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AIRS Sounder Data Assimilation at IARC

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Outline

1. Goal of the project

2. GINA-WRF model

3. Optimization of the physical options for GINA-WRF model

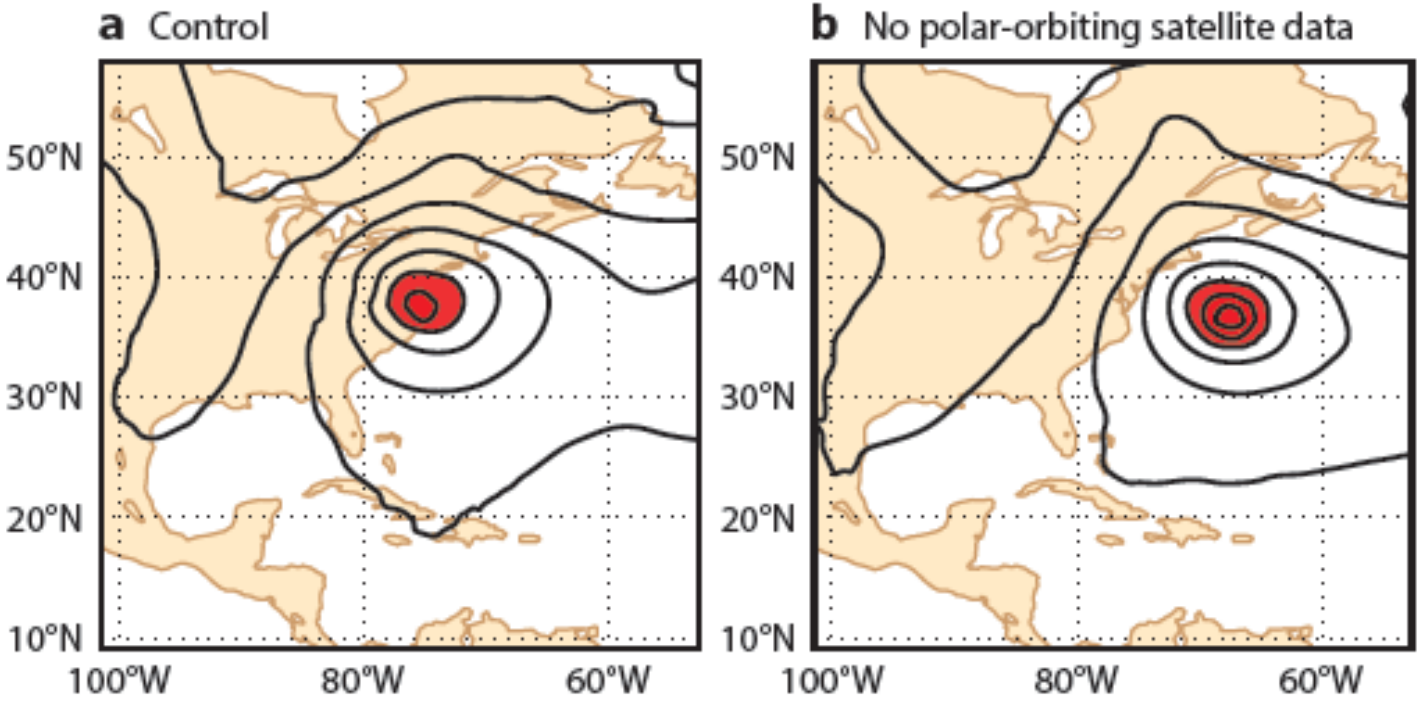
4. Case study

5. Summary

6. Further work

7. Acknowledgements

Known: Including Satellite Data in DA Can Improve NWP Performance



- "Data denial" experiment showed that polar orbiter data contributed to ECMWF's accurate forecast of Hurricane Sandy. (ECMWF Newsletter 134, pp5-6)
- Can AIRS/CrIS data improve regional / local WRF modeling in Alaska?

What to Study in Alaska? Stratus in the Lower Troposphere

- Broad decks of marine stratus that can advect inland over coastal areas; can occur in summer and winter
- Patchy "black stratus" that develops over Alaska's interior, most commonly during winter

Why choose stratus?

- **A real "forecast buster." Impact to aviation. Radiative influence can yield temperature swings of 10-20F at surface.**
- **WRF <u>can</u> depict stratus decks on regional or even local scale, but not necessarily with great skill…there is room for improvement**
- **Stratus can be observed by satellites, raobs, METARs, and pilot reports…such observations can be used to verify NWP model performance**

"Gentlemen, you're looking at our first target." –Admiral Helena Cain

Approach to the modeling effort

- Identify historical cases involving low stratus, clear skies above, and a quiet baroclinic environment over Alaska
- On these cases, run a "control" WRF with default parameters and no special data assimilation; WRF out of the box
- On these cases, run an "AIRS" WRF with parameters optimized for Alaska (as per work of Xiangdong Zhang) *and* including data from Aqua's AIRS instrument in data assimilation
- Compare the output of the two versions of WRF and verify against observational data

  …hopefully inclusion of AIRS data in DA scheme will improve WRF's ability to forecast stratus over Alaska

GINA-WRF MODEL

1. GINA-WRF model does two-way nested run with one input file, 4 times a day at 08,14, 20,and 02Z. Two domains are defined in Figure 1 with 18 km resolution for coarse domain and 6 km for nesting domain.
The Gridpoint Statistical Interpolation(GSI) 3D-var is used for data assimilation.

