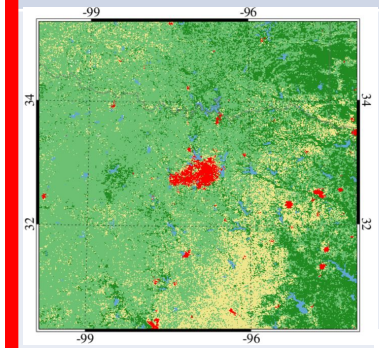
I-WRF Science Use Cases

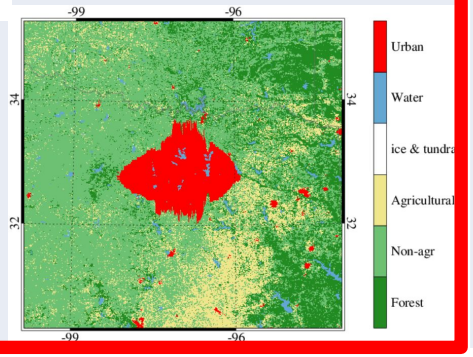
1. Land Use/Land Cover (LULC) Δ

Perturbation exp. to examine urban feedback to deep convection.

- WRF. Compute demand: Modest. Short duration (days), high res. (dx ~ 1.3 km), multiple perturbations & physics settings.
- WRF (multi-node), MET-plus (1-node)



DFW
v
DFW×8

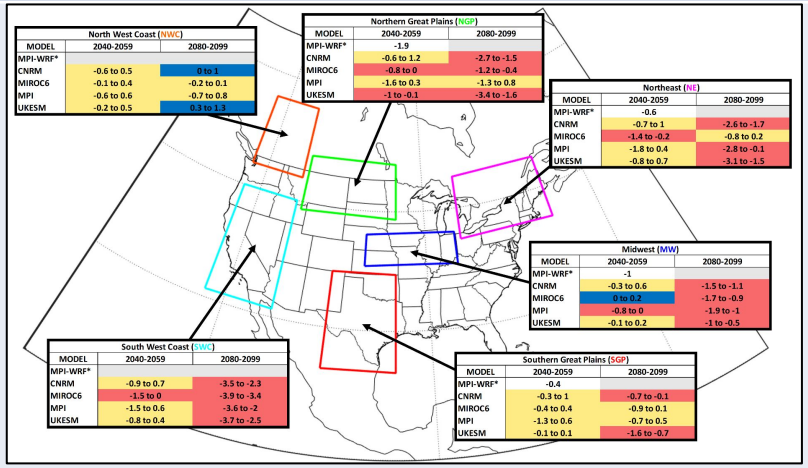


Zhou et al. (2024): *JGR* **129** 2023JD039972

2. Climate science & Renewable energy

Uniquely detailed resource projections for solar & wind under climate change.

- WRF. Compute demand: Large (<u>many</u> nodes). Long duration (multiple years/decades), moderate resolution (dx ~ 4 km)
- To increase IMPACT joined WCRP-CORDEX …..



North West Coast (NWC)

MODEL	2040-2059	2080-2099
MPI-WRF*		
CNRM	-0.6 to 0.5	0 to 1
MIROC6	-0.1 to 0.4	-0.2 to 0.1
MPI	-0.6 to 0.6	-0.7 to 0.8
UKESM	-0.2 to 0.5	0.3 to 1.3

Northern Great Plains (NGP)

MODEL	2040-2059	2080-2099
MPI-WRF*	-1.9	
CNRM	-0.6 to 1.2	-2.7 to -1.5
MIROC6	-0.8 to 0	-1.2 to -0.4
MPI	-1.6 to 0.3	-1.3 to 0.8
UKESM	-1 to -0.1	-3.4 to -1.6

Northeast (NE)

MODEL	2040-2059	2080-2099
MPI-WRF*	-0.6	
CNRM	-0.7 to 1	-2.6 to -1.7
MIROC6	-1.4 to -0.2	-0.8 to 0.2
MPI	-1.8 to 0.4	-2.8 to -0.1
UKESM	-0.8 to 0.7	-3.1 to -1.5

Midwest (MW)

MODEL	2040-2059	2080-2099
MPI-WRF*	-1	
CNRM	-0.3 to 0.6	-1.5 to -1.1
MIROC6	0 to 0.7	-1.7 to -0.9
MPI	-0.8 to 0	-1.9 to -1
UKESM	-0.1 to 0.2	-1 to -0.5

South West Coast (SWC)

MODEL	2040-2059	2080-2099
MPI-WRF*		
CNRM	-0.9 to 0.7	-3.5 to -2.3
MIROC6	-1.5 to 0	-3.9 to -3.4
MPI	-1.5 to 0.6	-3.6 to -2
UKESM	-0.8 to 0.4	-3.7 to -2.5

Southern Great Plains (SGP)

