



## Combination products and the IVS contribution to ITRF2014

### Routine Combination & ITRF2014

The IVS Combination Center is the central location for consolidating analyzed VLBI data, which is combined in a rapid and a quarterly operational mode. Additionally, the IVS Combination Center is responsible for the IVS contribution to the ITRF2014.

#### Contributing Analysis Centers (ACs)

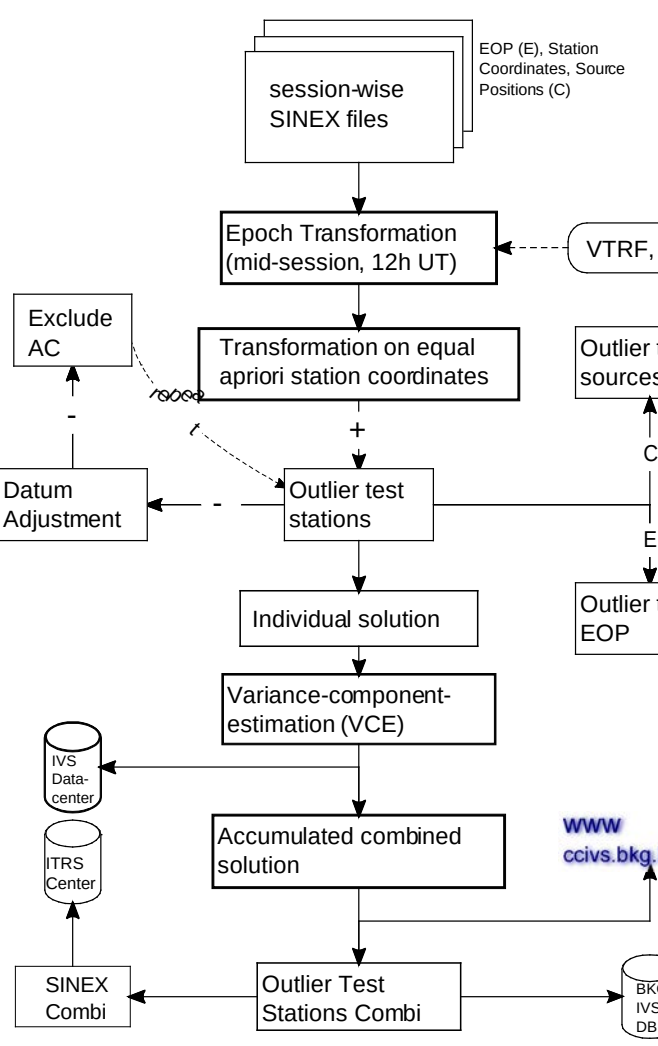
Currently, six analysis centers (ACs) contribute regularly to the routine combination; with two additional ACs - CGS (Centro di Geodesia Spaziale, Italy) and GFZ (German Research Centre for Geosciences, Germany) under review for the operational rapid and quarterly combination. The table below shows the contributing analysis centers and respective software packages used for both operational combination as well as the ITRF2014.

| AC   | Name                                                | Software       | Operational AC | ITRF2014 submitted | incl. |
|------|-----------------------------------------------------|----------------|----------------|--------------------|-------|
| AUS  | Geoscience Australia, Australia                     | OCCAM          | no             | yes                | no    |
| BKG  | Federal Agency for Cartography and Geodesy, Germany | Calc/(nu)Solve | yes            | yes                | yes   |
| CGS  | Centro di Geodesia Spaziale, Italy                  | Calc/(nu)Solve | under review   | yes                | yes   |
| DGFI | German Geodetic Research Institution                | OCCAM          | yes            | no                 | no    |
| GFZ  | German Research Center for Geosciences              | VieVS          | under review   | yes                | yes   |
| GSFC | Goddard Space Flight Center, USA                    | Calc/(nu)Solve | yes            | yes                | yes   |
| IAA  | Institute of Applied Astrometry, Russia             | Quasar         | yes            | yes                | yes   |
| NMA  | Norwegian Mapping Authority, Norway                 | Geosat         | no             | yes                | no    |
| OPAR | Observatory of Paris, France                        | Calc/(nu)Solve | yes            | yes                | yes   |
| SHAO | Shanghai Observatory, China                         | Calc/(nu)Solve | no             | yes                | yes   |
| USNO | US Naval Observatory, USA                           | Calc/(nu)Solve | yes            | yes                | yes   |
| VIE  | Vienna University of Technology, Austria            | VieVS          | no             | yes                | yes   |

AC NMA withdrew their contribution at short notice due to software bugs. AUS was excluded because of a significant higher Station WRMS compared to the other ACs, thereby improving the WRMS of the combined solution. The table on the right shows details of the contribution for the ITRF2008 and ITRF2014.

|           | ITRF2008        | ITRF2014        |
|-----------|-----------------|-----------------|
| Sessions  | 4539            | 5796            |
| Nb. ACs   | 7               | 9               |
| time span | 1979.0 – 2009.0 | 1979.0 – 2015.0 |

