Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2021 doi:10.20944/preprints202112.0183.v1

Atmospheric Lightning Essential Climate Variable (ECV) mapping over India using NRSC/ISRO Lightning Detection Sensor Network

Alok Taori[1], Arun Suryavanshi[2], Biswadip Gharai[1], M. V. R. Seshasai[1]

1. Earth & Climate Sciences Area, National Remote Sensing Centre, Balanagar, Hyderabad, Telangana, India.

2. Regional Remote Sensing Centre – Central, National Remote Sensing Centre, Nagpur, Maharashtra, India.

Abstract

Atmospheric lightning is an outcome of extreme complex physical processes occurring in the atmosphere. Cloud-to-ground (CG) lightning is considered as a natural disaster. Understanding the importance of CG lightning and implication of the lightning phenomena, Global Climate Observing System (GCOS), world meteorological organization, in its report in the year 2016, introduced the lightning as an Essential Climate Variable (ECV). The present report uses the Lightning Detection Sensor Network (LDSN) established by the National Remote Sensing Centre, Indian Space Research Organization over India to generate the Lightning ECV. A use case of the ECV map is also showcased for an event in Bihar, India, when 42 deaths were reported at locations with large number of CG occurrences.

1. Introduction:

Investigation of atmospheric lightning flashes/strikes occurrences is an important aspect in the climate sciences (*Price, 2013; Romps et al. 2014*). In terms of atmospheric dynamics, the convective processes can trigger a large amount of atmospheric gravity waves which alters the mesospheric dynamics to very large extent (*e.g., Ghodpage et al., 2016, Sivakandan et al., 2016*). These waves in-turn may reach higher above as a perturbation input to the ionospheric processes (*e.g., Taori et al., 2011, Sivakandan et al. 2019*). It is a growing understanding that Lightning data feed to numerical weather prediction model can bring significant improvements in severe weather warning systems and also to understand the production of NOx. Because of its widely accepted relevance, atmospheric lightning has been introduced as Essential Climate Variables (ECV) in the 2016 Global Climate Observing System Implementation Plan (IP), including a first definition for climate monitoring of lightning (*Aich et al., 2018*) as depicted in *figure 1.*

GCOS suggested lightning ECV

Product	Definition	Frequency	Resolution	Req. Uncer.	Stab.	Standard/ References
Number of Lightnings	Total number of detected flashes in the corresponding time interval and the space unit. Space unit should be equal to the horizontal resolution and the accumulation time to the observing cycle	1 day	10 km	-	-	MTGEURD[1]

Fig. 1. *Definition of Lightning ECV (https://gcos.wmo.int/en/essential-climate-variables/lightning/ecv-requirements)*

When it comes to the measurements, in terms of the space borne exploration, Lightning Imaging Sensor (LIS) on board the Tropical Rainfall Measuring Mission (TRMM), provided snap-shot information. At present, GOES-16 mission covers American/ Europe sector using the Global Lightning Mapper (GLM) sensor. However, for exact monitoring with unbiased temporal information for the societal applications ground based radio frequency receivers are found very useful (e.g., Rakov, 2013).

Based on the existing lightning detection network worldwide, NRSC/ISRO has established a network of 25 Boltek made LRX-1 sensors (*Taori et al., 2021*). The Boltek LRX sensors are long range sensors which work on time of arrival (TOA) algorithm where correlated lightning

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2021 doi:10.20944/preprints202112.0183.v1

flashes are determined based on GPS stamped waveforms. Further expansion of network is planned such as to cover full India with equal weighting of sensor distribution.

Present report explains the methodology adopted for the generation of lightning ECV as per the WMO criteria. Thus monitored ECVs are utilized to identify a vulnerable location over India during a disastrous event noted during 24-25 June 2020.

2. Generation of Lightning Essential Climate Variable

NRSC has installed Boltek LRX long range sensors which work on time of arrival (TOA) algorithm. The method of detection and geolocation has been elaborated by Taori et al. (2021). At present NRSC has LRX sensors deployed at 25 locations in India such as to cover North-East, East Coast, Central and Southern part of India. Current LDS network established by NRSC is shown in figure 2. The network is being expanded optimally for achieving the pan-India coverage.

