North American Reference Frame (NAREF) Working Group

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2nd SNARF Workshop

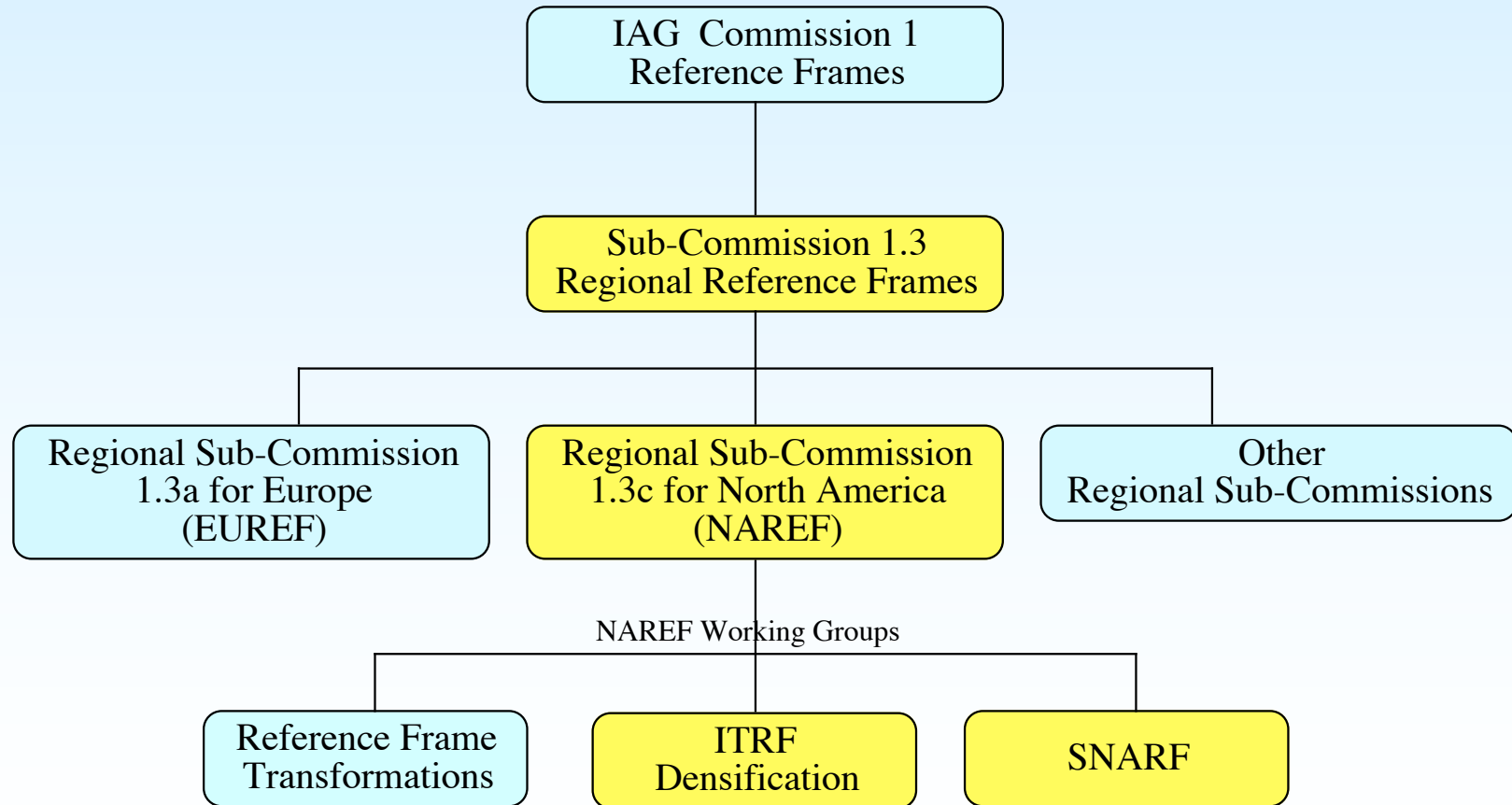Montreal, May 19, 2004

(Revised June 4, 2004)

Objective

To provide international focus and [cooperation](#) for issues involving the horizontal, vertical, and three-dimensional geodetic control networks of North America, Central America, the Caribbean and Greenland (Denmark).

Structure

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              ┌─────────────────────────┐
              │   IAG  Commission 1     │
              │    Reference Frames     │
              └─────────────────────────┘
                          │
              ┌─────────────────────────┐
              │   Sub-Commission 1.3    │
              │ Regional Reference Frames│
              └─────────────────────────┘
                          │
      ┌───────────────────┼──────────────────────────┐
┌──────────────────┐ ┌──────────────────────┐ ┌──────────────────────────┐
│ Regional Sub-    │ │ Regional Sub-        │ │          Other           │
│ Commission       │ │ Commission           │ │ Regional Sub-Commissions │
│ 1.3a for Europe  │ │ 1.3c for North America│ │                          │
│ (EUREF)          │ │ (NAREF)              │ │                          │
└──────────────────┘ └──────────────────────┘ └──────────────────────────┘
                          │
              NAREF Working Groups
          ┌───────────────┼──────────────────┐
┌──────────────────┐ ┌──────────────┐ ┌──────────────┐
│ Reference Frame  │ │    ITRF      │ │    SNARF     │
│ Transformations  │ │ Densification │ │              │
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NAREF Objectives

