Simulating Frigid Supercooled Clouds for McMurdo, Antarctica

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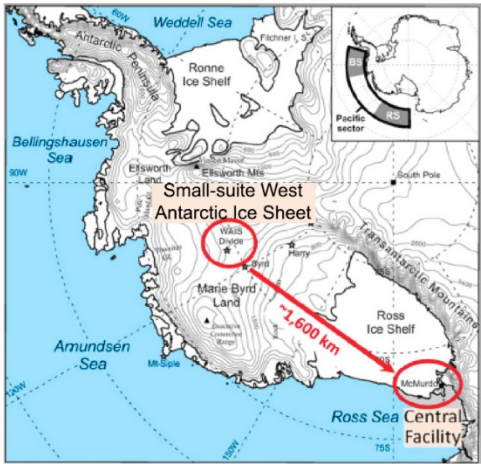

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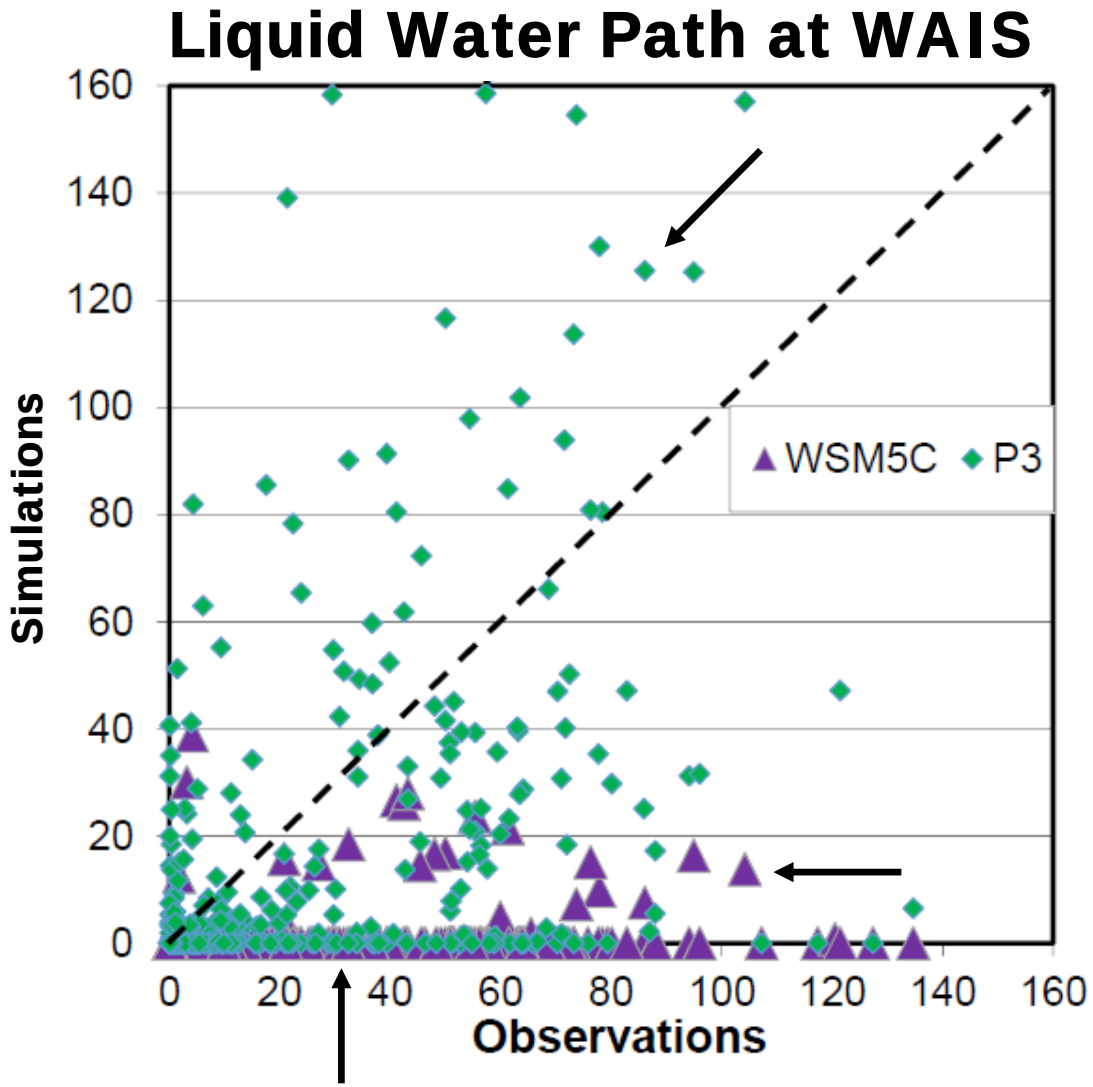
ARM CLIMATE RESEARCH FACILITY

Workshop on Antarctic Meteorology and Climate
21-23 June 2021

Previous AWARE PWRF Work for West Antarctica during Summer at WAIS Divide



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.

