Understanding Error in the Long-Term Simulation of Warm-Season Rainfall using the WRF model.

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Regional Climate Modeling

High resolution:

• more precise description of regional topographic forcings due to orography, land-sea contrasts and land surface characteristics.

• more precise description of smaller scale atmospheric phenomena such as mesoscale convection.

Low predictability of warm-season continental climate:

• dominated by small-scale convection, surface hydrological processes and weak large-scale flow.

Objectives

- Identify and understand robust errors in long-term simulation of warm-season rainfall.

- Model physics versus Model set-up
- Implications of Internal Model Variability (IMV): small changes to initial conditions can result in climate variability due to non-linearities in model physics and dynamics.

- Establish the WRF model as a valid tool for Regional Climate Research.

Model Details

• Single domain: 30km grid-spacing; 35 vertical levels.

• Initial, lateral and lower 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 and YSU boundary layer
  - Kain-Fritsch convection
  - WSM-6 microphysics
  - CAM radiation: includes aerosol effects and updated O_3

Simulations

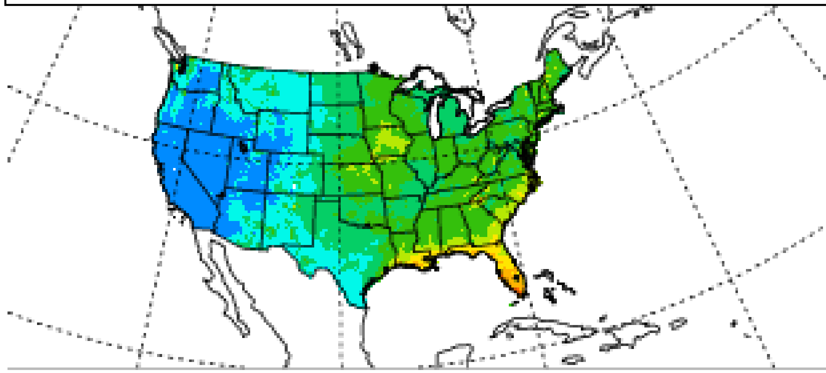
• 6-year climate simulation initialized at 00 UTC 1st Jan 1988.
  - large domain

• Physics sensitivity experiments. Initialized using restart file on 1st June 1993 (Summer Flood).
  - Convection,
  - Radiation,
  - Cloud Fraction.

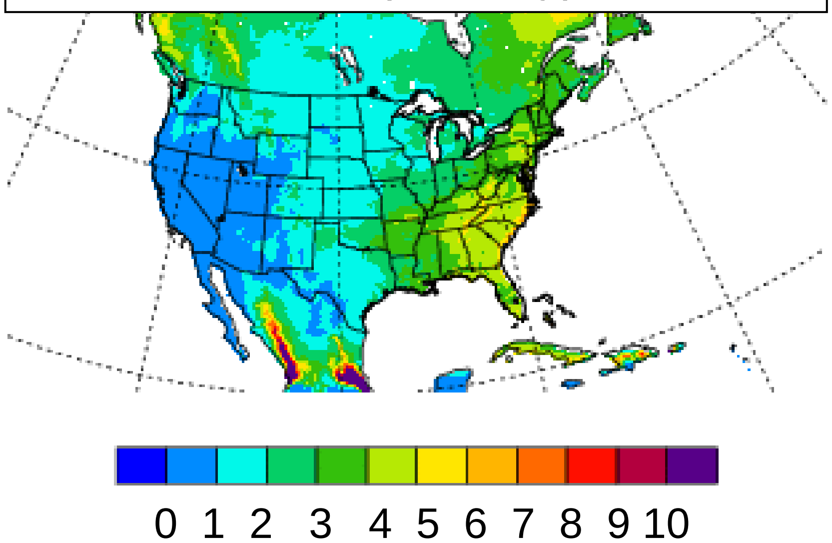
• Domain size.
• Initial Conditions.