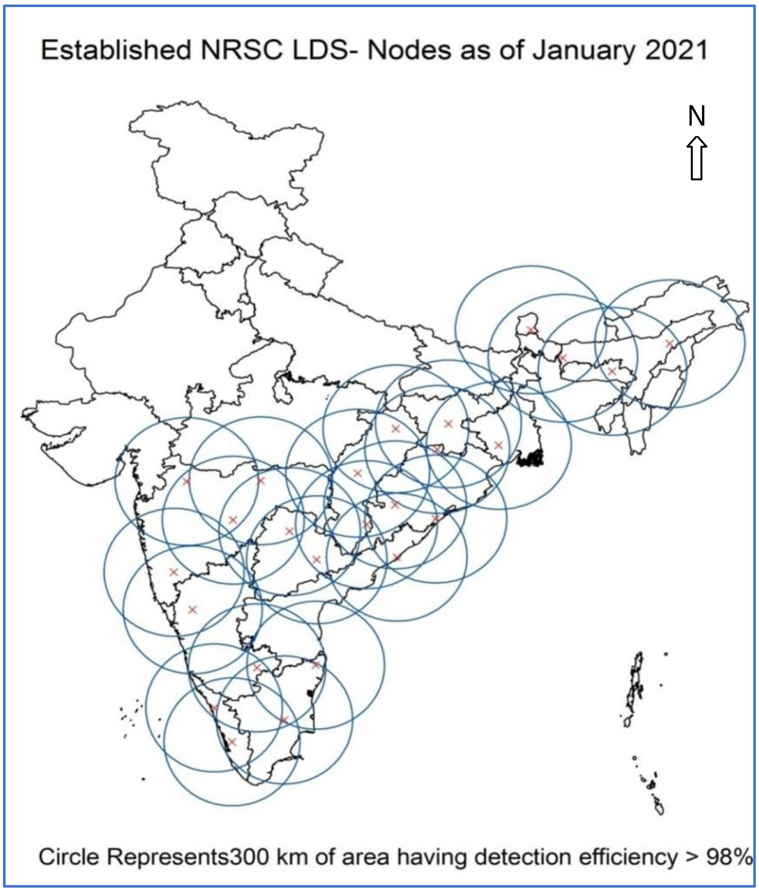

Figure 2: The NRSC-LDS network as of January 2021. The circle represents 300 km radius of sensor where signals are received with 98% confidence level.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2021 doi:10.20944/preprints202112.0183.v1

All the LDS locations are time synchronized with NRSC/RRSC server and all the measurements carry GPS time-stamping. Every lighting flash generates a static electrical pulse. The static pulse must be smoothed so that electrical noise arising by the local electrical noise (e.g., TV towers, Telephone lines, Cell phone towers, power grid, improper earthing) shall be either notched or smoothed out by appropriate temporal averaging. As the thunderstorm develops, static discharge starts and this static electrical pulse is transmitted by every host to the NRSC/RRSC server. The TOA calculations are then carried out by the server as shown in figure 3 and retrieved data is saved in MySQL database.

