

NOAA ROSES Semi-Annual Report

Reporting Period: September 2020 – February 2021 (1st report)

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Project Title: Enhancing forecast applications of the GOES-R GLM in tropical cyclones using multi-platform data fusion and AI to assess environment and storm structure

Executive Summary (1 paragraph max)

This project aims to utilize machine learning to aid in the development of an automated real-time predictive tool that can assess links between the Geostationary Lightning Mapper (GLM), tropical cyclone (TC) structure, and TC intensity change to improve intensity forecasts. The Year 1 milestones focus on data collection and data processing in anticipation for the machine-learning training and tool development in Years 2 and 3. The project is on track to achieve all Year 1 milestones on time and early work has begun on future milestones. The core project team holds bi-weekly meetings to maintain communication and keep the project on track.

Progress toward FY20 Milestones and Relevant Findings (with any Figs)

Year 1 milestones are focused on collection, assembly, and intercomparisons of the machine-learning data inputs. The bulk of this reporting period was focused on re-gridding the data to a common grid and applying appropriate quality control. The following datasets were collected and re-gridded to the GOES ABI grid and/or a 0.02° grid:

Lightning: GLM, WWLLN

Satellite imagery: ABI

Environmental data: Aerosol Optical Depth (AOD), GFS 0.25° analysis, GFS deep-layer vertical wind shear, Ocean Heat Content (OHC), Sea Surface Temperatures (SST)

Other: Land masks, distance to land grids

Additional datasets that were collected with no additional processing yet include:

Lightning: ISS-LIS (quality-controlled dataset released in December 2020)

TCs: ATCF a-decks, ATCF b-decks, SHIPS model database

Year 2 milestones were also started during this period. Initial machine-learning training datasets were assembled and sample sizes for overlapping data were examined. Machine learning can be an iterative process and we have taken the approach of starting this process early.

Deliverables completed during this reporting period include:

- 1) AGU Poster Presentation:

Kowaleski, A., S. Stevenson, K. Musgrave, and K. Hilburn, 2020: Enhancing Tropical Cyclone Forecast Applications using GLM with Machine Learning. *2020 Fall AGU Meeting*, virtual.

- Contributions to a “Quick Guide” on Tropical Cyclones and the Geostationary Lightning Mapper. This was assembled using the current literature as a baseline. We plan to update the quick guide with relevant findings uncovered by this machine-learning project.

Geostationary Lightning Mapper Tropical Cyclones Quick Guide

Why do we care about lightning in tropical cyclones?

Lightning in tropical cyclones is not ubiquitous. It occurs most frequently in the eyewall and outer rainbands of TCs, and less frequently in the intermediate stratiform region. In TCs, lightning is associated with anomalously strong updrafts in the mixed-phase region.

Increases in TC lightning may precede or occur in association with changes in storm intensity and/or structure, though previous studies have given ambiguous results about the relationship between lightning activity and TC intensity change.

Lightning can reveal important information about convection that may be obscured by the cirrus.

GLM Lightning products in TCs

Flash Extent Density (FED): Count of all flashes that pass through a grid cell during a specified time period. Small AFA values indicate lightning in convective cores, while large values indicate more expansive flashes in stratiform and arid regions of older convection.

Average Flash Area (AFA): Average area (km²) of all flashes that occur in each grid cell during a specified time period. Small AFA values indicate lightning in convective cores, while large values indicate more expansive flashes in stratiform and arid regions of older convection.

Total Optical Energy (TOE): Sum of all energy (J; 10⁻¹⁵ J) observed in each grid cell during a specified time period. It depicts the lightning optically observed by GLM and can identify areas of strengthening and weakening lightning activity.

Because lightning occurs less frequently in TCs compared to other convective storms, FED, AFA, and TOE are usually computed over longer time intervals (e.g. 10-30 min).

Thirty-minute GLM (a) FED, (b) AFA (km²), and (c) TOE (J; 10⁻¹⁵ J), with ABI 11.2 μm infrared imagery of Hurricane Michael at 2300 UTC 9 October 2018.

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Lightning and TC intensity change

The relationship between lightning and TC intensity change remains unclear, with studies finding contradictory results. Based on Stevenson et al. (2018), the following characteristics may be associated with future intensification:

- Lightning at or inside the RMW (more efficient diabatic heating).
- Inner-core lightning occurring downshear or downshear left.

Enhanced rainband lightning may also favor intensification.

Stevenson et al. (2018)

$\Delta V_{max} \approx 2-5 \text{ m s}^{-1} (24 \text{ h})^{-1}$

Lightning and TC structure

(a) 2311 UTC 20 Aug
(b) 2311 UTC 20 Aug
(c) 2311 UTC 20 Aug
(d) 2311 UTC 20 Aug
(e) 2311 UTC 20 Aug
(f) 2311 UTC 20 Aug

Higher detection efficiency (> 70%) than ground-based WWL/N, especially for lightning over oceans.

GLM observes lightning on 8 x 8 km grid, so spatial resolution is not as high as some ground networks.

Provides time-integrated quantities of lightning characteristics (FED, AFA, TOE).

Supplements ABI imagery by revealing what is occurring below cloud tops.

Lightning locations must be corrected for satellite parallax.

However, the absence of lightning does not indicate a lack of convection, as numerous regions of low brightness temperatures do not contain lightning.

Factors favoring TC lightning

SST > 27 °C

Night and morning

Moderate vertical wind shear

More in NATL compared to ENP

Close to a continent

Outward cooling pulse

GLM Parallax correction

In AWIPS, the GLM parallax is set to always equal that of ABI. The GLM parallax must be corrected when comparing GLM data with ground-based observations.

Corrections for GOES-17 (left) and GOES-16 (right) are shown.

Resources

Virtual Lab
Virtual Lab for the GLM
GOES-R GLM Training Hub
GOES-R GLM Training
Resources
GOES-R Virtual Faculty
Training
GLM Virtual Faculty Course
NESDIS/STAR - CISS-MID
Lightning Resources at CISS-MID
Hyperlinks not available when viewing material in AIR Tool

Plans for Next Reporting Period

The project team is on track to complete the Year 1 milestones during the next reporting period. This includes finishing the climatological comparisons between the lightning databases and AOD, SST, and OHC to determine if any normalization is required for the lightning dataset. Additionally, GLM and ISS-LIS data will be compared to determine boundaries where GLM is suitable for applications in the Atlantic and Pacific tropical oceans. We will also finish gathering other datasets relevant for TC structure, including microwave data, aircraft flight-level reconnaissance data, tail-Doppler radar data, and satellite-based RMW estimates for TCs in preparation for Year 2 milestones.