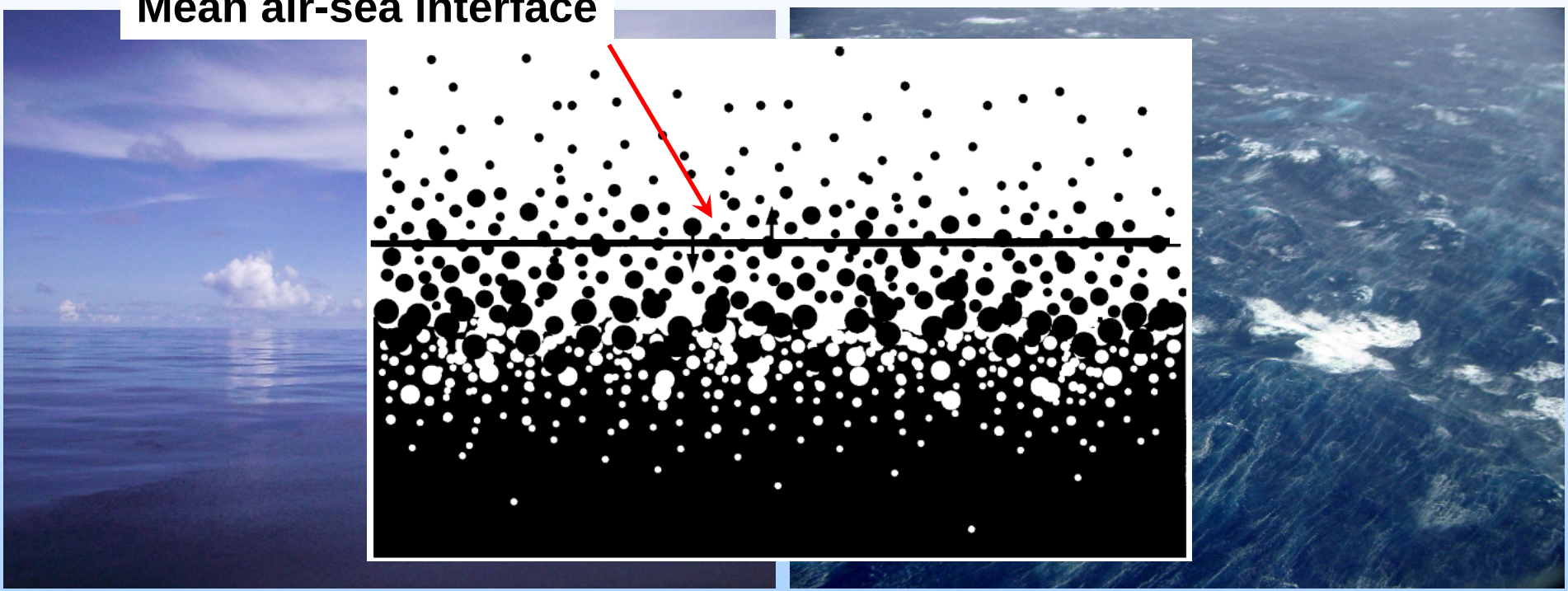


A parameterization of sea-spray effect on momentum and heat fluxes has been developed at NOAA/ESRL.

Droplet Effect in Fluxes at High Wind Speeds

Momentum flux: competing theories:

