VLBI懇談会シンポジウム
鹿児島大学18年12月27日

Probing the ionosphere by means of VLBI

ホビガー　トーマス、近藤哲朗、小山泰弘
情報通信研究機構鹿島宇宙技術センター

Preface:
Ionosphere monitoring using geodetic VLBI

VLBI drawbacks against GPS:

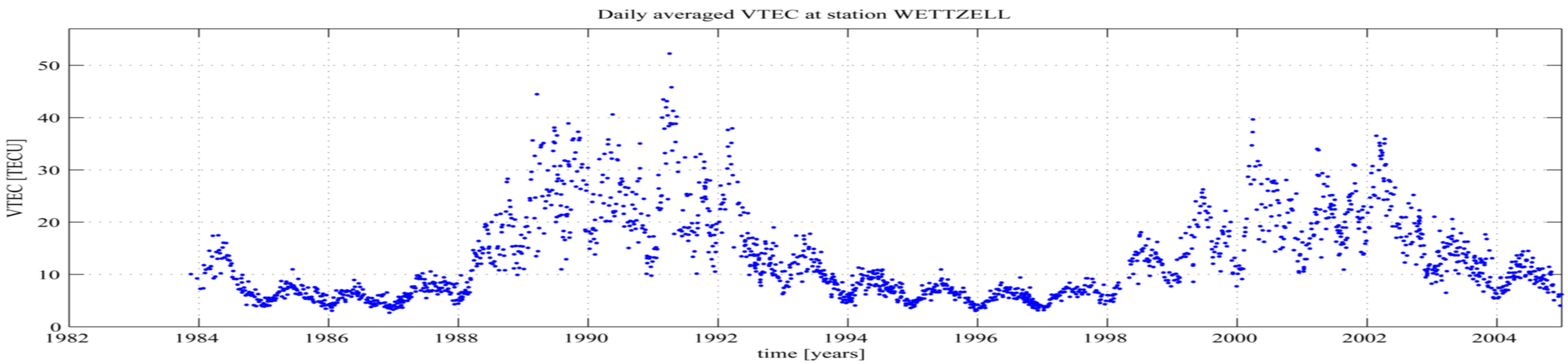
- VLBI is a differential technique, thus only differences in the ionosphere are measured (note: absolute values can be obtained by dedicated estimation techniques)
- Only one source is tracked by VLBI at one time; whereas GPS receivers track several satellites
- VLBI observations are not carried out 24h/365 days a year

BUT:

- VLBI has a long tradition of observing with dual frequency setup → long term studies of the ionosphere
- Fringe phase variations reveal even smallest changes in the dispersive media → detection of short-period variations in the ionosphere

Long-term studies of the ionosphere

- Values of vertical total electron content (VTEC) were obtained from group delay measurements for all sites contributing to IVS geodetic experiments



