# IGS Classic Products, Status and Towards the Future


Jake Griffiths

Kevin Choi

NOAA/NGS, USA

# IGS Core Product Series

| Series | ID | Latency | Issue times (UTC) | Data spans (UTC) | Remarks |
|---|---|---|---|---|---|
| **Ultra-Rapid (predicted half)** | IGU | real-time | @ 03:00, 09:00, 15:00, 21:00 | +24 hr @ 00:00, 06:00, 12:00, 18:00 | • for real-time apps<br>• GPS & GLONASS<br>• issued with prior IGA |
| **Ultra-Rapid (observed half)** | IGA | 3 - 9 hr | @ 03:00, 09:00, 15:00, 21:00 | -24 hr @ 00:00, 06:00, 12:00, 18:00 | • for near real-time apps<br>• GPS & GLONASS<br>• issued with following IGU |
| **Rapid** | IGR | 17 - 41 hr | @ 17:00 daily | ±12 hr @ 12:00 | • for near-definitive, rapid apps<br>• GPS only |
| **Final** | IGS | 12 - 19 d | weekly each Thursday | ±12 hr @ 12:00 for 7 d | • for definitive apps<br>• GPS & GLONASS |

# Popularity of IGS Core Products (1/2)

*- download statistics @ NASA/CDDIS (06/2010 thru 06/2012) -*

- **>3.6 million file downloads per month!**
  - total for all product lines (IGS, IGL, IGR, IGU, and experimental IGV)
- **5 biggest users of CDDIS/IGS files:**
  - United States @ 64.3%
    - from >11,300 IP addresses
  - Indonesia @ 19.3%
    - from ~250 IP addresses
  - Canada @ 1.64%
  - Sweden @ 1.57%
  - Belgium @ 1.16%
- **Overall, which products are downloaded most/least?**

***Courtesy: C. Noll (NASA/CDDIS)***

# Popularity of IGS Core Products (2/2)

*- download statistics @ NASA/CDDIS (06/2010 thru 06/2012) -*

- **Some details over past 6 months**

| Product | GNSS | Total Hits | SP3 (%) | ERP (%) | CLK (%) | SNX (%) | SUM (%) |
|---|---|---|---|---|---|---|---|
| IGU/IGA | GPS | 11,711,506 (≈ 4 * 2,927,877 daily) | 93.7 | 3.1 | | | 3.2 |
| IGS+IG1 | GPS | 1,359,656 | 60.7 | 6.8 | 24.8 | 5.8 | 2.0 |
| IGR | GPS | 887,986 | 65.6 | 8.7 | 16.9 | | 6.4 |
| IGL | GLO | 225,515 | 99.1 | | 0.3 | | 0.6 |
| IGV | GPS & GLO | 223,562 | 95.0 | | | | 5.0 |

***Courtesy: C. Noll (NASA/CDDIS)***

# IGS Core Product Accuracies (2011)

| Series | ID | Product Types | Accuracies | Output Intervals |
|---|---|---|---|---|
| **Ultra-Rapid (predicted half)** | IGU | • **GPS orbits** | ~ 5 cm (1D) | 15 min |
| | | • **GLONASS orbits** | ~10 cm (1D) | 15 min |
| | | • **GPS SV clocks** | ~3 ns RMS / ~1.5 ns Sdev | 15 min |
| | | • **EOPs: PM + dLOD** | ~250 µas / ~50 µs | 6 hr |
| **Ultra-Rapid (observed half)** | IGA | • **GPS orbits** | ~ 3 cm (1D) | 15 min |
| | | • **GLONASS orbits** | ~5 cm (1D) | 15 min |
| | | • **GPS SV clocks** | ~150 ps RMS / ~50 ps Sdev | 15 min |
| | | • **EOPs: PM + dLOD** | <50 µas / ~10 µs | 6 hr |
| **Rapid** | IGR | • **GPS orbits** | ~2.5 cm (1D) | 15 min |
| | | • **GPS SV & station clocks** | ~75 ps RMS / ~25 ps Sdev | 5 min |
| | | • **EOPs: PM + dLOD** | <40 µas / ~10 µs | daily |
| **Final** | IGS | • **GPS orbits** | <2.5 cm (1D) | 15 min |
| | | • **GLONASS orbits** | <5 cm (1D) | 15 min |
| | | • **GPS SV & station clocks** | ~75 ps RMS / ~20 ps SDev | 30 s (SVs) + 5 min |
| | | • **EOPs: PM + dLOD** | <30 µas / ~10 µs | daily |
| | | • **Terrestrial frames** | ~2 mm N&E / ~5 mm U | weekly |