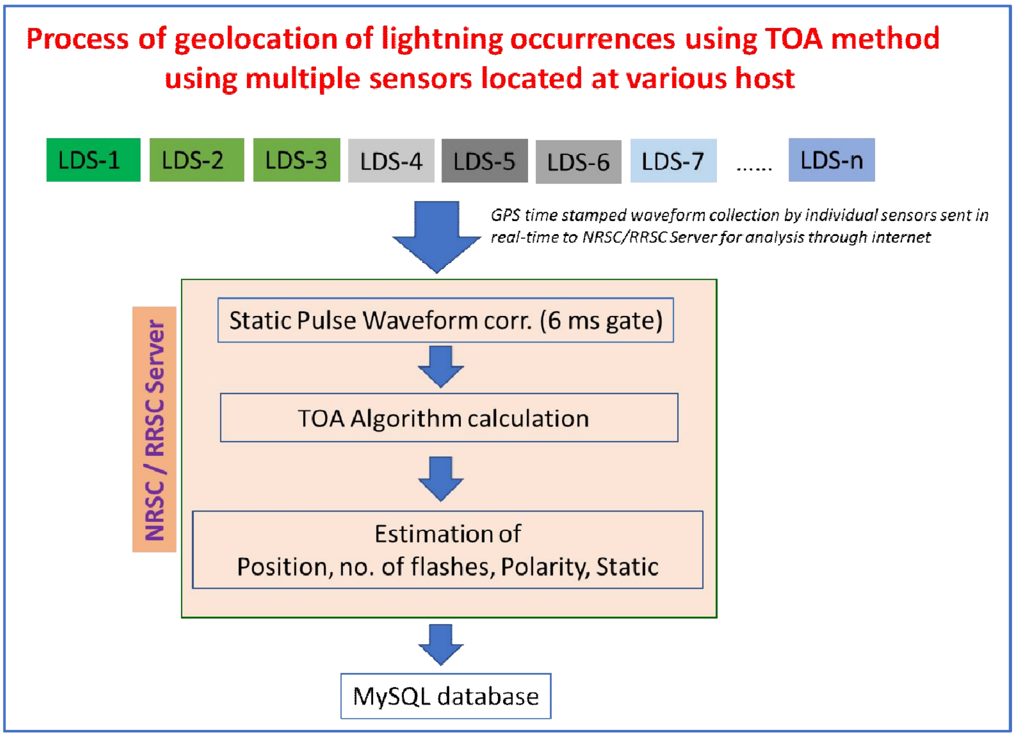

Figure 3. Processing of signal received from LDS stations for geolocating the event

Typical time to carry out the TOA calculations and geolocation analysis online is about 30 seconds. The requirement for error estimation is that at least 4 LDS shall record the event, so that through the standard deviation of the estimated location, an error can be assessed. This criterion is also suggested by the WMO and has been followed by so far existing lightning detection networks. We assess the variation of error estimates and number of sensors using the real data obtained by NRSC LDS network using the TOA algorithm from all the sensors. Error analysis reveals the positional accuracy to be within 100 meters when an event is monitored simultaneously by more than 6 detectors. Finding of the error estimates are shown in figure 4.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2021 doi:10.20944/preprints202112.0183.v1

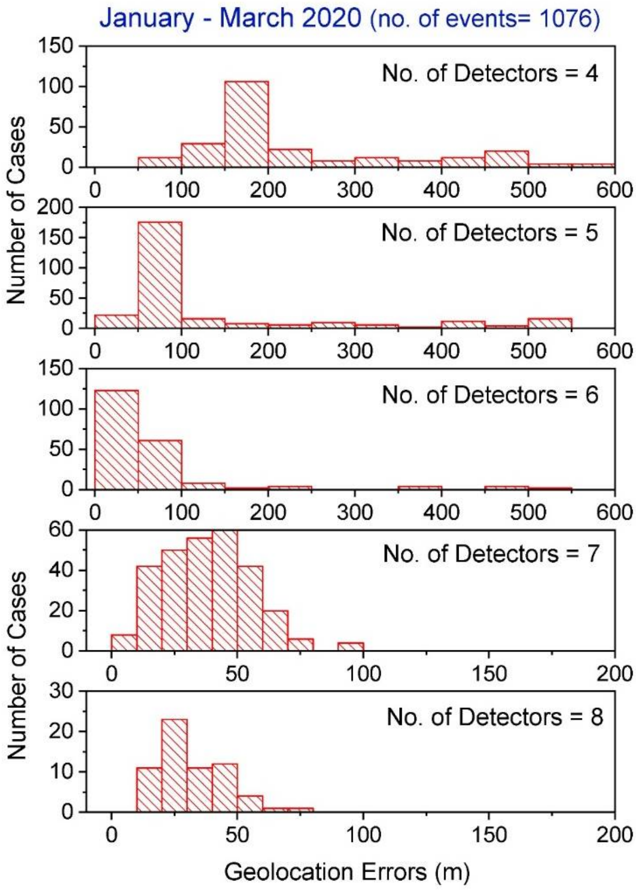

Figure 4: Errors in geo-locating a lightning occurrences with number of participating detections.

Lightning occurrences recorded at respective LDS nodes across India are pushed to LDS-LRX server located at regional centre of NRSC located at Nagpur, India. In this way entire database has been built and hosted on LDS-LRX server with MYSQL workbench database. MYSQL database caters the need of archiving Lightning database and is compatible with most of the operating systems and programming platforms available at present. We used Microsoft Visual studio for MYSQL database extraction. Current database scheme has details in terms of latitude, longitude, strike type, strike current, strike polarity with date and time. Figure 5 shows the flowchart for the generation of Lightning ECV.

