METEOROLOGY PANEL

GANIS2 Meteorology Session

Space Weather Services for Aviation – An Emerging Capability

Presented by Bob Rutledge
NOAA Space Weather Prediction Center

Outline

- Space Weather Primer/Sequence of Events
- The Need Space Weather Impacts on Aviation
- Services Within ICAO
  - Radiation
  - Communications
  - Satellite-based Positioning
- Evolution of Services and Needs

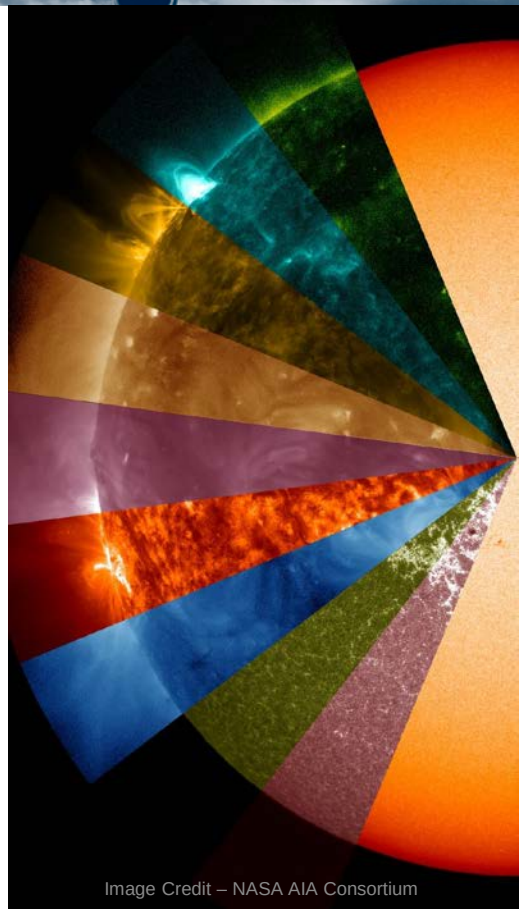
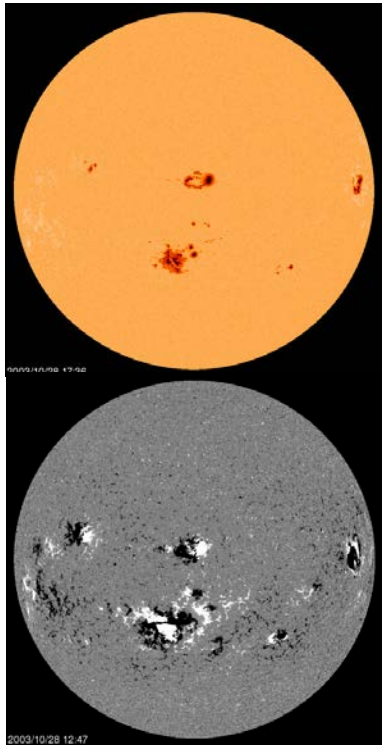
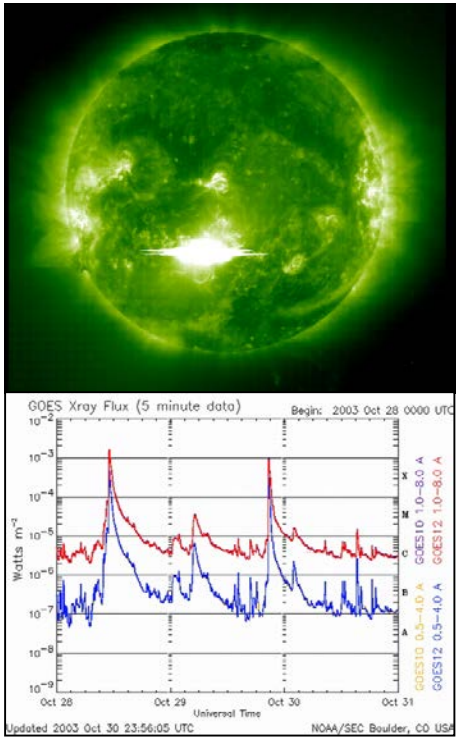


