Evaluation of cloud forecasting by AMPS/Polar WRF

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Byrd Polar Research Center
Polar Meteorology Group
The Ohio State University

Why evaluate clouds in AMPS?

Reliable cloud forecasts are important:

- for aircraft operations in Antarctica
- for non-operational applications (role of clouds in the radiation budget and hydrological cycle)

An evaluation of AMPS cloud forecasts was presented by Fogt and Bromwich (2008), when Polar MM5 was the AMPS forecasting model
What about AMPS cloud forecasts generated with Polar WRF?

What we did

The evaluation focuses on austral summer months (January and February)
Cloud forecasts from AMPS/MM5 and AMPS/WRF are contrasted:

- AMPS/MM5 for 2006, 2007 & 2008
- AMPS/WRF for 2009, 2010 & 2011

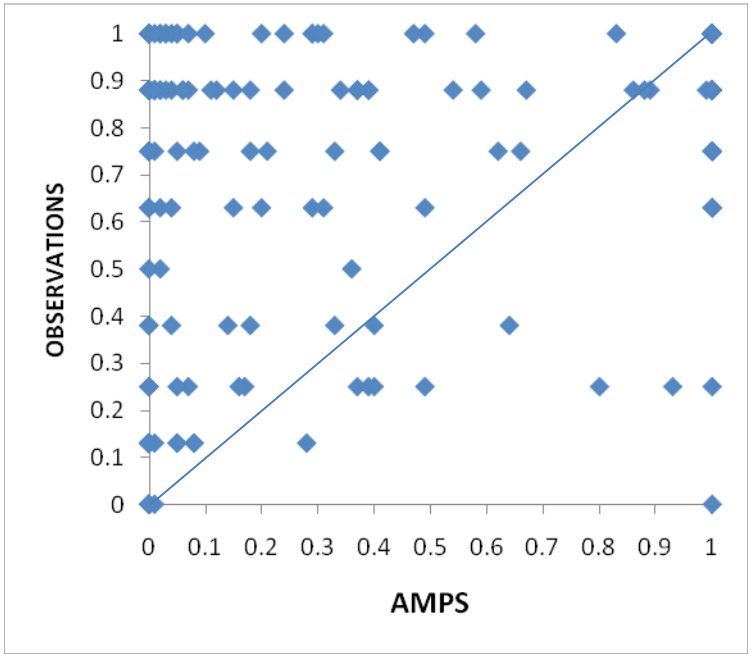
To evaluate AMPS forecasts, we used:

- joint satellite retrievals from CloudSat & CALIPSO produced by J. Kay (NCAR)
- Swath products from CALIPSO to investigate clouds on a specific day

Statement of the problem

Clear deficit of clouds in AMPS when compared to cloud reports from human observers at McMurdo in summer 2011
Consistent with the feedbacks from MacWeather forecasters
Is this confirmed by satellite observations?

Observed cloud fraction vs AMPS at McMurdo (Jan-Feb 2011)



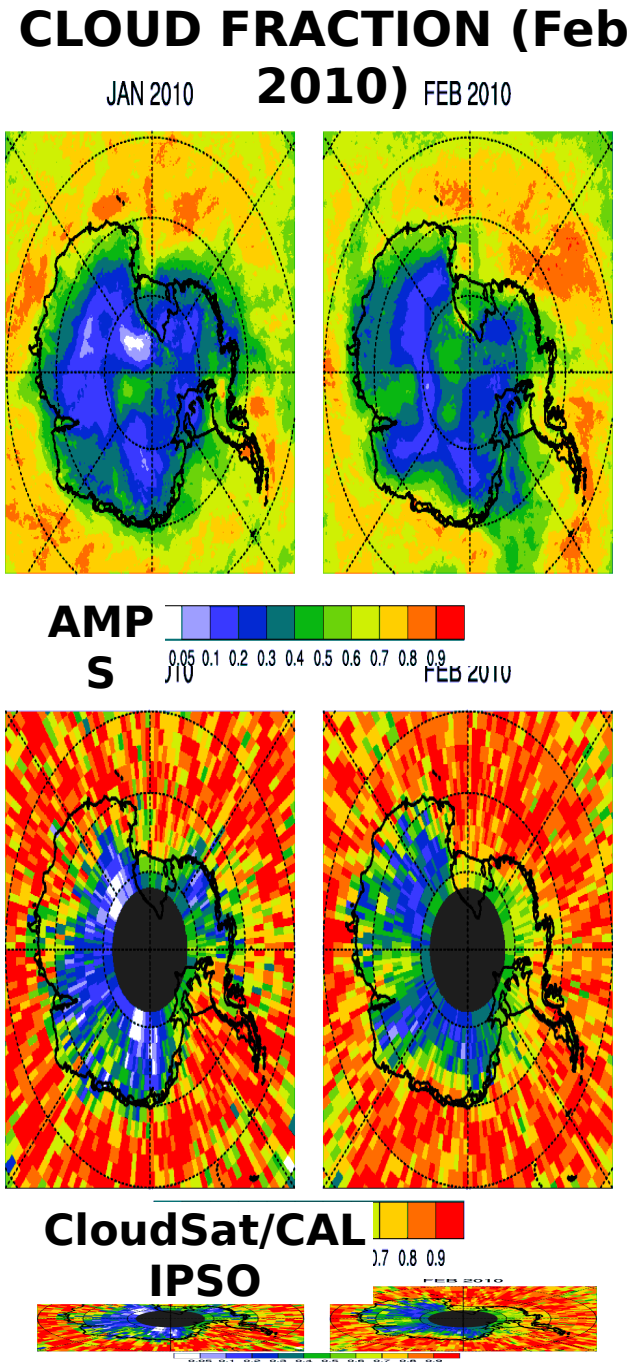
I. AMPS total cloud fraction/frequency in January-February

Cloud fraction vs frequency

In the following, we use
Total cloud fraction: the 6-hourly cloud fractions from AMPS are averaged to produce monthly means
Total cloud frequency: All model gridpoints with CF>0 are set to CF=1, before computing the monthly average. This approach better replicate the satellite cloud retrieval algorithm.

Total cloud fraction

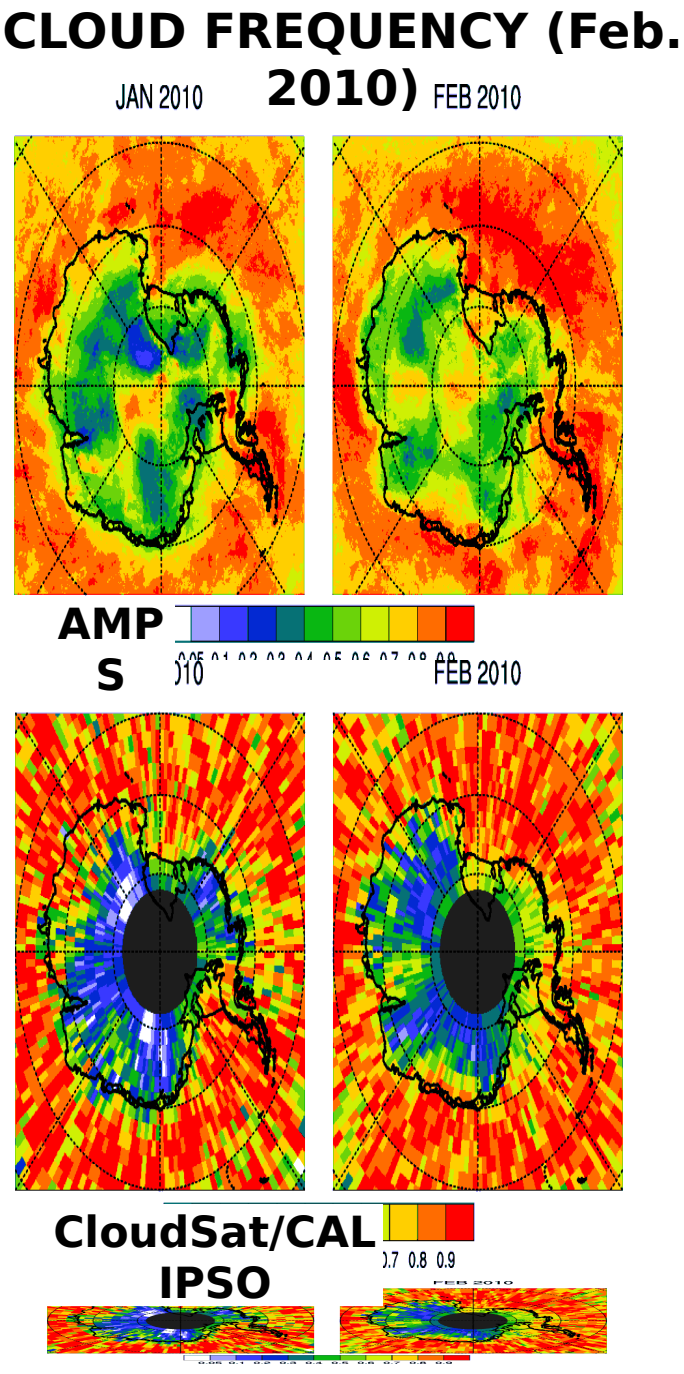
AMPS seems to underestimate the cloud amounts (by 20-30%) over the Southern Ocean
Relatively good skill in the East Antarctic interior



