The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

SMR 2333-37

Workshop on Science Applications of GNSS in Developing Countries (11-27 April), followed by the: Seminar on Development and Use of the Ionospheric NeQuick Model (30 April-1 May)

11 April - 1 May, 2012

Update on SCINDA Activities around the Globe

WEINS K.
Air Force Research Laboratory
101 West Eglin Blvd,. Ste. 268
Eglin AFB FL 32542-6810
U.S.A.

Air Force Research Laboratory

SCINDA Plans in Africa 2012-2013

25 April 2012

Ron Caton, Todd Parris
& Joshua Orfield
AFRL/RVBXI SCINDA
Air Force Research Laboratory

Integrity ★ Service ★ Excellence

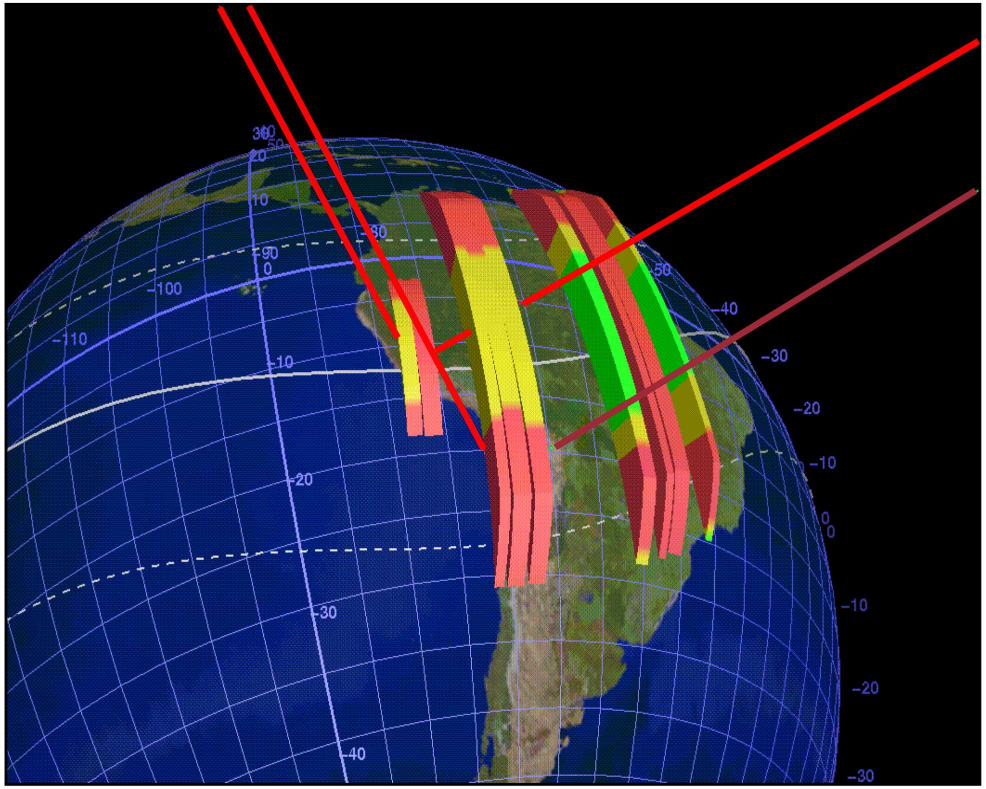
AFRL Relocation in July 2011

New Roles & Responsibilities in SCINDA

- AFRL officially relocated from the Boston area to Albuquerque, New Mexico at the end of July 2011
- "The Move" engaged most personnel for at least three months prior to departure and the dust is just now beginning to settle
  - New location, new organization, new ways of doing business
- Some personnel changed organizations as a result, but the team is still together in a slightly different form
- Ron Caton is the new SCINDA P.I.
  - His many years of experience with SCINDA have facilitated a smooth transition
  - And we gained outstanding new team members in the deal

SCINTILLATION NETWORK DECISION AID (SCINDA)

A *regional nowcasting system* to support research and users of space-based communication and navigation systems

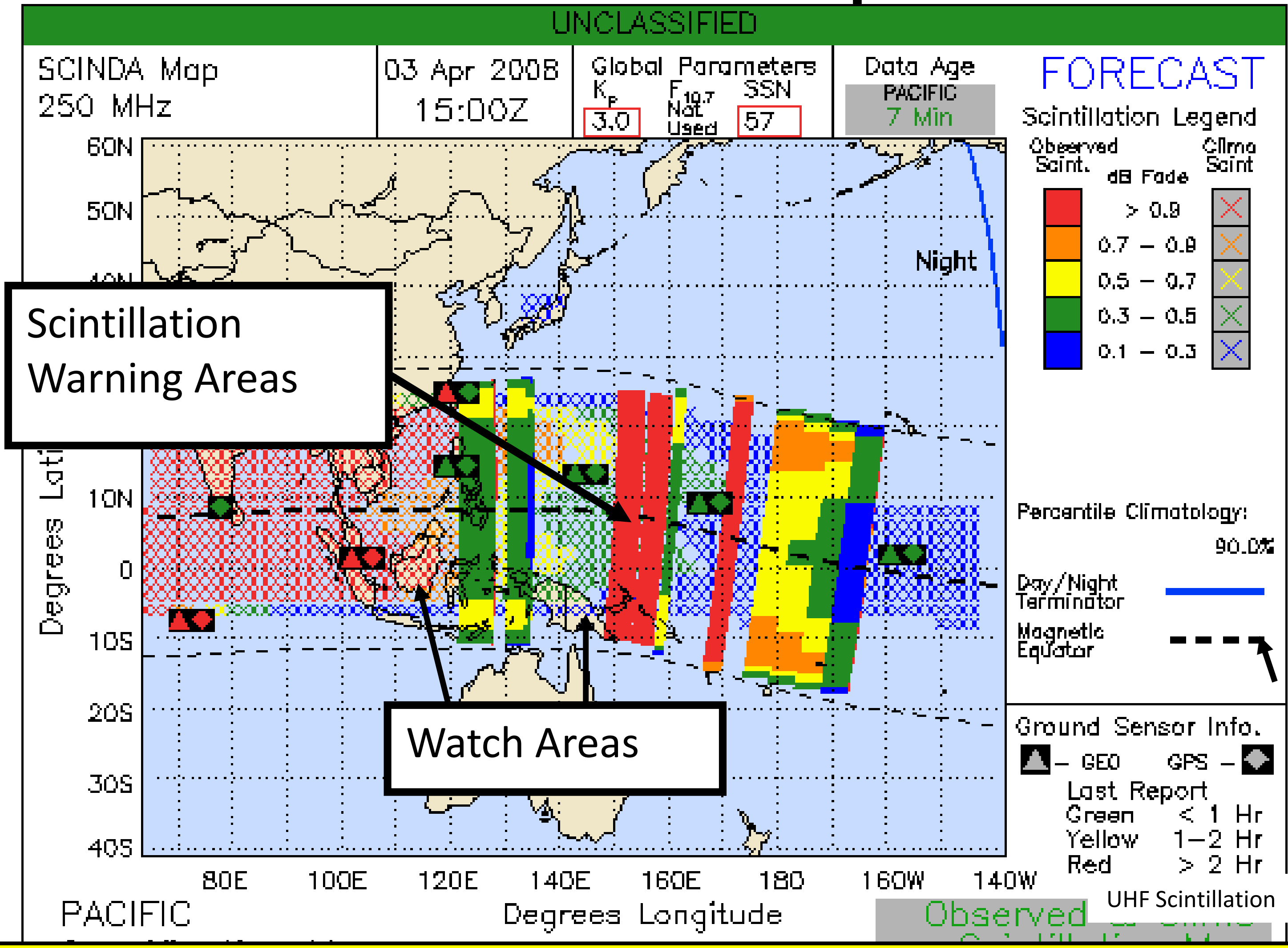


- Ground-based sensor network
  - Passive UHF / L-band /GPS scintillation receivers
  - Measures scintillation intensity, eastward drift velocity, and TEC
  - Automated real-time data retrieval via internet
- Data supports research and space weather users
  - Understand on-set, evolution and dynamics of large-scale ionospheric disturbances
  - Empirical model provides simplified visualizations of scintillation regions in real-time

