Lightning : An Essential Climate Variable

WMO/GCOS Task Team on Lightning Observations For Climate Applications (TT-LOCA)

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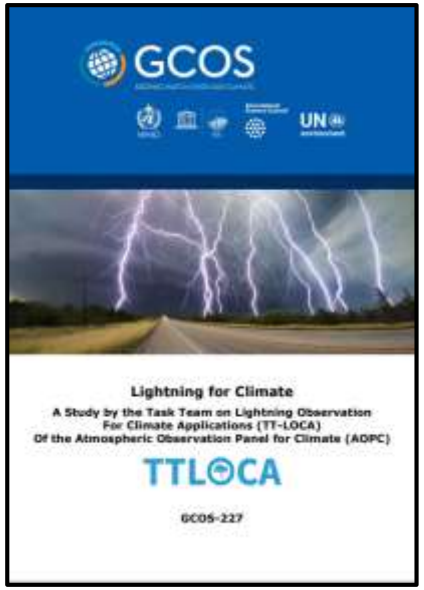
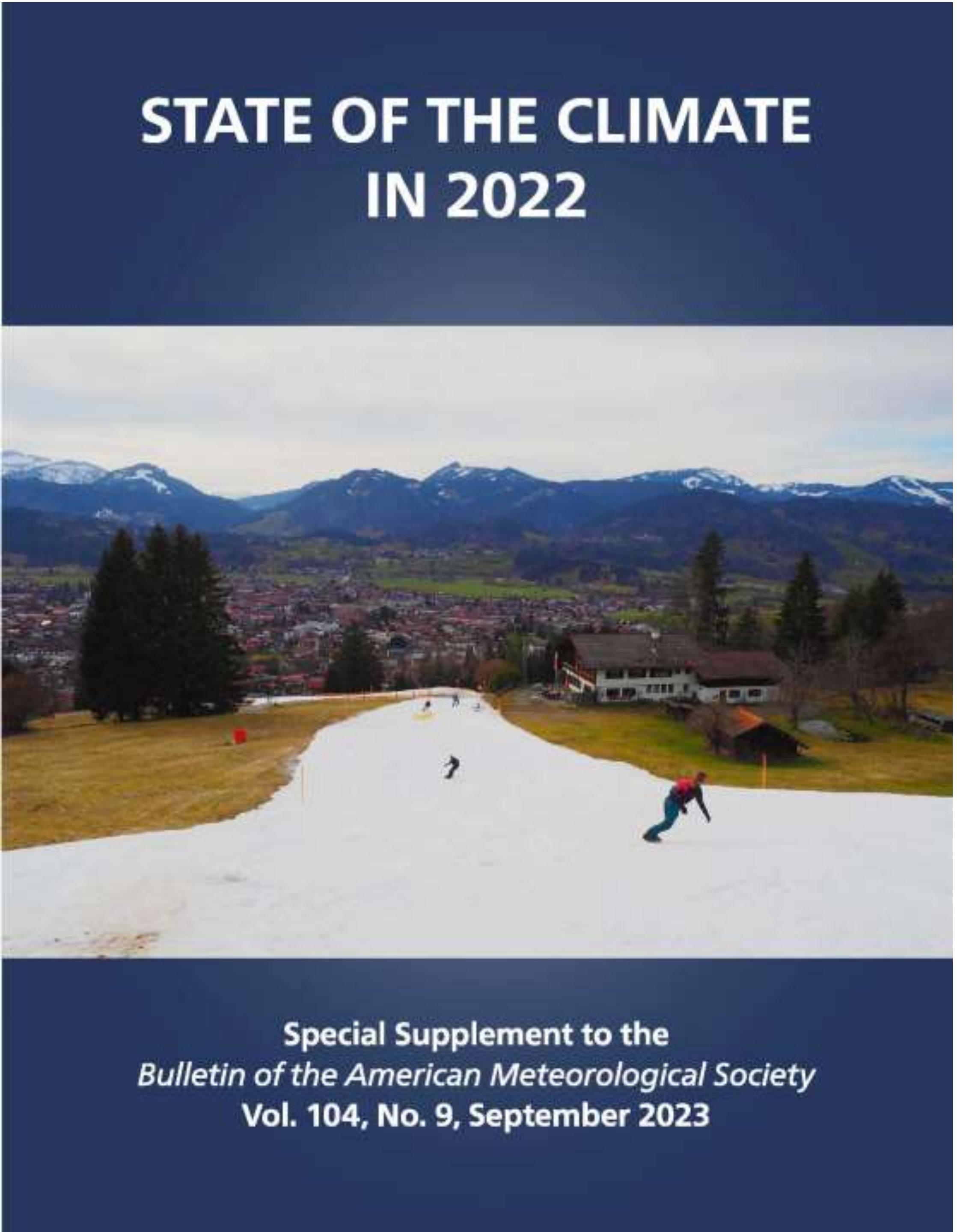
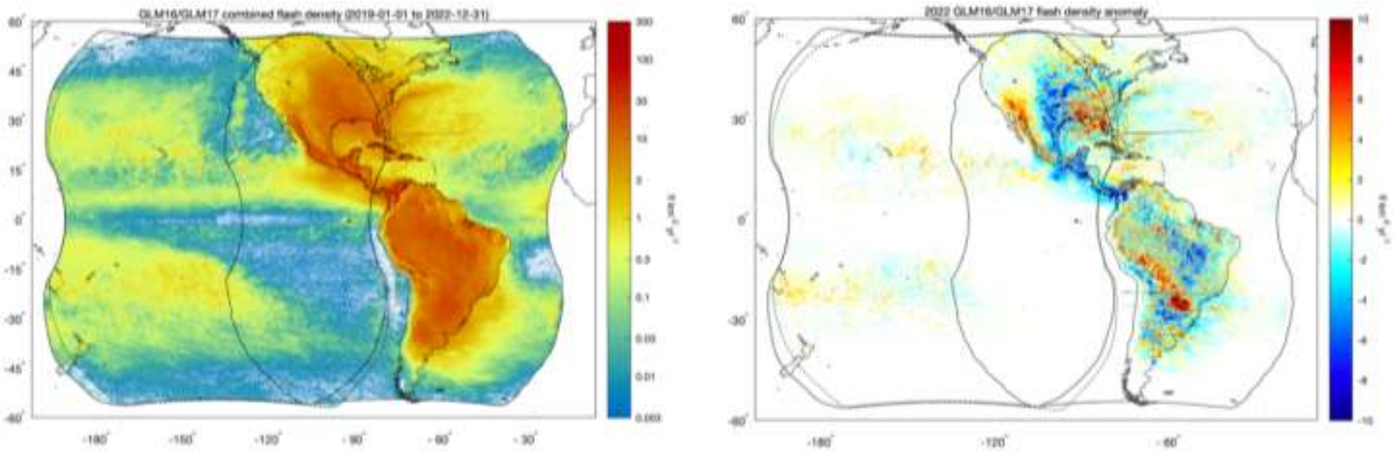


