Introduction to real-time applications in space geodesy

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Session 1: Move towards „real-time“ products
IERS Retreat 2013

Outline

- Introduction
- IVS
- ILRS
- IGS
- Session schedule

Introduction

EOP are a necessity for several fields and applications

- fundamental astronomical and geodetic reference systems
- monitoring and modeling earth rotation/orientation
- artificial satellite orbit determination
- space navigation
- geophysical and atmospheric research
- …

The demand on **low latencies** and **real-time** of the products is increasing and needs to be addressed.

-> Talk by B. Luzum: State-ot-the art of EOP prediction within the IERS

IVS: VLBI2010

Goals

- 1 mm position and 0.1 mm/yr velocity accuracy on global scales
- **continuous** measurements (time series of EOPs and baselines)
- turn around time to initial geodetic results **within less than 24 hours**
- low cost construction and operation

VLBI2010 - a completely new generation of VLBI hardware and software

IVS: VLBI2010

Strategies (with relevance for real-time)

- increasing broadband observations to get higher SNR
- compact, fast slewing antennas
- e-VLBI
- software correlation
- using Kalman filter for EOP in near real-time
- automation of data analysis
- remote control of VLBI telescopes

IVS: VLBI2010

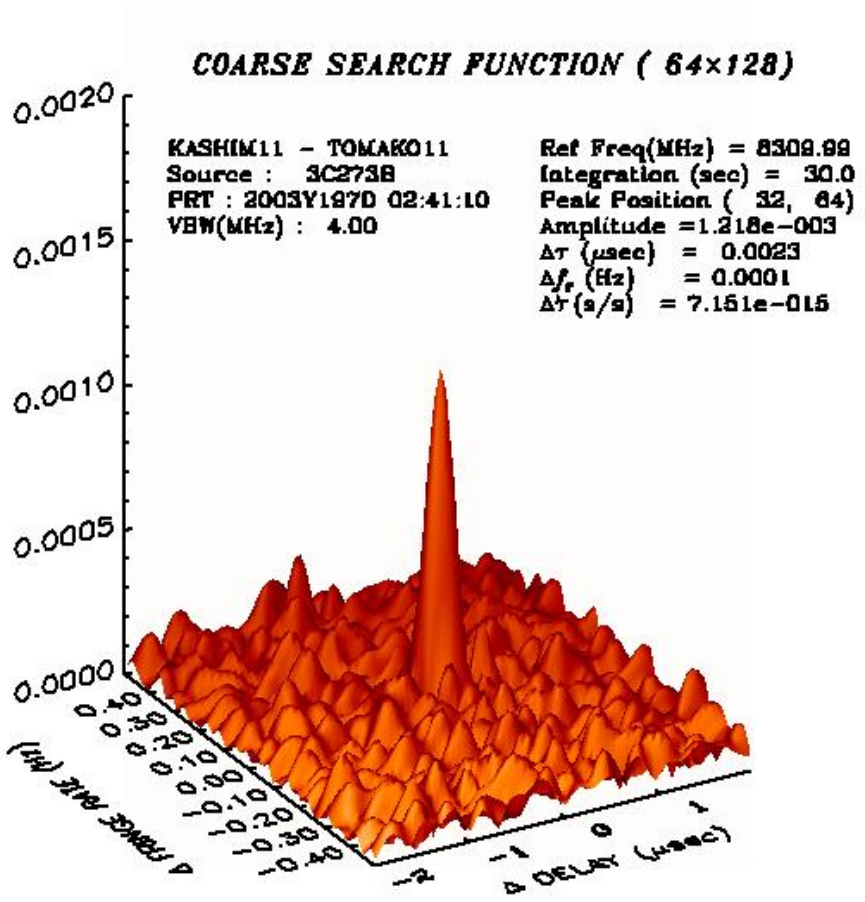
e-VLBI: High-speed optical fiber connections worldwide for VLBI in near real-time

Real-time e-VLBI demo at Super Computer Conference (Whitney 2005)