**see *Rotational Errors in IGS Orbit and ERP Products*, by J. Ray**
**Thursday AM @ 08:30**

# IGS Ultra Orbit Predictions Compared to Rapids

| IGU 6hr Prediction Differences (mm @ GPS altitude) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | dX | dY | dZ | RX | RY | RZ | SCL | RMS | wRMS | Medi |
| 2008 | 2.9 | 0.4 | 0.3 | -4.2 | -1.1 | 0.7 | -3.0 | >>> | 24.6 | 18.4 |
| ± | 4.5 | 4.4 | 3.6 | 20.8 | 22.6 | 35.8 | 3.2 | >>> | 6.4 | 2.9 |
| 2009 | 3.5 | -0.6 | 0.3 | 0.3 | 0.8 | 3.1 | -0.7 | 28.9 | 21.3 | 15.6 |
| ± | 4.7 | 4.9 | 3.4 | 13.9 | 16.4 | 27.3 | 2.6 | 19.7 | 8.0 | 2.6 |
| 2010 | 3.4 | 0.4 | -0.3 | 1.9 | -0.4 | 2.3 | -1.0 | 28.7 | 21.5 | 15.6 |
| ± | 5.2 | 4.9 | 3.2 | 14.0 | 16.5 | 25.7 | 2.6 | 31.2 | 13.5 | 2.6 |
| 2011 | 2.5 | 0.5 | -1.1 | 2.2 | -0.9 | 2.1 | -0.2 | 27.0 | 20.5 | 15.3 |
| ± | 5.2 | 5.4 | 3.2 | 14.1 | 16.8 | 22.4 | 2.3 | 24.4 | 6.6 | 2.6 |
| **IGU 24hr Prediction Differences (mm @ GPS altitude)** | | | | | | | | | | |
| 2008 | 1.0 | 1.0 | -0.0 | -5.8 | -3.5 | -2.9 | -3.2 | 72.6 | 52.6 | 33.9 |
| ± | 2.0 | 1.9 | 3.9 | 31.6 | 35.7 | 61.4 | 2.7 | 42.4 | 15.4 | 6.4 |
| 2009 | 1.1 | 0.3 | -0.1 | -0.5 | -0.6 | -0.9 | -1.3 | 64.7 | 47.3 | 30.2 |
| ± | 1.8 | 2.0 | 3.8 | 22.0 | 31.3 | 52.1 | 1.9 | 33.3 | 16.3 | 6.0 |
| 2010 | 0.6 | 0.9 | -1.4 | 5.5 | -2.9 | 0.1 | -1.8 | 70.3 | 47.0 | 30.1 |
| ± | 2.1 | 2.0 | 3.8 | 23.8 | 32.6 | 50.1 | 2.1 | 171.7 | 25.3 | 5.7 |
| 2011 | 0.6 | 1.4 | -2.1 | 5.9 | -3.2 | -2.4 | -0.5 | 59.4 | 45.3 | 30.5 |
| ± | 1.9 | 2.1 | 3.6 | 25.6 | 31.9 | 42.8 | 1.7 | 25.2 | 14.1 | 5.4 |

* rotations are equatorial @ GPS altitude; 24hr predictions from 00 UTC IGUs only