6-Year Average Warm-Season (JJA) Rainfall

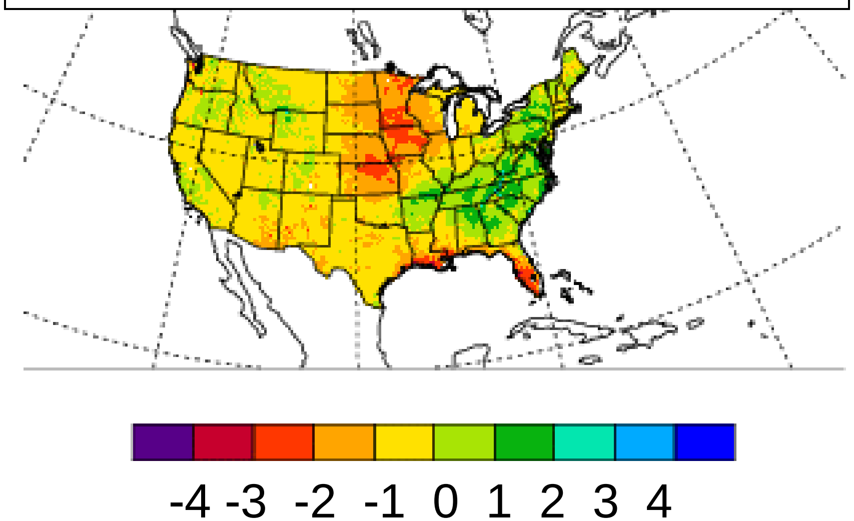
Observation (mm/day)



WRF (mm/day)



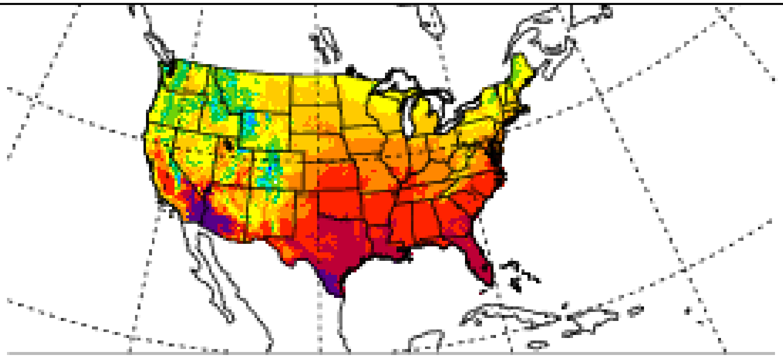
WRF – Observation (mm/day)