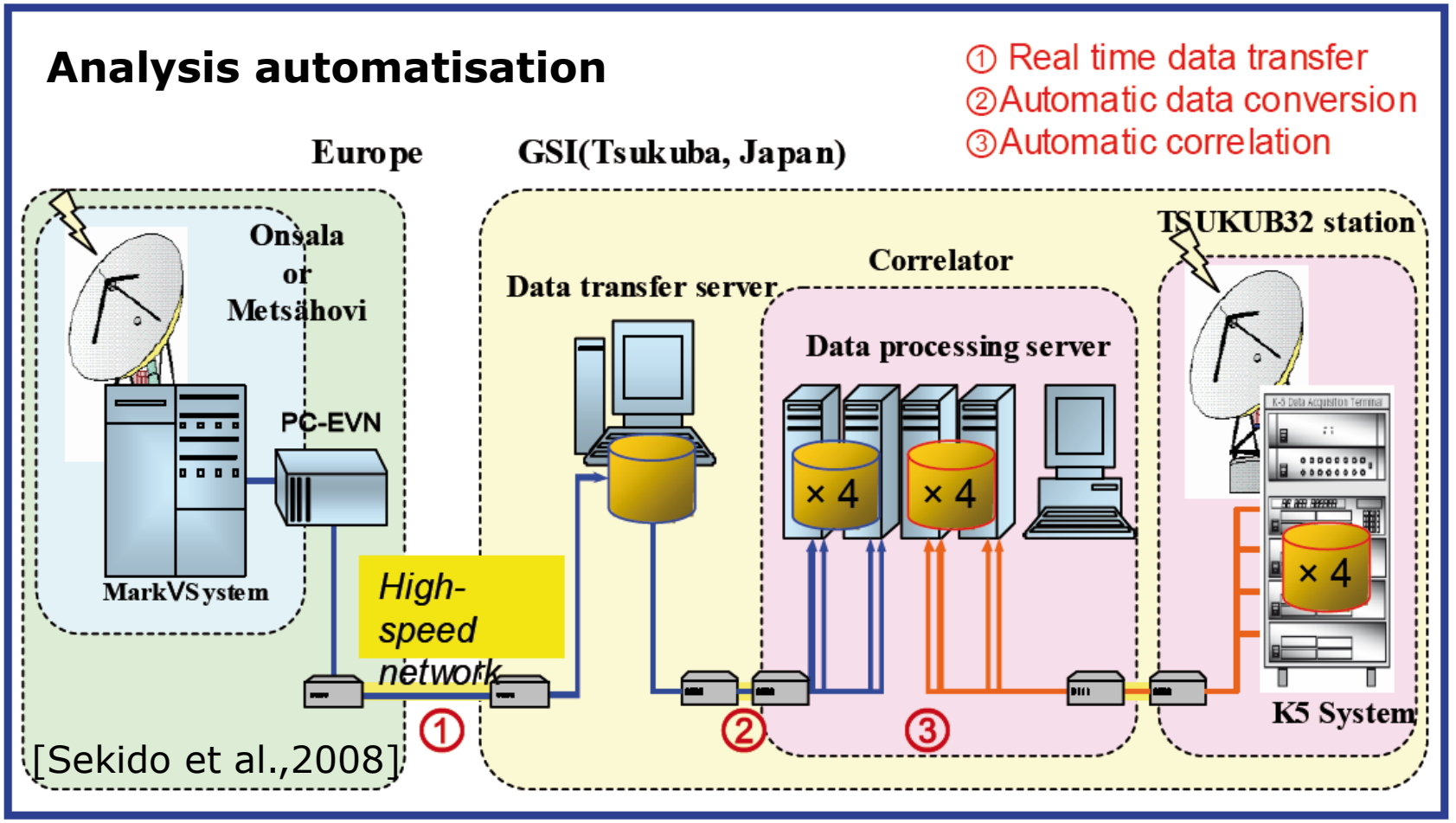
IVS: VLBI2010

Software correlation:

- Since 2009 software correlators in Kashima, Perth, Bonn
- In 2013 software correlation is standard