# IGS Ultra Orbit Predictions Compared to Rapids

due to UT1 prediction errors

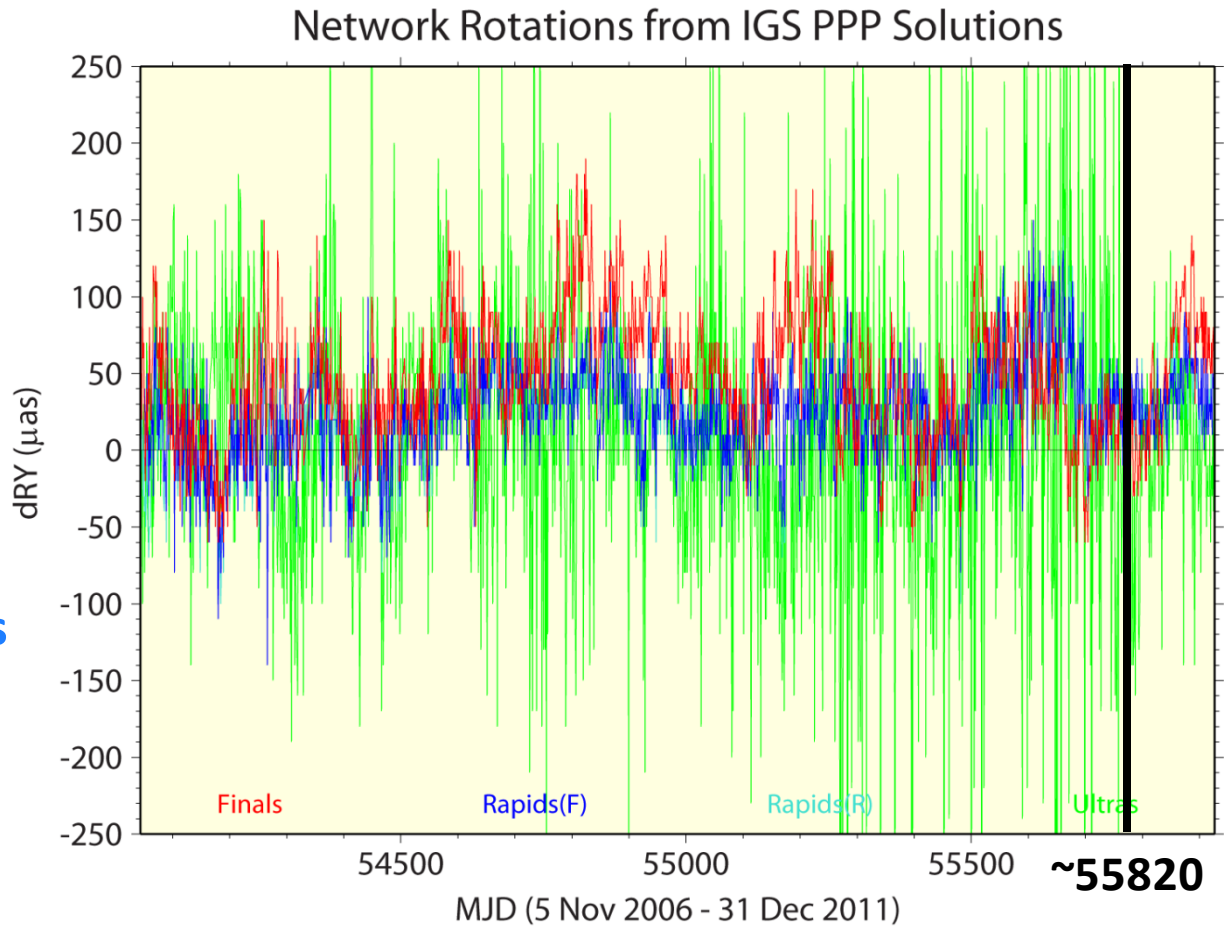
| IGU 6hr Prediction Differences (mm @ GPS altitude) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | dX | dY | dZ | RX | RY | RZ | SCL | RMS | wRMS | Medi |
| 2008 | 2.9 | 0.4 | 0.3 | -4.2 | -1.1 | 0.7 | -3.0 | >>> | 24.6 | 18.4 |
| ± | 4.5 | 4.4 | 3.6 | 20.8 | 22.6 | 35.8 | 3.2 | >>> | 6.4 | 2.9 |
| 2009 | 3.5 | -0.6 | 0.3 | 0.3 | 0.8 | 3.1 | -0.7 | 28.9 | 21.3 | 15.6 |
| ± | 4.7 | 4.9 | 3.4 | 13.9 | 16.4 | 27.3 | 2.6 | 19.7 | 8.0 | 2.6 |
| 2010 | 3.4 | 0.4 | -0.3 | 1.9 | -0.4 | 2.3 | -1.0 | 28.7 | 21.5 | 15.6 |
| ± | 5.2 | 4.9 | 3.2 | 14.0 | 16.5 | 25.7 | 2.6 | 31.2 | 13.5 | 2.6 |
| 2011 | 2.5 | 0.5 | -1.1 | 2.2 | -0.9 | 2.1 | -0.2 | 27.0 | 20.5 | 15.3 |
| ± | 5.2 | 5.4 | 3.2 | 14.1 | 16.8 | 22.4 | 2.3 | 24.4 | 6.6 | 2.6 |

| IGU 24hr Prediction Differences (mm @ GPS altitude) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 1.0 | 1.0 | -0.0 | -5.8 | -3.5 | -2.9 | -3.2 | 72.6 | 52.6 | 33.9 |
| ± | 2.0 | 1.9 | 3.9 | 31.6 | 35.7 | 61.4 | 2.7 | 42.4 | 15.4 | 6.4 |
| 2009 | 1.1 | 0.3 | -0.1 | -0.5 | -0.6 | -0.9 | -1.3 | 64.7 | 47.3 | 30.2 |
| ± | 1.8 | 2.0 | 3.8 | 22.0 | 31.3 | 52.1 | 1.9 | 33.3 | 16.3 | 6.0 |
| 2010 | 0.6 | 0.9 | -1.4 | 5.5 | -2.9 | 0.1 | -1.8 | 70.3 | 47.0 | 30.1 |
| ± | 2.1 | 2.0 | 3.8 | 23.8 | 32.6 | 50.1 | 2.1 | 171.7 | 25.3 | 5.7 |
| 2011 | 0.6 | 1.4 | -2.1 | 5.9 | -3.2 | -2.4 | -0.5 | 59.4 | 45.3 | 30.5 |
| ± | 1.9 | 2.1 | 3.6 | 25.6 | 31.9 | 42.8 | 1.7 | 25.2 | 14.1 | 5.4 |

* rotations are equatorial @ GPS altitude; 24hr predictions from 00 UTC IGUs only

