Determination of Reference Frame Scale with VLBI

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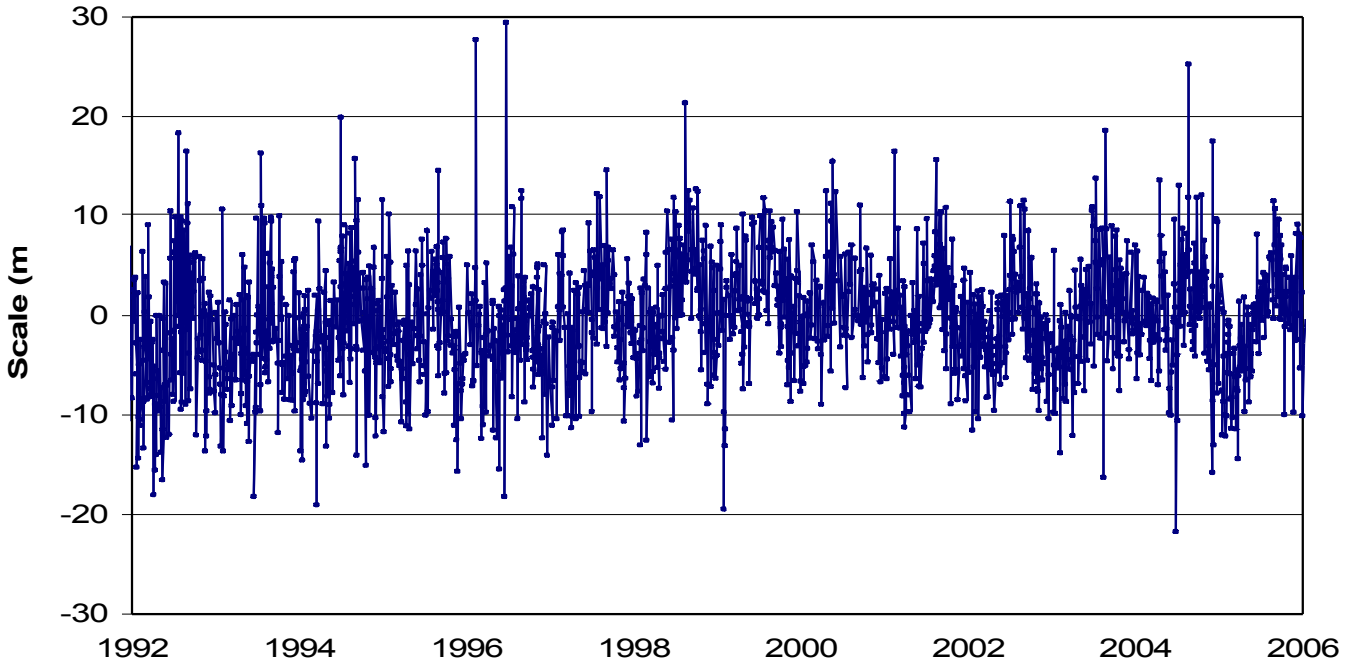
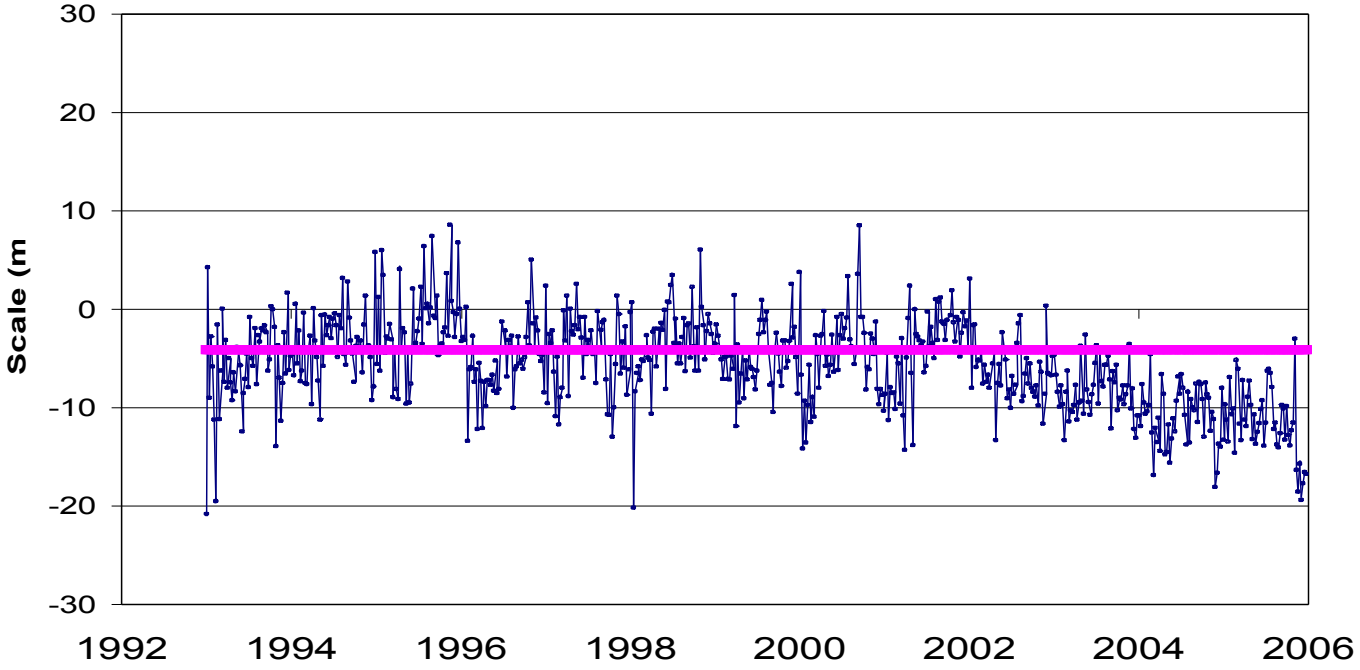
Overview