IVS: VLBI2010



IVS: VLBI2010

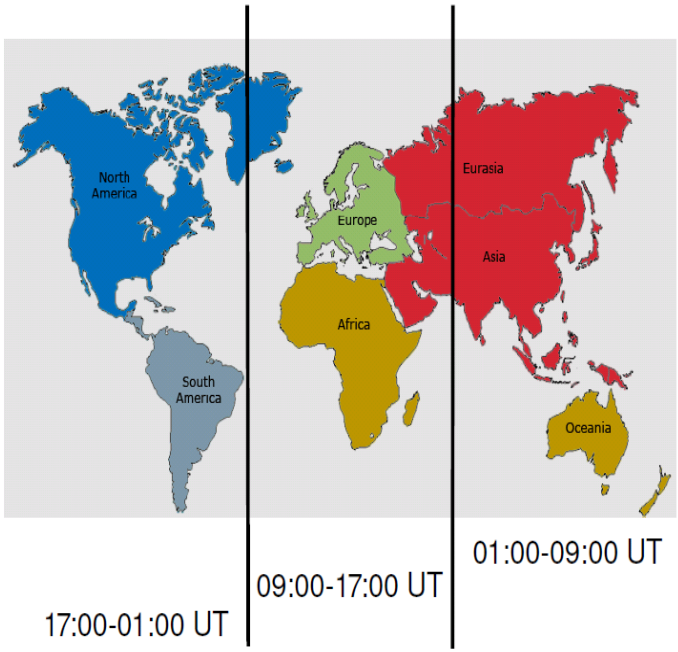
Global cooperation within the IVS – remote control of radio telescopes

Future VLBI2010: VLBI observations seven days/week.

Idea: use remote control of the telescopes. At night a telescope is controlled remotely from another telescope where it is daytime [A. Neidhardt, Wettzell]

Requirements:

- ✓ Stable internet connection.
- ✓ Stable and standardized software for remote control.



IVS-Intensives (INT)

Currently there are three IVS-INT-series for daily determination of dUT1:
1 hour long, using long east-west baselines

- INT1: Wettzell – Kokee
  - (Monday – Friday)
- INT2: Wettzell – Tsukuba
  - (Saturday + Sunday)
- INT3: Wettzell – Tsukuba – Ny-Ålesund
  - (Monday mornings)

IVS-Intensives

Observations

- 1 hour of observations
- between 20 (INT1/INT2) and 80 (INT3) baseline observations
- e-transfer (offline or real-time) to correlator

Correlation

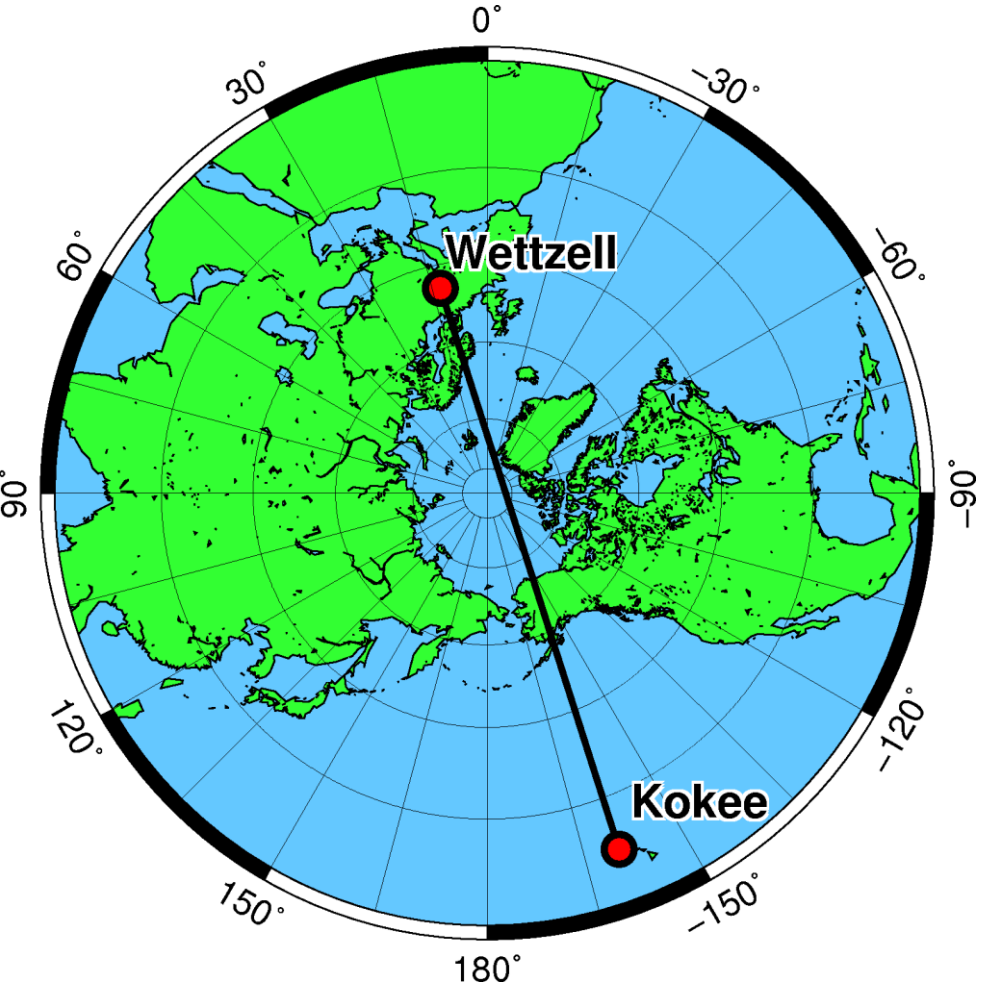
- in Washingon (INT1), Tsukuba (INT2), and Bonn (INT3)

