Incorporation of GOES-R Lightning Mapper Observations into the Gridpoint Statistical Interpolation System for use in GDAS

Karina Apodaca[1] (karina.apodaca@colostate.edu), Milija Zupanski[1], Lewis D. Grasso,[1] and Robert DeMaria[1]
[1]Colorado State University/Cooperative Institute for Research in the Atmosphere

Preparation of the Global Data Assimilation System (GDAS) for the use of GLM Observations

- We have previously developed a nonlinear lightning observation operator suitable for GDAS (based on maximum vertical velocity) (Apodaca et al. 2014)
- We are currently focusing on adding this particular operator in the GSI framework (used as a 3DVAR DA system, Hybrid GSI-possibility)
- Preparing this capability for future GOES-R GLM observations
- Development of a lightning data assimilation interface with experimental network lightning data as a proxy for future GLM

- Control variables: T, Q, U, V, P, θ
- The goal is to minimize the 3DVAR GSI cost function:

$$J=\frac{1}{2}\left[\boldsymbol{x}^{T}\mathbf{B}^{-1}\boldsymbol{x}+\left(\mathbf{H}\boldsymbol{x}-\boldsymbol{y}\right)^{T}\mathbf{R}^{-1}\left(\mathbf{H}\boldsymbol{x}-\boldsymbol{y}\right)\right]$$

- where ***x*** are the control variables, **H** is the lighting observation operator, *y* are the lightning observations **B** and **R** are the background and observation error covariances

GSI-Lightning Observation Operator Algorithm 1

- Starts by calculating maximum vertical velocity (w_{max}) from a reduced form of the continuity equation

$$w=\frac{1}{g}\left(v\cdot\nabla_{\sigma}\Phi+\dot{\sigma}\frac{\partial\Phi}{\partial\sigma}\right)$$

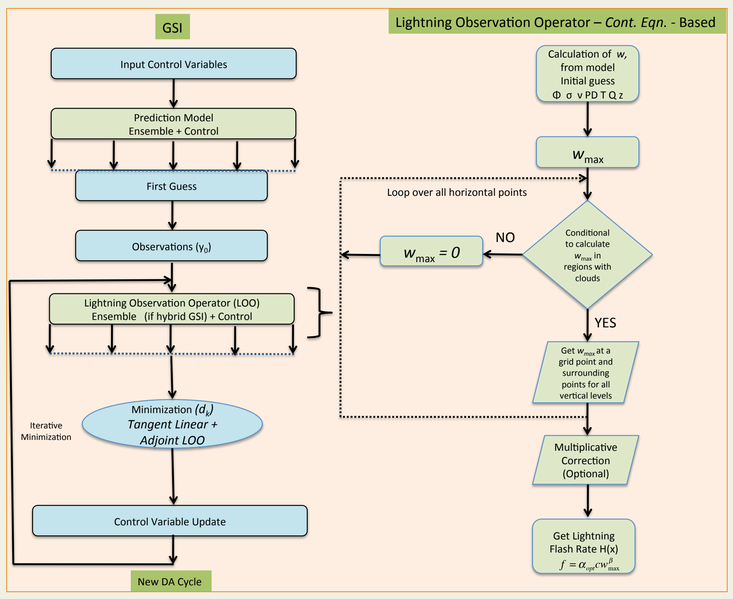
- An empirical relationship between lightning flash rate and vertical velocity is used (Price and Rind, 1992)

$$f=c\alpha_{opt}w_{\max}^{\beta}$$

$c=5e^{-6}$, α_{opt}= correction parameter (optional), β= 4.5

- Flow chart of the GSI DA system and Lightning Observation Operator shown to the right

GSI (left) and continuity eqn. based lightning observation operator (right) flow chart



GSI-Lightning Observation Operator Algorithm 2

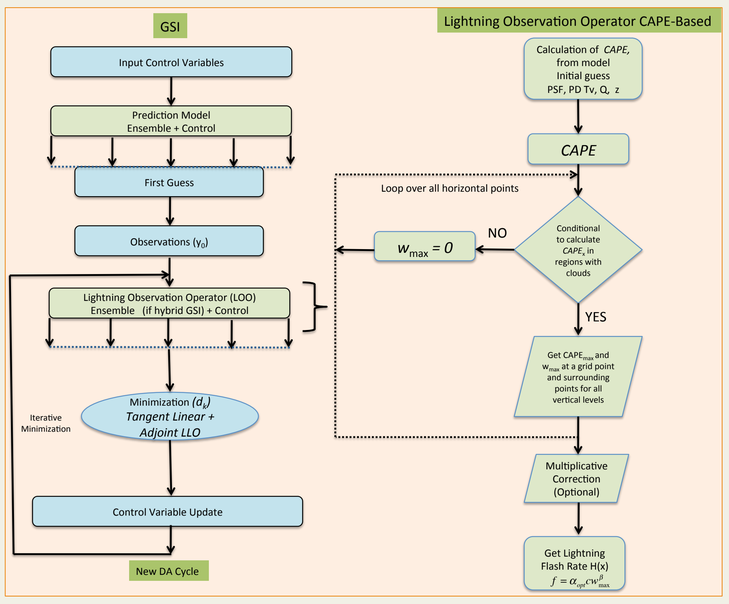
- Starts by calculating *CAPE* from the guess fields

