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WORLD METEOROLOGICAL ORGANIZATION	INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

TTLOCA

Report of the first meeting of the GCOS/CCl Task Team on Lightning Observations for Climate Applications (TTLOCA-1)

Greenbelt, Maryland, USA

5-7 February 2018

GCOS-213

UNITED NATIONS ENVIRONMENT PROGRAMME	INTERNATIONAL COUNCIL FOR SCIENCE

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Note this report does not describe all the presentations but summarises the discussions and actions agreed.

Presentations are made available via the link within the electronic version of the document or by request at **gcos@wmo.int**

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1st Meeting of the GCOS/CCL Task Team on Lightning Observations for Climate Applications (TTLOCA) 5-7 February 2018

1. OPENING OF THE MEETING

1.1 Welcome and introductions

The meeting opened with a welcome to all participants from the Task Team on Lightning Observations for Climate Applications (TTLOCA) Chairman, Robert Holzworth. He introduced the panel and participating Global Climate Observing System (GCOS) secretariat staff, Valentin Aich and Caterina Tassone.

The list of participants can be found in Annex 1.

1.2 Adoption of the Agenda

The agenda provided in Annex 2 was adopted.

1.3 Introduction of participants

All participants introduced themselves and their interest in the Task Team. Yuriy Kuleshov, who represents the Commission for Climatology (CCl) of WMO could not attend the meeting in person and therefore followed the meeting remotely. He participated during the whole meeting from Melbourne, New Zealand.

1.4 Conduct of Meeting

Steven Goodman and Scott Rudlosky explained the logistics at the Cooperative Institute for Climate & Satellites-Maryland (CICS), who agreed to host the meeting.

1.5 Aims and expectations

Presentation	
Robert Holzworth	Aims and expectations (link to presentation (Ctrl+click))

Robert Holzworth explained the main expectations of the meeting according to the draft Terms of references of the task team:

- Identify the potentials and challenges for lightning as climate variable and propose a plan on how to establish operational monitoring of lightning for climate applications;
- Review and update current requirements for the Essential Climate Variable (ECV) lightning;
- Define standards and requirements for data management and data exchange of lightning monitoring for climate applications;
- Propose strategy for open data access for lightning climate applications given the dominance of the private sector in lightning monitoring;
- Encourage space agencies and operators of ground-based systems to provide global coverage and reprocessing of existing datasets.

2. SETTING THE SCENE

2.1 Overview on WMO (GCOS and CCl) including introduction of Essential Climate Variables and current Implementation Plan

Presentation

Caterina Tassone	Overview on GCOS (link to presentation (Ctrl+click))

Caterina Tassone presented an overview about GCOS. She presented the GCOS Implementation Plan of 2016 (GCOS IP) and important actions from the report. She also introduced the work of the other task teams of the Atmospheric Observation Panel for Climate (AOPC) like the one on the use of radar observations for Climate, the one on the instigation of a GCOS Surface Reference Network and the one on the GCOS Upper-Air Network (GUAN). She also presented the GCOS Reference Upper-Air Network (GRUAN), an international reference observing network of sites measuring ECV above Earth's surface through the troposphere and into the stratosphere.

During the following discussion, Colin Price suggested that GRUAN could be used to make measurements for the Global Circuit. This discussion was continued under item 5.

2.2 Expectations on TTLOCA work results from WMO (GCOS and CCl) and discussion

Presentation

Valentin Aich	GCOS and CCl expectations (link to presentation)

Valentin Aich presented the context of the establishment of the task team. Lightning was introduced as an Essential Climate Variable (ECV) in the GCOS IP in 2016. The related action (A 29) asks "To define the requirement for lightning measurements, including data exchange, for climate monitoring and to encourage space agencies and operators of ground-based systems to provide global coverage and reprocessing of existing datasets." Therefore AOPC charged the GCOS secretariat to establish a task team on lightning for climate applications. It was decided to have the task team jointly with WMO's CCl since a CCl Task Team on the Use of Remote Sensing Data for Climate Applications (TT-URSDCM) already started addressing about lightning. The TTLOCA continues this work.

CCl suggested for TTLOCA to elaborate guidelines on the use of lightning observations for climate applications by considering:

- Application examples;
- Observational requirements;
- Data management requirements (including metadata);
- International data holdings including access conditions;
- How to collaborate with private sector lightning detection networks ;
- Utility and data holdings re thunder days.