Data Analysis

- interactive analysis at NASA (INT1/3) and Tsukuba (INT2)
- simple parameterization for clocks and atmosphere
- station positions, polar motion and nutation kept fixed

-> Talk by R. Haas: The IVS Intensive sessions on their way to near real-time

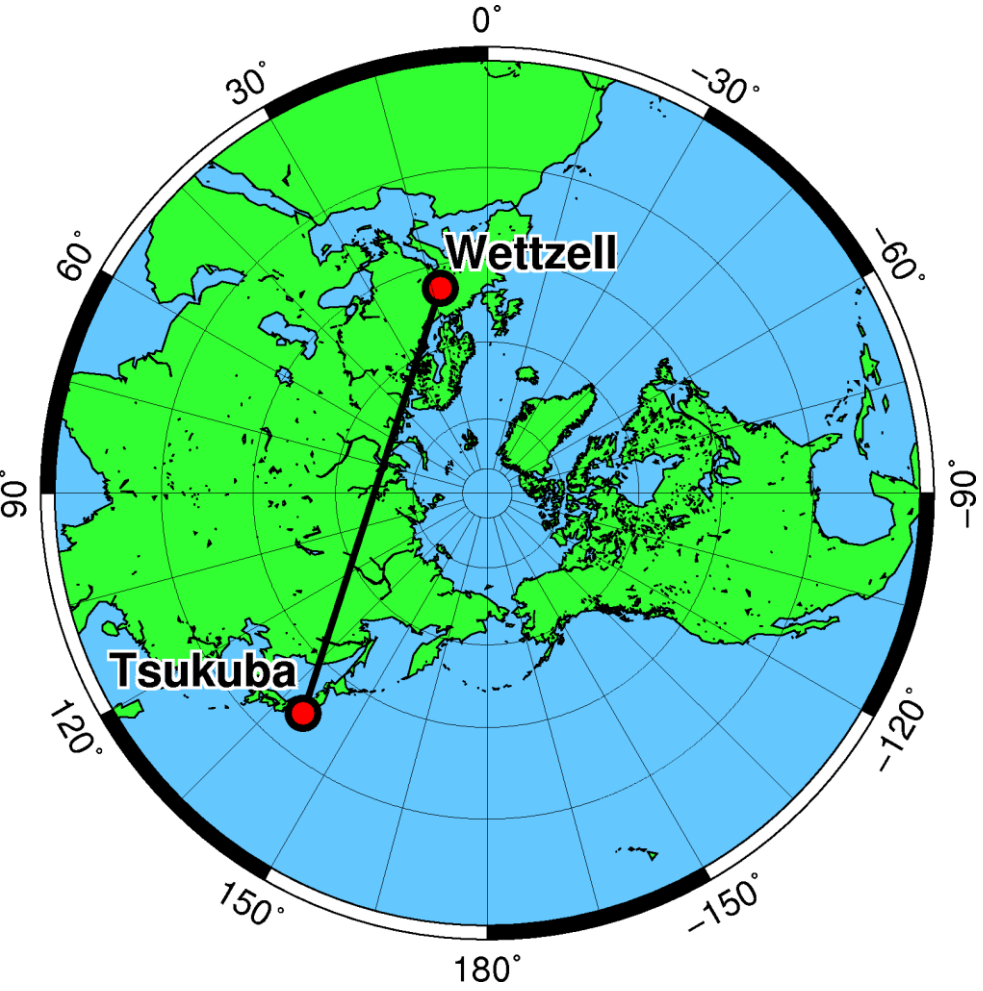
IVS-Intensives



INT1

- XY-baseline length 10072 km
- Monday-Thursday: 18:30-19:30 UT
- Fridays:18:45-19:45 UT
- Offline e-transfer to Washington correlator

