Predicting thunderstorms, lightning and sprites for global observations from the International Space Station

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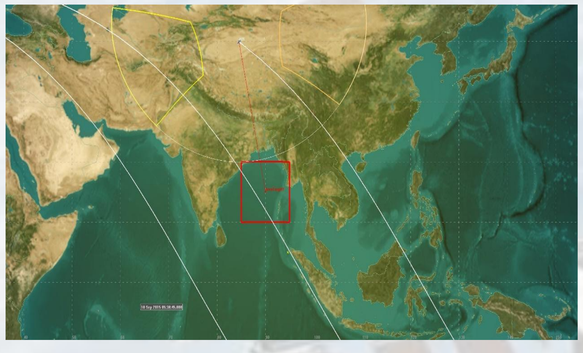
Introduction

The THOR experiment on the International Space Station (ISS) was conducted by Danish astronaut, Andreas Mogensen, during September 1-10, 2015. The aim was to observe over-shooting cumulonimbus turrets, lightning and Transient Luminous Events (e.g. sprites, elves, blue-jets) with an optical camera through the windows of the PIRS module. To maximize the chances of success, we developed a strategy to predict locations of thunderstorm targets up to three days in advance.

The long lead-time was required by the astronaut activity planners that attempted to accommodate many experiments during a short time. The prediction strategy relied on the methodology developed for the MEIDEX experiment on board the space shuttle Columbia (Ziv et al. 2003) and later refined for JAXA's Cosmic Shore campaign from the ISS (Yair et al., 2013).



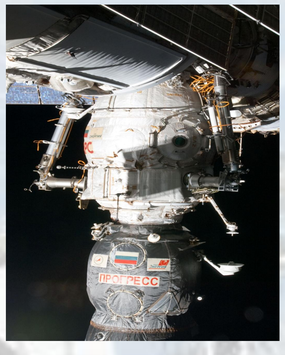


Figure 1: (a) schematic representation of ISS orbits and the computed field-of-view from the Pirs Module (b) with 45 degrees relative to the velocity vector. The red rectangle represents the region of interest (ROI) for the observation.

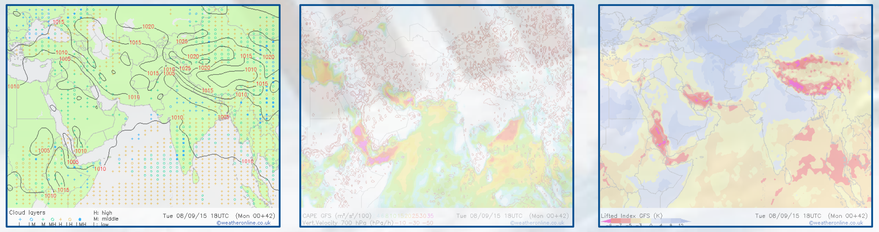


Figure 2: Forecast maps used for Region Of Interest (ROI) definition: Clouds (Water vapour, left) – "Lifted index" (instability, centre) – CAPE (upward motion, right). Target region and time: 22.00-23.00 UTC, Indian Ocean and adjacent coastal regions near Chennai (12°-16°N, 78°-83°E), India.

References

Yair, Y., L. Rubanenko, K. Mezuman, G. Elhalel, M. Pariente, M. Glickman-Pariente, B. Ziv, Y. Takahashi and T. Inoue (2013). New color images of transient luminous events from the International Space Station. *Jour. Atmos. Sol. Terr. Phys.*, 102, 140-147.

Ziv, B., Y. Yair, K. Pressman and M. Fullekrug, 2004: Verification of the Aviation Center global forecasts of Mesoscale Convective Systems. *Jour. App. Meteor. Clim.*, 43, 720-726.

Acknowledgment

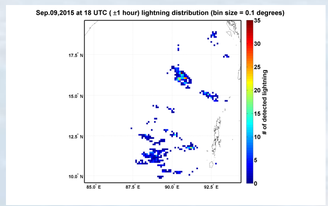
WWLLN data are used courtesy U. of Washington, US.

