TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

7th IVS General Meeting
www.oan.es/gm2012/
March 4-9, 2012. Madrid. Spain

Session 3

Universal Time from VLBI Intensives with ray-traced delays

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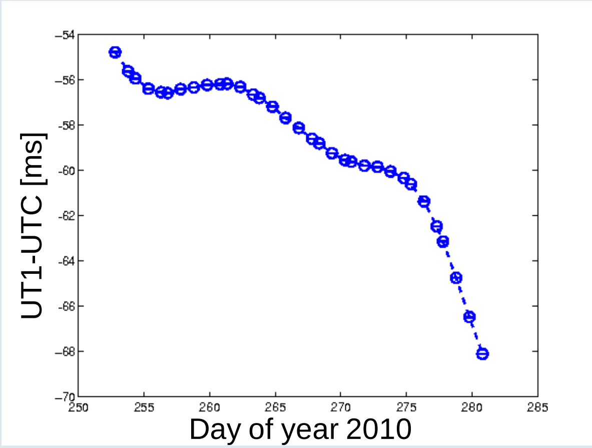
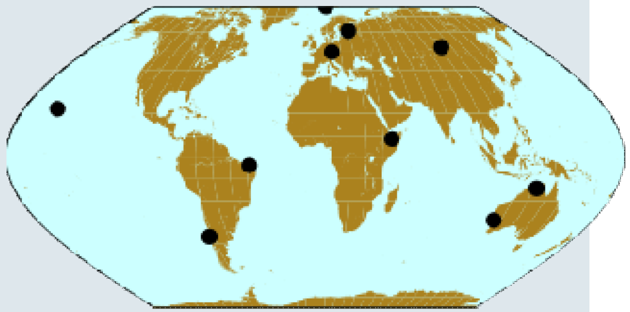
Introduction

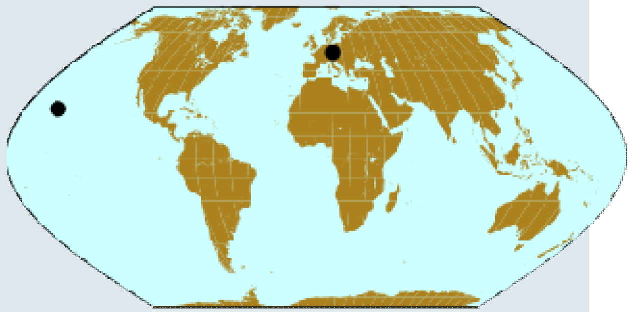
- VLBI is primary space geodetic technique for Universal Time (mid- and long term)
- EOP are important for positioning and navigation on Earth and in space
- Predictions require accurate EOP in near real-time



Introduction

- 24h sessions (2-3 times per week): EOP estimation
  - Latency: 2 weeks
- 1h Intensive sessions: Single baseline, UT1 estimation
  - Latency: 3 minutes to 2 days