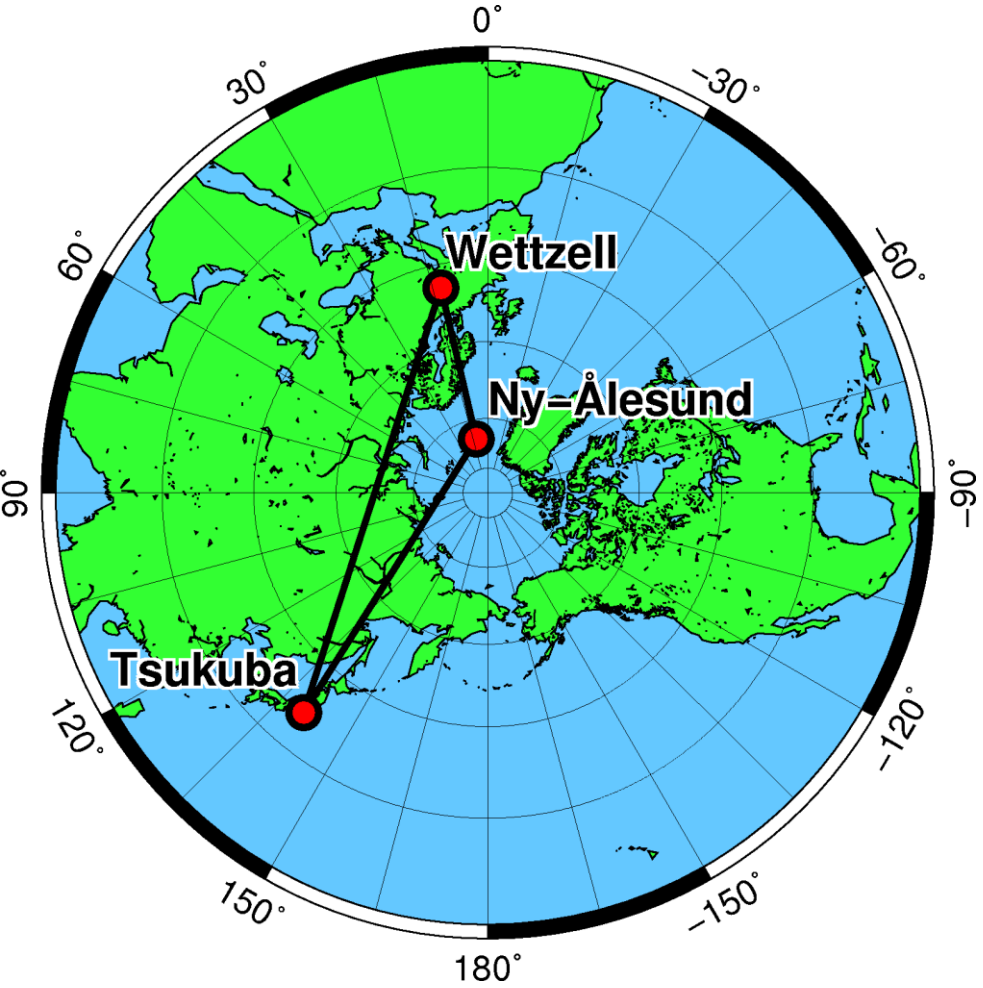
IVS-Intensives



INT2

- XY-baseline length 8378 km
- Saturday/Sunday 07:30-08:30 UT
- Real-time e-transfer to Tsukuba correlator

IVS-Intensives



INT3

- XY-baseline lengths 8378 km, 5998 km, 2952 km
- Monday 07:00-08:00
- Offline e-transfer to Bonn correlator

