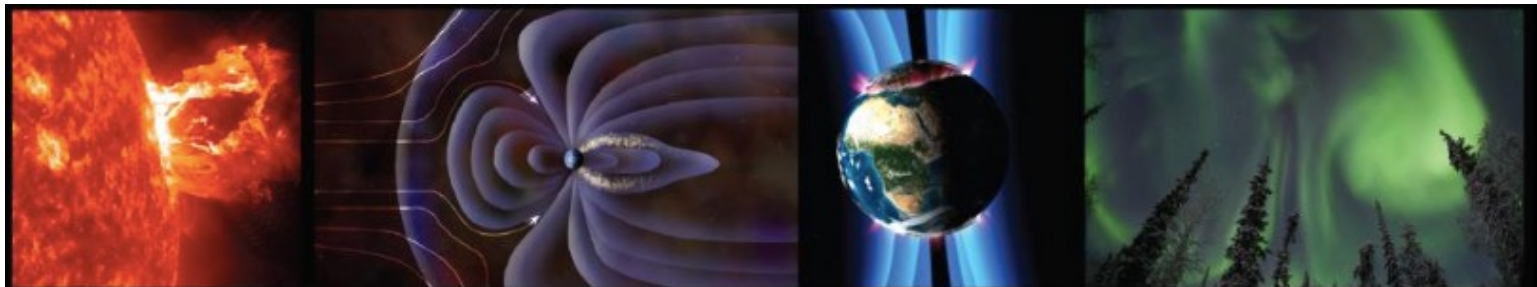


Space Weather Roundtable: *GNSS Ground based Networks*

Anthea Coster, MIT Haystack Observatory
Michael Hartinger, UCLA

Space Weather Applications
Real-time and Post-Analysis Networks
Networks in need of operational support