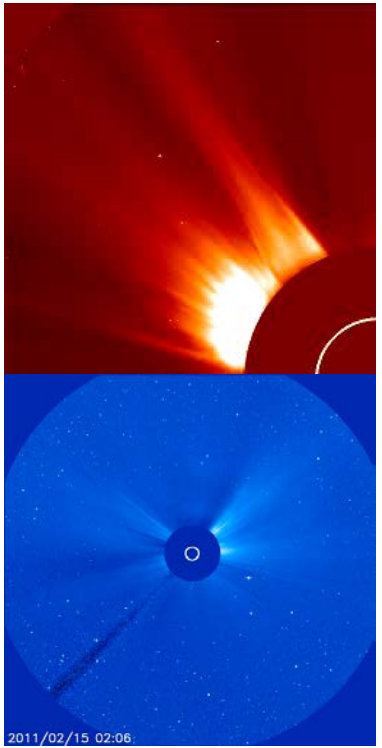
Image Credit – NASA AIA Consortium



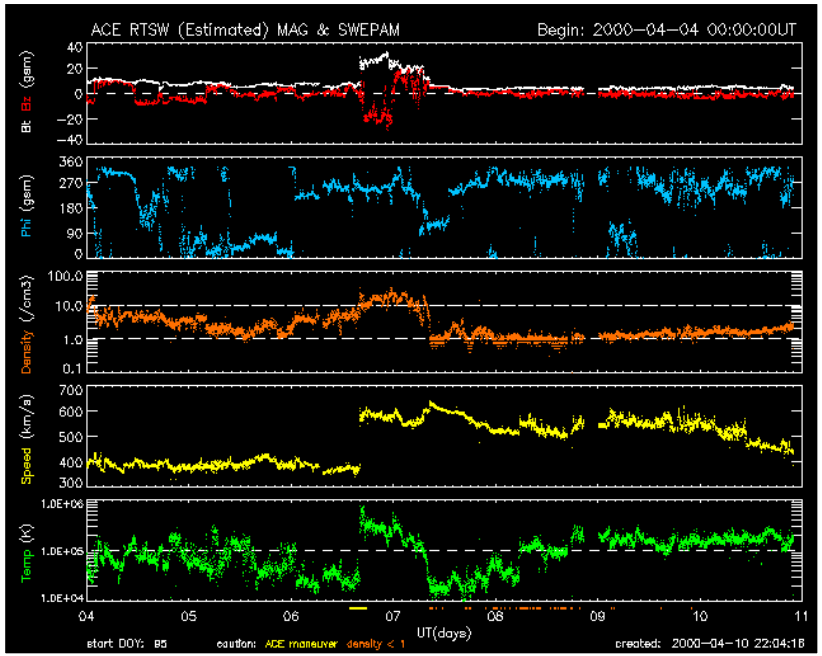
Conditions are Favorable for Activity

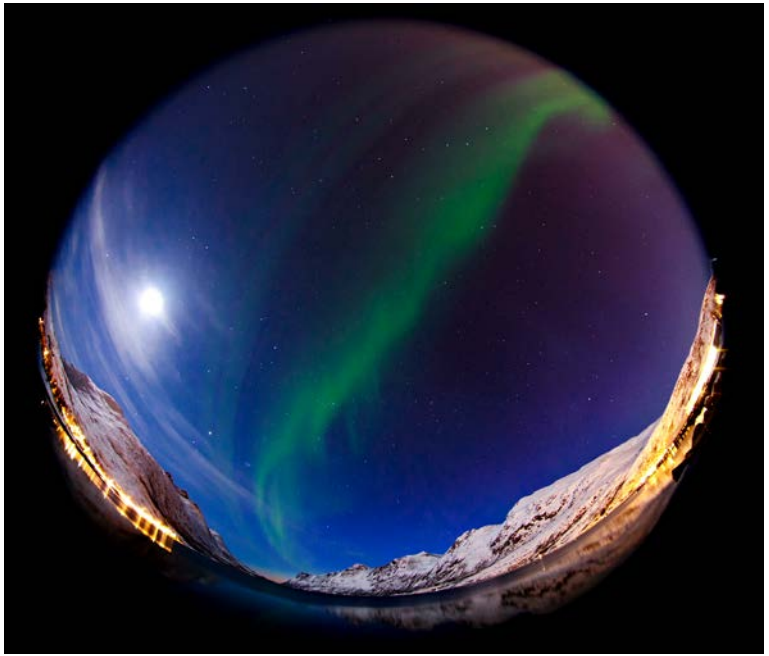


Event Occurs



Coronal Observations

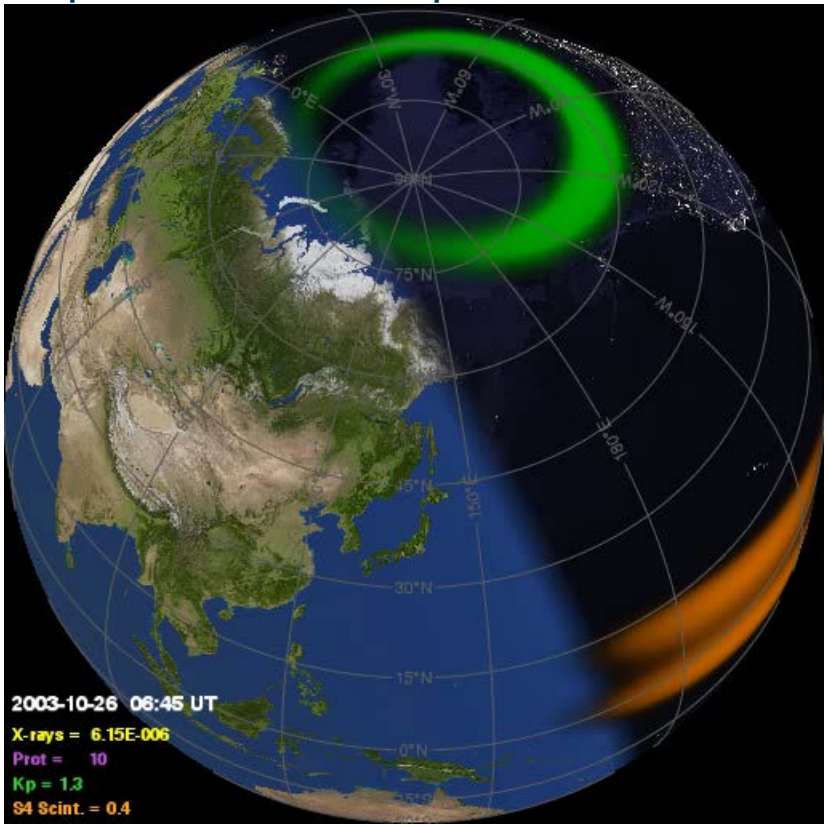




In situ Solar Wind Observations

Geomagnetic Storm Occurs

Space Weather Impacts on Aviation



Services Within ICAO

- Services proposed for inclusion in Amendment 78 to Annex 3
  - HF Communications (propagation, absorption) — HF COM
  - Communications via satellite (propagation, absorption) — SATCOM
  - GNSS-based navigation and surveillance (degradation) — GNSS
  - Radiation at flight levels (increased exposure) — RADIATION
- Event-driven advisories for Moderate or Severe effects
- Applicability in November 2018
- Service model discussion still maturing

