

Advanced Data Analysis

FLEET OF EXPLORER WORKSTATIONS

Ivan Galkin and GIRO Software Team

UMass Lowell Space Science Laboratory



22 SEPTEMBER PRE-FORUM SCIENCE DAY

IGF 2025

23-26 SEPTEMBER XVI INTERNATIONAL GIRO FORUM

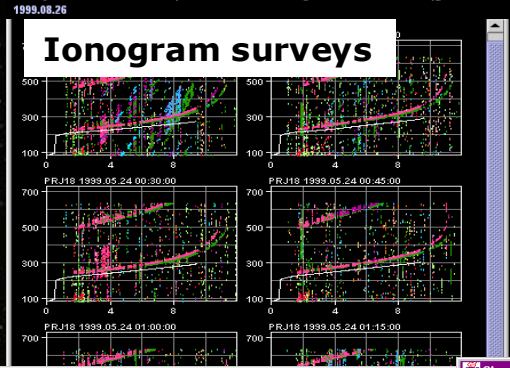
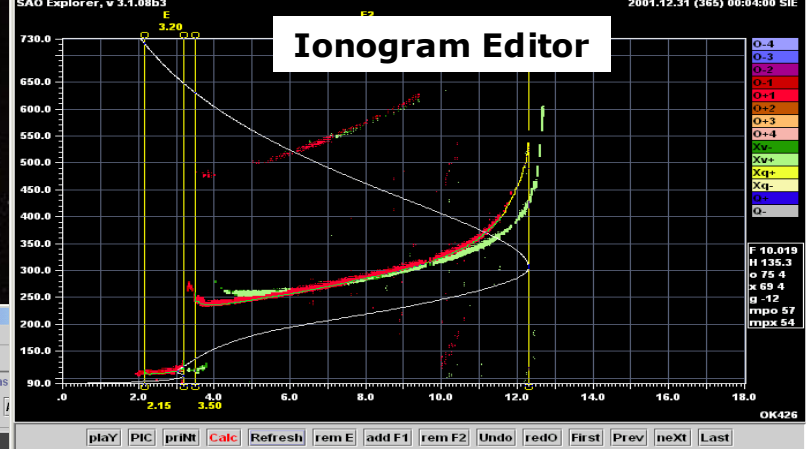
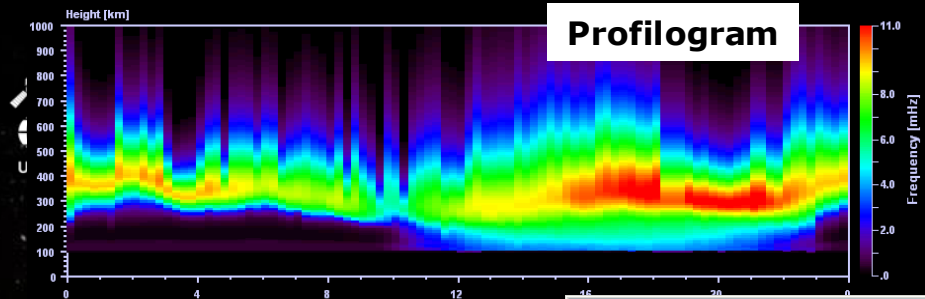
Digisonde Explorers

- SAO Explorer (ionograms)
- Drift Explorer (skymaps and drift velocities)
- GAMBIT Explorer (IRTAM and VTEC)
- TID Explorer (D2D for detection of TIDs)
- DUX (raw spectra/time-domain data in UMS)
- Sky6 (skymap clustering)



Ionogram data analysis:

SAO EXPLORER



Char Table

SAO Explorer v 3.1.08b3 (UMILCAR DIDB is online)

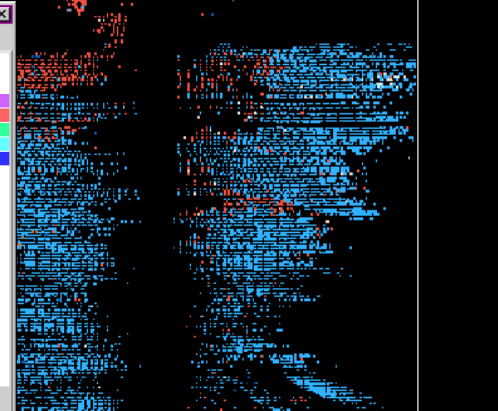
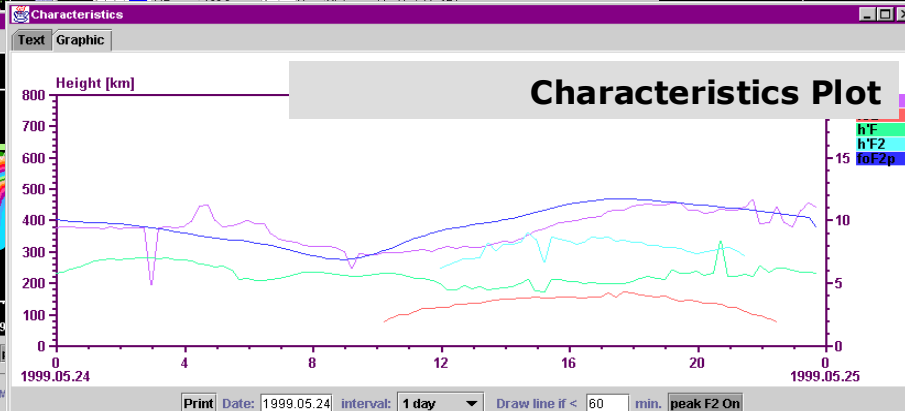
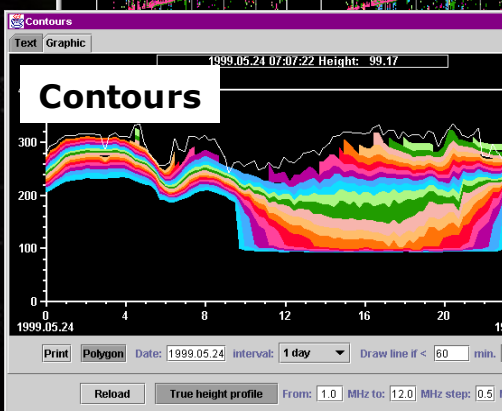
File View Settings Mode

