Use of Remote Sensing Data to Improve Air Quality Decision Support Systems Used to Protect Public Health

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4. The Lake Michigan Air Directors Consortium (LADCO)
5. California Air Resources Board (CARB)
6. Texas Commission on Environmental Quality (TCEQ)
7. Georgia Environmental Protection Division (Georgia-EPD)
8. U.S. Environmental Protection Agency (USEPA)

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NSSTC

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

PROJECT INFORMATION

TOPIC: **Use of Remote Sensing Data to Improve Air Quality Decision Support Systems Used to Protect Public Health**

POP: 8/24/2018 - 8/23/2021 (ROSES17-A.39) – **NCE till 8/23/2022** **(Continuing Project – Third Year Report)**

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Partners: California Air Resources Board (CARB), USEPA, Texas Commission on Environmental Quality (TCEQ), Georgia Environmental Protection Division (GA-EPD), The Lake Michigan Air Directors Consortium (LADCO - representing states of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin).

NASA Assets: NASA's GOES Product Generation System (skin T, surface insolation and albedo, cloud top T, cloud albedo); MODIS/VIIRS products (Skin Temperature, surface insolation and albedo)

Objective: To employ NASA assets and satellite products to improve the air quality management Decision Support Tools (DSTs) used in defining emission control strategies for attainment of air quality standards.

Specific Objectives

In This Project NASA Assets and Satellite Data Will Be Used to Improve the Quality and Accuracy of Retrospective Baseline Simulation in Which Proposed SIP Emission Reductions Are Tested

Upgrading Data Generation and Archiving System

- **Upgrading GOES Product Generation System (GPGS):** Collaborating with the NASA's the Short-term Prediction Research and Transition (SPoRT) Center, GPGS is being recoded to process GOES-16, 17, data.

Improving Representation of Physical Atmosphere

- **Improved Characterization of Surface Energy Budget:** Using satellite derived skin temperature to retrieve soil moisture and improve surface evapotranspiration performance in WRF.

- **Improving Boundary Layer Development in the Model:** By improving BL moisture and temperature structure.

- **Improving Model Cloud Field:** Assimilating satellite observed clouds in WRF.

Improving Emission Estimates in AQ Model

- **Utilization of Satellite Derived Lightning Generated NO (LNOx) Emissions:** This activity utilizes newly available lightning optical energy from the Geostationary Lightning Mapper (GLM) to produce lightning-generated NO emissions input for air quality models.

SCHEDULE / MILESTONES

Major Tasks	FY19	FY20	FY21
Retooling retrieval software for GOES-16 Advanced Baseline Imager (ABI)	New insolation retrieval code completed	Testing & evaluation	Reprocessing to fill the archive
GOES Skin-T retrieval (SPoRT)	Work has started, 2016 being priority	Testing & evaluation	Reprocessing to fill the archive
New Cloud Assimilation System	Software were revised and tested	Performing simulation for the summer of 2016	Test and evaluation with GOES16 products
LNOx Emission Estimates Using GLM obs.	Lightning NOx (LNOx) algorithm development	Testing & evaluation within AQ models	Realtime generation to be added to GPGS (Revised)
Testing skin-T assimilation over regions of interest		2016 simulations using moisture adjustment (California)	Impact of moisture adjustment for eastern U.S.
Benchmarking (multiple activities)	Performing simulations for 2016, testing CAS	Performing simulations for 2016, testing LNOx emissions	Performing Benchmarking soil moisture adjustment
Transition (LADCO, TCEQ, G-EPD, …)		2016 SIP simulations	Coordinating with EPA and GAEPD
Initial health and economic impact analysis		Using BenMAP	

Completed (green)
Ongoing (yellow)
Future (red)

Stakeholder Involvement/Interaction

- Monthly meetings with our partner organizations have been useful.
- Atlanta results generated interest. Were invited to make a presentation for other regulatory agencies.
- Working with EPA to transition tools related to LNOx work
- Working with GAEPD to transition tools related to cloud assimilation work.
- Have already provided data and relevant computer codes for model evaluation to LADCO.

RISKS & ISSUES

- Same as last year, the major challenges are due to the restricted working conditions under the pandemic. Our NASA partners at NSSTC are still working virtually.
- Disparity in the definition of a “lightning flash” for GLM vs NLDN, combined with recent changes in NLDN classification of a cloud-to-ground flash, and GLM upgrades are introducing new challenges for validation efforts. This has delayed the benchmarking for LNOx work.
- Availability and quality of insolation retrievals is still a concern. We are still examining the use of COD as a possible option to replace insolation in CAS. The preliminary results haven’t been satisfactory.

