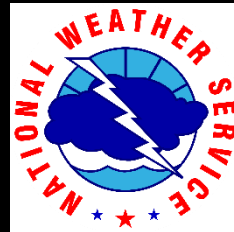
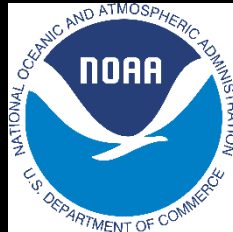


Challenges and Opportunities in Aviation

Bob Rutledge

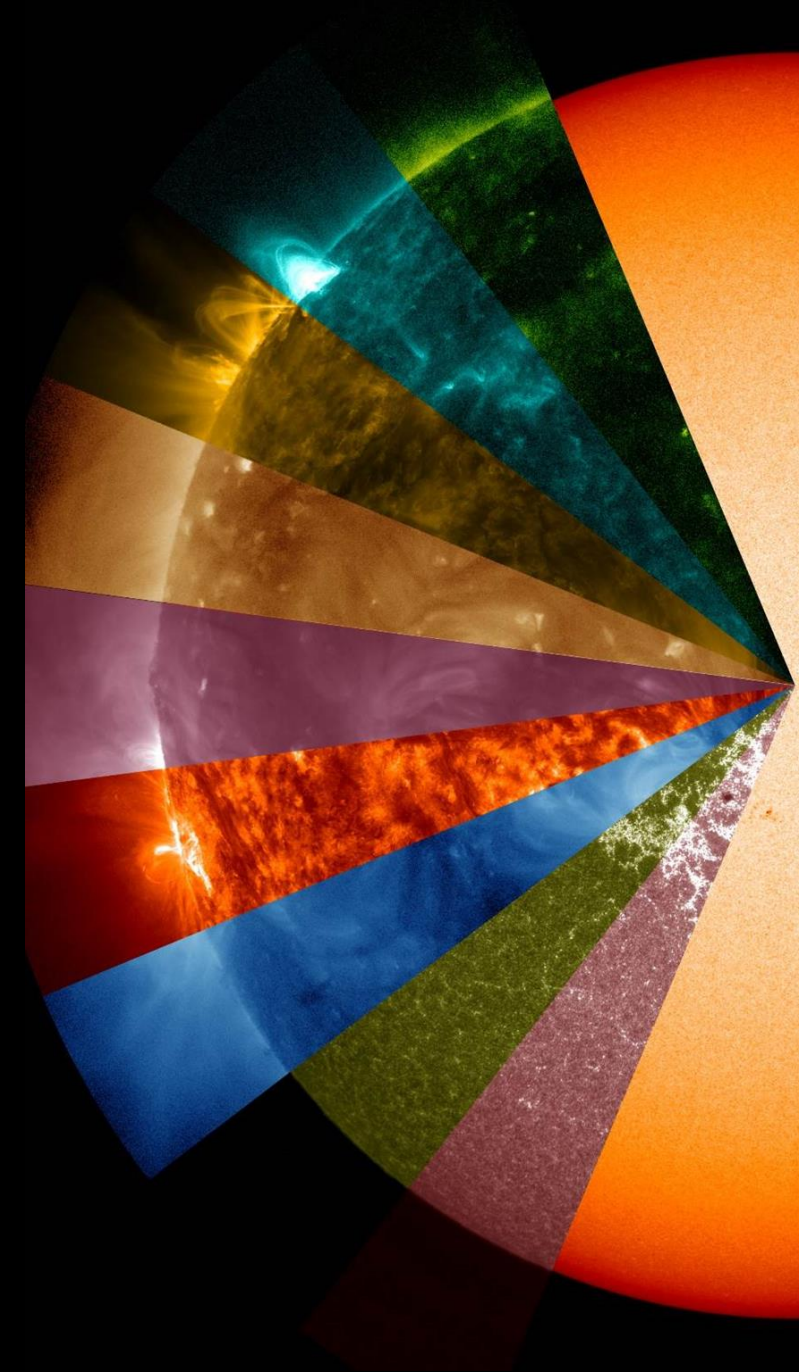
NOAA Space Weather Prediction Center, Boulder, CO



- ✈️ Aviation services/services within ICAO
- ✈️ Challenges in service provision
- ✈️ Evolution of services and needs

Services Within ICAO

- ✈ Services proposed for inclusion in Amendment 78 to Annex 3
 - ✈ HF Communications (propagation, absorption)
 - ✈ Communications via satellite (propagation, absorption)
 - ✈ GNSS-based navigation and surveillance (degradation)
 - ✈ Radiation at flight levels (increased exposure)
- ✈ Event-driven advisories for Moderate or Severe effects
- ✈ Applicability in November 2018
- ✈ Global/regional service model