View

Ionogram i 2001.12.31 (365) 00:04:00 SIE

Total records: 1 Station Number: 026 Name: Okinawa Modet DPS-1 URSI code: OK426

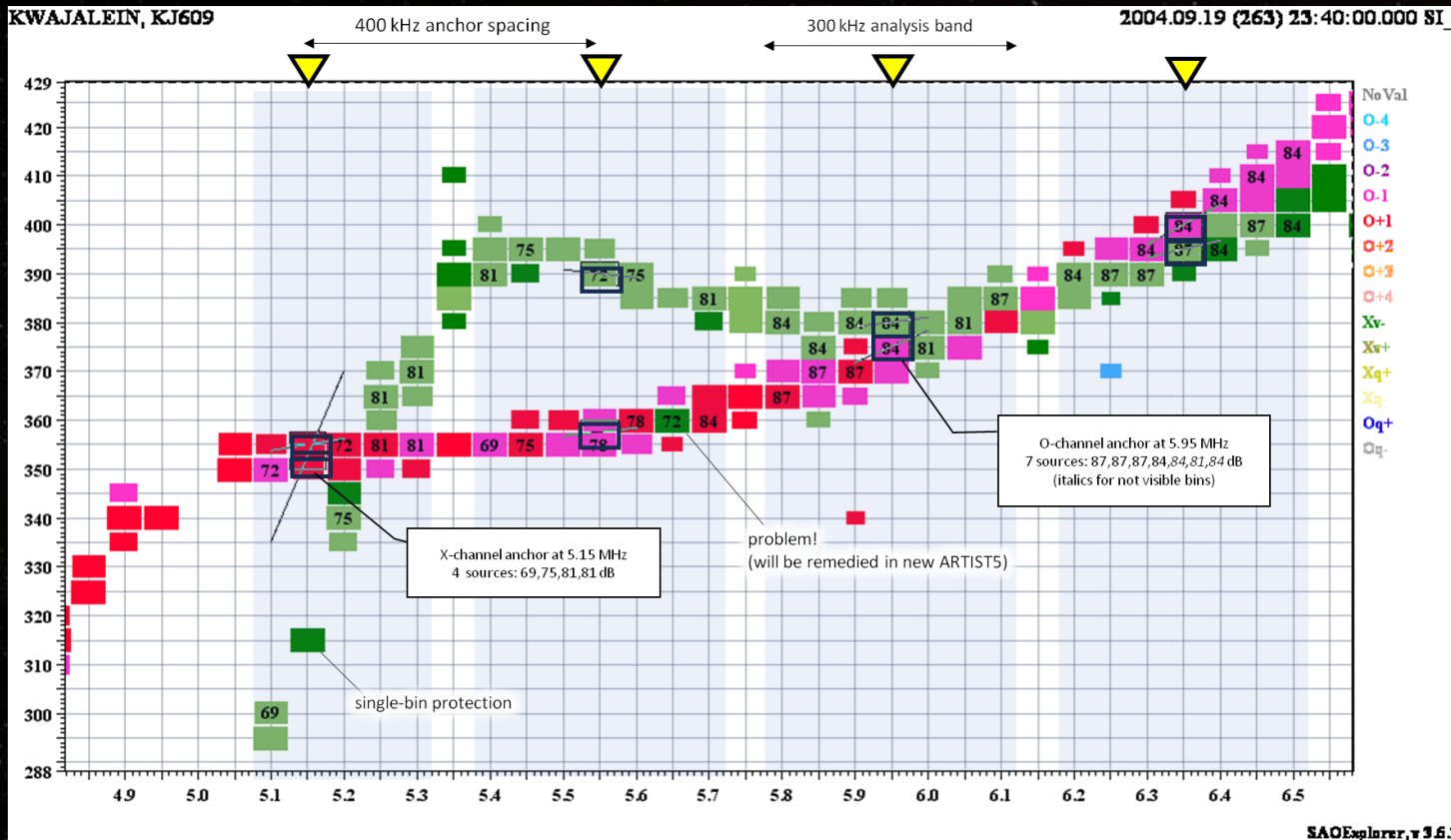
Show	Color	Title	Value	Q	D	Flags	Characteristic description
☒	Blue	foF2	12.300	/	/	EV	F2 layer critical frequency
☐	Blue	foF2p	11.39	/	/	P	Predicted value of foF2
☐	Blue	foF1	NoValue	/	/	V	F1 layer critical frequency
☐	Yellow	foF1p	NoValue	/	/	P	Predicted value of foF1
☐	Red	fminF	3.50	/	/	EV	Minimum frequency of F-layer echoes
☐	Red	foE	3.21	/	/	V	E layer critical frequency
☐	Blue	fminE	2.97	/	/	V	Minimum frequency of E-layer echoes
☐	Blue	fmin	2.15	/	/	V	Minimum frequency of ionogram echoes
☐	Blue	hmf2	305.9	/	/	V	Peak height F2-layer
☒	Blue	h'F2	238.5	/	/	V	Minimum virtual height of F2 trace
☐	Blue	h'F	238.5	/	/	V	Minimum virtual height of F trace



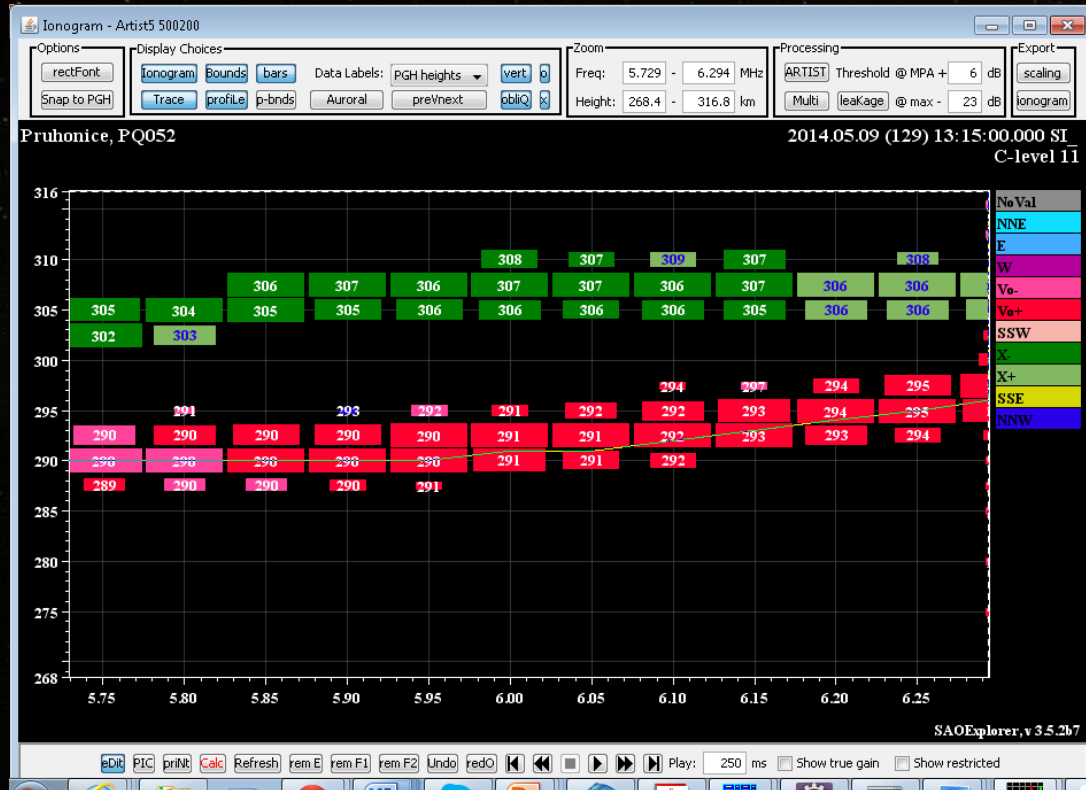
SAO-X New Feature: D-layer

- Comparison of O- and X-polarization amplitudes to glean the D-layer density profile
 - SAO-X to prepare the standard input file for GPSII
 - ARTIST O-polarization trace available
 - Trace points may need manual adjustment
 - X-polarization points are searched automatically
 - In the vicinity of the O-trace point
 - Gradient of $h'(f)$ computed for defocusing estimate

SAO-X New Feature: D-region



Tips and Tricks: Ionogram Mode



- Use shortcut keys
 - W and F10 = Run ARTIST
 - X = next
 - Z = previous
 - C = Run NHPC
 - Use tooltips
- Use Data Labels
 - PGH
- Navigate using keys
 - Arrows
 - +, - and Esc for zoom
- No need to hit “o” exactly to move layer bounds
- Use Right button for Es
- Double click on color legend to change colors

Tips and Tricks: Chars Window

SAO Explorer v 3.1.08b3 (UMLCAR DIB is online - scaler Grigori Khmyrov)

File View Scaler Help

Scaler (DIDBase and SAO.XML)

