Simulation of Warm Season Rainfall using the WRF Regional Climate Model

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Regional Climate Modeling

- Current GCMs lack the spatial resolution to represent regional scale processes and feedbacks.
- High resolution → more precise description of regional topographic forcings due to orography, land-sea contrasts and land surface characteristics.

Applications

Downscaling of climate variability and change at the regional scale (e.g for impact assessment and resource management).
Process studies (e.g. land-atmosphere interactions; cloud-radiation feedbacks)
Upscaling of regional phenomena with global consequences.

Objective

- Identify and understand robust errors in long-term simulation of warm-season rainfall.
- Warm-season rainfall over central US has been idenitified with physical mechanisms at both planetary and local scales – ideal for RCM evaluation (Liang *et al.* 2001).

- *Case Study:* Record flooding occurred in the Mississippi River Basin during June and July 1993 (Kunkel *et al.* 1994).

  - floods coincided with an anomalous southward displacement of the Upper Level Jet (ULJ) and a sustained Low-Level Jet (LLJ) → enhanced moisture convergence and frequent mesoscale convection.

Kunkel, K. E., S. A. Changnon, and J. R. Angel, 1994: Climate aspects of the 1993 upper Mississippi basin flood. *Bull. Amer. Meteor. Soc.*, **75**, 811- 822.

Liang, X. -Z., K. E. Kunkel, and A. N. Samel, 2001: Development of a Regional Climate Model for U.S. Midwest Applications. Part I: Sensitivity to Buffer Zone Treatment. *J. Climate*, **14**, 4363-4378.

Model Details

- Single domain: 30km grid-spacing; 31 vertical levels.

- Initial and boundary conditions provided by the NCEP NCAR Reanalysis Project (NNRP): 2.5°, 6-hourly.

- Sea surface temperature (SST), vegetation fraction and albedo are updated every 6 hours.

- Physics parameterizations
  - Noah land surface
  - Grell-Devenyi convection
  - Ferrier microphysics
  - RRTM and Dudhia radiation

Experiments

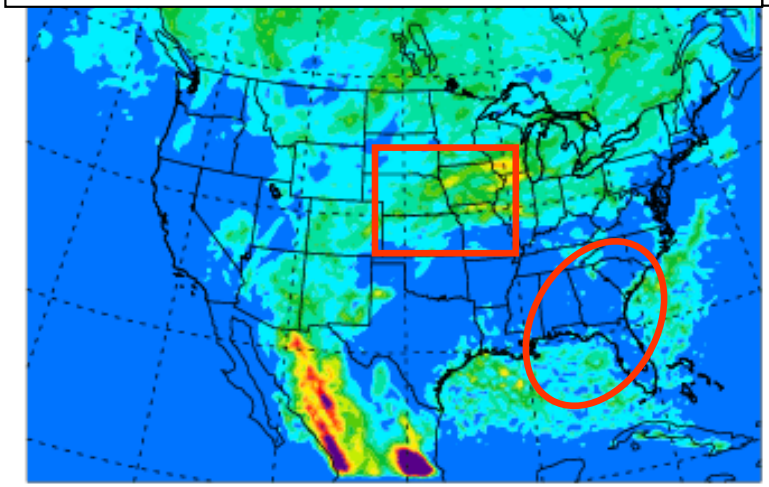
- Climate simulation initialized at 00 UTC 1st Oct 1992.

- Forecast Experiment:
  - Use same model setup as climate simulation.
  - Forecasts initialized at 12 UTC every day during July 1993.
  - 12-36 hour periods concatenated.

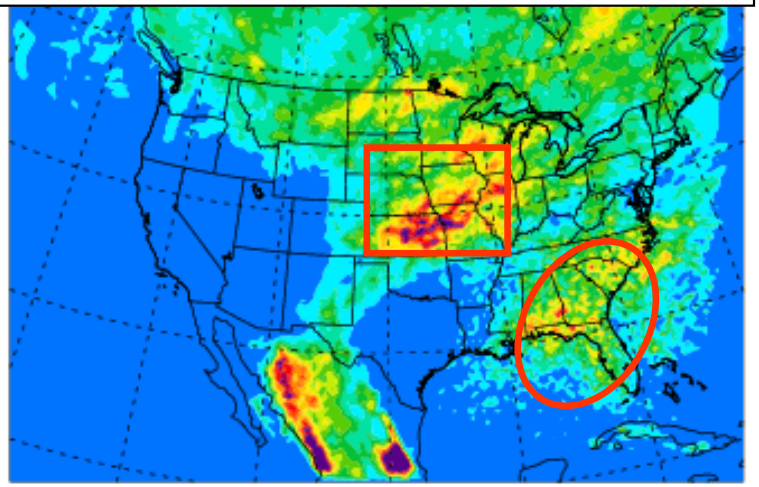
- Climate Sensitivity Experiments:
  - Convection scheme.
  - Land Surface model.
  - Land Surface state.
  - Gulf SSTs.

