Microphysics of Summer Clouds in Central West Antarctica Simulated by Polar WRF and AMPS*

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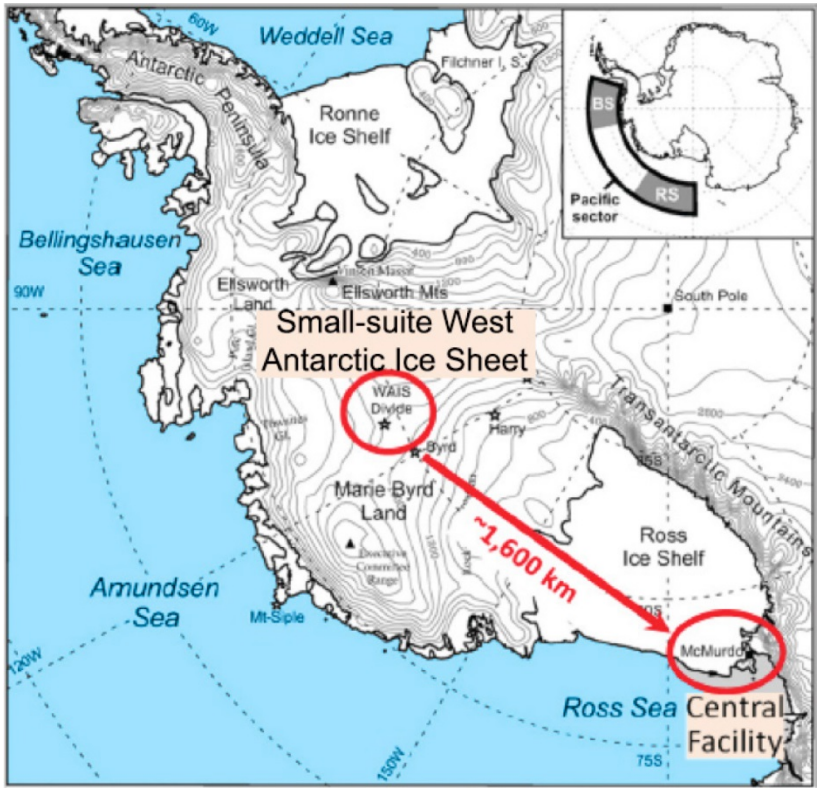
https://youtu.be/723763A24Fw

ARM West Antarctic Radiation Experiment (AWARE)

OBSERVATIONS: 23 NOVEMBER 2015 - 5 JANUARY 2017

Observations at West Antarctic Divide (WAIS) and McMurdo

West Antarctic warming during January 2016

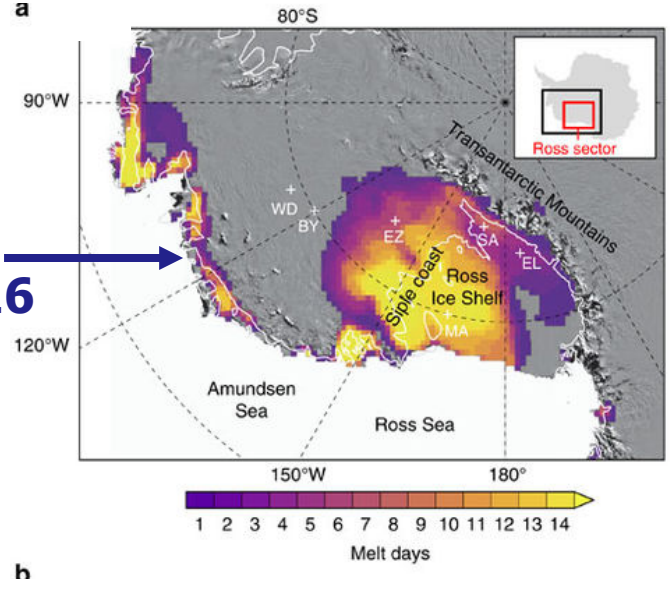


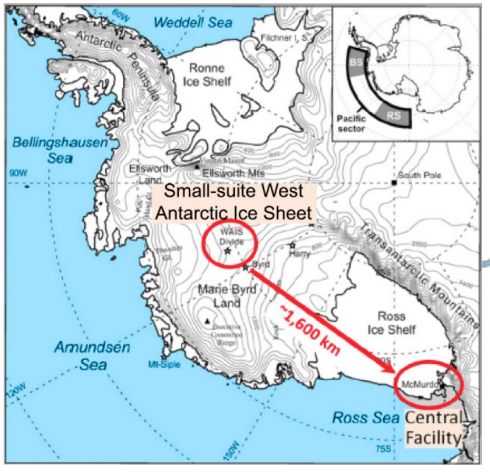
AWARE aimed to gain insight into the factors behind recent climate change in West Antarctica by quantifying the role of changing air masses on the surface energy balance. The field campaign used some of the most advanced atmospheric research instrumentation to conduct cloud, radiative, and aerosol observations.

AWARE: ARM West Antarctic Radiation Experiment

2015-2017 Cloud and Radiation Observations
Sites at West Antarctic Divide and McMurdo
Included January 2016 melting event
Evaluate AMPS real-time Antarctic forecast
Evaluate Polar WRF (distributed by OSU) simulations

Did clouds impact the January 2016 melting?





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Important for AWARE and WRF

Does our knowledge of Arctic clouds carry over to high southern latitudes?