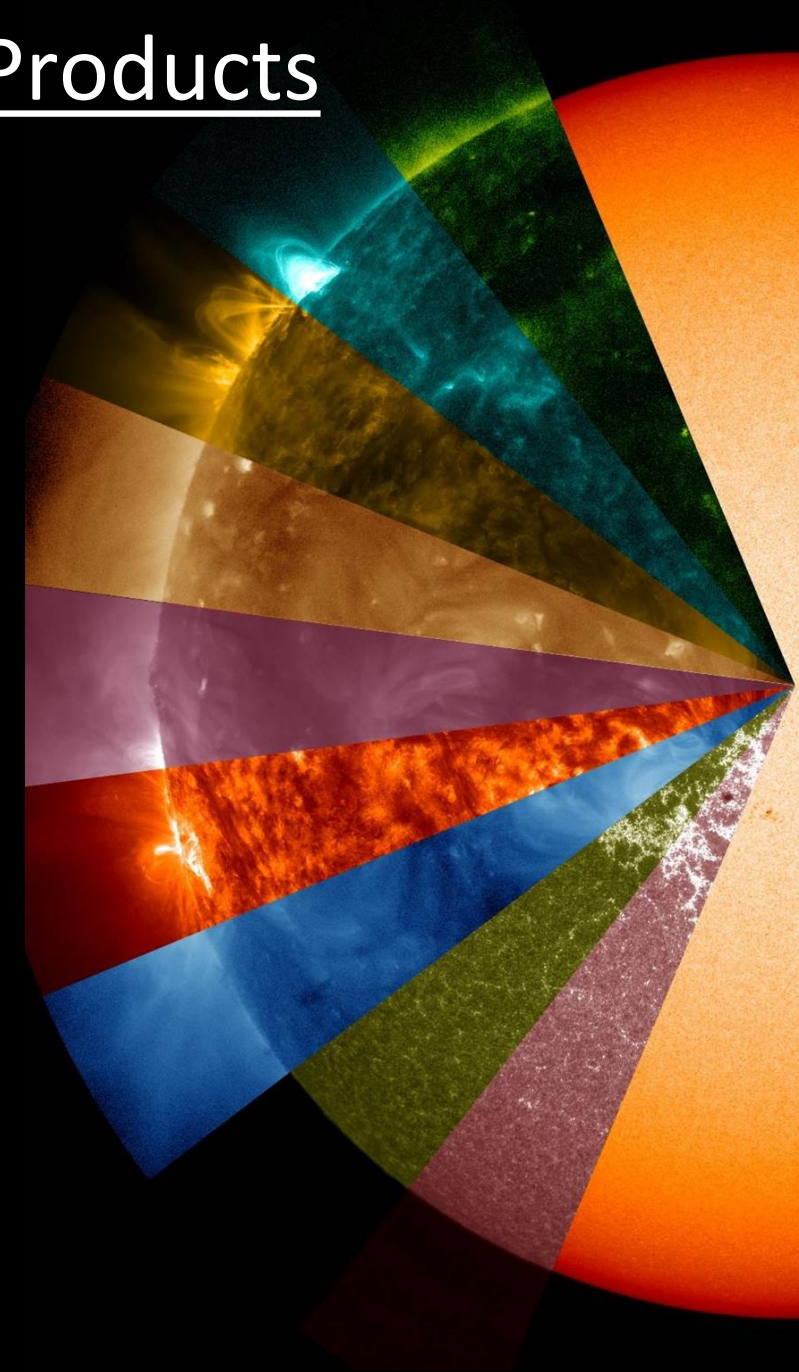
Services Within ICAO – Example Products

Example A2-4: Space weather advisory message (RADIATION effects)

(communication header)	
SWX ADVISORY	
DTG:	20161108/0000Z
SWXC:	(to be determined)
SWX EFFECT:	RADIATION MOD
ADVISORY NR:	2016/2
FCST SWX:	20161108/0100Z HNH HSH E18000 – W18000 ABV FL350
FCST SWX +6 HR:	20121108/0700Z HNH HSH E18000 – W18000 ABV FL350
FCST SWX +12 HR:	20161108/1300Z HNH HSH E18000 – W18000 ABV FL350
FCST SWX +18 HR:	20161108/1900Z HNH HSH E18000 – W18000 ABV FL350
FCST SWX +24 HR:	20161109/0100Z NO SWX EXP
RMK:	RADIATION LEVELS HAVE EXCEEDED 100 PERCENT OF BACKGROUND LEVELS AT FL350 AND ABOVE. THE CURRENT EVENT HAS PEAKED AND LEVELS ARE SLOWLY RETURNING TO BACKGROUND LEVELS. SEE WWW.SPACEWEATHERPROVIDER.WEB
NXT ADVISORY:	NO FURTHER ADVISORIES

