Ionosphere Equivalent Conversion Methods from Oblique to Vertical using Oblique Measurement Data

Cheol-Oh Jeong [1] (e-mail : cojeong@etri.re.kr), Jin-Ho Jo[1]
[1] Electronics and Telecommunications Research Institute

March 02- 05, 2015

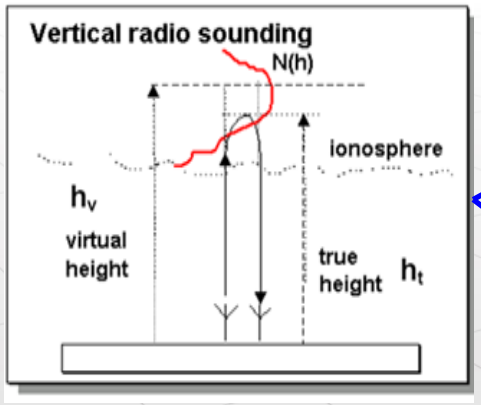
ETRI
한국전자통신연구원

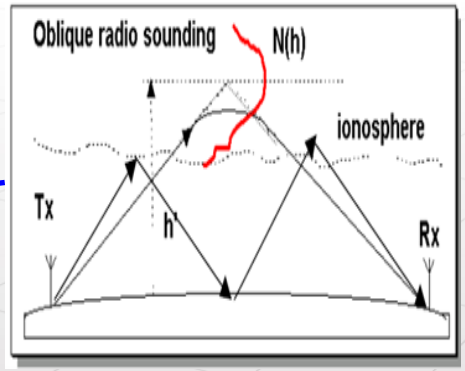
Contents

1. Background
2. Outline of Ionosonde in Korea
3. Development Flow
4. Trace Extraction
5. Trace Conversion from O to V
6. Electron Density & Parameter Extraction
7. Summary

Background (1/2)

- **Korean Space Weather Center(KSWC) of Radio Research Agency (RRA) has function to forecast the space weather like space weather indicators in radio range.**
- **KSWC is performing routine observation of ionosphere using 2 digisonde systems deployed at Jeju site & Ichon site.**
  - Delivers daily ionosphere status information through homepage, e-mail, etc. to users.
- **As a part of KSWC's plan, ionosphere measuring and analysis project was started since January 2013.**
  - to checkup and verify oblique sound mesearing function between two digisondes
  - to make conversion technology from oblique ionogram data to converted vertical parameters at mid point of between two digisondes





Background (2/2)

☐ **The project was performed by ETRI funded by KSWC for Developing Ionosphere Measuring and Analysis Technology**

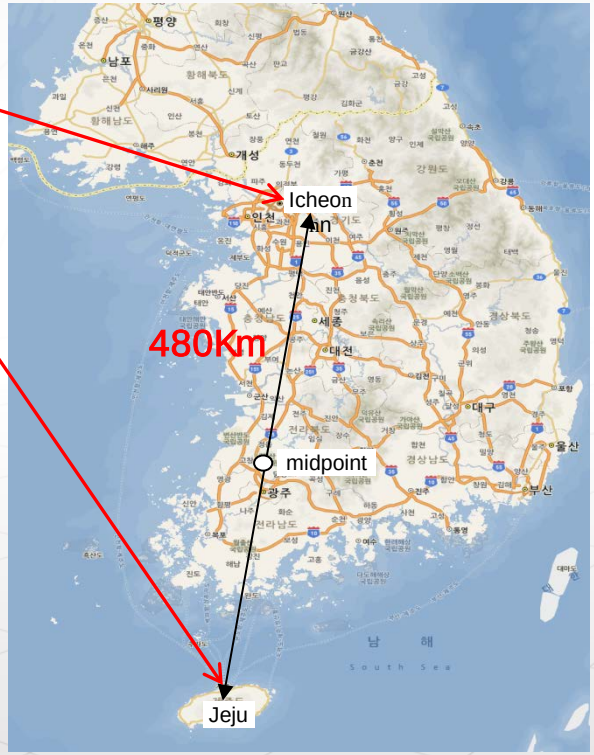
- The purposes of this project were as follows ;
  - to **re-check & verify oblique function** of existing Digisonde systems
  - to develop **SW for extracting ionogram data** from raw data (RSF file)
  - to develop **algorithm for extracting ionogram trace data** from ionogram data
  - to develop **algorithm for converting ionogram trace data** from Oblique to Vertical
  - to develop **algorithm for extracting ionospheric N-profile & parameters** from converted vertical ionogram trace data
  - to **implement SW**

