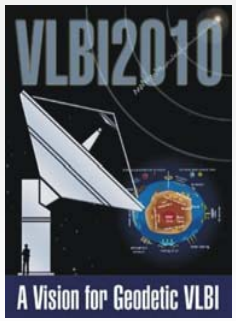
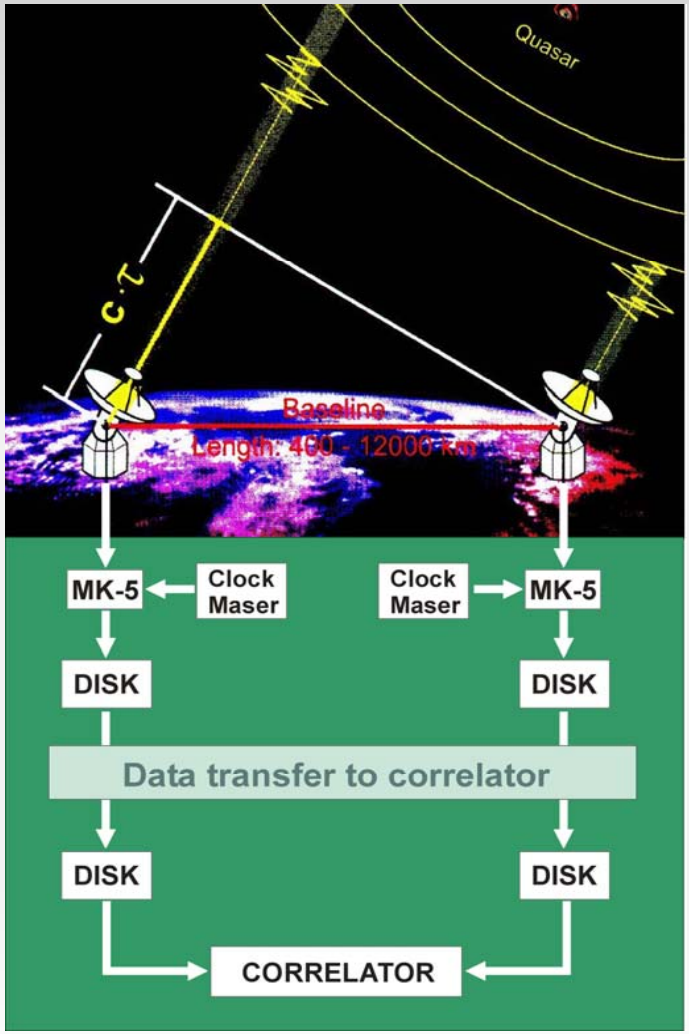
Current State and Future Developments of the IVS and Geodetic VLBI

H. Schuh, D. Behrend, A. Niell,
B. Petrachenko, and
R. Heinkelmann



Bologna, 26-Sept-2008

Geodetic VLBI



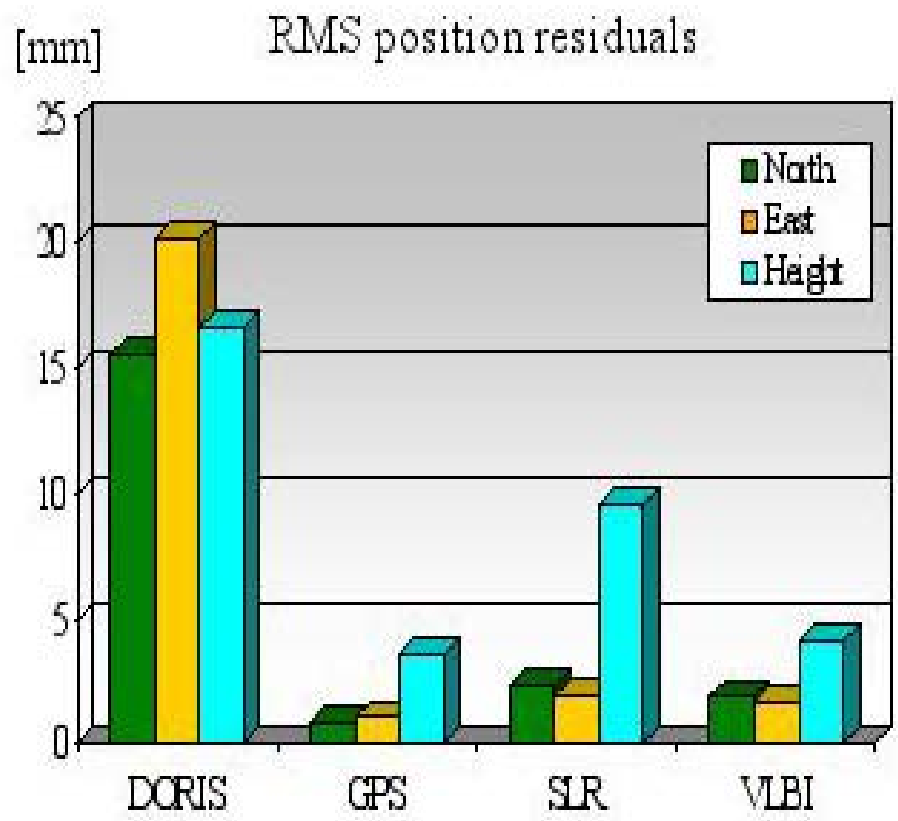
- Unique technique for
  - CRF
  - Precession/Nutation
  - DUT1 = UT1 - UTC
- Primary technique for
  - EOP (complete set of parameters)
  - TRF (most precise technique for long baselines, scale)
- Observing S/X band

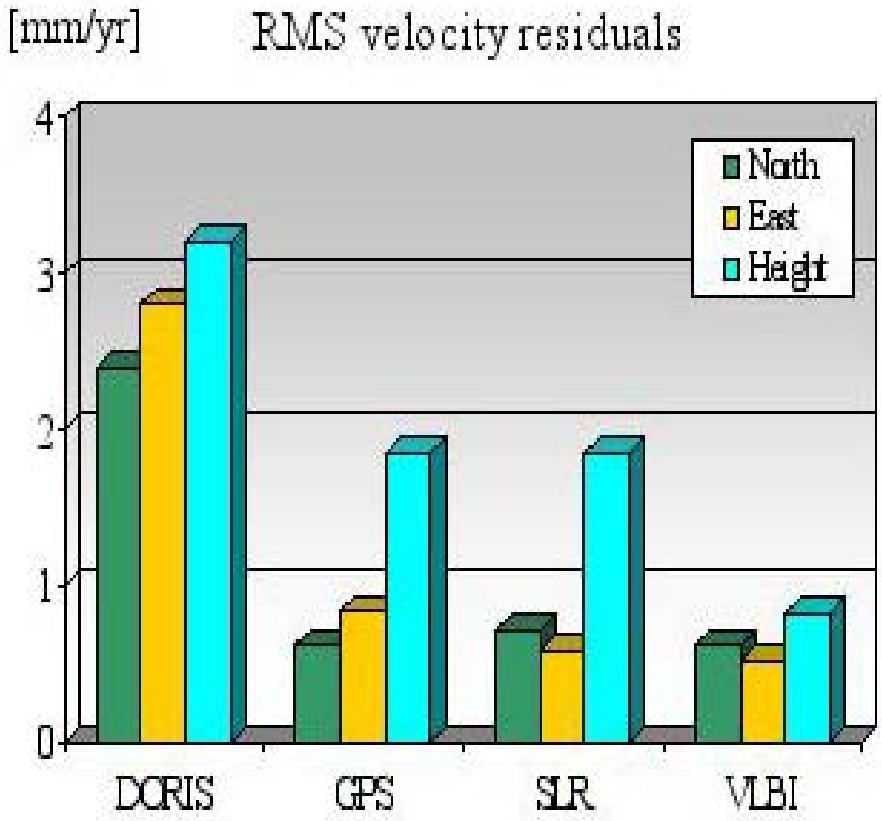
VLBI provides unique parameters

(M. Rothacher)

Parameter Type	VLBI	GNSS	DORIS	SLR	LLR	Altimetry
ICRF (Quasars)	**X**					
Nutation	**X**	(X)		(X)	X	
Polar Motion	X	X	X	X	X	
UT1	**X**					
Length of Day	(X)	X	X	X	X	
ITRF (Stations)	X	X	X	X	X	(X)
Geocenter		X	X	X		X
Gravity Field		X	X	X	(X)	X
Orbits		X	X	X	X	X
LEO Orbits		X	X	X		X
Ionosphere	X	X	X			X
Troposphere	X	X	X			X
Time Freq./Clocks	(X)	X		(X)		

RMS of Space Geodetic Techniques





(From a global TRF solution derived by DGFI, Munich)

International VLBI Service for Geodesy and Astrometry

IVS is an international collaboration of organizations, which operate or support Very Long Baseline Interferometry (VLBI) components