Overall Objective: To Reduce the Uncertainties in Regulatory Air Quality Simulations Through the Use of NASA Science and Satellite Data Products

In SIP modeling it is imperative to reproduce the observed atmosphere. Model uncertainties translates into uncertainties in emission control strategy which has significant economic consequences.

Fundamental Approach in Air Quality Modeling Systems

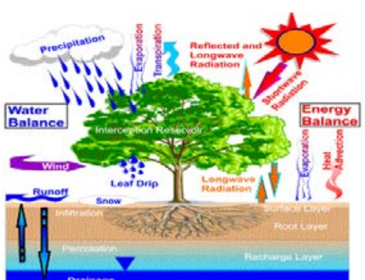
Physical Atmosphere

Models: e.g. WRF, Recreates the physical atmosphere (winds, temperature, precipitation, moisture, turbulence etc) during the design period

Clouds and microphysical processes

Atmospheric dynamics

Boundary layer development



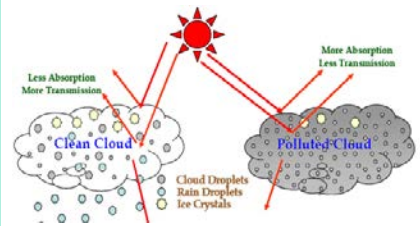
Fluxes of heat and moisture

LSM describing land-atmosphere interactions

Winds, temperature, BL height, Radiation, moisture, surface properties, surface fluxes, precipitation

Chemical Atmosphere

Models: CMAQ, CAMx
Recreates the chemical atmosphere



Heterogeneous chemistry, aerosol

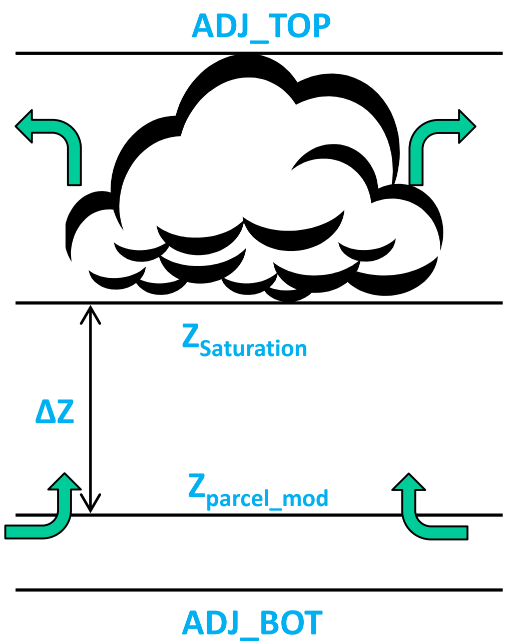
Transport and transformation of pollutants

Photochemistry and oxidant formation

Natural and antropogenic emissions, Surface removal

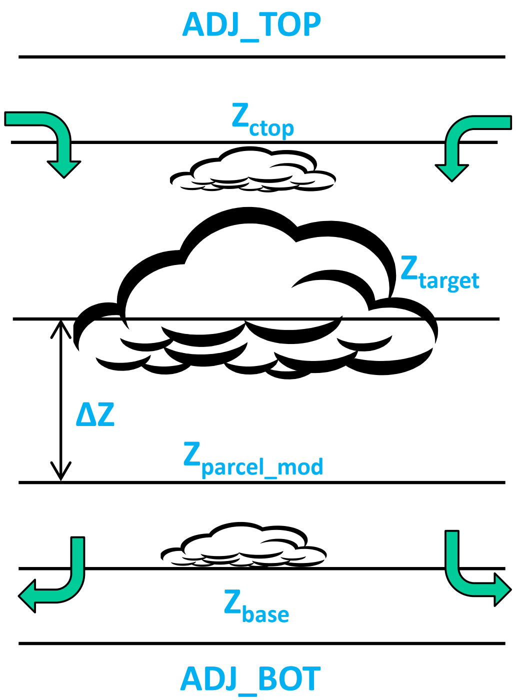
Cloud Assimilation System (CAS)
for
Weather Research and Forecasting (WRF)
Model

Correcting Under-Prediction



- Lift a parcel to saturation using ***satellite*** info.
- Estimate the location and thickness of the observed cloud from GOES derived cloud top temperature and cloud albedo.
- Given the estimated cloud thickness, determine the minimum height a parcel at a given model location needs to be lifted to reach saturation.

