



# The NAREF Initiative to Densify the ITRF in North America

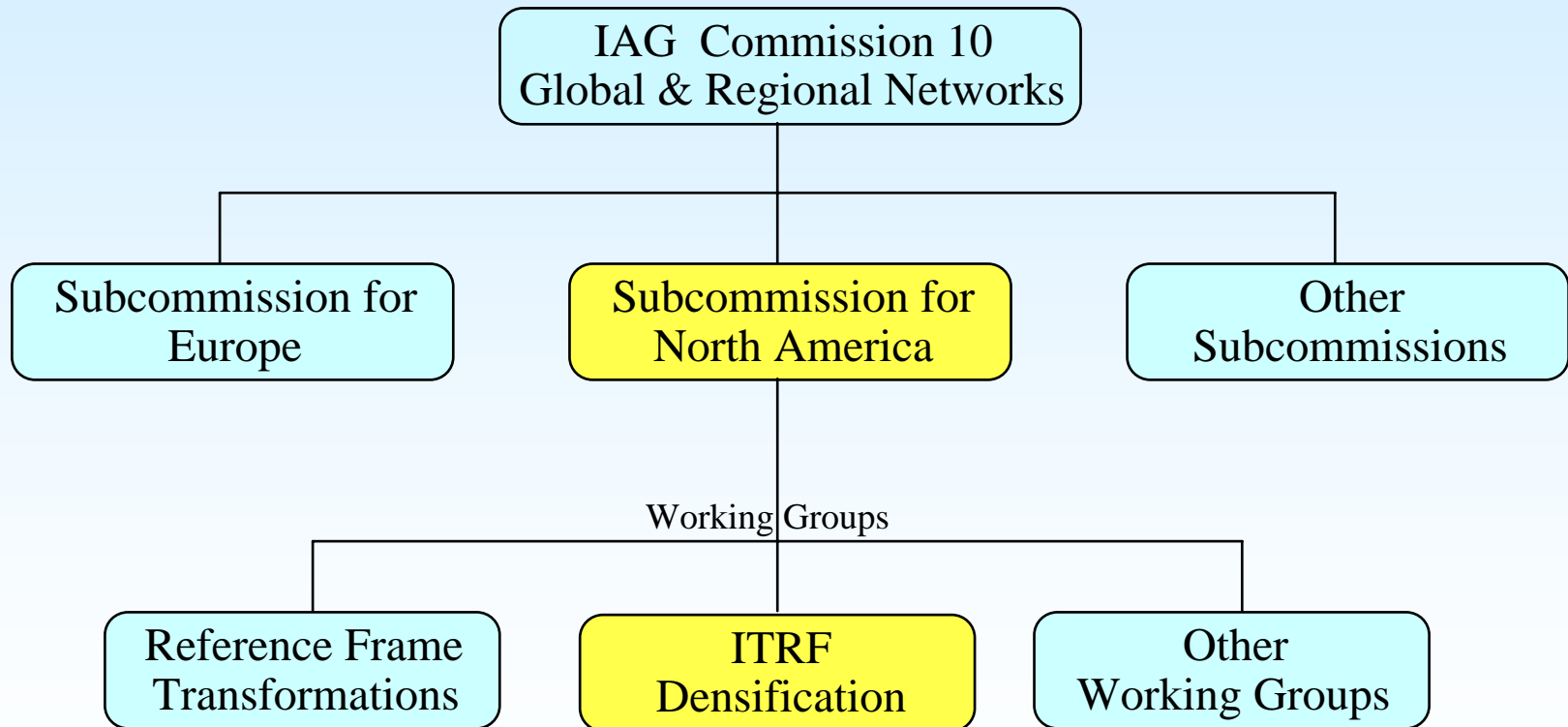
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3<sup>rd</sup> EPN Local Analysis Centers Workshop  
31 May - 1 June 2001  
Warsaw, POLAND

# Outline

- NAREF Initiative
- Regional solutions
- Combination procedure
- Combination results
- Future work

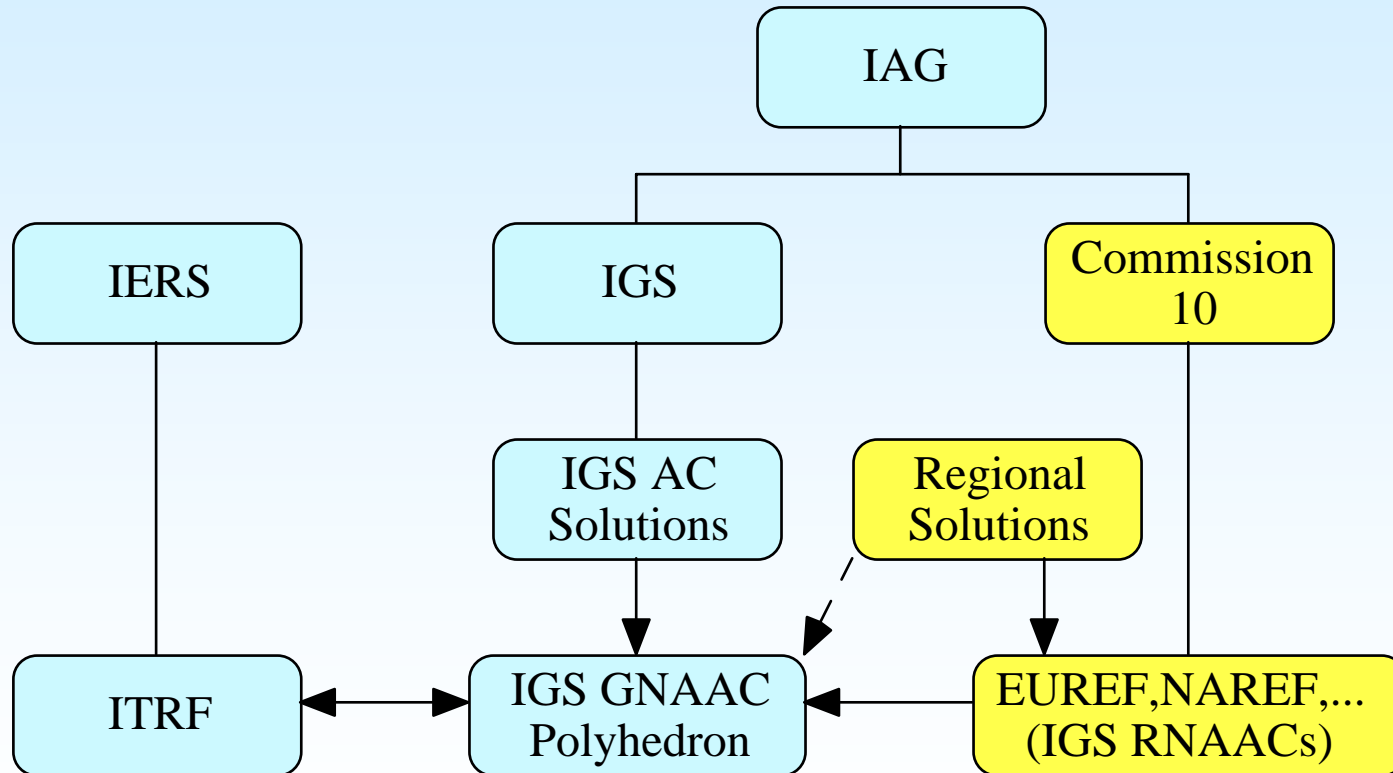
# NAREF Initiative



# NAREF Objectives

- To densify the ITRF reference frame in NA
- Consolidate regional networks into a continental one
- Integrate into ITRF via IGS global network
- Produce coordinate solutions
  - *Weekly regional solutions*
  - *Weekly combinations of regional solutions*
  - *Cumulative solutions with velocity estimates*