Polar cloud observations (and modeling studies) much more extensive in Arctic than Antarctic

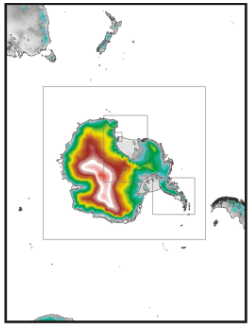
Antarctica is colder, drier and more pristine

AWARE observations suggest clouds less extensive than over the Arctic basin, however vertical motions are larger in these locations

Cloud water at very low air temperatures

Vertical cloud distribution is different

The Antarctic Mesoscale Prediction System (AMPS)



- **Adapted numerical weather prediction system for Antarctica**
  - **Polar WRF (Weather Research and Forecasting Model)**
  - **Variable resolution to 0.9 km**

- **Priority Mission: U.S. Antarctic Program (USAP) Weather Support (clouds important for aircraft!)**

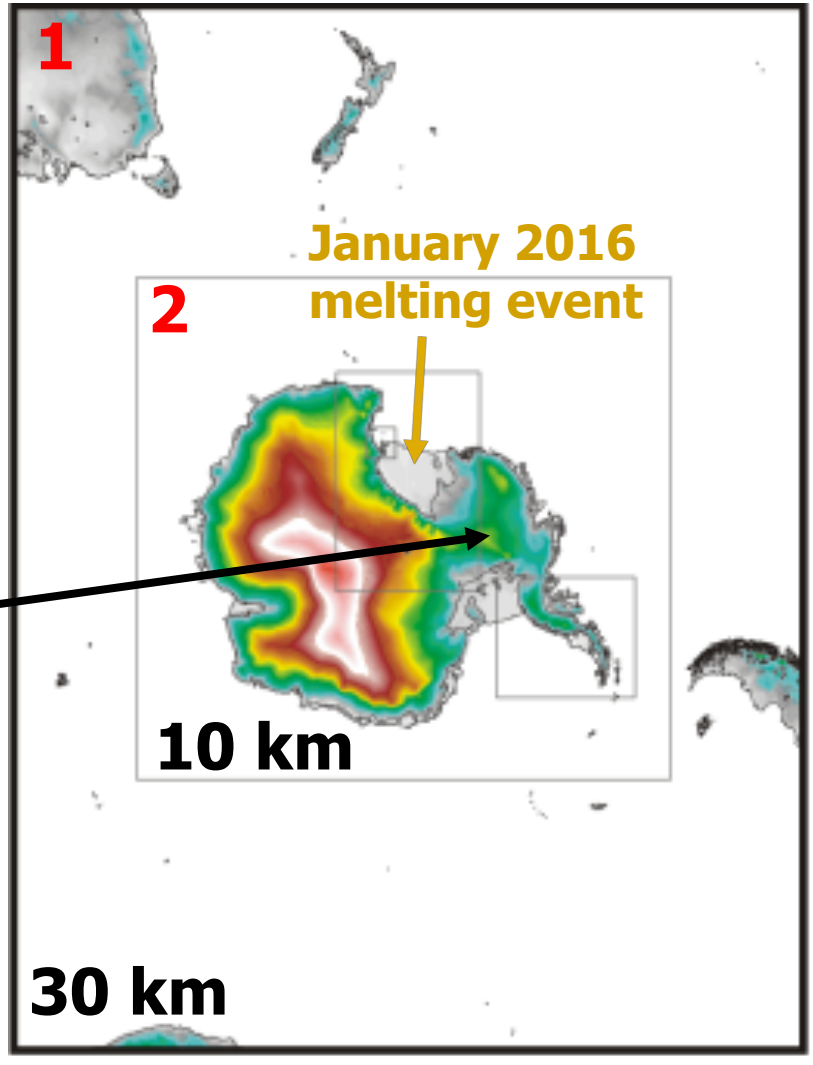
- **Collaborators: NCAR and OSU BPCRC**

- **Powers et al. (2012) A decade of Antarctic science through AMPS. BAMS, 93, 1699-1712.**
- **http://www.mmm.ucar.edu/rt/amps**

NCAR

National Science Foundation NSF

AMPS GRIDS



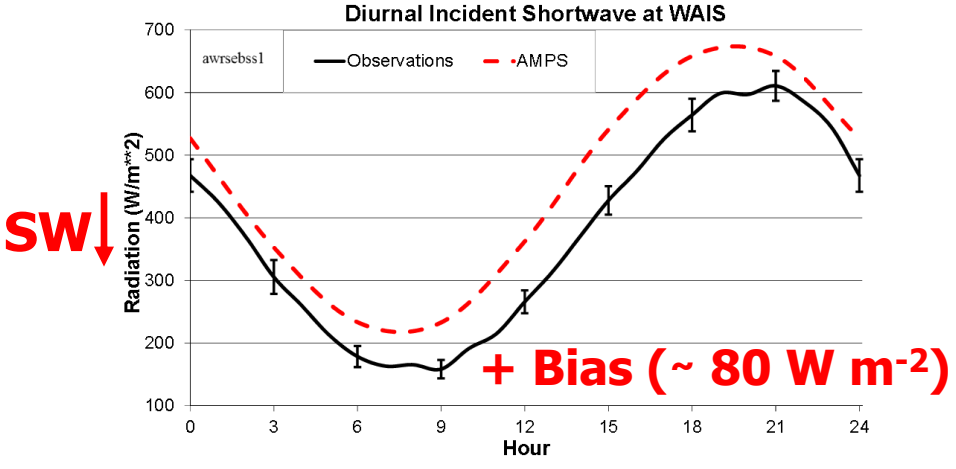
Use AMPS grid 2 for WAIS evaluation

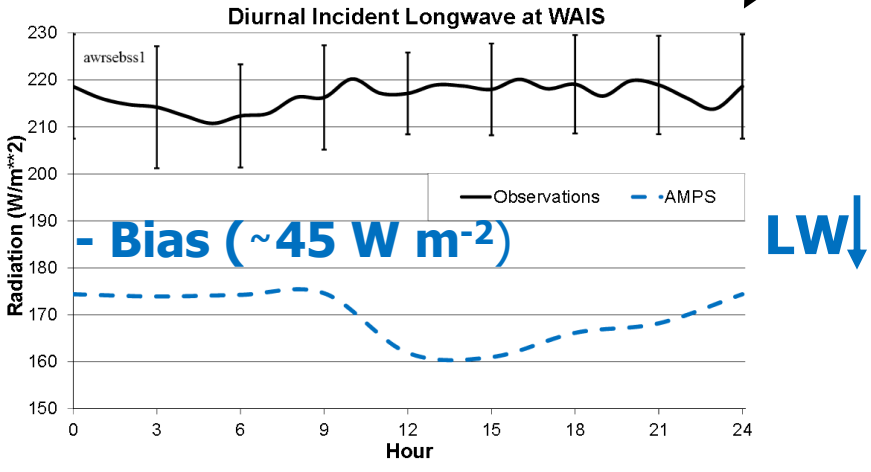
Use December 2015 and January 2016 AMPS forecasts and WAIS observations

