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Using High-Resolution ARM Observations to Evaluate High-Resolution WRF Simulations

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ARM Supersite Data

HI-SCALE Campaign Data

HRRR

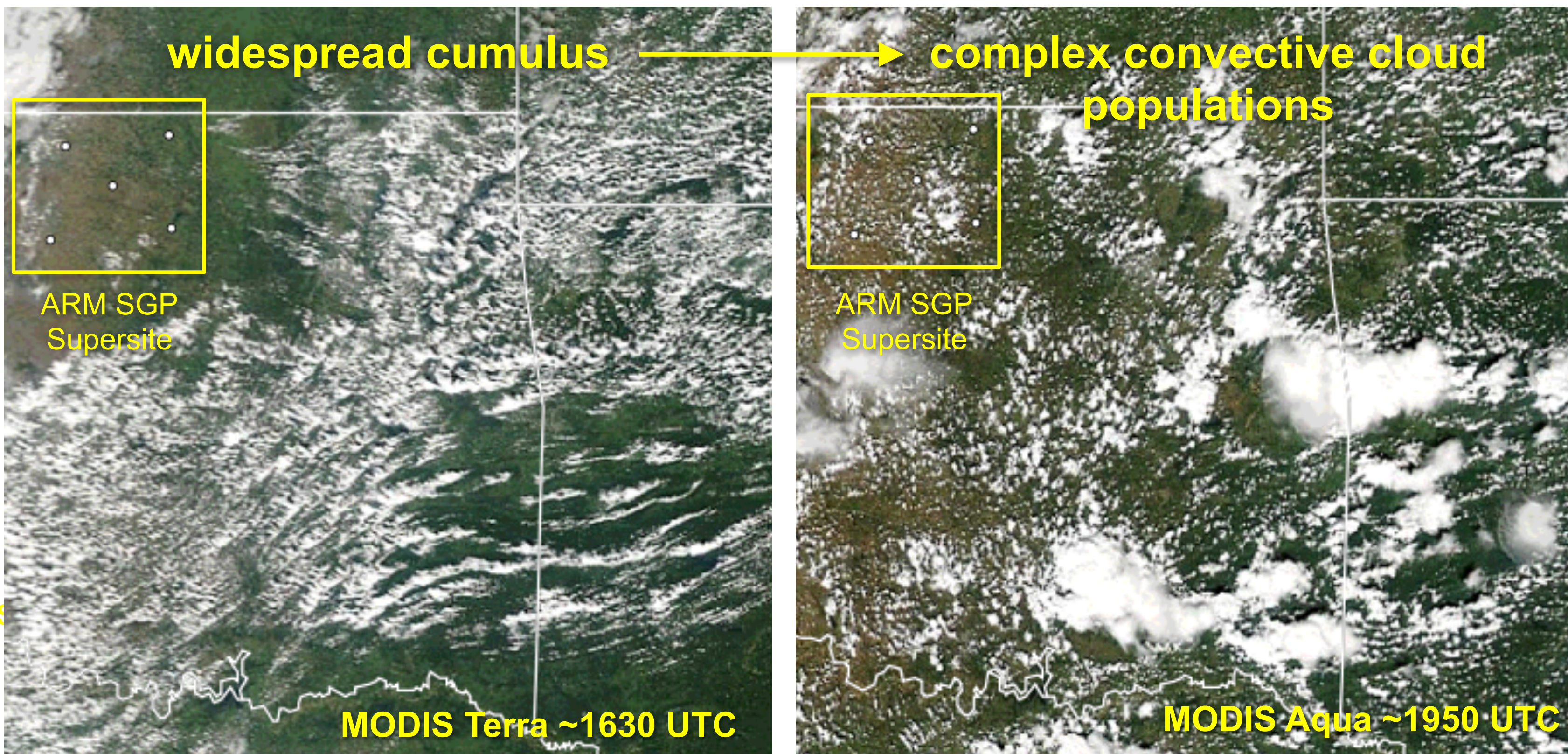
ASR Atmospheric System Research

ARM CLIMATE RESEARCH FACILITY

EMSL

Motivation

- **Cumulus convection** is an important component of the **radiation budget and hydrologic cycle** over many regions of the world, but …
- Convective **cloud parameterizations contain uncertainties** due partly to insufficient coincident data coupling cloud macro- and microphysical properties to inhomogeneities in boundary layer and aerosols.



ARM Southern Great Plains "Supersite"

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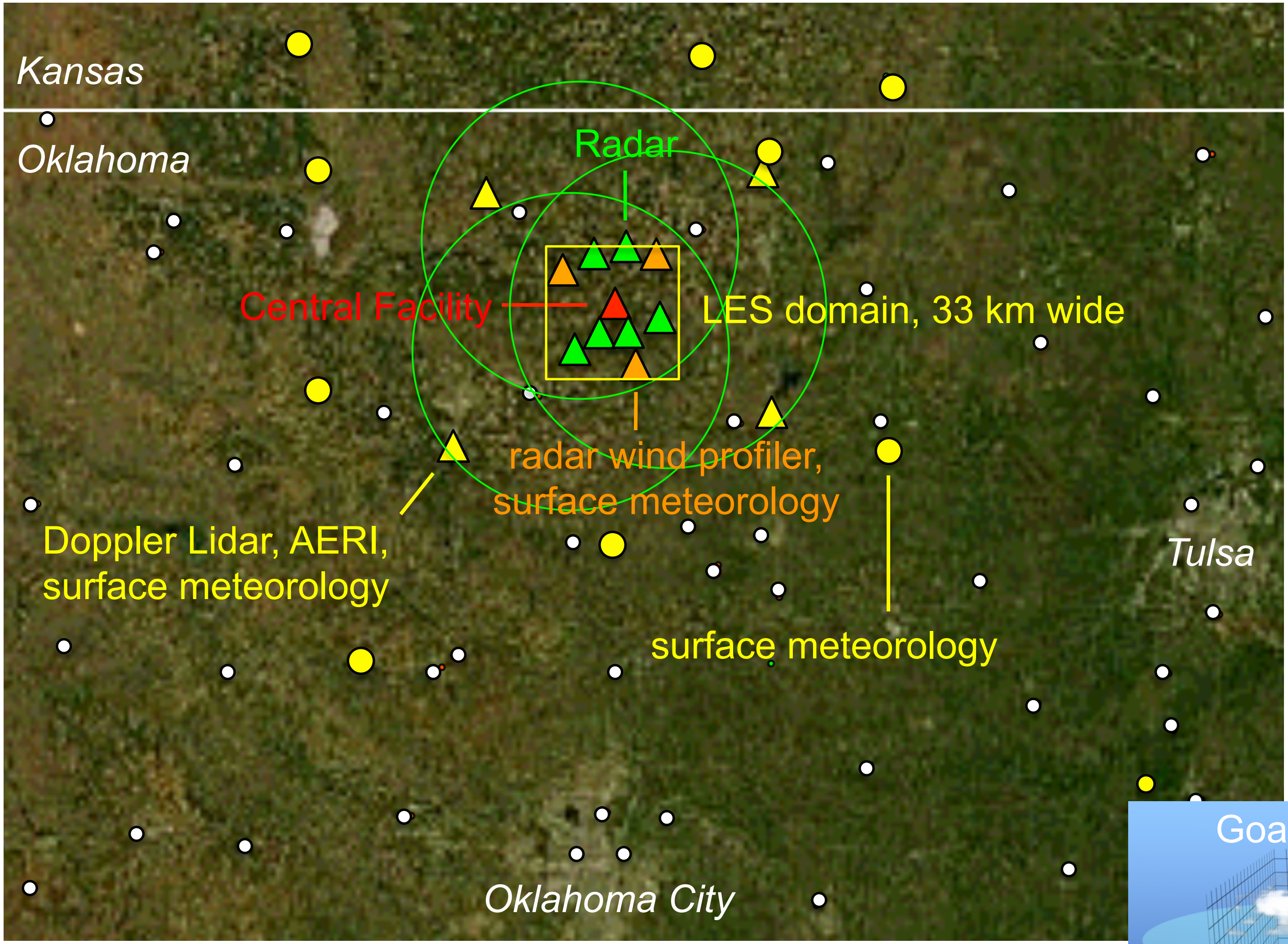


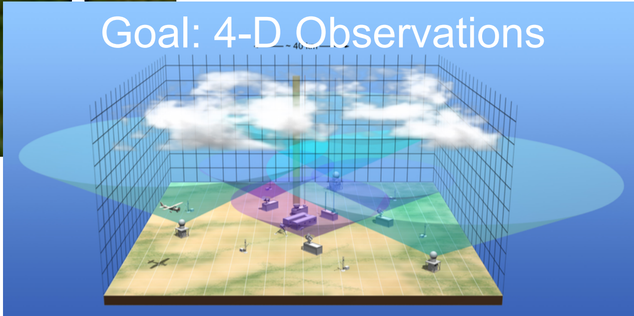
white dots = Oklahoma mesonet

ARM Instrument Sites

Central Facility

- Radiosonde (4 / day)
- Radar Wind Profiler
- Doppler Lidar
- Micropulse Lidar
- Raman Lidar
- Atmospheric Emitted Radiance Interferometer (AERI)
- surface meteorology

surface meteorology includes radiation, fluxes, soil moisture



Holistic Interactions of Shallow Clouds, Aerosols and Land Ecosystems (HI-SCALE) Campaign

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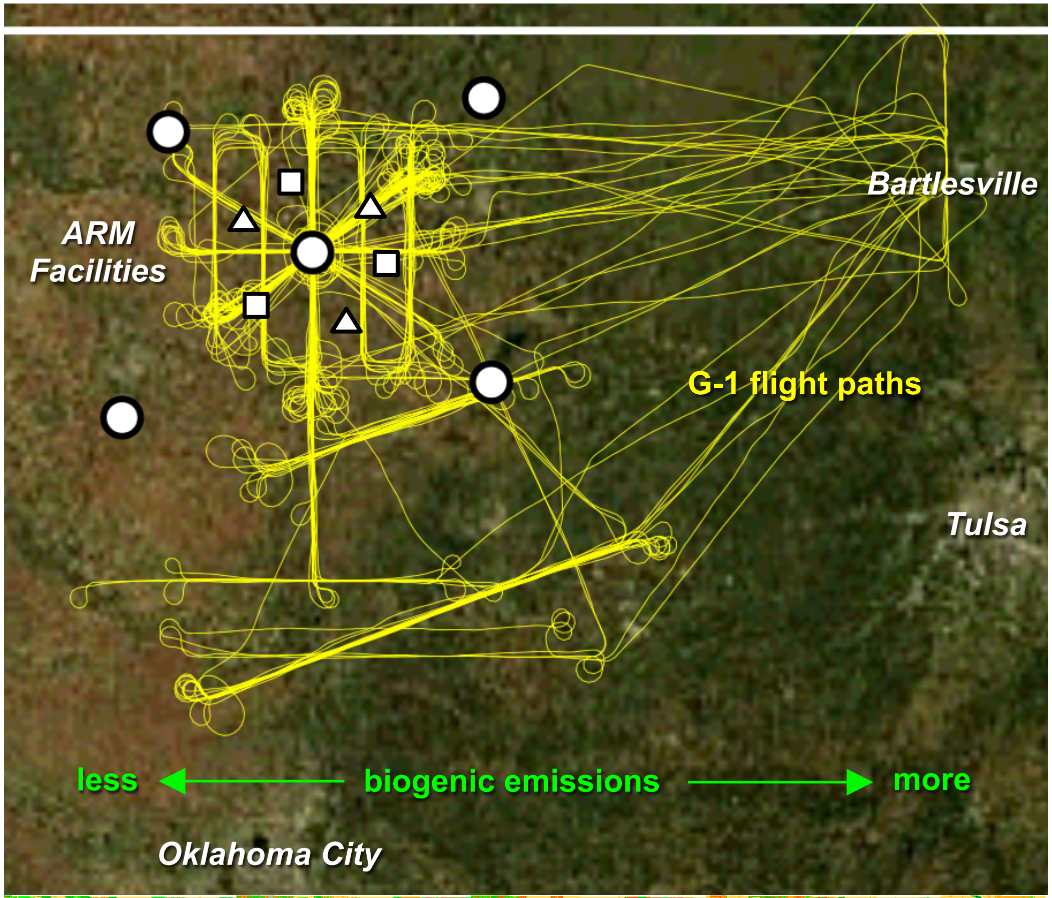
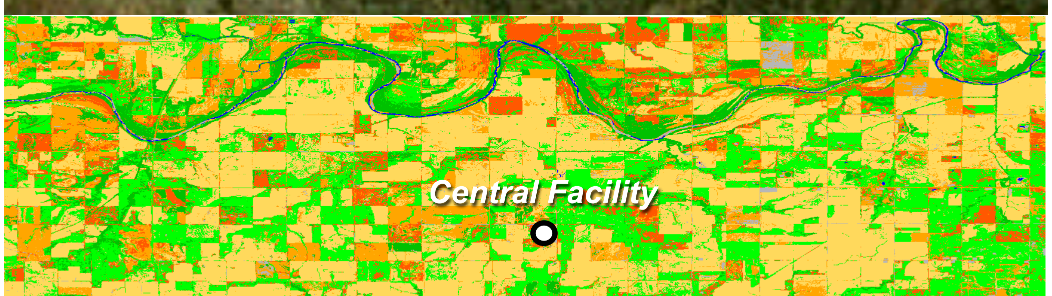