$$CAPE=g\int_{LFC}^{EL}\frac{\theta(z)-\bar{\theta}(z)}{\bar{\theta}(z)}dz$$

and $CAPE_{\max}$

- Then we can use the Price and Rind, 1992 relationship between lightning flash rate and vertical velocity as before
- Flow chart of the GSI DA system and CAPE-based Lightning Observation Operator shown to the right
- maximum vertical velocity (w_{max}) is then calculated from $CAPE_{\max}$ using: $W_{\max}\approx W_{CAPE\max}=\sqrt{2(CAPE_{\max})}$

GSI (left) and CAPE-based lightning observation operator (right) flow chart



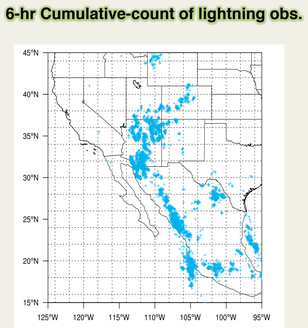
TESTING AND PRELIMINARY RESULTS

GSI Processing of new lightning data

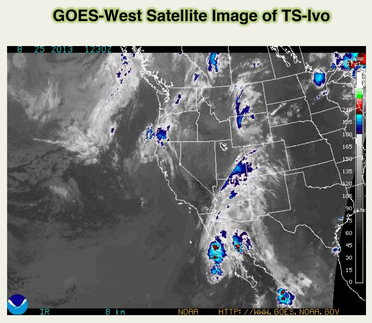
- Converting geo-located lightning strikes into BUFR format
- Created an adequate read subroutine (read_light.f90)
- Processing of lightning data through the nonlinear observation operator algorithm by comparing the guess to observations (setup_light.f90, setuprhsall.f90)
- Further processing of lightning observations inside the inner-loop minimization: tangent linear and adjoint of observation operator

Test Case: Tropical Strom Ivo

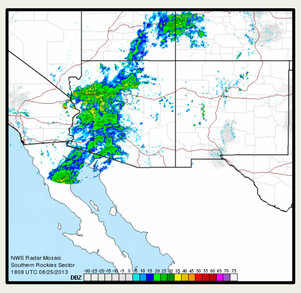
6-hr Cumulative-count of lightning obs.



GOES-West Satellite Image of TS-Ivo



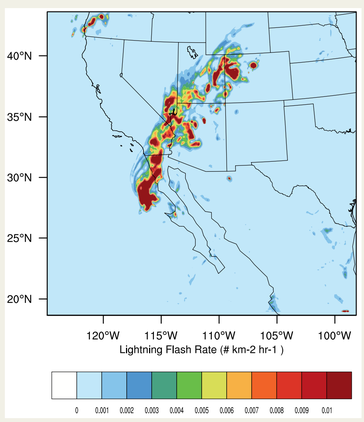
NWS Radar Mosaic for Ivo Remnants



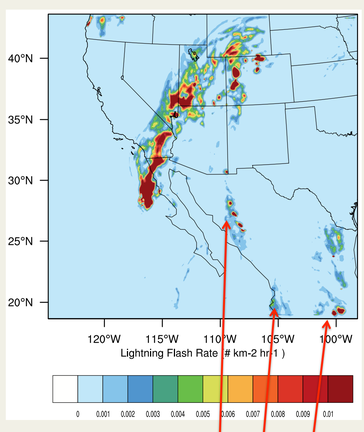
- **Tropical Storm Ivo** (August 22-25, 2013) making landfall on the Baja California peninsula during late NAM season
- Ivo's remnants triggered flash floods over the Southwest United States on the afternoon of the 26th of August (Nevada, Colorado)
- Using WRF for initial testing

