# Weather forecasting for power outage prediction

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## 1. INTRODUCTION

UCONN outage prediction model (OPM), employing correlations between storm severity and power outages, has been operated with meteorological inputs from the numerical weather prediction systems (NWPs). This study is focused on:

1) Evaluation of uncertainties of weather parameters used in power-outage prediction

2) Examination of two post-processing techniques to improve wind speed prediction

3) Assessment of NCAR ensemble which will be used for the power-outage modeling system

4) Future work on gridded domain post-processing for error correction

## 2. ASSESSMENT OF PREDICTION UNCERTAINTY
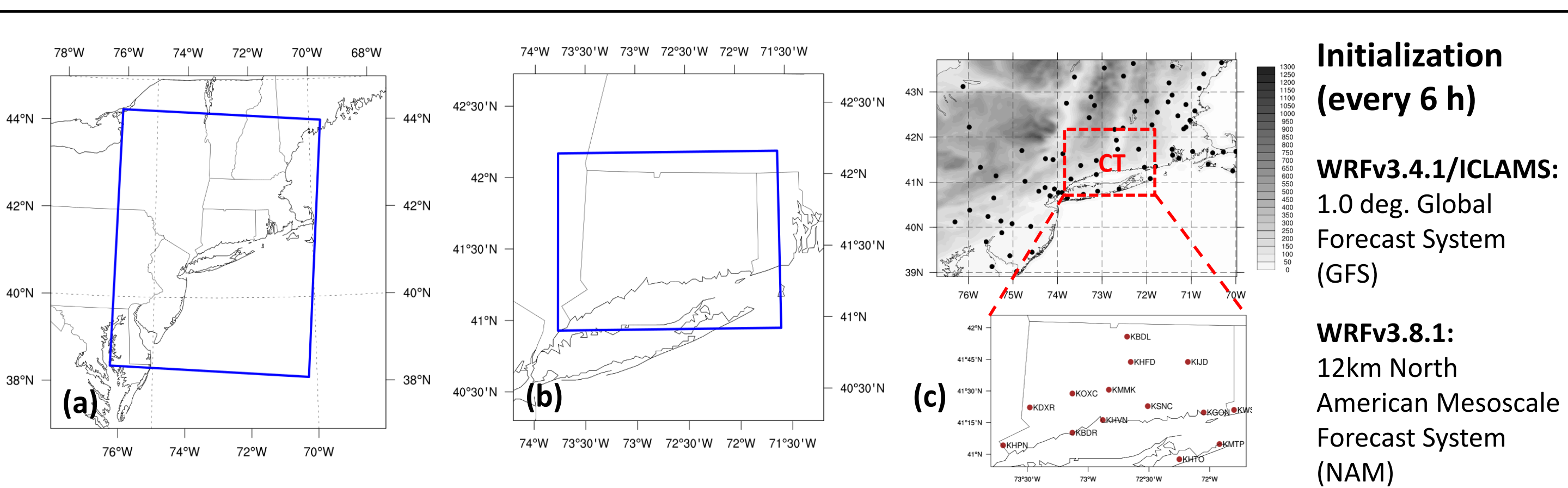
### 2.1 Model domain and observations



**Initialization (every 6 h)**

WRFv3.4.1/ICLAMS: 1.0 deg. Global Forecast System (GFS)

WRFv3.8.1: 12km North American Mesoscale Forecast System (NAM)

