IVS Products for Precise Global Reference Frames

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- About IVS
- IVS products and related observing programs
- Operational improvements
- VISION 2010

I V S - International VLBI Service for Geodesy and Astrometry

IVS is a service of

- **IAG** - International Association of Geodesy
- **IAU** - International Astronomical Union
- **FAGS** - Federation of Astronomical and Geophysical Data Analysis Services

Main tasks of the IVS

- global coordination of VLBI components in order to guarantee the provision of the products for
  - **Celestial Reference Frame (CRF)** **VLBI is fundamental and unique for CRF**
    - **IAU Resolution, August 2000**
  - **Terrestrial Reference Frame (TRF)** **VLBI contributes strongly to TRF (scale)**
  - **Earth Orientation Parameter (EOP's)** **VLBI provides complete set of EOP, uniquely DUT1**

Basis for collaboration and contributions

- **Call of Participation in 1998**
- **Proposals for 73 permanent components,**
  - **from 37 Institutions in 17 countries,**
  - **~ 250 Associate Members**

Map of the IVS Components

Step to meet Service Requirements

- When IVS started the demand for continuity in maintaining the reference frames forced to employ the existing observing programs (NEOS, CORE, ... INT)

- 2001 review of products and observing programs
  ==> **Working Group 2**

  - **Basis for improving products and evolving observing programs to meet service requirements**

Review of Products (examples from Working Group 2 Report)

Products		Status 2001	Goals(2002-2005)
polar motion	accuracy	x_p ~100 µas, y_p ~200 µas	x_p, y_p: 50 ... 25 µas
	latency	1-4 weeks... 4 months	4 - 3 days...1day
	resolution	1 day	1 day...1h... 10min
	freq. of sessions	~3 d/week	.........7d/week
UT1	accuracy	5... 20 µs	3.................. 2 µs
	latency	1 week	4 - 3 days 1day
	resolution	1 day	1 day 10min
$\Delta\varepsilon$, $\Delta\psi$	accuracy	100... 400 µas	50...25 µas
	latency	1-4 weeks... 4 months	4 - 3days... 1 day
	resolution	1 day	1 day
	freq. of sessions	~3 d/week	.... 7 d/week
TRF (x,x,z)	accuracy	5-20 mm	5 .... 2 mm
	....	....	....
CRF	accuracy	0.25-3 mas	0.25 mas (improved distribution)
	freq. of solution	1 y	1 y
	latency	3-6 months	3 .... 1 month(s)
......	....	....	....

Improvements within IVS Observing Program

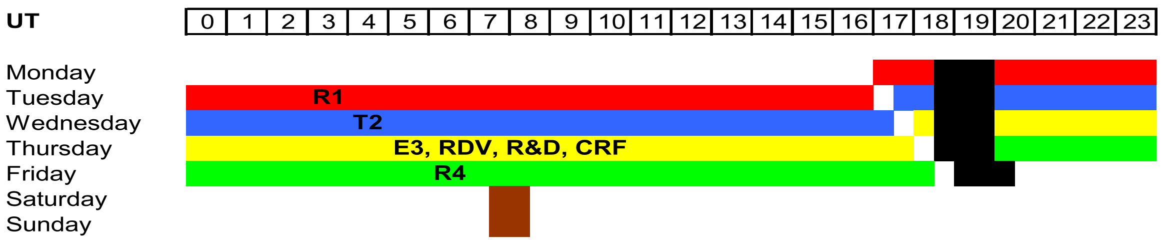
- **Appropriate observing programs started 2002 for**
  - **Earth Orientation Parameters (EOP): IVS-R1 ... IVS-R4 …, IVS-INT1/2**
    - Two rapid turn-around sessions each week,
    - Comparable xp, yp results.
    - Additional sessions employing S2 and K4 techniques **(IVS-E3, IVS-INT2)**
  - **Terrestrial Reference Frame (TRF): IVS-T2**
    - Monthly TRF sessions with 8 stations
  - **Celestial Reference Frame (CRF): RDV and IVS-CRF**
    - RDV: Bi-monthly RDV sessions using the VLBA and up to 10 geodetic stations,
      - USNO: Source structure, NASA: TRF, NRAO: high precise source positions
    - IVS CRF (8-10 per year): Astrometric observations for new sources
  - **CONT, whenever required IVS-CONT02**
    - 14-day continuous sessions to demonstrate the best results that VLBI can offer
    - in 2002: CONT-session, October 16-31, 2002
  - **Monthly R&D sessions: IVS-R&D**
    - to investigate instrumental effects, research the network offset problem

⇨ **Geodetic VLBI observations increased by**

- ⇨ **about 30% in 2002 compared to 2001**
- ⇨ **about 15% in 2003 compared to 2002**
- ⇨ **about 15% in 2004 compared to 2003**