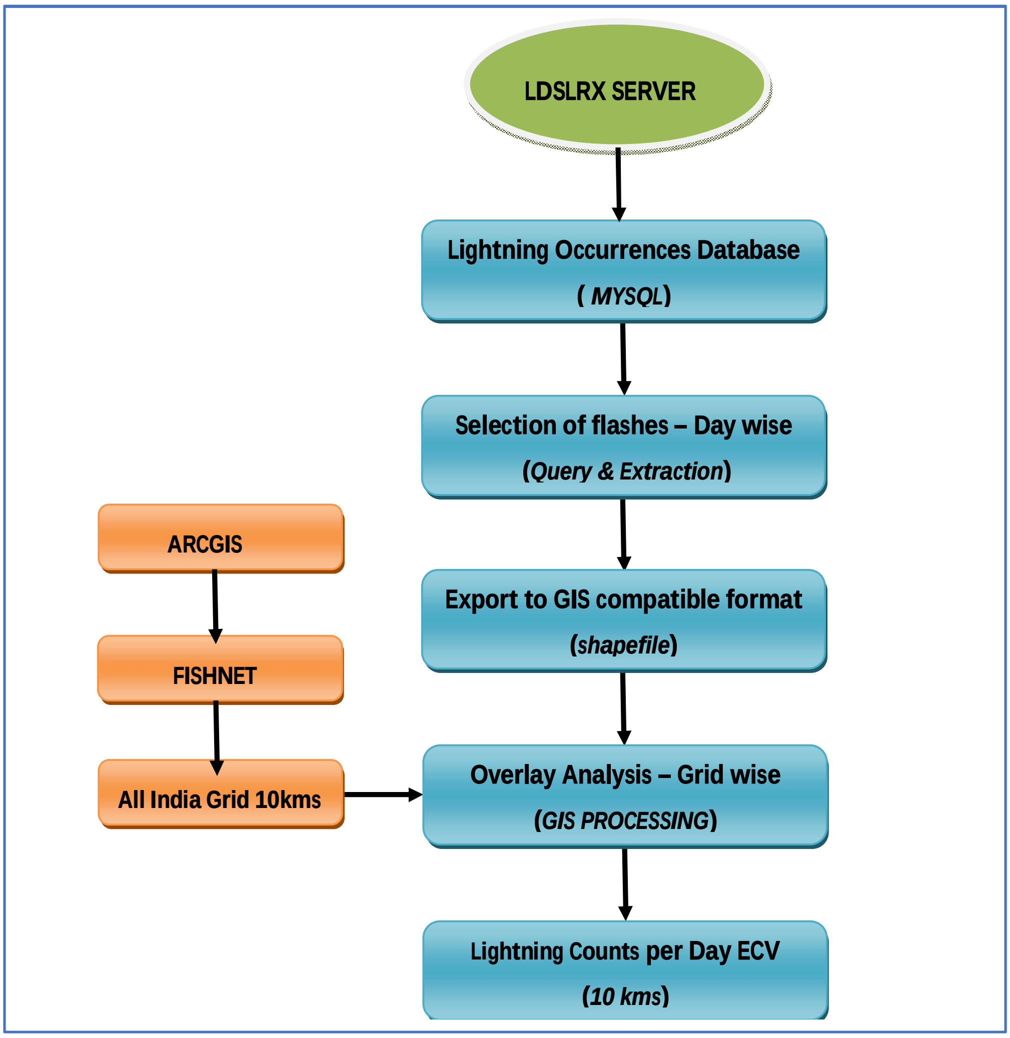

Figure 5. Flow Chart for Creation of Lightning Count per Day per 10 km ECV

Main objective of ECV generation is to deliver lightning counts occurred over 10km x 10 km area per day. Hence, 10 km cell size grid was generated using FISHNET tool of ARCGIS software. This grid constitutes 96000 grid cells covering Indian region. As ECV need to be on daily basis, selection was applied on database for a particular day so that processing load on the database is minimal. Visual basic .net programming interface was used for data extraction purpose. Such selected records are then converted to GIS compatible format i.e. shapefile. In terms of GIS processing, overlay analysis was performed using 10km grid file and day specific shapefile to extract the number of lightning events in each grid cell for that particular day. In this way output is lightning counts per day ECV in the form of 10km x10km grid cells. This quantity is defined as the Lightning ECV as stated in earlier section. Figure 6 shows the prepared grids having 10 km x 10 km resolutions and the NRSC LDS gridded data of 29 May 2020 to prepare map of ECVs.

