A Comparison Study of Effects of Surface Roughness Representation in WRF and COAMPS on Hurricane Intensity Forecasts

Yi Jin

Sue Chen, Shouping Wang, James Doyle, Chi-Sann Liou, Jerome Schmidt, and Richard Hodur

Naval Research Laboratory
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Introduction

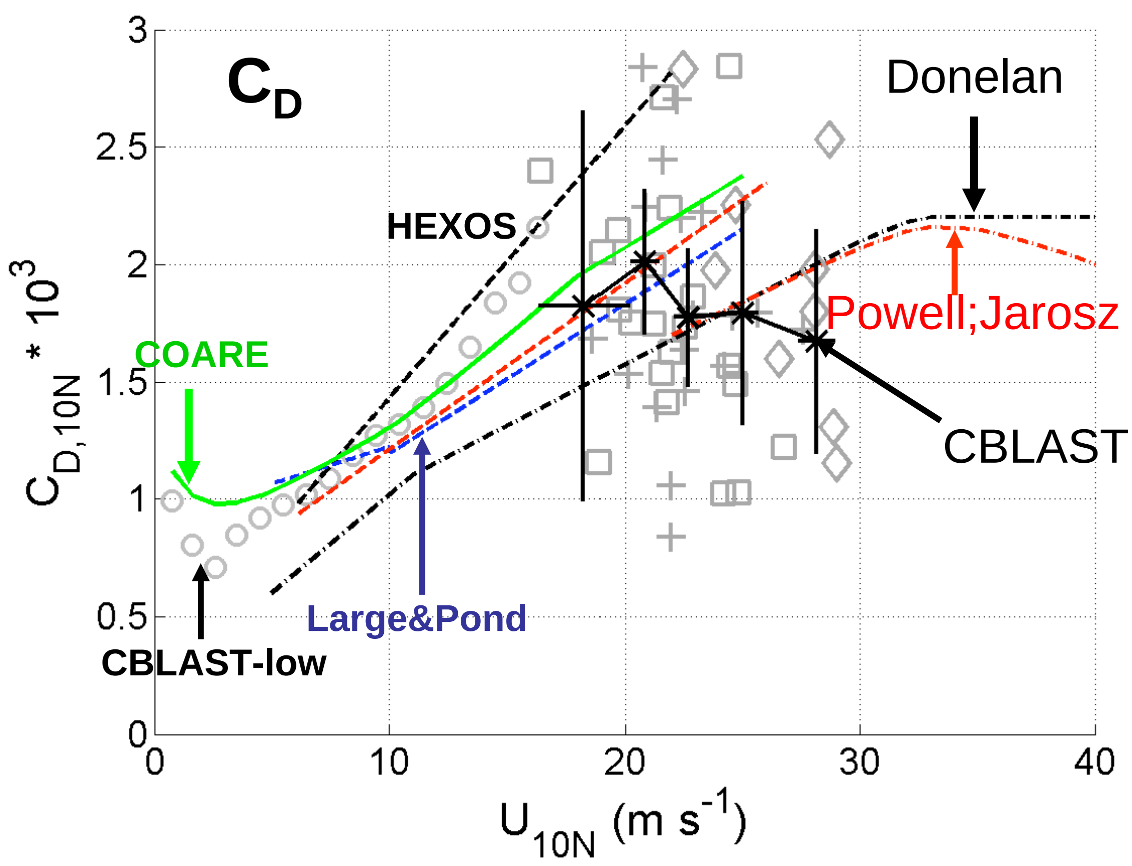
Objectives

- ➢Evaluate transfer coefficient calculations used by NWP models for TC intensity forecasts.
- ➢Incorporate new findings from recent observational studies (e.g., CBLAST) into NWP models to improve TC intensity forecasts

Experimental Design

- ➢Various NWP transfer coefficient calculations implemented in a 1-D model.
- ➢COAMPS® simulations of Hurricane Isabel (2003) (5-km) used to evaluate various schemes

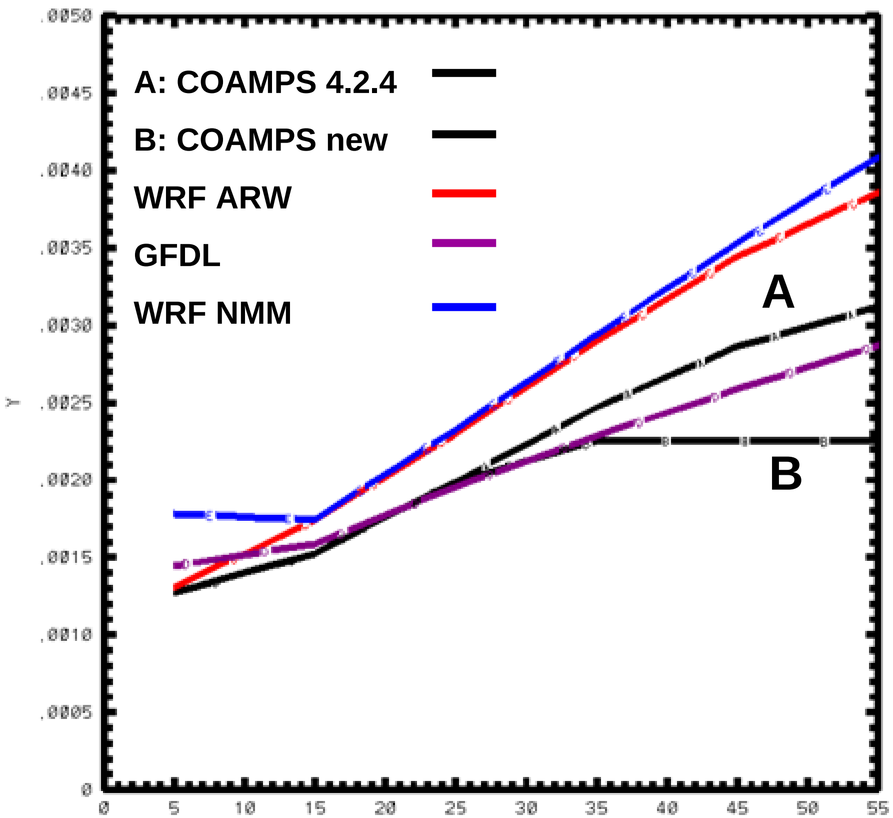
Drag Coefficients Derived from Observations