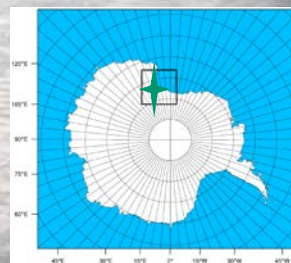
Test Modifications to the P3 (Predicted Particle Properties) Microphysics Scheme to 2016 McMurdo Observations

PWRF 4.1.1 on 10 km and 2 km grids with ERA5-driven initial and boundary conditions

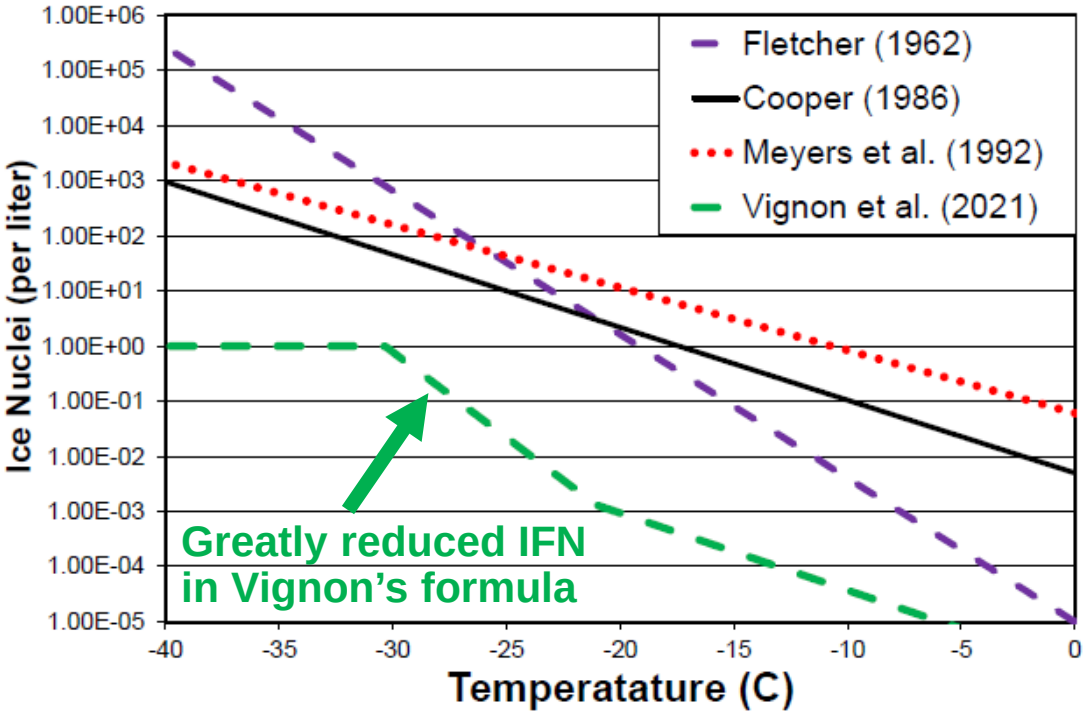
Morrison Milbrandt P3 microphysics (avoids arbitrary cloud and precipitation categorization) – can be considered an advancement to the Morrison microphysics

Data assimilation to Rawinsondes and AWS observations for improved setting for realistic cloud development

Hines et al. 2021 submitted to JGR



Ice Freezing Nuclei (IFN) as a function of Temperature



Many formulas: IFN increases with decreasing T

"Plenty" of IFN available at low T by classic formulas

Vignon et al. (2021) new IFN formula for the Southern Ocean based upon observations.