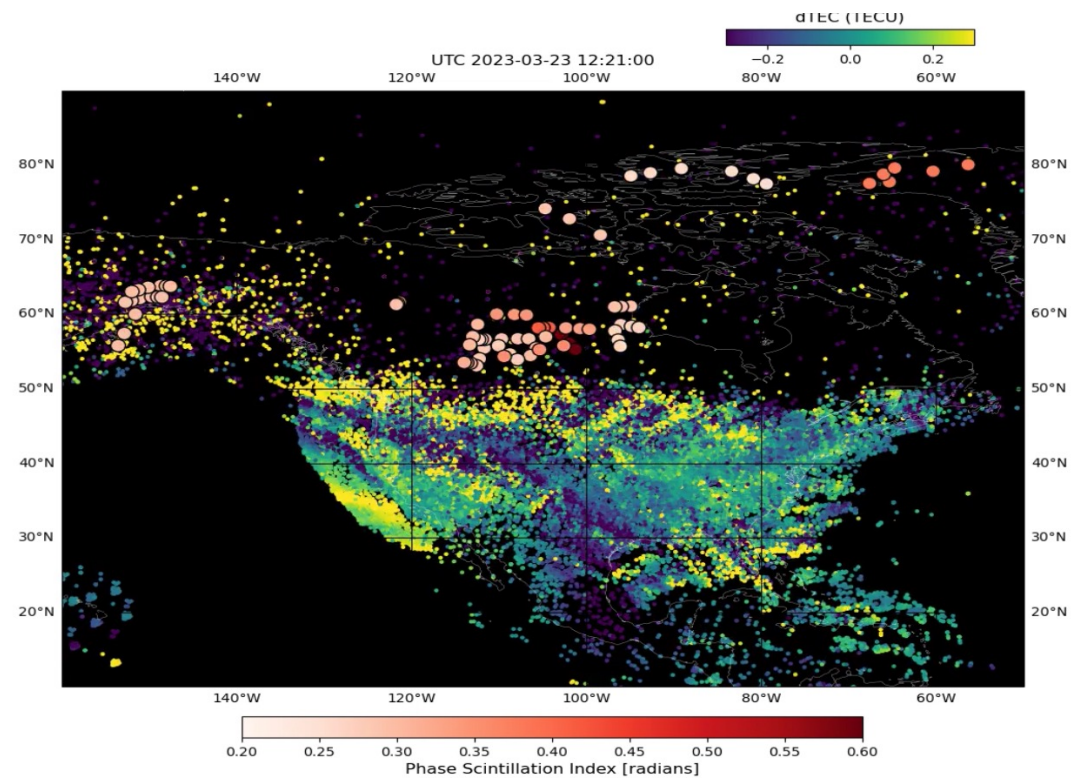


Measuring Space Weather with GNSS

Differential TEC overlaid with Scintillation Parameters

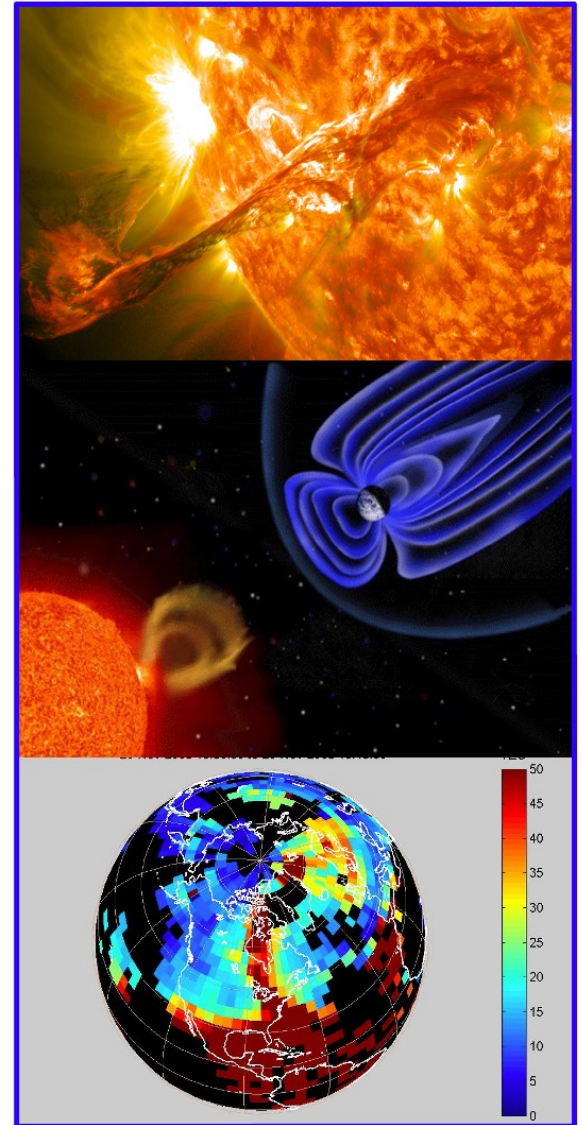
March 23, 2023, Kp=8-

Distributed networks of sensors yield global physics unattainable with single-point measurements

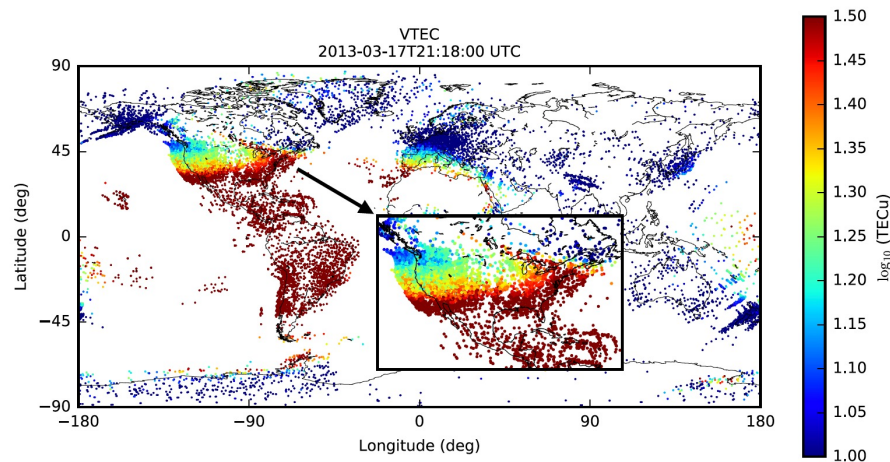


Strengths of Ground-Based Systems

- Cost-effective for space weather monitoring
- Provide direct measure of the parameters relevant to effects on critical infrastructure
- Ground-based facilities needed to calibrate space-based missions and validate space weather models