# Persistent Rotational Scatter in IGU products

- About half of total IGU error
- Reduced since mid-Sep. 2011 (MJD 55820), when combi. toler. changed
- Possible sources
  - errors in *a priori* EOPs
  - poor IGU clocks
  - rotational mis-alignment of IGU orbits




- Currently testing new orbit combination approach in IGV

# Initial Results from New Testing in IGV

- **Operational IGU**
  - GPS only (5/9 ACs – WHU & NGU new; used only for comparison)
  - uses all 48h (observed & predicted) parts to align AC orbits
- **Experimental IGV**
  - mixed GPS (5/9 ACs) & Glonass (4/4 ACs)
  - uses first 24h (observed) part to align AC orbits
    - improves agreement w/ IGR
    - rotational misalignments still significant

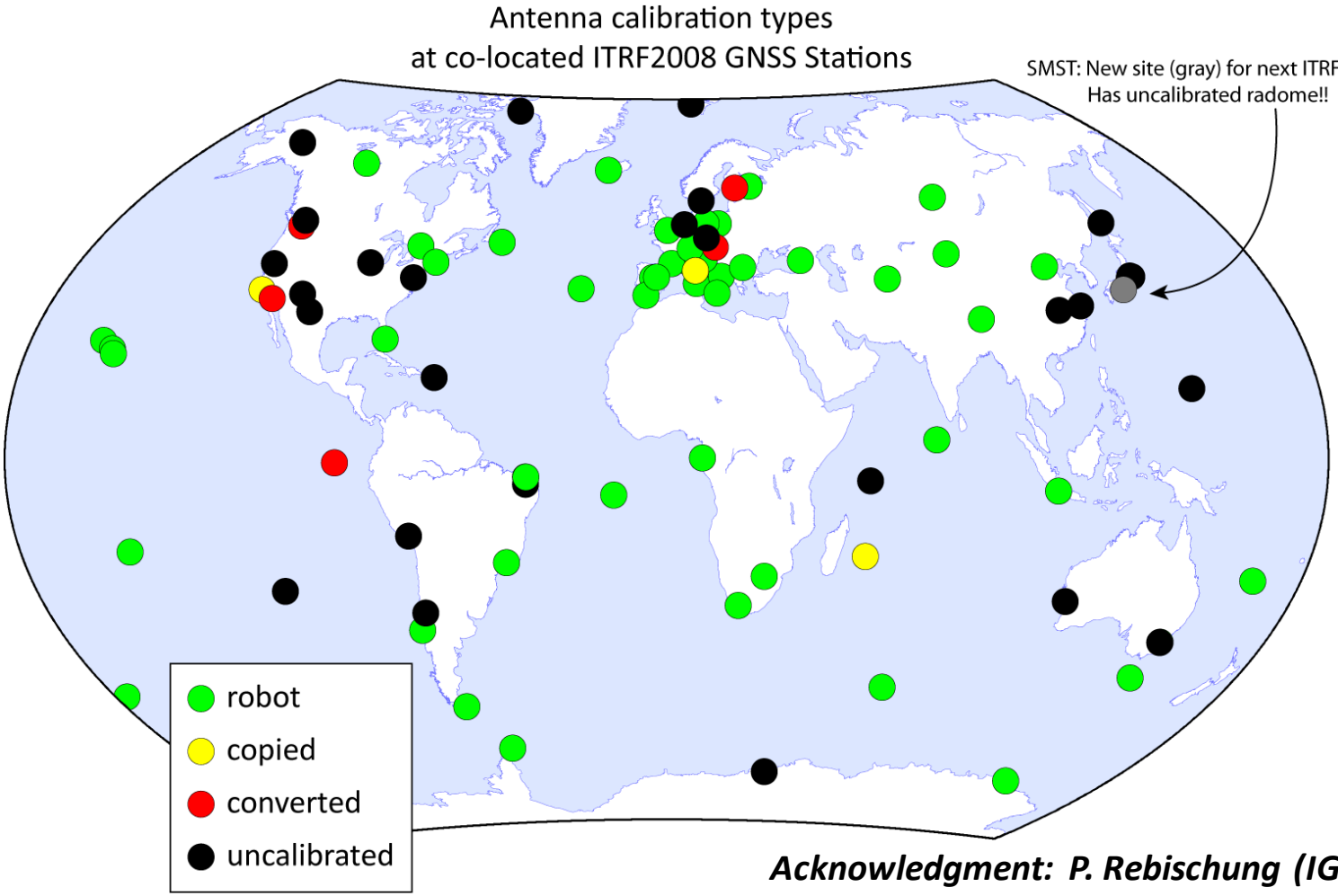
| | TX [mm] | TY [mm] | TZ [mm] | RX [uas] | RY [uas] | RZ [uas] | SCL [ppb] | RMS [mm] | WRMS [mm] |
|---|---|---|---|---|---|---|---|---|---|
| igu-igr | 0.87 | -0.10 | -0.66 | 24.33 | -21.50 | 5.56 | -0.020 | 9.23 | 8.33 |
| + / - | 1.15 | 1.02 | 1.20 | 25.47 | 20.00 | 64.74 | 0.044 | 1.58 | 1.35 |
| igv-igr | 0.90 | -0.15 | -0.40 | 17.83 | -15.55 | -2.43 | 0.001 | 9.07 | 8.12 |
| + / - | 1.10 | 1.00 | 1.33 | 25.30 | 19.35 | 56.94 | 0.050 | 1.69 | 1.37 |