2005 Observing Plan Summary

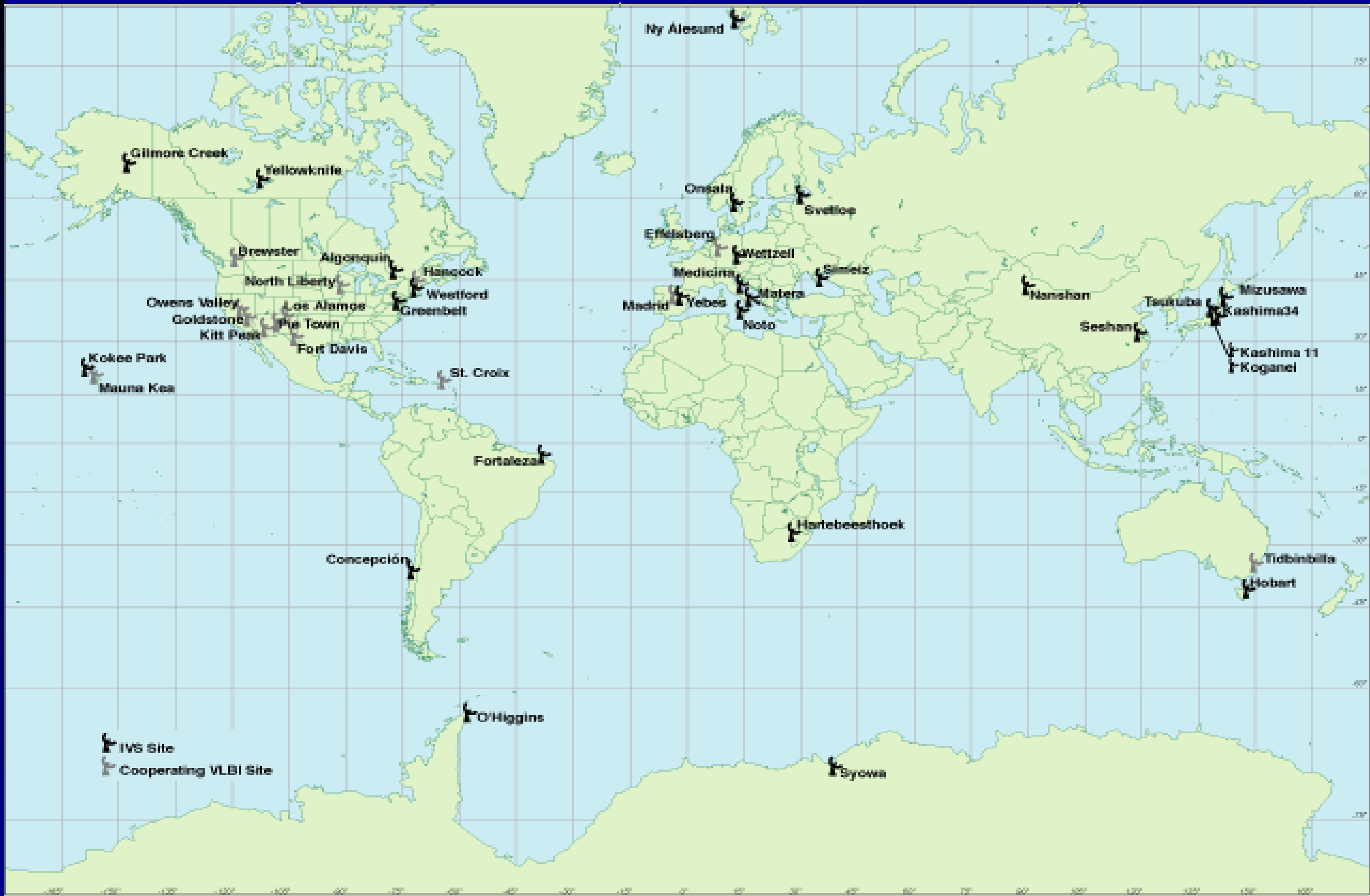
Session purpose	Session code	# sessions	Typical # stations	Total station days	Average GB per station per day	Mb/s for transfer in 1 day	Total TB per year
Rapid turnaround EOP (Monday)	IVS-R1	52	7.0	364	1200	111	437
TRF, all stations 3-4 times per year	IVS-T2	6	16.0	96	400	37	38
EOP, TRF using S2	IVS-E3	12	6.0	72	600	56	43
Rapid turnaround EOP (Thursday)	IVS-R4	52	7.0	364	500	46	182
CRF, emphasis on south	IVS-CRF	13	3.0	39	400	37	16
20-station EOP/TRF/CRF sessions	RDV	6	20.0	120	1000	93	120
R&D Gb/s	IVS-R&D	10	6.0	60	3000	278	180
Regional - Antarctica	IVS-OHIG	6	6.0	36	300	28	11
Regional - Europe	EURO	4	9.0	36	300	28	11
Regional - Antarctica	SYOWA	4	3.0	12	300	28	4
Regional - Asia/Pacific	APSG	2	6.0	12	300	28	4
	Totals	**167**		**1211**			**1045**



■ = Intensive session Kokee-Wettzell
■ = Intensive session Tsukuba-Wettzell

... + CONT05?

IVS sites and cooperating VLBI sites



Products for CRF

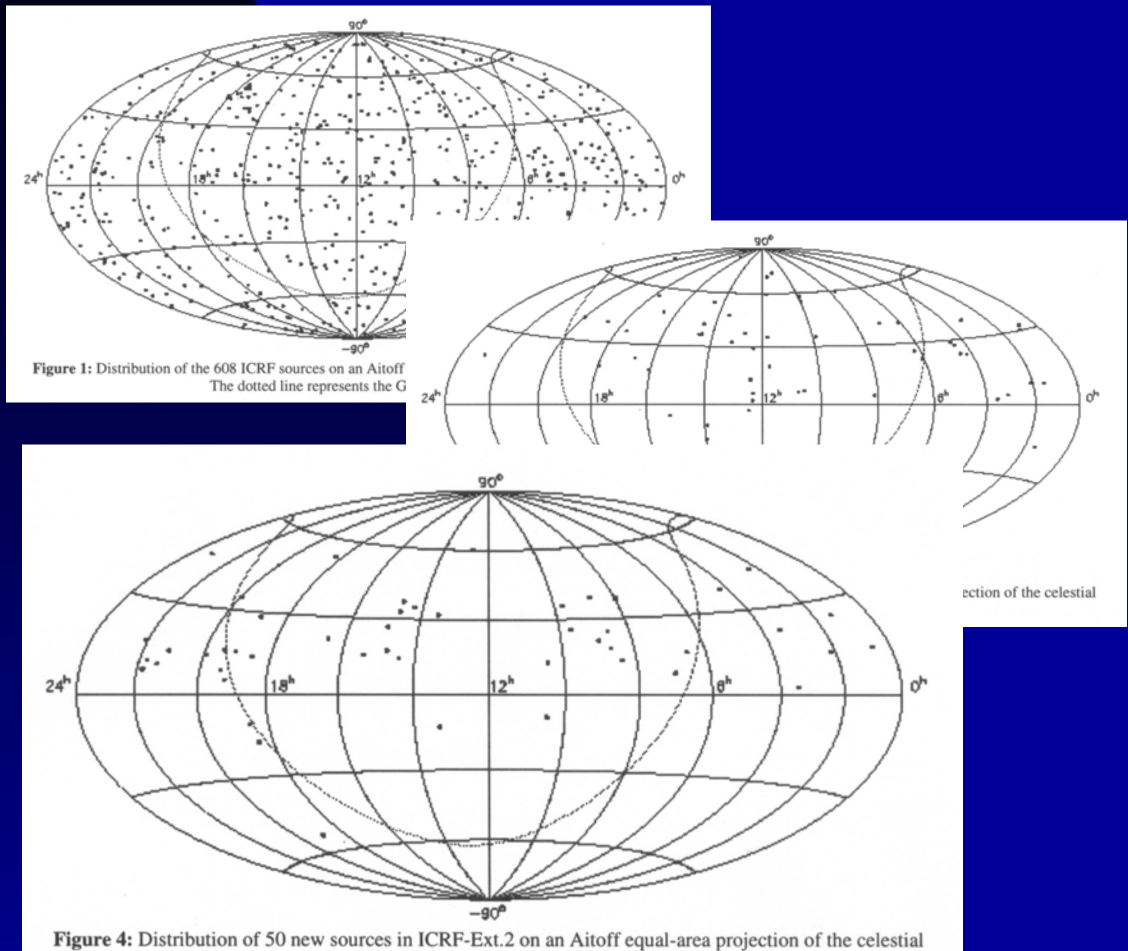
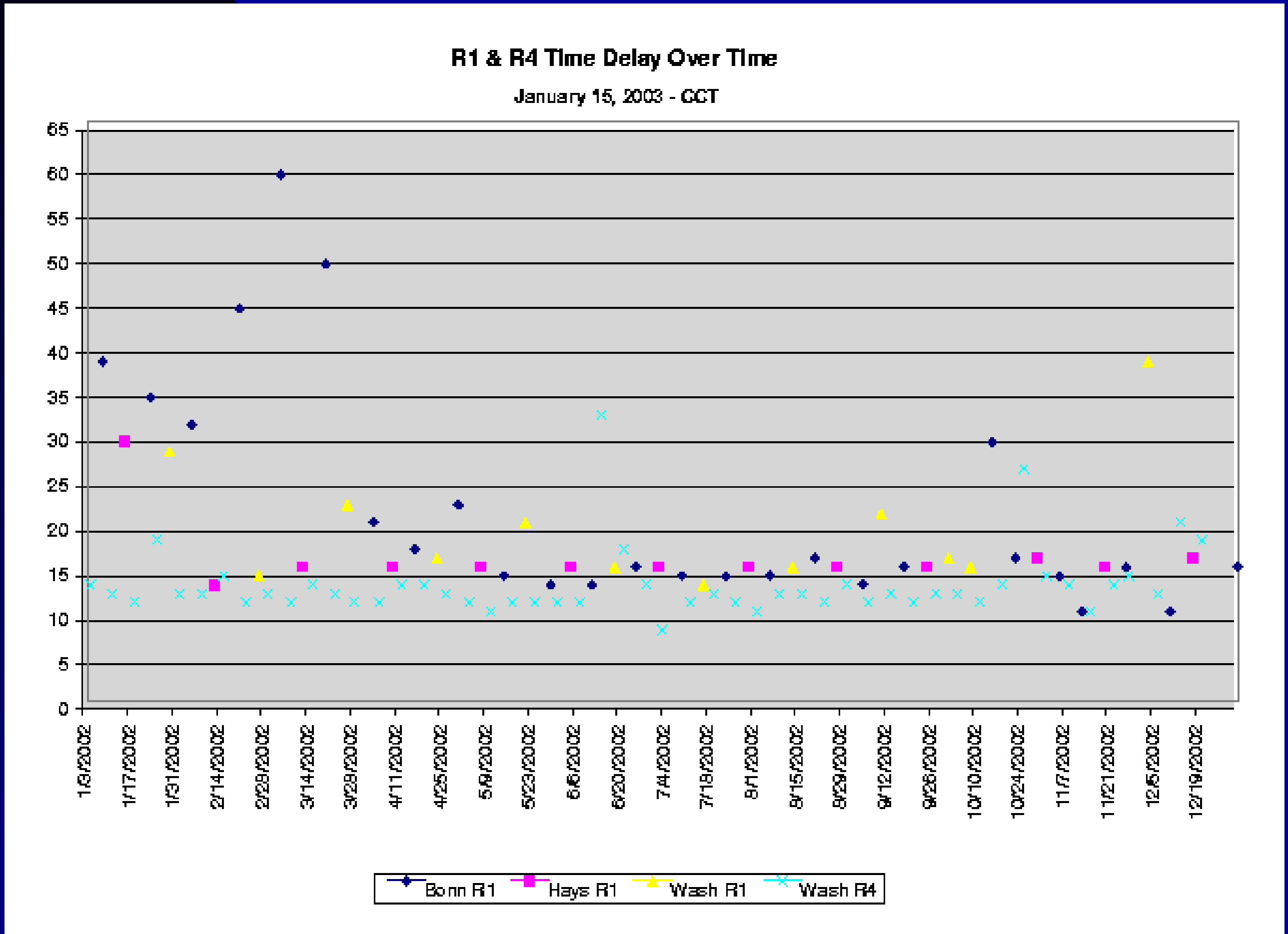