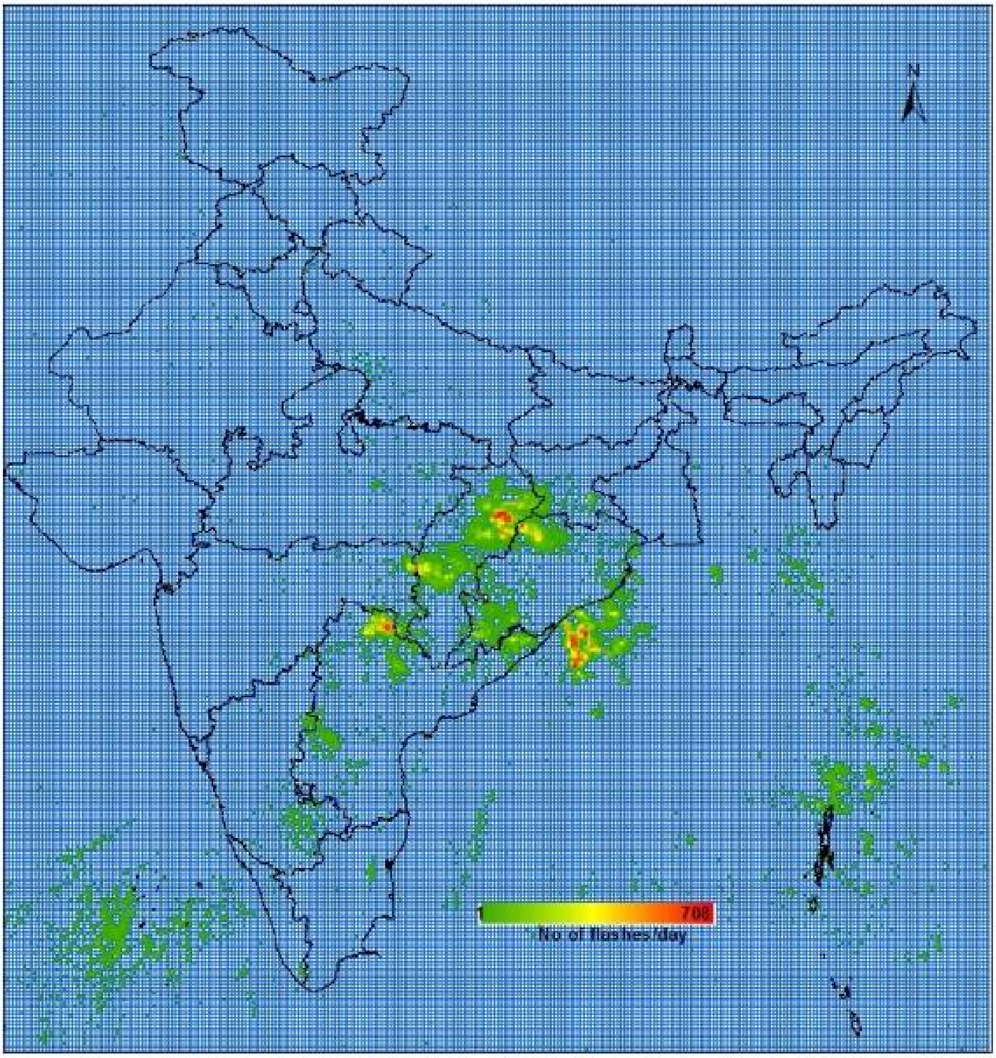

Figure 6. LDS data averaged over the 10 km x 10 km grids for the preparation of ECVs

After these grid analyses the data can be showcased as map or .shp file for appropriate showcasing or distribution for the users. These data are now available at https://bhuvan-app1.nrsc.gov.in/lightning/. When a user clicks on a location, the map provides information on the number of cloud-to-ground strikes/ flashes per day per 10 km x 10 km grid which is defined as the atmospheric lightning ECV by WMO. These we believe are the first effort worldwide to provide the lightning ECV for public usages.

