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IMPROVING CLOUD NOWCASTING WITH SATELLITE IMAGERY VIA INCORPORATION OF CLOUD TYPE

Eric M Guillot,[1] Thomas H. Vonder Haar, [1,2] and John M. Forsythe [2]

Corresponding author: guillot@cira.colostate.edu

[1] Colorado State University Dept. of Atmospheric Science, Fort Collins, CO, 80521

[2] Cooperative Institute for Research in the Atmosphere (CIRA), Fort Collins, CO, 80521

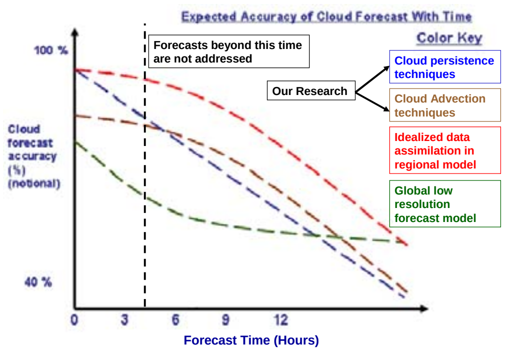
Motivation

Cloud nowcasting (0 – 4 hour forecasts) is a formidable problem for numerical weather forecast models. Fast techniques without spin-up time are needed to address the cloud nowcast problem, otherwise the period of time in which a forecast is needed can pass as a model processes the data. In addition, persistence forecasts perform reasonably well in most situations and are considered the "standard to beat" for other methods.

Potential applications include:

- Solar energy production
- Surface temperature forecasts
- Military (UAV deployment/risk, satellite reconnaissance imaging)

We are testing the hypothesis that persistence is a more effective nowcast for clouds forced by surface topography (such as cumulus) as opposed to higher-level clouds that advect with the wind (such as cirrus).



Methodology

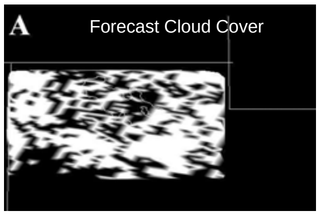
A 5km resolution cloud mask is determined from the Moderate Resolution Imaging Spectrometer (MODIS) aboard both the NASA Terra and Aqua spacecraft. The orbits that both Terra and Aqua maintain allow for Earth to be sampled by each within a four hour window. This allows us to initialize a forecast with the Terra data, and validate it roughly three to four hours later with the Aqua data.

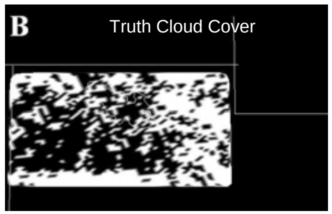
Three forecast methods are introduced:

1. Persistence Forecast: Created by comparing the location of cloud/no cloud pixels in an initial Terra MODIS image to a truth Aqua MODIS image.

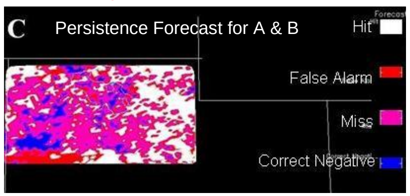
2. 700mb Wind Advection: Created by calculating a mean GOES Cloud Drift wind speed and direction at 700mb and advecting all clouds at this speed.

3. Various Wind Advection: Incorporates the MODIS cloud-top pressure product to associate each cloud with a pressure level. Winds at various heights are calculated from GOES Cloud Drift winds, allowing the clouds to advect at various speeds based on their height.