Data-Driven Scintillation Map

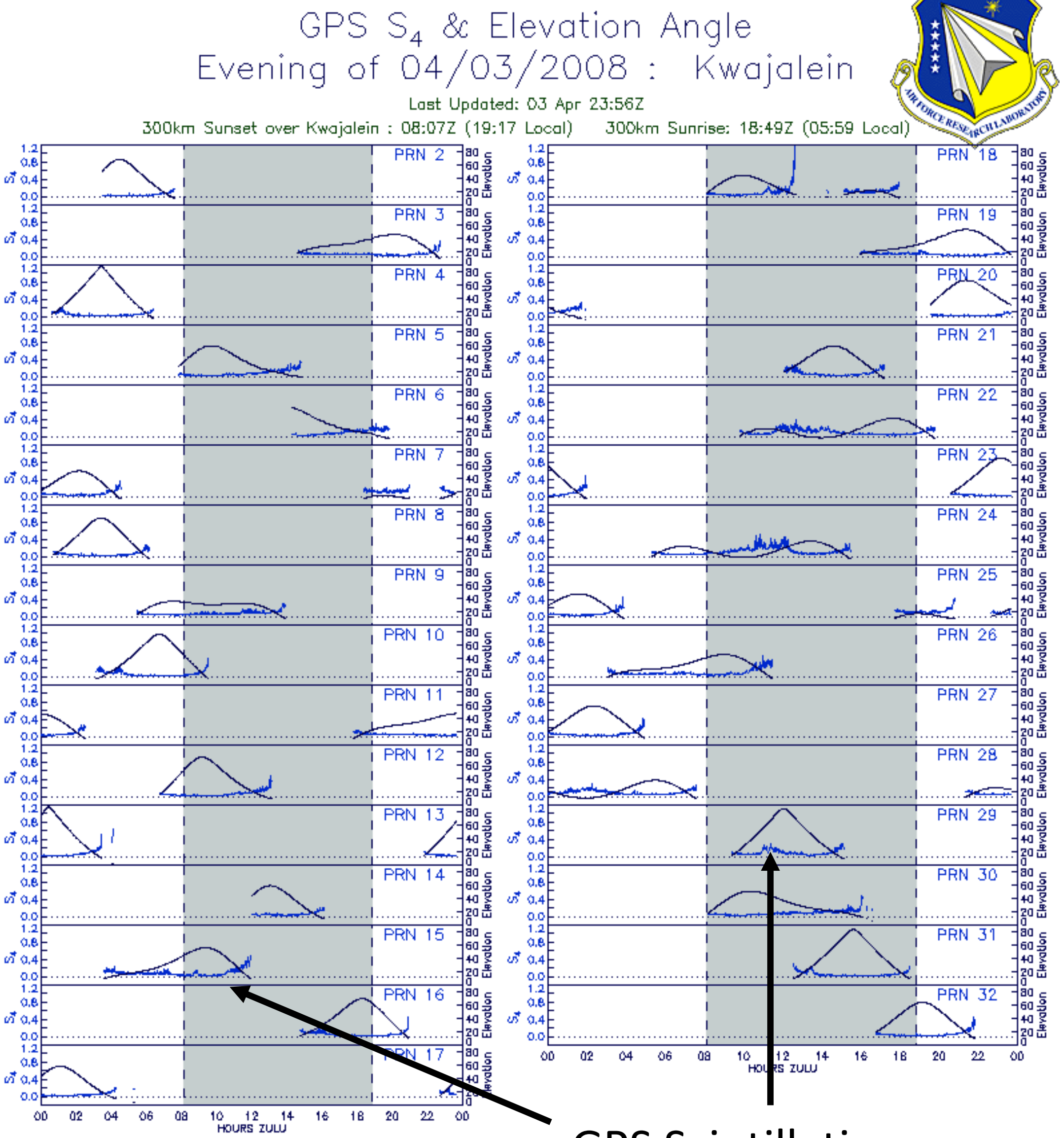
April 2008

SCINDA User Product Example for 250MHz



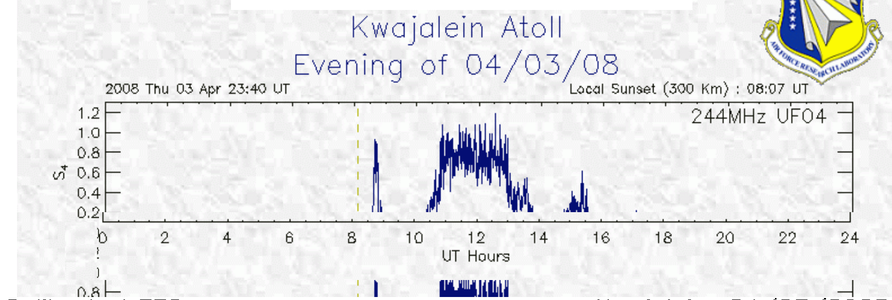
VHF Radio Signals impacted even during solar maximum

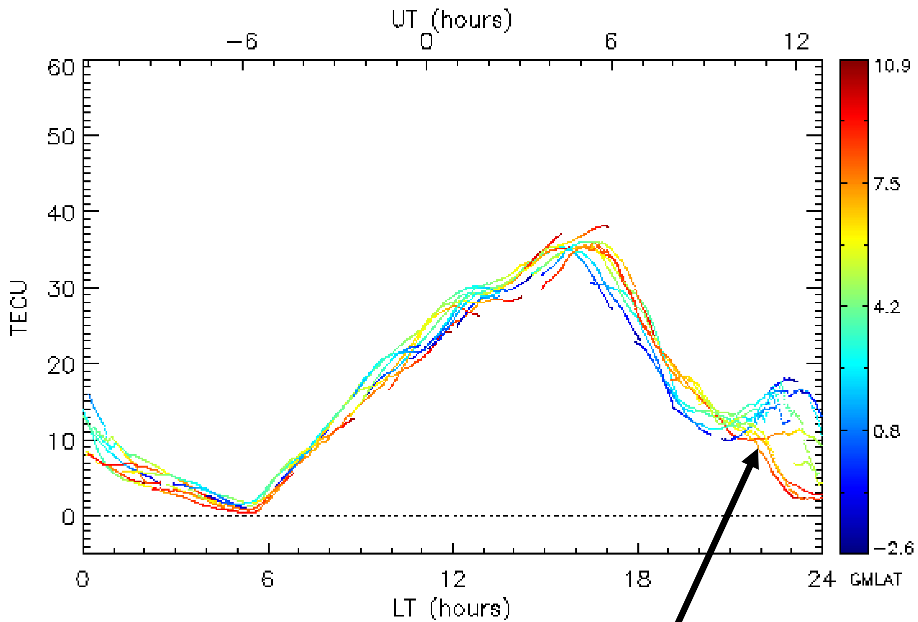
GPS Scintillation in Same Environment Much Weaker than VHF