- Densify the ITRF reference frame in NA
  - Densify IGS global network
  - Combine various regional and local networks
- Generate coordinate solutions
  - Weekly combinations of regional solutions
  - Cumulative solutions with velocity estimates
- Provide transformations
  - Between NAD83 and ITRF/IGS

Standards

- Site selection
  - Dual frequency data, 24 hr/day, 10° elevation mask angle
  - Continuous operations (min. 5 days/week)
  - Stable geodetic-quality monumentation (or classify?)
  - Complete & up to date station logs
- Overlapping networks/solutions desired
  - Stations in multiple solutions
  - Allows for outlier detection & relative weighting
  - Average out software "noise"

Standards (con't)

- ## Regional processing
  - Follow IGS & EUREF standards as much as possible
  - Fix IGS orbits & EOPs (preferably "final")
  - Different software essential for quality control checks

- ## Problems
  - Regional centers operate independently with different objectives
  - Difficult to impose standards
  - Take what we can get

Regional Solutions

- Since 2001.0
  - ✓ GSD Bernese regional network
  - ✓ GSD GIPSY regional network
  - ✓ PGC Western Canada Deformation Array (Bernese)
  - ✓ CORS network (PAGES)
  - ✓ SIO PBO Solution (GAMIT)
- Plan to include more Canadian stations
  - ➢ New 64-bit computer to handle more stations
  - ➢ Add BCACS, Quebec DGPS, others ??
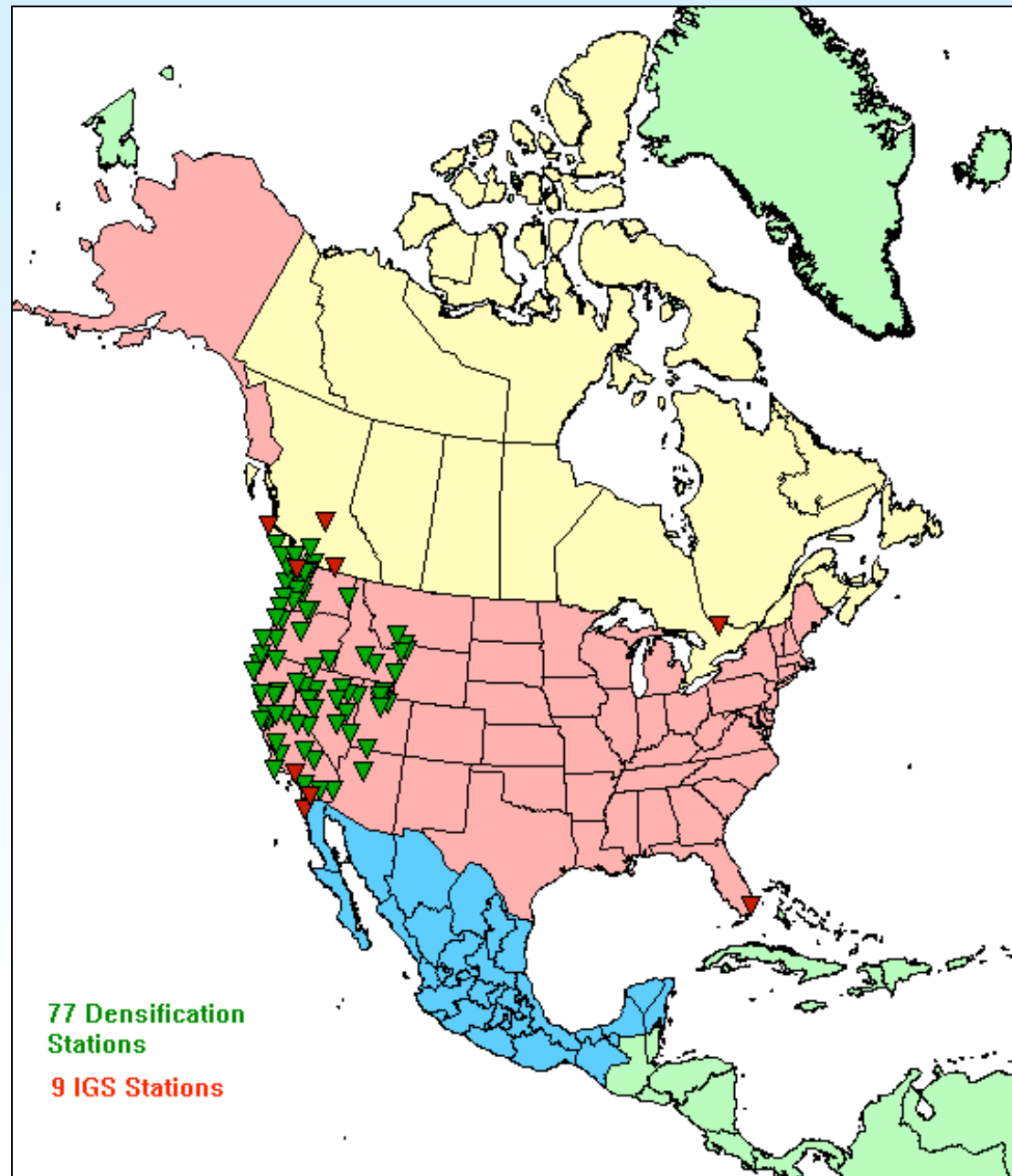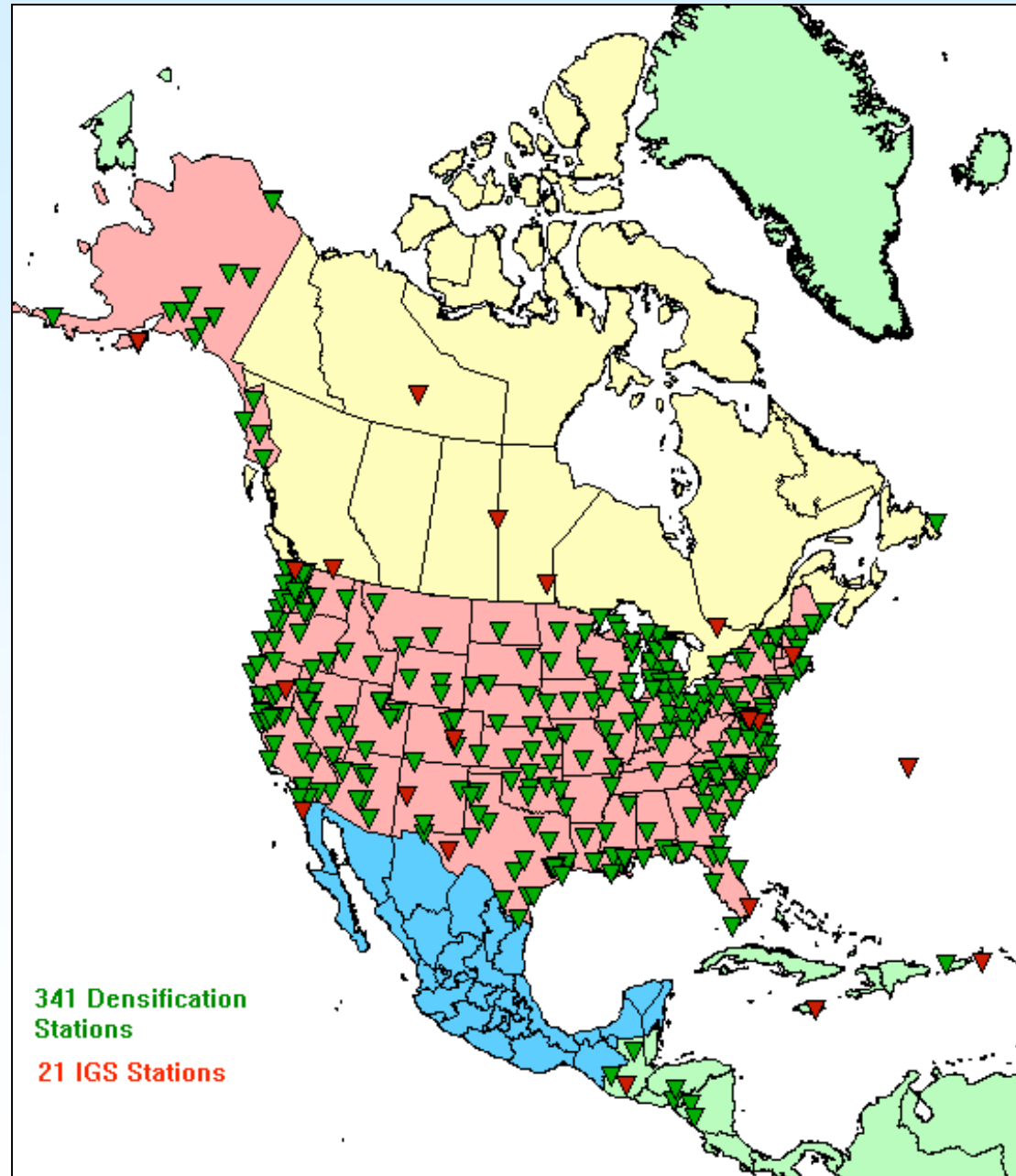
GSD Bernese Regional Network (GSB)
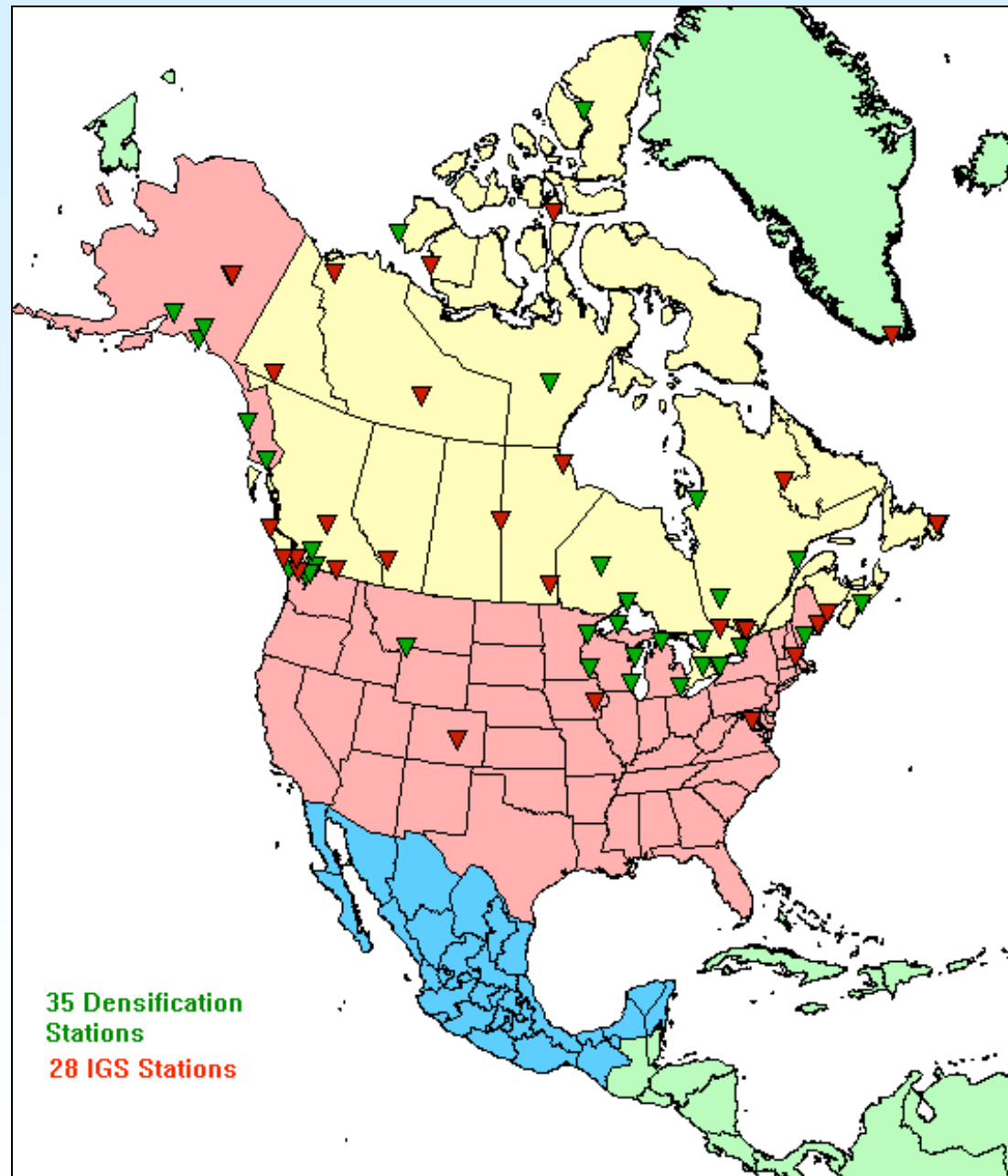
35 Densification Stations