**Fig. 1 (a)** WRF v3.4.1/ICLAMS domain (2km); **(b)** WRFv3.8.1 domain (4km); **(c)** NCEP/NWS/NOAA stations.

### 2.2 Weather uncertainty (66 rain/wind events in the period 2005-2016)



(a) *Global error metrics*

(b) *Event-based error metrics*
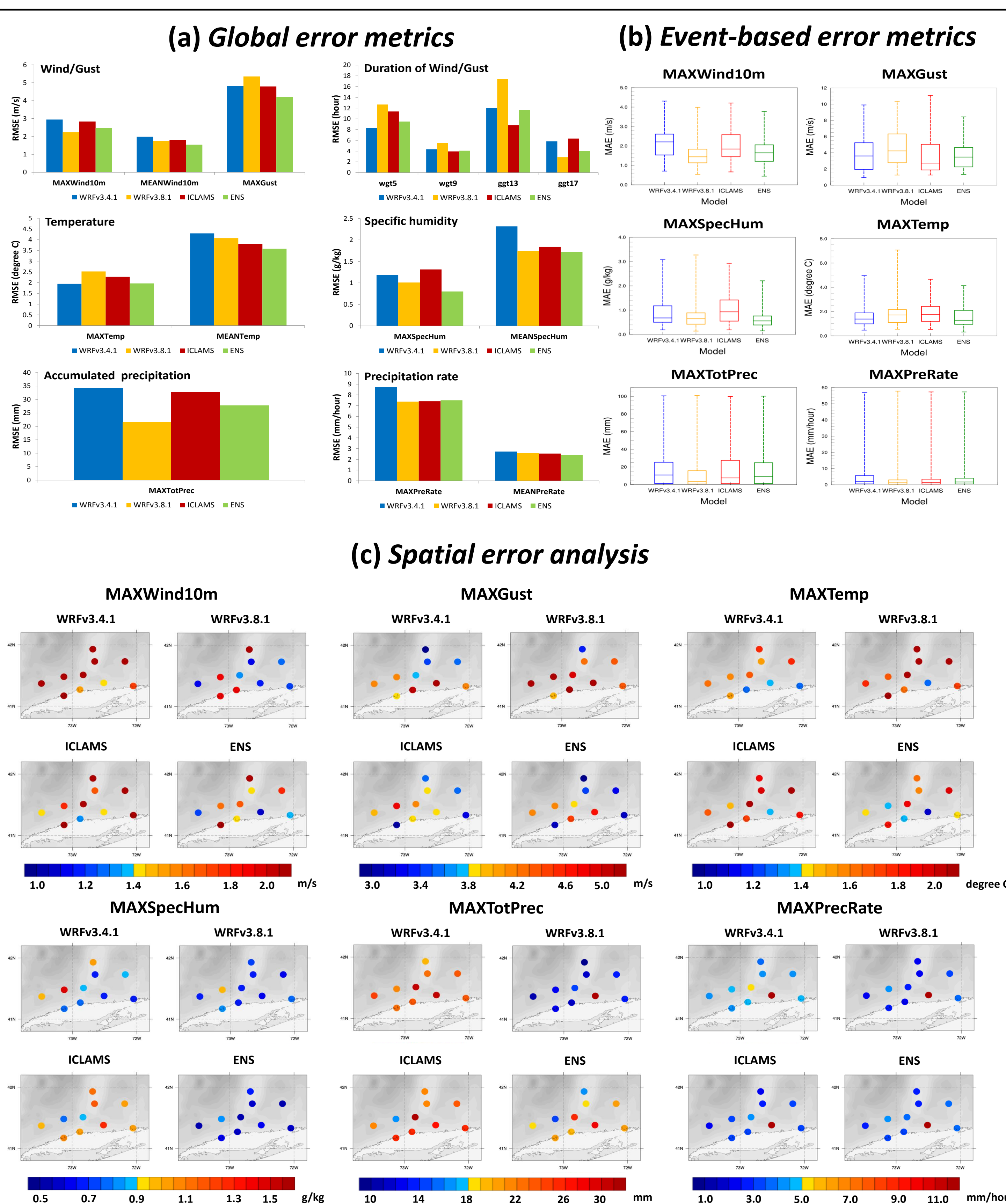
(c) *Spatial error analysis*