GLM Science Meeting, November 13-15, 2023



Lightning is one of the Essential Climate Variables in the WMO Global Climate Observing System (GCOS)

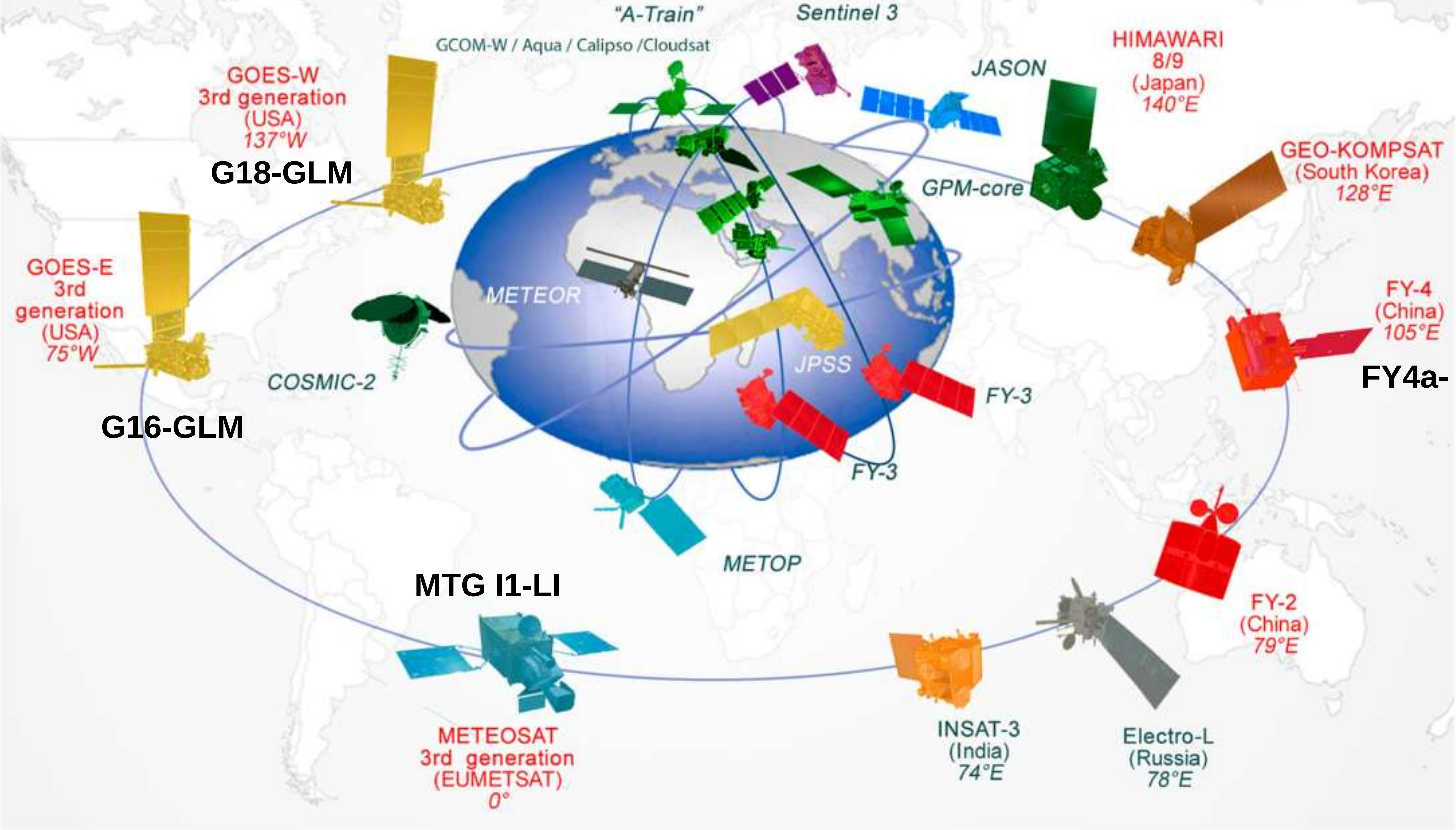


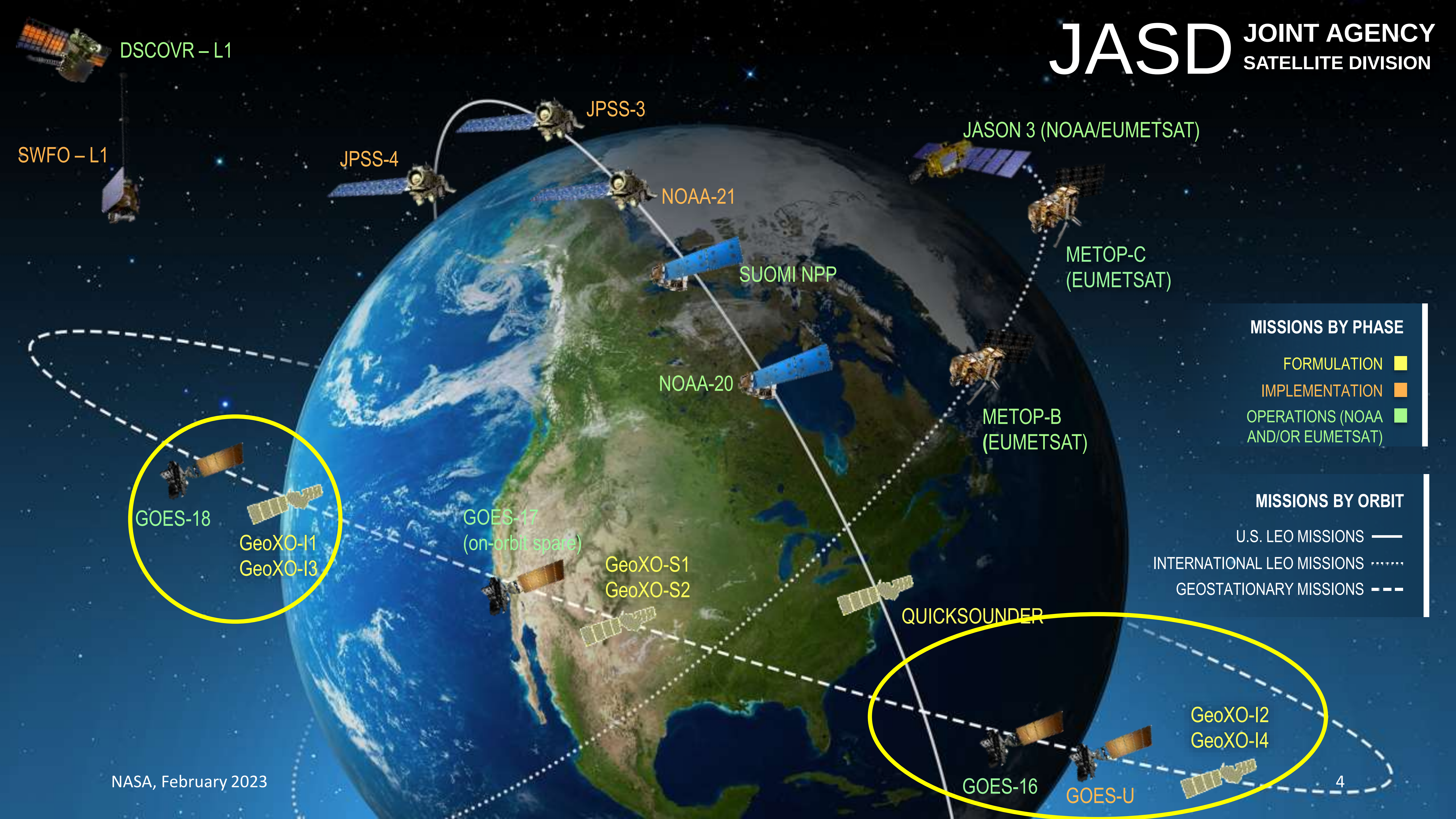
- Combined G16 and G17 GLM flash density and anomaly for 2022 that are calculated relative to the 2019-2021 mean.
- Triple-dip 3-year La Niña ending March 2023
- COVID-19 with reduced industrial emissions

Upcoming: AMS 2024 Session on Climate Variability and Change

Space-based Component of the Global Observing System