Outline of Ionosonde in Korea (1/2)

- **Ionosonde deployed at KSWC in Korea**
  - Fully digital ionosonde made by LDI, model DPS-4D
    * LDI : Lowell Digisonde International

- **Ionosonde sites in Korea**
  - North site at Icheon (37.1°N, 127.5°E)
  - South site at Jeju (33.4°N, 126.3°E)

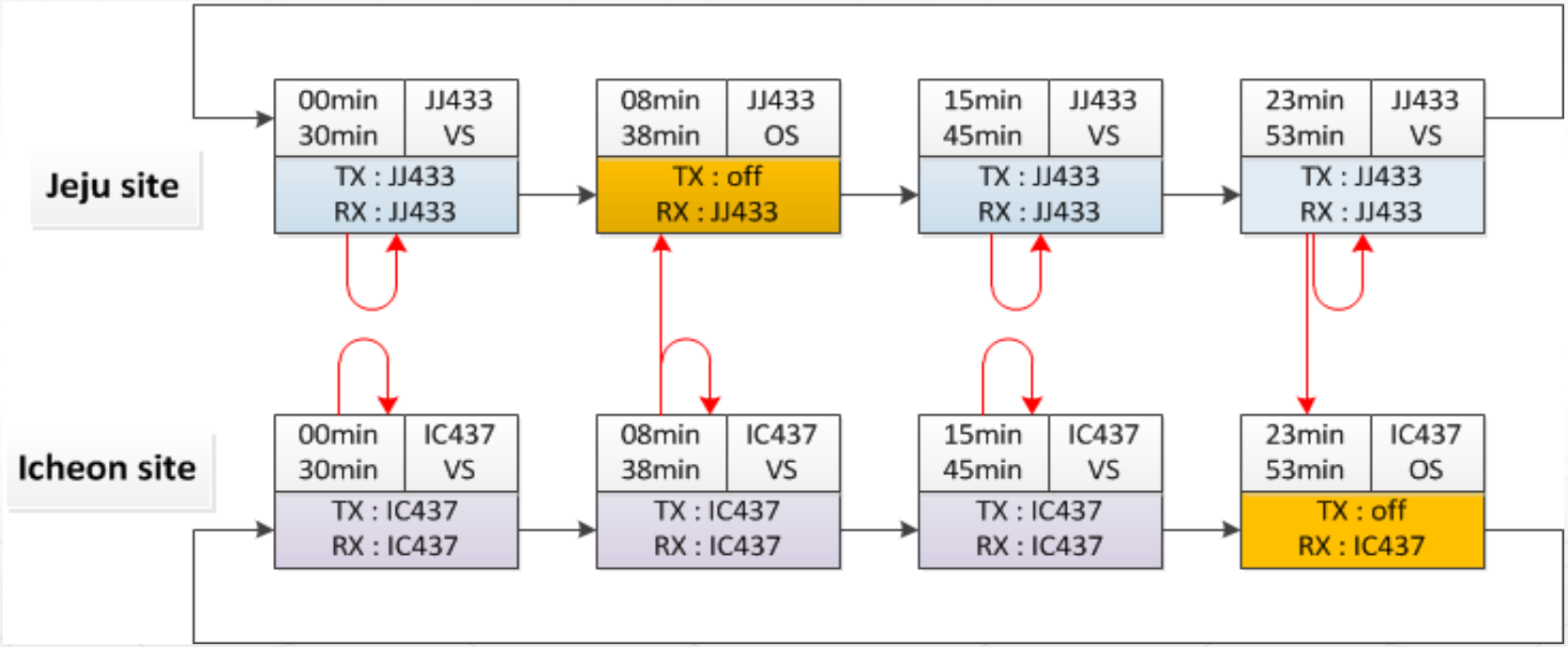
    ※ distance between two site : 480Km



- **Oblique sounding in Korea**
  - Frequency range 1MHz ~ 16MHz
  - Frequency step 25kHz
  - Sounding interval 30 minute