**Fig. 2** (a) Global RMSE, (b) Event-based MAE, and (c) Spatial MAE of 3 models and their average (ENS).

## 3. WRF and ICLAMS FORECAST

➤ **3 rain/wind events**
- 12/17/2016
- 01/23/2017
- 03/01/2017

➤ **Initialization**

Every 3h
- WRFv3.4.1 and ICLAMS: 0.25 deg. GFS
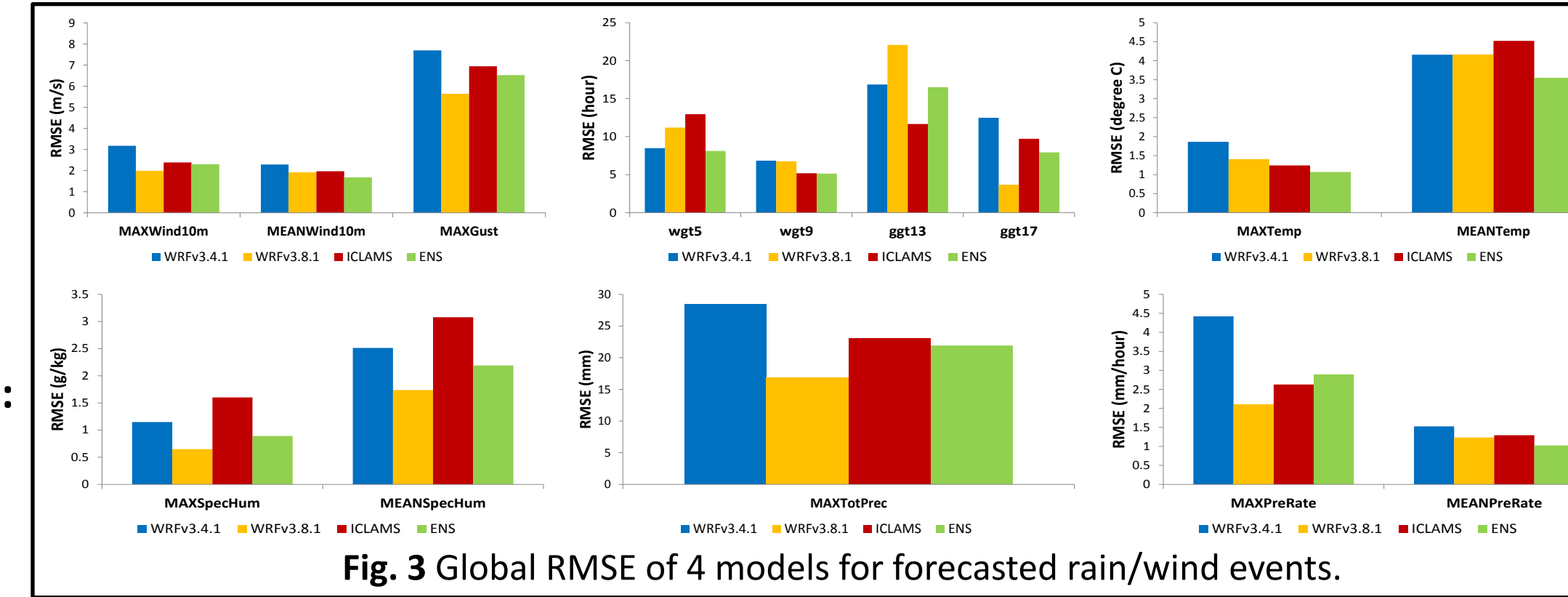- WRFv3.8.1: 12km NAM



**Fig. 3** Global RMSE of 4 models for forecasted rain/wind events.

## 4. POST-PROCESSING TO IMPROVE WIND SPEED PREDICTION

➤ Two post-processing techniques to improve storm wind speed prediction
- Bayesian linear regression (**BLR**, Yang et al. 2017a).
- Analog ensemble (**AnEn**, Yang et al. 2017b; Delle Monache et al. 2013).