Example: Wettzell, Germany, data from 1982-2005

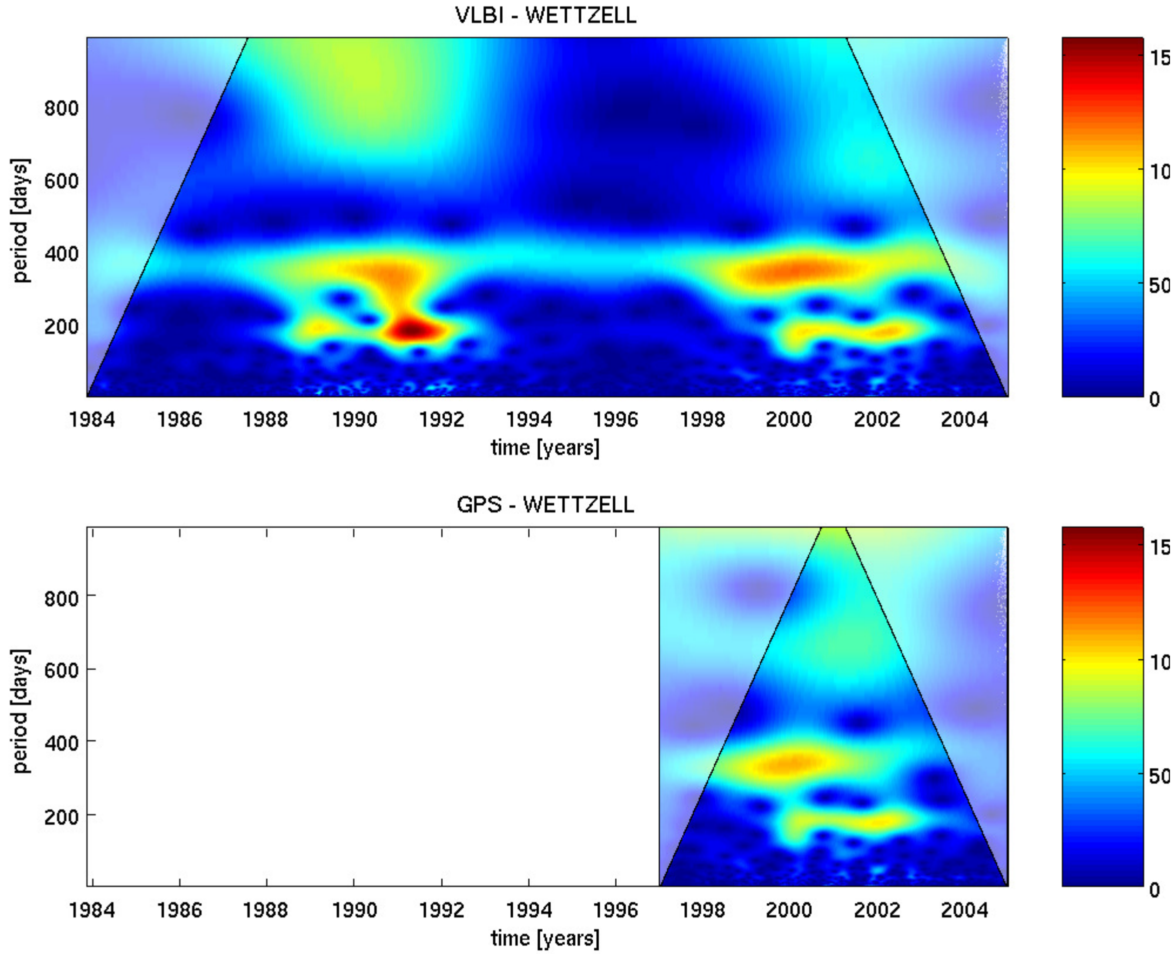
Hobiger, T., T. Kondo, and H. Schuh (2006), Very long baseline interferometry as a tool to probe the ionosphere, Radio Sci., 41, RS1006, doi:10.1029/2005RS003297.

Long-term studies of the ionosphere

W E T T Z E L L

VLBI

GPS



Fringe phase and its information content for short-period studies of the ionosphere

$$\phi_i(t) = 2\pi f_i \Delta\tau(t) - 2\pi \frac{40.28}{c f_i} \Delta STEC(t) + \hat{\phi}_i + \epsilon$$

- $\phi_i(t)$: fringe phase
- $\Delta\tau(t)$: intra-scan delay variation
- $\Delta STEC(t)$: ionospheric variation
- $\hat{\phi}_i$: phase offset
- ϵ: random noise