Outline of Ionosonde System in Korea (2/2)

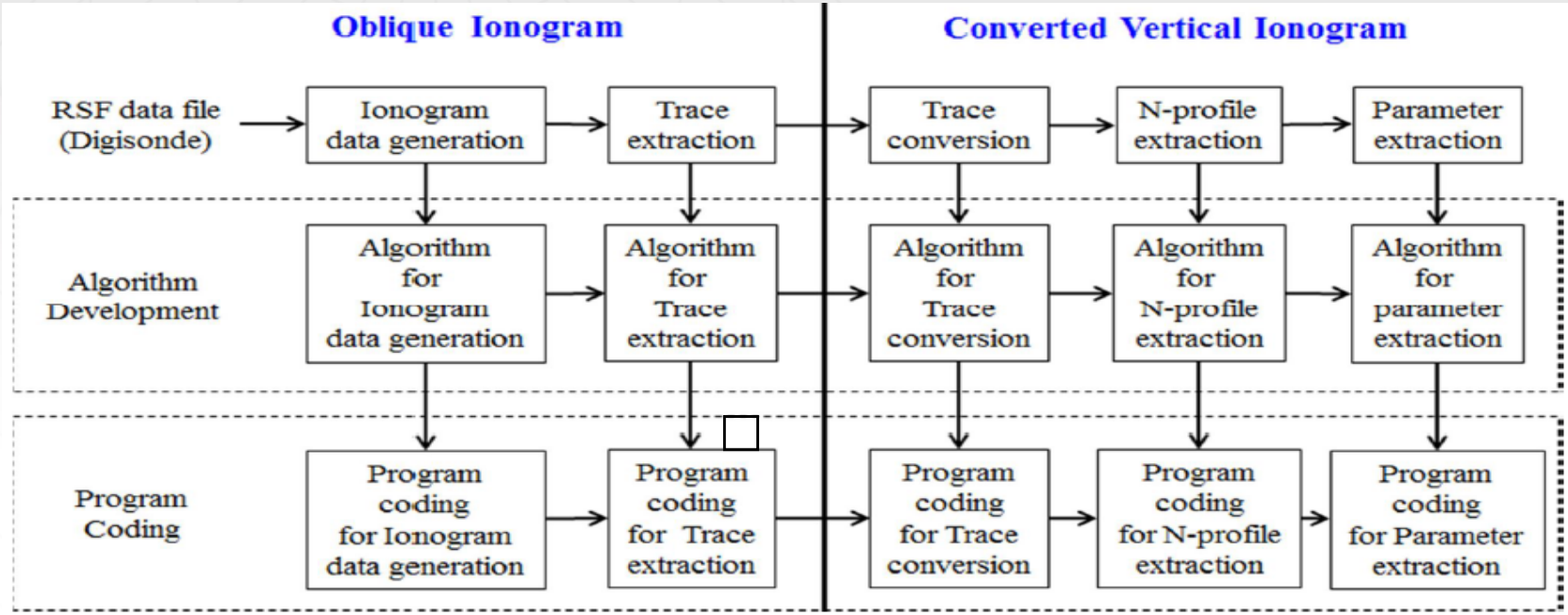
- **Measurement schedule**
  - Vertical sounding measurement : 8 minutes interval
  - Oblique sounding measurement : 30 minutes interval
- Total 4 oblique ionogram are produced every hour



- JJ : Jeju
- IC : Icheon
- TX : Transmission
- RX : Receive
- VS : Vertical Sounding
- OS : Oblique Sounding

Development Flow (1/2)

- ETRI divided this project into 5 tasks as follows;

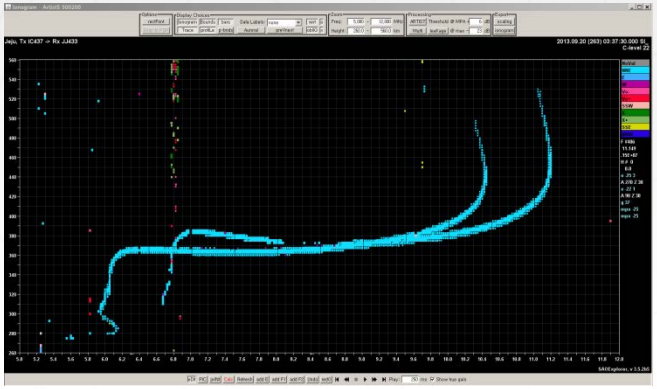


  - Generation oblique ionogram data from RSF data file of Digisonde
    ※ RSF : Routine Scientific Format
  - Oblique trace data extraction from the oblique sounding ionogram
  - Trace conversion from oblique to vertical
  - Get electron density profile from the converted vertical ionogram
  - Extraction ionospheric parameters from electron density
- This project was performed by ETRI with IPS & LDI and SELab support