# Distributed Processing



# Regional Solutions


- Weekly solutions

- ✓ GSD (Bernese) solutions – 65 pts


- ✓ GSD (GIPSY) solutions – 27 pts

- ✓ PGC WCDA (Bernese) solutions – 17 pts

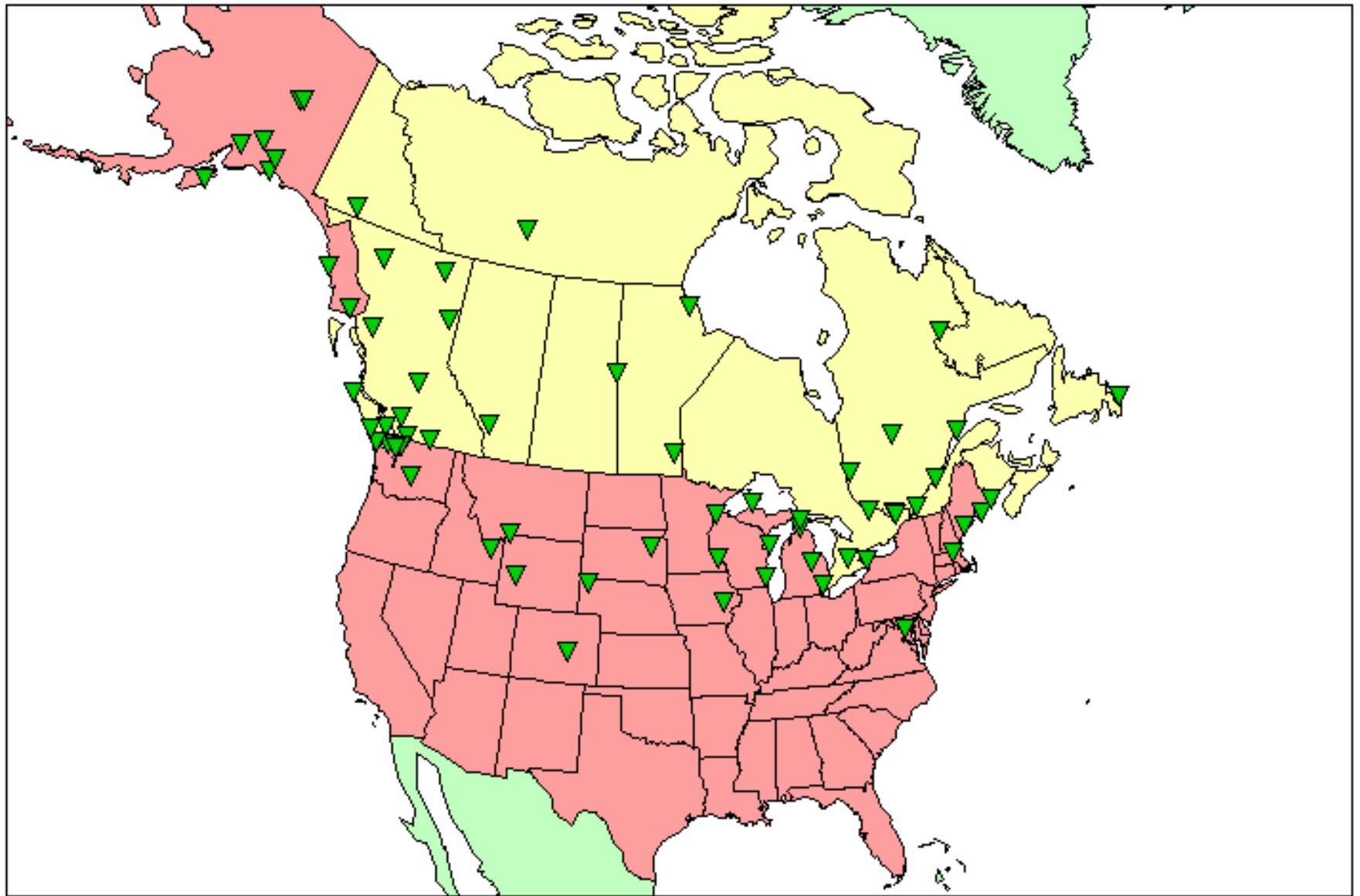
- ✓ SIO PBO (GAMIT) solutions – over 300 pts (only northern part of solution was included)

-  U. Alaska (GIPSY) solutions – about 10 pts  
(unable to contribute due to lack of resources)

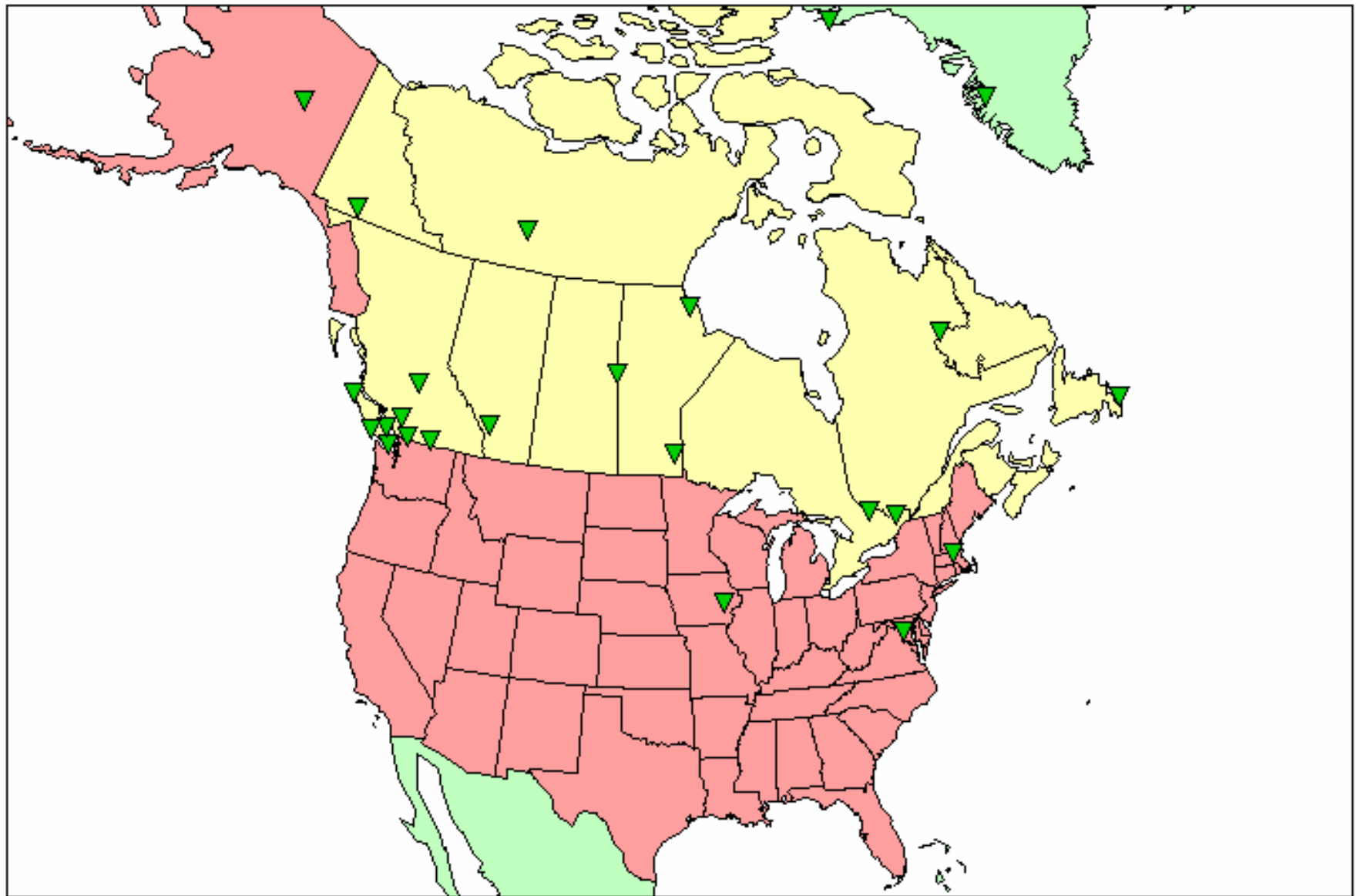
- ★ *Need more solutions for US, Mexico & Denmark*

