Space Weather affects aviation radiation environment, GPS navigation, and HF radio communication – solution options

W. Kent Tobiska

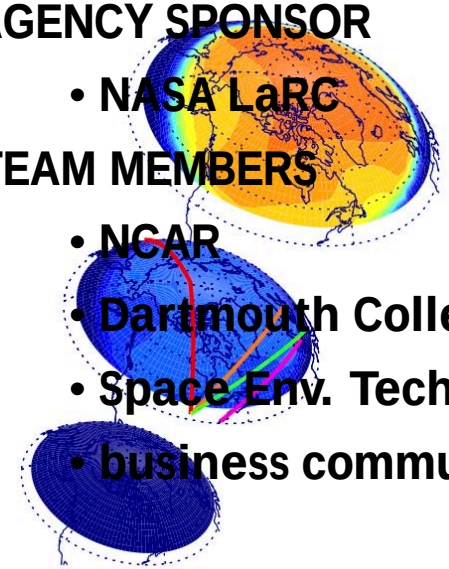
Aviation Challenge 1: Specify radiation environment and air crew dosimetry

AGENCY SPONSOR

- NASA LaRC

TEAM MEMBERS

- NCAR
- Dartmouth College
- Space Env. Tech.
- business community



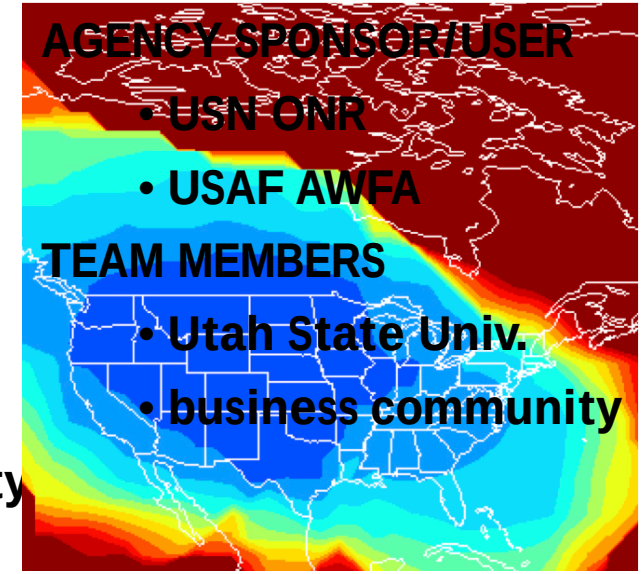
Aviation Challenge 2: Reduce GPS navigation uncertainty and increase WAAS availability

AGENCY SPONSOR/USER

- USN ONR
- USAF AWFA

TEAM MEMBERS

- Utah State Univ.
- business community



Aviation Challenge 3: Improve polar and transoceanic HF radio communication coverage

AGENCY SPONSOR/USER

- USN ONR
- USAF AWFA

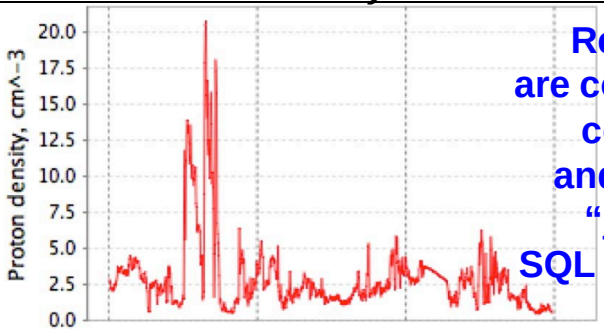
TEAM MEMBERS

- Utah State Univ.
- business community

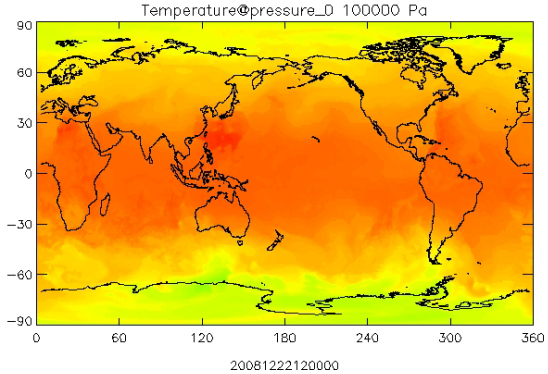
Space Weather affects aviation radiation