Figure 4: Distribution of 50 new sources in ICRF-Ext.2 on an Aitoff equal-area projection of the celestial sphere. The dotted line represents the Galactic equator.

- ICRF
  - CRF
    - 212 defining sources
    - 294 Candidate sources
    - 102 other sources
  - ICRF-Extension 1
    - Completed 1999
    - Adding 59 Sources
  - ICRF-Extension 2
    - Completed 2002
    - Adding 50 Sources
- **IVS as service of IAU contributes to the maintenance of CRF by monitoring Sources** **(**Positions, Structures) in close relation to IAU WG on Reference Frames and IERS

Improved delay from observation to product availability



2 time series per week

- IVS R1 (Bo, Ha, Wa)
- IVS R4 (Wash)

Results available

- approximately after two weeks

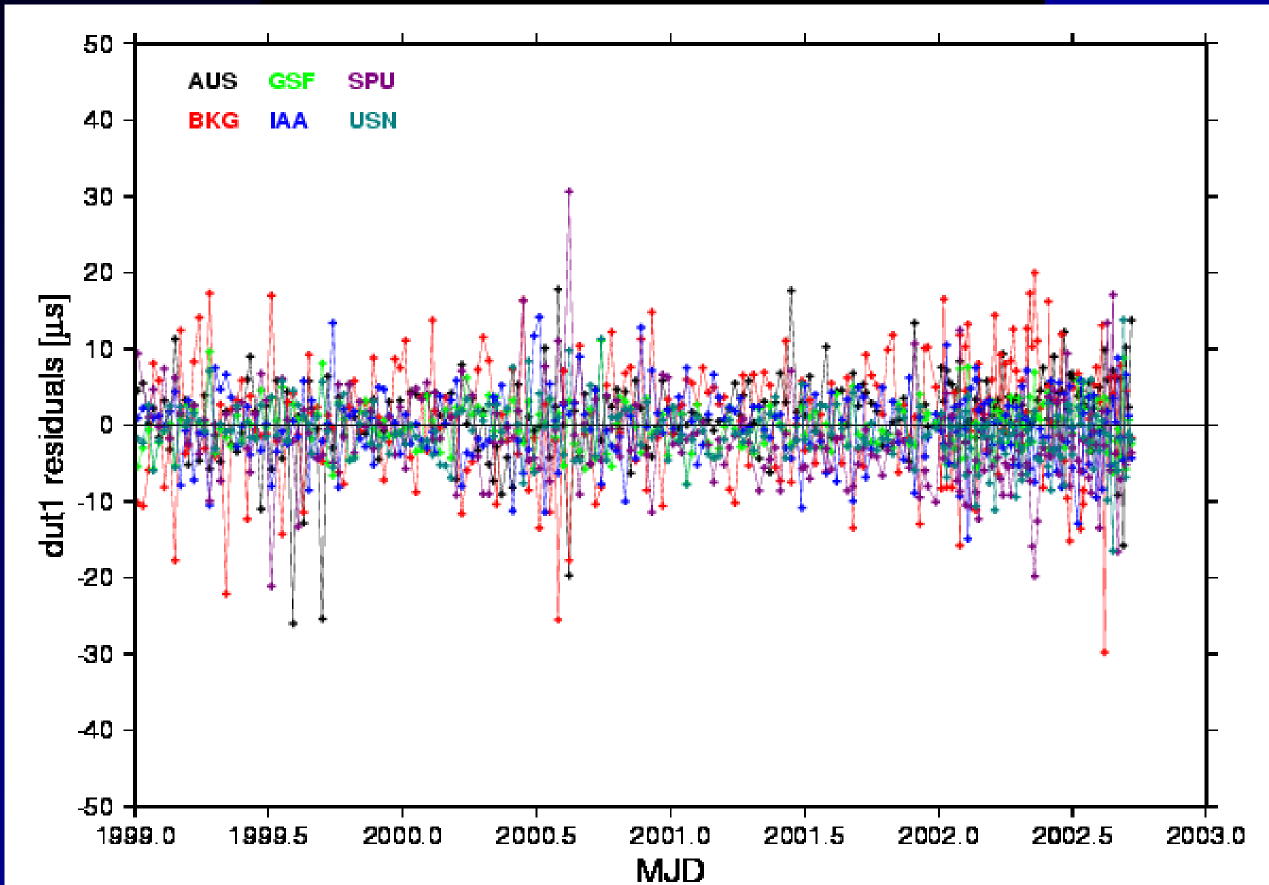
Potential for Improvements

- Acceleration of Transportation
- (e-VLBI)
- Correlator processing (employing MK5)