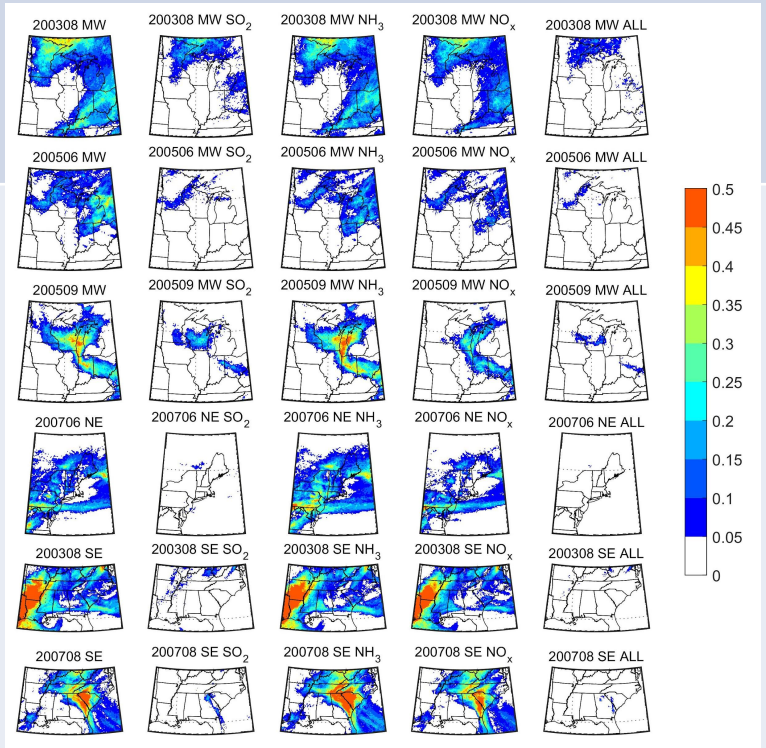
MODEL	2040-2059	2080-2099
MPI-WRF*	-0.4	
CNRM	-0.3 to 1	-0.7 to -0.1
MIROC6	-0.4 to 0.4	-0.9 to 0.1
MPI	-1.3 to 0.6	-0.7 to 0.5
UKESM	-0.1 to 0.1	-1.6 to -0.7

Coburn & Pryor (2023): *JAMC* **62** 81-101

3. Air quality in an evolving climate

Detailed simulations of interplay between emission changes, LULC change & climate evolution.

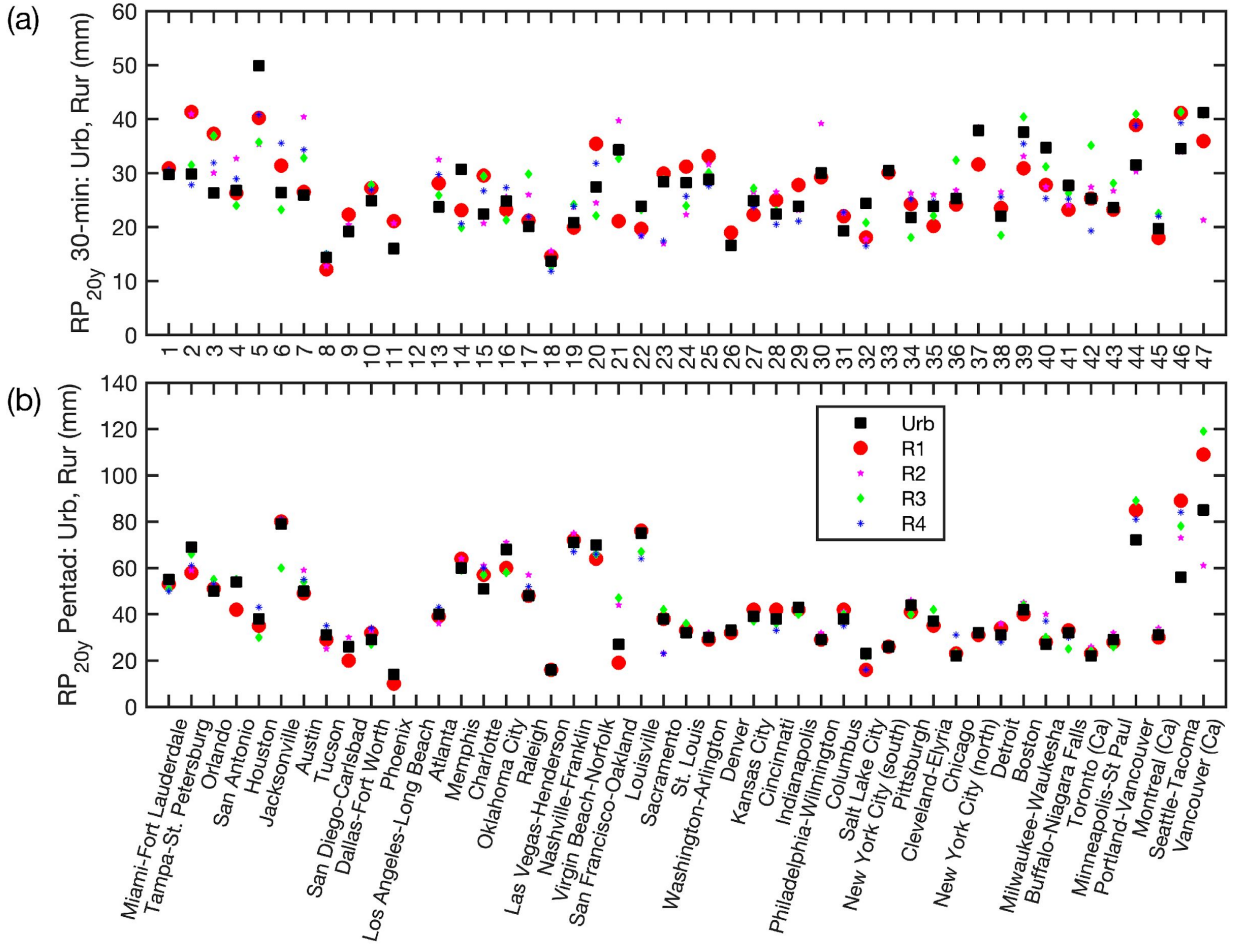
- WRF-Chem (1st time containerized). Compute complexity = high.



