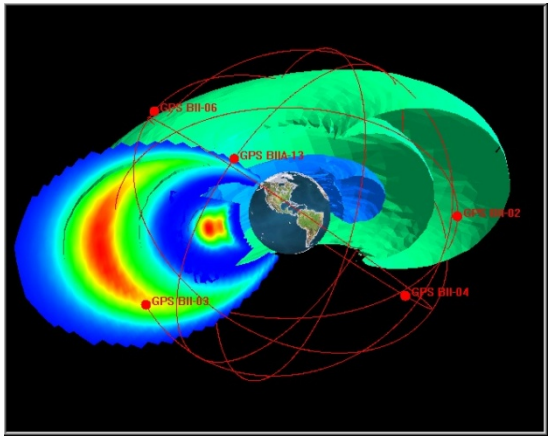
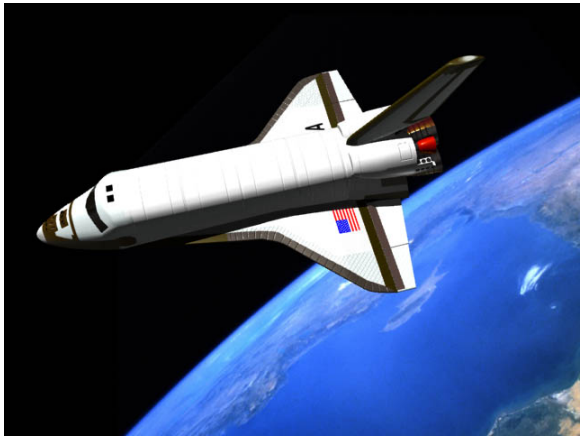
The Institute for Scientific Research

From the Space Age to the Information Age

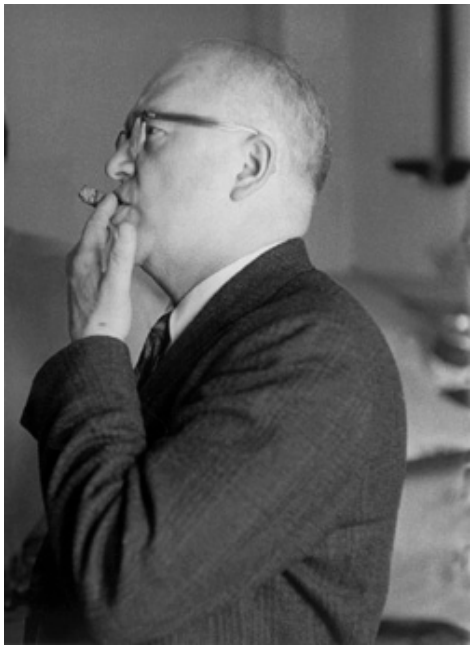
Patricia Doherty, Director
Institute for Scientific Research, Boston College

NEROC -- 2nd Annual Radio Science Symposium
MIT Haystack Observatory
November 8, 2017





History of the Institute for Scientific Research



Professor Rene Marcou, Mathematics. Awarded BC's first government sponsored research grant in late 1950's

$5K to map the ionosphere and define its effect on radio waves

1950's: Ionospheric Research Laboratory

1960-1970's: Space Data Analysis Lab

1980's: Institute for Space Research

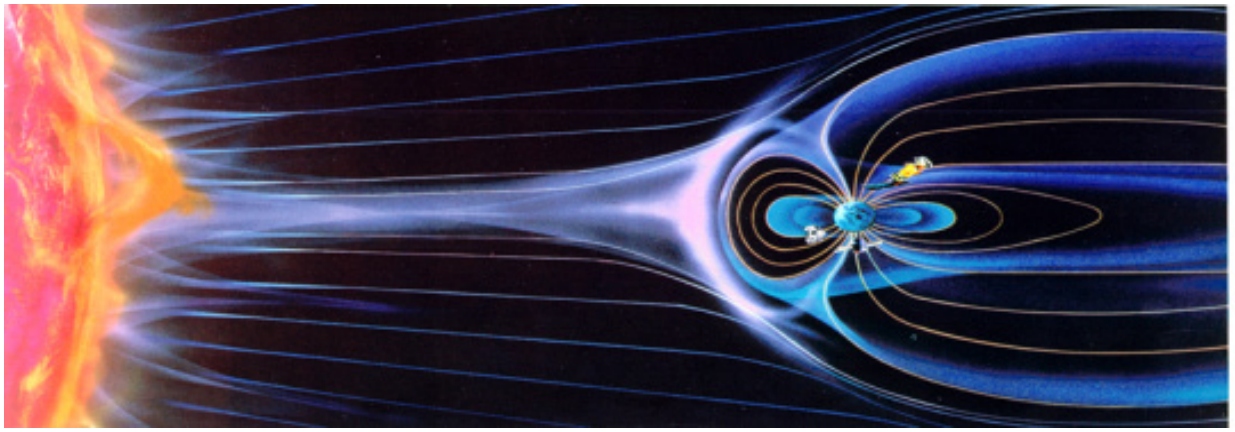
1990-2000's: Institute for Scientific Research