Total cloud frequency

Better agreement between AMPS and CloudSat/ CALIPSO over the Southern Ocean

But this method tends to overestimate the cloud amounts where CF is low (e.g. East Antarctica)

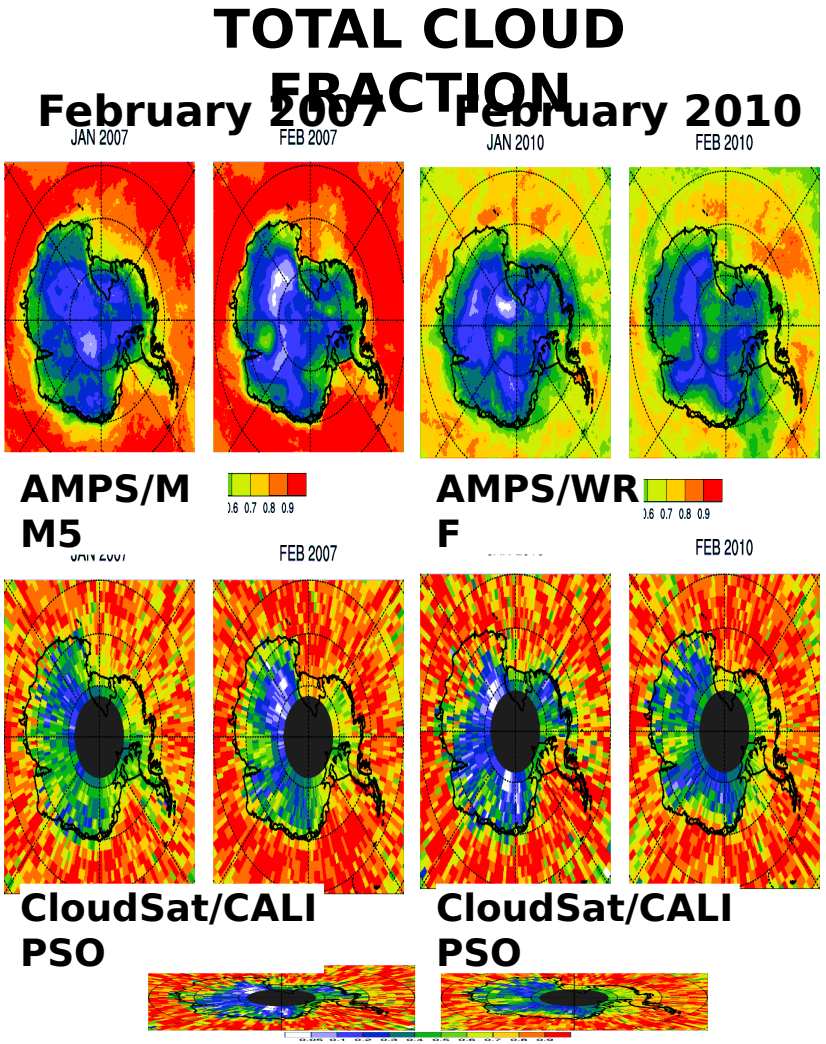


AMPS/MM5 vs AMPS/WRF

CloudSat/CALISPO suggests no significant change in cloud cover over the Southern Ocean between Feb 2007 and Feb 2010

Yet, much greater cloud fraction in AMPS/MM5 (>80%) than in AMPS/WRF (50-80%)

The conclusions are the same for the cloud frequency



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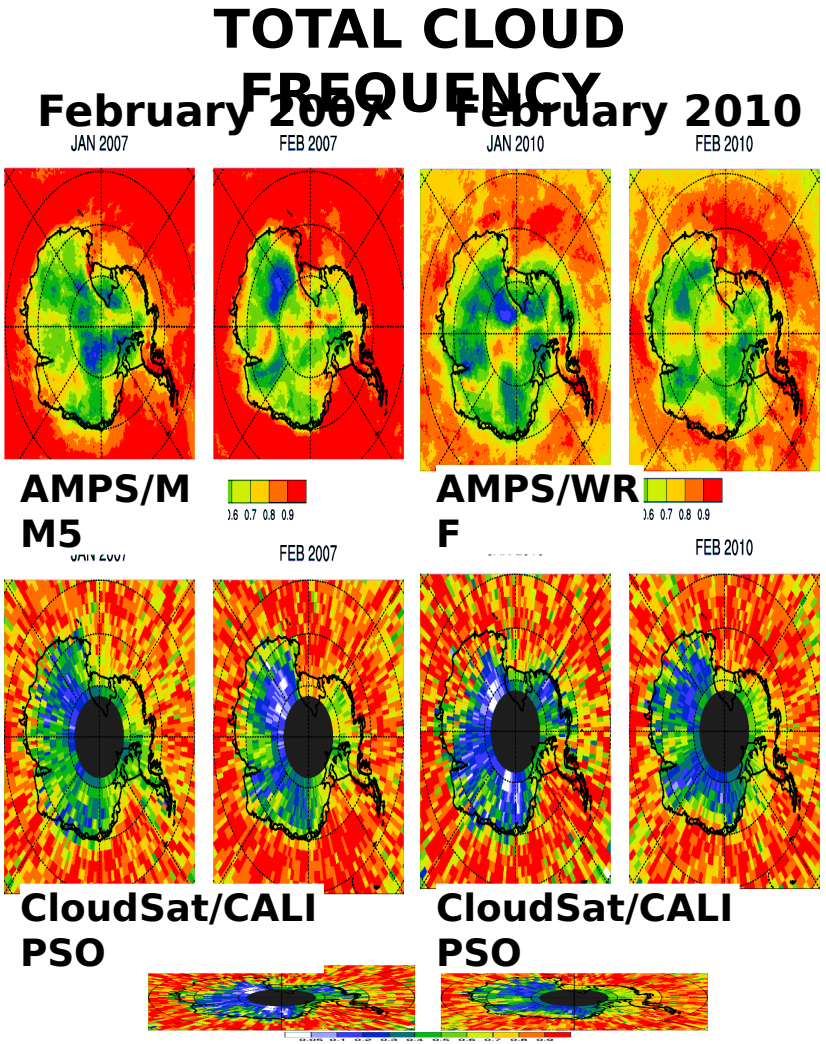