- founded in 1.3.1999 as **a** service of

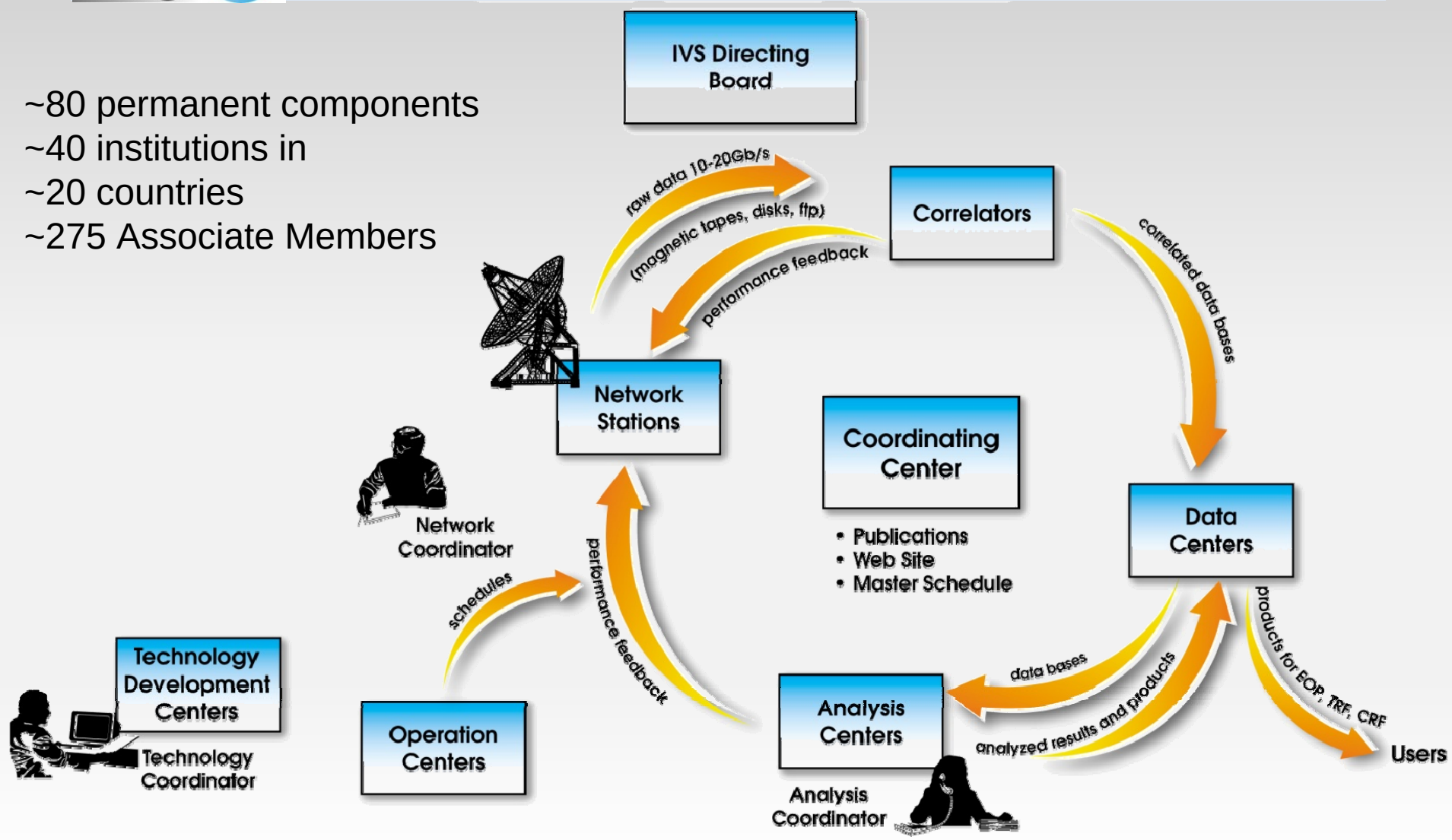
- **IAG** - International Association of Geodesy
- **IAU** - International Astronomical Union
- **IERS** - International Earth Rotation and Reference Systems Service
- **FAGS** - Federation of Astronomical and Geophysical Data Analysis Services

Objectives:

- Support geodetic, geophysical and astrometric operational **activities** and research
- Promote **research and development** in geodetic and astrometric VLBI technique
- **Interact** with the user community of VLBI products and **integrate** VLBI into a global Earth observing system

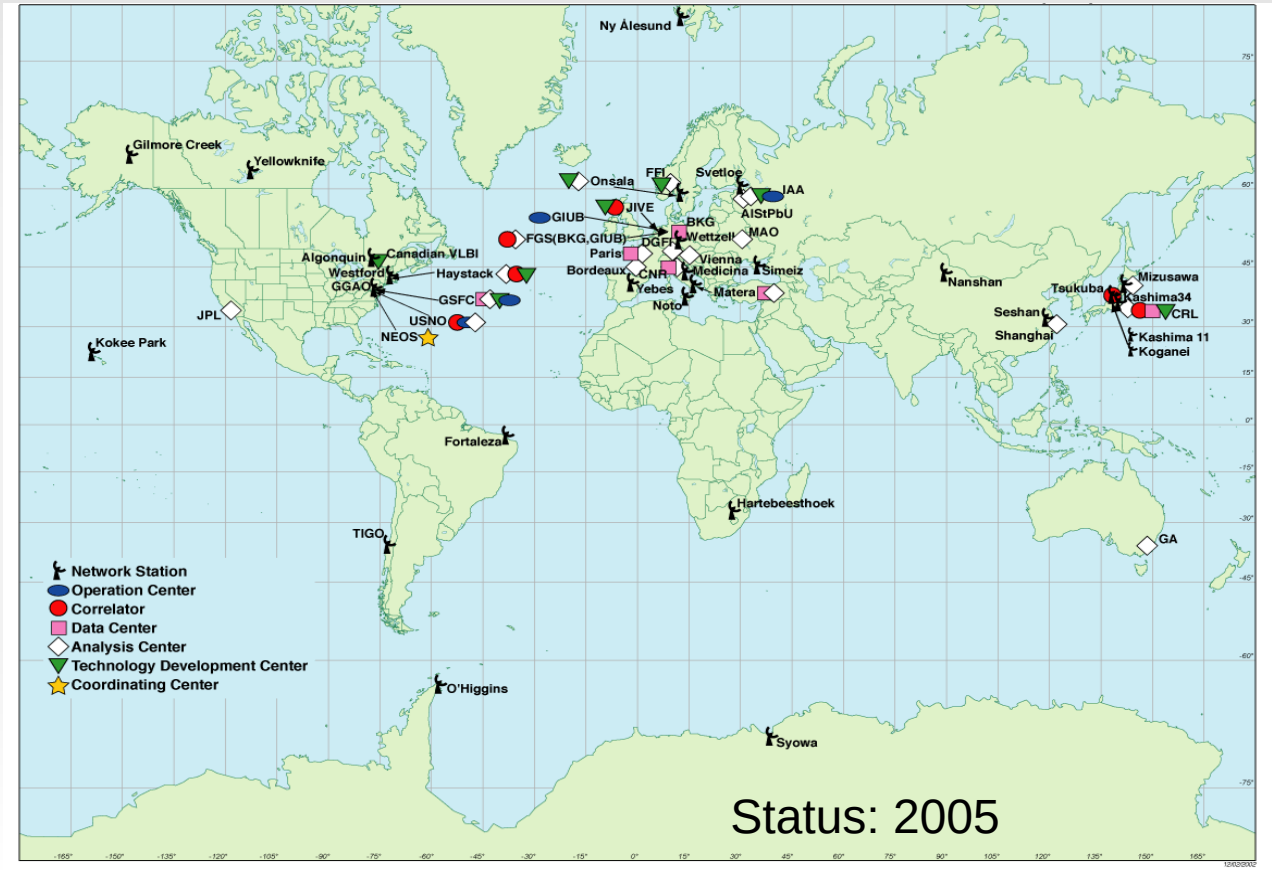
Organization

~80 permanent components
~40 institutions in
~20 countries
~275 Associate Members



Components

- call (due 1-Sept-2008) for
  - IVS Combination Centers
  - IVS Analysis Centers (operational/associate)



network stations

27 most active sites

- Antarctica (2)
- Australia
- Brazil
- Chile
- China (2)
- Germany
- Italy (3)
- Japan (5)
- Norway
- Russia (3)
- Spain
- South Africa
- Sweden
- Ukraine
- USA (3)

network stations

O'Higgins - 9 m

27 most active sites

Antarctica (2)
Australia
Brazil
Chile
China (2)
Germany
Italy (3)
Japan (5)
Norway
Russia (3)
Spain
South Africa
Sweden
Ukraine
USA (3)

http://ivs.bkg.bund.de/vlbi/ohiggins/

network stations

TIGO@ Concepción - 6m

27 most active sites

- Antarctica (2)
- Australia
- Brazil
- Chile
- China (2)
- Germany
- Italy (3)
- Japan (5)
- Norway
- Russia (3)
- Spain
- South Africa
- Sweden
- Ukraine
- USA (3)

network stations

Shanghai - 25 m

27 most active sites

- Antarctica (2)
- Australia
- Brazil
- Chile
- China (2)
- Germany
- Italy (3)
- Japan (5)
- Norway
- Russia (3)
- Spain
- South Africa
- Sweden
- Ukraine
- USA (3)

