Principles of Dynasonde Data Acquisition and Processing

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'Dynasonde' is a generic name for a unique methodology of ionospheric radio sounding which commenced development in the mid '60s at NOAA's forerunner in Boulder, Colorado, the Institute for Telecommunication Sciences and Aeronomy.

Now, there are several hardware options for those who want to install and run a dynasonde system. Three of them have been presented today.

1.NOAA's legacy HF Radars, operating as dynasondes since the early 1980s. (Mike Rietveld's paper)

2.The new fully-digital HF Radar designed and manufactured by Scion Associates Inc. (Dick Grubb's paper)

3.The latest UMLCAR's digisonde model, DPS-4D, allows application of non-digisonde data analysis software and has technical characteristics similar to #2 above. (Bodo Reinisch's paper)

4.The latest versions of Canadian ionosonde, CADI.

With this broadening basis for its applications, the ideological foundation of the dynasonde needs to be explained as largely independent of the hardware choice.

The dynasonde ideology of ionospheric radio sounding has a long history, is complete, is developed in great detail, and, since 2002, provides fully autonomous data processing.

The only other ideology that provides fully autonomous data processing is UMLCAR's *Digisonde*.

Dynasonde ideology has the following distinguishing properties.

Principles of Dynasonde Sounding and Data Processing

- ► The *Radio Echo* is the basic physical object in ionospheric sounding. An echo is defined by at least 6 precisely determined parameters, each with its individual error estimate. There is no use of the artificial notion of “frequency-range bins”.
- ► Group ranges of high precision by the Stationary Phase principle. In short pulse sets the radio frequencies are slightly offset (by 1-4 kHz) from the base frequency in a carefully designed pattern to enable precision range measurements (to within a few tens of meters).
- ► Direct attention to physical properties of the raw data. No Fourier transforms; no pulse coding; no coherent summations. The phase and amplitude of received signals (from raw I & Q) are used directly. Consequence: excellent statistics of recognized echoes. The same echo recognition and characterization process rejects false echoes and noise.
- ► Diverse and sophisticated methods of higher-level data processing. An autonomous classification of the echoes into traces and subsequent inversion procedures are accomplished, based on physics-based criteria rather than by using indirect and subjective procedures (such as image analysis).
- ► Limited impact to other uses of the radio spectrum. No long sequences of pulses at the same base frequency. Instead, short sequences (3 to 8) of narrowband (30 kHz) pulses are used.

In Dynasonde ideology a natural physical object, *the echo*, replaces entirely an artificial notion of the "frequency-range bin" as used by others.