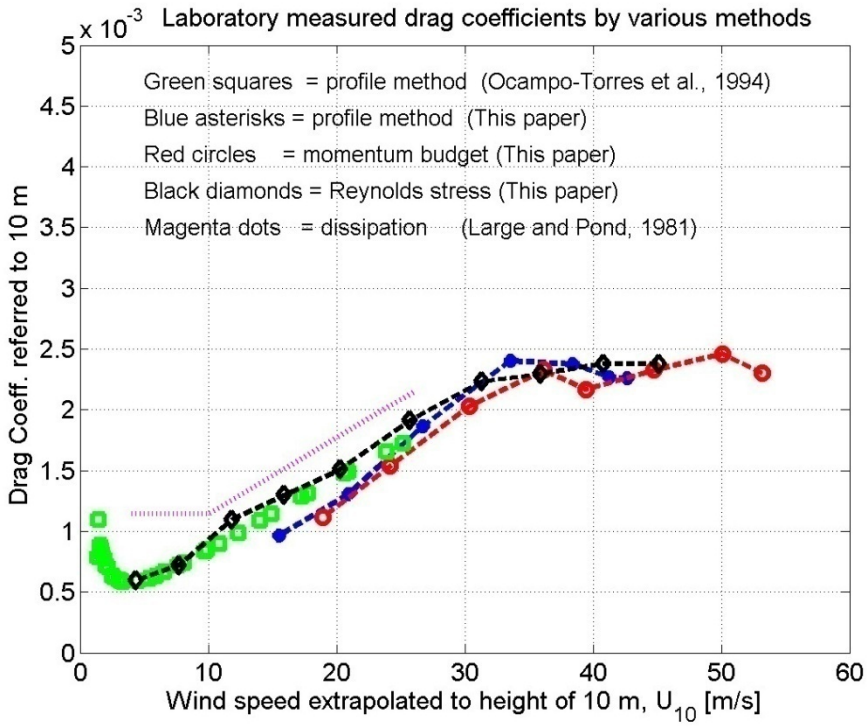
- Spray is generated at the expense of the mean-wind momentum, therefore reduces surface winds.

- Spray is generated at the expense of turbulence kinetic energy, increases the surface layer stability, and thus increases surface winds by reducing the surface drag.

Droplet Effect in Fluxes at High Wind Speeds

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.



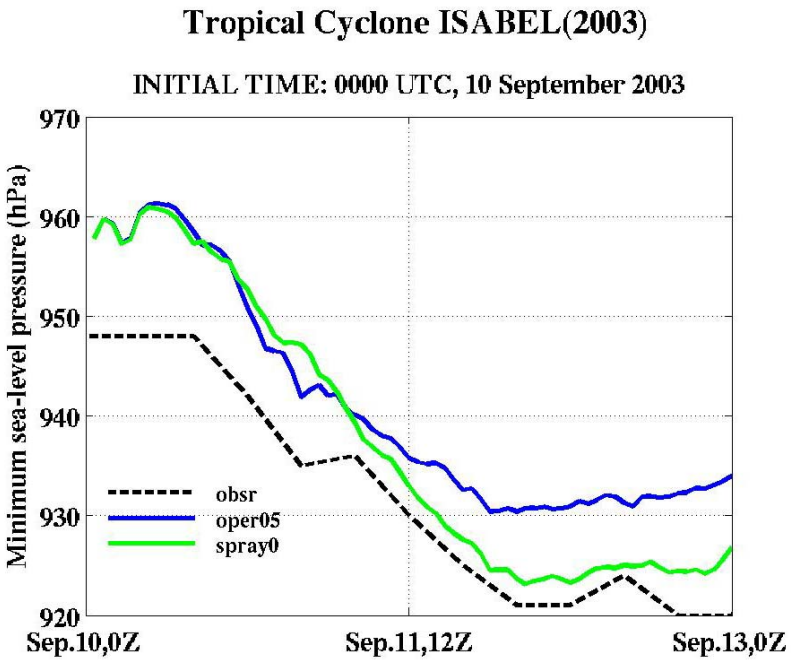
Droplet Effect in Fluxes at High Wind Speeds

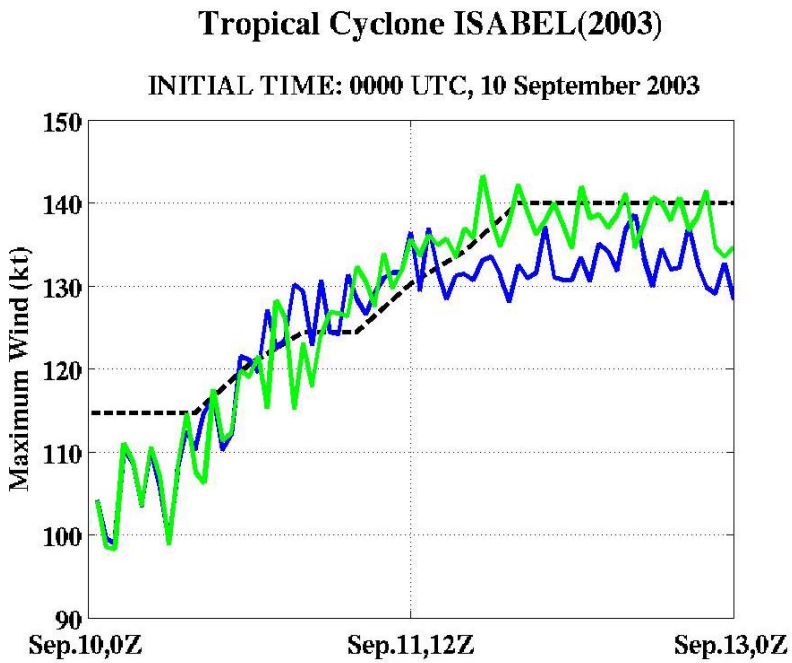
Sensible and latent heat fluxes: spray-size dependent