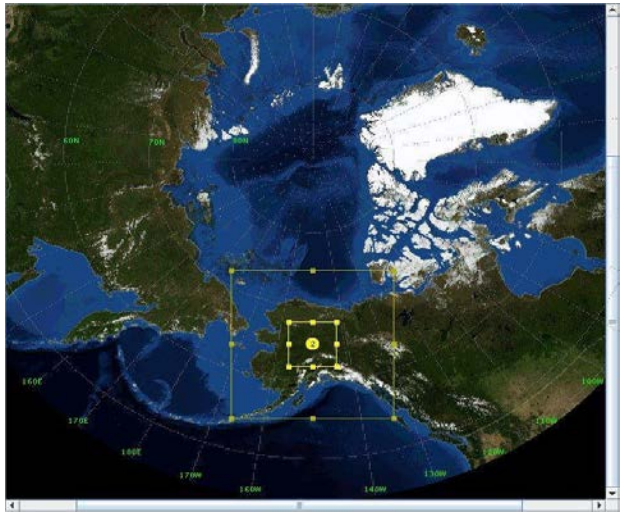


Figure 1, Domains for GINA-WRF model

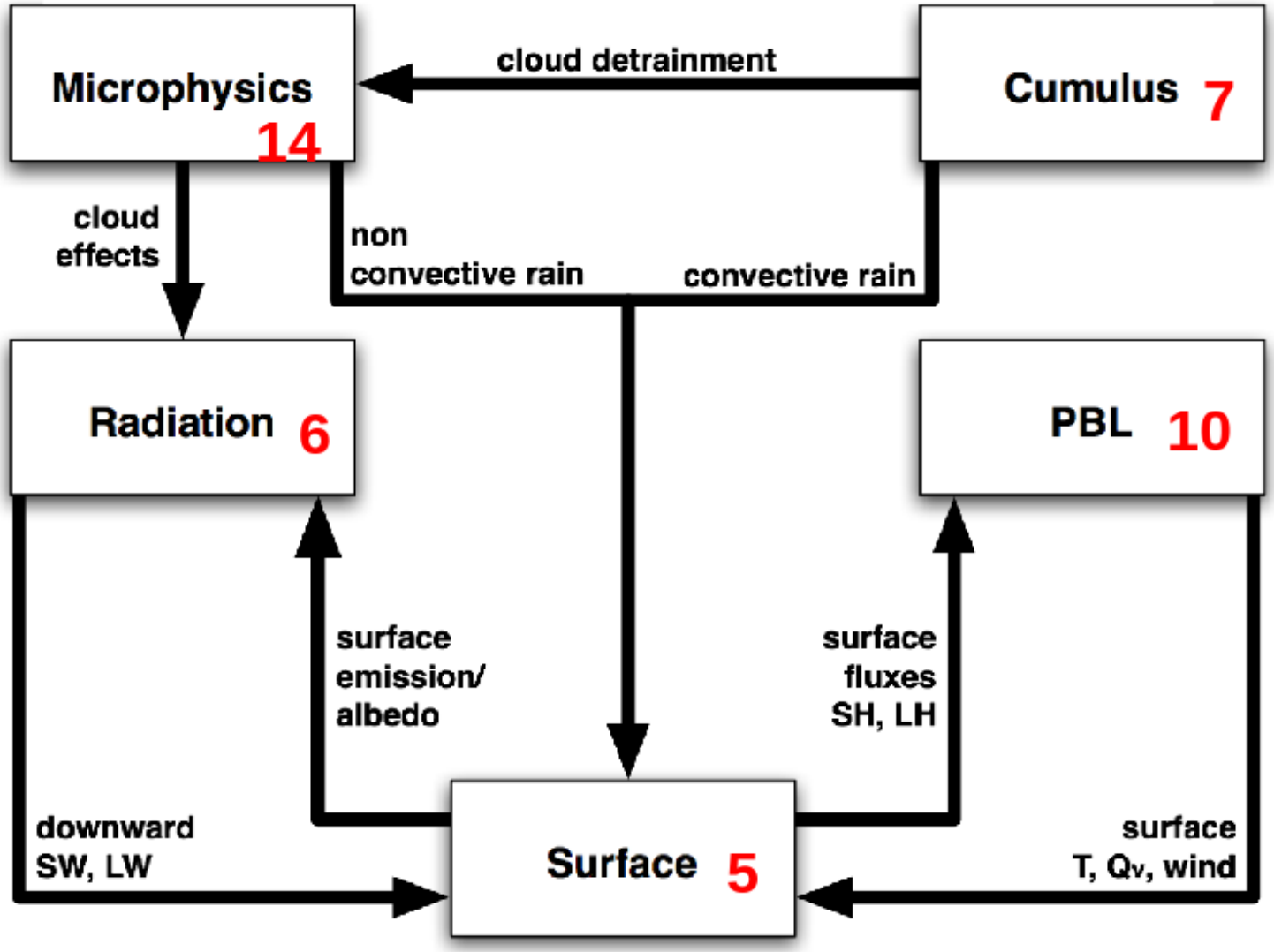
2. Requested data
GFS provides initial and boundary conditions; available 8 hours after the GFS analysis times of 00, 06, 12, and 18Z.
AIRS sounder data combined with GDAS data are used in data assimilation; available 8 hours after 00, 06,12, and 18Z.

3. Choice of Physical options

Optimization of the WRF and WRF Data Assimilation System

WRF Model Physics Parameterizations

Many Options !



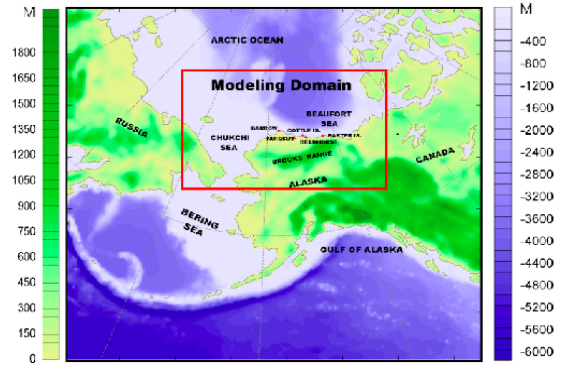
From WRF

The Chukchi-Beaufort Seas Mesoscale Meteorological Modelling Project produced 30 years (1979 to 2009) of Chukchi-Beaufort high resolution reanalysis (CBHAR) with a set of optimal physical parameters