- VLBI – SLR scale difference in ITRF2005
- Systematic effects that contribute to the VLBI scale
- VLBI scale error budget



VLBI daily series relative to ITRF2005



SLR weekly series relative to ITRF2005

1993-2002 bias = -4.3 mm

=> -0.68 ppb

Systematic Errors Contributing to VLBI Scale

- Antenna Thermal Deformation
- Pressure Loading and Hydrology Loading
- Atmospheric Delay Modeling
- Radio source structure
- Pole tide

Antenna Thermal Deformation

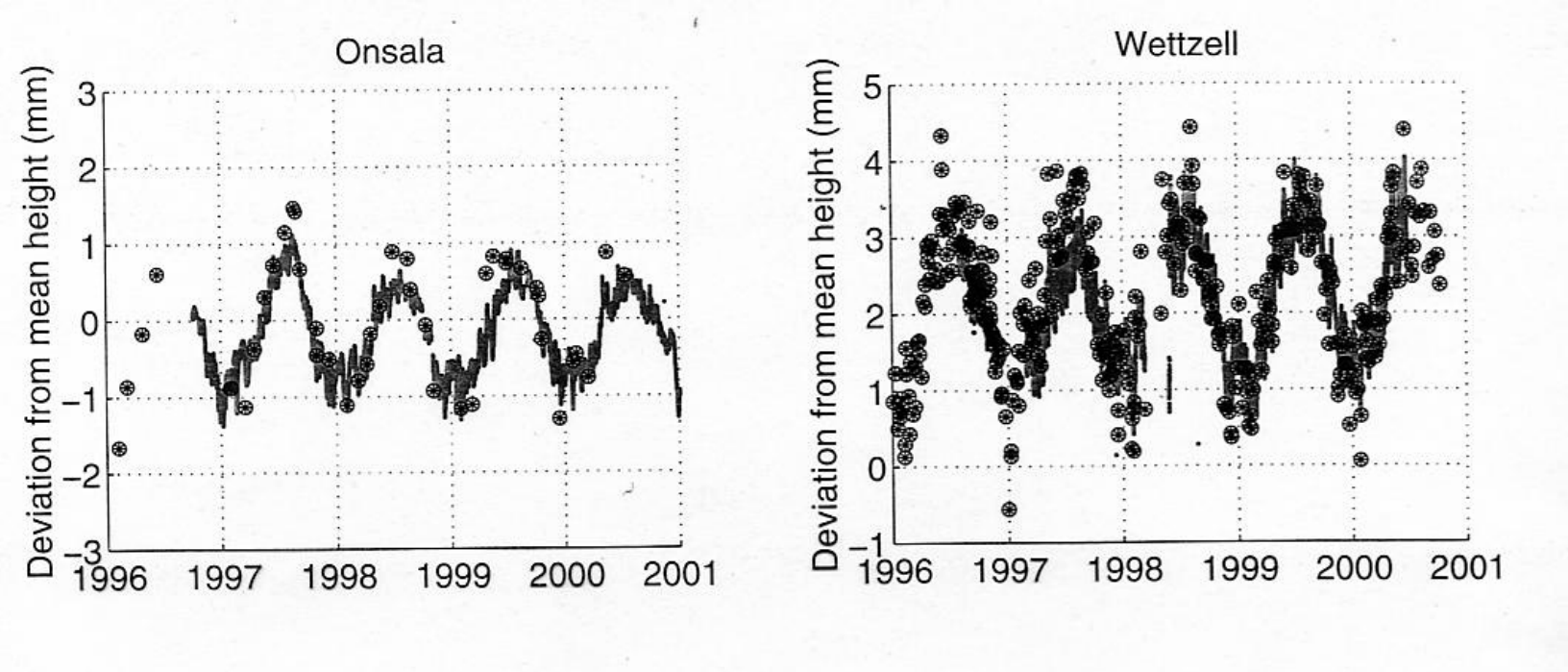
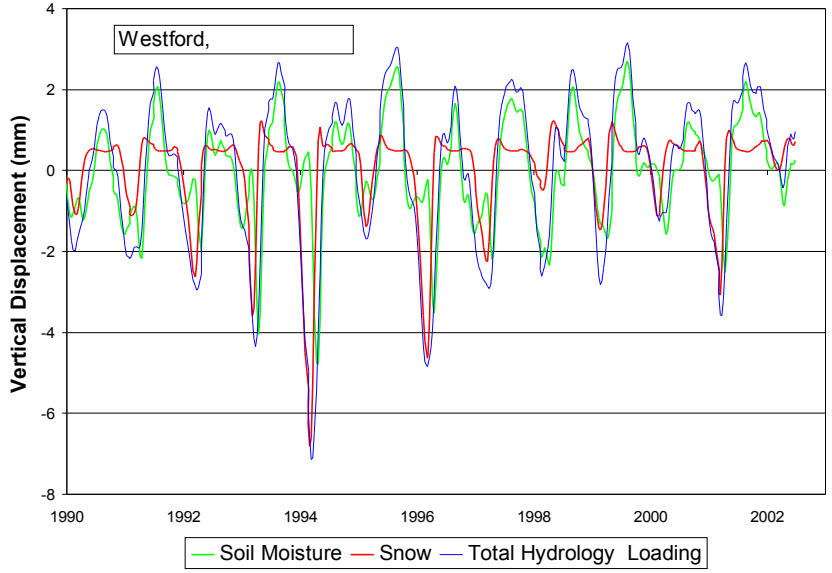
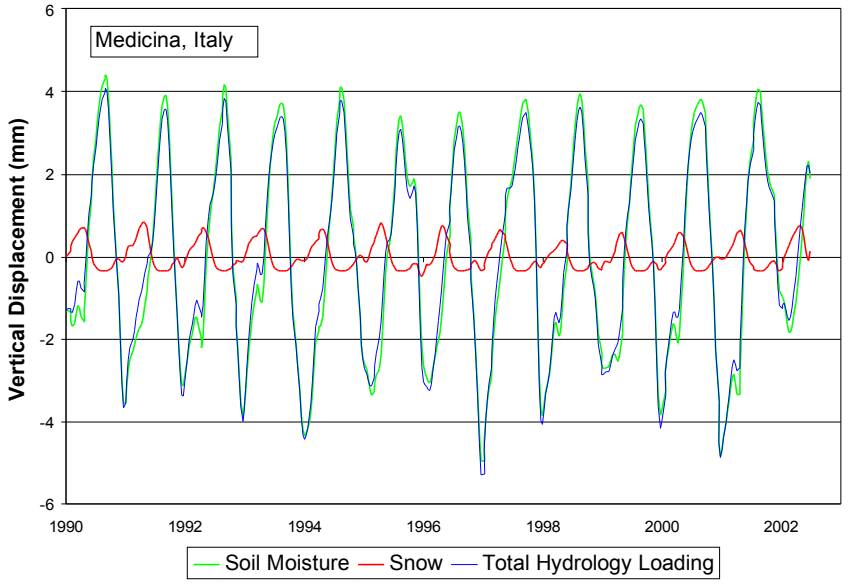