1) **Thermal conduction and evaporation occur on different time scales.**
2) **Time scales of both are highly dependent on drop size.**

- **Small droplets do not add to the total enthalpy flux, but cool and moisten the surface layer, and thus decrease hurricane intensity.**
- **Large droplets increase the enthalpy flux, warm the surface layer, and increase hurricane intensity.**

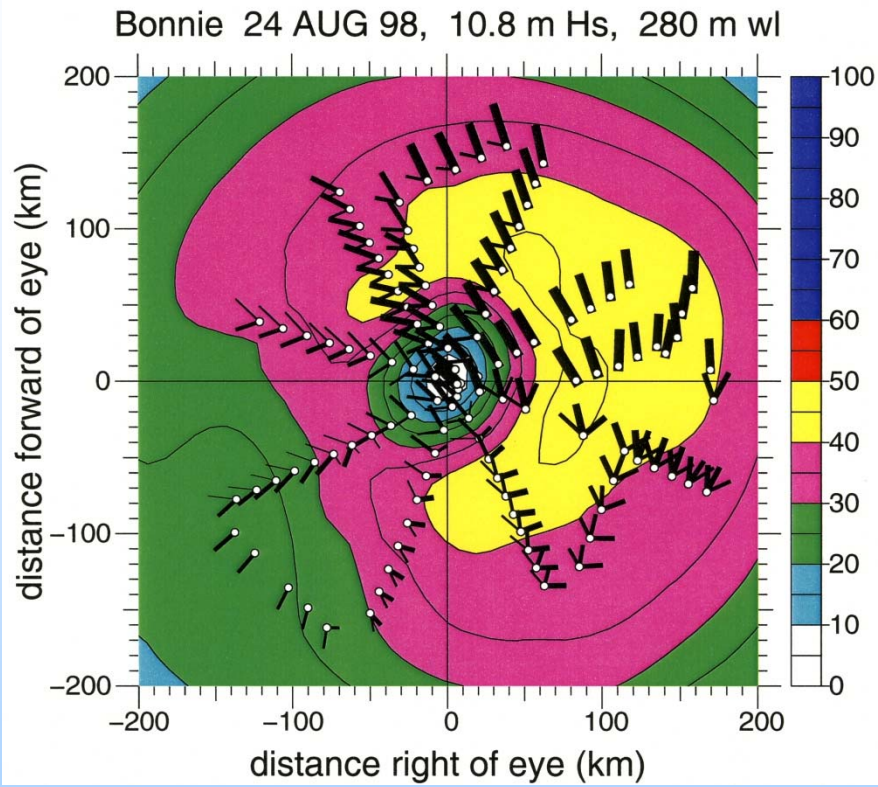
Simulation with GFDL Operational Model: Isabel