Monthly Precipitation (July 1993)

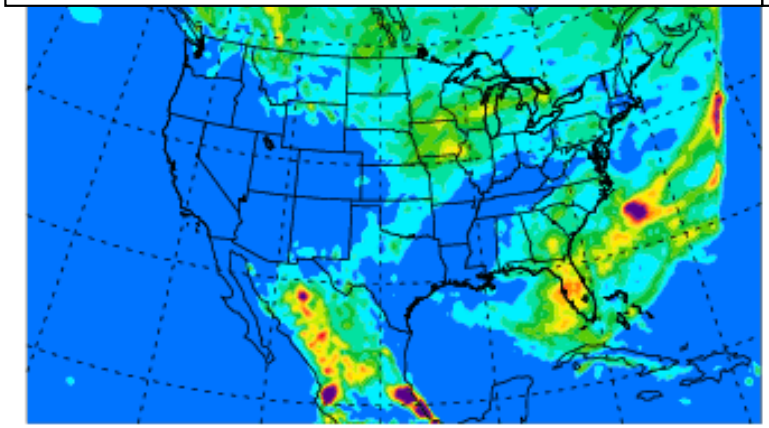
WRF Climate



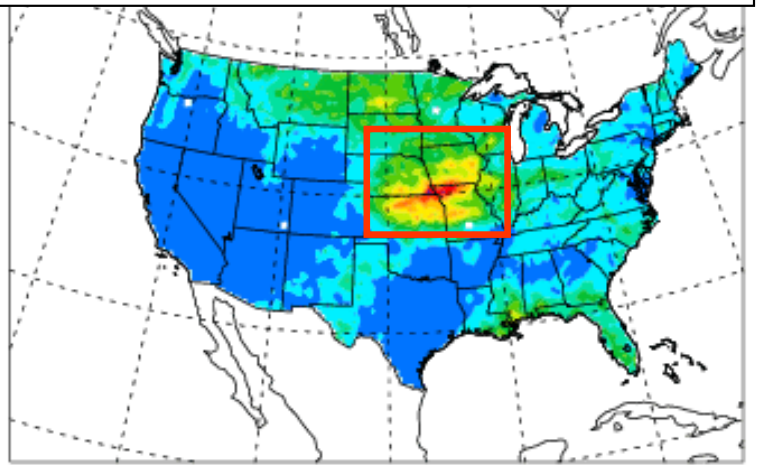
WRF Forecasts



MM5 Climate

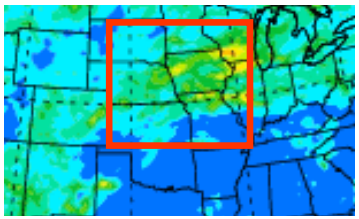


Obs (1/24°, ~4km)

