Adjoint observation impact for a limited area model

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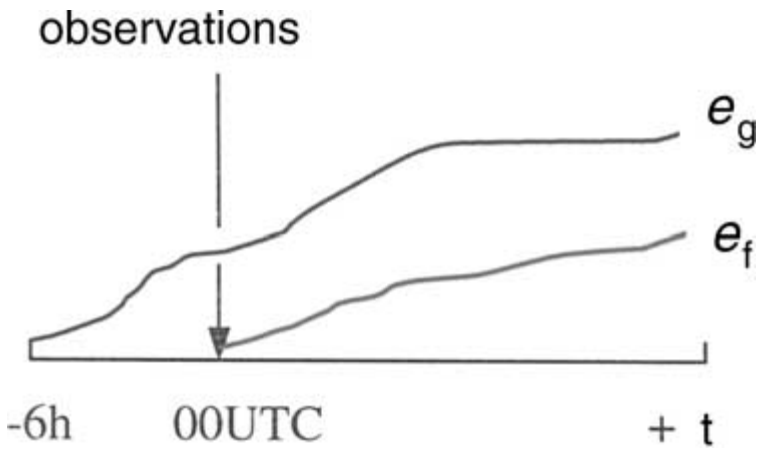
Adjoint Observation Impact

For global systems:

- $e_g > e_f$
- Reduction in error due to assimilation of obs

For limited area model:

- Error not necessarily reduced
- Lateral boundaries vary



Error

Time

Langland and Baker (2004)

COAMPS – US Navy mesoscale model, nonhydrostatic, relocatable

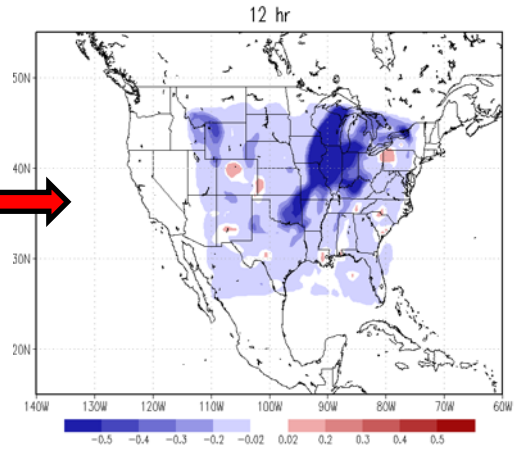
NAVDAS – 3D-Var, conventional obs, satellite winds + retrievals

COAMPS Observation Impact

Adjoints of forecast model and DAS quantify value of each observation in reducing short term forecast error

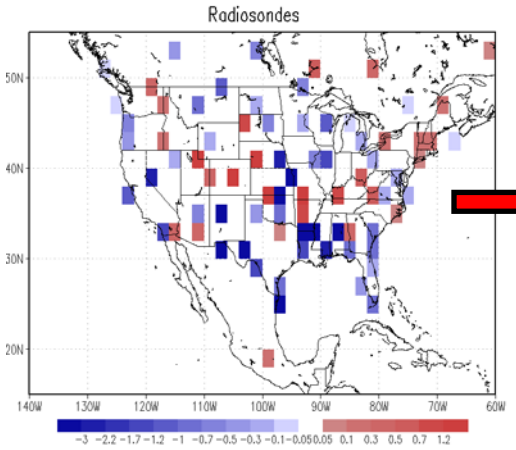
Forecast Error

COAMPS Adjoint



Analysis Impacts

NAVDAS Adjoint



Observation Impacts

- Error only calculated over part of domain
- Analysis grid is larger than model grid

Lateral Boundary / Trajectory Considerations

$$\Delta e_g^f = \left\langle (\mathbf{x}_f - \mathbf{x}_g), \left(\frac{\partial J_f}{\partial \mathbf{x}_f} + \frac{\partial J_g}{\partial \mathbf{x}_g} \right) \right\rangle$$