Courtesy of Sixth international Workshop on Tropical Cyclone. Special Focus on Field Experiments related to Tropical Cyclone structure: CBLAST. (Black and Chen 2006)

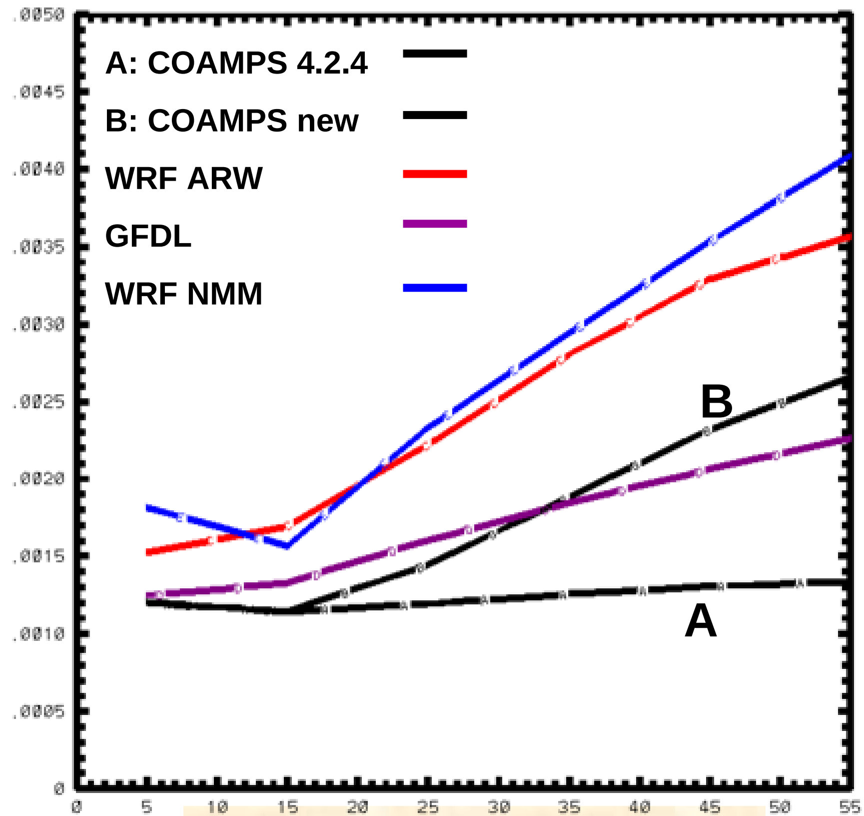
Transfer Coefficients (I)

Drag Coefficient (C_D)



10-m Wind Speed (ms^{-1})

Heat Transfer Coefficient C_H

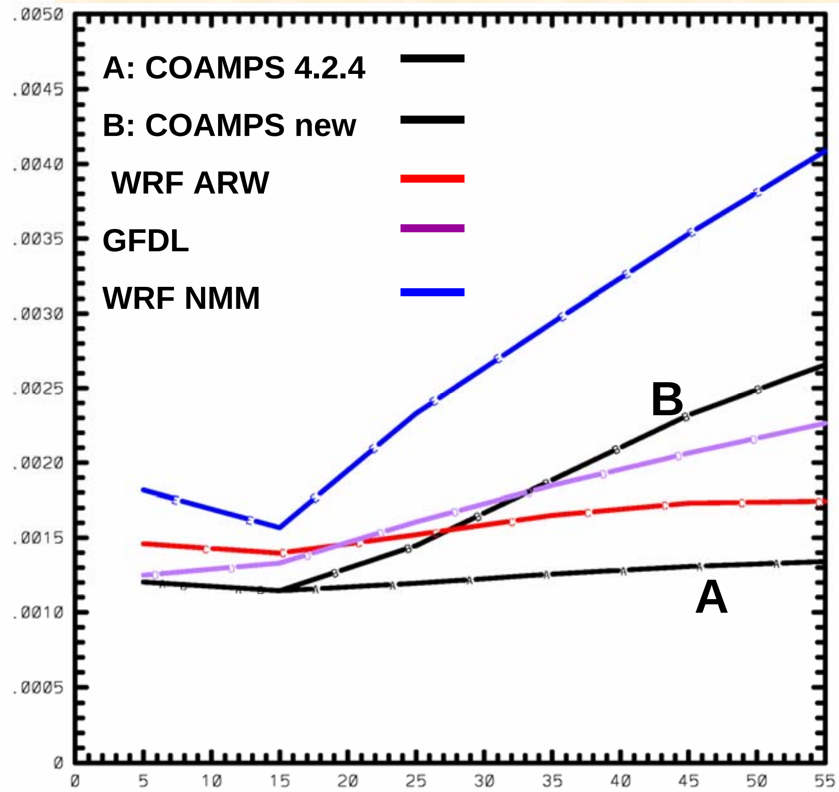


10-m Wind Speed (ms^{-1})

- Large disparity in both C_D and C_H calculations in mesoscale models
- WRF ARW uses the same roughness length for momentum, heat and moisture (z0=z0h=z0q)
- COAMPS new has level-off drag coefficient for high winds