Guo et al. (2021): *JGR* **126** e2020JD033759

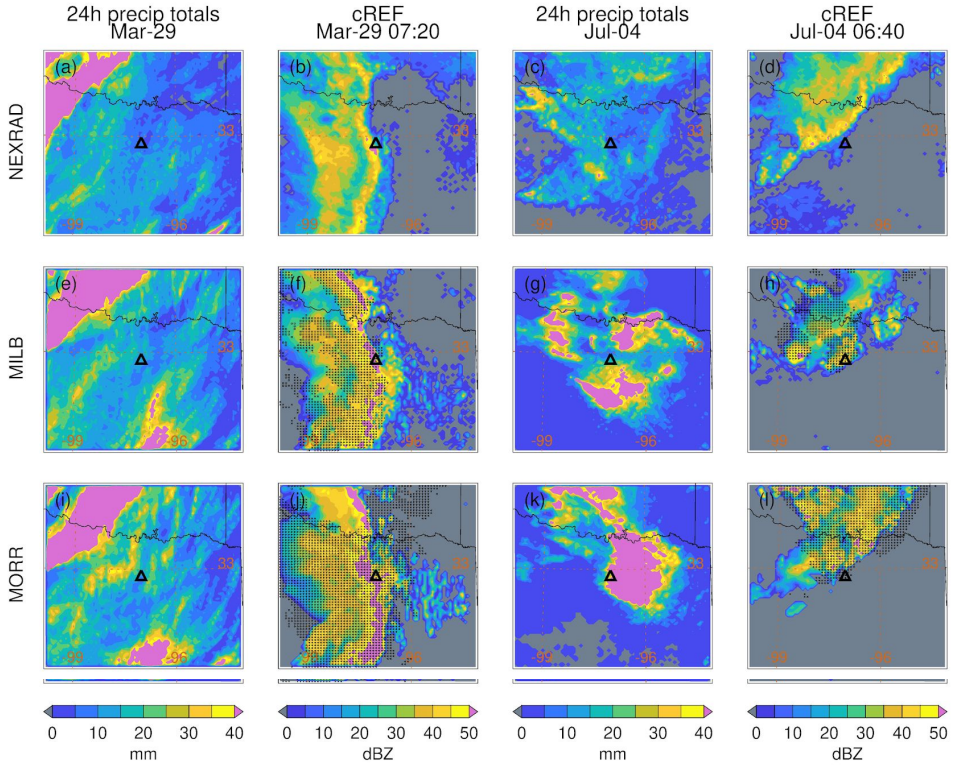
I-WRF: Science Use Case #1: Why?

- Urbanization a global trend
- SOME research has indicated urban areas intensify deep convection… but not uniform & MECHANSITIC information hard to extract from observations & models allow ‘what-if’ scenarios…
- Societal impact: urban flooding (NY declared state of emergency 31 July 2025)



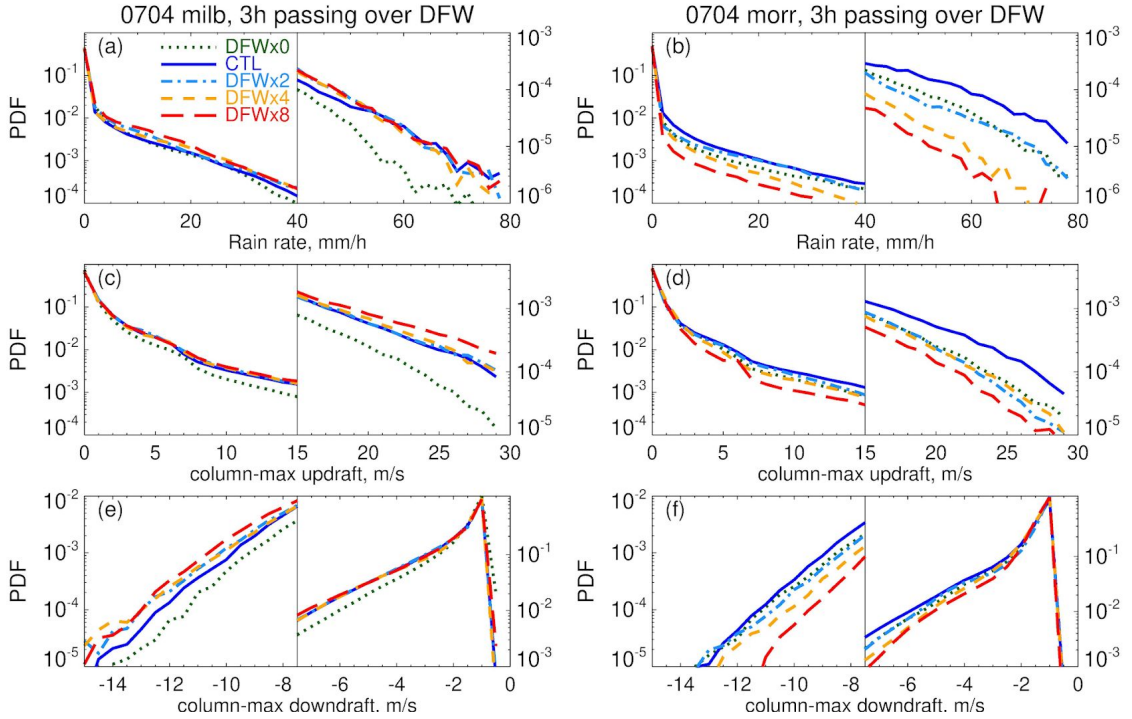
I-WRF: Science Use Case #1:

- Dallas Fort Worth: Isolated urban area, rapidly expanding, frequent deep convection
- Control simulations (DFW as is): Highest fidelity for MORR & MILB.