Institute for Scientific Research in 2017

- ~ 40+ employees (+37 R&D/SMEs, 3 Admin)
- Numerous peer reviewed journals (~50/yr)
- National/international partnerships
- 20 active contracts and grants
  - AFRL, AFOSR, DoD, FAA, NASA, NSF, ONR, NRL, INDUSTRY, IARPA, DARPA
  - Basic and applied scientific research
- Offices in Newton and Albuquerqu

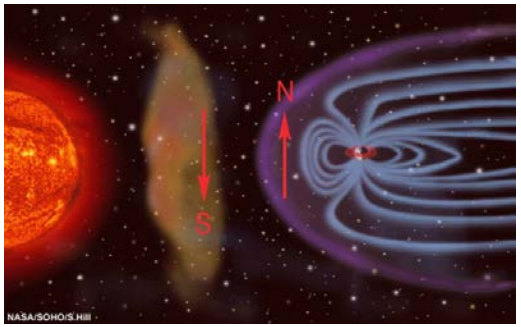
ISR supports the research mission of Boston College to conduct national and international significant research that advances insight and understanding, enriches culture, and addresses pressing social needs. Through our research and workshops, ISR also fosters the intellectual development of young scientists from around the world.

BC's sponsored space R&D - a critical contributor to space systems survivability & military ops.

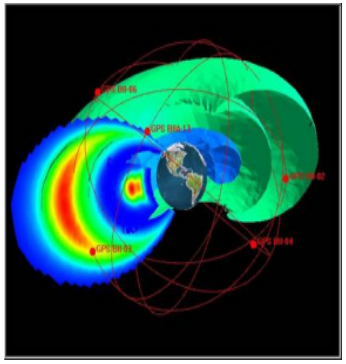


Current/Recent R&D Topics – 1
Support to Air Force Space Programs

- **SPACE WEATHER**
  - Physics of Space Weather Events (R&D)
  - Solar Flares,Van Allen Radiation Belts, HF Propagation
  - Develop AFWA Space Weather Forecast Tools
  - Assess Impact on Comm/Nav/Radar/Geoloc Systems
  - Collect/Analyze Space Environment Data
  - Develop Space Weather Forecasts and Hazards Models
  - Ground- and Space-based scintillation monitoring



- **SPACE AND PLASMA CHEMISTRY LAB SUPPORT**
  - Ion Beam Sources and Mass Spectrometry
  - Investigate Chemical Kinetics in Space
  - Spacecraft Material Deterioration
  - Develop/Test Nano Materials

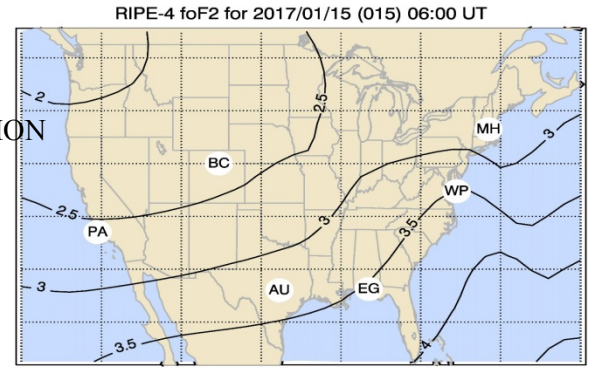


- **SENSOR DEVELOPMENT AND CALIBRATION**
  - Calibrate Satellite Sensors/Instruments
  - Small Satellite Design

Current/Recent R&D Topics – 2
Ionospheric Models for HF Geolocation/Propagation

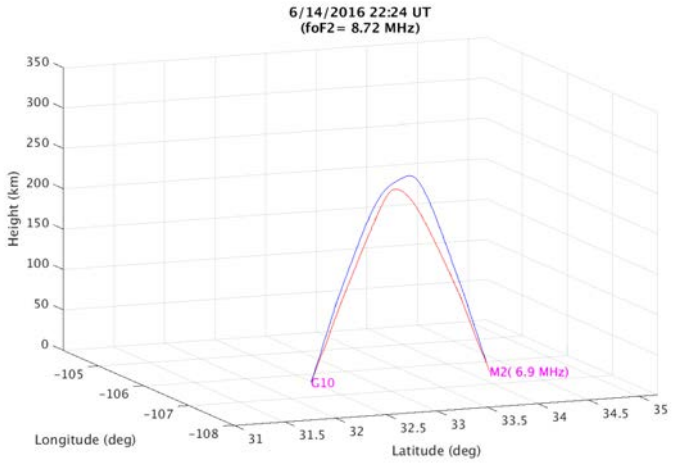
K. Groves, C. Carrano, V. Paznukhov

- **Regional Ionospheric Profile Estimation (RIPE)**
  - Scale IRI parameters based on available digisonde data
  - Interpolate scale factors to generate profiles at desired location
  - Provides background model input to assimilative model