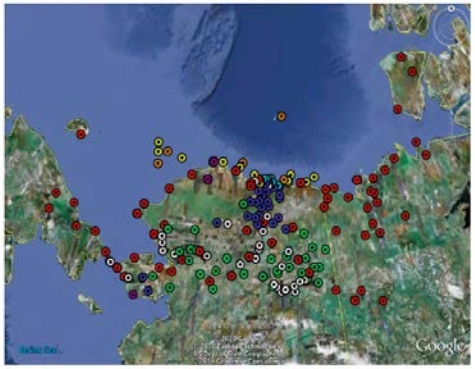
WRF-ARW Domain

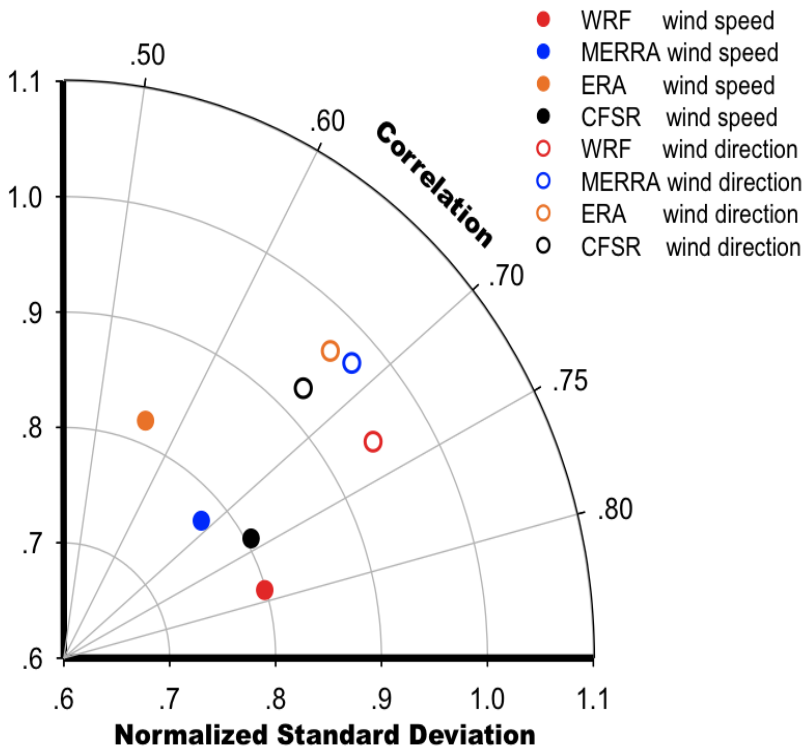
Spatial resolution 10 km

Temporal resolution 1 hour



Collected surface-based observations





compare reanalysis data against observation data in terms of correlation and normalized standard deviation

The CBHAR (WRF in the left figure) shows an overall better performance than all existing 3rd generation global reanalysis data sets

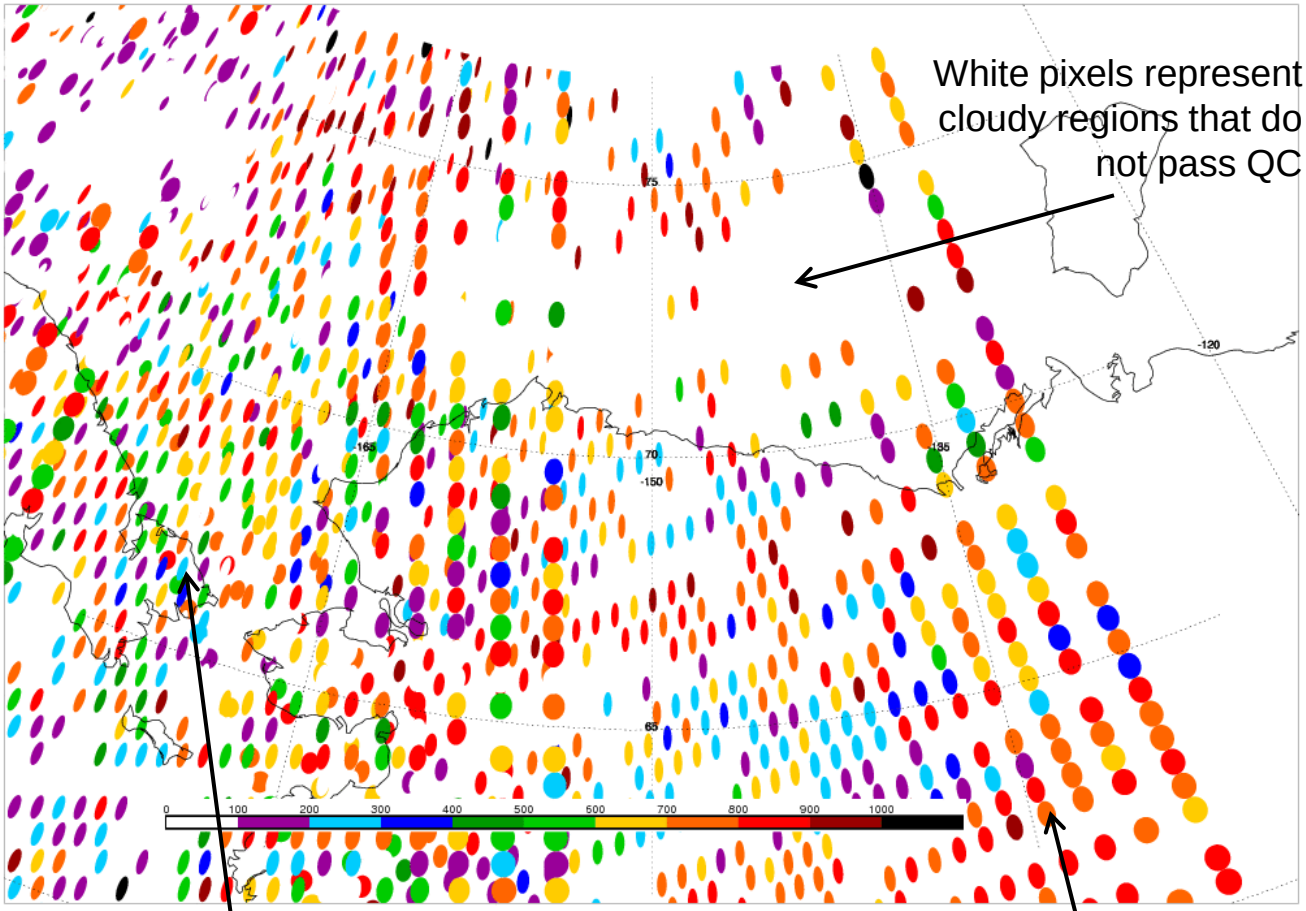
Two WRF parameterization Sets

Physics Options	Default	Optimal
microphysics	WRF Single-Moment 3-class scheme (3)	Morrison double-moment scheme (10)
ra_lw_physics	RRTM scheme (1)	RRTMG scheme (4)
ra_sw_physics	Dudhia scheme (1)	RRTMG scheme (4)
sf_sfclay_physics	MM5 similarity (1)	Eta similarity (2)
sf_surface_physics	Noah Land Surface Model (2)	Noah Land Surface Model (2)
Planetary Boundary Layer	Yonsei University scheme (1)	Mellor-Yamada-Janjic scheme (2)
cumulus Parameterization	Kain-Fritsch scheme (1)	Grell 3D (5)