Shanghai Astronomical Observatory
Chinese Academy of Sciences

network stations

Kashima - 34 m

27 most active sites

- Antarctica (2)
- Australia
- Brazil
- Chile
- China (2)
- Germany
- Italy (3)
- Japan (5)
- Norway
- Russia (3)
- Spain
- South Africa
- Sweden
- Ukraine
- USA (3)

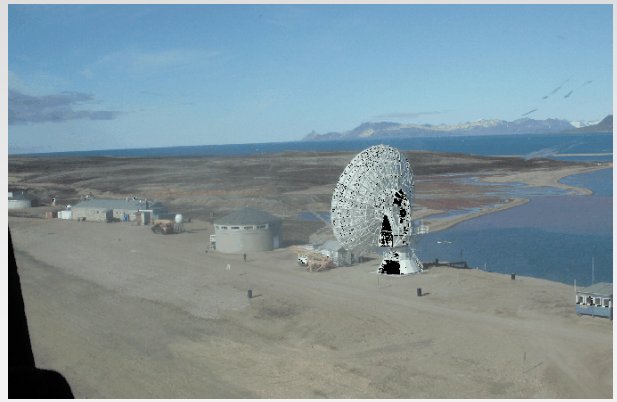
NiCT National Institute of Information and Communications Technology

network stations

Ny Ålesund - 20 m

27 most active sites

- Antarctica (2)
- Australia
- Brazil
- Chile
- China (2)
- Germany
- Italy (3)
- Japan (5)
- Norway
- Russia (3)
- Spain
- South Africa
- Sweden
- Ukraine
- USA (3)



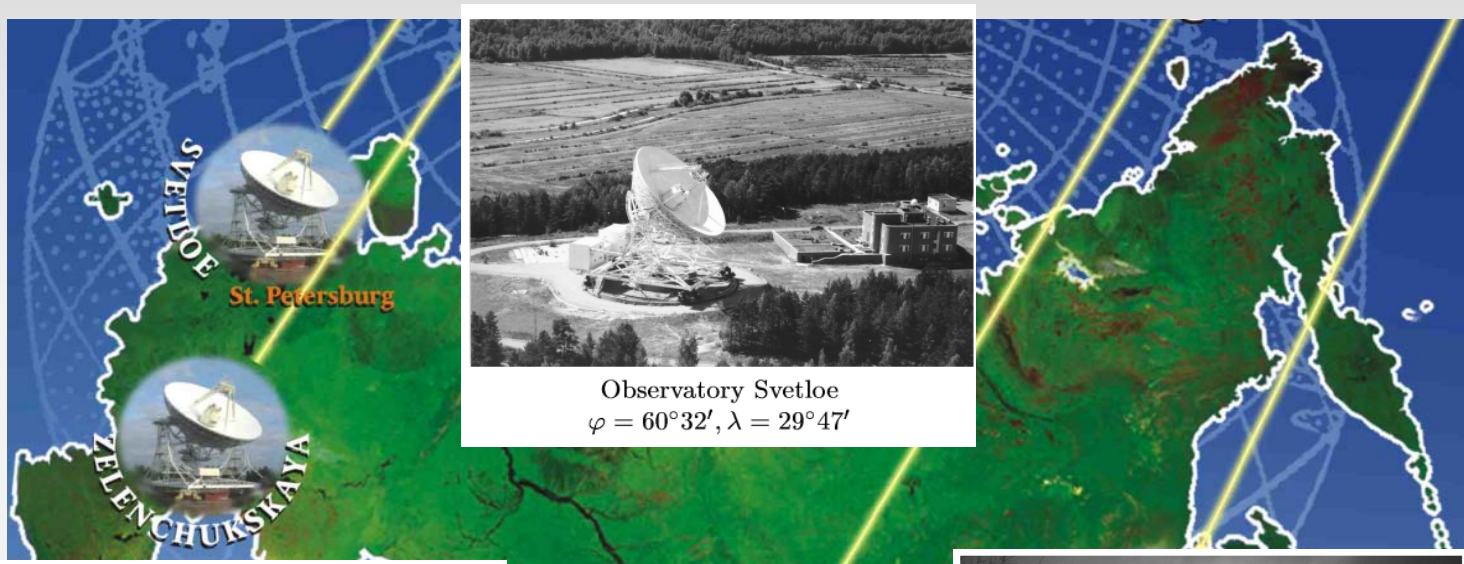
STATENS KARTVERK

network stations

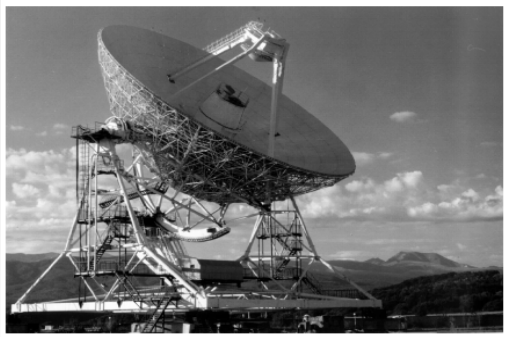
3 of 4 Russian Quasar network stations have joined the IVS

27 most active sites

- Antarctica (2)
- Australia
- Brazil
- Chile
- China (2)
- Germany
- Italy (3)
- Japan (5)
- Norway
- Russia (3)
- Spain
- South Africa
- Sweden
- Ukraine
- USA (3)