- **Regional Optimal Assimilation Model (ROAM)**
  - Assimilates profiles and angles of arrival (AoAs) to refine ionospheric estimate and infer local gradients
  - Gradients can be shifted in space to account for motion of TIDs
  - Optimization can be applied to both ground-to-ground and ground-to-space HF links; parameters include AoAs, Group Delay and Doppler

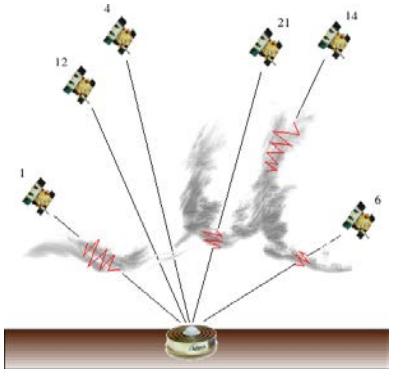
- **Applications**
  - Natural Hazard detection
  - HF Geolocation
  - Trans-ionospheric HF propagation
  - Travelling ionospheric disturbance monitoring
  - Explosion Detection



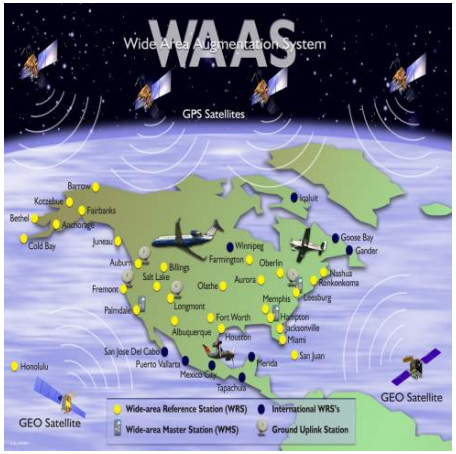
Current/Recent R&D Topics – 3
Space Weather and Ionospheric Effects on GNSS

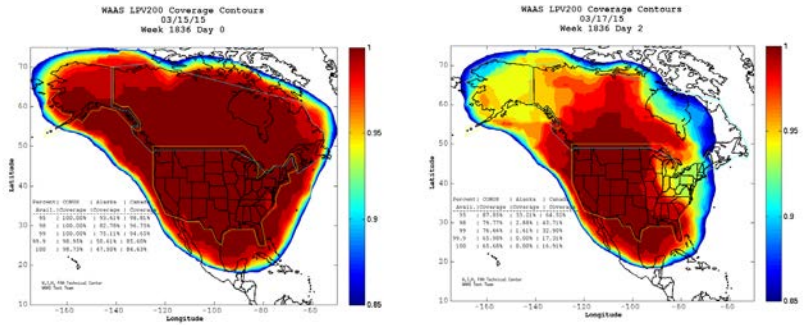
P. Doherty, K. Groves, E. Yizengaw, R. Pradipta

- EFFECTS ON GNSS BASED AVIATION SYSTEMS
  - FOCUS ON NEXT GEN CAPABILITIES
    - MODELING NEW SIGNALS AND CONSTELLATIONS
  - MONITORING SPACE WEATHER EFFECTS ON WAAS SYSTEM DISRUPTION
  - SCINTILLATION EFFECTS ON SBAS/GBAS SYSTEM DISRUPTIONS
  - REPRESENTING FAA ON INTERNATIONAL STUDY GROUP
  - GBAS DEVELOPMENTS AT LOW-LATITUDES

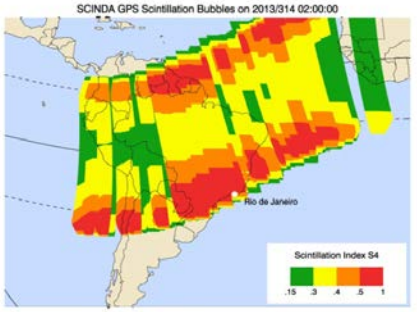


Scintillation Degrades/Denies/Disrupts GNSS Signals





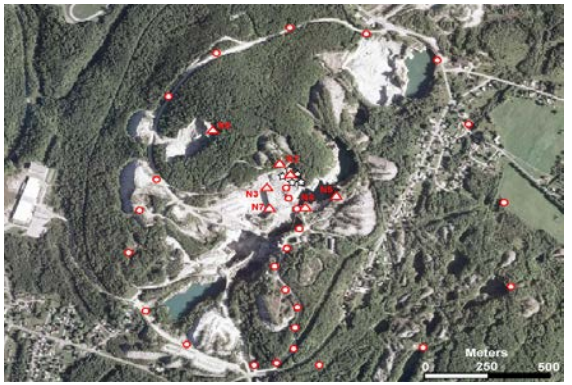
WAAS Availability Before/During Space Weather Storm of 3/17/2015