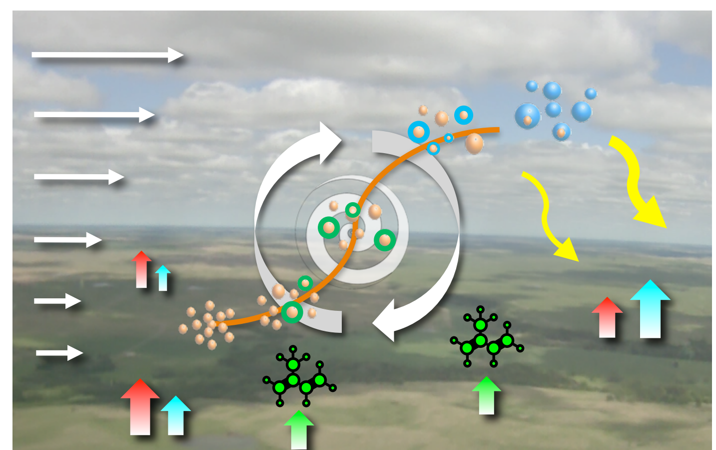


IOP 1: April 24 – May 20

- 17 flights, 57.8 hours total
- 3.4 h average duration

IOP 2: Aug 28 – Sept 23

- 21 flights, 47.8 hours total
- 2 flights / day on 5 days



High-Resolution Rapid Refresh (HRRR)

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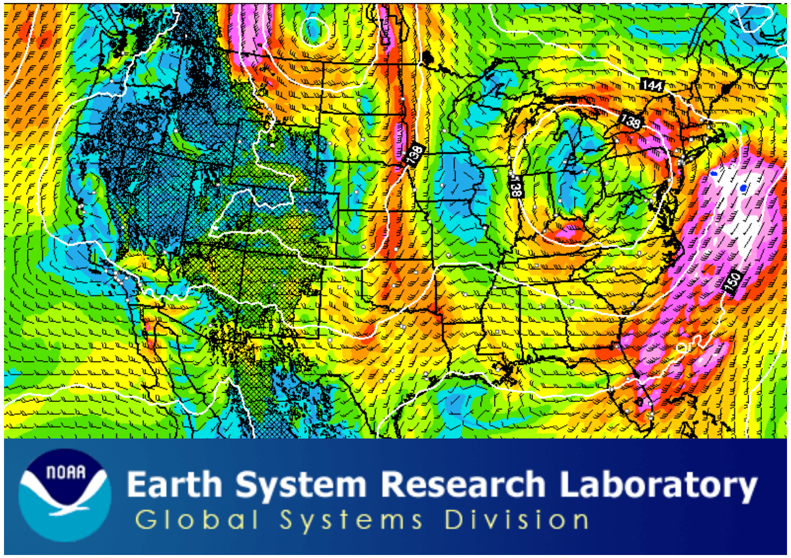
- Real-time operational forecasts for the CONUS (Dx = 3 km)
  - Forecasts produced every 1 h for up to 15 h forecast
  - Data assimilation used to create initial conditions, but does not use ARM data that can be used as an independent data set
  - In this study, 15-h forecasts (at hourly intervals) starting from 00, 06, 12, and 18 UTC with a focus on 1-6 h forecasts



April	May	June	July	August	September

HI-SCALE IOP 1

HI-SCALE IOP 2

HRRR v2

HRRR v3

microphysics: Thomspon
surface-layer and BL: MYNN
land-surface: RUC
radiation: Goddard
cumulus convection: off

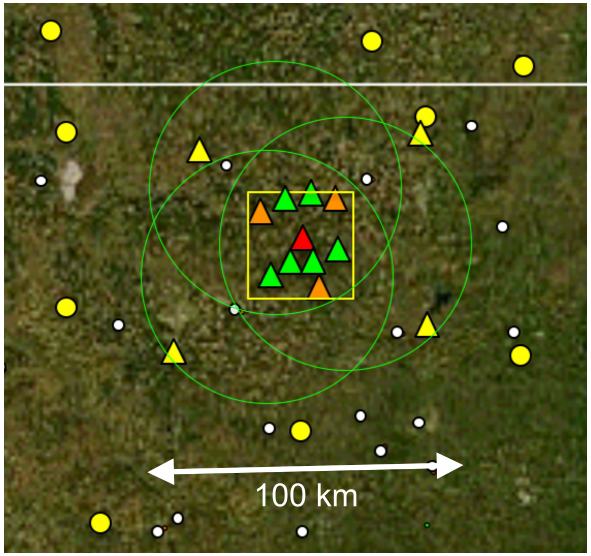
known “low-level warm dry bias”

microphysics: Thomspon /aerosol
surface-layer and BL: MYNN
land-surface: RUC
radiation: RRTMG
cumulus convection: off

Questions

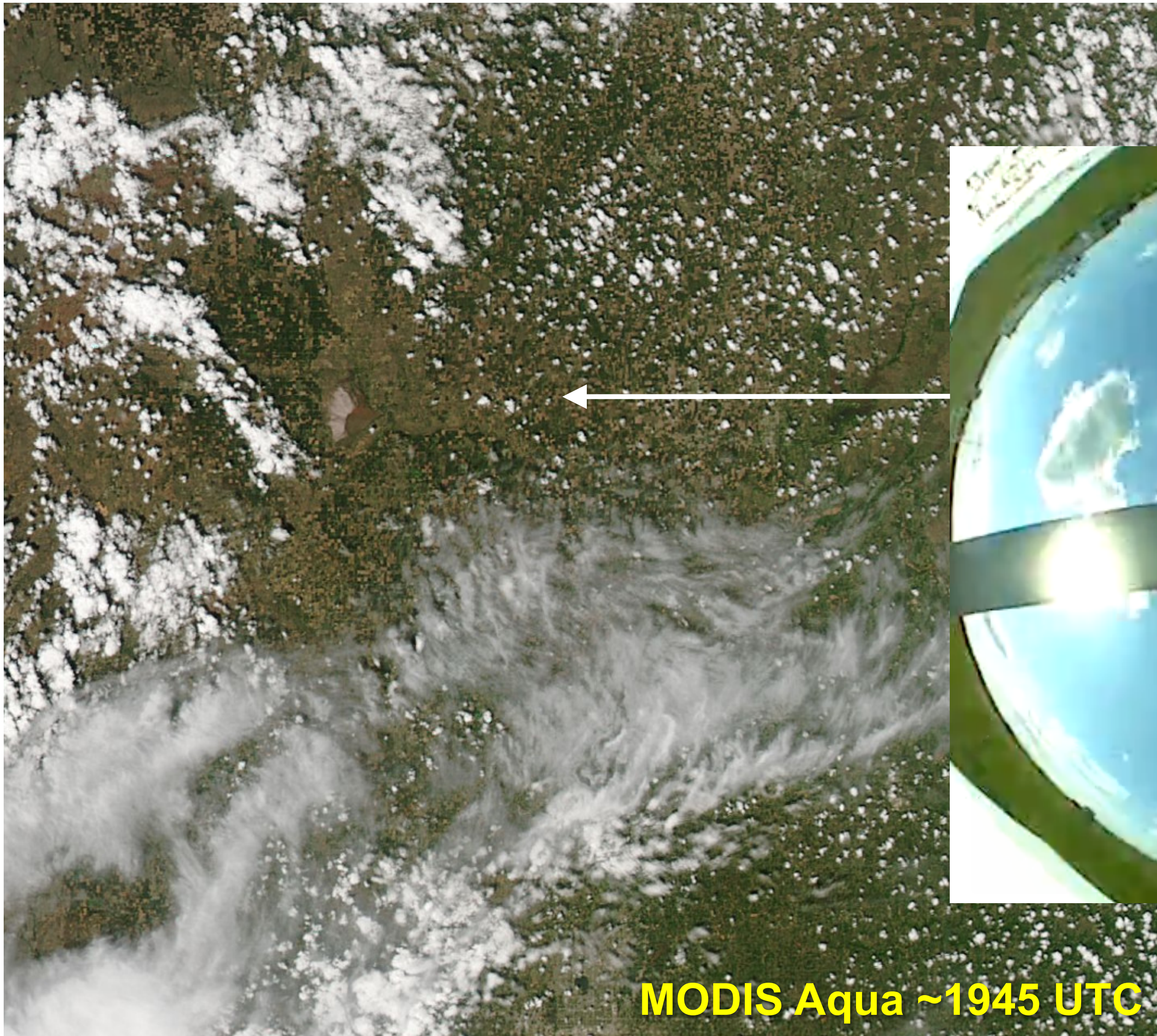
- How well does HRRR / WRF represent the observed atmospheric conditions, particularly **cloudiness and its effect on radiation**, in the vicinity of the SGP site?

- How well does HRRR / WRF represent the **spatial and temporal variability** that is seen in the observations?



Comparison with ARM Operational and HI-SCALE Campaign Measurements

Cloudiness on May 3



Observed and Simulated Radiation: May 3

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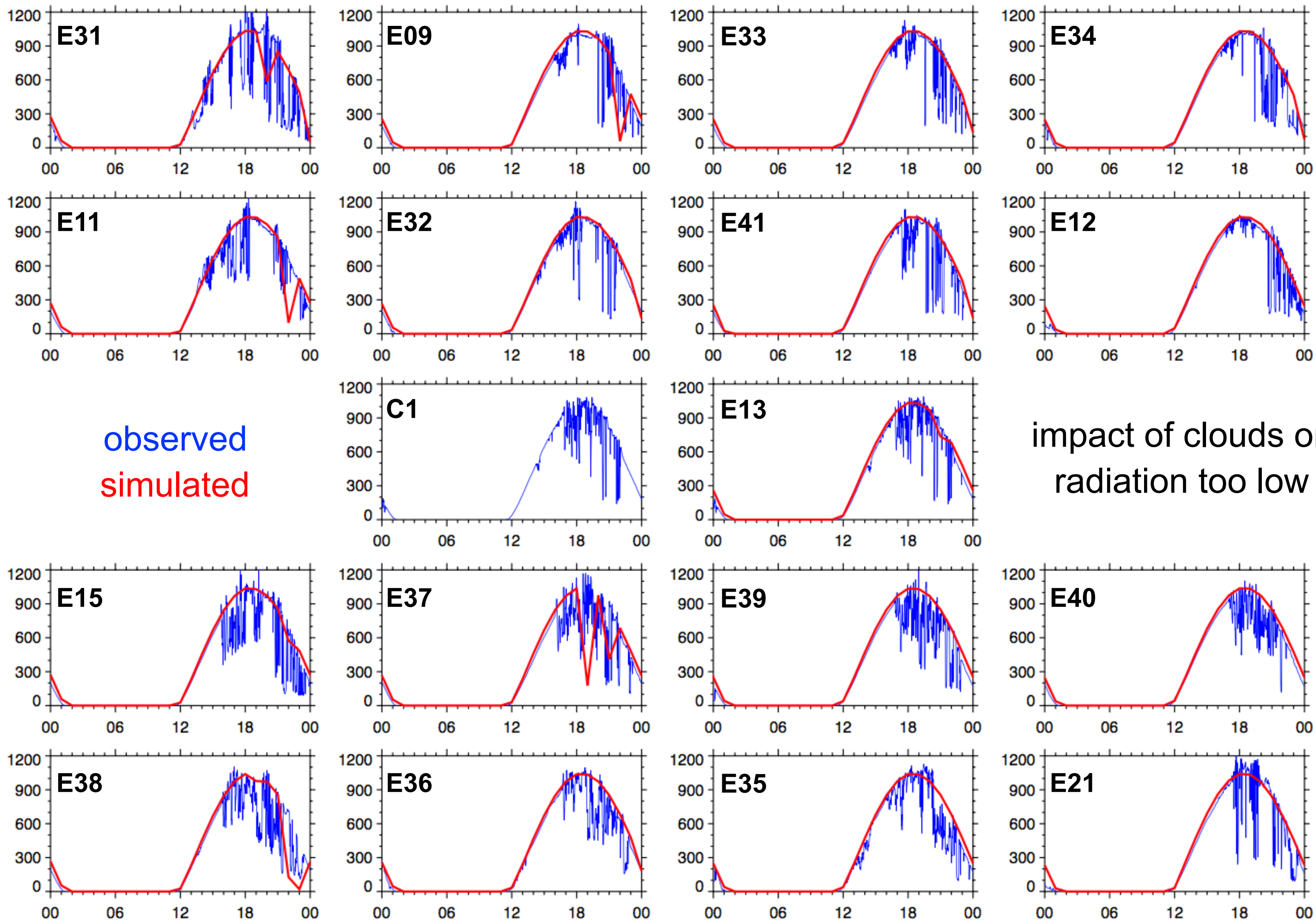

