Flash Frequency Parameterization Insights from the Geostationary Lightning Mapper

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Goals

Compare various lightning frequency parameterizations using reanalysis/observational variables to GLM flash frequency observations.

The most correlated parameterizations can be used in model development of lightning parameterizations in GFDL's Atmospheric Models.

The lightning frequency parameterization model development is a prerequisite to examining development of LNO_x, and tropospheric ozone and methane estimates within the model.

MERRA2 Reanalysis 3D Flux of Ice Convective Precipitation at ~ 450 hPa

Precipitating ice particles in convection

Likely to go through collisions to trigger lightning

$kg/m^2\ s^1$

Slightly different than upward ice flux in Finney et al. (2014) which includes non-precipitating ice

CAPE x Total Precipitation (TP)

Romps et al. (2014 and 2018)

CAPE represents instability, vertical, and charge separation

Precipitation rate eludes to areal coverage

CAPE x TP has been normalized by a single multiplicative factor ($7.8 \times 10^{-12}\ J^{-1}$) to convert from units of W/m^2 to units of $1/m^2\ s^1$.

Works best for parameterizing CG flashes

Cheng et al. (2021)

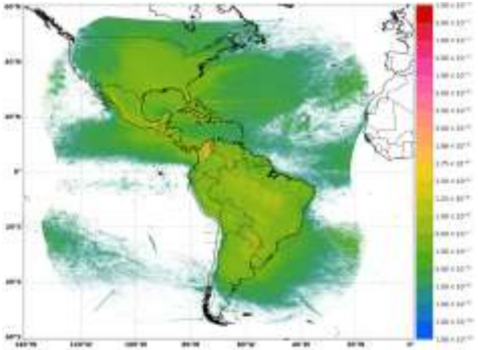
1) There will be minimal lightning activity where there is CAPE ≤ 225 J/kg

1) "The storm size required to produce lightning appears to be disproportionately high in low CAPE environments (≤ 225 J/kg)"

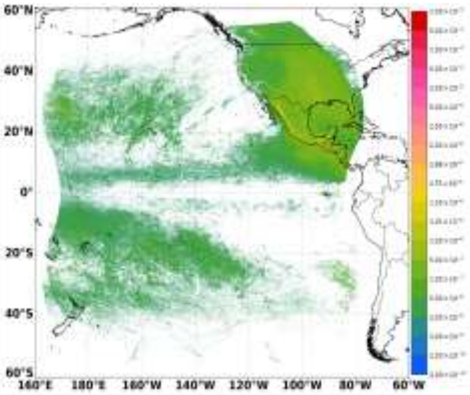
Geostationary Lightning Mapper

Instrument	A near-infrared, optical sensor on both the NOAA GOES-16 (G16) and -17 (G17) satellites that continuously detects light perturbations and their duration and energy every 2 ms.
Instrument Spatial Resolution	2 km^2 curvilinear grid
Instrument Field of View (FOV)	~ 145°W - 18°W/±54° latitude
Product	Flash locations
Processed Data Resolution	Binned to 2 km^2 grid cells per minute
Literature Reference	Rudlosky et al. 2019
G16/-17 Analysis Time Period	Jan. 2018 - Dec. 2020 Dec. 2018 - Dec. 2020
Data Regridding Method	Conservative
Detection Efficiency (DE)	0.8 (Assumed across entire domain)
Calculation of flash frequency (ff)	Conversion to flash frequency (flashes km^2 s^{-1}) with latitude weighting

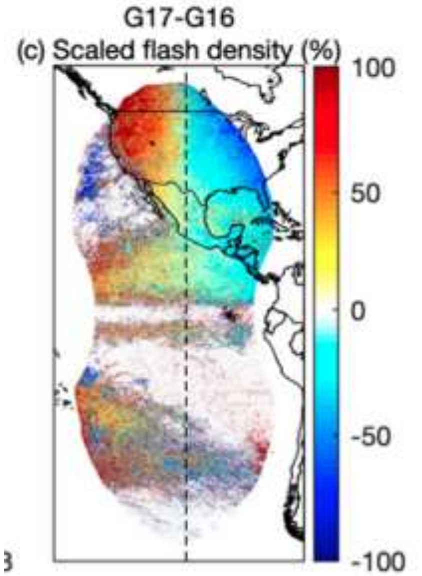
2 km^2 G16 GLM Jan. 2018 - Dec. 2020
Flash frequency in flashes/km^2/month