Correcting Over-Prediction



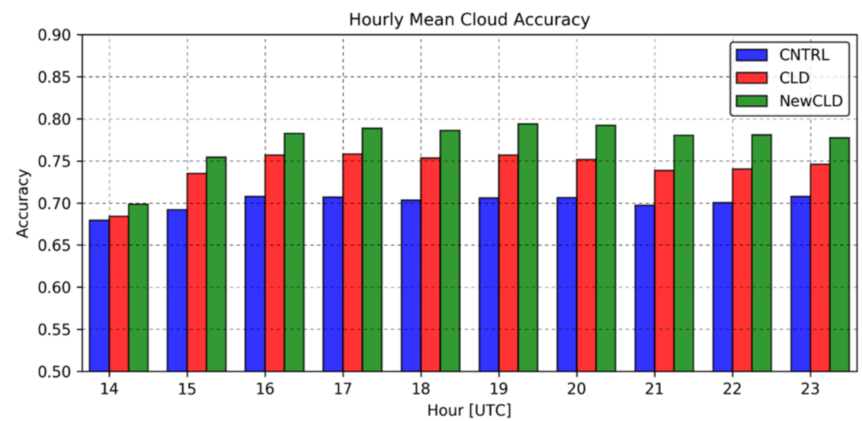
- Create subsidence within the ***model*** to evaporate cloud droplets.
- Determine the model layer with the maximum amount of cloud liquid water (CLW) and how far it has to move to completely evaporate.

The displacement height is used to estimate vertical velocity.

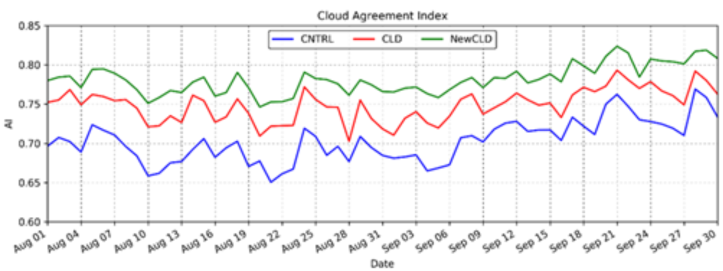
Cloud Assimilation System (CAS) Was Further Improved
White et al. 2022 (NewCLD)

AI = (A+D) / (A+B+C+D)		WRF		TOTAL
		Cloudy	Clear	
GOES	Cloudy	A	B	A+B
GOES	Clear	C	D	C+D
TOTAL		A+C	B+D	A+B+C+D