Example A2-3: Space weather advisory message (GNSS and HF COM effects)

(communication header)	
SWX ADVISORY	
DTG:	20161108/0100Z
SWXC:	(to be determined)
SWX EFFECT:	GNSS MOD AND HF COM MOD
ADVISORY NR:	2016/1
OBS SWX:	20161108/0100Z HNH HSH E18000 – W18000
FCST SWX +6 HR:	20121108/0700Z HNH HSH E18000 – W18000
FCST SWX +12 HR:	20161108/1300Z HNH HSH E18000 – W18000
FCST SWX +18 HR:	20161108/1900Z HNH HSH E18000 – W18000
FCST SWX +24 HR:	20161109/0100Z NO SWX EXP
RMK:	LOW-LEVEL GEOMAGNETIC STORMING IS CAUSING INCREASED AURORAL ACTIVITY AND SUBSEQUENT MOD DEGRADATION OF GNSS AND HF COM AVAILABILITY IN THE AURORAL ZONE. THIS STORMING IS EXPECTED TO SUBSIDE



Adding Value

✈ Radiation

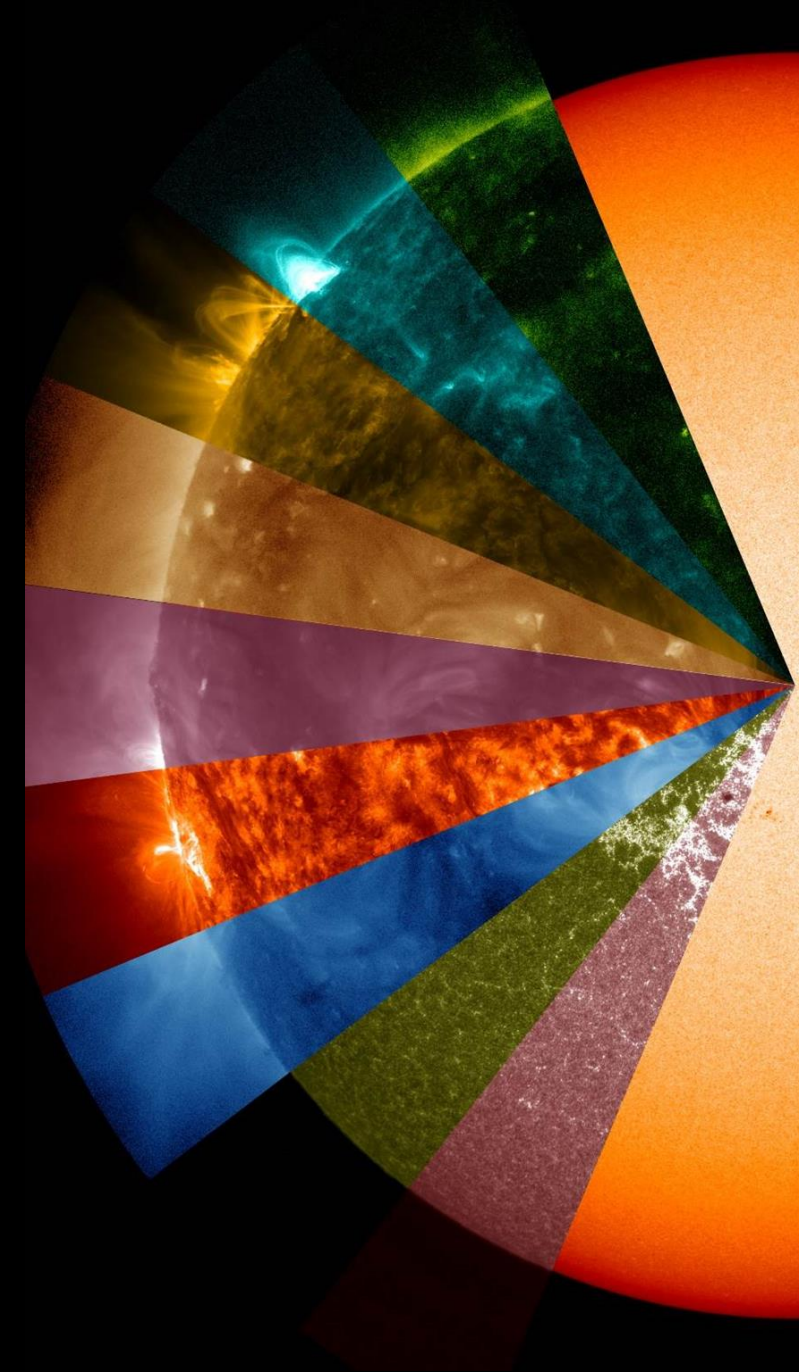
- ✈ For the September GLE/radiation storm, operations were affected, but to what degree should they have been? Peak of the event on the order of the ICAO Moderate event threshold