However, CCl does not expect perfect guidelines at this point in time and they suggested that a collection of best practice examples analogous to the current approach adopted by the task team on radar observations for Climate will be sufficient for WMO Members.

The formulated expectations from GCOS for the meeting were:

- Overview on current status, opportunities and challenges of lightning research, observations and use for climate applications;

- Updating the requirements for lightning observations;
- Develop a plan on how to come up with requirements for lightning data management for climatological applications;
- Initiate a discussion on data sharing and the role of the private sector.

3. VIEWS AND IDEAS OF THE TASK TEAM

3.1 Presentation of Panel members

All present panel members presented their work and their ideas/point of view on the work of the task team.

3.1.1. Robert Holzworth

Presentation	
Robert Holzworth	Presentation (link to presentation (Ctrl+click))

Robert Holzworth presented on the World Wide Lightning Location Network (WWLN) of which he is the director. The network provides a combined product with the private company Earth Networks called Earth Networks Global Lightning Network (ENGLN). His fields of interest in research are lightning climatology, severe weather/strong convection and high altitude influences (Ionosphere, Magnetosphere). During the discussion it was decided to add a glossary to the foreseen White Paper (see item 9) that will be produced to define the terminology.

Action TTL 1	Who	When
Provide a list of technical terms which can be defined by the experts and added as glossary to the White Paper.	GCOS Secretariat	For White Paper

3.1.2. Colin Price

Presentation	
Colin Price	Presentation (link to presentation (Ctrl+click))

Colin Price presented his research about lightning and climate. This includes the link of lightning patterns and severe weather, the impact of climate change on thunderstorms, now- and forecasting of thunderstorms using lightning data, the influence of weather on atmospheric chemistry (positive feedback effect for climate change), cube-satellite observations of lightning and ground lightning detection networks.

In the discussion following his presentation the use of GRUAN for further research on the global circuit was discussed. The final discussion with actions took place under item 5.2.

3.1.3. Steven Goodman

Presentation	
Steven Goodman	Presentation (link to presentation (Ctrl+click))

Steven Goodman presented on the use of satellites for lightning observations. He reported that over 70% of total (in-cloud and cloud-to-ground) lightning flashes are detected by the Geostationary Lightning Mapper (GLM) as designed. GLM covers to 54° N/S with 20 sec product latency and detects the time, location, and radiant energy of each lightning flash from electrically active storms and the areal extent of the lightning threat. It offers a new Nowcasting capability in identifying strengthening and weakening storms and monitors convective mode and storm evolution. Thereby it supplements radar data where coverage is poor and helps to characterize storms as they transition offshore. Another important application area is the provision of insights into changes in tropical cyclone intensity changes. Lastly, the GLM extends for 2-3 decades the previous space-based lightning climatologies begun with the NASA low earth-orbiting Optical Transient Detector (1995-2000) and Lightning Imaging Sensor (1997-2015).

3.1.4. Earle Williams

Presentation	
Earle Williams	Presentation (link to presentation (Ctrl+click))

Earle Williams presented about his research on the Schumann resonances. He concluded that multi-station extremely low frequency (ELF) methods show promise for continuous monitoring of global lightning in absolute units, with far fewer stations than are required for very low frequency (VLF) analysis. This was again discussed under item 5.2.

3.2 Lightning climatology

Presentation	
Yuriy Kuleshov	Lightning climatology (link to presentation (Ctrl+click))

Yuriy Kuleshov presented an overview on the usage of lightning data in Australia, including thunder day data. Lighting is a very relevant hazard in Australia and the observations are needed for early warning but also for risk mapping. Especially thunder day reports have been used for the thunderstorm climatology of Australia and even though the data needs to be analysed with caution, it is very valuable. He also presented on the lightning protection standard in Australia and New Zealand and new generation of meteorological satellites equipped with Lightning Imagers. The main points of his presentation are:

- Given the potential hazards associated with thunderstorms, knowledge about spatial and temporal distributions of thunderstorm and lightning activity is of great importance;
- Long-term thunder-day records are useful source of information about thunderstorm occurrences and trends;
- Instrumental records obtained by Lightning Flash Counters (LFC), Lightning Location Systems (LLS) and space-based optical sensors provide detailed information about distribution of lighting activity;
- One of important climate applications is using lightning climatology for developing comprehensive lighting protective measures;
- New Generation Meteorological Satellites equipped with Lightning Imagers (optical detectors) will provide National Meteorological & Hydrological Services (NMHSs) with long-term data to describe total lightning activity.