Thus: observing at different frequencies allows to separate the effects

Functional and stochastical model

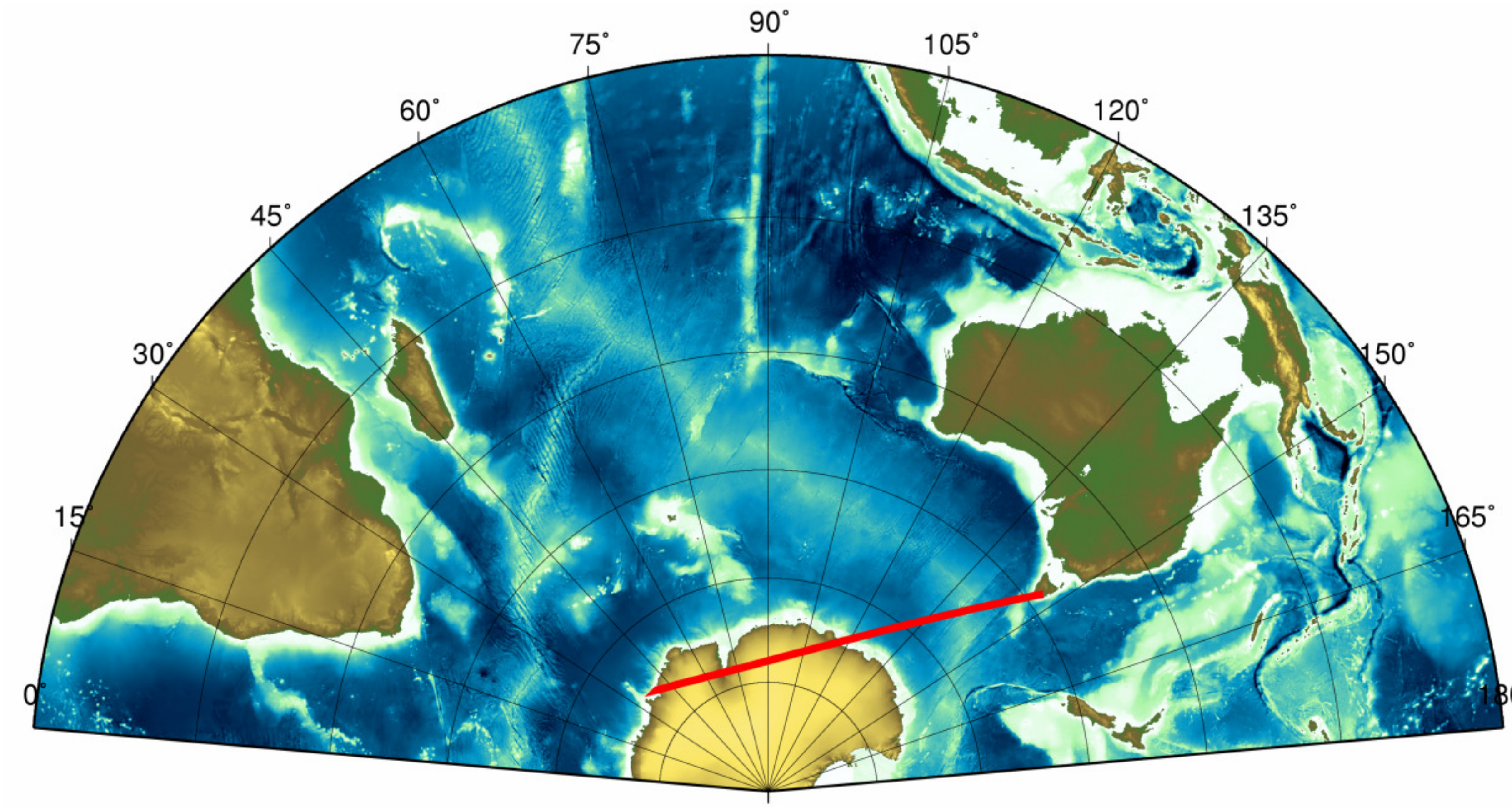
We select a quadratic B-spline base-function Ψ to represent temporal variations of the unknown parameters

$$\phi_i(t) = 2\pi f_i \sum_{j=0}^{N} A_j \cdot \Psi(t - t_j) - 2\pi \frac{40.28}{c f_i} \sum_{j=0}^{N} B_j \cdot \Psi(t - t_j) + \hat{\phi}_i$$