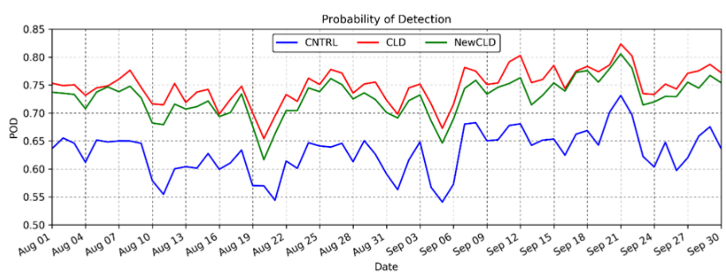
Hourly Mean Cloud Accuracy



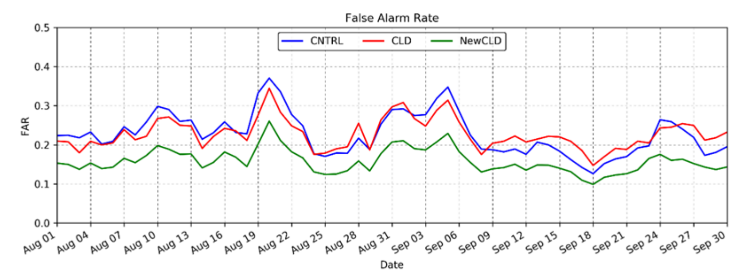
Cloud Agreement Index



Probability of Detection

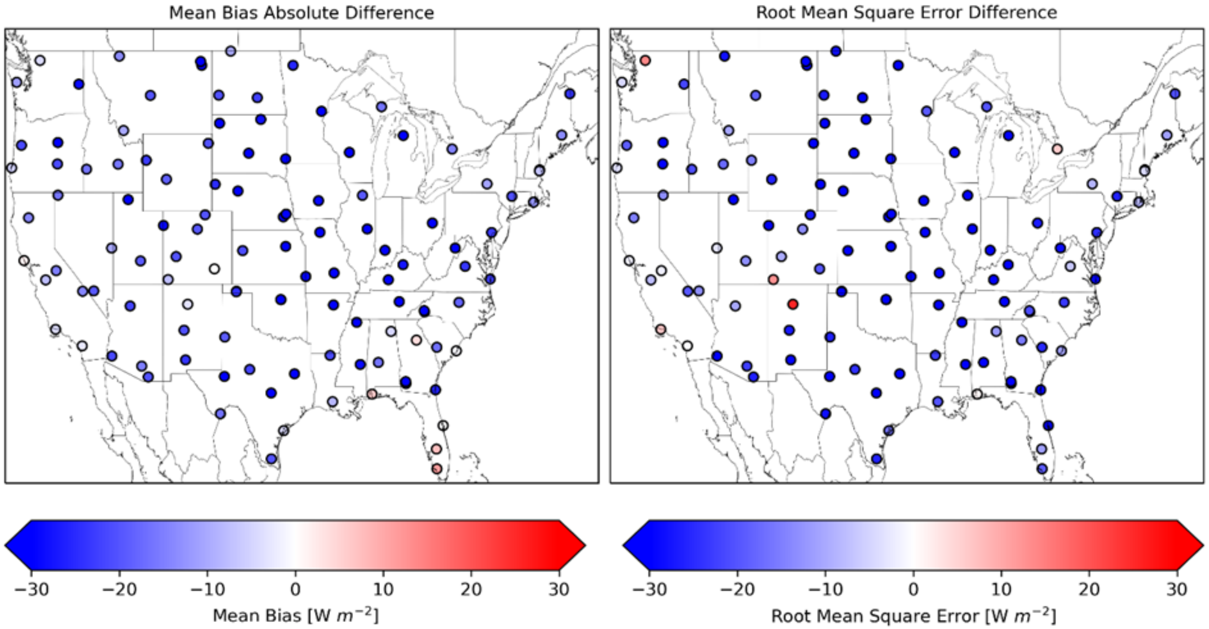


False Alarm Rate



Mixed results for surface statistics for wind, temperature, humidity (some improve and some degrade). Overall, no significant change.

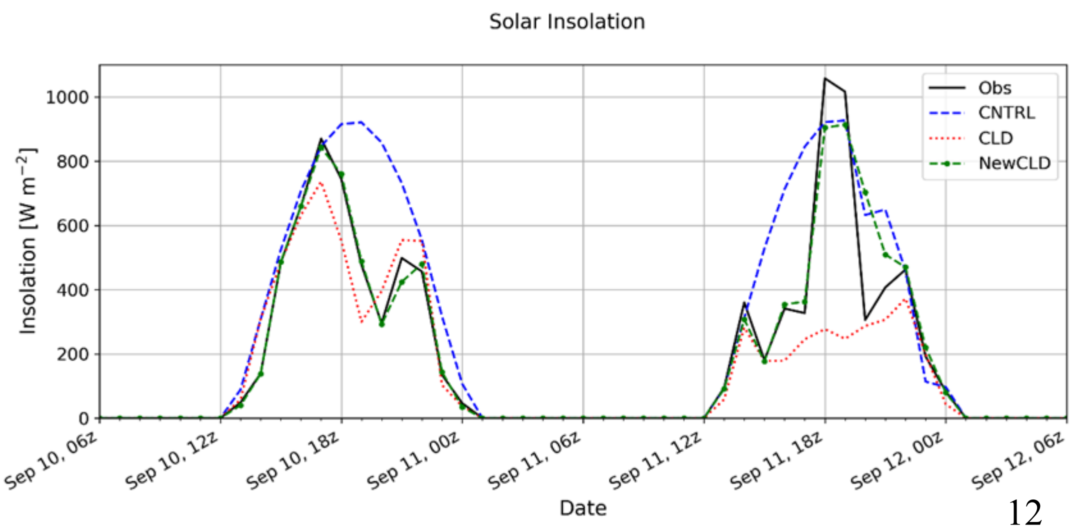
Significant Improvement in Surface Radiation



Results discussed in White et al., 2022

Model performance with respect to USCRN pyranometers observations. (left) Mean bias absolute difference and (right) the RMSE difference between the CNTRL and NewCLD (negative indicates a reduction in bias and error when cloud assimilation is performed).

Time series comparison of surface insolation between the observation (black) and WRF simulated: CNTRL (blue), CLD (red) and NewCLD (green) at the USCRN station located near Austin, TX.