4. AVAILABLE LIGHTNING DATA

The goal of this brainstorming session was to create a list of available data on lightning and lightning proxy-data. The list distinguished between observations from space- and ground-based systems (see Annex 3).

It was further discussed to do a survey on available lightning data based on this data sources.

Action TTL 2	Who	When
Prepare a survey for existing lightning data using monkey survey. The list can be based on the datasets known to the committee members who will provide contacts.	1st draft Valentin Aich	End of March 2018

Lightning data is only monitored in the past decades. Therefore it cannot be used reliably to produce climate trends. A common proxy for lighting data are thunder days, which have already been observed in the 19th century.

Presentation

Earle Williams — Thunder Days (link to presentation (Ctrl+click))

Earle Williams gave a presentation on thunder days, in which he explained historical studies of thunder days including Brooks 1925, WMO 1953 and the Global Surface Summary of the Day (GSOD) from 1972. The data have been proven to provide insights in thunderstorm activity, however, due to the nature of the observation as being directly observed by humans it has to be analysed with caution. National studies such as the Lightning climatology for Australia from Yuriy Kuleshov could show clear trends for lightning. Unfortunately this is currently not possible on a global scale since historical thunder day data are archived centrally and GSOD data are available mostly after 1972. Therefore it was decided to explore options for how this data might be collected by WMO member states and the following actions were decided.

Action TTL 3	Who	When
Contact Matt Menne (NOAA) who is responsible for the GSOD data set that includes thunder day data to inquire if they are open to a data collection prior to 1972.	Valentin Aich	End of March 2018
Action TTL 4	**Who**	**When**
Prepare a short summary (1-pager) describing thunder day data and the advantages of such a data collection for climate applications. This suggestion will then be presented by the chair at AOPC for discussion.	Earle Williams	Before AOPC
Action TTL 5	**Who**	**When**
Prepare survey for thunder days, addressed to WMO countries on the existence of thunder day data.	1st draft Earle Williams	End of March 2018
Action TTL 6	**Who**	**When**
Prepare and curate list of known archives of thunder day data	GCOS	Start with

Action TTL 3	Who	When
based on the outcome of the survey.	Secretariat	survey, ongoing

5. CLIMATE SCIENCE/MODELLING NEEDS

5.1 Operational use of lightning observations

Presentation

Steven Goodman	Operational lightning data use (link to presentation (Ctrl+click))

Steven Goodman presented on the operational use of lightning data. He reported that forecasters and scientists have documented a wide range of operational applications for lightning data. As an example he explained the National Weather Service Forecasters Advanced Weather Interactive Processing System (AWIPS) of the United States National Weather Service's software which includes lightning data. Basically, there are three main application areas for lightning data:

1. Lightning Jump: Rapid increase in total lightning that signifies an increased threat for severe weather – supports warning decisions;
2. Lightning Safety: IC lightning typically precedes the first CG, and the GLM provides insights beyond point observations, revealing the spatial extent and distance lightning flashes travel;
3. Situational Awareness: Rapidly updating GLM data reveal convective storm development and evolution throughout the GOES-16 field of view.

During the discussion new methods to include lightning data in forecasting were discussed. These improve substantially the forecast skills of models by allowing the identification of convective systems. It was decided that Steven Goodman would make suggestions for update relevant documents of WIGOS since lightning is already very relevant and this is not reflected in the respective WMO documents.

Action TTL 7	Who	When
Suggestions for updating relevant WIGOS documents like the WIGOS Vision 2040 or resolution 40 in regard of lightning data.	Steven Goodman, Valentin Aich to provide documents	End of March 2018

5.2 Opportunities and challenges of lightning data in the climate community

Presentation

Colin Price	Challenges and opportunities (link to presentation (Ctrl+click))
Earle Williams	Topics on lightning and climate (link to presentation (Ctrl+click))

Colin Price gave an overview on current challenges in lightning research in regard of climate. Main topics are:

- Lightning in drier climates under climate change;
- The influence of ENSO on the global thunderstorm and lightning activity;

- The integration of lightning in climate models;
- The impact of air pollution (aerosols) on lightning;
- The feedback of lightning to climate through the production of NOx as source of O_3;
- Lightning as a tool to understand upper tropospheric water vapour ;
- Global Circuit.