-  NGS CORS (PAGES) solution?? – about 150 pts  
(expecting contributions later this year)

# NRCan Bernese Regional Network (NRC)

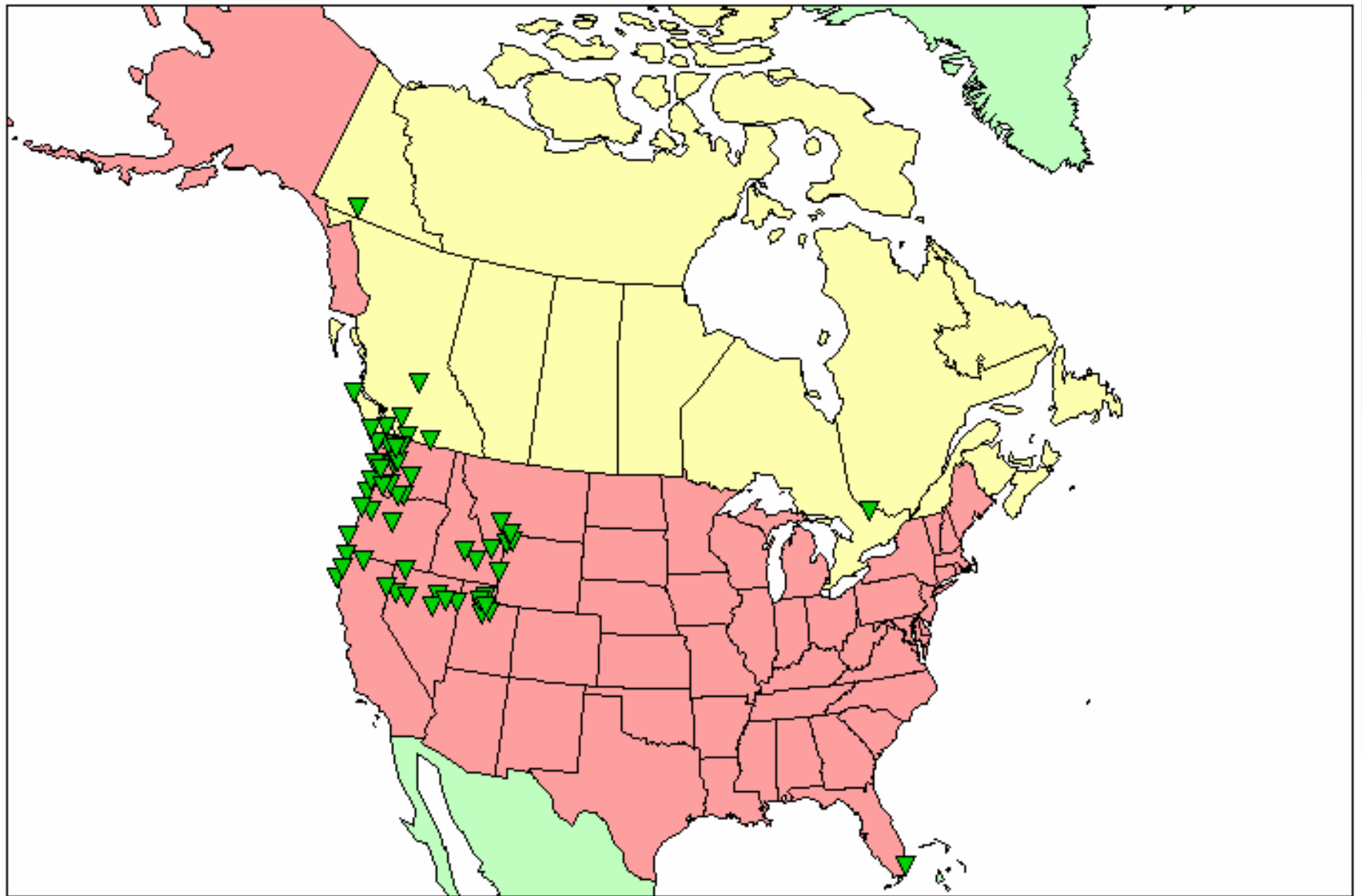


# NRCan GIPSY Regional Network (EMR)

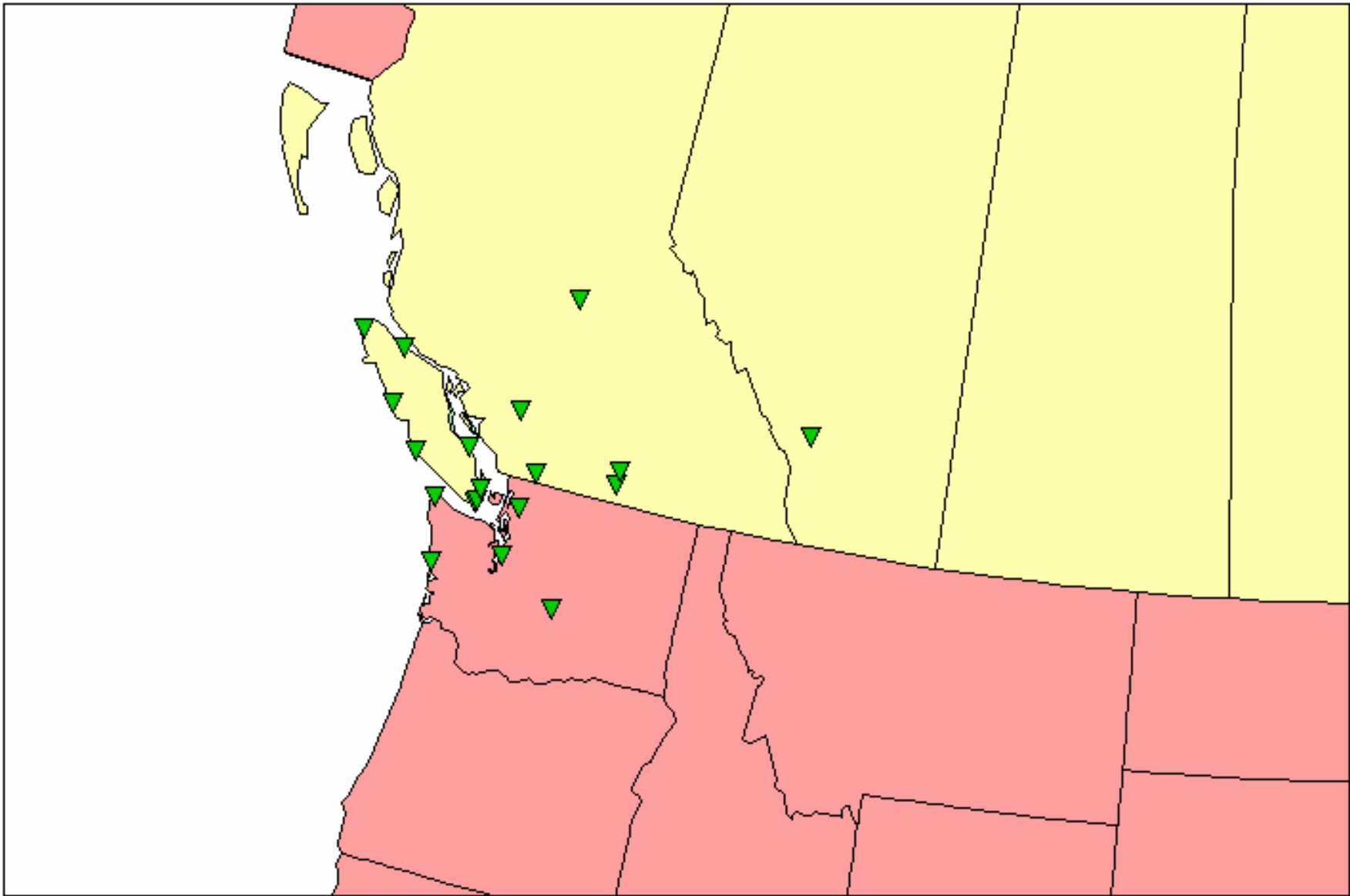




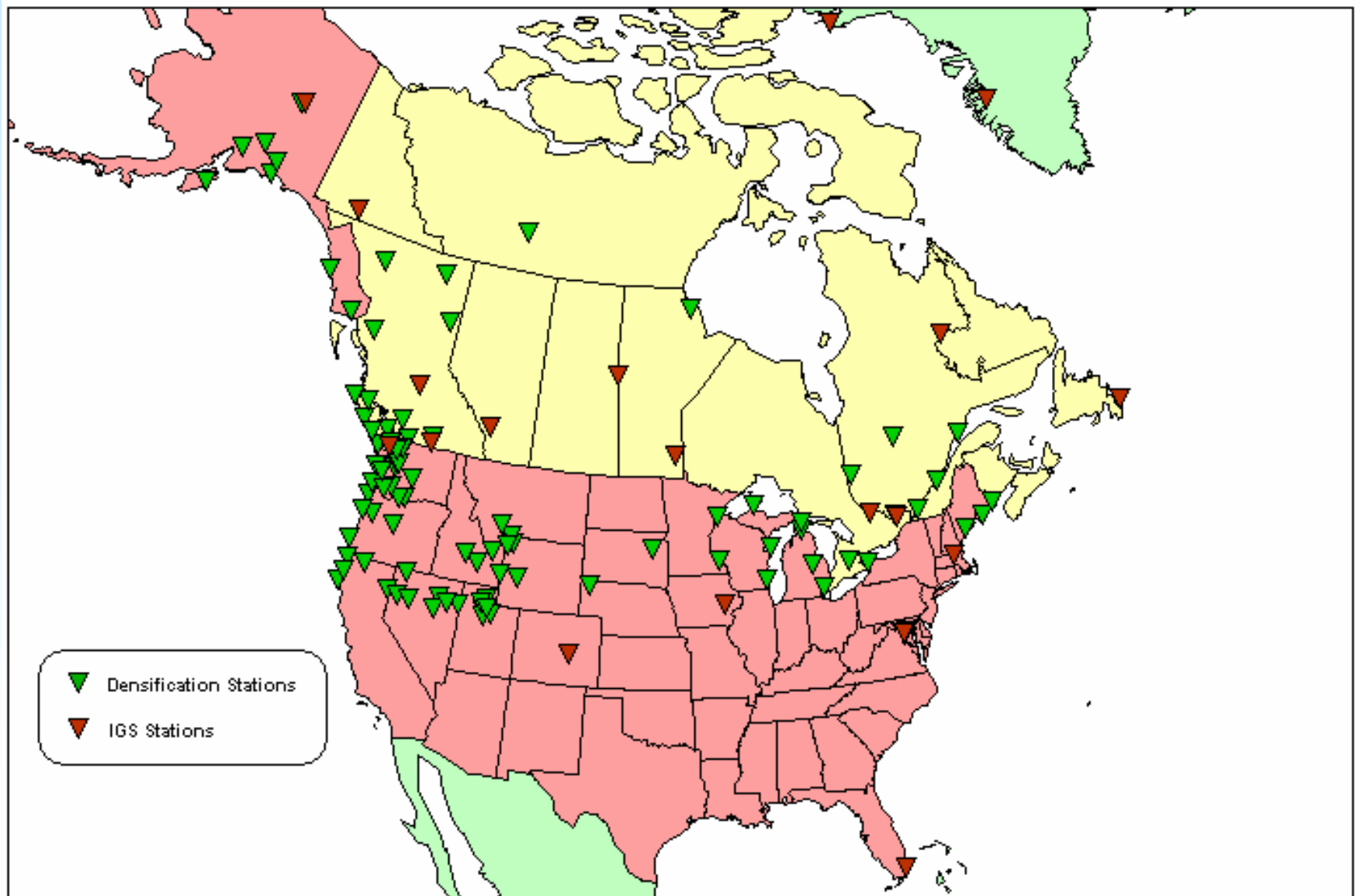
# SIO Plate Boundary Observatory (PBO)



# PGC Western Canada Deformation Array



# NAREF Densification Network



# Regional Processing

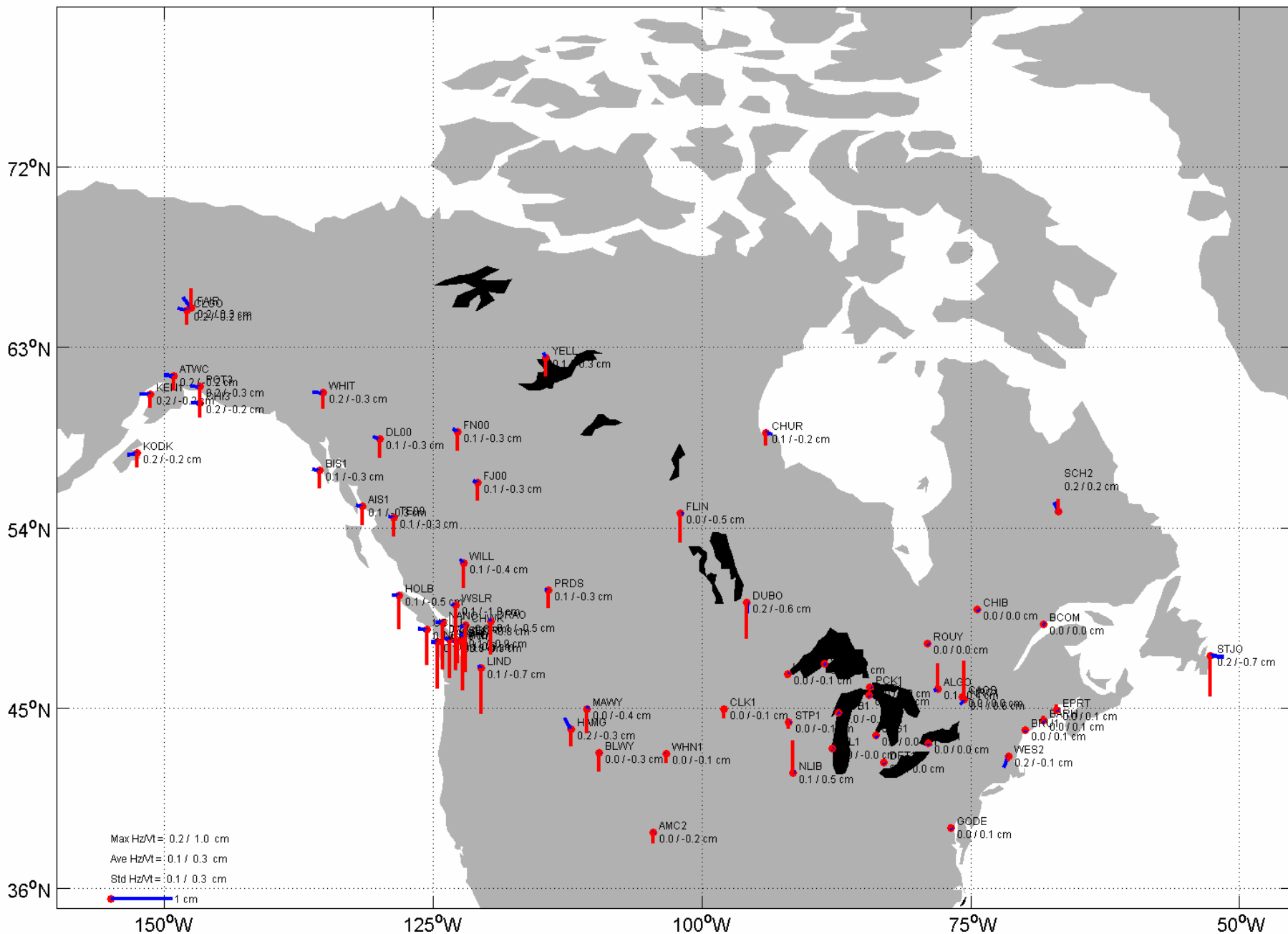
	<b>NRC</b>	<b>EMR</b>	<b>PBO</b>	<b>PGC</b>
<b>Agency</b>	<b>GSD NRCan</b>	<b>GSD NRCan</b>	<b>SIO</b>	<b>PGC NRCan</b>
<b>Software</b>	<b>Bernese v4.2</b>	<b>Gipsy Oasis II</b>	<b>Gamit v9.72</b>	<b>Bernese v4.2</b>
<b>Observations</b>	<b>Double differenced</b>	<b>Undiferenced</b>	<b>Double differenced</b>	<b>Double differenced</b>