(source, WMO Space Program)

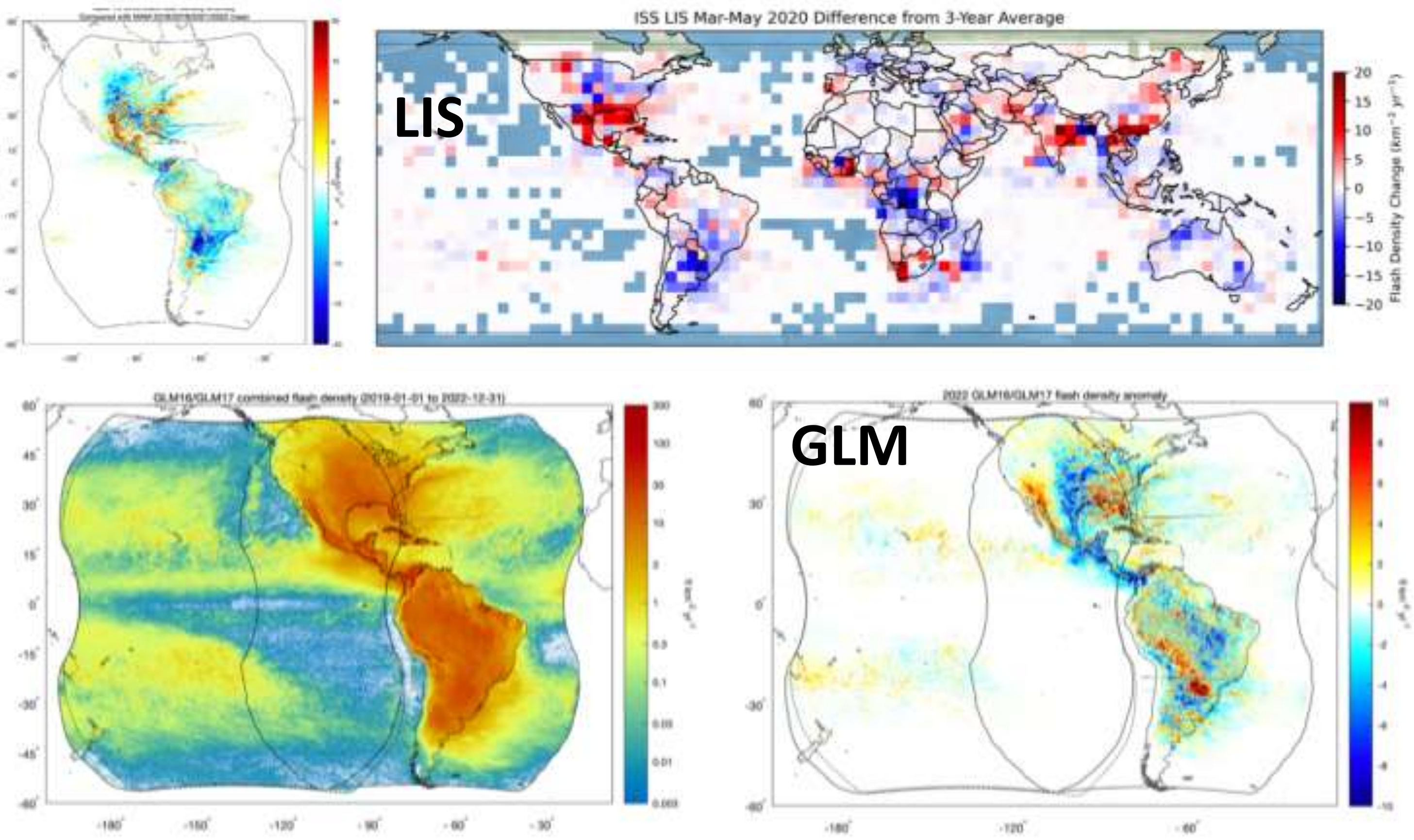



JASD
JOINT AGENCY
SATELLITE DIVISION
DSCOVR – L1
SWFO – L1
JPSS-3
JPSS-4
NOAA-21
SUOMI NPP
NOAA-20
JASON 3 (NOAA/EUMETSAT)
METOP-C
(EUMETSAT)
METOP-B
(EUMETSAT)
GOES-18
GeoXO-I1
GeoXO-I3
GOES-17
(on-orbit spare)
GeoXO-S1
GeoXO-S2
QUICKSOUNDER
GeoXO-I2
GeoXO-I4
GOES-16
GOES-U
MISSIONS BY PHASE
FORMULATION
IMPLEMENTATION
OPERATIONS (NOAA
AND/OR EUMETSAT)
MISSIONS BY ORBIT
U.S. LEO MISSIONS
INTERNATIONAL LEO MISSIONS
GEOSTATIONARY MISSIONS