impact of clouds on radiation too low

Variability in Downward SW on May 3

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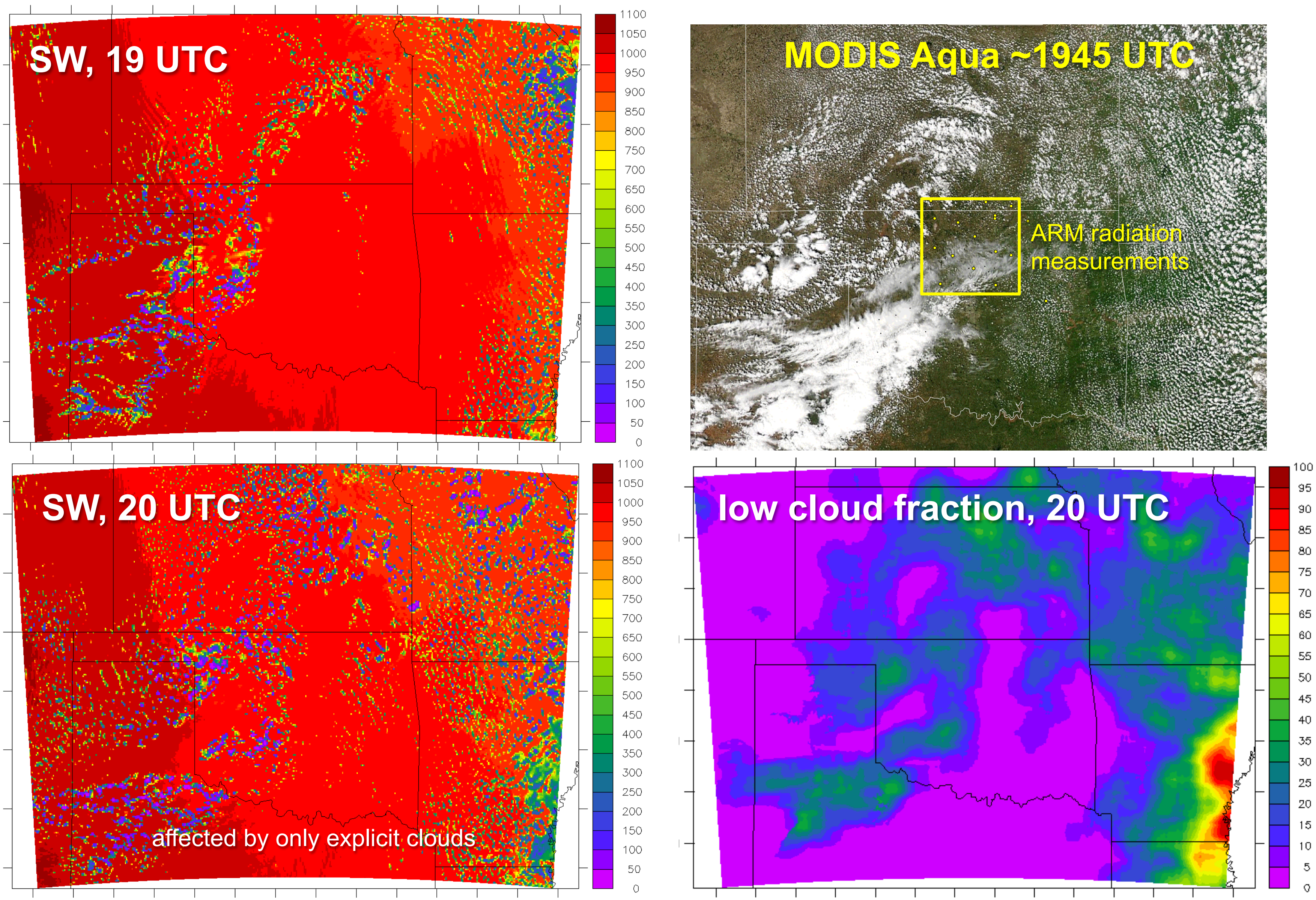

Spatial Variability of Radiation during IOP 1

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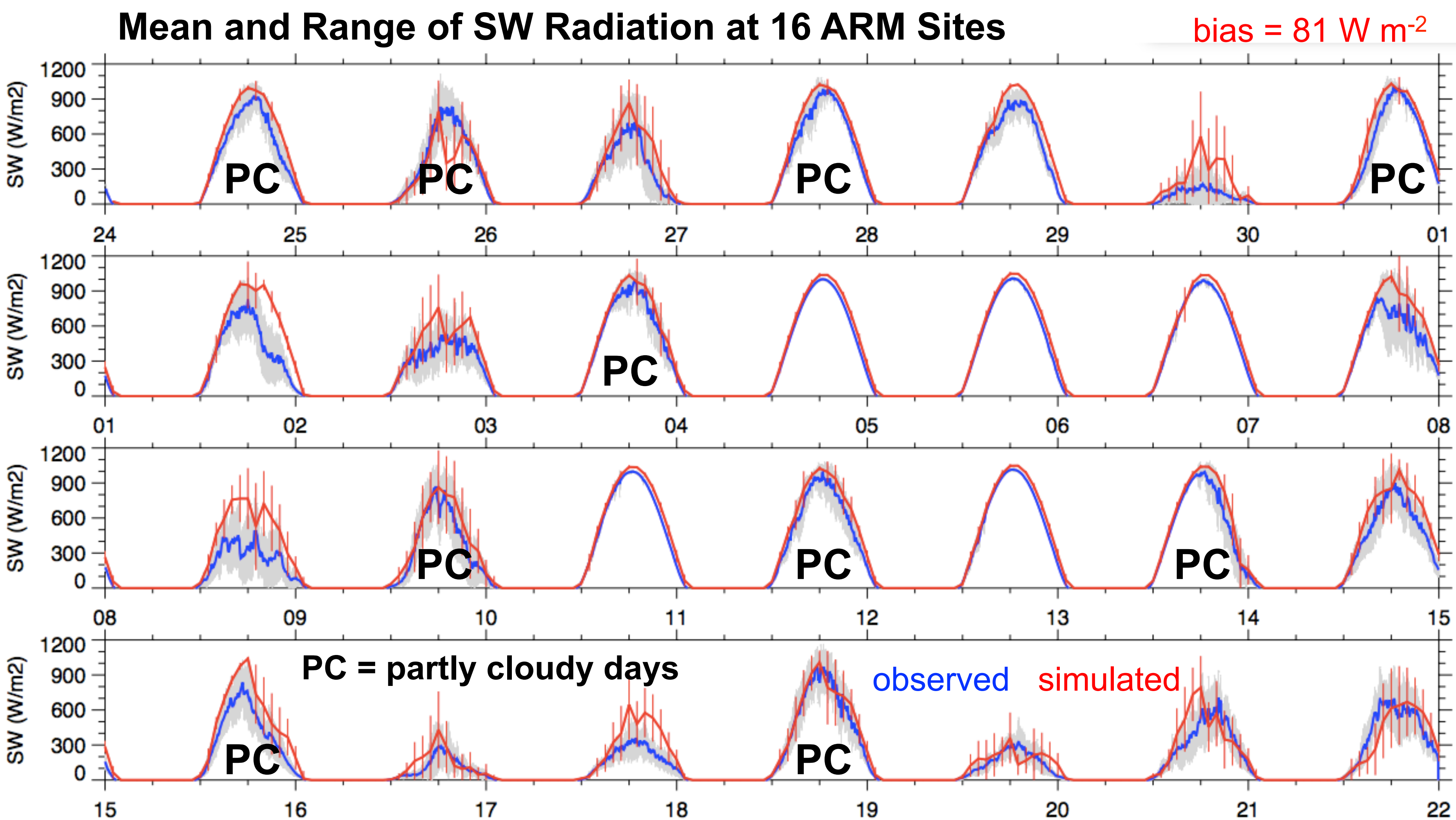
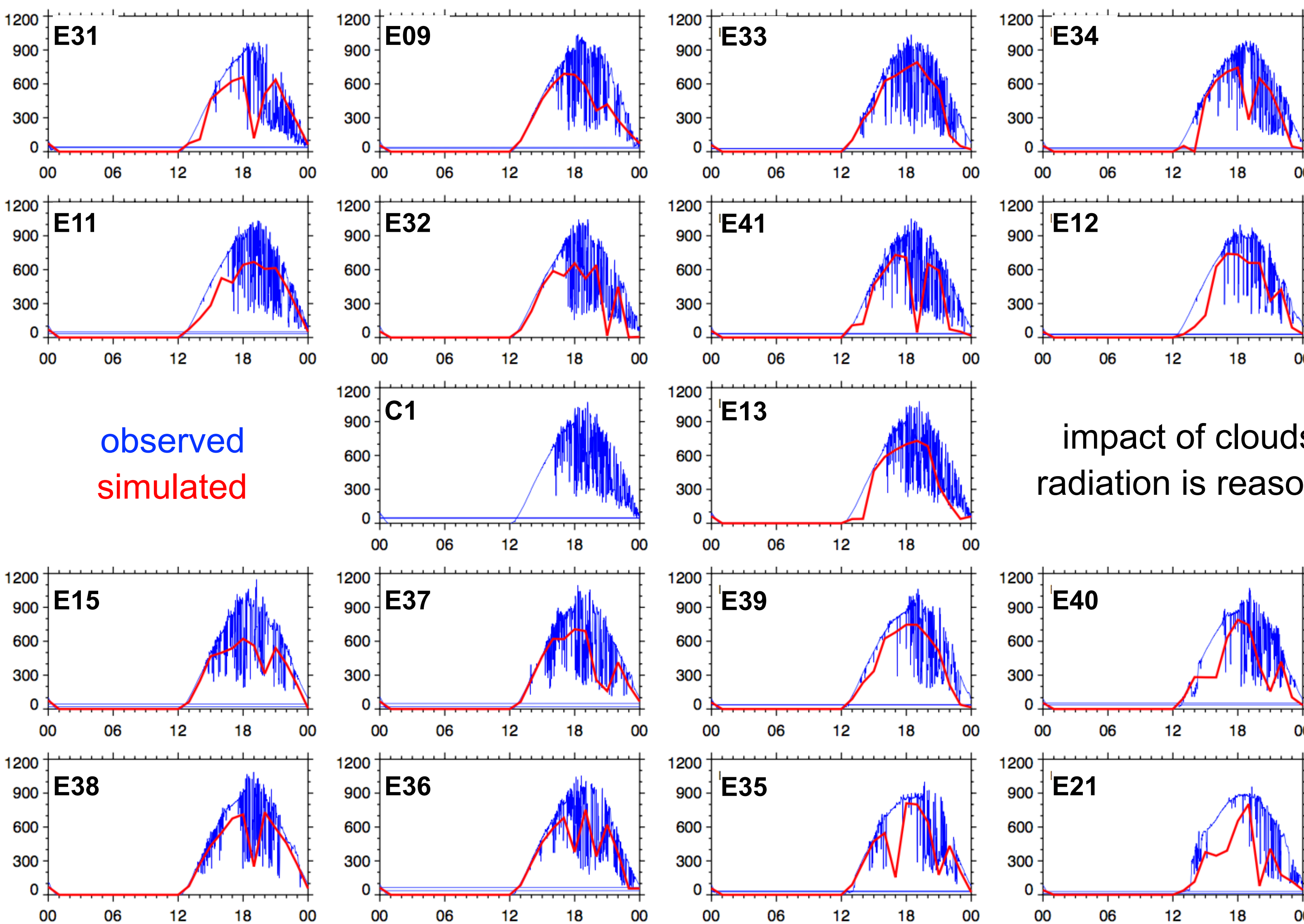


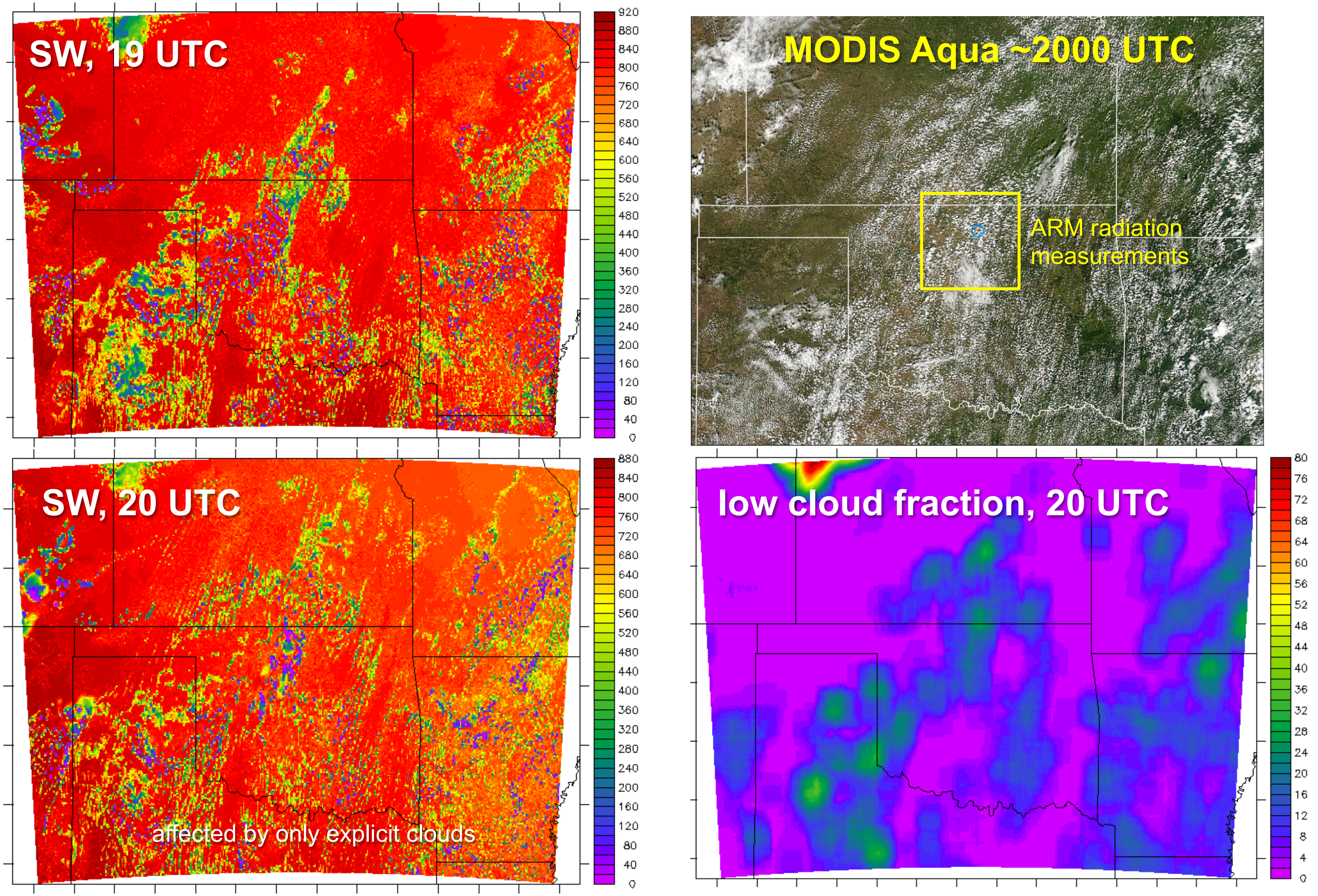
- simulated radiation too high on most partly cloudy days
- simulated radiation also too high on cloudy days