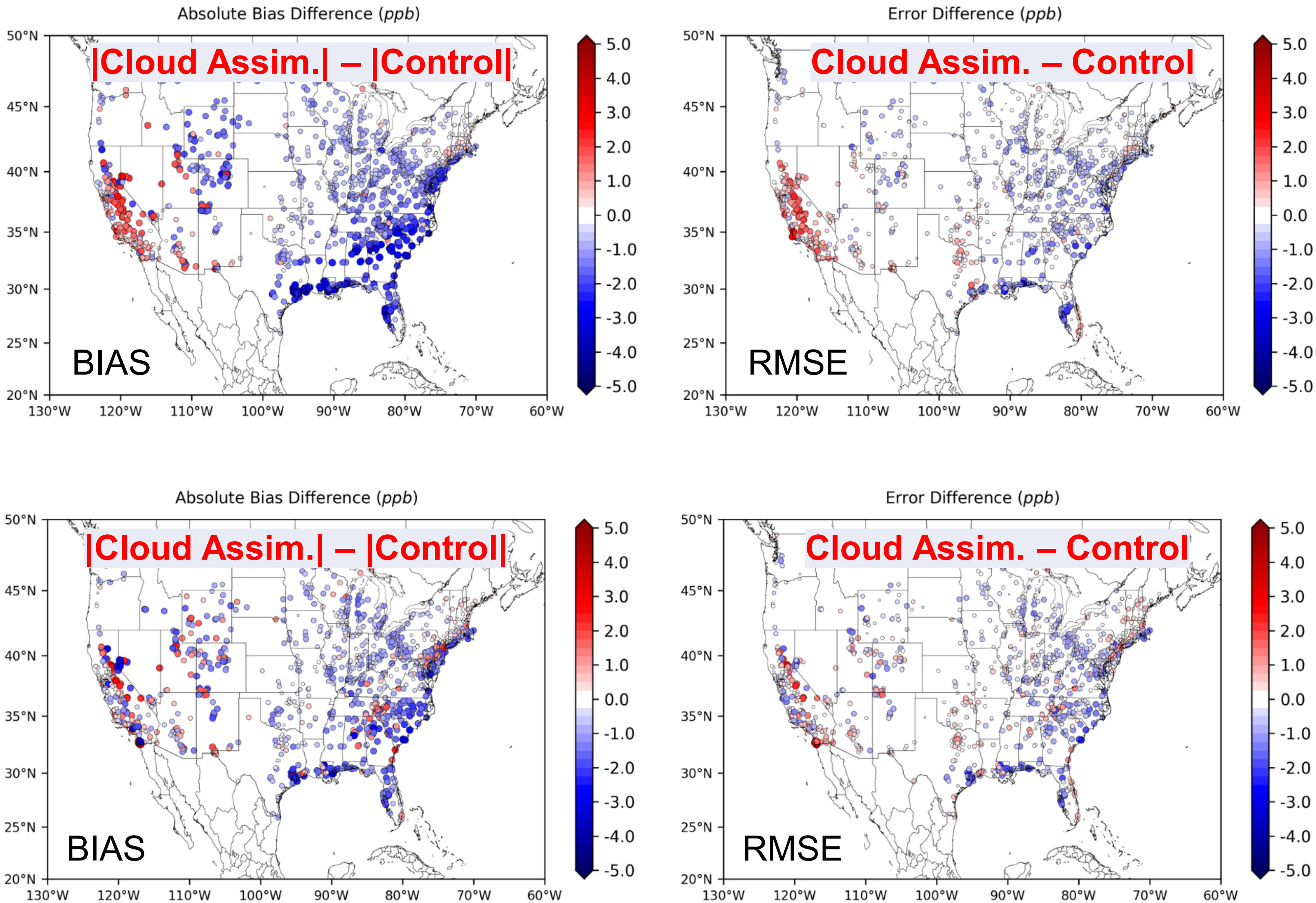


Impact of Cloud Assimilation
on
2016 Air Quality Simulations

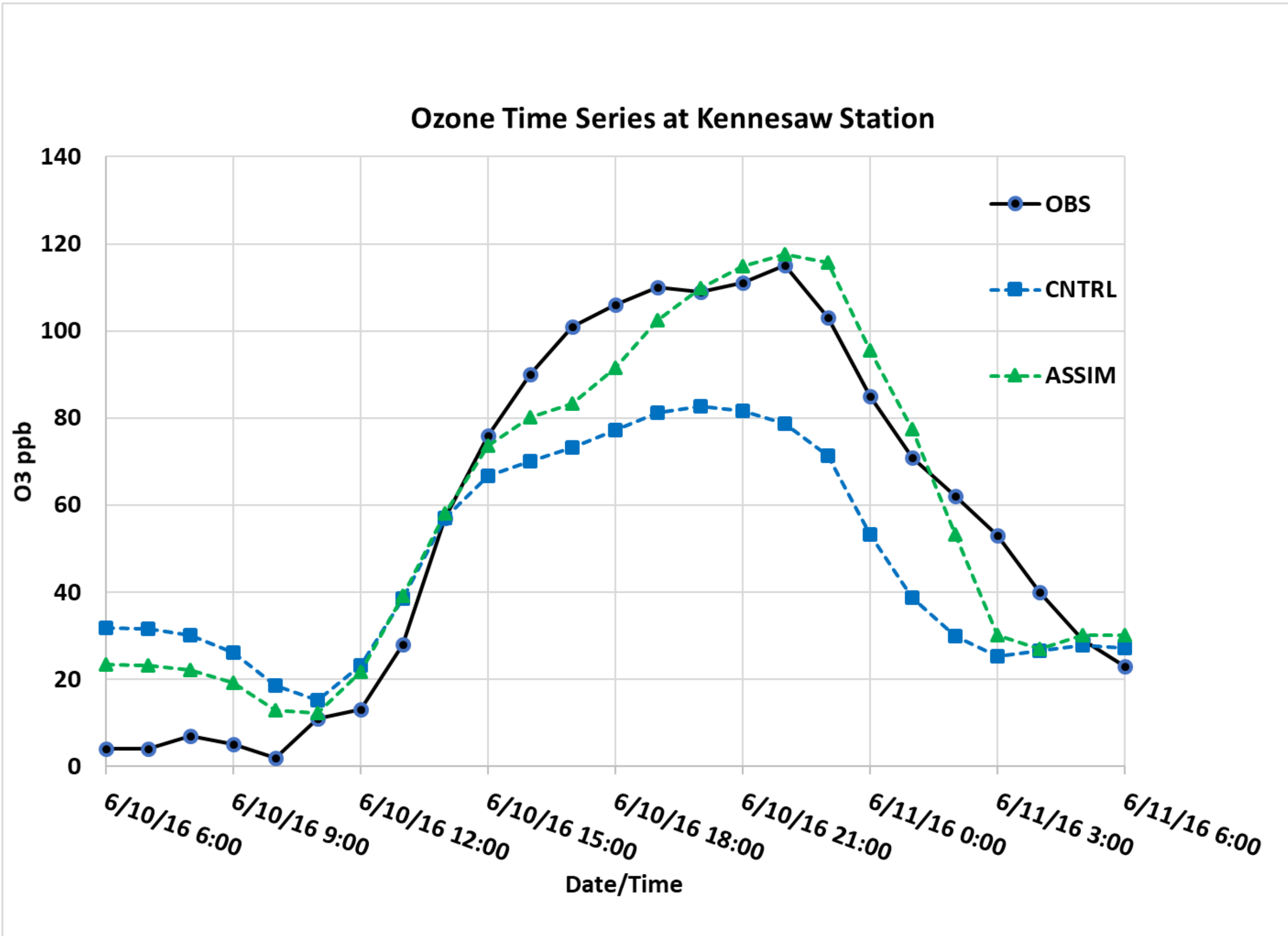
Improvement in ozone BIAS and RMSE (June-September 2016)

DAYTIME

NIGHTTIME