As already discussed in the introduction, in order improve the understanding of the global circuit GRUAN might be a useful partner to launch regular sensors for the global circuit. It was suggested that an initial campaign would bring more insights of the advantages and that a request to AOPC should be prepared in order to have this discussed during the next meeting. It was decided that Colin would write a summary describing the request which then could be presented and discussed at the AOPC meeting in Darmstadt, Germany in March 2018.

Action TTL 8	Who	When
Prepare a short summary (1-pager) describing the measurements needed and why they are needed. This suggestion will then be presented by the chair at AOPC for discussion.	Colin Price, Earle Williams	Before AOPC

The presentation of Earle Williams complemented the opportunities and challenges by focusing on lightning and climate change. In general, the majority of evidence on natural time scales shows an increase of lightning with warming, though that is not finally proven. An additional collection of thunder day data as suggested under item 4 is likely to bring more insight into this still open question.

5.3 Future Improvements needed for better use in Climate Science and Modelling

This discussion served mainly to come up with an outline of the White Paper and is therefore summarized under item 9.

6. OBSERVATION REQUIREMENTS

6.1 Introduction on current requirements

Valentin Aich showed the current requirements for lightning observations in the GCOS Implementation Plan 2016, explaining that these were derived from the Meteosat Third Generation (MTG) Lightning Imager (LI) which will be launched in 2021. The need for expertise for these requirements was one reason for creating the task team.

6.2 Discussion on observation requirements for lightning observation for climate applications

The team discussed products for capturing the relevance of lightning for climate. During the discussion it became evident that the current requirements are not sufficient and that also some definitions in the OSCAR database of WIGOS need review. The suggested observational requirements for lightning are attached in Annex 4. These requirements already include a rationale and the definitions of the product.

Action TTL 9	Who	When
Review agreed-upon products and requirements in Meeting report before submitting to AOPC.	All	For AOPC
Action TTL 10	**Who**	**When**
Suggestions for updating lightning entries for OSCAR	Robert Holzworth	After AOPC

7. DATA MANAGEMENT

The task team discussed the need for metadata standards for lightning data. All members agreed that in order for the global community to be able to use the data, the current situation is unsatisfactory. There is no common standard and all public, research or private data providers use different standards. In order to overcome this situation in the long run, the task team decided to review current standards and to come up with a suggestion for a lightning metadata standard.

Action TTL 11	Who	When
Defining metadata standards: Explore metadata practices for satellite in order to translate that into suggestions. Prepare suggestion for metadata standards in situ	Steven Goodman (contact EUMETSAT and CMA) Robert Holzworth, Valentin Aich	Preliminary before AOPC

8. PRIVATE SECTOR

8.1 Presentation of private sector representative with their view on lightning observations and their data policy

Presentation	
Jim Anderson	Earth Networks Lightning Activities (link to presentation (Ctrl+click))

Jim Anderson from the private company Earth Networks Inc. (ENI) was invited as a representative of the private sector to provide their view on lightning data. Beforehand, the GCOS secretariat invited the private sector via the Association of Hydro-Meteorological Equipment Industry (HMEI), but had not received any positive answer. Therefore the team was thankful that Jim Anderson from Earth Networks had accepted the invitation to share his point of view on short notice.

Jim Anderson gave an overview on the Earth Networks Total Lightning Network, how their data are used and what kind of research EN is currently conducting. Currently EN has a network of over 12,000 weather stations and 1700 lightning sensors. The sensors are deployed in over 90 countries and they are currently expanding mainly outside of Europe.

Their clients include NHMS from many countries, including UNDP financed projects for some African countries.

An important project is the merging of satellite and ground based data. The observations do not provide identically the same information but provide complementary information, and coverage does not overlap 100%.. The location and the classification of the lightning improved strongly through the merging and especially for feeding the data into NWP. This technique is therefore very useful.

8.2 Discussion on how to integrate private sector for climate applications

This discussion followed the presentation of Jim Anderson. The main use of archived lightning data is for engineering of infrastructure, e.g. power lines and forensic use, e.g. for insurance claims. The real-time data is used for safety alert systems, e.g. for airports, golf courts or critical infrastructure.

Private companies see lightning networks as a good solution for developing countries, that cannot afford or maintain radar, since the lighting data can be used as proxy for convective precipitation. These ground based networks are easy to operate, require low maintenance and are very cost effective.

