A Case Study of Cloud Seeding Impacts Using WRF-WxMod Simulations and SNOWIE Observations

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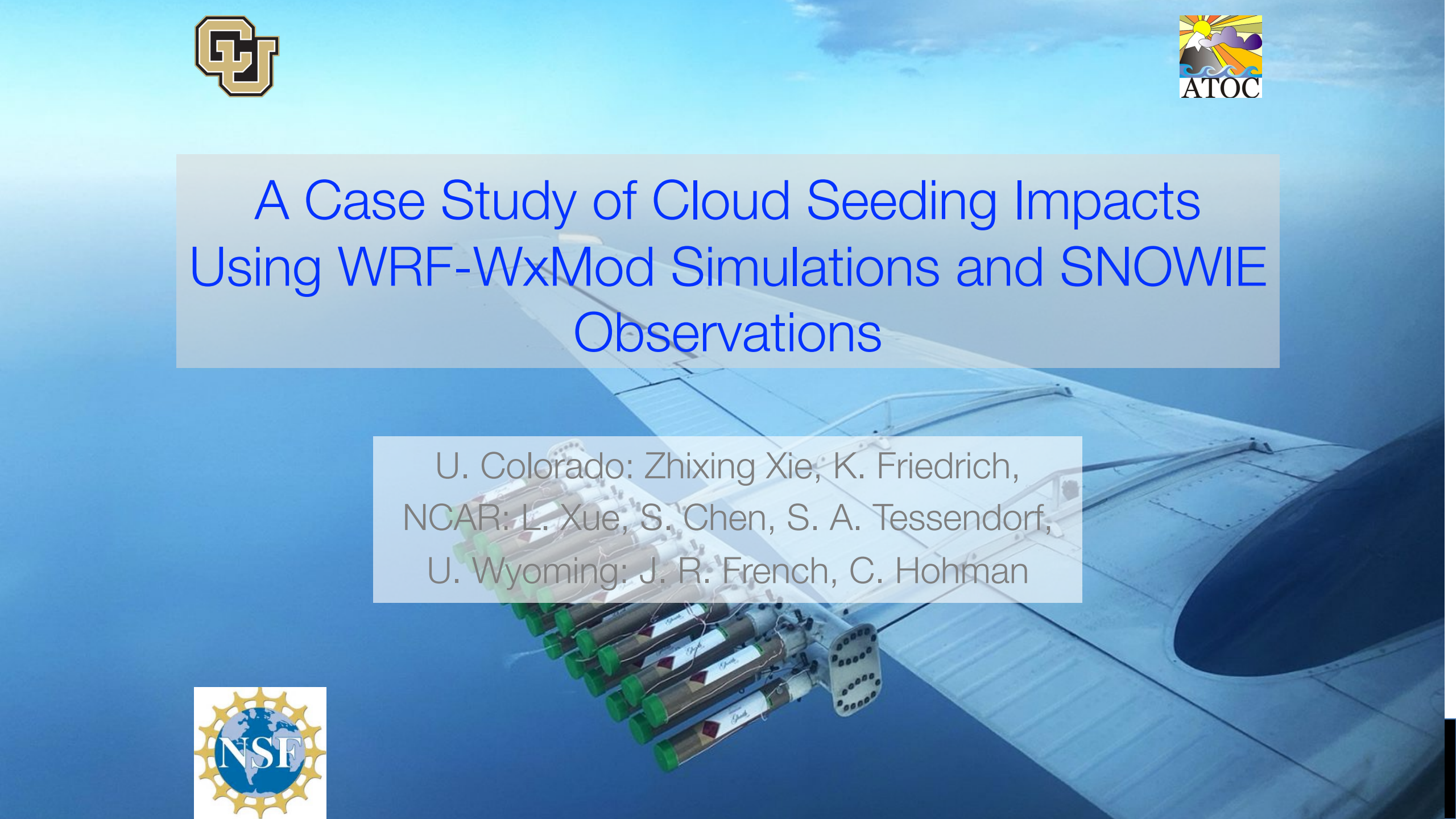
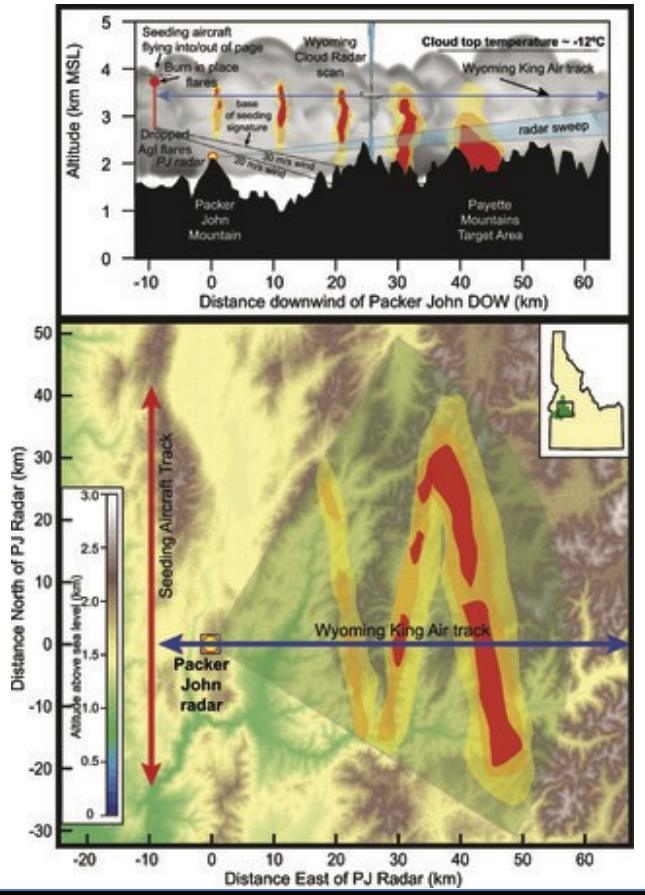


SNOWIE Seeding Case Analysis

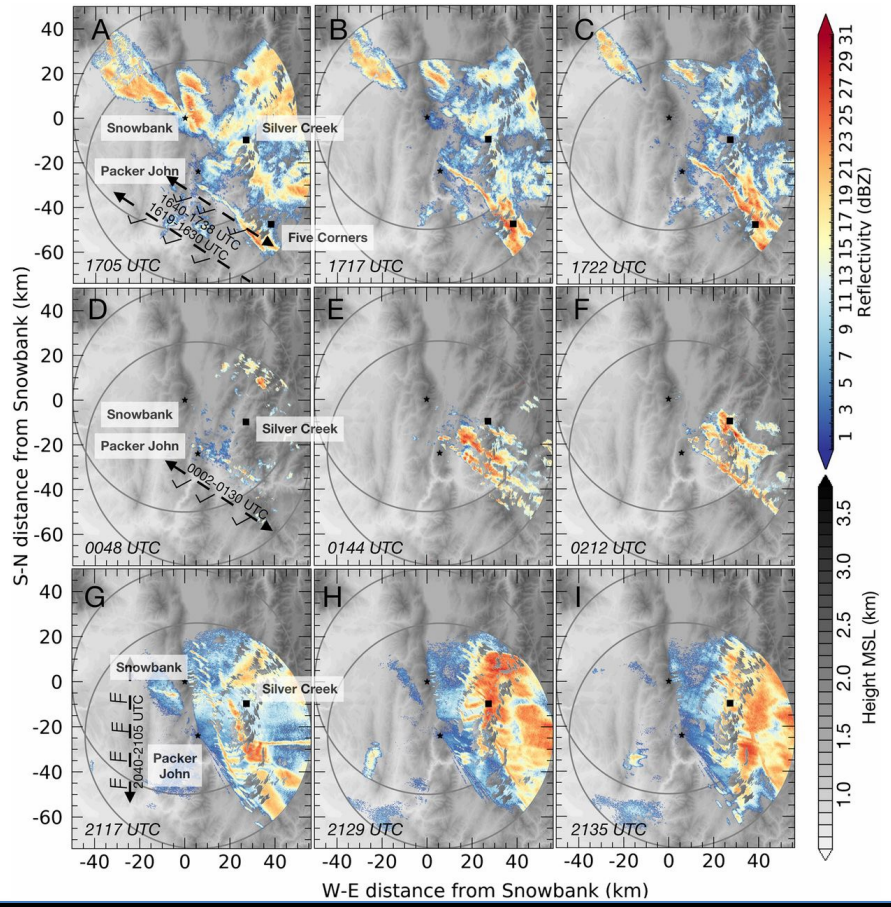
Theory of cloud seeding

Tessendorf et al. BAMS 2020



Cases with observed seeding lines

Friedrich et al. PNAS 2020 JAMC 2021



What is new here?