28 IGS Stations

GSD GIPSY Regional Network (GSG)

11 Densification Stations

25 IGS Stations

PGC Western Canada Deformation Array (WCDA)

26 Densification
Stations

6 IGS Stations

10
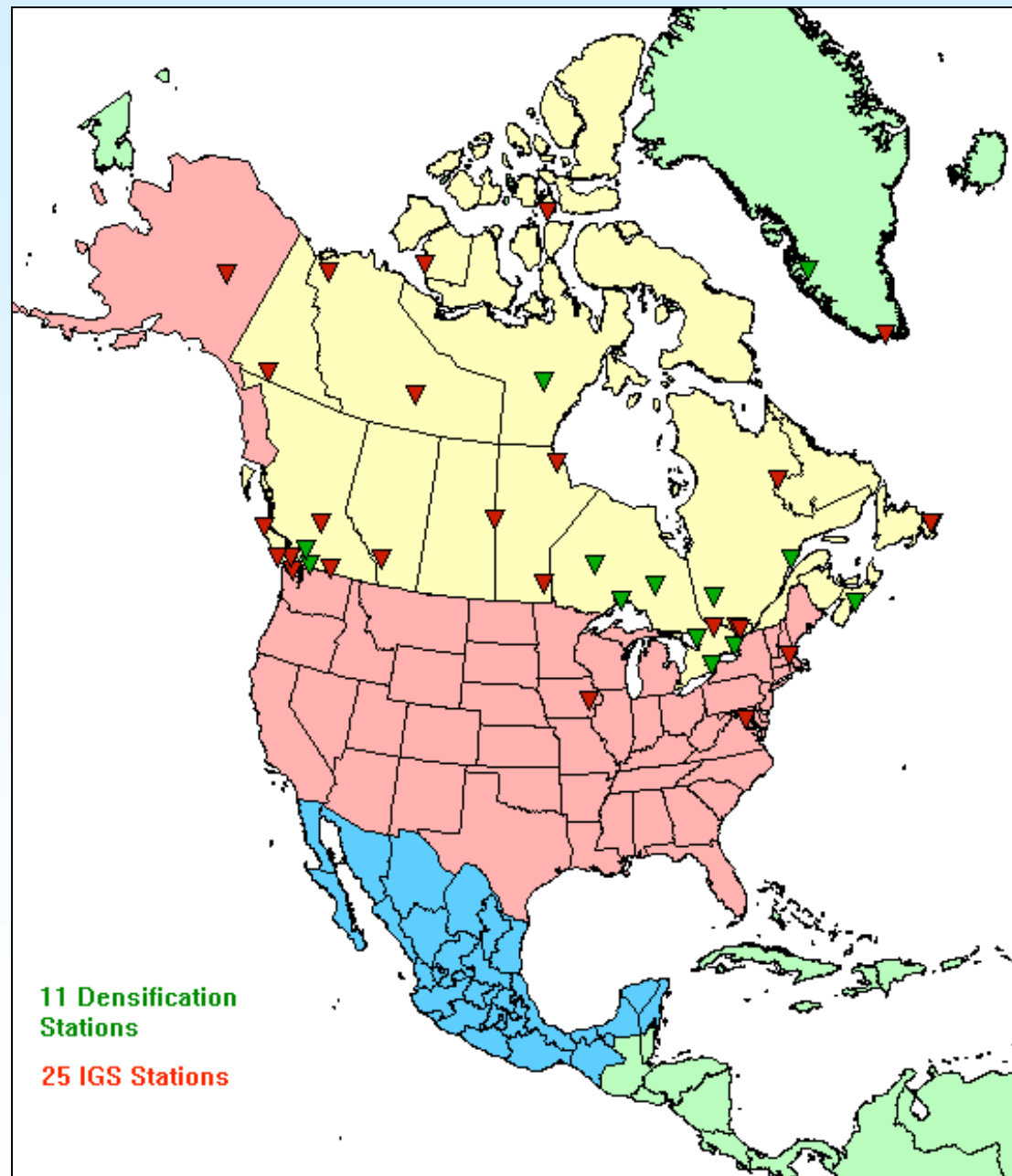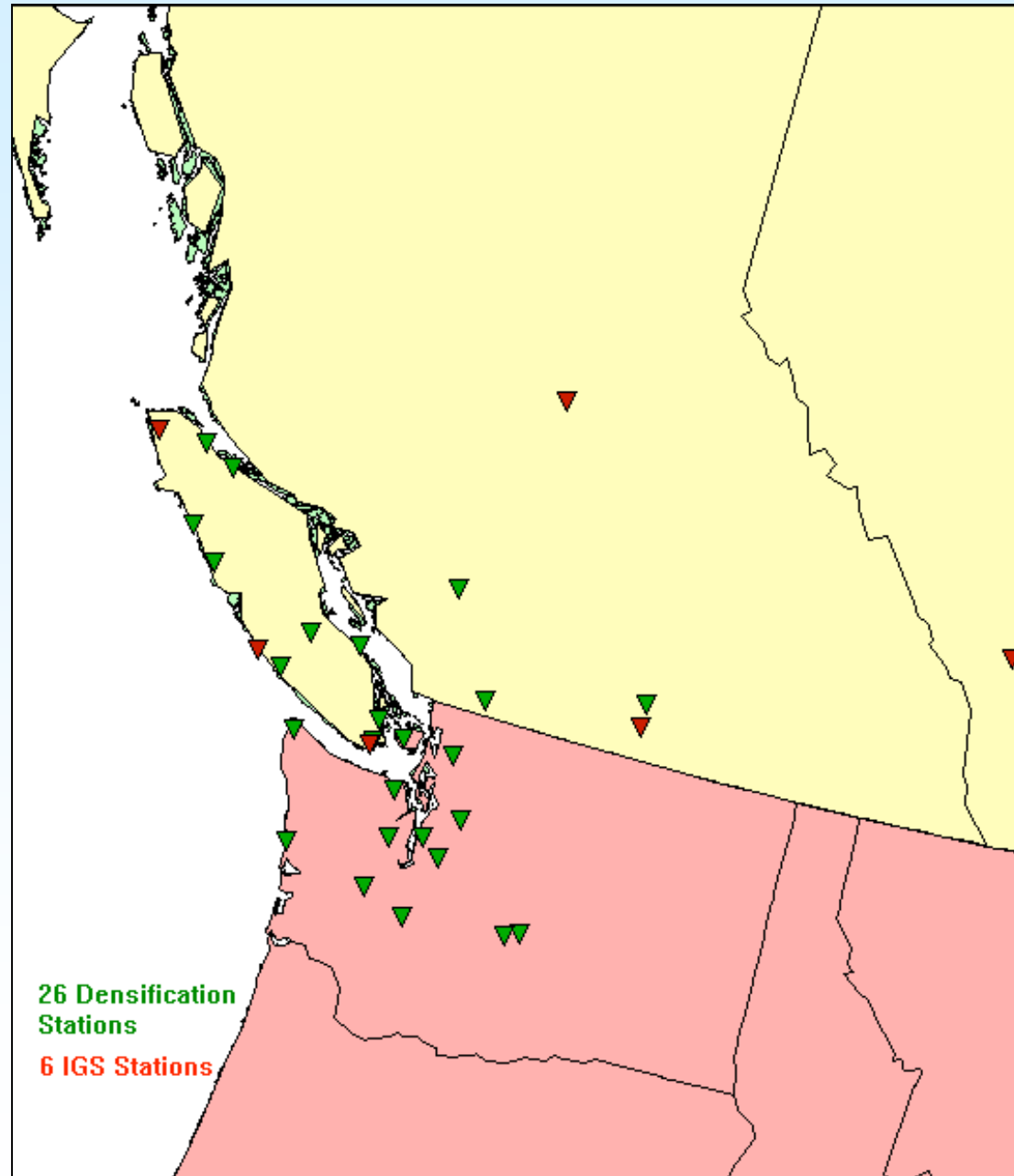
SIO Plate Boundary Observatory (PBO)