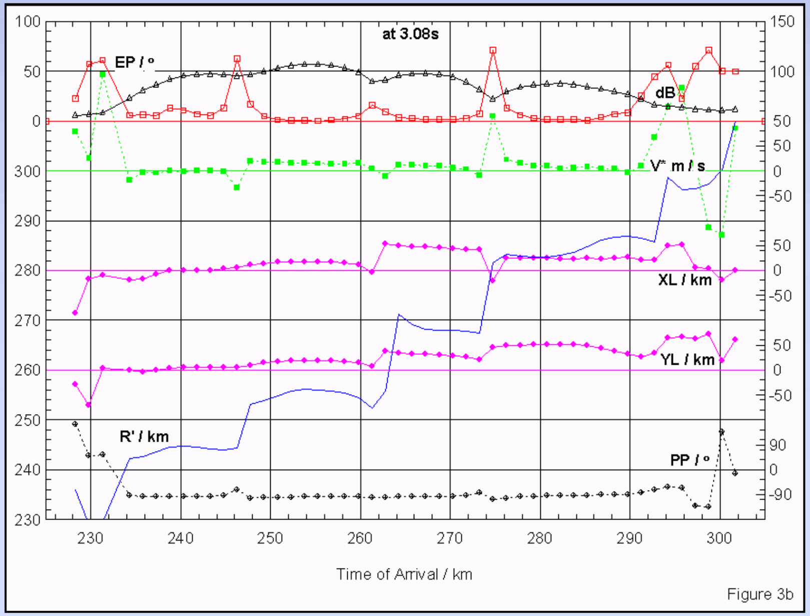


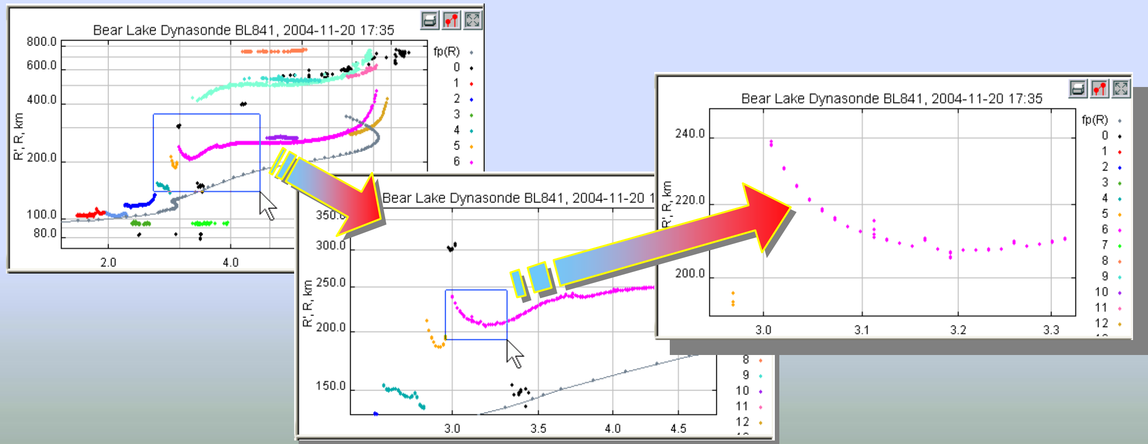
Figure 3b

High resolution of raw I & Q data is carried over to echo physical parameters. Mainly ionospheric roughness determines actual uncertainties. Average values for Tromsø:

Group Range	± 100 m
Horizontal echolocations	± 1 km
Doppler Velocity	± 3 m/s
Polarization	± 1 deg

Zooming (demonstrated below) reveals individual echoes.

The figure above illustrates the phase-based echo recognition procedure performed in time domain. The result is excellent statistics of recognized echoes (up to several thousand per ionogram recording).



The statistical ensemble of echoes, defined by their essential physical attributes, each supplied with its accurate error estimate, provides the basis to accomplish the following tasks:

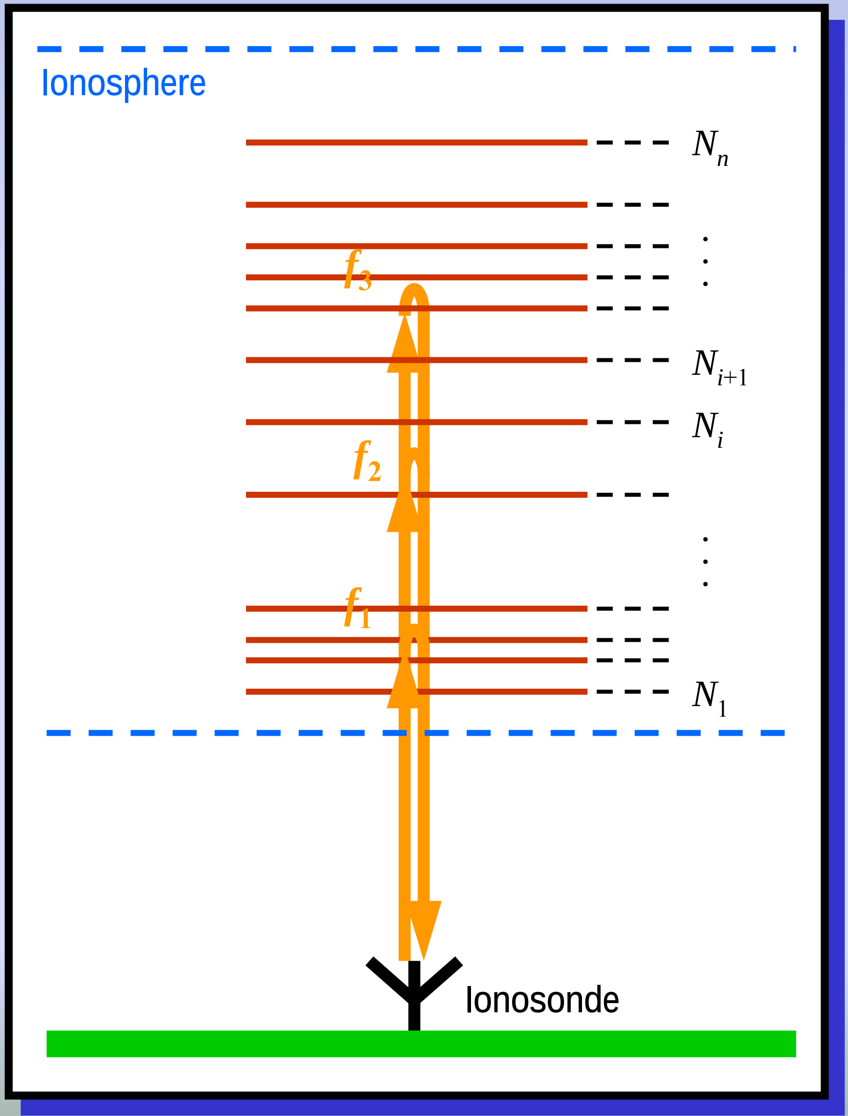
1. Echo classification into traces based on **physical criteria** (not merely upon their approximate position in the ionogram image).