II. AMPS cloud liquid water (CLW) and cloud ice water (CIW) in the Ross Sea sector

CLW and CIW in AMPS

Part of the differences between MM5 and WRF may come from the parametrization of total cloud fraction, “tuned” for MM5 following Fogt and Bromwich (2008)
Looking directly at the **cloud liquid water (CLW)** and **cloud ice water (CIW)** avoids the uncertainties related to this parameterization
Terminology:

CLW and CIW are mixing ratios, i.e. mass of droplets or ice crystals per unit mass of air (units: kg kg-1)

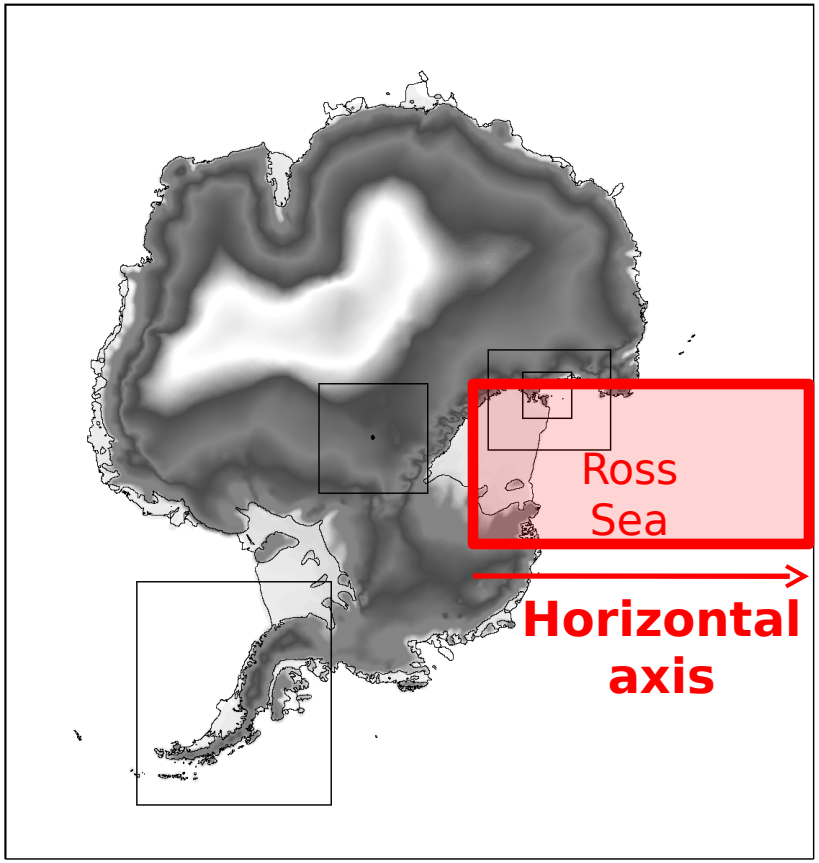
Cloud liquid water path (CLWP): CLW vertically integrated throughout the atmospheric column (units: kg m-2)

Ditto for **cloud ice water path (CIWP)**

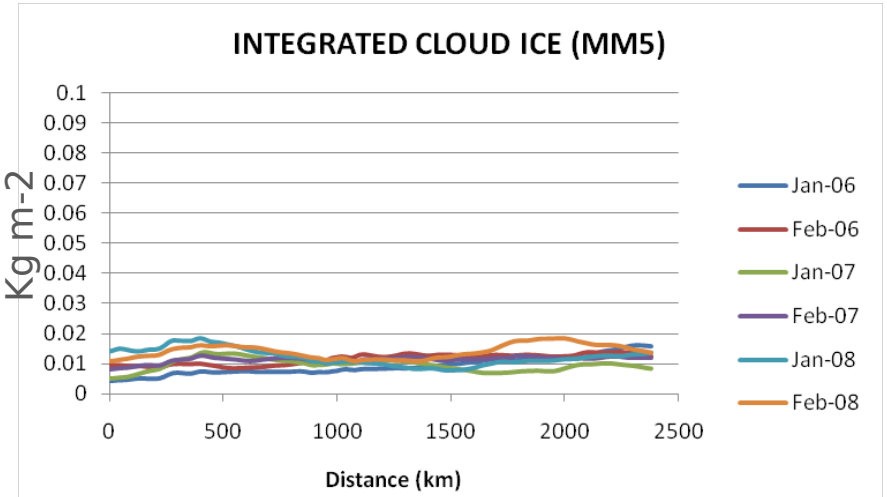
CLWP and CIWP in AMPS
(Ross Sea sector)

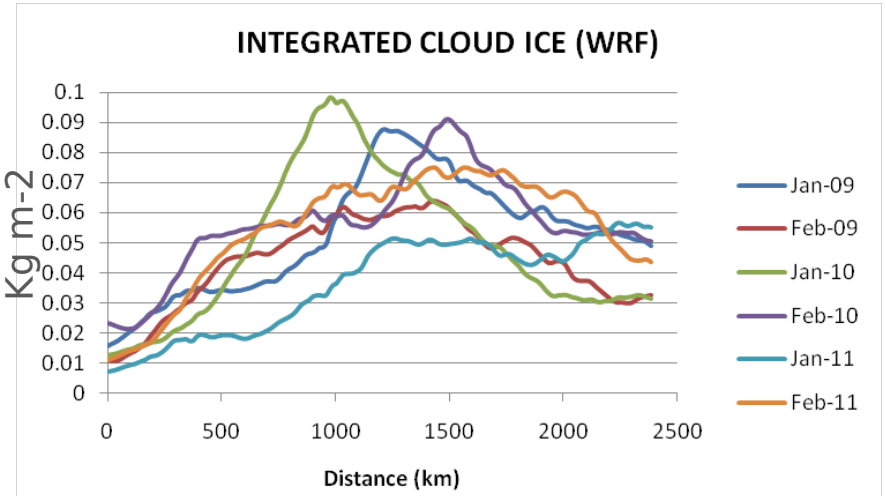
In the next 3 slides, CLWP and CIWP are shown:

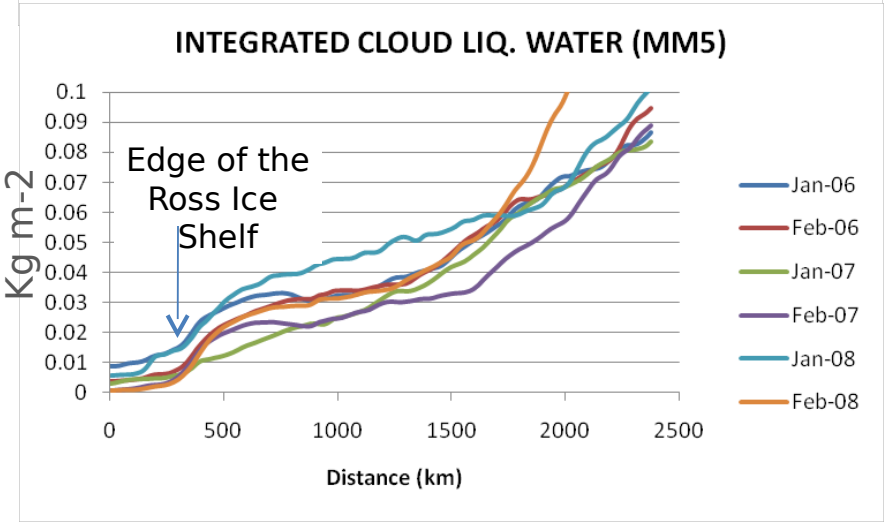
- "zonally" averaged over the Ross Sea sector (red rectangle)
- as a function of the distance between the Ross Ice Shelf and the edge of the domain