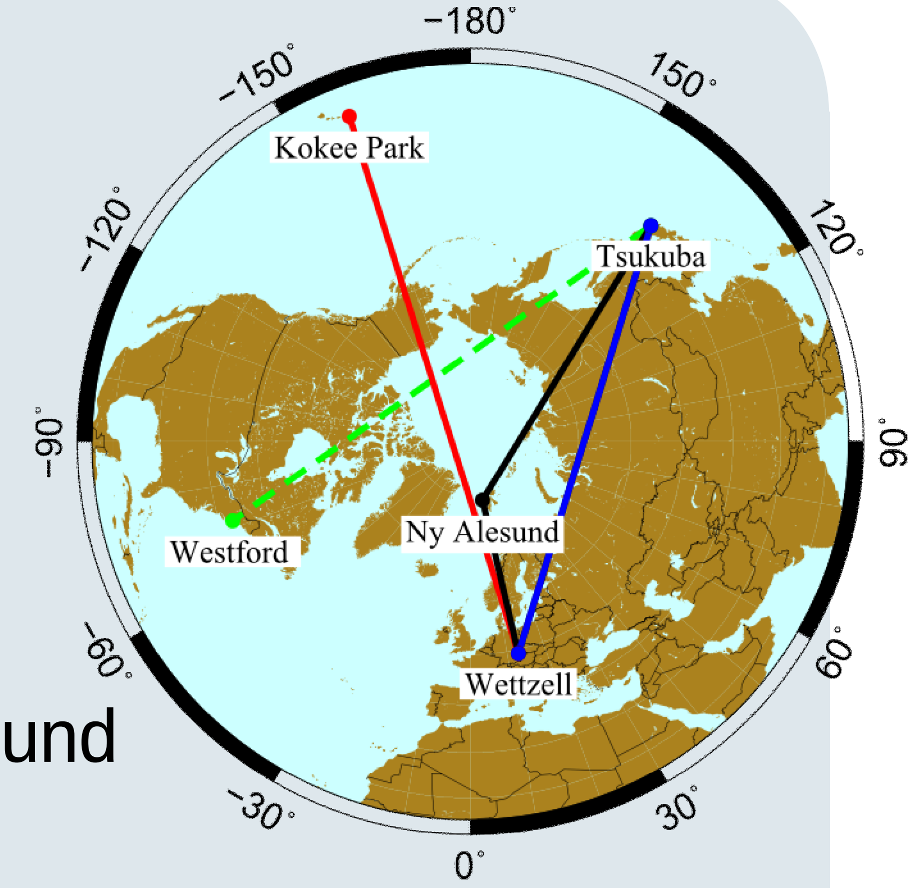




→ Less accurate but shorter delay

Introduction

- INT1
  - Kokee-Wettzell
- INT2 (e-transfer)
  - Tsukuba-Wettzell
- INT3 (e-transfer)
  - Tsukuba-Wettzell-NyAlesund
- Temporary
  - Tsukuba-Westford