Zhou et al. (2024): *JGR* **129** 2023JD039972

- Perturbation experiments: Sign of responses to removal/expansion of DFW = f (MP scheme)



  - May explain divergent responses past LULC pert. exp. that have typically used only one MP

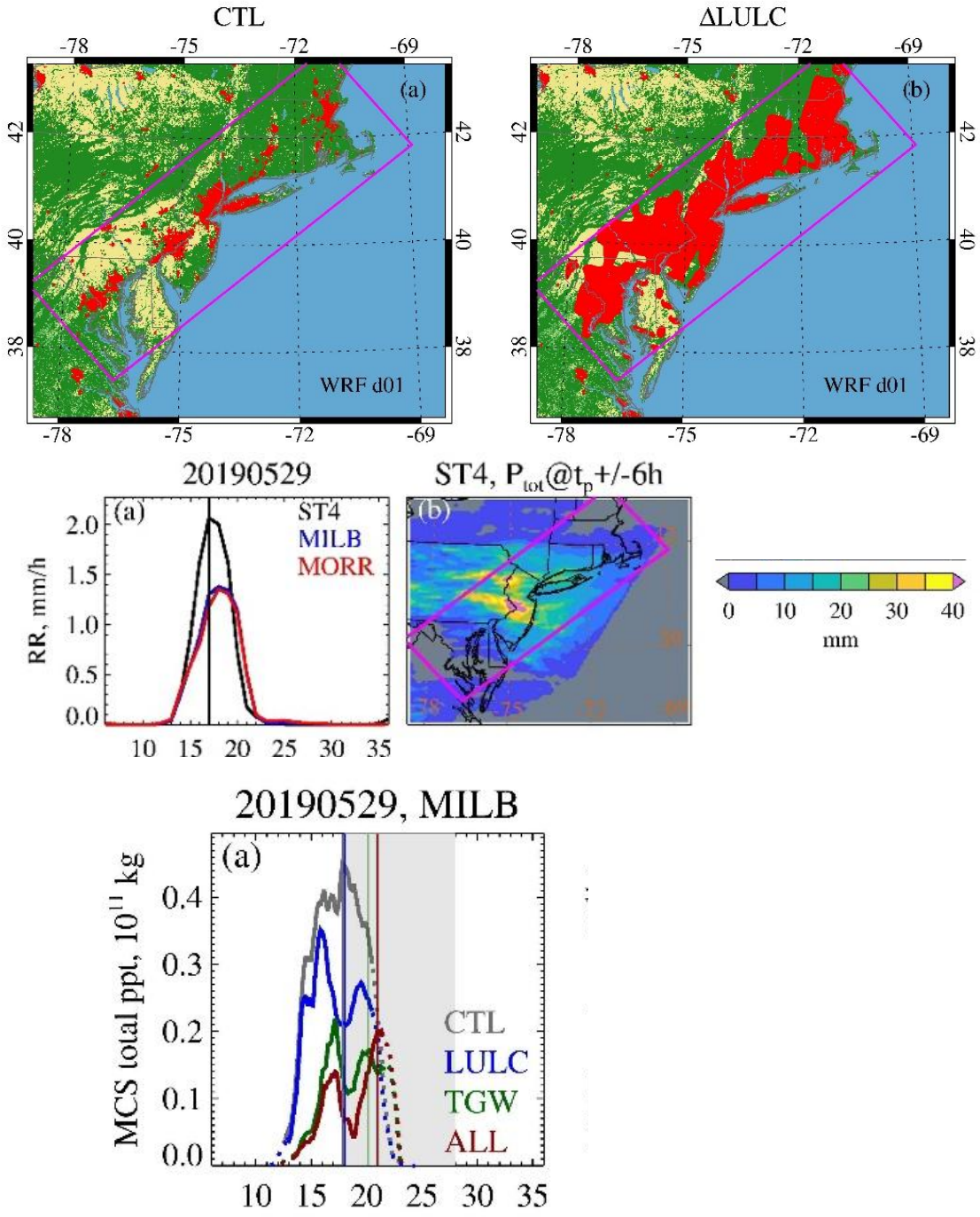
- **Basis of the LULC demo in container.**

WRF

I-WRF: Science Use Case #1

- BOSWASH: Massive spatial extent, high conc. of people & capital assets
- 13 Meso-scale convective events
  - 2 MP param.
  - Perturbations consistent with SSP585
    - LULC: 4* urban area
    - Climate change (TGW, T & humidity)
    - LULC + TGW
- Results in terms of total precipitation in BOSWASH (magenta box!)
  - Climate change signal > LULC signal
  - LULC & TGW TEND to ⬇️ PPT over urban corridor (but intensify downwind)

Zhou X. and Pryor S.C. (2025): JGR *in review*



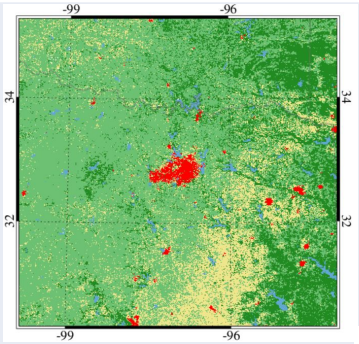
WRF

I-WRF Science Use Cases

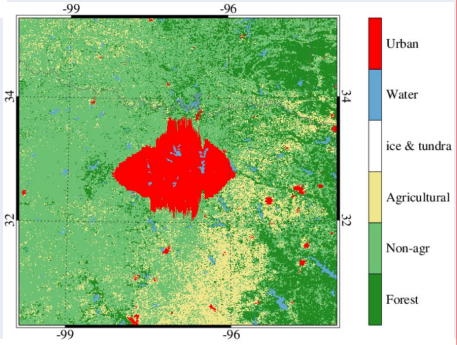
1. Land Use/Land Cover (LULC) Δ

Perturbation exp. to examine urban feedback to deep convection.