77 Densification Stations

9 IGS Stations

NGS CORS Network (NGS)

341 Densification Stations

21 IGS Stations

Regional Combinations

- Combine solutions in ITRF/IGS

    – Regular weekly coordinate solutions

    – Currently 550+ stations (nearly 50 in Canada incl. IGS)

    – 4 week latency (2 weeks after precise orbits available)

    ➢ Working towards cumulative solutions with velocities

    – Using Remi Ferland's SINEX software (IGS combo)

NAREF Combined Densification Network

375 Densification Stations

40 IGS Stations
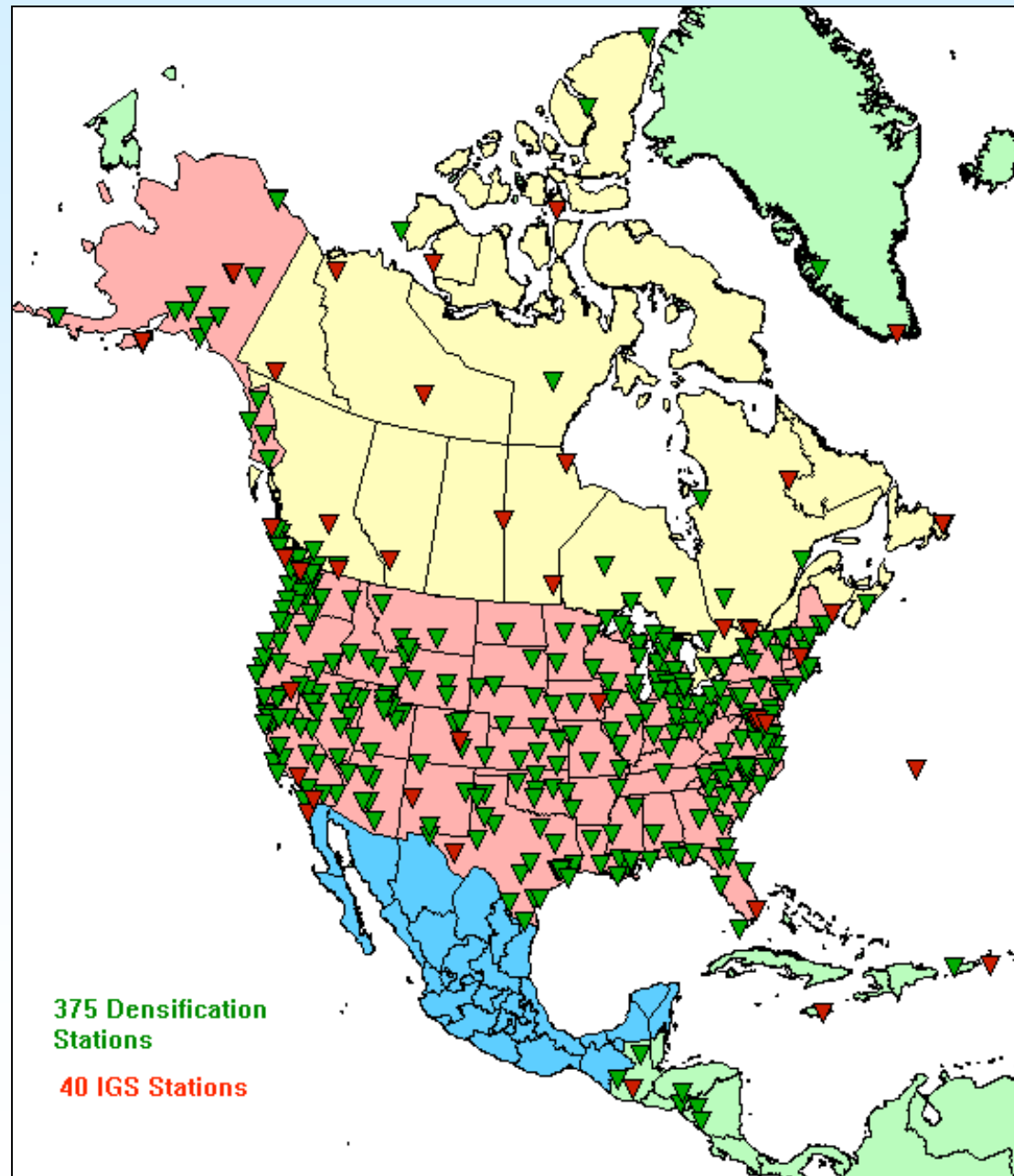
Combination Method

Alignment of Each Regional Solution

1. A priori datum constraints removed