2 km^2 G17 GLM Dec. 2018 - Dec. 2020
Flash frequency



G16/17 GLM Overlap Region



Blue - Best observed by G16
Yellow/red - Best observed by G17
Figure 2c from
Rudlosky and Virts (2021)

Correlations
GOES-16/-17 GLM FF vs
MERRA2 3D Flux of Ice Convective Precipitation at 450 hPa

Location	Annual	DJF	MAM	JJA	SON
GOES-16 GLM Land	0.59	0.46	0.05	**0.67**	0.35
GOES-16 GLM Ocean	0.65	0.08	0.38	**0.69**	0.36
GOES-16 GLM Overall	**0.71**	0.59	0.19	**0.69**	0.52
GOES-17 GLM Land	0.60	0.54	-0.05	0.61	**0.81**
GOES-17 GLM Ocean	0.21	0.09	0.22	0.32	0.35
GOES-17 GLM Overall	0.35	0.10	0.18	0.58	0.52

Mean January 2018 - December 2020

MERRA2 3D Flux of Ice Convective

Precipitation

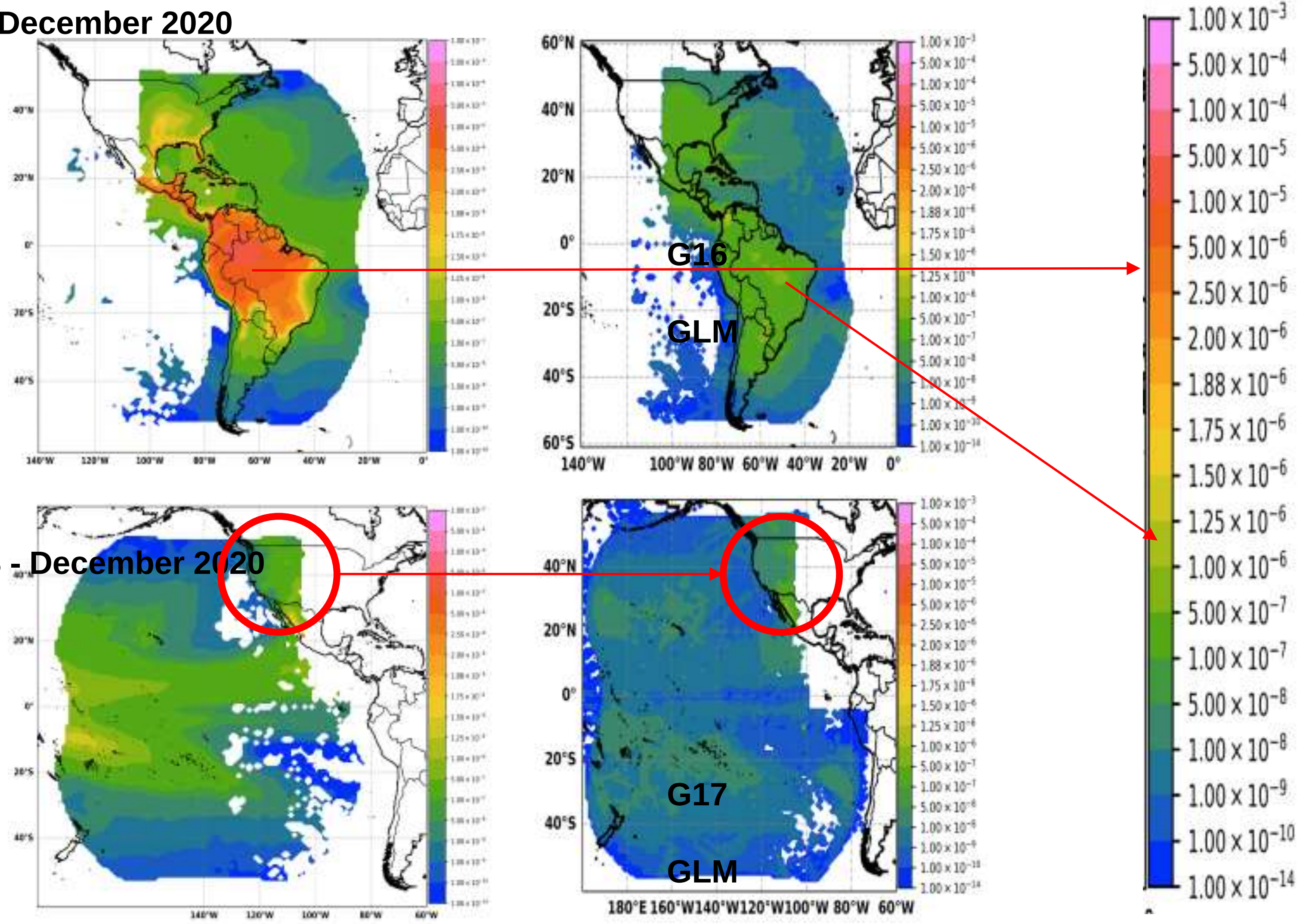
Over G16 Domain

Mean December 2018 - December 2020

MERRA2 3D Flux of Ice Convective

Precipitation

