



# Canadian Contributions to the NAREF Initiative to Densify the ITRF in North America

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[www.naref.org](http://www.naref.org)

## ABSTRACT

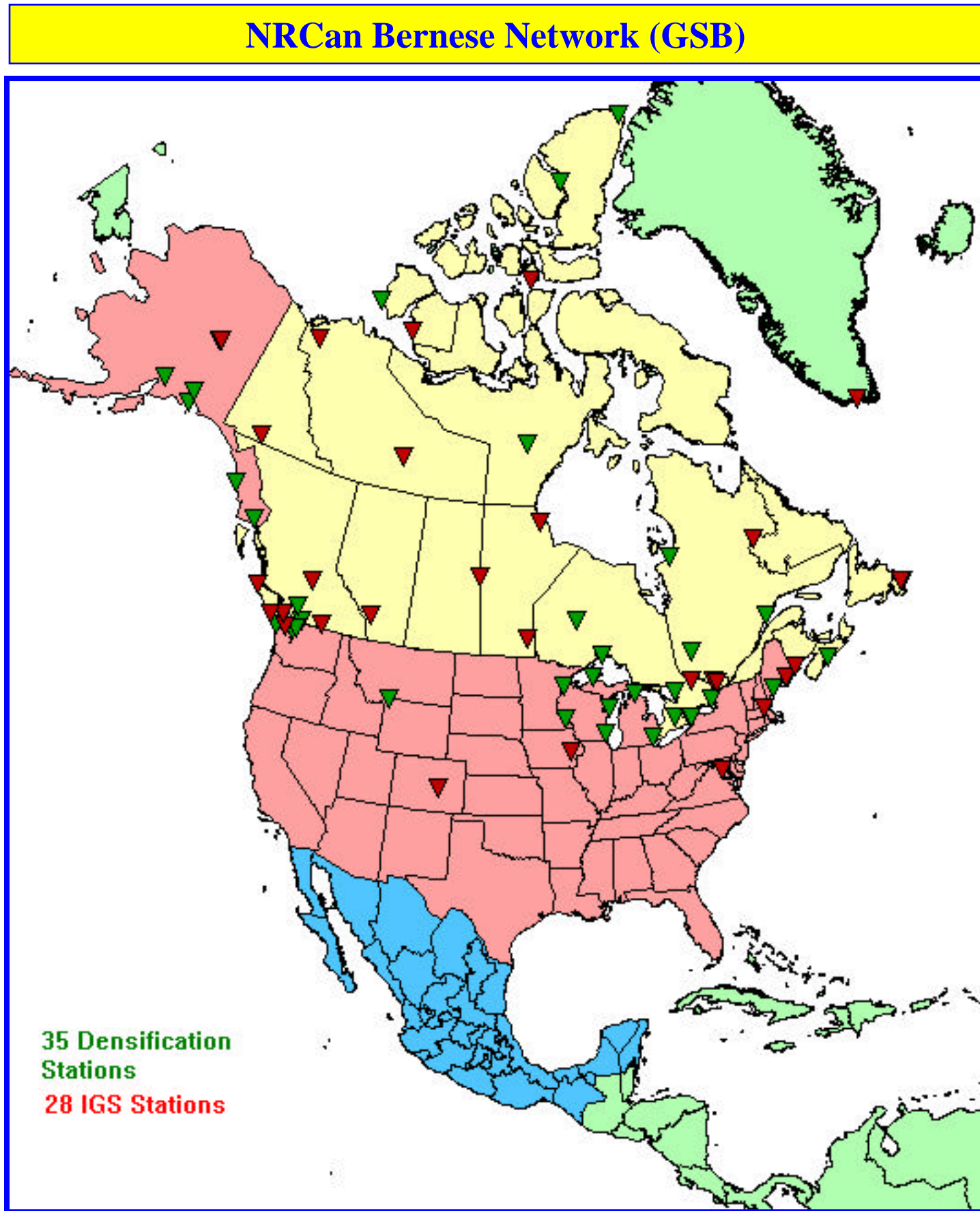
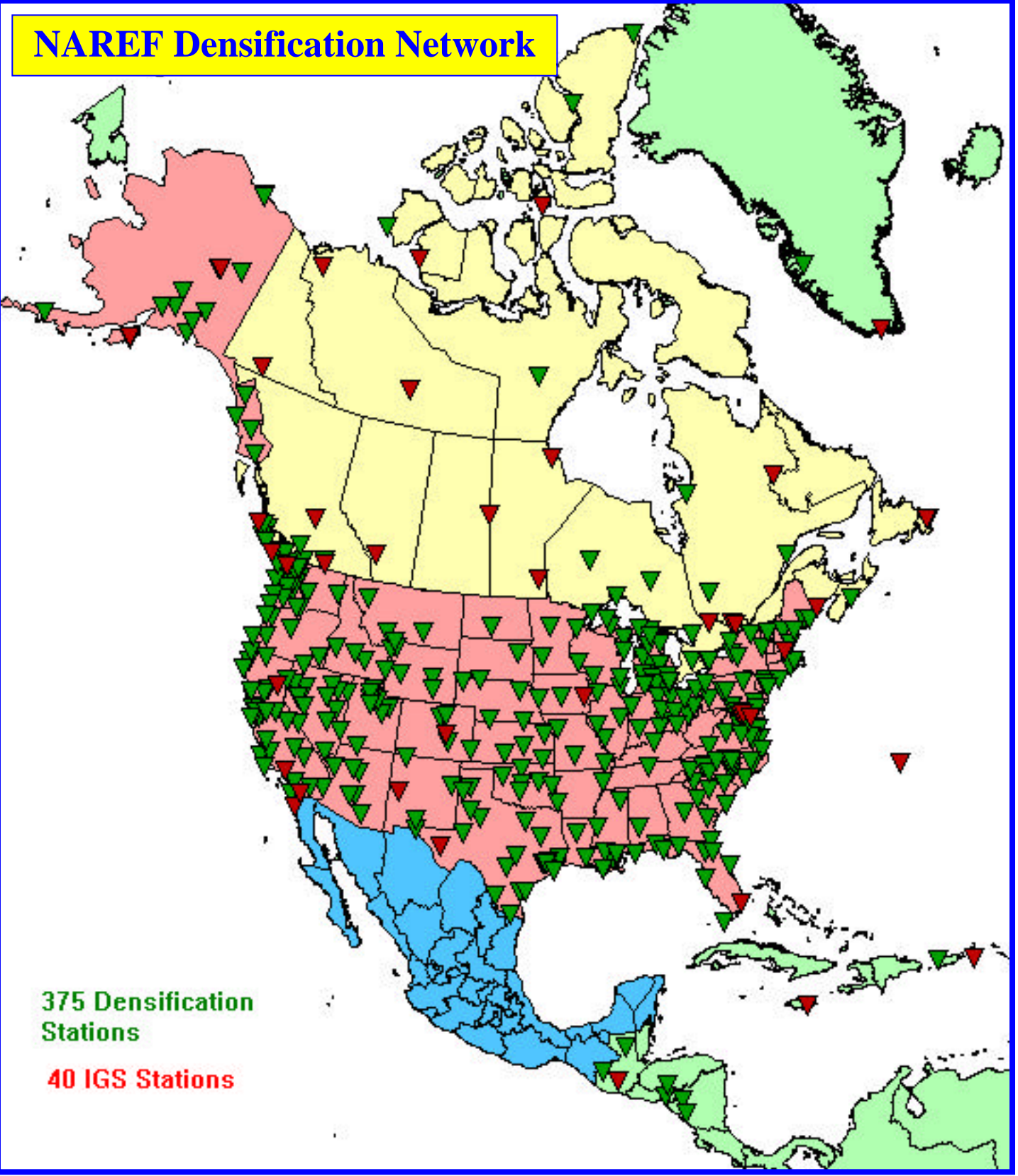
In an effort to densify the ITRF in North America, the IGS initiated a program of distributed regional processing to better manage the computational effort. Under the auspices of the North American Reference Frame (NAREF) Working Group, the Geodetic Survey Division (GSD) has been contributing to this initiative on two fronts: the provision of weekly regional GPS solutions for continuous GPS arrays in Canada and the combination and integration of regional solutions for other arrays across North America.