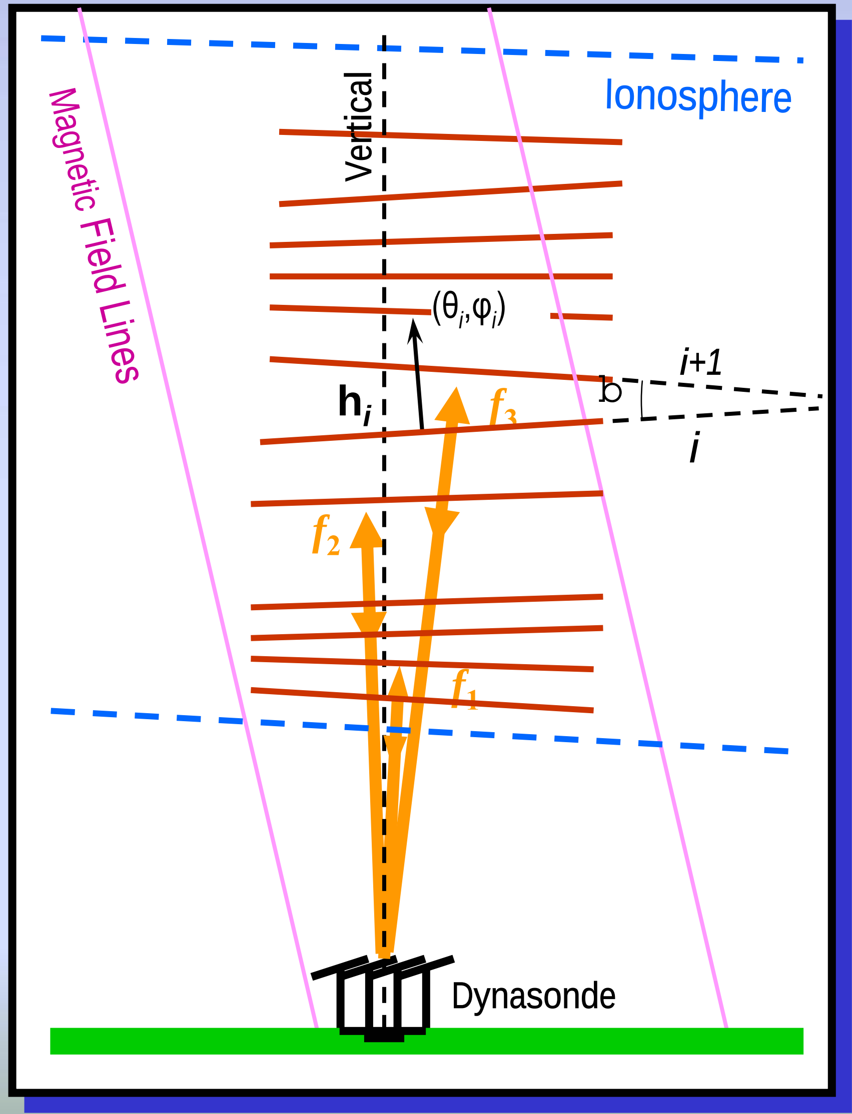
2. Application of high-level routines producing diverse products:

- Standard E, F region parameters;
- 3-D plasma density inversion;
- Vector velocities for plasma-contour movement;
- Quantitative parameters of the km-scale irregularity spectrum.

