CGMS-XXXIII
WMO WP-24
Prepared by WMO
Agenda item: II/4

THE CASE FOR INTERNATIONAL COOPERATION ON LIGHTNING OBSERVATION FROM THE GEO ORBIT

(Submitted by WMO)

Summary and purpose of document

The document contains a discussion prepared by Dr Bizzarri at the request of WMO The document highlights the case for operational observation of lightning from space, in particular to improve convective precipitation estimates, support to aviation and atmospheric research. It proposes the outline of a coordinated lightning mapping mission, with a two-headed lightning mapper to be considered for implementation on the next series of geostationary meteorological satellites.

ACTIONS PROPOSED

(1) CGMS is invited to note the case for operational observation of lightning from space;

(2) CGMS is invited to consider the goal of implementing lightning missions on future geostationary satellites.

Introduction

1. This discussion paper recalls the basic motivations for observing lightning from space, specifically from the geostationary orbit. It highlights the sensing principle, showing that the instrument may be rather small if its Field Of View (FOV) is limited to few degrees. To achieve continuous global coverage of low-mid latitudes (that is a main requirement) it is necessary that all geostationary satellites be equipped with an appropriate instrument, and that the instruments are operated according to coordinated pointing. It is therefore suggested that CGMS members consider a coordinated implementation of the lightning observing mission from their future GEO satellites.

Benefits of lightning observation

2. Theoretical lists of lightning observation applications are very long, but a short list follows:

- Improved precipitation estimate:
  - more reliable cloud type classification: lightning follows from charged particle separation due to ice updraft, thus clouds associated to lightning are easily classified as convective;
  - improved convection index maps: current operational products (GCD, Global Convection Diagnostics) based on IR and WV imagery are rather unreliable; fusion with lightning information strongly reduces ambiguities;
  - information on convection maturity stage: whereas ground-based lightning networks are mostly sensitive to cloud-to-ground lightning, space-based observation is also sensitive to cloud-to-cloud lightning, much more numerous and preceding rainfall;
  - support for cloud radiative model selection when processing MW observations: the most accurate space observation technique by microwave radiometry makes use of maximum-likelihood retrieval methods; best results are achieved if the precipitating cloud is *a-priori* well characterised, as allowed by lightning information.
- Aviation aid:
  - risk from storms during take-off and landing: during these delicate phases information on lightning is useful both as indicative of turbulence and direct probability of strokes;
  - passenger comfort during the cruise phase: obviously, lightning is associated to turbulence.
- Atmospheric research:
  - production of NO_x: these species (NO, NO_2, NO_3) are precursors of HNO_3, the most important nitrogen reservoir in the ozone cycle, that plays an important role in heterogeneous chemistry in polar stratospheric clouds and hence in ozone depletion;
  - study of the Earth's electric field: a background information to understand solar-terrestrial interactions, ionosphere and space weather, also impacting on telecommunications.

Principle of sensing

3. Lightning from space is observed by CCD cameras where each detector of an array images one earth's spot (pixel). Flashes are detected against the background (night and day) by a very-narrow-band filter in an atmospheric absorption band that screens out solar radiation reflected by the earth's surface (generally 777.4 nm, in an O_2 band). The measurement consists of flash intensity and rate. From GEO, one pixel is continuously monitored on a single detector. From LEO, the pixel is viewed from different detectors as the satellite moves, for a time interval of very few minutes. The narrow-band (interferometric) filter requires little divergence of the beam perpendicular to the focal plane. From GEO, where large-aperture optics are required for sensitivity reasons, this limits the acceptable FOV to few degrees (say, 5 to 10°). From LEO, where there is plenty of energy, wide-angle optics can be used (say, 80°) that provide global coverage every 1.5-2 days. Thus, the lightning mission is optimally served from GEO !

4. However, so far, lightning instruments have only been flown on LEO. Apart from early experiments on DMSP, the first mission was OTD (Optical Transient Detector) on Microlab-1 (also called OrbView-1), flown in the period 1995-2000; the second, LIS (Lightning Imaging Sensor) on 2
TRMM, was launched in 1997 and is still operational. It was actually the same instrument, provided by NASA/MSFC, in different configurations. ***Figure 1*** shows an 8-year lightning climatology built by means of the two instruments. For reasons that will be clearer later, we note that very little lightning is observed at very high latitudes (and (l) over the oceans.