IVS-Intensives
Time to results ('Latency') - sample week April 2013

Session name	Observing date/time	Correlation	Analysis	Latency correl. since end of observ.	Latency dUT1-res. since end of observ.
INT3 – 089	Apr 08, 07:00-08:00	Apr 08, 14:51	Apr 08, 18:26	06:51	10:26
INT1 – 089	Apr 08, 18:30-19:30	Apr 09, 04:54	Apr 09, 05:10	09:24	09:40
INT1 – 099	Apr 09, 18:30-19:30	Apr 10, 04:32	Apr 10, 17:45	09:02	22:15
INT1 – 100	Apr 10, 18:30-19:30	Apr 11, 02:15	Apr 11, 17:48	06:45	22:18
INT1 – 101	Apr 11, 18:30-19:30	Apr 12, 02:26	Apr 12, 03:19	06:56	07:49
INT1 – 102	Apr 12, 18:45-19:45	Apr 15, 15:10	Apr 15, 17:48	19:25	24:03
INT2 – 103	Apr 13, 07:30-08:30	Apr 15, 09:57	???	49:27	???
INT2 – 104	Apr 14, 07:30-08:30	Apr 15, 09:59	???	25:29	???

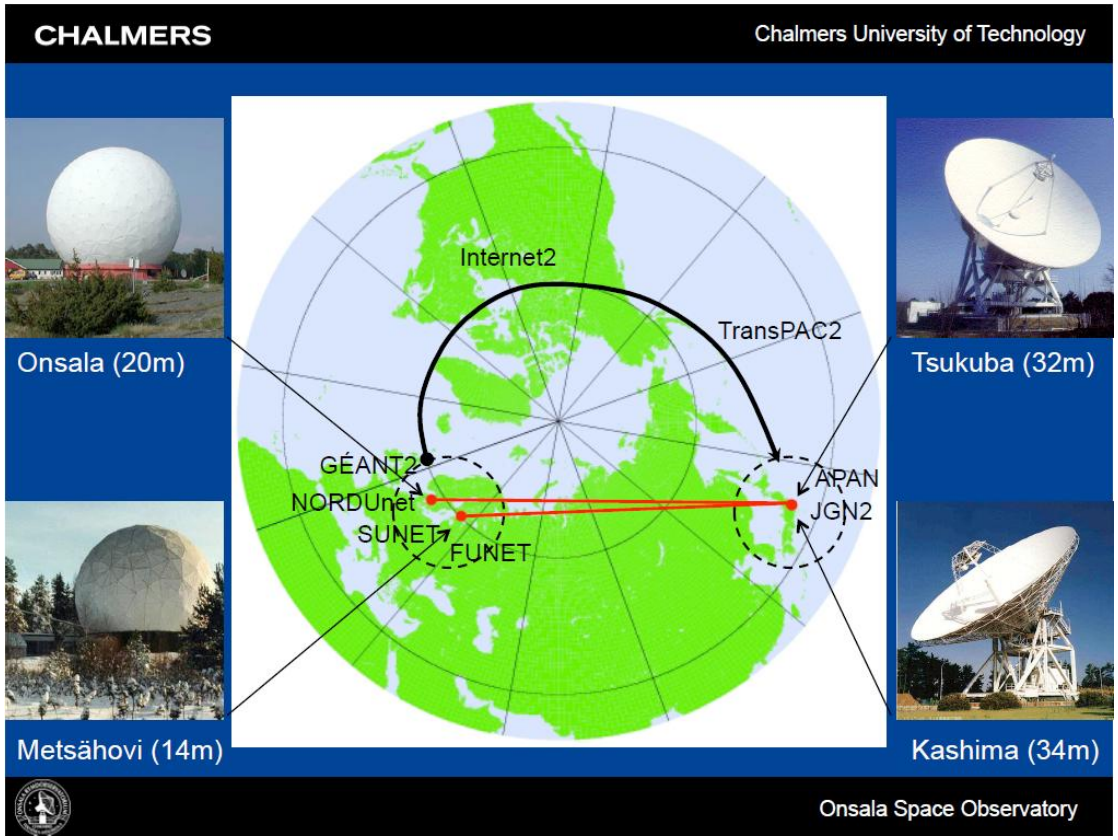
IVS: VLBI2010

e-VLBI Intensives (1h)

