Quantifying Uncertainties in WRF Hindcast of 21 July 2012 Beijing Super-Storm

Fei Chen[1], Shiguang Miao[2], Mukul Tewari[1]

Jimy Dudhia[1], Paty Romero-Lankao[1],

Joshua Sperling[1]

[1]Research Applications Laboratory, NCAR, Boulder, CO

[2] Institute of Urban Meteorology, Beijing, China

ICUC-9, 21 July 2015, Toulouse, France

"Right Forecast " but for Wrong Reasons
(Zhang et al., 2013 GRL)

- **21 July 2012 in Beijing: heaviest rainfall in 6 decades; 460 mm rain in 18 hours with hourly rates exceeding 85 mm.**

- Models predicted rain mainly from topographical lifting and the passage of cold front; Obs: extreme rainfall occurred in the warm sector ahead of front.

- How accurately WRF can predict the location and amount of the precipitation? Do cities impact this rainfall event?

RADAR obs

Merged CMORPH obs

NCAR
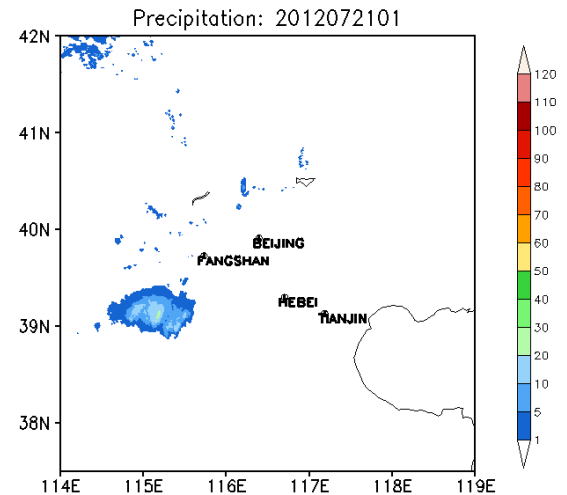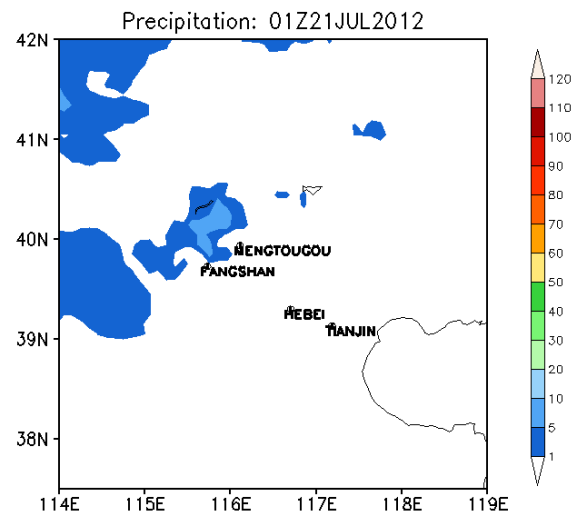
Scientific Questions

- **What are main uncertainties impacting the Beijing Super-storm prediction?**

- **Does ensemble approach provide a useful guidance for forecasting this case?**