✈ GNSS

- ✈ Augmentation systems generally monitor performance and shut down accordingly, but knowing that ahead of time may lead to different flight planning

✈ Communications

- ✈ For the same September event, reports of loss of communication with a US cargo aircraft for ~90 minutes between ATC in French Guyana and New York
- ✈ ATC in Miami had issues with lost communications for aircraft flying oceanic routes around Hurricane Irma



Interpreting Products – Exposure Example

A common substance example:

Median Lethal Dose (LD_{50})

- 192 milligrams per kilogram in rats
- (Estimated) ~150-200 milligrams per kilogram in humans

Holmgren, et al. 2004

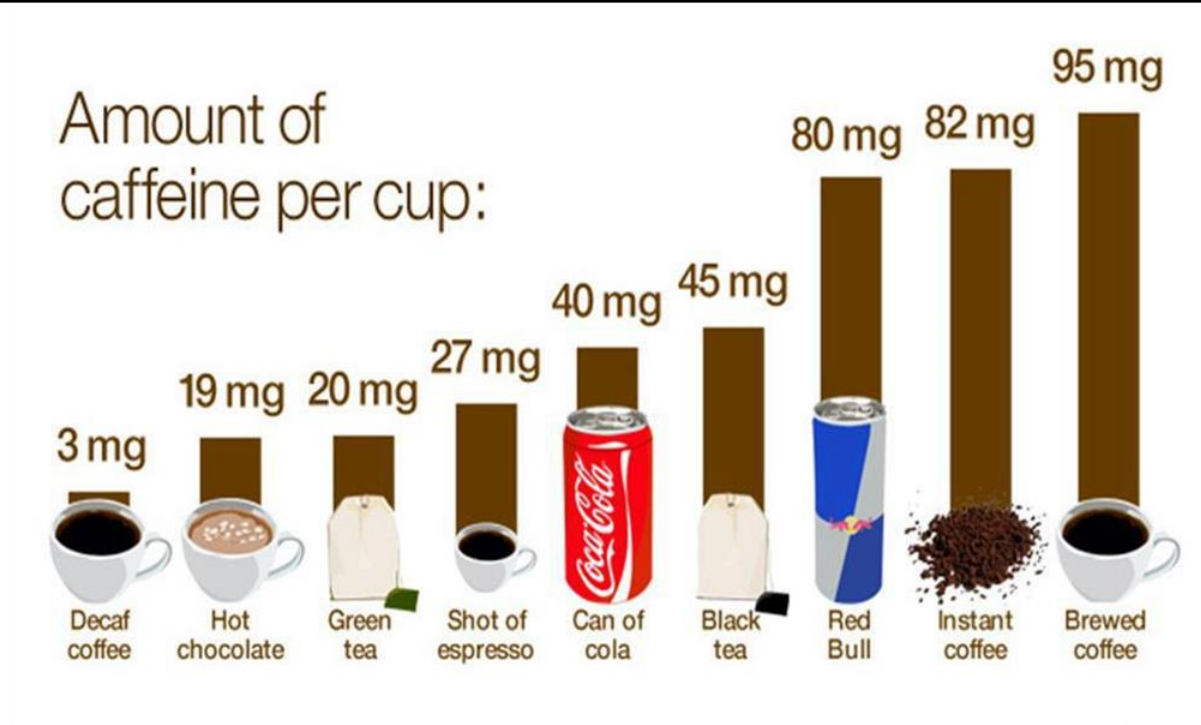
Interpreting Products – Exposure Example

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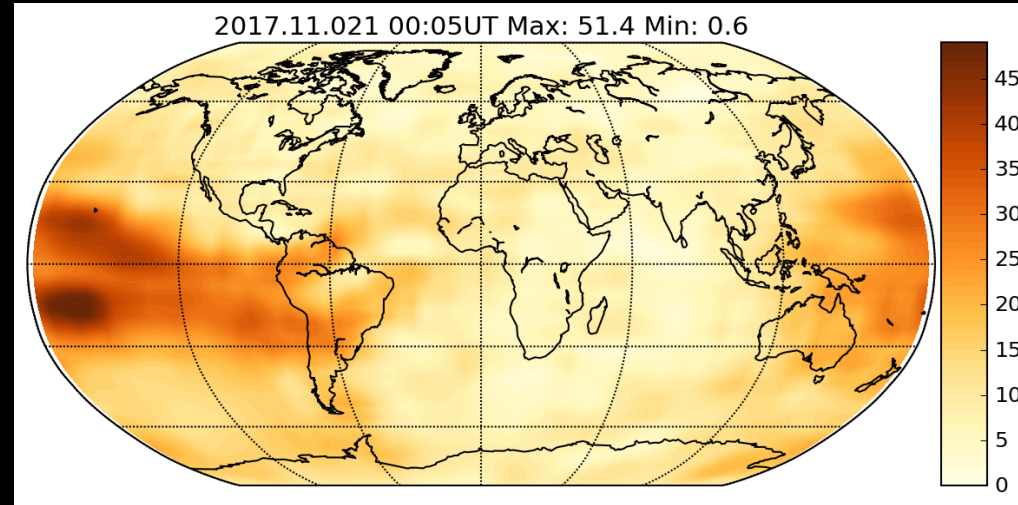
Holmgren, et al. 2004