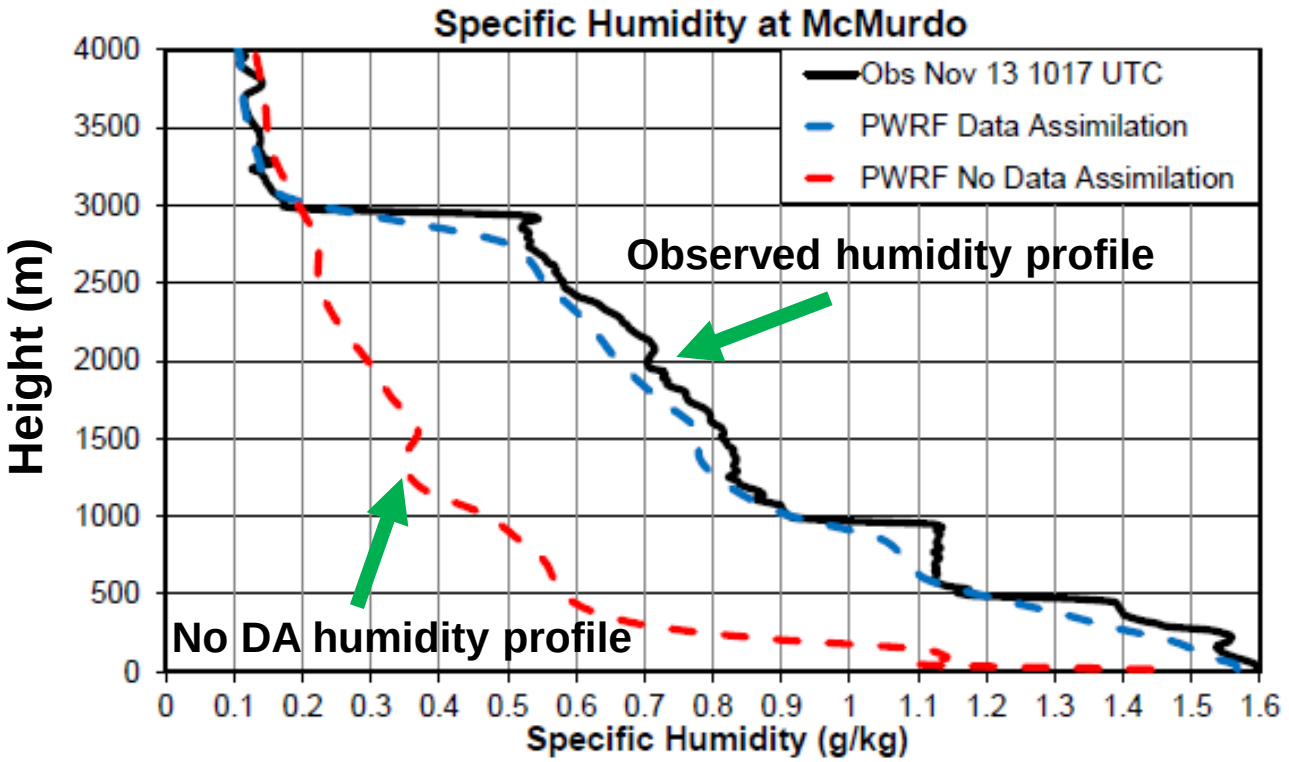
IFN are limited over High Southern Latitudes

- limits ice formation in clouds

Region is known to be pristine

New IFN observations (McCluskey et al. 2018)

Data Assimilation of Radiosondes and Local AWS Observations Improves Cloud Simulations in Polar WRF



ERA5 is biased dry for coastal Antarctica?