100 uas ≈ 13 mm @ GPS

Based on 3 weeks: 1693 thru 1696

# Other Challenges: Uncalibrated Radomes

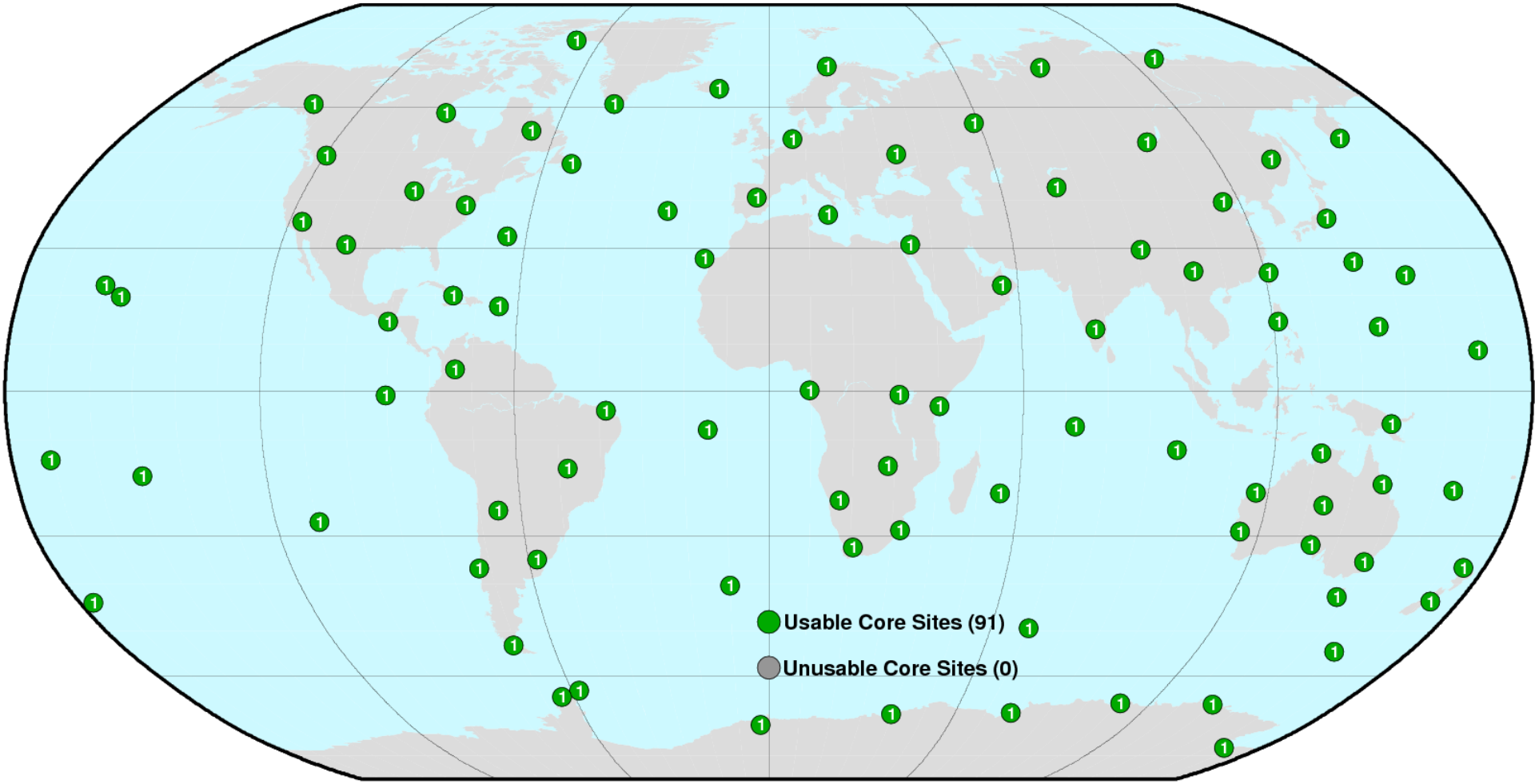
- **28/92 (≈ 30%) co-located sites have an uncalibrated radome**
  - **nearly half (13/28) operated by JPL**