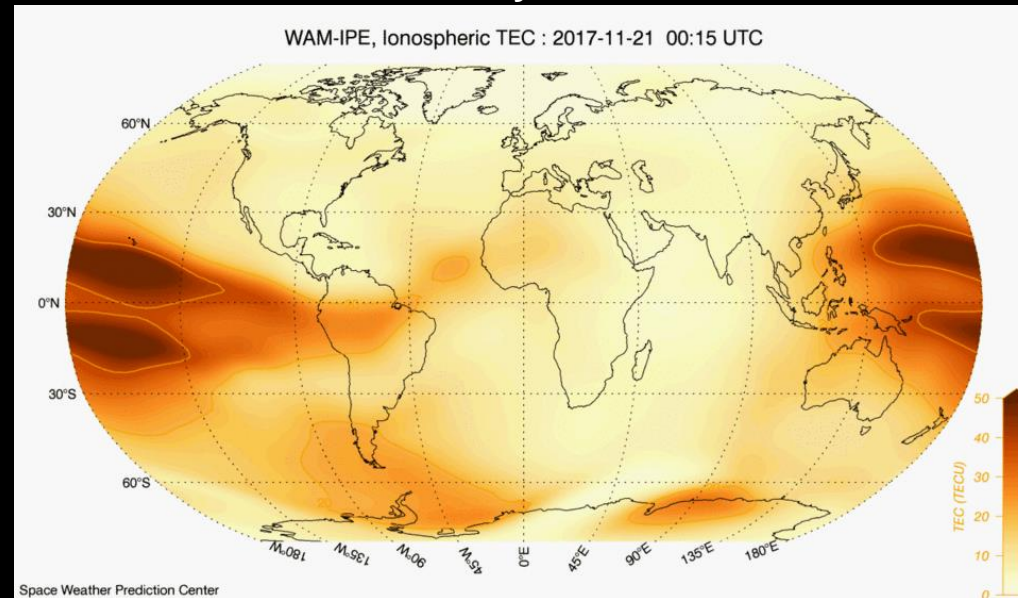
<http://www.mountainstrongdenver.com/caffeine-and-sports-performance/>

Modeling Progress....