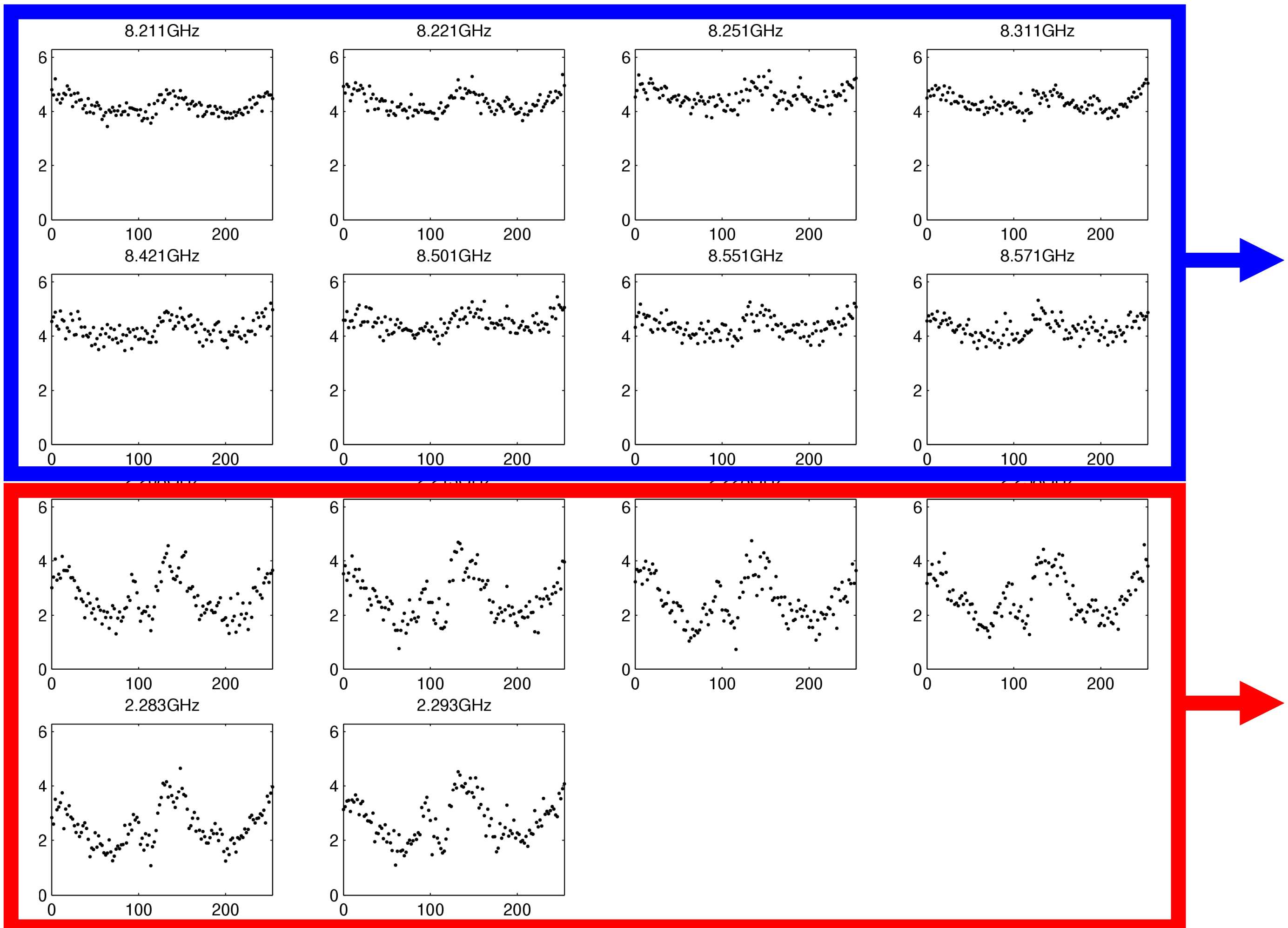
The weight matrix for least squares adjustment is found to be :

$$P_{nm} = \begin{cases} SNR_{nm}^2 & (n = m) \\ 0 & (n \neq n) \end{cases}$$

Example: Baseline Syowa – Hobart
August 18th, 2004, 10:10:12-10:14:28 UT, Src: 1921-293