- Ultra-rapid Intensives between Europe and Japan
- Onsala-Tsukuba Metsähovi-Kashima
- UT1 turnaround within < 30 minutes

21. Feb. 2008:

Results within 4min after last scan [Matsuzaka et al., 2008]



[Haas et al., 2011: Ultra-rapid dUT1-observations with e-VLBI]

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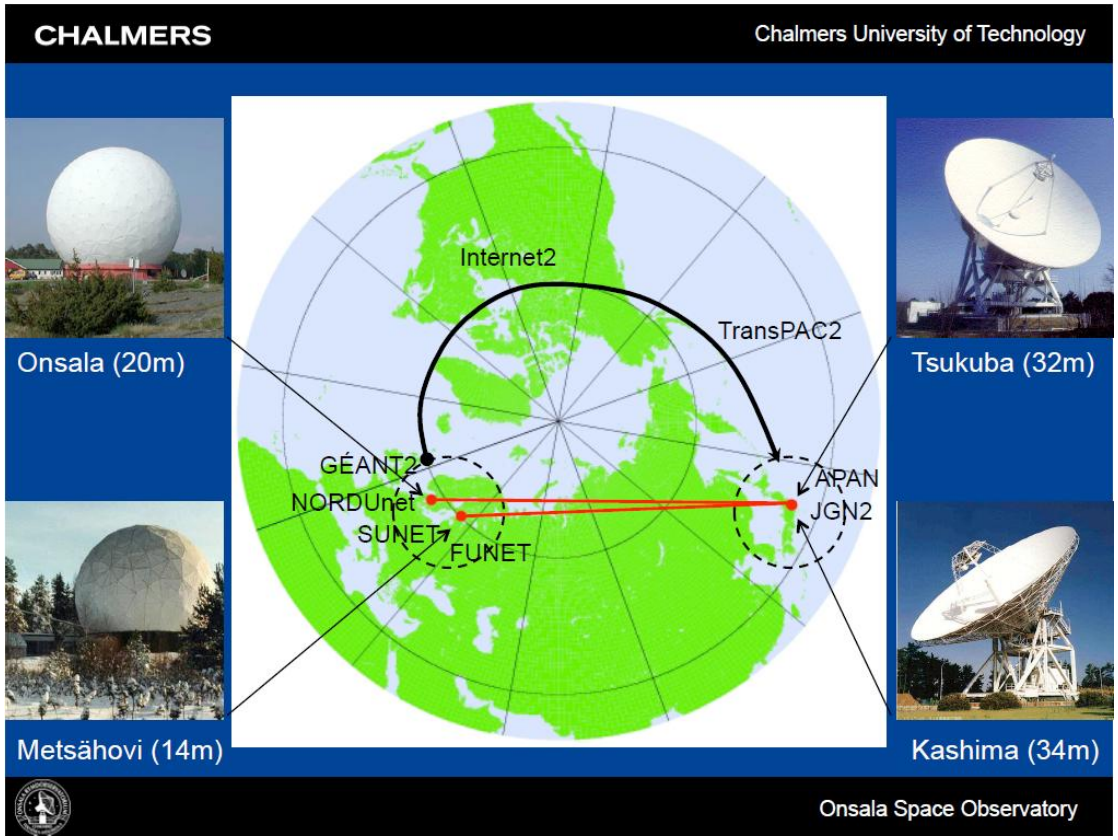


[Haas et al., 2011: Ultra-rapid dUT1-observations with e-VLBI]

VGOS – the **V**LBI2010 **G**lobal **O**bserving **S**ystem **mid range plan**

Deploy Broadband Systems Globally

- The VLBI2010 Project Executive Group (V2PEG) needs to stimulate, support, and organize broadband system deployment
- The goal is 15-20 broadband systems deployed by 2017.

Develop a Mid Range Plan for Sustainable VGOS Operations, e.g.