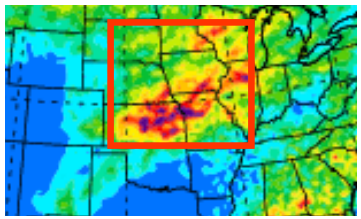


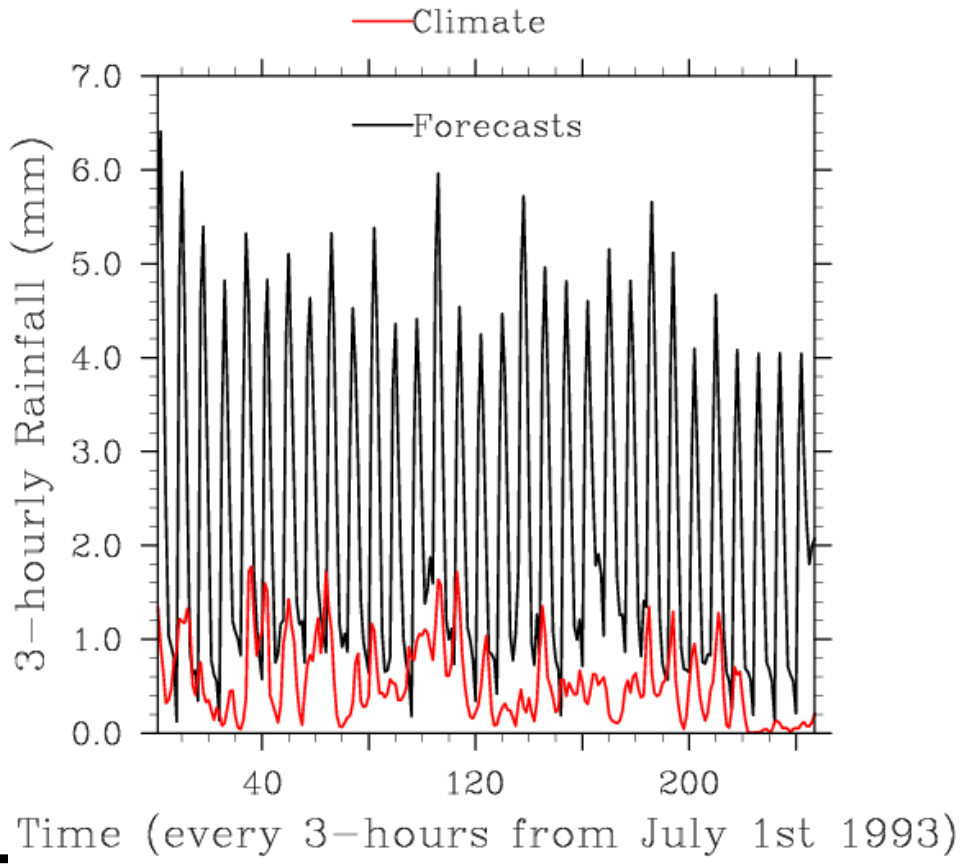
Flood Region Precipitation (July 1993)