Development Flow (2/2)

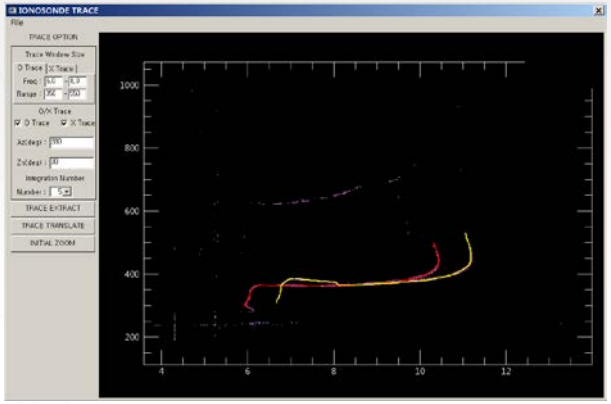
❖ **Concept of O2V Ionogram Conversion Procedure**

Oblique Ionogram (measured)

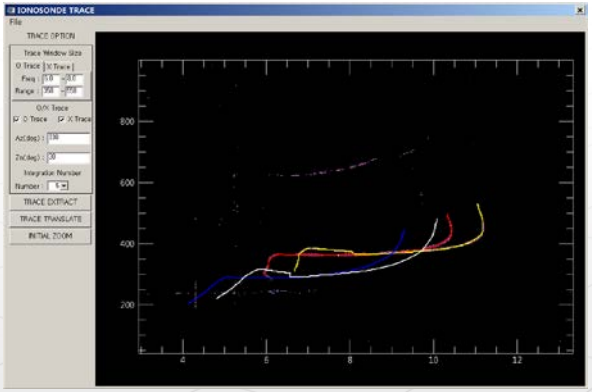


Trace extraction

Extract Oblique Ionogram Trace



O to V conversion



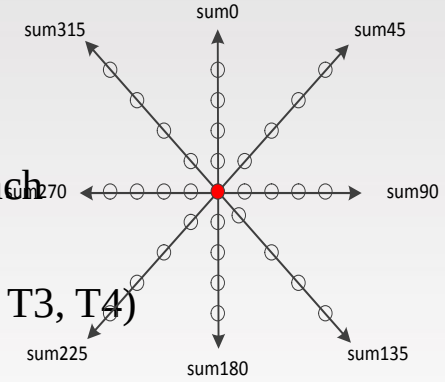
N-profile & Parameter extraction

Ionosperic N-profile & parameter

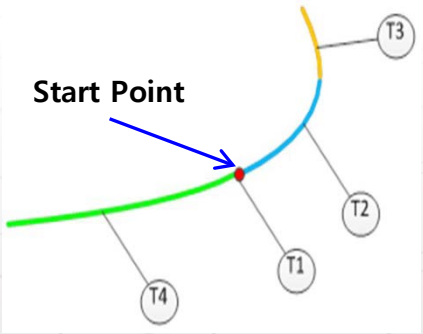
Vertical Ionogram Trace (converted)

Trace Extraction (1/2)

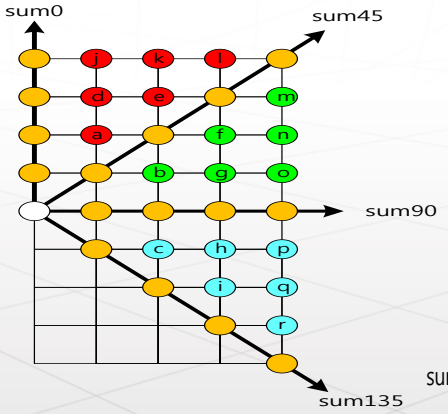
- **Vector tacking algorithm**
  - is for trace extraction from the scattered data in the ionogram
  - calculate 8 direction amplitude sum of echo signal up to 4 echoes in each directions (T1)
  - Move trace coordination to direction of maximum amplitude sum (T2, T3, T4)