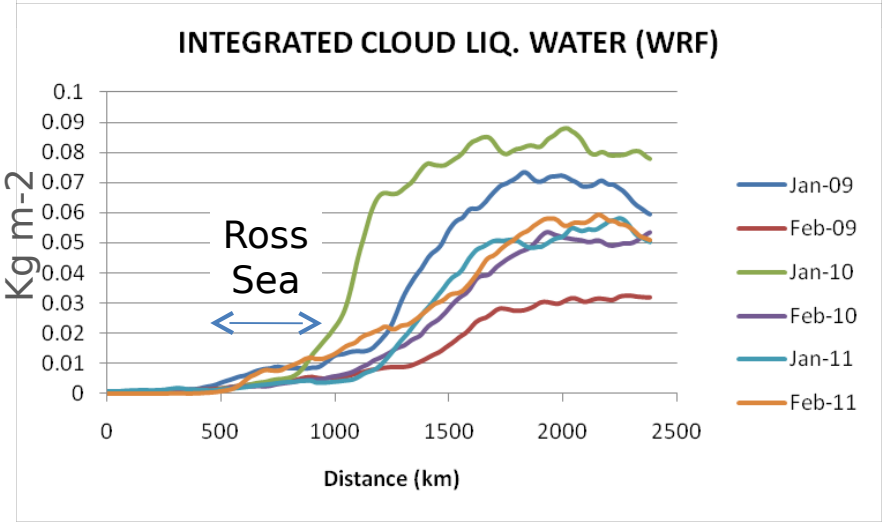


CLWP and CIWP in AMPS
(Ross Sea sector)