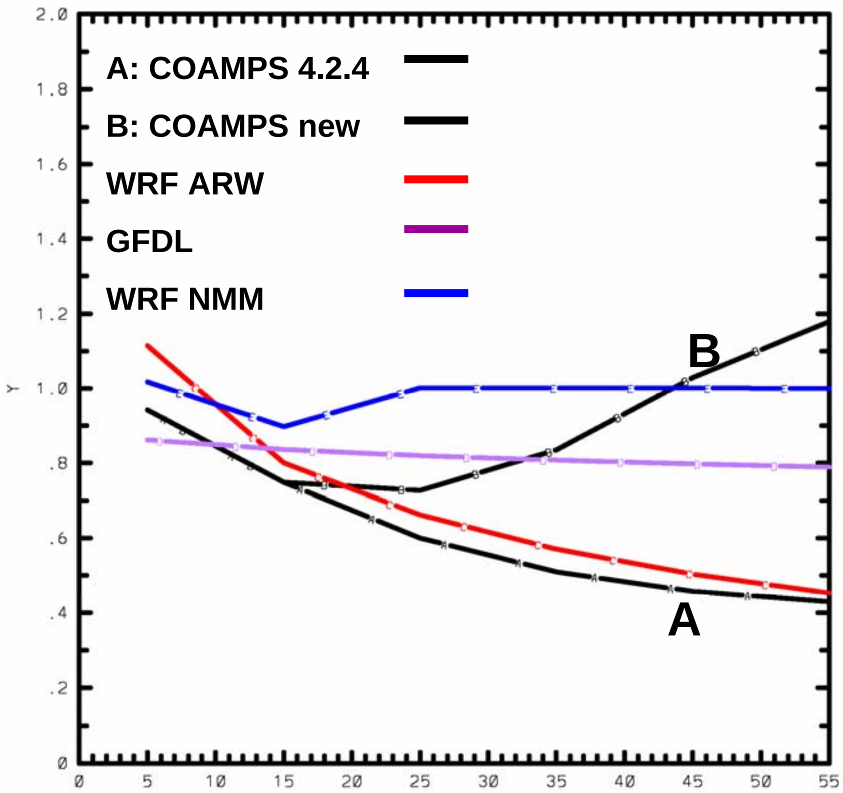
Transfer Coefficient (II)

Moisture Transfer Coefficient (C_E)



10-m Wind Speed (ms^{-1})

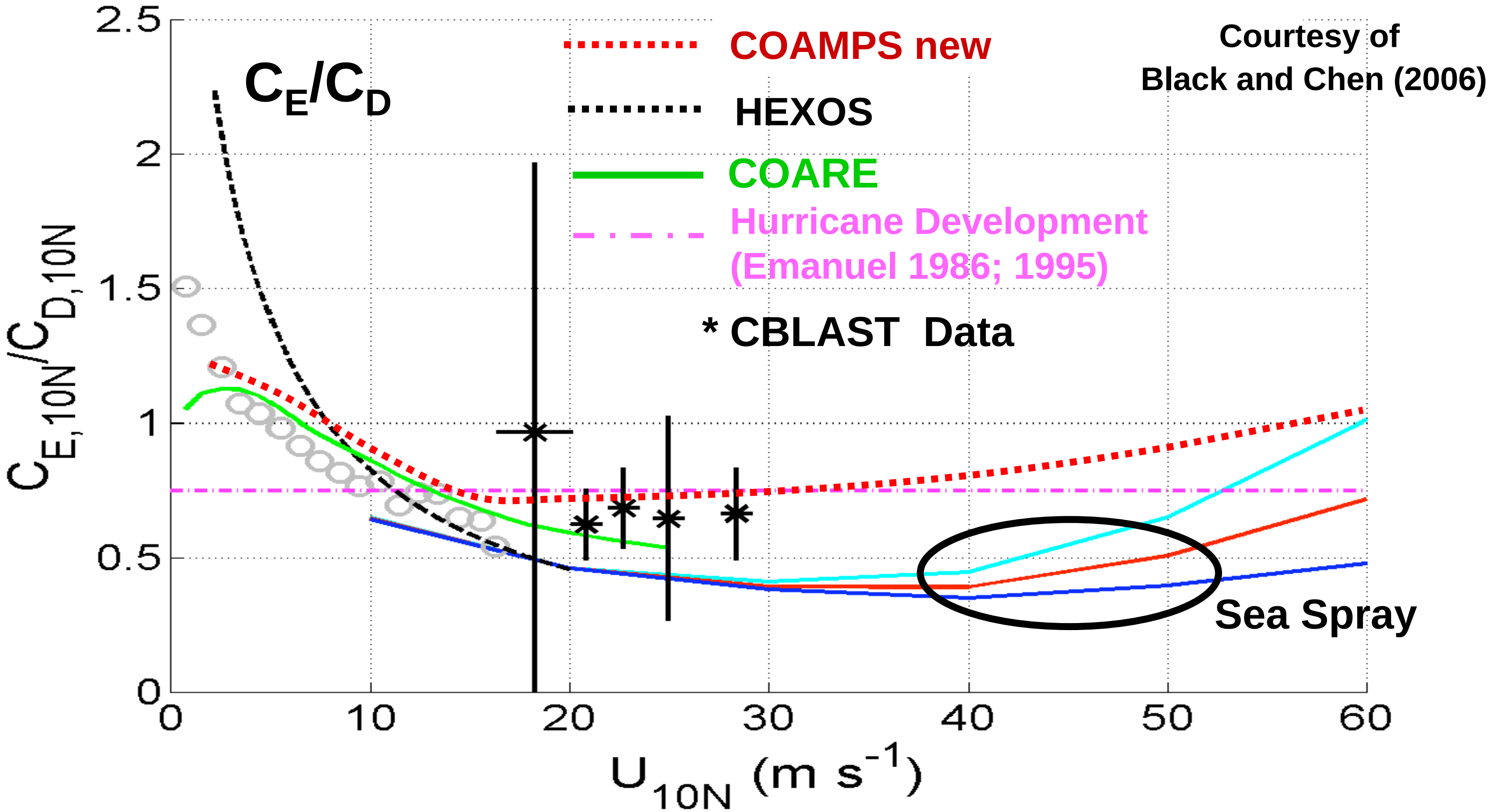
Ratio of C_E/C_D



10-m Wind Speed (ms^{-1})