- WRF. Compute demand: Modest. Short duration (days), high res. (dx ~ 1.3 km), multiple perturbations & physics settings.
- WRF (multi-node), MET-plus (1-node)



DFW
v
DFW×8

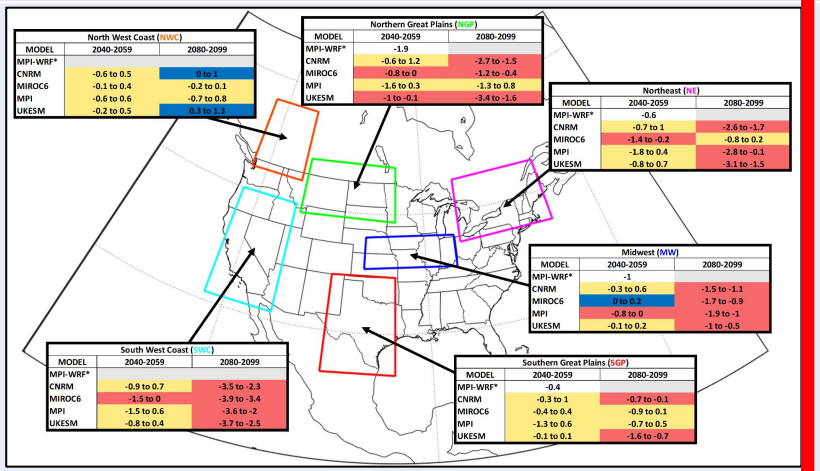


Zhou et al. (2024): *JGR* **129** 2023JD039972

2. Climate science & Renewable energy

Uniquely detailed resource projections for solar & wind under climate change.

- WRF. Compute demand: Large (<u>many</u> nodes). Long duration (multiple years/decades), moderate resolution (dx ~ 4 km)
- To increase IMPACT joined WCRP-CORDEX …..

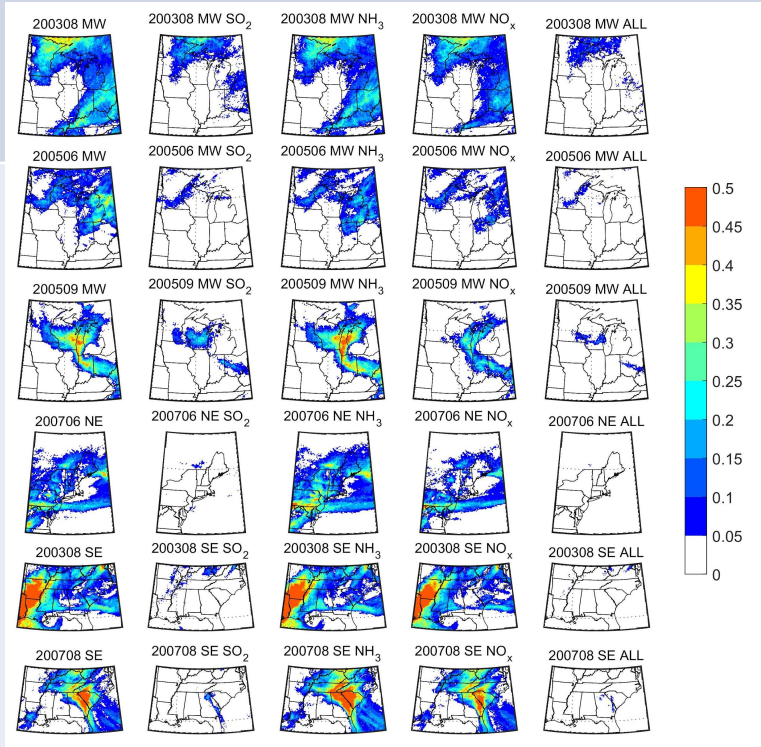


Coburn & Pryor (2023): *JAMC* **62** 81-101

3. Air quality in an evolving climate

Detailed simulations of interplay between changes reductions, LULC change & climate evolution.

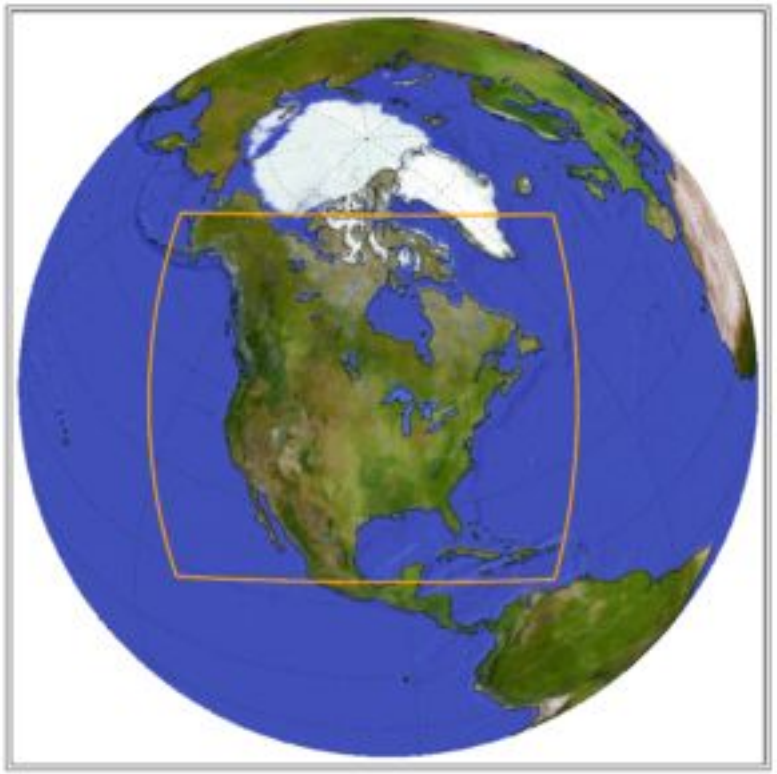
- WRF-Chem (1st time containerized). Compute complexity = high.