- **What are impacts of future climate change on this extreme rainfall event?**

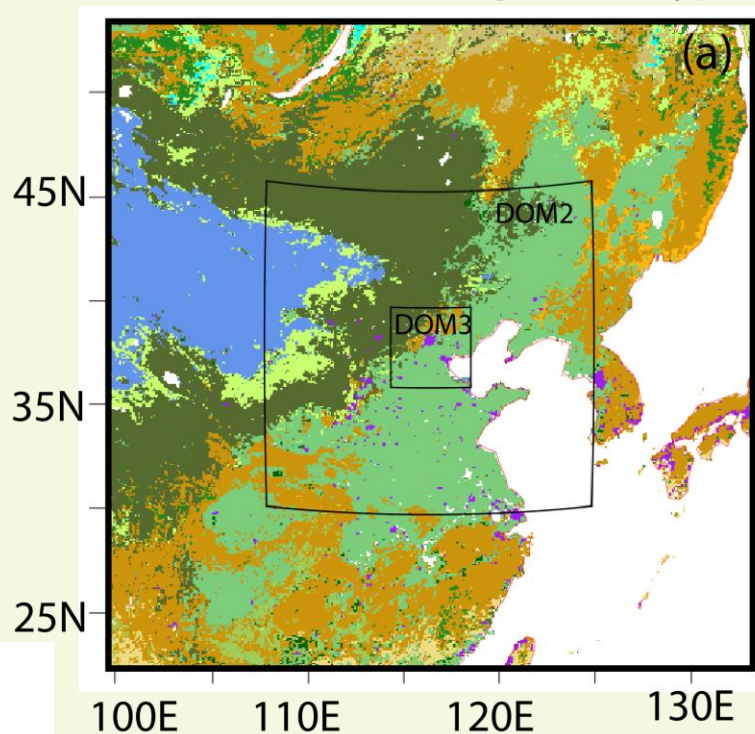Dynamic and thermal effects of city significantly impact rainfall simulation
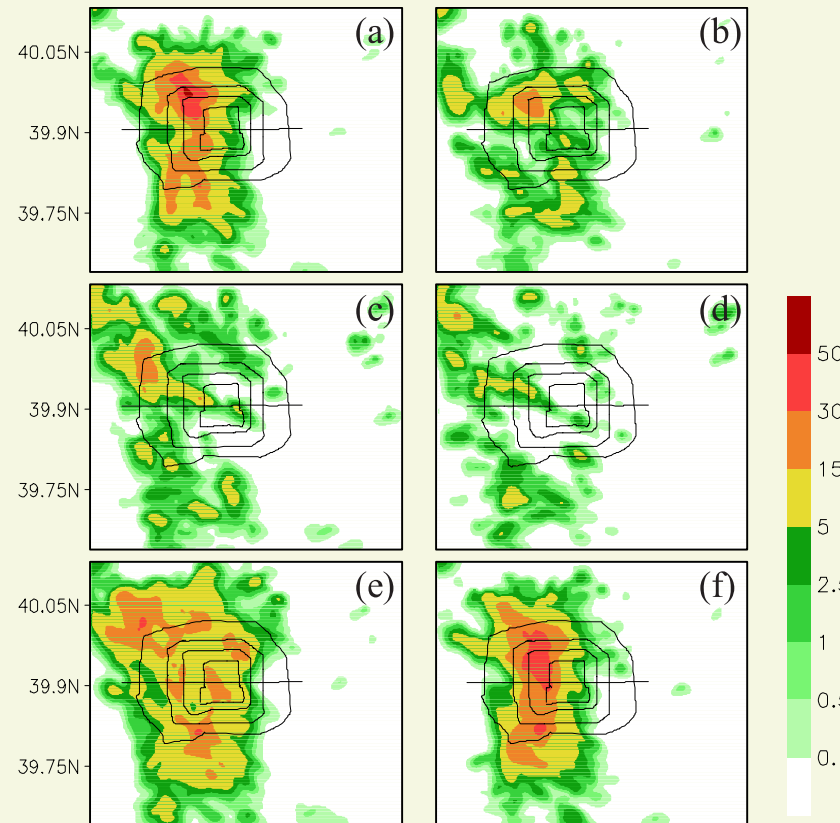
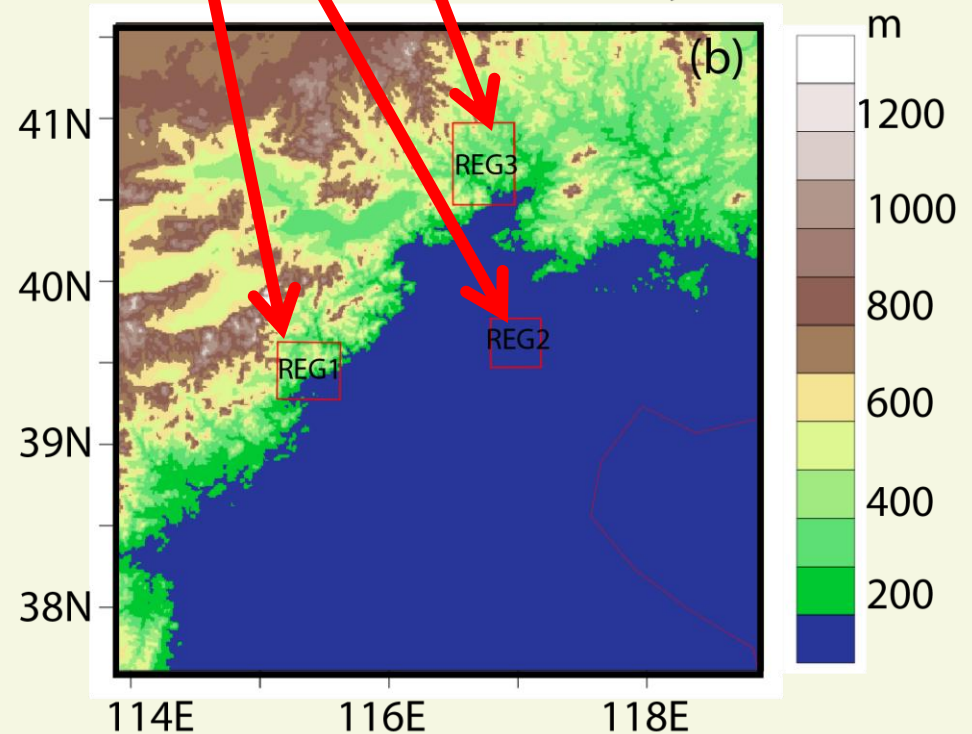Miao et al. 2007, JAMC

WRF Configurations and Domains

- **3 nested domains: 9km, 3km and 1km, 38 vertical levels.**
- **Physics options: RRTMG (LW/SW), Tiedtke Cumulus for 9km, Noah LSM**
- **Focus on rainfall in three regions**

Region1: Fangshan, heaviest rainfall
Region2: Beijing city
Region3: downwind from storm

NCAR

WRF Ensemble Hindcast Experiments

	12Z19July2012	00Z20July2012	12Z20July2012	00Z21July2012
Microphysics	Thompson WSM6 WDM6	Thompson WSM6 WDM6	Thompson WSM6 WDM6	Thompson WSM6 WDM6
Boundary Layer	Thompson + MYJ Thompson +YSU	Thompson + MYJ Thompson +YSU	Thompson + MYJ Thompson +YSU	Thompson+ MYJ Thompson +YSU
Urban schemes	Thompson+MYJ+SL UCM Thompson+MYJ+BEP Thompson+MYJ+BEP_BEM	Thompson+MYJ+SL UCM Thompson+MYJ+BEP Thompson+MYJ+BEP_BEM	Thompson+MYJ+SL UCM Thompson+MYJ+BEP Thompson+MYJ+BEP_BEM	Thompson+MYJ+SL UCM Thompson+MYJ+BEP Thompson+MYJ+BEP_BEM
Initial and boundary conditions	FNL ERA-interim	FNL ERA-interim	FNL ERA-interim	FNL ERA-interim
Urban land-use data	MODIS 2001 2009 Beijing data	MODIS 2001 2009 Beijing data	MODIS 2001 2009 Beijing data	MODIS 2001 2009 Beijing data
No Urban (replace cities with grass)	Thompson+MYJ	Thompson+MYJ	Thompson+MYJ	Thompson+MYJ