***Acknowledgment: P. Rebischung (IGN/LAREG)***

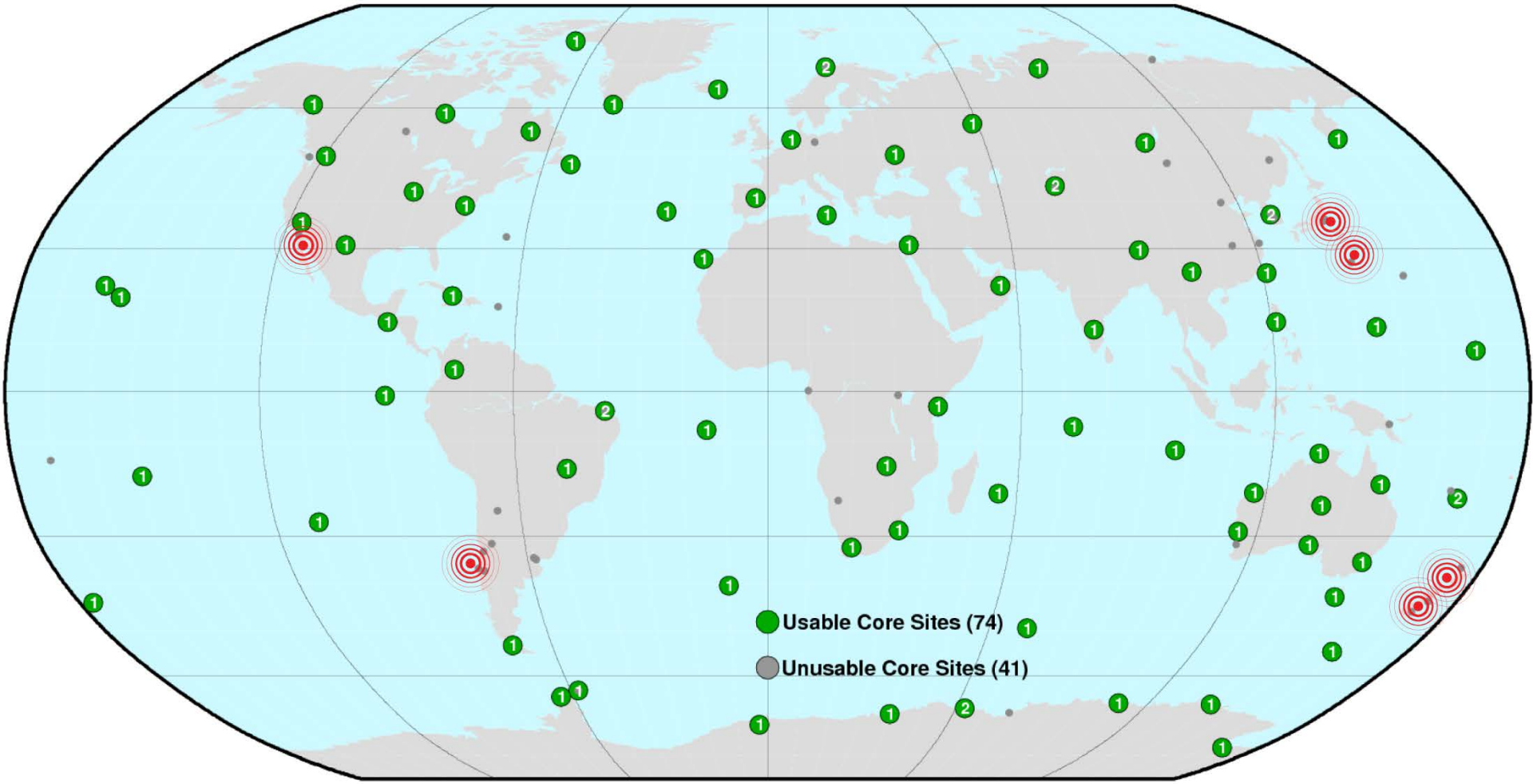
# Other Challenges: Loss of IGS08 Core Stations (1/4)