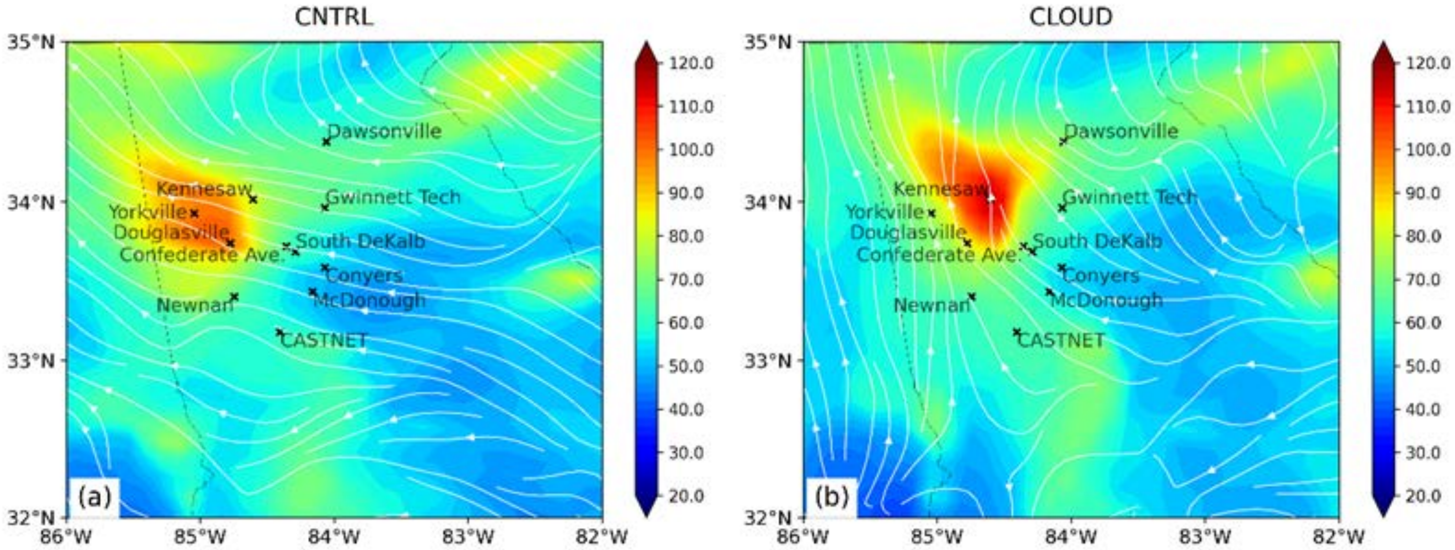


2016 Simulations for Atlanta Performed Exceptionally Well for Ozone Exceedance Days



The improvement was due to wind correction by CAS

Surface Ozone Mixing Ratio (ppb) (2016-06-10 21:00:00)