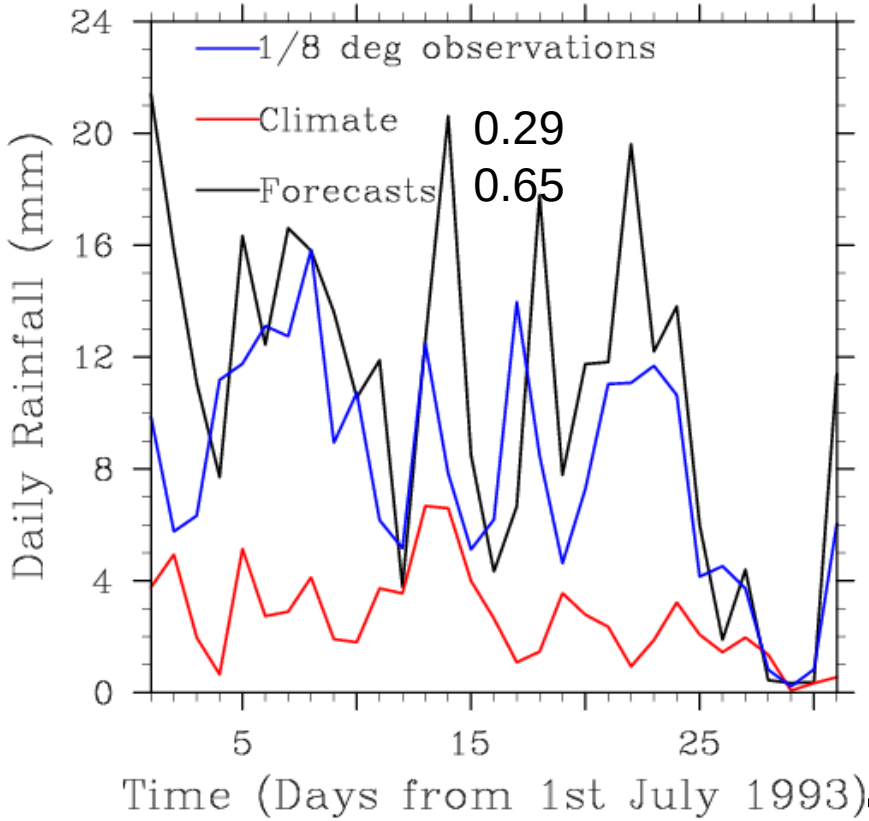
WRF Climate



WRF Forecasts

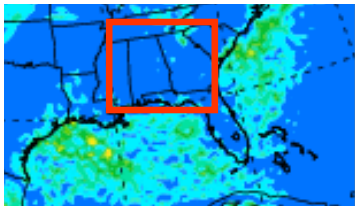


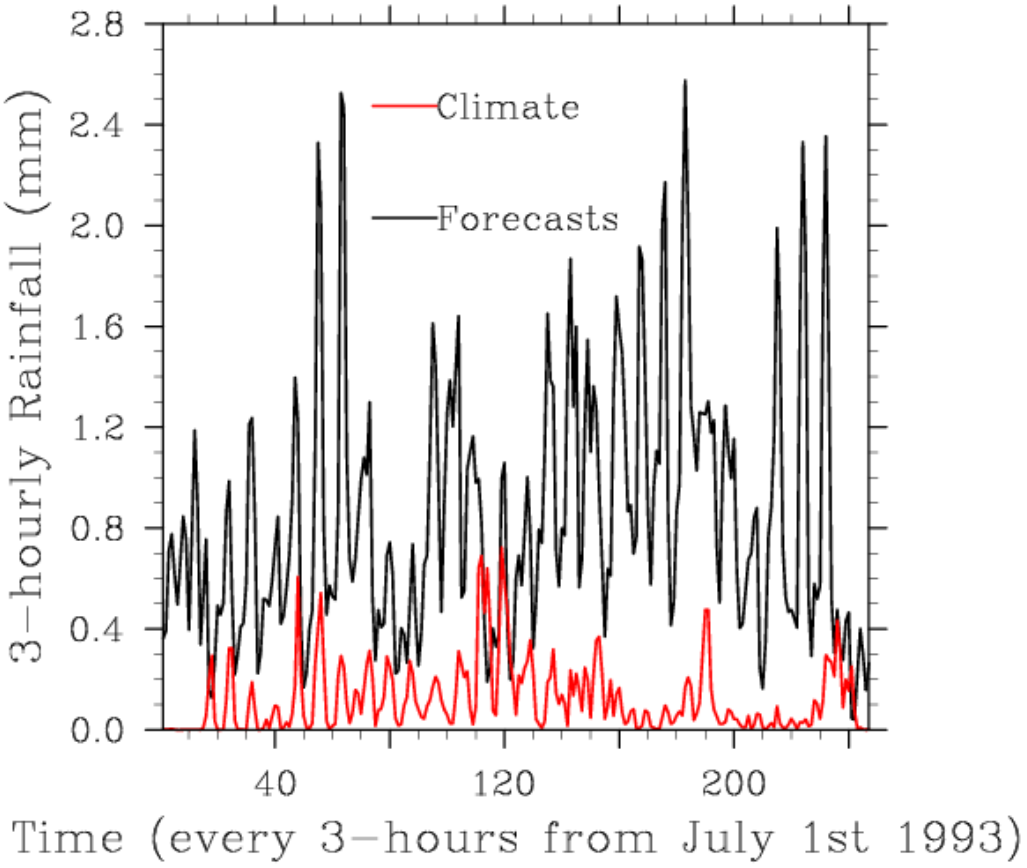




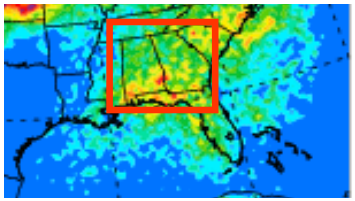
Southeast US Precipitation (July 1993)