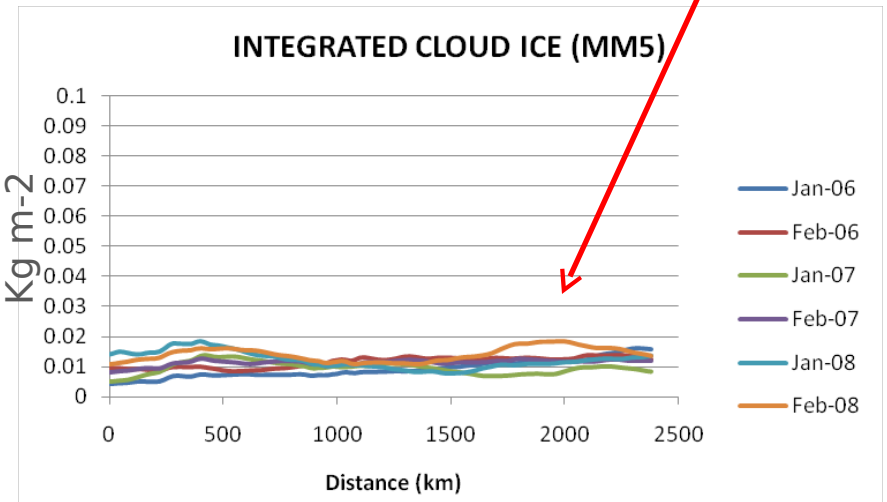


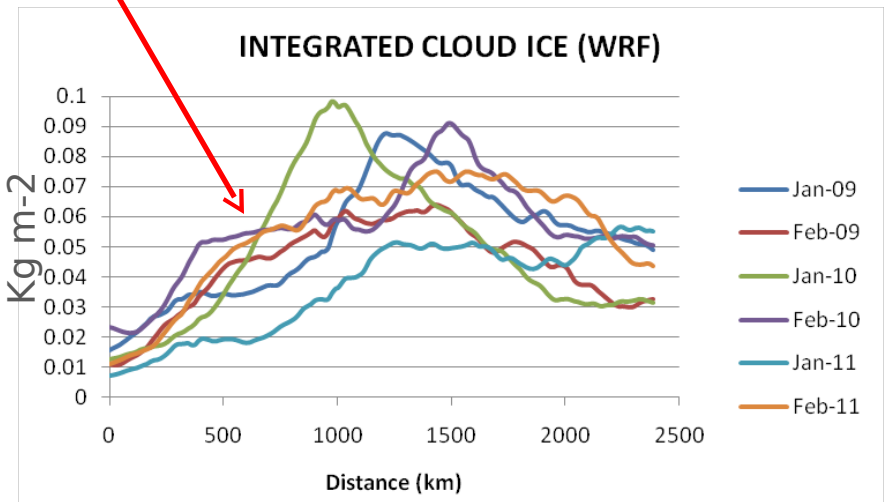


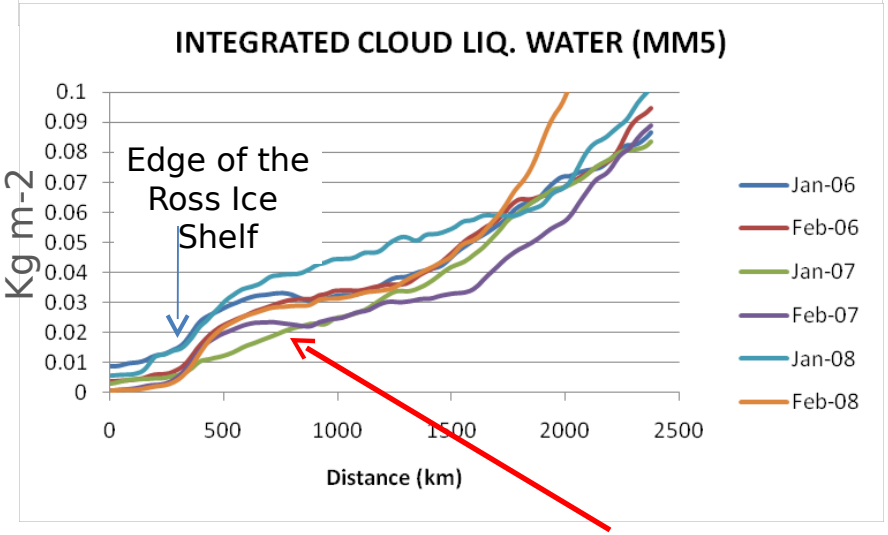


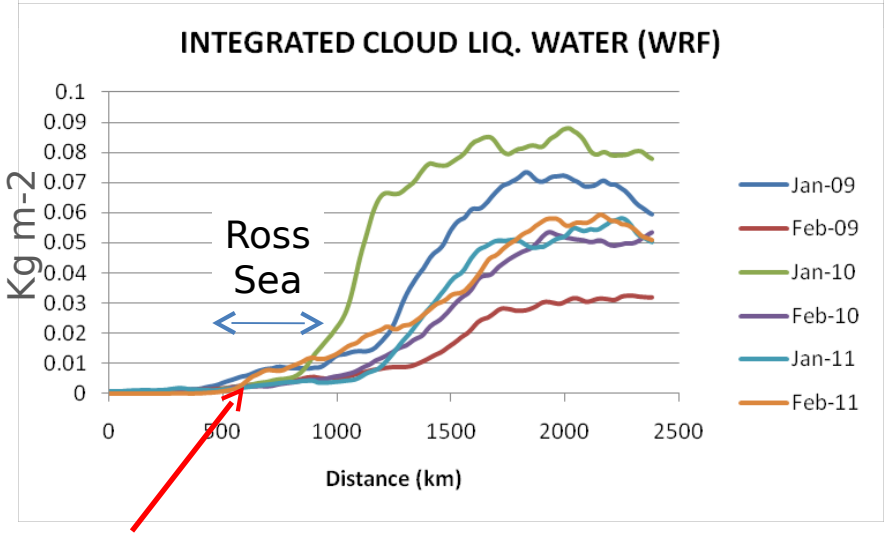


- AMPS/WRF produces substantially MORE ICE CLOUD than AMPS/MM5…



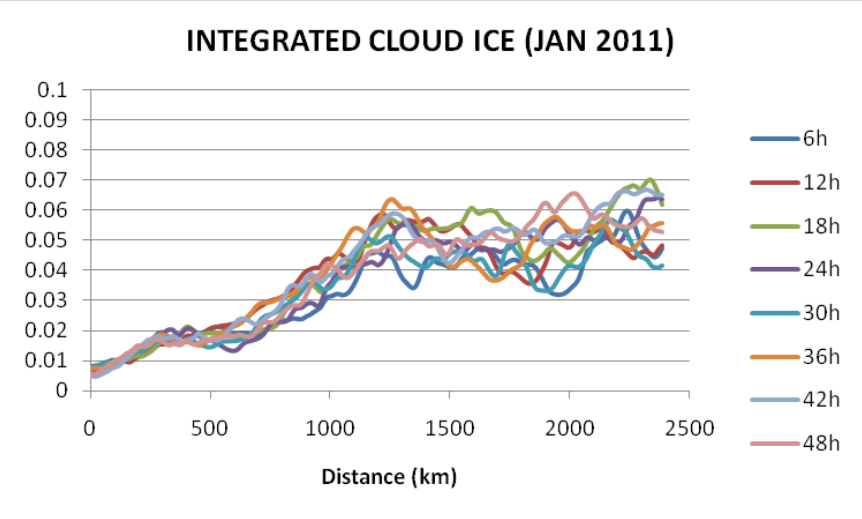


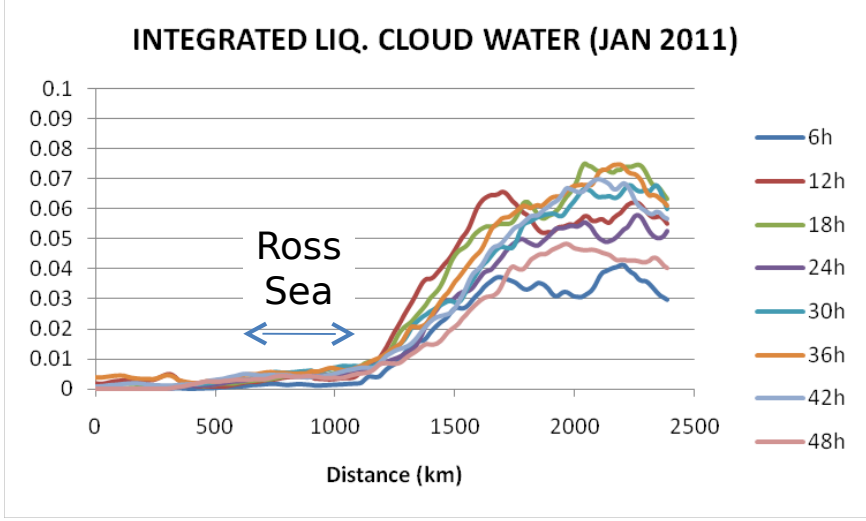




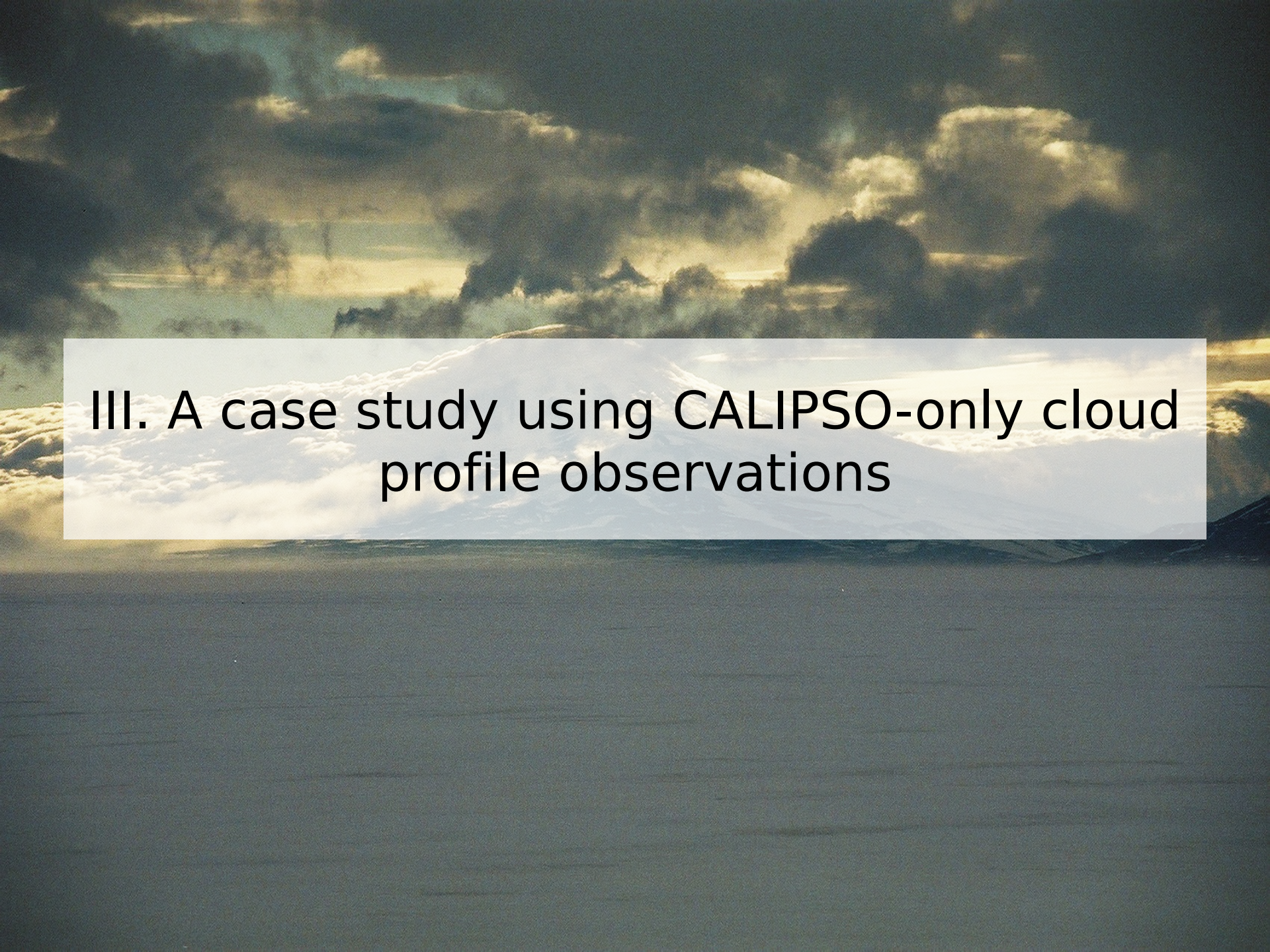
- … but significantly LESS CLOUD LIQUID WATER over the Ross Ice Shelf/Ross Sea

CLWP and CIWP in AMPS
(Ross Sea sector)





Does the amount of CLW and CIW vary with the forecast hours?
No, based on the two figures (for Jan. 2011), although the 6h forecasts are generally drier (model spin-up)
The deficit of CLW over the Ross Sea persists throughout the model run.