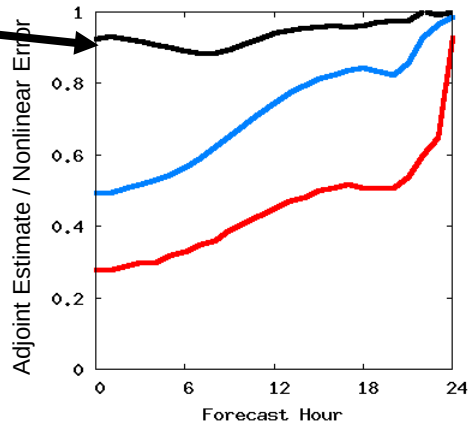
Nonlinear Error

$$\delta e_g^f = \left\langle (\mathbf{x}_a - \mathbf{x}_b), \left(\frac{\partial J_f}{\partial \mathbf{x}_a} + \frac{\partial J_g}{\partial \mathbf{x}_b} \right) \right\rangle$$

Model Space Estimate of Nonlinear Error

Lateral Boundary

Estimate is ~90% of actual value, similar to NOGAPS

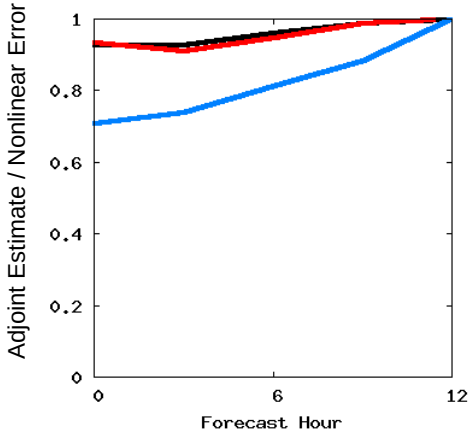


Error box to the east
Outer 7 pts removed
All points

Gradient information propagates through lateral boundaries.

Trajectory

Dry Trajectory
No Ice Physics
All Physics



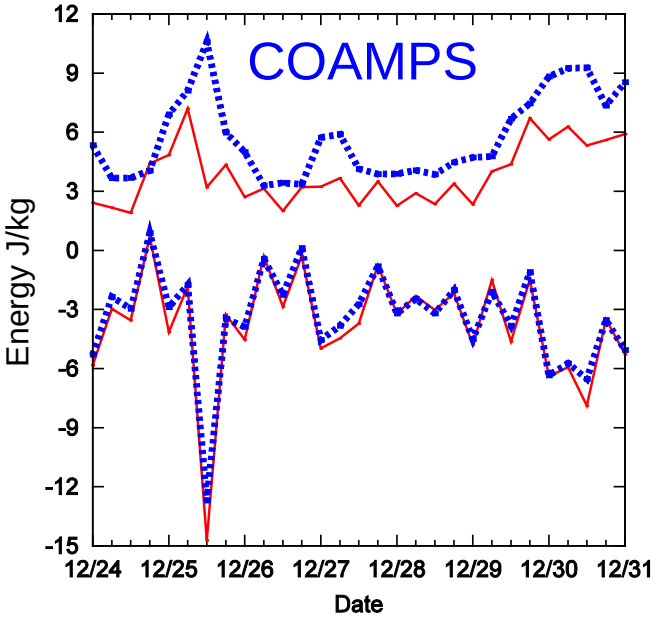
Ice processes degrade trajectory for dry adjoint model integration.

COAMPS Forecast Error and Observation Impact

1 wk 12/24-12/31/2010 COAMPS forecasts over US

60 km horizontal grid spacing – 30 vertical levels

For COAMPS (limited area model), error information is more variable than global systems