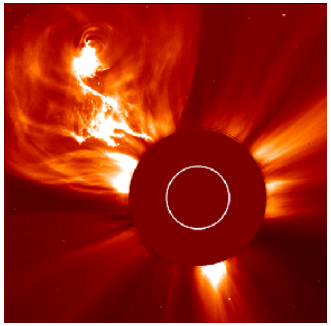


Scintillation Nowcast/Forecast over South America

Current/Recent R&D Topics – 4
Other Topics

- **RADIO-OCCULTATION MODELING**
- DIGITAL SIGNAL/IMAGE PROCESSING
- SOFTWARE DESIGN AND DEVELOPMENT
- SPACE SITUATIONAL AWARENESS STUDIES
- OPTICAL TECHNOLOGIES FOR SIGNATURE EXPLOITATION
- **STEM EDUCATION**
  - GNSS TRAINING LOCAL AND INTERNATIONAL
  - ANNUAL GNSS WORKSHOP FOR DEVELOPING COUNTRIES
  - NASA AND UN SPONSORED
  - COLLABORATION WITH ICTP, TRIESTE, ITALY
- DATA BASE MANAGEMENT (GROUND AND SPACE BASED)
- **HIGH PERFORMANCE COMPUTING, DMSP DATA MANAGEMEN**

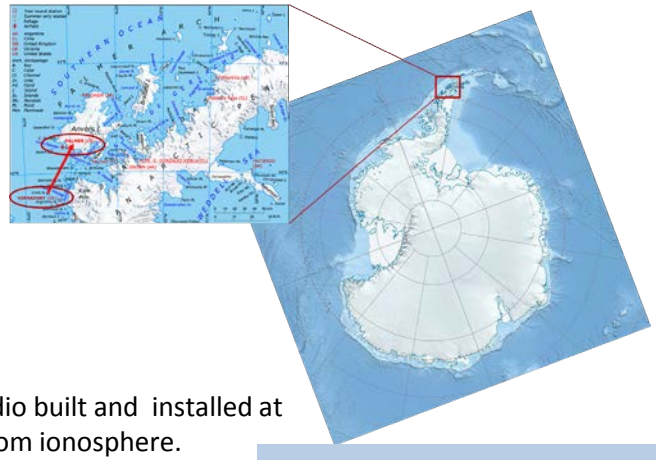


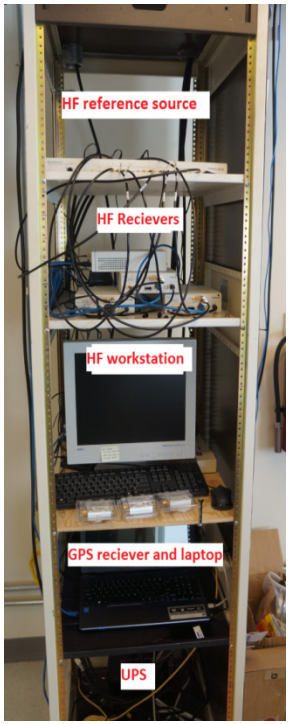


BC/ICTP GNSS Workshop

TID observations in Antarctic Peninsula region: Dr. Vadym Paznukhov

Drake Passage in Antarctica generates severe tropospheric waves, i.e., it is associated with cyclones, convective plumes, enhanced zonal winds, orographic waves, etc. This makes it a very good candidate for studying tropospheric-ionospheric interaction and propagation of the weather disturbances from the ground level to the ionospheric heights.



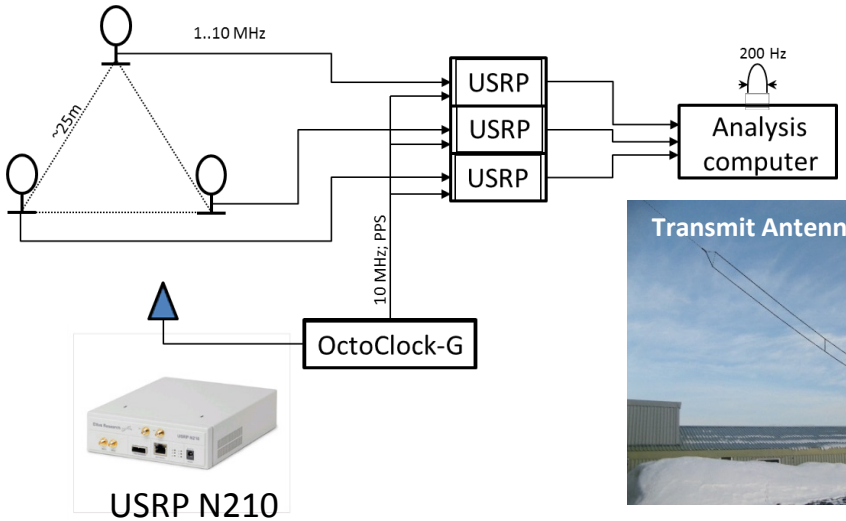


Bistatic HF System

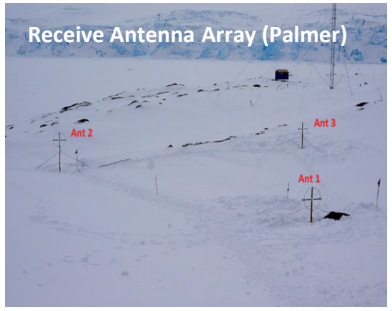
- Three-channel HF receive system based on software-defined radio built and installed at Palmer Station to measure parameters of HF signals reflected from ionosphere.
- Transmitter is installed at Vernadsky station (50 km due south).
- Raw data (decimated IQ samples) shipped by sea to Boston College