Combined EOP's are regular IVS Products

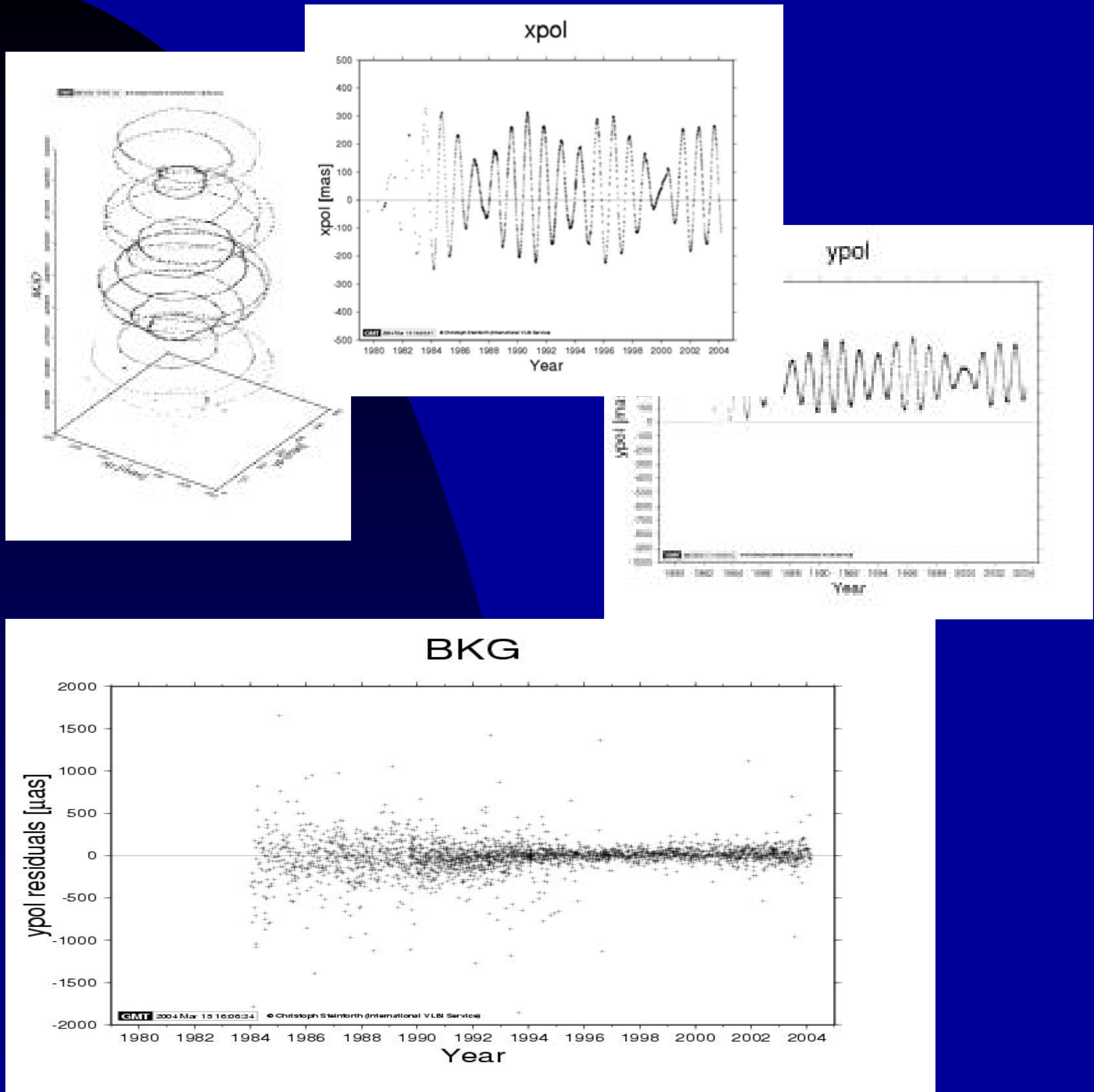
Analysis Coordinator: Axel Notnagel, Univ. Bonn

Example: DUT1 form R1 and R4



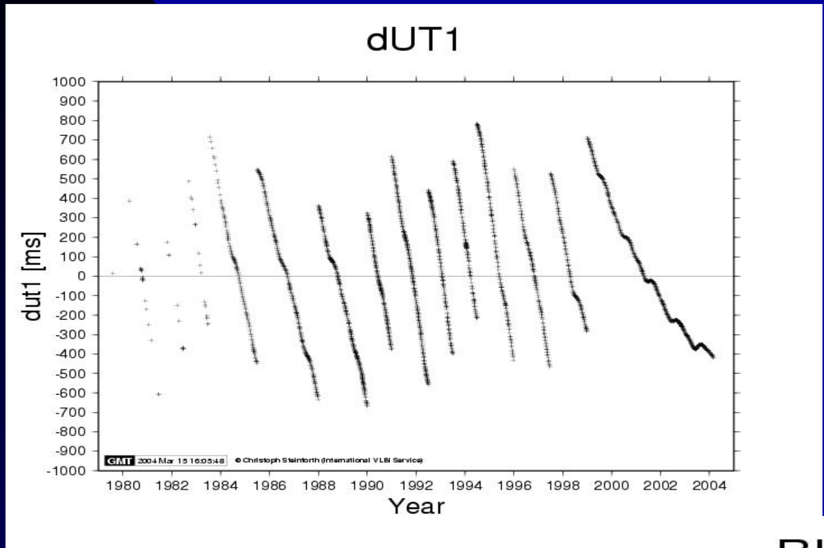
- **Complete set of EOP's**
  - **$d\psi$, $d\varepsilon$**
  - **x_p ,y_p**
  - **UT1-UTC**
- **Combined Solution from 5 (6) Analysis Centers**
- **20-30% improved**
  - **accuracy**
  - **robustness**
- **R1 & R4 since 2002**