Aviation Challenge 1: Specify aviation dosimetry

- Air crew members and frequent air travelers sustain radiation dose rates that are higher than U.S. radiation workers
- Accurate and real-time radiation dose and dose rates are needed from persistent Galactic Cosmic Ray (GCR) and intermittent Solar Energetic Particle (SEP) sources
- Radiation calculations are dependent on air mass, neutron monitor counts, magnetosphere cutoff rigidity, and solar energetic particle fluxes
- ***Real-time radiation specification requires modeling runs coordinated with asynchronous data streams***

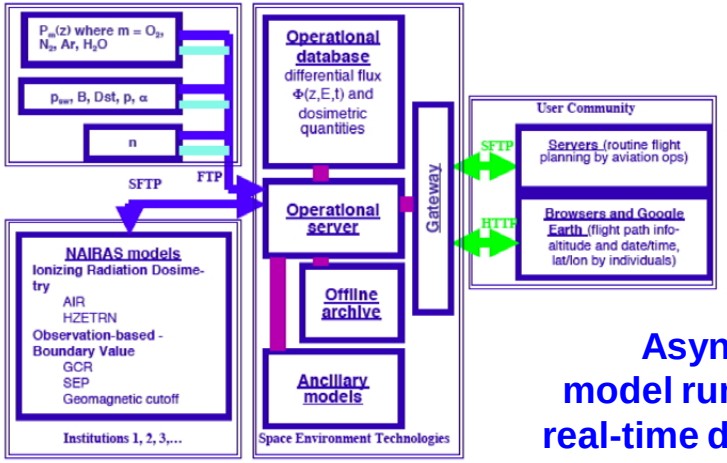


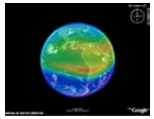
Real-time data are collected by a central server and hosted in a "just-in-time" SQL database for model use



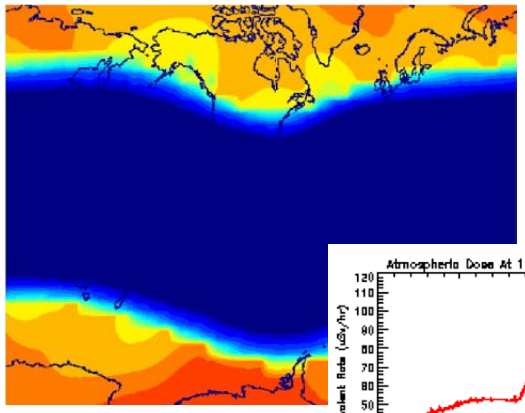
Aviation Solution 1: Produce real-time dose rates 0-15 km

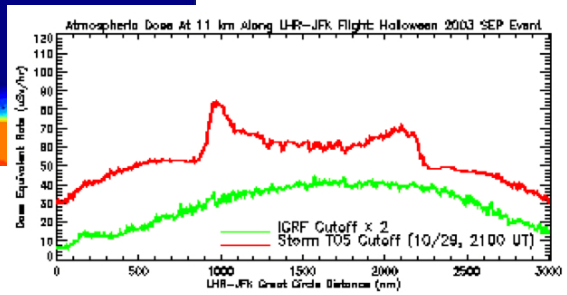
- Models will be run at geographically-distributed institutions and data collected from world-wide sources
- ***A distributed network is robust implementation solution***





Asynchronous model runs use the real-time data linked in a distributed network to provide global dose info as well as specific flight information