Lightning Climate Data Requirements

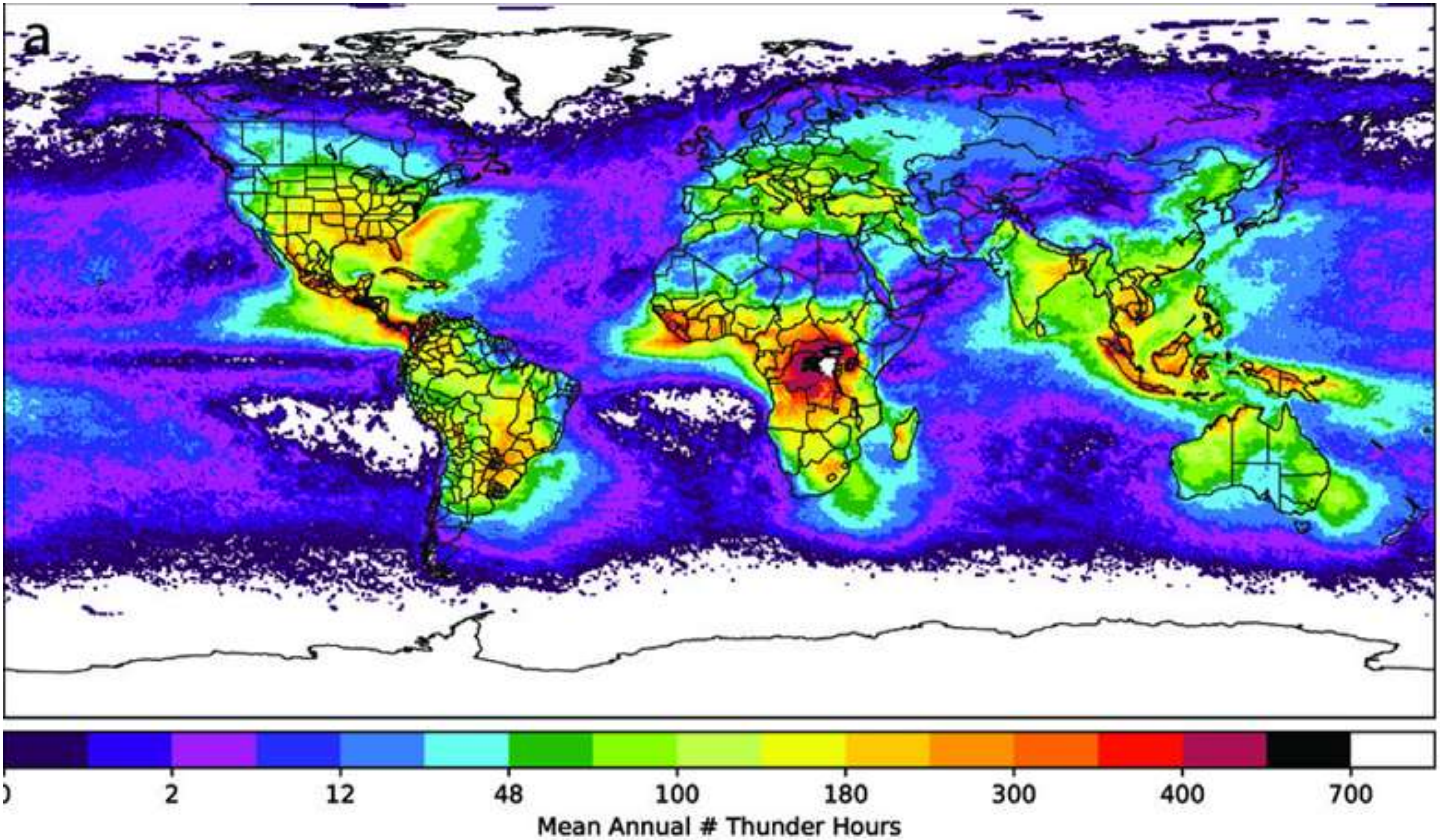
- **Total Lightning Stroke Density**
  - **Consistent, Harmonized Data**
- **Global 10 km x 10 km (0.1 x 0.1 deg)**
- **Temporal (Monthly, Daily, Hourly)**
- **Space-based Optical:**
  - **NASA TRMM/ISS - LIS**
  - **NOAA/NASA GOES - GLM**
  - **CMA FY-4 - LMI**
  - **EUMETSAT MTG - LI**
- **Ground-based RF (commercial data):**
  - **GLD360 (Vaisala)**
  - **ENTLN (Earth Networks)**
  - **WWLLN (Univ. Washington)**
  - **Regional Networks (IC/CG)**

Space-based: Total Lightning Flash Density



Top) Lightning Imaging Sensor (LIS) seasonal lightning density anomalies for March-May 2020; Bottom) Combined G16 and G17 GLM flash density anomaly for 2022 that are calculated relative to the 2019-2021 mean.