The Lightning ECV map can be used to see the vulnerability of a location as well. For an example, we take the case of 24 June 2020, when about 83 deaths were reported by various agencies such as India Today (https://www.indiatoday.in/india/story/bihar-lightning-deaths-toll-updates-1692705-2020-06-25) and Indian Express (https://indianexpress.com/article/cities/26-killed-in-lightning-strikes-in-bihar-gopalganj-

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2021 doi:10.20944/preprints202112.0183.v1

worst-hit-6476194/). We looked at particular Bihar region to find out the relative vulnerability. Figure 7 shows the ECV map for Bihar region for 24 June 2020.

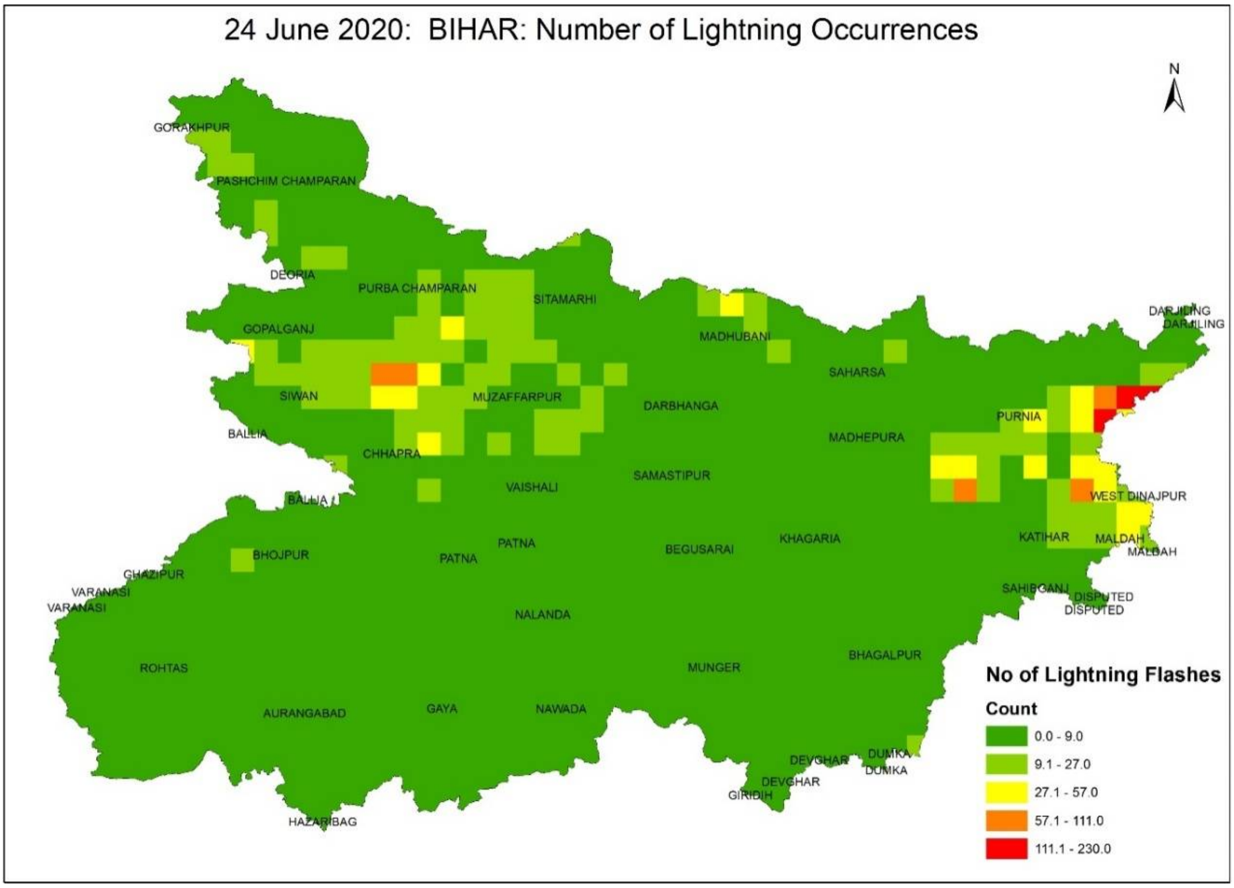

Fig. 7. Lightning ECV distribution in Bihar region on 24 June 2020 over Bihar.