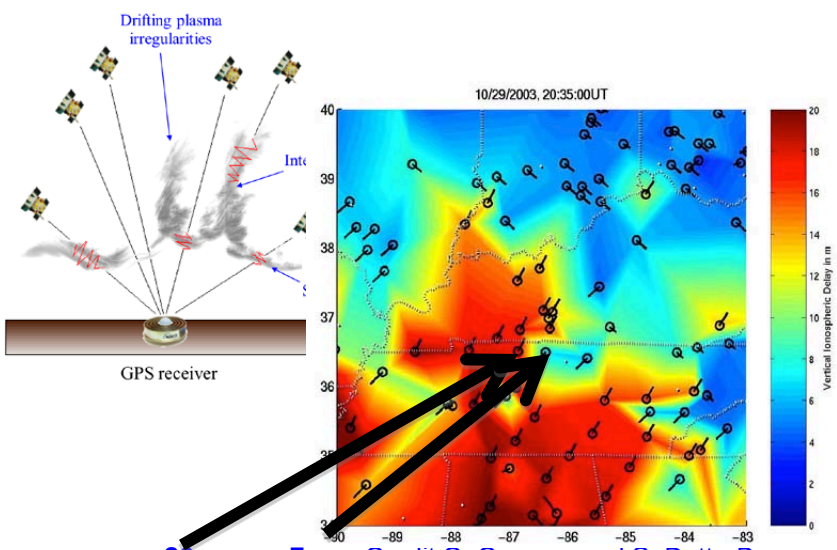




Space Weather affects aviation GPS uncertainty & WAAS

Aviation Challenge 2: Reduce GPS uncertainty

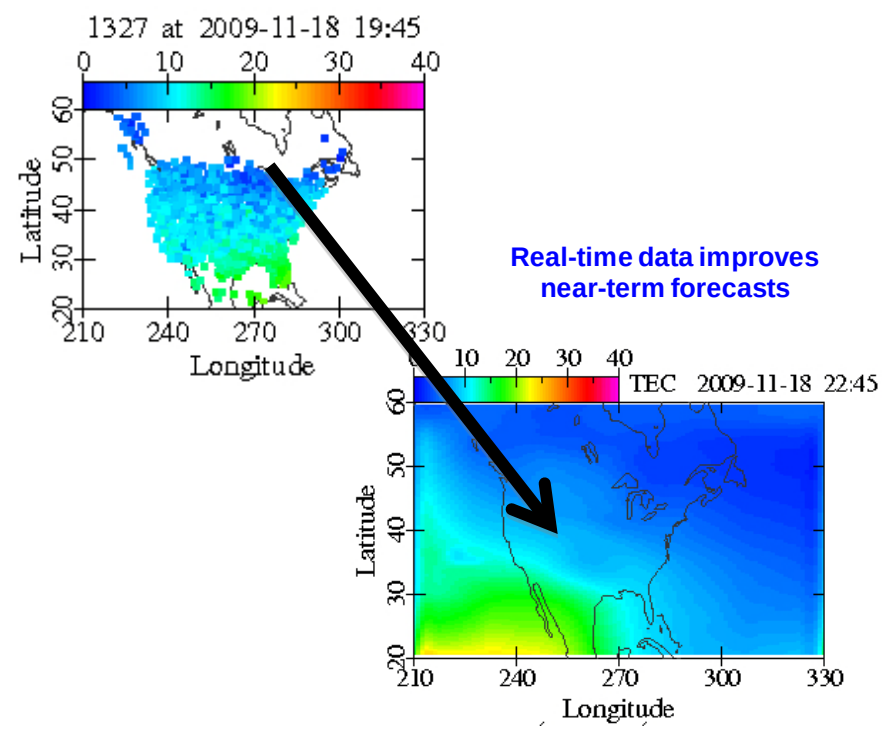
- GPS navigation: increased aviation efficiency, safety, and operating cost reduction
- GPS alone does not meet aviation accuracy and reliability requirements
- GPS uncertainty: ~15m due to receiver clock error, multipath, orbital error, number of satellites visible, satellite geometry, as well as tropospheric and ionospheric signal delay
- Ionospheric delay is significant *AND* variable from TEC changes due to solar, geomagnetic, scintillation activity
- WAAS provides corrections to ~3m but has sharp gradients, e.g., see vertical ionospheric delay (m) on Oct 29 2003; ***must reduce storm gradient uncertainty***