View List of Records Submit in DIB

Ionogram i Jason Conway 2001.03.31 (090) 00:00:05 SI_ Current

Total records: 96 Station Number: Name: QAANAAQ Model: DGS-256 URSI code: THJ77

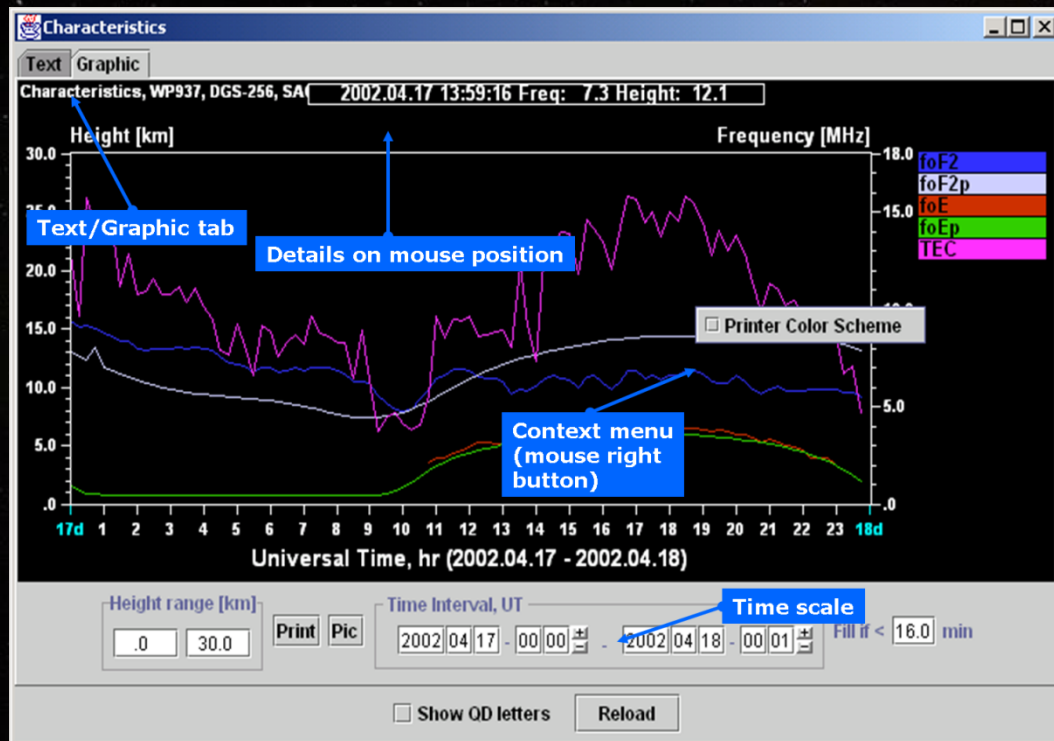
Show	Color	Title	Value	Q	D	Flags	Characteristic description
☒	Blue	foF2	7.700	/		EV	F2 layer critical frequency
☒	Light Blue	foF2p	5.09	/	/	P	Predicted value of foF2
☐	Blue	foF1	NoValue	/		V	F1 layer critical frequency
☐	Blue	foF1p	NoValue	/	/	P	Predicted value of foF1
☐	Blue	fminF	2.90	/		EV	Minimum frequency of F-layer echoes
☐	Orange	foE	NoValue	/		V	E layer critical frequency
☐	Green	foEp	1.38	/	/	P	Predicted value of foE
☐	Blue	fminE	NoValue	/		V	Minimum frequency of E-layer echoes
☐	Blue	fmin	2.90	/		EV	Minimum frequency of ionogram echoes
☐	Blue	hmF2	320.8	/		V	Peak height F2-layer
☐	Blue	h'F	269.5	/		EV	Minimum virtual height of F trace
☐	Blue	h'F2	269.5	/		EV	Minimum virtual height of F2 trace
☐	Blue	h'E	NoValue	/		EV	Minimum virtual height of E trace
☐	Blue	fd	8.70	/		V	Maximum frequency of F trace
☐	Blue	FF	.31	/		EV	Frequency spread between fxF2 and fd
☐	Blue	FE	NoValue	/		V	Frequency spread beyond foE
☐	Blue	QF	15.0	/		V	Average range spread of F-layer
☐	Blue	foP	NoValue	/		V	Highest ordinary wave critical frequency of F region patch trace
☐	Blue	QE	NoValue	/		V	Average range spread of E-layer

List of records

Ionospheric characteristics set.
Drag and drop to change order.

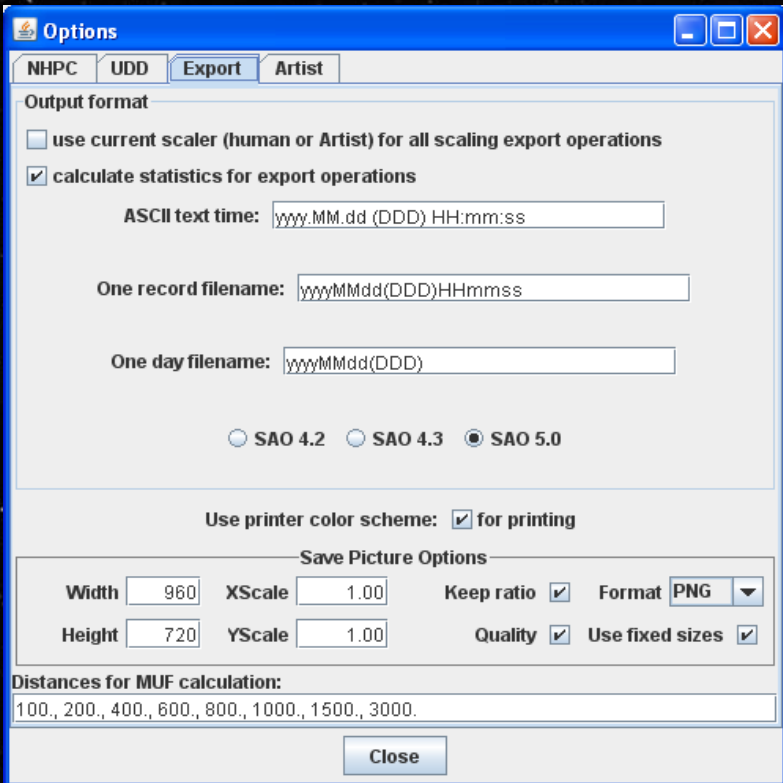
- Drag and Drop to rearrange the order of chars

Tips and Tricks: Time Series



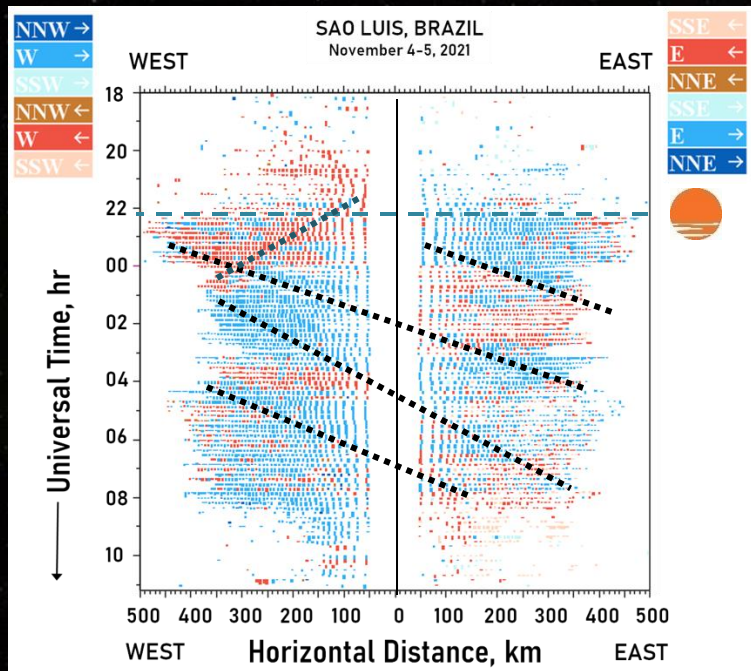
- Use Fast Chars from DIDBase for fastest access

Tools and Tricks: Figure Making



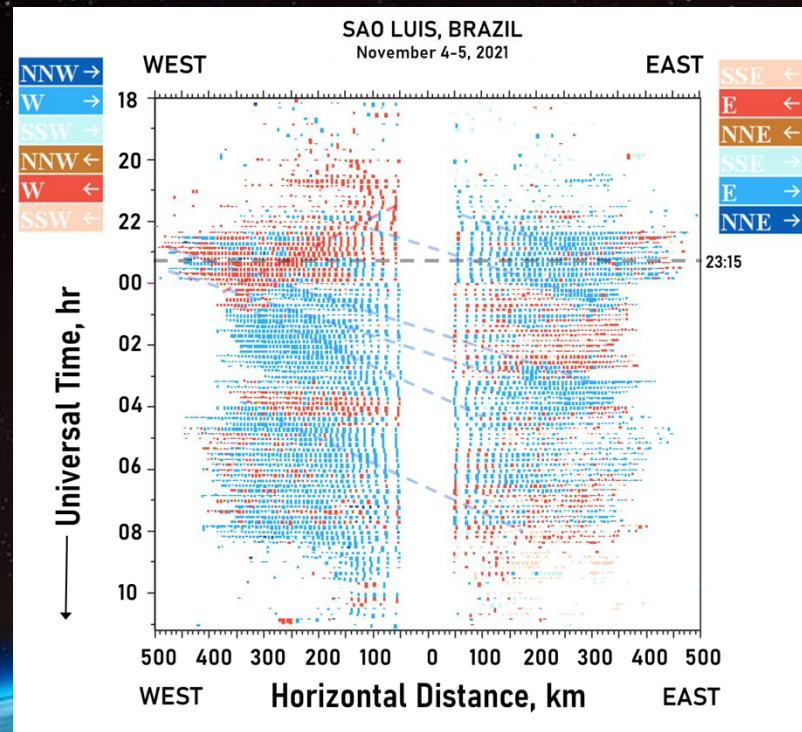
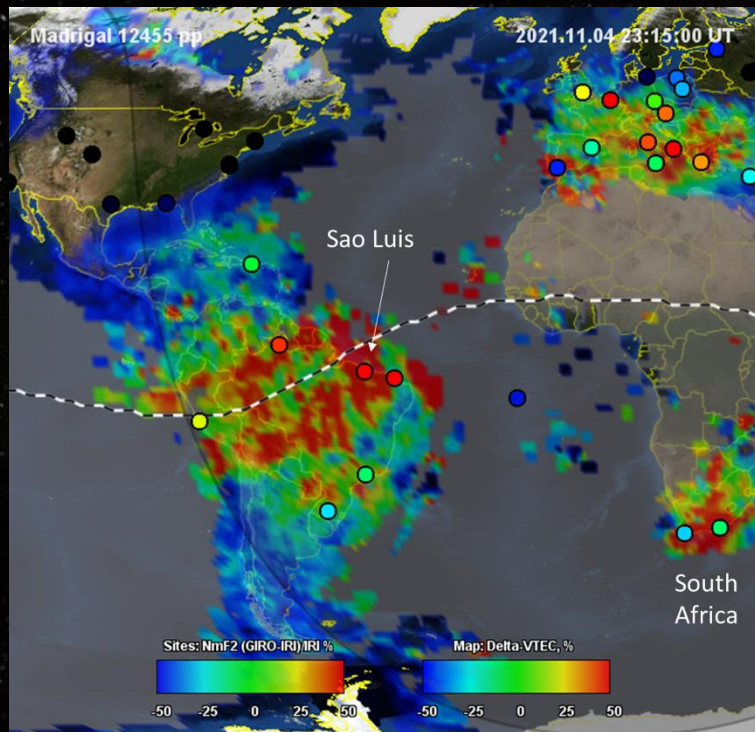
- No need to use Option window to change file format
 - Just put needed extension to the filename: .PNG, .JPG, .BMP
- Best quality for publications: EPS
 - Use a **small** window size and EPS format, edit in Adobe Illustrator
 - Alternatively, use a **small** window size, PNG format, and double the X and Y scales