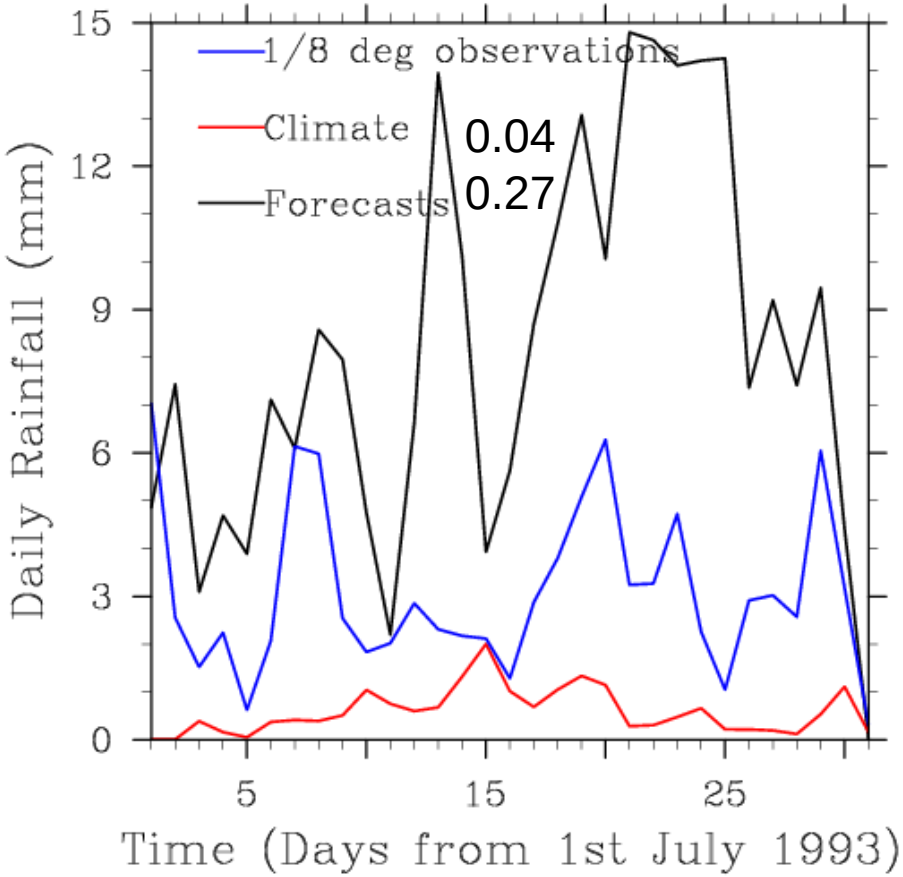
WRF Climate



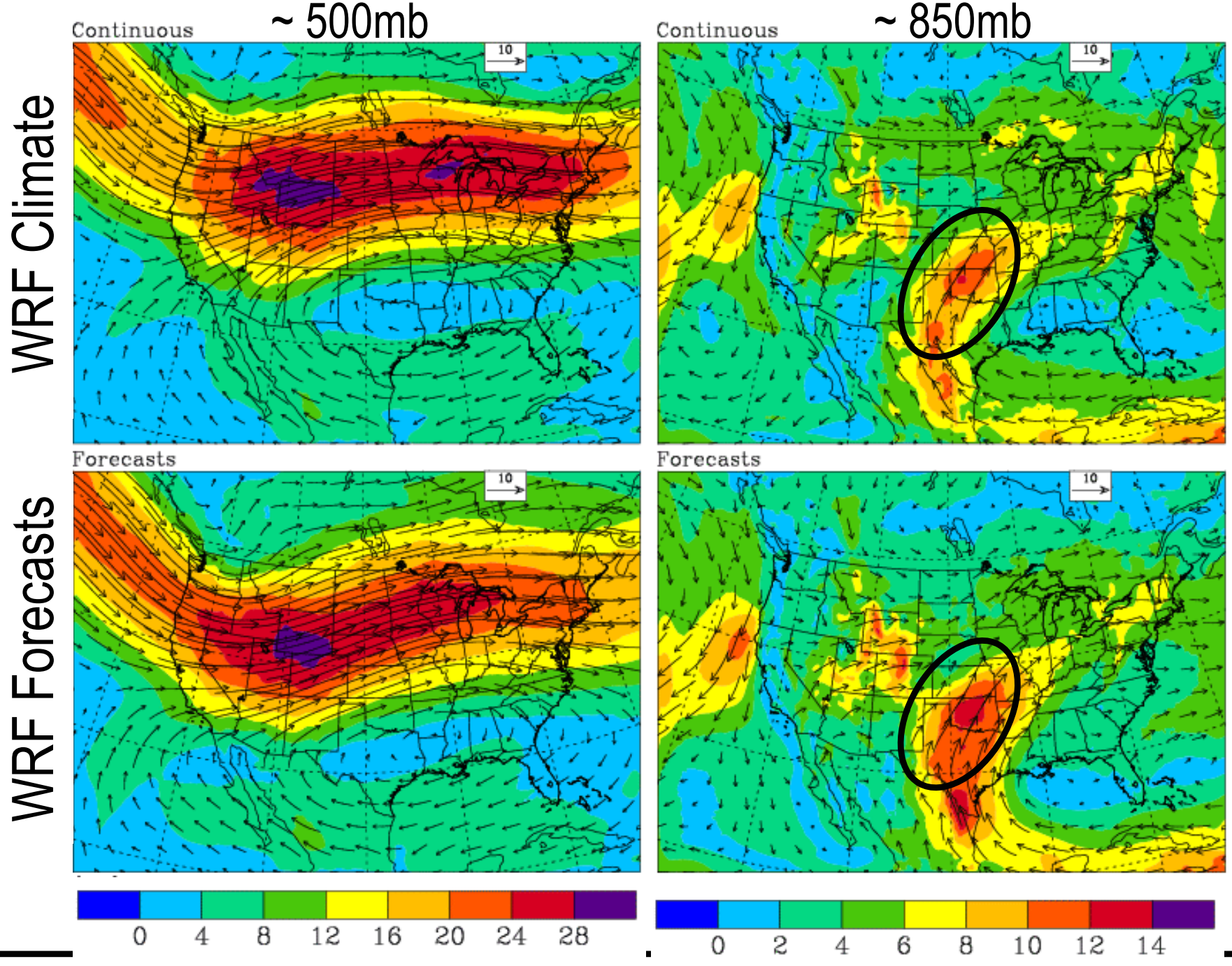