GloTEC TEC: Data Driven Assimilative Model



WAM-IPE TEC Physics-based Model



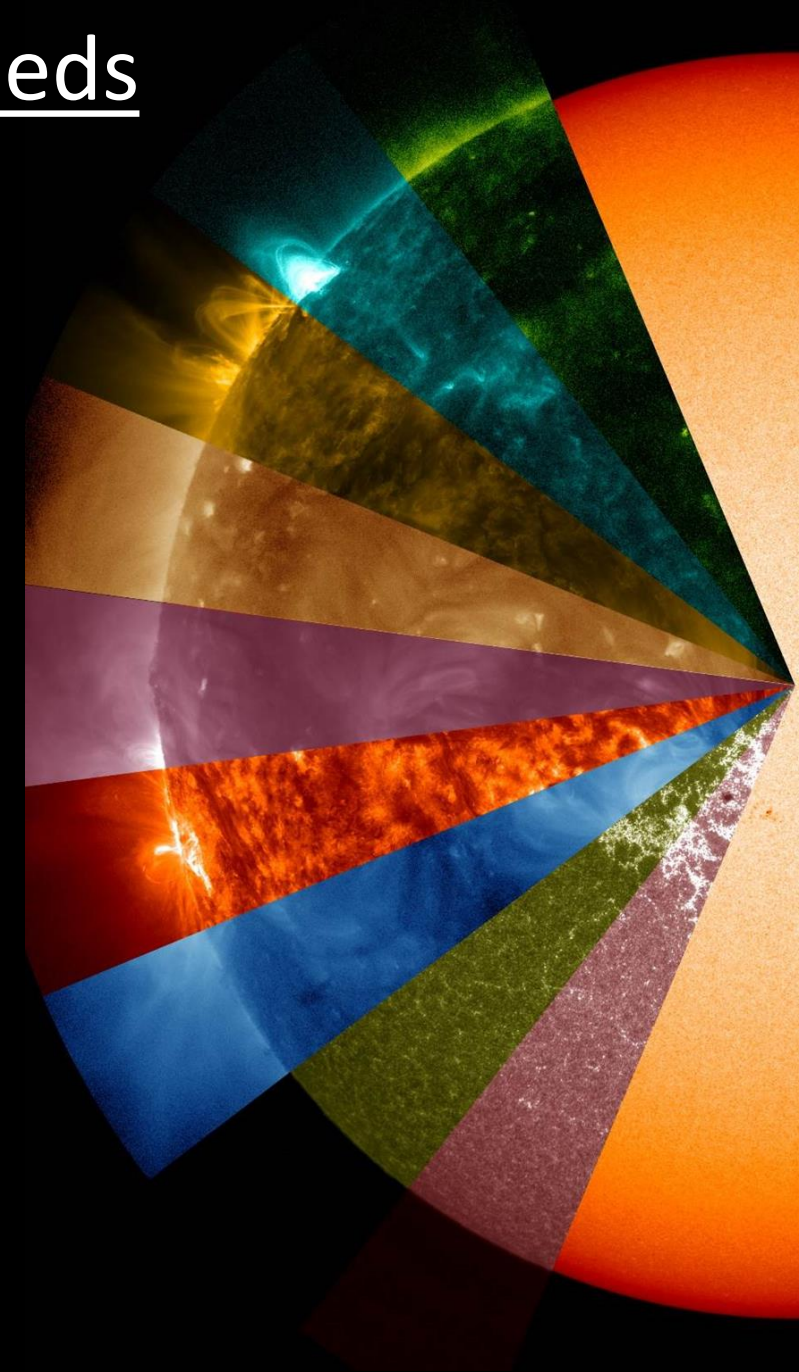
Evolution of Services and Needs

✈️ **Radiation**

- ✈️ As aircraft fly farther and longer, exposures will increase
- ✈️ In situ observations will help with model validation, data assimilation, and operational decision making

✈️ **GNSS**

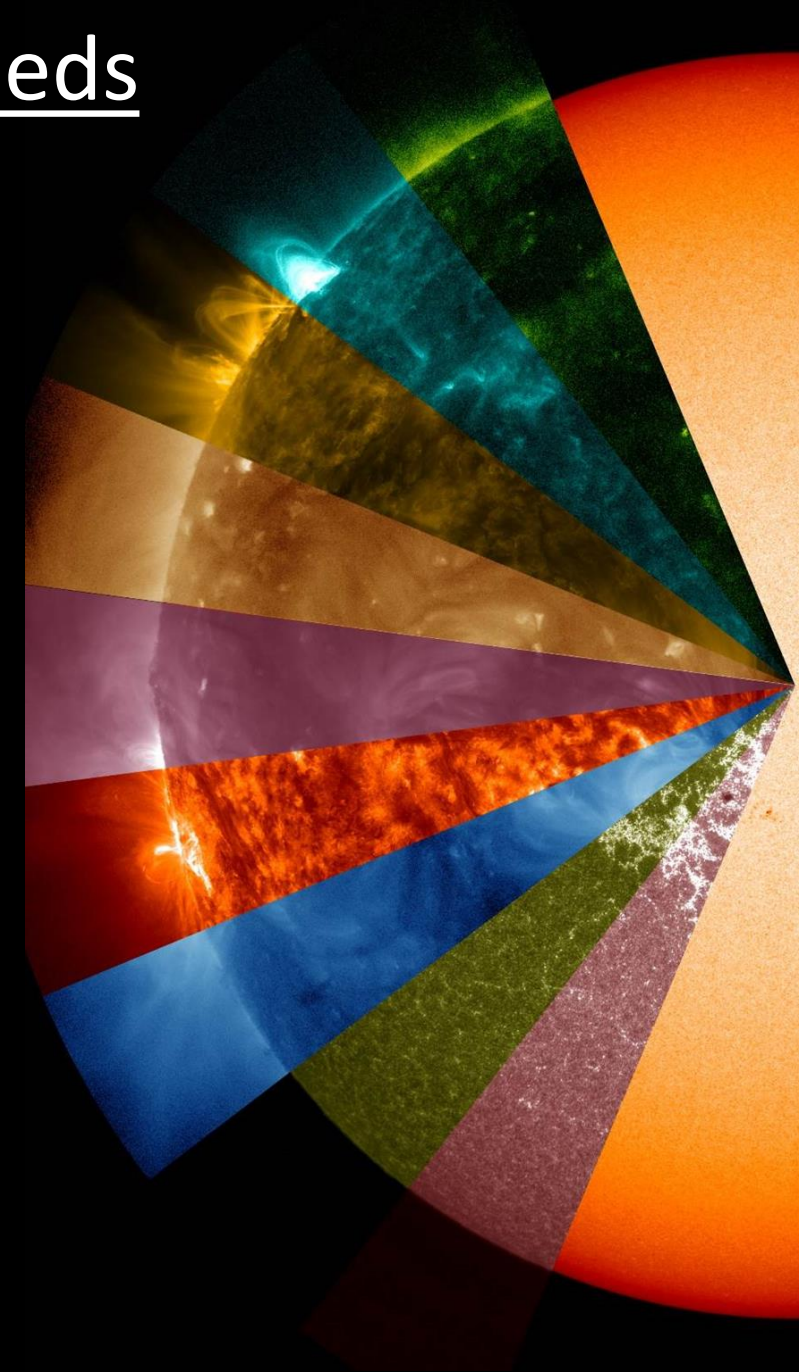
- ✈️ Additional GNSS frequency adoption can largely eliminate ionospherically-induced position errors
- ✈️ Engineers with time and money can engineer around some challenges, but some will remain
- ✈️ Scintillation will likely remain the primary issue



