Forecast of extreme weather events in Northeast and Mid-Atlantic U.S. – Effects of natural particles in predicting precipitation and wind speed

UCONN SCHOOL OF ENGINEERING

Marina Astitha*, Emmanouil Anagnostou, Jaemo Yang, Xinxuan Zhang, Maria Frediani

University of Connecticut, Department of Civil & Environmental Engineering, 261 Glenbrook Road, Storrs-Mansfield, CT, USA

1. INTRODUCTION

- Extreme weather events associated with high wind speed and precipitation have severe impacts in human lives and the environment.
- The storm type, strength and duration dictate the severity of the consequences to infrastructure and every-day life as well as human life itself.
- The linkages between weather prediction, weather impacts and resiliency are the current focus for legislators and scientists.
- We present the framework under which we use state-of-the-science numerical weather prediction models to forecast extreme weather events.
- We further analyze past storm cases that affected NE U.S. and work towards understanding the complicated interactions and improve the model predictions for the region.

2. MODEL CONFIGURATION AND OBSERVATIONS

The numerical weather prediction models used are:

- Weather Research and Forecasting Model (**WRF-ARW** v3.4.1; Skamarock et al. 2008)
- Regional Atmospheric Model **RAMS/ICLAMS** (Cotton et al. 2003; Solomos et al. 2011; Kushta et al. 2014)

In the view of assessing the uncertainty of atmospheric variables we implemented two different and, at the same time, similarly configured modeling systems.

Model configuration: 3 nested gridded domains (Fig. 1 left and middle) with horizontal resolution of 18km (outer), 6km (middle), and 2km (focus area). Both models were initialized using the Global Forecast System (GFS) every 6h at 1.0deg horizontal resolution produced by NCEP. The RAMS/ICLAMS configuration is slightly different for IPHEx : 20km, 4km and 1km.

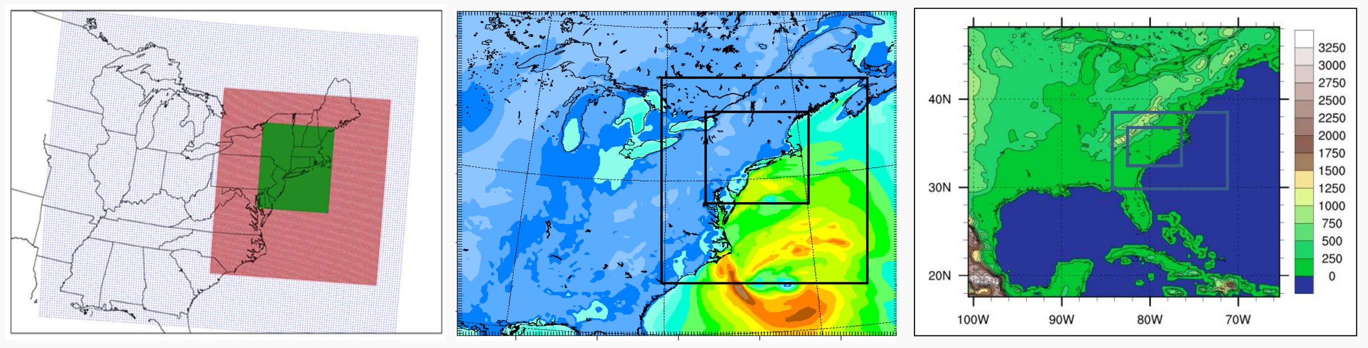


Fig. 1: Model domains: (left) WRF NE U.S. (middle) RAMS/ICLAMS NE U.S. (right) RAMS/ICLAMS Mid-Atlantic.

Observations:

- Wind speed at 10m and precipitation from airport stations provided by the National Weather Service (NWS) for NE U.S.
- Data from approximately 106 stations in the area have been obtained and used for the wind speed model evaluation.
- During the IPHEx campaign in North Carolina, rainfall as well as other atmospheric parameters were measured from a wide range of instruments and sensors (radar, gauges, radiosondes, aircraft) deployed for the IOP (http://iphex.pratt.duke.edu/node/50).