Methodology

The list of potential targets was modified and updated daily based on GFS/CAPE values and Convective Cloud Top height predictions (Fig. 2). The locations of hurricanes and typhoons were updated based on NOAA/NHC and JTWC. The selected targets are verified against the locations of lightning flashes observed by the WWLLN lightning detection network with 0.1 degree resolution. We show 10x10 degree rectangle centered on the coordinates of the ROI (Figs. 3 - 5).

Target 23	TLEs above Bay of Bengal	Quality ***
Day	2015/09/09 Night-time	
Start Time	252/19:49	
End Time	252/19:54	
ISS Site Pointing	Target on PORT side, coming from horizon Start Az: -44.2 ° El -19.9 ° End Az: -103.1 ° El -21.4 °	

Figure 3a: Operational message for the target in the Bay of Bengal, including angles and observation times



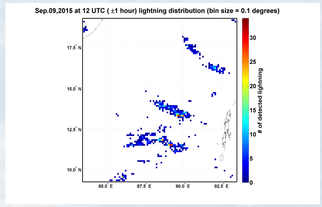
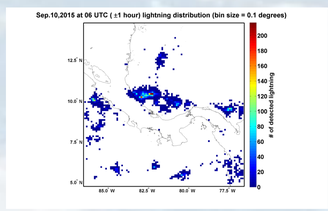


Figure 3b: The WWLLN lightning detections one hour before and after inside a 10x10 degrees box centered on the predicted location of lightning activity

Target 5	TLEs above Caribbean	Quality ***
Day	2015/09/10 Nightime	
Start Time	253/08:15	
End Time	253/08:19	
ISS Site Pointing	Target on STBD side, moving toward horizon Start Az: 118.4 ° El -42.5 ° End Az: 167.9 ° El -19.9 °	

Figure 4a: Operational message for the target in the Caribbean including angles and observation times.



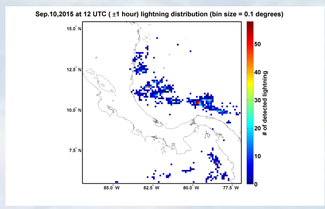
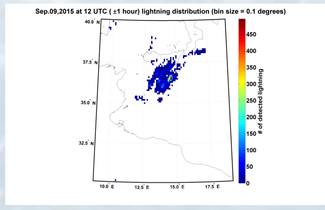


Figure 4b: The WWLLN lightning detections one hour before and after inside a 10x10 degrees box centered on the predicted location of lightning activity

Target 10	CTs above Tunisia	Quality ***
Day	2015/09/09 Daytime	
Start Time	252/12:42	
End Time	252/12:46	
ISS Site Pointing	Target on PORT side, coming from horizon Start Az: -49.3 ° El -20.0 ° End Az: -100.5 ° El -20.8 °	

Figure 5a: Operational message for the target in the Mediterranean including angles and observation times.



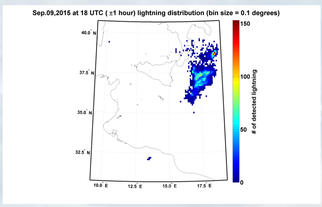


Figure 5b: The WWLLN lightning detections one hour before and after inside a 10x10 degrees box centered on the predicted location of lightning activity

Summary

We developed an operational scheme for predicting convective centers with high probability of penetrating turrets and substantial lightning activity. The update cycle of this list allowed refining the targets' locations and enabled us to better define the observation windows and the camera pointing angles. This was done daily for 6-hour forecast times (00 UT, 06 UT, 12 UT and 18UT). TLEs and Cloud Turrets were successfully imaged, even with the very short observation time of a few minutes (Chanrion et al., EGU 2016).

We checked 68 defined ROIs along the mission, and verified them against WWLLN data. Results show that in 57 targets, lightning were present either 1h before or after the time (~80% success rate). This is likely due to the persistence of the conditions for deep convection over extended periods of time. The presented forecast cycle can be easily reproduced for future missions.