Observatory Svetloe
$\varphi = 60°32', \lambda = 29°47'$



Observatory Zelenchukskaya
$\varphi = 43°47', \lambda = 41°34'$

Observatory Badary
$\varphi = 51°46', \lambda = 102°14'$

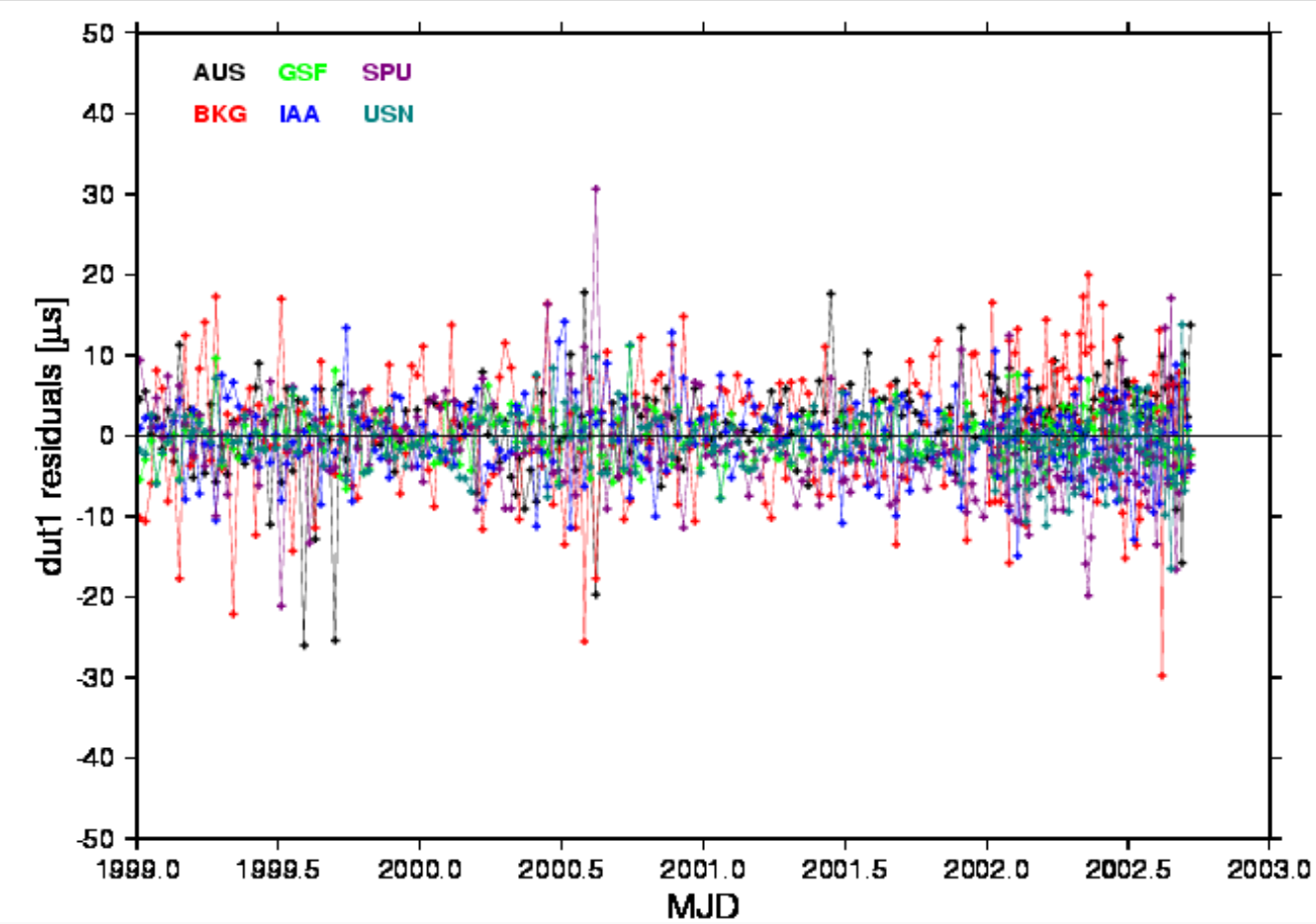
Products

- EOP
- TRF + IVS Pilot Project Baseline Length
- CRF
- Tropospheric parameters

- Delivery time of products

Products: Combined EOP

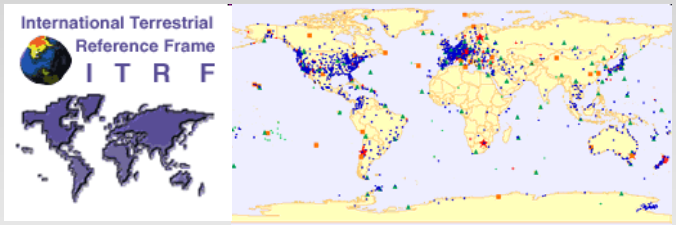
Analysis Coordinator: Axel Nothnagel, Univ. Bonn



- **Complete set of EOP**
  - $d\psi$, $d\varepsilon$
  - x_p ,y_p
  - UT1-UTC
- **Combined solution from 6 Analysis Centers**
- **20-30% improvement**
  - accuracy
  - robustness
- **R1 & R4 since 2002**

Products: Individual and combined TRF

- ITRF2005
  (Altamimi et al., 2007)



Combination Center

BKG
DGFI
GSFC
SHA
USNO

IVS Analysis Centers
(Vennebusch et al., 2007)

- VTRF2005
  (Nothnagel, 2005)

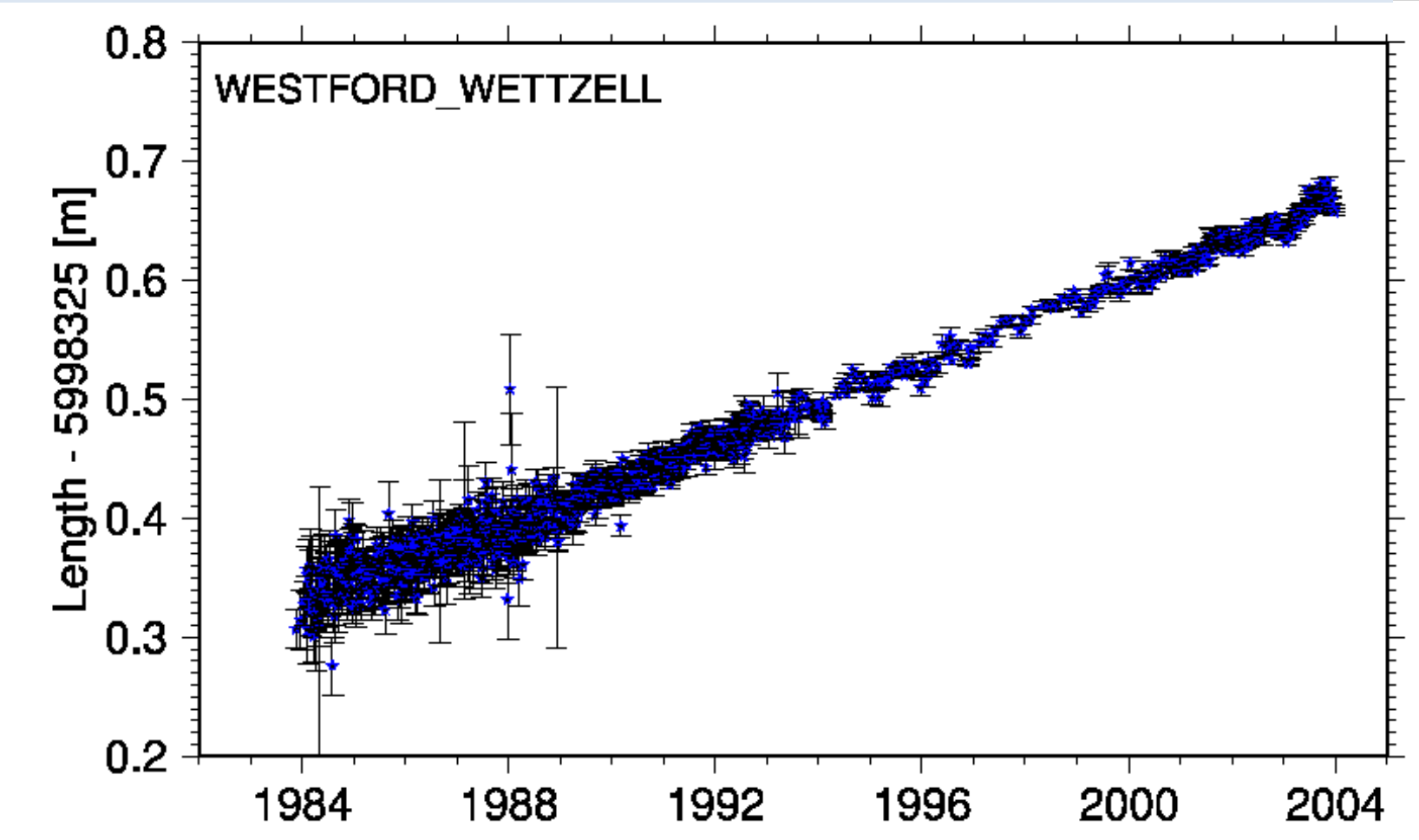
AUS
BKG
DGFI
GSFC
MAO

IVS Analysis Centers

- Individual TRF

BKG
CGS
GSFC
MAO
IAA
…

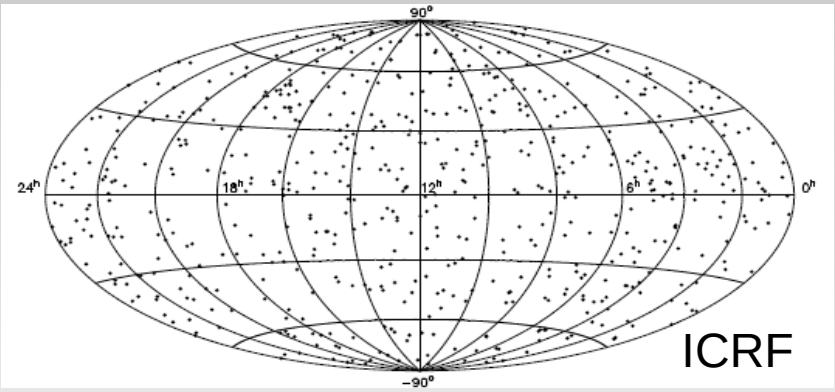
IVS Pilot Project: Time Series of Baseline Lengths



service available at http://vlbi.geod.uni-bonn.de/baseline-project/

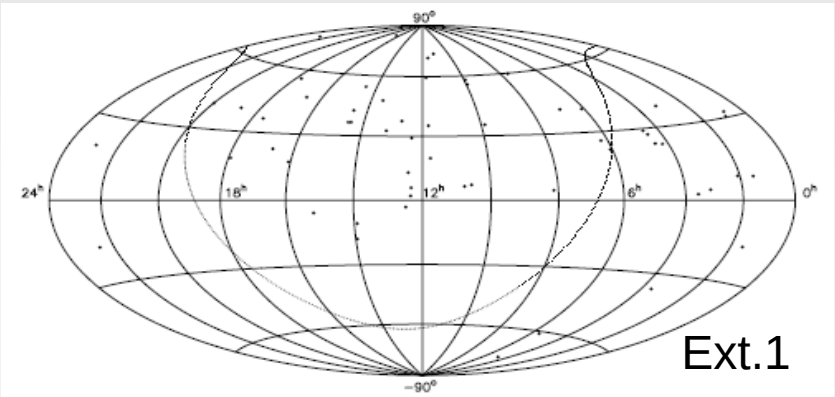
IVS products: ICRF

- ICRF (Ma et al, 1998)
  - 212 defining
  - 294 candidate
  - 102 others



ICRF

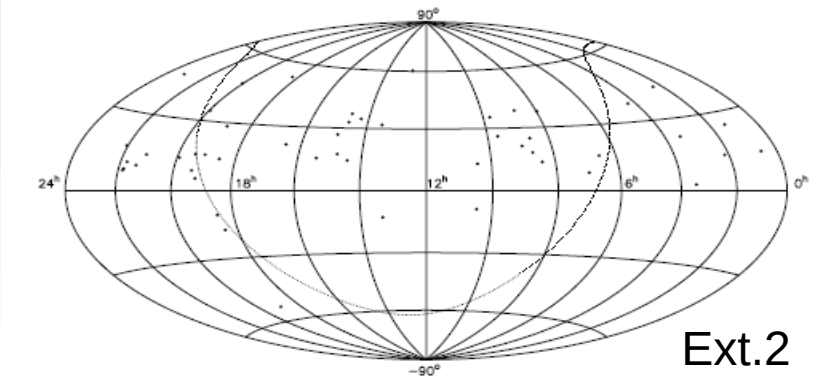
- ICRF-Ext.1 (IERS, 1999) — additional 59 new