All products are obtained in **standard** ionogram mode.

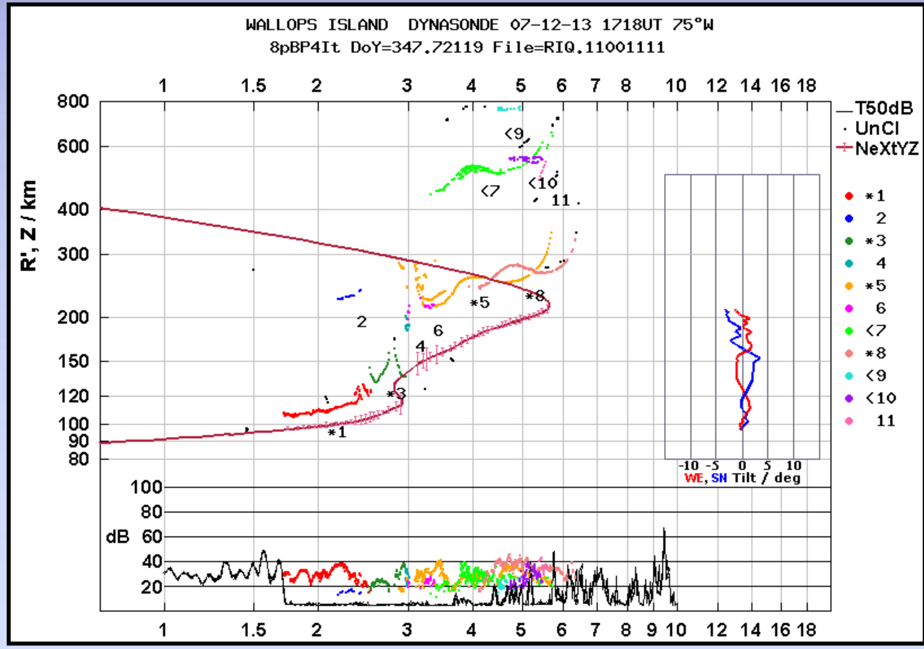
NeXtYZ (“Next Wise”):
3-D Plasma Density Inversion Procedure