Dry atmosphere – less clouds in PWRF

Mesoscale data assimilation for better humidity

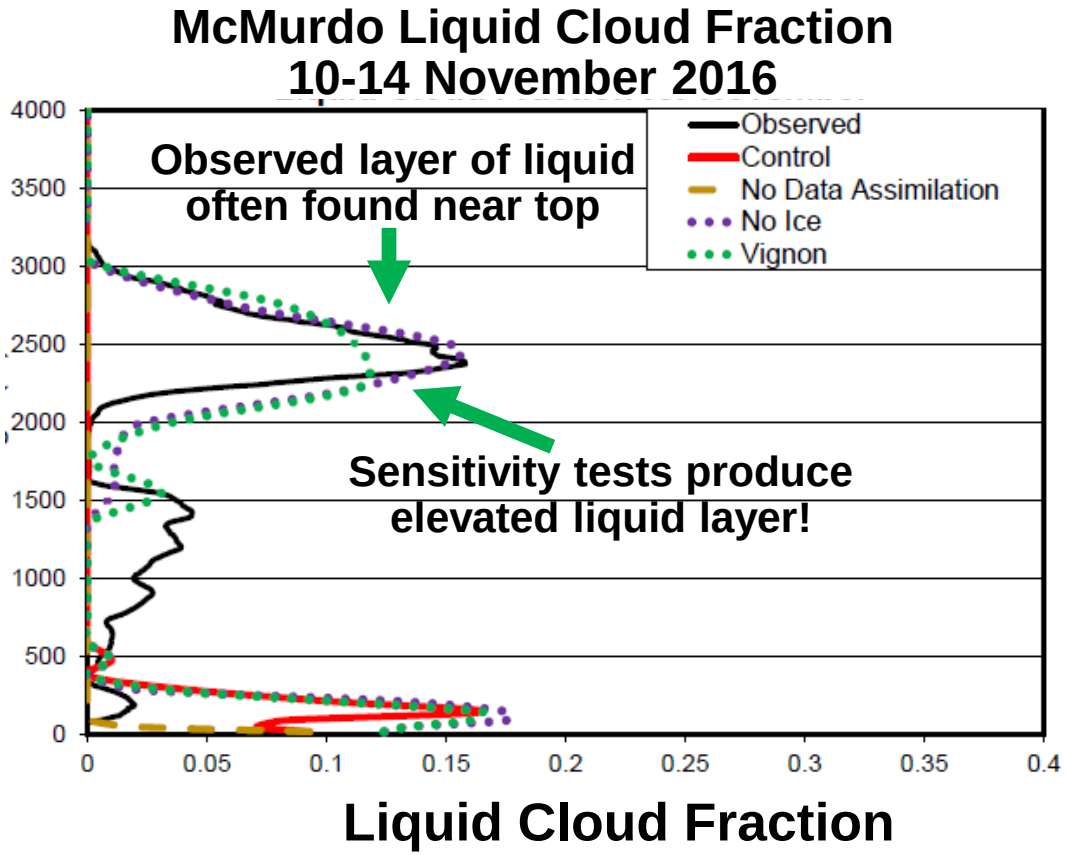
More humidity – more clouds and better match to cloud observations!

Data assimilation important for cloud studies!

Polar Meteorology Group, Byrd Polar and Climate Research Center, The Ohio State University, Columbus, Ohio

Test of Modified WRF P3 Microphysics in PWRF Simulations for Coastal Antarctica

Reduce ice freezing nuclei (IFN) in ice physics to match pristine observations



Liquid cloud layers near cloud top in coastal Antarctic (also Arctic) clouds

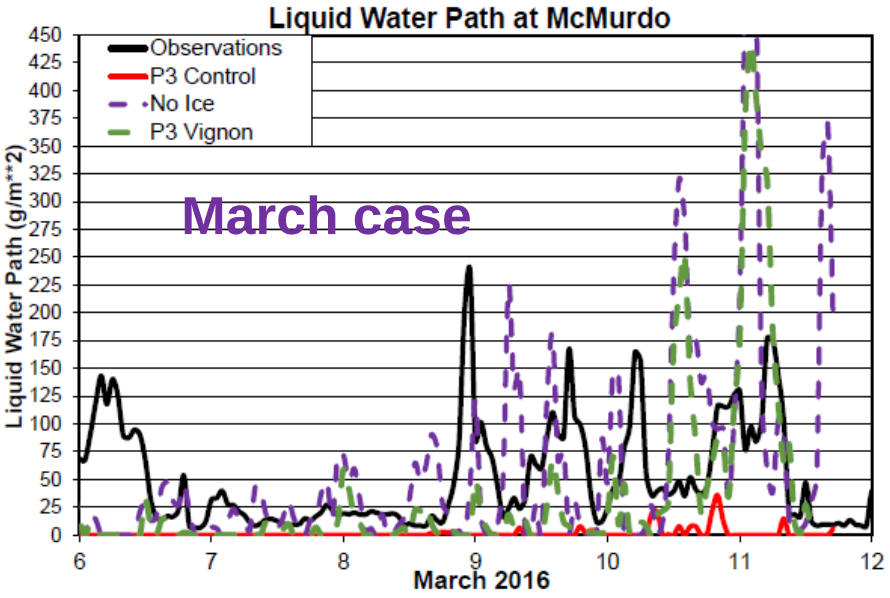
Small IFN concentration observations over Southern Ocean