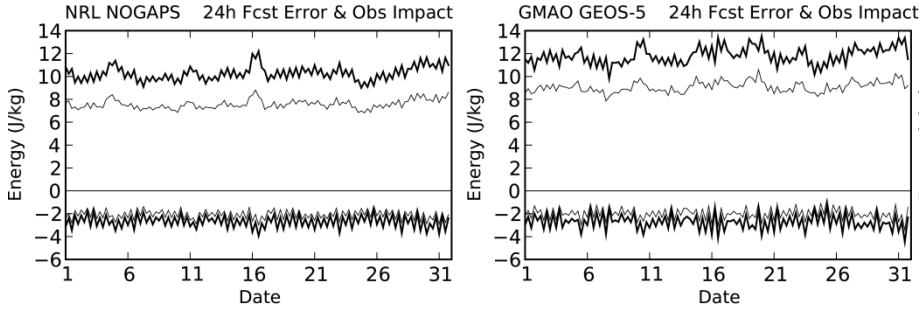


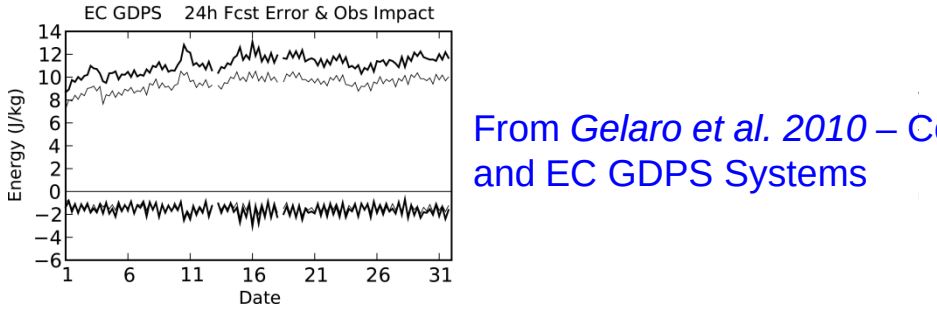
18 hr $\mathbf{x}_b$ error

12 hr $\mathbf{x}_a$ error

Adjoint error estimate

Nonlinear error





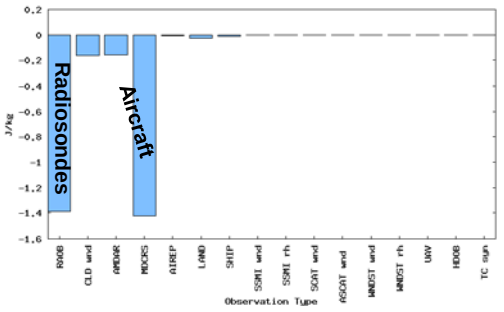
From *Gelaro et al. 2010* – Comparison of NRL NOGAPS, GMAO GEOS-5, and EC GDPS Systems