Observed and Simulated Radiation: Sept. 6

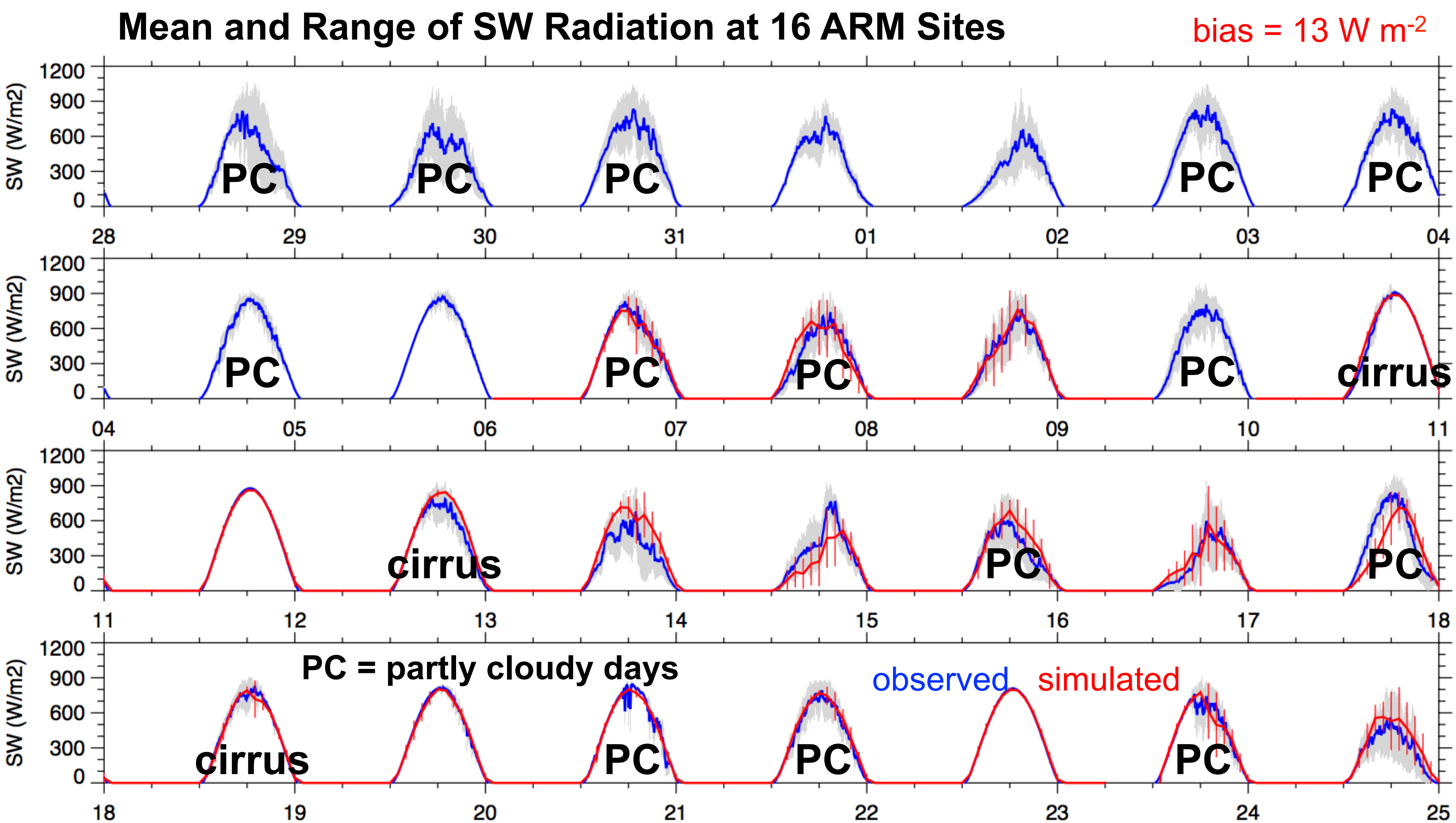


impact of clouds on radiation is reasonable

Variability in Downward SW on September 6



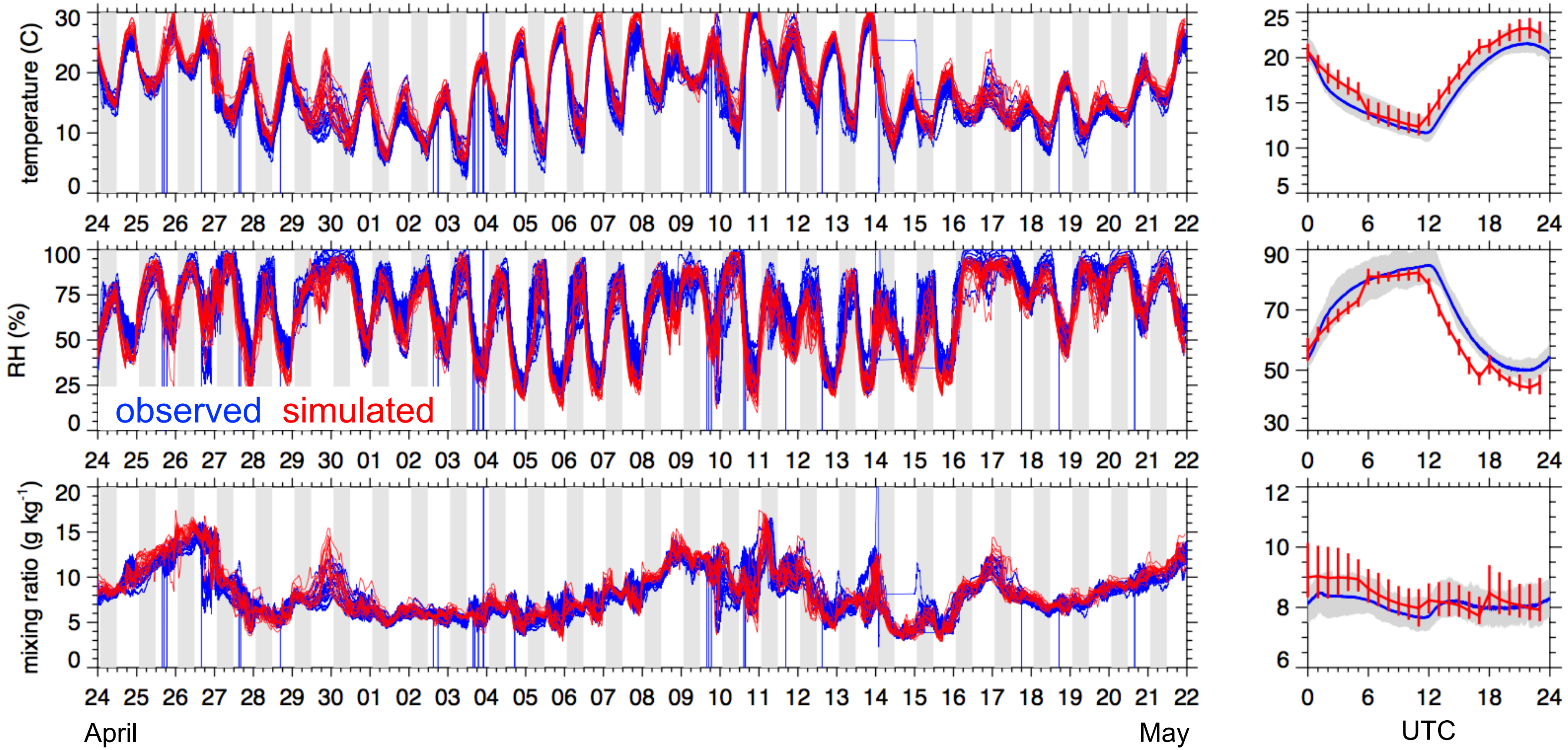
Spatial Variability of Radiation during IOP 2



- range of simulated radiation closer to observed than during IOP 1

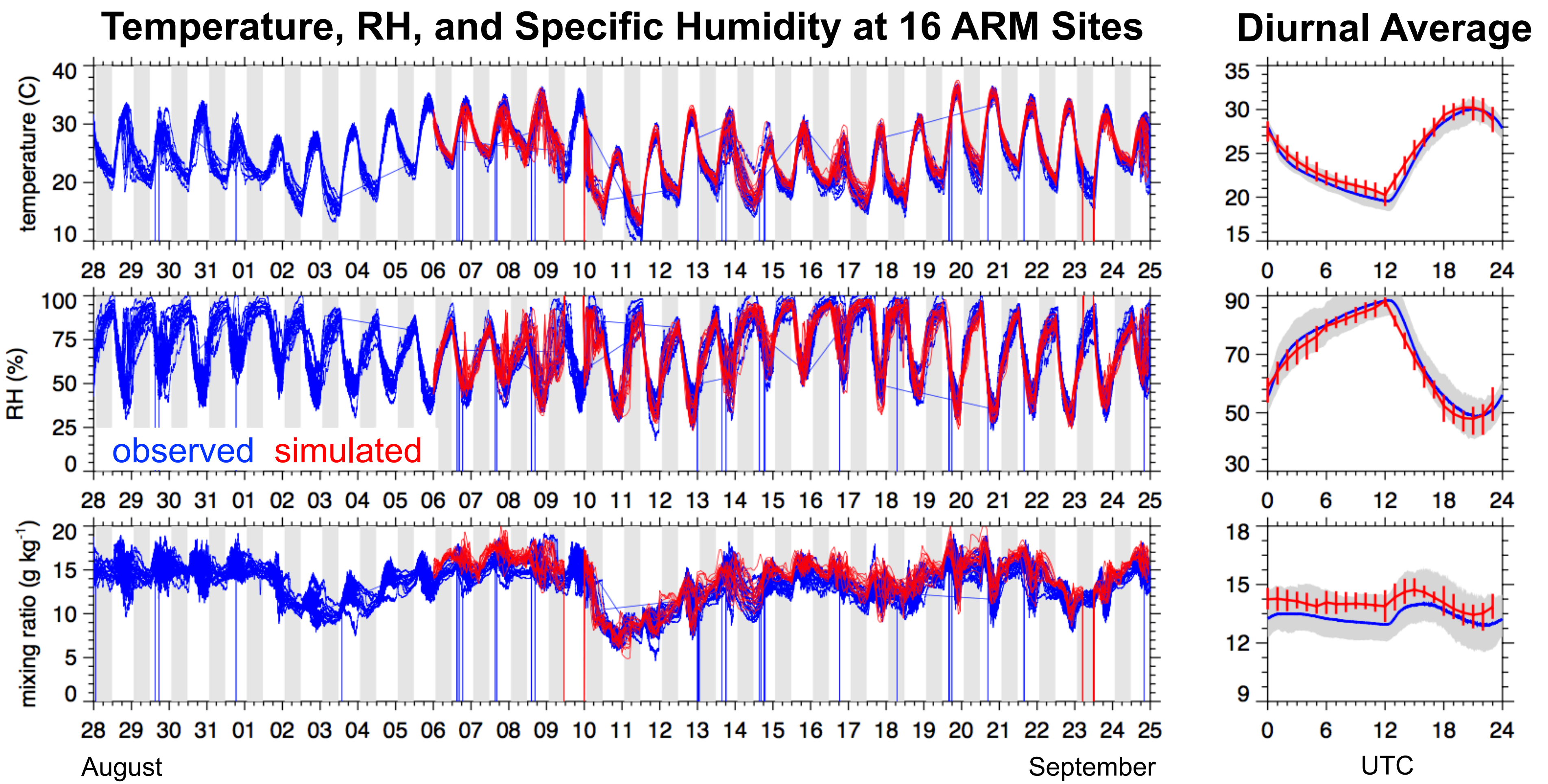
Surface Temperature and Humidity during IOP 1