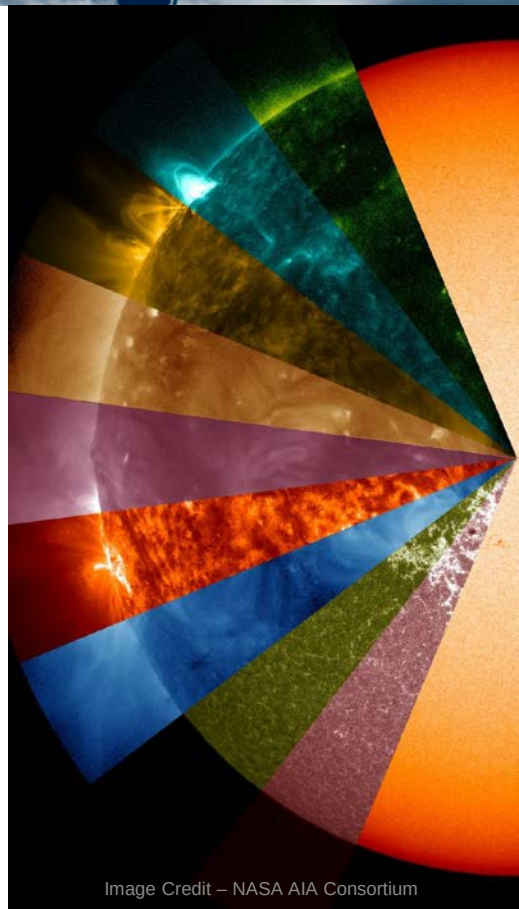


Image Credit – NASA AIA Consortium

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
	20161108/0100Z HNH HSH E18000 – W18000 ABV FL350
	20121108/0700Z HNH HSH E18000 – W18000 ABV FL350
	20161108/1300Z HNH HSH E18000 – W18000 ABV FL350
	20161108/1900Z HNH HSH E18000 – W18000 ABV FL350
	20161109/0100Z NO SWX EXP
	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
	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

Services Within ICAO - Timeline

Schedule for Establishing Space Weather Information Capability

Start Date	End Date	Description	Responsibility
May 2017	June 2017	Issue State Letter requesting interest in providing the space weather information service.	ICAO
May 2017 September 201/	June 2017 October 201/	a) Request WMO assistance to evaluate candidate Provider States through site assessment visits and audits (without list of candidates States); and; b) Provide WMO with a list of candidates States.	ICAO
June 2017	September 201/	Respond to State Letter indicating ability to meet criteria for space weather information providers, including funding for site assessment visit and audit (to be conducted by WMO).	Candidate Provider States
October 2017	February 2018	Conduct site assessment visits and audits of candidate Provider States for space weather information capability.	WMO
March 2018	April 2018	Complete report to ICAO on candidate Provider States for space weather information capability.	WMO
April 2018	April 2018	Review of WMO audits report and recommend optimal number of space weather information providers.	METP
May 2018	June 2018	Review METP recommendations and provide proposals for designation of providers of space weather information for Council consideration.	ICAO ANC
June 2018	July 2018	Designate provider(s) of space weather information capability.	ICAO Council
July 2018	November 2018	Commence production and dissemination of space weather information.	Space Weather Provider(s)