- **Primary core network @ 2009.5 (best case—all data avail.)**



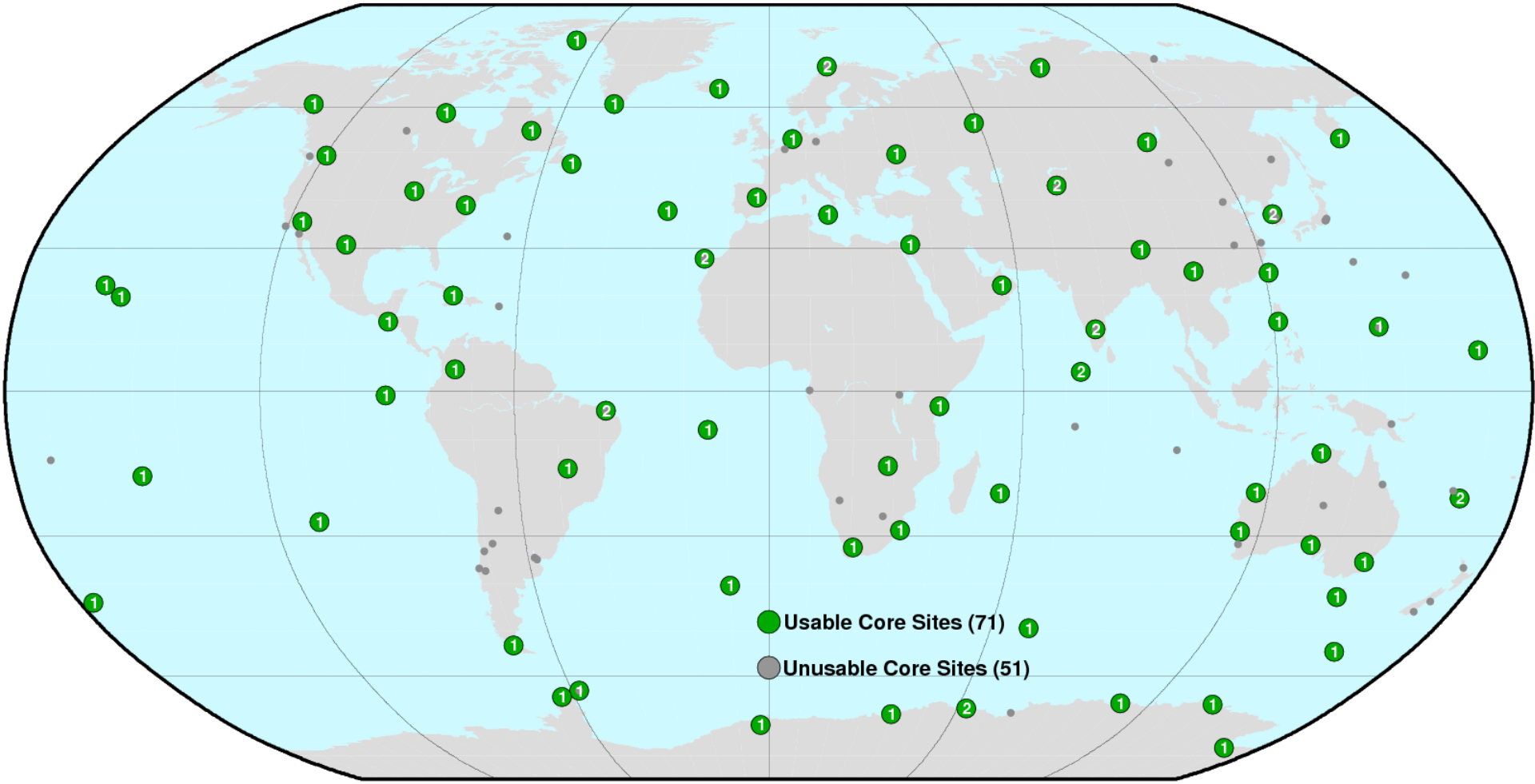
# Other Challenges: Loss of IGS08 Core Stations (2/4)

- Wk 1632: IGS08 adopted; ~22 primary already lost (e-quakes & equip. changes)