Temperature, RH, and Specific Humidity at 16 ARM Sites **Diurnal Average**



- ~2^{o} warm bias during the day that leads to dry RH bias; bias increases significantly with forecast period
- simulated spatial variability somewhat smaller than observed

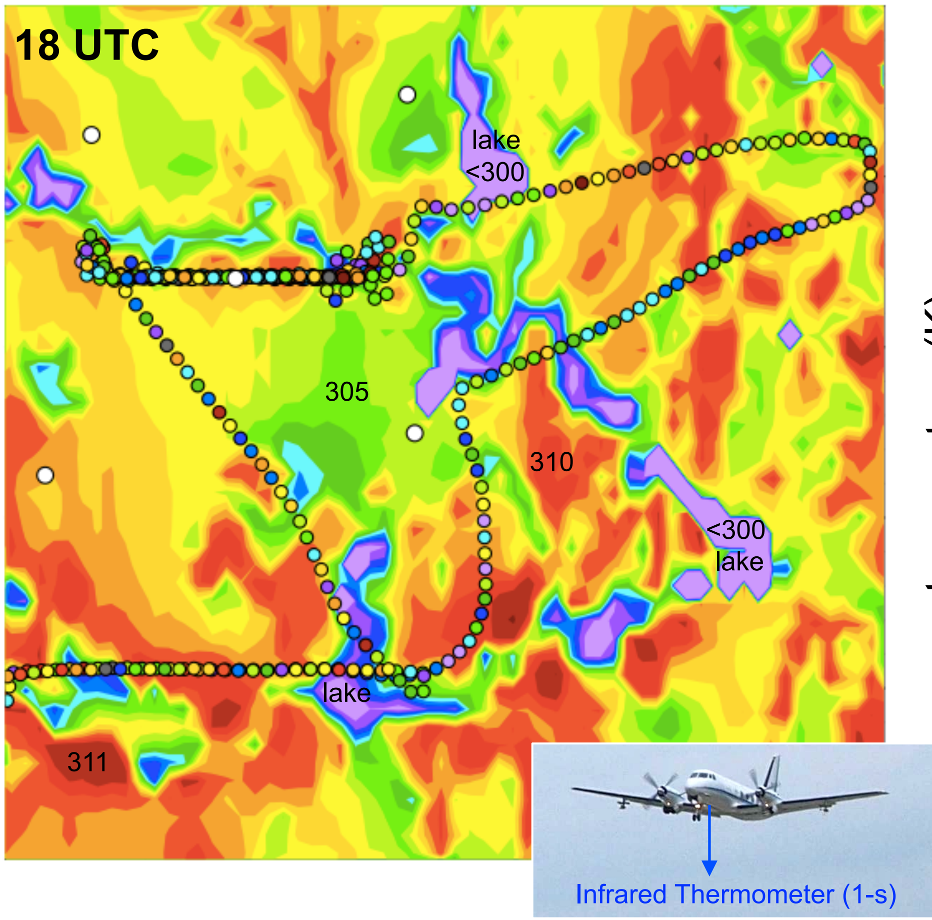
Surface Temperature and Humidity during IOP 2



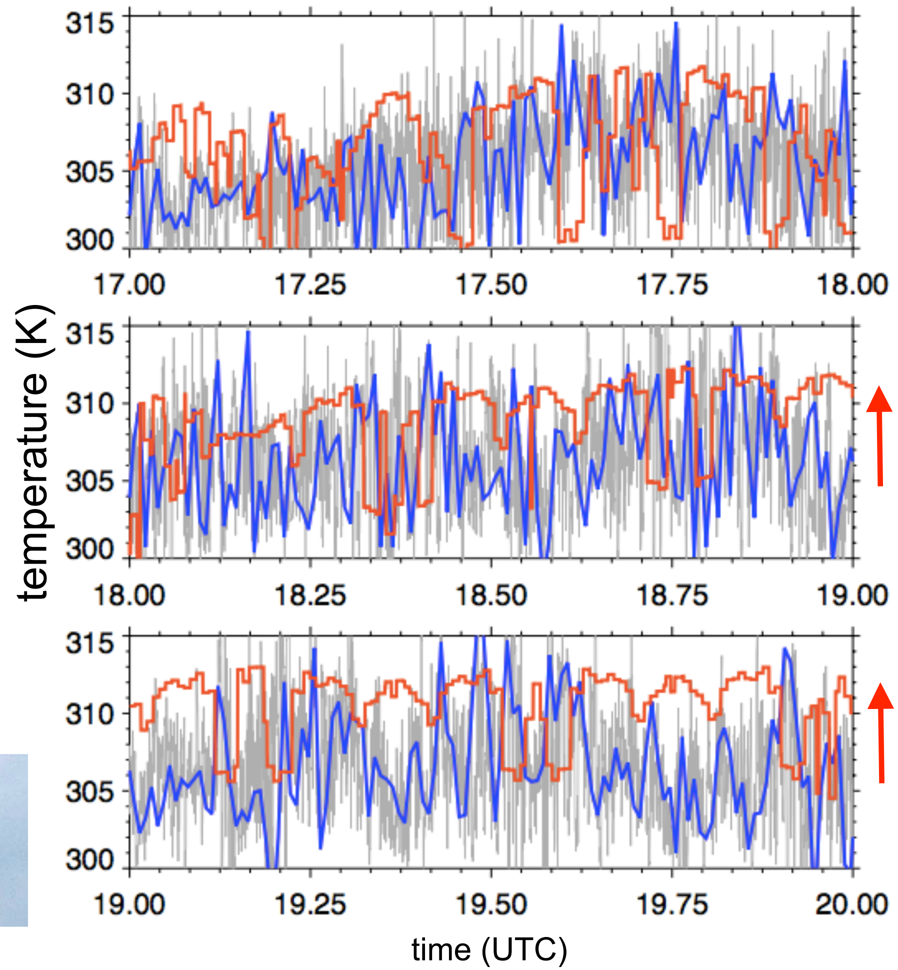
- much smaller temperature and RH bias than during IOP1, but bias in mixing ratio is higher during IOP2
- simulated spatial variability less than observed

Skin Temperature: May 6 (Clear Sky, IOP 1)

Simulated Surface Temperature (contours)



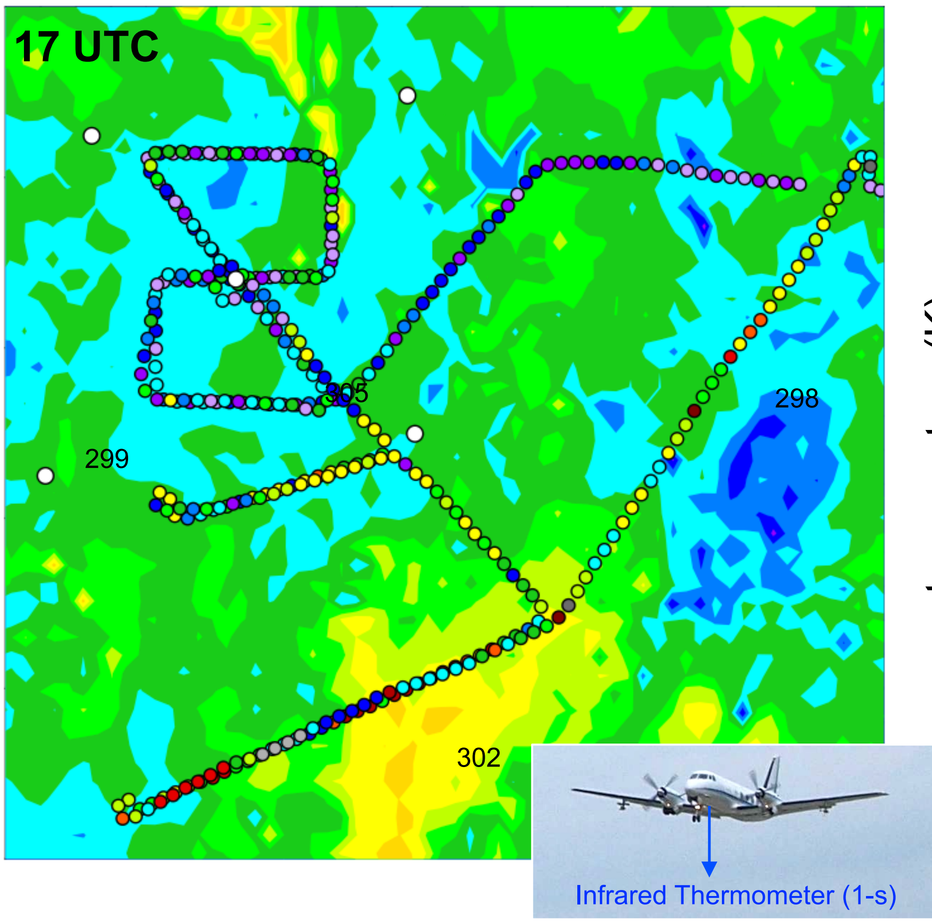
simulated observed (30-s average)

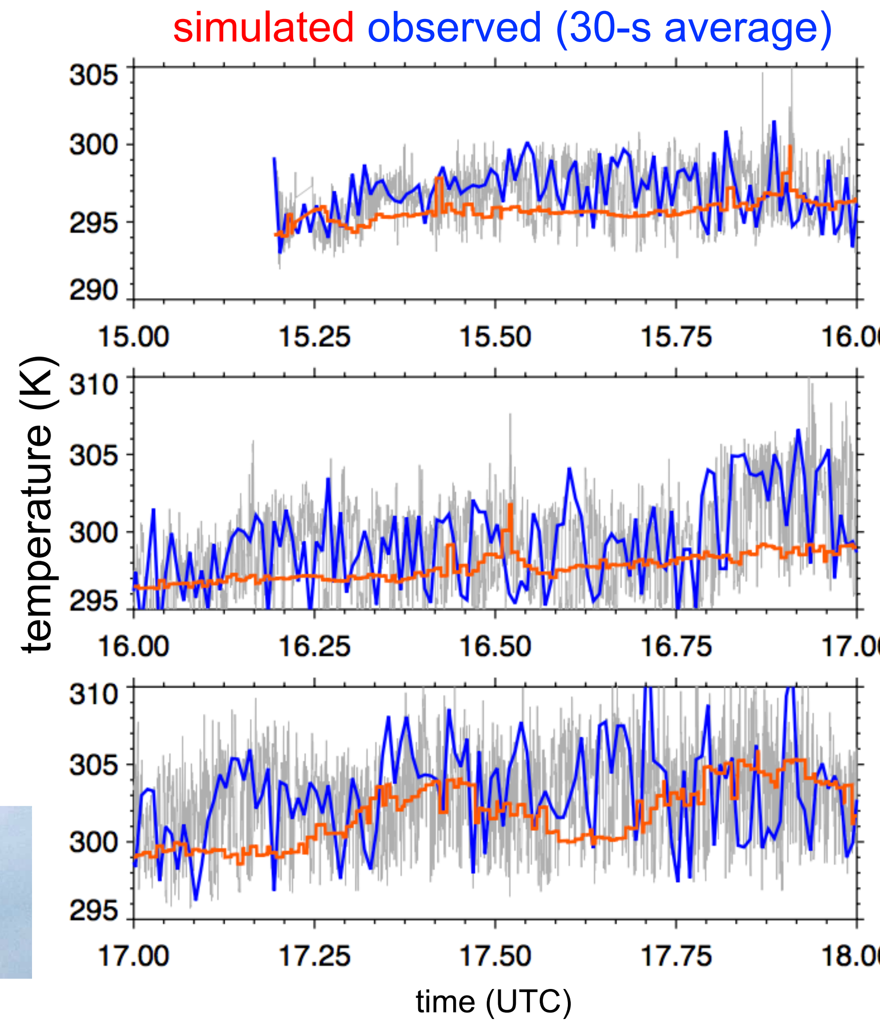


- Simulated skin temperature less variable and often too high. Does this bias contribute to the near surface temperature bias?