Credit C. Carrano and S. Datta-Barua

Aviation Solution 2: Finer spatial GPS specification

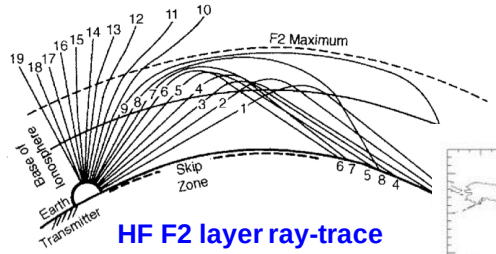
- WAAS uses 38 reference stations and 3 master stations with a dated ionosphere model – cannot reach few km resolution with this level of accuracy
  - Data assimilation using CORS (~400 receivers) can be applied to WAAS model to improve spatial and temporal characterization of gradients, thus improving the percent time of WAAS availability
- Quality real-time high latitude data needs to be ingested with improved electrodynamics models for better higher latitude ionosphere specification



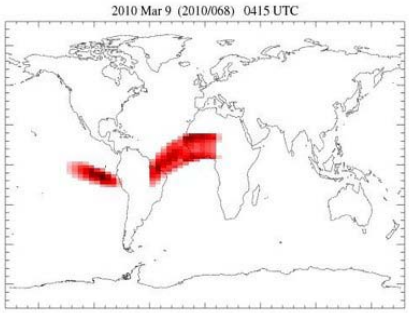
Space Weather affects aviation HF radio communication

Aviation Challenge 3: Improve polar and transoceanic HF radio communication

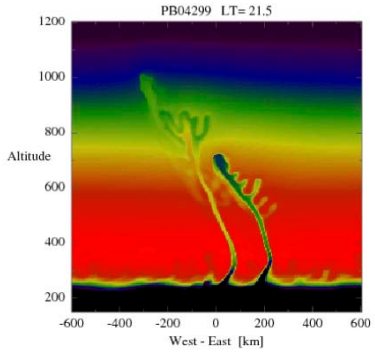
- HF radio communication is a mainstay of aviation, especially on polar and transoceanic routes
- During solar and geomagnetic activity, scintillation, radio links are severely degraded or lost
- Ray-trace paths through highly variable and non-homogenous plasma structures are calculated to obtain accurate comm links at HF frequencies
- ***Must improve local plasma characterization to get accurate radio propagation paths***



HF F2 layer ray-trace



UHF scintillation
Credit: J. Retterer



F2 layer (red) and plasma bubbles

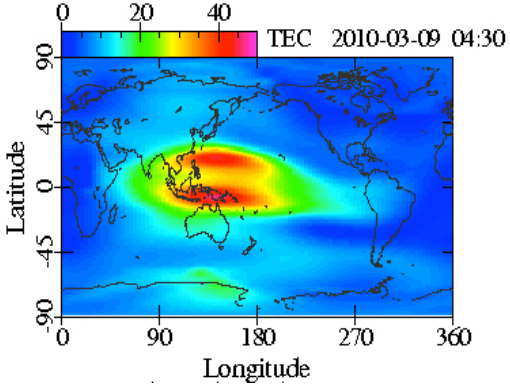
Credit: O. de La Beaujardiere

Aviation Solution 3: Need more data & better forecasting

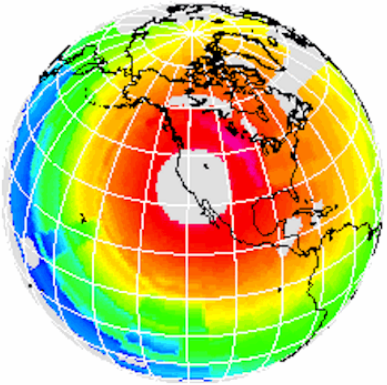
- Improved data sources (ionosonde, UV, top-side, satellite slant TEC tomography) not only improve current epoch specification but aid in near-term forecasts out to 3 hours
- Ionosphere forecasting for the time frames below will improve the percentage of time for successful HF communications and for reduced GPS uncertainty