- Large disparity in C_E/C_D values among various schemes
- COAMPS 4.2.4 has small C_E/C_D; COAMPS new increases C_E/C_D
- WRF ARW has large C_E/C_D at low-moderate winds

C_E/C_D Estimated from Observations

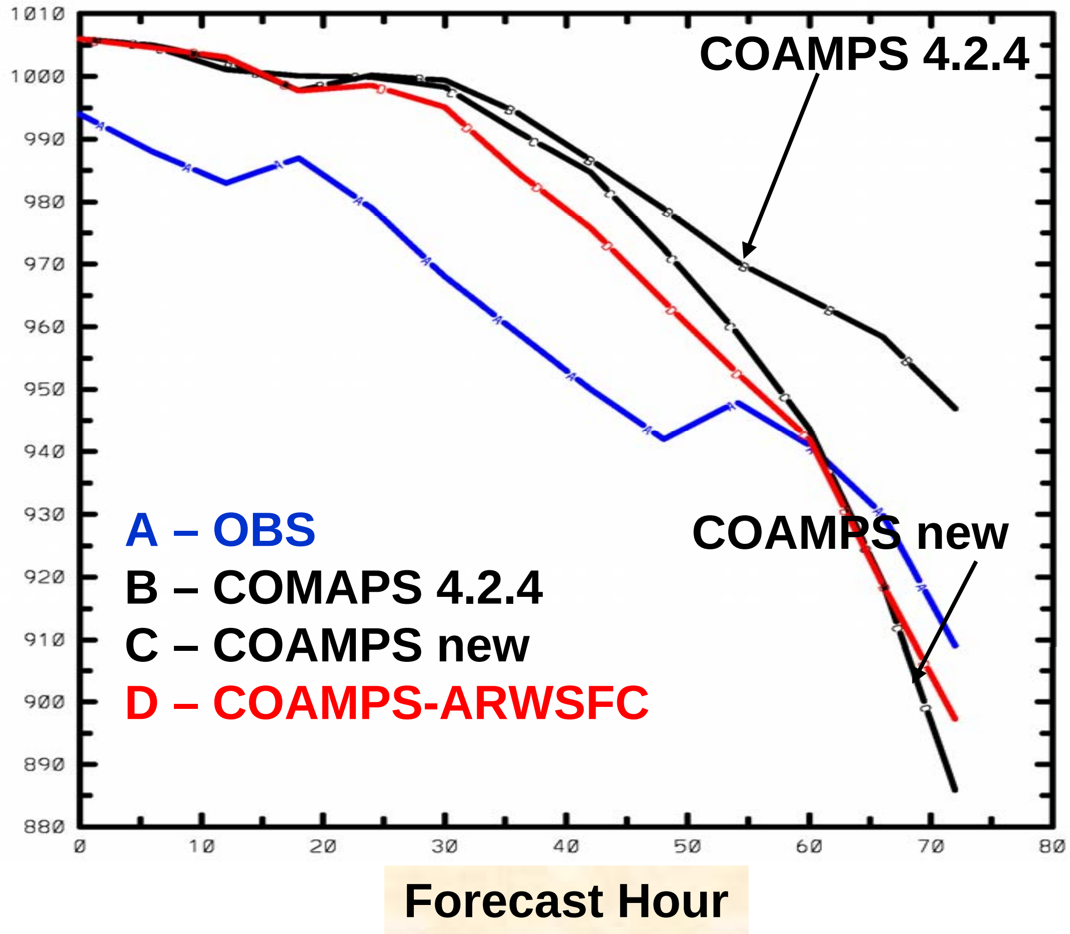


- COAMPS new ratio is consistent with the CBLAST observations
- The increase at high-wind speed represents sea spray effect

COAMPS® Simulation - Katrina (2005082512)
Minimum MSLP for 72 hr domain 3 (3-km)

COAMPS-ARWSFC:
COAMPS model implemented with the WRF ARW surface scheme.

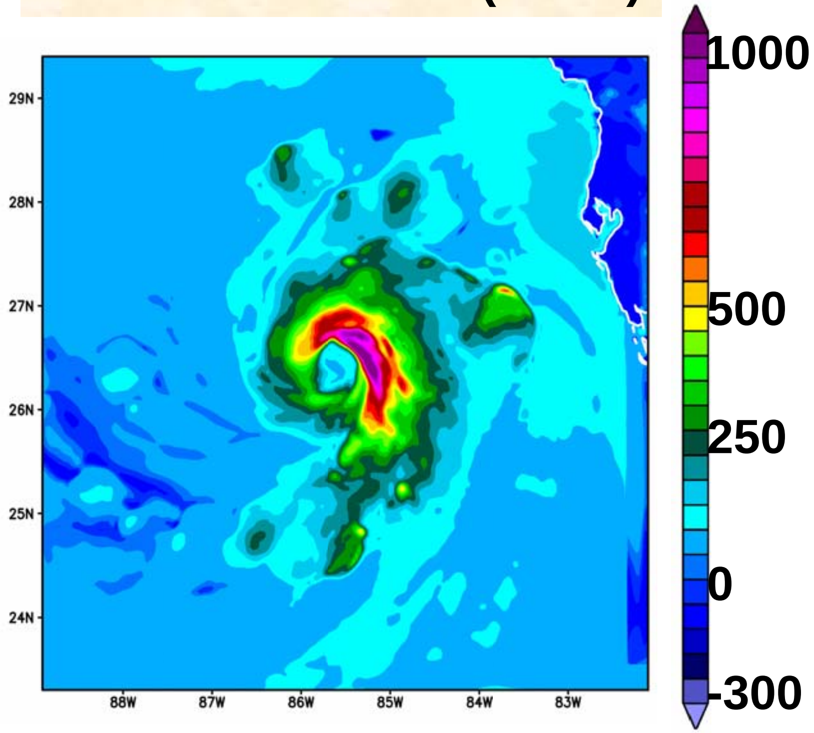
COAMPS new has weaker winds than COAMPS-ARWSFC during the first 2 days.