3. MODELING EXTREME WEATHER EVENTS

3.1 Case 1: North-Eastern U.S. (100 storms from 2001-2014, ranging from thunderstorms, snow and ice storms to hurricanes)

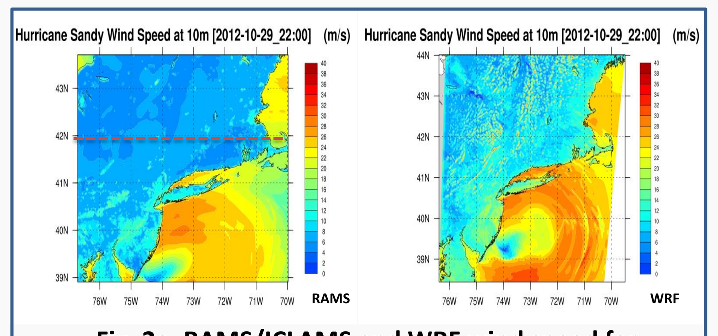


Fig. 2a: RAMS/ICLAMS and WRF wind speed for Hurricane Sandy

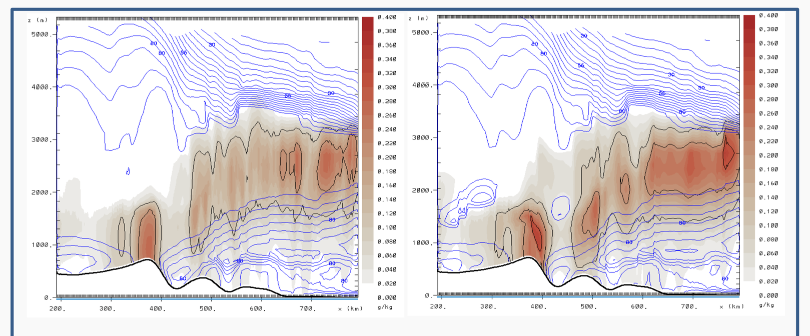


Fig. 2b: xz cross section at 42N showing RH (blue lines) and rain mixing ratio (colored palette) with and without Sea Salt (SS)

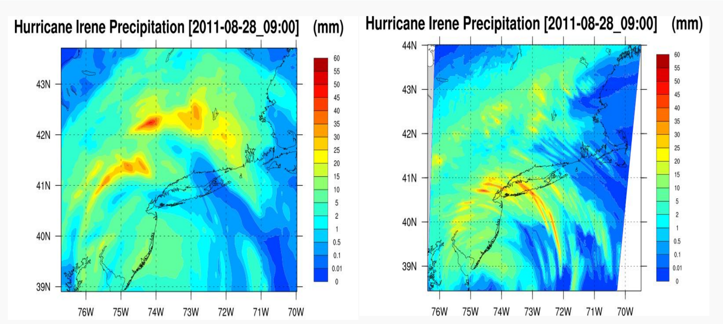


Fig. 2c: RAMS/ICLAMS and WRF precipitation for Hurricane Irene

3.2 Case 2: Mid-Atlantic U.S. (IPHEx experiment; supports the Global Precipitation Measurement (GPM) mission; IOP May-June 2014)