- What are the characteristics of the seeding lines and background precipitation?
- How do model results compare to observational results?
- What is the difference in snowfall between the different model runs?

Also Check out

J3.3 Investigating Seeded Orographic Cloud Microphysics during SNOWIE Using WRF-WxMod
Christopher Hohman (Monday)

J3.2 Observed Microphysical Evolution of a Seeded Cloud during SNOWIE
Jeffrey R. French (Monday)

Weather Research and Forecasting Model-WxMod

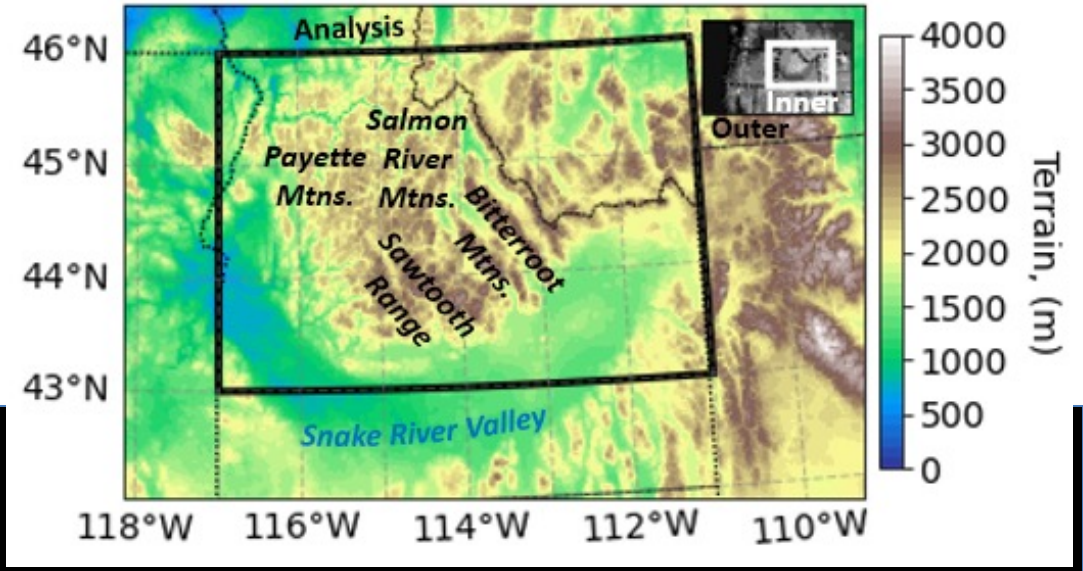
WRF model

- 0000-0900 UTC 11 January
- 900 m resolution initiated with ERA5, ERAI, NARR, CFS2
- 81 terrain-following levels
- Thompson and Eidhammer aerosol-aware microphysics scheme
- Mellow-Yamada Nakanishi and Niino 2.5 planetary boundary layer scheme
- Noah-MP land surface model
- Rapid Radiative Transfer Model

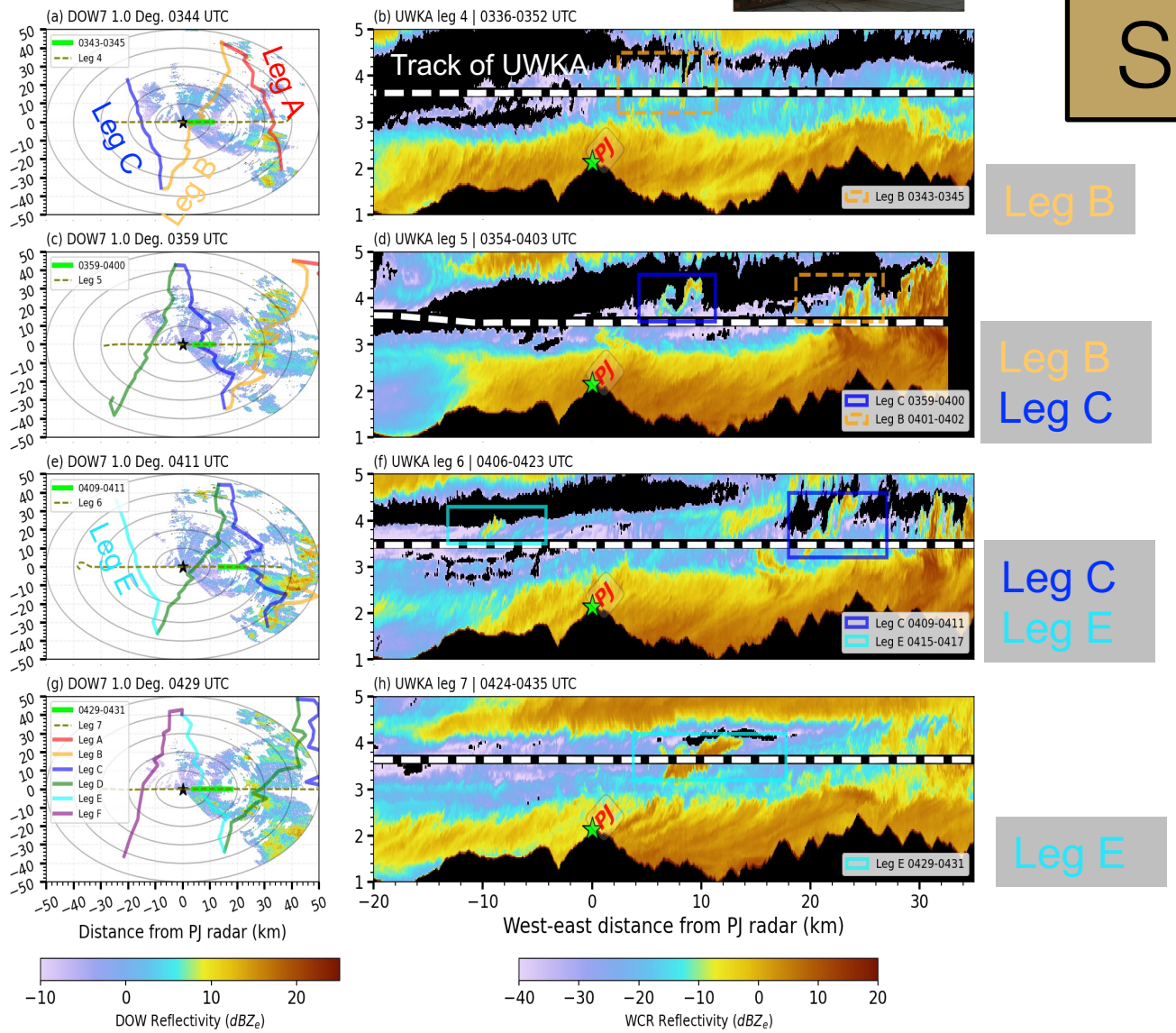
CTRL	SEED	Driving Data	Configuration
900m_ERA5_CTRL	900m_ERA5_SEED	ERA5	Horizontal grids: 900×600 Time step: 5 s Simulation time: 0000-0900 UTC 11 Jan 2017 Vertical coordinate: 81 terrain-following ETA levels Land surface model: Noah MP PBL scheme: MYNN Microphysics: Thompson-Eidhammer **LES mode**: None **CCN**: Climatology
900m_ERAI_CTRL	900m_ERAI_SEED	ERAI	
900m_NARR_CTRL	900m_NARR_SEED	NARR	
900m_CFS2_CTRL	900m_CFS2_SEED	CFS2	
900m_ERA5_03CCN_CTRL	900m_ERA5_03CCN_SEED	ERA5	**CCN**: 30% Climatology