Parameter	Value	Comments
Operating frequency	2-10 MHz	appropriate for the location
Radiated power	< 50 W	CW
Output sample rate	100 Hz-1 kHz	reduces data storage requirements
Input Rx Impedance	50 Ohm	compatible standard
Operating system	Linux	real-time system

By measuring the parameters of the ionospherically reflected HF signal it's possible to monitor and to measure the characteristics of TIDs



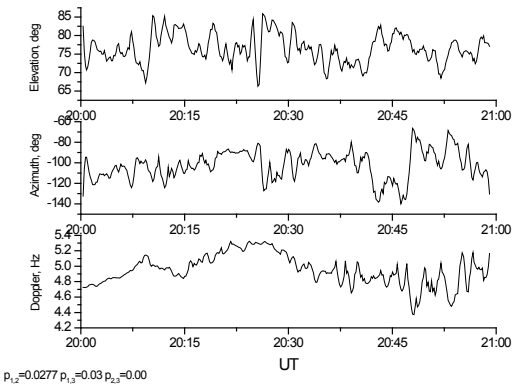
Three channel coherent HF receive system together with GNSS receiver

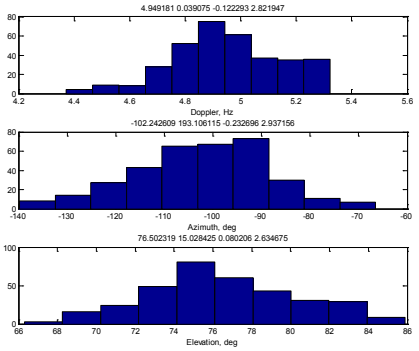


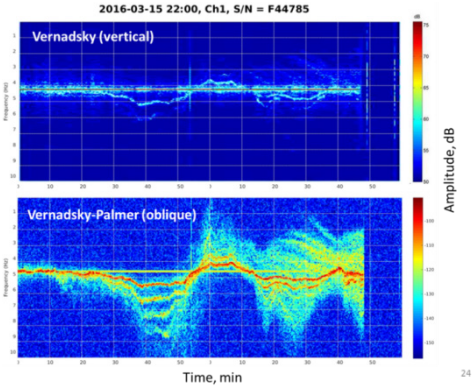
Transmit and receive antennas

First results of TID observations (V. Paznukhov, K. Kraemer)

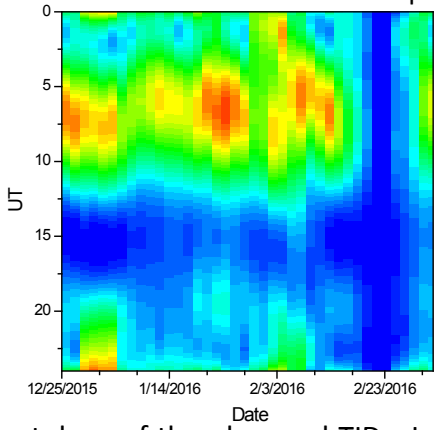
Disturbances in the ionosphere (e.g., TIDs) affect the propagation of the HF radio waves. By measuring the parameters of the ionospherically reflected HF signal it is possible to monitor and to measure the characteristics of TIDs. Here the Frequency and Angular Sounding (FAS) method is used, e.g., Paznukhov et al., ASR, 49, p.700-710,2012.

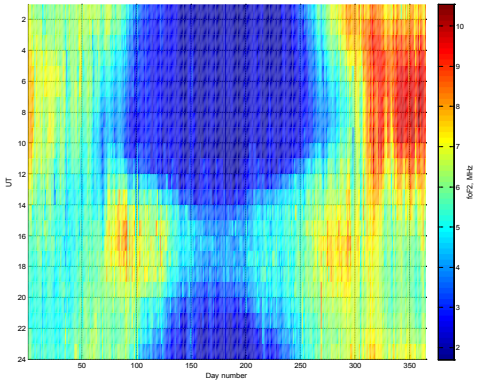


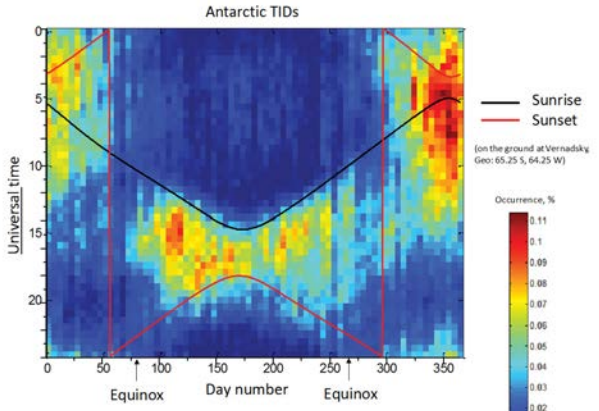




Examples of the measured signal characteristics. Left: Doppler shift and AoA signal variations recorded in the oblique sounding mode on December 1, 2015. Center: Calculations of the statistical distributions of the measured AoAs and Doppler shift make it possible to implement several quality controls (correlation between azimuth and elevation; symmetry of the AoA histograms). Right: Simultaneous measurements at Vernadsky in a vertical mode allow calculation of the north-south propagation speed using Doppler shift measurements only.