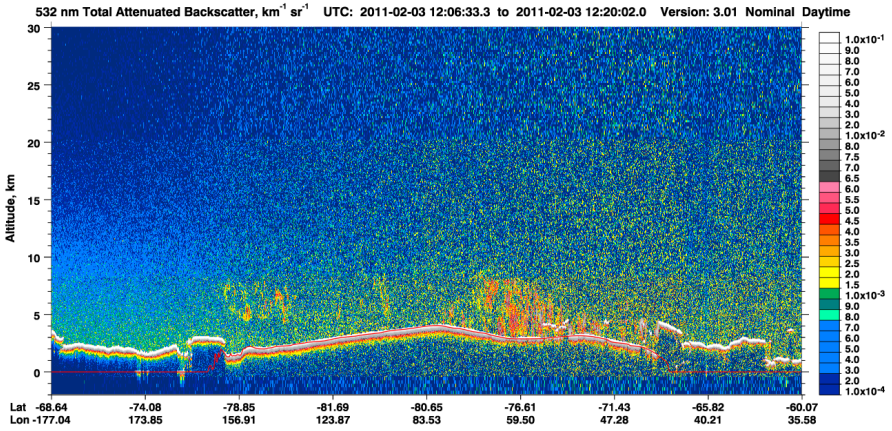
III. A case study using CALIPSO-only cloud profile observations

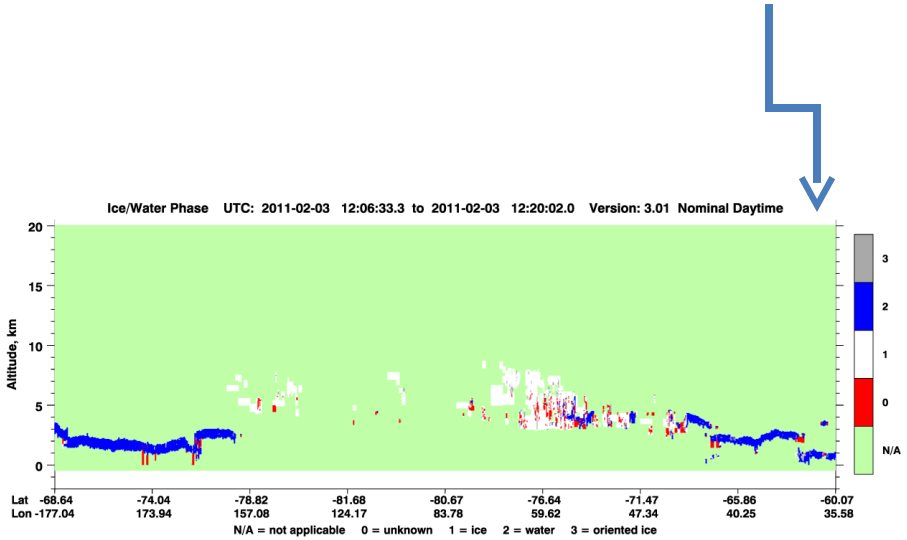
CALIPSO/CALIOP

CALIPSO satellite flies over the Ross Sea up to 4 times/day approx.
Its lidar (CALIOP) is sensitive to:

the presence of clouds (lidar backscatter)

the phase of cloud particles (polarization ratio)

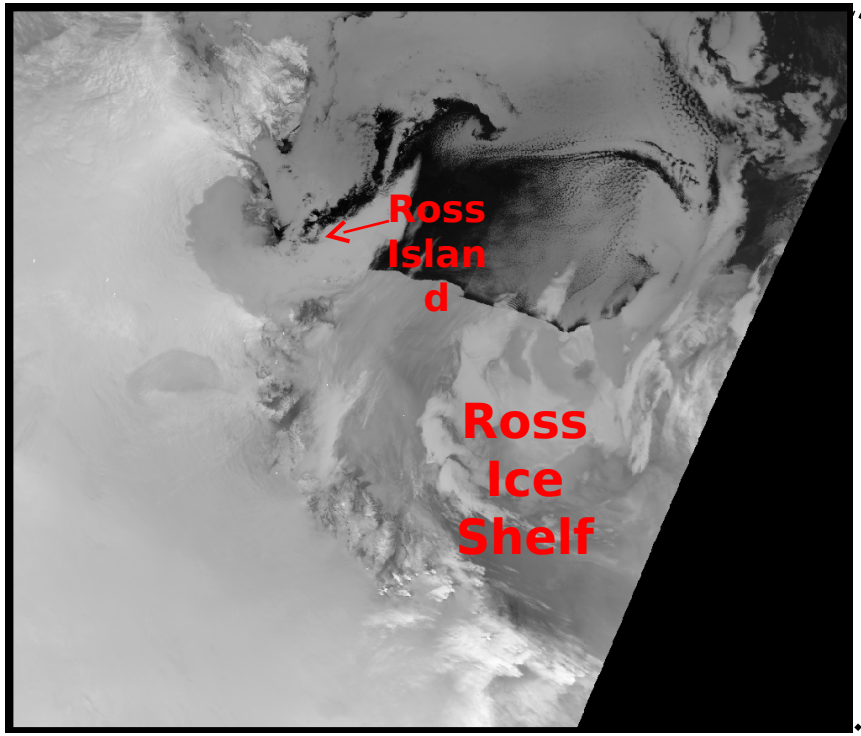




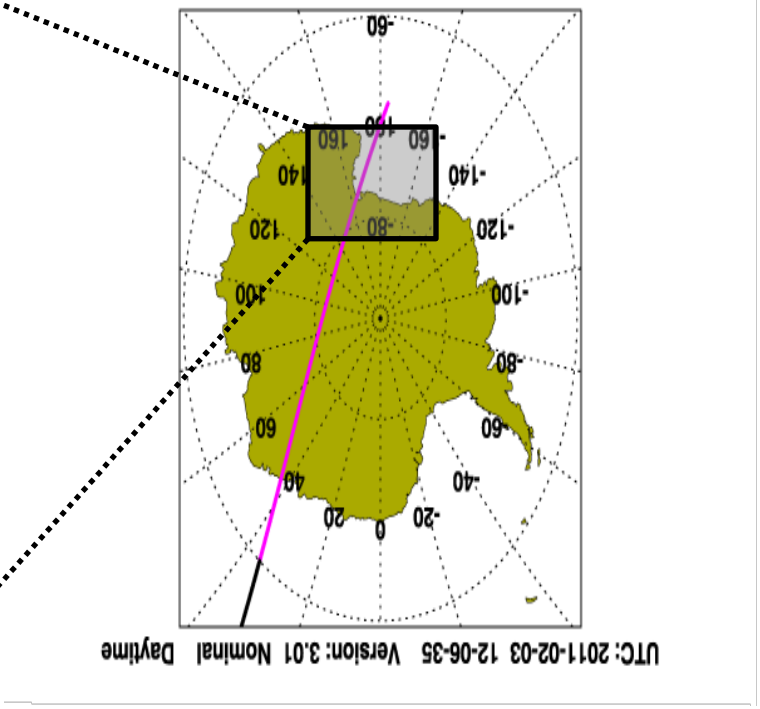
Images from http://www-calipso.larc.nasa.gov/