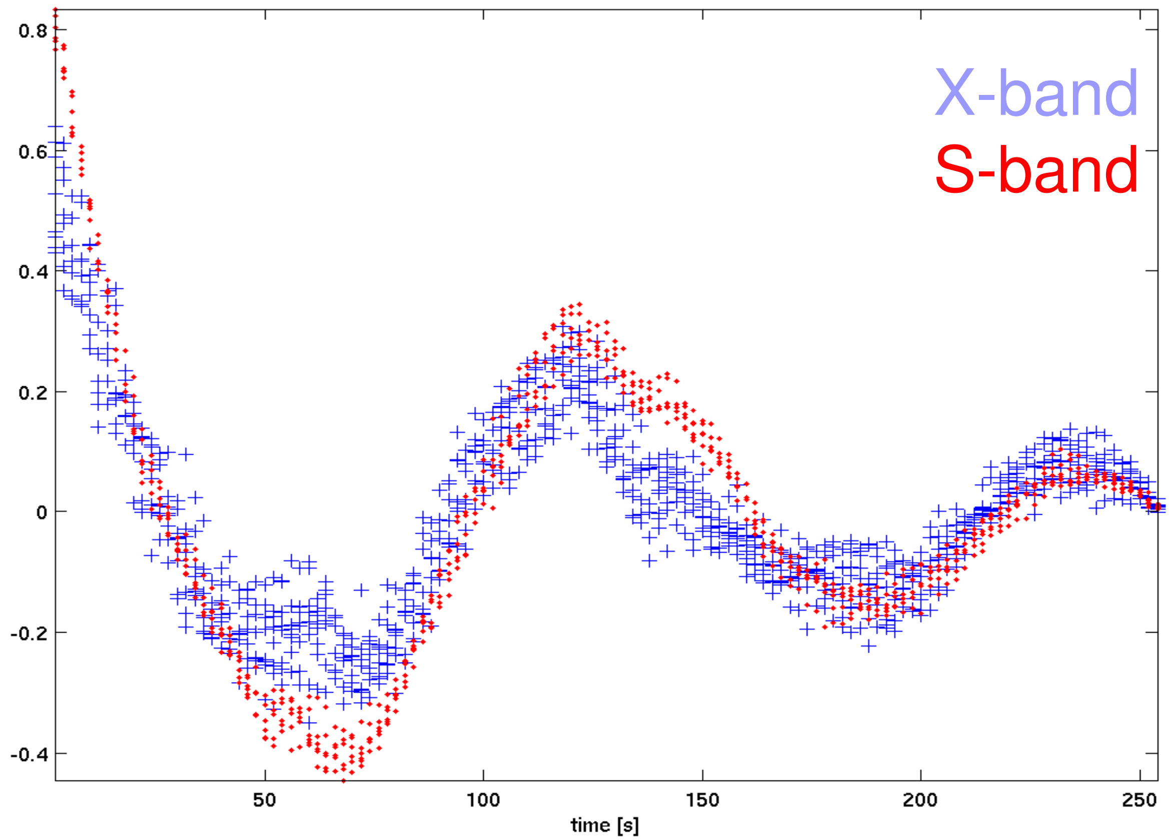
Fringe phases from this scan



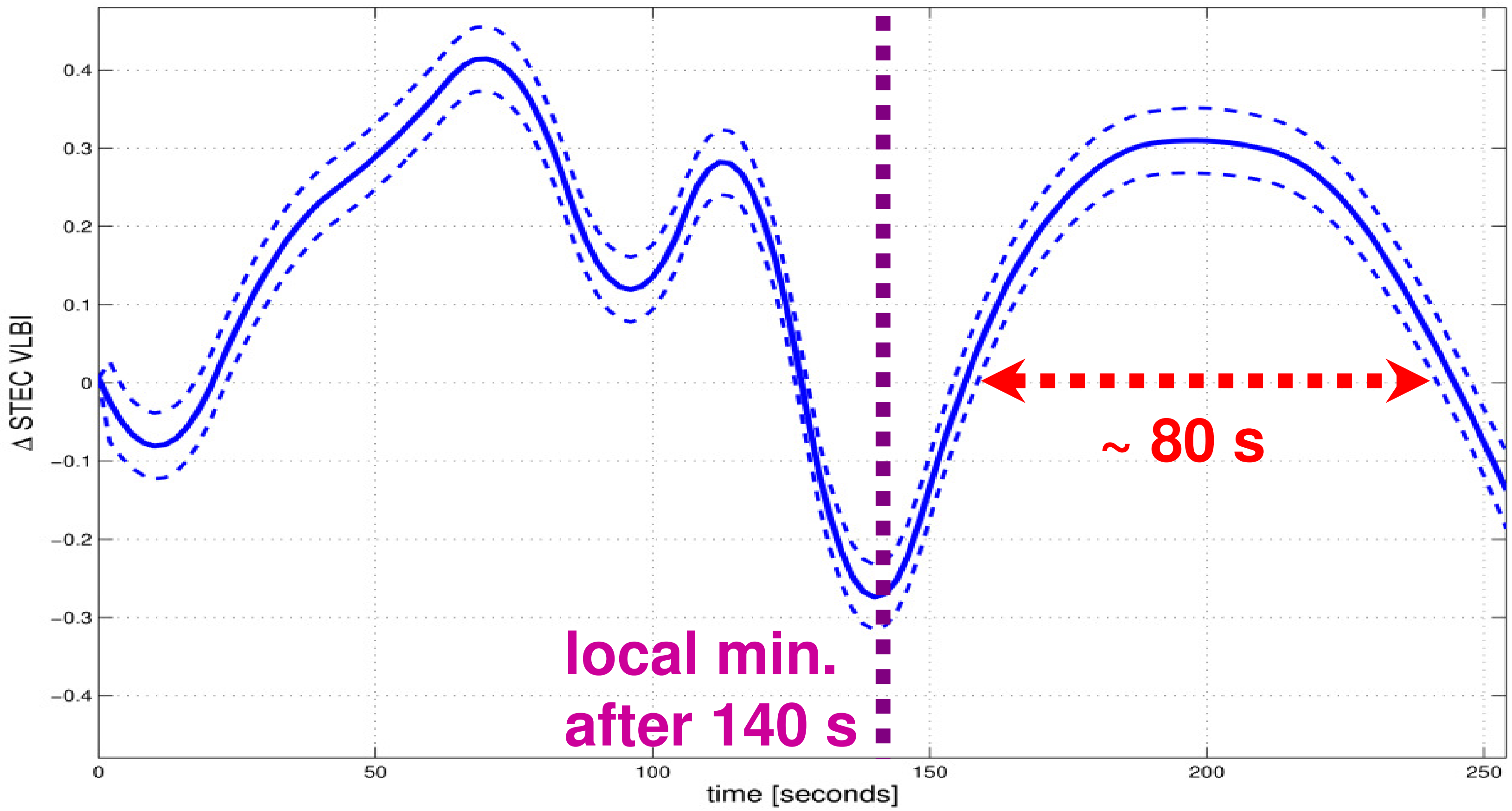
X-band ~8.4 GHz

S-band ~2.1 GHz

Cross-correlation of fringe phase scaled by frequency (~ ionospheric content)



