EnKF Assimilation of Cloud Properties Retrieved from GOES

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Objectives:

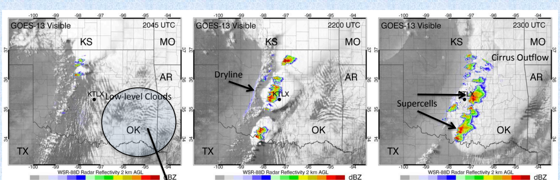
- Assimilate satellite derived cloud properties in hi-resolution NWP models
- Validate that the assimilation improves analysis fields relative to not using satellite data
- Investigate the potential for improved 0 – 3 hour convection forecasts
- Use results as basis for developing procedures for assimilating the array of satellite products to be generated by the GOES-R staring in 2015-16.

Satellite Data:

- GOES-13 (East) 1 km resolution cloud property retrievals from algorithms developed at NASA Langley Research Center.
- Retrieved properties include:
  - Cloud Top Pressure (CTP)
  - Cloud Base Pressure (CBP)
  - Cloud Phase
  - Cloud liquid water (or ice) path (CLWP, CIWP)
- Uncertainty in CTP / CBP is approximately ±1 km
- Use retrievals to determine locations of cloud vs. cloud-free areas to create cloud and humidity variables suitable for data assimilation

Case Study Characteristics:

- Evaluate satellite data assimilation on a severe weather outbreak from **10 May 2010**
- This event produced multiple reports of severe wind, hail, and tornadoes during the late afternoon in Oklahoma (OK) and Kansas (KS)
- Supercells developed ahead of an eastward progressing dryline around 2000 UTC
- Convection moved eastward at speeds of approximately 25 ms^{-1}
- Convection widespread by 2300 UTC generating large cirrus shield in eastern OK



2045 UTC **2200 UTC** **2300 UTC**

East-west wave pattern in low-level cloud field

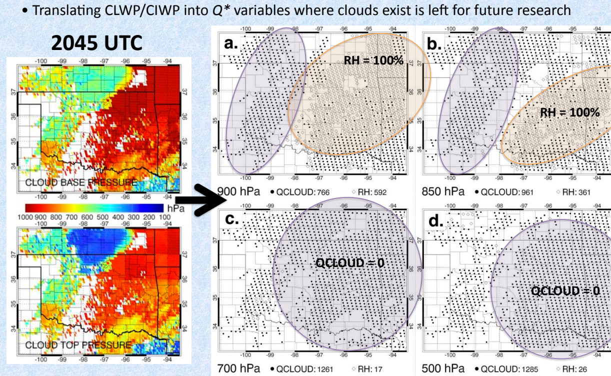
Model Characteristics:

- Advanced Weather Research Forecast (WRF-ARW) forecast model version 3.2.1
- Thompson microphysics, MYJ boundary layer physics, Noah LSM
- Use Ensemble Kalman Filter (EnKF) data assimilation approach: 36 members
- Assimilate traditional observations (surface, marine, aircraft, and radiosondes) into 15 km resolution mesoscale run at hourly intervals between 1200 - 2100 UTC 10 May 2010
- Assimilate cloud and humidity variables at 15 minute intervals starting at 1800 UTC in nested 3 km domain using mesoscale analyses as boundary conditions
- Generate forecast output at 15 minute intervals staring at 2100 UTC
- Compare two experiments: one that assimilates the satellite derived variables **(CLD)** and an otherwise identical run that does not **(NOCLD)**

Satellite Retrievals to Model Variables:

- Retrieved products such as CTP, CBP, CLWP are not suitable for direct assimilation into model as they are strictly 2-D variables where 3-D information is needed
- Instead, use retrieved products to generate cloud and humidity variables corresponding to WRF model state variables:
  - Cloud liquid water content (QCLOUD)
  - Cloud ice content (QICE)
  - Graupel (QGRAUP)
  - Cloud Rain (QRAIN)
  - Relative Humidity (RH)
- Create new 3-D variables using same horizontal resolution as satellite data with a vertical resolution of 50 hPa from 950 – 200 hPa
- If no clouds are present: $Q^* = 0.0$
- Where CBP > pressure > CTP: $RH = 100\%$
- Translating CLWP/CIWP into Q^* variables where clouds exist is left for future research

2045 UTC



Assimilated Data at 2045 UTC:

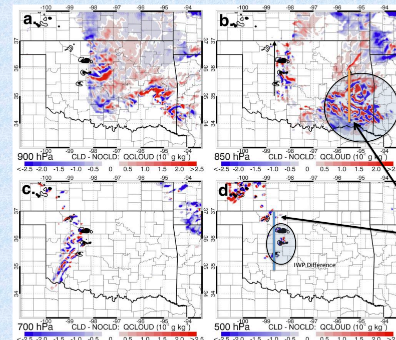
- Large number of null cloud microphysical variables assimilated (e.g. *QCLOUD* = 0)
  - Primarily in western OK, southern KS below 850 hPa, everywhere above
  - No clouds detected at these locations and/or levels from GOES data
- Relative Humidity (*RH* = 100%) assimilation confined to low-levels in eastern OK
  - Corresponds to cloud field observed in GOES visible imagery
- Other assimilation times show similar characteristics

VARIABLE	N_{TOTAL}	N_{ASSIM}	$\%_{ASSIM}$
QCLOUD	205482	187042	91.0
QICE	205482	190796	92.8
QRAIN	205482	190380	92.6
QGRAUP	205482	196392	92.6
RH	37189	22357	60.1
TOTAL	*859117*	*780967*	*90.9*

Total 18-2100 UTC Sample Size

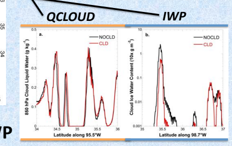
CLD minus NOCLD Cloud Liquid Water (*QCLOUD*) at 2045 UTC

- RED = CLD greater BLUE = NOCLD greater



Results:

- *QCLOUD* Differences greatest at lower levels
- Wave-like difference pattern in southeast OK similar to the cloud pattern observed by GOES-13
- Further differences in west-central OK near developing convection
- Small differences in *IWP* analysis also present (black shading)

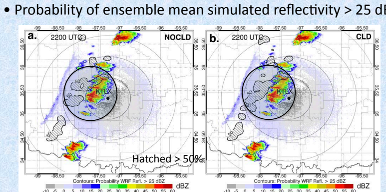


South-North cross sections of QCLOUD and IWP

- Small differences in location (5 – 10 km) and magnitudes between **CLD** and **NOCLD**

Reflectivity Probability Forecast at 2200 UTC

- Probability of ensemble mean simulated reflectivity > 25 dBZ



Color contours = KTLX WSR-88D Reflectivity at 2 km AGL

Results:

- Forecast reflectivity west of observations for both models
- Both capture central OK storm
- **CLD** generates higher probabilities in south-western OK
- Neither model skillful over the other

Summary:

- Assimilating GOES derived cloud and humidity variables produced a measurable effect on model analysis and forecast fields
- Greatest differences occur with water clouds at or below 850 hPa
- Interesting match in *QCLOUD* difference patterns and GOES visible imagery
- One hour simulated reflectivity forecast changed, but no significant increase in skill produced

Ongoing Work:

- Derive and assimilate vertical profiles of CLW and CIW from satellite data
- Determine appropriate cloud microphysical schemes to implement
- Test different vertical and horizontal localization radii
- Determine impacts of assumptions about cloud property uncertainties and errors
  - Very non-Gaussian
- Use idealized storm and environment to tune model to take full advantage of satellite data

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