Since the beginning of 2001, GSD has been computing two independent Canada-wide weekly solutions using GIPSY-OASIS II and the Bernese GPS Software. These solutions include all known geodetic-quality, continuous GPS stations across Canada as well as stations from neighboring arrays in the U.S. In addition, we have been receiving regional weekly solutions for two other continuous GPS arrays in North American: the Western Canada Deformation Array from the Geological

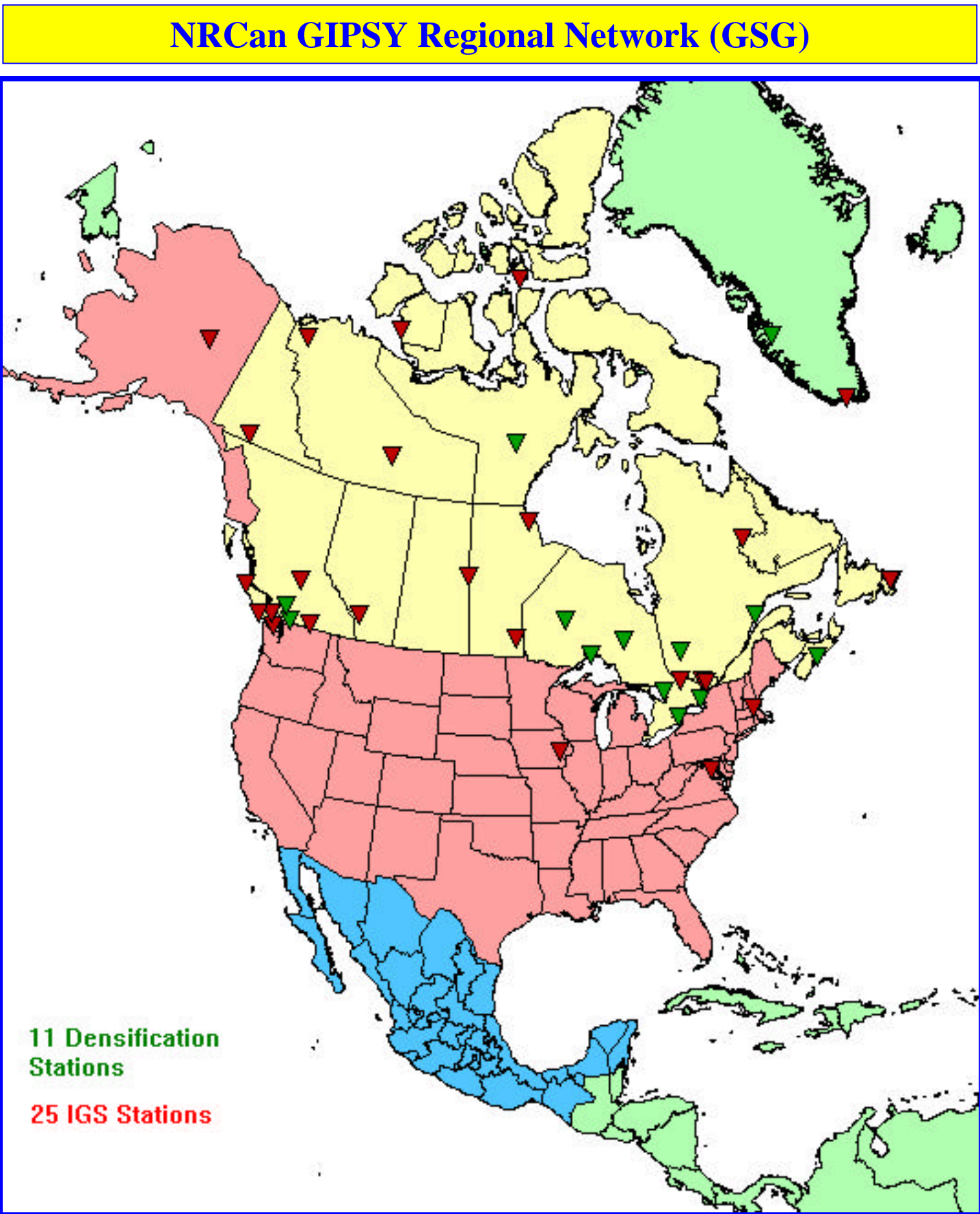
Survey of Canada - Pacific Division and the Plate Boundary Observatory from the Scripps Institution of Oceanography. The later covers most of the western seaboard of the U.S. Most recently, we have also been receiving weekly solutions from the U.S. National Geodetic Survey for their entire national CORS network. This contribution now makes NAREF truly North American in scope.

GSD has also been combining these regional solutions into weekly NAREF combinations in order to provide a time series of consistent, high accuracy coordinates for continuous GPS stations in North America. Overlap among these regional arrays provide redundancy checks and allow for the determination of correct relative weighting of different solutions and a more realistic assessment of accuracy. The agreement among the regional solutions is generally less than a couple of mm horizontally and about 4-5 mm vertically. Agreement of the minimally constrained NAREF combinations with the IGS weekly combinations is of the order of 2-3 mm

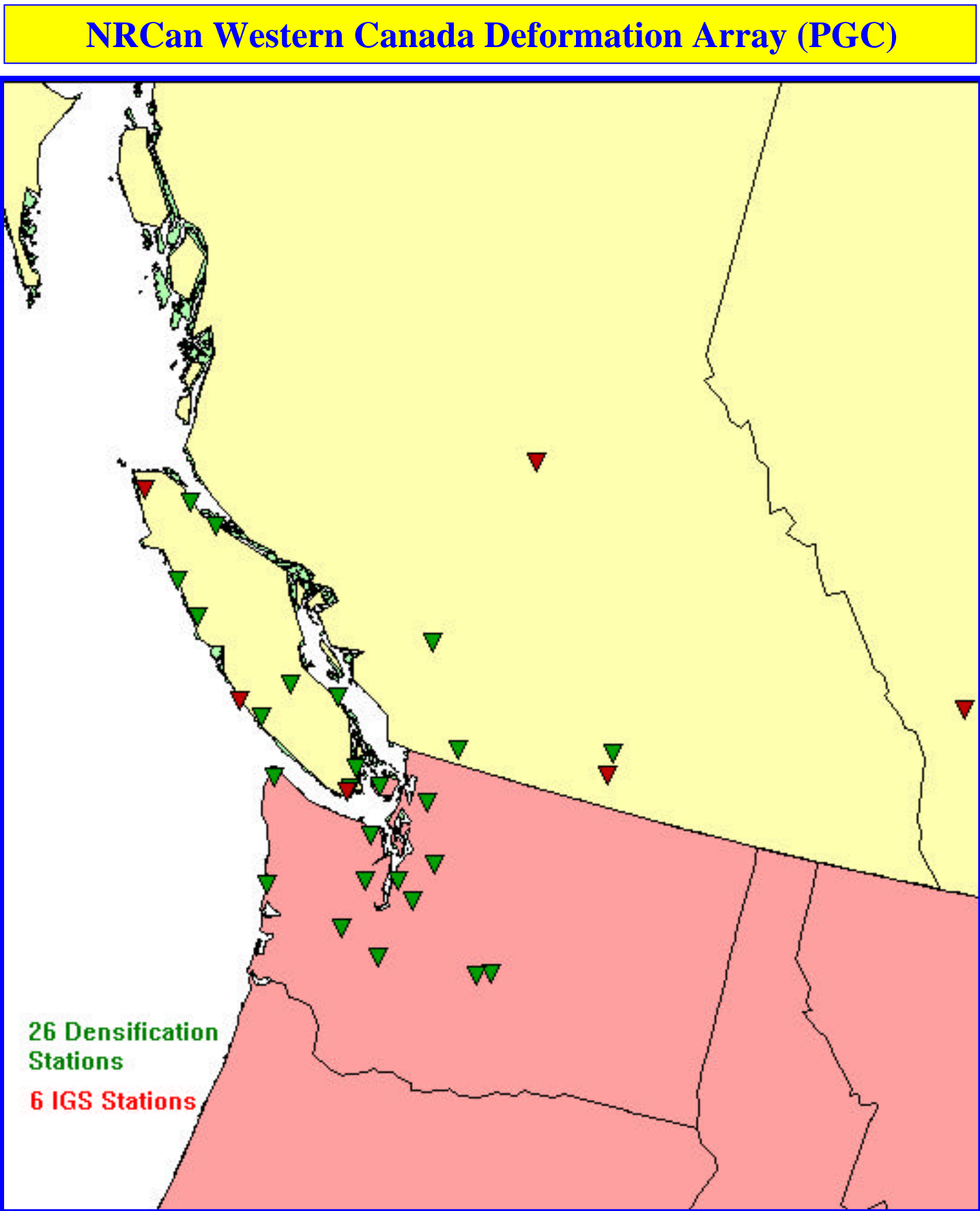
horizontally and 5-8 mm vertically. These combinations have been integrated into the IGS global network using a combination of Helmert transformation and a priori weighting of IGS global stations. Agreement of these integrated NAREF combinations with the IGS solutions is about 1 mm horizontally and 4 mm vertically.