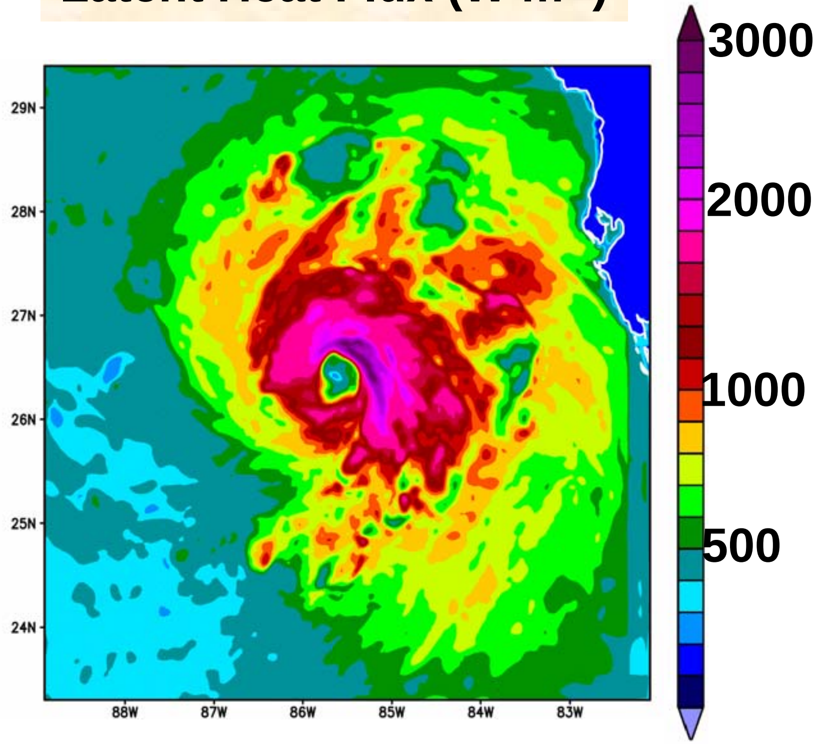
- COAMPS new significantly improves the intensity forecast
- High sensitivity of TC intensity to surface schemes

COAMPS® Simulation - Katrina (2005082512)
Using WRF ARW sfc scheme (3-km) at 48H

Sensible Heat Flux (W m-2)



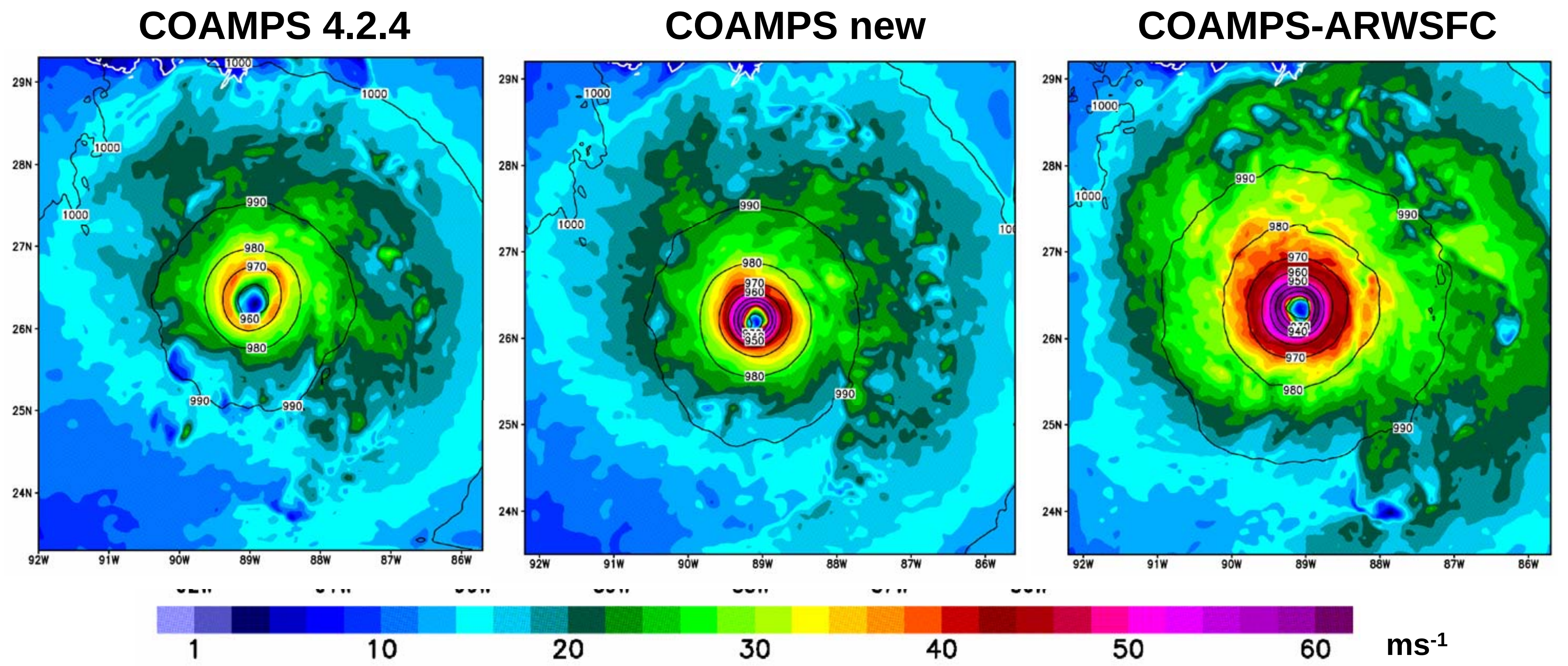
Latent Heat Flux (W m-2)



• WRF ARW scheme produces high values of surface sensible (1200 Wm^{-2}) heat flux and latent heat flux early into the simulation.