Over G17 Domain



GLM	CAPE ≤225 J/kg = 0 J/kg	Total Precipitation	Location	Annual	DJF	MAM	JJA	SON
GOES-16	ERA5 CAPE	ERA5 MTPR	Land	0.48	0.32	-0.02	0.58	0.24
GOES-16	ERA5 CAPE	ERA5 MTPR	Ocean	0.62	0.10	0.48	0.59	0.31
GOES-16	ERA5 CAPE	ERA5 MTPR	Overall	0.61	0.45	0.14	0.55	0.24
GOES-16	ERA5 CAPE	IMERG PR	Land	0.59	0.58	0.05	**0.72**	0.39
GOES-16	ERA5 CAPE	IMERG PR	Ocean	**0.75**	0.15	0.53	**0.79**	0.40
GOES-16	ERA5 CAPE	IMERG PR	Overall	**0.69**	**0.67**	0.22	**0.69**	0.42
GOES-17	ERA5 CAPE	ERA5 MTPR	Land	0.20	0.14	0.28	0.20	0.43
GOES-17	ERA5 CAPE	ERA5 MTPR	Ocean	0.22	0.10	0.25	0.37	0.30
GOES-17	ERA5 CAPE	ERA5 MTPR	Overall	0.11	0.13	0.30	0.10	0.15
GOES-17	ERA5 CAPE	IMERG PR	Land	0.12	0.20	0.35	0.14	0.32
GOES-17	ERA5 CAPE	IMERG PR	Ocean	0.23	0.10	0.29	0.40	0.34
GOES-17	ERA5 CAPE	IMERG PR	Overall	0.11	0.14	0.34	0.10	0.16