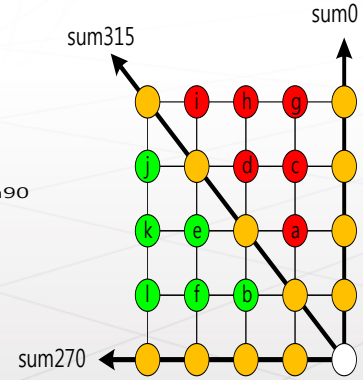
- **3 steps of trace extraction**
  - Find maximum amplitude echo signal in the ionogram, that will be T1
  - Trace extraction of right part of ionogram from the maximum amplitude point by the vector tracking algorithm (T2, T3)
  - Trace extraction of left part of ionogram from the maximum amplitude point by the vector tracking algorithm (T4)



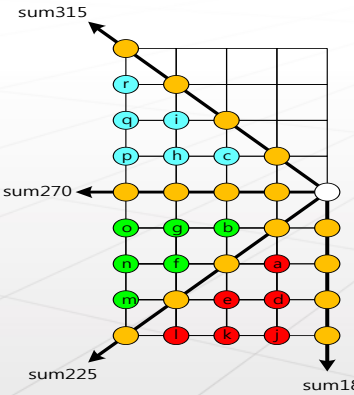
Find maximum amplitude echo (T1) in ionogram