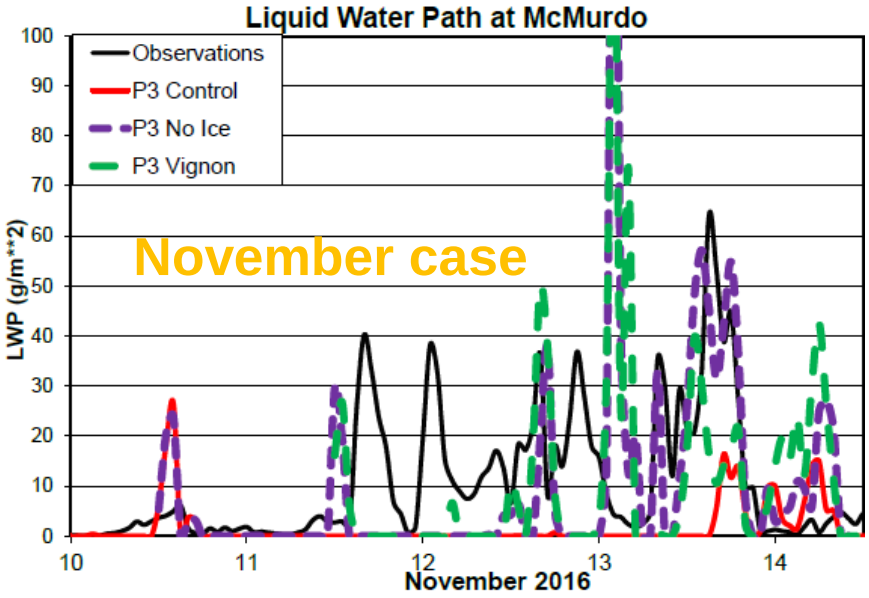
Control simulation (red) – no upper liquid layer

Sensitivity tests (dashed) with Polar WRF – reduce ice formation

LWP amounts increase and become more realistic

Liquid Water Path for Simulations of Frigid Mixed-Phase Clouds for March and November 2016





Control and two sensitivity tests

Control simulation undersimulates Liquid Water Path (LWP)

Changes to the microphysics increase the LWP at McMurdo

Changes to the microphysics decrease the IWP at McMurdo

Summary

Frigid (T ~ -30°C) mixed-phase clouds observed during AWARE at McMurdo in pristine coastal Antarctica

Polar WRF 4.1.1 simulations examine cases during March and November 2016

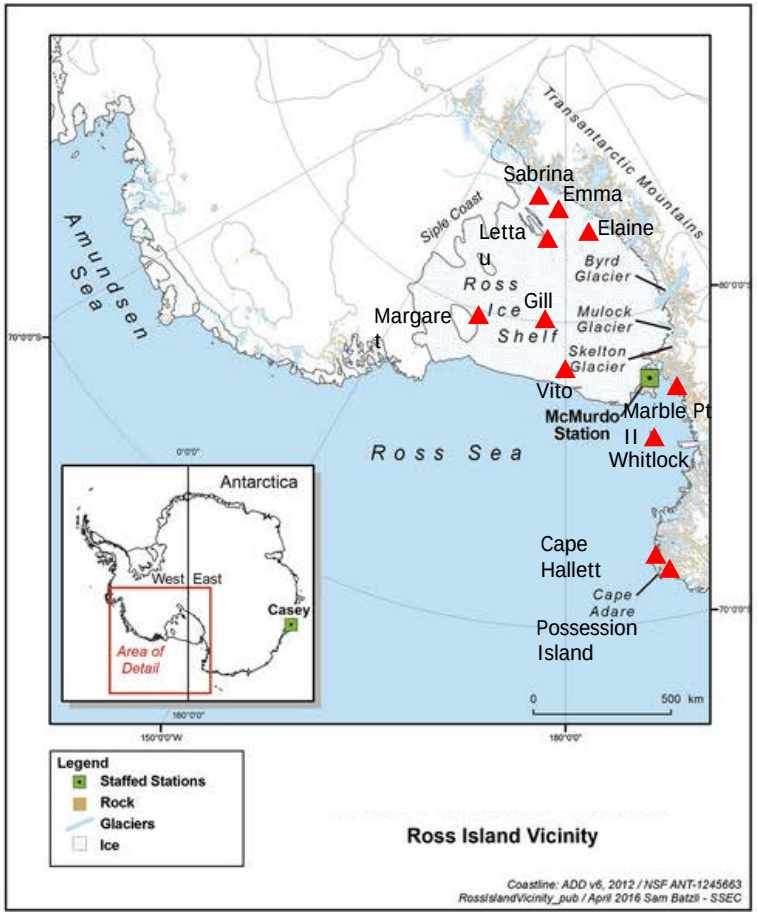
Data assimilation increases humidity and improves cloud simulations