**146 storms in the period 2005-2016**



(a) Spring (18 storms), Summer (43 storms), Fall (30 storms), Winter (55 storms)
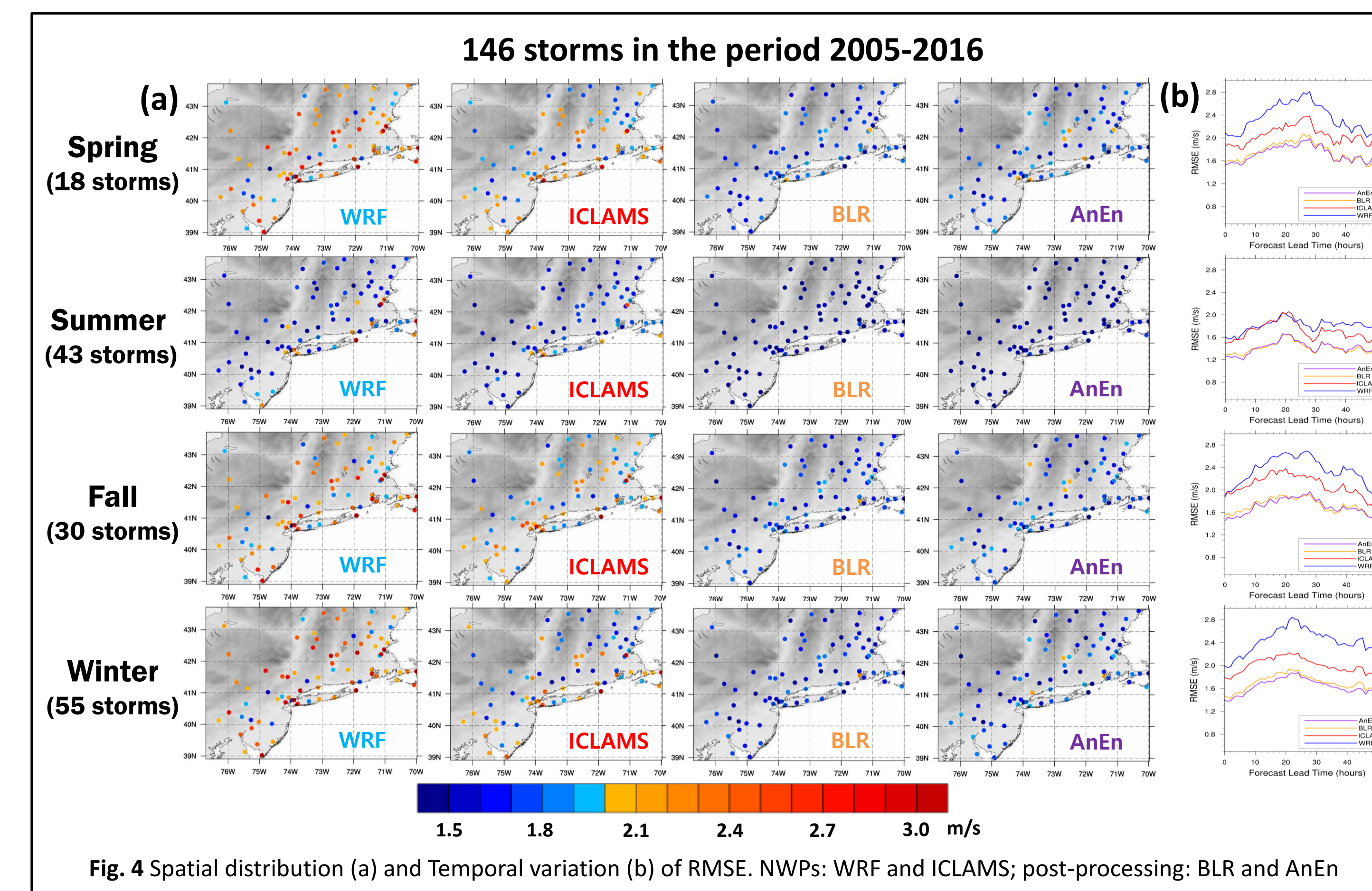
WRF  ICLAMS  BLR  AnEn

**Fig. 4** Spatial distribution (a) and Temporal variation (b) of RMSE. NWPs: WRF and ICLAMS; post-processing: BLR and AnEn

## 5. NCAR ENSEMBLE UNCERTAINTY AND IMPROVEMENT

➤ **3km NCAR Real-time Ensemble Forecasts (10 members, Schwartz et al. 2015)**
- Wind speed error analysis (37 storms in the period 2015-2016).
- Application of BLR to improve wind peed prediction of NCAR ensemble.



