ARE THIRD GENERATION WAVE MODELS ABLE TO PROVIDE ACCURATE STRESS ESTIMATES FOR HURRICANE PREDICTIONS?

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Are third generation wave models able to provide accurate stress estimates for hurricane predictions?

**Hurricane Katrina, 2005**

- Peak strength – Category 5
- Landfall – Category 4
- Fatalities – 1,245 – 1,836
- Damage - $108 billion

Tropical Depression Twelve (AL12)

NCEP GFS Ensemble track guidance valid 0600 UTC, 24 August 2005
Wind-Wave-Current Interaction in Tropical Cyclones

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Drag Measurements in Hurricanes

Powell et. al. (2003) 331 wind profiles

Holthuijsen et. al. (2012), 1149 wind profiles

- Drag is sea state dependent
- Swells affect $C_d$ in hurricanes
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- Third generation wave models are proven capable of simulating wave parameters under hurricanes (Phadke et al. 2003, Moon et al. 2003, Xu et al. 2007, Fan et al. 2009b, Allard et al. 2014)

- Fully coupled Atmosphere-wave-ocean model is suggested for accurate hurricane predictions as well as corresponding ocean responses (Chen et al. 2007, Fan et al. 2009a, Liu et al. 2011, Chen et al. 2013)

- Does third generation wave models give reasonable wave spectrum for stress calculations?
Are third generation wave models able to provide accurate stress estimates for hurricane predictions?

Model Domain and Measurements in Hurricane Ivan, 2004

- WAVEWATCH III, ST4 Source Term Package (Ardhuin et. al. 2010)
- Hurricane Research Division (HRD) wind; HYCOM currents
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Model & Data comparison

- Significant wave height ($H_s$)
- Dominant wave length ($D_{len}$)
- Dominant wave direction ($D_{dir}$)

![Graphs showing model and data comparison](chart.png)
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Scanning Radar Altimeter (SRA) Spectra

SRA resolve waves equal or longer than 50m (~ 0.17 Hz)
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**Drag Coefficient \((C_d)\) Comparison**  
(Donelan et. al. 2006)

- **Sept. 9**
- **Sept. 12**
- **Sept. 14**
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Drag Coefficient ($C_d$) Comparison

- WWIII spectra
- WWIII spectra with diagnostic tail
- SRA spectra with diagnostic tail
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Model & Data comparison

- Significant wave height ($H_s$ [m])
- Dominant wave length ($L_c$ [m])
- Dominant wave direction ($D_{dir}$ [°])

(a1), (a2), (a3): Sept. 9, Sept. 12, Sept. 14

Plots show comparisons between model predictions and SRA data at various locations (P1 to P6) for different days.
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Drag Coefficient ($C_d$) Comparison

Sept. 9

Sept. 12

Sept. 14
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Drag Coefficient ($C_d$) Comparison

- + WWIII spectra
- + WWIII spectra with diagnostic tail
- O SRA spectra with diagnostic tail

September 9

September 12

September 14
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Spectra Comparisons

Purple line gives $U_p/c = 1$

$c$ – phase speed

$U_p = 1.7U_{10\_wave}$

(Tracy et. al. 2007)
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**Spectra Comparisons**

Purple line gives

\[ U_p/c = 1 \]

\[ c = \text{phase speed} \]

\[ U_p = 1.7U_{10\_wave} \]

(Tracy et. al. 2007)
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**Effect of Wind Sea Spectra Shape**

Parametric Spectra
Donelan et. al. (1985)

Wind Speed = 20 m/s

- Factors that decrease $C_d$
  - Increase wind – wave angle
  - Increase directional spreading

- Factors that increase $C_d$
  - Increase wind sea energy

- Multi-peak spectrum produce higher $C_d$
Discussion / Conclusion

• WAVEWATCH III is not capable of providing sensible stress calculations in the left - rear quadrants of the hurricane.
• HRD wind do not represent fine structure of wind field
• Source function not for high wind condition
• Model dissipation to low for swells & too high for wind sea
• Wind sea part is more problematic