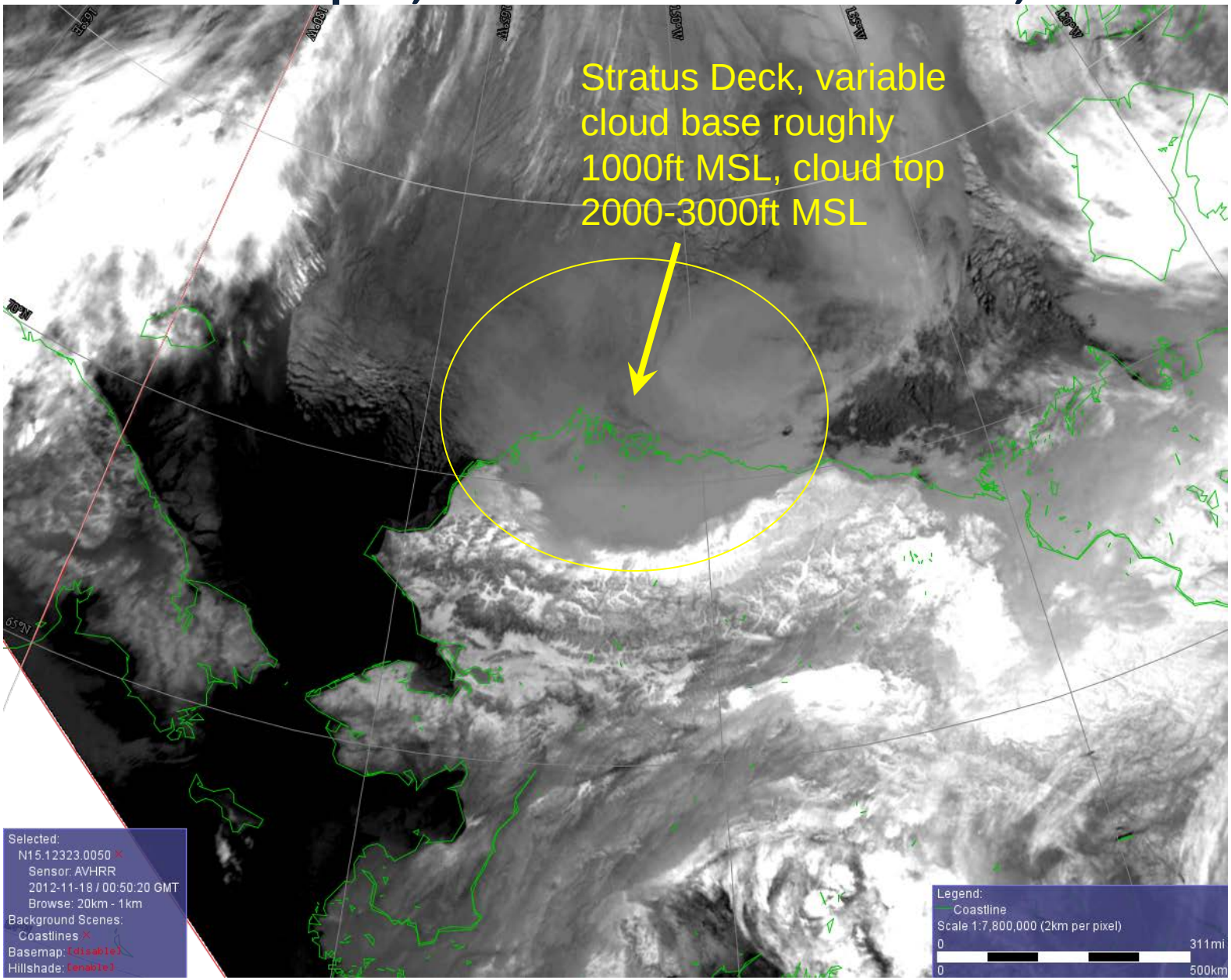
4. Choice highest quality AIRS data for data assimilation

- AIRS is a hyperspectral sounder aboard NASA's Aqua polar orbiting satellite
- Provides temperature and moisture profiles of the atmosphere in clear and partly cloudy scenes
- A quality indicator, P_{best}, approximates the cloud level for low, single-level clouds and is used to select only the most favorable data from each profile for assimilation into GSI

P_{best} value for data assimilated at 0000 UTC on 18 November 2012



North Slope, November 17-19, 2012



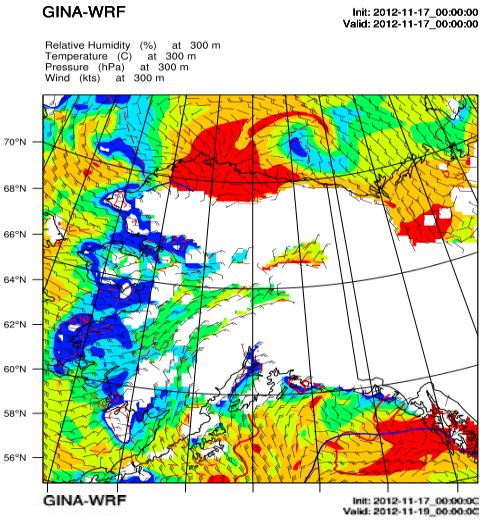
Comparison of WRF outputs with different parameterization sets