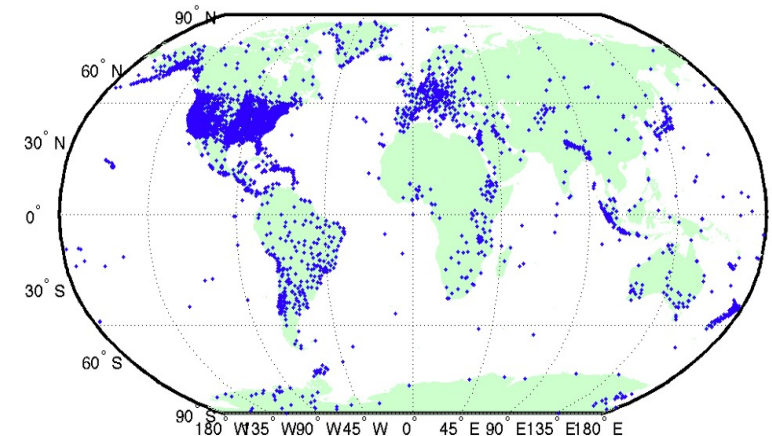
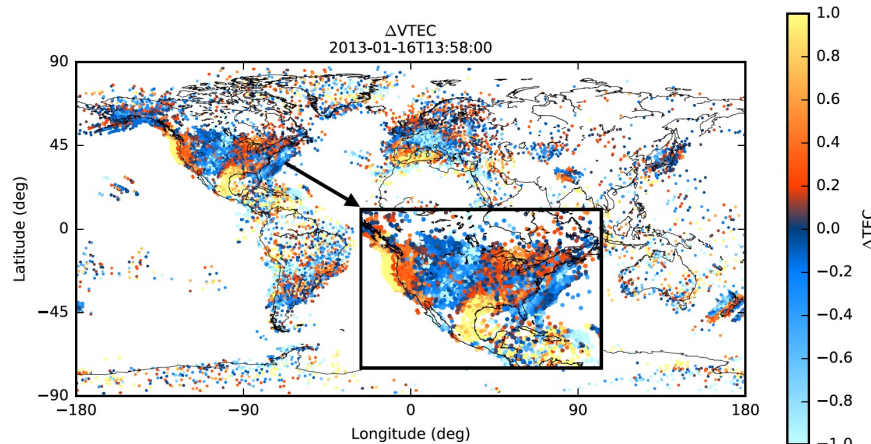
Space Weather Observations available through GNSS TEC Observations



NSF CEDAR Madrigal Database downloads and processes GNSS data from about 6000 receivers daily (<http://cedar.openmadrigal.org/>)

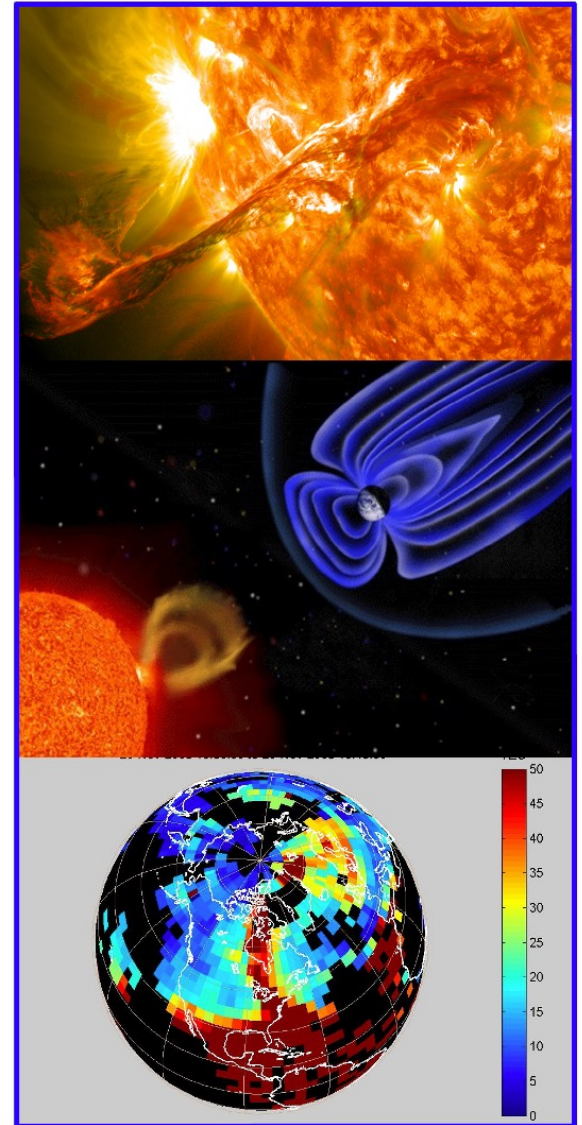
JPL and NOAA receive data from ~500 receivers in real-time