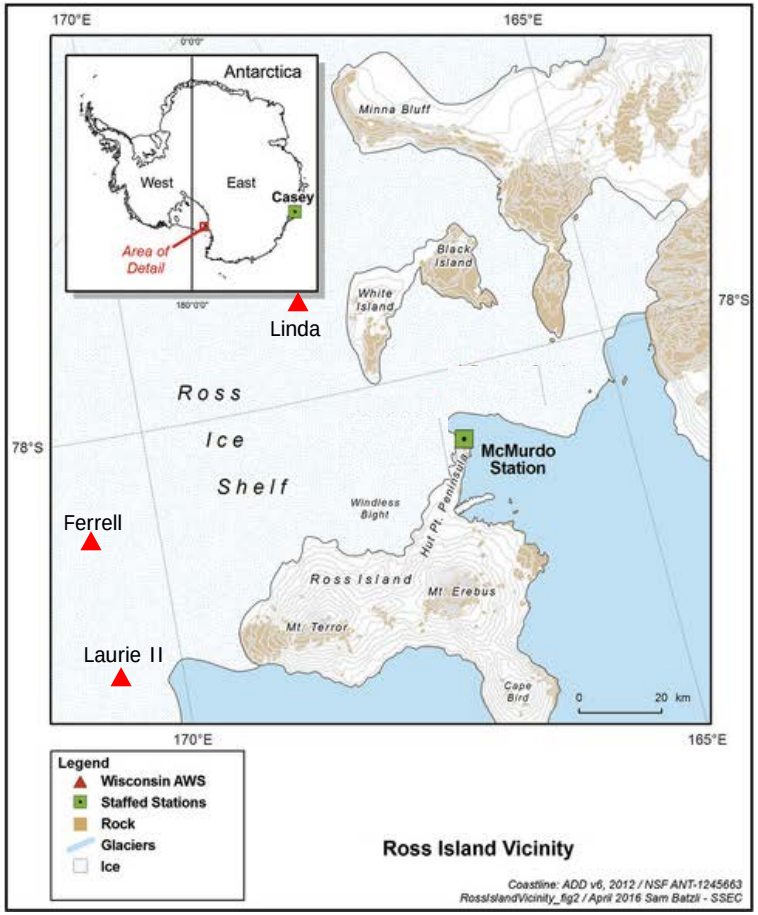
Sensitivity tests modify the P3 microphysics for reduced ice cloud production

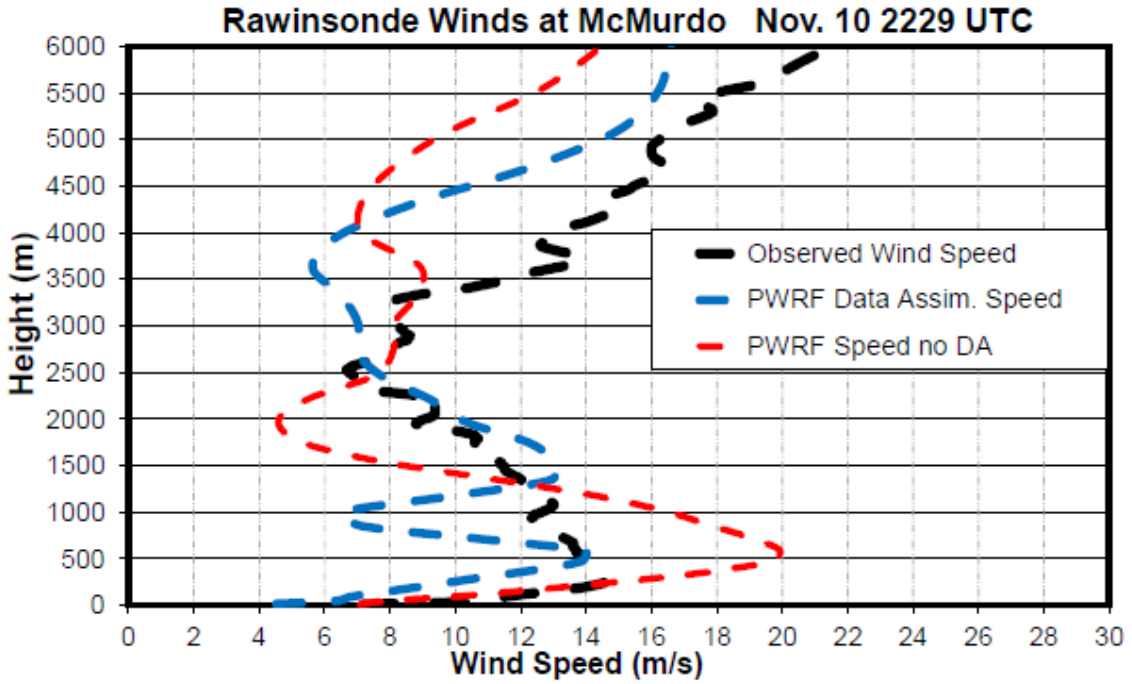
Reduced IFN concentrations slow the transformation from supercooled liquid to ice