<b>Sampling Rate</b>	<b>3 minutes</b>	<b>7.5 minutes</b>	<b>2 minutes</b>	<b>30 second</b>
<b>Elevation cut off</b>	<b>10 deg</b>	<b>15 deg</b>	<b>10 deg</b>	<b>10 deg</b>
<b>Orbits &amp; ERP</b>	<b>Fixed IGS</b>	<b>Fixed IGS</b>	<b>Fixed SIO</b>	<b>Fixed IGS</b>
<b>TZD</b>	<b>Every 2 hours</b>	<b>Random walk</b>	<b>Random walk</b>	<b>Every 2 hours</b>
<b>Mapping function</b>	<b>Niell – dry</b>	<b>Niell – wet</b>	<b>Niell – dry &amp; wet</b>	<b>Niell – dry</b>
<b>Tropo. Gradient</b>	<b>1 per day</b>	<b>Random walk</b>	<b>1 per day</b>	<b>4 per day</b>
<b>Ambiguity</b>	<b>QIF strategy</b>	<b>No</b>	<b>Resolved &lt; 500km</b>	<b>QIF strategy</b>
<b>Ocean loading</b>	<b>No</b>	<b>IERS 96</b>	<b>IERS 96</b>	<b>LOADSDP v5.02</b>
<b>Constrain</b>	<b>DRAO to IGS97</b>	<b>DRAO to IGS97</b>	<b>IGS site to IGS97</b>	<b>DRAO to ITRF97</b>