Trace extraction in T2 zone



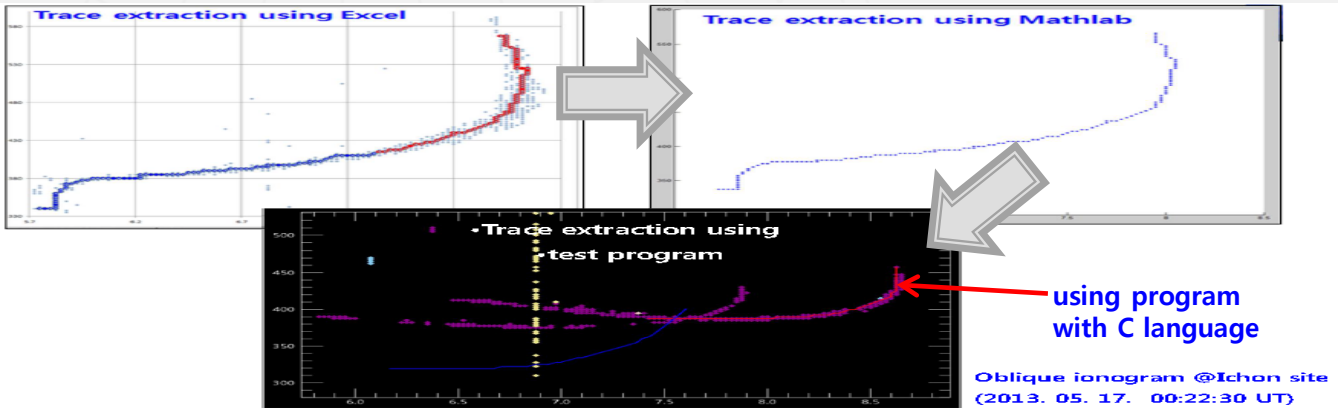
Trace extraction in T3 zone



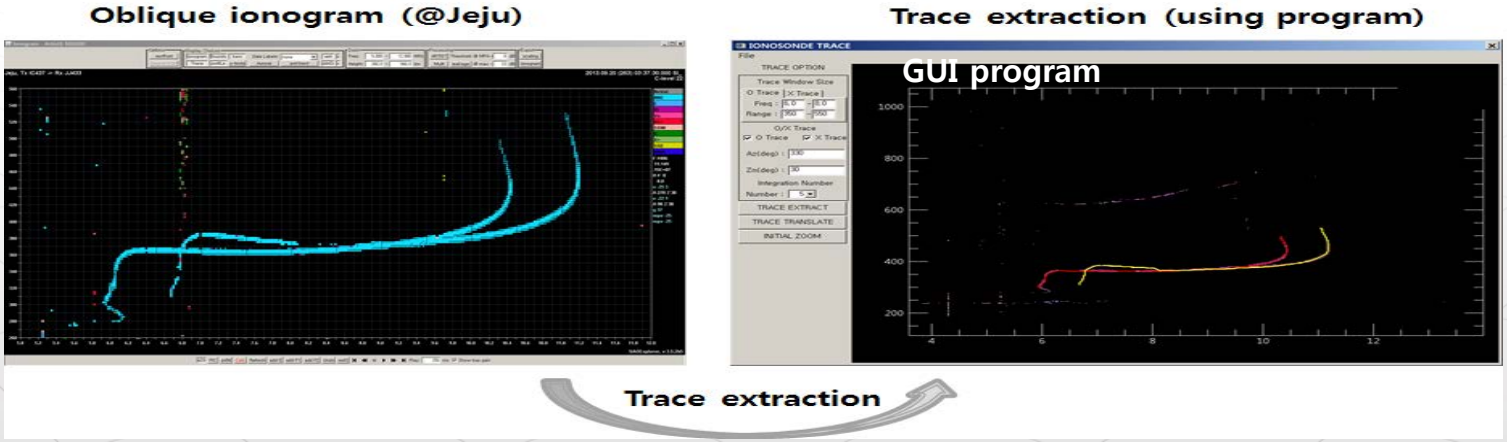
Trace extraction in T4 zone

Trace Extraction (2/2)

- Validation Process of trace extraction
  - 3 steps development were performed
    - Algorithm verify using Excel ➔ Algorithm verify using Matlab ➔ S/W program



- Trend of extraction trace is seemed to be similar to oblique ionogram

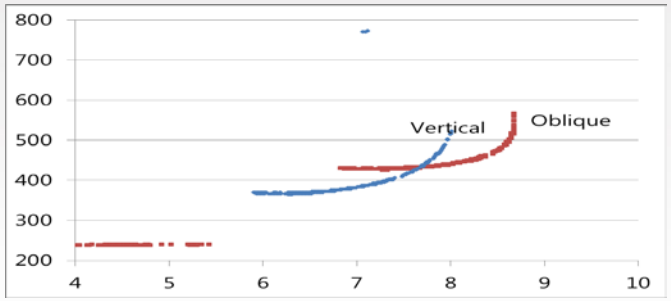


Trace Conversion from O to V (1/2)

- Equivalent conversion theory was applied to trace conversion from O to V
- The vertical frequency (f_v) and virtual height (h'_v) can be derived from the oblique frequency (f_{ob}) and virtual path (P'_{ob})

$$f_v = \frac{f_{ob}}{1.002}\cos\left(\sin^{-1}\left(\frac{428.8748}{P'_{ob}}\right)\right)$$

$$h'_v = -3.6097 + \frac{214.4374}{\tan\left(\sin^{-1}\left(\frac{428.8748}{P'_{ob}}\right)\right)}$$



- Validation of Trace Conversion
  - Compare vertical ionogram between measured and converted was impossible because there was no digisonde at mid point and there was not available vertical measured ionogram
  - Alternative validation method was considered that is compare converted vertical ionogram to measured vertical ionogram before and after oblique sounding measurement
    - Converted vertical ionogram at midpoint can be compared with measured vertical ionograms at TX and RX station for the validation
    - If converted vertical ionogram at midpoint is located between the vertical ionograms of TX and RX station, conversion algorithm seems to be validated

- **Breit-Tuve [1926], Martyn's equivalent path theorem [1935]**
- **Smith [1970], Rao [1973], Reilly [1985, 1989], Kotovich [2006]**

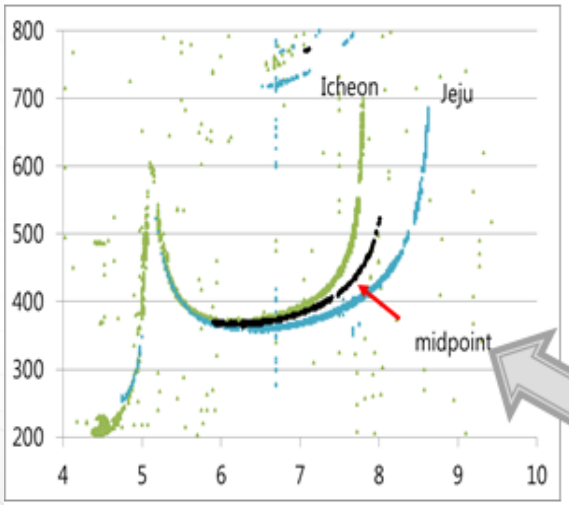
Trace Conversion from O to V (2/2)