Results discussed in Cheng et al., 2022

GLM-Derived LNOx

UAH LNOx model from GLM – based on Koshak 2014

$$P = \sum_{k=1}^{N} P_k = \beta \frac{Y}{N_A} \sum_{k=1}^{N} q_k = N\bar{P}$$

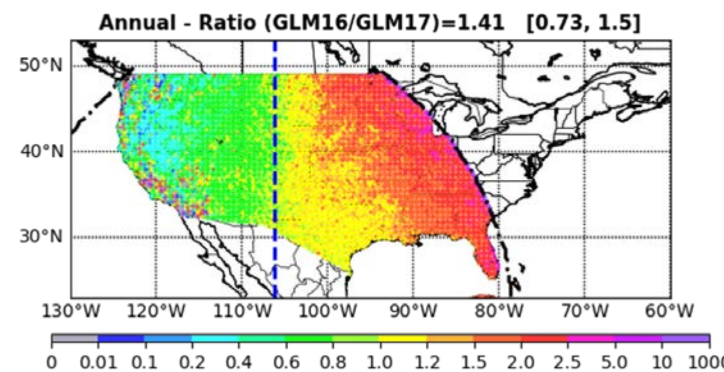
N = Number of flashes
$\bar{P}$ = 250 moles/flash
Y = 10^{17} molecules/J (thermo-chemical yield of NOx)
N_A = 6.022x1023 molecules/mol (Avogadro's number)
q_k = flash optical energy detected by GLM
β = scaling factor (accounting for all the uncertainties)

$$\beta = \frac{N_A N \bar{P}}{Y \sum_{k=1}^{N} q_k}$$

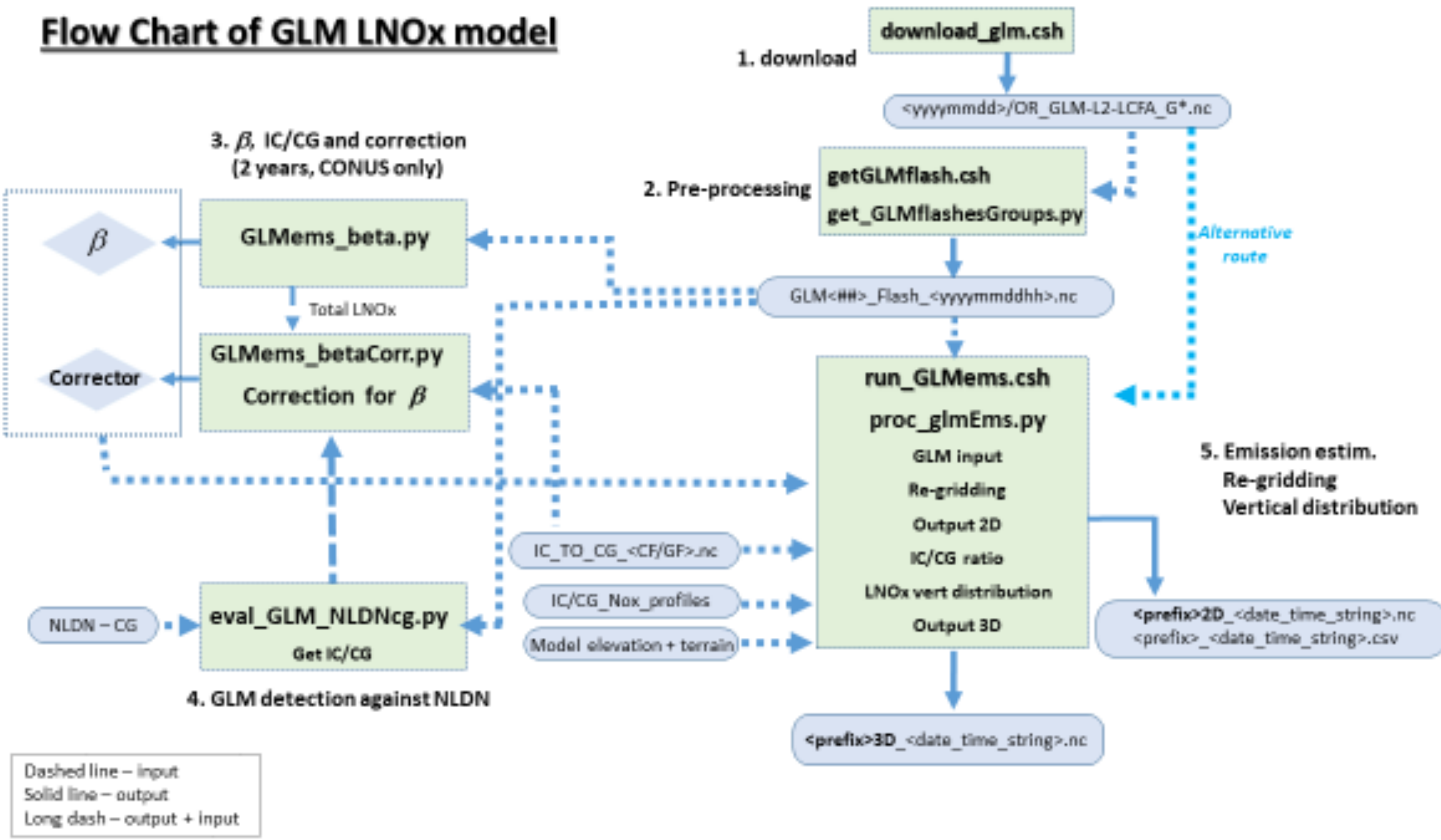
With N being total number of GLM flashes for 2019-2020