Test West Antarctic Summer Results for AMPS with WAIS Observations

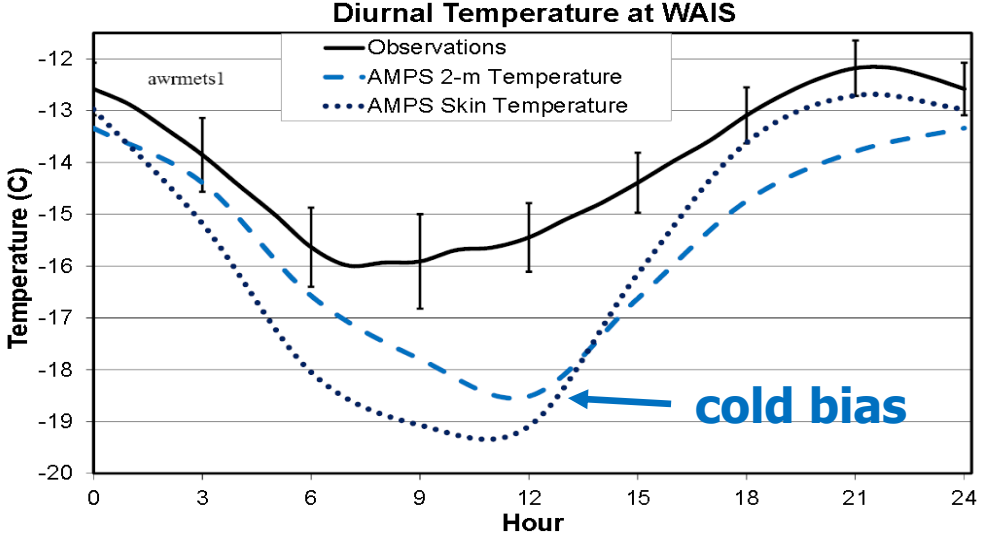
Surface Energy Balance: Excess shortwave and deficit in longwave → Cloud deficit?

t-test

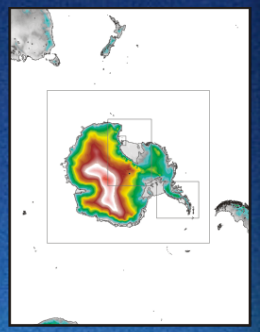




AMPS shows 2m-T biases suggesting a better Antarctic cloud simulation is needed



Test Microphysics Schemes vs. WAIS Observations



PWRF 3.9.1 on AMPS Grid 2 (10 km) with ERA-I I.C. + B.C. (AMPS uses GFS)

WRF Single-Moment 5-Class (same as AMPS)

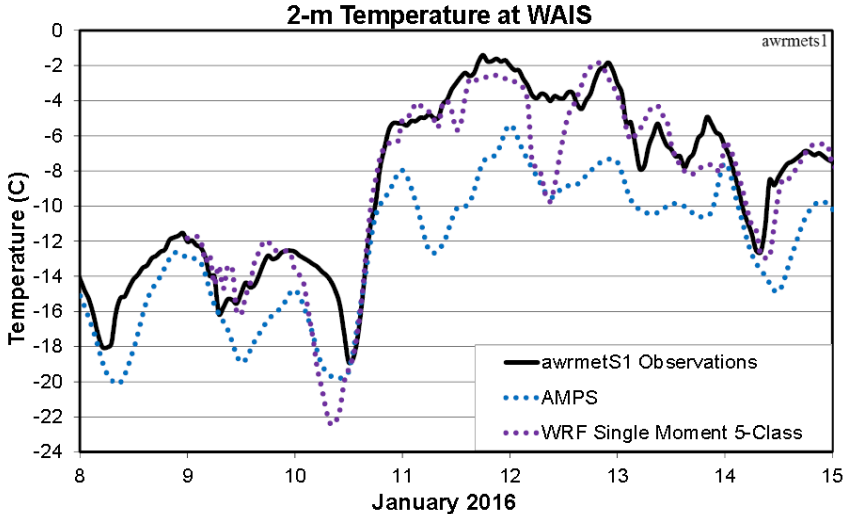
Morrison 2-Moment (slight polar modifications)