Figure 13: Vertical height changes of the VLBI radio telescopes at Onsala and Wettzell: solid lines - measured by the invar rod measuring systems; stars in circles - modelled with a simple model based on daily mean temperature from the VLBI data base, thermal expansion coefficient, and the telescope dimensions.

Average vertical bias due to not modeling antenna deformation
=> 0.04 mm ~ 0.016 ppb

Hydrology Loading





Loading based on Milly Shmakin hydrology model

- Scale dependence on hydrology+pressure loading

Effect of pressure loading

=> 0.006 ± 0.002 ppb/yr

=> −0.05 ± 0.01 ppb

Effect of hydrology loading

=> 0.001 ± 0.002 ppb/yr

=> −0.003 ± 0.001 ppb

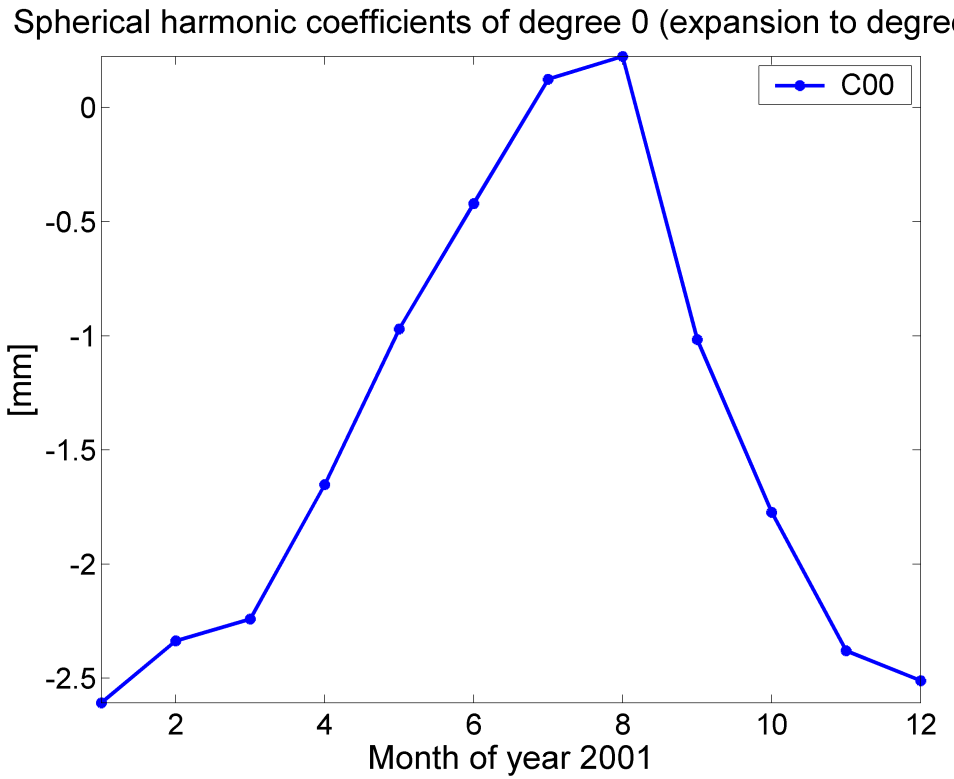
Seasonal Length Scale Variation from VLBI