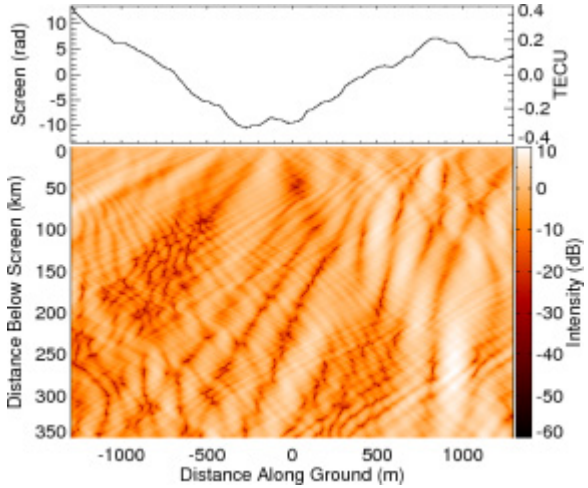
Climatology of the observed TIDs. Left: Intensity of the TIDs measured with the HF sounder during the winter of 2015-2016. Center: Typical plasma density distribution (in terms of foF2) during the year (2012) measured with the ionosonde at Vernadsky. Right: TID climatology measured with GNSS TEC technique during 2011-2013.

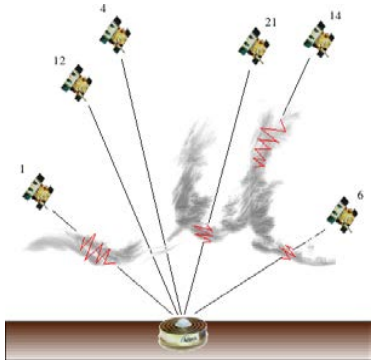
HF observations show that during the Antarctic summer time, *TIDs are predominantly observed during the night time*, when the local peak density is at its maximum (Weddell Sea Anomaly). Such plasma distribution is illustrated with the data from Vernadsky ionosonde. Therefore, TID intensity is directly proportional to the background plasma density. It is also worth noting that HF measurements show more disturbances during the night time.

Ionospheric Scintillation: Dr. Charles Carrano

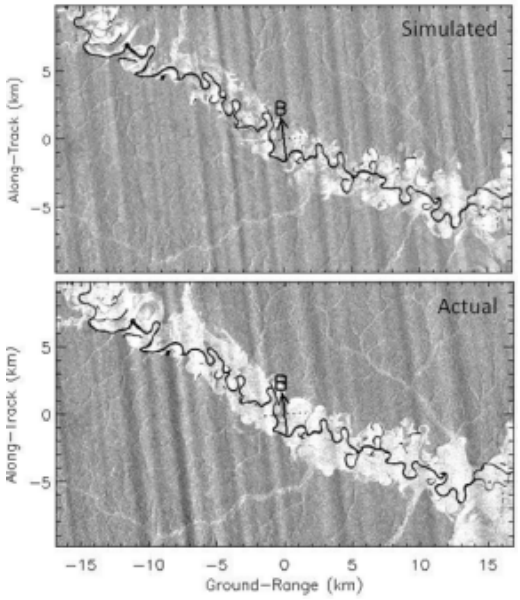
BOSTON COLLEGE ISR INSTITUTE FOR SCIENTIFIC RESEARCH

- **Scintillation Monitoring and Impacts on Systems**
  - GNSS (GPS, GLONASS, Galileo)
  - Beacon satellites (C/NOFS, SSAEM)
  - Radio Occultation (CORISS, COSMIC)
  - Synthetic Aperture Radar (PALSAR)





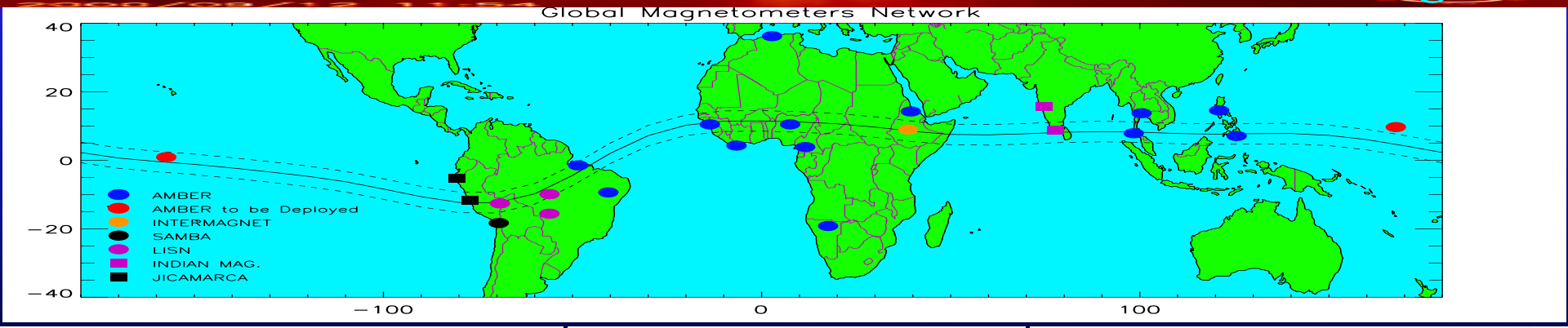
- **High Fidelity Radio Propagation Modeling: Phase Screen, PWE, FPE**