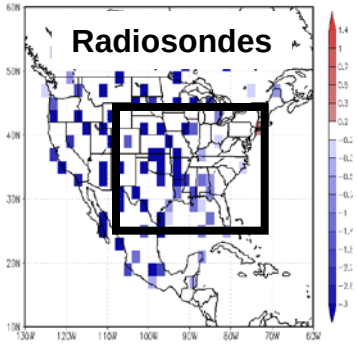
Impacts for different domains

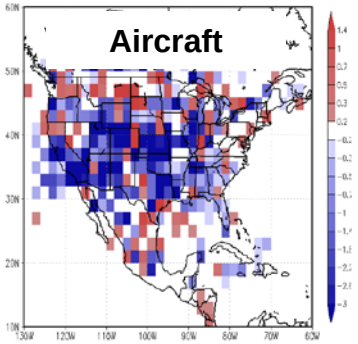
12/24-31 2010

Per Forecast

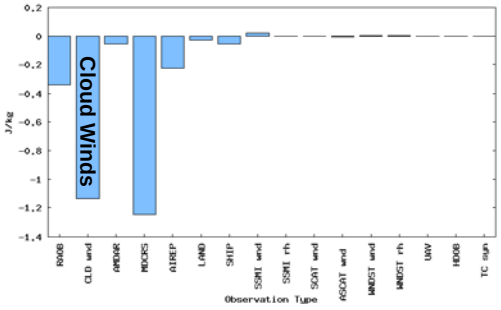
CONUS

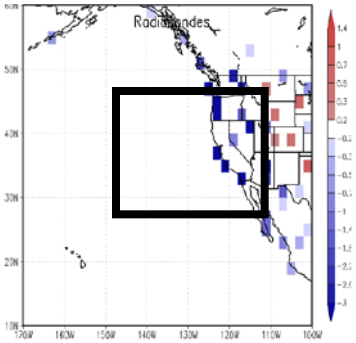


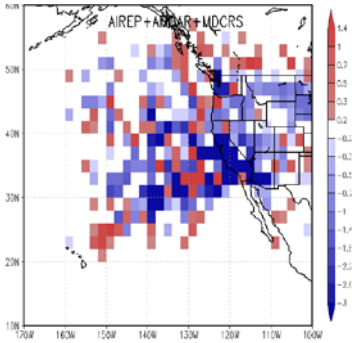




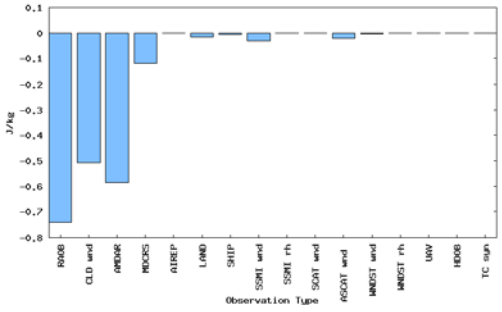
EPAC

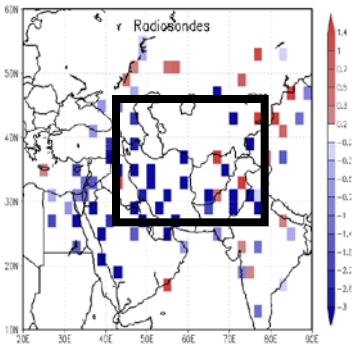


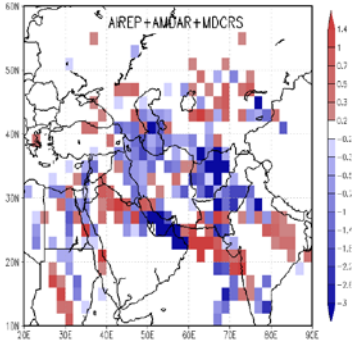




SW Asia





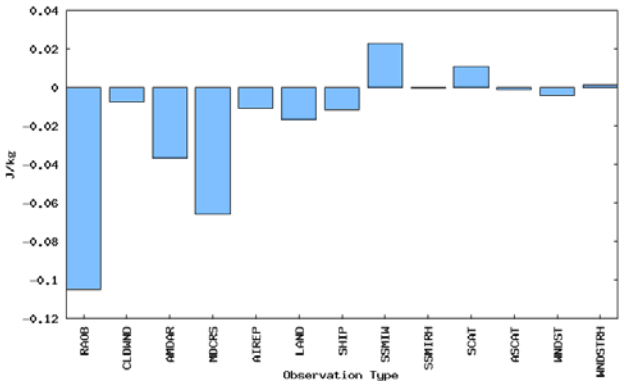


Value of observations depends on area where error is calculated