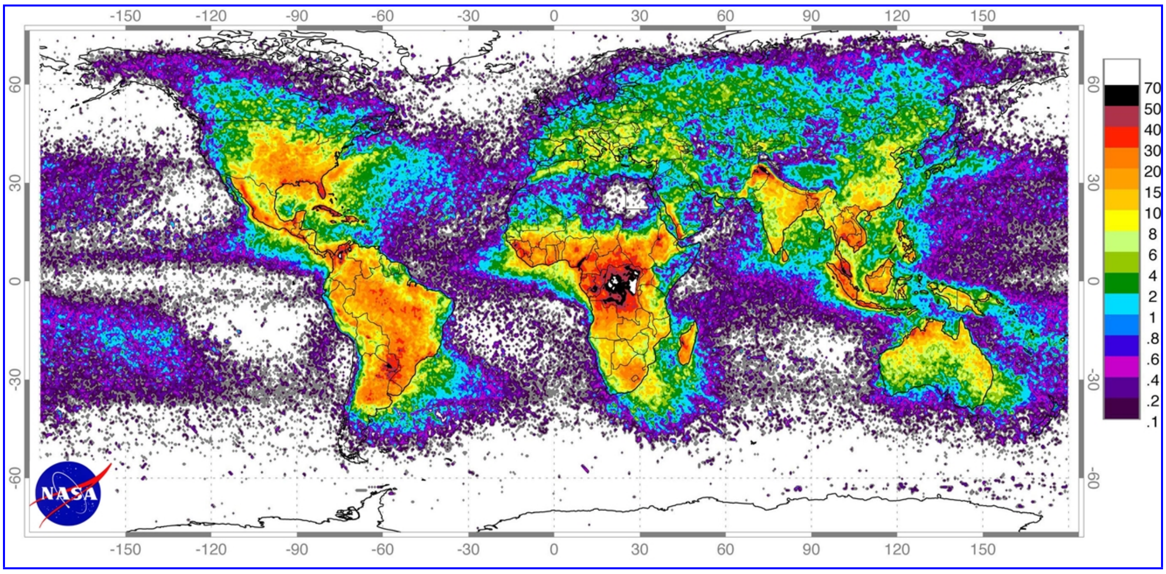

Fig. 1 – High Resolution Full Climatology Annual Flash Rate: Global distribution of lightning April 1995 – February 2003 from the combined observations of the NASA OTD

Lightning from GEO

5. The problem of transferring the lightning mission in GEO stems from the conflicting requirements of sensitivity, that requires telescopes with large-aperture, and narrow FOV. In practise, if full disk has to be covered, four distinct optical heads are required. This is the current nominal plan of EUMETSAT for LI (Lightning Imager) on Meteosat Third Generation (MTG). The NOAA plan for GLM (Geostationary Lightning Mapper) on GOES-R only uses two optical heads (***Fig. 2***).

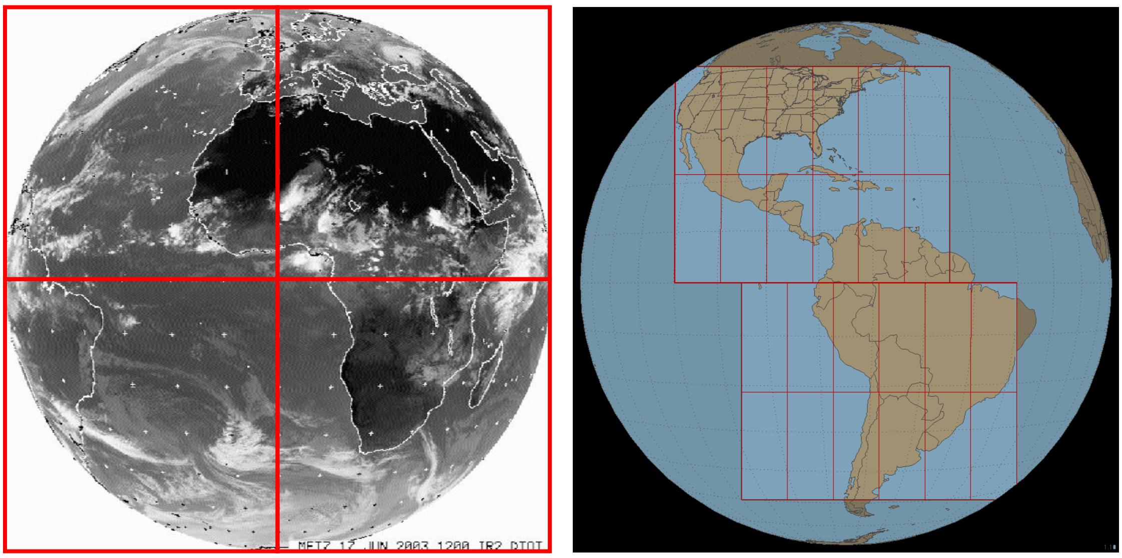

Fig. 2 – Coverage with four optical heads (LI on MTG at 0°) and with two (GLM on GOES-R at 95°W)