Applying loading contributions to site displacement
=> Small reduction in amplitude

	Annual		Semi annual	
	Amplitude ppb	Phase deg	Amplitude ppb	Phase deg
No Loading	0.51 ± 0.03	48 ± 3	0.18 ± 0.03	276 ± 6
Loading	0.37 ± 0.03	46 ± 3	0.19 ± 0.03	275 ± 6

Loading contributions include:
2) Atmospheric pressure loading
3) Hydrologic loading
4) Non tidal ocean loading

Atmospheric Delay Modeling Error



Scale Difference (VMF – NMF) between frames computed using the VMF or the NMF mapping functions assuming a uniform global coverage of sites.

If only VLBI sites are considered, the peak to peak amplitude is reduced to ~1.25 mm (= 0.2 ppb). [ref. Johannes Boehm]

Atmospheric Delay Modeling

- Errors in atmospheric modeling at low elevations

- Scale dependence on elevation cutoff

10º - 5º elevation cutoff solutions
=> −0.01 ± 0.005 ppb/yr
=> −0.13 ± 0.05 ppb

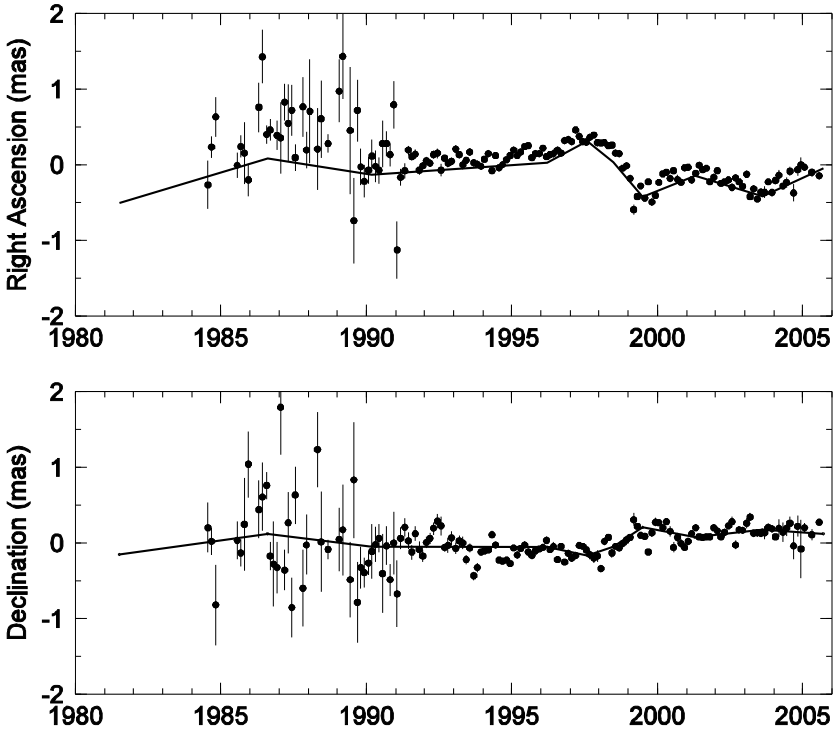
- Mapping function error

VMF – NMF => bias ~ -0.1 ppb
seasonal amplitude ~ 0.1 ppb

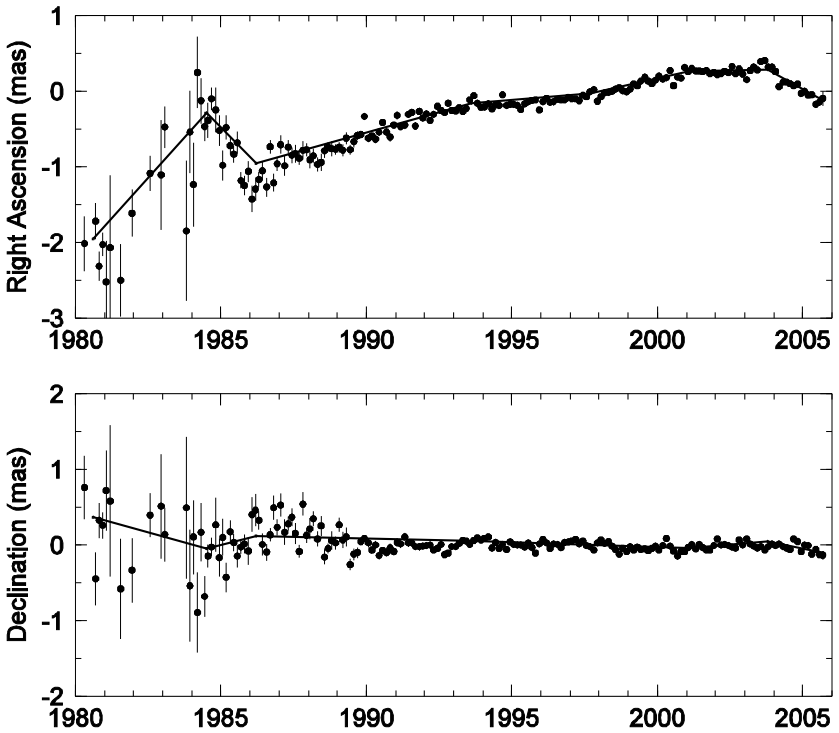
Radio Source Instability

- Radio source position estimates can have large rates or even nonlinear variation

- Identified sources with unstable position time series from among the most frequently observed (geodetic) sources



Radio source 2145+067



Radio source 4C39.25

Radio Source Instability

- Modeled the position variation of unstable sources either by

(3) estimating global spline parameters to fit the variation