Fitted ionospheric variation from VLBI

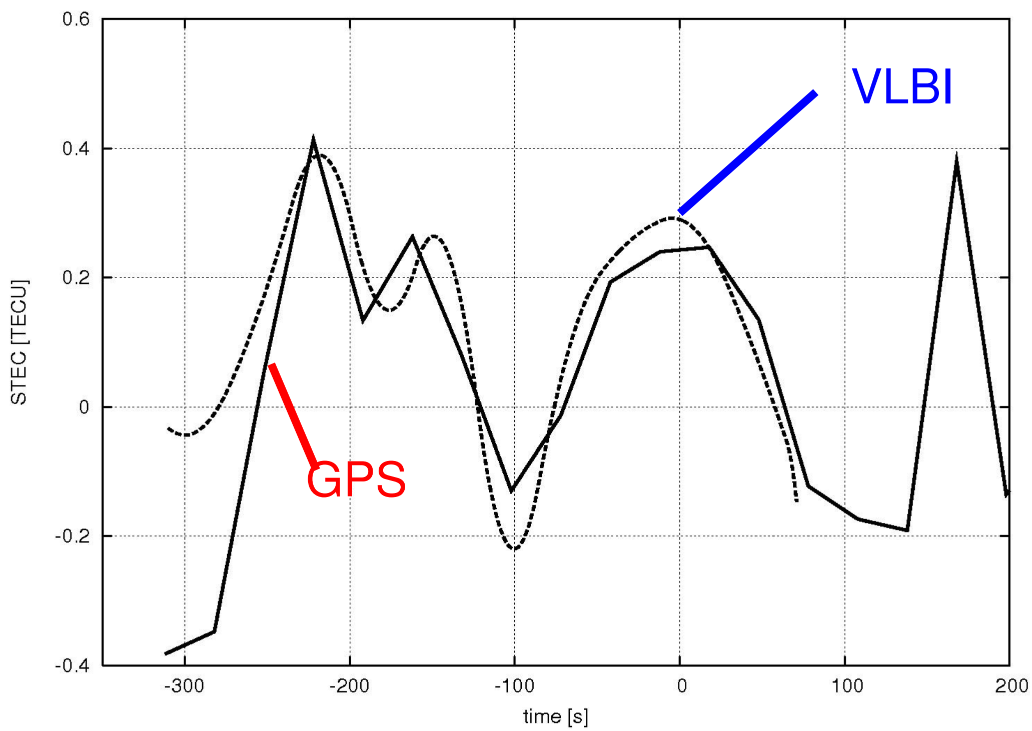


Comparison to measurements of nearby GPS receivers

- **Slant TEC from the GPS satellite which was closest to the observing direction was analyzed**
- **HOBART: no ionosphere variation**
- **SYOWA: same pattern as VLBI, but time shifted and scaled (caused by different geometry since VLBI and GPS are not observing exactly in the same direction)**

→ **"A short-period ionosphere variation took place around SYOWA station"**

Time-shifting and scaling GPS measurement with respect VLBI result gives propagation speed and direction



- Propagation velocity is about <u>1000m/sec</u>
- Ionosphere disturbance is <u>originated from the auroral oval</u>
- <u>F10.7 and Kp show no clear hint</u> that explains this event
- Day of the observation was <u>geomagnetically quiet</u>

But: <u>IMF was directed southwards</u>, which permits communication between the auroral oval and the solar wind. Considering all circumstances **<u>plasma patches</u>** are assumed to be the likely cause for the disturbance.

Conclusions & Outlook

- VLBI is able to contribute to long-term studies of the ionosphere
- VLBI is capable of detecting short period ionosphere disturbances with high precision
- together with GPS it is possible to assign these effects to a station and to conclude on physical origins

---

- Knowledge about intra-scan delay variations can also be used for atmosphere studies, spacecraft navigation .....

THANK YOU FOR YOUR ATTENTION

ACKNOWLEDGEMENTS TO:

独立行政法人日本学術振興会
Japan Society for the Promotion of Science

NiCT

GSI VLBI

IGS
International GNSS Service
Formerly the International GPS Service