Skin Temperature: Sept. 11 (Clear Sky, IOP 2)

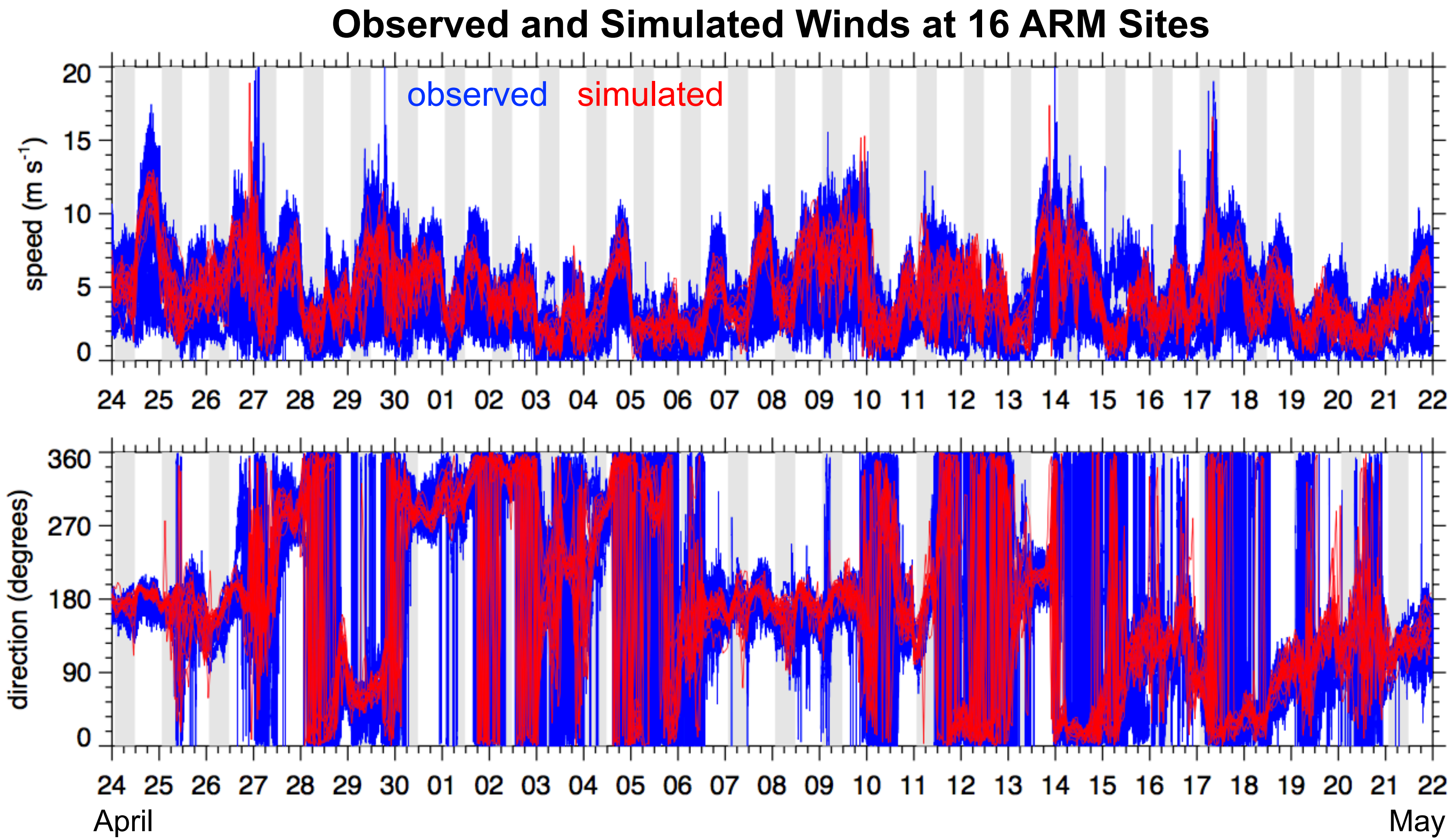
Simulated Surface Temperature (contours)





- Simulated skin temperature less variable, but bias is much smaller than during IOP1

Surface Wind Variability during IOP1



- Simulated winds are less variable in space than observed

Surface Wind Variability during IOP2

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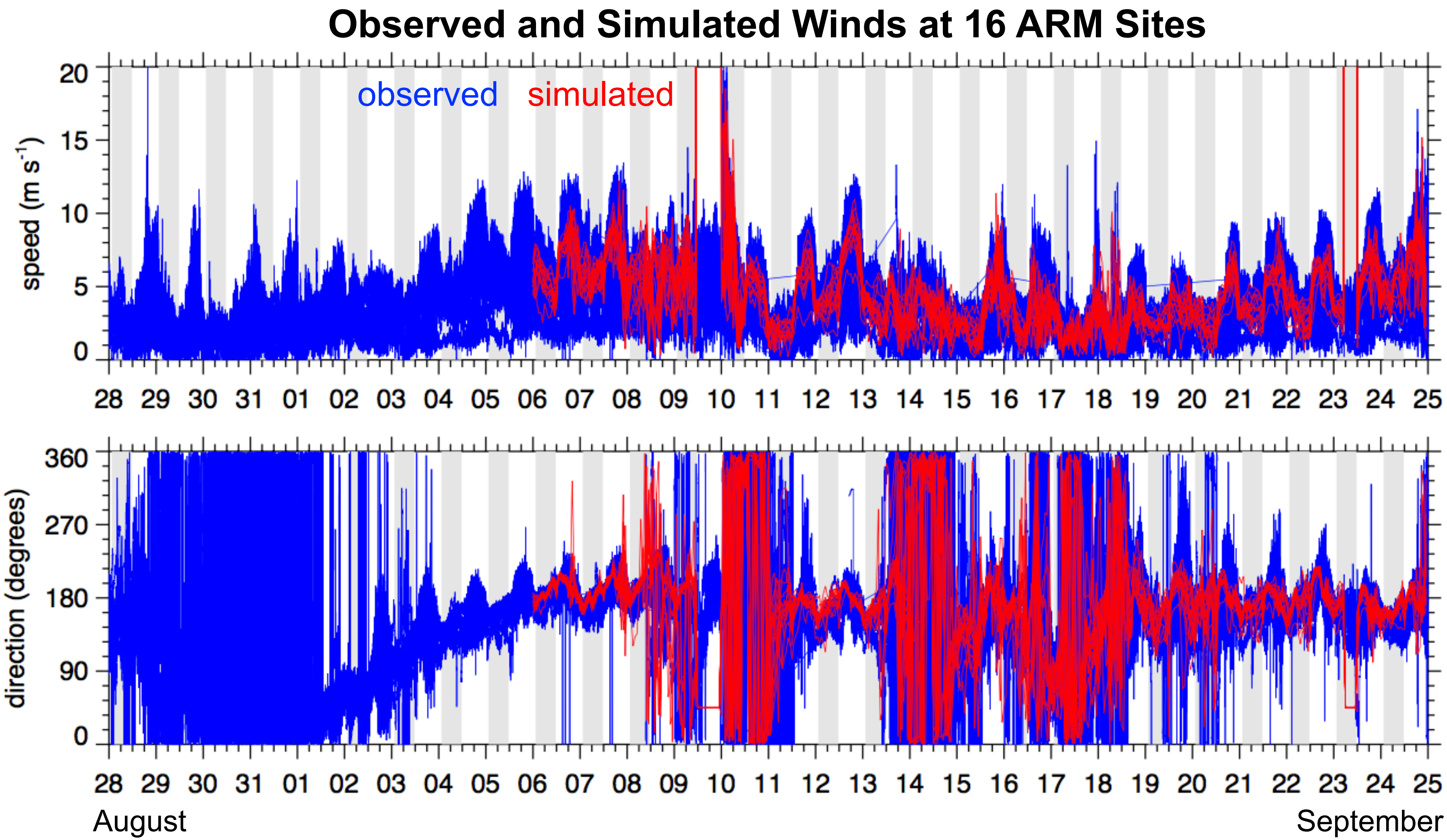
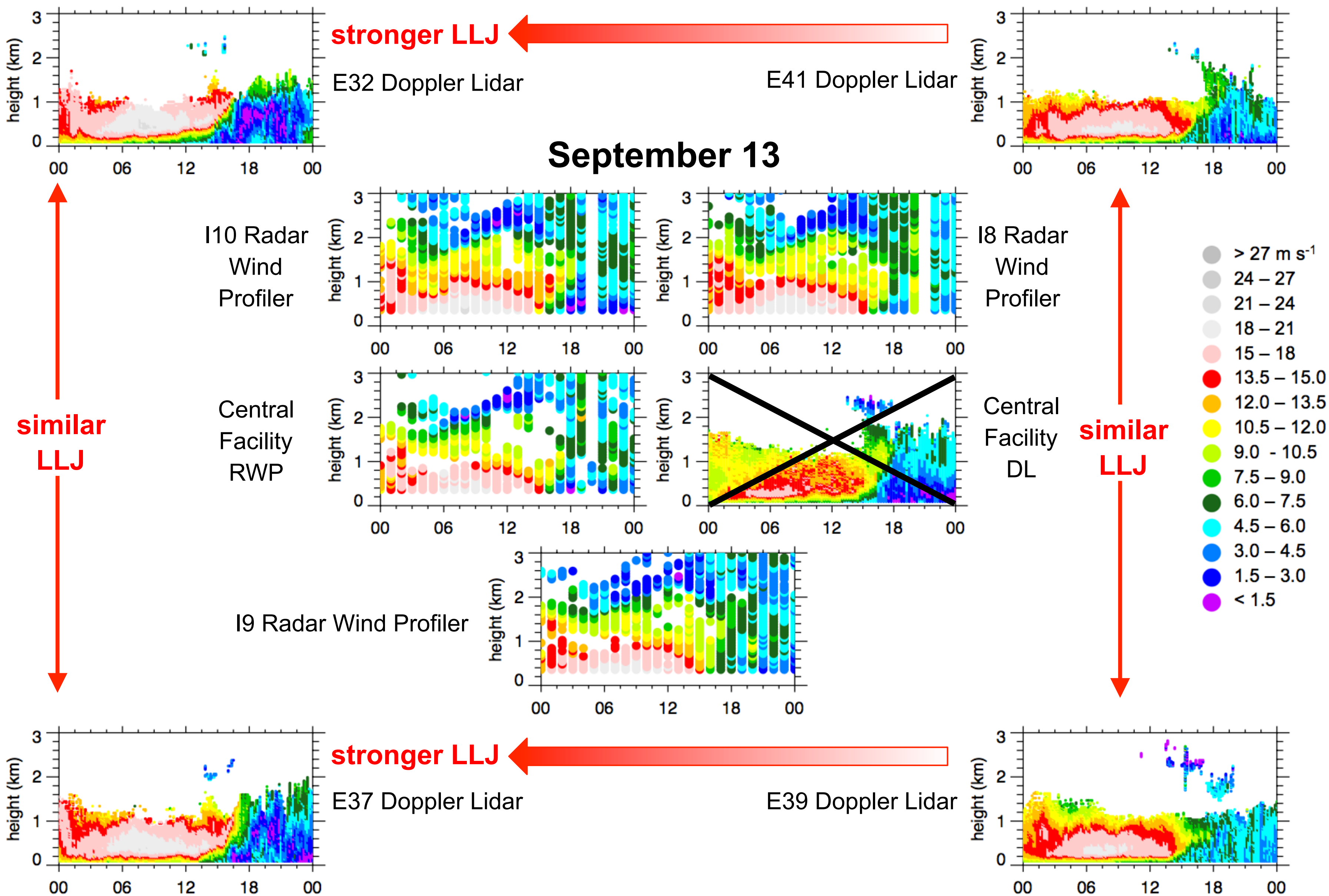