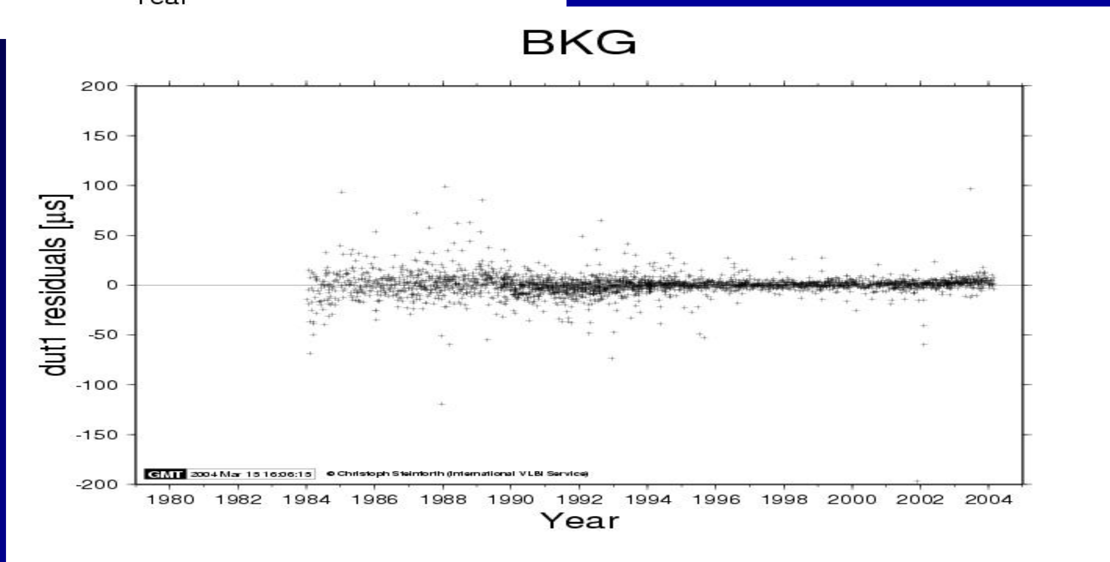
IVS Combined Product: Polar Motion



	X-Pol [µas]		Y-Pol [µas]	
AC	**X-Bias**	**WRMS**	**Y-Bias**	**WRMS**
AUS	-13,5	196,0	1,1	217,4
BKG	-2,1	68,4	6,3	56,1
GSF	2,0	52,1	-1,9	44,2
IAA	0,9	87,5	-2,3	83,1
USN	0,8	70,9	-3,4	58,7

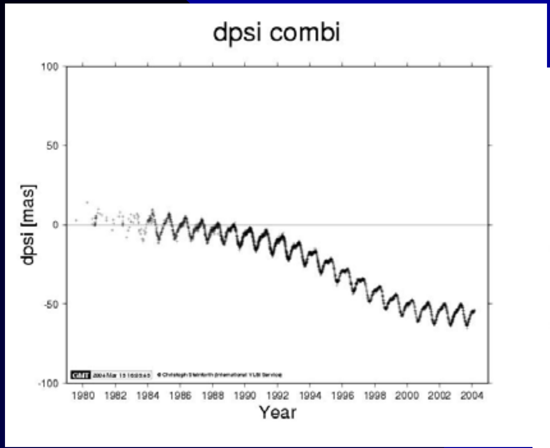
IVS Combined Product: UT1-UTC

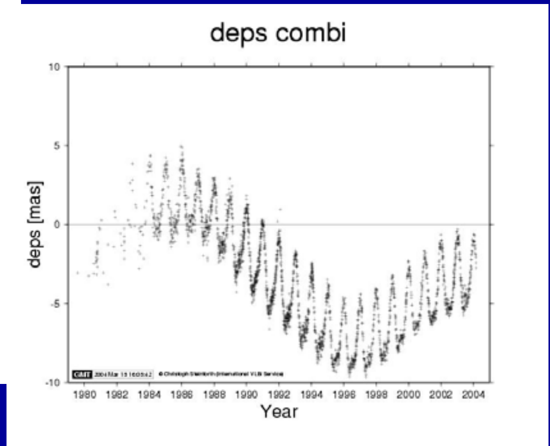


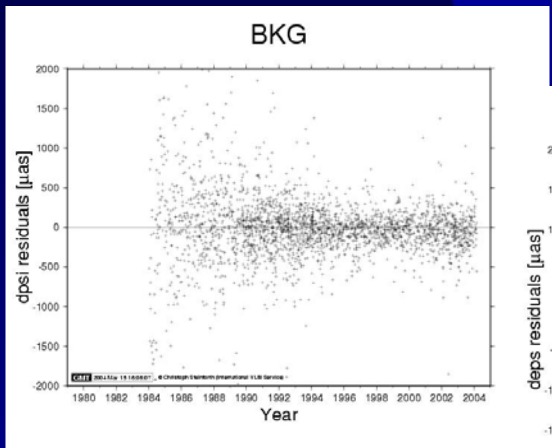


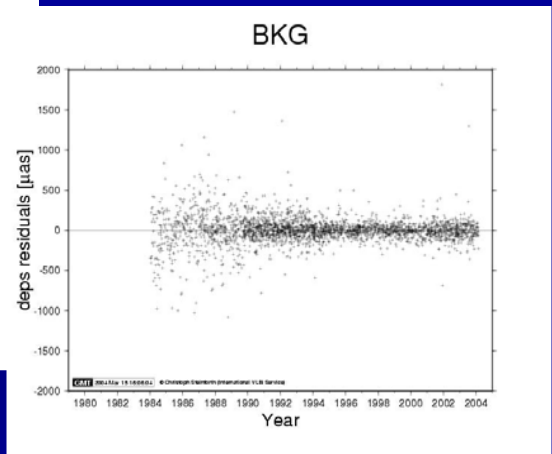
	UT1-UTC [µs]	
AC	X-Bias	WRMS
AUS	O,9	10,8
BKG	0,3	2,8
GSF	0,1	2,1
IAA	-0,4	2,4
USN	-0,2	2,4