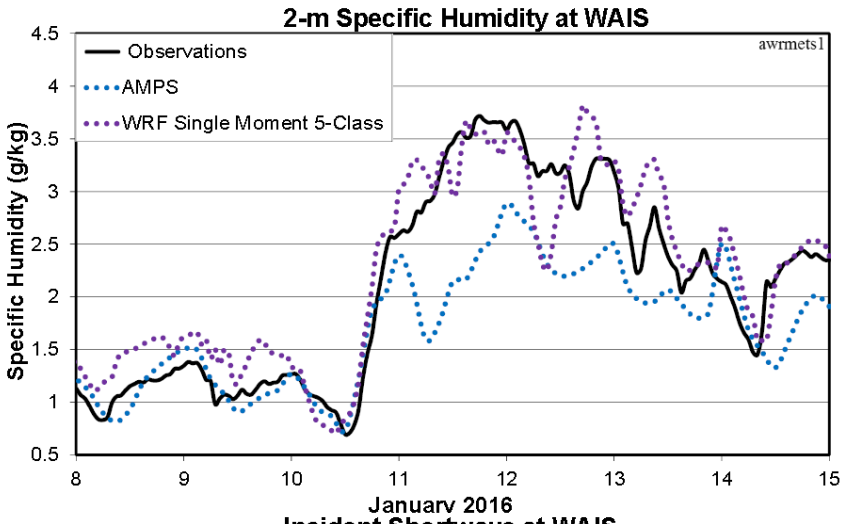
Thompson-Eidhammer Aerosol Aware

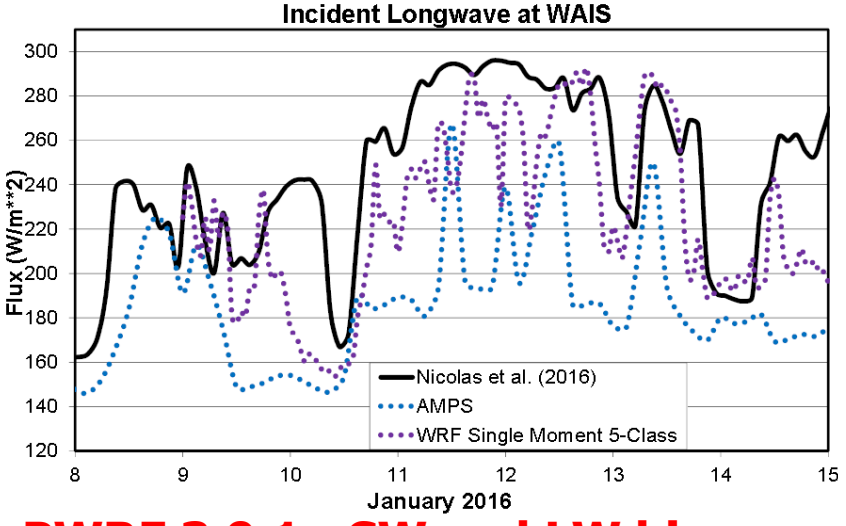
Morrison-Milbrandt P3 (avoids arbitrary cloud and precipitation categorization)

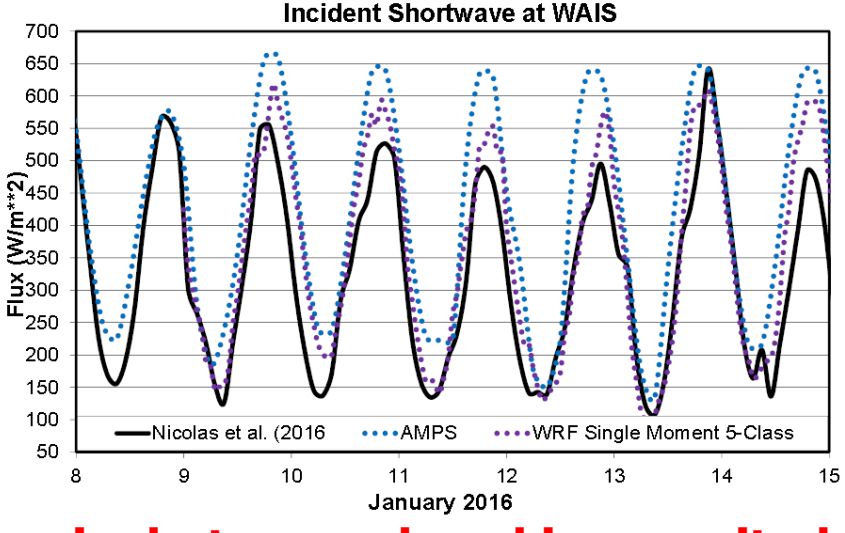
ERA-Interim best source for I.C. and B.C.