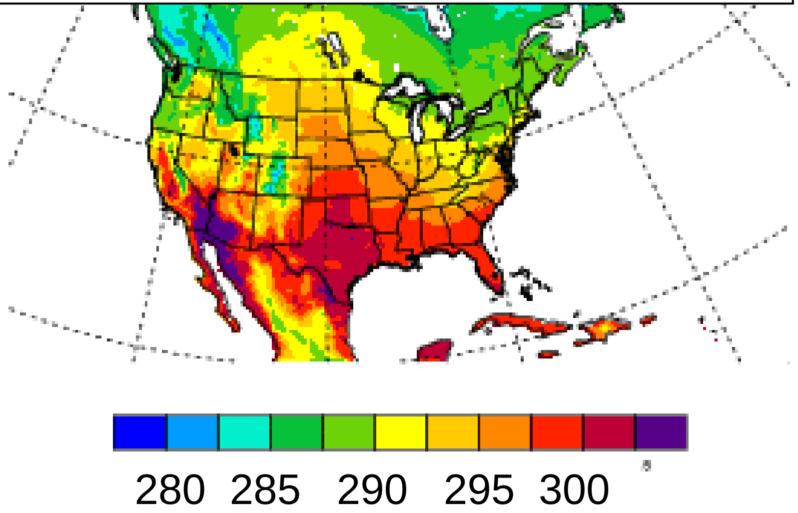
• Dry bias over the MidWest

6-Year Average Warm-Season 2m Temperature

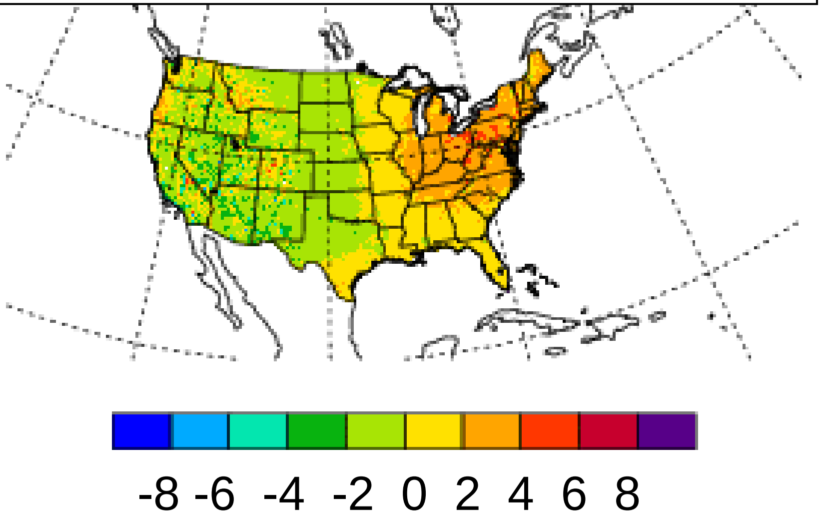
Observation (K)



WRF (K)