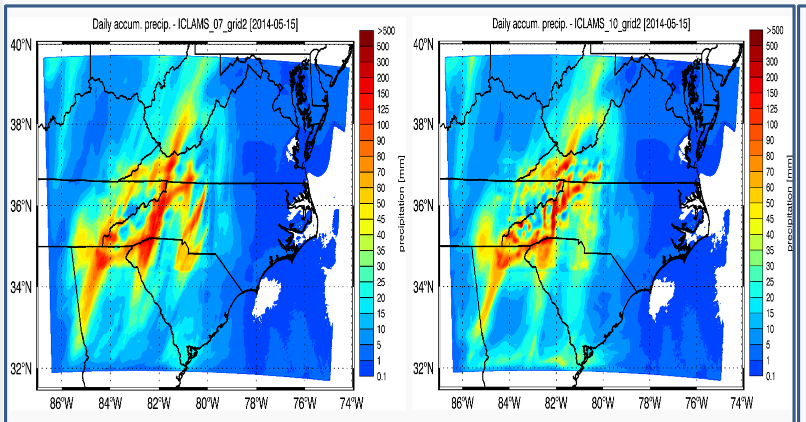


Fig. 3a: RAMS/ICLAMS daily precipitation for May 15, 2014. (left: without sea salt; right: activated sea salt aerosol). Grid 2 (4km).

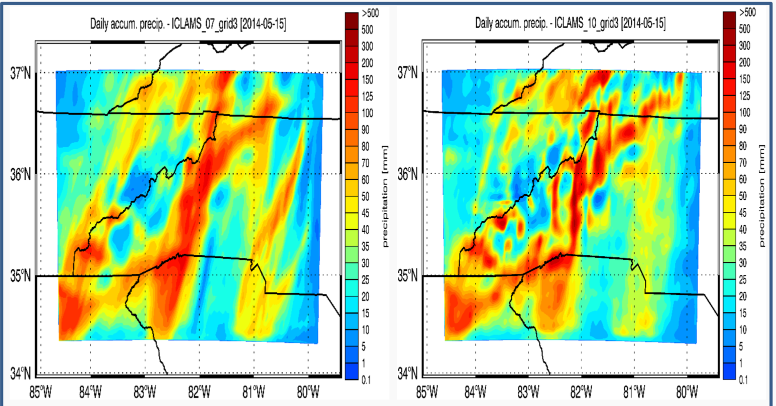


Fig. 3b: RAMS/ICLAMS daily precipitation for 04/15/2014. (left: without sea salt; right: activated sea salt aerosol). Grid 3 (1km).

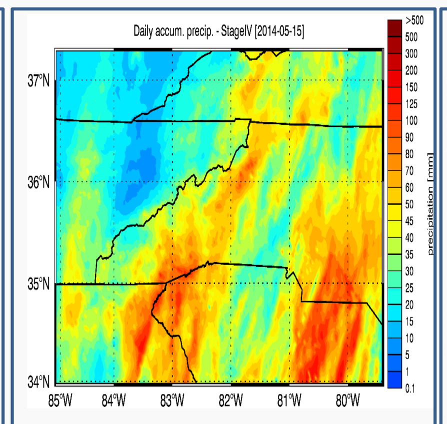


Fig. 3c: Stage IV rainfall data

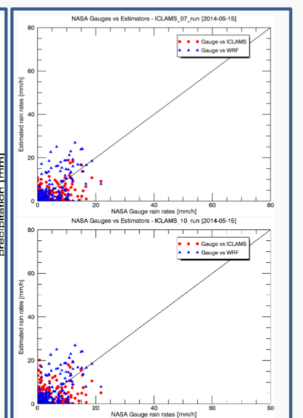
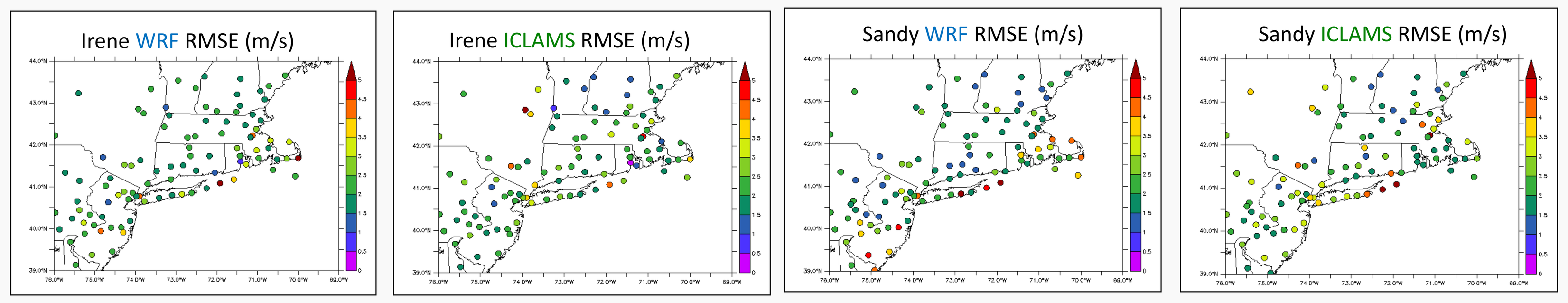