Horizontal Grid Spacing

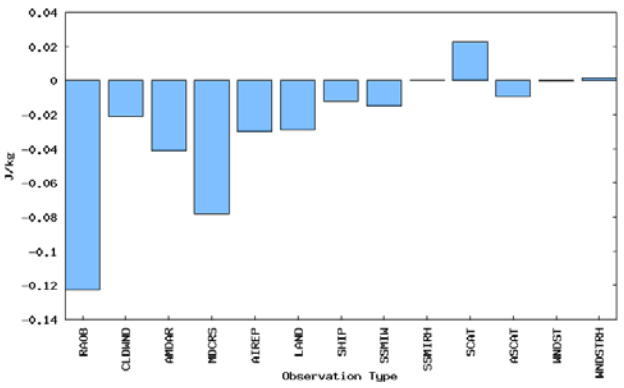
COAMPS 12 hr impacts 05/21-28 2011

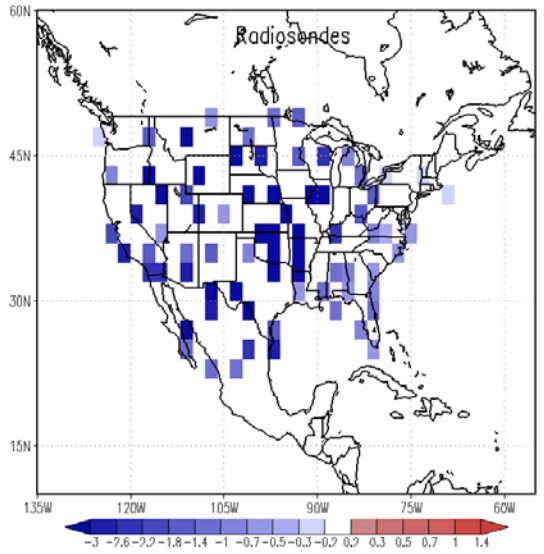
45 km

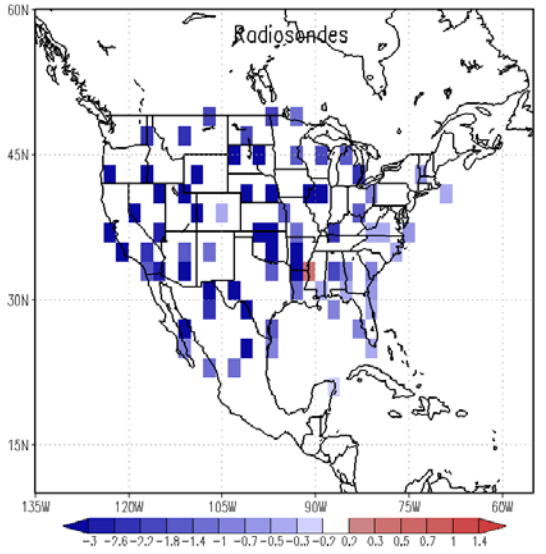


Per Observation

20 km







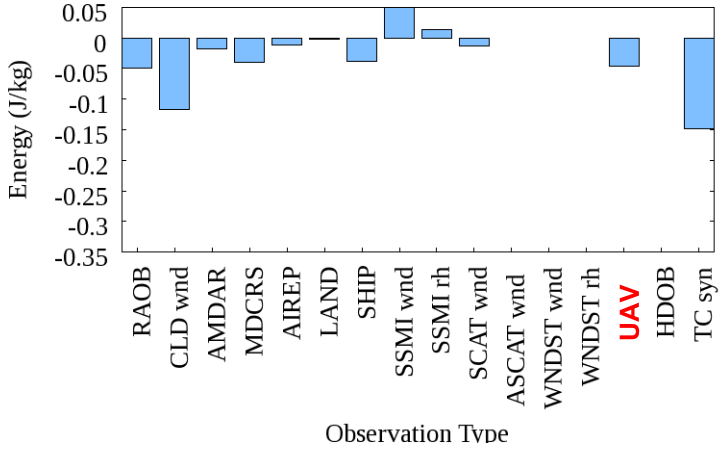
35% of 20 km COAMPS adjoint runs failed

Similar results for successful cases

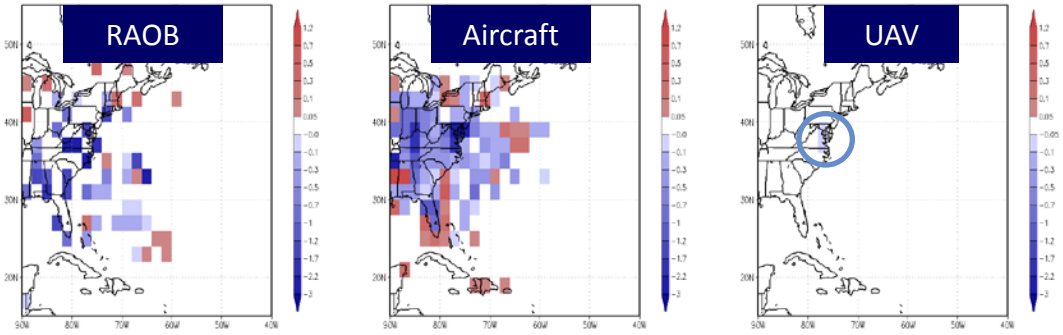
UAV Observations

COAMPS forecasts over W. Atlantic (Δx=45 km – 30 levels)
08/19 12Z - 08/22 00Z 2009. ~ 500 UAV Observations