Tips and Tricks: Directogram



- Good for ESF research
- What can be done better?
 - Select primary axis (currently only W-E)
 - Plot sunset time (currently use “i” button)

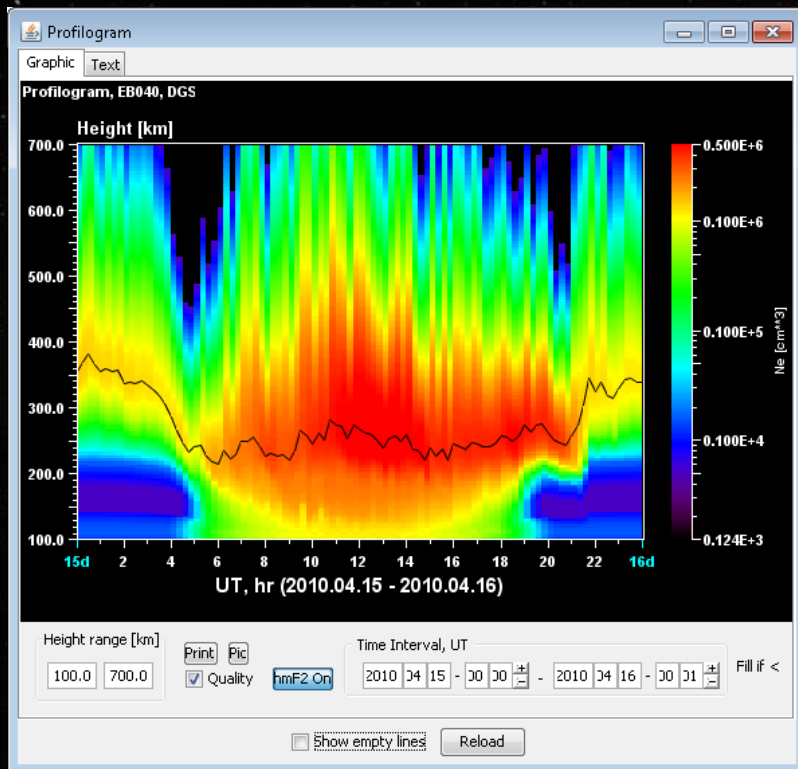
Hi-res VTEC and Directogram



VTEC data courtesy of Anthea Coster, MIT Haystack Observatory

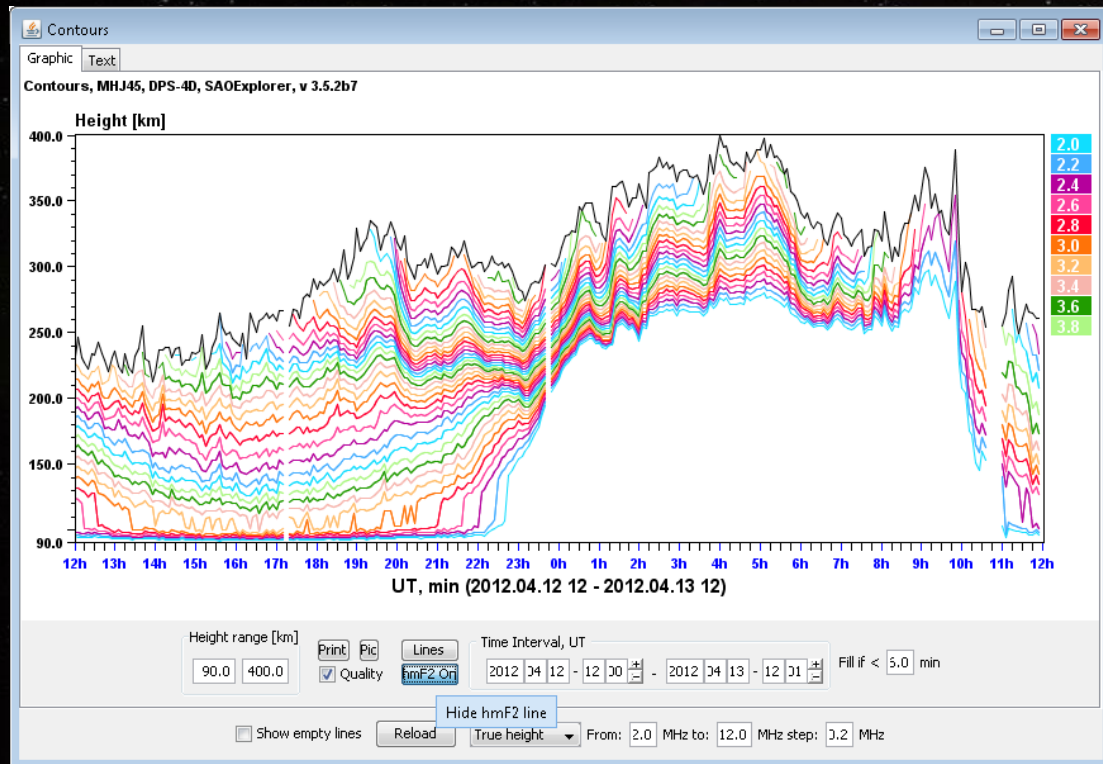
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Tips and Tricks: Profilogram



- Add hmF2 to visually separate bottomside (observed) and topside (modeled) F2 layer
- Work on ionogram scaling until perfect hmF2

Tips and Tricks: Contours

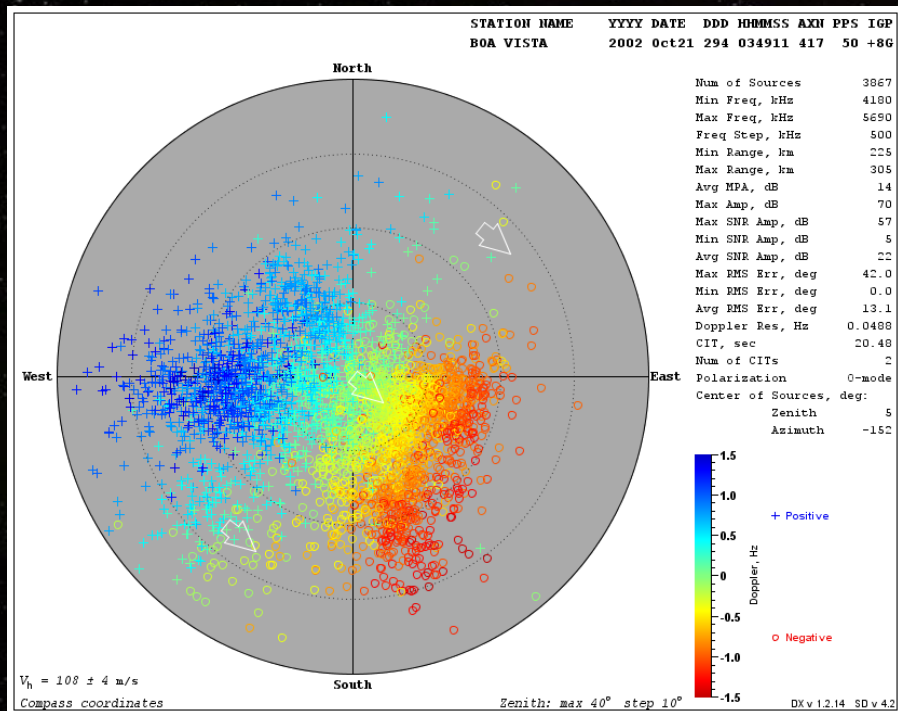


- Try virtual ranges
- Enable peak height

DFT data analysis:

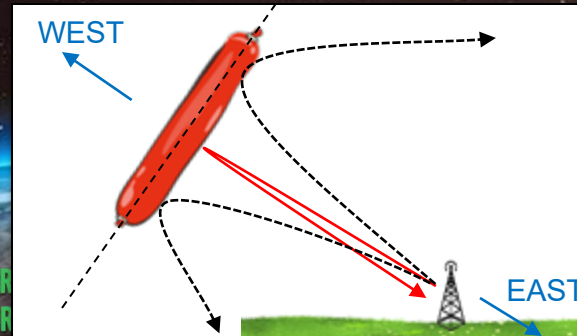
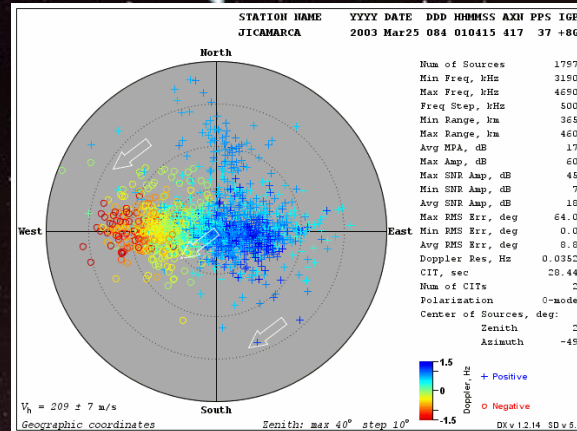
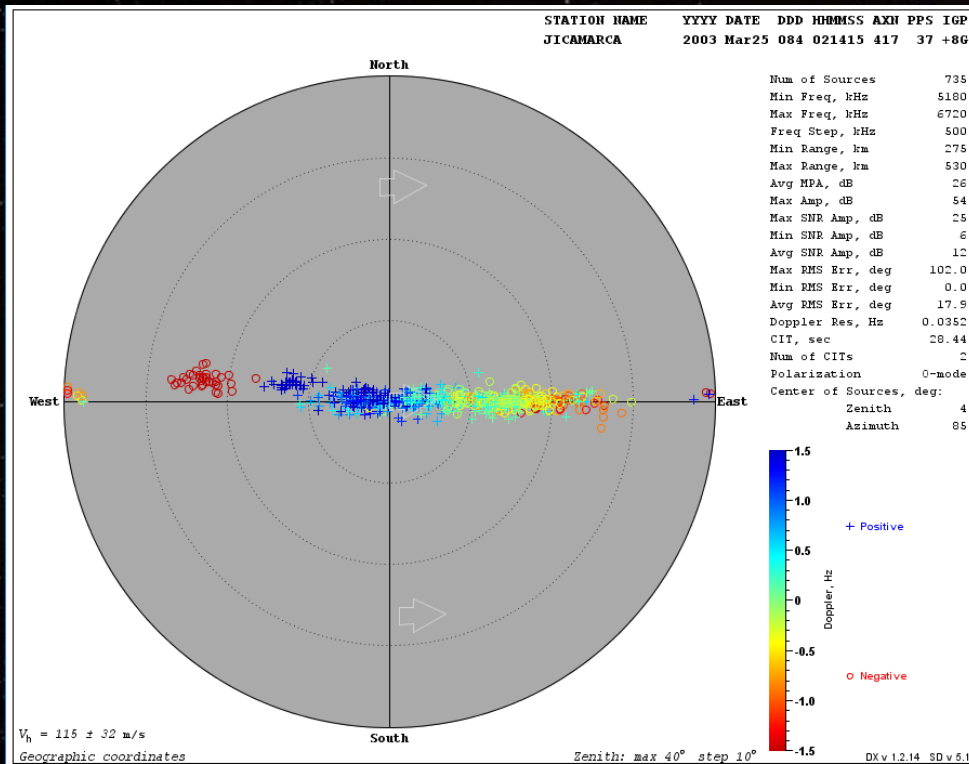
DRIFT EXPLORER

Doppler Skymapping of Ionosphere

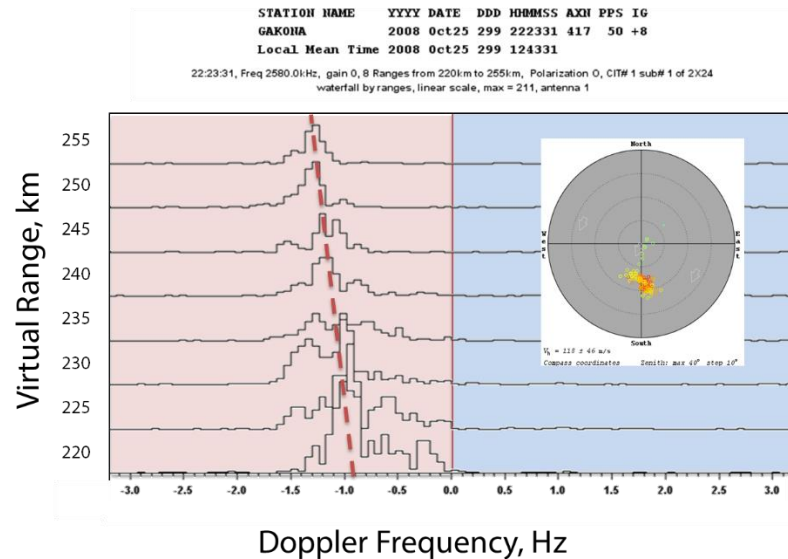
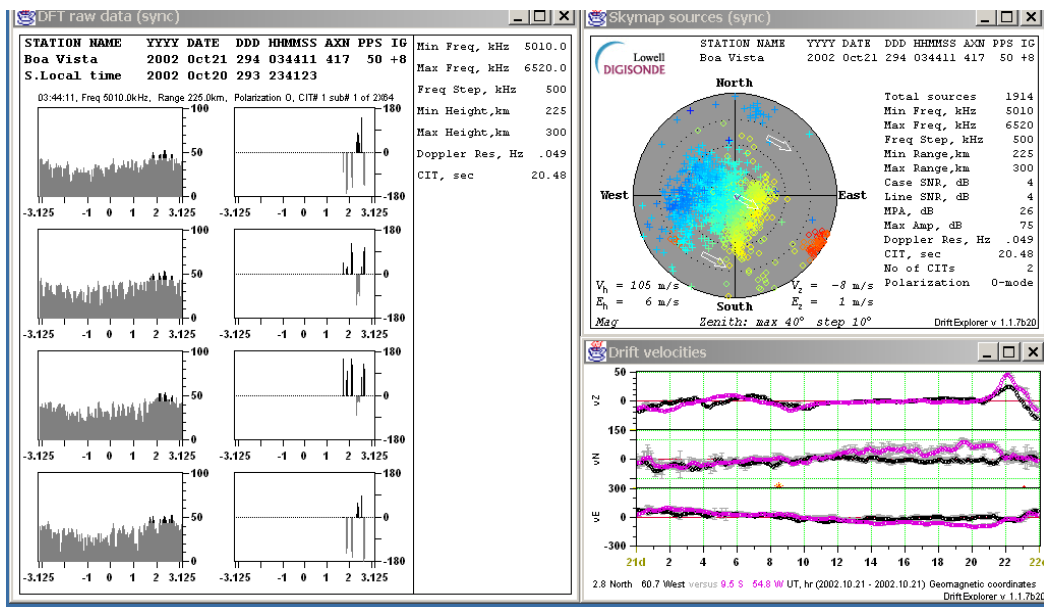


- Digisonde illuminates the entire sky above the station
- If the ionosphere is flat and undisturbed, the only echoes will come from the zero zenith in the skymap center
- Off-vertical echoes are possible if plasma irregularities exist of the right scale and orientation
- Doppler frequency analysis allows determination of the plasma density drift vector

Sausages in the Sky



Plasma Drift and SkyLITE



4-channel DFT data

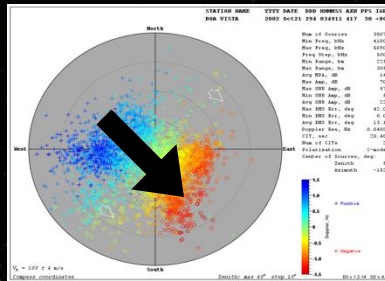
Skymap & Vector Drift Velocity

HAARP Heating Experiment

Two methods for drift velocity

DDA

- Single plane solution is fitted to all skymap sources, resulting in one bulk velocity vector