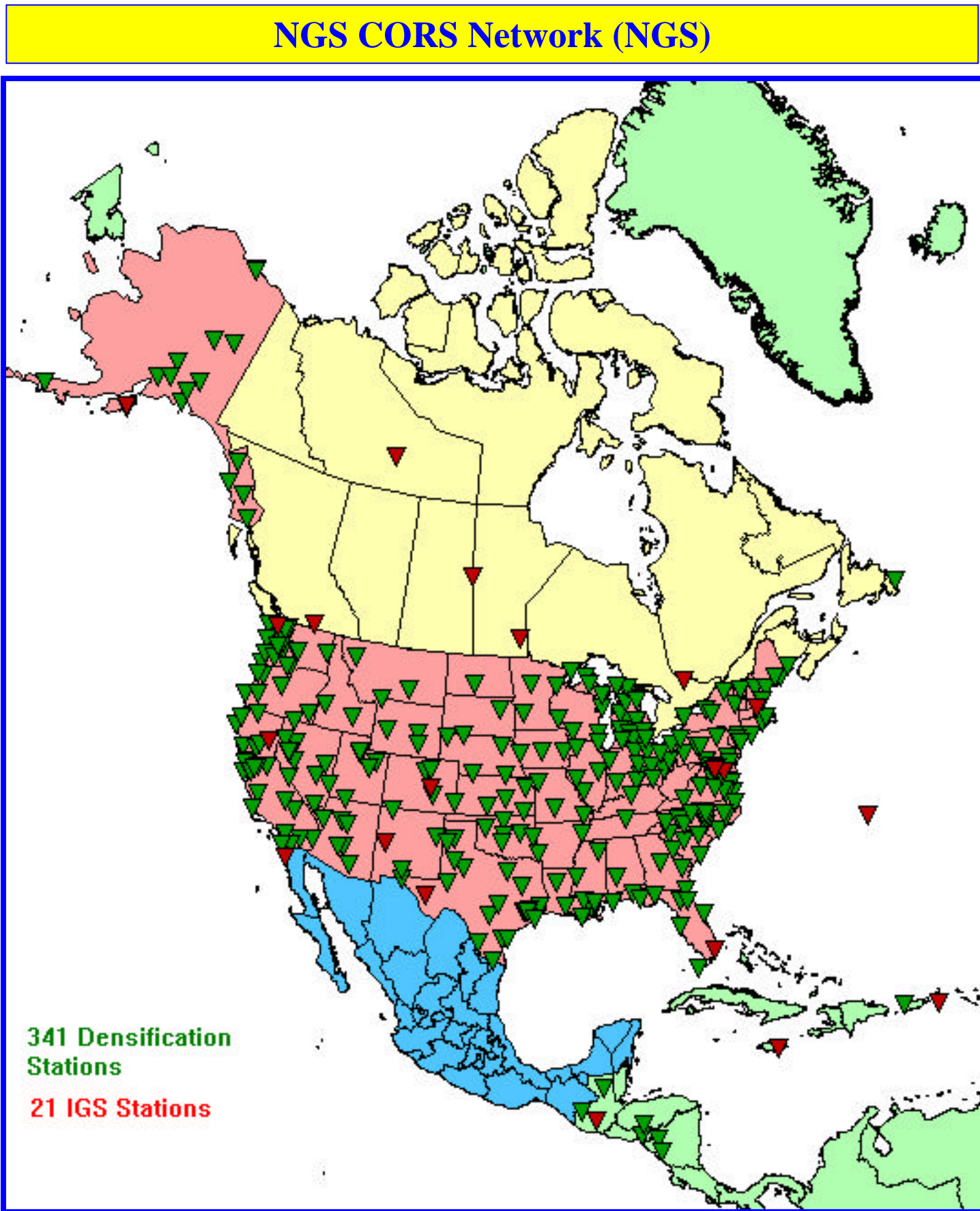
- From Geodetic Survey Division, NRCan
- Bernese GPS Software Version 4.2
- Double differenced observations
- 3 minutes data sampling
- 10 deg elevation cut off
- Fixed IGS precise orbits & ERP
- Tropospheric zenith delay (every 2 hours)
- Niell mapping function (dry)
- Tropospheric gradient (1/day)
- QIF ambiguity resolution with regional ionosphere model
- LOADSDP v.5.0 ocean loading model
- 1 IGS reference frame station (DRAO) constrained to IGS00



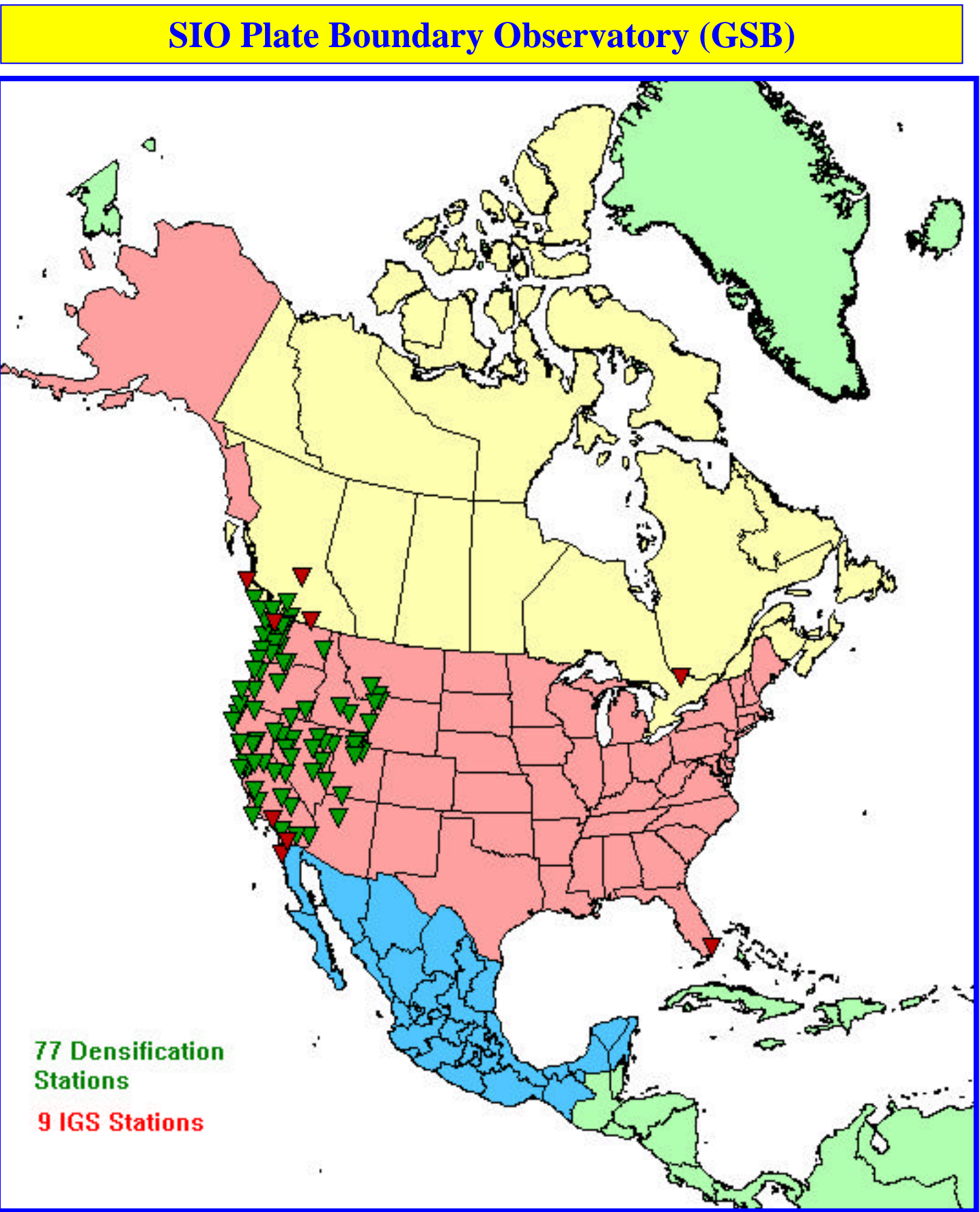
- From Geodetic Survey Division, NRCan
- GIPSY-OASIS II software
- Undifferenced observations
- 7.5 minutes data sampling
- 15 deg elevation cut off
- Fixed IGS precise orbits & ERP
- Tropospheric zenith delay (random walk)
- Niell mapping function (wet)
- Tropospheric gradient (random walk)
- Ambiguity resolution applied
- IERS96 ocean loading model
- 1 IGS reference frame station (DRAO) constrained to IGS00