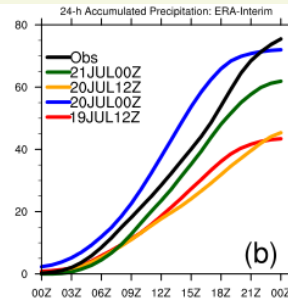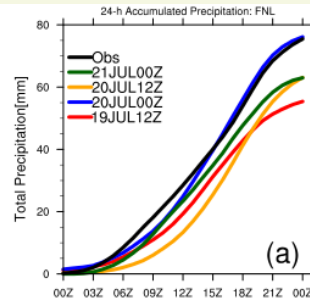# WRF model captures rainfall pattern well

NCAR
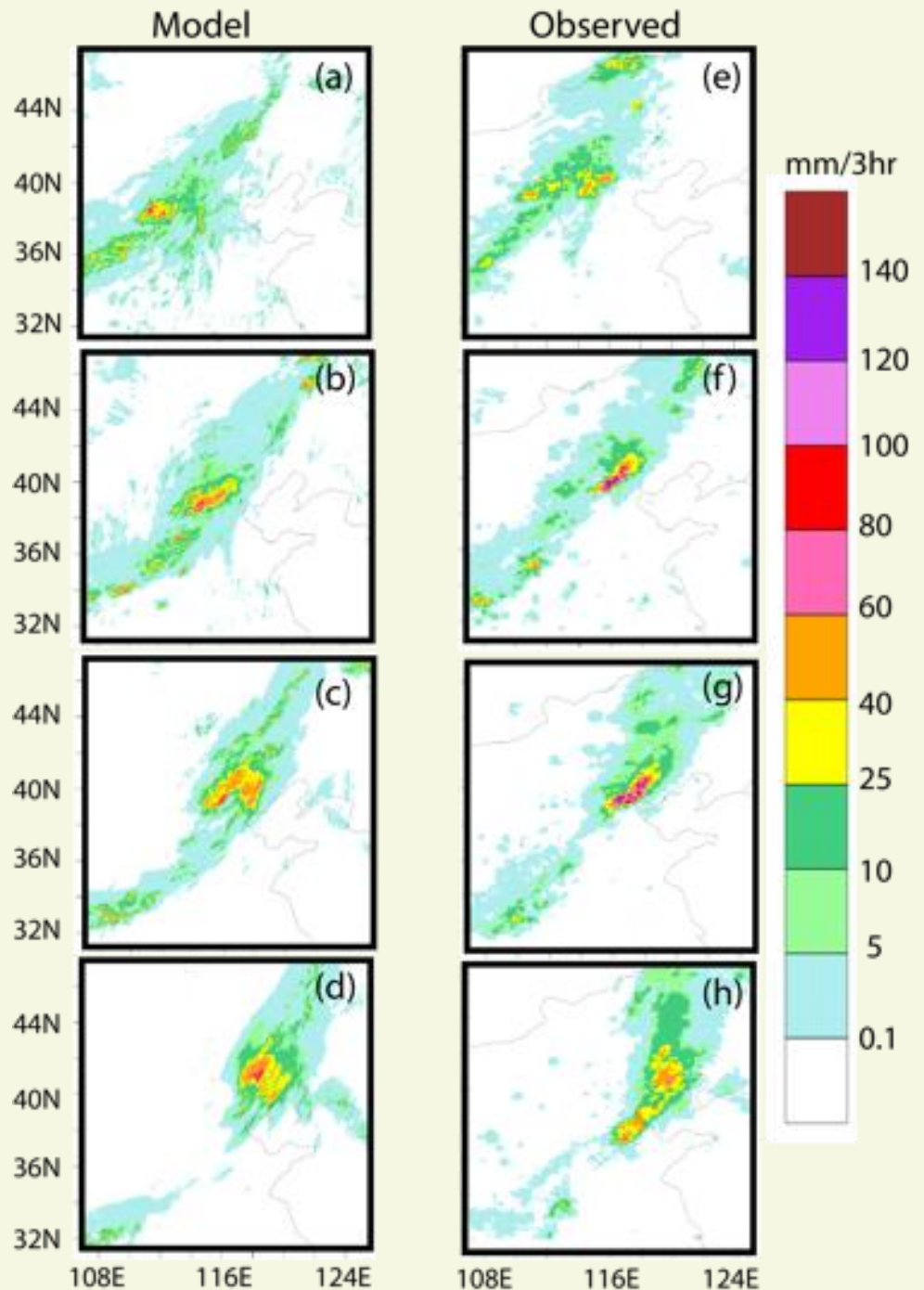
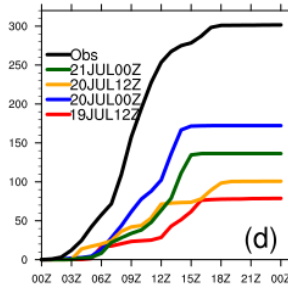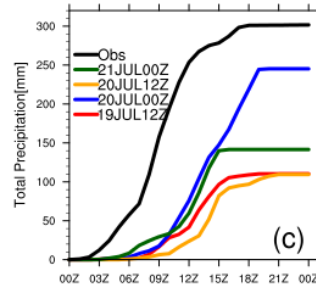# Uncertainty in Initial Conditions and Initialization Time