2. Aligned to IGS weekly solution (3 translations, 3 rotations, scale change)

3. Covariance matrix scaled by WRMS of residuals

4. Residuals tested for outliers (outliers removed –> iterate #2-4)

Combination of Regional Solutions

5. Summation of normals of (scaled) regional solutions

6. Aligned to IGS weekly solution (3 translations., 3 rotations, scale change)

7. Covariance matrix scaled by WRMS of residuals

8. Residuals tested for outliers (outliers removed –> iterate #2-8)

9. Integrated into IGS weekly solution using IGS coordinates & covariance matrix for common stations as weighted pseudo-observations
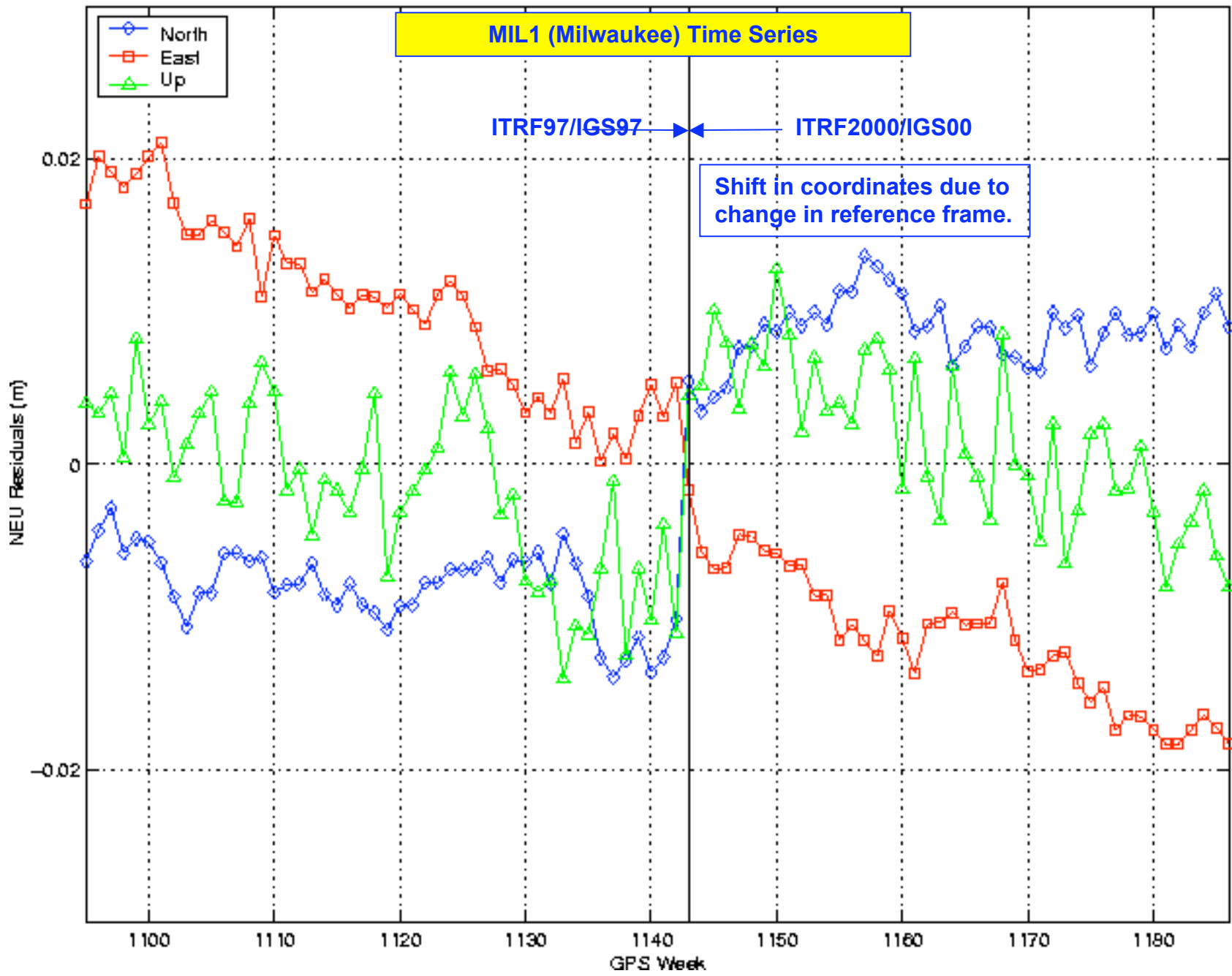
Problems