CALIPSO/CALIOP

Aqua/MODIS IR 3 FEB 2011 1203 UTC

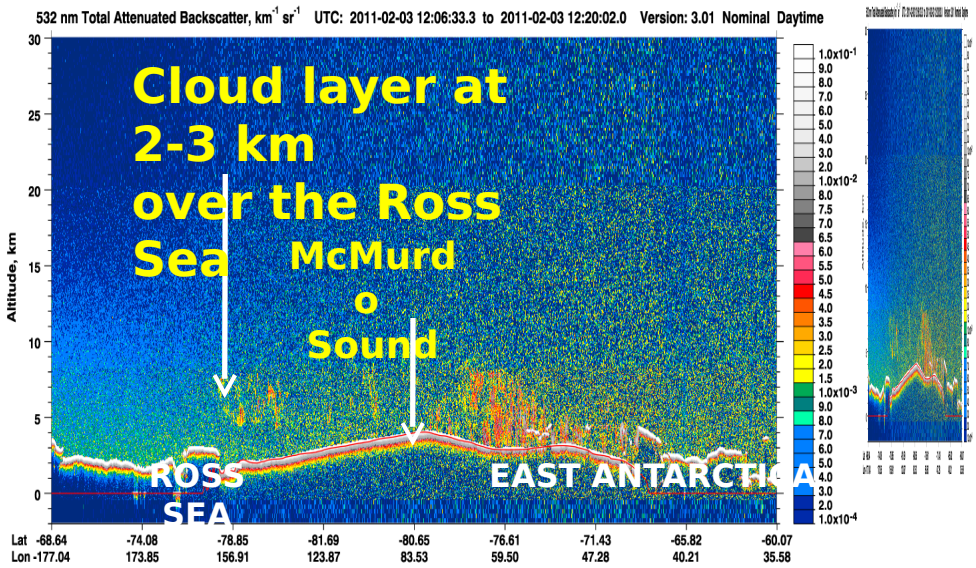


CALIPSO orbit track

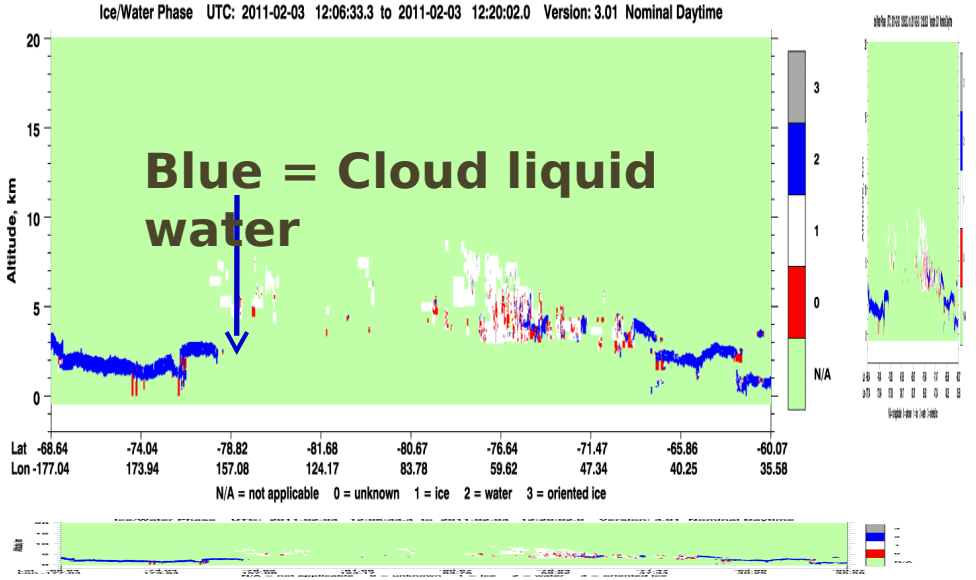


On 3 Feb. 2011 ~12:00 UTC, CALIPSO flew over Ross Island and the Ross Sea

MODIS IR image shows extensive clouds over the area



CALIPSO/CALIOP observations on 3 Feb. 2011 ~12 UTC

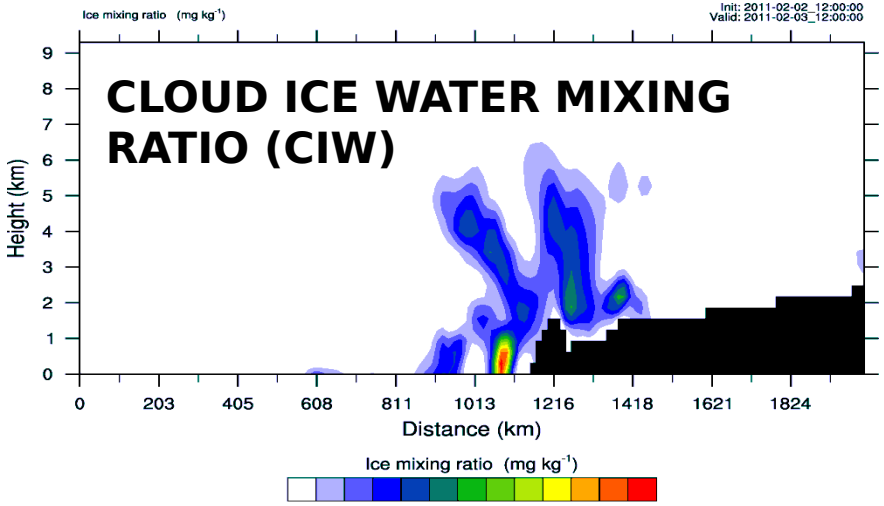


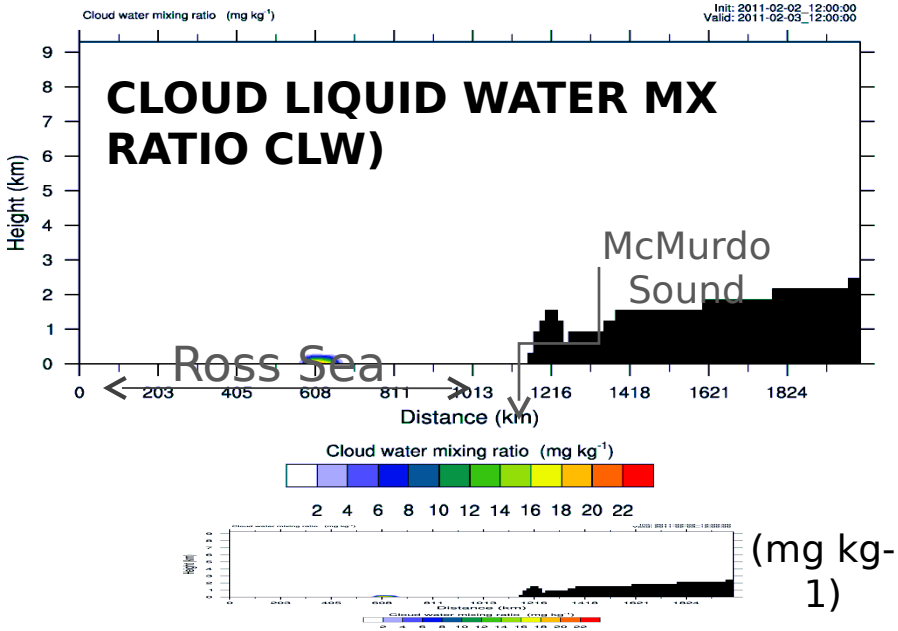
Cloud layer at 2-3 km over McMurdo Sound and Ross Sea Clouds composed only of liquid water droplets

What AMPS shows

Along the same orbit track as CALIPSO, AMPS shows:

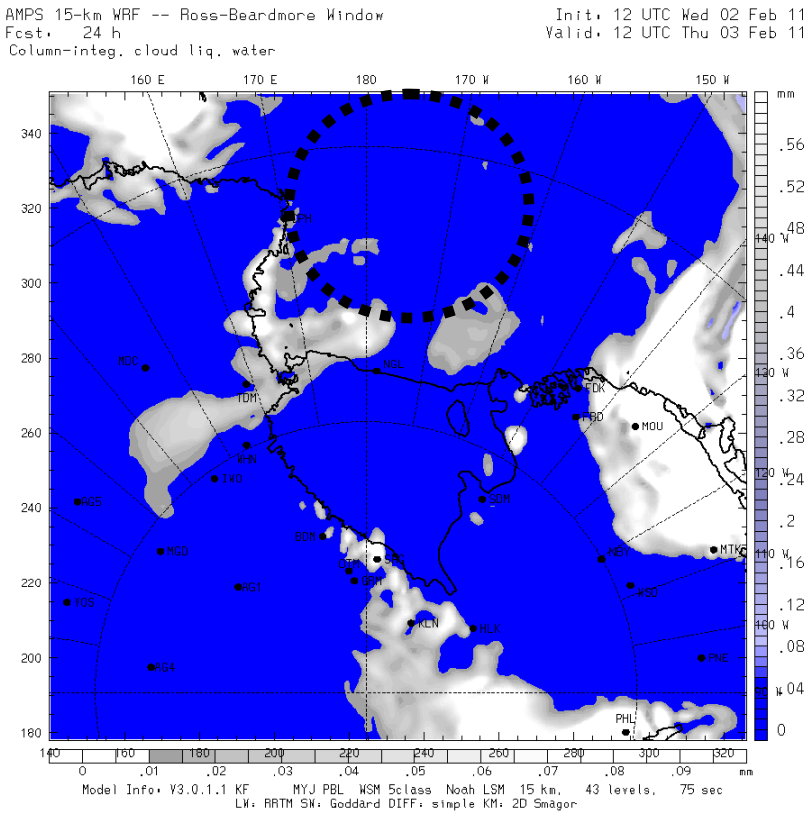
- Abundant ice clouds in western Ross Sea, esp. in lower levels
- Quasi-total absence of cloud liquid water