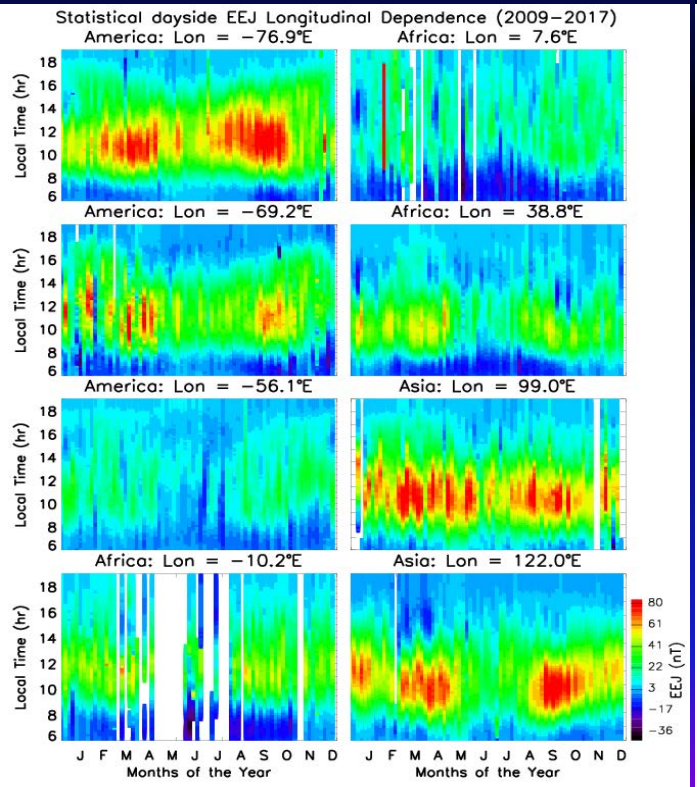


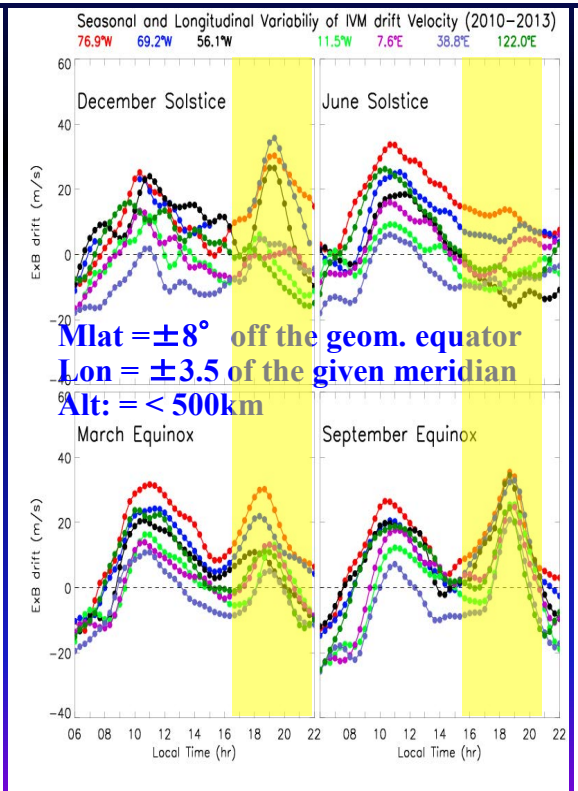
- **Novel techniques to geolocate irregularities, monitor irregularity drift, and characterize plasma turbulence using scintillation measurements**

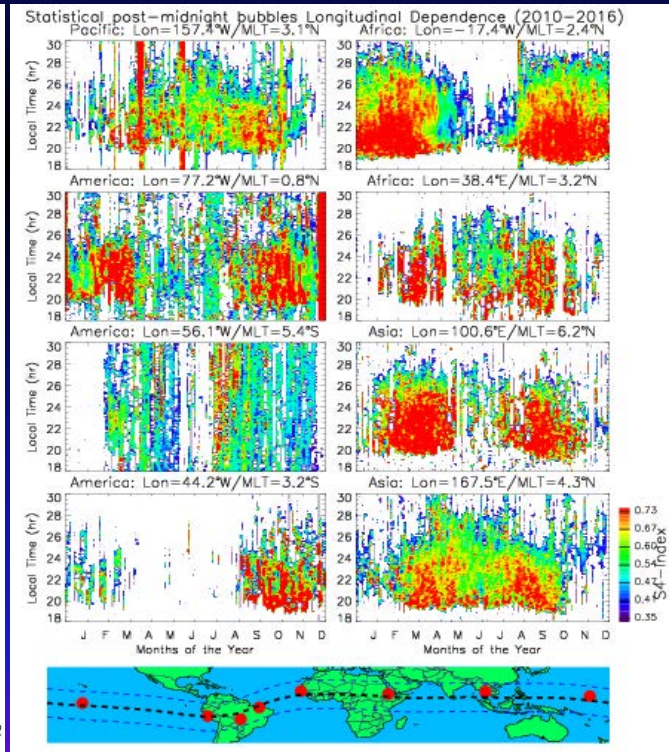
AMBER Network & Longitudinal variability of Dayside EEJ and Drift