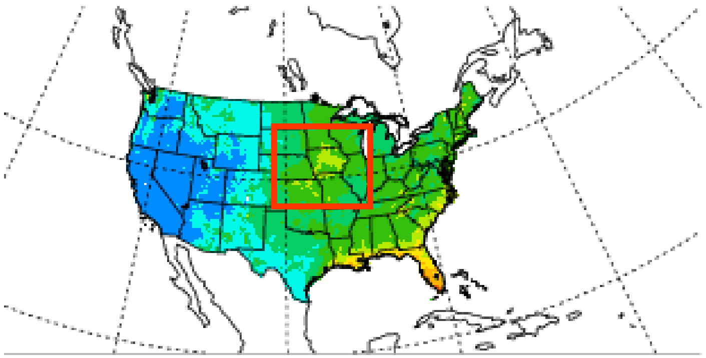


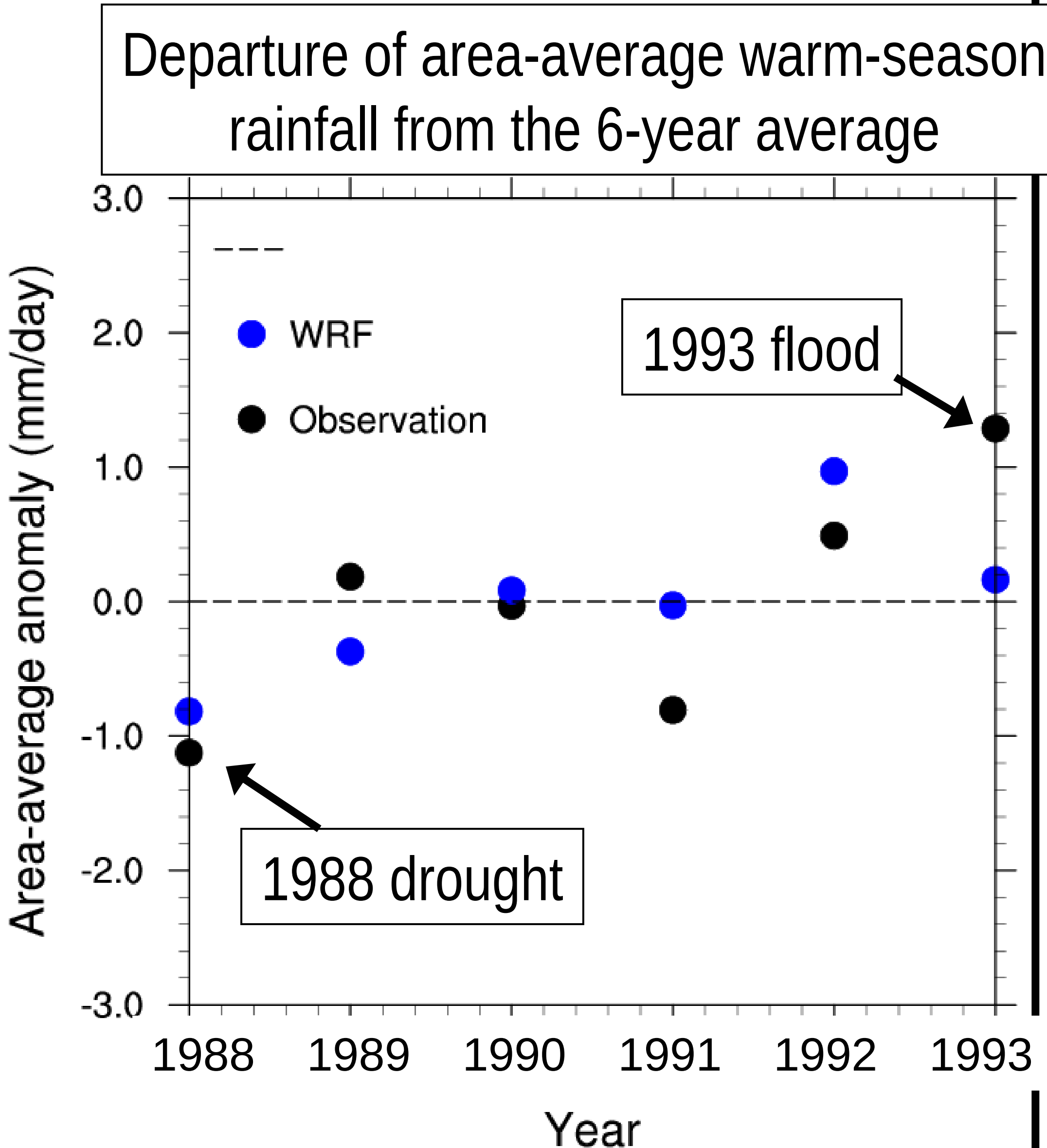
WRF – Observation (K)