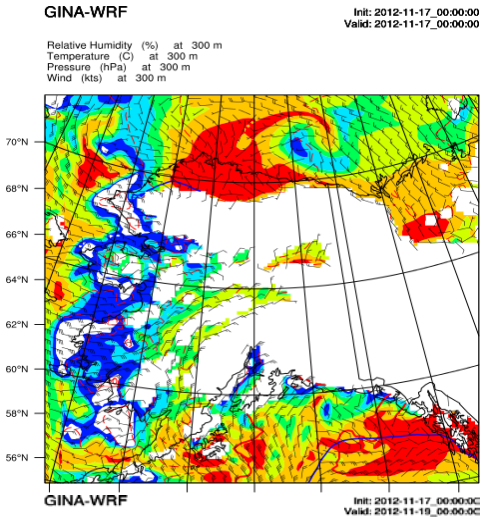
Default parameter set

Optimal parameter set

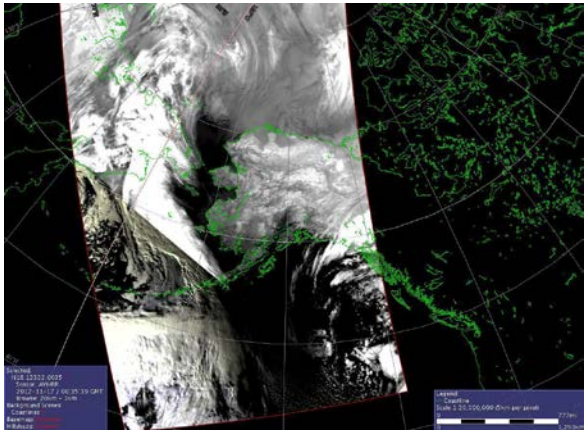
AVHRR IR Image

00Z

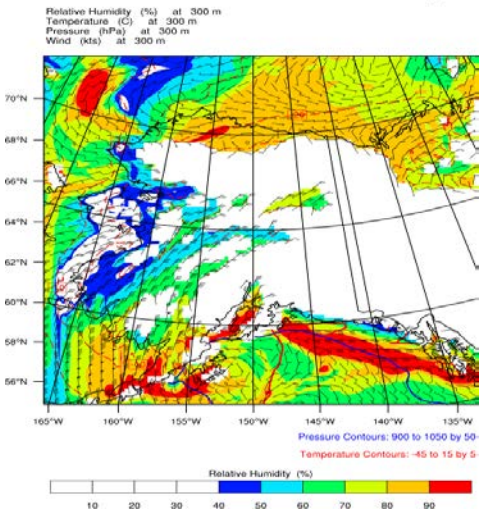


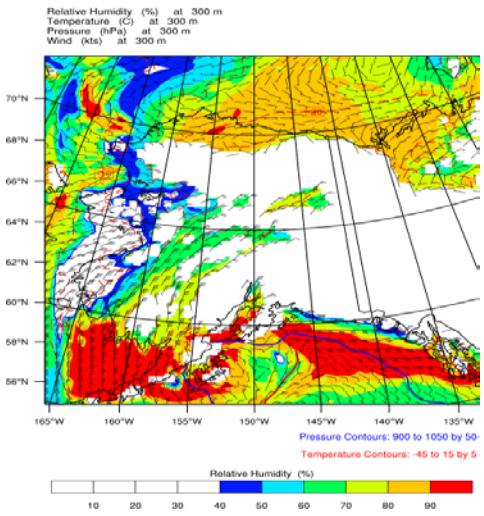


17 00:39Z

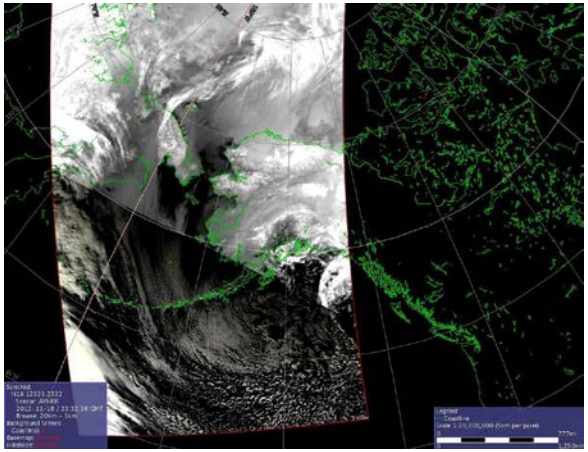


48Z





18 23:36Z

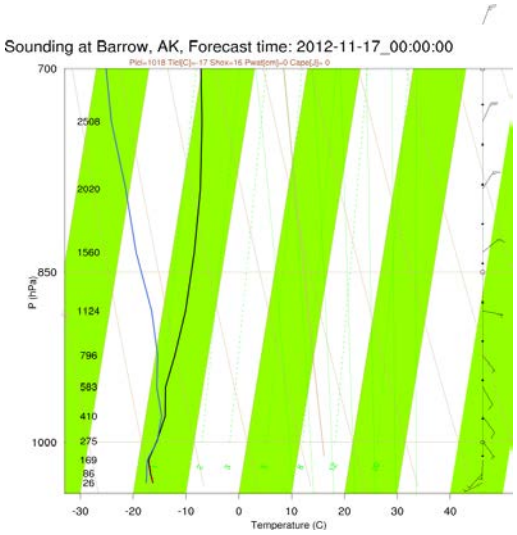


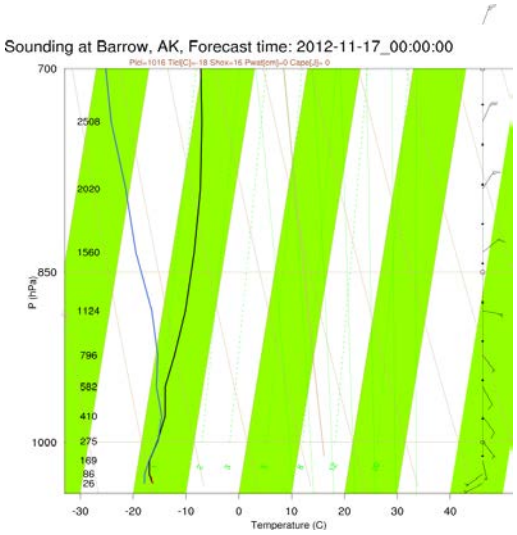
This shows relative humidity at 300 m above the MSL. At 00Z, the outputs from two runs are pretty similar; after 48 hours the forecasts show some differences. The output produced from the WRF running the optimal set shows better representation of target cloud -black stratus over the North Slope.