IVS Combined Product: dφ and dε





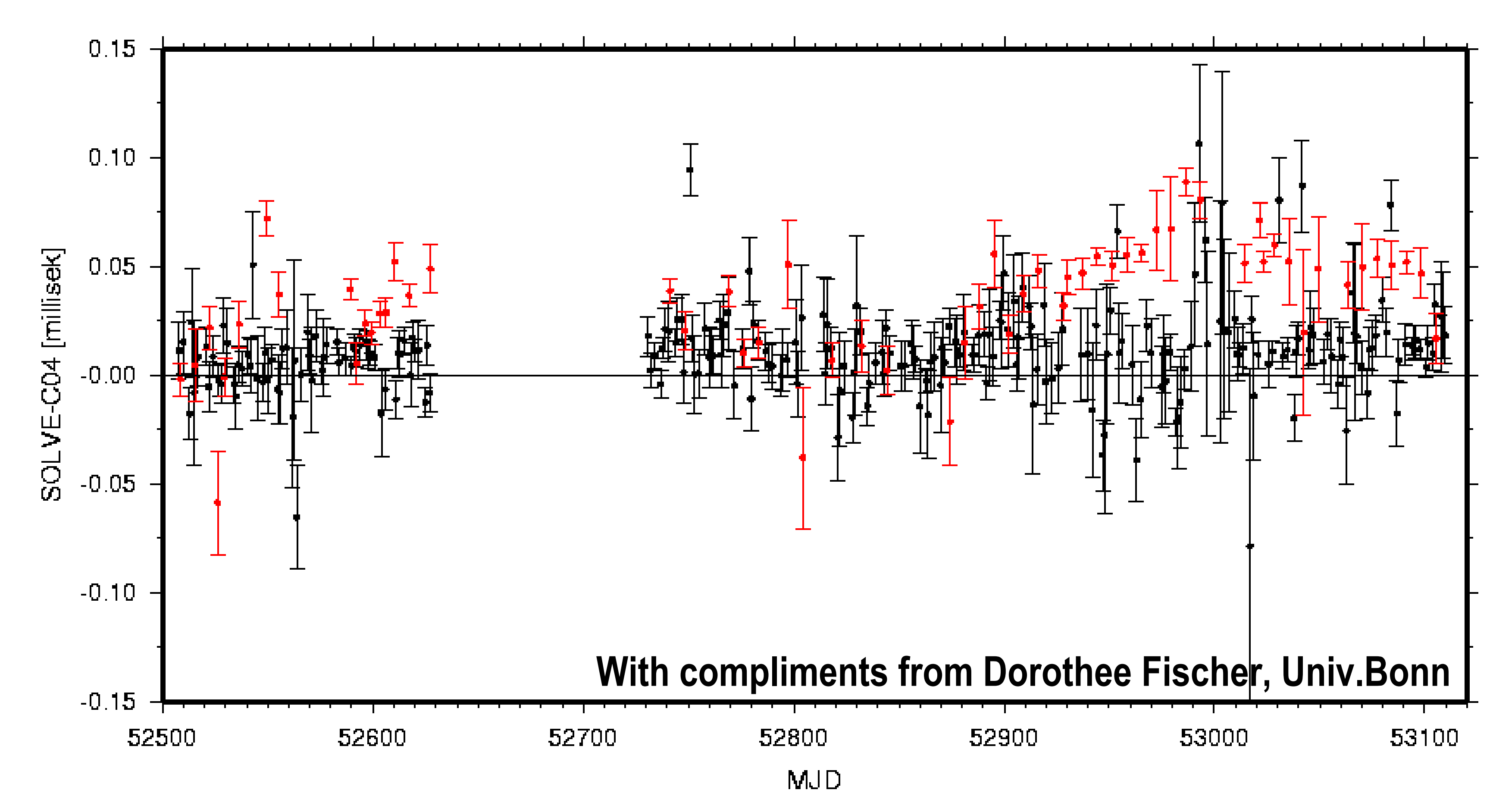




	dpsi [µas]		deps [µas]	
AC	X-Bias	WRMS	Y-Bias	WRMS
AUS	7,7	188,1	-18,9	89,4
BKG	-23,9	209,2	0,4	80,5
GSF	-53,1	196,4	-10,1	76,6
IAA	22,9	140,8	14,6	59,7
USN	-8,0	219,7	6,8	82,2

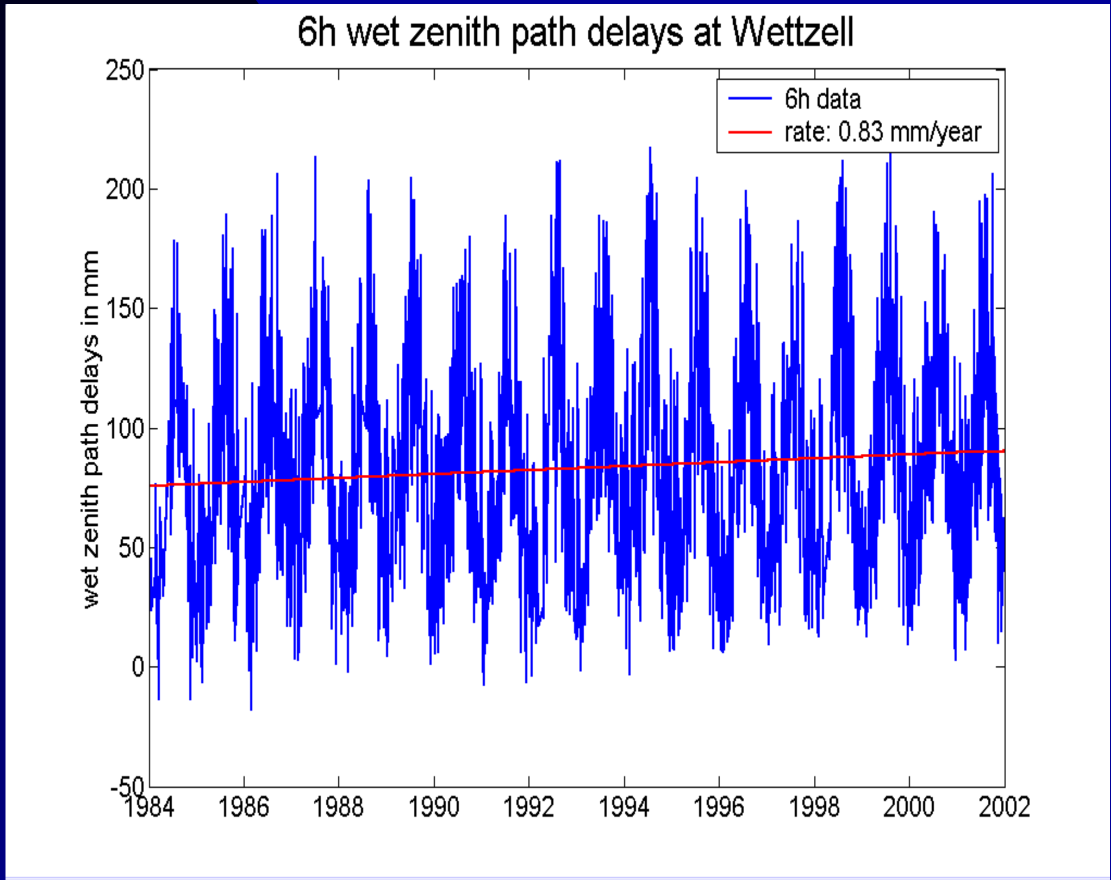
UT1-UTC from INTENSIVES with reference to CO4

MK4: Wettzell - Kokee Park (black) and K4: Wettzell – Tsukuba (red)