(a) *NCAR ensemble members*

Gray: ensemble members
Red: ensemble mean

(b) *Performance comparison (global metric)* — RMSE

(c) *Spatial analysis*

MEM1 MEM2 MEM3 MEM4 MEM5 MEM6 MEM7 MEM8 MEM9 MEM10 MEAN BLR_NCAR WRF ICLAMS BLR_UCONN
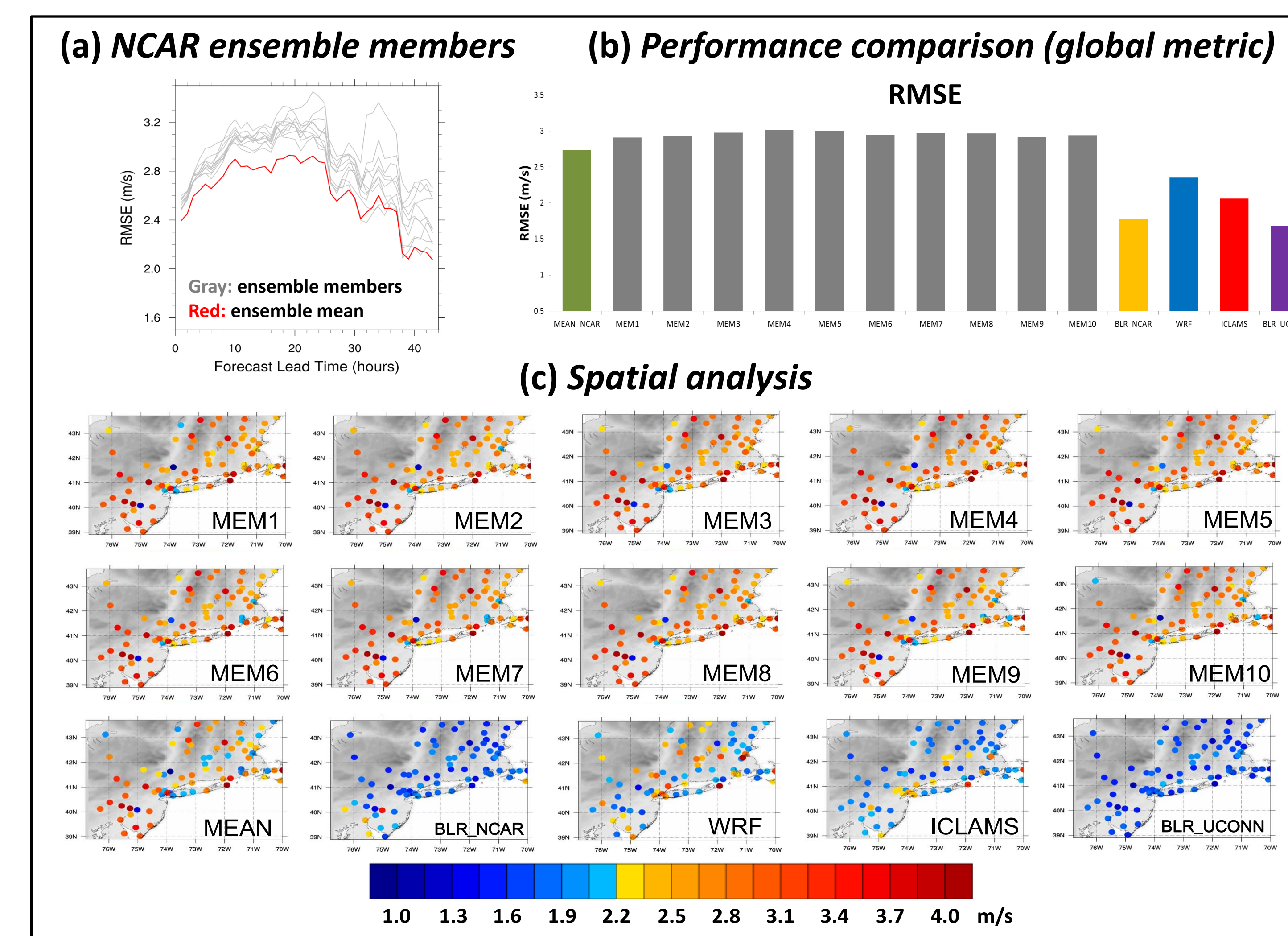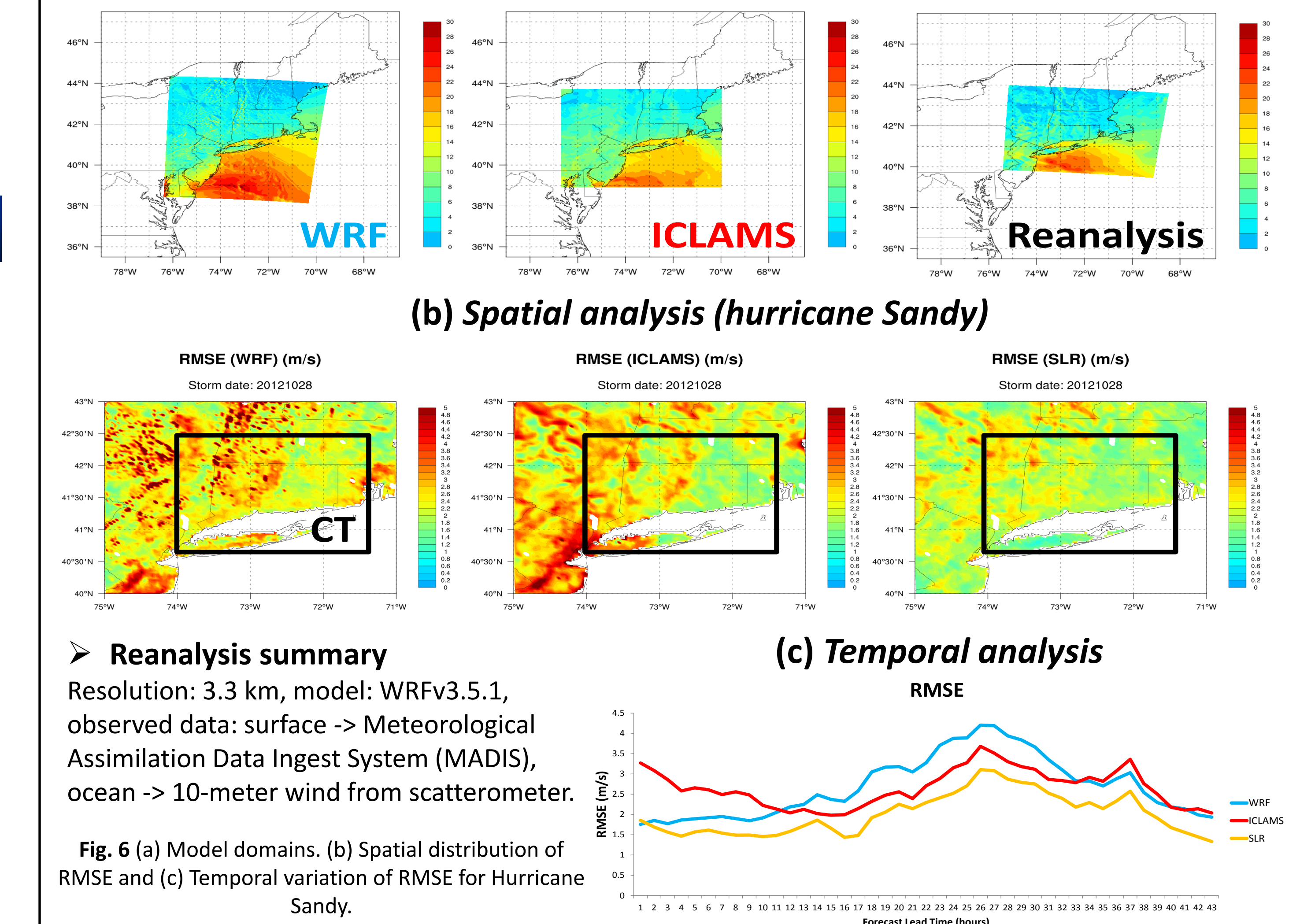
**Fig. 5** (a) Temporal RMSE variation of NCAR ensemble, (b) Global RMSE of NCAR, UCONN (2km WRF/ICLAMS) and BLR products, and (c) Spatial RMSE of all models for 37 storms.