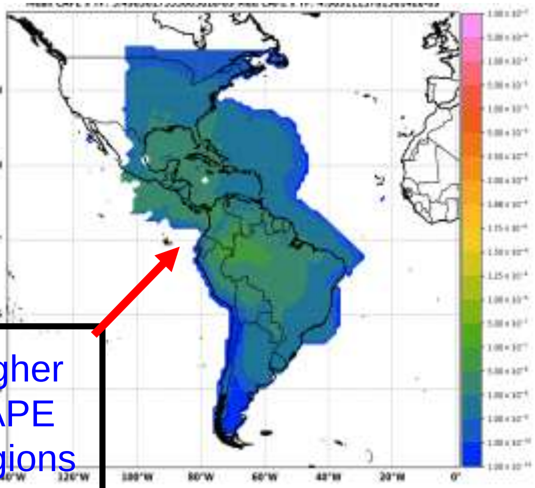
Mean January 2018 - December 2020

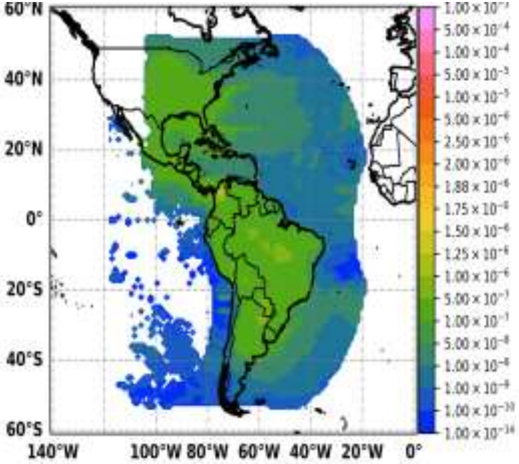
ERA5 CAPE x IMERG

Total Precipitation

(CAPE > 225 J/kg from Cheng et al. 2021) Over G16 Domain

Higher CAPE regions





Mean December 2018

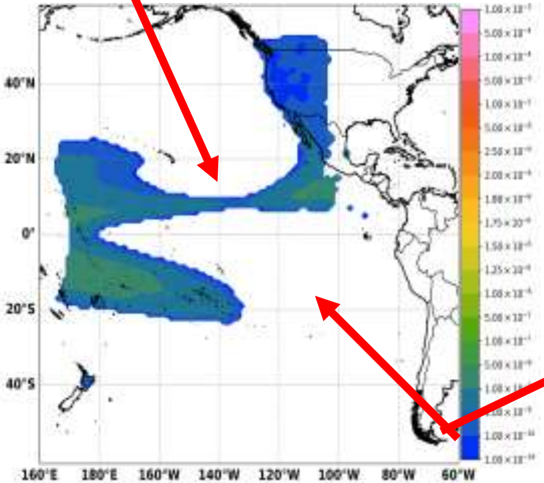
ERA5 CAPE x IMERG

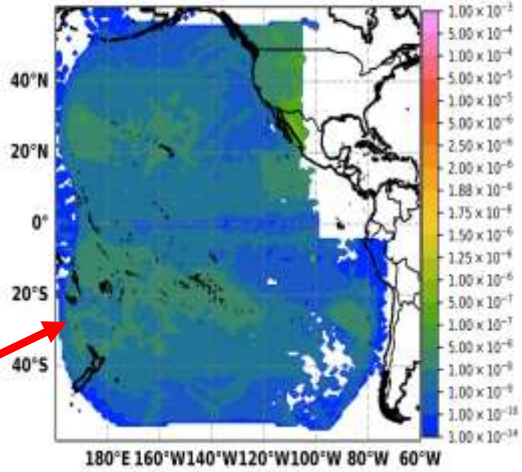
Total Precipitation

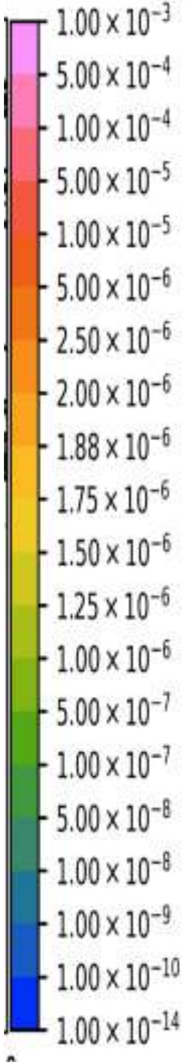
(CAPE > 225 J/kg)

Over G17 Domain

Correlations improve, but removing low CAPE does not sufficiently parameterize the spatial coverage of lightning activity