Near Surface Fields at WAIS 8 – 15 January 2016



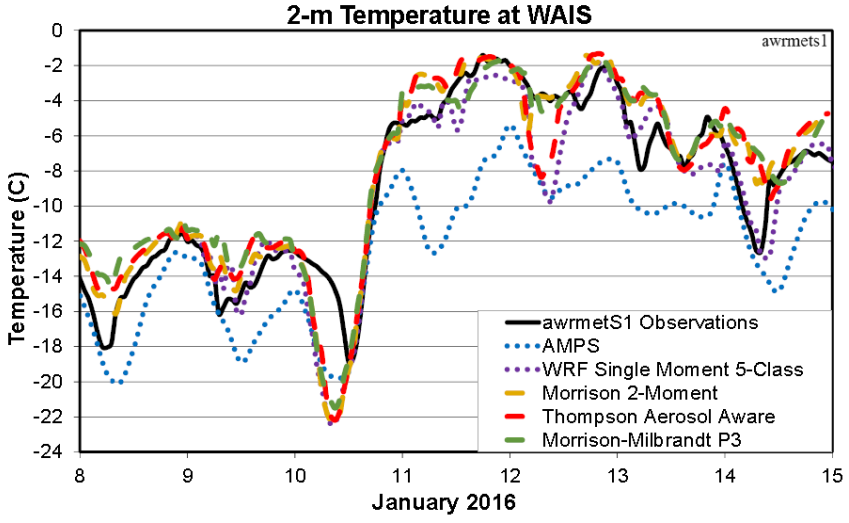


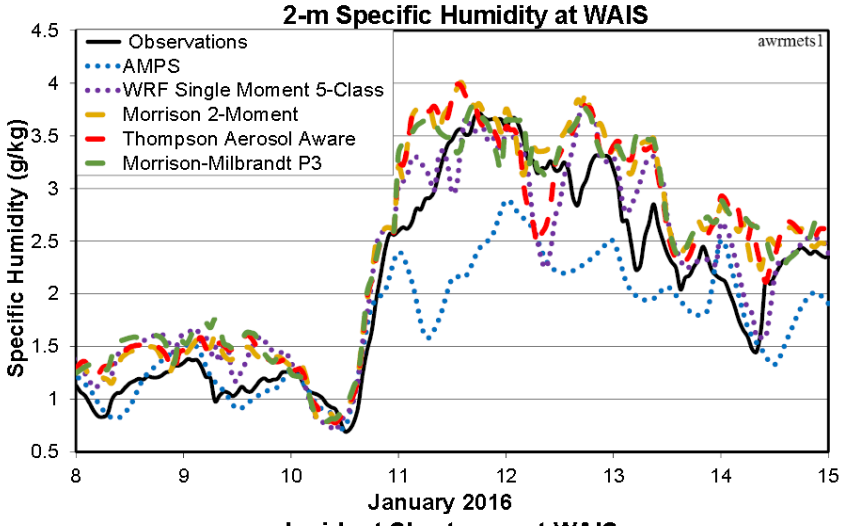


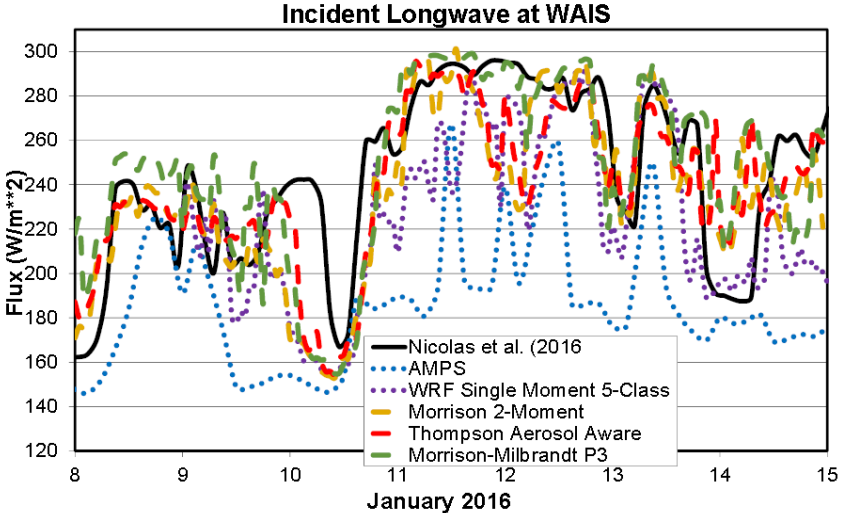


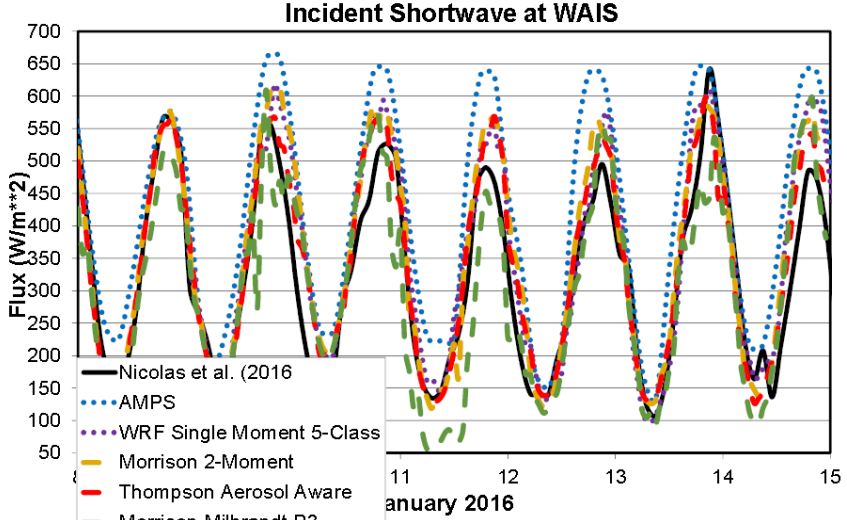
PWRF 3.9.1: SW and LW biases remain, but are reduced in magnitude due to ERA-I. Temperature and humidity biases are largely removed. Can use PWRF 3.9.1 to explore Antarctic cloud biases (AMPS linked).