COAMPS® Simulation - Katrina (2005)

Sfc Winds and SLP at 66 hr (valid for 06Z 28 Aug) (3-km)

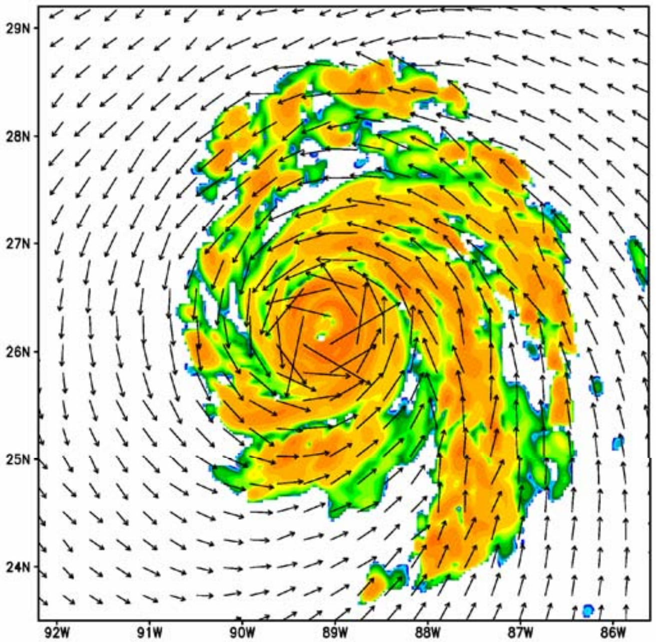


- COAMPS new surface winds compare better with best-track observations (reduce the wind speed error by 22 ms^{-1})
- COAMPS-ARWSFC produces a much larger area of high winds.

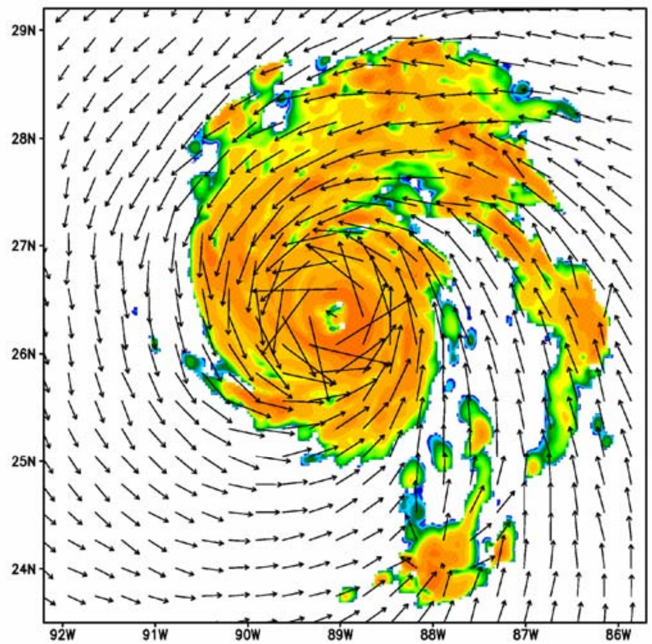
COAMPS® Simulation - Katrina (2005)

Radar Ref. and Sfc Winds at 66 hr (valid for 06Z 28 Aug) (3-km)

COAMPS new



COAMPS-ARWSFC



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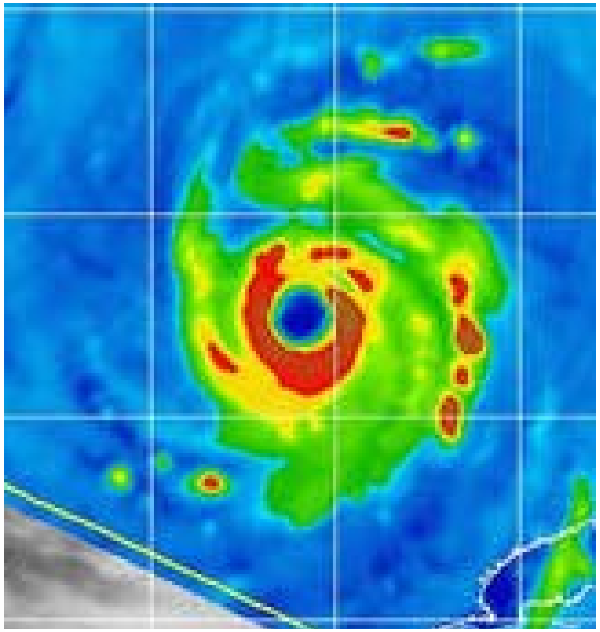


- COAMPS new produces well-organized precip bands.
- COAMPS-ARWSFC captures the distinct outer band.

Summary

- TC intensity forecasts highly sensitive to representation of the transfer coefficients; yet large disparity in parameterizations of these transfer coefficients in models
- Observations from the field experiments and previous studies providing opportunities to test new formulations of fluxes across air-sea interface
- Transfer coefficient values at both high and low winds important for TC development
- Continuing effort at NRL to incorporate and update WRF physics in COAMPS and vice versa.