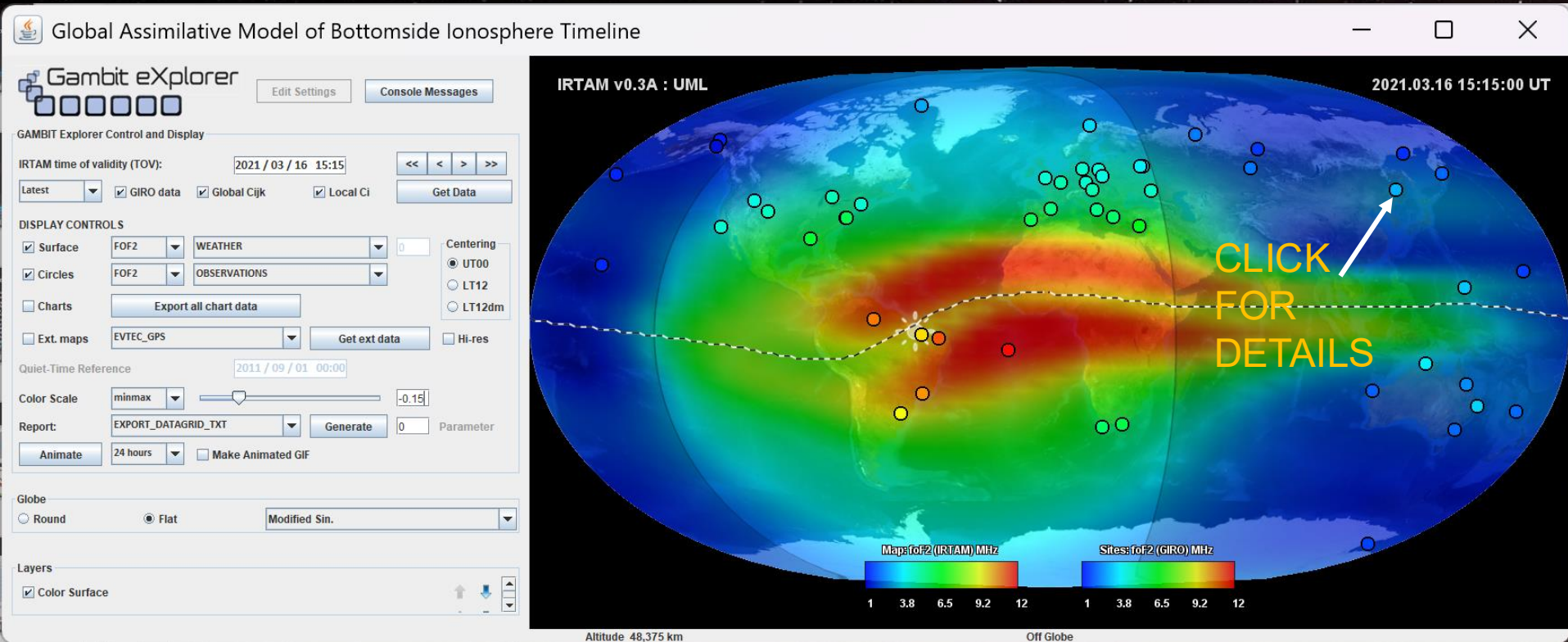


GDDA

- All sources are used combinatorially to form triplets and fit a velocity vector to each triplet. Then a probability histogram of all solutions is built to select most probable solution(s)

IRTAM and Various GNSS products

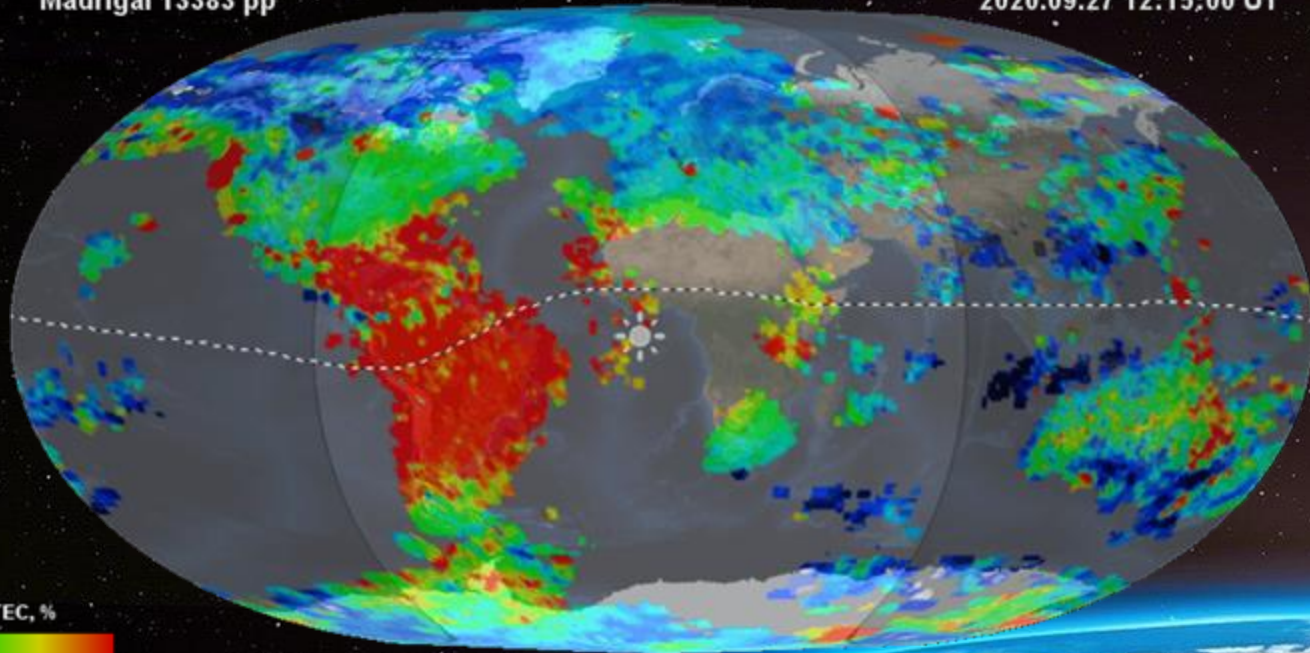
GAMBIT EXPLORER



GAMBIT Explorer: access to GNSS

Madrigal 13383 pp

2020.09.27 12:15:00 UT



Map: Delta-VTEC, %



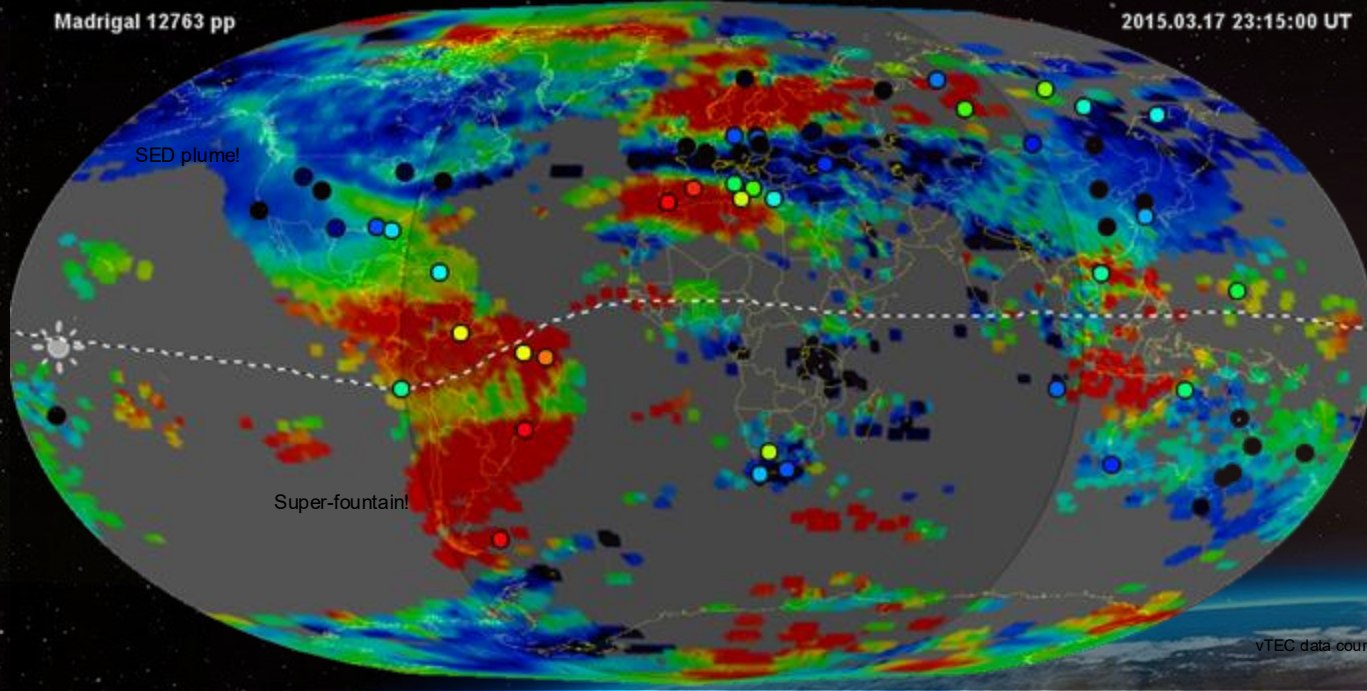
VTEC data courtesy Anthea Coster, MIT Haystack Observatory