Dr. Endawoke Yizengaw







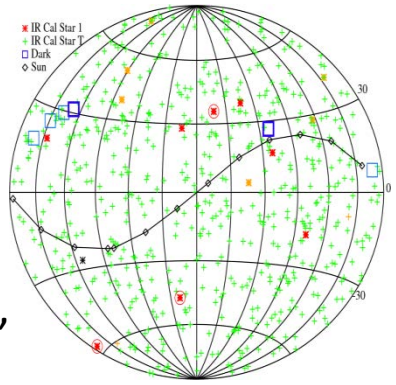


✈ If not the drift, then what controls the longitudinal variability of bubbles?

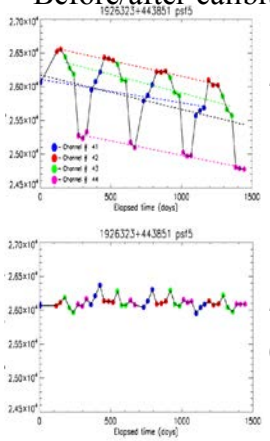
Astrophysics : Dr. Kathleen Kraemer

- Sensor Calibration – all-sky network of calibration quality spectra for 700+ spectrophotometric stars that can be used for sensor calibration
- *Part of the JWST calibration working group*
- *Projects to improve calibration of Spitzer, Kepler, ISO, MSX*, AF & DoD assets

Distribution of calibration stars



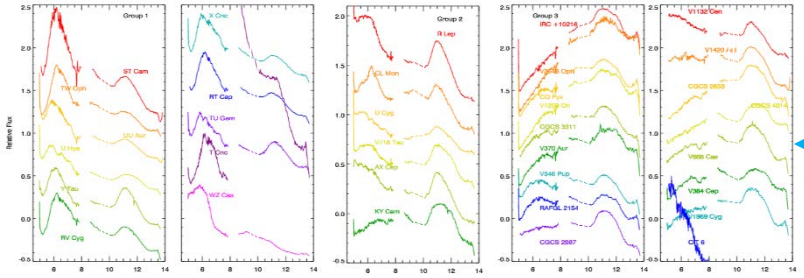
Before/after calibration for star



Kepler FFI raw

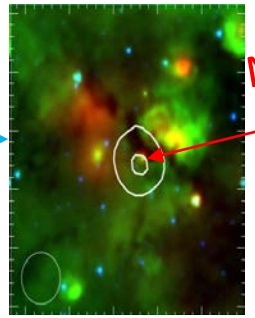
Kepler FFI corrected

Carbon-rich chemistry in Galactic evolved stars from ***SOFIA***



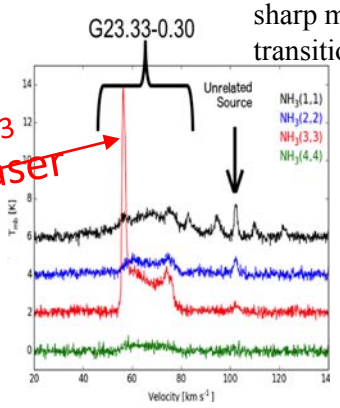
- Stellar Evolution: old stars & planet. nebulae
  - Variability, optical, IR, long & short period
  - Dust & molecule production & chemistry
  - Chemical enrichment of the Universe

- Star Formation (SF) – near & far
  - IR photometry+spectroscopy: dust & gas
  - Radio (cm, mm, submm) masers
  - Redshift 1-3 ionized gas emission



SF region in the IR

NH_3 spectra inc. sharp maser transition



Kraemer, Kuchar, Engelke, Mizuno

PROFESSIONAL OUTREACH

- Chair, International Beacon Satellite Symposium
  - Premier meeting for Signal Radio Propagation Research and Development
- Chair, Ionospheric Effects Symposium
  - Bridging the gap between research and applications of space weather
  - Focus on propagation effects on government applications and systems
- Chair, International STEM Outreach Programs (GNSS)
- Committee Members/Chairs:
  - AGU, ION, URSI, USRA, IHY, ISWI, LISN
  - International SBAS Working Group
  - International Committee on GNSS (ICG)
  - Past President, Institute of navigation (2012-2014)
  - International Union of radio Scientists (URSI), Chair/Comm G
  - Universities Space Research Association (USRA), Board of Trustee Member

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