

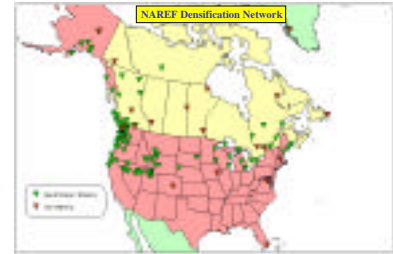


# The NAREF Initiative to Densify the ITRF in North America

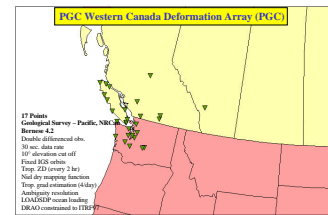
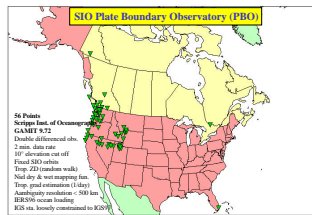
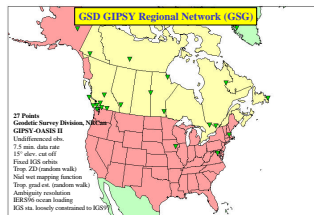
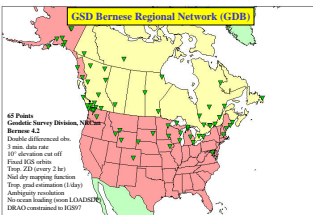
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## ABSTRACT

The International Association of Geodesy (IAG) is undergoing growth and evolution, particularly in providing and coordinating geodetic services. The most prominent example of such services is the International GPS Service (IGS), which promotes international standards for GPS data acquisition and analysis, deploys and operates a global GPS tracking network, and distributes data and data products, such as precise orbits, clock estimates and coordinate solutions in the International Terrestrial Reference Frame (ITRF). In an effort to densify the ITRF, the IGS initiated a program of distributed regional processing to better manage the computational load. The North American Subcommittee of the International Association of Geodesy's Commission X has formed a North American Reference Frame (NAREF) Working Group to promote and coordinate such regional processing in North America. The Geodetic Survey Division (GSD) of Natural Resources Canada has been leading this promotion and coordination which has involved the adoption of standards and guidelines for station selection, operation, data processing, archiving, redundancy, and the combination and integration of regional solutions within the ITRF and IGS global network. Most of these standards and guidelines have been adopted from those proposed by the IGS and those used by the European Reference Frame (EUREF) Technical Working Group, NAREF's sister group in Europe. Presently, two independent Canada-wide solutions from the GSD, a western Canada solution from the Geological Survey of Canada – Pacific and a Plate Boundary Observatory solution from the Scripps Institution of Oceanography are being combined on a weekly basis into a single NAREF solution. Overlap among these regional networks provide redundancy checks and allow for the determination of correct relative weighting of the different solutions relative to each other. These weekly solutions will soon be submitted to the IGS on a regular basis for eventual incorporation into the official IGS densification network and ultimately into future realizations of the ITRF.



## REGIONAL SOLUTIONS



## REGIONAL COMBINATION PROCEDURE

### Alignment of Each Regional Solution

1. A priori datum constraints removed from each regional solution
2. Each regional solution aligned to IGS weekly solution (3 translations, 3 rotations & scale change)
3. Covariance matrix of each regional solution scaled by WRMS of residuals
4. Residuals tested for outliers (outliers removed)

### Combination of Regional Solutions

5. All (scaled) regional solutions combined (summation of normals)
6. Combined solution aligned to IGS weekly solution (3 translations, 3 rotations & scale change)
7. Covariance matrix for combined solution scaled by WRMS of residuals
8. Residuals tested for outliers (outliers removed)
9. Minimum constraint introduced (DRAO constrained to IGS97)

### Software

- SINEX Software v1.0 by R. Ferland (use for IGS global combinations)

## NAREF COMBINATION RESULTS

- Completed 27 weeks since beginning of 2001
- Individual station discrepancy vectors plotted for week 1095