Quiet-time reference: 2020.09.23

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Anomaly maps by IGS and GIRO

St. Patrick storm
March 17, 2015 23:15



Gambit eXplorer
giro.uml.edu/GAMBIT

$\Delta N m F 2$ @ 60 GIRO sites



Map: Delta VTEC, %



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$\Delta v T E C$ @ 6342 GNSS sites

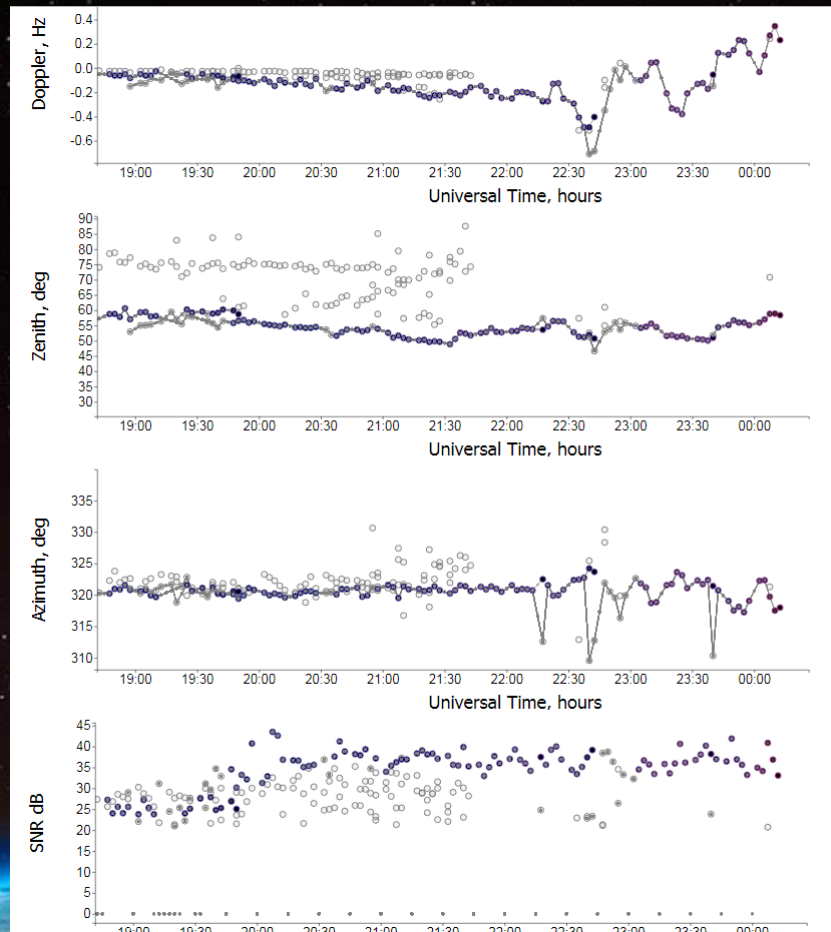
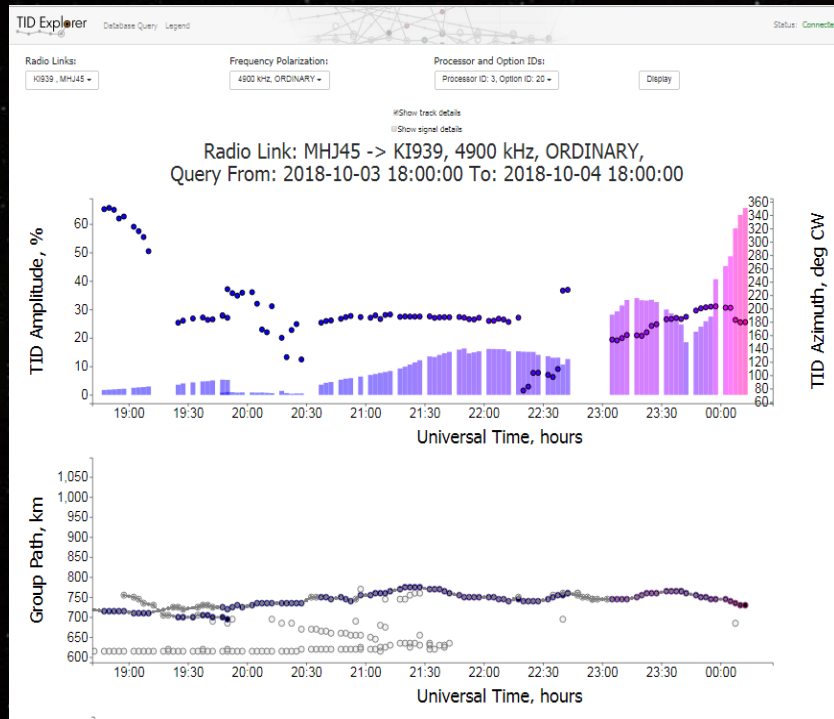
Traveling Ionospheric Disturbances

TID EXPLORER

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TID Explorer

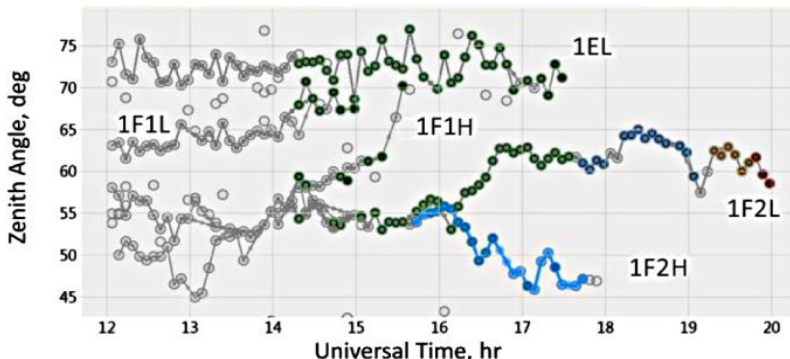
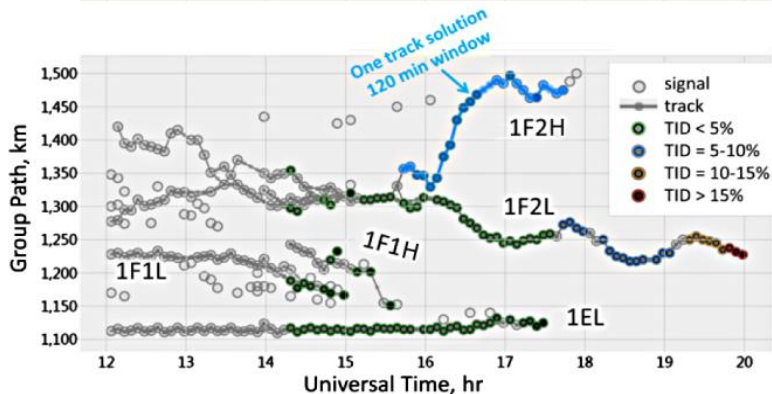
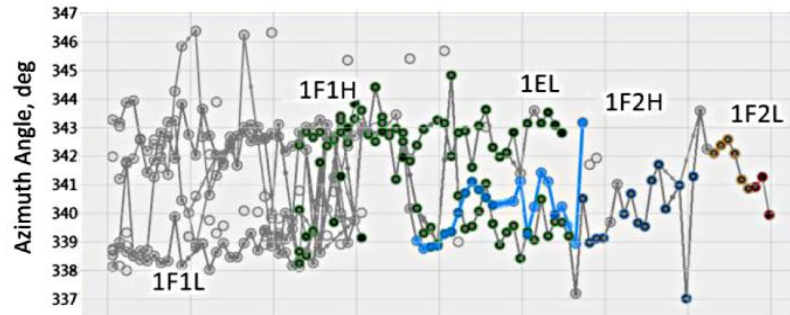
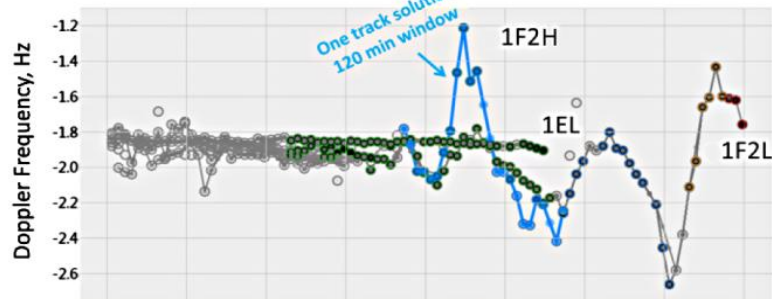
with full-day display capability