GPS Scintillation

VHF Scintillation





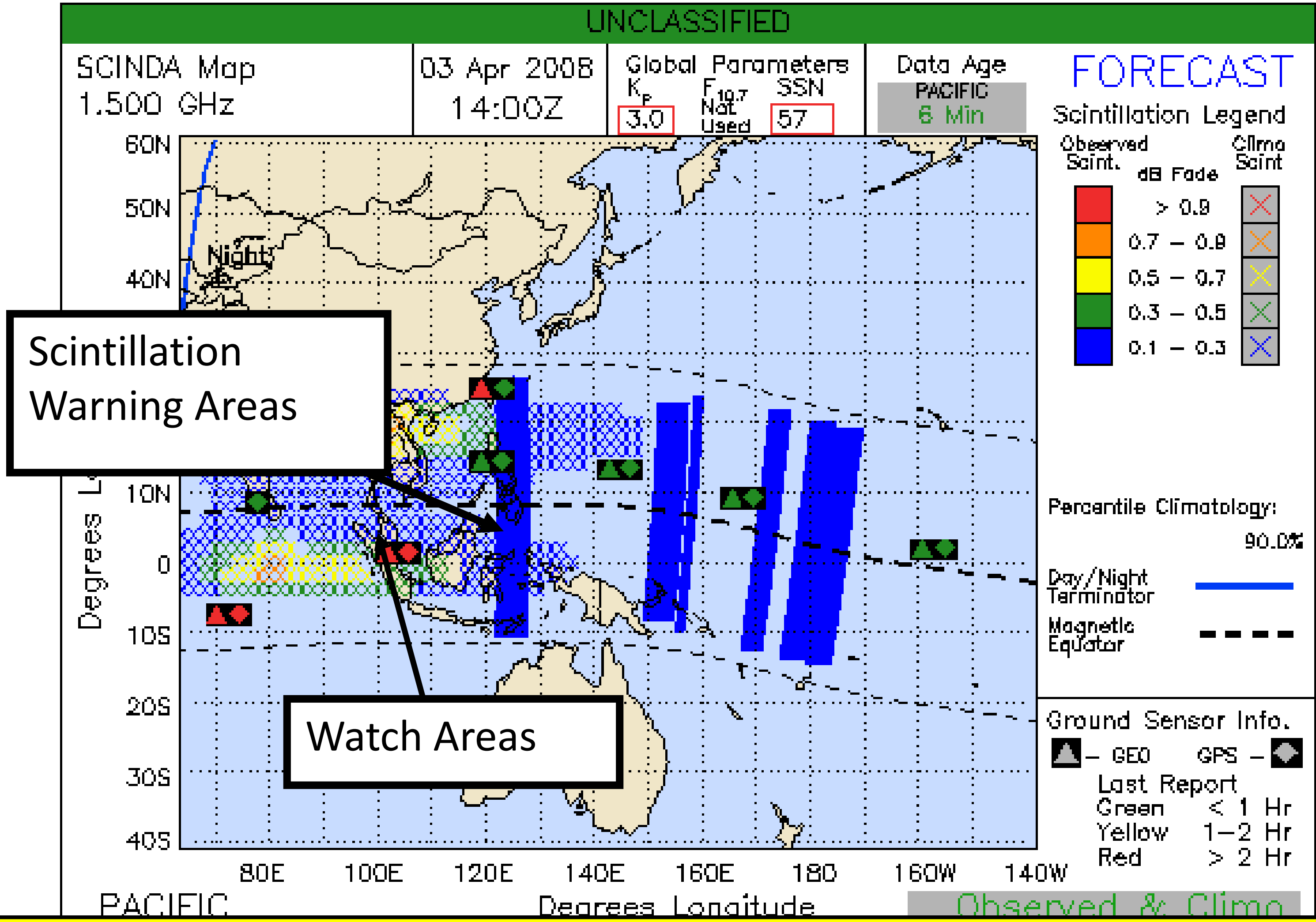
Latitude variation

DISTRIBUTION STATEMENT A – Unclassified, Unlimited Distribution

Data-Driven Scintillation Map

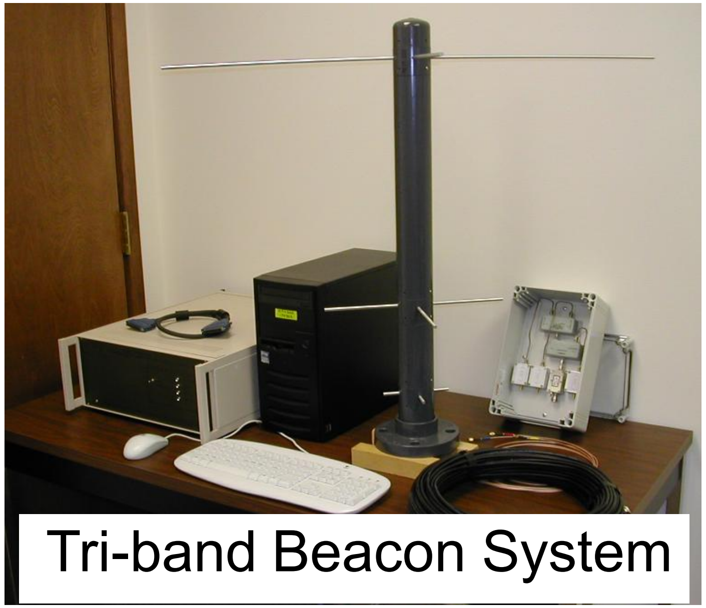
April 2008

SCINDA User Product Example for GPS



Modest Effects on GPS Frequencies During Solar Min

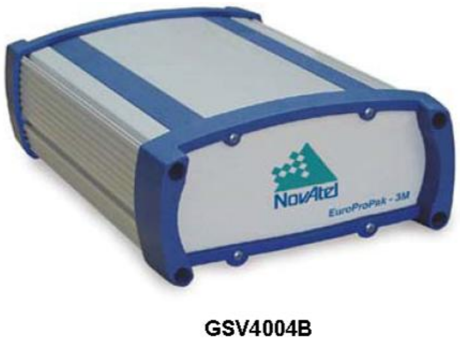
SCINDA Sensor Suite



Tri-band Beacon System

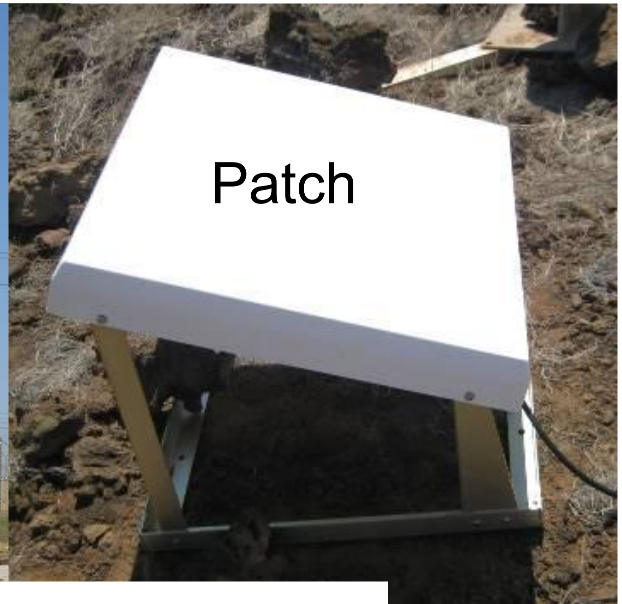
Single channel VHF Receiver

USRP VHF Receiver



GPS Receiver

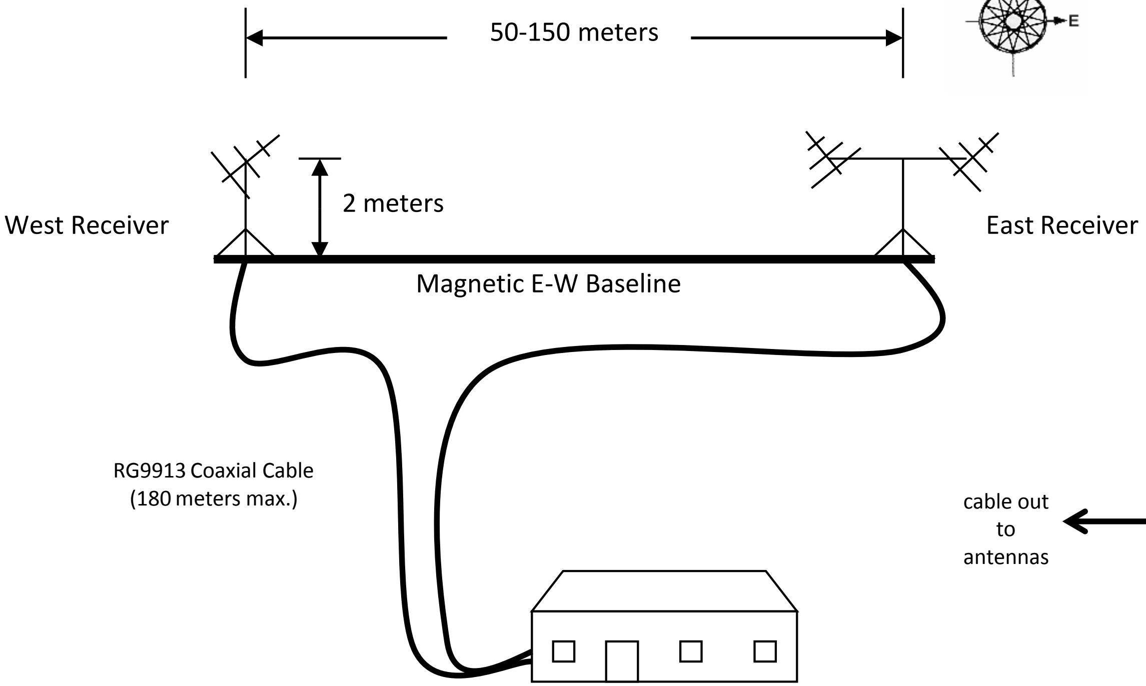
GPS Antenna

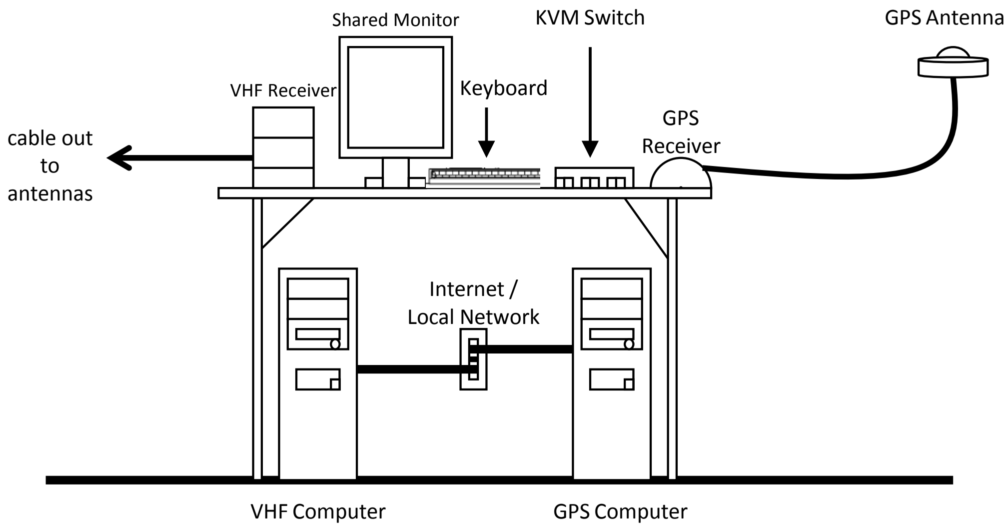


UHF Antenna

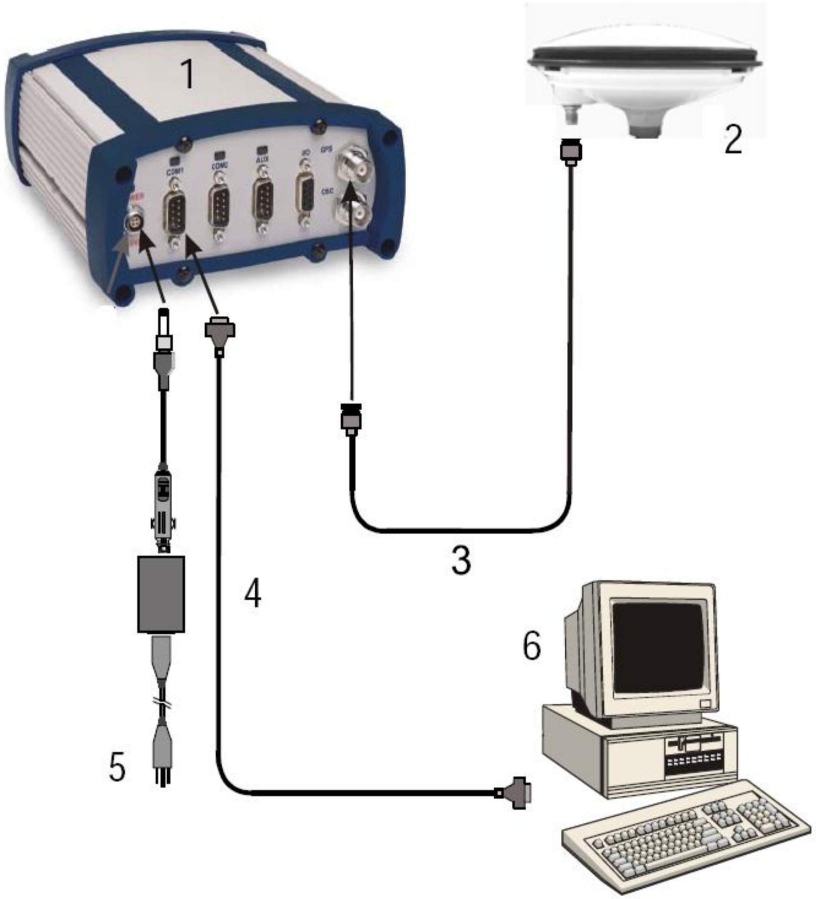
Typical Hardware Configuration

Antenna Layout





Receivers Set-Up



Equipment List

1: NovAtel GSV 4004B GPS receiver

2: NovAtel dual frequency antenna

3: Antenna cable (30 meter maximum)