Near Surface Fields at WAIS 8 – 15 January 2016



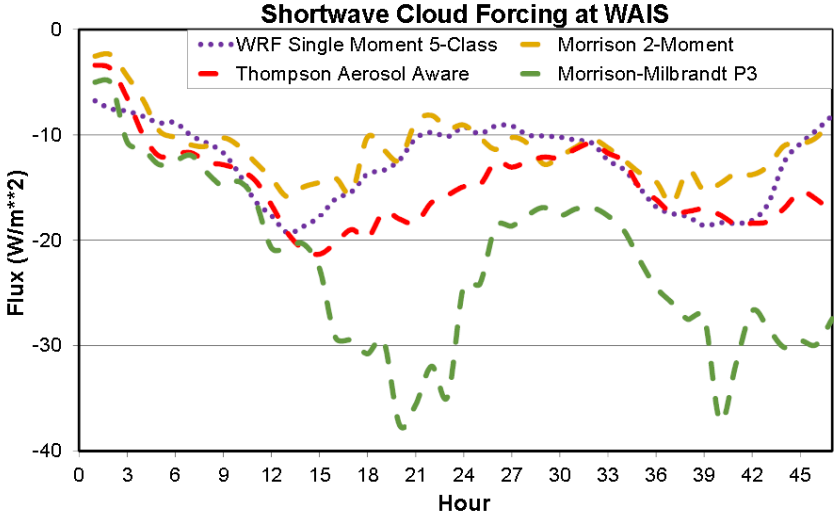


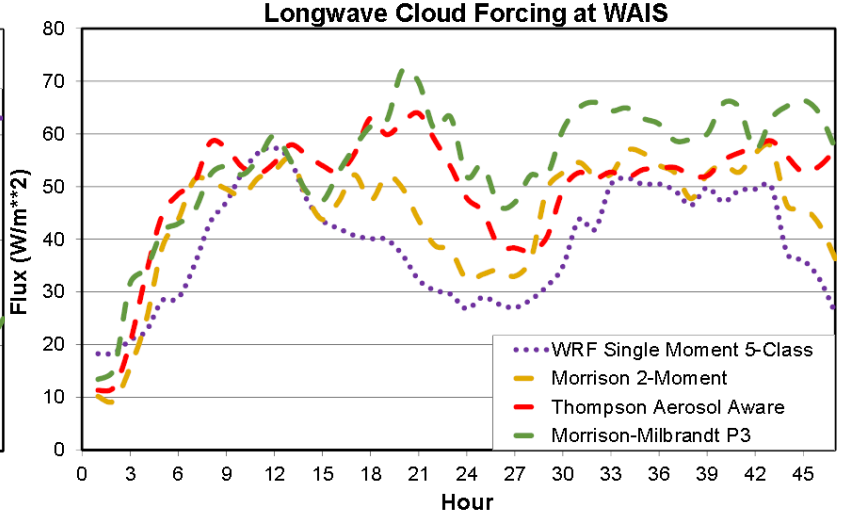


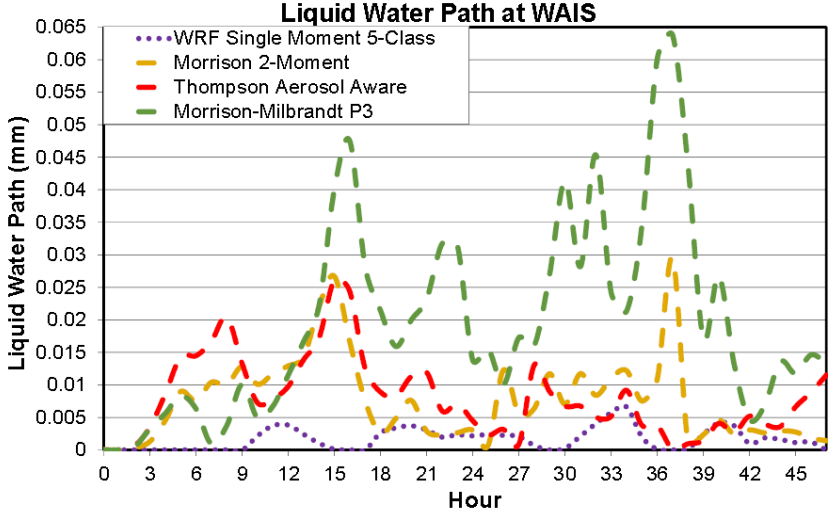


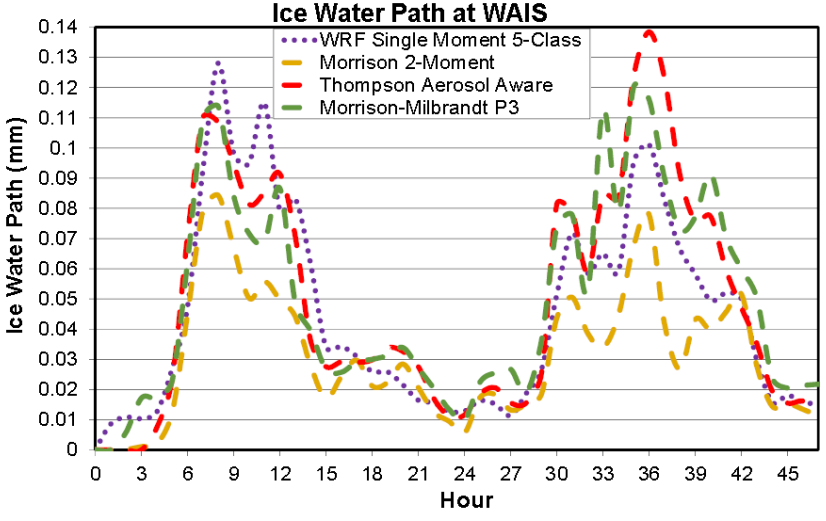
Run with more advanced microphysics schemes: Warm bias in 2-m T?
Schemes increase LW and reduce SW radiation – positive result!

Cloud Forcing at WAIS 8 – 15 January2016





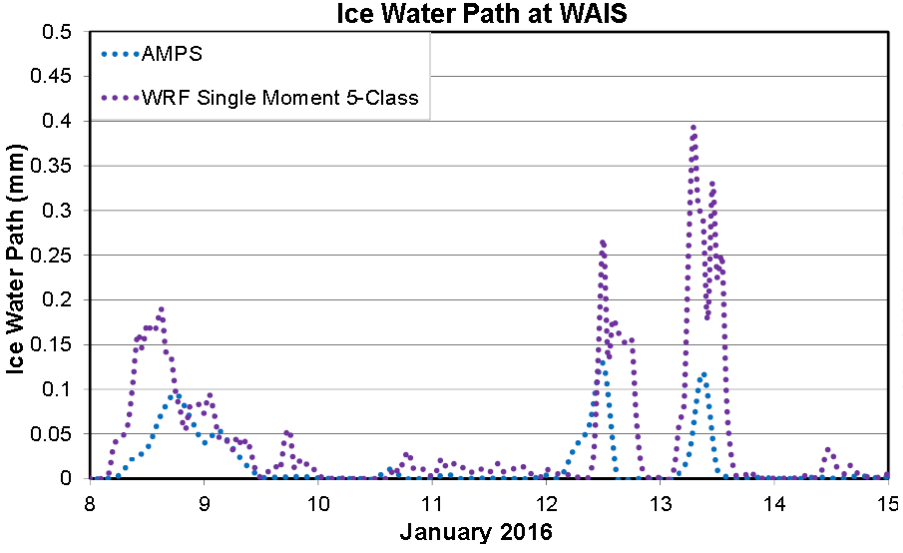


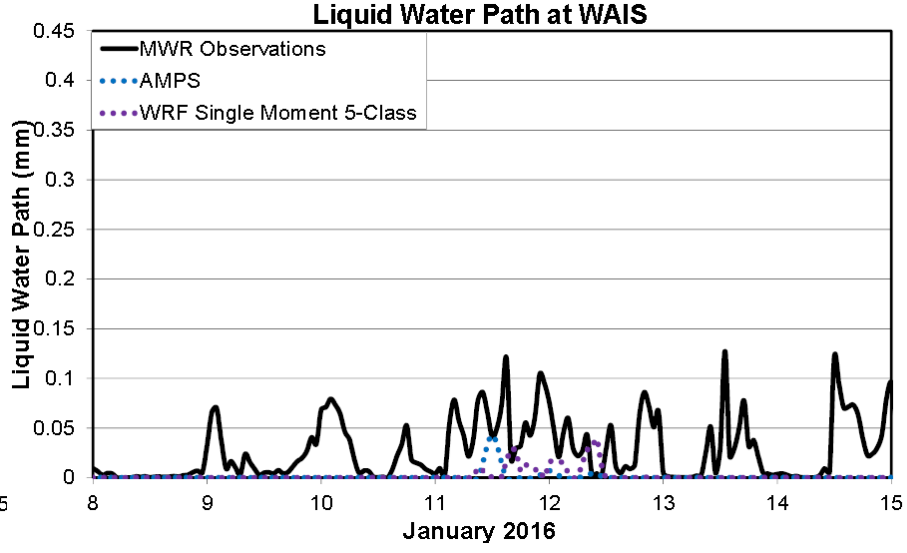


WSM5C has smallest LWP and slow spin-up of longwave cloud forcing.
M-M P3 scheme has largest LWP and stronger SWCF.
Microphysics schemes impact cloud radiative effects for Antarctica!