- Cool bias in West
- Warm bias in East

Interannual Variability of Precipitation





• Reasonable simulation

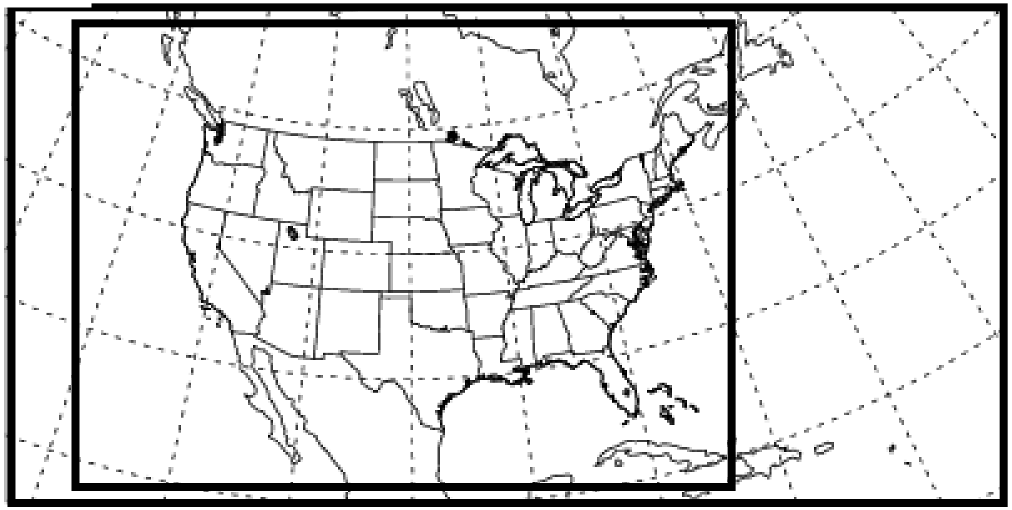
Physics Sensitivity Experiments

Data	Change	Flood-Region Average Rainfall Jul 93 (mm/day)	% Rainfall From Convection Scheme
WRF	Default Model Set-Up	3.19	75
WRF	Betts-Miller Convection	3.66	16
WRF	Grell-Devenyi Convection	5.33	48
WRF	RRTM/Goddard Radiation	3.91	77
WRF	0/1 Cloud Fraction	2.81	72
Obs	-	7.43	-

- Generally low sensitivity to physics
- Exception: Grell-Devenyi convection

Sensitivity to Domain Size I

Large Domain: 150 X 300
Small Domain: 140 X 200



- Small domain initialized on 1st June 1993 using:

- NCEP-NCAR Reanalyses: Atmosphere
- WRF restart soil conditions from the large-domain 6-year simulation.