4: Serial cable

5: Power cable

6: Personal computer running Linux

GPS-SCINDA System Software

GPS-SCINDA Scintillation Monitoring System

- Operating System: Debian Linux
- Software runs in text mode in a Linux console
- Configurable via command line interface
- Sends data via Internet connection and SFTP

GPS Data Logging

What we measure: GPS System Outputs

- GPS L1 signal (1575 MHz)
  - S4 scintillation index
- GPS L2 signal (1228 MHz)
  - S4 scintillation index (not useful at this time)
- Both the L1 and L2 signals
  - Total Electron Content (TEC)
  - Rate of TEC Change (ROTI)
- Raw amplitude and phase data (50 Hz) can be recorded as desired
- New data plotting and analysis tools available
  - C. Carrano presentation

Mounting the GPS Antenna

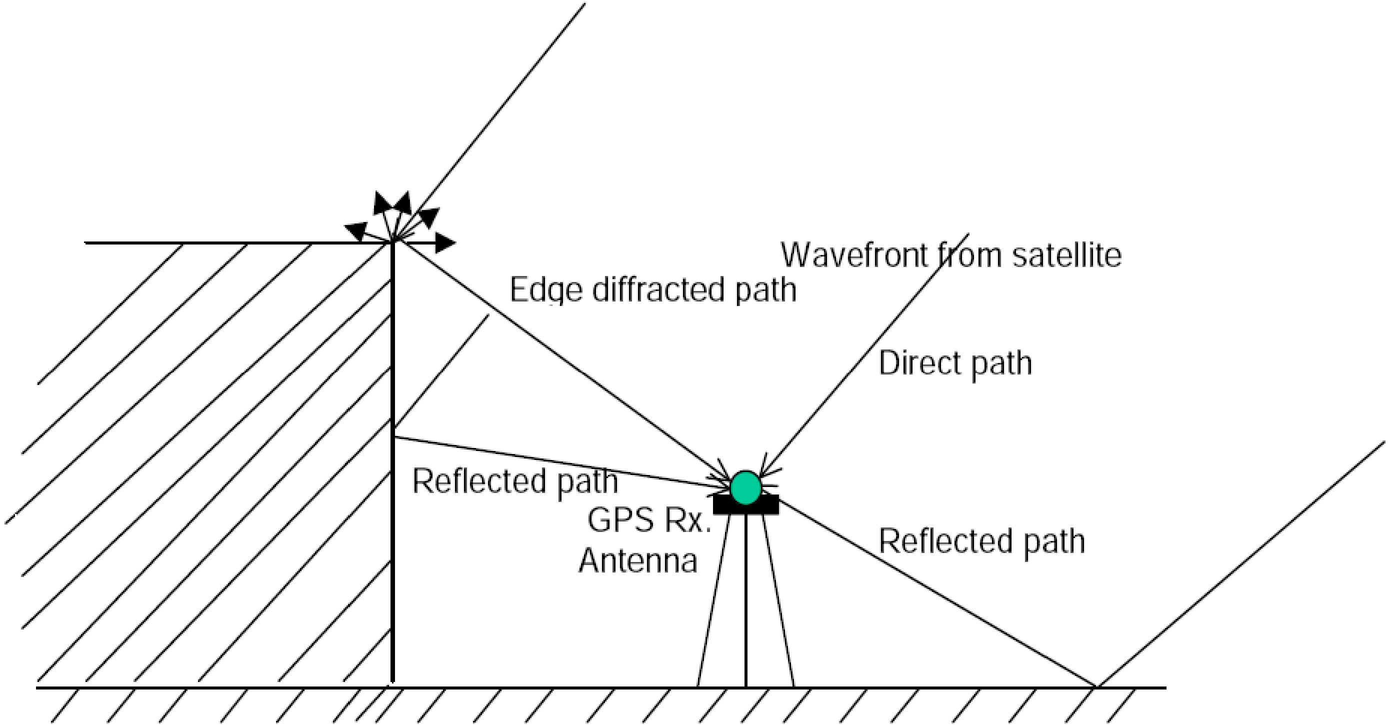
GPS Antenna should be installed high, with minimal obstructions from buildings, other antennas and equipment, power lines, and trees. Antenna cable length should not exceed 30 m to limit signal losses.

GPS antenna

Important: Moving the antenna or changing cables can change the receiver bias.

GPS Multipath

Only the portion of the signal that travels along the direct path from the satellite is useful. All other contributions are called multipath.



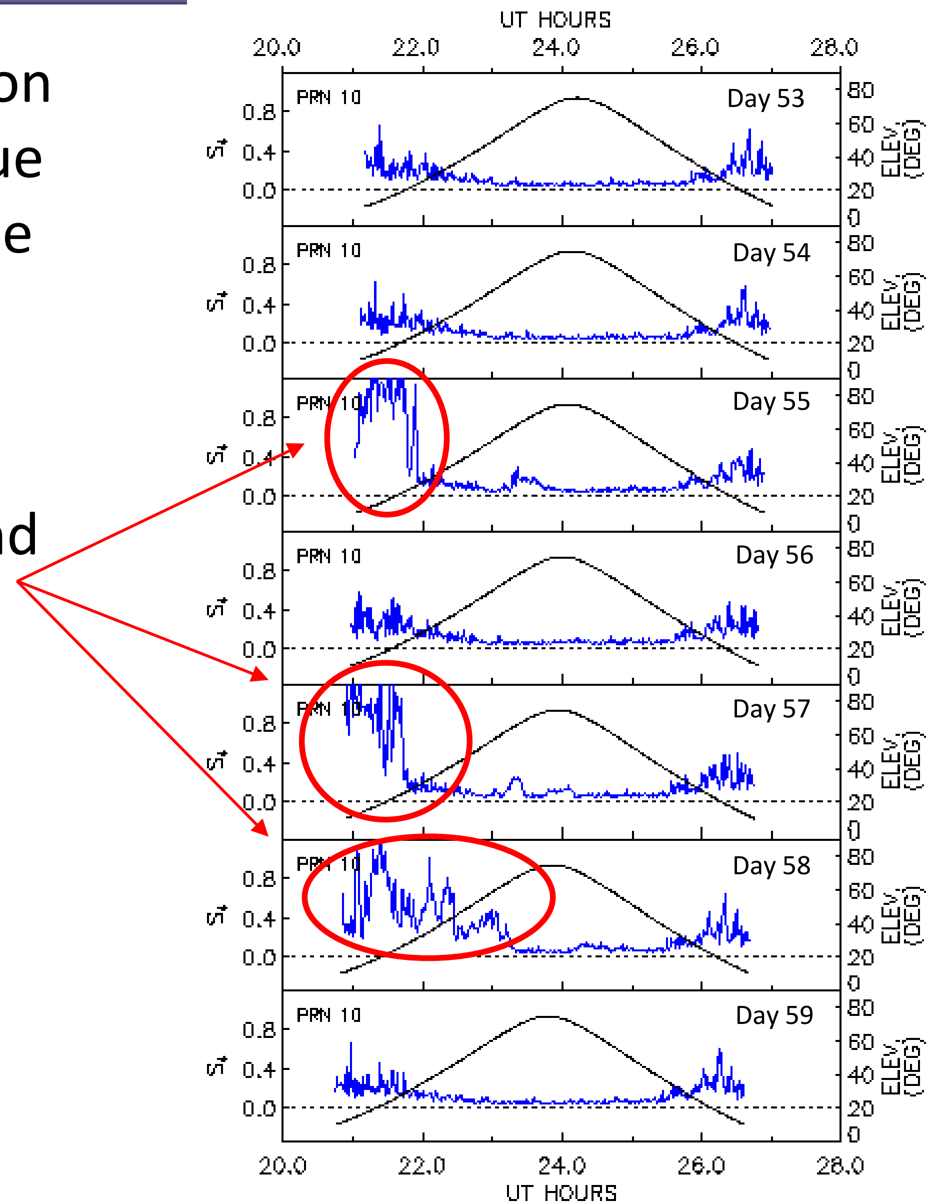
Signal interference at the antenna due to multipath causes fluctuations that can resemble scintillation, but these fluctuations are not caused by the ionosphere.

Multipath and Scintillation

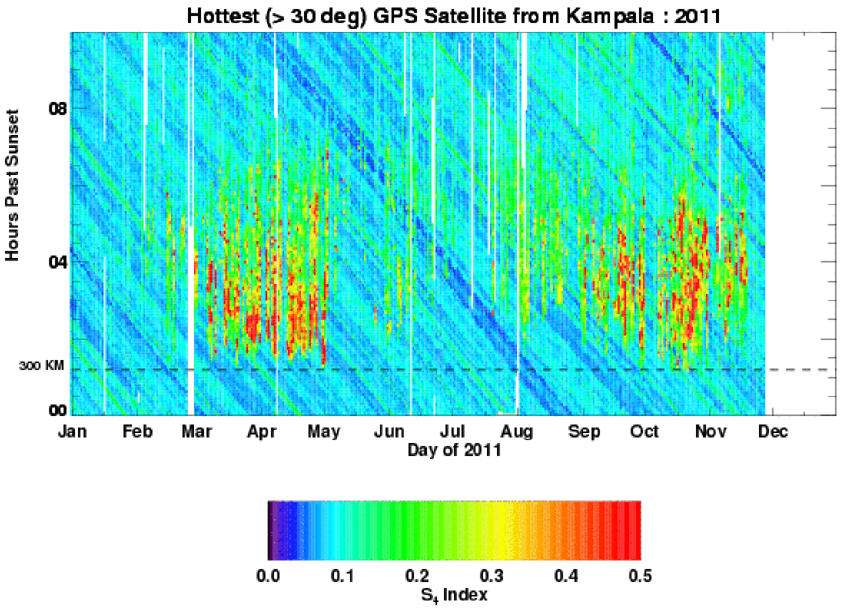
The pattern of multipath scintillation changes slowly from day to day (due to the 4 minute daily rotation of the GPS constellation)