WRF Forecasts



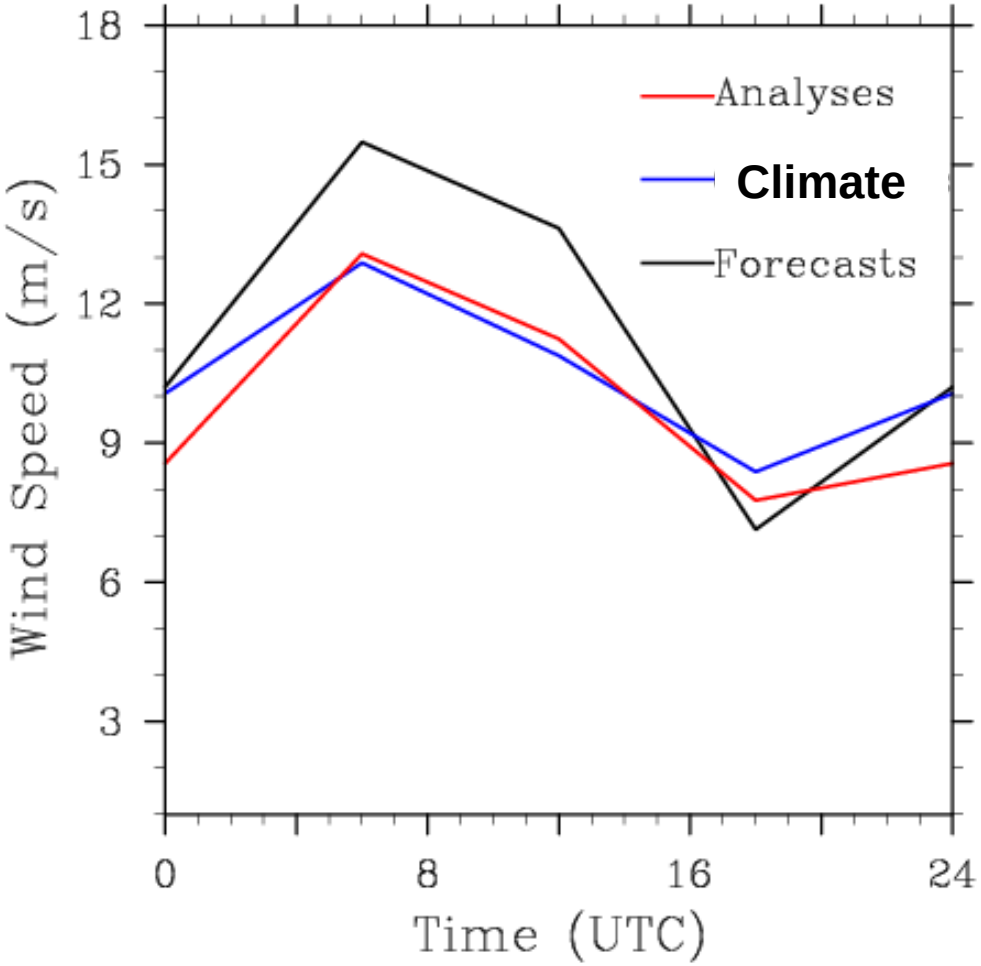


Monthly Winds (July 1993)