Cloud Condensate Path at WAIS 8 – 15 January 2016

AMPS and PWRF 3.9.1 with WRF Single-Moment 5-Class (WSM5C)





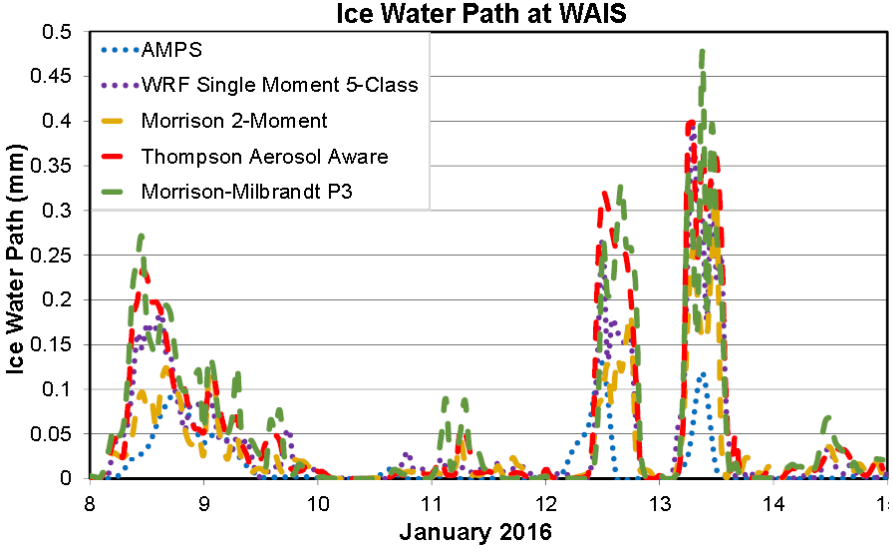
AMPS and PWRF 3.9.1 with WSM5C microphysics show much more ice water path than liquid water path.

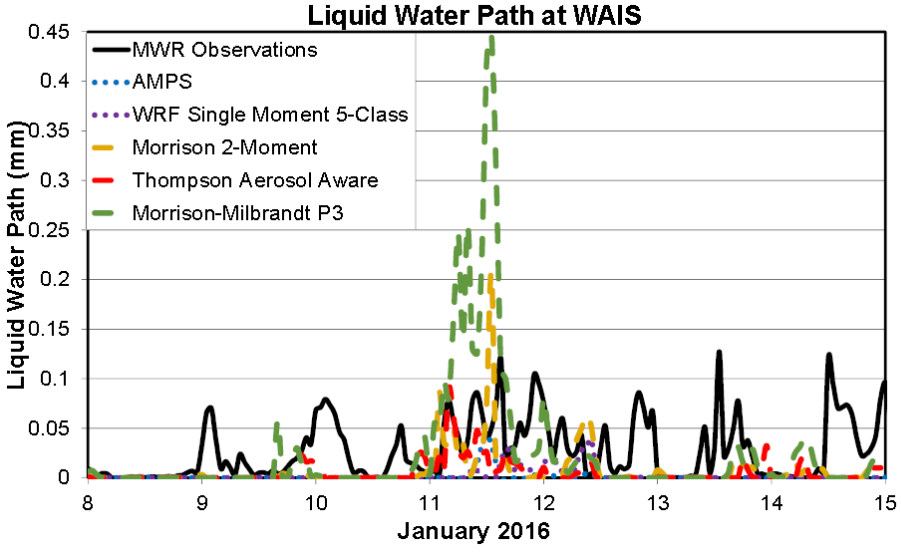
Simulated LWP is much less than values measured by the microwave radiometer (MWR).

Liquid has greater impact on downwelling radiation than ice.

Antarctic observations show liquid cloud at very low temperature.