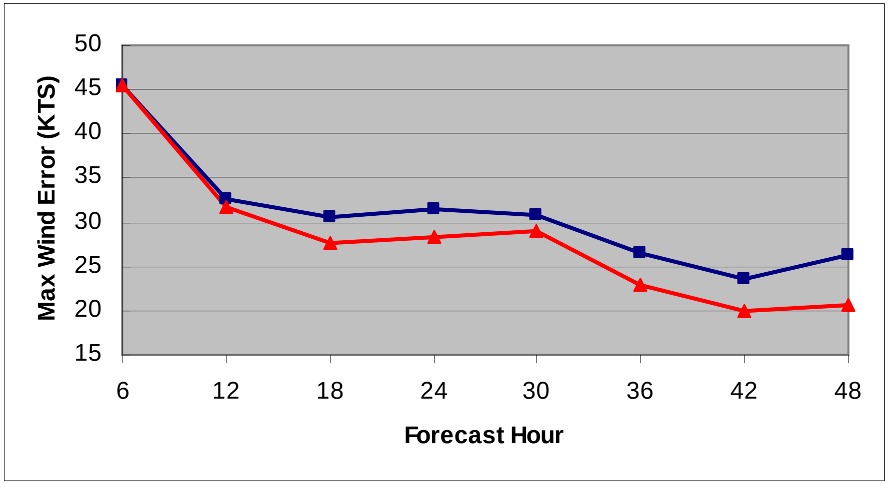
Future Research

- Observation-based and physically consistent transfer coefficients (e.g., different roughness lengths for momentum, heat and moisture).
- Impact of sea-spray (parameterization schemes)
- Coupled ocean-wave-atmospheric simulations

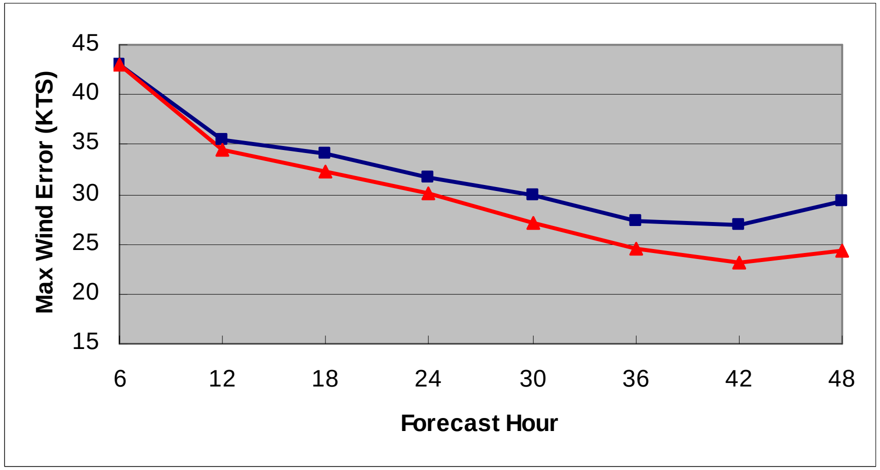
COAMPS® Simulation – 18 TC cases (48 hr run)

Average forecast errors of surface max winds

5-km domains



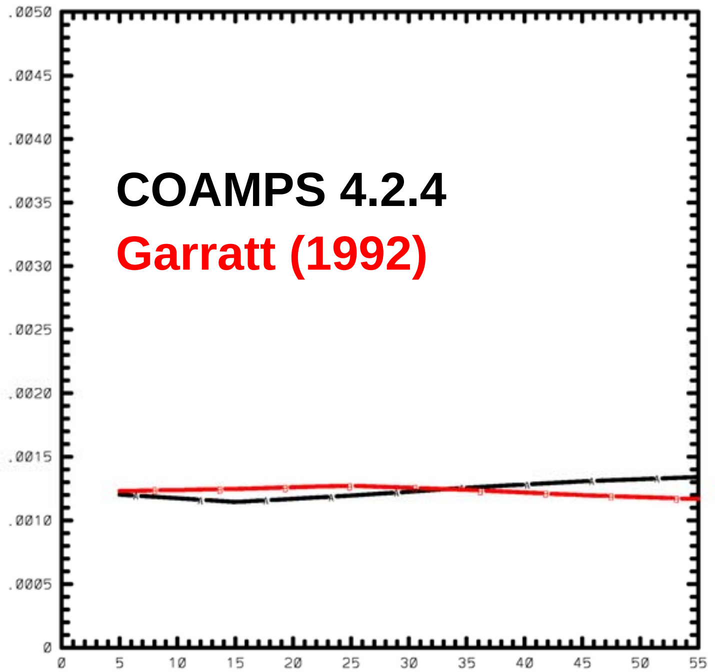
15-km domains



- COAMPS new produces better intensity forecasts in both domains.
- COAMPS new does not over-intensify weak storms.

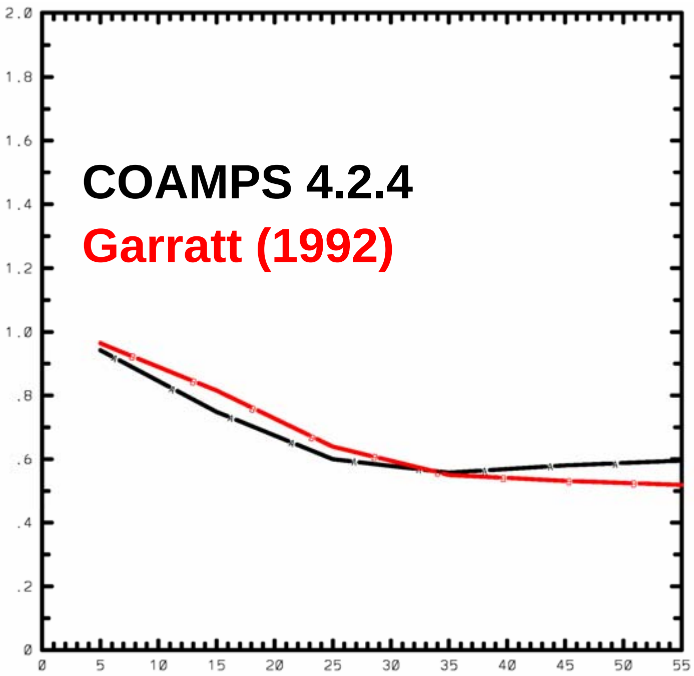
Garratt (1992) roughness lengths vs. COAMPS 4.2.4