Using FNL   Using ERA-Interim

Full domain

Region 1

Region 2

Region 3

24-h (00z21-00z22July) accumulated rainfall on different domains
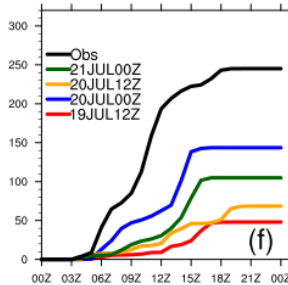
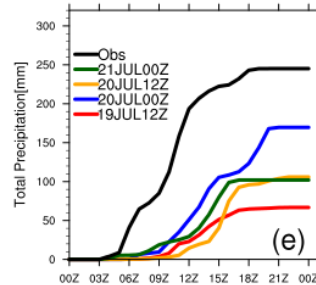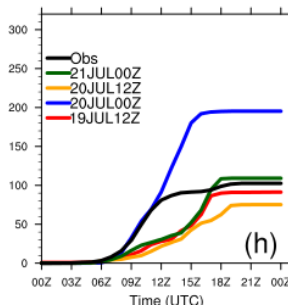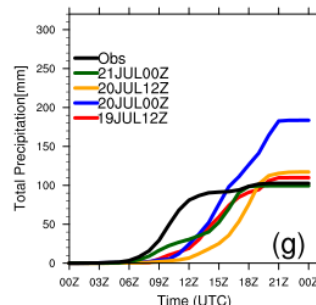## Initialization time:
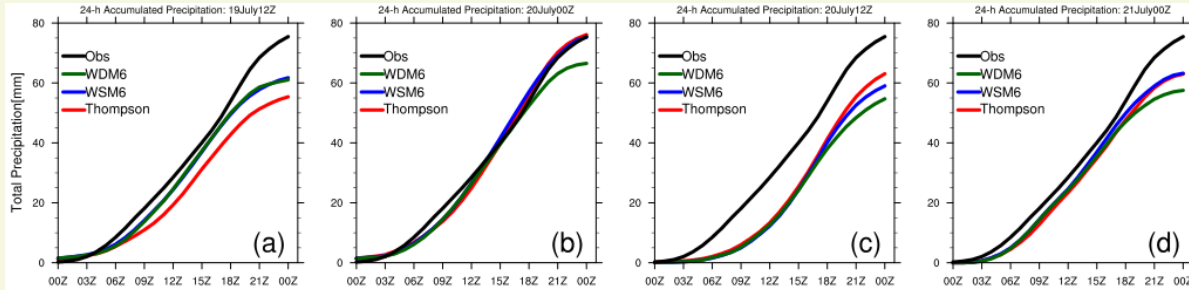
12Z19Jul, 00Z20Jul, 12Z20Jul, 00Z21Jul
Observed

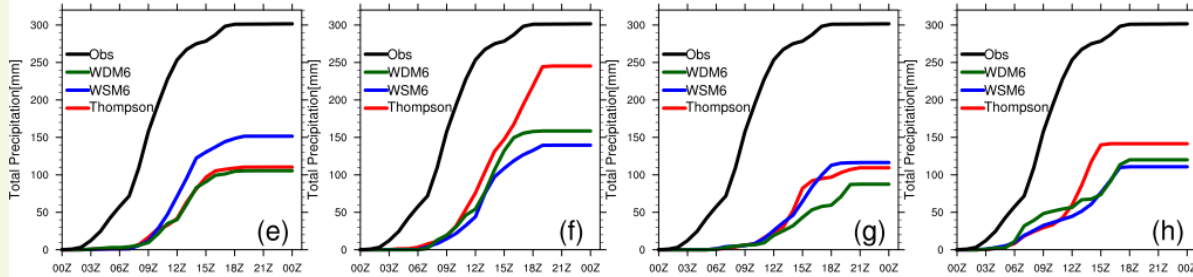Initializing WRF at 00Z20July using FNL produced the "best" control simulation

NCAR

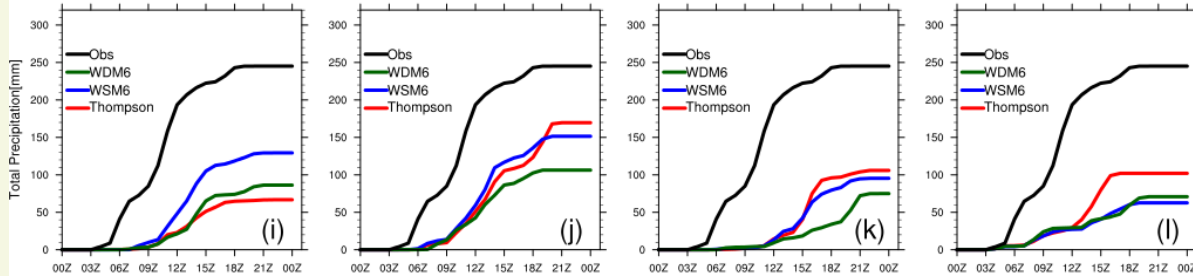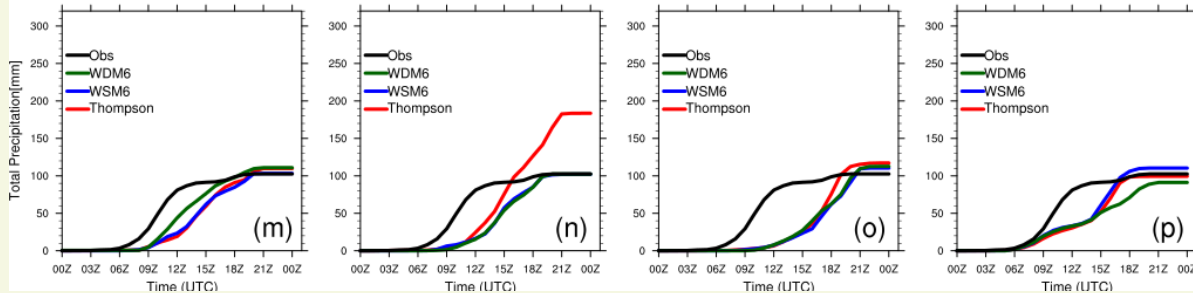# Uncertainty in Microphysics Schemes