Guo et al. (2021): *JGR* **126** e2020JD033759

I-WRF: Science Use Case #2

- What is CORDEX?
  - Coordinated Regional Climate Downscaling Experiment https://cordex.org/
  - Why join?
    - To provision climate projections to wide audience. **(term CORDEX yields 27,900 hits on google scholar!)**



WORLD METEOROLOGICAL ORGANIZATION
Weather Climate Water

WCRP
World Climate Research Programme

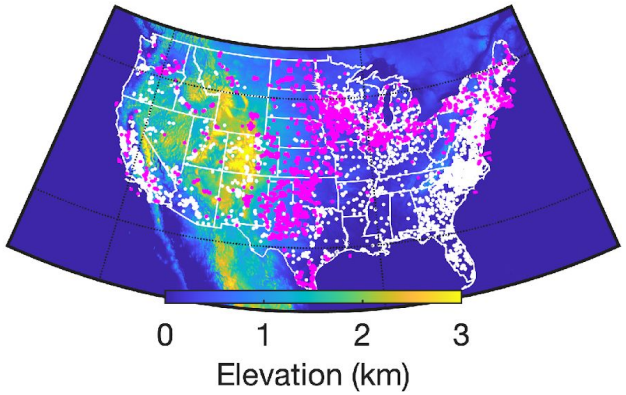
RIfS
Regional Information for Society

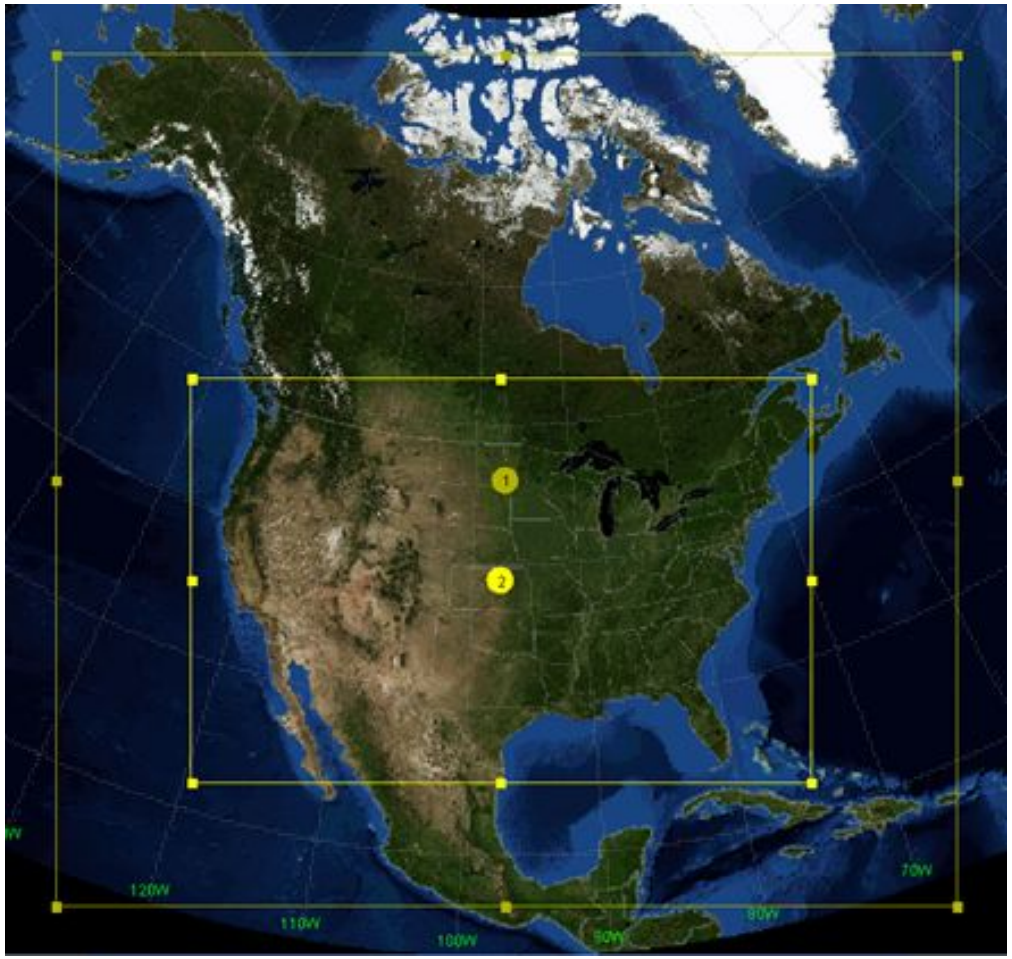
CORDEX
Coordinated Regional Climate Downscaling Experiment

I WRF

I-WRF: Science Use Case #2

- WRF simulations (1960-1989 & 2040-2069 SSP585, LBC: MPI-ESM)
  - D01 (663 x 630): dx = 12km: NA-CORDEX
  - D02 (1369 x 898): dx = 4km: CONUS selected years
    - Milbrandt-Yau microphysics (double-moment)
    - MYNN PBL with EDMF (shallow convection)
    - RRTMG LW/SW (with solar irradiance partitioning)
    - Noah-MP (versatile treatments of surface properties)
    - Time varying SST & AOD
    - Nudging above PBL
- Why focus on energy applications?
  - Utility scale solar PV & wind energy now 15% global electricity. CONUS WT IC > 155 GW, solar PV > 130 GW