❖ Ionogram Trace Conversion verification

✓ O to V conversion verification method

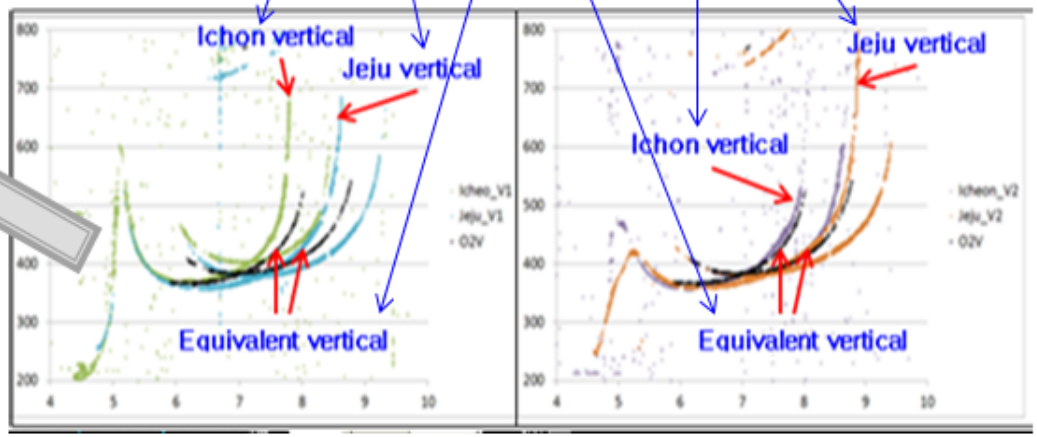
- Compare converted vertical ionogram to measured vertical ionogram of Jeju and Ichon site digisonde (450Km apart between 2 sites)

✓ O to V conversion verification (using 13 ionograms @Ichon site, 2013.05.27)



Equivalent vertical O trace
vs. Vertical O-trace (Jeju & Icheon)

Schedule / Site	00 min 30 min	08 min 38 min	15 min 45 min	23 min 53 min
Jeju	Vertical	Oblique Rx	Vertical	Vertical Tx
Midpoint		Equivalent Vertical		Equivalent Vertical
Icheon	Vertical	Vertical Tx	Vertical	Oblique Rx

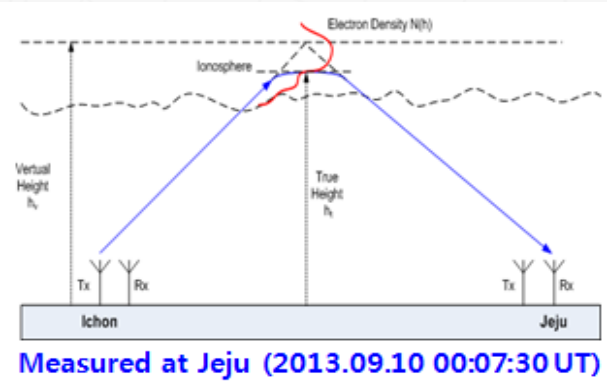


Vertical trace (before oblique measurement)
vs. Equivalent trace

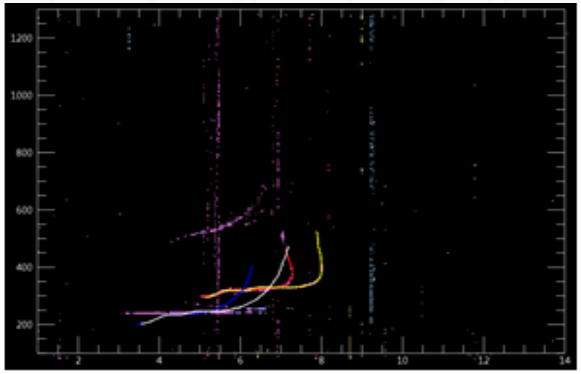
Vertical trace (after oblique measurement)
vs. Equivalent trace