Earth Networks assured that they are willing to share their historical data free of charge and they think other companies would do the same. It was agreed to include these opportunities in the White Paper and come up with suggestions for WMO on how to promote the sharing of lightning data also by the private sector.

9. WHITE PAPER

The task team agreed that the main outcome of the task team should be a white paper, covering all relevant fields and making suggestions for the promotion of lightning observations and usage for climate applications. It was suggested that a first draft should be finished before the next meeting of the International Commission on Atmospheric Electricity (ICAE) in mid-June. The discussed draft outline for the White Paper is attached in Annex 5

Action TTL 12	Who	When
Prepare White Paper on lightning observations for climate applications.	Overall lead Robert Holzworth	Mid June

10. TOR, ACTIONS/WORKPLAN

All actions were agreed upon as in Annex 6.

11. ANY OTHER BUSINESS

None

12. CLOSING DISCUSSION AND DECISIONS

The GCOS Secretariat and the meeting participants expressed their sincere gratitude to the hosts of the meeting, Scott Rudlosky of NOAA and Steven Goodman. The TTLOCA benefited greatly from the provision of excellent meeting facilities and thoroughly enjoyed the generous hospitality of CICS.

ANNEX 1: LIST OF PARTICIPANTS

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ANNEX 2: AGENDA

Day 1: Monday, 5th February 2018 (Status quo)					
Time		**ITEM**	**N°**	**Presenter**	**Targeted outcome**
13:00–13:30	Opening	**Opening of the Meeting**	**1.**		
		Welcome and introductions	1.1	Holzworth	
		Adoption of Agenda	1.2	Holzworth	
		Introduction of participants	1.3	All	
		Conduct of the Meeting	1.4	Goodman	
		Aims and expectations	1.5	Holzworth	
13:30–14:15		**Setting the scene**	**2.**		
		Overview on WMO (GCOS and CCI) including introduction of Essential Climate Variables and current Implementation Plan	2.1	Tassone, Aich	
		Expectations on TTLOCA work results from WMO (GCOS and CCI) and discussion	2.2	Aich	
14:15–15:00		**Views and ideas of task team**	**3.**		
		Each panel member to present 15 minutes about his work on lightning and his ideas/point of view on the work of the task team	**3.1**	Holzworth, Price, Goodman, Williams	Get ideas on opportunities of TTLOCA
15:00–15:30		**Coffee Break**			
15:30–17:30		Continuation of presentations	3.1		
		Presentation on lightning climatology (30 minutes) and afterwards discussion	3.2	Kuleshov	Get overview on how lightning data is used currently for climate applications
		First visit of draft ToR	3.3	Holzworth /All	Check draft ToR against ideas
17:30		**End of day 1**			

Day 2: Tuesday, 6th February 2018 (Vision and Requirements)					
Time		**ITEM**	**N°**	**Presenter**	**Targeted outcome**
09:00–10:00	Status quo and Vision	**Available lightning data**	**4.**		
		Identification of current and historical lightning and lightning-proxy data sets (brainstorming) • Space (Optical/Radio stroke location) • Ground-based (global/regional) • Thunder Day Data • Lightning related data		All	Get overview on existing lightning observation landscape
10:00–10:30		**Coffee Break**			
10:30–12:30		**Climate Science/Modelling needs**	**5.**		
		Presentation on operational use of lightning observations (20 min)	5.1	Goodman	Get overview on how lightning data is used operationally
		Presentation on opportunities and challenges of lightning data in the climate community (30 min)	5.2	Williams, Price	Provide food for thought on potential use of lightning data for climate applications
		Future Improvements needed for better use in Climate Science and Modelling: discussion on how networks may improve to serve climate community	5.3	All	Vision on overall goal of task team