# 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 (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 (outliers removed)
- 1 IGS reference frame station (DRAO) constrained to IGS97 (min constraint)
- Generated SINEX file for combined solution (NAREF solution)

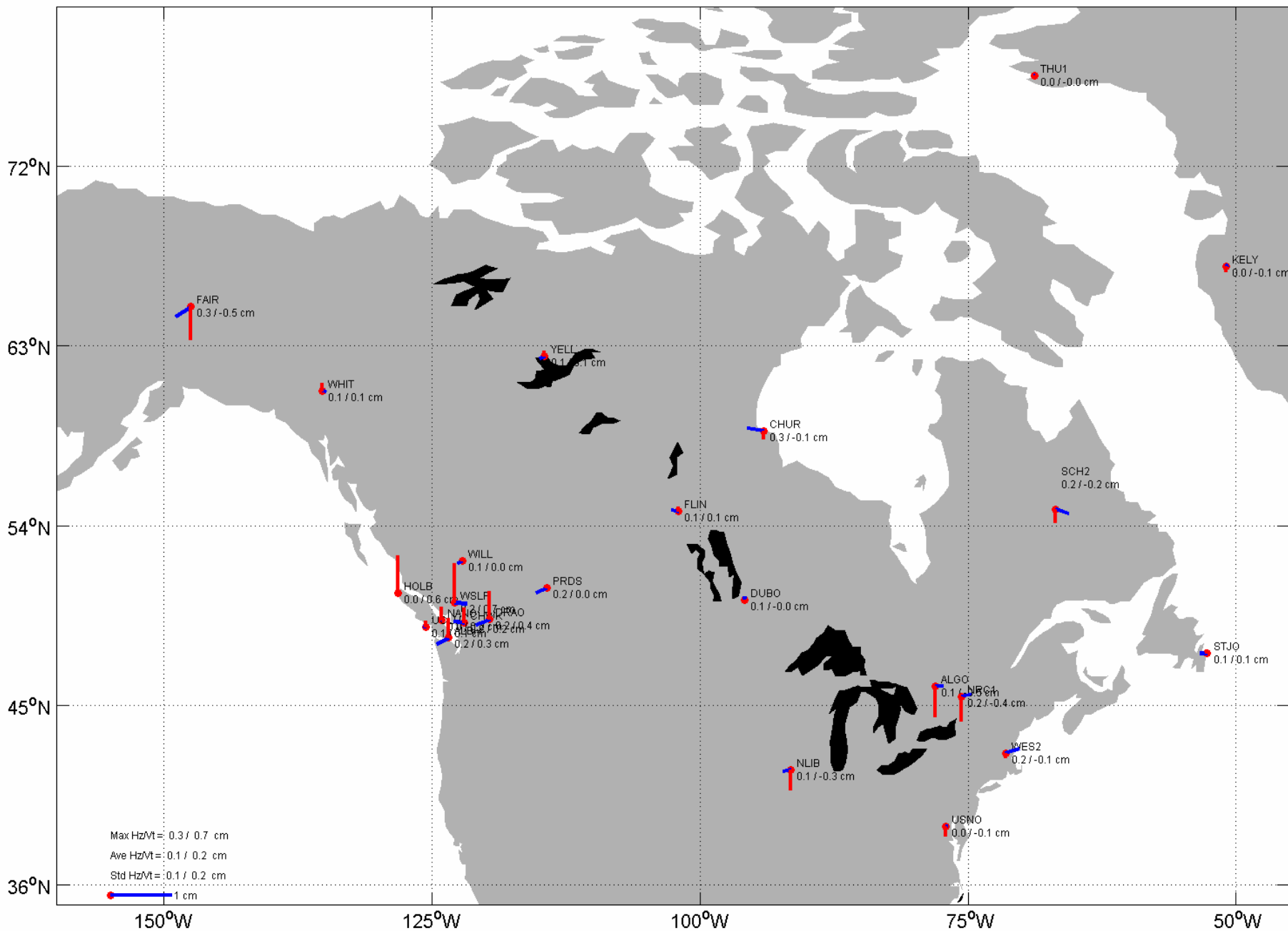
# Week 1095 Residuals

# NRCan BERNSE Solution



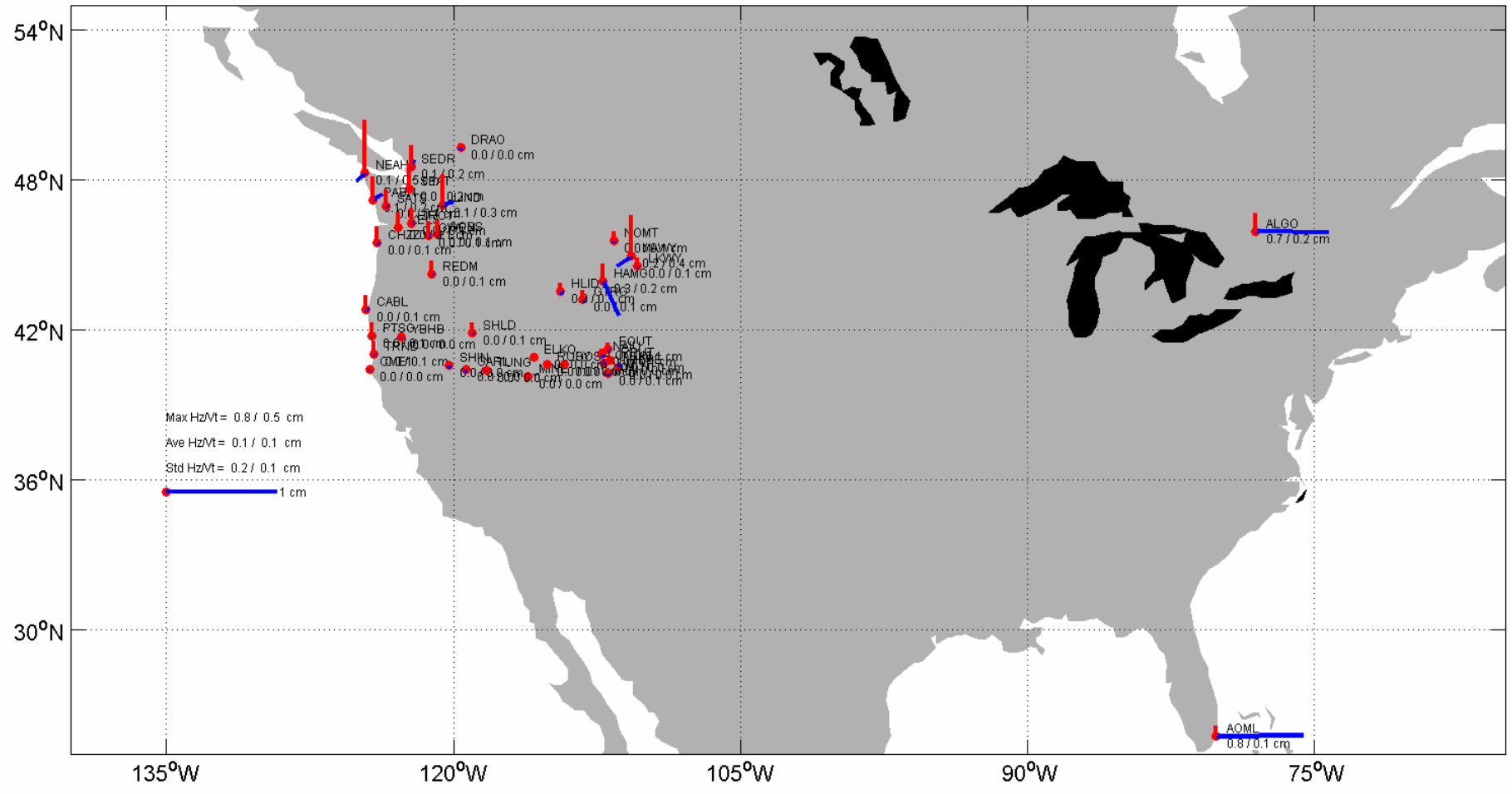
# Week 1095 Residuals

# NRCan Gipsy Solution



### Week 1095 Residuals

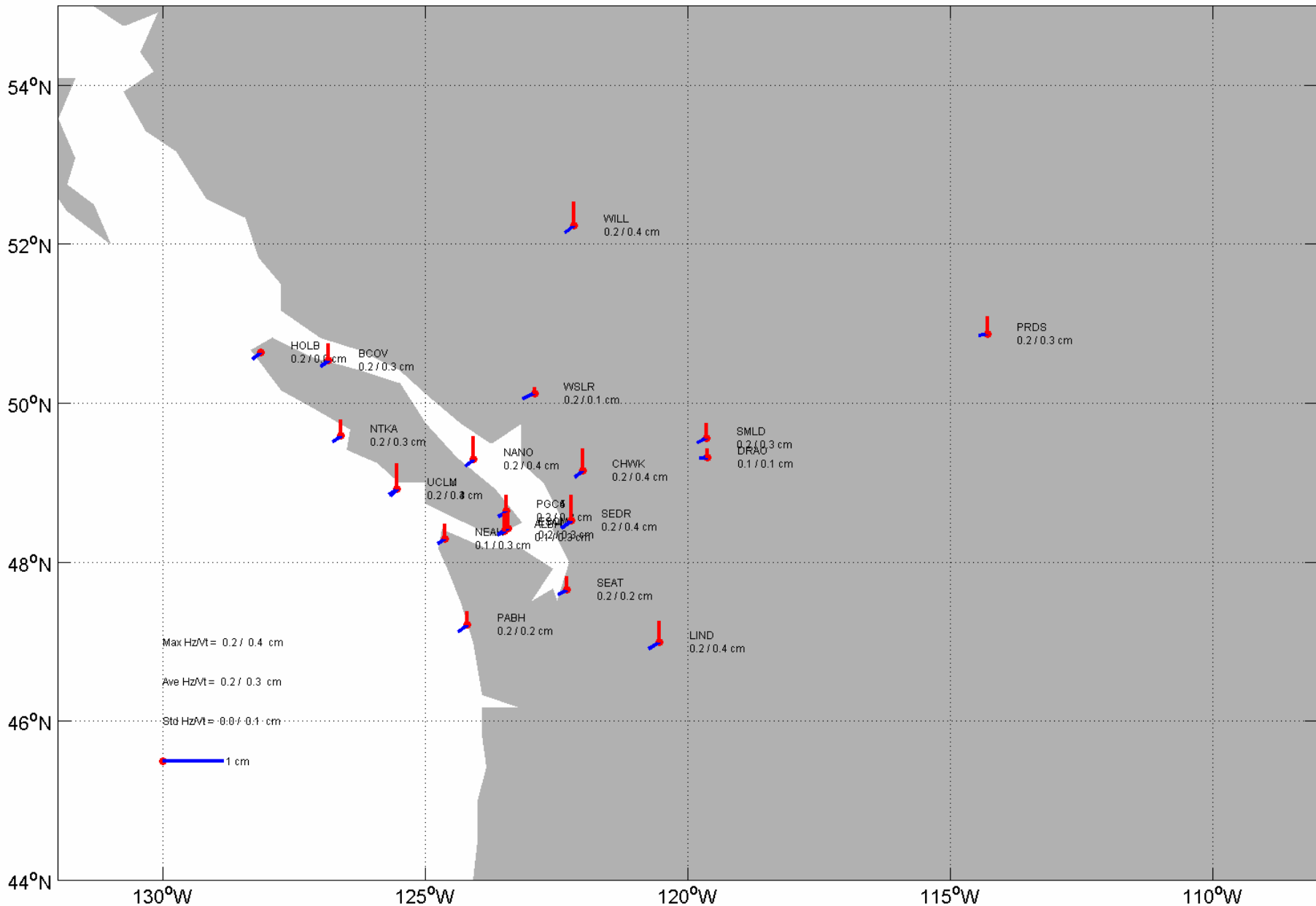
### SIO PBO Solution



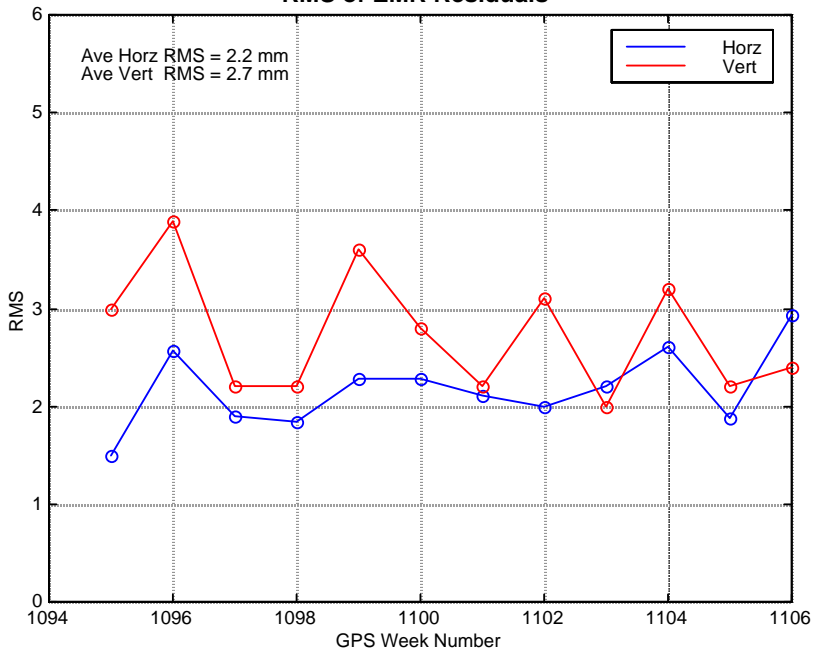