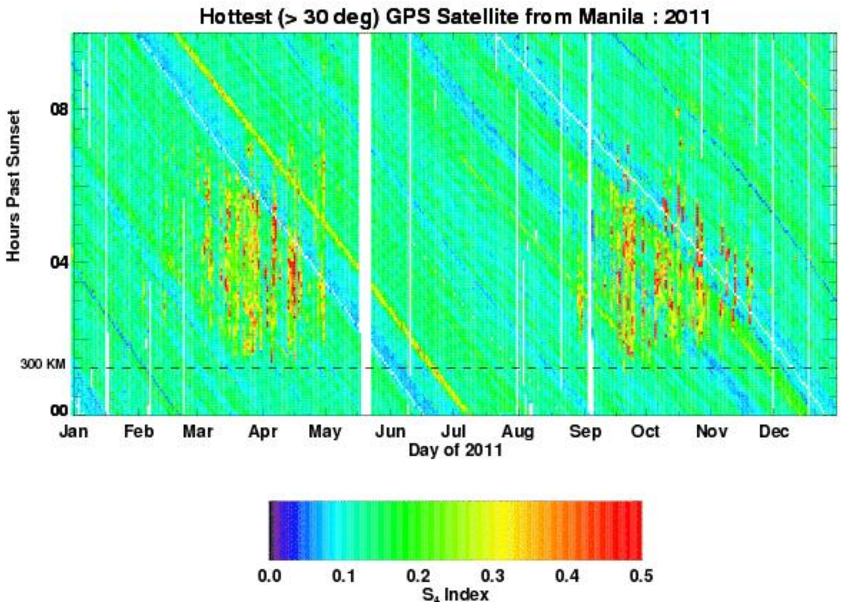
Ionospheric scintillation changes quasi-randomly from day to day and is superimposed on the multipath background

Multipath due to ground-based obstructions of the sky is usually encountered at low elevations



The Good, the Bad and the Ugly

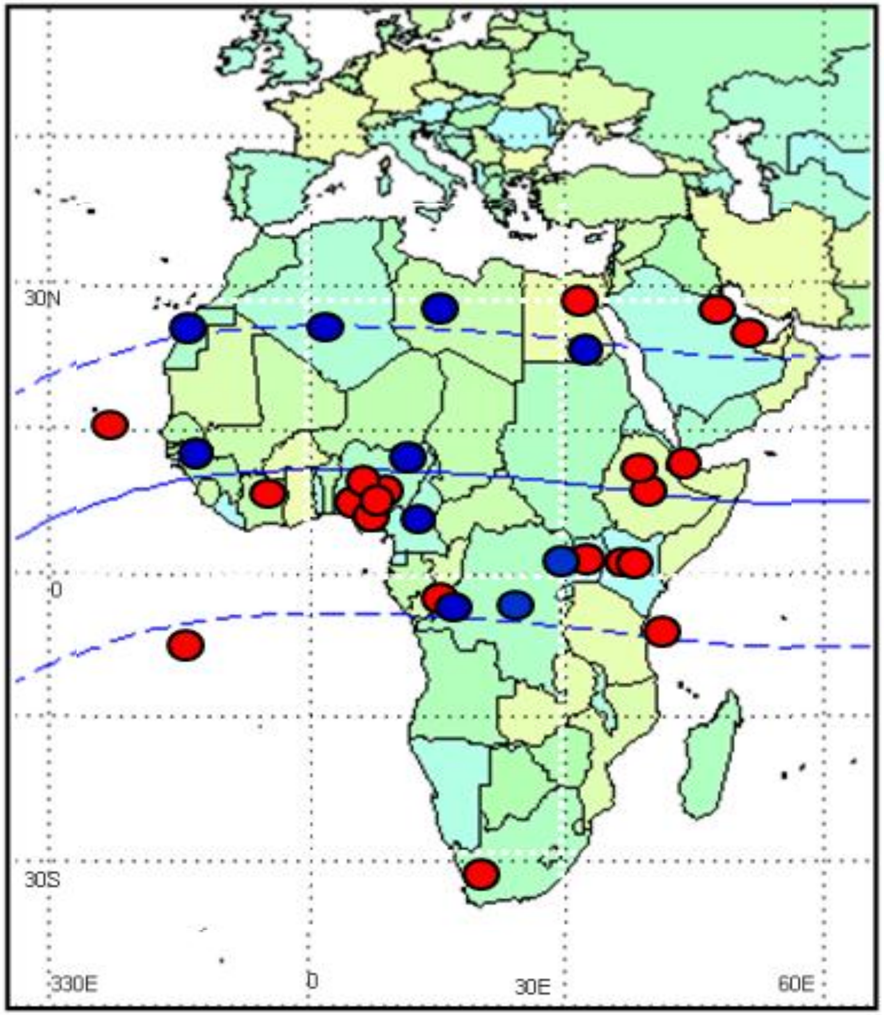




- The multipath environment can make a significant difference in data quality
- Examples above of a good site (Kampala) and a relatively bad site (Manila) where the GPS facility is surrounded by large antennas and other metal structures

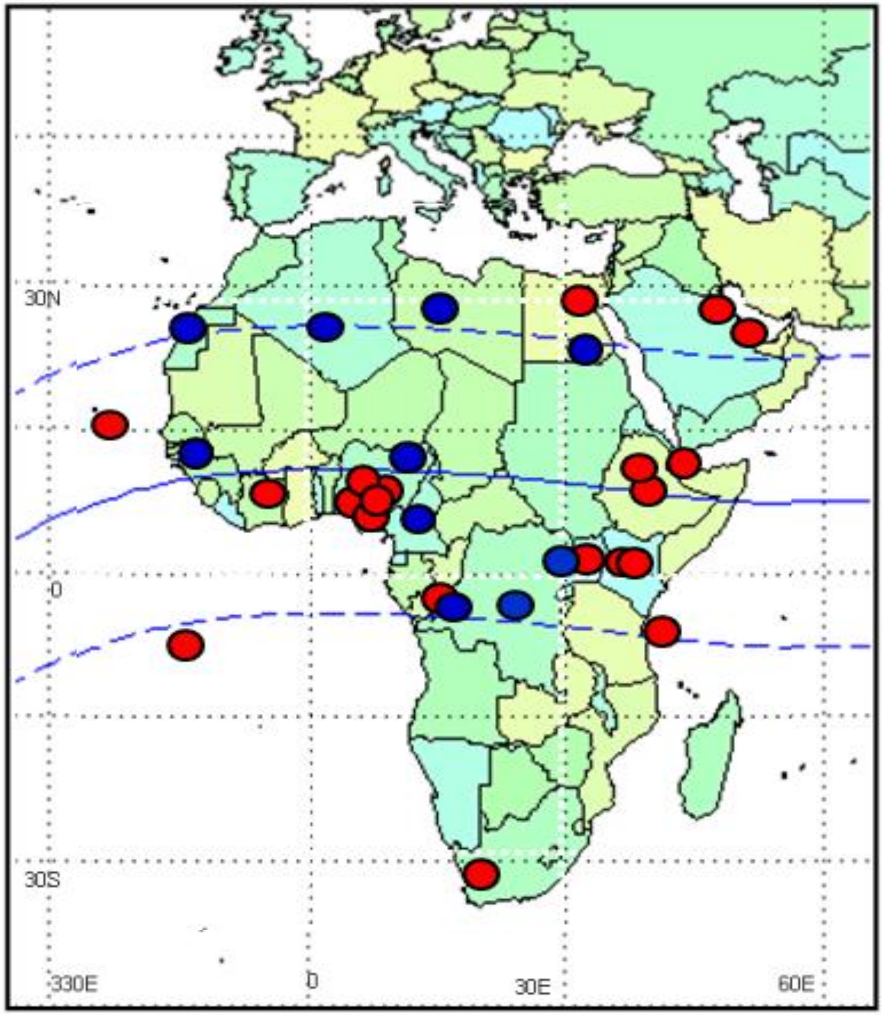
Air Force supported sensors in African sector

- SCINDA
  - 6 VHF SATCOM scintillation receivers
  - 23 GPS TEC and scintillation receivers
- 2 ionosondes



Air Force collaboration with SANSA

- Broaden research objectives to include response of ionospheric-thermospheric-magnetospheric system to impulsive solar events
- Data server to assimilate data from AFRL SCINDA instruments and South African instruments
  - GPS receivers, VHF receivers, Ionosondes, Magnetometers
- Install 4-5 new SCINDA instrument suites in Africa; can consider non-equatorial sites
- Host workshop in 2013 (April/May?)
- Improve infrastructure/reliability and augment sensors at existing SCINDA sites
- Deploy an equatorial coherent backscatter VHF radar



SCINDA/IHY Workshops:
How we got here today

2006 – Sal, Cape Verde

- 20 participants representing 7 nations

2007 – Addis Ababa, Ethiopia

- ~50 participants from 12 nations at 2007 IHY in Ethiopia

2009 – Livingston, Zambia

- 116 delegates from 27 nations including 79 representing 19 African countries

2010 – Nairobi, Kenya, Bahir Dar, Ethopia, Cairo, Egypt*

- The beginning of **ISWI**

2013 – Hermanus, RSA? April/May?