SpWx event	Fcast hours	Current ops	Serv. prep	schedule	plan
Flare, storm evolution	3	X			
Flare probability, storm evolution	12	X	X		
Flare, storm probability	24		X	X	
Flare, storm probability	72			X	X

GAIM Gauss Markov TEC on 09 Mar 2010 04 30



15 MHz HF signal strength for Los Angeles 11 Mar 2010 23 04



Agency assets applied to operational solutions

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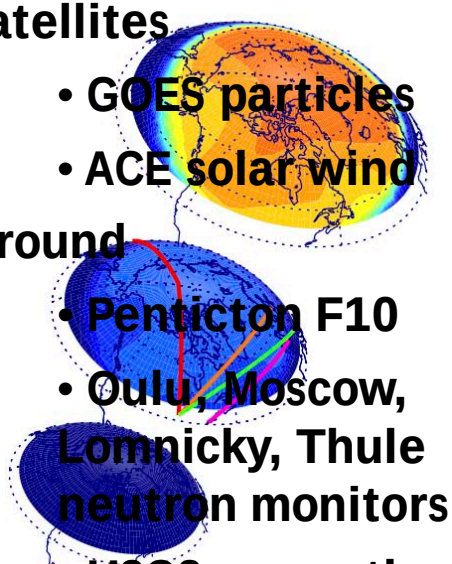


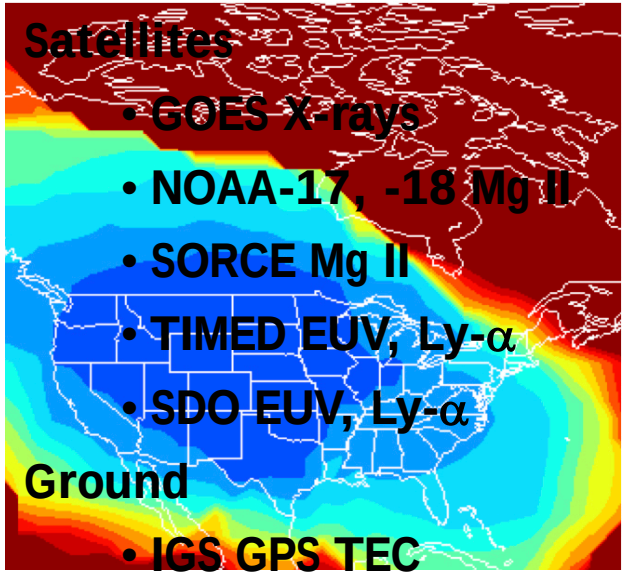
Satellites

- GOES particles
- ACE solar wind

Ground

- Penticton F10
- Oulu, Moscow, Lomnicky, Thule neutron monitors
- USGS magnetic observatories (NOAA/USAF) ap
- Kyoto Univ. Dst
- NCEP/NWS grib T, p

Aviation Solution 2: Finer spatial GPS specification



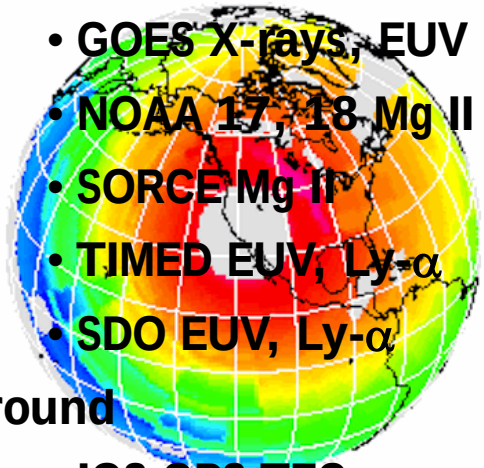
Satellites

- GOES X-rays
- NOAA-17, -18 Mg II
- SORCE Mg II
- TIMED EUV, Ly-α
- SDO EUV, Ly-α

Ground

- IGS GPS TEC
- CORS GPS TEC
- ionosondes
- Penticton F10
- USGS magnetic observatories (NOAA/USAF) ap

Aviation Solution 3: More data & better forecasting



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- GOES X-rays, EUV
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