12:30–13:15		**Lunch**			
13:15–15:30		**Tour of the NOAA National Center for Weather and Climate Prediction (NCWCP)**			
15:30–16:00	**Requirements and data managment**	**Observation Requirements**	**6.**		
		Short introduction on current requirements	6.1	Aich	
		Discuss and prepare observation requirements for lightning observation for climate applications	6.2	All	Suggest updated requirements for next GCOS Implementation Plan and OSCAR (WIGOS)
16:00–17:30		**Data Management**	**7.**		
		Discussion on data quality standards	7.1	All	Workplan on how to define data quality standards
		Discussion on Metadata	7.2	All	Workplan on how to define metadata standards
		Discussion on data management and access, including a potential data center	7.3	All	Workplan on how to define standards for data management/access
17:30		**End of day 2**			
Day 3: Wednesday, 7th February 2018 (Private Sector and closure)					
Time		**ITEM**	**N°**	**Presenter**	**Targeted outcome**
08:30–09:45	**Private Sector**	**Private Sector**	**8.**		
		Presentation of private sector representative(s) on their view on lightning observations and their data policy	8.1	Private sector representative	Information about point of view of private sector
		Discussion on how to integrate private sector for climate applications	8.2	All	Decide strategy how to integrate private sector data
09:45–10:00		**Coffee Break**			
10:00–11:00	**Decisions and Closing**	**White Paper**	**9.**		
		Discussion on content, format (journal etc.) and responsibilities		All	Workplan for White Paper
11:00–12:30		**ToR, Actions/Workplan**	**10.**		
		Revisit ToR and decide	10.1	All	ToR for TTLOCA
		Discuss and decide on actions/workplan	10.2	All	TTLOCA-1 actions and workplan for first year
12:30–13:30		**Lunch**			
13:30–14:00		**Any other business**	**11.**		
14:00–15:00		**Closing discussions/decisions**	**12.**		
		Modus operandi; next teleconferences, memberships,...			
15:00		**End of Meeting**			

ANNEX 3: LIST OF DATA SOURCES FOR LIGHTNING

Space:

- Geostationary Lightning Mapper (GLM) (US GOES-16/17);
- Tropical Rainfall Measuring Mission (TRMM)/Lightning Imaging Sensor (LIS);
- TRMM/Optical Transient Detector (OTD);
- International Space Station (ISS)/LIS;
- Meteosat Third Generation (MTG) Lightning Imager (LI) planned for 2021;
- GLI (Geostationary Lightning Imager) (Chinese Fenguyn 4a geostationary satellite);
- Ionosphere Sounding Satellite "UME-2" (ISS-b) (Japanese);
- Defense Meteorological Satellite Program (DMSP) (United States Department of Defense) ;
- Global Positioning System (GPS) satellite\ Los Alamos National Laboratory (LANL);
- Fast On-Orbit Recording of Transient Events (FORTE)\LANL .

Ground based:

- World Wide Lightning Location Network (WWLLN);
- Global Lightning Dataset (GLD) 360 from Vaisala;
- Arrival Time Difference Network (ATDNet) from MetOffice;
- Lightning Network from EarthNetworks Inc. (ENI);
- Earth Networks Global Lightning Network (ENGLN) (WWLN+EN);
- VHF Lightning Mapping Array (LMA) / Lightning Detection and Ranging Network (LDAR);
- VLF (national networks: ZEUS (Europe), STARnet (Brazil);
- EUropean Cooperation for LIghtning Detection (EUCLID);
- National Lightning Detection Network (NLDN) for US (Vaisala);
- Canadian Lightning Detection Network (CLDN) for Canada (Vaisala);
- New Zealand Lightning Detection Network (NZLDN) from Transpower and MetService;
- Other National Lightning Detection Systems National Networks Australia, Taiwan, Greece, Israel, Russia, China, South Africa, Brazil, Portugal, Japan, Spain;
- Extreme Low Frequency Networks (Schumann resonances, 15 countries, 30 stations);
- Very Low Frequency /Low Frequency lightning detection network (LINET) (spin-off from University Munich, Germany);
- United States Precision Lightning Network/North American Precision Lightning Network (USPLN/NAPLN).