It is clear in figure 7 that some of the locations in Bihar had larger lightning occurrences compared to the other locations in Bihar. In particular, Gopalganj, Siwan, Purnia and West Dinajpur show dangerous lighting occurrences. This information is in agreement with ground reports that most of the human life losses were reported from Gopalganj and Siwan locations. This suggests that Lightning ECV maps can be utilized for the administrative purpose as well. However, such calamities can be averted by the proper ingest of these data into the numerical weather prediction model which is under progress.

 doi:10.20944/preprints202112.0183.v1

8. Acknowledgements: The NRSC-LDS network is funded through National Information System for Climate and Environment Studies (NICES) program of NRSC, ISRO, Dept. of Space. Authors thank Director, NRSC for his continuous support and encouragements. The support of Chief General Manager, RC's, NRSC; Dr. G. Sreenivasan (RC-Central); Dr. D. Dutta & Dr.Chirinjivi Jayaram (RC-East) and Dr. Ganesh Raj & Dr. S. Rama Subramoniam (RC-South) in establishing and maintaining various LDS nodes is duly acknowledged. The help provided by Shri J. P. Singh, Dhruva Technology, New Delhi, in troubleshooting at various sites from time to time is duly acknowledged. We thank all the host institutes for their valuable support in providing needed infrastructure to the Lightning Detection Systems.

References:

Aich, V., R. Holzworth, S. J. Goodman, Y. Kuleshov, C. Price, and E. Williams (2018), Lightning: A new essential climate variable, Eos, 99, https://doi.org/10.1029/2018EO104583, 07 September 2018.

GCOS (Global Climate Observing System), 2016. Public Review of GCOS Requirements for Essential Climate Variables Survey. GCOS Review of Requirements for Climate Monitoring. https://gcos.wmo.int/en/essential-climate-variables.

Ghodpage, Rupesh N., Michale P. Hickey, Alok K. Taori, Devendraa Siingh, and Parashram T. Patil, 2016, Response of OH airglow emissions to mesospheric gravity waves and comparisons with full-wave model simulation at a low-latitude Indian station, Atmos. Chem. Phys., 16, 5611–5621, doi:10.5194/acp-16-5611-2016, 2016

Price, Collin G., 2013.Lightning Applications in Weather and ClimateResearch, Surveys in Geophysics, 34, 755–767,doi: 10.1007/s10712-012-9218-7.

Rakov, V. A., 2013, Electromagnetic Methods of Lightning Detection, Surv. Geophys, 34, 731–753, DOI 10.1007/s10712-013-9251-1.

Romps, D. M., Seeley, J. T., Vollaro, D., and Molinari, J., 2014. Projected increase in lightning strikes in the United States due to global warming. Science, 346, 6211, 851–854.doi:10.1126/science.1259100.

Sivakandan, M., I. Paulino, A. Taori and K. Niranjan, 2016, Mesospheric gravity wave characteristics and identification of their sources around spring equinox over Indian low latitudes', Atmos. Meas. Techniques, 9, 93–102, doi: 10.5194/amt-9-93-2016.

Sivakandan, M., I. Paulino, T. K. Ramkumar, A. Taori, A. K. Patra, S. Sripathi, K. Niranjan, A. Bilibio, Multi-instrument investigation of troposphere-ionosphere coupling and the role of gravity waves in the formation of equatorial plasma bubble', *J. Atmos. Sol. Terr. Phys.*,189, 65-79, doi:10.1016/j.jastp.2019.04.006, 2019

Taori, A., A. K. Patra, and L. M. Joshi, Gravity wave seeding of equatorial plasma bubbles: an investigation with simultaneous F-region, E-region and middle atmospheric measurements, *J. Geophys. Res.*,116, doi:10.1029/2010JA016229, 2011.

Taori, A., Suryavanshi, A., Pawar, S. And M V R Seshasai, 2021, Establishment of lightning detection sensors network in India: generation of essential climate variable and characterization of cloud-to-ground lightning occurrences. Natural Hazards, https://doi.org/10.1007/s11069-021-05042-8.