#### Analysis Strategy



The contributions by the individual ACs in form of datum-free normal equations, are formatted in SINEX and contain station coordinates as well as Earth Orientation Parameters (EOP). The individual contributions are transformed to 12h UT and to equal *a priori* station coordinates. An outlier test for station coordinates, as well as a variance component estimation for determining the weighting factor for each AC, are both performed before assembling the weighted individual normal equations with a combined solution. SINEX files with the combined normal equations are then submitted to the IERS ITRS Center for ITRF2014 generation. When generating long-term series, systematic behavior may also be discovered. The combination process is based on the orbit and geodetic parameter estimation software (DOGS-CS) of the German Geodetic Research Institute/Technical University of Munich (DGFI-TUM).

#### Results:

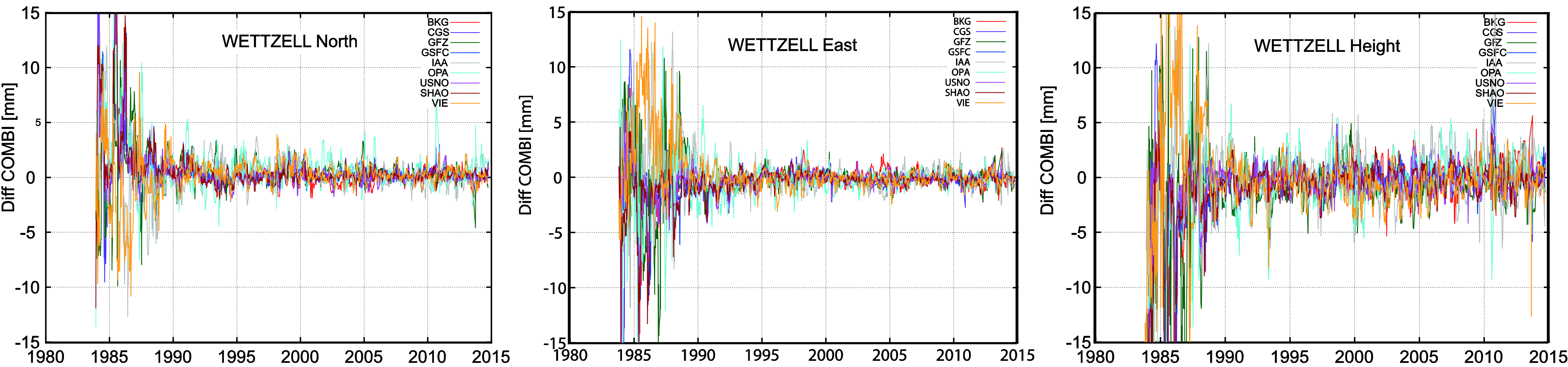


Figure 1: Smoothed station coordinate time series for station WETTZELL in north, east, and height.

Major differences in comparison to the IVS ITRF2008 contribution:

|                              | ITRF2008                           | ITRF2014                                |
|------------------------------|------------------------------------|-----------------------------------------|
| Epoch of EOPs                | Mid-session                        | 12h UT                                  |
| Outlier test                 | Static threshold                   | Dynamic (Least Median of Squares Meth.) |
| Solid Earth Tide, Pole Tides | IERS Conventions 2003              | IERS Conventions 2010                   |
| Nutation                     | IAU2000A. excl. free core nutation | IAU2006 without free core nutation      |
| Troposphere Gradients        | Mac Millan(1995) with wet VMF1     | Chen Herring model                      |

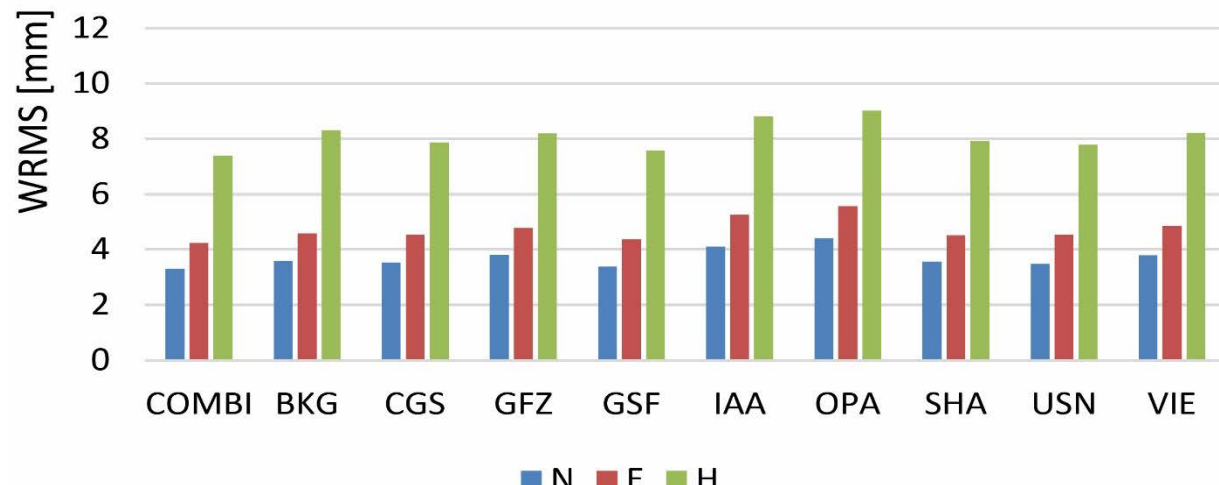
#### Results of IVS Contribution to ITRF2014