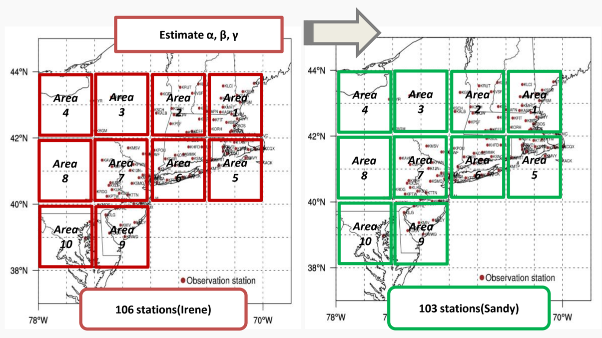
Fig. 3d: Model-gauges comparison

4. DUAL-MODEL APPROACH

The basic concept behind the dual-model approach is to take advantage of the strengths of two state-of-the-science modeling systems and limit their weaknesses which are related to systematic and random errors in the numerical prediction of physical processes. The method presented herein is a preliminary attempt to minimize the root mean square error of the two models by applying a conditional regression analysis.

The minimization of the RMSE occurred through random generation of weighting factors α, β, γ. The preliminary results indicate a significant improvement in the correlation coefficient of the modeled-observed pairs as well as the mean absolute error. The figures that follow show the application of the dual-model approach to Hurricane Irene and Hurricane Sandy for in-sample and out-of-sample applications.



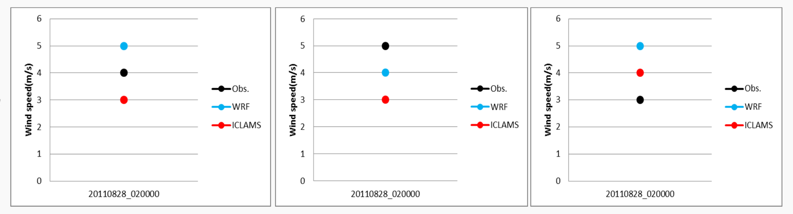


$$M(x,y,t) = aM_1(x,y,t) + \beta M_2(x,y,t)$$

$$M(x,y,t) = \frac{1}{2}\gamma(M_1(x,y,t) + M_2(x,y,t))$$

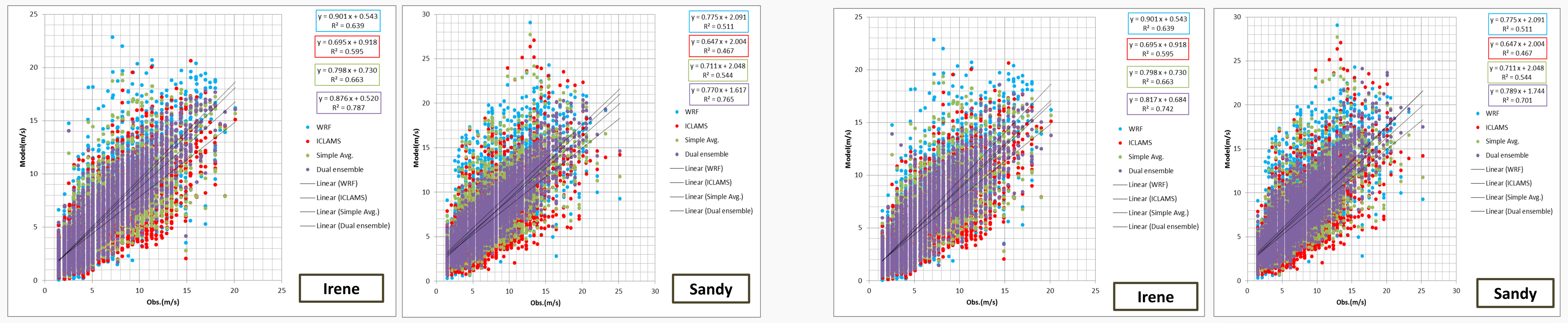
Conditions: $a + \beta = 1$, $0<\gamma<1$ or $1<\gamma<2$