## 6. ON-GOING WORK

➤ **Gridded post-processing techniques to improve wind speed/precipitation for all locations**
- Use high-resolution reanalysis data and multi-sensor (radar + gauges) observations
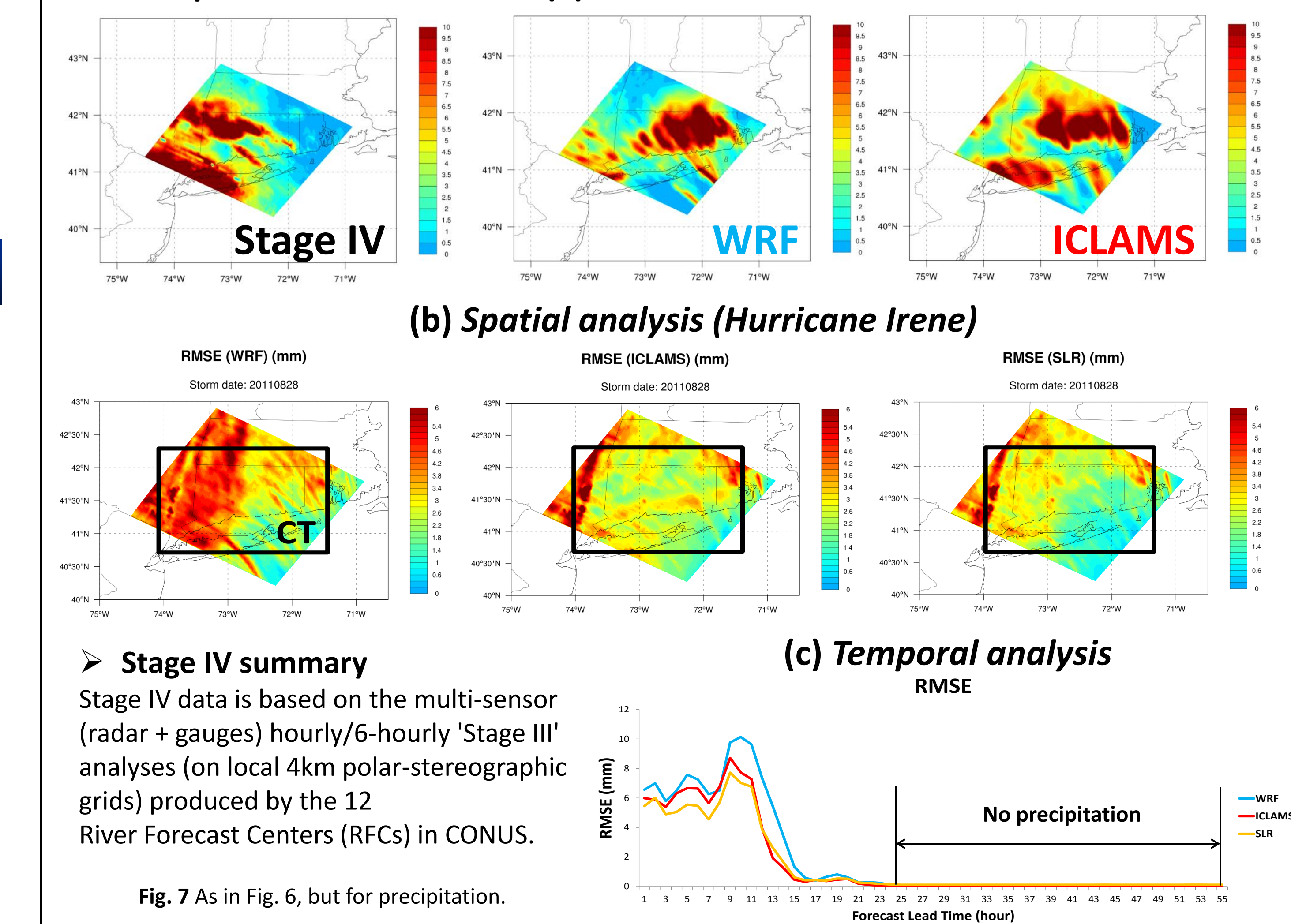- Apply regression techniques for all grid points