Default parameter set

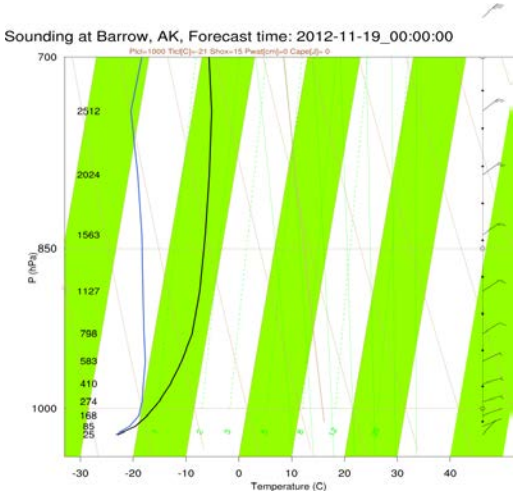
Optimal parameter set

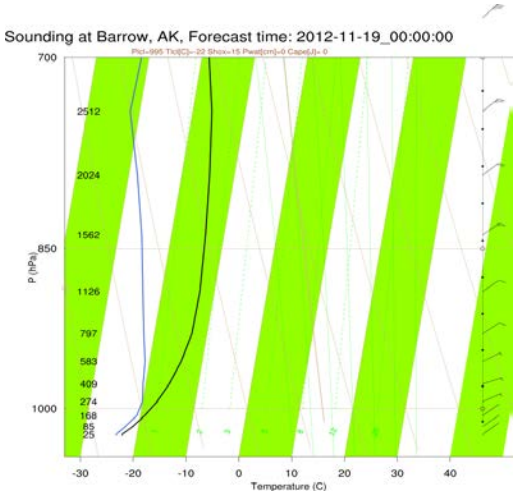
00Z





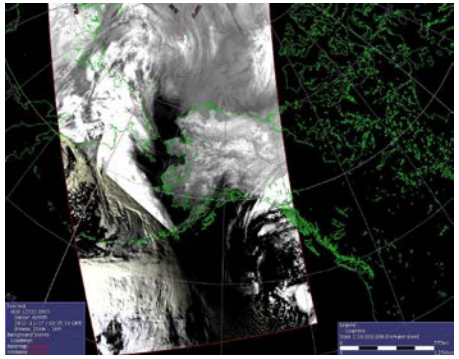
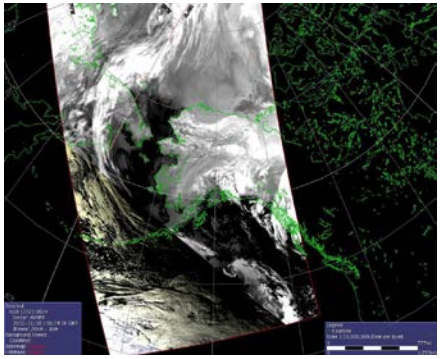
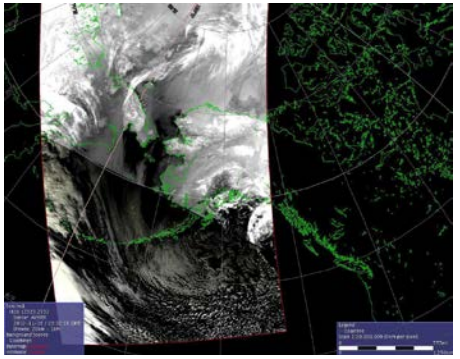
48Z



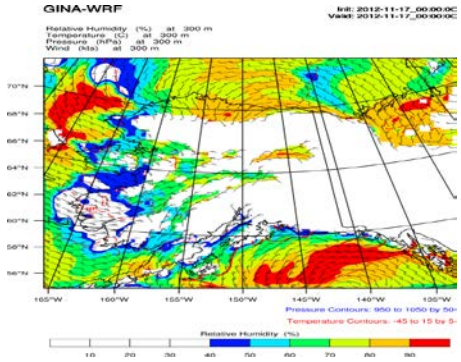


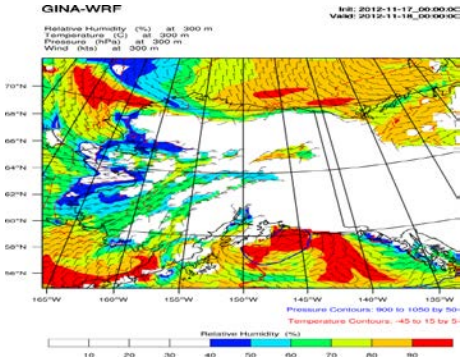
Again, forecasts of the two WRF runs with two different parameter sets are very similar at 00Z forecast time. But, with increasing forecast time, the difference between the outputs increases.