Ext.1

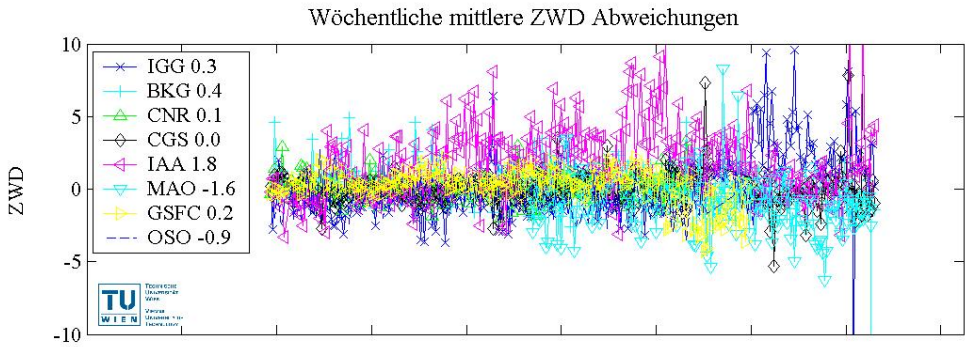
- ICRF-Ext.2 (Fey et al., 2004) — additional 50 new

717 total

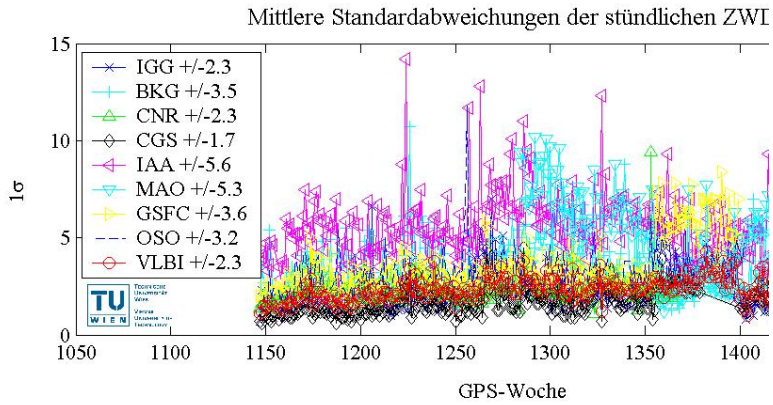


Ext.2

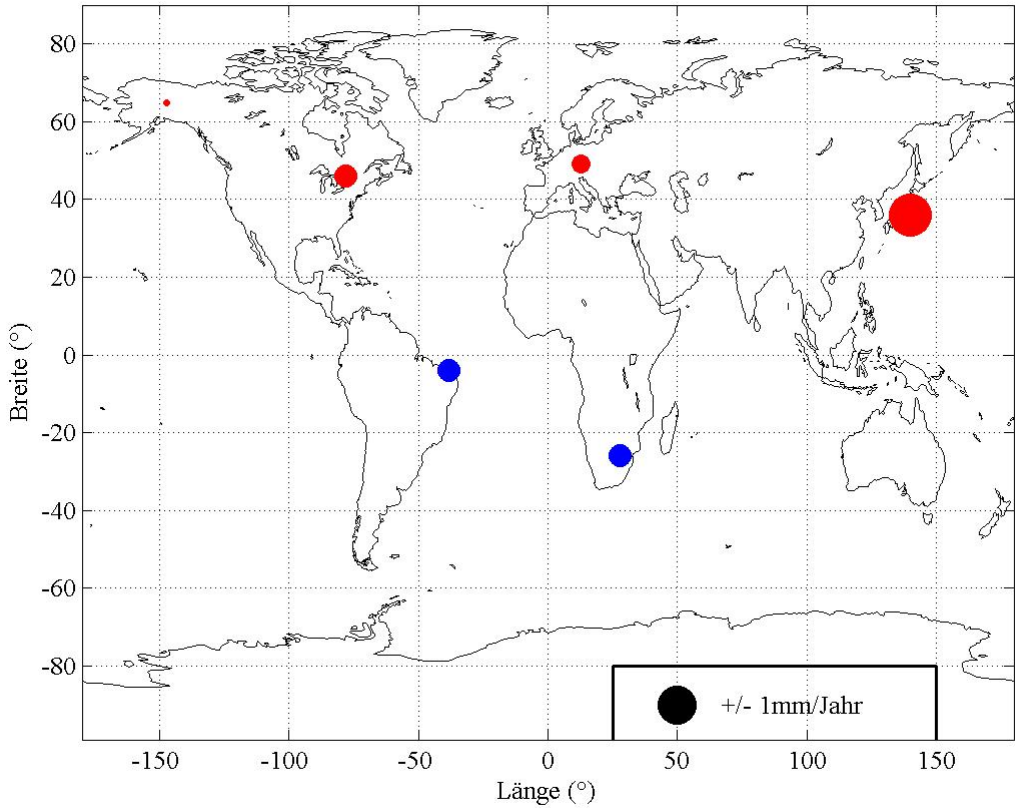
IVS tropospheric products



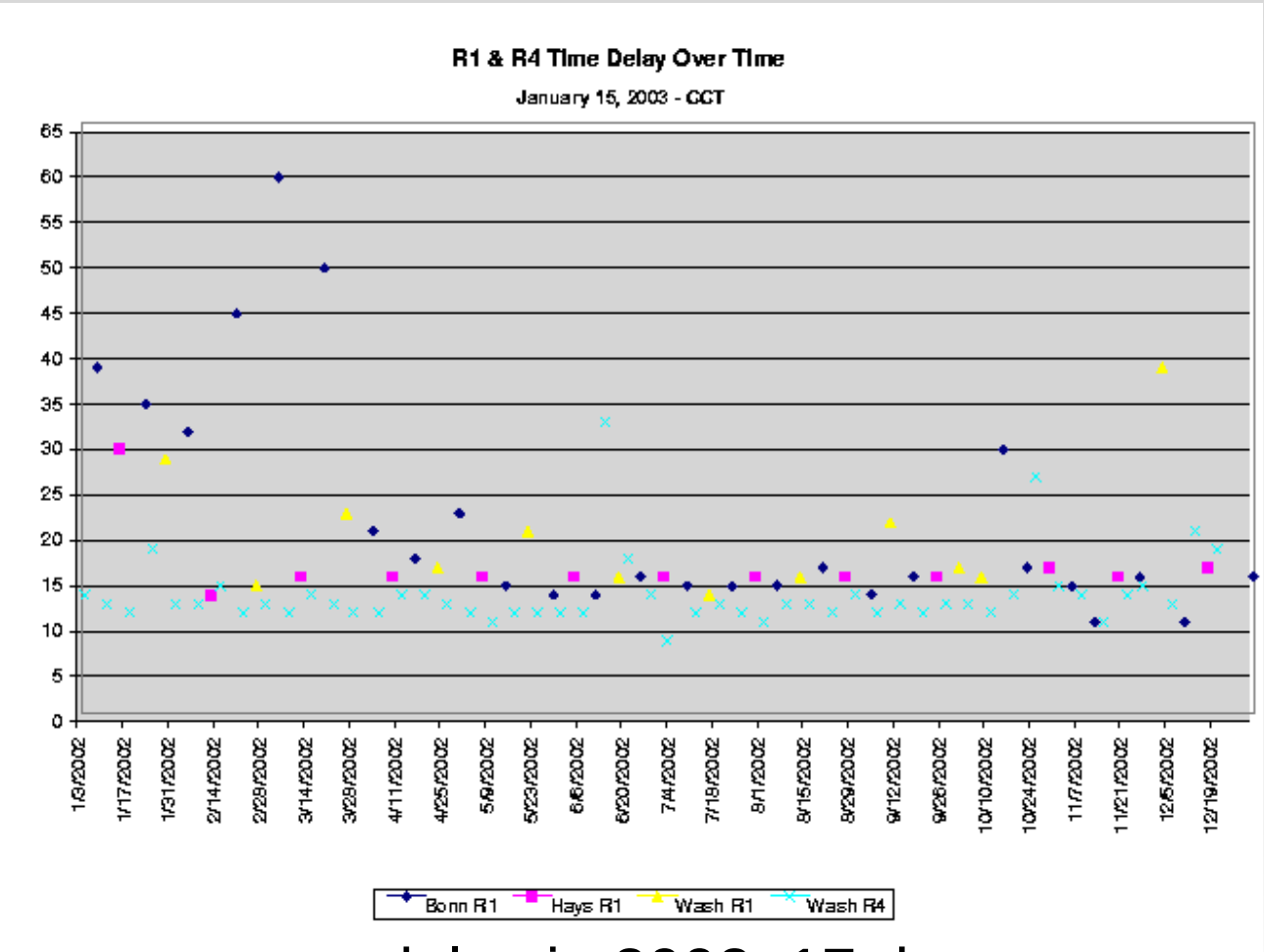
• long-term combination ↓



• rapid combination ↑



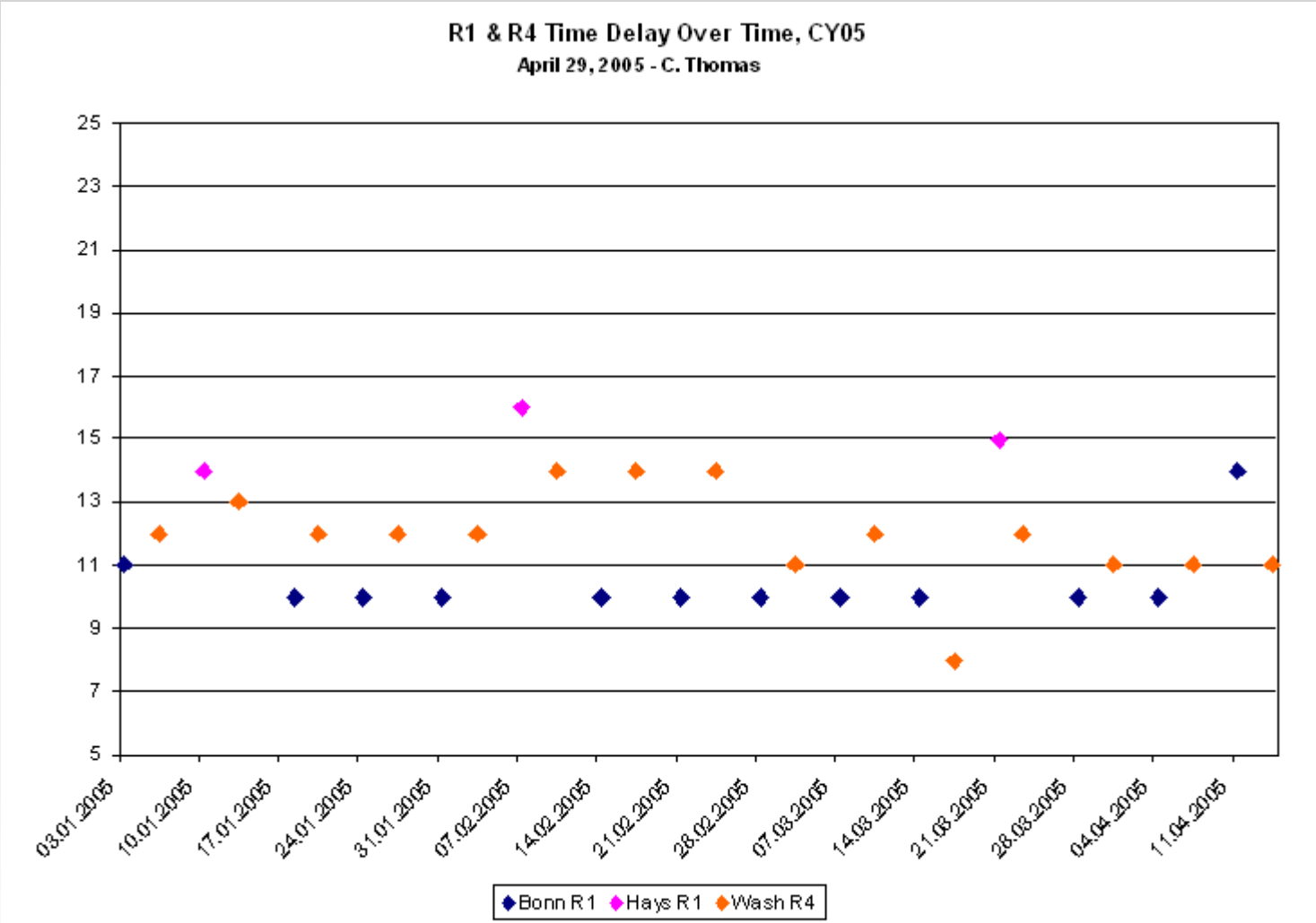
Improved delay from observation to product availability (1)



average delay in 2002: 17 days

- 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)

Improved delay from observation to product availability (2)



average delay in 2006: 11 days

Working Groups and Committees

- WG1: GPS Phase Center Mapping (closed by 2000)

- WG2: IVS Product Specification and Observing Programs (closed by 2003) now
  + Observing Program Committee (OPC)

- WG3: VLBI2010 (closed by 2005) now
  + VLBI2010 Committee (V2C)

- WG4: VLBI Data Structures (very recently established)

- IERS/IVS WG: Second Realization of the ICRF (since 2007)

IVS WG2

IVS Working Group 2 for Product Specification and Observing Programs

Final Report
(13th of February 2002)

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*) *Institute of Geodesy and Geophysics, University of Technology Vienna, Gusshausstr. 27-29, 1040 Wien, Austria*

Based on WG2 report: IVS observing programs started in 2002

=> Geodetic VLBI observations increased year by year