- CTRL: Turn off the seeding package
- SEED: Turn on the seeding package

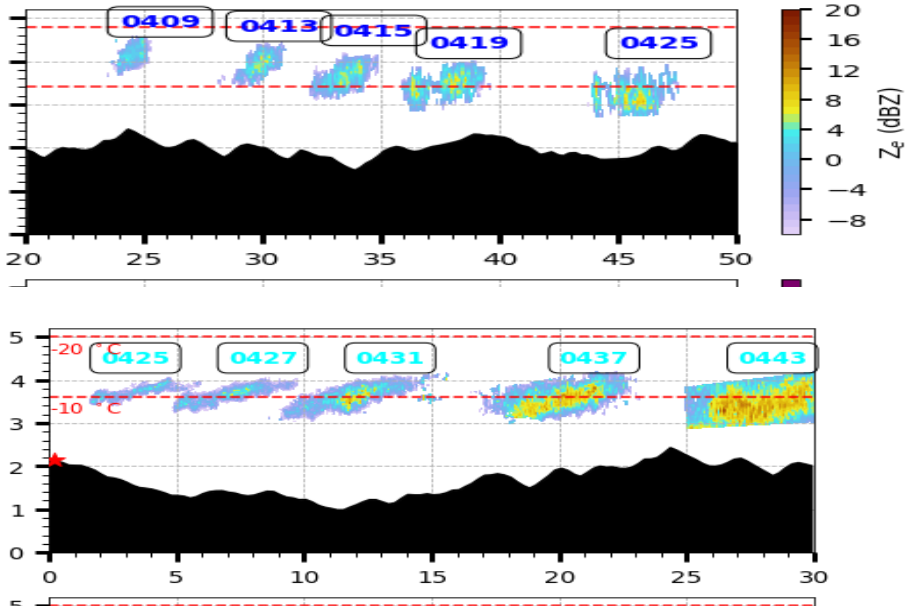
(The model simulates the way seeding aircraft released AgI spatially and temporally. The released amount of AgI for all the driving datasets is the same)



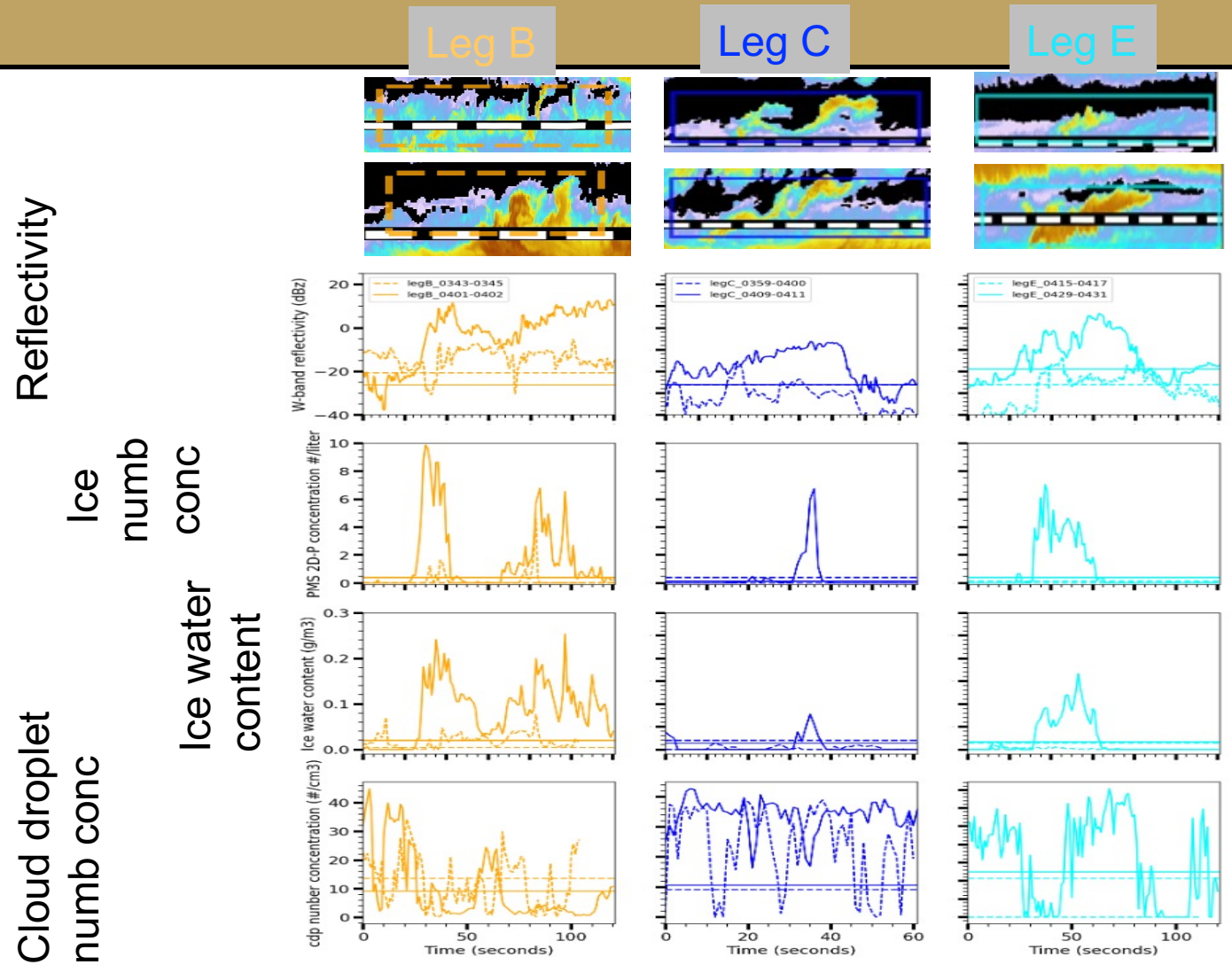
Tracking and Evolution of Seeding Lines



- Projected location seeding lines (solid lines) based on combined model/observed wind fields are combined with DOW X-band reflectivity field (right panel) PPI and UWKA WCR W-band cross sections (left panel)



In-situ Observations within Seeding Lines



Earlier

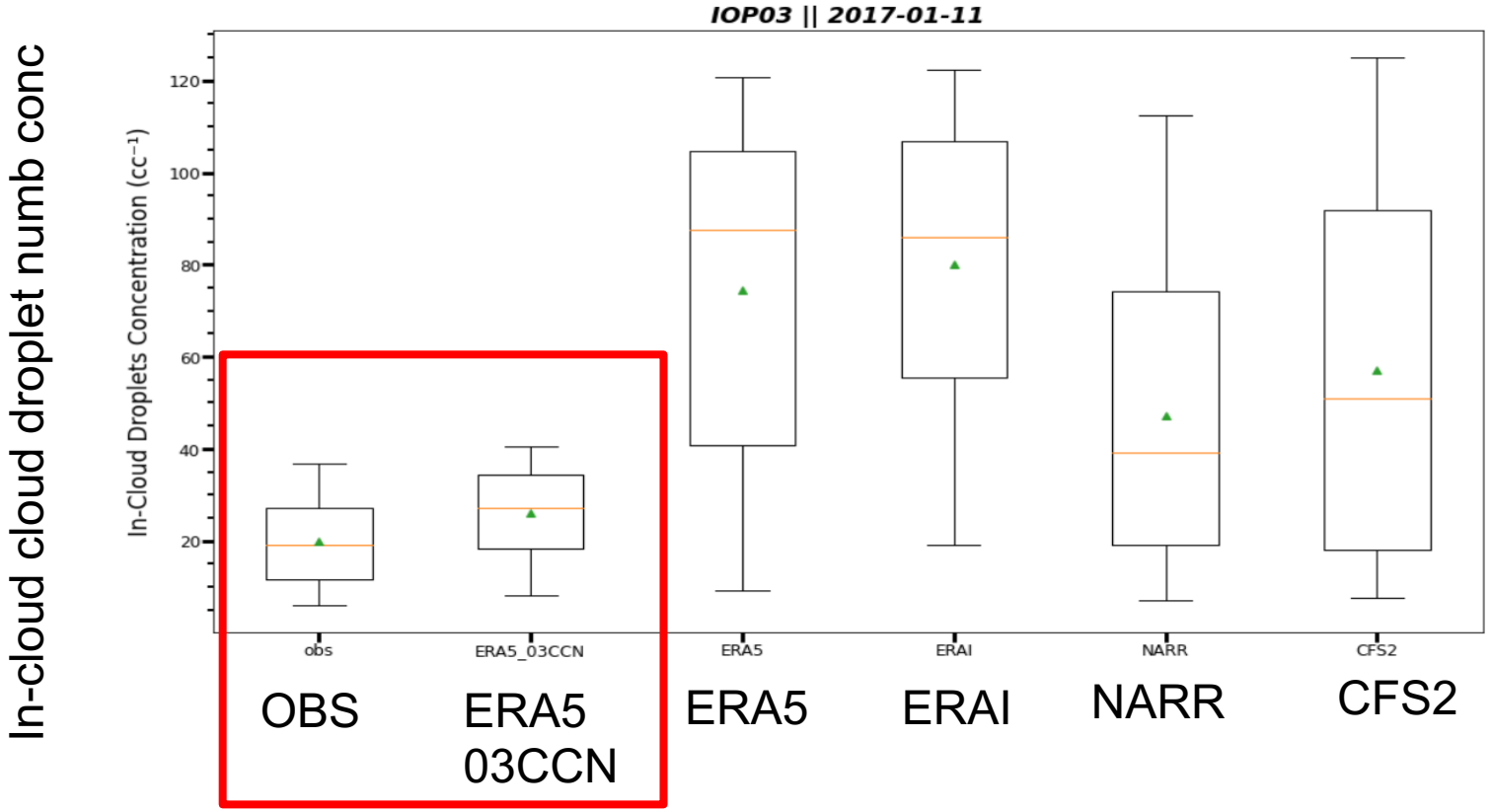
Later

- Reflectivity increases by 6 dB with time
- Ice concentration increase with time
- Cloud droplet concentration remains similar
- It takes 22-35 min for ice to grow into precipitating size in the three seeded clouds