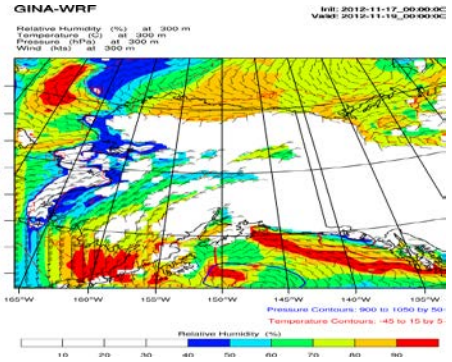
00z 24z 48z

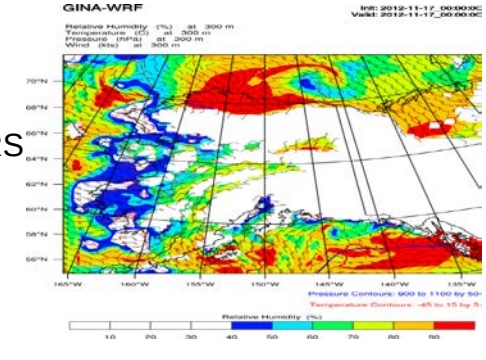
No DA

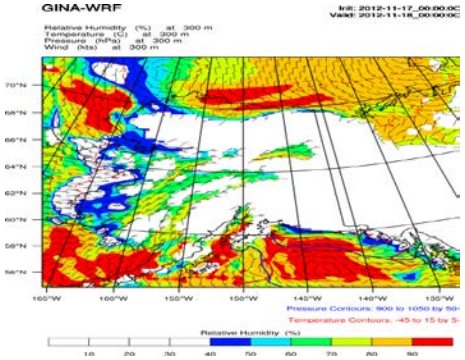


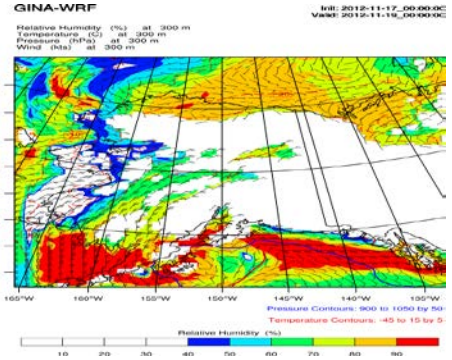




GDAS+AIRS

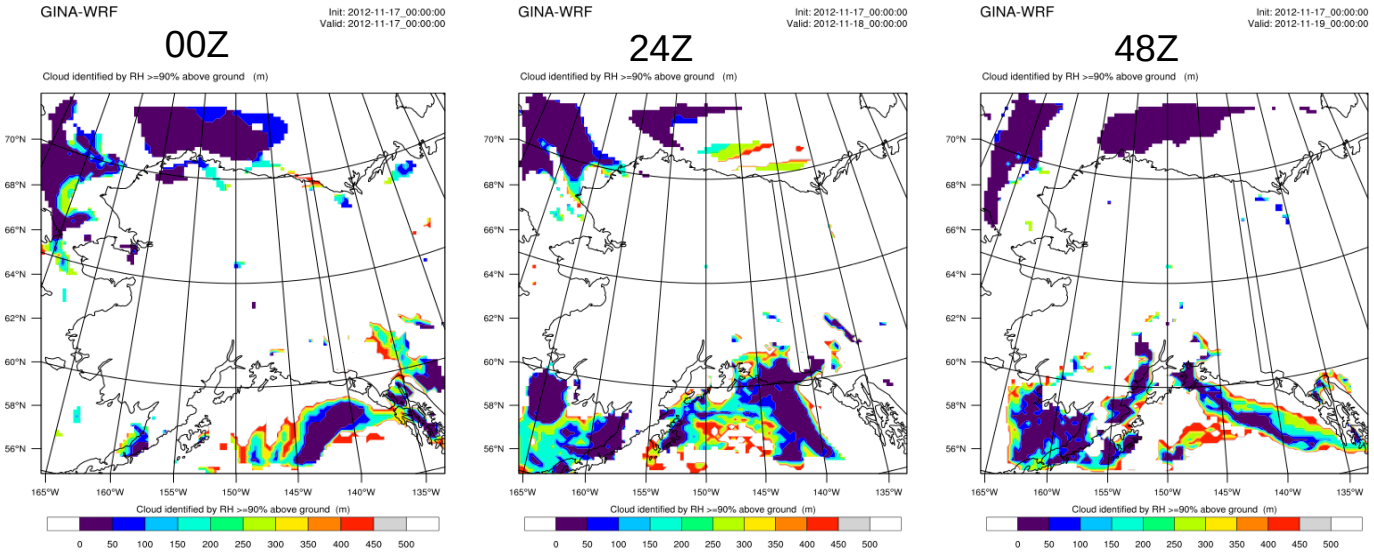




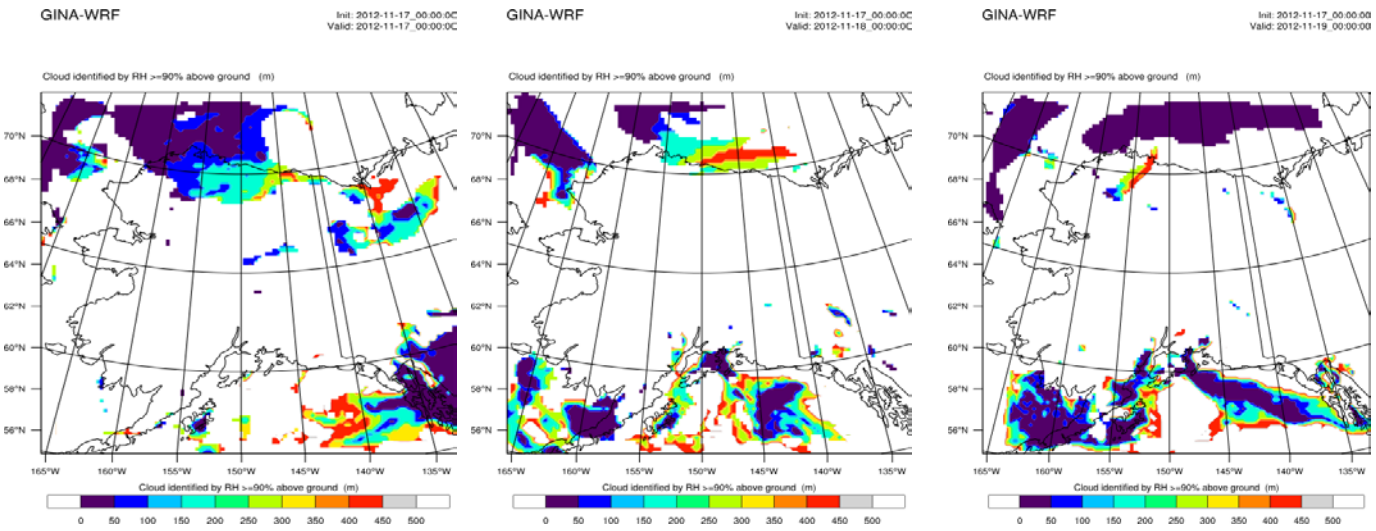


Back stratus over Brooks range were observed during the 48 hours starting from 2012/11/17 00Z. The clouds dissipated over time.
Control run did not show the back stratus. However, WRF with data assimilation matched the observation.
The data assimilated run also captured the dissipation of clouds.