Full domain

Region 1

Thompson, WSM6, WDM6, Observed

Region 2

Region 3

Uncertainty in PBL schemes

Using MYJ   Using YSU
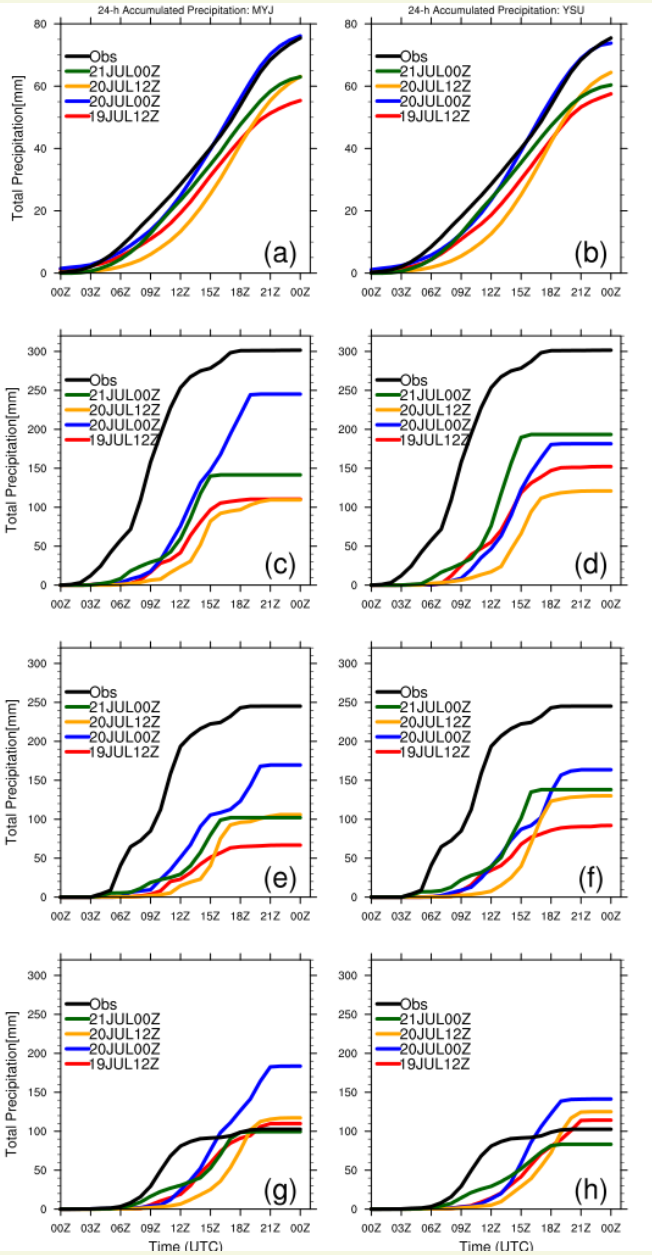
Red: MYJ
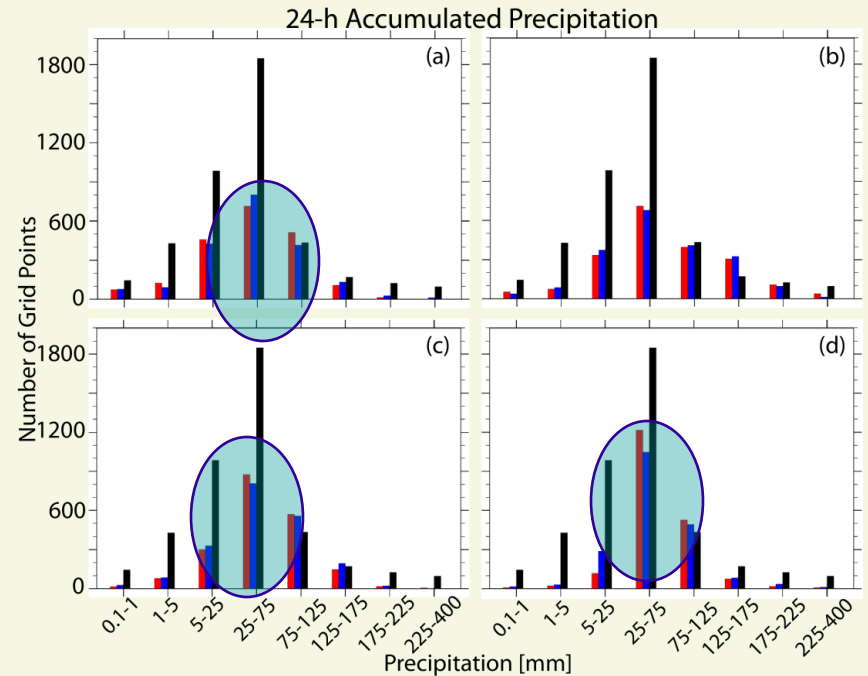Blue: YSU