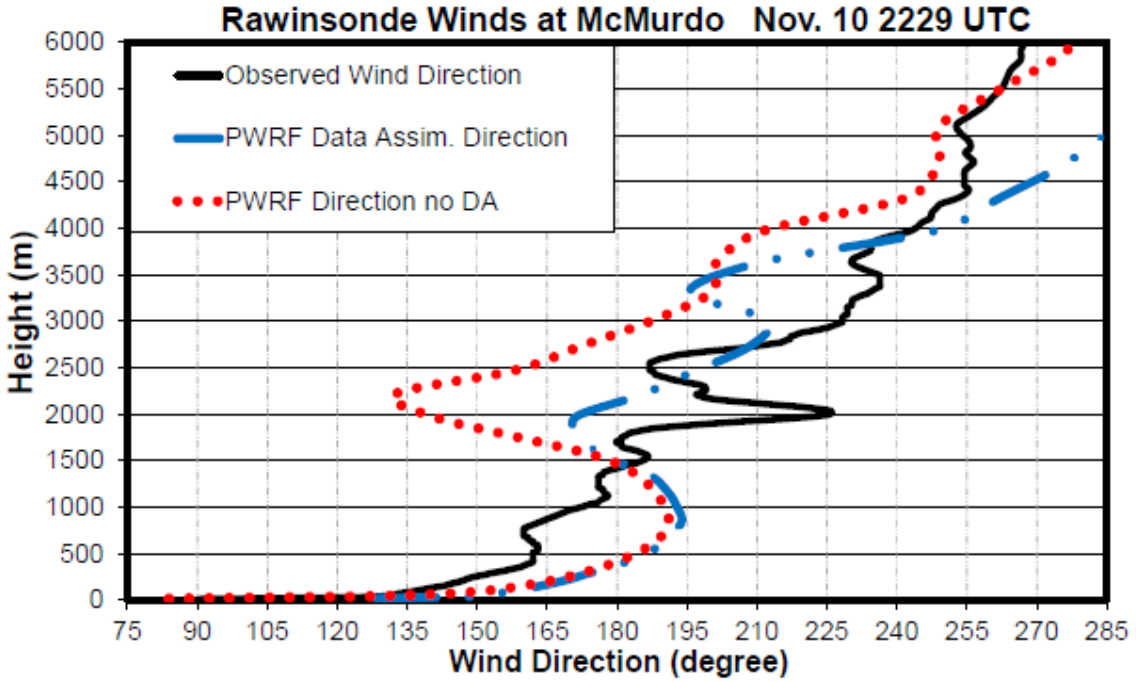
Modified microphysics increases cloud liquid and improves the simulation realism (including sfc radiation)