Images taken over northern Utah



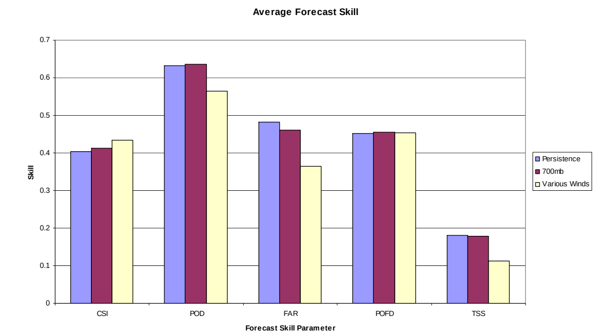
A) Initial (forecast) MODIS 5km Cloud Mask from Terra at 18:55 UTC on 21 March 2009

B) Final (truth) MODIS 5km Cloud Mask from Aqua at 20:40 UTC on 21 March 2009

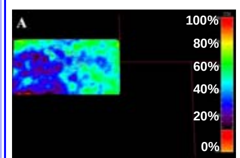
C) Example persistence forecast using Terra image as forecast values and Aqua image as truth values

Preliminary Results

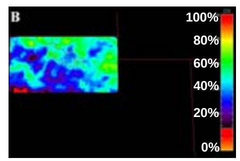
Sixteen cases were used for the initial dataset, taken between 19th-26th of March, April, May, and June 2009 over northern Utah. Skill scores were computed for these cases, and averages of said scores were calculated for each forecast method in question. All three forecast methods performed similarly in terms of Critical Success Index (CSI) with the best results from the various wind advection method (as expected). However, the Probability of Detection (POD) was much lower for various wind advection than it was for the other two methods, and the Probability of False Detection (POFD) was also much higher (thus leading to the relatively lower True Skill Statistic (TSS) score).



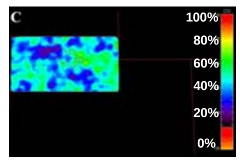
It is also possible to contour skill scores over the region by forecast method. By comparing CSI skill to terrain features in our domain, one can begin to draw conclusions regarding the regional CSI variability. For example, the western part of the domain is a desert climate, thus it makes sense that a persistence forecast would not perform well in this region (one would expect clouds to either dissipate or advect along with the wind). The eastern part of northern Utah, however, is very mountainous. It is here that you would expect advection forecasts to not perform as well as persistence forecasts since clouds over mountain ranges are often orographically generated and tend to stay in the same place.



Contour plot of CSI for Persistence Forecast Method over northern Utah



Contour plot of CSI for 700mb Wind Advection Method over northern Utah



Contour plot of CSI for Various Wind Advection Method over northern Utah

- Must determine which skill score is best representative of overall skill for each forecast method, and whether or not the type of clouds in question influences this (for example, perhaps for orographic clouds, the CSI is the best representation of skill, but for high cirrus the TSS is a better skill metric).

- A fourth forecast method will be introduced, such that clouds located over a region with mountainous terrain will be persisted, while all other clouds will be advected through the region.

- More cases/different regions

- This M.S. thesis topic has an anticipated date of completion of Summer 2010

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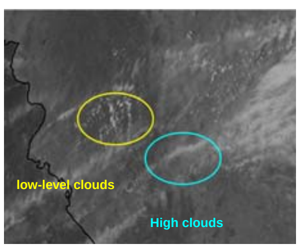
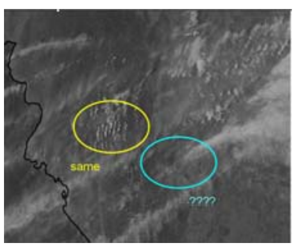
Example of How Cloud Type Influences Nowcasting

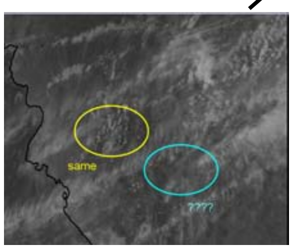
t = 0 hour



t = 1 hour



t = 2 hours



GOES visible imagery of clouds over western Mexico at 20:15, 21:15, and 22:15 UTC respectfully on 18 Feb 2009

When complex topography is involved, low-level clouds tend to remain stationary while high-level clouds simply advect with the wind (out of the domain in this case).

Data Sources

- 5km Cloud Mask from the Moderate Resolution Imaging Spectrometer (MODIS) aboard both NASA Terra and Aqua satellites

- GOES Cloud Drift Winds

-MODIS Cloud-Top Pressure Product