Upgrades to Improve System Reliability

- Autonomous SCINDA system upgrades:
  - Low power computer (6-8 W)
  - Deep cycle UPS (with optional solar panel addition)
  - 3G cellular USB modem (to augment network connection)
  - Solar powered version available if required (first deployment May 2011)

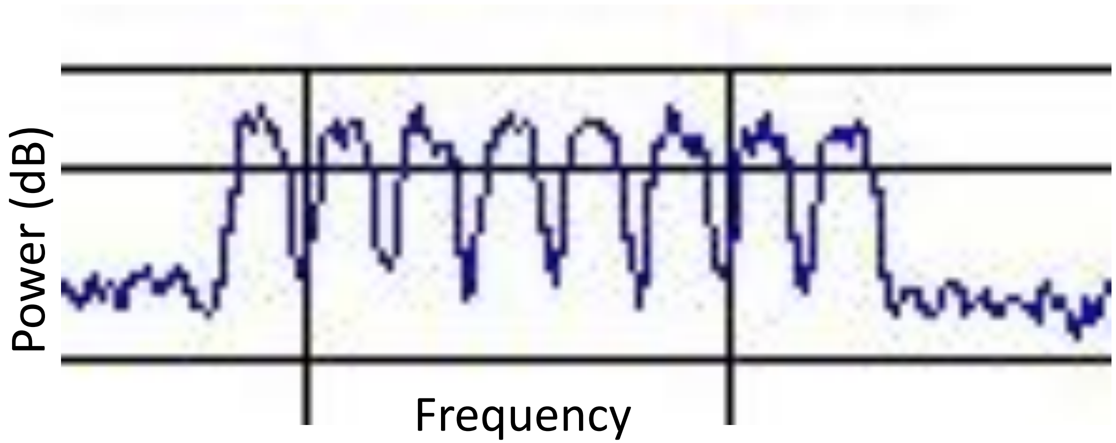
Low power, compact Fit-PC

Goal is to establish a “get-well” plan for each existing site and implement it efficiently

VHF Scintillation Sensor

Software Digital Radio (SDR)

VHF channels in Spectrum Analyzer



SDR monitors multiple VHF GEO channels

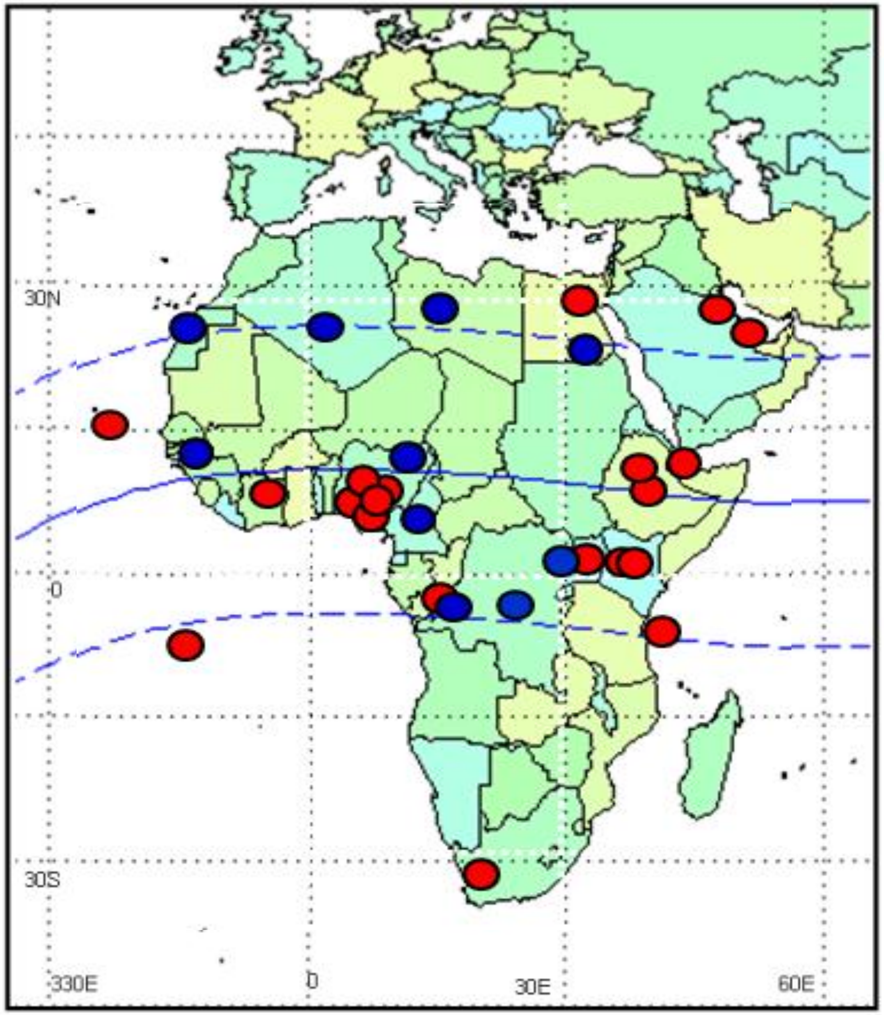
- AFRL/RVBXI has developed a VHF geostationary beacon sensor exploiting software digital radio technology
  - Much greater capability (10x), much less costly (1/10) than existing hardware receiver
  - Enables sensor proliferation→ sustenance for data-starved models
  - Plan is to adopt technology for other RF monitoring systems (e.g., C/NOFS beacon receiver)

New Site Selection

Selection Criteria

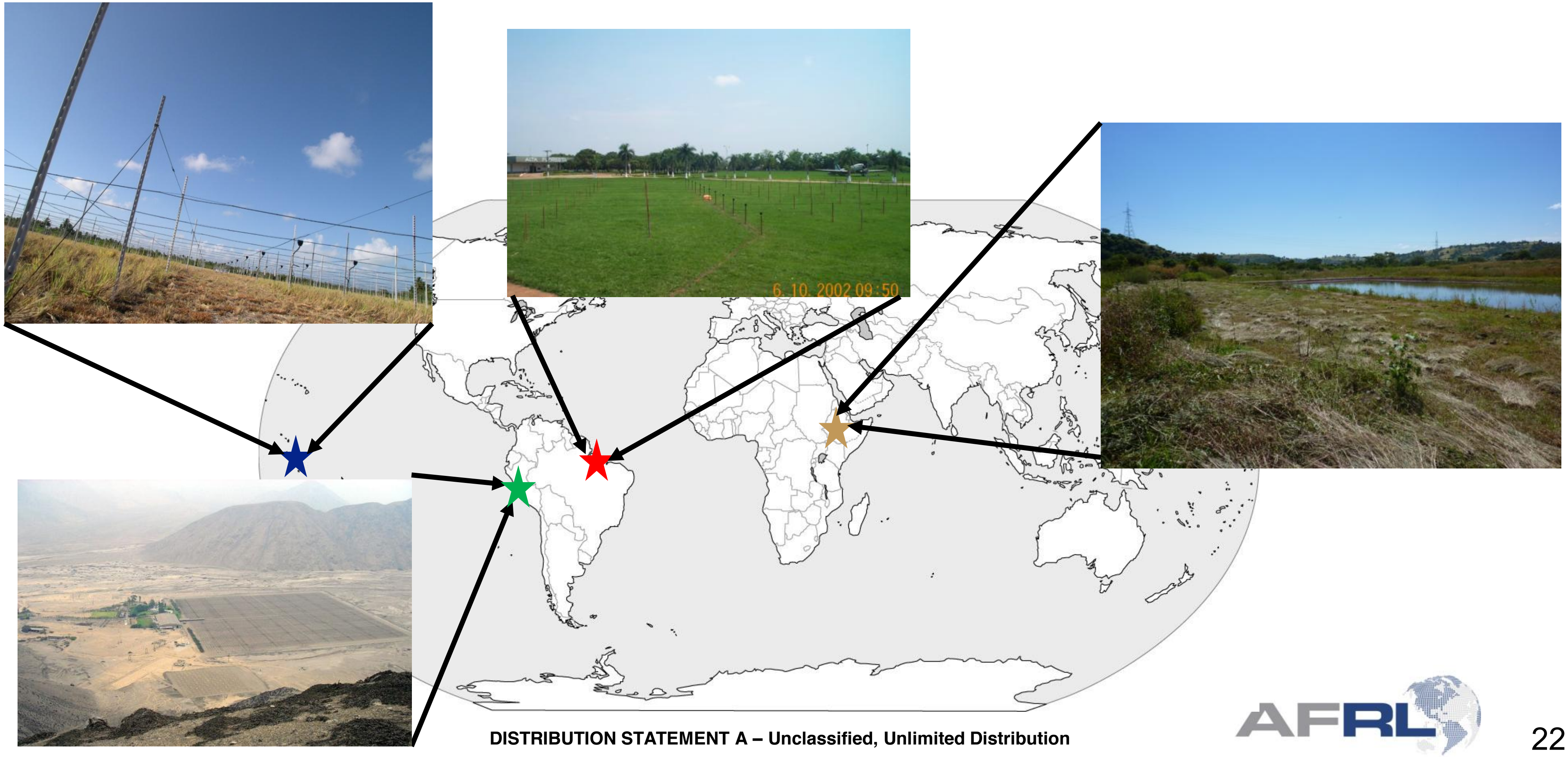
- Equatorial anomaly sites (Mlat = 10 -15)
- West Africa
- Non-equatorial sites that bridge gap between equatorial belt and South Africa’s sensor network
- “Targets of Opportunity” that satisfy all sensing requirements

New sites will be tested prior to sensor installation to determine support needed to insure a successful data collection experience