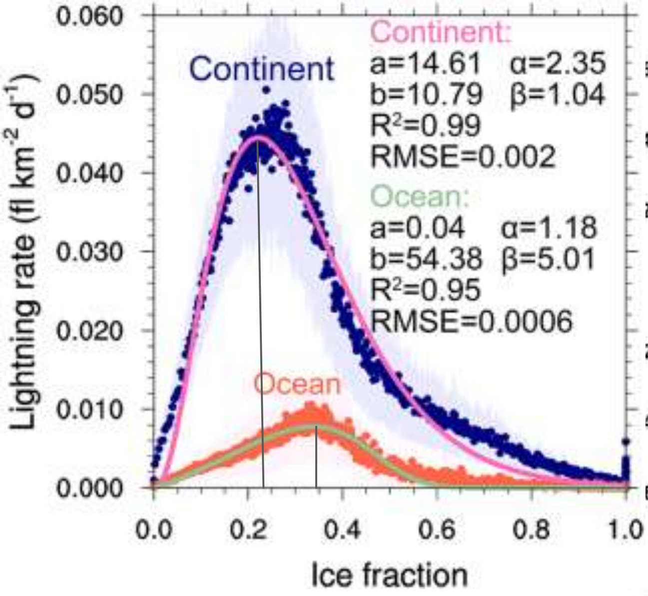
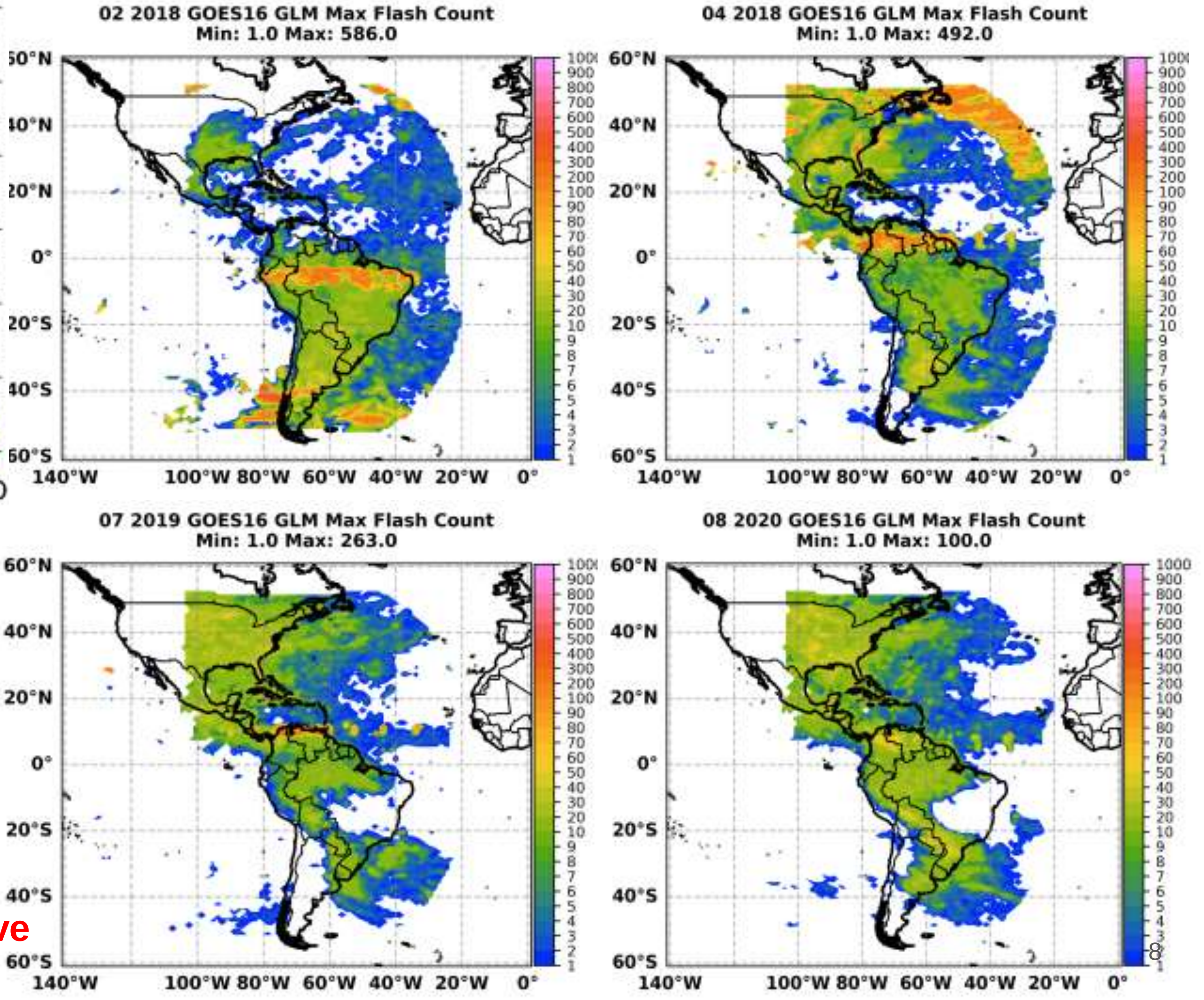


Figure 2 from Han et al. (2021)

Cloud Ice Fraction Scheme - Han et al 2021:

1) A specific ice fraction corresponds with maximum flash rate which is associated with deep convective clouds
2) “When the ice fraction of the clouds decreases (increases) and they tend to be the liquid (ice) clouds, the lightning flash rates will decrease.”



What is the best method to resolve these anomalously flash counts?

Observation and Parameterization Summary

<u>MERRA2 3D Flux of Ice Convective Precipitation at ~ 450 hPa</u>

Correlations near 0.59-0.71 annually and JJA over land, ocean, and overall for DJF

G17 GLM strongly correlated over land: 0.81 which is evident spatially

The scheme overpredicts lightning by 1-2 OOM over Central America, Northern S. America, and the Central Pacific Ocean

<u>ERA5 CAPE x ERA5 TP and ERA5 CAPE x IMERG P</u>

0.1 - 0.3 rise in correlation when using IMERG P as opposed to ERA5

For example, over G16 GLM ocean 0.54 to 0.77

Removing the low CAPE regime renders a slight increase in the correlations but less lightning parameterized spatially

Poor overall G17 GLM and CAPE x P correlations

<u>What methods should we employ to remove the anomalous values for cloud ice fraction scheme?</u>

1) Masking grids with high values with percentile values
   Lower these percentiles until anomalous values are masked out

1) Remove the intermittent specific files that contain the anomalous values

References

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