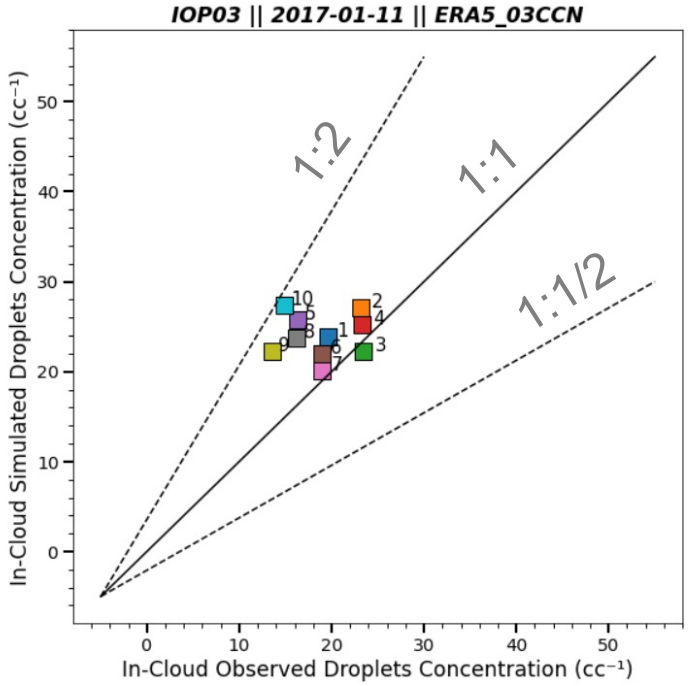
WRF-WxMod: Model Evaluation

1. Cloud Droplet Concentration

ERAS_03CCN closest to UWKA in-situ observations

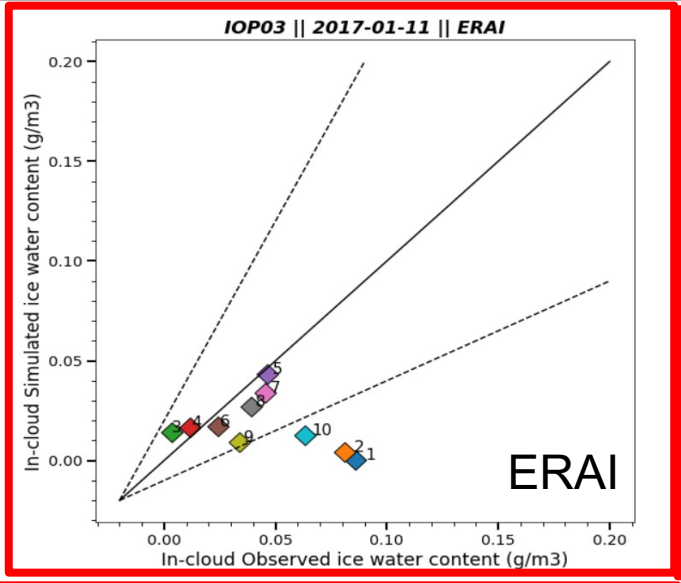


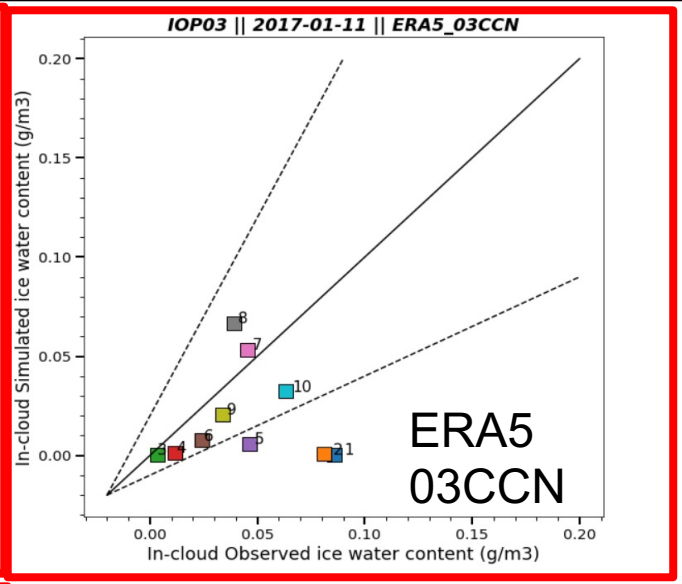
ERAS_03CCN comparison of each UWKA flight leg