=> about 30% in 2002 compared to 2001

=> about 15% in 2003 compared to 2002

=> about 15% in 2004 compared to 2003

=> 2005 similar to 2004

=> 2006 similar to 2005

=> about 5% in 2007 compared to 2006

Summary of current IVS main products status and goals (WG2)

Products	Specification	Status 2002	Status 2006	Goals (2010)
Polar Motion (x_p, y_p)	accuracy product delivery resolution frequency of solution	x_p ~ 100, y_p ~ 200 µas 1 – 4 weeks – 4 months 1 day 3 days/week	x_p , y_p: 50 – 80 µas 8 – 12 days 1 day	25 µas 1 day 10 min – 1 h 7 days/week
UT1-UTC (DUT1)	accuracy product delivery resolution	5 – 20 µs 1 week 1 day	3 µs 3 – 4 days 1 day	2 µs 1 day 10 min
Celestial Pole ($d\varepsilon$; $d\psi$)	accuracy product delivery resolution frequency of solution	100 – 400 µas 1 – 4 weeks – 4 months 1 day ~ 3 days/week	50 µas 3 – 4 days 1 day	25 µas 1 day 7 days/week
TRF (x, y, z)	accuracy	5 – 20 mm	5 mm	2 mm
CRF (α; δ)	accuracy product delivery frequency of solution	0.25 – 3 mas 3 – 6 months 1 year	0.25mas (improv. distribution) 3 months 1 year	0.25 mas (improv. of freq. bands) 1 month

IVS WG3

VLBI2010:
Current and Future Requirements for Geodetic VLBI Systems

Arthur Niell (co-chair)
Haystack Observatory, Massachusetts Institute of Technology, USA

Alan Whitney (co-chair)
Haystack Observatory, Massachusetts Institute of Technology, USA