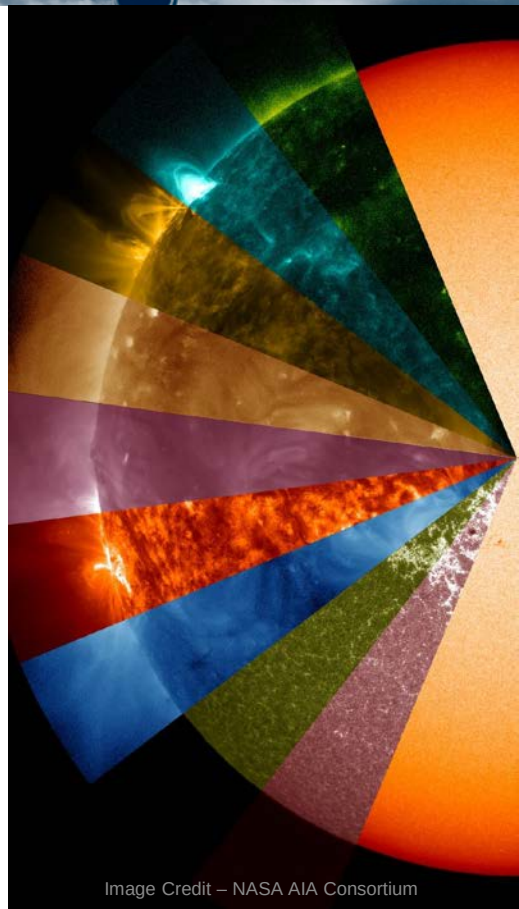


Image Credit – NASA AIA Consortium

Radiation Information – Understanding Exposure

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

Radiation Information – Understanding Exposure

A common substance example: **Caffeine**

Median Lethal Dose (LD_{50})

- 192 milligrams per kilogram in rats
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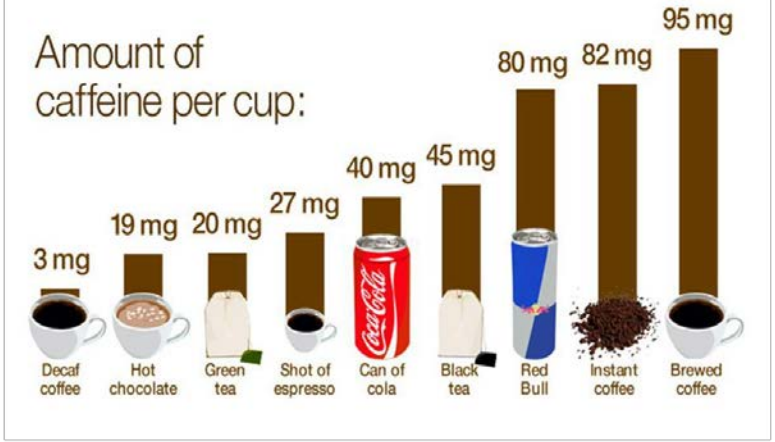
Holmgren, et al. 2004



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

GNSS and Communications

- **GNSS**
  - Nowcasting fairly mature where observational data is available
  - Skill improving in short-term forecasting (10’s of minutes)
  - Longer range forecasts remain challenging, both pre-eruption and when awaiting commencement of a storm
- **Communications**
  - High Frequency (HF) blackout can be nowcast and forecast probabilistically
  - Limited skill in satellite communications, both in nowcast and forecast phases
  - Longer range forecasts remain challenging, both pre-eruption and when awaiting commencement of a storm as well