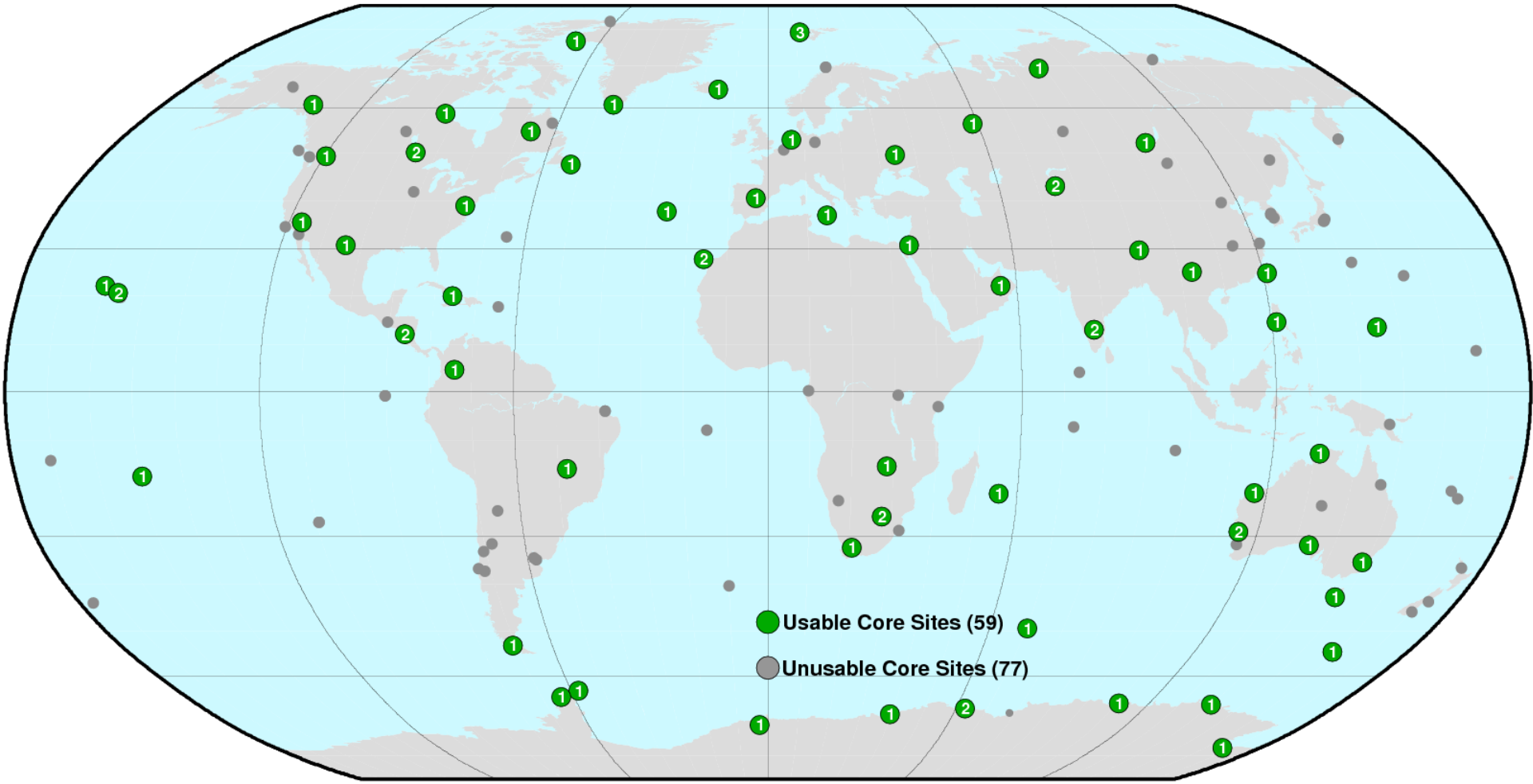
# Other Challenges: Loss of IGS08 Core Stations (3/4)

- **Today: ~71 useable sites (assumes all data are available)**



# Other Challenges: Loss of IGS08 Core Stations (4/4)

- **Today: accounting for data availability, ~59 useable core sites**



# Summary of Persistent Challenges

- **Rotational errors in all products; largest in IGU**
- **Uncalibrated radomes at co-location sites**
  - one recently available at SMST!! (co-located w/ SLR; unavail. for ITRF2008)

see *Strengths and Weaknesses of the IGS Contribution to ITRF*, by Z. Altamimi
Friday AM @ 9:06

- **Loss of IGS08 core stations**
  - anthropogenic site disturbances (incl. many equip. changes)
  - data loss, and earthquakes & other physical processes
- **Known biases and other systematic errors**
  - harmonic and sub-daily alias errors in all IGS products
  - site-specific errors *[e.g., Wetzell observations by Steigenberger et al., REFAG2010]*

see *BRUX: A New EPN and IGS Reference Station in Brussels*, by W. Aerts
Tuesday PM (1:30 – 3:00)

see *Investigation of Non-Tectonic Signals at GPS Stations*, by C. Meertens
Wednesday AM @ 09:50

# Upcoming Events

- **Switch to Finals products based on daily TRF integrations**
  - to facilitate further study of non-tidal loading effects
    - station position RMS increases by factor of 1.0 to 1.5 (mostly in E & U)
    - 0.5 mm RMS increase in orbit
    - 2.5 ps RMS increase over clock ensemble
    - kinematic PPP results show that impact to users is very small
    - CODE orbits & SNX will be included for comparison only
    - may yield better internal consistency due to removal of AC over-constraints
  - see IGSMail #6613 for more details
- **Next reprocessing (details at acc.igs.org/reprocess2.html)**
  - expect to finalize analysis standards this week!
  - should result in improved inter-AC agreement & reduced systematic errors
  - but some issues not likely to be resolved
    - to remain: sub-daily tidal EOP errors & tracking station inadequacies
  - aiming for early 2014 delivery of combined SNX for next ITRF

# Recommendations

- Need more Ultra-rapid (IGU & IGV) ACs
- Further study of IGU <-> IGR <-> IGS inconsistencies
- Improve tracking stations, esp at co-location sites
  - remove uncalibrated radomes
  - prevent/eliminate unnecessary antenna changes
  - study electronic instability and other local effects
  - RF and co-located stations to be closely monitored by a dedicated Network Coordinator
- Update IERS model for sub-daily EOP tidal variations
- Finalize analysis standards for repro2 (this week!)
  - RF and co-located stations to be processed with priority
  - AC networks to be as stable & connected (in time) as possible
  - aiming for early 2014 delivery of combined SNX files for ITRF2013
    - consider excluding co-location sites w/ uncalibrated radomes in ITRF combination (ACs should still process their data)

# Extra Slides