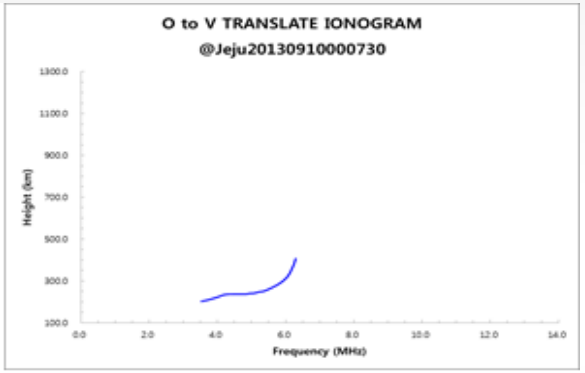
Electron Density & Parameter Extraction

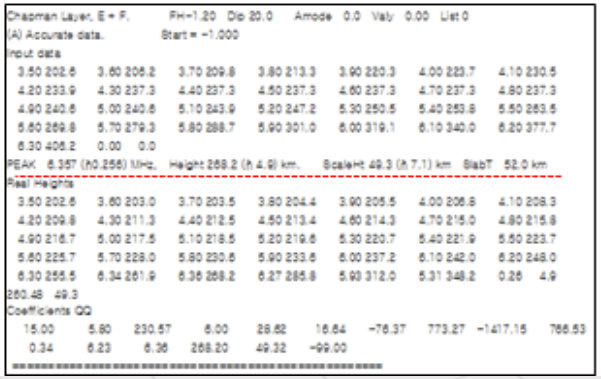
- POLAN algorithm has adopted to extract electron density and ionospheric parameters
- Validation of POLAN algorithm
  - By comparing with ARTIST of Digisonde for same measured vertical ionogram data

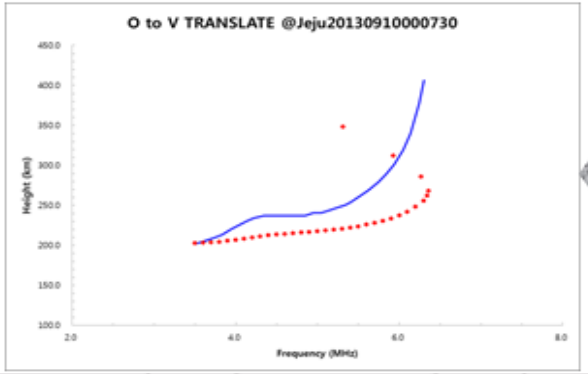


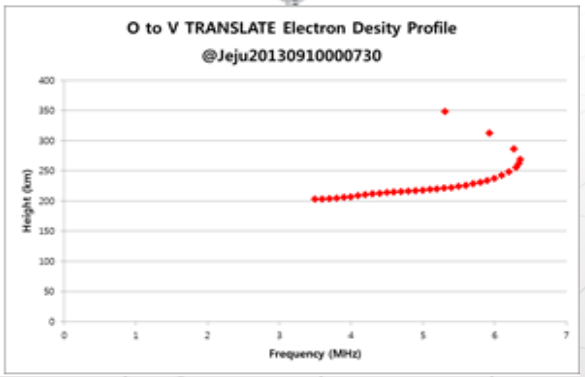
Measured at Jeju (2013.09.10 00:07:30 UT)











Summary

- This project had been completed end of 2013
  - Oblique sounding measurement data between Jeju and Icheon stations was used
  - To build sw program on server in KSWC was completed
    - Trace extraction from the oblique measured ionogram data
    - Conversion from oblique to vertical ionogram trace
    - Extraction of electron density & ionospheric parameters from converted vertical ionogram data
- Future Works
  - KSWC has a plan to perform 2nd phase of ionosphere measuring and analysis project from this year with domestic institute and company
    - to upgrade the O2V conversion SW algorithm developed in 2013 and the SW to be user friendly more
    - to perform long distance (around 1,000Km) O2V conversion algorithm development to measure ionosphere status information above sea between NICT and KSWC
    - to install new ionosonde receiving system only for receiving the signal from NICT's new ionosonde

Thank you!