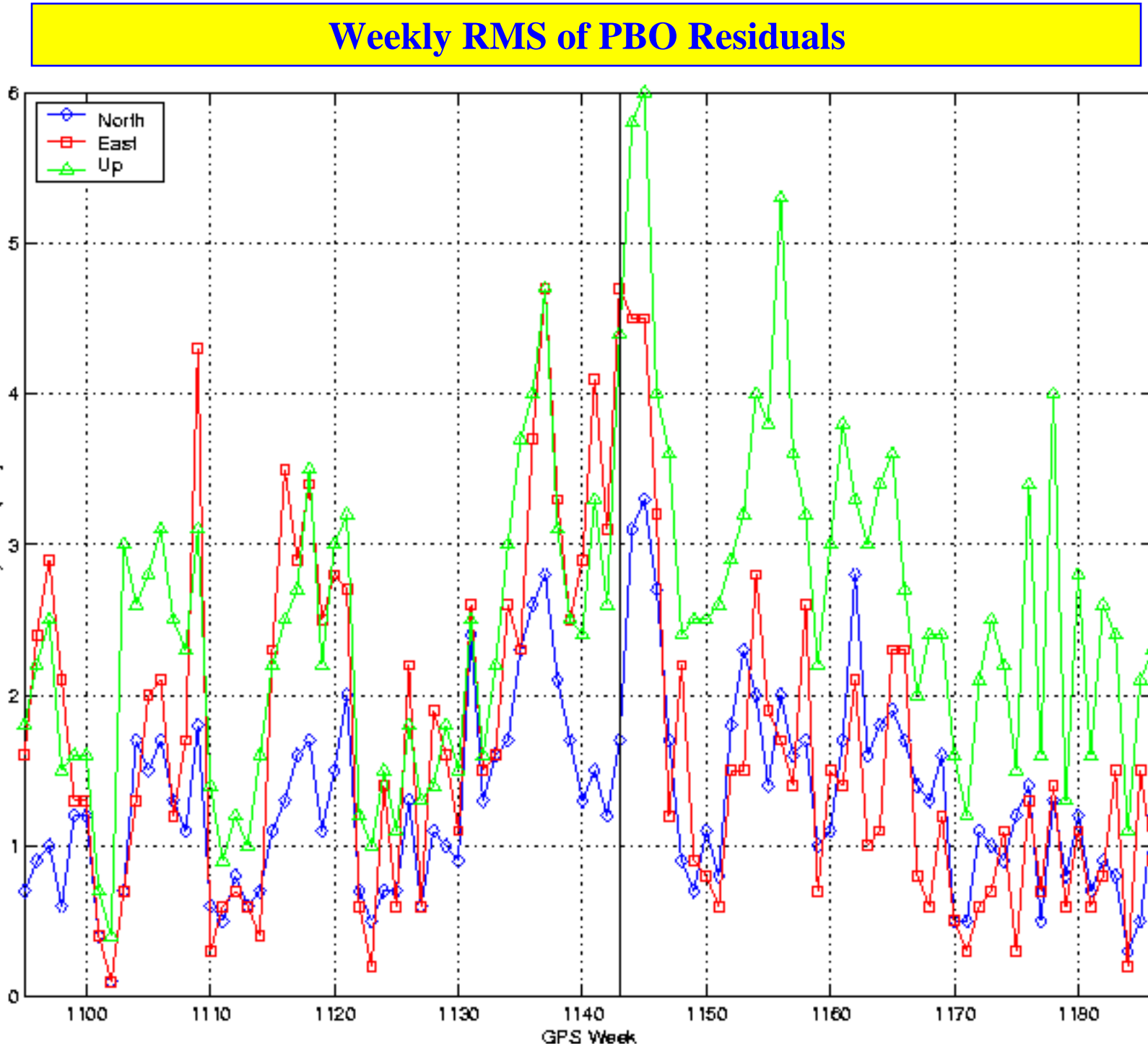
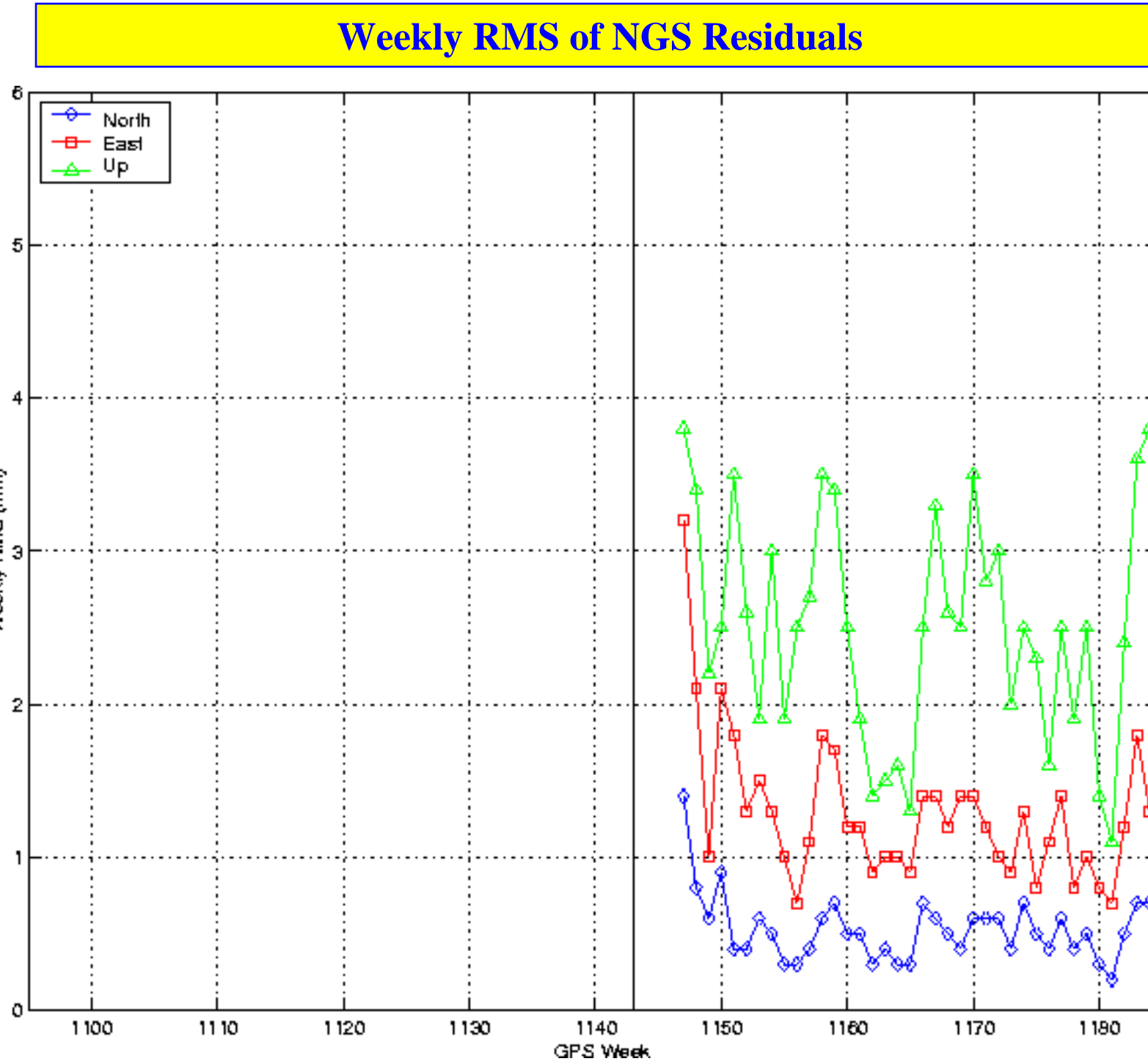
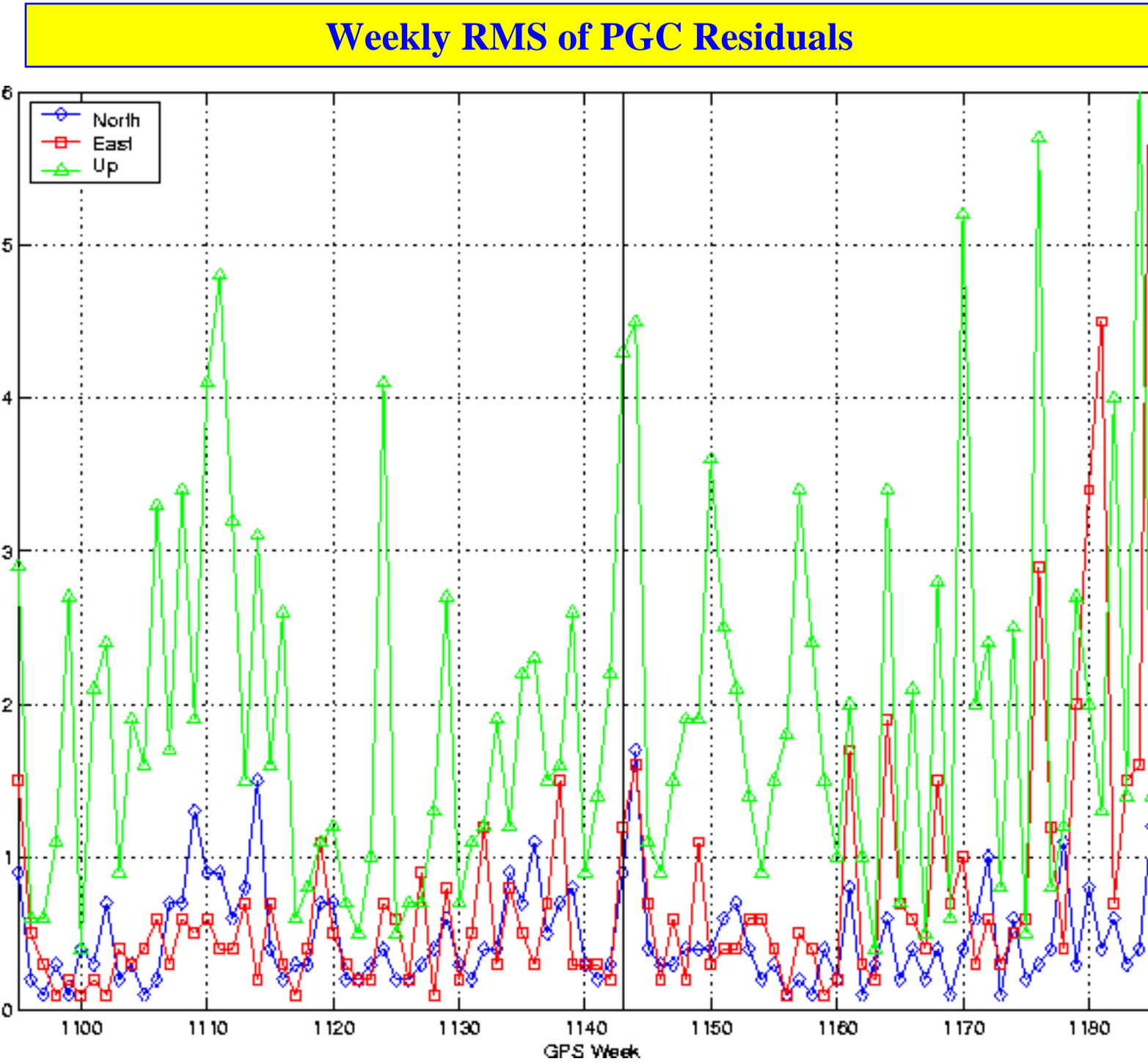
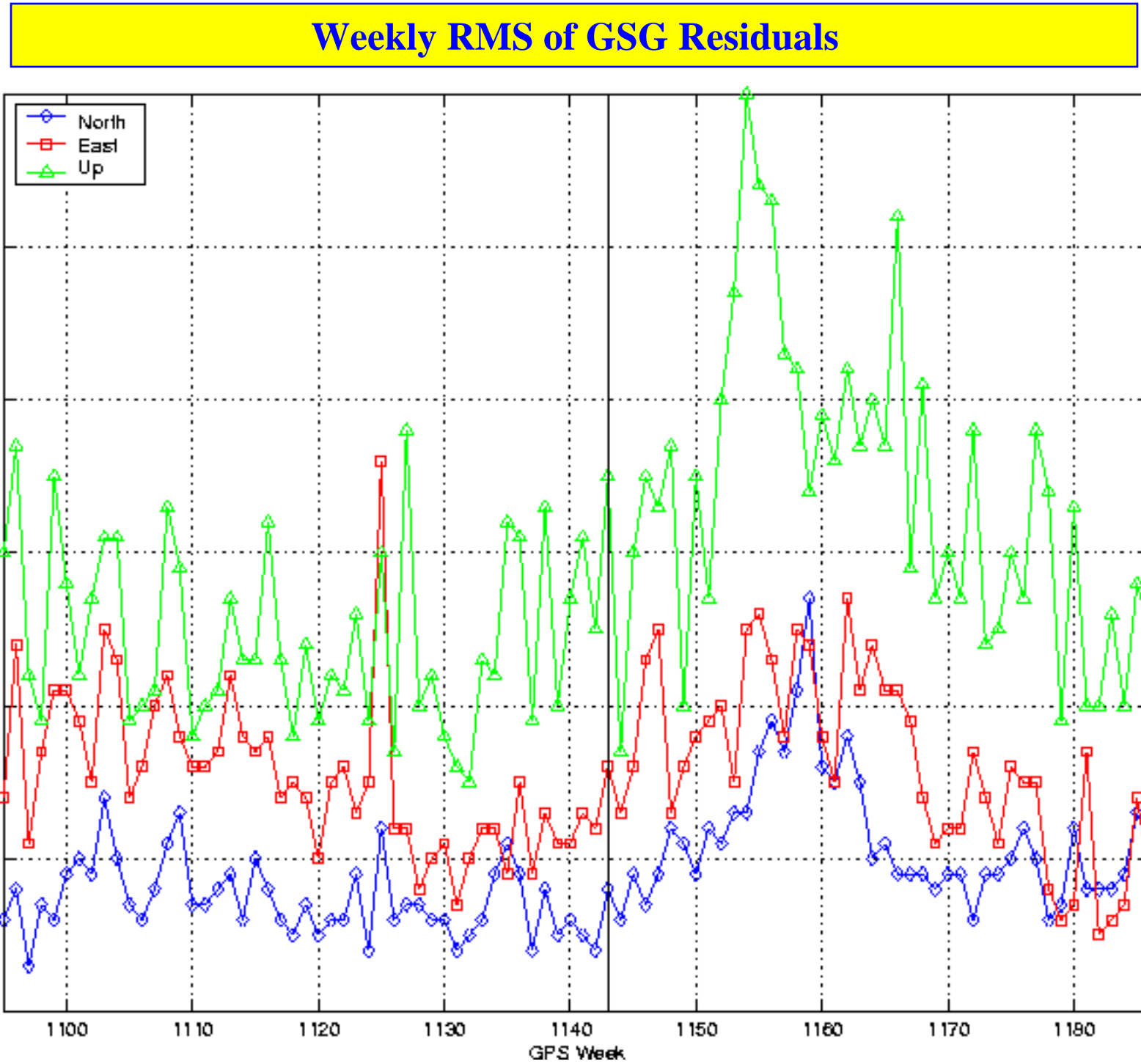
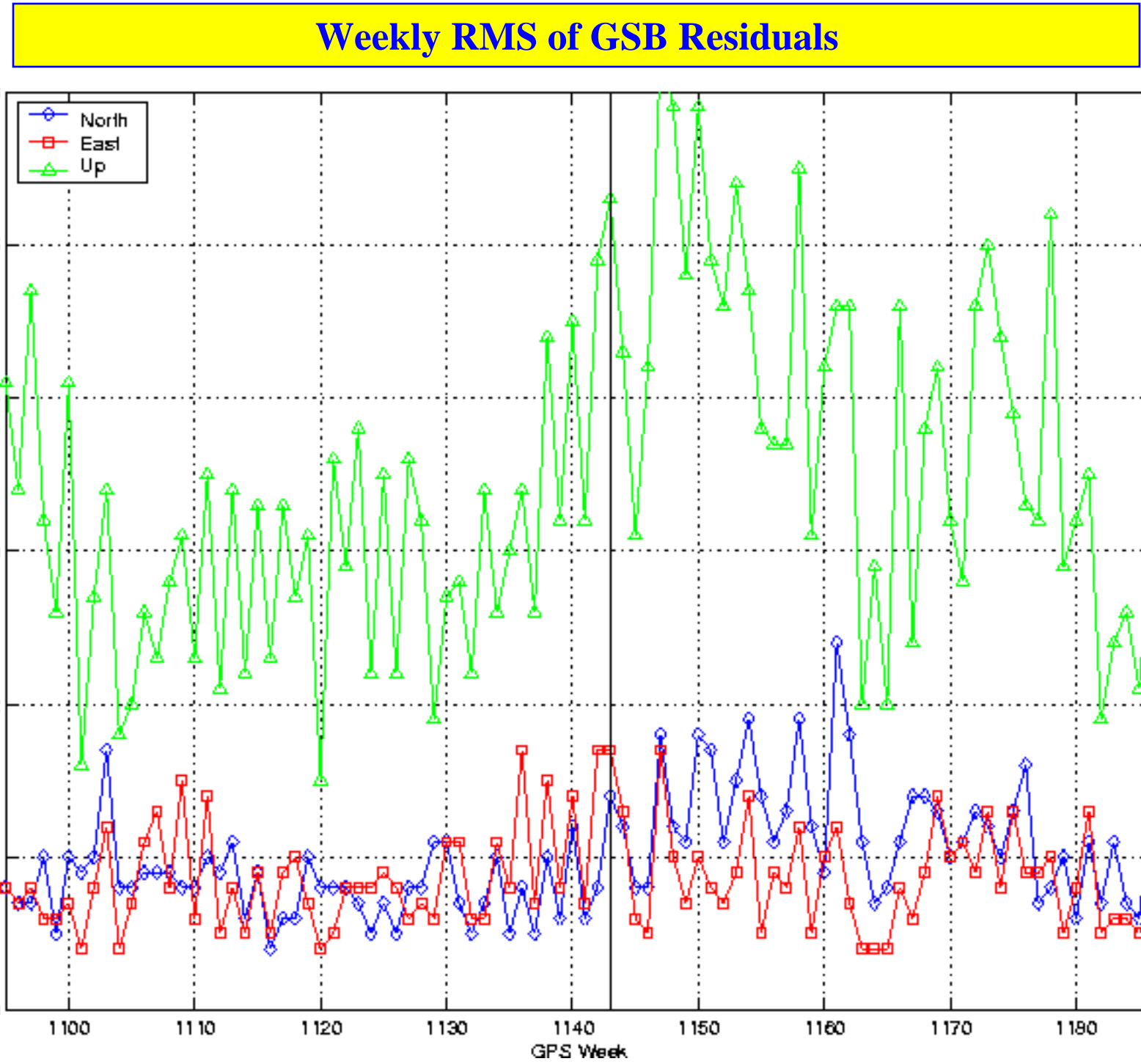
- From Herb Dragert, Pacific Geoscience Centre (PGC), NRCan
- Bernese GPS Software Version 4.2
- Double differenced observations
- 30 second data sampling
- 10 deg elevation cut off
- Fixed IGS precise orbits & ERP
- Tropospheric zenith delay (every 2 hours)
- Niell mapping function (dry)
- Tropospheric gradient (4/day)
- QIF ambiguity resolution
- LOADSDP v5.02 ocean loading model
- 1 IGS reference frame station (DRAO) constrained to ITRF97