ANNEX 4: SUGGESTED PRODUCTS FOR LIGHTNING AND THEIR OBSERVATION REQUIREMENTS

Product	Definition	Frequency	Rationale	Resolution	Required measurement uncertainty	Stability (per decade)	Standards/ references	Entity	
								Satellite	In situ
Hourly total lightning stroke density (gridded)	See WIGOS, but flashes-> strokes	Hourly (accumulated)	Lifetime of thunderstorm cell, diurnal cycle	0.1 x 0.1 degree	Quantification of detection efficiency	Need for documentation	ATBD, MTG EURD, Nag et al. 2015	NOAA, NASA, EUMETSAT, CMA	VLF, LF, ELF
Daily total lightning stroke density (gridded)		daily (accumulated)	Weather patterns, weekly and intraseasonal patterns like MJO	0.1 x 0.1 degree	Quantification of detection efficiency	Need for documentation	ATBD, MTG EURD	NOAA, NASA, EUMETSAT, CMA	VLF, LF, ELF
Monthly total lightning stroke density (gridded)		Monthly (accumulated)	Climate scale	0.1 x 0.1 degree	Quantification of detection efficiency	Need for documentation	ATBD, MTG EURD[1]	NOAA, NASA, EUMETSAT, CMA	VLF, LF, ELF
Thunder Day	Thunder heard per day (yes\no)	Daily	Cover period without lightning data, trend analysis, proxy for lightning	Point sources	na	na	WMO Bulletin 1953, Brooks 1925		
Schumann resonances	Calibrated ELF magnetic field 3 first modes	Daily	Proxy for lightning	Global index	Calibrated magnetic field pT^2\Hz	na	Polk 1982		ELF

ANNEX 5: DRAFT OUTLINE OF WHITE PAPER

Item	Short description	Responsible
1.Relevance of lightning data for climate applications	• Casualties, injuries • Loss and damage • Proxy for connectivity/storms including	Yuriy Kuleshov (with input from others)
	• Current use of lightning data (CCl, who are customers?) • Integration and improvement of nowcasting and forecasting for EWS and Adaptation, Earle to add work from Lincoln Lab	Steven Goodman
	• Positive feedback mechanism, NO_X	Colin Price
2. Thunder days	• Relevance	Earle Williams
3. Open research questions	• Drier climate, ENSO, model parametrization, aerosols, chemistry (feedback mechanism for climate change), Global Circuit • Questions to which lightning data can contribute	Colin Price
4. Observing systems and data	• Relevance of satellite and ground based being complimentary	Robert Holzworth, Steven Goodman
	• Satellite	Steven Goodman
	• Ground based	Robert Holzworth
	• ELF	Earle Willams
	• Emerging technologies (cube satellites, …)	Colin Price
	• Table of data in Annex	
5. Global Circuit	• Describe relevance • Propose how GRUAN campaign could provide useful information	Colin Price , Earle Williams
6. Data policy	• Metadata ground based • Metadata for Satellite • Best practices of data holding, data mapping?	Robert Holzworth, Steven Goodman
7. Private Sector		Robert Holzworth
8. Glossary		GCOS Secretariat

ANNEX 6: LIST OF ACTIONS

N°	Action	Who	When
TTL1	Provide a list of technical terms which can be defined by the experts and added as glossary to the White Paper.	GCOS Secretariat	For White Paper
TTL2	Prepare a survey for existing lightning data using monkey survey. The list can be based on the datasets known to the members who will provide contacts.	1st draft Valentin Aich	End of March 2018
TTL3	Contact Matt Menne (NOAA) who is responsible for the GSOD that includes thunder day data if they are open for a data collection prior to 1972	Valentin Aich	End of March 2018
TTL4	Prepare a short summary (1-pager) describing thunder day data and the advantages of such a data collection for climate applications. This suggestion will then be presented by the chair at AOPC for discussion.	Earle Williams	Before AOPC
TTL5	Prepare survey for thunder days, addressed to WMO countries on the existence of thunder day data.	1st draft Earle Williams	End of March 2018
TTL6	Prepare and curate list of known archives of thunder day data based on the outcome of the survey.	GCOS Secretariat	Start with survey, ongoing
TTL7	Suggestions for updating relevant WIGOS documents like the WIGOS Vision 2040 or resolution 40 in regard of lightning data.	Steven Goodman, Valentin Aich to provide documents	End of March 2018
TTL8	Prepare a short summary (1-pager) describing the measurements needed and why they are needed. This suggestion will then be presented by the chair at AOPC for discussion.	Colin Price, Earle Williams	Before AOPC
TTL9	Review agreed products and requirements in Meeting report before submitting to AOPC.	All	For AOPC
TTL10	Suggestions for updating lightning entries for OSCAR	Robert Holzworth	After AOPC
TTL11	Defining metadata standards: Explore metadata practices for satellite in order to translate that into suggestions. Prepare suggestion for metadata standards in situ	Steven Goodman (contact EUMETSAT and CMA) Robert Holzworth, Valentin Aich	Preliminary before AOPC
TTL 12	Prepare White Paper on lightning observations for climate applications.	Overall lead Robert Holzworth	Mid June

TTLOCA

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