D2D Signal tracking

room for improvement

Dourbes to Roquetes D2D April 21, 2017



Other TID Detection scripts

- Textual output for robotic downloads
 - TID Detector output
 - https://lgdc.uml.edu/rix/tid-detector?time=2022.04.28T10&window_min=1200
 - TID Find Tracks
 - https://lgdc.uml.edu/rix/find-tracks?time=2020.04.28&window_sec=100000&rx=EB040&tx=DB049
 - TID Track Info
 - <https://lgdc.uml.edu/rix/track-info?tid=2000>

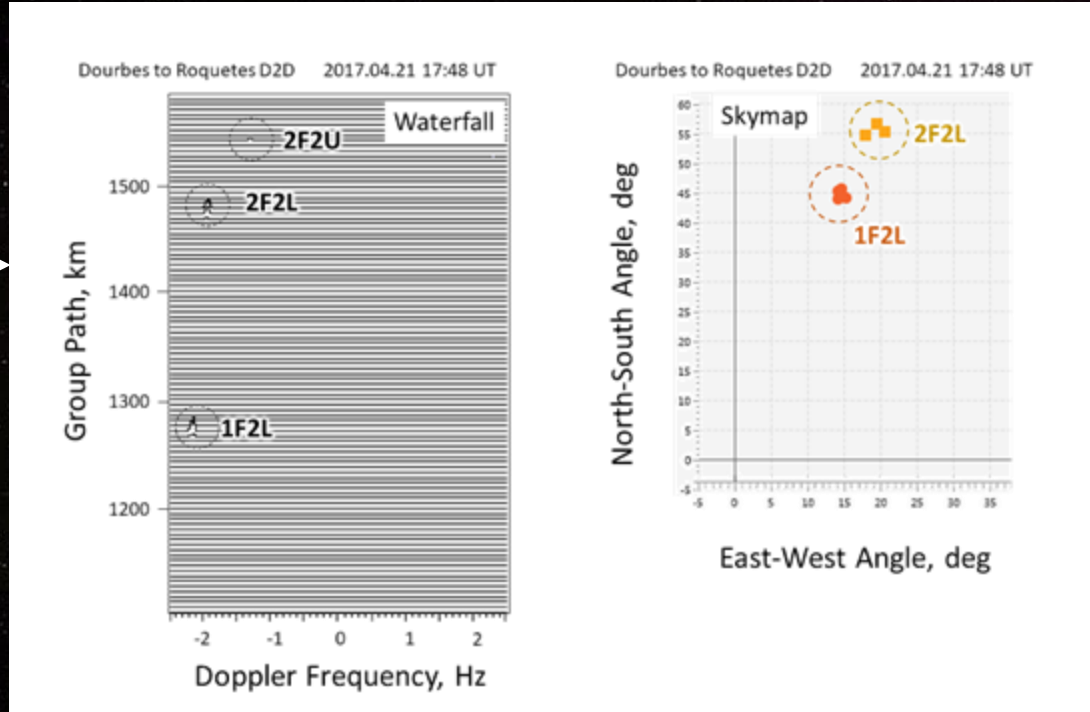


Digisonde UMS Explorer

DUX

Raw D2D data viewer

DUX

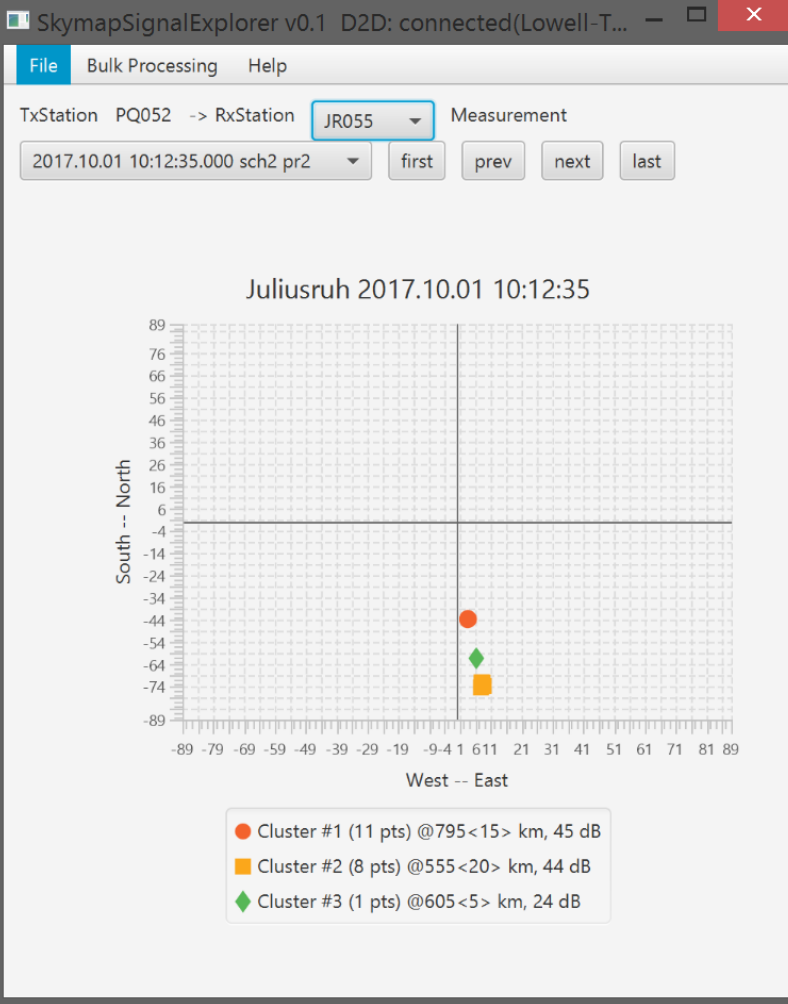


Sky6



Skymap Clusterization Explorer

SKY-CX



- Connects to D2D database
- Calculates AoA and runs clustering
- Cluster information

Options

Skymap Calculator

Maximum zenith, deg: 89.0 Maximum clusters to show: 4

Amplitude Threshold, dB: 21.0 ☒ Use negative dB for MPA

Calculated Azimuth 70.0 delta, deg: 35.0

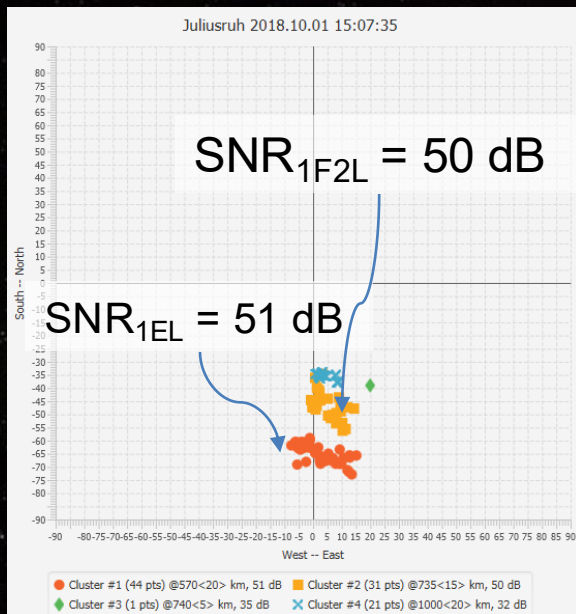
☐ Expected Zenith, deg: 70.0 delta, deg: 20.0

☒ Fit Error threshold, deg: 15.0 ☒ Doppler Line threshold, Hz: 5.0

OK Cancel

128-chip code, 20 sec D2D runs

Radiolink: Pruhonice to Juliusruh



Data credits: Dan Couba and Jens Mielich

- Future work: 128-chip complementary codes
 - Pros:
 - Easy 50 dB of SNR on 500 km links
 - 20 sec running time
 - Cons:
 - Pulse compression leakage, especially on longer links
 - Additional SW work is needed
 - Older DPS4D needs Tx card update

Dalu

감사합니다

Gracias

Danke

Ευχαριστίες

THANK YOU

Obrigado

Köszönöm

Dank

Спасибо

谢谢

Merci

ありがとう

Tack

Grazie

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