- Simulated winds are less variable in space than observed

Wind Profiles: Observed Low-Level Jet



Wind Profiles: Simulated Low-Level Jet

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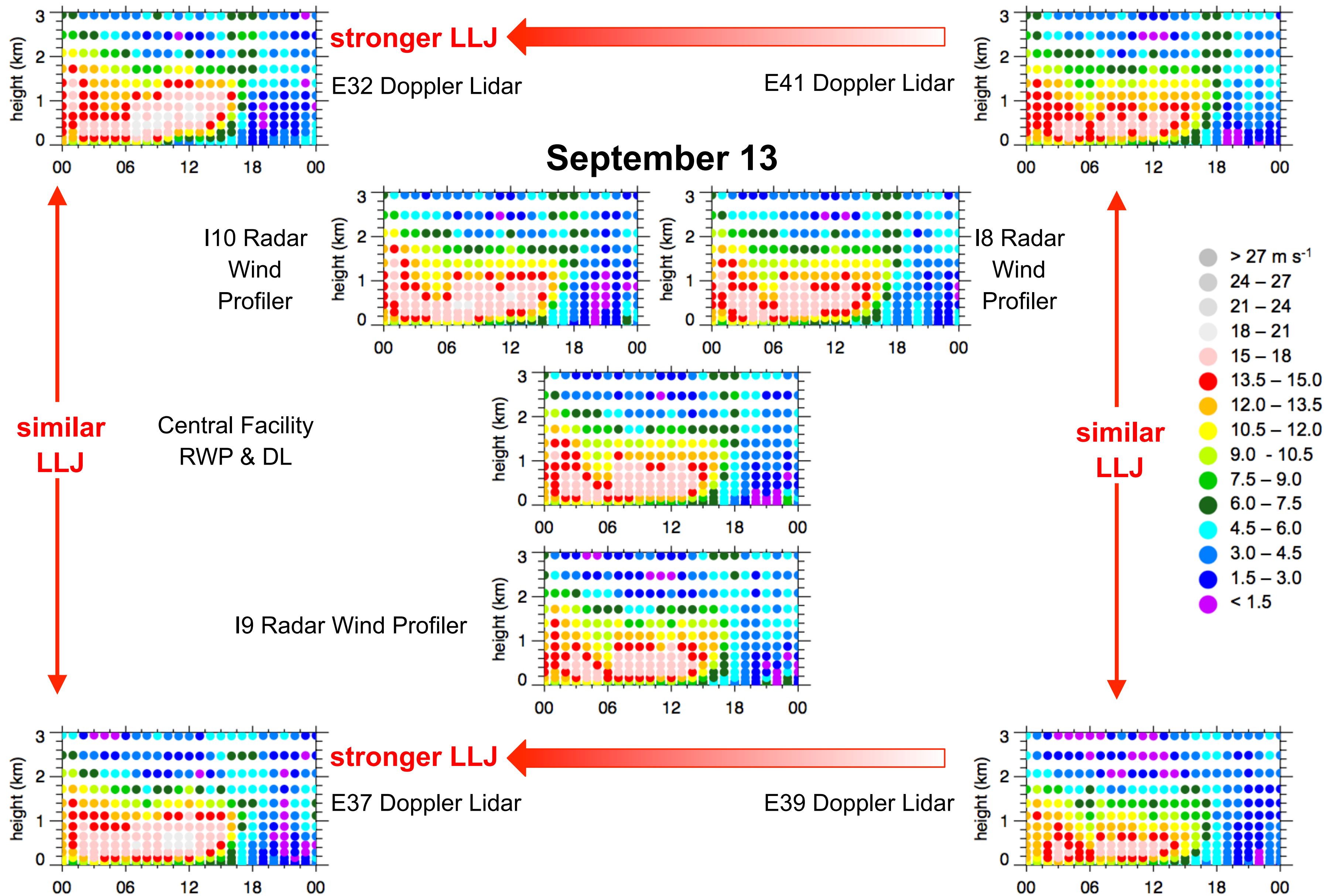
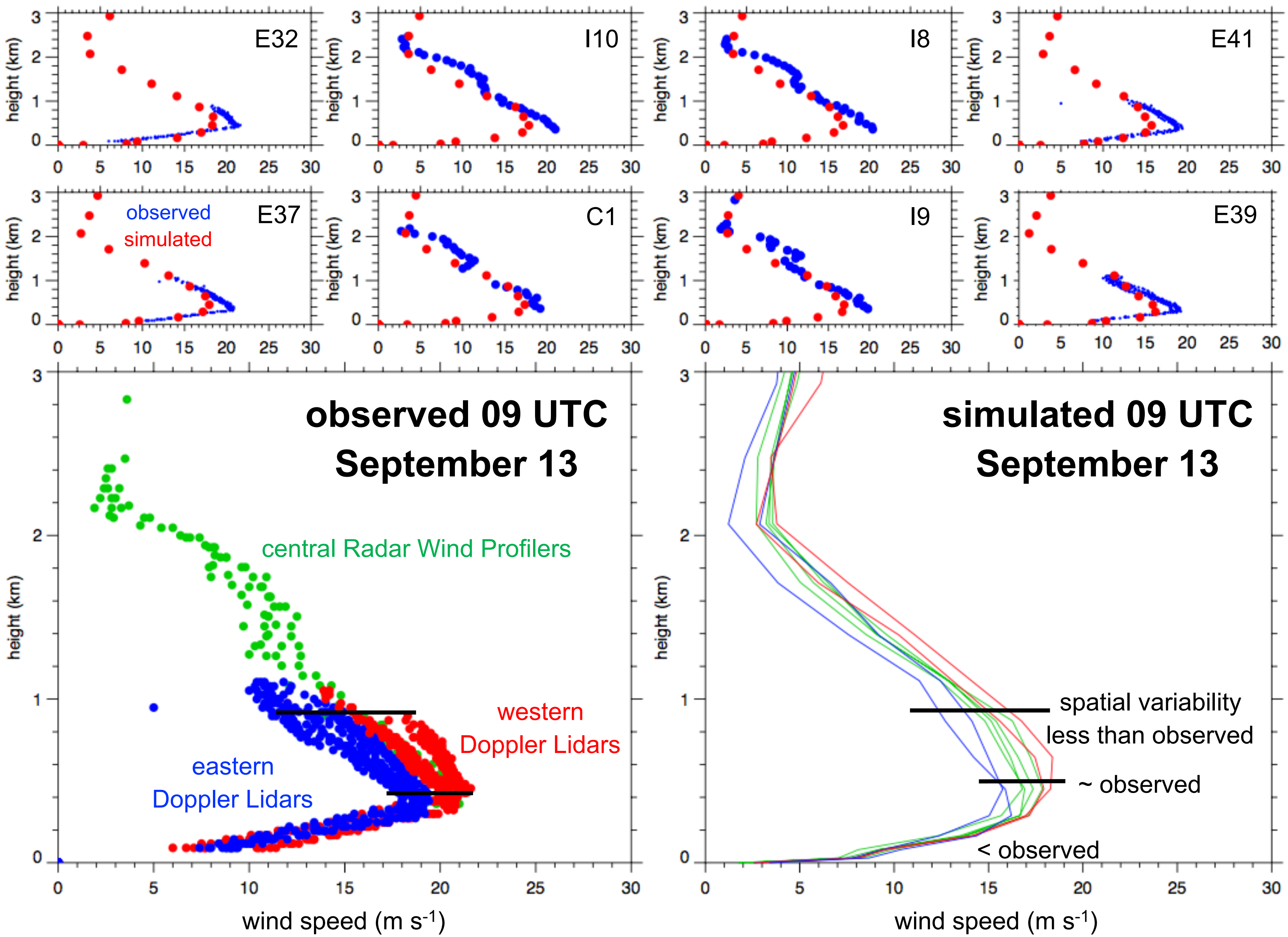


Wind Profile Variability



Boundary Layer Depth during IOP 1

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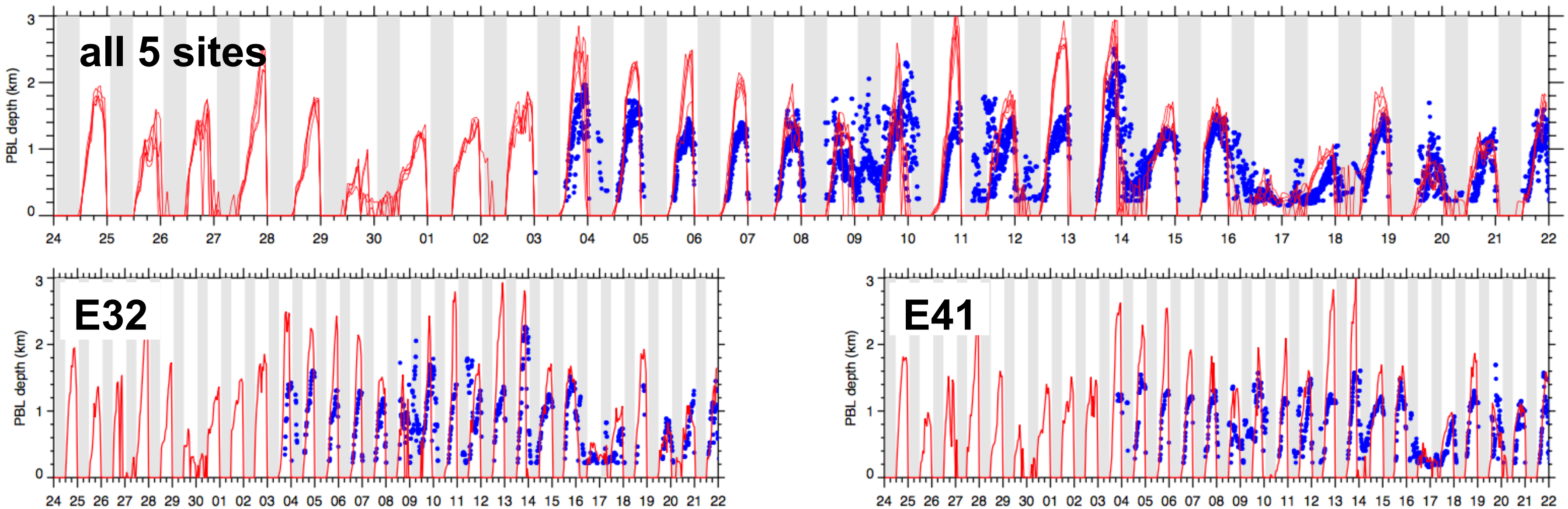
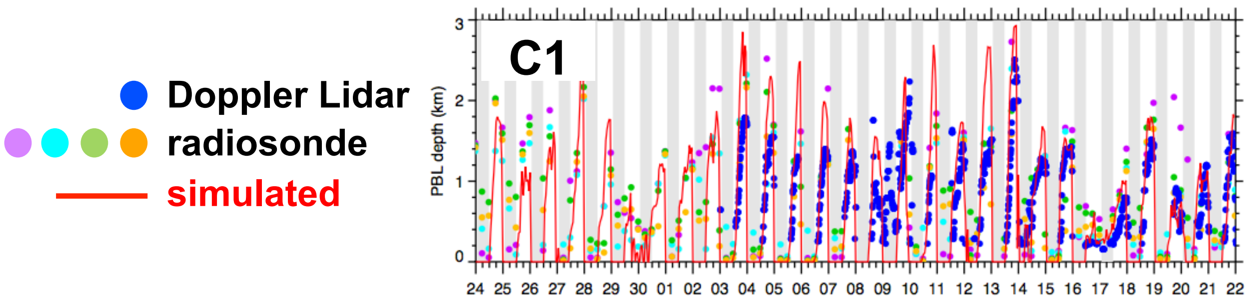
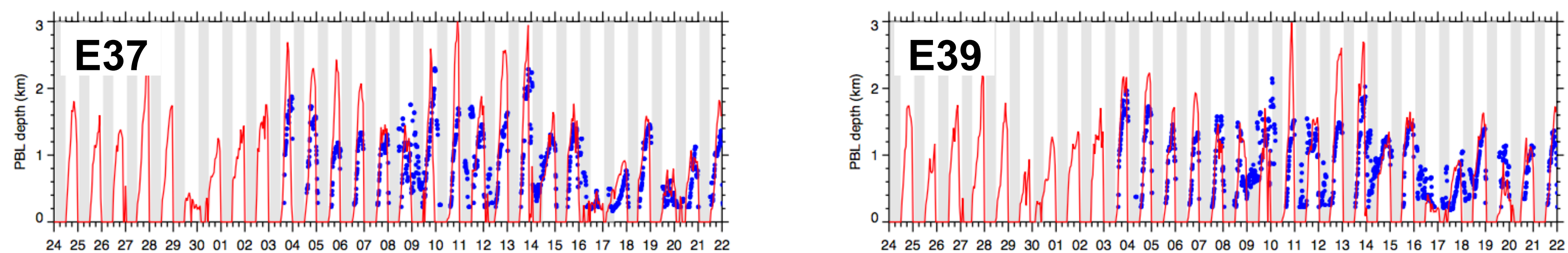




- Simulated boundary layer too high on many days – consistent with temperature



Boundary Layer Depth on May 5 (Clear Sky)