- 2014: Begin **one weekly 24-hour VGOS-only session**
  - 2-5 stations at the start and growing with time
- 2015: Begin daily sessions with VGOS-only network
  - **four 1-h bursts at 6-hour intervals** (~400 scans/station/day)
    - four 1-h bursts over six days is equivalent operationally (data transport, power, etc) to one 24-hour session
  - Long term goal remains continuous 24/7 operations
- 2017: Significant network will be operational on a daily basis

4 1-h bursts in 24h with the VGOS (2017) network should perform at or better than CONT11 24-h data sets

	# of sites	# of scans/site	X-pole(uas) VLBI-GPS (rms)	Y-pole(uas) VLBI-GPS (rms)	Scale (mm)
R4[2] (24-h)	6-9	180-350	112	112	See plot
R1[2] (24-h)	6-11	200-500	95	87	See plot
CONT05 (24-h)	11	320	65[1]	40[1]	-
CONT08 (24-h)	11	480	48[1]	48[1]	-
CONT11 (24-h)	13	380	31[1]	31[1]	See plot
VGOS(2017) (4 1-h bursts)	15-20	~400	<~CONT11	<~CONT11	<~CONT11

[1]Organization, Correlation, and First Results of CONT11, Behrend et al, 2012
[2]Dan MacMillan, private communication, 2013

ILRS

Current status

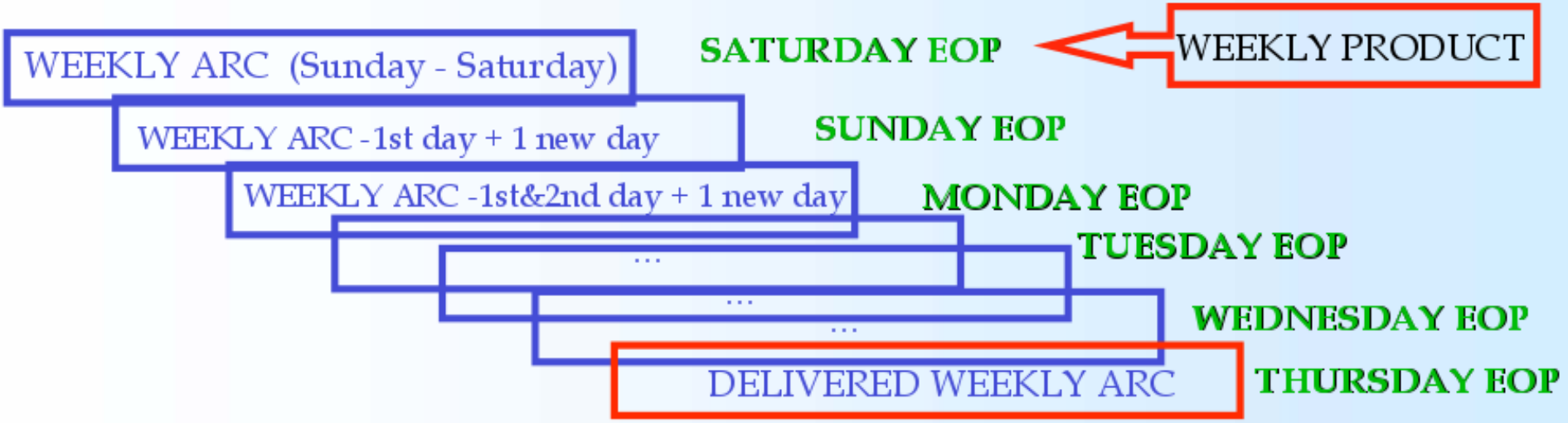
- 95% of **data** available after 1 hour
- since 01.05.2012 **daily** POS & EOP **products**
  - Latency **2** days
  - Used mainly for USNO EOP predictions

Future plans:

- **Products** at approx. **hourly** intervals

ILRS

- The operational scheme for the daily products is:



IGS: Real-Time Service

Current status:

- GPS satellite orbit and clock corrections as single epoch combination or Kalman filter solution
- Working on including solutions for additional constellations, starting with GLONASS

-> Talks by U. Hugentobler and J. Wickert: Real-time projects of the IGS

J. Wickert: Real-time GNSS applications

IERS Retreat 2013

Paris 23.-24.05.2013

Session 1: ***Move towards "real-time" products***

- H. Schuh: Introduction to real-time applications in space geodesy
- B. Luzum: State-of-the-art of EOP prediction within the IERS
- U. Hugentobler and J. Wickert: Real-time projects of the IGS
- J. Wickert: Real-time GNSS applications
- R. Haas: The IVS intensive sessions on their way to near real-time

Thank you for your attention!