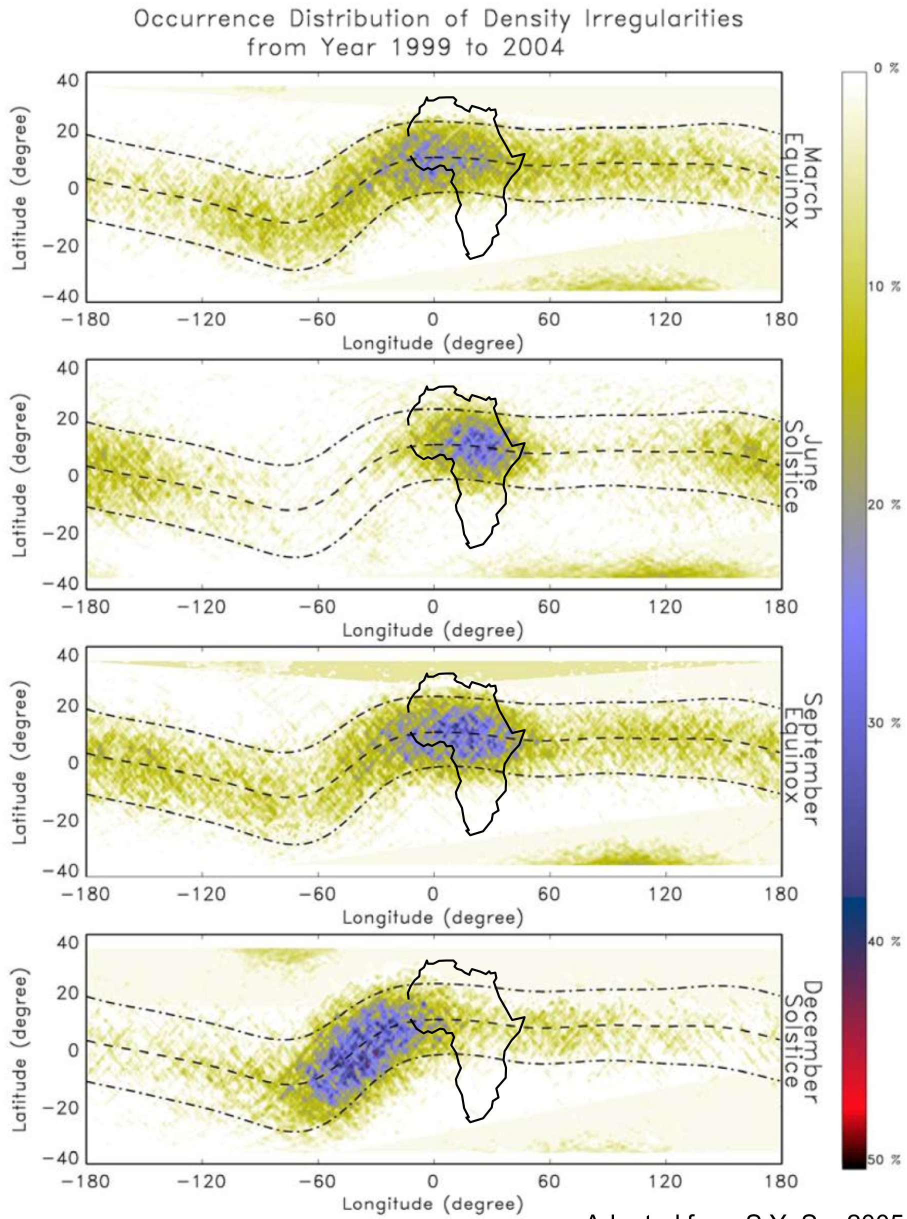
Equatorial Coherent Backscatter Radars

- Currently radars at 3 locations– Sao Luis, Brazil, Jicamarca, Peru & Christmas Island, Kiribati
- Initial site survey for Bahir Dar, Ethiopia completed Fall 2010



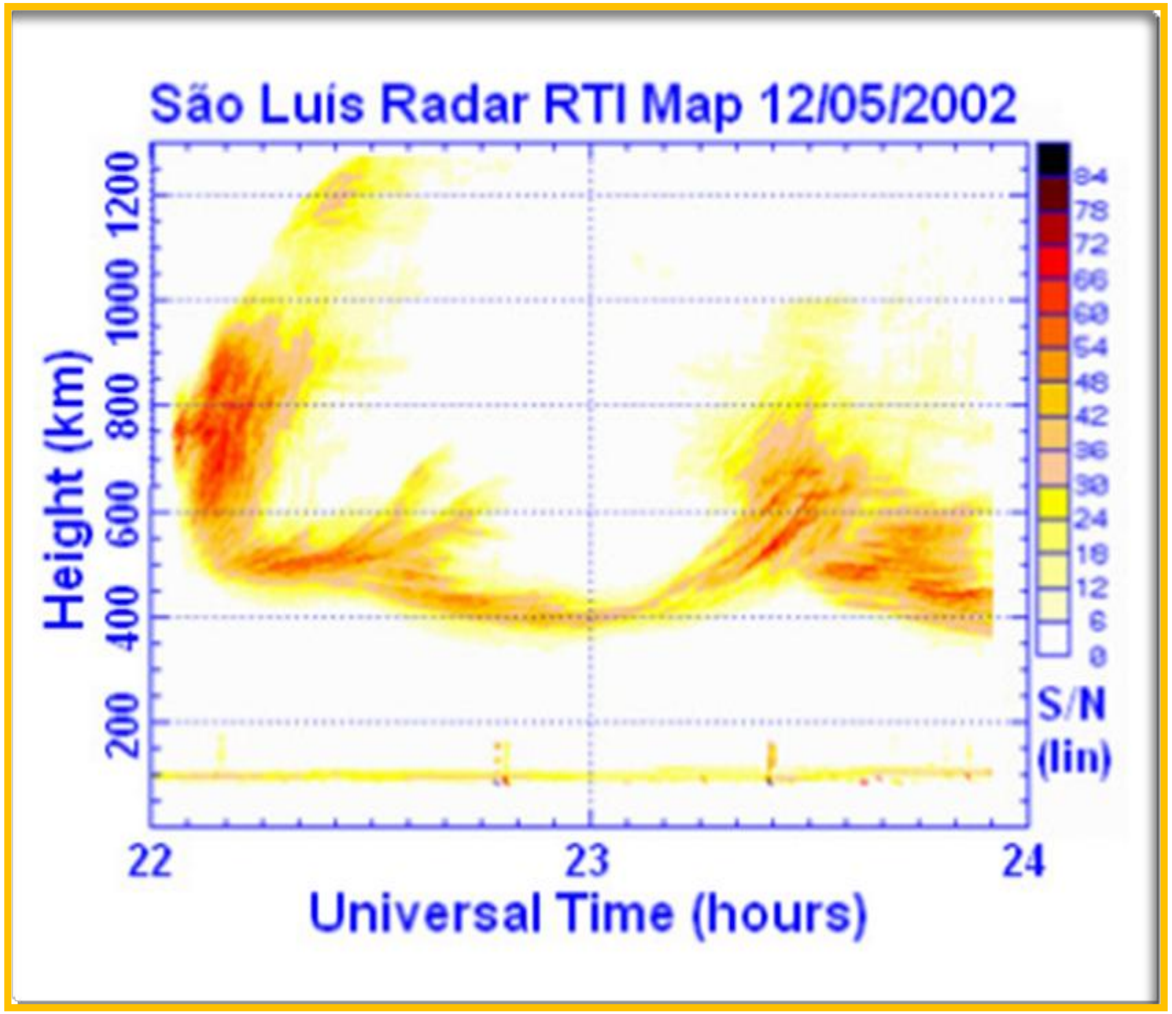
Why African sector?

- Fills a gap in global equatorial coherent scatter radar coverage
- Indication that physics may be different over African sector than American sector
- Complements existing SCINDA instruments
  - SCINDA instruments detect scintillation, and measure TEC
  - VHF radar provides information of formation, scale size, and spatial extent of irregularities
  - Help provide a more complete picture of the physical processes involved
  - ISR would help complete this picture
- Great partners in Africa
  - SANSA
  - Bahir Dar University



Adapted from S.Y. Su, 2005

Coherent Backscatter Radar System

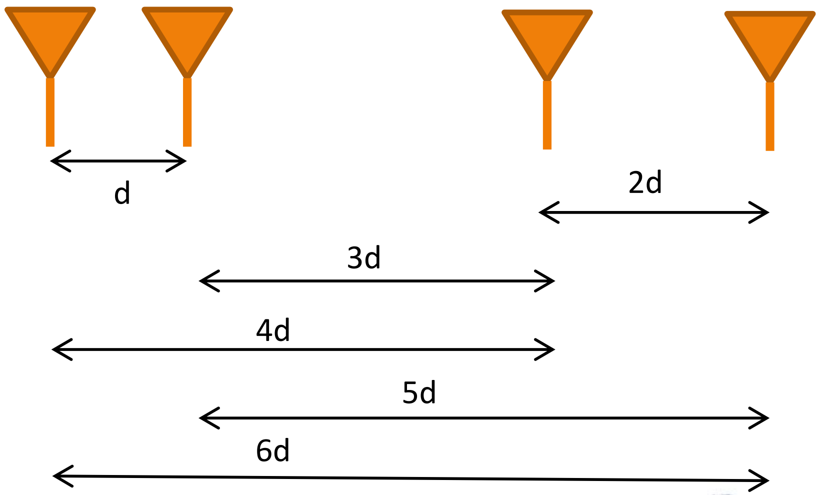


Reproduced from Emanoel Costa

- Sample data from 30 MHz Radar in Sao Luis, Brazil
- Equivalent to a slit-camera
- Radar beam steered perpendicular to local magnetic field
- Coherent (Bragg) backscatter from turbulence at ½ the radar wavelength (small scale irregularities, on the order of ~1 m)

Radar details?

- Location?
  - Bahir Dar University, Ethiopia?
  - Satellite campuses or other universities in Ethiopia?
- Single large aperture array?
  - 100m x 100m collinear, coaxial
- Radar interferometry imaging?
  - 4 sub-arrays, 4 receivers, 6 interferometry baselines?
  - 5 sub-arrays, 5 receivers, 10 interferometry baselines?
  - 6 sub-arrays, 6 receivers, 15 interferometry baselines?
  - 4 antennas per sub-array?
  - 16 antennas per sub-array?
  - Antenna types? Yagis, log-periodic, other?
  - Steerable?
  - Other antenna/array options?
- System power?
  - 4kW, 8kW, 16kW?
- Frequency?