Evolution of Services and Needs

✈ **Communications**

- ✈ Application of HF is changing. HF datalink use still increasing...
- ✈ Geosynchronous and LEO-based satellite communication
- ✈ Short-term forecasting gains are coming
- ✈ However, no paradigm shifts in multi-day forecasting are likely in the foreseeable future
- ✈ **Given the chaotic, eruptive nature of the phenomena, space weather may never be like weather, but we can try...**

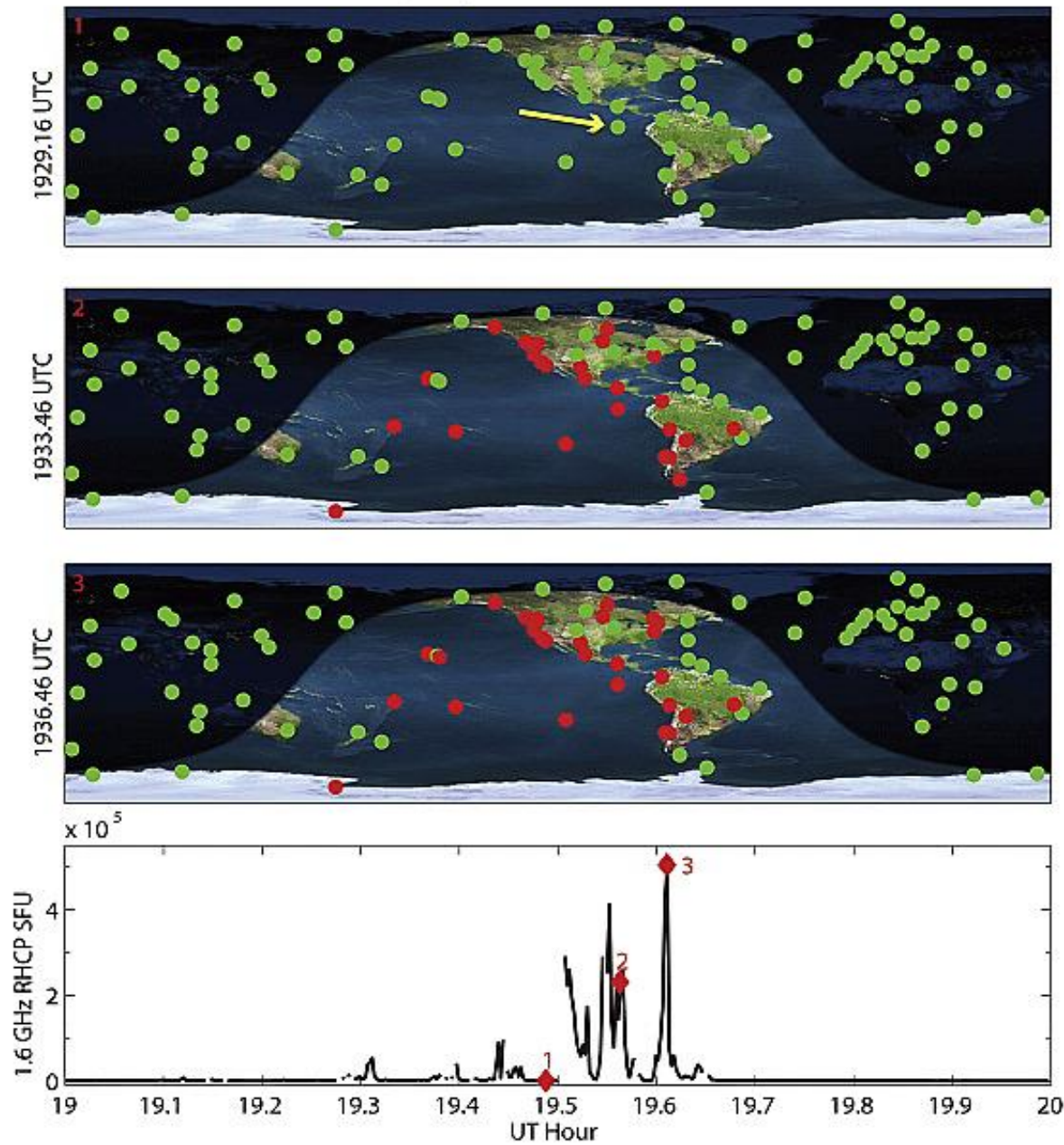