### 6.1 Wind speed



(a) *Model domain* — WRF, ICLAMS, Reanalysis

(b) *Spatial analysis (hurricane Sandy)* — RMSE (WRF) (m/s), RMSE (ICLAMS) (m/s), RMSE (SLR) (m/s); Storm date: 20121028

(c) *Temporal analysis* — RMSE

➤ *Reanalysis summary*

Resolution: 3.3 km, model: WRFv3.5.1, observed data: surface -> Meteorological Assimilation Data Ingest System (MADIS), ocean -> 10-meter wind from scatterometer.

**Fig. 6** (a) Model domains. (b) Spatial distribution of RMSE and (c) Temporal variation of RMSE for Hurricane Sandy.

### 6.2 Precipitation



(a) *Model domain* — Stage IV, WRF, ICLAMS

(b) *Spatial analysis (Hurricane Irene)* — RMSE (WRF) (mm), RMSE (ICLAMS) (mm), RMSE (SLR) (mm); Storm date: 20110828

(c) *Temporal analysis* — RMSE

No precipitation

➤ *Stage IV summary*

Stage IV data is based on the multi-sensor (radar + gauges) hourly/6-hourly 'Stage III' analyses (on local 4km polar-stereographic grids) produced by the 12 River Forecast Centers (RFCs) in CONUS.

**Fig. 7** As in Fig. 6, but for precipitation.

## 7. ACKNOWLEDGEMENTS

## 8. REFERENCES

Delle Monache, L., F. A. Eckel, D. L. Rife, B. Nagarajan, and K. Searight, 2013: Probabilistic weather prediction with an analog ensemble. *Mon. Wea. Rev.*, **141**, 3498–3516, doi:10.1175/mwr-d-12-00281.1.

Schwartz, C. S., G. S. Romine, R. A. Sobash, K. R. Fossell, and M. L. Weisman, 2015: NCAR's experimental real-time convection-allowing ensemble prediction system. Wea. Forecasting, **30**, 1645–1654, doi:10.1175/WAF-D-15-0103.1.

Yang, J., M. Astitha, E. N. Anagnostou, and B. M. Hartman 2017a: Using a Bayesian regression approach on dual-model windstorm simulations to improve wind speed prediction. *J. Appl. Meteor. Climatol.*, **56**, 1155–1174.

Yang, J., M. Astitha, L. Delle Monache, S. Alessandrini, 2017b: *Using an Analog Ensemble to improve storm wind speed prediction using a dual NWP model approach. Manuscript in preparation for submission to Monthly Weather Review.*