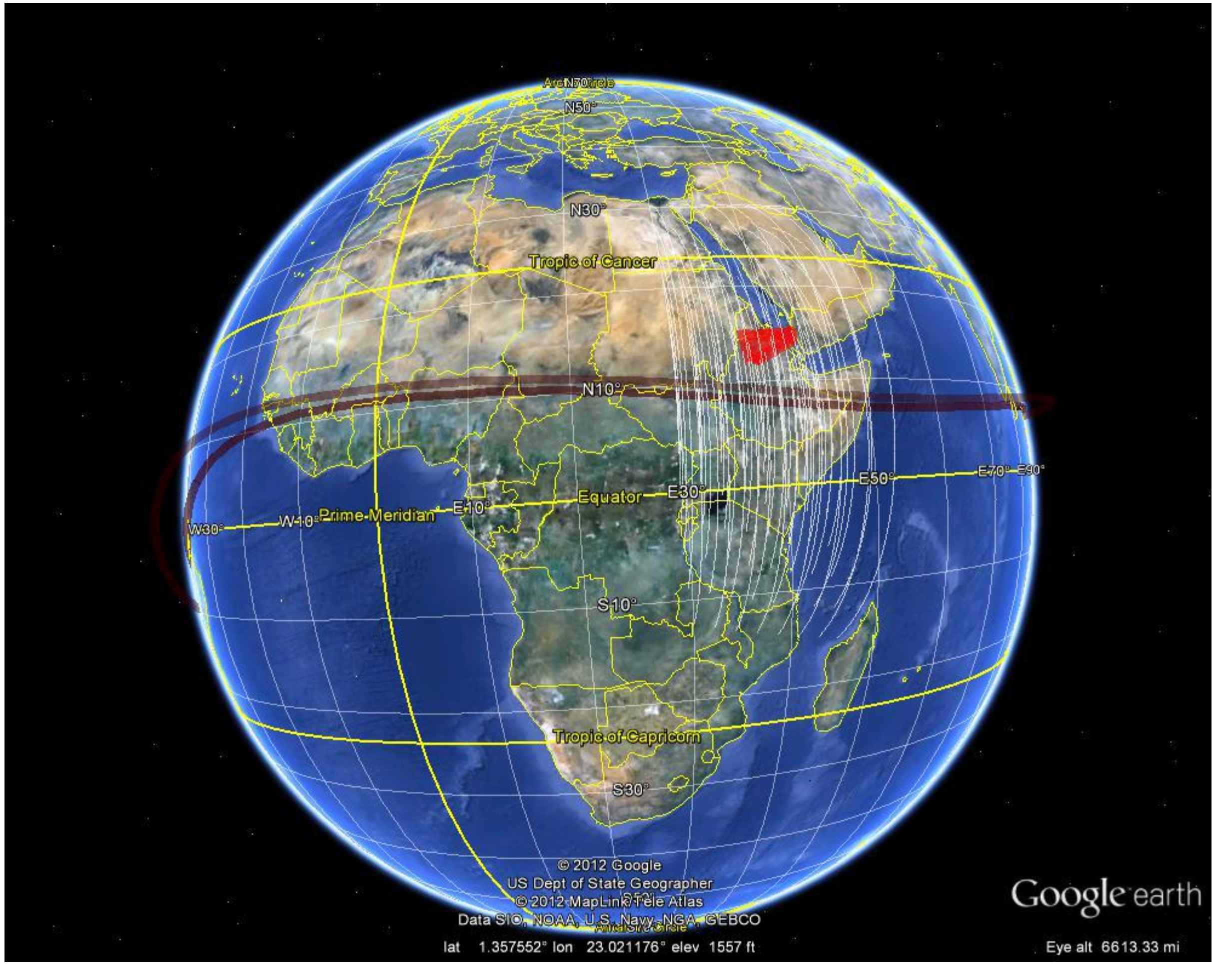
Likely radar details

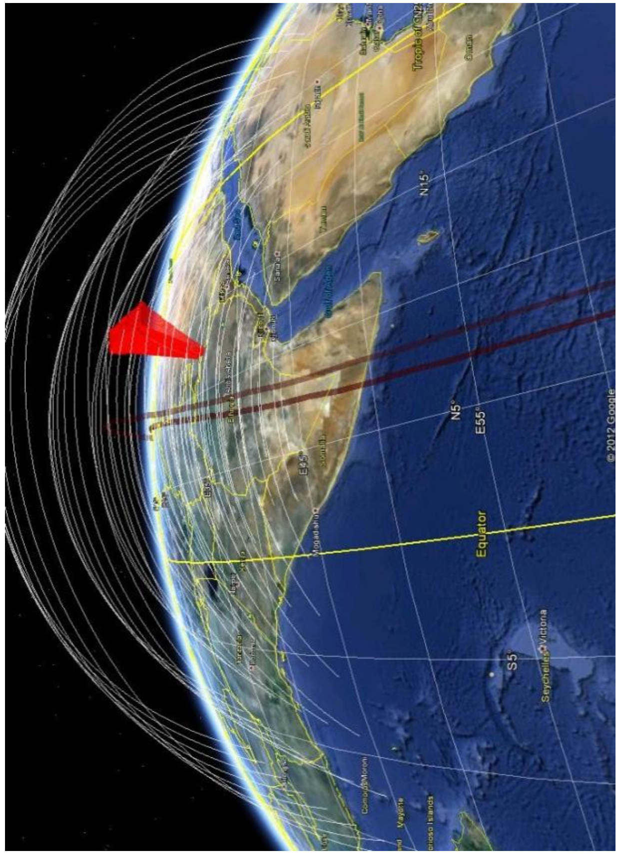
- 30 MHz Imaging radar
- 6 antenna arrays, 15 interferometry baselines
- 5 element commercially available Yagis, 10dBi directivity
- 4 to 16 antennas per array
- 24-96 antennas total
- 8kW peak power, up to 10% duty cycle, commercially available transmitter
- Fully digital waveform generation
- Fully digital receivers
- Campaign mode collection of raw data
- Real time processing of Fourier radar images
- Similar to Sao Luis 30MHz radar
- Based largely on Dave Hysell's design
  - Has shared his hardware designs
  - Has agreed to share his radar control software and signal processing tools

Possible locations

- Bahir Dar University as a partner
  - Dr. Baylie Damtie, President
  - Faculty support
  - Graduate student support
  - Infrastructure support
  - Construction support
- Bahir Dar University main campus as a location
  - 2.4° magnetic latitude
  - ~5° dip angle
  - 2.7° magnetic latitude at 300km
- Other University sites possible

Coherent radar in Africa





Tentative timeline

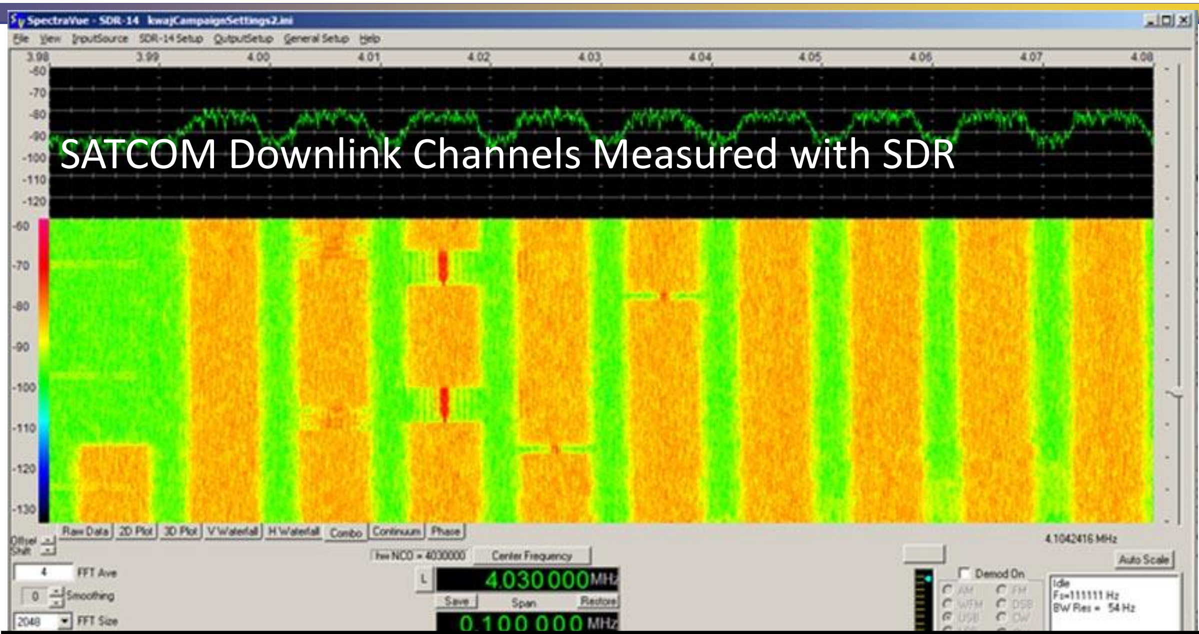
- Finalize details of radar design in March/April, 2012
- Formal site visit in spring/summer, 2012
- Start site prep in summer, 2012
- Acquire/assemble/test radar subsystems in summer and fall, 2012
- Final assembly and test of radar system in fall/winter, 2012
- Install radar in winter, 2012, or spring 2013

Up and running for the peak of the current solar cycle

Questions?

VHF Scintillation Sensor

Software Digital Radio (SDR)



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