Initialization
Time:
12Z19Jul,
00Z20Jul,
12Z20Jul,
00Z21Jul

Observed

Four panels represent
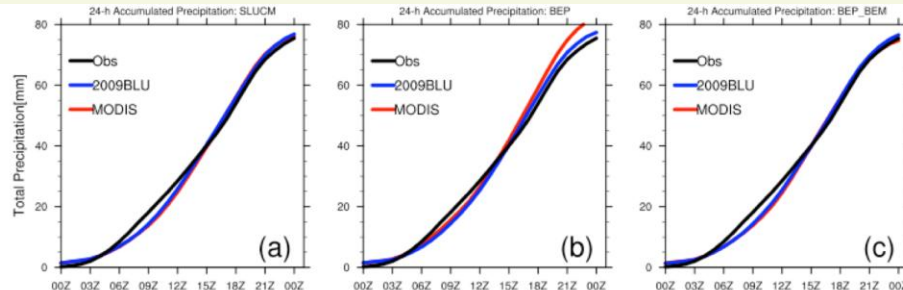initialization time

NCAR

Uncertainty in Treating Urban Canopy
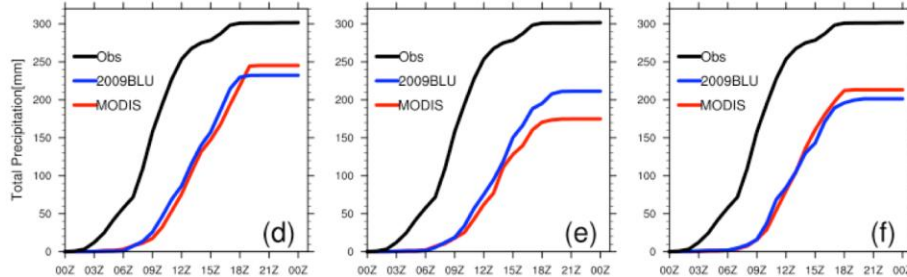
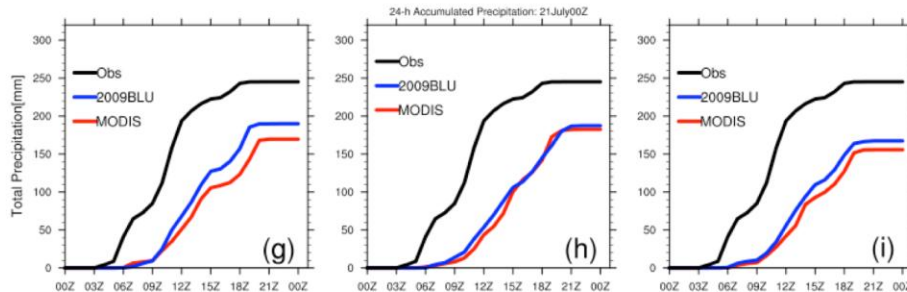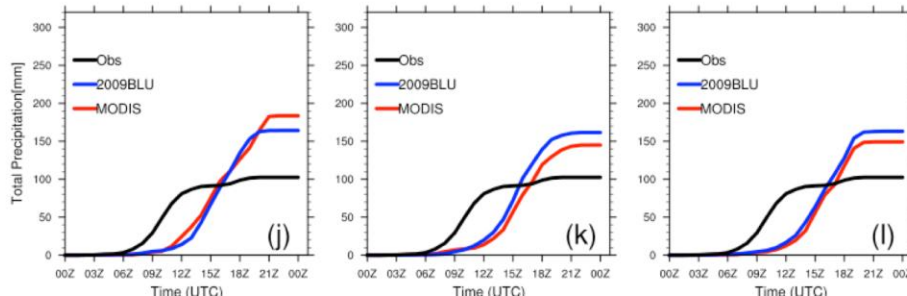Single-layer UCM   BEP   BEP+BEM

Full domain

Region 1

Region 2

Region 3

MODIS
2009 LULC
Observed

Differences in modeled rainfall using different UCMs are smaller than that using different LULC.

NCAR

Assess impacts of Super Sandy in future climate

Simulated Hurricane Sandy track in CNTL (cyan), F2020 (purple), F2050A (gold), F2050B (red), F2050C (blue), and F2090 (green) simulations.