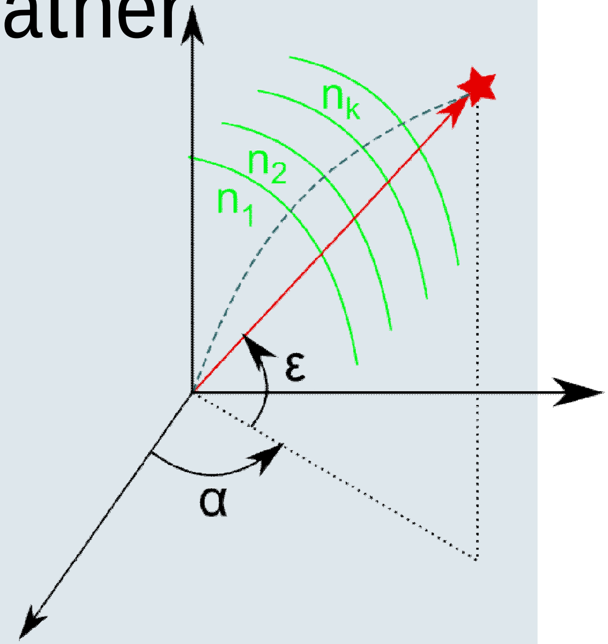
Ray-tracing

- Ray direction from numerical weather models (NWM)
- Eikonal equation

$$\left|\nabla L\right|^2 = n^2(\vec{r})$$

$\nabla L =$ ray direction

$n =$ refractive index

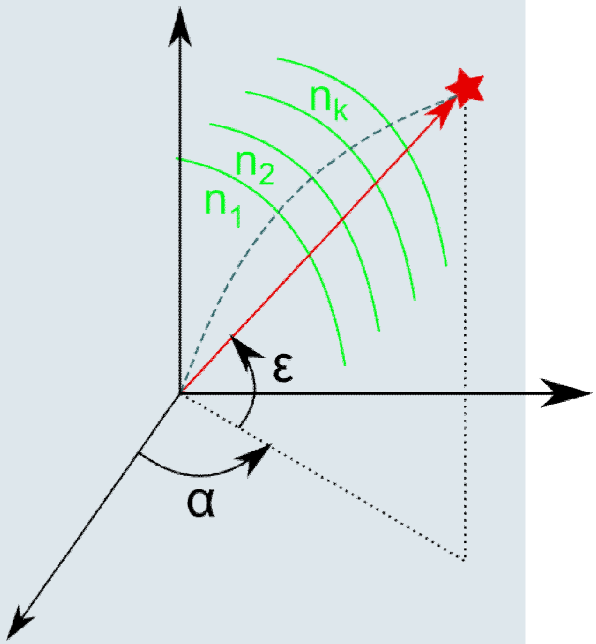


- 3D trajectory of ray → path delay and bending effect

Ray-tracing

- 7 differential equations
- 6 solved simultaneously (Runge Kutta)
- Matlab (slow)

  → 2D
- ECMWF operational data
- 0.5° spatial resolution



Nafisi et al., 2011

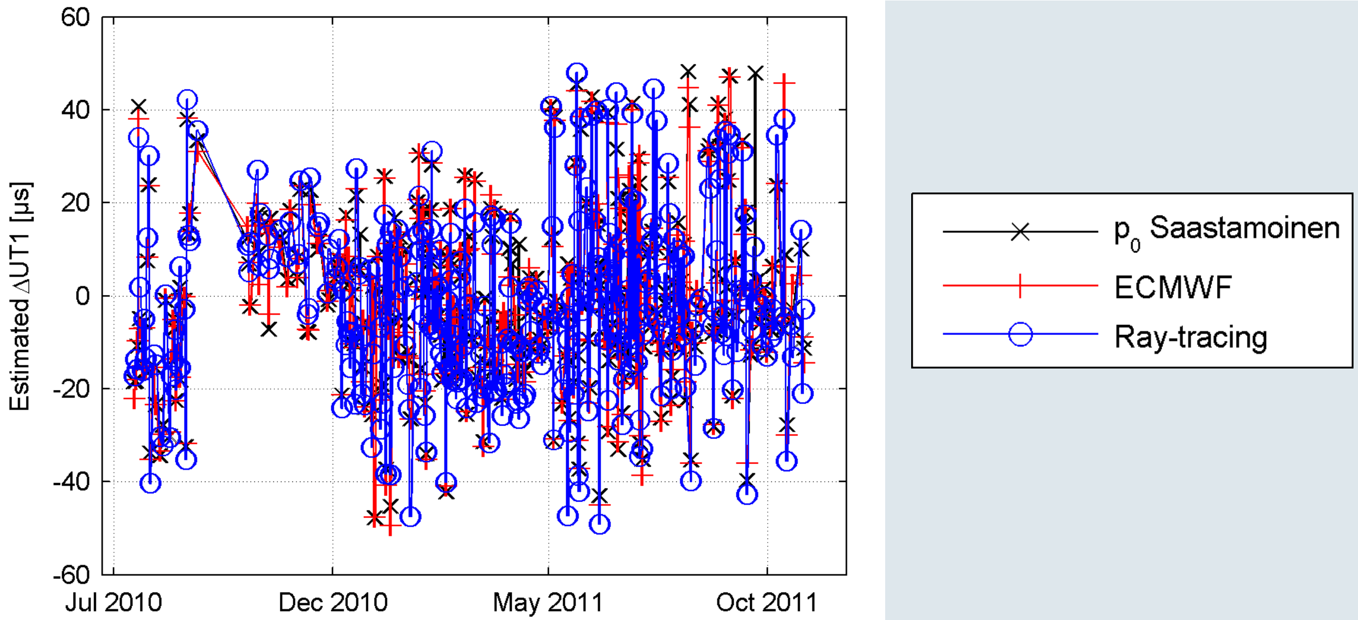
Intensive analysis

- 355 sessions from 15.07.2010 – 26.10.2011
- Vienna VLBI Software VieVS
- VTRF2008, modified due to Tsukuba Earthquake
- ICRF2
- High Frequency EOP (IERS Conventions 2010)
- IERS EOP daily rapid data (“finals”) nutation offsets and polar motion