Bill Petrachenko
Natural Resources Canada, Canada

Wolfgang Schlüter
Bundesamt für Kartographie und Geodäsie, Germany

Nancy Vandenberg
NVI Inc./Goddard Space Flight Center, USA

Hayo Hase
Bundesamt für Kartographie und Geodäsie, Germany

Yasuhiro Koyama
Kashima Space Research Center, NICT, Japan

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Harald Schuh
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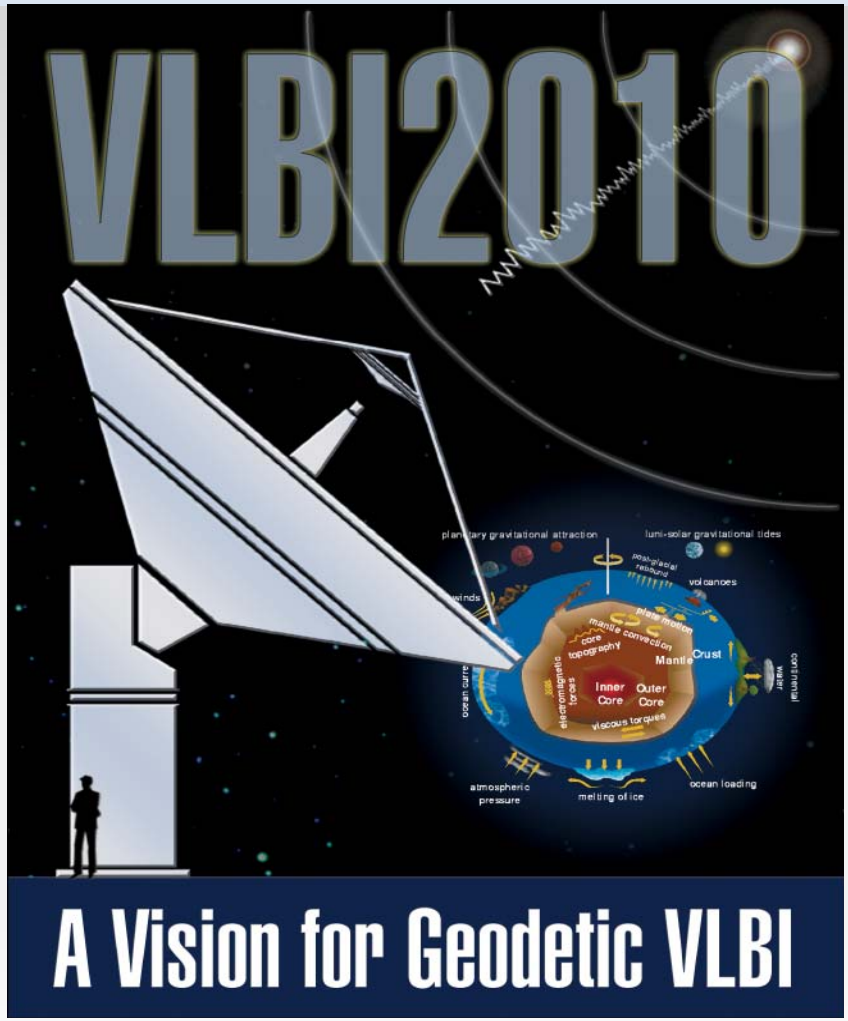
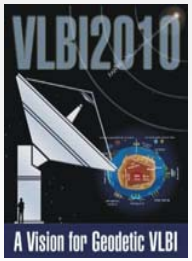
Gino Tuccari
Italian National Astrophysical Institute – Radio Astronomy Institute, Italy

September 16, 2005



IVS WG3 Motivation (1)

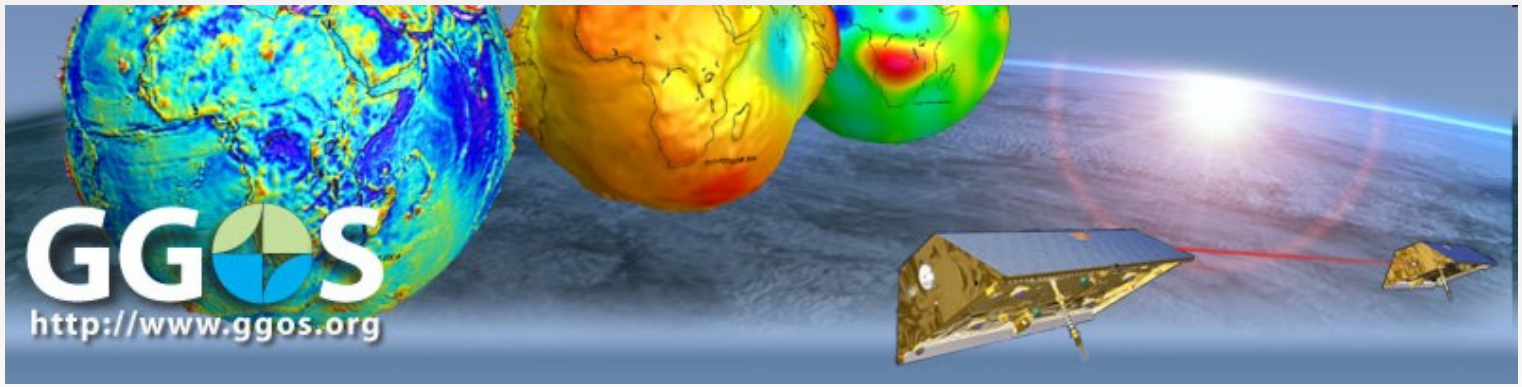
- **Status**
  - Most of VLBI equipment developed in 70's and 80's pushed to its limits
  - Radio interference at S-Band increased
  - Old slow moving antennas make it difficult to provide agile whole sky coverage
  - Location of antennas is unbalanced in global distribution
  - Operation costs remain high
  - Processing time to final results is too long



IVS WG3 Motivation (2)

- **Aim**
  Meet the requirements of GGOS IAG's Global Geodetic Observing System (http://www.ggos.org)

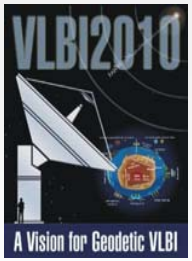
  - < 1 mm (position) < 0.1 mm/year (velocity)
  - 7 days/week
  - near real-time availability of products



VLBI2010 A Vision for Geodetic VLBI

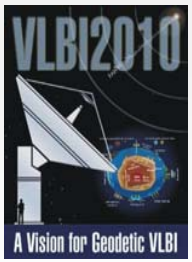
VLBI2010 – Recommendations (1)

- Design a new observing system based on small antennas (10 -12m), fast moving, unattended operation, mechanically reliable, economically replicable
- Broad band delay, frequency range (e.g. 2 -18 GHz) includes S- and X-band
- Upgrade of large antenna to preserve continuity, maintaining CRF



VLBI2010 – Recommendations (2)

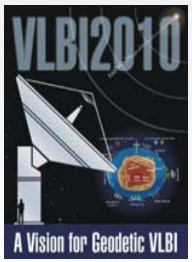
- Transfer data with combination of high speed networks and high rate disk systems
- Examine the possibilities for a new correlator system (software correlator?)
- Automate and streamline the complete data analysis pipeline



VLBI2010 – plans (1)

VLBI2010 is supporting some proposals:

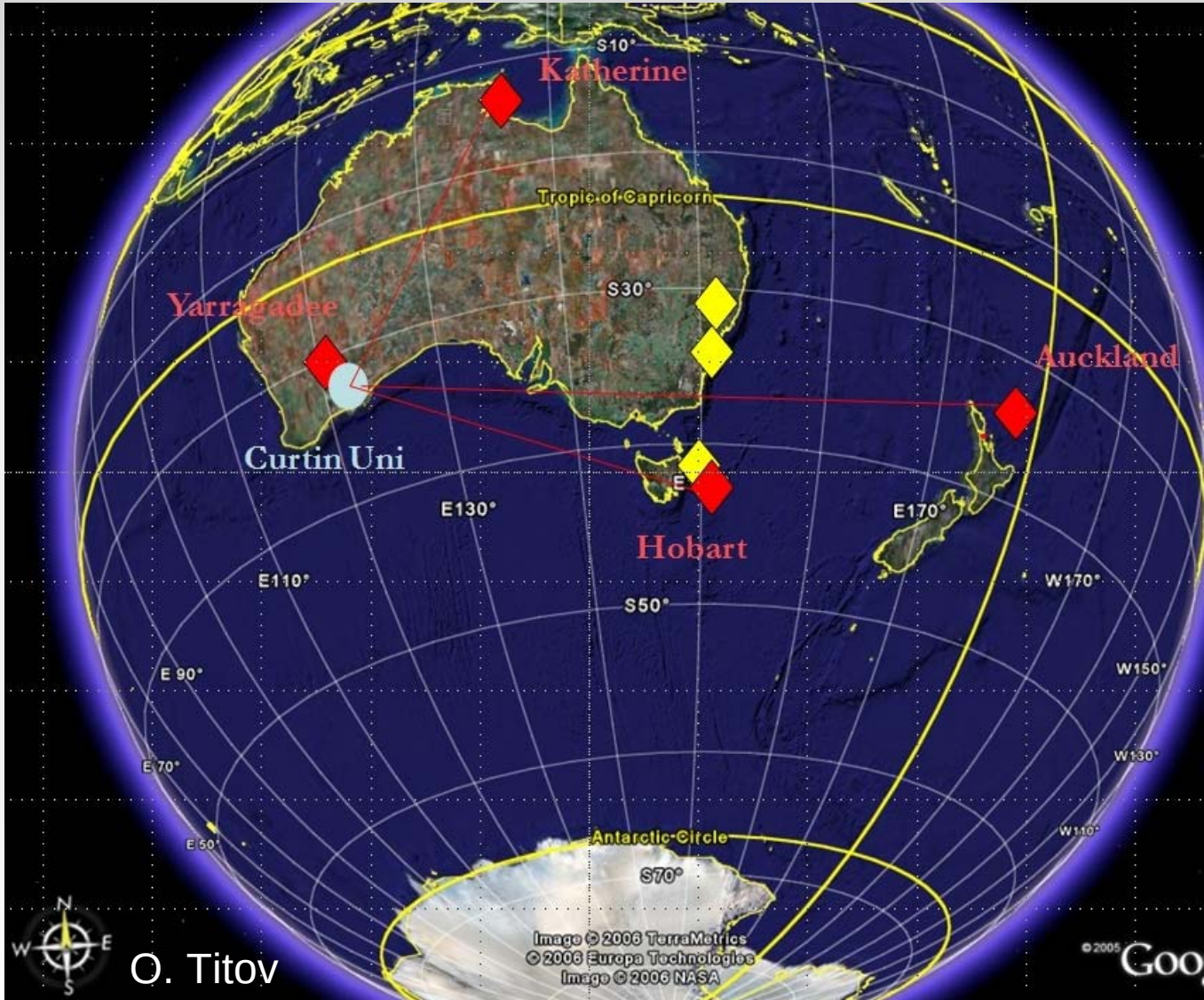
- Korean Institutes (KASI, NGII, Ajou Univ.)
- Geoscience Australia: proposal for 3 fundamental stations
- Univ. Tasmania (Hobart): getting operation money
- University of Concepcion/Chile: developing a telescope
- ISRO, India: 32m telescope for lunar mission extended for geodetic VLBI
- NASA Haystack: support of VLBI 2010 telescope / Gilmore Creek
- BKG: twin-telescope 2008-2010