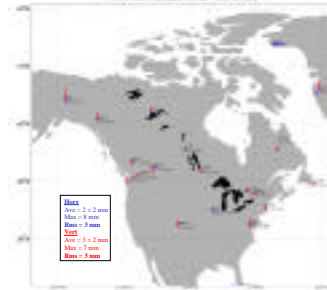
### Comparison with IGS

- Differences between NAREF & IGS weekly solutions at IGS stations:
- Week 1095: Better than 3 mm on average (see plot)
- Time series of RMS of discrepancies for 27 weeks (see plot)
  - + 2.5 mm horizontal
  - + 4.0 mm vertical
- Within accuracy of IGS solutions

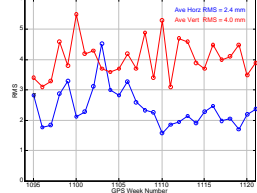
### Residual Fit of Individual Solutions

- Difference with respect to final NAREF combination
- Week 1095: Better than 3 mm on average (see plots)
- Better than 3 mm on average (see plots)
- Time series of RMS of fits for 27 weeks (see plots):
  - + 3.5 mm horizontal
  - + 5.5 mm vertical

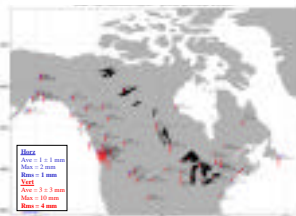
Week 1095 NAREF Combination vs. IGS Weekly Solution



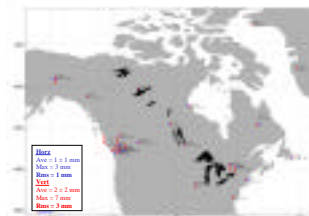
RMS of Weekly NAREF Combinations w/ IGS Weekly Solutions



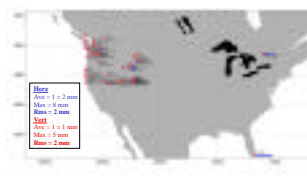
Week 1095 Combination Residuals: GSD Bernese Solution (GSB)



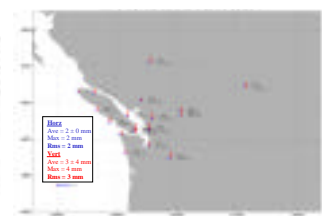
Week 1095 Combination Residuals: GSD GIPSY Solution (GSG)



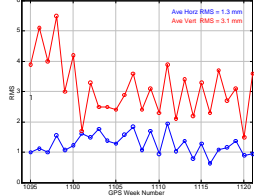
Week 1095 Combination Residuals: SIO PBO Solution



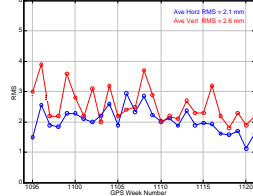
Week 1095 Combination Residuals: PGC WCDA Solution



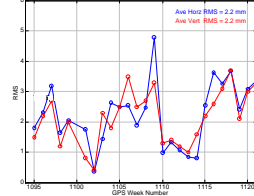
RMS of GSB Residuals



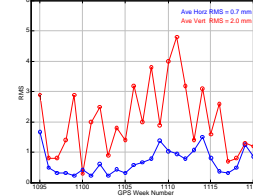
RMS of GSG Residuals



RMS of PBO Residuals



RMS of PGC Residuals



## FUTURE WORK

- Incorporate other regional solutions
  - NGS CORS network (>150 stations across entire US)
  - Mexican permanent GPS network (about 10 stations)
  - Western Arctic Deformation Network (3 stations) – 2001
  - Post-glacial uplift monitoring network (6 stations) – 2001
  - OSU Great Lakes CORS network (21 Stations) – 2002
- Station classification standards
- Strategy for integration into ITRF/IGS network
- Regular cumulative solutions with velocities

## ACKNOWLEDGEMENTS

- Brian Donahue & Caroline Huot (Geodetic Survey Division)
  - GSD GIPSY solutions
- Herb Dragert (Pacific Geoscience Centre)
  - PGC solutions
- Matthijs van Donselaar (Scripps Institution of Oceanography)
  - PBO solutions
- Remi Ferland (Geodetic Survey Division)
  - SINEX software & combination procedure
- Jan Kouba (Geodetic Survey Division)
  - General advice & guidance

## FURTHER INFORMATION

- See the NAREF web site at [www.naref.org](http://www.naref.org)
- Available material:
  - Papers and presentations
  - Recent results
  - Portal to the NAREF Data Archive for regional and NAREF SINEX solutions