GOES Sounder and Cloud Optical-Depth Data Impact on Variational LAPS Analysis and Forecast

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Introduction

Humidity and cloud analysis is the one of most influential factors for nowcasting and short range forecasts of severe weather applications. Direct observations are not sufficient. Remotely sensed data could fill in the gap if it is appropriately assimilated.

The Community Radiative Transfer Model (CRTM) provides a general forward operator and its adjoint for assimilating radiance data in nonlinear and complex process.

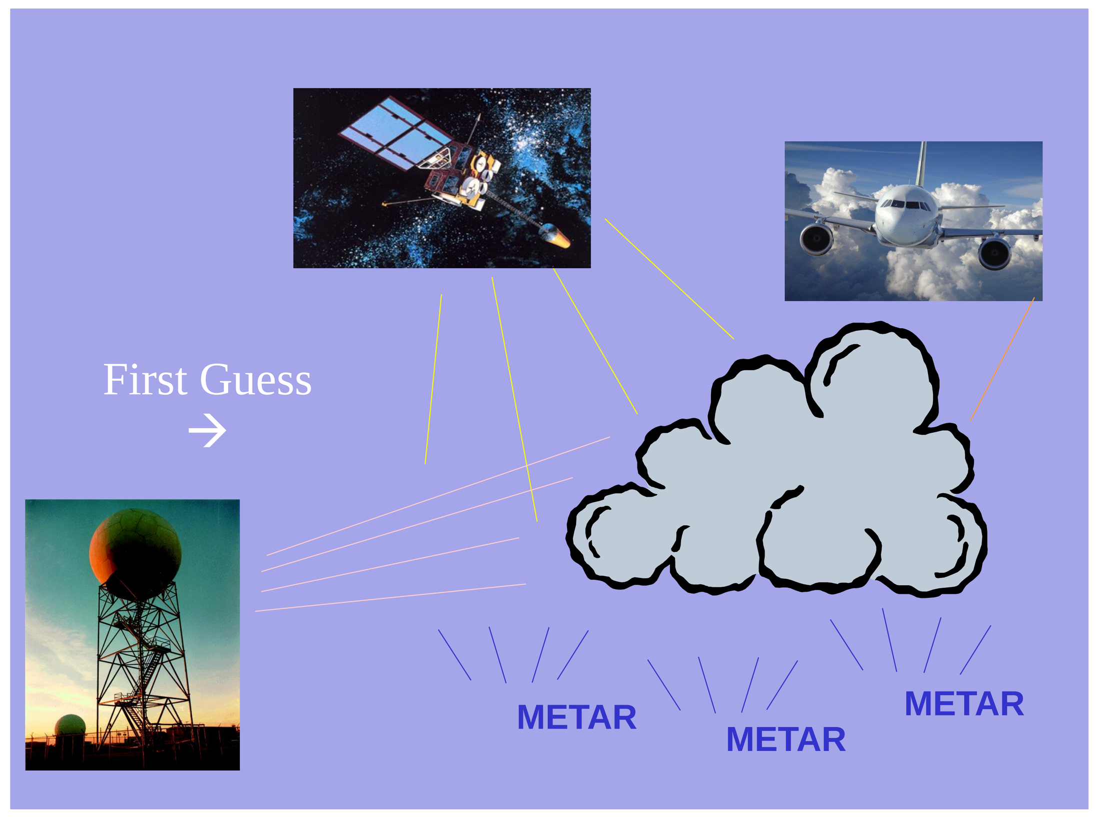
NOAA NESDIS and CIMSS have developed satellite products, such as cloud optical depth and GOES sounder integrated water vapor, etc. Successfully assimilating these products helps understand the potential of direct radiance assimilation through CRTM and identify additional information that could improve direct radiance data assimilation.

Working with CIMSS and NESDIS, these satellite products are assimilated into variational LAPS (vLAPS) for evaluation. This experiment examines the data impact of these products in conjunction with a wide range of observations that are currently being assimilated into vLAPS.