→ Minimize RMSE → Estimate α,β,γ



In-sample

Out-of-sample



Irene->Irene	RMSE	MB	MAE
WRF	2.409	-0.016	1.766
ICLAMS	2.425	-0.812	1.827
Simple Avg.	2.165	-0.414	1.609
Dual model	**1.672**	**-0.186**	**1.287**

Sandy->Sandy	RMSE	MB	MAE
WRF	2.824	0.531	2.063
ICLAMS	2.758	-0.443	2.071
Simple Avg.	2.498	0.044	1.832
Dual model	**1.699**	**0.020**	**1.299**

Sandy->Irene	RMSE	MB	MAE
WRF	2.409	-0.016	1.766
ICLAMS	2.425	-0.812	1.827
Simple Avg.	2.165	-0.414	1.609
Dual model	**1.850**	**-0.357**	**1.398**

Irene->Sandy	RMSE	MB	MAE
WRF	2.824	0.531	2.063
ICLAMS	2.758	-0.443	2.071
Simple Avg.	2.498	0.044	1.832
Dual model	**1.972**	**0.278**	**1.508**

5. CONCLUDING REMARKS

- ✓ Extreme weather events are predicted for NE and Mid-Atlantic U.S. for past and future cases. Model evaluation has provided confidence in the model performance.
- ✓ The dual-model approach has shown significant improvement in the out-of-sample applications for the wind speed at 10m.
- ✓ More simulated storms are analyzed to gain confidence in this approach and investigate the efficacy of the method to wind direction and precipitation as well.
- ✓ The effect of sea-salt particles in the cloud formation and development are not pronounced, mainly because the sea salt aerosols do not penetrate far inland during the studied storm events. Work is still in progress.

6. APPLICATION: Damage prediction model

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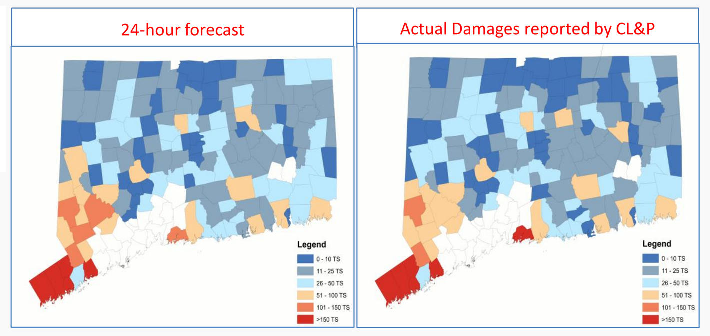

Damage Modeling and Forecasting System of the NU Center Bridge-Funding ($1.1M). 04/15/2013-05/31/2015. PI: E. Anagnostou (CEE), Co-PIs: B. Hartman (Math), M. Rudnicki (NRE), M. Astitha(CEE).

Wanik et al. 2014 (in preparation)

7. ACKNOWLEDGMENTS

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8. REFERENCES

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CONTACT

Email: astitha@engr.uconn.edu. Group Website: http://airmg.uconn.edu.