VLBI2010 – plans (2)

Approved projects or new proposals

Australia &
New Zealand (4)



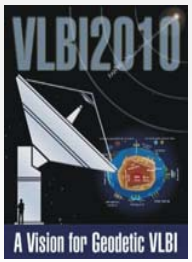
O. Titov

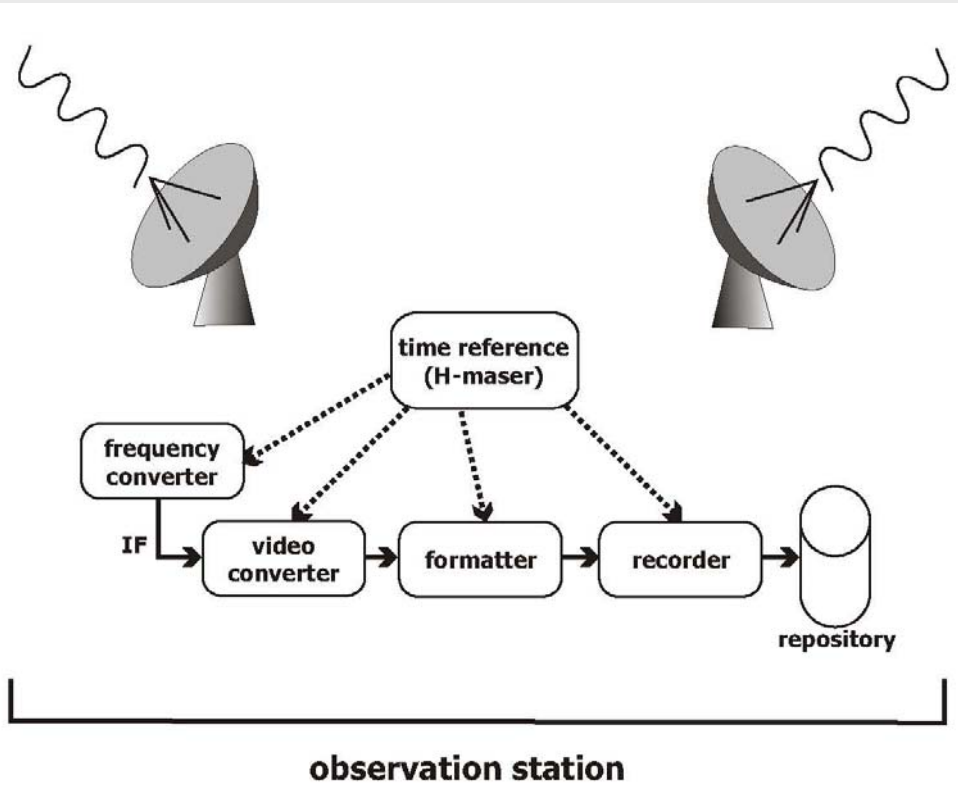
VLBI2010 – plans (3)

"twin-telescope" at Wettzell, Germany

Advantage:

- higher observation density
- continuous observations
- better determination of systematic effects
- one frequency standard
- one more local tie

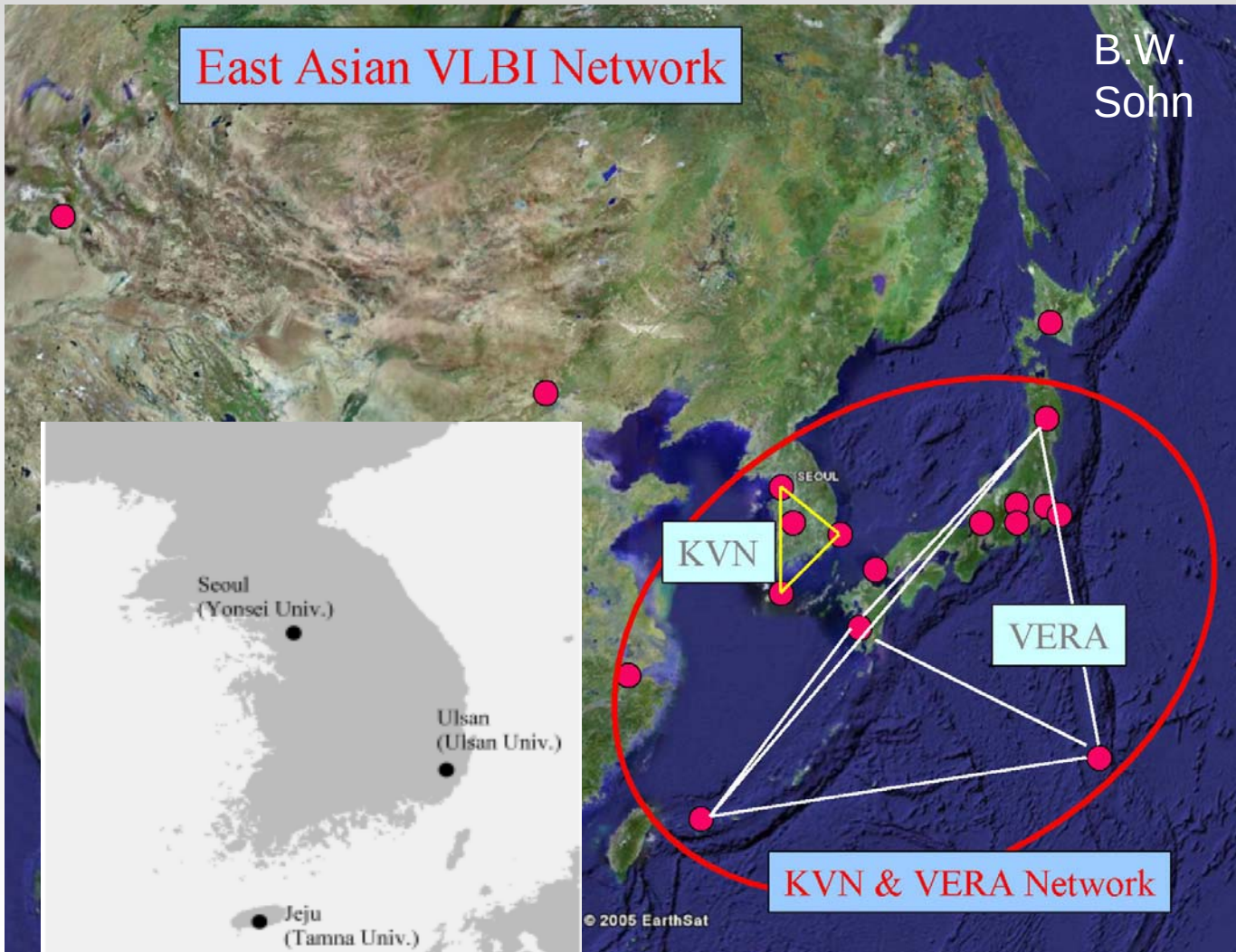


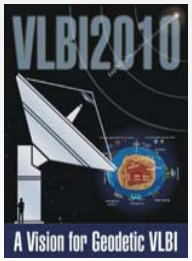


VLBI2010 – plans (4)

Approved projects or new proposals

Australia &
New Zealand (4)
Germany
(twin-telescope)
South-Korea (3)





IERS/IVS WG on ICRF-2

- ICRF-2 to be completed Aug 2009

+

Tentative Milestones

Generation of position time series:	first pass - April 2007 update - April 2008
Analysis of position time series:	first pass - October 2007 update - June 2008
Analysis of catalogue noise:	first pass - October 2007 update - June 2008
Source structure catalogue:	first pass - October 2007 update - June 2008
Source structure evolution:	first pass - March 2008 update - June 2008
Selection of stable and/or unstable sources:	July 2008
Selection of defining sources:	August 2008
Second ICRF catalogue:	December 2008
Presentation to IAU WG:	March 2009
Presentation to IAU GA:	August 2009

http://rorf.usno.navy.mil/ICRF2

Continuous VLBI campaign 2008: CONT08

- August 12 – 26 2008, 15 days of continuous observation
- Best possible data quality
- 11 stations, collocated with GPS, DORIS, SLR
- special issue of Journal of Geodesy planned

Recent Publications

Journal of Geodesy special issue "VLBI"

- Volume 81, Numbers 6-8
- June 2007
- 17 articles including preface

Thank you for your attention!

rob@mars.hg.tuwien.ac.at