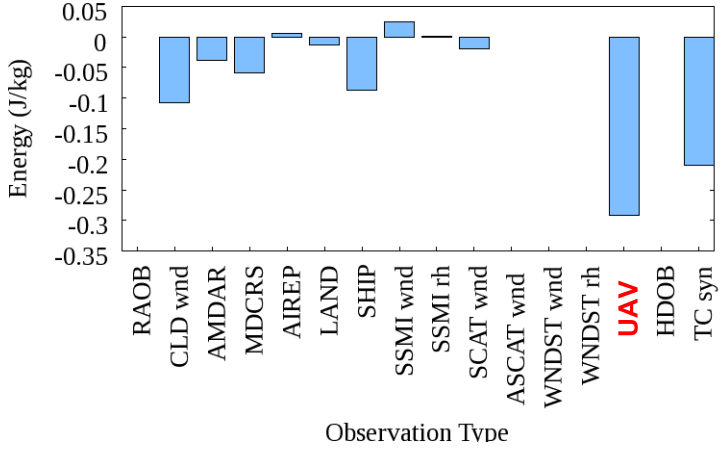
Per Observation * 1000

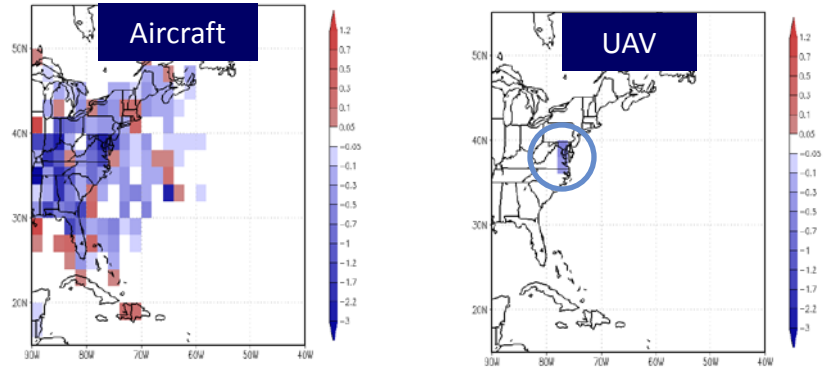


Observation Impacts in 2°x2° boxes



No Radiosondes

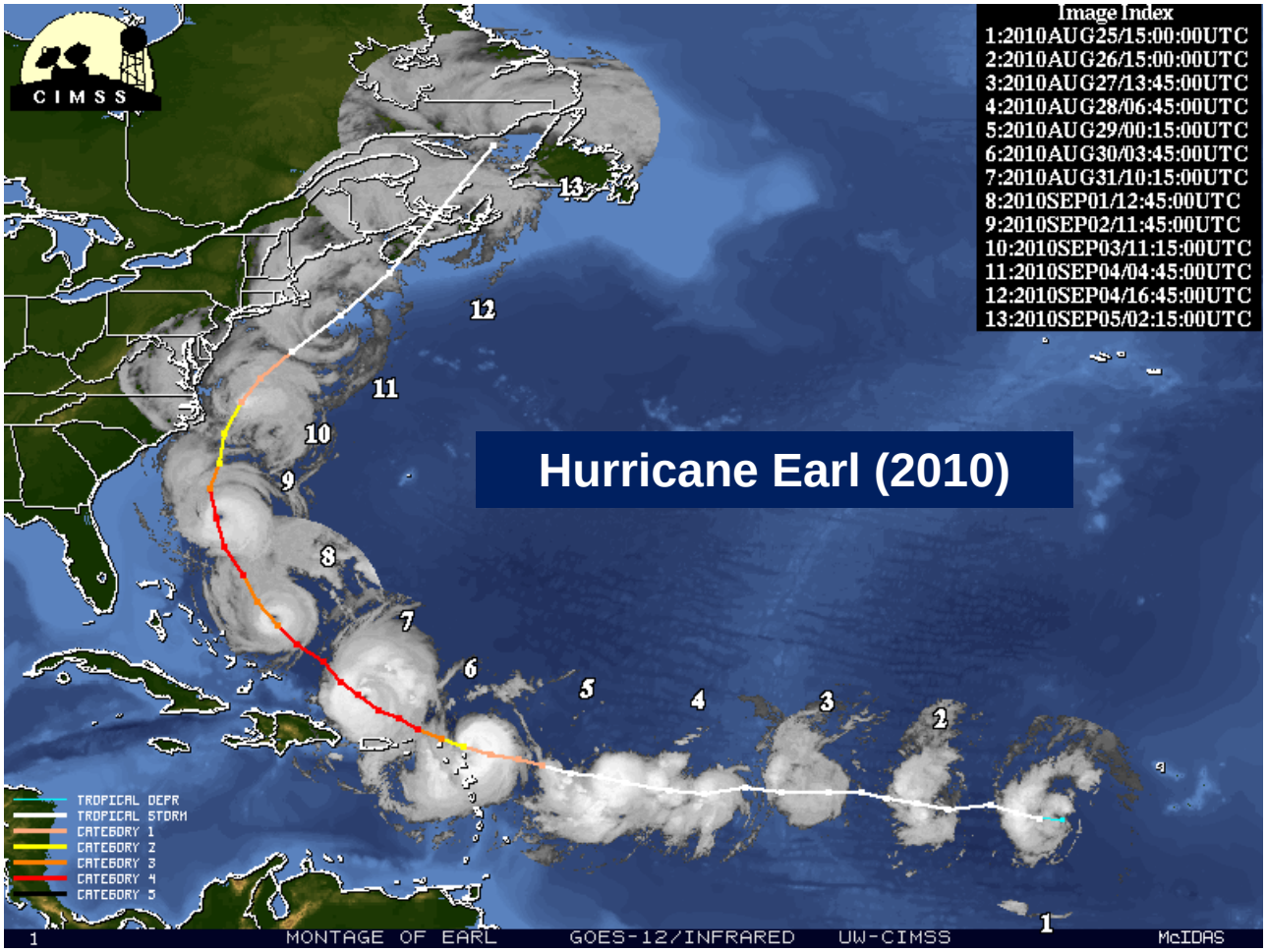