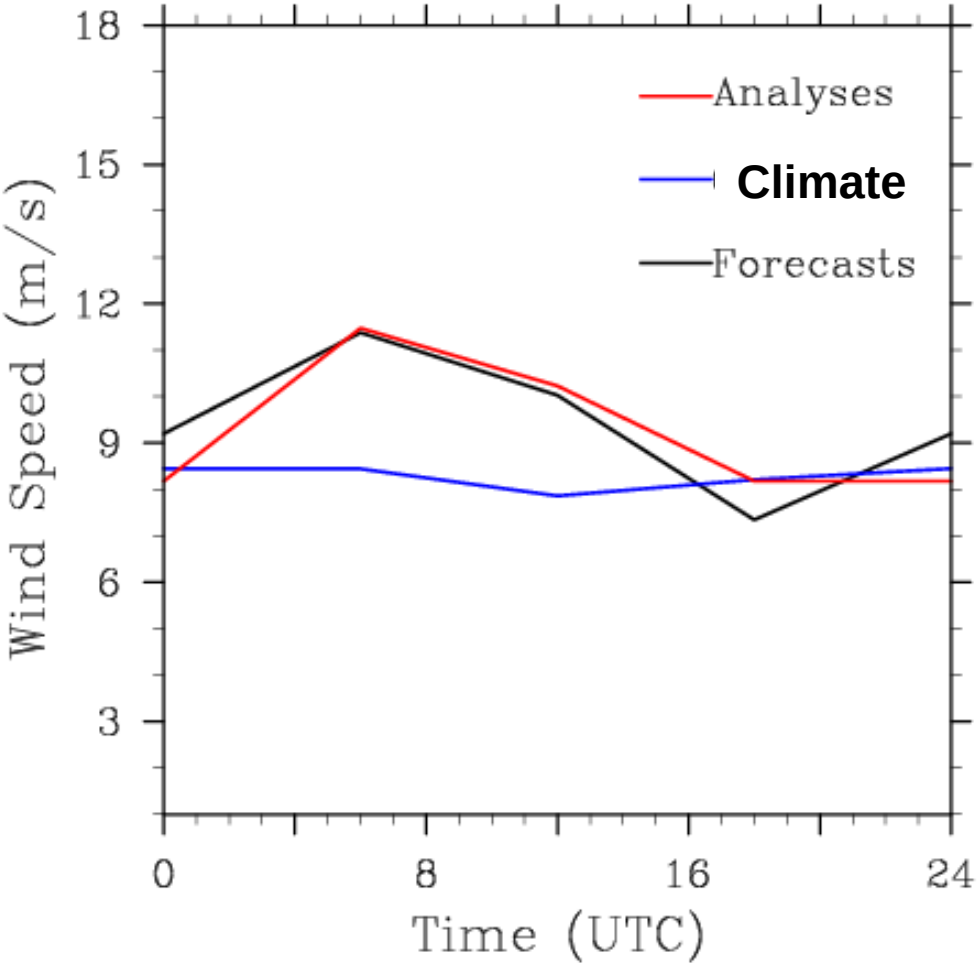


Diurnal Cycle of Winds (July 1993)