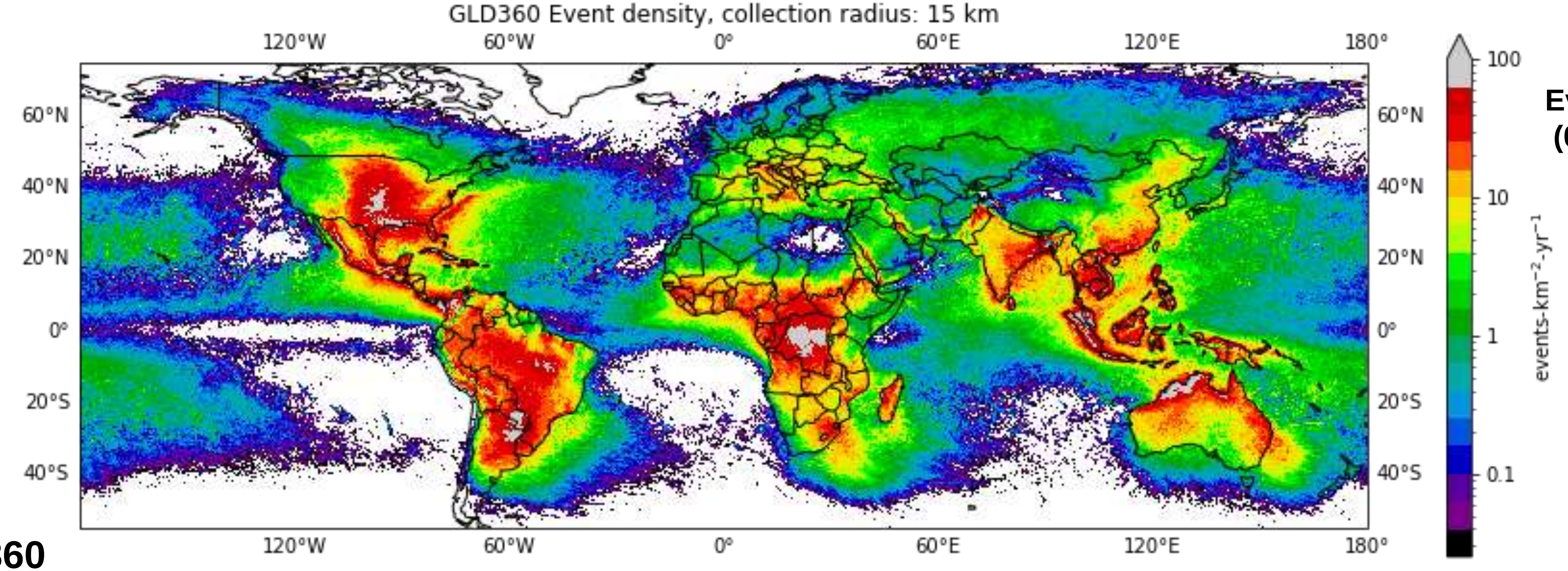
ENGLN
IC+CG



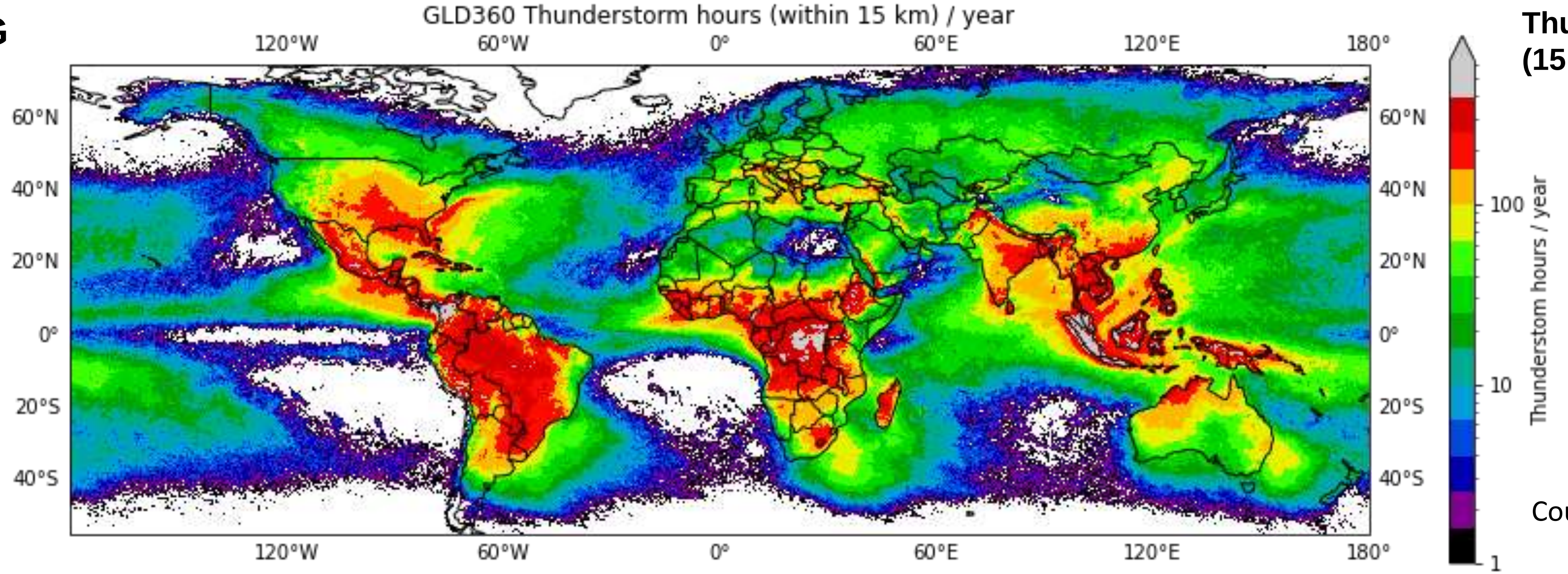
2015-2019

Mean annual ENGLN thunder hour counts for the entire globe from 2015-2019.
(DiGangi et al., 2022, BAMS Early Online Release: 10.1175/BAMS-D-20-0198.1.

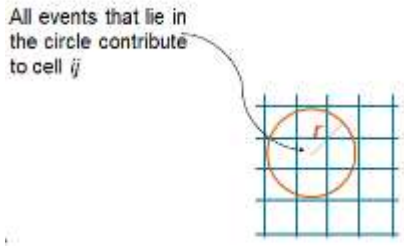
GLD360
IC+CG



Event Density 2015-2019
(0.1 deg grid)



Thunder Hours 2015-2019
(15 km radius)