Importance of UAV observation increases when radiosondes are not available

High Density Hurricane Hunter Observations

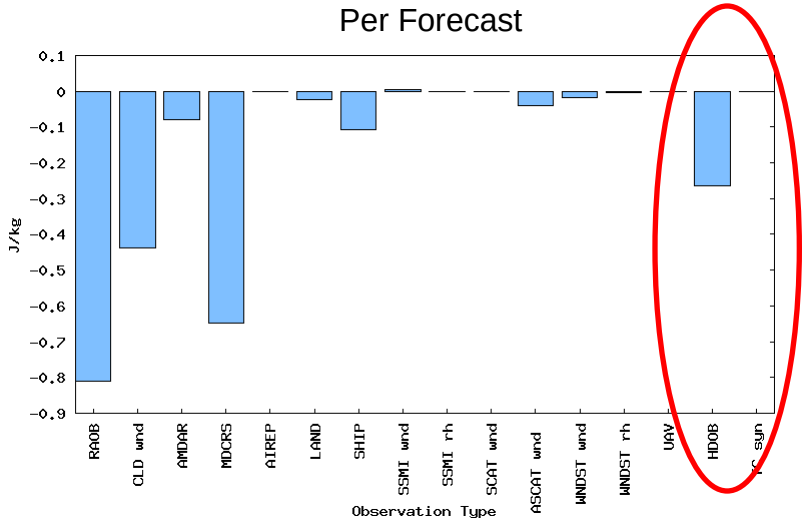
30 sec flight level data in vicinity of storm (includes moisture)