Variational LAPS Attributes

- Blends a wide variety of in-situ and remotely sensed data sets (e.g. METARs, mesonets, radar, satellite)
- LAPS analyses **(with active clouds)** are used to initialize a meso-scale forecast model (e.g. WRF)
- Adjustable horizontal, vertical, and temporal resolution
- Highly portable and efficient software
- **Utilizes 1km - 15min visible satellite imagery along with IR for rapid updating**
- **More info: http://laps.noaa.gov**

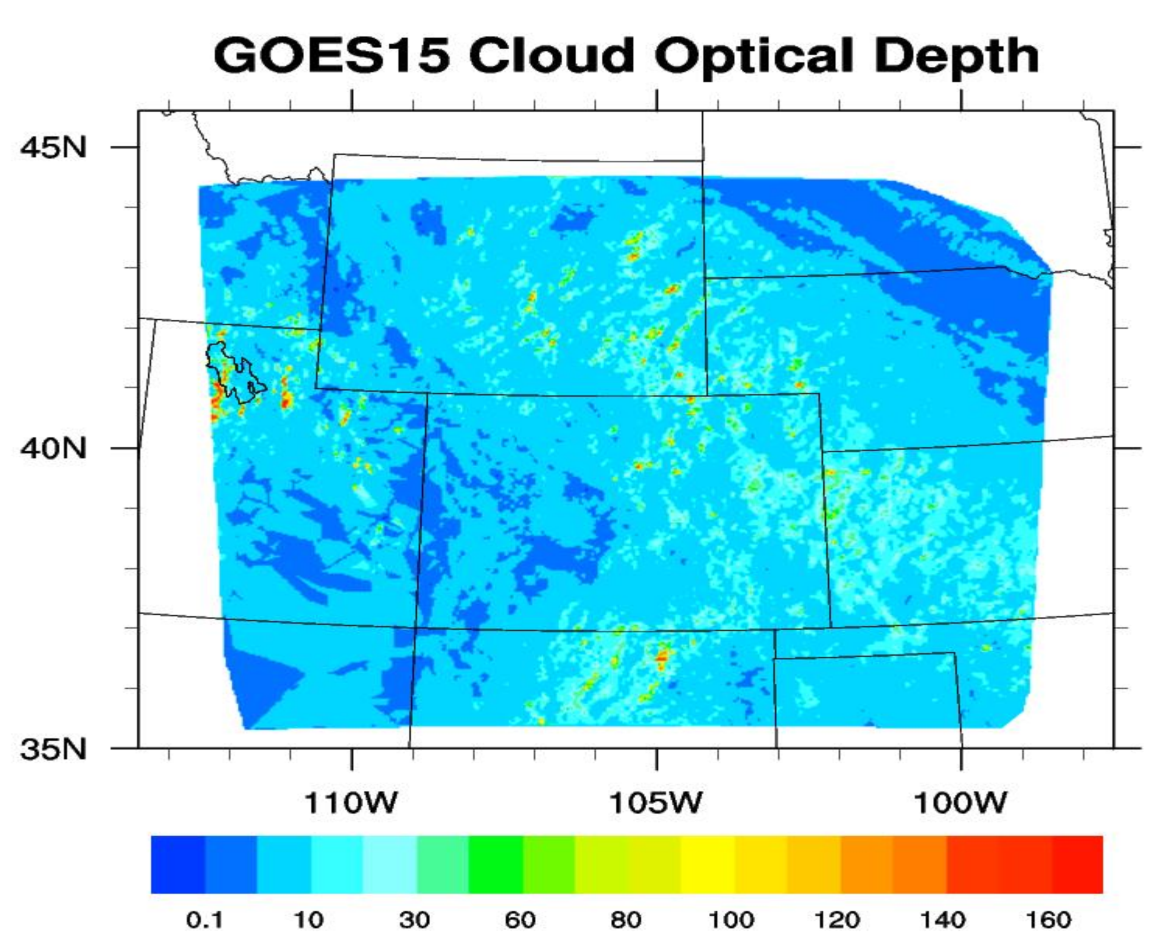
Cloud Analysis



LAPS has been used in real time analysis and forecasting for decades but it is based on an objective analysis approach, and it is a challenge to assimilate remotely sensed data. A variational LAPS analysis is under development following an object-oriented design (*see poster 898, Kalnay Symposium*). It is being tested and can be applied to other data assimilation systems without much effort. The satellite products from NESDIS/CIMSS are tested in this system with full real-time observations for evaluating the additional impact from these products. WRF forecasts initialized with vLAPS analysis are compared to observations for this evaluation.