Ionospheric Service Challenges – An Example

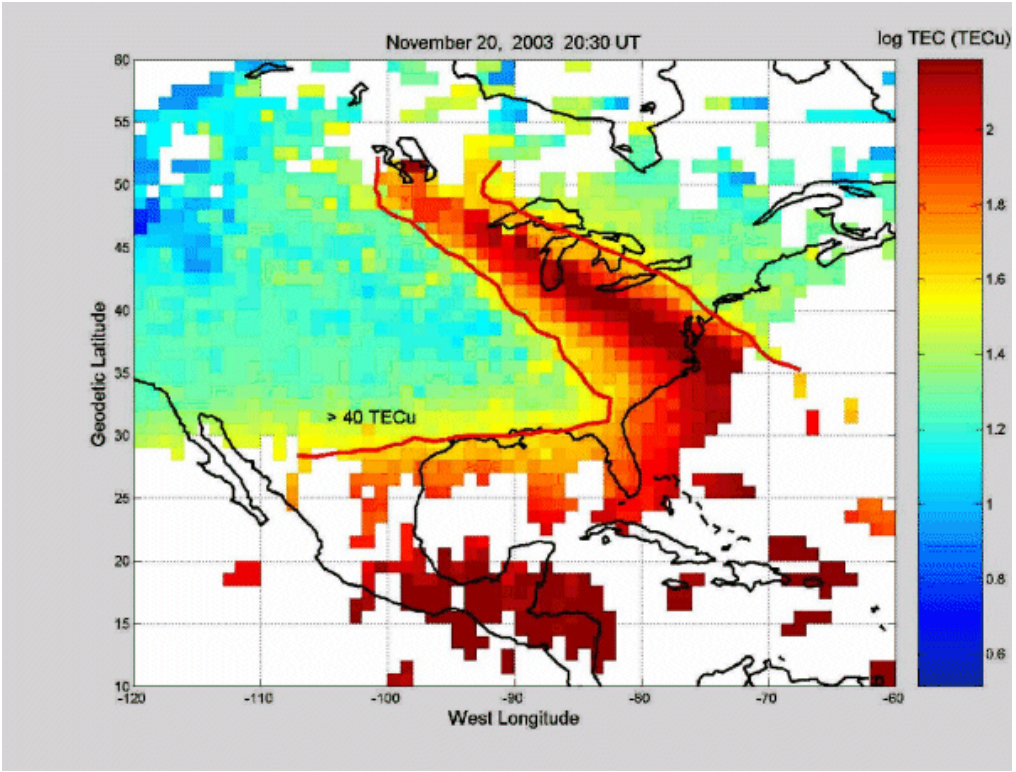


Image: Anthea Coster/John Foster/MIT

Adding Value…

- **Radiation**
  - In September, 2017 - “The solar storm we saw on September 10th was very strong… In a storm of this magnitude we will encounter increased radiation levels domestically”
  - Operations were affected, but should they have been? For a flight over the pole, timed to see all of the event, exposure *may* have been double the daily background
- **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 period, ATC in Miami had issues with lost communications for aircraft flying oceanic routes around Hurricane Irma
  - Lack of awareness caused confusion and exacerbated the situation

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

- **Communications**
  - Application of HF is changing. HF datalink use still increasing…
  - Geosynchronous and LEO-based satellite communications evolving

- Short-term forecasting gains are coming in the 3-5 year timeframe
- However, no paradigm shifts in longer-term 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…**