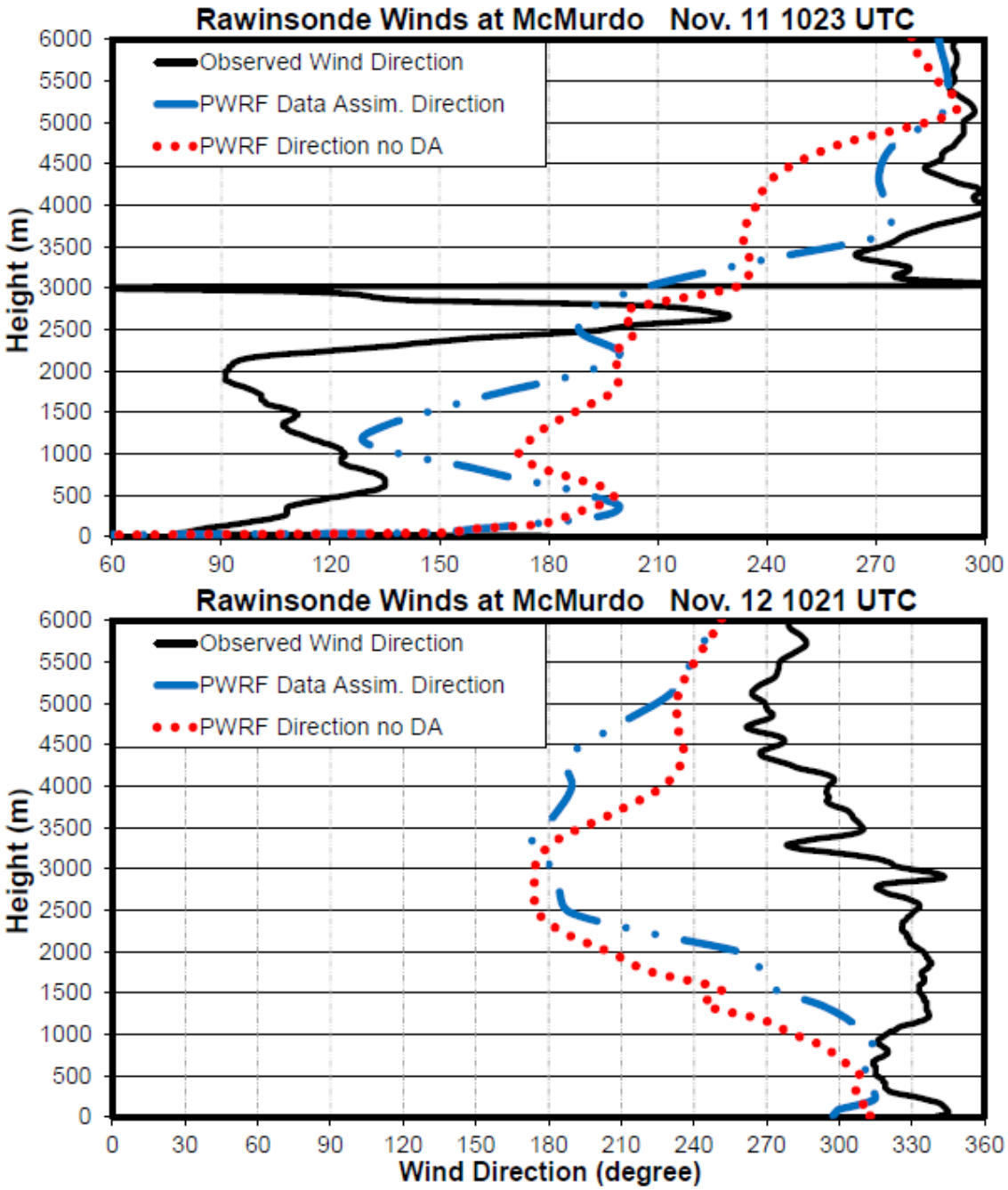
Automatic Weather Stations (AWS) near McMurdo






Rawinsonde Winds at McMurdo Nov. 10 2229 UTC
Height (m)
Wind Speed (m/s)
Observed Wind Speed
PWRF Data Assim. Speed
PWRF Speed no DA


Rawinsonde Winds at McMurdo Nov. 10 2229 UTC
Height (m)
Wind Direction (degree)
Observed Wind Direction
PWRF Data Assim. Direction
PWRF Direction no DA


Rawinsonde Winds at McMurdo Nov. 11 1023 UTC
Observed Wind Direction
PWRF Data Assim. Direction
PWRF Direction no DA
Height (m)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
60
90
120
150
180
210
240
270
300
Rawinsonde Winds at McMurdo Nov. 12 1021 UTC
Observed Wind Direction
PWRF Data Assim. Direction
PWRF Direction no DA
Height (m)
0
30
60
90
120
150
180
210
240
270
300
330
360
Wind Direction (degree)