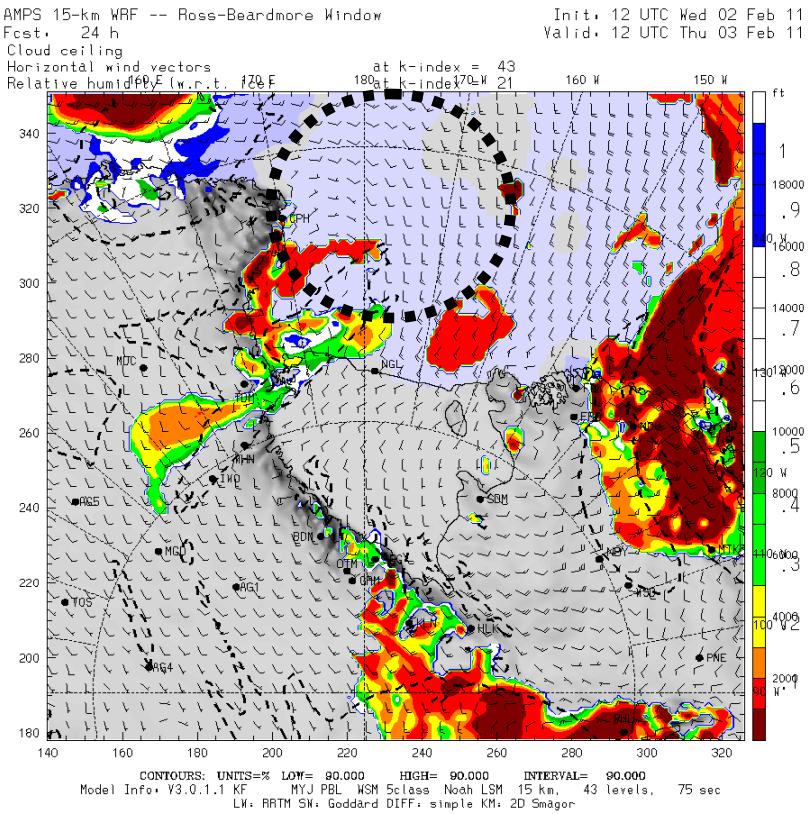




What AMPS shows

The absence of clouds in AMPS over the Ross Sea is confirmed by the pseudo-satellite and cloud base products for the same day/time





Conclusions

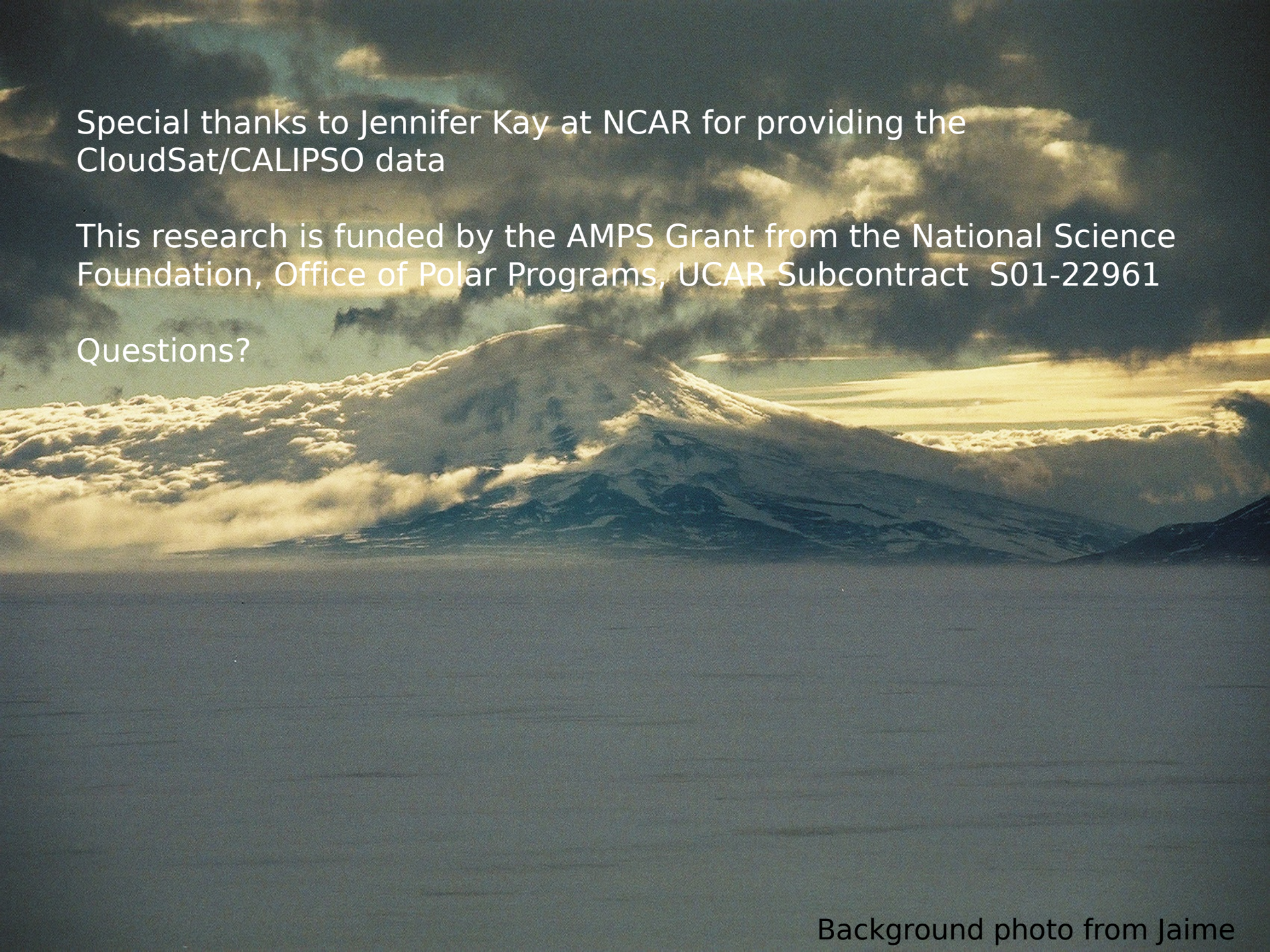
Significantly less clouds in AMPS/WRF over the Southern Ocean compared to AMPS/MM5

Clear deficit of cloud liquid water over the Ross Sea, which impacts clouds forecasts around McMurdo

This cloud bias probably arises because of the cloud microphysics scheme (WSM 5-class)

These results also suggest that the parameterization of total cloud fraction, developed for Polar MM5, may not be suited for Polar WRF

Future work will include identifying the causes for this bias and extending the evaluation to the winter months



Special thanks to Jennifer Kay at NCAR for providing the CloudSat/CALIPSO data

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Questions?

Background photo from Jaime