Using Pseudo Global Warming (PGW) approach to conduct future WRF simulations
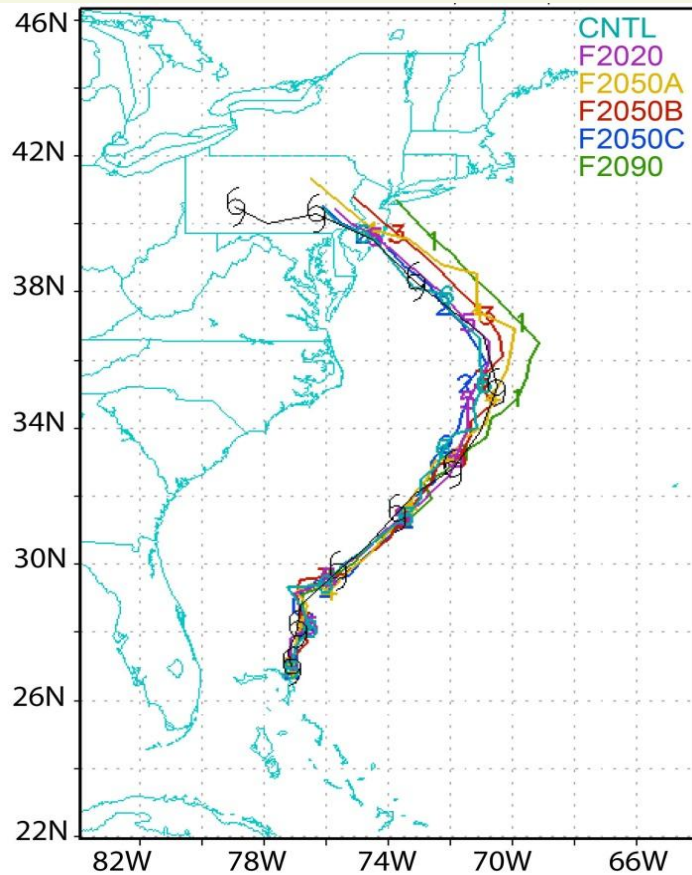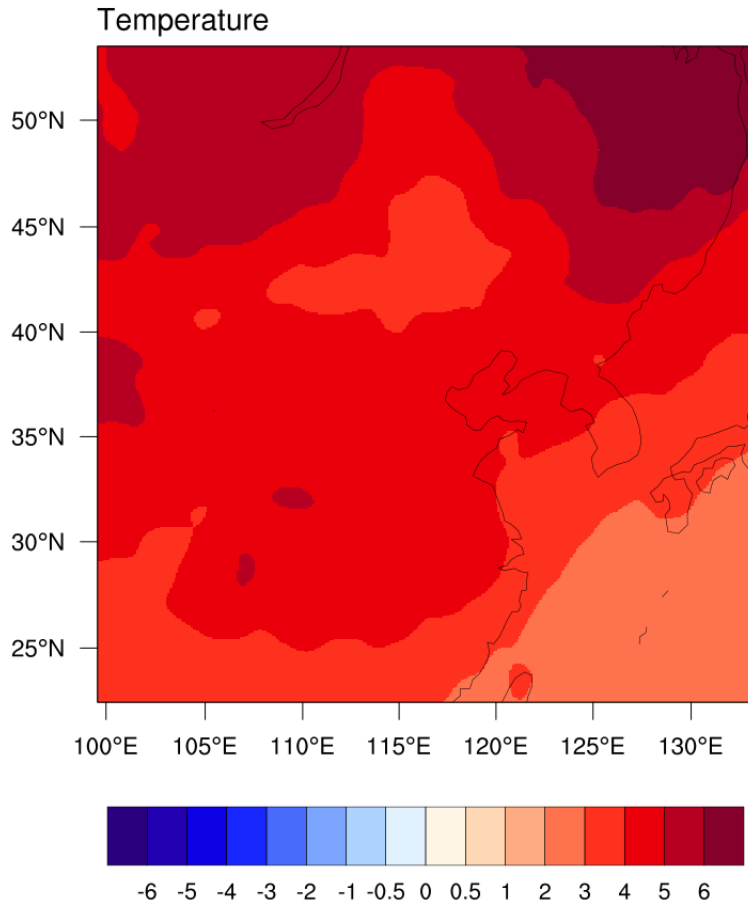

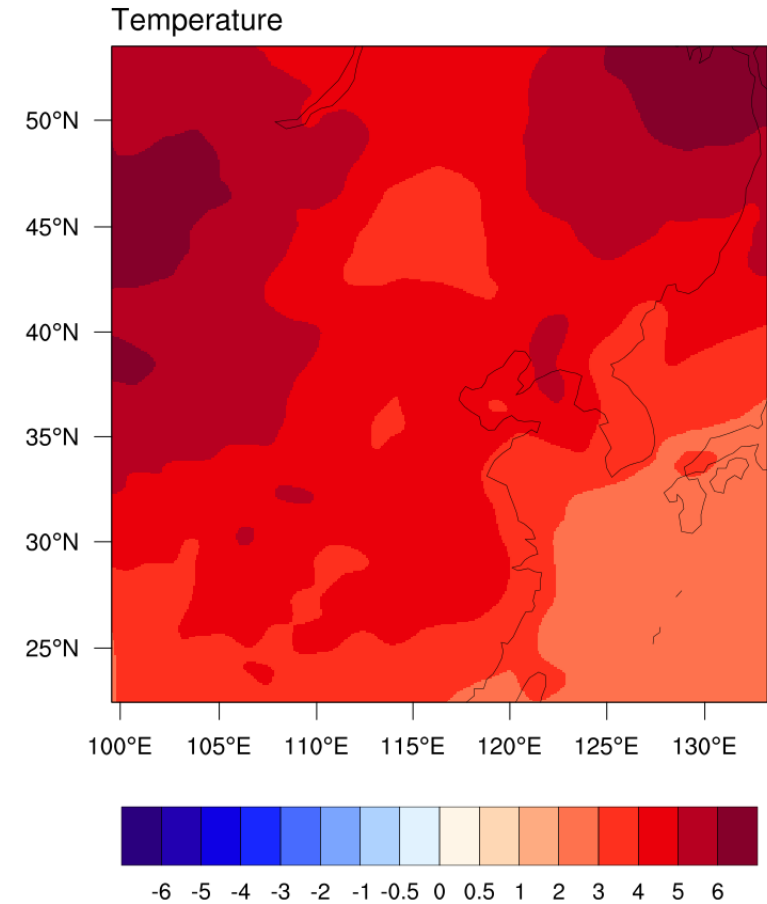*Simulation of flooding extent in 2090.* Credit: DNV GL