Tropospheric Parameter

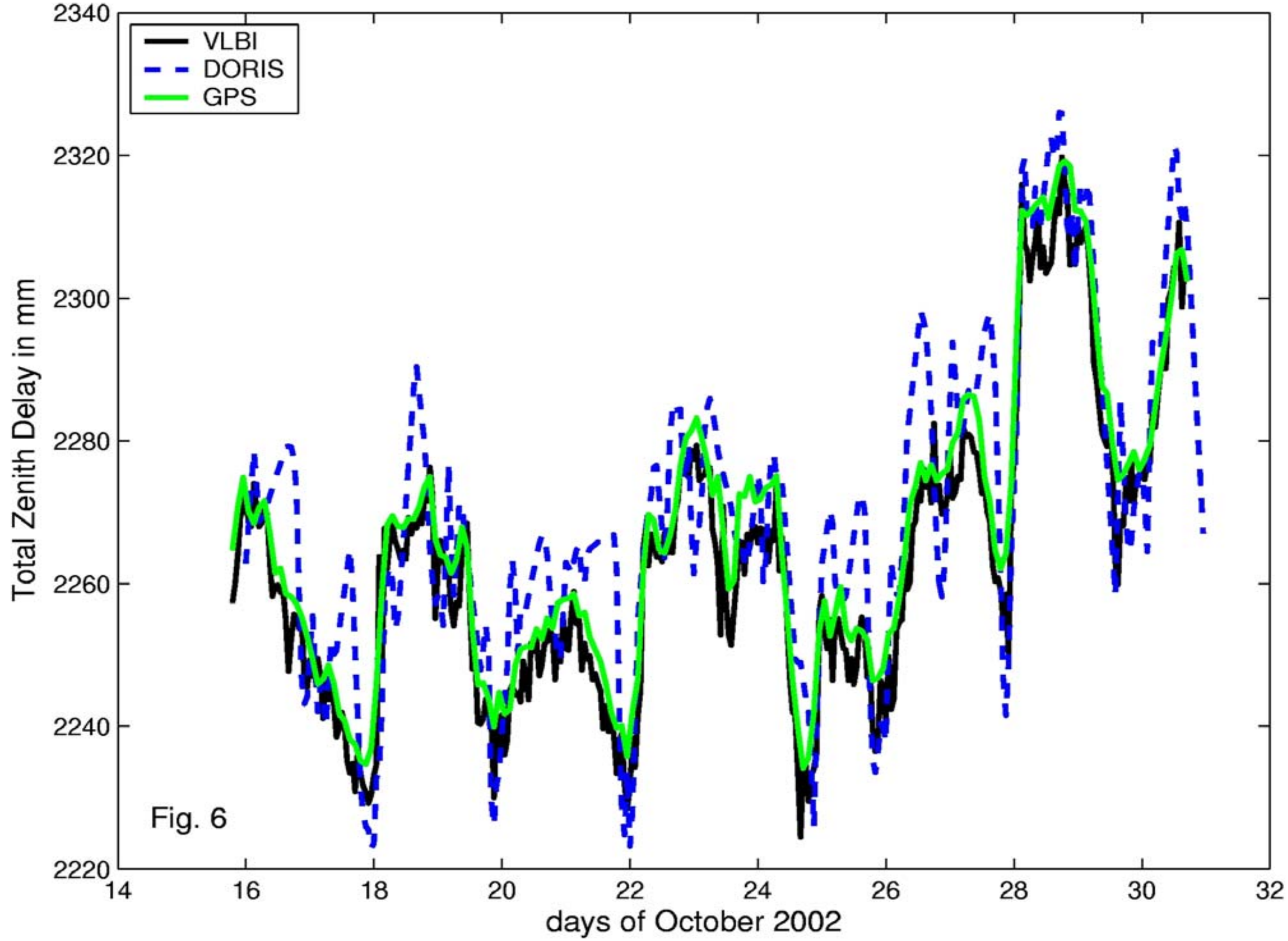
WZD as IVS product



With compliments from H.Schuh et.al., TU-Vienna

- Wet Zenith Delay
  - Regular for each R1 or R4
  - Hourly resolution
- Solution of 5 Analysis Centers
- Combined by TU-Vienna
- Combined IVS product officially accepted at the 9th DB-meeting
- 2-3mm precission comparable to GPS (or better?)