Intensive analysis

- Estimated:
  - Linear clock and 1 ZWD per station (partial derivative: wet mapping function)
  - One UT1 value per session
- A priori tropospheric delays
  - Pressure at station, Saastamoinen, VMF1 (hydrostatic only)
  - ECMWF, VMF1 (hydrostatic and wet)
  - Ray-tracing (hydrostatic and wet)

Results



Tropospheric model	RMS w.r.t. IERS finals	Mean error
p_0 Saastamoinen	17.8 µs	13.1 µs
ECMWF (hw)	17.8 µs	13.0 µs
Ray-tracing	18.3 µs	13.0 µs

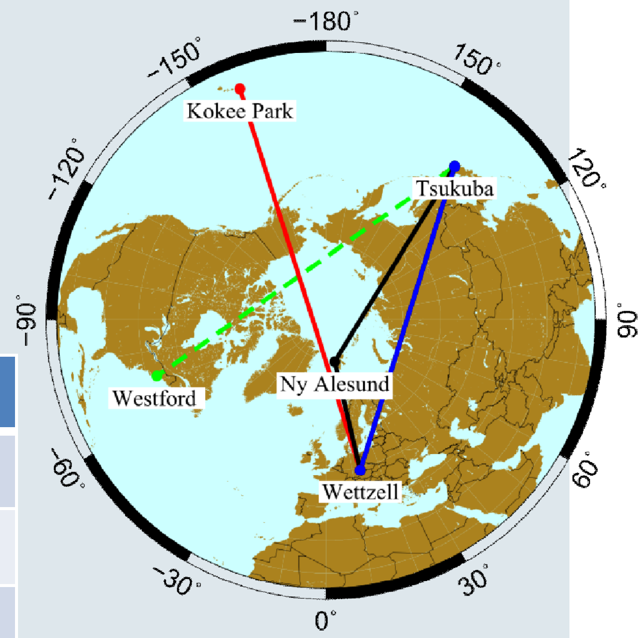
- 335 Sessions
- 35 Outliers:
  - ± 50µs
  - < 100µs error

error = formal uncertainty

Results

- Session separation
- RMS w.r.t. IERS finals (mean error)

	INT1	INT2/3	Ts-Wf
Ray-traced delays	only Wz	Ts and Wz	only Ts
Sessions	251	81	23
Scans (mean)	7-30 (16.7)	13-45 (39.7)	18-39 (30.6)
P_0 Saastamoinen	17.6 (14.6)	18.6 (9.3)	9.5 (8.2)
ECMWF	17.7 (14.5)	18.4 (9.1)	9.2 (7.6)
Ray-tracing	18.3 (14.5)	17.8 (9.0)	8.1 (7.5)