Cloud Condensate Path at WAIS 8 – 15 January 2016



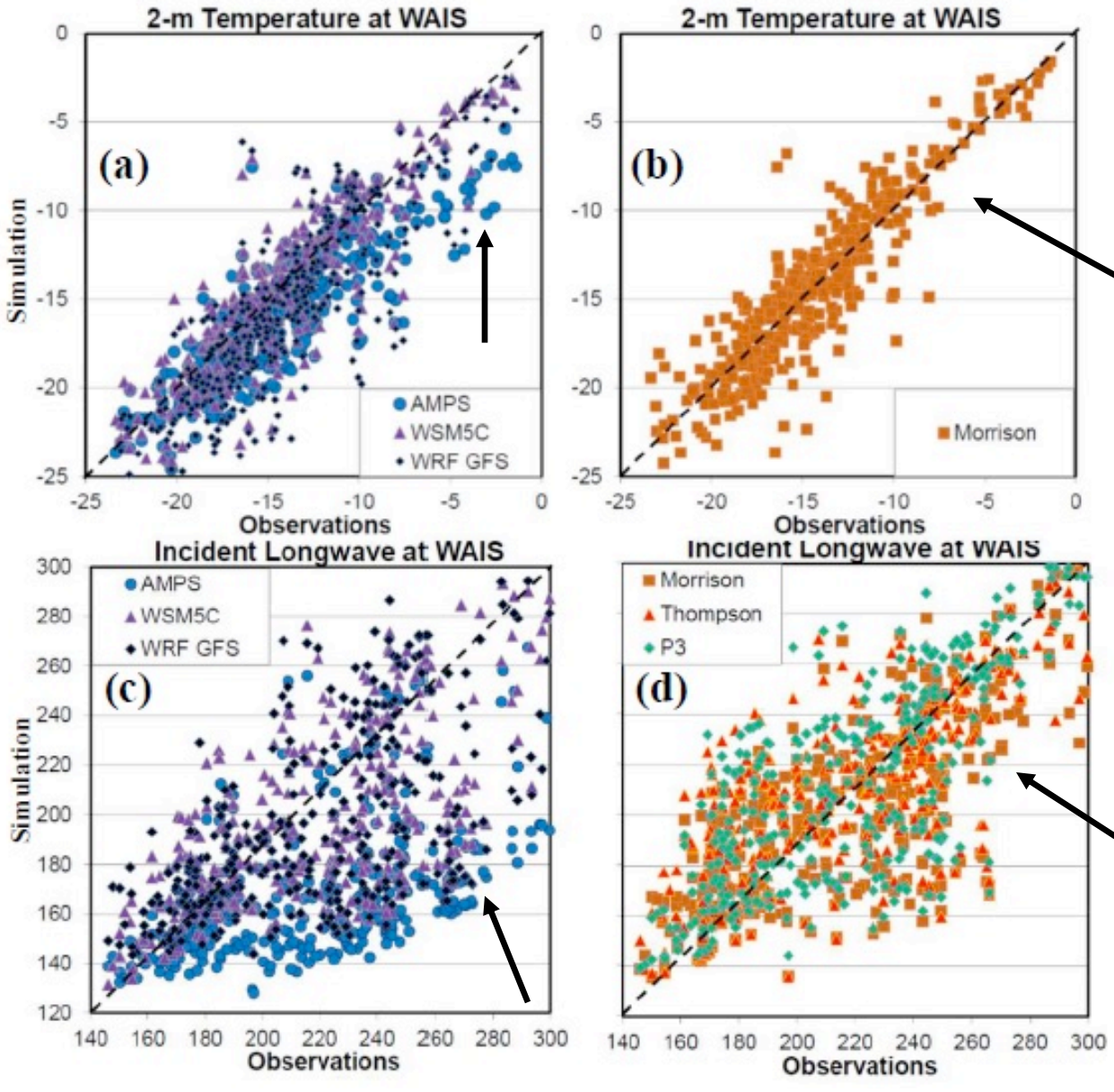


More advanced microphysics schemes increase ice water path and greatly increase liquid water path.

Morrison-Milbrandt P3 scheme shows a spike in liquid water on 11 January.

Day-to-day match of simulated and observed LWP is poor.

Simulating cloud water on cold days needs research.

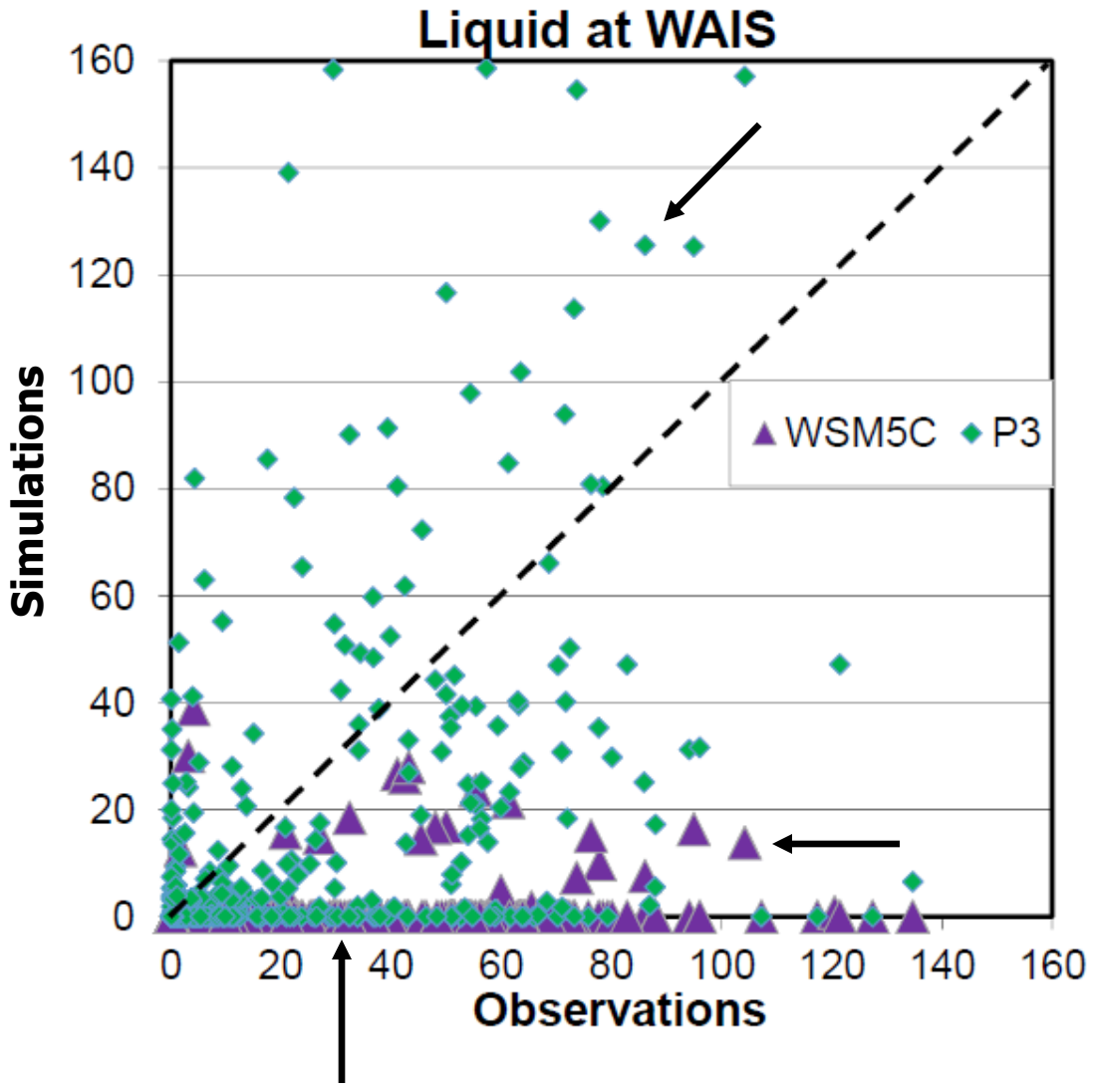


AMPS with WRF Single-Moment 5 Class is too cold, especially at warm temperatures

Polar WRF with Morrison microphysics is reasonable

WSM5C runs show too little downwelling longwave for cloudy skies

Two-moment runs show reasonable downwelling longwave.



Many cases when cloud water is observed very little cloud water is simulated.

Simulations with the WRF Single-Moment 5 Class microphysics produce too little cloud water.

Simulations with double-moment microphysics produce more cloud water, yet still not enough.

Summary of AMPS and PWRF Findings with the AWARE Project

Liquid water deficit in AMPS clouds

Cloud radiative effect of AMPS clouds is too small

More advanced microphysics schemes increase the simulated liquid water and increase the cloud radiative effect

Which microphysics scheme is best? – not certain

Need to work more on simulating cloud water at colder temperatures.

Clouds are critical for improving AMPS forecasts