Yates et al., 2014, *IEEE Special Issue on Climate Change Adaptation*

NCAR

Differences in surface air temperature:
FUTURE (2050) climate – CURRENT climate
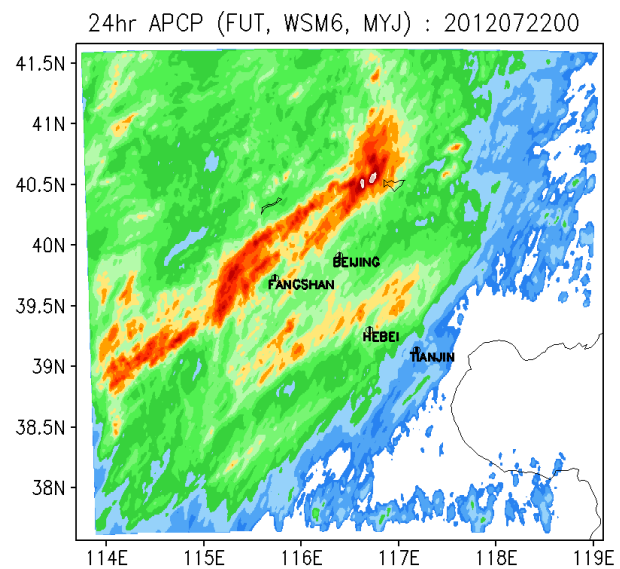

Future-Current: July
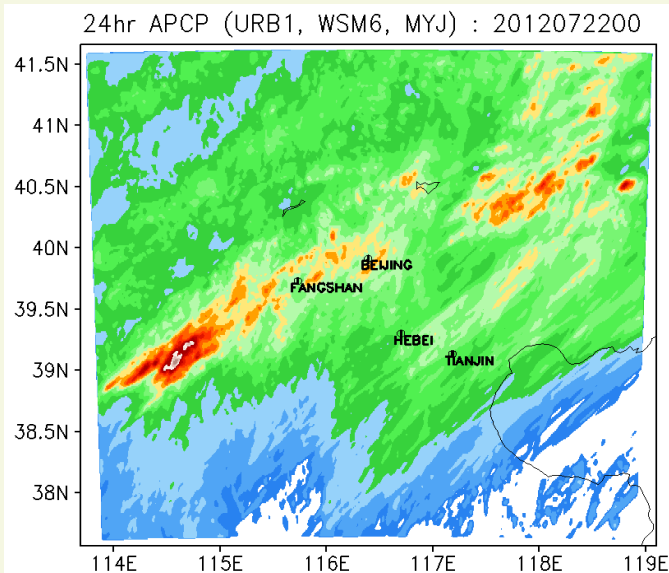
Future-Current: August
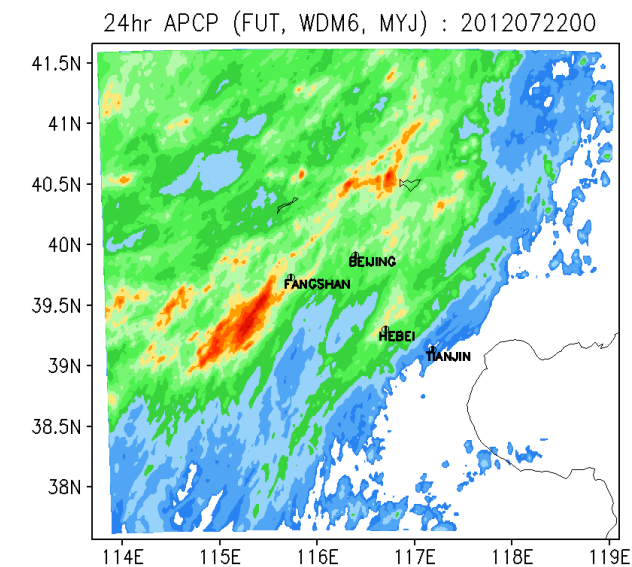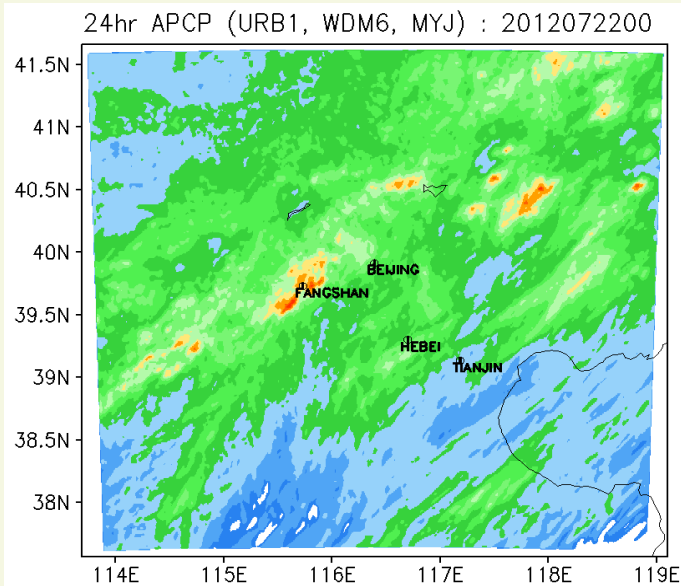
Greneral Warming of ~3-6 C.

24-h Accumulated Precipitation Valid at 22 July 00Z

WSM6

WDM6

CURRENT

FUTURE

Conclusions

- **Among the ensemble members, microphysics schemes and the time of initialization contributes to the highest uncertainty in the prediction of the Beijing Storm.**

- **Uncertainty in the initial conditions and model physics parameterizations leads to the suggestion of ensemble prediction, and the ensemble mean shows good promise.**

- **The impact of cities on the Beijing Super-Storm is relatively minor.**

NCAR

Merci de votre attention!

NCAR