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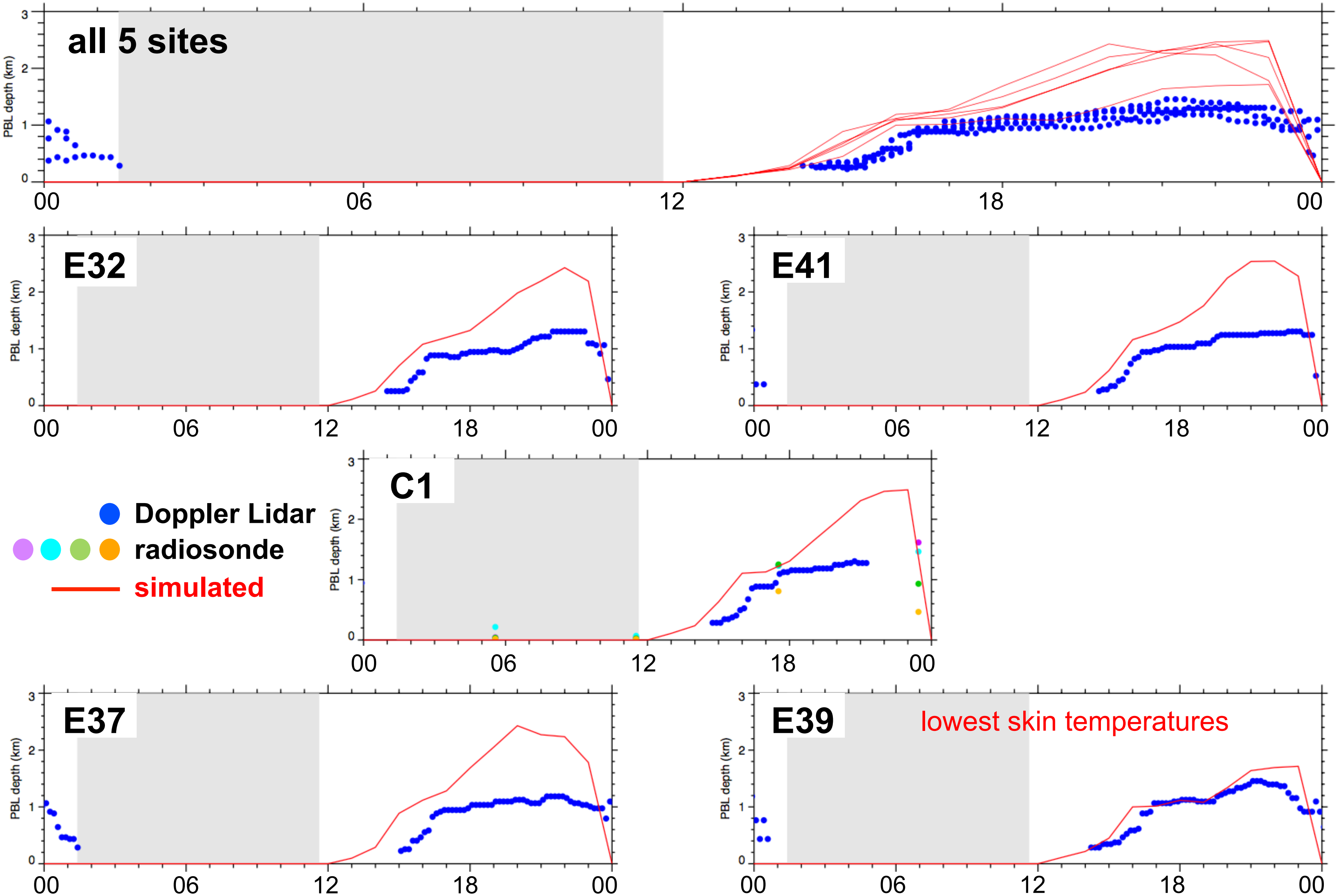
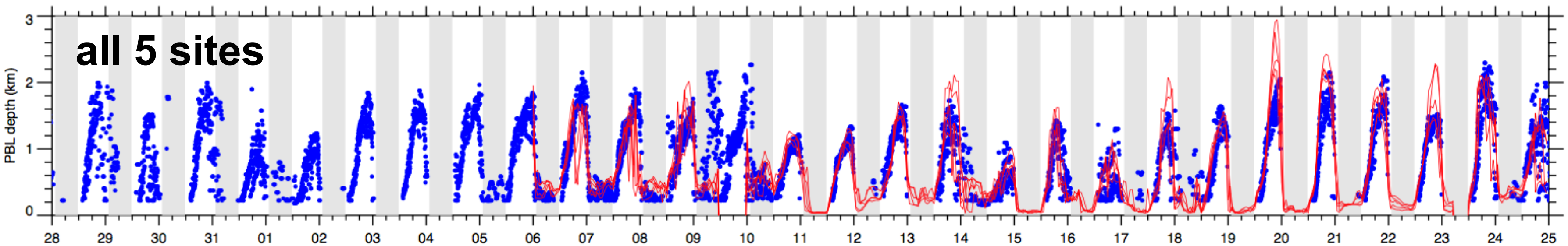
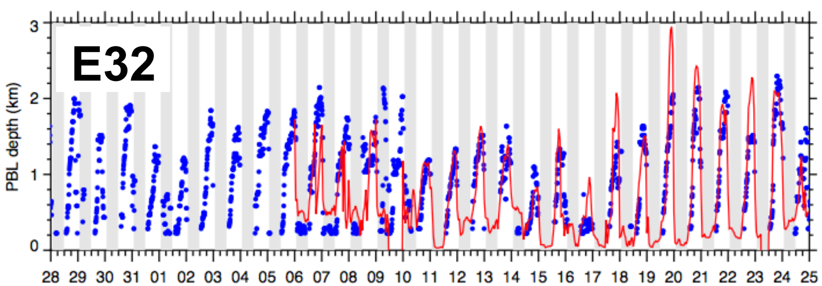
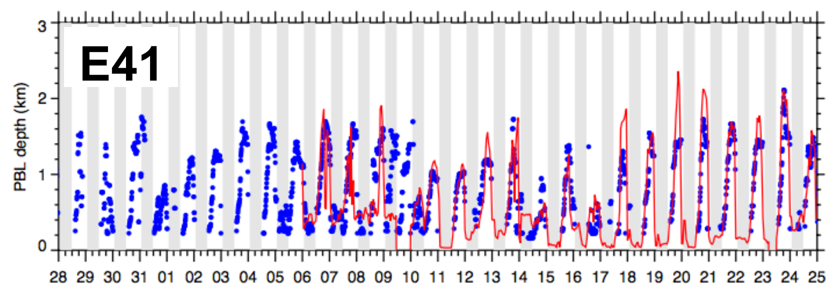
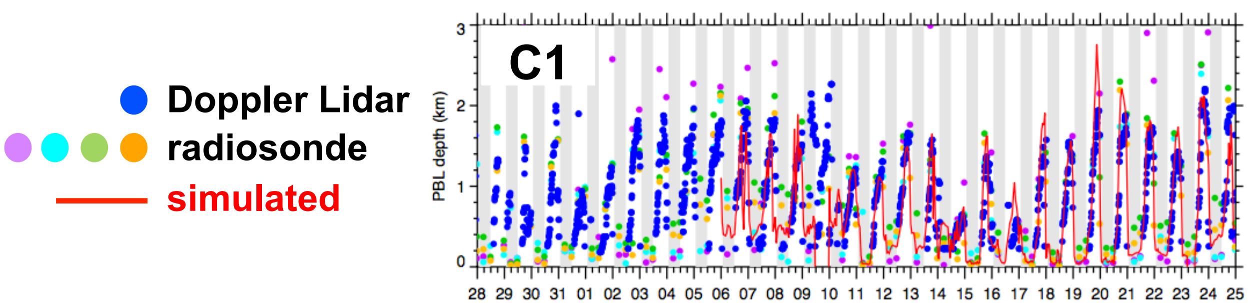


Boundary Layer Depth during IOP 2

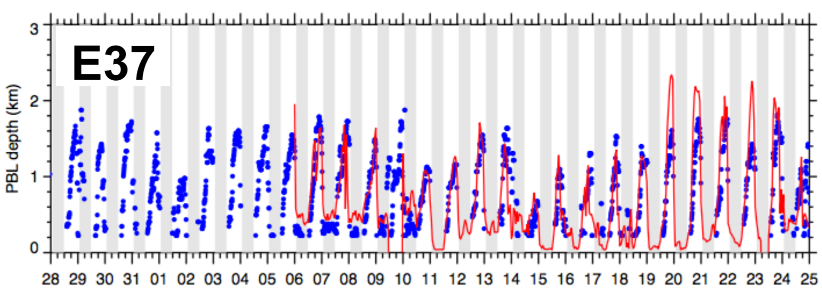


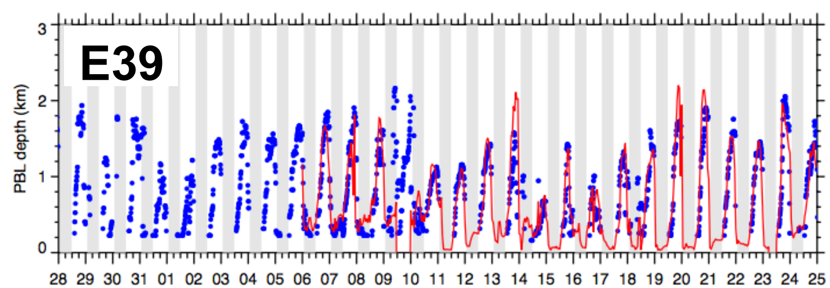




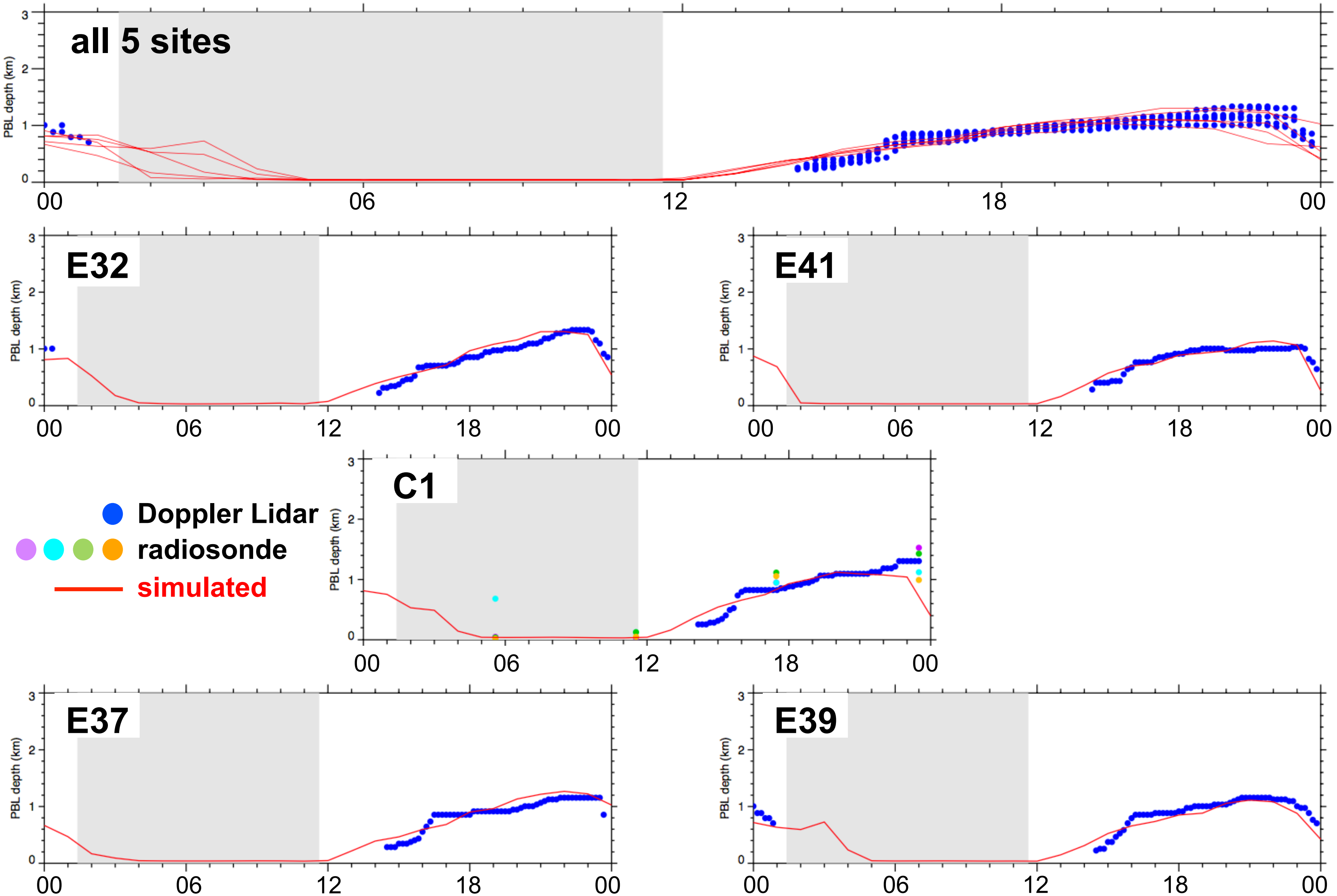


- Positive bias seen in IOP 1 is greatly reduced during IOP 2





Boundary Layer Depth on Sept. 11 (Clear Sky)



Summary

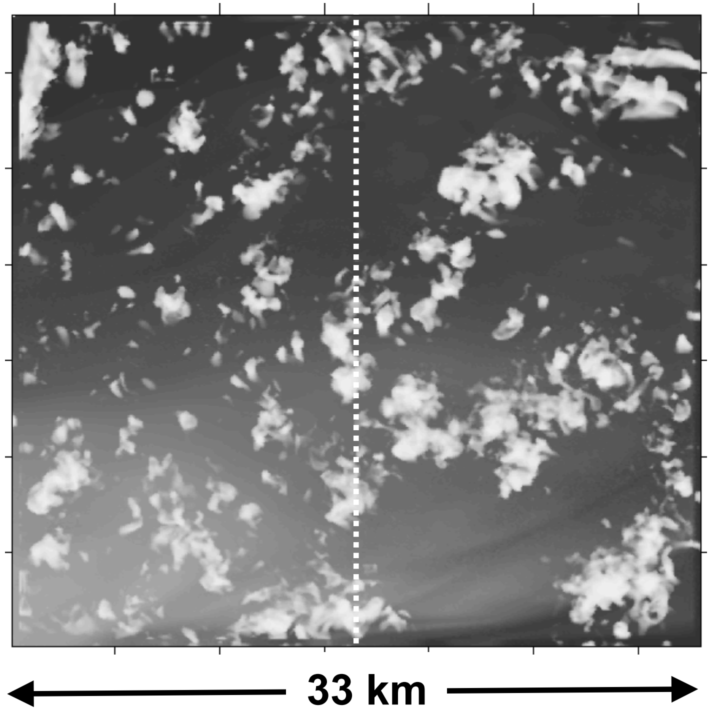
- HRRR v3 performs much better when compared to ARM operational and HI-SCALE field campaign measurements
- HRRR represents some of the spatial variability of meteorological quantities across the ARM supersite with Dx = 3 km, but the observations exhibit somewhat more variability
- While the simulated radiation on partly cloudy days is better during IOP 2, HRRR can still underestimate the amount of cloudiness in regions where cloud fraction small

Lots of Work Remains to be Done

- Evaluation of shallow convective parameterizations
- More extensive evaluation of cloud properties and radiation
- Inclusion of more heterogeneous variable land properties and inclusion of aerosol chemistry in WRF
- Use of LES for insights into shallow cloud processes

LES Representation of Clouds

WRF LES 1950 UTC (Dx = 100 m)



MODIS AQUA 1950 UTC (Dx ~ 1 km)