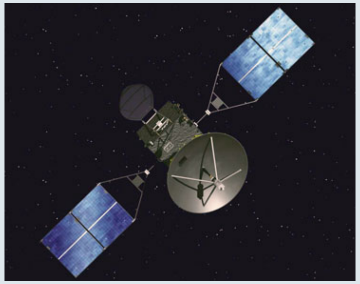
Mean error = mean formal uncertainty

Results

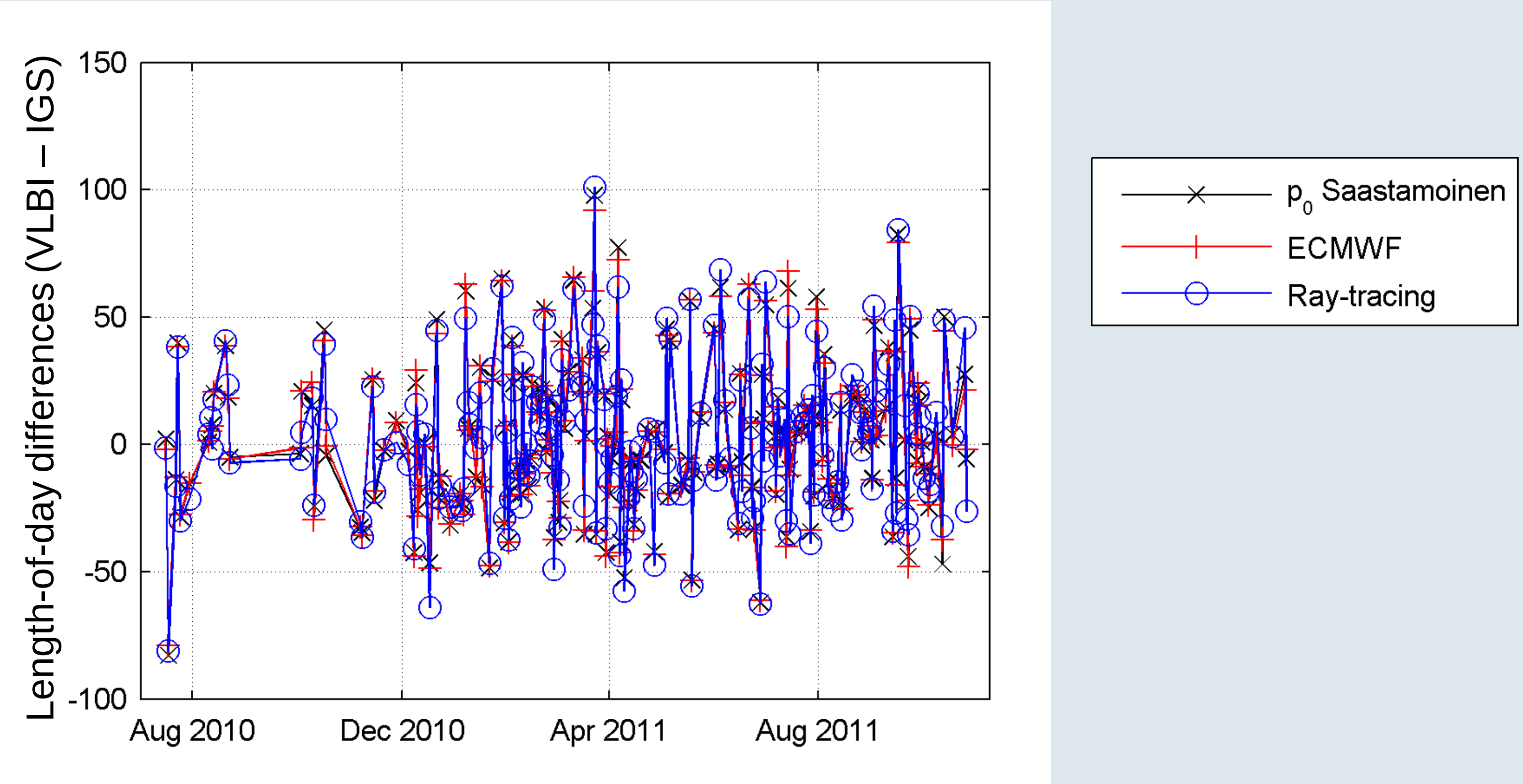
- External validation desirable
- Convert to length-of-day (lod)

$$\mathrm{lod} = -\frac{\delta \Delta \mathrm{UT1}}{\delta t}$$

- Compare to IGS lod
  - IGS final Earth rotation parameters



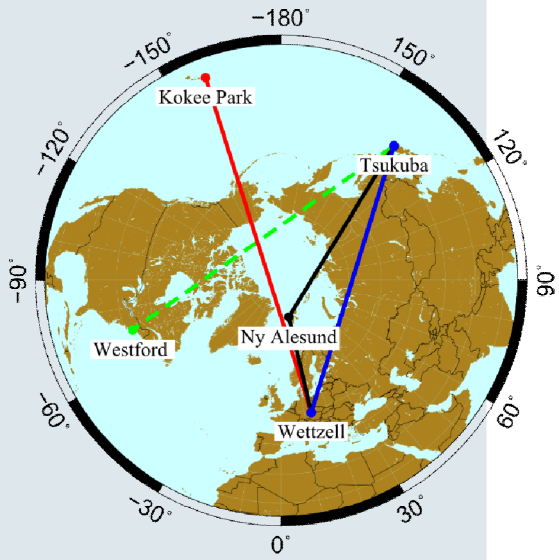
- Comparison to length-of day from IGS (VLBI – IGS) [µs]