Cloud Optical Depth (COD):

It measures the attenuation of light passing through the atmosphere due to scattering and absorption by cloud droplets.



Integrated Water Vapor (IWV):

The integrated water vapor between 300mb to 700mb has been evaluated with high accuracy.

These products have better spatial coverage compared to other data sources. Additional information could help vLAPS improve its humidity and cloud analysis so that a WRF from the analysis can produce better forecasts.

Forward Operators:

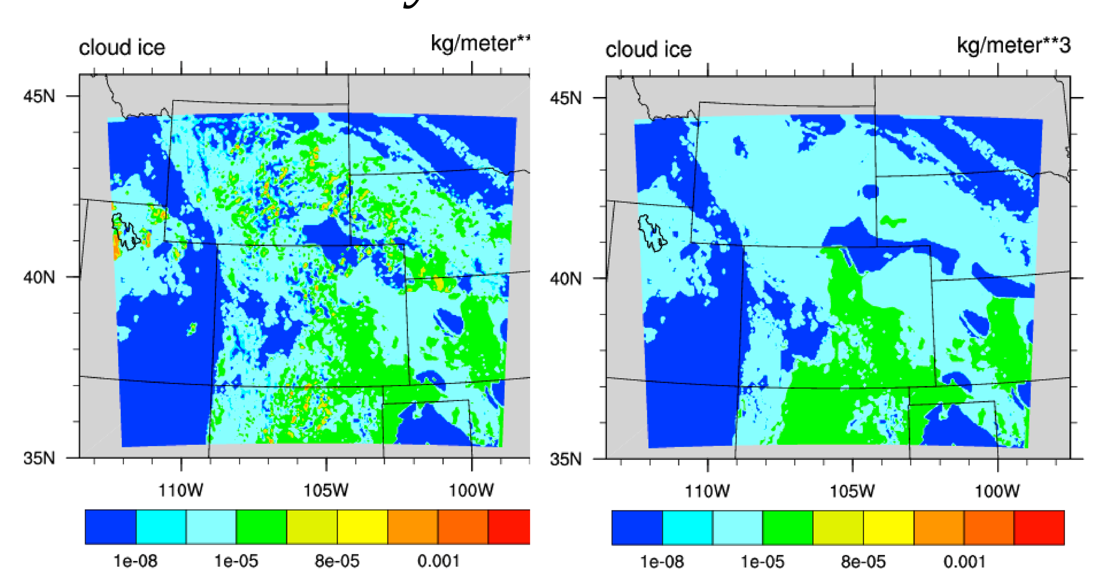
For the experiments, we started with some simple operators.

IWV: an integrated value of vLAPS humidity is calculated and compared to observations for evaluation

COD: an integrated of cloud water, ice, rain, snow and graupel

$$\int_{sfc}^{top} (A\times cloud\ water + B\times cloud\ ice + C\times rain + D\times snow + E\times graupel)\cdot dh$$