Courtesy of Ryan Said, Vaisala

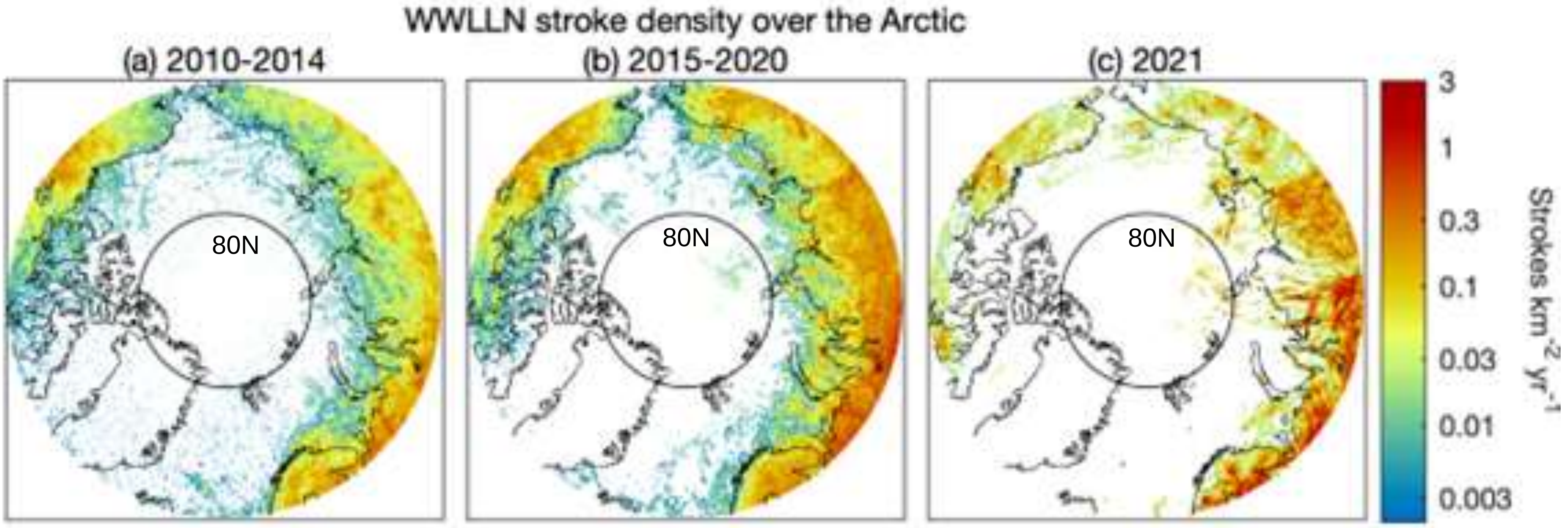
Metadata

- **Metadata** – Product = Total Lightning Stroke Density
  - Satellite imagers optical flash density vs ground-based RF network stroke density (Global and Regional Networks) - Complementary
  - How is satellite event/group/flash related to RF strokes?

- **Toward harmonized, consistent space and ground-based data set(s)**
  - Desire for # stations (ground-based), Detection Efficiency, resolution (time, space), and other cal/val performance parameters (e.g., network flash type – IC/CG discrimination) needed to make a climate data set most useful.
  - Note no network or space measurement is 100% DE effective over its entire coverage area.

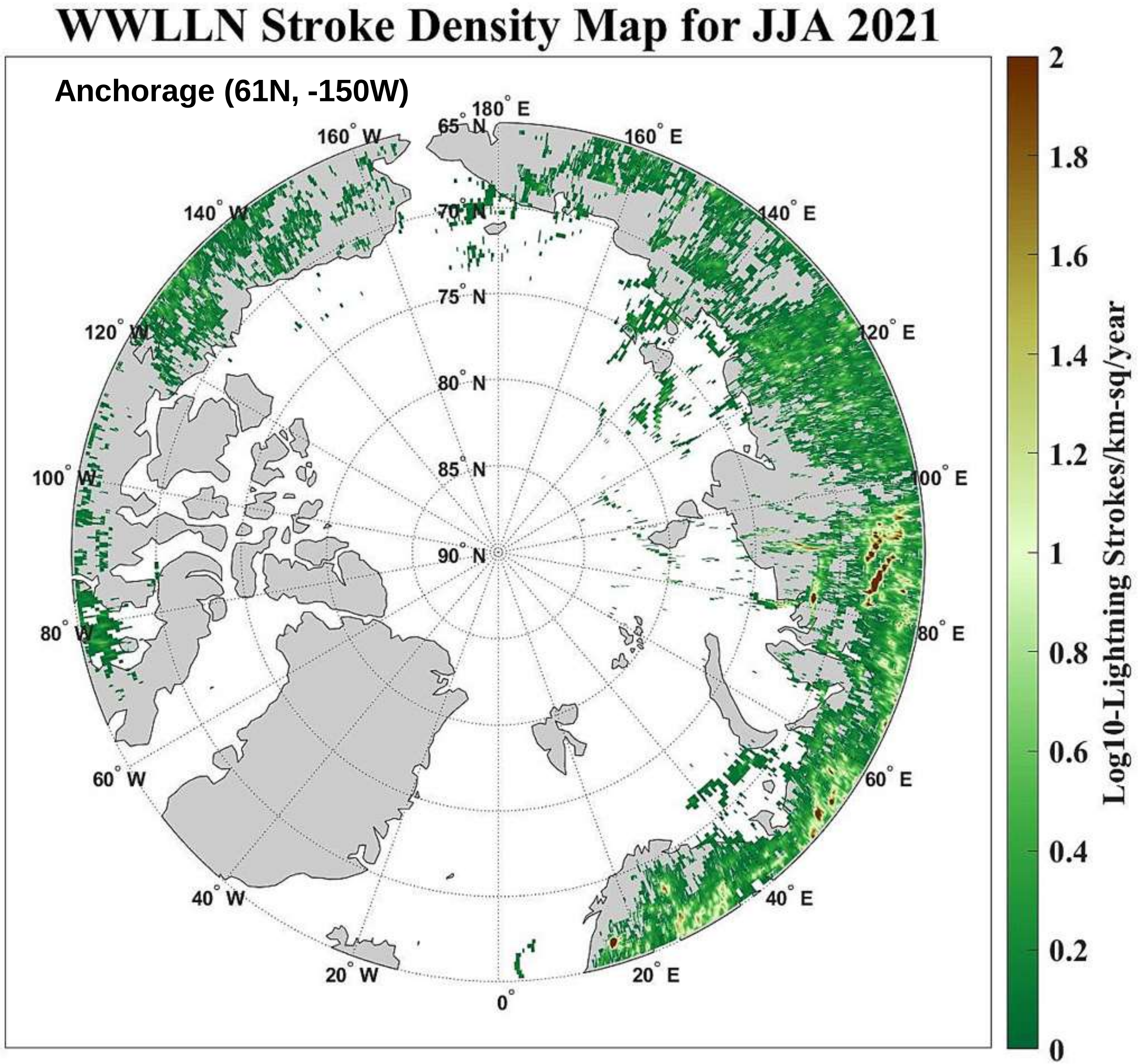
Climate Change and Adaptation

Attribution : How is the increase in high latitude lightning linked to a warming Arctic?



Arctic lightning densities recorded by the World Wide Lightning Location Network (WWLLN) and averaged over the years 2010-2014, 2015-2020, and 2021. The lightning flash densities increased during 2015-2020 when compared to 2010-2014. In 2021, northern Europe and much of northern Russia continued to experience higher overall lightning densities. Eastern Russia and northern North America generally experienced less lightning than the previous 2015-2020 period.