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Thank You

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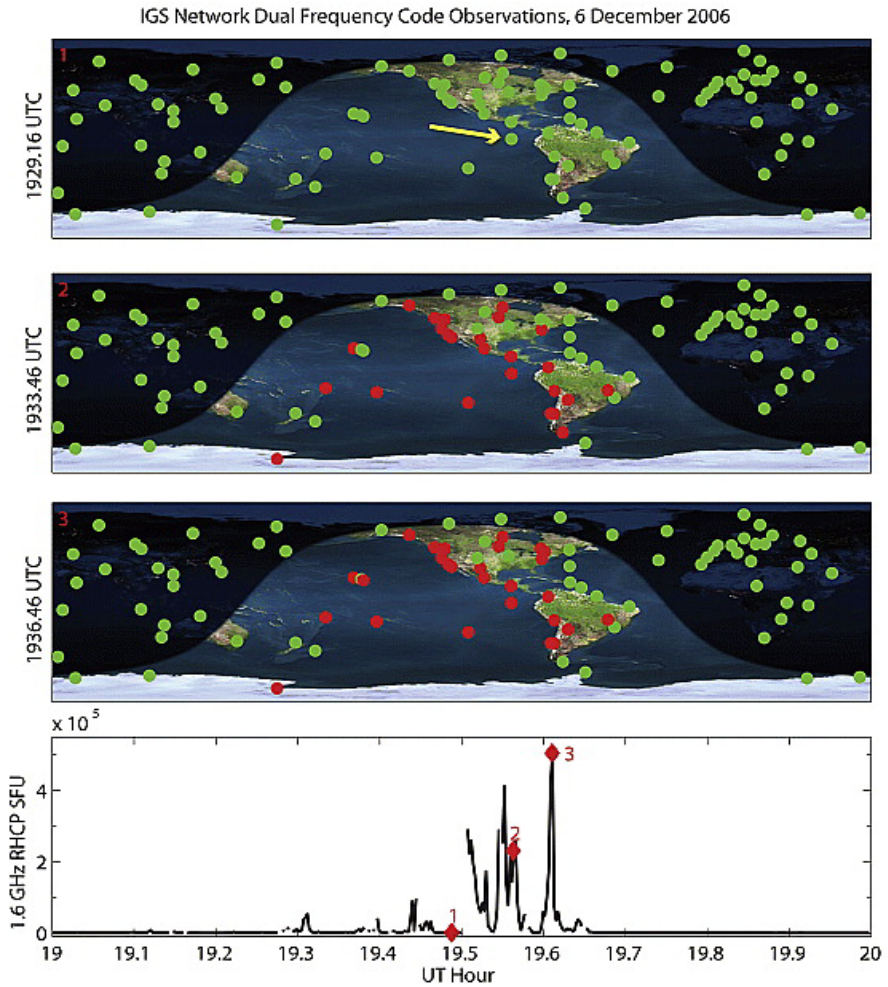
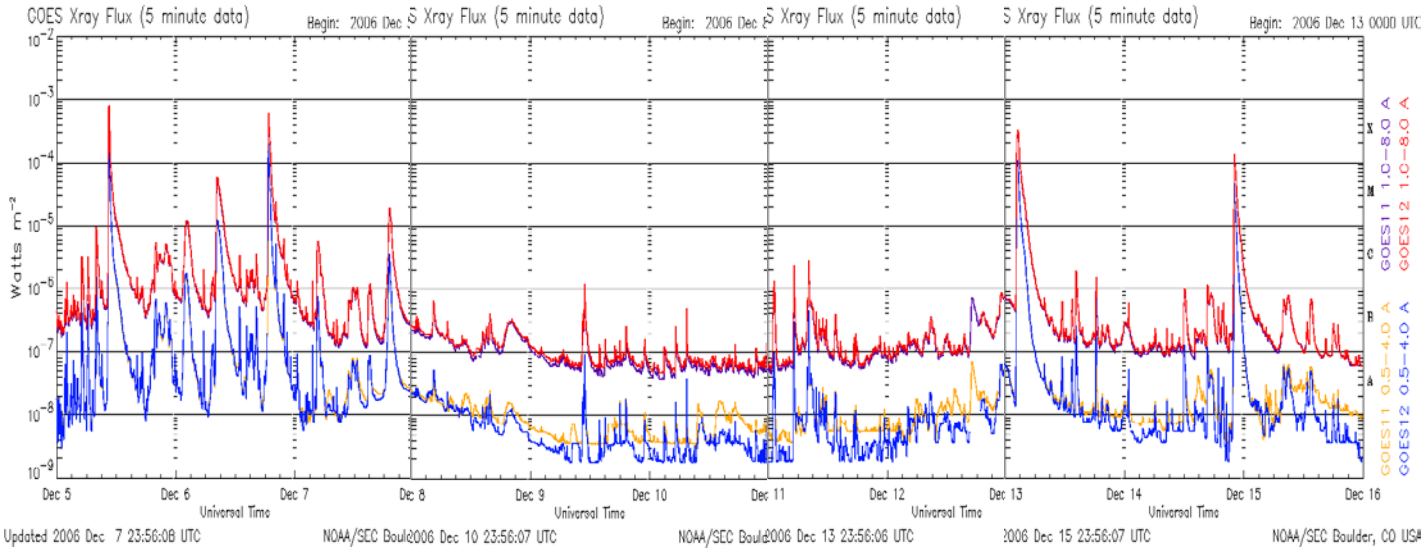


Cerruti, A. P., P. M. Kintner Jr., D. E. Gary, A. J. Mannucci, R. F. Meyer, P. Doherty, and A. J. Coster (2008), Effect of intense December 2006 solar radio bursts on GPS receivers, Space Weather, 6, S10D07, doi:10.1029/2007SW000375.

December 2006 – 1415MHz Radio Bursts



December 2006 – 1415MHz Radio Bursts