Cloud Ice Analysis



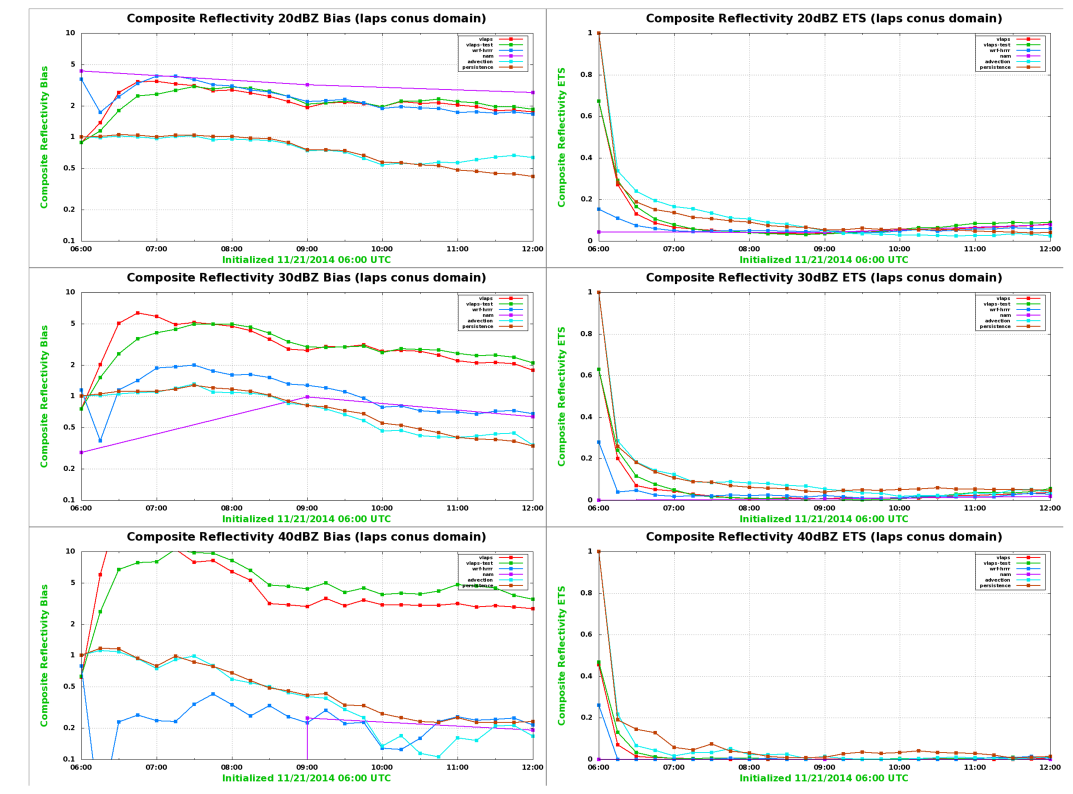
Left: vLAPS analysis with COD

Right: vLAPS analysis w/o COD

The major differences are the cloud ice value. Since LAPS cloud analysis uses visible data, the horizontal pattern is similar. In vLAPS COD analysis, cloud phase products are also used and helped in forming detailed cloud ice information.

Forecast threat score comparison

Threshold(mm)	STMAS+LAPS	STMAS+COD	Growth Rate
1.0	0.20096463	0.20866804	3.8%
2.0	0.12833828	0.13869347	8.1%
3.0	0.09655172	0.10429770	8%
5.0	0.05228758	0.05330701	2%
8.0	0.01094092	0.01160542	3.4%
10.0	0.00000000	0.00000000	0



An initial experiment was to assimilate all datasets along with and without COD and GOES IWV into vLAPS under the same environment for direct comparison and evaluation. The above ETS scores (right column) and bias (left) show the COD and GOES IWV data impact, where the green curves show the vLAPS WRF forecasts initialized by a vLAPS analysis assimilating COD and IWV datasets and the red curves show the one without these products. The scores and biases are calculated between WRF forecasts and radar reflectivity obs in 3 categories, 20, 30, and 40 dBZ.

Comparison:

- ETS scores are higher, particularly at early hours where data impact is more effective;
- Biases are slight lower.

These products indeed help the analysis!

Future Work

- Statistical ETS and bias evaluation over longer time period
- Improvement of vLAPS variational cloud analysis
- Comparison of CRTM direct radiance assimilation to these product assimilation for further improvement of CRTM direct radiance assimilation
- Test of these operators for other data assimilation systems, such as GSI
- Consider physical balance and statistical correlations among humidity, cloud and other analysis variables