- From U.S. National Geodetic Survey (NGS)
- Page5, v0205.22
- Double differenced observations (iono-free combination)
- 30 second data sampling
- 15 deg elevation cut off
- Fixed IGS rapid orbits & ERP
- Tropospheric zenith delay (every 2 hours)
- Niell mapping function (dry & wet)
- No tropospheric gradient estimation
- No integer ambiguity resolution
- IERS 96 ocean loading model
- 8 IGS stations constrained to ITRF2000 values



- From Scripps Institution of Oceanography (SIO)
- GAMIT v9.72 software
- Double differenced observations
- 2 minute data sampling for final solution
- 10 deg elevation cut off
- Fixed SIO precise orbits & ERP
- Tropospheric zenith delay (random walk)
- Niell mapping function (dry & wet)
- Tropospheric gradient (1/day)
- Ambiguities resolved for lines < 500 km
- IERS 96 ocean loading model
- IGS reference frame stations loosely constrained to IGS00



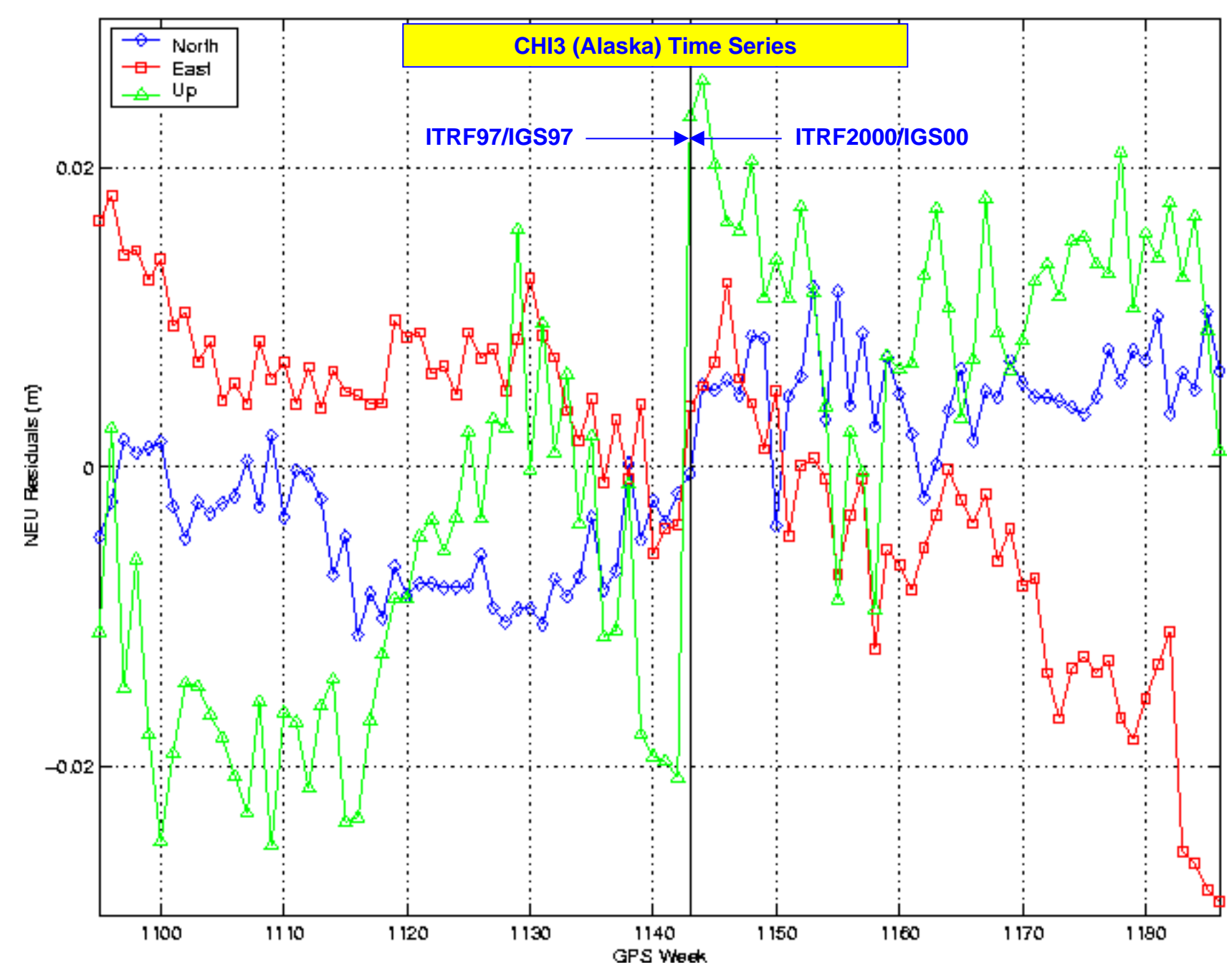
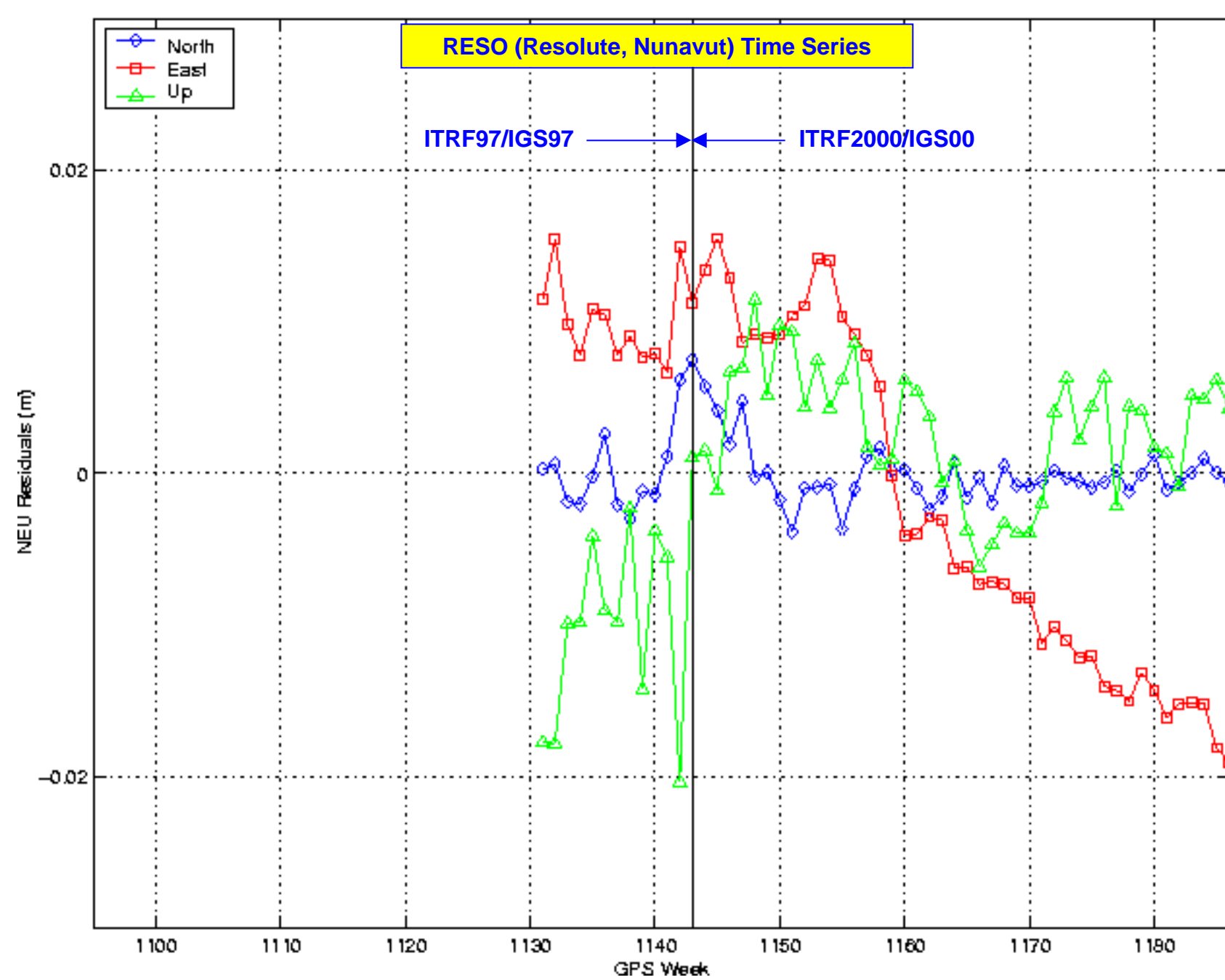
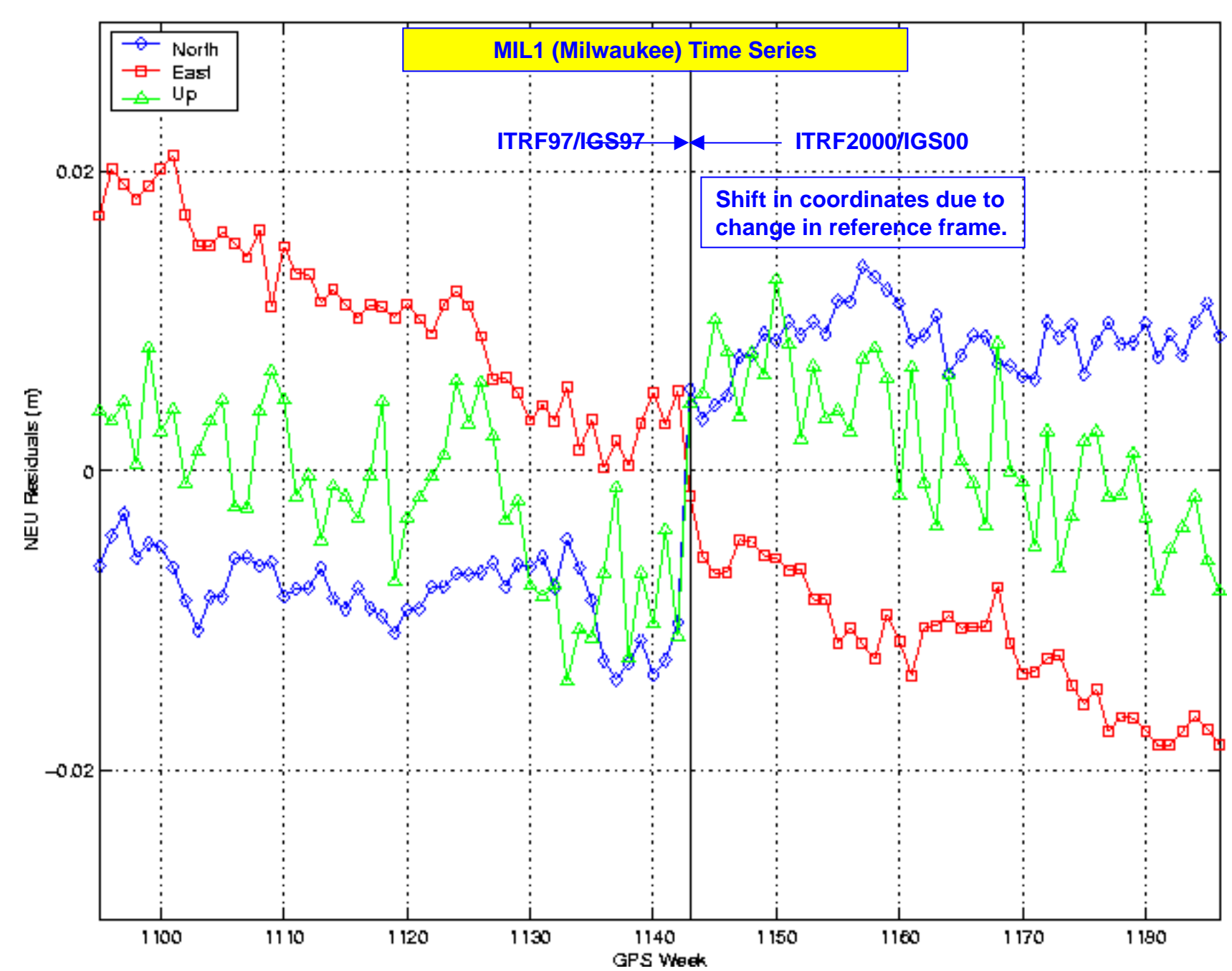
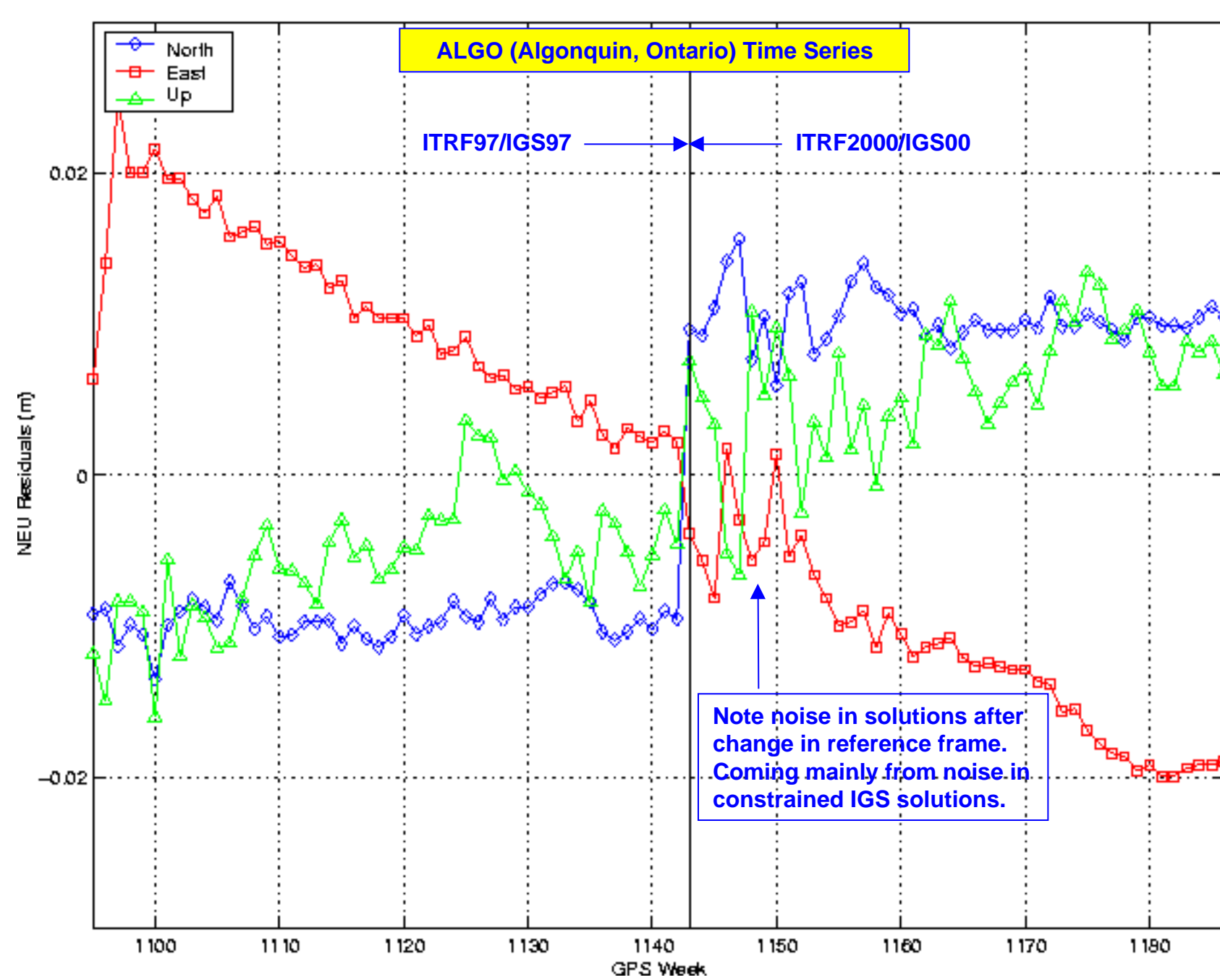
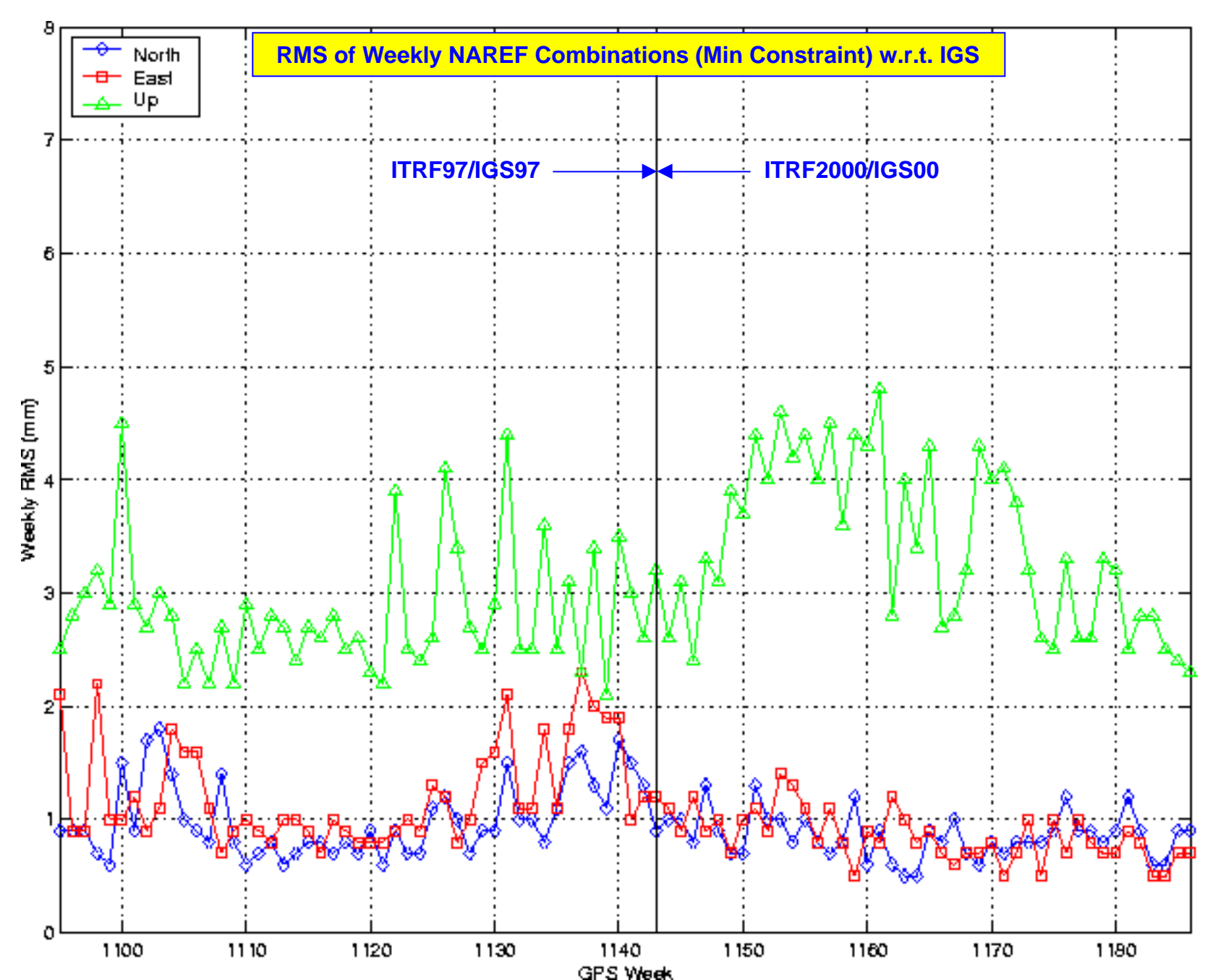
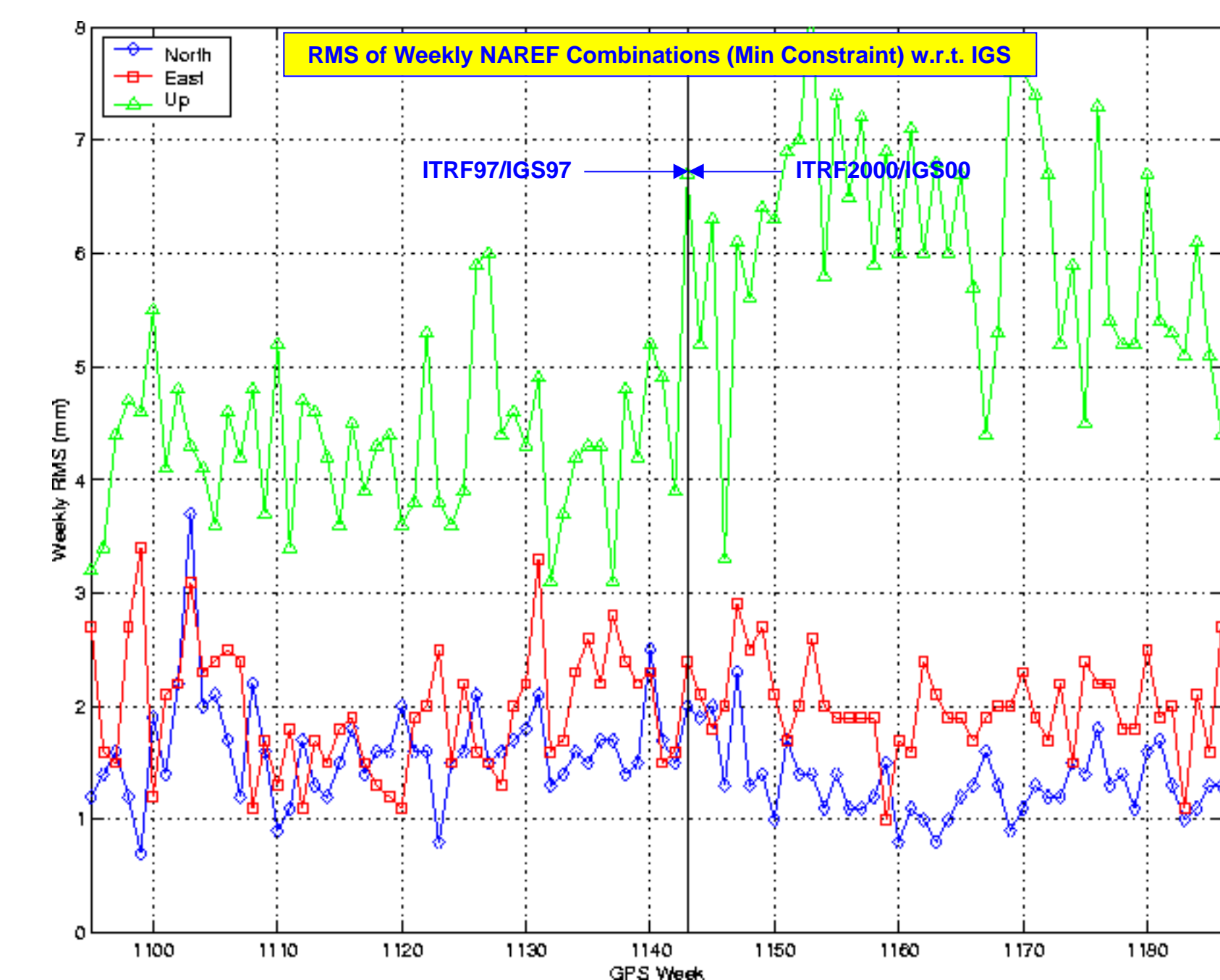