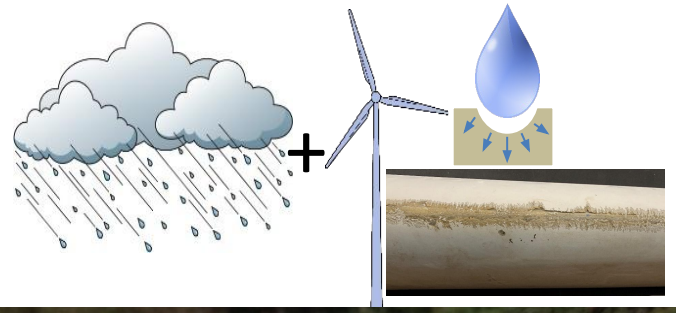


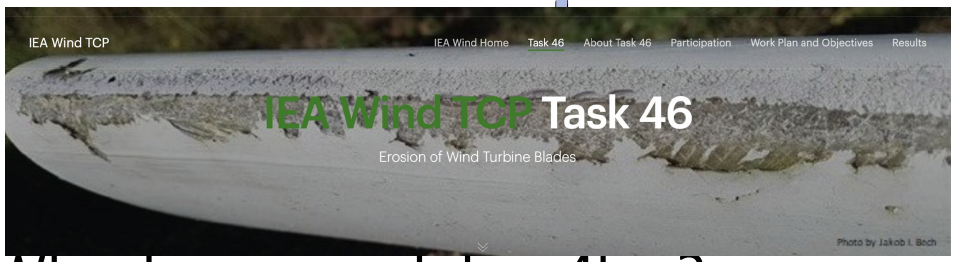
Status	NA-CORDEX	CONUS
Historical	21 years	Pending
Future	14 years	Pending

I WRF

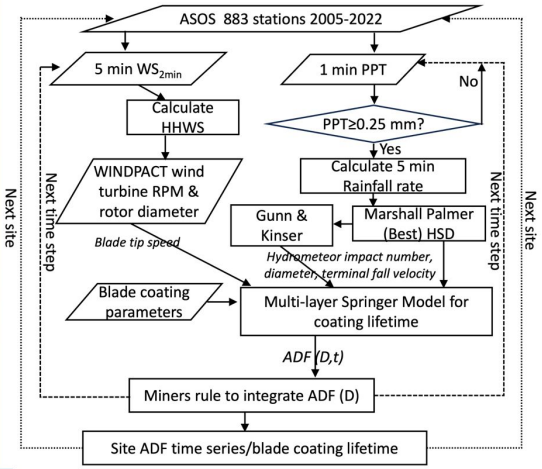
I-WRF: Science Use Case #2

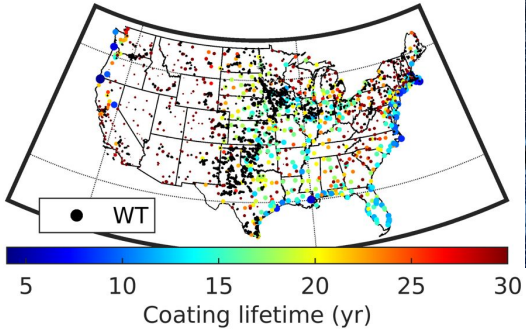
- E.g. science questions we will answer using these simulations:
  - Extreme hydroclimate as damage vector for solar PV & wind turbine blades

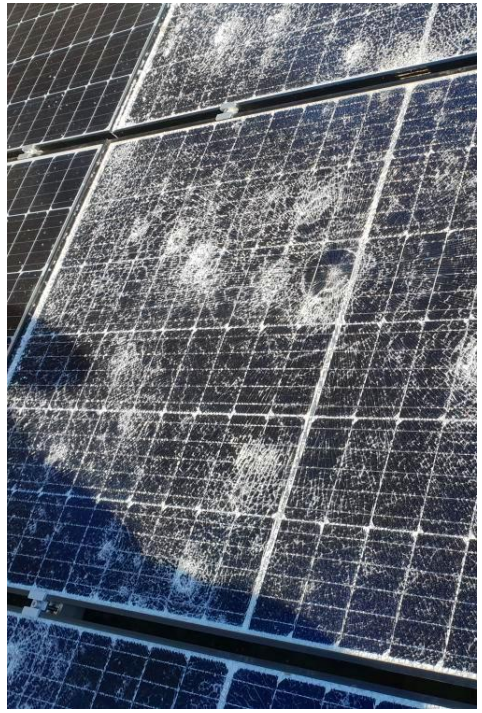


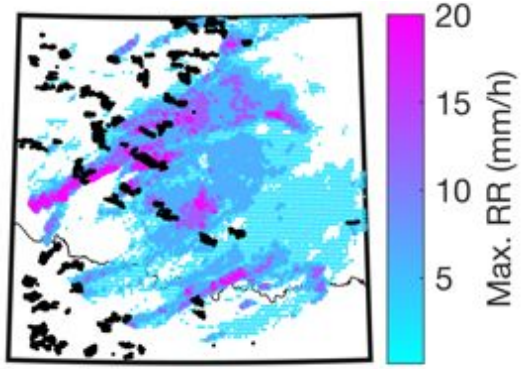


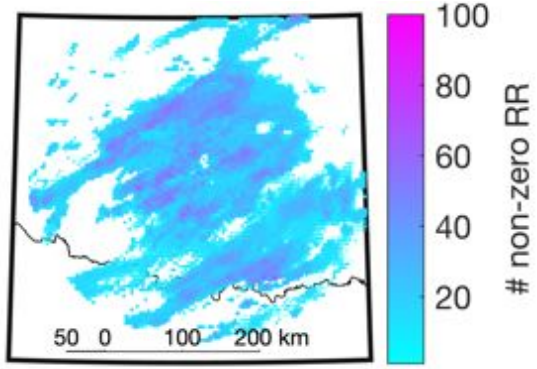
- Why do we need dx = 4km?
  - Convection permitting! Needed for damaging events (hail & extreme precipitation)
  - Wind speeds (& wind resources) vary on small scales