6. A lightning mapper from GEO, if full disk coverage is required, may weigh ~ 100 kg and require an electrical power of ~ 200 W. If two optical heads only are used, we have ~ 50 kg / ~ 100 W. However, in this case global coverage would require international cooperation and coordination. 3

7. ***Figure 3*** shows the coverage that would be achieved if all the geostationary satellites of the Global Observing System (GOS) were equipped with a two-head lightning mapper shaped as GLM, and the instrument points to appropriately coordinated locations. It is noted that very-high latitudes are (of course) not covered, but Fig. 1 shows that there is no much lightning there. The fact, also from Fig. 1, that there is very little lightning over the oceans makes it not critical that the coverage of FOV's from adjacent satellites be so well phased as in Fig. 3 gaps can be tolerated if on the oceans.

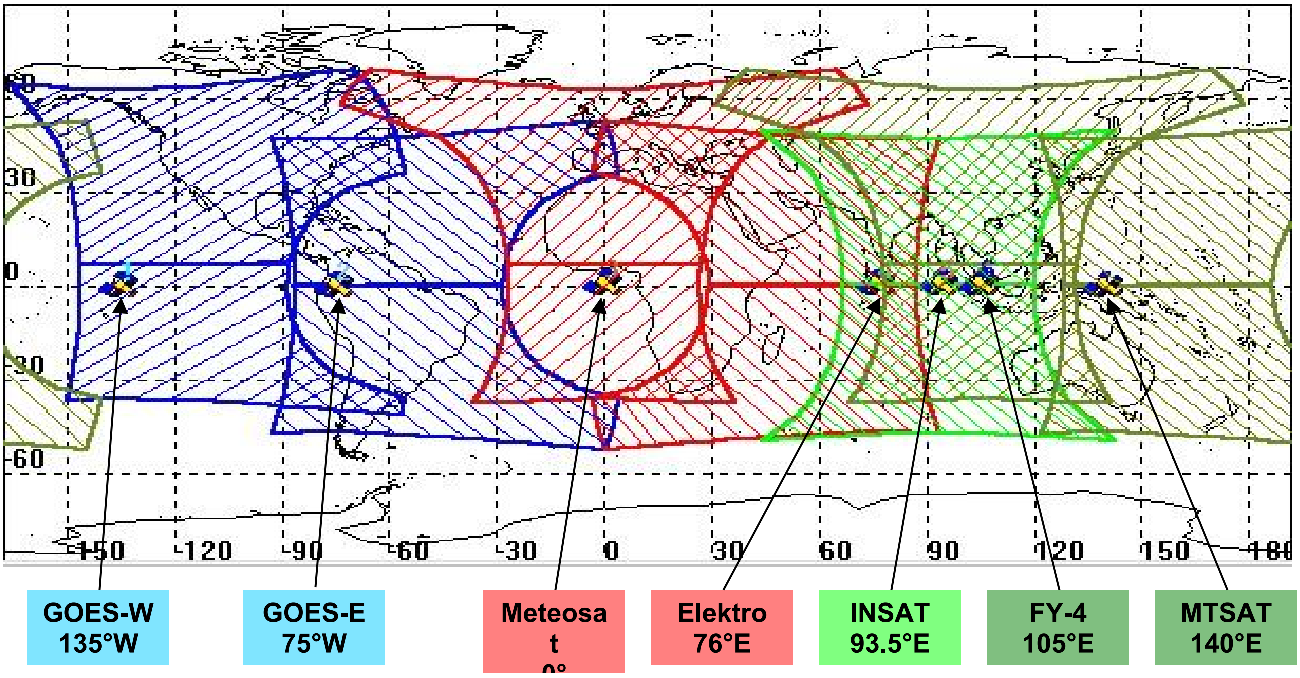

Fig. 3 - Lightning mapping coverage with two optical heads on each operational satellite

Conclusions

8. CGMS has already agreed the following goals for new generations of GEO satellites:

- all VIS/IR imagers to be upgraded to at least the level of MSG/SEVIRI (CGMS-31.36);
- all satellites to be equipped with high-resolution IR sounding spectrometers (CGMS-31.36);
- demonstration missions to be pursued through the IGeoLab initiative (CGMS-32.19).

9. It should be recalled that at its Extraordinary session in 2002 CBS approved a vision for the space-based global observing system in 2015 to include several R&D missions with the GEO lightning capability.

10. A possible operational goal is proposed:

- all satellites to be equipped with a lightning imager.

11. Implementing the new mission would imply:

- a small payload: mass ~ 50 kg, required electrical power ~ 100 W;
- limited impact at system level: no moving parts, low data rate (< 100 kbps).