Domain	Flood region rainfall July 1993 (mm/day)
Large	3.19
Small	1.71

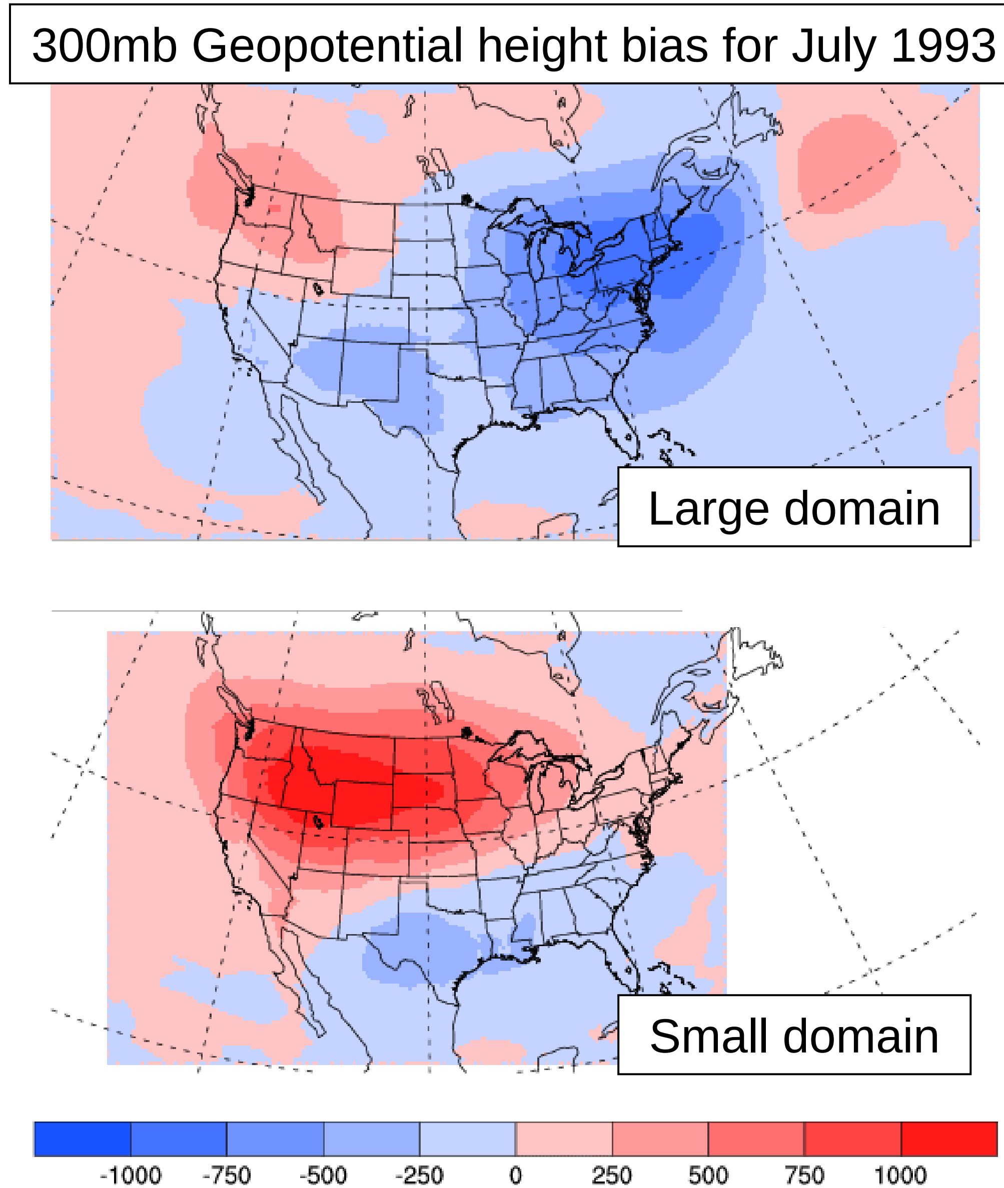
Bias Patterns in the Large-Scale Flow

- Bias pattern very different using different domain sizes

- Bias pattern very similar using different physics (not shown).

- Bias pattern determined by domain size rather than physics.

- Possible to get improved rainfall under similar large-scale pattern, as evidenced by the simulation using Grell-Devenyi convection.



Caution: Internal Model Variability (IMV)

- IMV: Function of season, domain size, domain location and analysis variable
- IMV is largest for warm-season rainfall over continental regions using a large domain.

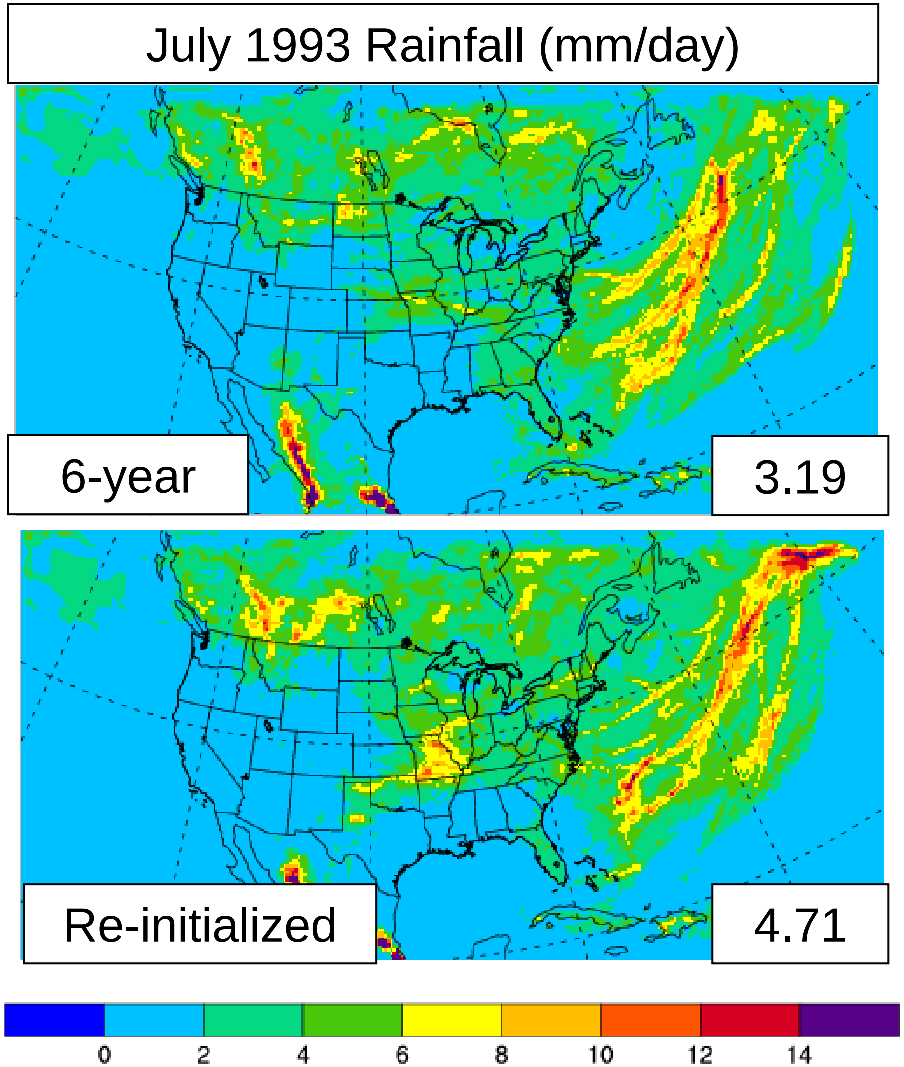
Initial Condition Experiment:

- Large domain initialized on 1st June 1993 using:

- NCEP-NCAR atmosphere

- WRF restart soil conditions from the 6-year simulation.

- Difference in warm-season rainfall total due to IMV is similar to the difference due to changes in physics or domain size.



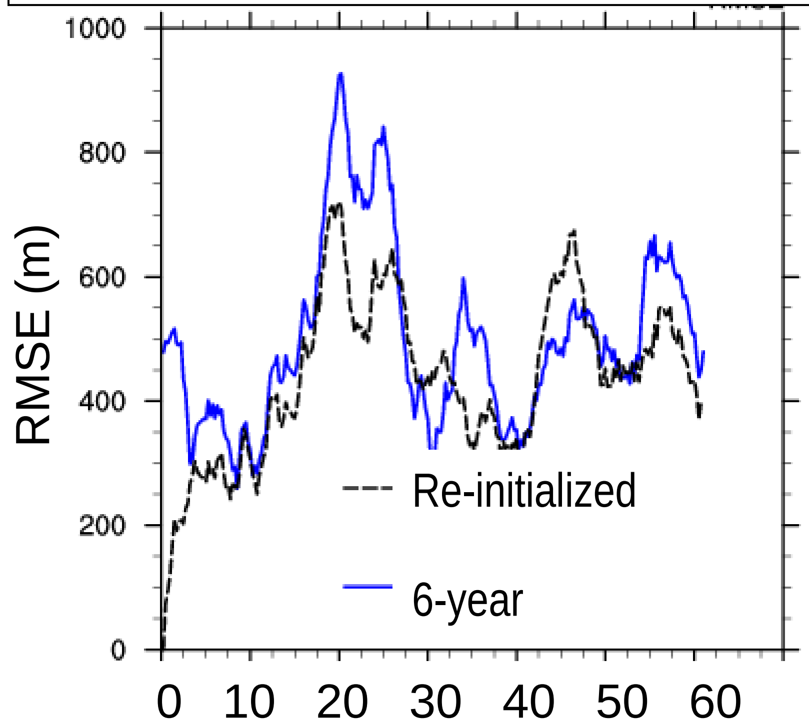
Caution: Internal Model Variability (IMV)

• Atmospheric spin-up: 10-12 days.

• RMSE alternates between the two simulations. Variability on synoptic timescales.

• Substantial impact of IMV on individual weather events. Impacts spatial distribution of warm-season rainfall.

Timeseries of domain average RMSE of 300mb Geopotential height (m)



Time from 1st June 1993 (days)

Summary

- All climate simulations (different physics, domain size, initial conditions and year) show a lack of warm-season rainfall over the central U.S.
- Large-scale height bias largely determined by domain size.
- Rainfall determined by physics, domain size and IMV.
- Internal Variability in a Regional Climate Model is significant for warm-season rainfall over the central U.S. Implications for climate sensitivity studies.