Forecasting lightning flash rate

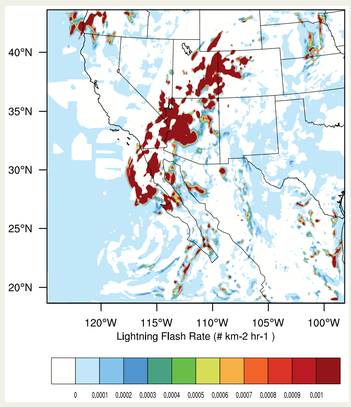
Forecast: Conventional obs. only



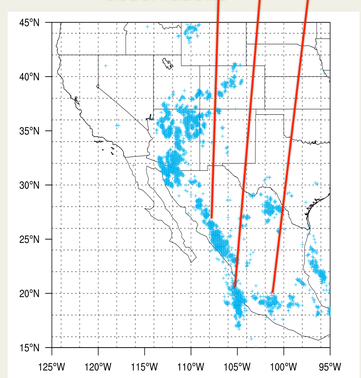
Forecast: Conventional + lighting



Difference between experiments



Surface-network lightning observations

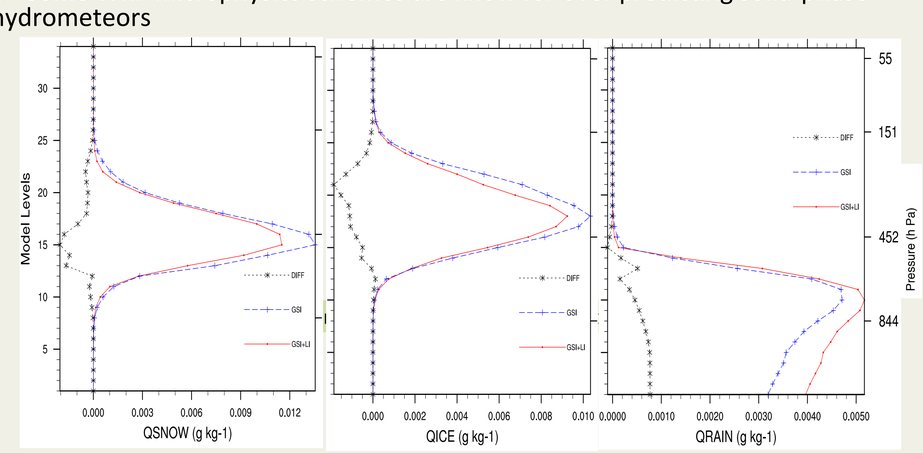


- The assimilation of lightning data (CONV+LIGHT) improved the forecast of lightning in several areas as compared to conventional observations (CONV-only)
- Results were verified with WWLLN data as GLM-proxy

Impact on cloud microphysics and precipitation

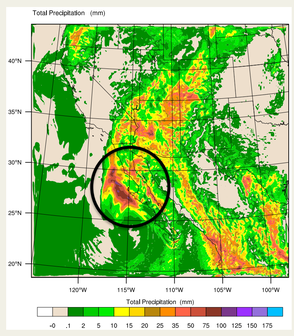
(If using a cloud-resolving model)

- The assimilation of lightning data impacted cloud hydrometeors – shown: ice, snow, rain mixing ratios as shown in vertical profiles (below)
- (CONV+LIGHT) red lines, produced less ice and snow, but more rain mixing ratio as compared to (CONV-only)
- Some WRF microphysics schemes are know for over predicting solid-phase hydrometeors

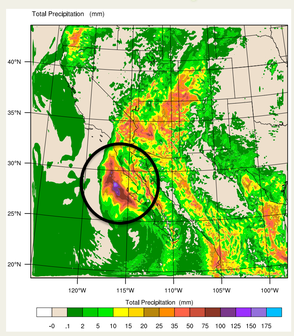


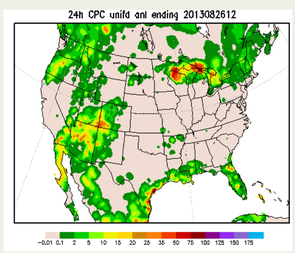
- Initial assessment of the impact of lightning data on 24-hr accumulated precipitation indicates most of the impact occurring over the ocean, at the location of the tropical cyclone
- GOES-R data will provide a valuable opportunity for observing and verifying forecasts of precipitation at very high resolution

CONV-only Experiment



CONV-LIGHT Experiment





Future Work

- Complete the lightning data assimilation interface for GDAS
- Conduct testing for different types of meteorological phenomena

Acknowledgements and References

Acknowledgements:

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References:

Apodaca, K., Zupanski, M., DeMaria, M., Knaff, J. A., and Grasso, L. D.: Development of a hybrid variational-ensemble data assimilation technique for observed lightning tested in a mesoscale model, Nonlin. Processes Geophys., 21, 1027-1041, doi:10.5194/npg-21-1027-2014, 2014.
Price, C. G. and Rind, D.: A simple lightning parameterization for calculating the global lightning distribution, J. Geophys. Res., 97, 9919–9933, 1992.