BAMS Special Issue on Climate, 2022



Spatial distribution of lightning stroke density (strokes/ km2/year) in June, July and August (JJA) months of 2021 above 65◦N (Saha et al., Atmos. Res., 2023).

Projected increase in lightning strikes in the United States due to global warming

DAVID M. ROMPS , JACOB T. SEELEY, DAVID VOLLARO, AND JOHN MOLINARI

***SCIENCE*,** 14 Nov 2014, [DOI: 10.1126/science.1259100]

Here we propose that the lightning flash rate is proportional to the convective available potential energy (CAPE) times the precipitation rate. Using observations, the product of CAPE and precipitation explains 77% of the variance in the time series of total cloud-to ground lightning flashes over the contiguous United States (CONUS). Storms convert CAPE times precipitated water mass to discharged lightning energy with an efficiency of 1%. When this proxy is applied to 11 climate models, CONUS lightning strikes are predicted to increase 12 +/- 5% per degree Celsius of global warming and about 50% over this century.

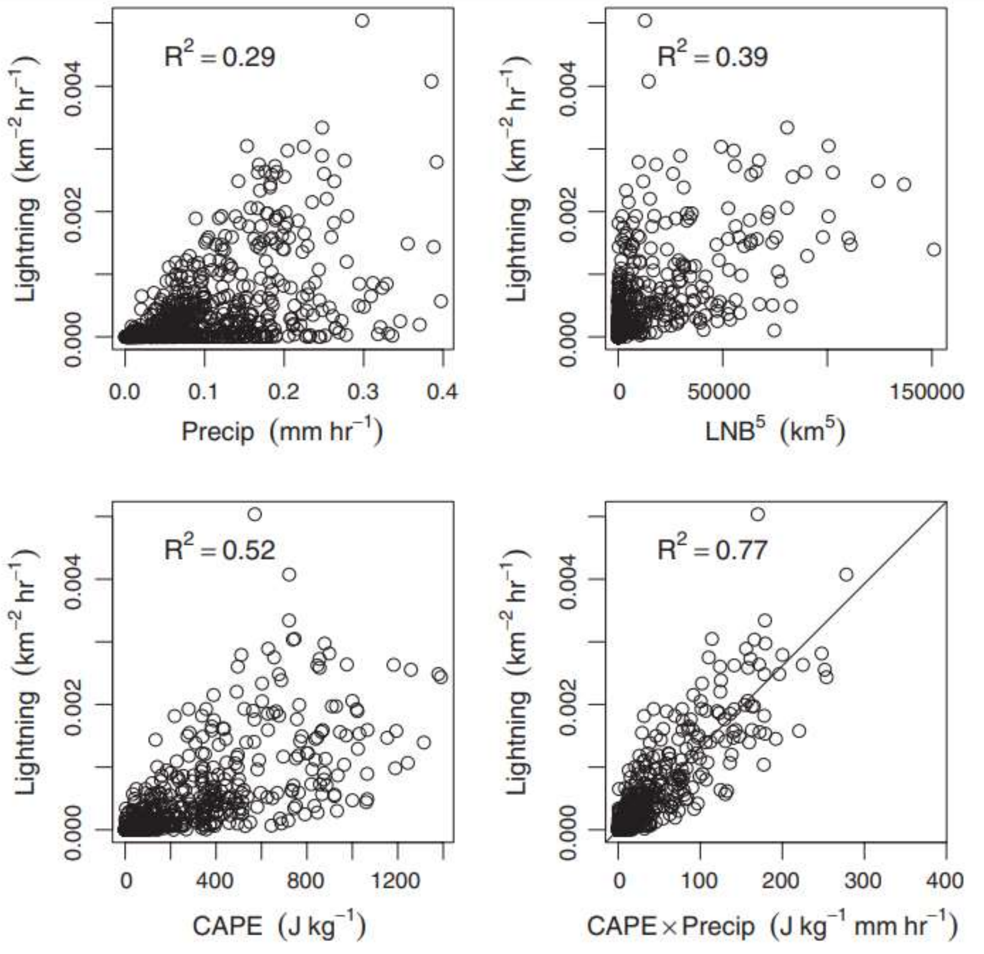


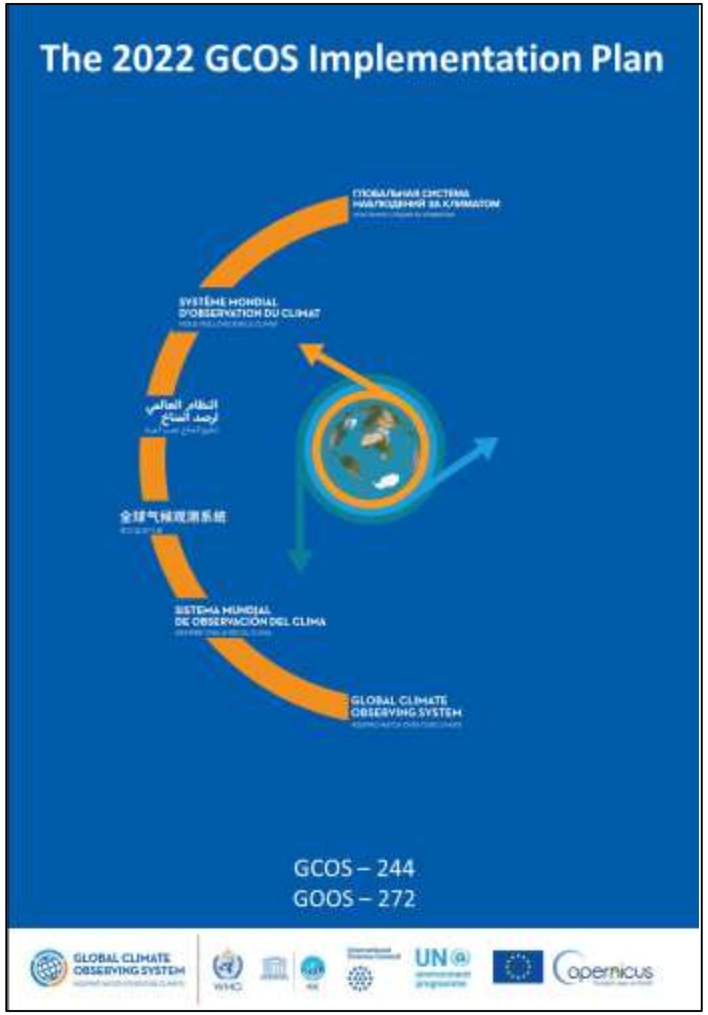
Fig. 3. Lightning versus various proposed proxies. For the year 2011, scatter plots are shown of the time series of 0 and 12 GMT CONUS mean lightning against **(top left)** precipitation, **(top right)** LNB to the fifth power, **(bottom left)** CAPE, and **(bottom right)** CAPE times precipitation.