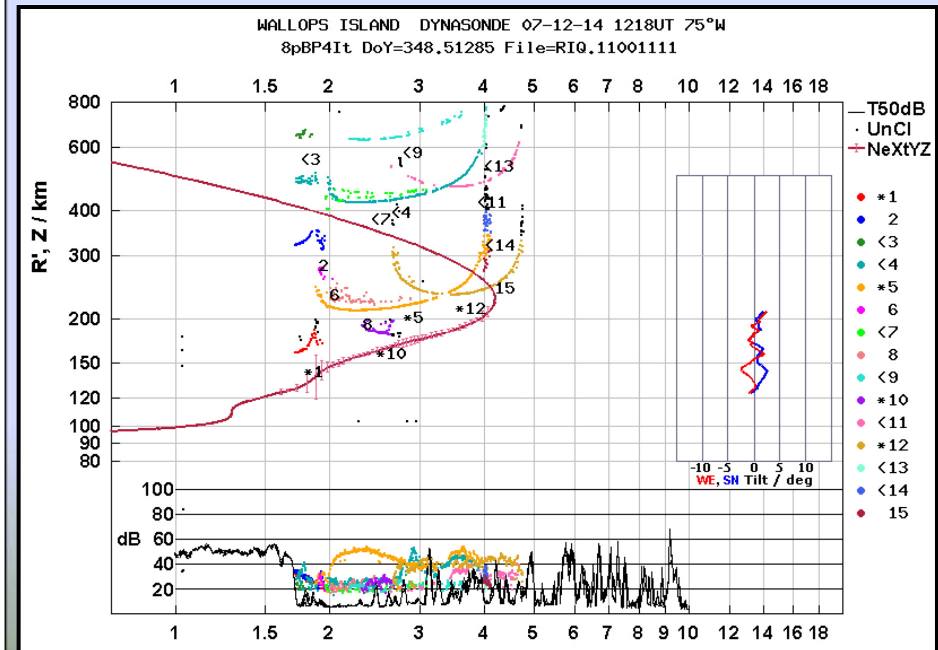


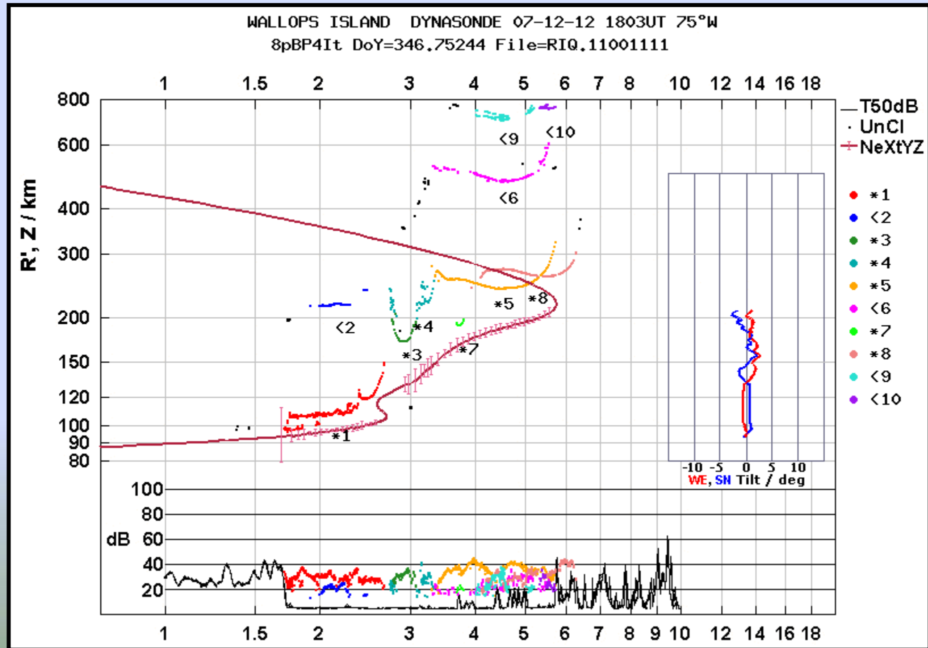


NeXtYZ products as represented in processed ionogram images

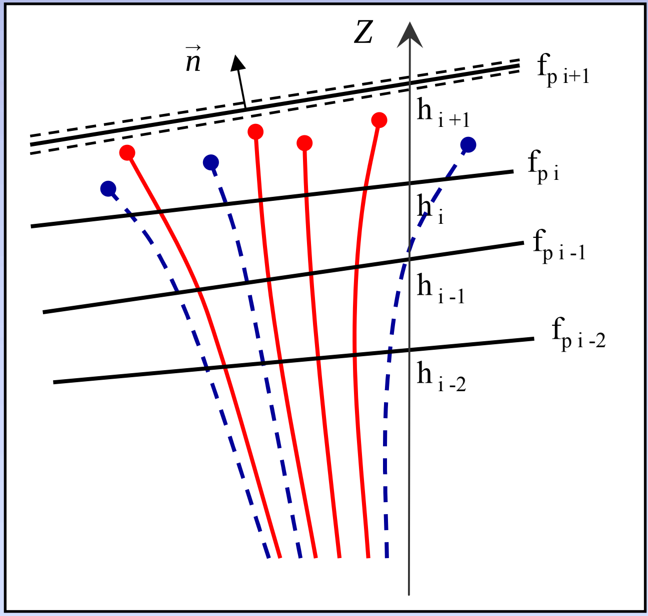
- true vertical profile N(h)
- horizontal gradients
- profile uncertainties
- objective E-F valley & night E







Error bars on electron density profiles by NeXtYZ:

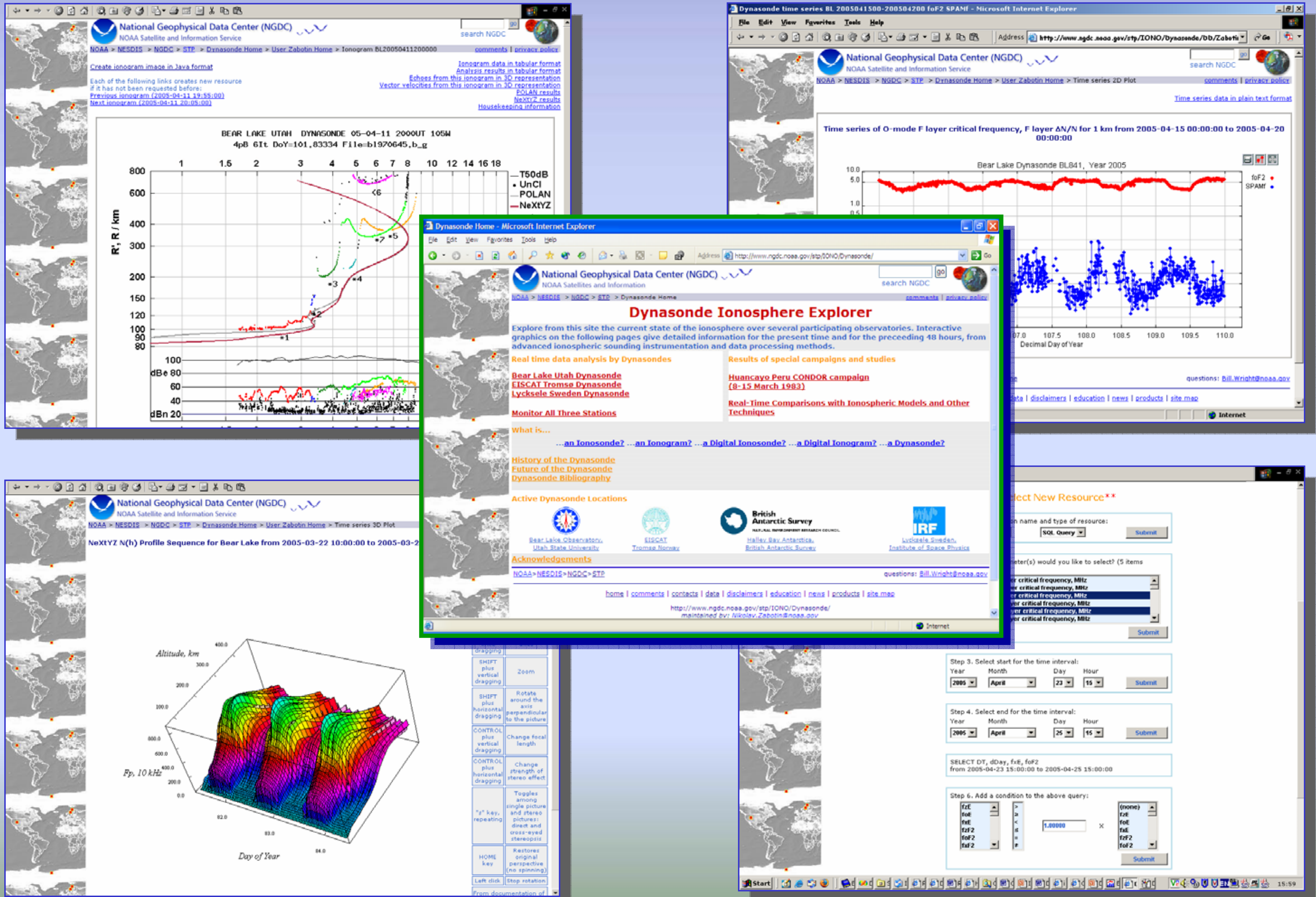


1. Position and orientation of the upper boundary of a wedge is determined by a subset of echoes (usually several tens) that are reflected within this wedge.
2. A least squares procedure minimizes the difference between measured and calculated group ranges and echo-locations.

3. The residual is a statistical characteristic of the local discrepancy between the data set and the solution for the current wedge.

This is **the only available** algorithm that produces profile uncertainties satisfying requirements of Kalman-Filter-based assimilative models.

Dynasonde principles are implemented in Dynasonde 21 Software Suite that has been tested in multi-year real time operation:



Concluding Remarks

1. Scientific and operational customers of advanced ionosonde systems now have excellent hardware and software choices never available before.

2. Dynasonde sounding modes and methods of data analysis may be compatible with your choice of radar hardware.