## COMBINATION PROCEDURE

- Using SINEX Software v1.0 by R. Ferland (used for official IGS global combinations)
- A priori datum constraints removed from each regional solution
- Each regional solution aligned to IGS weekly solution (3 translations, 3 rotations & scale change)
- Residuals tested for outliers (removed)
- Covariance matrix of each regional solution scaled by WRMS of residuals
- All (scaled) regional solutions combined (summation of normals)
- Combined solution aligned to IGS weekly solution (3 translations, 3 rotations & scale change)
- Covariance matrix for combined solution scaled by WRMS of residuals
- Residuals tested for outliers (removed)
- 1 IGS reference frame station (DRAO) constrained to IGS00 (min constraint)
- Generated SINEX file for combined solution (NAREF solution)

## COMBINATION RESULTS

- **Differences between weekly NAREF combinations (minimum constraint) & IGS weekly solutions** show agreement at IGS stations to better than 3 mm horizontally and 5 mm vertically before inclusion of NGS solution and 8 mm after (see plot below at left).
- **Differences between weekly NAREF combinations (integrated via over-constraints) & IGS weekly solutions** show good agreement at IGS stations to better than about 1 mm horizontally and 4 mm vertically (see plot below at right).
- **Residual discrepancies between individual regional solutions (transformed) and final NAREF combinations** show good agreement on average to better than 2 mm horizontally and about 4 mm vertically (see plots at bottom left of poster).
- **Coordinate time series** (see plots below at bottom) show typical variations for some densification points (residuals are with respect to mean). Note shift in coordinates due to change in reference frame from ITRF97 to ITRF2000.



## FUTURE WORK

- Continue submitting weekly combination solutions to IGS (solutions for 2002 available at CDDIS)
- Begin cumulative solutions for velocity estimation
- Enhance SINEX software to handle larger regional networks

## ACKNOWLEDGMENTS

- Herb Dragert, Pacific Geoscience Centre, for WCDA solutions
- Bill Dillinger & Mike Cline, US National Geodetic Survey, for CORS solns
- Scripps Institution of Oceanography, for PBO solutions
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