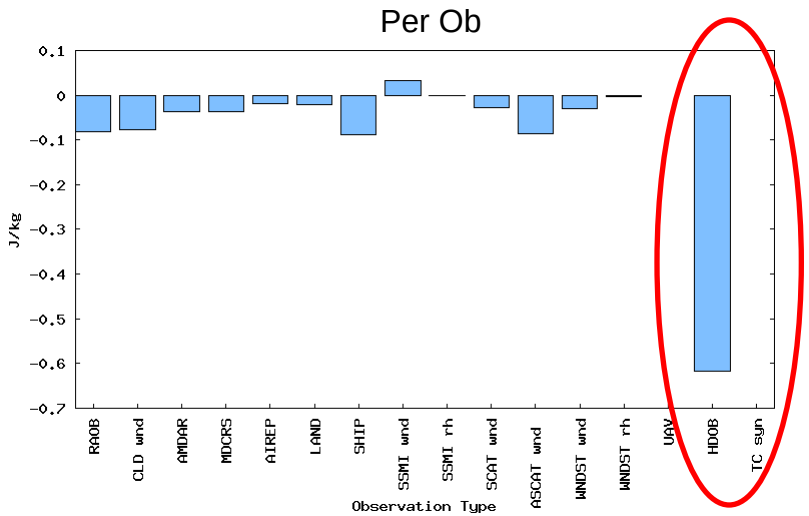


Tropical Cyclones – Synthetics vs High Density Obs

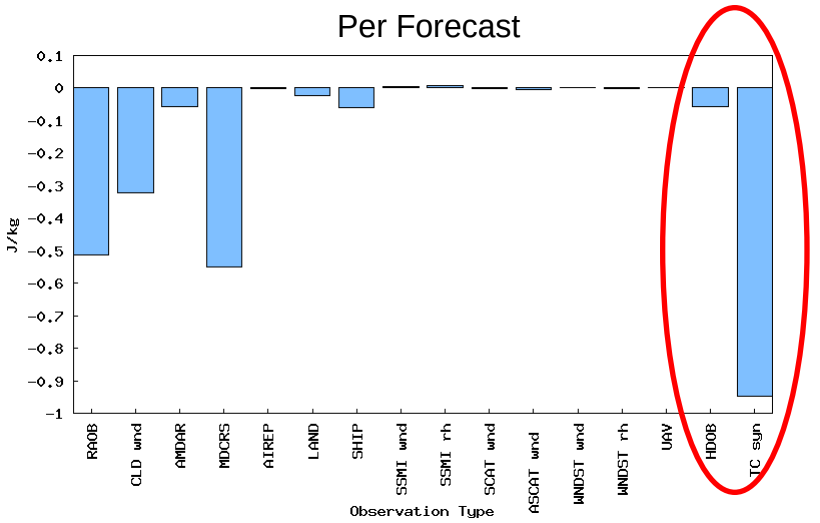
COAMPS Ob Impacts 12 hr forecasts 08/28/00Z- 09/04/12Z (TC Earl 2010)

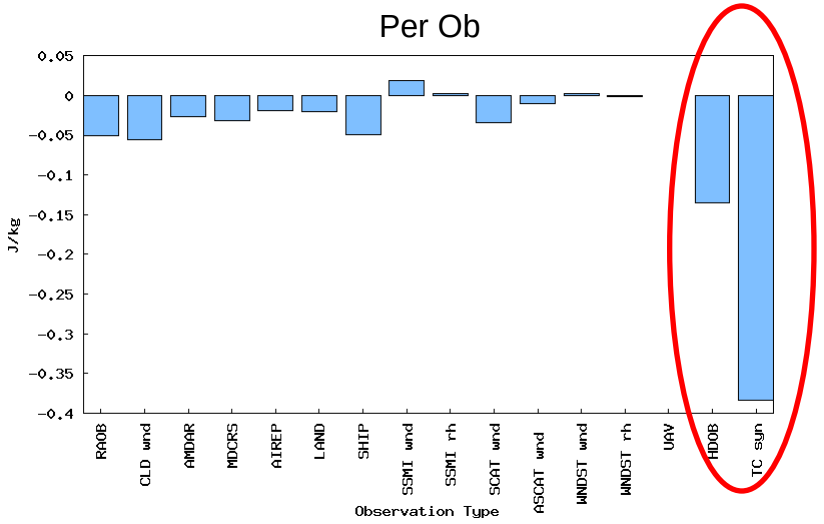
No Synthetics





With Synthetics





Future Considerations

- Consistent “Truth”
- Different metrics
- Impacts for tactical scales (space and time)

Error Estimate

Difference in error can be estimated from observation or model grid point sensitivity

$$\Delta e_g^f = \left\langle (\mathbf{x}_f - \mathbf{x}_g), \left(\frac{\partial J_f}{\partial \mathbf{x}_f} + \frac{\partial J_g}{\partial \mathbf{x}_g} \right) \right\rangle$$

Quantification of Error at Verification Time

$$\delta e_g^f = \left\langle (\mathbf{x}_a - \mathbf{x}_b), \left(\frac{\partial J_f}{\partial \mathbf{x}_a} + \frac{\partial J_g}{\partial \mathbf{x}_b} \right) \right\rangle$$

Model Space Estimate

$$\delta e_g^f = \left\langle (\mathbf{y} - \mathbf{H}\mathbf{x}_b), \frac{\partial J_f^g}{\partial \mathbf{y}} \right\rangle$$

Observation Space Estimate