No DA

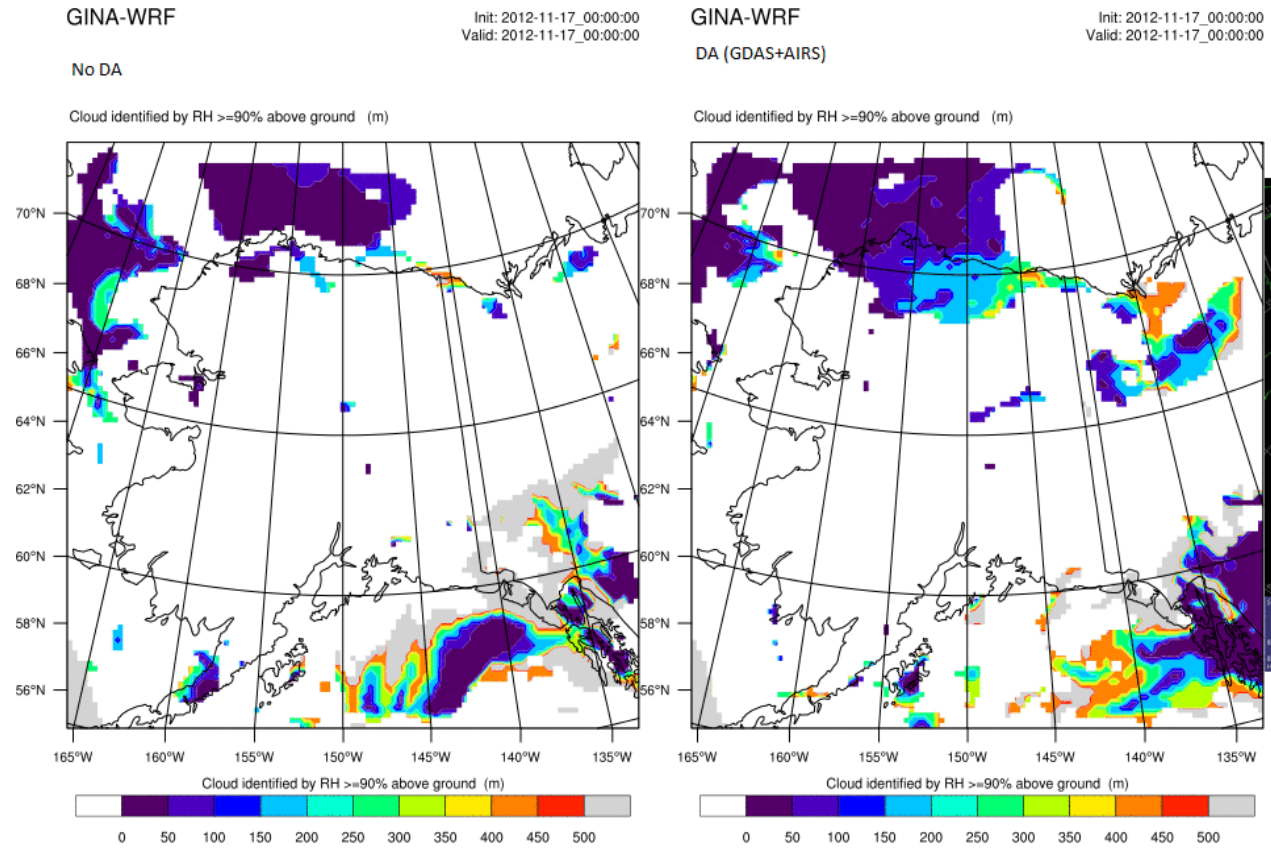


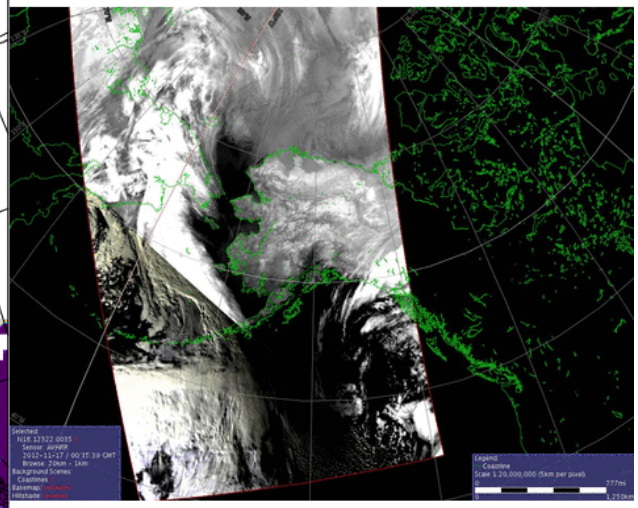
GDAS+AIRS



Clouds are identified by RH>=90%. The "No DA" WRF has fewer clouds over the North Slope than the WRF run with GDAS and AIRS DA. Cloud ceiling varies with time. The WRF run with GDAS and AIRS captures lower stratus clouds. Animation of variation of cloud ceiling with time indicates clouds north of Brook Range exists during the 48 hours forecasting period.

Animation of cloud ceiling from control and DA runs





Summary

1. Sounder data assimilation for WRF model improves the short-term forecast.
2. Regional WRF model is sensitive to physical option. UAF parameter set does good job.

Future work

1. do more case studies, including over Interior where terrain is more complex.
2. use satellite simulator to convert WRF model output to brightness temperatures and compare them with the satellite imagery from AVHRR.
3. develop quantitative method for evaluation of GINA-WRF model.
4. Using this method as a template, substitute CrIS for AIRS.
5. provide operational short-term weather forecast data to NWS--possible use in IFPS for the "nowcasting" period?

Acknowledgements

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- Colleagues in GINA for techinical support,
- IARC and ARSC for providing computational resources.

THANK YOU !