- Uses both GLM16 and GLM 17 (options of either or both)
- β – model approach
- Default β over 2 years of CONUS average
- 3D emissions (options of 2D or/and 3D emissions)
- Empirical IC/CG LNOx vertical distribution
- Z-ratio (IC to CG) options (default, empirical, or against NLDN CG)
- Works for various grid specifications (map projections)
- User output specifications
- Parallel processing

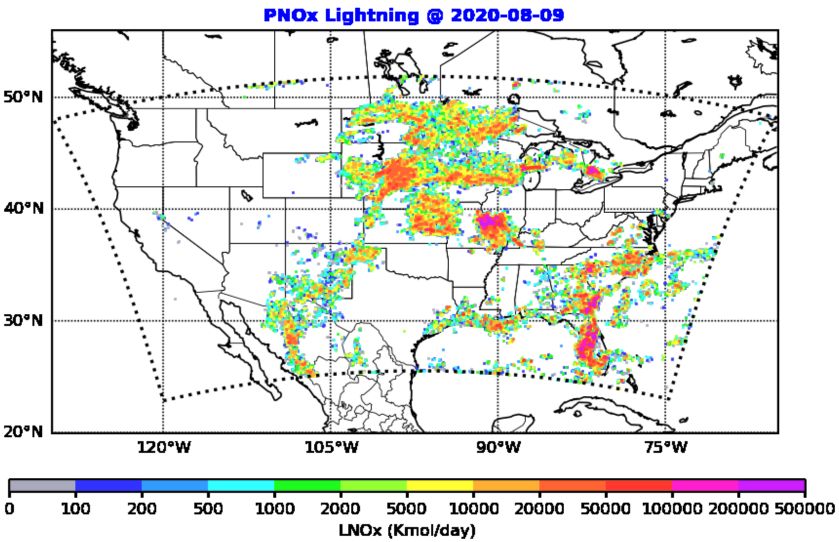
Detection degrades as the viewing angle increases

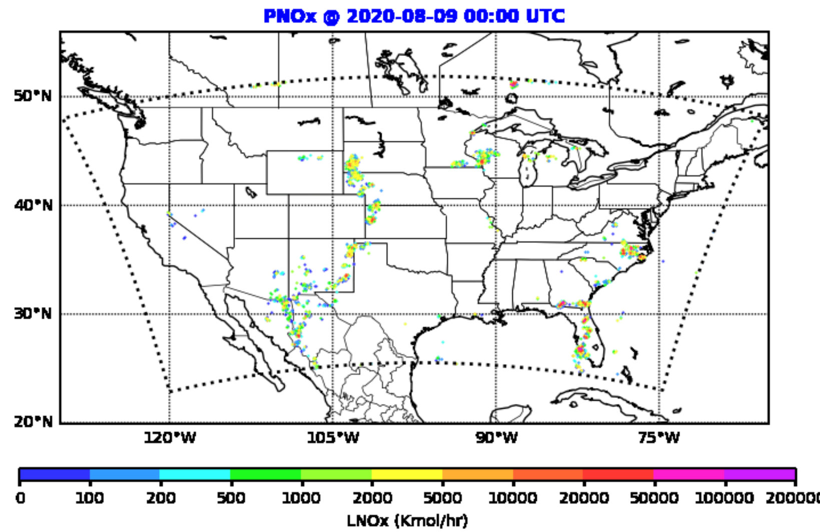


Tool is Ready and Tested, But More Analysis is Needed



Daily vs hourly – August 2020 case
Animation 8/9/2020 00:00 UTC - 8/14/2020 23:00 UTC





Thank You