Moisture Transfer Coefficient (C_E)



10-m Wind Speed (ms^{-1})

C_E/C_D

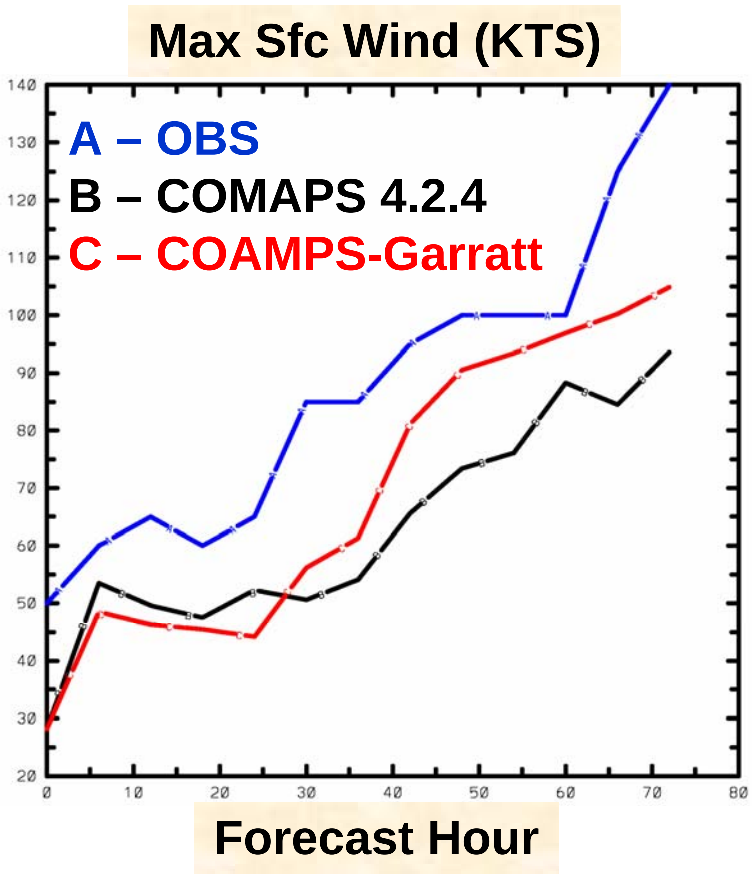


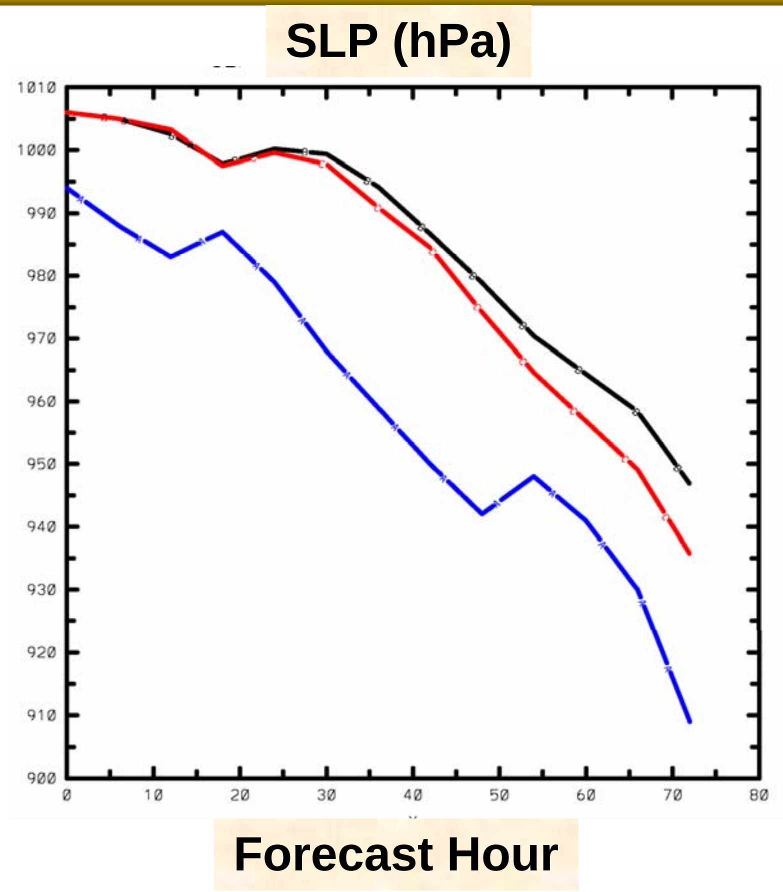
10-m Wind Speed (ms^{-1})

- There is small difference in C_E and C_E/C_D between COAMPS 4.2.4 and Garratt (1992).
- C_E and C_E/C_D in Garratt is slightly larger than in COAMPS 4.2.4 for low to moderate winds (<20ms^{-1}).

COAMPS® Simulation - Katrina (2005)

Using Garratt roughness lengths (COAMPS-Garratt)





- COAMPS-Garratt has better intensity forecasts (9 mb deeper and 12 KTS stronger) than COAMPS 4.2.4.
- Slightly high C_E at low-moderate winds is important for TC development.