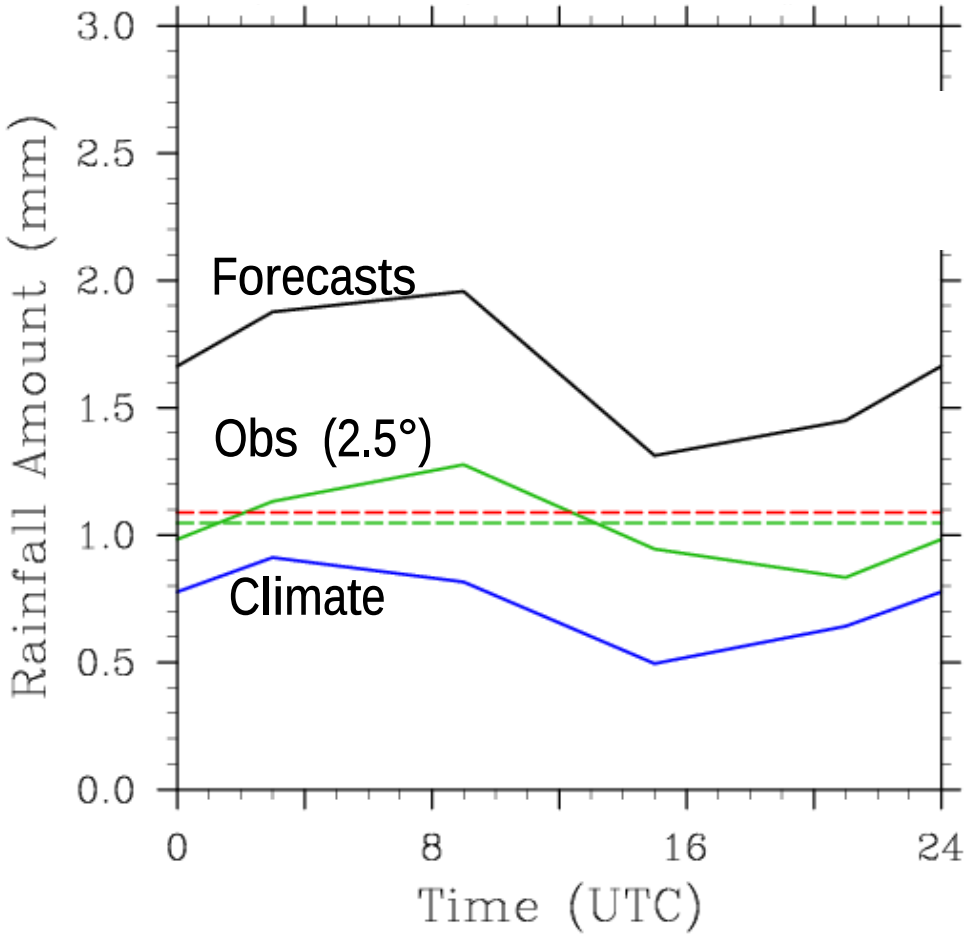
~ 885hPa



~ 820hPa



Diurnal Cycle of Flood-Region Precipitation (July 1993)



Sensitivity Experiments

Data	Convection Scheme	Surface Model or Surface Conditions	Flood-Region Average Rainfall
WRF Climate	GD	Noah LSM	97
WRF Climate	BM	Noah LSM	97
WRF Climate	KF	Noah LSM	80
WRF Climate	GD	RUC LSM	91
WRF Climate	GD	Soil M X 1.3 on 1st June	104
WRF Climate	GD	Gulf SSTs increased by 1.5K	107
MM5 Climate	KF	OSU LSM	95
WRF Forecasts	GD	Noah LSM	233
Obs (1/24°)			165

Summary

- All climate simulations (different convection schemes, land surface schemes and initial land/sea surface states) underpredict precipitation intensity in the central Great Plains during July 1993.
- Comparison of forecast and climate runs shows weaker upper-level trough and weaker and shallower nocturnal LLJ in the climate runs.
- Both climate and forecast runs correctly captured the nocturnal maximum in winds and precipitation.
- All climate simulations using WRF RCM underpredict precipitation intensity in the Southeast US.

Lack of Warm-Season Rainfall in RCMs: Candidate Mechanisms

- Poor representation of longer timescale feedback mechanisms (e.g. convective cloud-radiation feedbacks)

- Presence of unphysical feedbacks due to model setup (e.g. interactions and reflection of the internal domain dynamics with the lateral boundaries, as evidenced in Miguez-Macho et al. 2005)