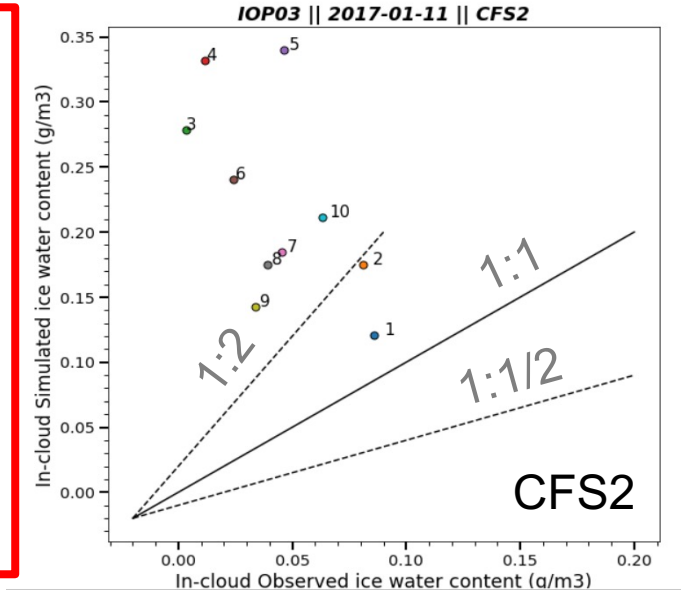


WRF-WxMod: Model Evaluation

2. Ice-Water Content

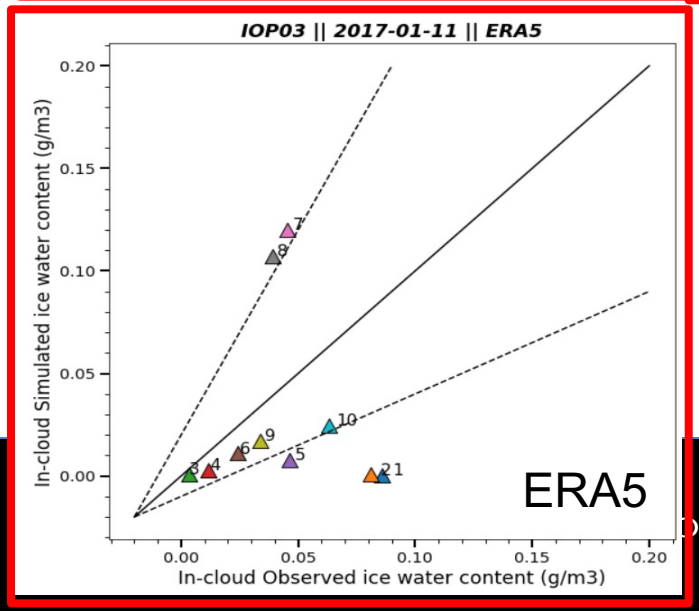


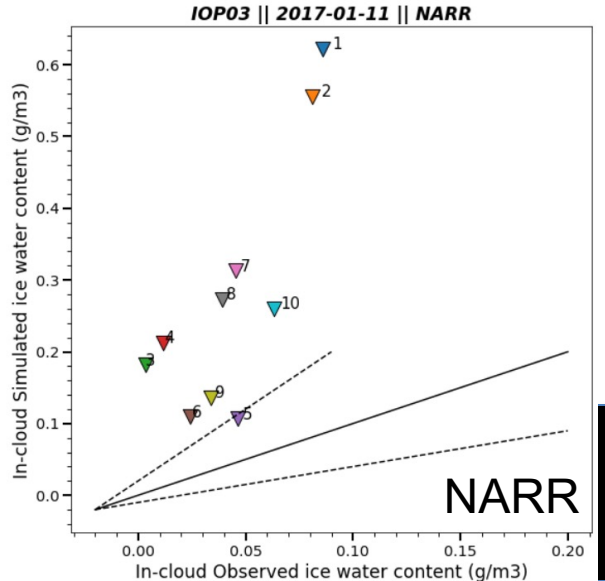




Simulation

Observation

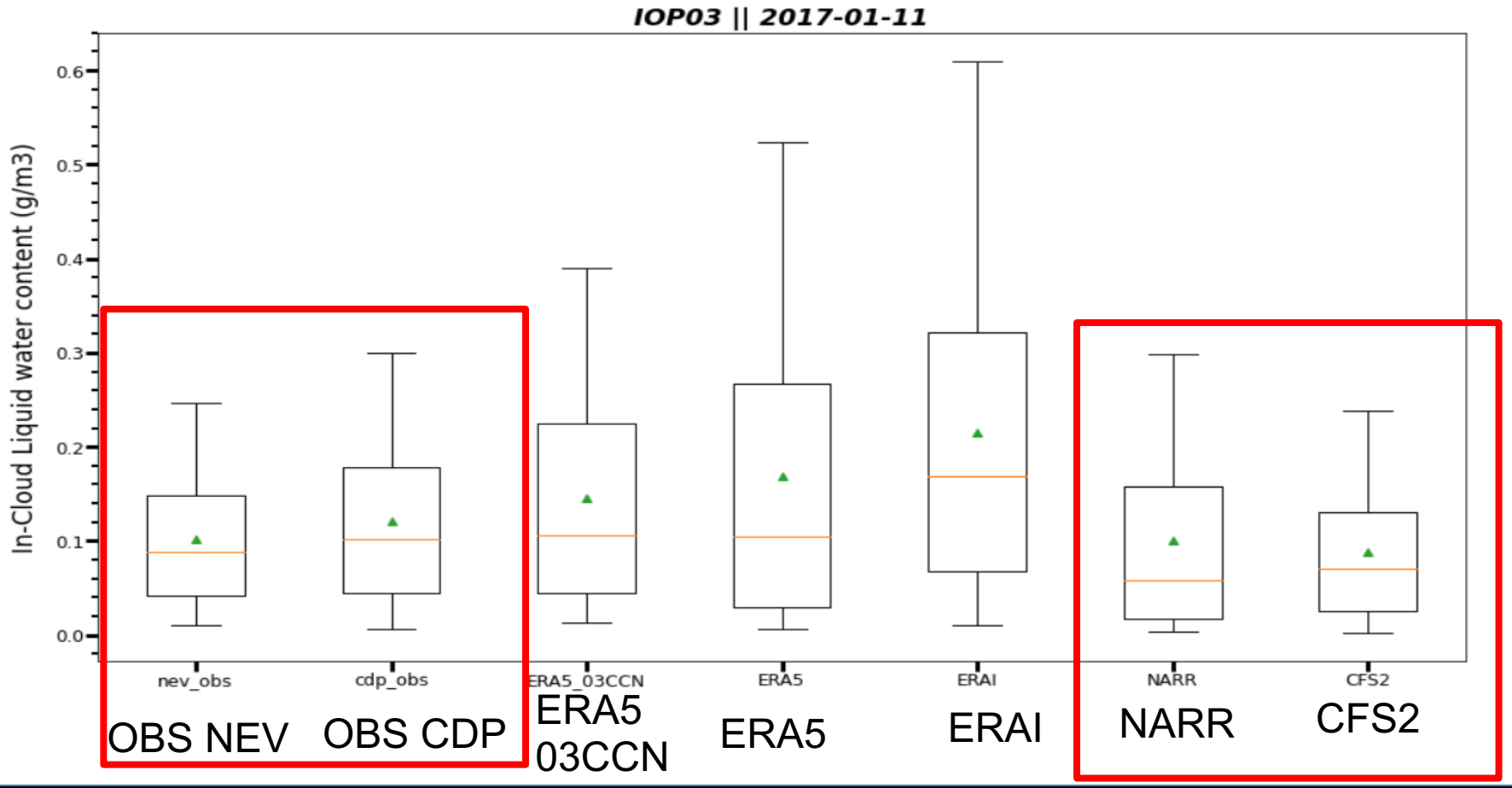


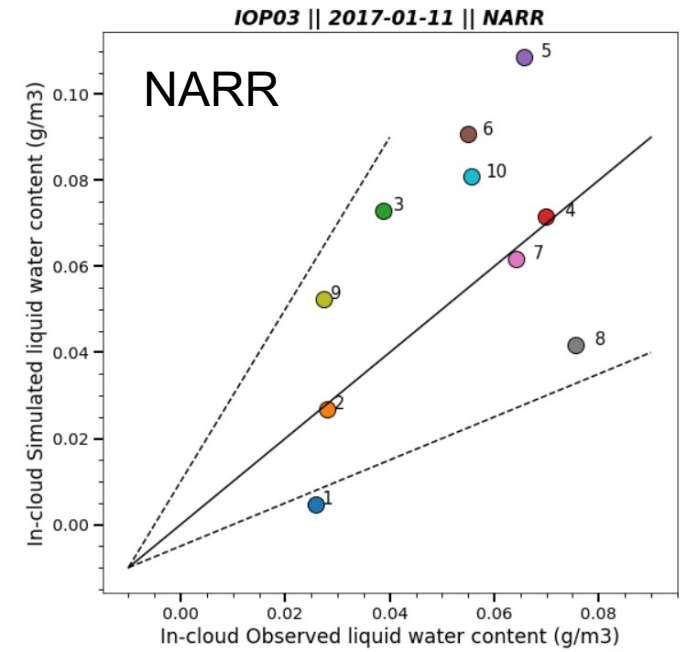


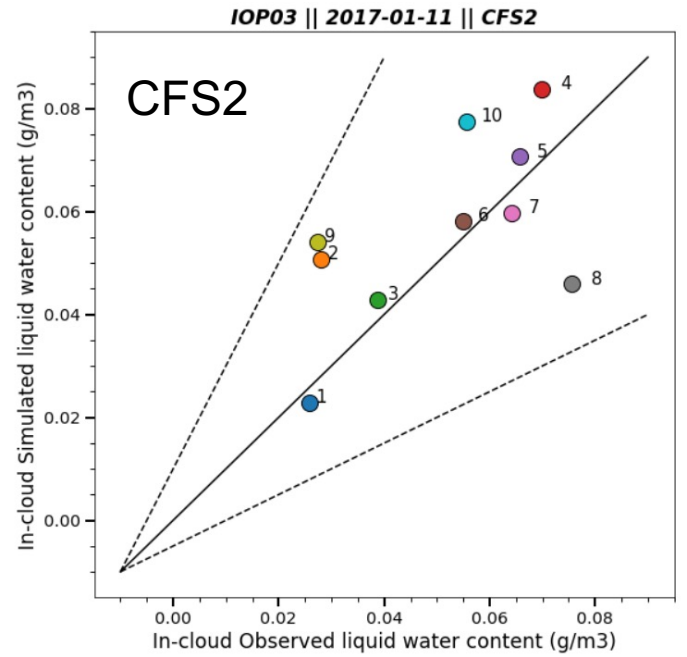
ERA5_03CCN, ERA5, and ERAI had better performance on ice water content than NARR and CFS2