Results

- Comparison to length-of day from IGS

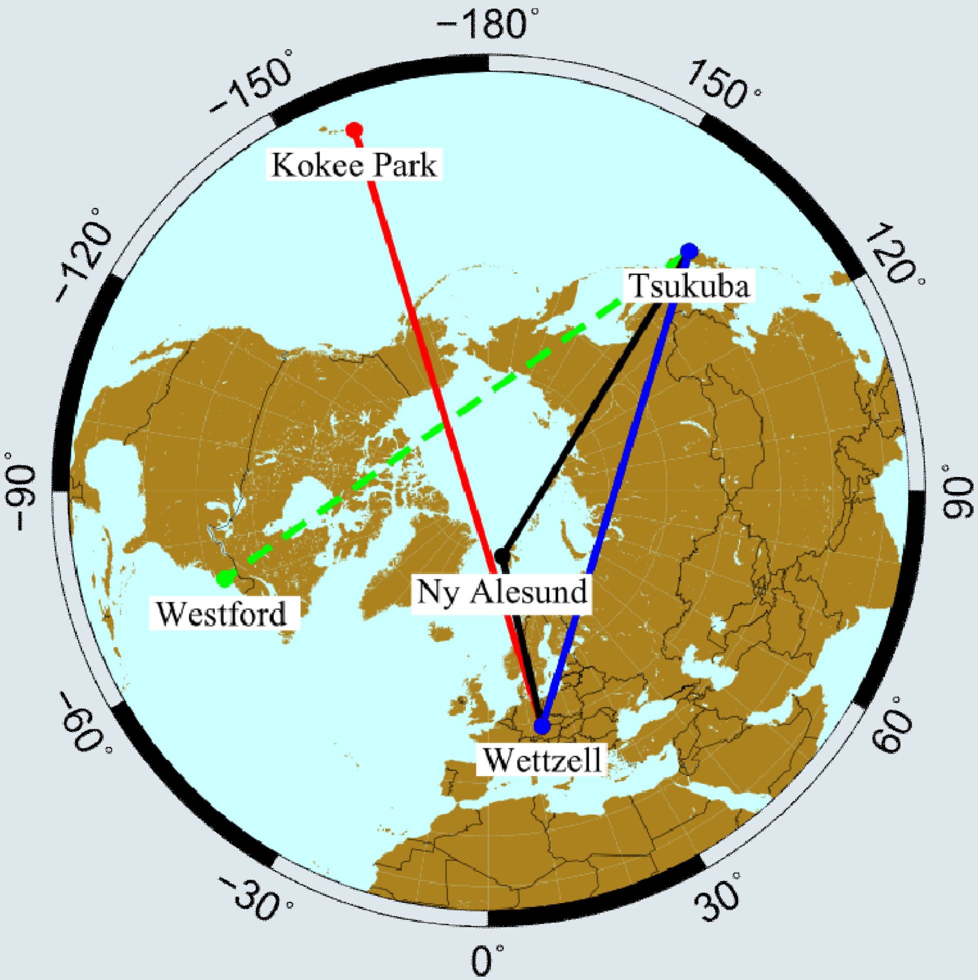
Model	RMS lod w.r.t. IGS-lod [µs]			
	INT1	INT2/3	Ts-Wf	all
p_0 Saastamoinen	30.8	27.1	24.6	29.8
ECMWF	30.4	26.1	25.1	29.3
Ray-tracing	30.8	25.3	23.5	29.5



Conclusion / Outlook

- Intensives are important for UT1 estimation and prediction
- Ray-tracing slightly improves accuracy of some ΔUT1 estimates (e.g. those including Tsukuba)
- Delays are calculated routinely for Intensives
- Improve Analysis / Ray-tracing
  - 3D Ray-tracing
  - Gradients estimation

Thank you



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