2022 GCOS AOPC IP – Lightning Actions Accomplishments, Status, and Plans

Lightning

Thunder Days

Ionospheric Potential- GRUAN



BAMS SotC, August 31, 2022

Sidebar 2.1: **Lightning**—M. FÜLLEKRUG, E. WILLIAMS, C. PRICE, S. GOODMAN, R. HOLZWORTH, K. VIRTS, AND D. BUECHLER

The World Meteorological Organization (WMO) recently declared lightning flashes to be an essential climate variable (ECV), based on a recommendation by the Task Team on Lightning Observation for Climate Applications (TT-LOCA) as part of the Atmospheric Observation Panel for Climate (AOPC) of the WMO and the Global Climate Observing System (GCOS; Aich et al. 2018; WMO 2019a). This endorsement reinforces the WMO Integrated Global Observing System (WIGOS) Vision 2040 (WMO 2019b) toward the operational observation of lightning by space agencies during the coming decades.

Lightning flashes are generated by thunderstorms, which develop when hot and humid air destabilizes the atmosphere and enables deep convection. As a result, the lightning ECV is grouped with other ECVs describing the atmosphere (Bojinski et al. 2014) which are closely related to thunderstorm development, such as the Earth radiation budget, upper-air temperature, water vapor, wind speed, and cloud properties (see sections 2f1, 2b1, 2b5, 2d2, 2e2, and 2d6). The lightning ECV is also related to ECVs that impact atmospheric composition, such as lightning NOx and cloud condensation nuclei (see sections 2g3 and 2g6).

Lightning is a natural hazard associated with the severe weather impacts of thunderstorms including high wind speeds with falling trees and branches, intense precipitation causing flooding, large hail affecting transport vehicles and crops, and cloud-to-ground lightning which can lead to casualties, ignite wildland fires, and cause significant damage to infrastructure, such as power lines (Cooper and Holle 2019; Holle 2016). Lightning has significant societal implications for public safety (Holle et al. 1999), power distribution (Piantini 2020), aviation (Ryley et al. 2020), and wildfires (Holzworth et al. 2021). Wildfires can increase convective instability for pyrocumulus to develop (Rudlosky et al. 2020; Liu et al. 2021; Augustine et al. 2021). Lightning is

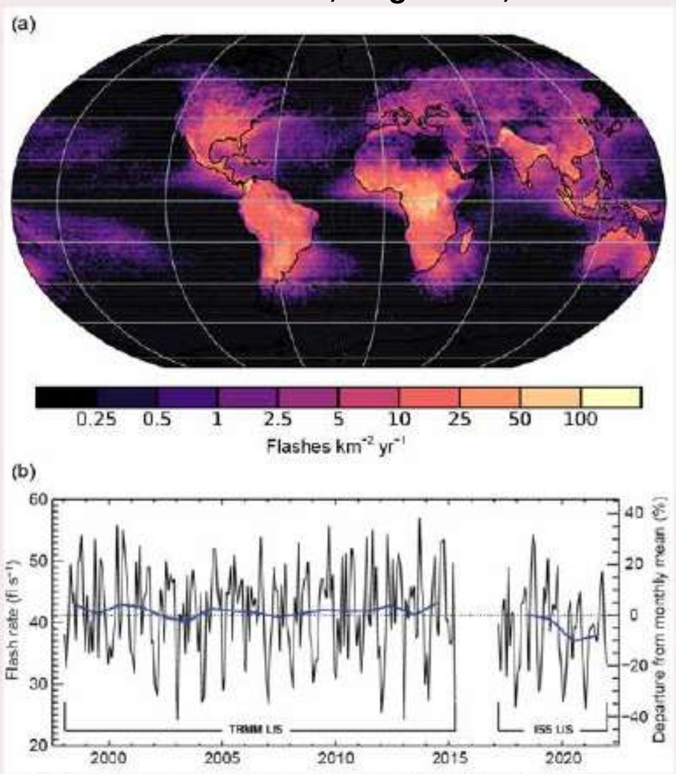


Fig. SB2.1. Lightning observations from space. (a) Global distribution of lightning flash rate density (fl km^{-2} yr^{-1}) for the period of record 1995–2021 from NASA's low earth orbit lightning imagers OTD (Optical Transient Detector, May 1995–Apr 2000), TRMM LIS (Lightning Imaging Sensor, Jan 1998–Dec 2014) and ISS LIS (Feb 2017–Dec 2021). Global lightning is dominant over the continental tropical belt. (b) Monthly (solid black) and annual (blue) mean lightning flash rates (fl s^{-1}) observed by the TRMM and ISS LIS instruments within the ±38° latitudinal coverage of the TRMM orbit. The black dotted line is the combined mean monthly global flash rate (41.2 fl s^{-1}). The mean monthly flash rate varies from ~24 to 57 fl s^{-1}. The seasonal variations are due to the annual cycle of lightning activity linked to the larger land area of the Northern Hemisphere. (Source: Courtesy of the NASA Lightning Imaging Sensor Science Team.)

Summary

2022 GCOS 5-year Implementation Plan: Remaining and Additional Activities

- Activity
  - TT-LOCA two year extension planned principally to establish the stewardship of the Lightning ECV. Naming a liaison to the AOPC for further coordination through 2024 also under consideration to evaluate the space-based and ground-based ECV data sets, reprocessing, and initial results from the MTG-LI.
  - Continue outreach to operators of regional ground-based lightning networks to provide ECV compatible data sets.
  - Drafted a summary report to follow the initial GCOS-227 Report “Lightning for Climate”.
- Plans for ECV Data Stewardship
  - Global VLF operators (GLD360, ENGLN, WWLLN) offered to provide stewardship, maintain and update their ECV product (monthly gridded product, Thunder Hour)
  - **NOAA NCEI** - stewardship of operational and GLM reprocessed data
  - **NASA** – GHRC DAAC stewardship of the OTD/LIS reprocessed data, and Cloud Service landing page(to be developed and coordinated with NCEI) for all Lightning ECV products.