WRF-WxMod: Model Evaluation

3. Liquid-Water Content





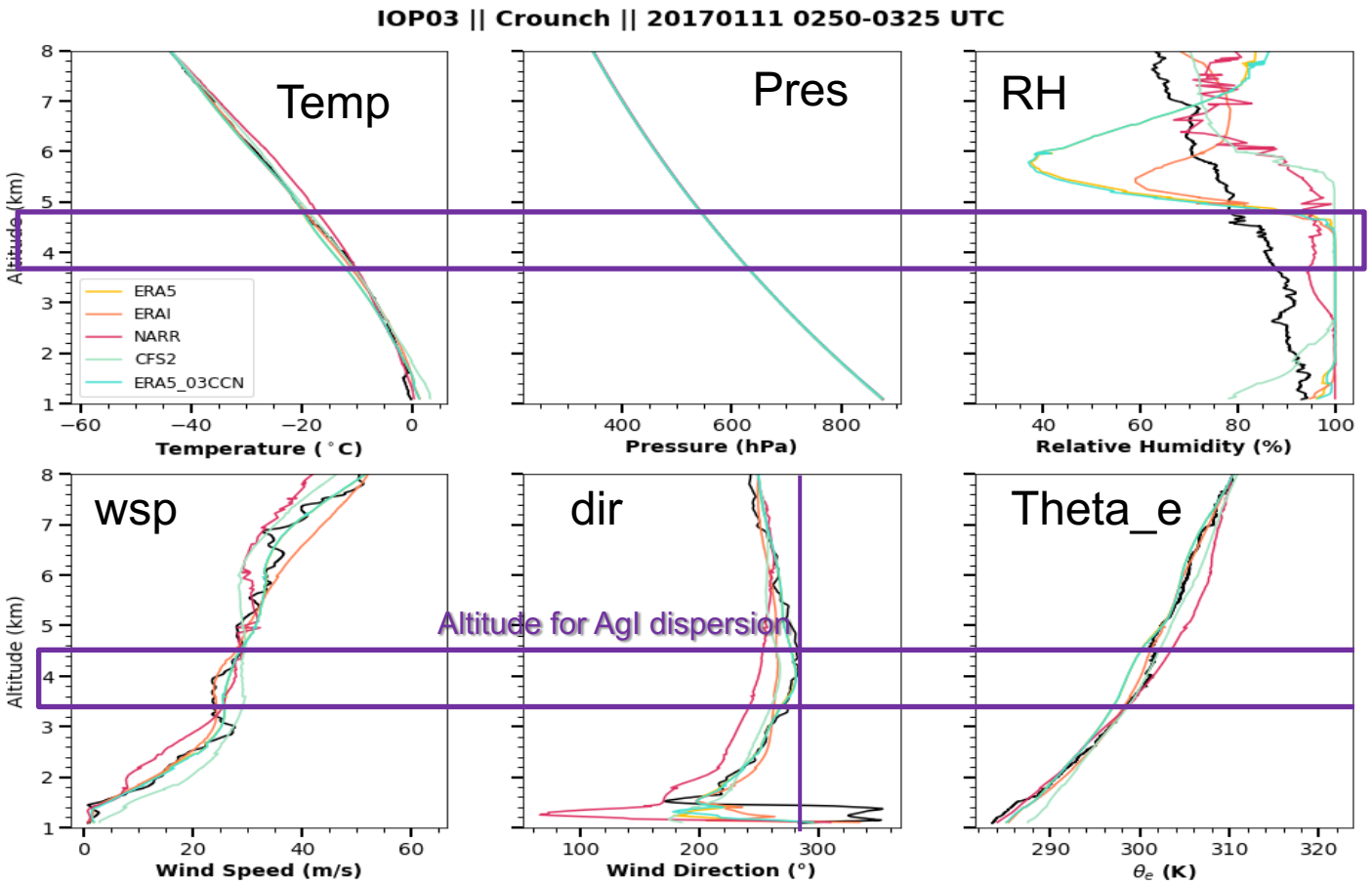


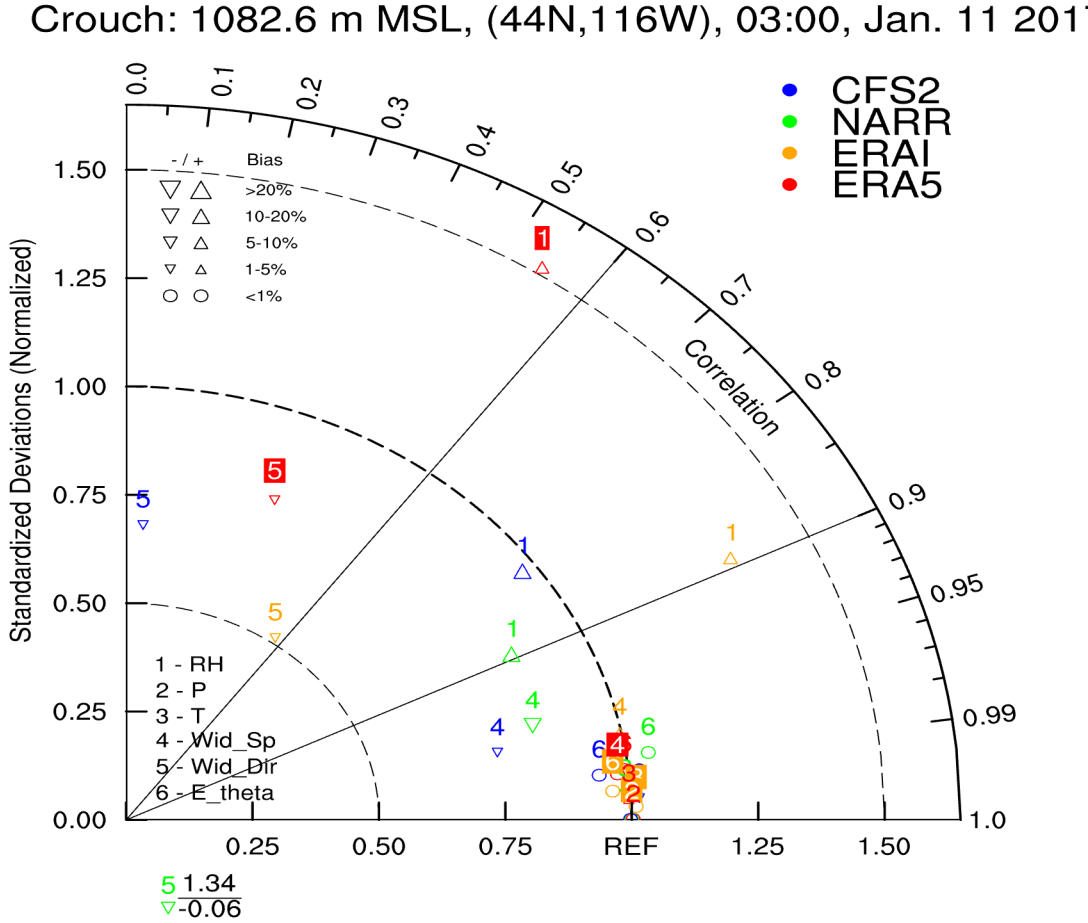
Simulation

Observation

WRF-WxMod: Model Evaluation

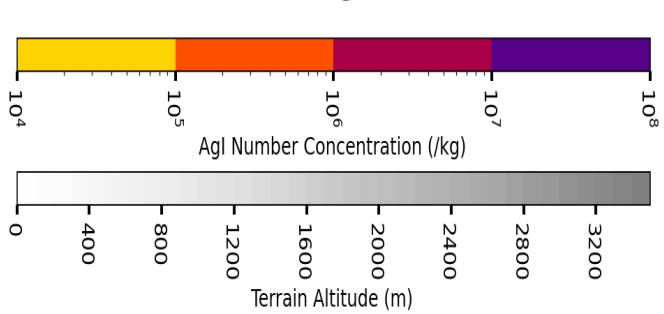
3. Comparing to Soundings



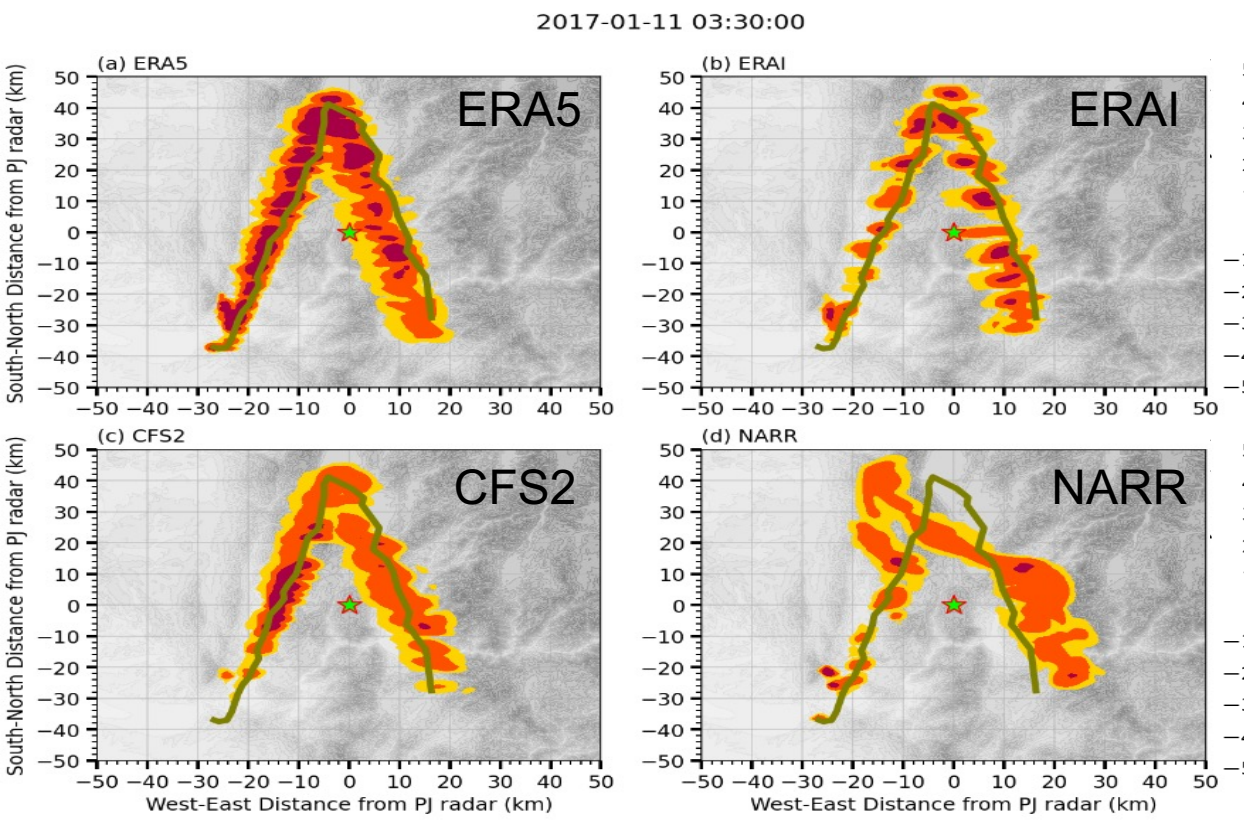


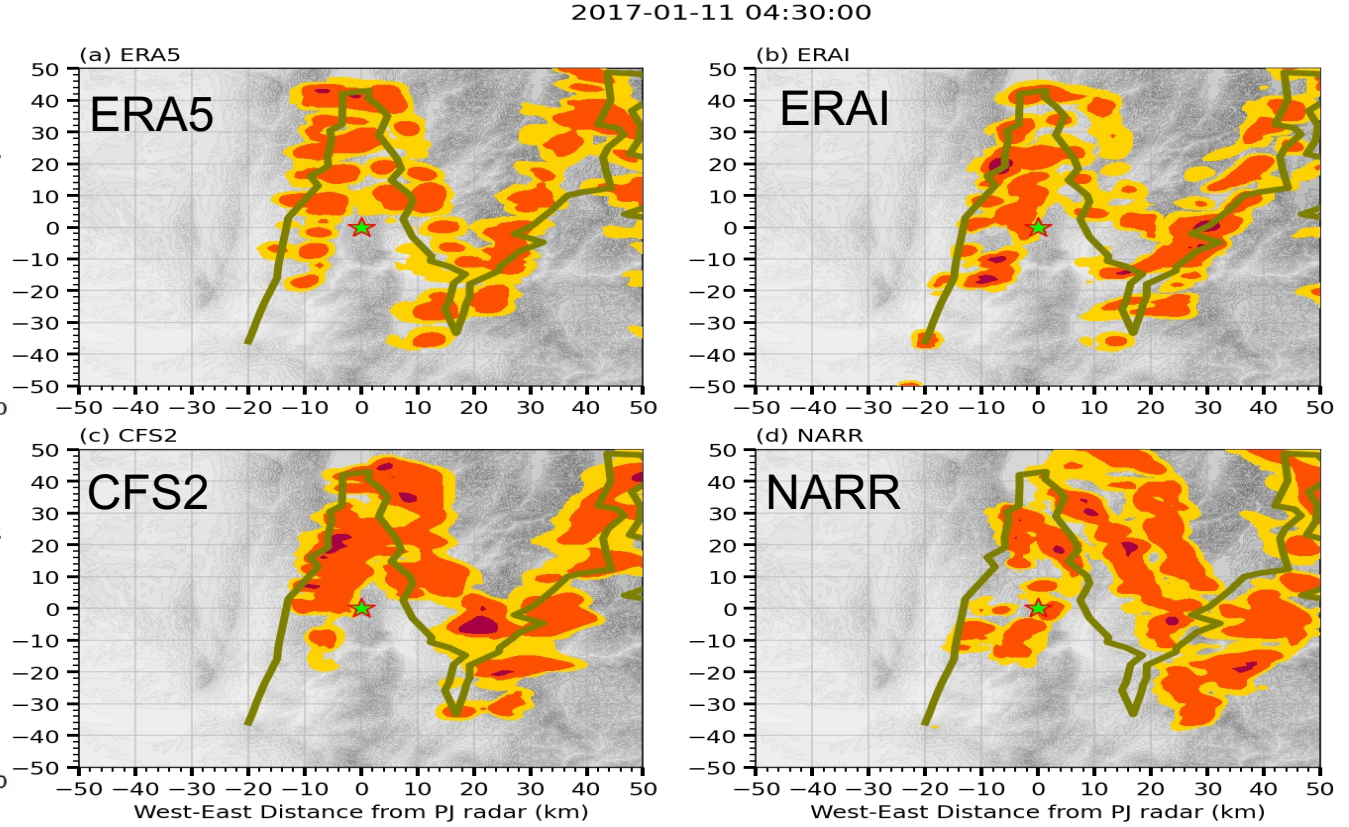
WRF-WxMod: Seeding Lines

1. AgI Concentration @ 4 km MSL (close to AgI release height)



Projected seeding lines based on obs



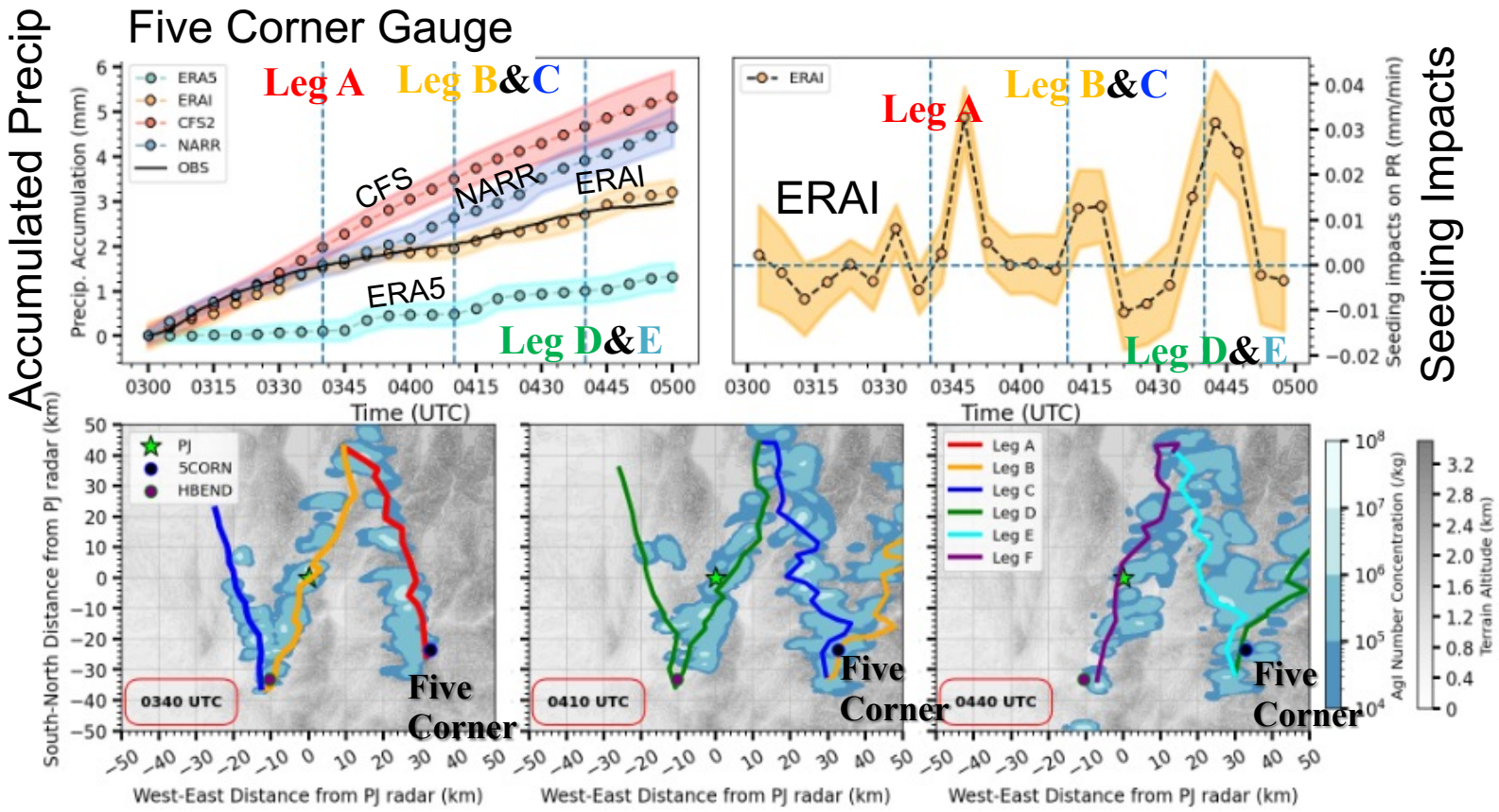


WRF-WxMod: Seeding Lines

3. Snowfall (comparison to gauge)

Seeding impacts on precipitation rate (PR) (mm/min) =