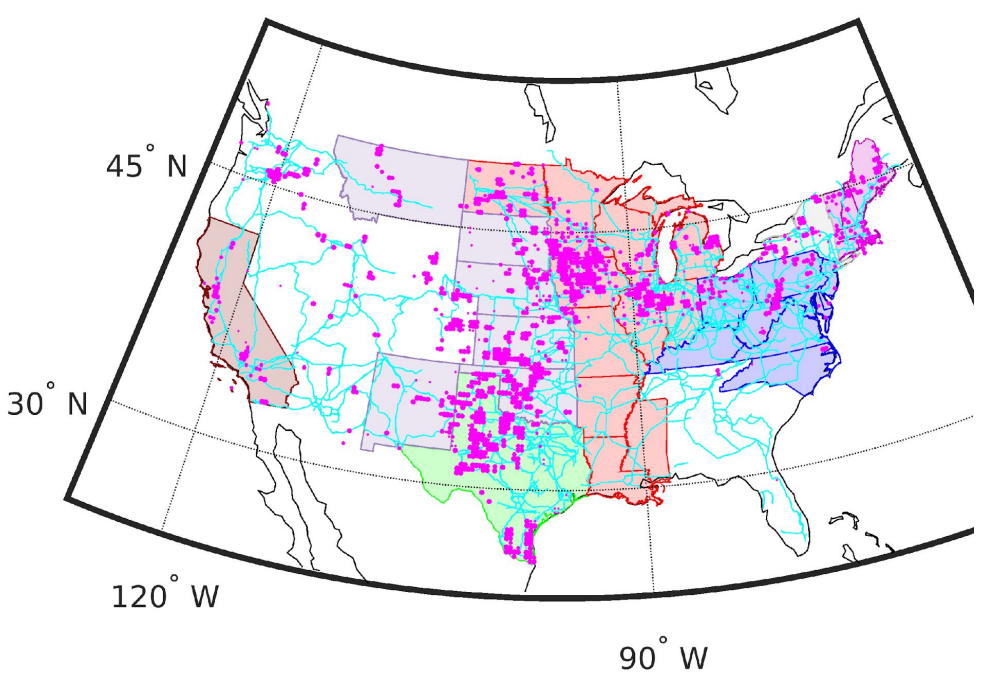


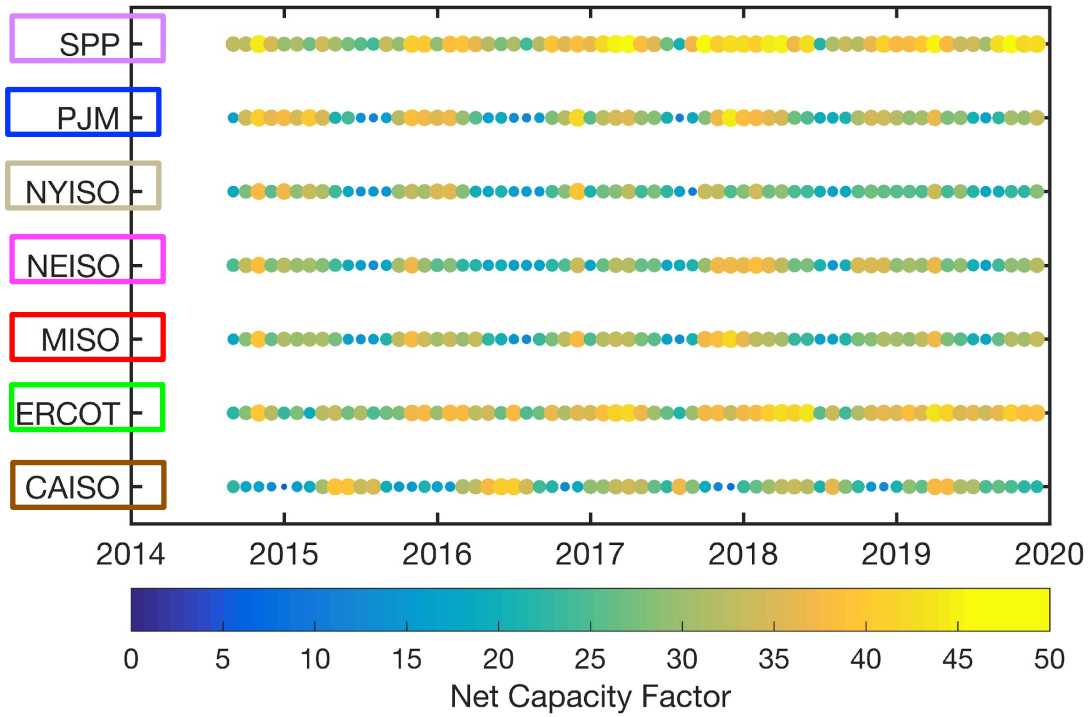
Pryor et al. (2025): *Energies* **18**, 425; doi: 10.3390/en18020425

I WRF

I-WRF: Science Use Case #2

- E.g. science questions we will answer using these simulations:
  - Solar & wind resources in a changing climate. Including electricity production droughts (extended periods with LOW generation – e.g. Q1, 2015).





Pryor et al. (2020): *JAMC* **59** 2021-2039

- Cornell U MEng student recruited for this science use case (co-supervised SCP & XZ).
- **What demo will go into the container?** *Likely* focus on production droughts…

I WRF