The IVS contribution to ITRF2014 was successfully finished in February 2015.

##### • Station coordinate time series

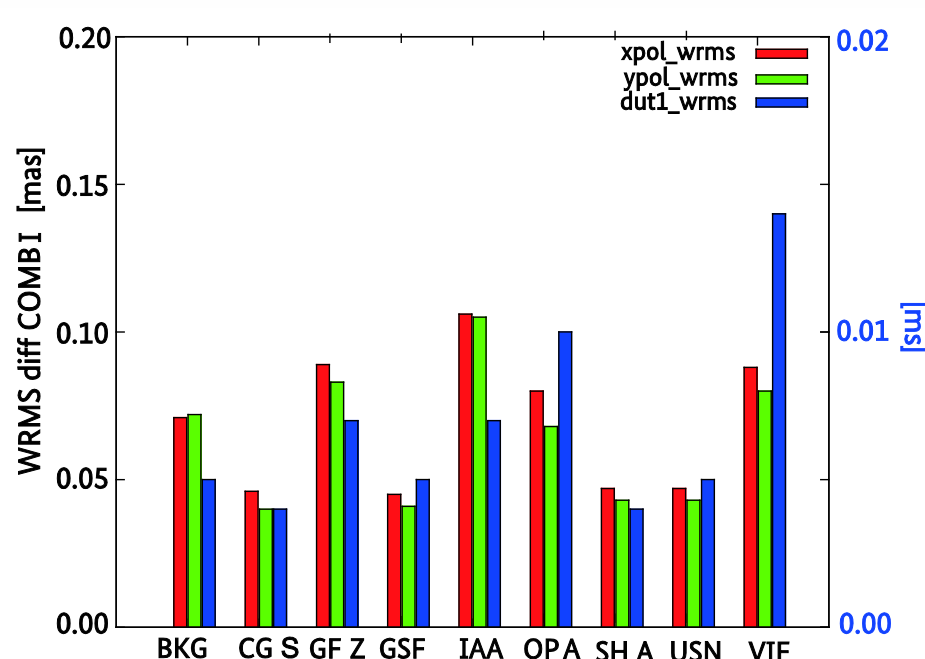
Figure 1 shows a smoothed time series of station WETTZELL as an example.

The WRMS value of the combined solution is about 3-4 mm for the horizontal and about 7 mm for the vertical component. All ACs show a similar quality.



##### • EOP

The ACs show a good agreement at the level of 50-100µs for X- and Y-Pole and 4-15µs for dUT with respect to the combined solution.



##### • VTRF

A Terrestrial Reference Frame based on stacked combined normal equations was computed, providing a set of piece-wise linear station coordinates and velocities for VLBI stations. The table on the right shows the Helmert transformation (HT) between the VTRF2014 and the ITRF2008. The strength of VLBI and its contribution to the ITRF2014 is its ability to determine the scale and to set it for the ITRF2014 together with SLR.

| HT Parameter         | ITRF2008 Positions | ITRF2008 Velocities (per yr) |
|----------------------|--------------------|------------------------------|
| T <sub>x</sub> [mm]  | -0.4 (± 0.6)       | -0.4 (± 0.6)                 |
| T <sub>y</sub> [mm]  | 0.6 (± 0.6)        | -0.4 (± 0.6)                 |
| T <sub>z</sub> [mm]  | -1.3 (± 0.5)       | -0.1 (± 0.5)                 |
| R <sub>x</sub> [mas] | -0.003 (± 0.002)   | -0.0008 (± 0.002)            |
| R <sub>y</sub> [mas] | 0.001 (± 0.002)    | 0.0003 (± 0.002)             |
| R <sub>z</sub> [mas] | 0.0002 (± 0.002)   | 0.0008 (± 0.002)             |
| Scale [ppb]          | 0.42 (± 0.08)      | -0.03 (± 0.08)               |

#### Website CCIIVS

In the second half of 2015 the newly designed IVS Combination Center website (<http://ccivs.bkg.bund.de/>) will be set up with more functions, including information about the current combination status, a glossary and search function, and a map tool. The final results of the ITRF2014 will also be officially released on our website as soon as they are available.



Figure 3: Main page of the newly designed IVS Combination Center website

#### Further information:

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