or (2) estimating positions for each 24-hour observing session

Effect of radio source instability =>

1) Spline	-0.02 ± 0.01 ppb	0.004 ± 0.002 ppb/yr
2) Local	-0.02 ± 0.02 ppb	0.008 ± 0.002 ppb/yr

Pole Tide Model

- IERS2003 Convention specifies that a mean pole model referenced to 2000.0 be subtracted from polar motion in computing the deformation effect
- Most (3 out 4) IVS Analysis Centers did not use this convention in generating their submissions for ITRF2005
- Reference frame scale effect of NOT applying the IERS2003 specification is +0.45 ppb

Scale Error Budget

Error Source	Annual	Rate ppb/yr	Bias ppb
Thermal Deformation	0.1	---	- 0.02
Loading	0.14	0.01	- 0.05
Atmosphere Modeling	0.1	- 0.01	- 0.13
Radio source instability	---	0.01	- 0.02
Pole Tide	0	0.01	- 0.45*.75
Total	< 0.34	0.02	- 0.54

Summary

- Most (0.54 ppb) of the scale bias (VLBI-SLR) of 0.68 ppb in ITRF2005 can be explained by inconsistent application pole tide model convention, atmosphere delay model error, and smaller contributions from loading

- VLBI scale has a real annual variation, which is equivalent to modulating the scale by ~ 0.5 ppb, due to annual site variations of various effects (hydrology loading, antenna thermal deformation, etc.) and the predominance of VLBI sites in the Northern hemisphere

- Hydrology loading, pressure loading, antenna thermal deformation, and mapping function error contribute about 0.3 ppb to the annual variation of scale