VLBI Scale Effects

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Overview

Systematic Errors Contributing to VLBI Scale

- Pressure loading and hydrology loading
- Antenna gravitational deformation
- Atmospheric delay modeling
- Radio source structure
VLBI Scale Series

VLBI daily series relative to ITRF2008
GSFC2011b sinex
weighted mean difference = 1.98 mm (0.33 ppb)
(from Z. Altamimi)
ITRF2008 paper:
(1980-2008 data)
(Altamimi et al.)
=> 0.53 ± 0.10 ppb
Hydrology Loading
Hydrology Loading

Vertical WRMS Reduction (mm)

ALGOPARK  BADARY  FORTLEZA  GILCREEK  HARTRAO  HOBART26  KOKEE  MATERA  MEDICINA  NYALES20  ONSALA60  SESHAN25  SVETLOE  TIGOCONC  TSUKUB23  WESTFORD  WETZELL  ZELENCHK
## Loading

<table>
<thead>
<tr>
<th></th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Offset ppb</td>
</tr>
<tr>
<td>No Loading</td>
<td>0.44 ±0.03</td>
</tr>
<tr>
<td>Atmos Loading</td>
<td>0.44</td>
</tr>
<tr>
<td>Atmos+Hydro Loading</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Clark and Thomsen (1988) model for signal path delay depends on variations of:

1) focal length
2) vertex position
3) receiver position

\[ \Delta L(e) = \alpha_F \Delta F(e) + \alpha_V \Delta V(e) + 2\alpha_R \Delta R(e) \]

- Coefficients depend on dimensions and structure of antenna
- The functions F, V and R have to be measured for each antenna
Gravitational Deformation

- Measurements of Noto and Medicina (Sarti and Abondanza, 2009, 2010)
  laser scanner (F)+ terrestrial survey (R)+ finite element model (V)

- Model of deformation from Clark and Thomsen (1988)
  XY mount antenna at Fairbanks (26 meter diameter)

\[ \Delta L(e) = -2.4 \left( 1 - \sin(e) \right) \text{ mm} \]
## Gravitational Deformation

<table>
<thead>
<tr>
<th>Model</th>
<th>Offset (ppb)</th>
<th>Rate (ppb/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Model</td>
<td>0.44 ± 0.03</td>
<td>0.005 ± 0.003</td>
</tr>
<tr>
<td>Medicina Model</td>
<td>1.24</td>
<td>0.014</td>
</tr>
<tr>
<td>Noto Model</td>
<td>0.89</td>
<td>0.011</td>
</tr>
<tr>
<td>Fairbanks Model</td>
<td>0.75</td>
<td>0.01</td>
</tr>
</tbody>
</table>

- Scaled each model delay (~ Diam^2) to the antenna diameter of each antenna in the solution.

Troposphere Raytracing

- Compute total (dry+wet) delays and wet mapping function from numerical weather model for each VLBI observation

- Weather model is the NASA/GSFC GEOS 5.9.1
  - parameters: pressure, temperature, specific humidity, geopotential height
  - time resolution: 3 hours
  - horizontal resolution: 0.5º x 0.625º (~ 50 km)
  - vertical resolution: 72 levels

- Refractivity along raypath is determined by interpolation of the 4D refractivity field

- Use piecewise linear approach to compute raytraced delays

- Constrain propagation of the ray to a plane of constant azimuth (to minimize computation time)
CONT11 Baseline Lengths

Improvement Relative to VMF1

- Ordered by baseline length for each site
Elevation cutoff test: Difference $5^\circ$ and $12^\circ$ solutions CONT11 (2011) => measure of atmosphere model error

Raytrace: 0.017 ppb  VMF1: 0.075 ppb  NMF: 0.061 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
  
  (1) 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
## Scale Error Budget

<table>
<thead>
<tr>
<th>Error Source</th>
<th>Annual Cos</th>
<th>Annual Sin</th>
<th>Rate ppb/yr</th>
<th>Bias ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravitational Deformation</td>
<td>--</td>
<td>--</td>
<td>−0.005 to −0.009</td>
<td>−0.78 to −0.31</td>
</tr>
<tr>
<td>Hyd Load</td>
<td>−0.16</td>
<td>−0.31</td>
<td>0.008</td>
<td>0.14</td>
</tr>
<tr>
<td>Atm Load</td>
<td>0.04</td>
<td>0.03</td>
<td>0.004</td>
<td>0</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>--</td>
<td>--</td>
<td>0.010</td>
<td>0.08</td>
</tr>
<tr>
<td>Radio source</td>
<td>---</td>
<td>--</td>
<td>−0.006</td>
<td>0.02</td>
</tr>
<tr>
<td>ITRF2008</td>
<td>−0.16 ± 0.02</td>
<td>−0.30 ± 0.02</td>
<td>0.025 ± 0.010</td>
<td>0.53 ± 0.10</td>
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</tbody>
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