Total Zenith Delay derived from CONT02 at Gilcreek



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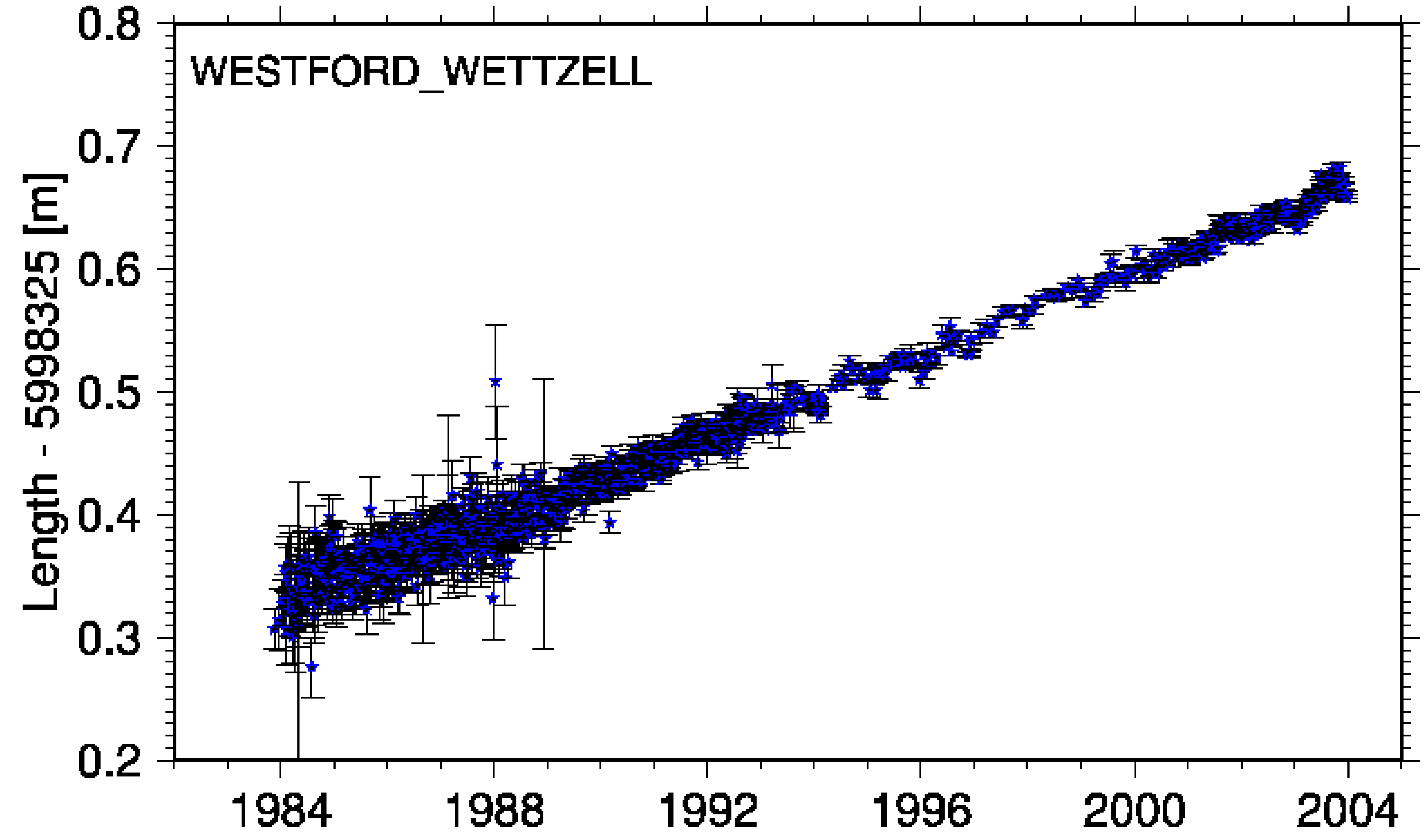
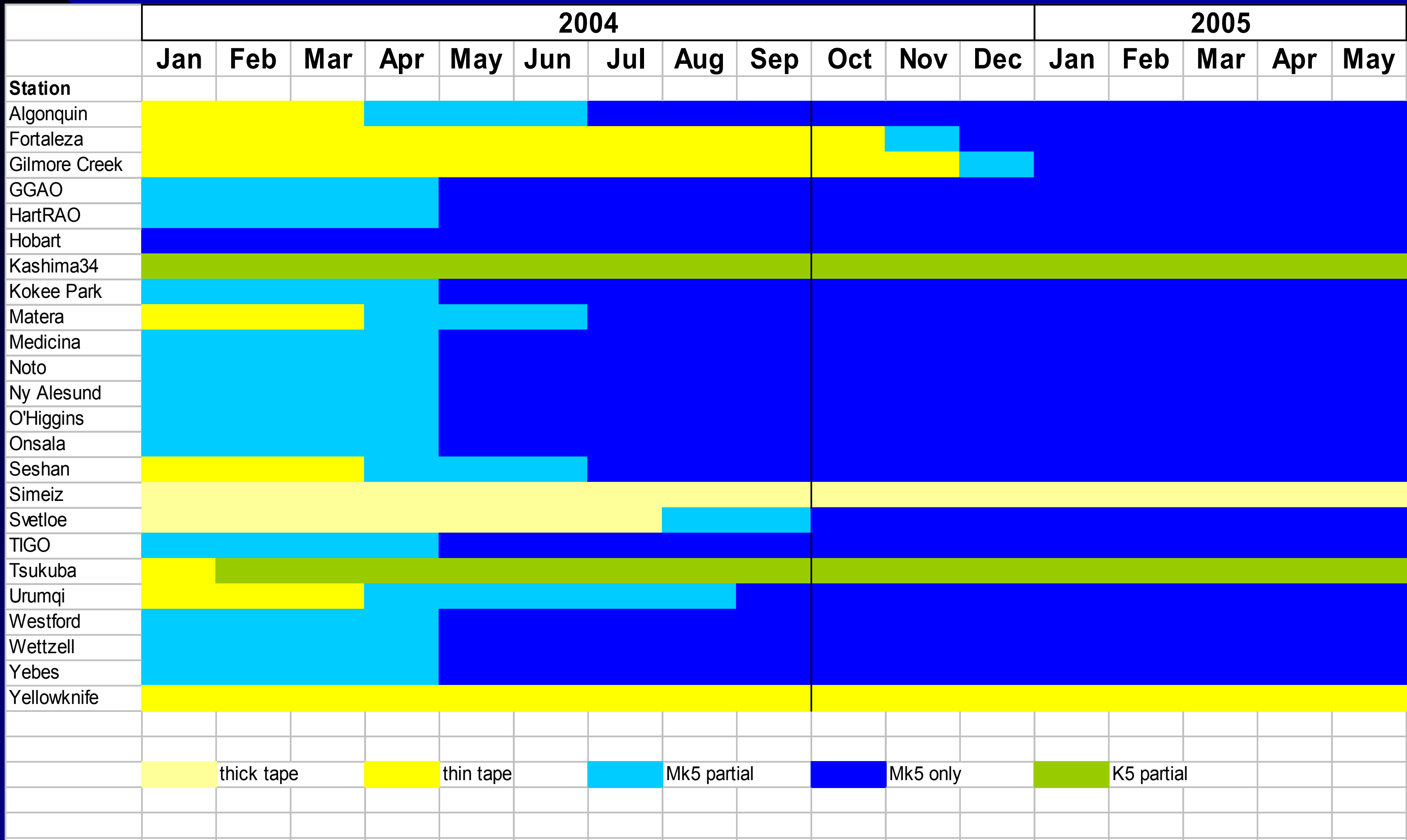
IVS Pilot Project: Time Series of Baseline Lengths



Operational Improvements

- Digital Recorder
  - MK5A … MK5b
  - K5
- VSI
- e-VLBI
  - near real time
  - real time

Mk 5/K5 Usage Plan



Employing Internet for Datatransmission „e-VLBI“

Required time for the transfer

(max. throughput 60%)

Connection	R1	R4	INT	costs / a (WiN)
64 kbit/s	-	-	100 d	
2 Mbit/s	93 d	69 d	3 d	
34 Mbit/s	6 d	4 d	5 h	~ 50.-k€
155 Mbit/s	1,2 d	1 d	1 h	~180.-k€
622 Mbit/s	7 h	5 h	15 m	~450.-k€
....				
2,4 Gbit/s	1,9 h	1,3 h	4 m	

Connectivity of geodetic-VLBI components

- Haystack, USA-Ma (2.5 Gbps)
- Kashima, Japan (1 Gbps; 2 x 1 Gbps soon)
- Tsukuba, Japan (1 Gbps)
- GGAO, USA-Md (1 Gbps)
- Onsala, Sweden (1 Gbps)
- Westford, USA-Ma (1 Gbps)
- Wettzell, Germany (34 Mbps)
- Kokee Park, USA-Ha (nominally ~30 Mbps, but problems)

Vision Paper 2010
focus on „next generation“ geodetic VLBI

Working Group WG 3 established at the 10 DB-Meeting:

- Needs for a vision paper:
  - Increasing requirements e.g from GGOS/IAG
  - RFI, frequency bands?
  - Aging antennas
  - Long term planning
- Goals:
  - Unattended observing, more regular
  - Improved global coverage
  - Electronic data transfer
  - Near real time correlation and product provision
  - Report end 2004
- Close collaboration with Radio-Astronomers (SKA)

WG3: VISION 2010

- **Chaired by Alan Whitney and Arthur Niell**
- **Subgroups**
  - Observing Strategies (Bill Petrachenko)
    - Frequency Bands, RFI
    - Fieldsystem and Scheduling
    - Source strength /structure /distribution
    - Antenna network configuration and observing strategies
  - RF/IF, Frequency and Time (Hayo Hase)
    - Antennas and Feeds
    - RF/IF and Calibration
    - Time and Frequency Standards
  - Backend Systems (Gino Tuccari)
    - Backends, digital filtering and BBC's
  - Data acquisition and transport (Alan Whitney)
  - Correlation and fringe finding (Yasuhiro Koyama)
  - Data analysis (Harald Schuh)
  - Data archiving and management (Chopo Ma)

Thank you !