Receivers from many collaborative groups (NOAA, NSF, NASA, DOT, ...)



Needs of Ground-Based Systems

- An operational home with long-term stable funding
- Need for specification of which agencies (or agency) are responsible.
- Support for real-time, continuous operations, better communication infrastructure and predictable data quality.
- Support for big-data analysis.
- Coordinated collaborative efforts between scientific and operational needs.



Map of Norway showing the locations of 40 meteorological stations. Stations are marked with black dots and labeled with codes. Red stars indicate stations with specific data availability. The map shows the coastline and major water bodies.

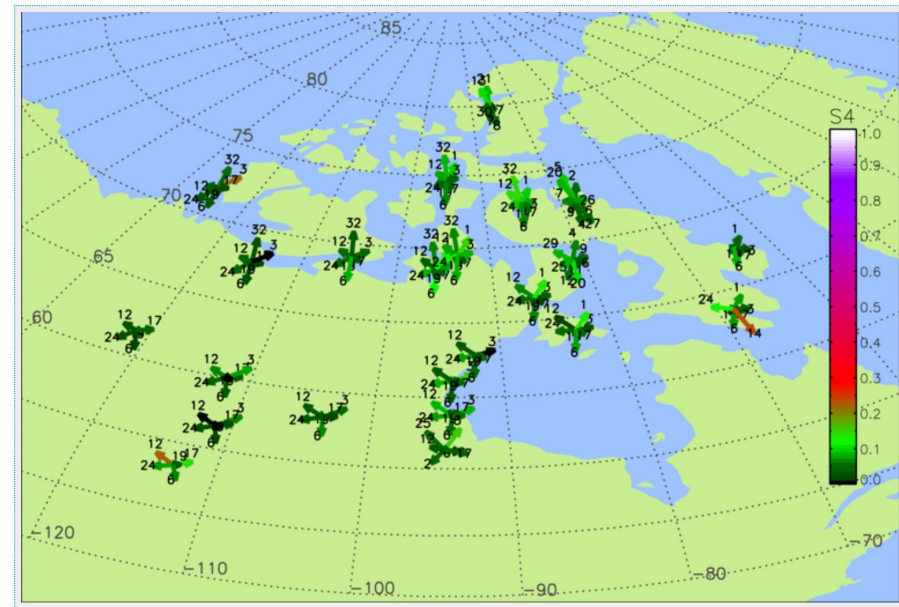
Stations marked with red stars (indicating specific data availability):

- THU2/THU4
- KULL
- UPVK
- QAAR
- QEQE
- AASI/AAS2
- SISI
- KLY2
- KAPI
- NUUK
- PAMI
- QAA1/QAQ2
- DMHN
- SCOR
- HE2
- ISOR
- KBUG
- TREO
- LYNS
- HJOR
- TIMM
- NNVN
- SENU

Other stations marked with black dots:

- KMPJ
- JWLF
- KMOR
- JGBL
- NORD/STNO
- HRDG
- LEFN
- BLAS
- NRSK
- GROK
- GMMA
- YMER
- LBIB
- DANE
- WTHG
- MSVG
- DGJG
- VFDG
- KUAQ
- MIK2
- PLPK
- KULU
- KSNB
- HEL2
- ISOR
- KBUG
- TREO
- LYNS
- HJOR
- TIMM
- NNVN
- SENU
- UTMG
- KAP1
- KLY2
- KLSQ
- KELY
- TIN1
- AASI/AAS2
- QEQE
- QAAR
- RINK
- SRMP
- UPVK
- ASKY
- DKSG
- MARG
- KAGZ
- SCBY

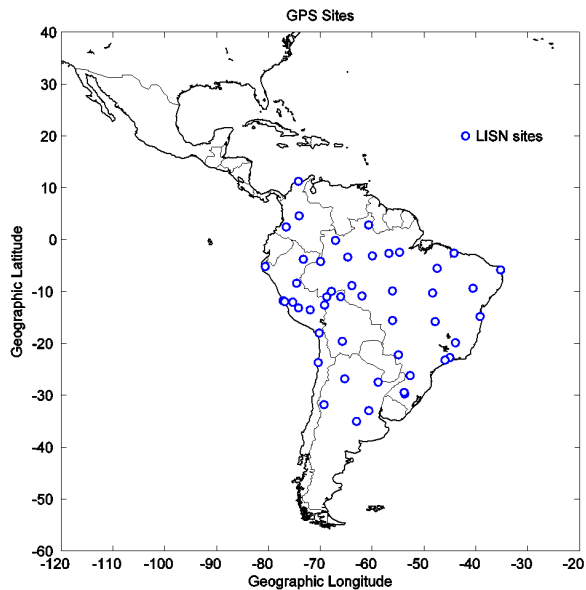
CHAIN Real-time Scintillation Map



US NSF supported GNSS network – in need of operational support

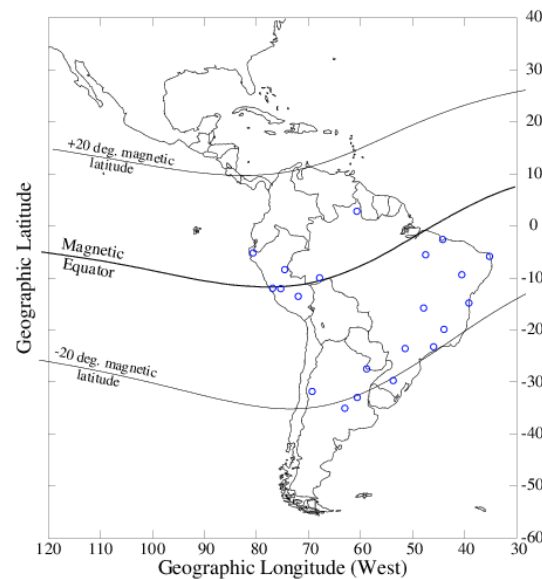
Low-latitude Ionosphere Sensor Network (LISN) of GPS/GNSS receivers

LISN GPS 2007-2016



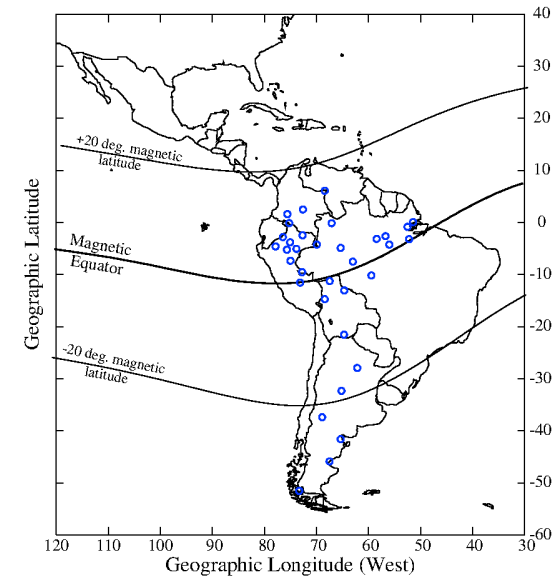
50 GPS Novatel rx

LISN GPS 2021



20 GPS receivers

AFOSR-DURIP Grant



34 GNSS Septentrio PolaRx5s

<http://lisn.igp.gob.pe>