# Week 1095 Residuals

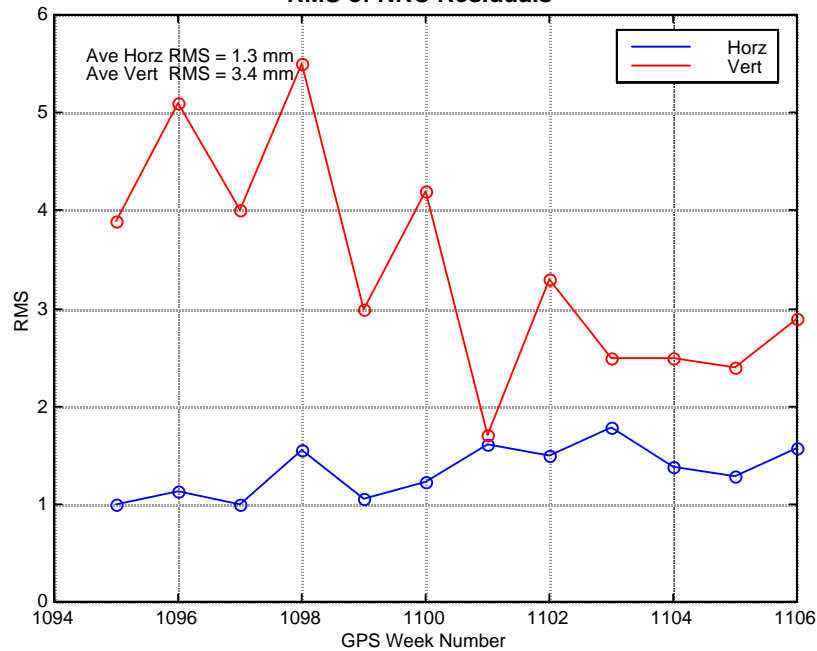
# PGC Bernese Solution



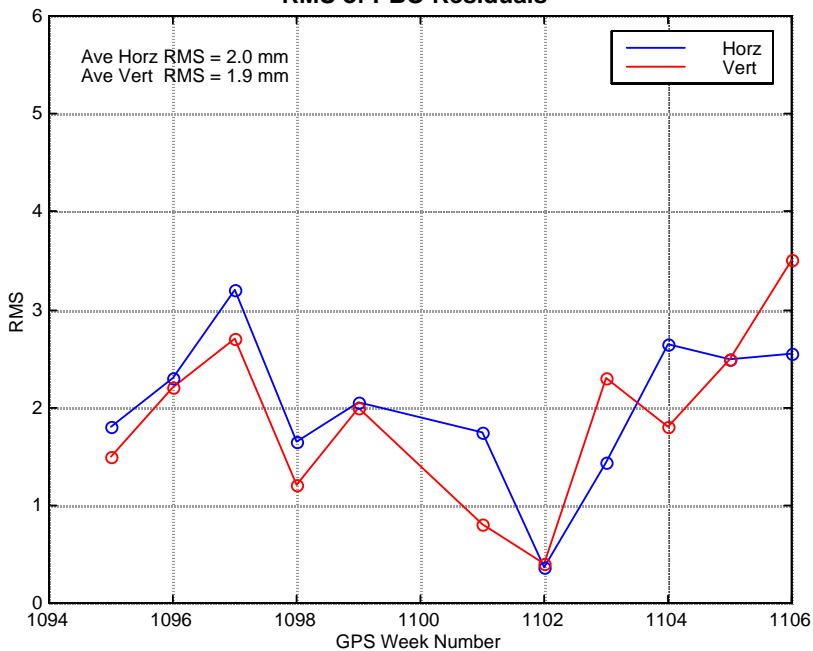
### RMS of EMR Residuals



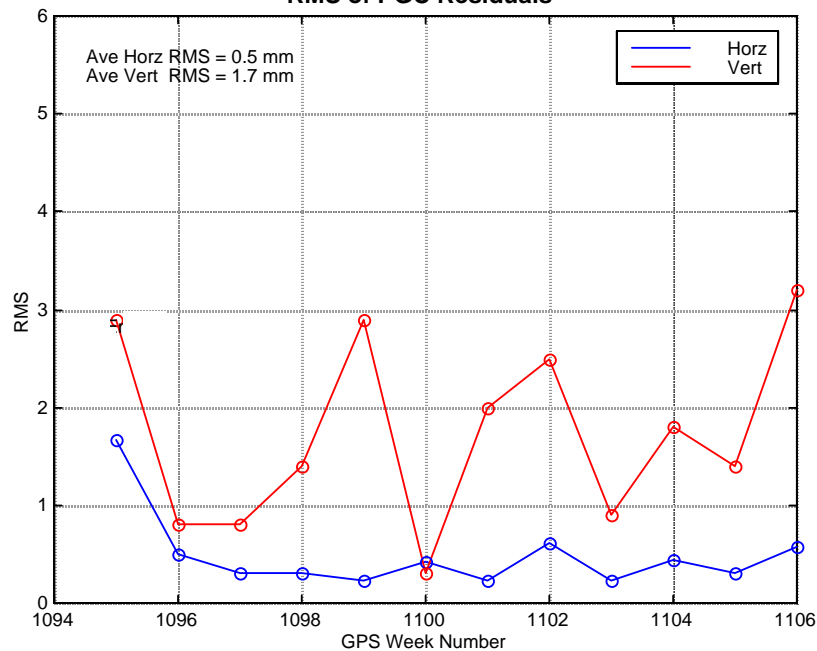
### RMS of NRC Residuals



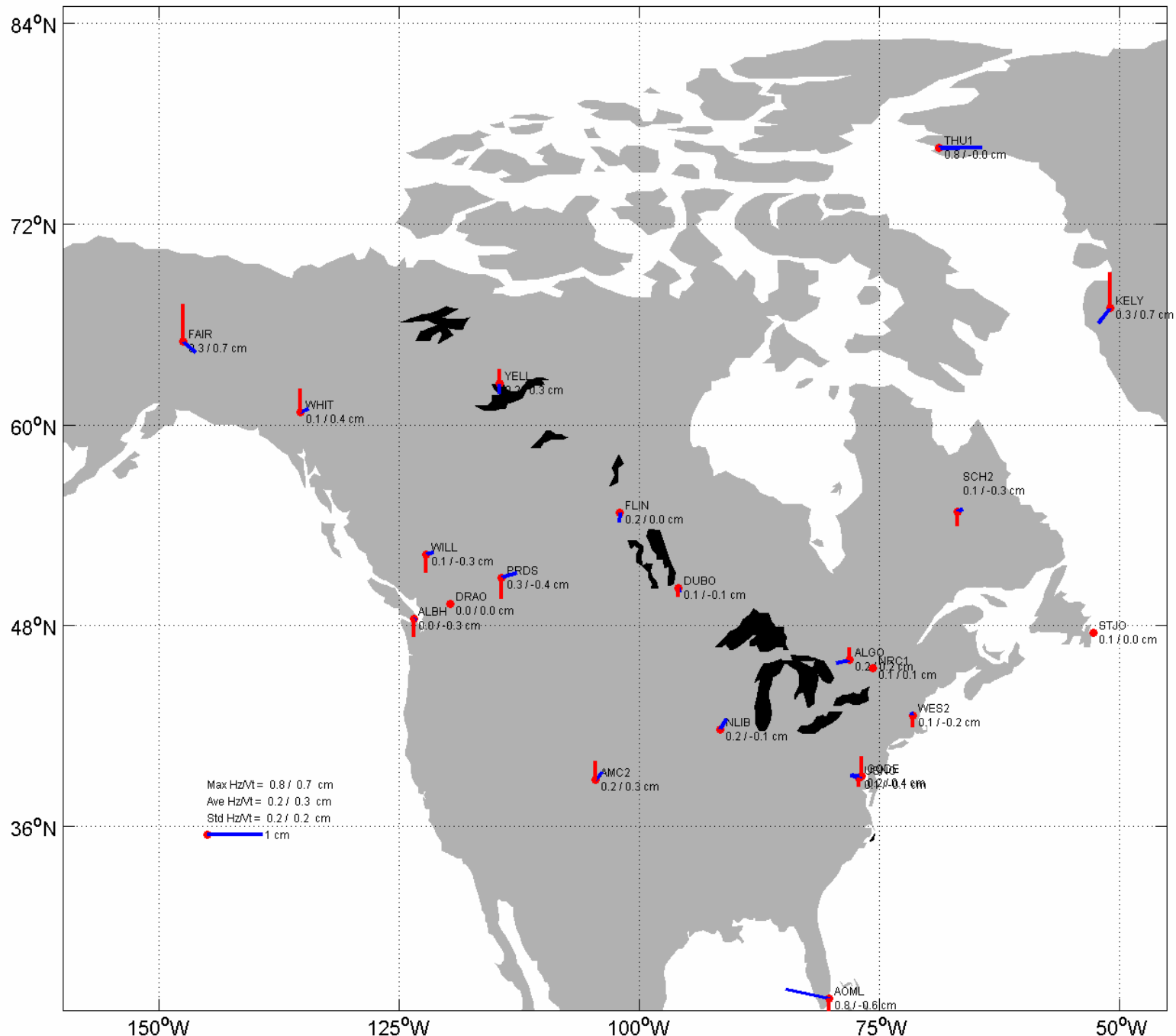
### RMS of PBO Residuals



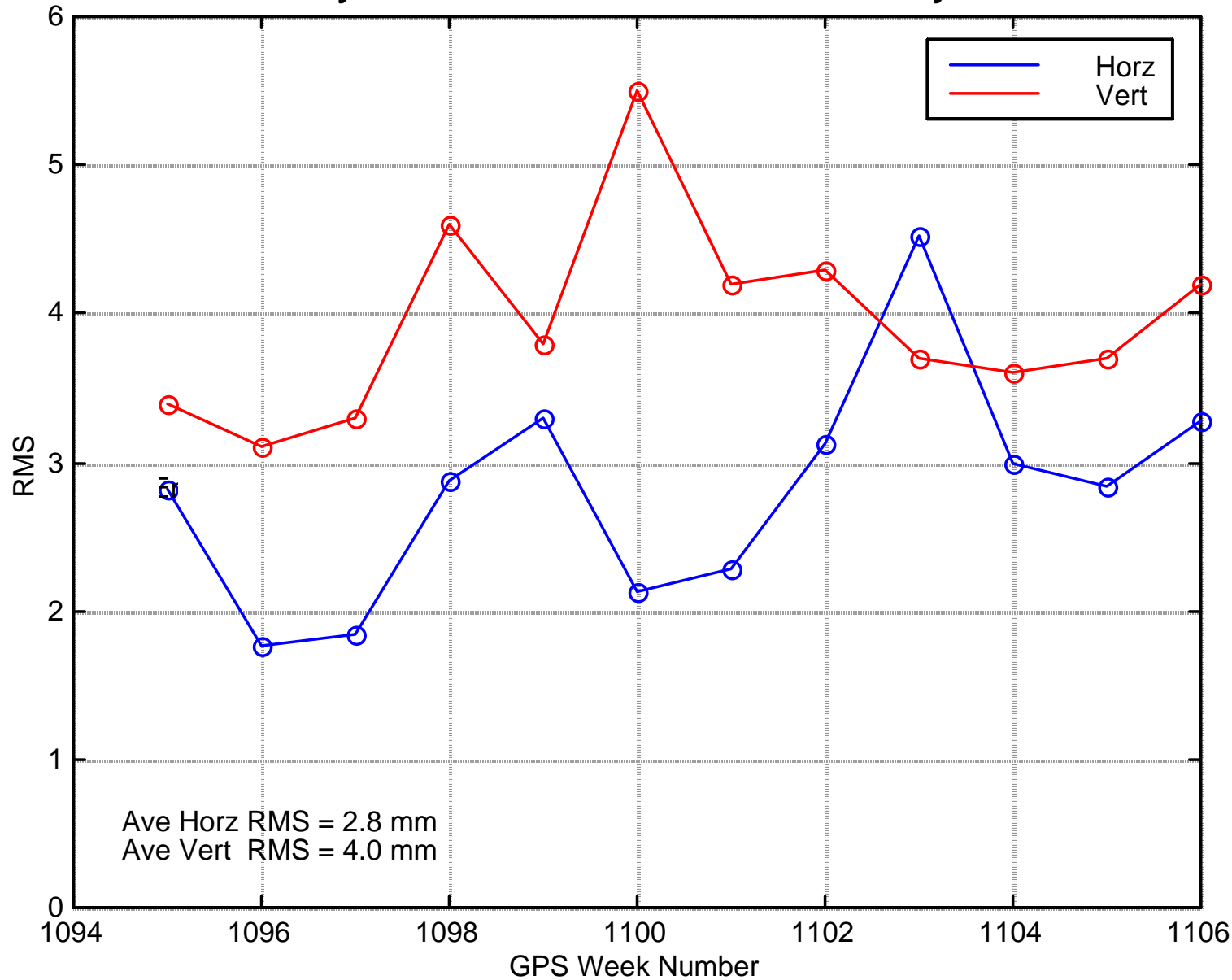
### RMS of PGC Residuals



# Week 1095 Differences NAREF - IGS Weekly



# RMS of Weekly NAREF Combinations w.r.t. IGS Weekly Solutions



# Summary of Results

- Residual fit of individual solutions
  - Ave. Horizontal RMS: < 2 mm
  - Ave. Vertical RMS: < 3 mm (except for NRC)
- Differences with IGS weekly solutions
  - Ave. Horizontal RMS: 3 mm
  - Ave. Vertical RMS: 4 mm
  - Compatible with accuracy of IGS solutions

# Future Work

- Incorporate other regional solutions:
  - NGS CORS stations (>150 stations across entire US)
  - New Western Arctic Deformation Network (3 permanent stations)
  - New Post-Glacial Uplift Monitoring Network (6 permanent stations)
- Station selection/classification standards needed
- Develop official strategy for integration into global IGS network
- Perform regular cumulative solutions after collecting a year of weekly solutions (estimate velocities)

# Acknowledgements

- Herb Dragert, Pacific Geoscience Centre, for contributing WCDA solutions
- Brian Donahue & Caroline Huot, Geodetic Survey Division (GSD), for contributing NRCan GIPSY solutions
- Matthijs van Domselaar, Scripps Institution of Oceanography, for contributing PBO solutions
- Remi Ferland, GSD, for SINEX software & combination procedure
- Jan Kouba, GSD, for general advice