NOAA Space Weather Prediction Center

Boulder, Colorado

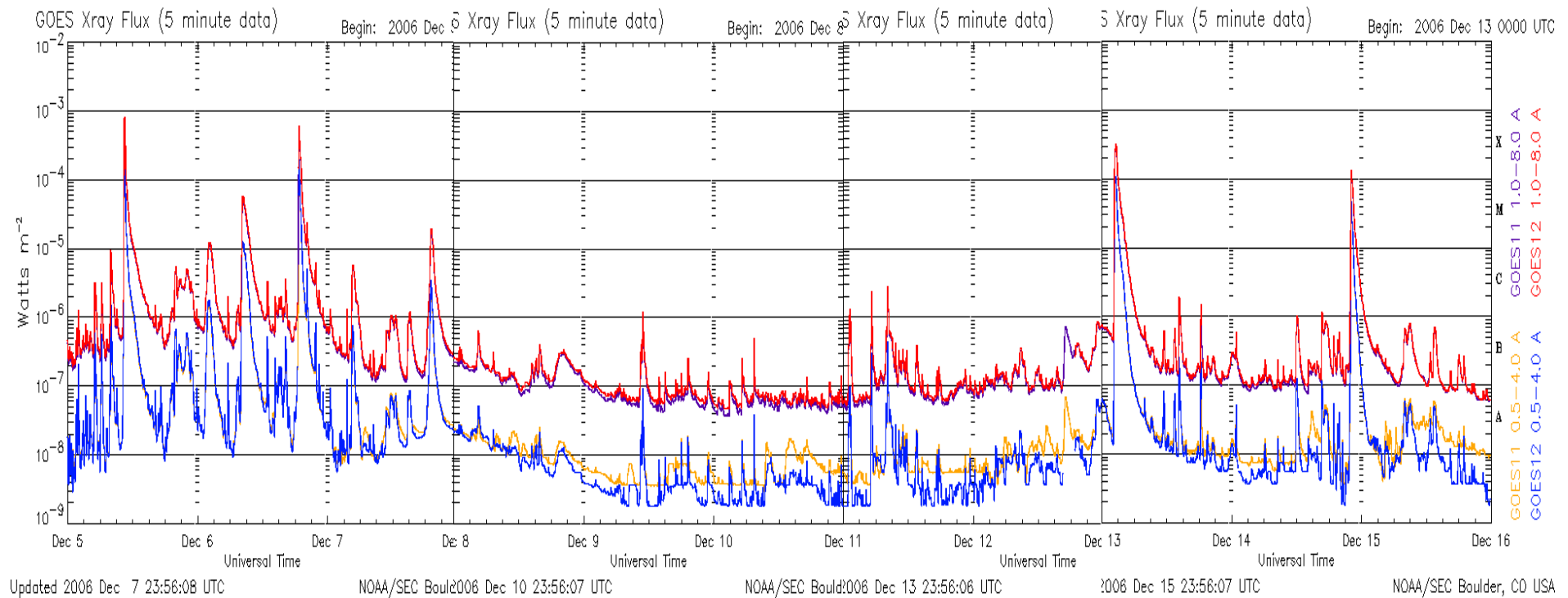


www.spaceweather.gov



Cerruti, A. P., P. M. Kintner Jr., D. E. Gary, A. J. Mannucci, R. F. Meyer, P. Doherty, and A. J. Coster (2008), *Effect of intense December 2006 solar radio bursts on GPS receivers*, *Space Weather*, 6, S10D07, doi:[10.1029/2007SW000375](https://doi.org/10.1029/2007SW000375).

December 2006 – 1415MHz Radio Bursts



December 2006 – 1415MHz Radio Bursts

Cerruti et al. (2008)