$$\frac{(\text{RAINNC\_seeding\_at\_}t_n - \text{RAINNC\_seeding\_at\_}t_{n-1}) - (\text{RAINNC\_control\_at\_}t_n - \text{RAINNC\_control\_at\_}t_{n-1})}{5\ min}$$

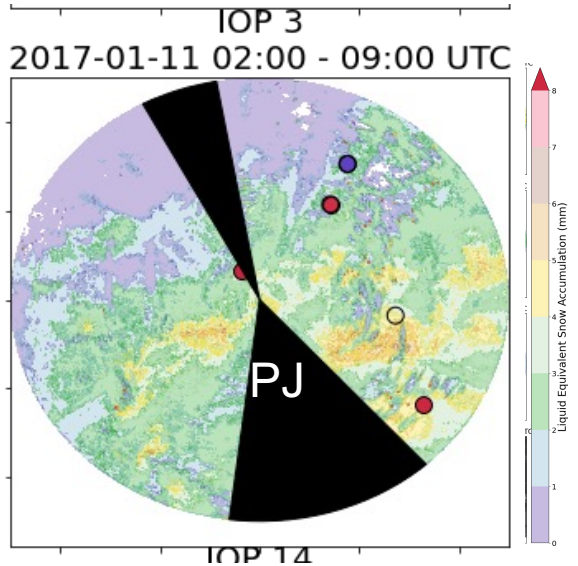


- CFS2 best at Silver Creek (seeding impacts on changes of precipitation = 2.9%)
- ERAI best at Five Corner and High Valley (seeding impacts on changes of precipitation 17.5% and 0.47%)
- large spatial variability might be attributed to environmental differences
- not a single model simulation induces the best results for all the gauge stations.

WRF-WxMod: Seeding Lines

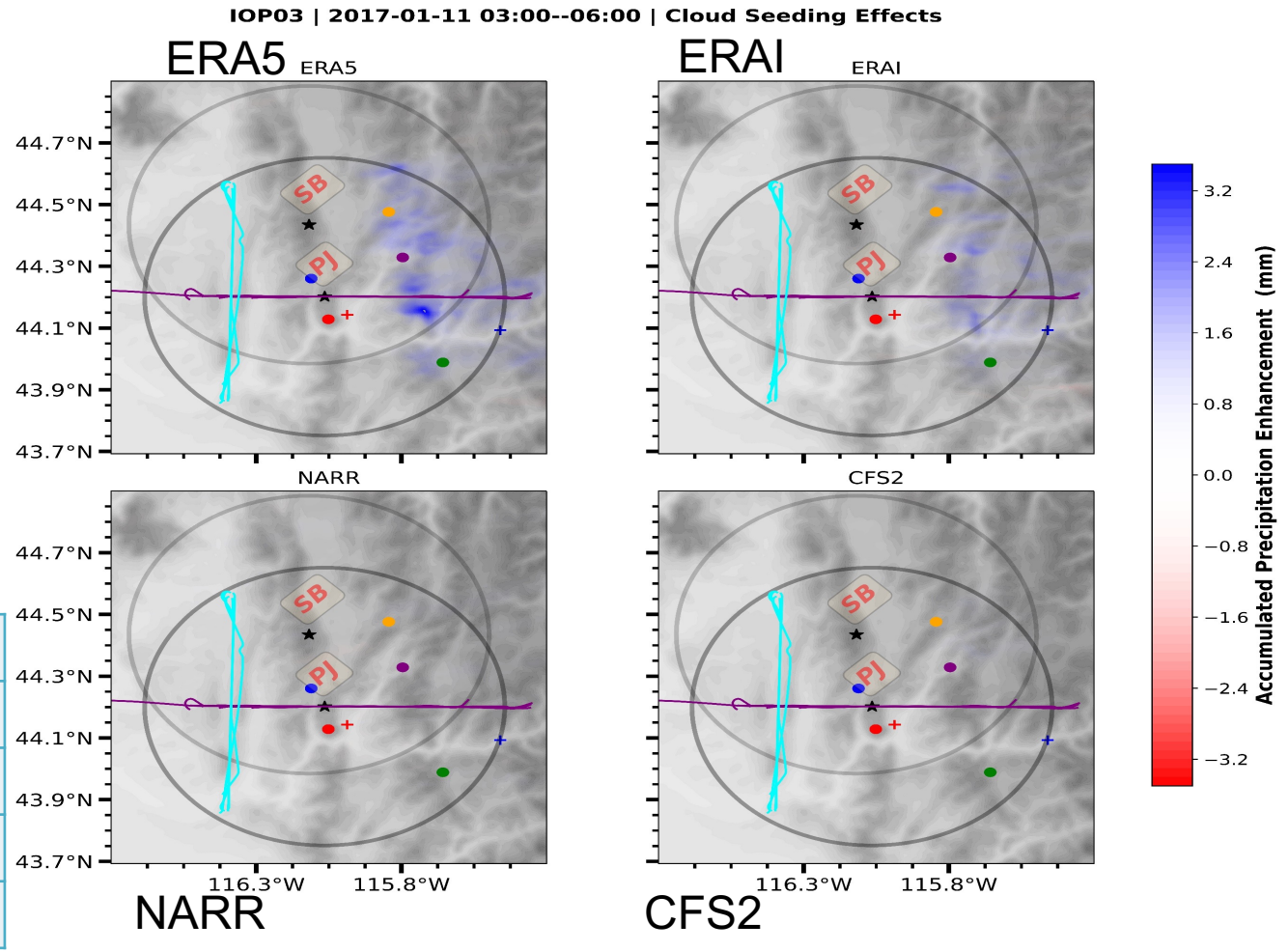
4. Regional Precipitation Enhancement

Obs (total)



0300-0600 UTC Precipitation Enhancement

Case	CTRL Precip (af)	SEEDED Precip (af)	Diff (af)
ERA5_900m	15367.51	17471.39	2104
ERAI_900m	19989.07	21520.7	1532
NARR_900m	40007.04	40432.31	425
CFS2_900m	36947.8	37180.28	232



Conclusion

Observations:

- Radar reflectivity increases from 0 dBZ to 12 dBZ over 15 mins / 25 km
- Precipitation falls out but cloud tops can remain at 4 km MSL (one of the two seeding lines)
- Water content and ice particles increase with time; Supercooled liquid water does not decrease as ice particles grow (in-situ obs)

Modeling Results

- Models compare differently in different categories; ERAx data slightly better
- All models are capably of representing seeding lines
- Wind affects the distribution (comparison with gauges)
- Seeding effect (precipitation amount differences 200-2000 af)