International GNSS Service (IGS)

Troposphere Products and Working Group Activities

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Agenda

- IGS overview: mission, receiver network
- Why IGS estimates troposphere delay
- IGS Final Troposphere Estimates: generation, usage
- IGS Troposphere Working Group: structure, meetings, projects, how to join
IGS overview (founded 1994)

• Mission:
  • provide highest-quality GNSS data, products, services…
  • in support of applications benefiting science, society (e.g.,
    terrestrial reference frame, PNT, earth-science research)…
  • openly-available basis

• Activities:
  • coordinate global GNSS-receiver network, archiving of its data
  • produce estimates from those data: GNSS satellite orbits,
    receiver coordinates, earth rotation parameters, sat/receiver clock
    values, iono/tropo values…
  • working groups: improve science to improve estimates

• To learn more: http://igs.org
IGS receiver network, data analysis

- 400+ permanent continuously-operating dual-frequency carrier-phase receivers
- Record one or more of: GPS, GLO, GAL, BeiDou, QZSS, SBAS
- Data archives (publicly-accessible):
  - Four global IGS data centers
  - Regional data centers

IGS analysis centers process measurements, contribute “products” (e.g., orbits) to IGS AC Coordinator, who produces official IGS products:
  - ultras (NRT); rapids (24-h later); finals (best)
Why IGS estimates troposphere delay

- Original reason: “nuisance parameter” – must estimate to achieve cm- or mm-level GNSS positioning
  - 2.2 m @ zenith; tens of m @ low elevation (e.g., 15 or 7 deg)
  - \( Z_{TD_{\text{GNSS}}} = Z_{TD_{\text{dry}}} + Z_{TD_{\text{wet}}} \)
  - \( Z_{TD_{\text{dry}}} \): ~2 m, can model
  - \( Z_{TD_{\text{wet}}} \): 0.1-0.25 m, changes too quickly/locally to model -> must estimate from GNSS or get from, e.g., WVR

- But now: use \( Z_{TD_{\text{GNSS}}} \) -> \( Z_{TD_{\text{wet}}} \) -> PWV

- Atmospheric science!
  - Low-latency, high-density PWV: weather forecasting
  - Decades-long record, 300+ sites worldwide, values every five minutes: climate studies
IGS Final Troposphere Estimates

- USNO/Dr S Byram generates
  - One 24 hr file per IGS station
    - ZTD, gradients every 5 min
    - 325-6 stations/d, 2013-4
  - Computed using Bernese GPS SW, GMF, PPP using IGS Final Orbits/EOPs/SV clocks
  - Thus ~ 21 d latency
  - Used by scientific researchers as reference (e.g. Wang et al. 2013* radiosonde study)
  - 12.3 M downloads in 2014
  - ftp://cddis.gsfc.nasa.gov/gps/products/troposphere/zpd

Example: IGS Final ZTD, 29 June 2012

TOTAL ZENITH TROPOSPHERE DELAY, 30 JUNE 2012

FRACITION OF DAY

MM

CEDU
DAV1
KOKB
POL2
THU3
USN3
“Reprocessing” campaigns:
- IGS adopts new physical models -> changes ZTD estimates (though same atmosphere) -> complicates long-term studies
- To address: reprocess entire timespan of IGS GNSS measurements using one, best-to-date model set
- “Repro 1”: ftp://cddis.gsfc.nasa.gov/gps/products/zpd/repro1
- “Repro 2”: will do when Repro 2 orbits/clocks/EOPs complete

Upcoming improvements to IGS FTEs:
- Reduce day-boundary discontinuities (non-physical few-mm ZTD-value jumps between end of one 24-hr file, beginning of next)
- Upgrade to newer version of Bernese SW, newer models
IGS Troposphere Working Group

- Mission: improve accuracy, usability of GNSS troposphere estimates
- Members: 50+ worldwide; all are welcome!
- Two meetings/yr (simulcast using gotomeeting.com):
  - December: splinter @ Am. Geophysical Union Fall Meeting
  - Spring/Summer: either IGS Workshop or splinter @ EGU
- Major activities:
  - Working group projects (next page).
  - Coordinate technical sessions (plenary, poster) at IGS Workshop.
    - Plenary: three oral presentations, big-picture projects
    - Poster: goal = foster technical exchange -> seek maximum participation
    - Links to 2014 IGS Workshop contributions in printed version of this presentation
IGS TWG projects

Automated, continuous comparisons of tropo estimates from independent techniques (GNSS, VLBI, radiosondes…)

- Comparison of answers yields better uncertainty estimates -> improves accuracy
- Primary development @ GOP; contributions from GFZ, USNO, more
- Partially funding, CZ-US Kontakt II grant # LH14089
- Complete 2016

Support of tropo_sinex (ZTD-dissemination) format standardization

- Ad-hoc format evolution in different geodetic communities
- IGS Tropo WG members R Pacione, J Dousa spearheading COST Action GNSS4SWEC WG 3 effort to redefine/expand format
- Status: just started Fall 2014
Conclusion: join us!

For more information on…

• IGS: http://igs.org
• IGS Final Troposphere Estimates:
  • Download here: ftp://cddis.gsfc.nasa.gov/gps/products/troposphere/zipd
  • Questions about them?
    • Dr Sharyl Byram: sharyl.byram@usno.navy.mil
    • Dr Christine Hackman: christine.hackman@usno.navy.mil
• IGS Troposphere Working Group:
  • Questions: christine.hackman@usno.navy.mil
  • Website (under development): http://igs.org/projects-working-groups/twg
  • Join email list: http://igscb.jpl.nasa.gov/mailman/igs-twg

Thank you for your attention!
Troposphere Gradients

\[ \delta \rho_{trp}(z, A) = f_h(z) \cdot \delta \rho_h^0 + f_w(z) \cdot \delta \rho_w^0 + N \frac{\partial f_w}{\partial z} \cos A + E \frac{\partial f_w}{\partial z} \sin A \]

- slant delay (measured)
- hydrostatic delay (modelled)
- wet delay (estimated)
- NS and EW gradients (estimated)

Example:
Gradient of 1 mm

Tilt of 1.5°

Projection of zenith delay vector: 1 mm

Asymmetry of 1 mm at z=38°

Asymmetry 15 mm at z=75°