GFDL Model, spray-modified (green) surface fluxes: with and without sea spray

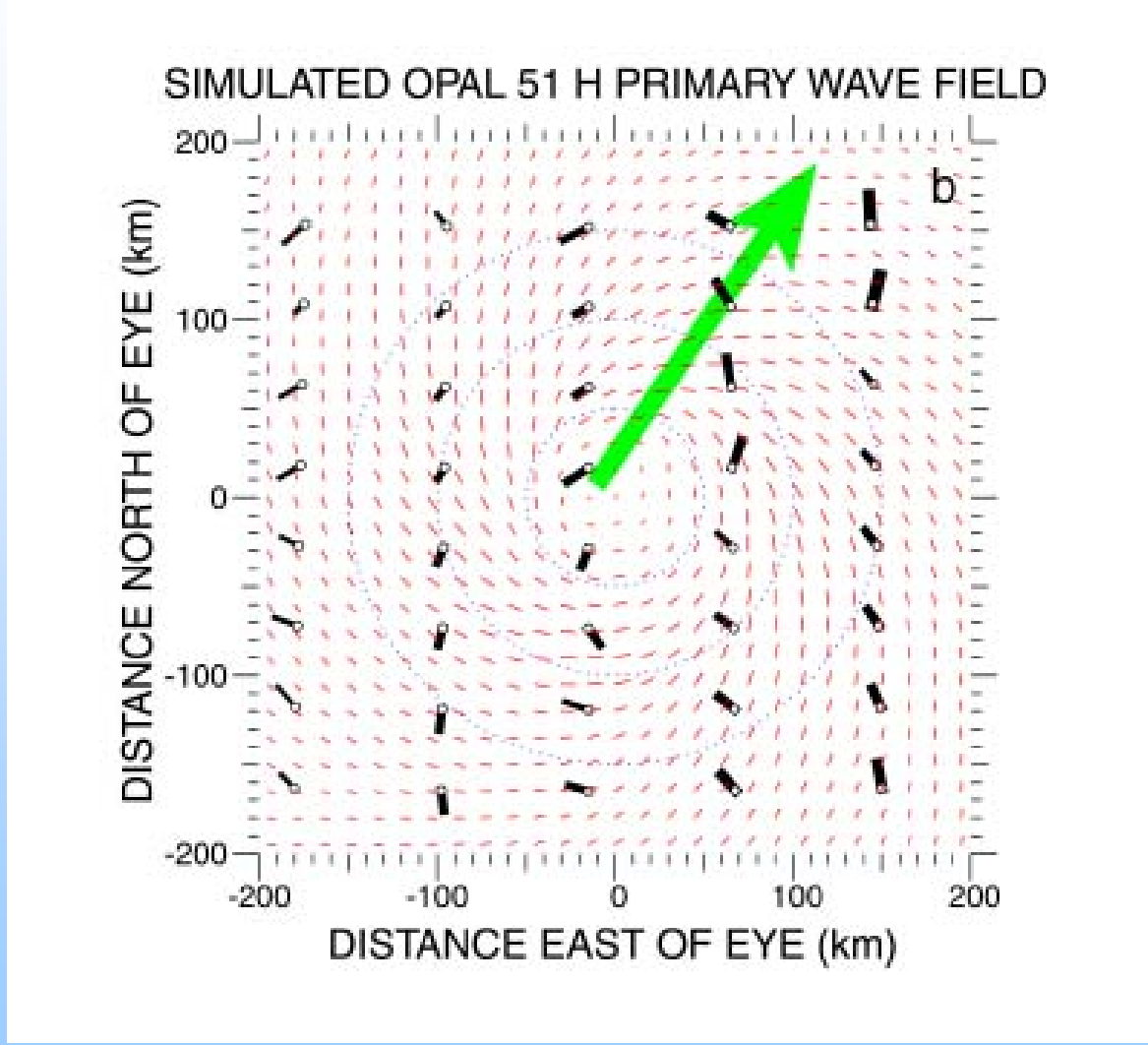
Unresolved Problems in High Resolution: Wave-Property Dependent



Black radials extend in the wave propagation direction with a distance proportional to the wavelength. Their width is proportional to the significant wave height. Wind contours at 5 m/s, and the color scale changes at 10 m/s intervals.

Courtesy of E. J. Walsh

Unresolved Problems in High Resolution: Wave-Property Dependent



Air-Sea Coupled Modeling Provides Potential Research Opportunities

- General parameterization of air-sea fluxes: high wind speeds and oceanic mixing
- Gas transfer: General theory for all gases, bubbles, direct measurements
- Linking to fundamental processes (wave breaking and spray/bubble generation)
- Near-surface observations in hurricanes
- Transition from Research to Operations

Some Exciting New Developments at ESRL

- New NOAA funds (!!?): DTC
- New observing systems (W-band radar for P-3, buoy turbulence/spray)
- Cooperation with NWS on *Hurricane* Weather Research Forecasting Model