- Meta-data (site logs)
  - Often incomplete and sometimes contradictory
  - Not always updated on a timely basis
  - Verification an on-going & time consuming task
- Uneven redundancy
  - Some stations in many regional solutions
  - But many stations (eg, CORS) in only one solution (no checks on quality)
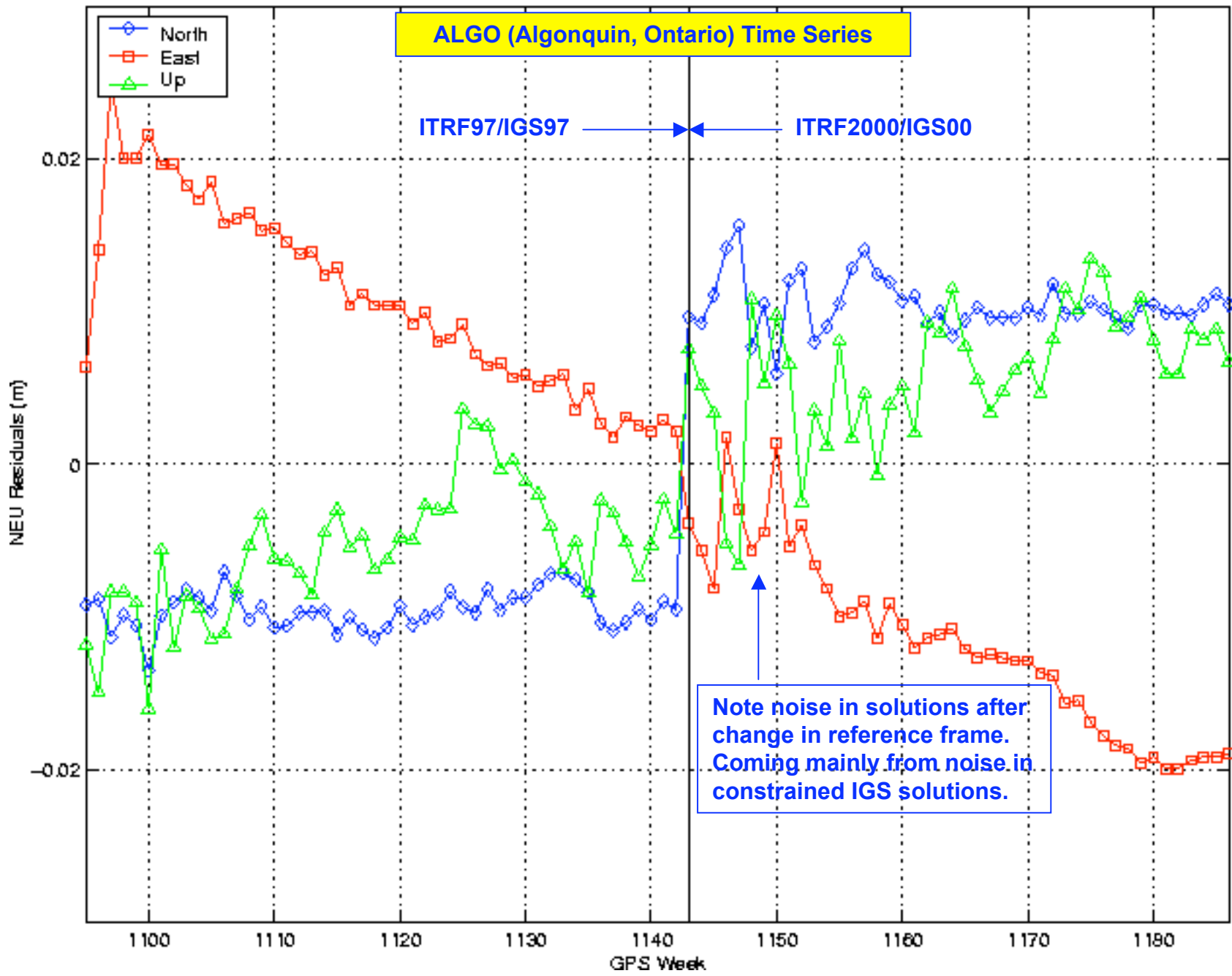 - Causes uneven weighting of stations

Problems (con't)

- Identification of outlier station solutions
  - Difficult and time consuming
  - Need a reliable automated procedure
- Water loading around Great Lakes
  - Affects Great Lakes CORS network
  - 2 foot range in water levels between Spring & Fall
  - 4? foot variations between decades (climate variations)
  - Secular variations due to post-glacial rebound?
  - Loading models possible?

Problems (con't)

- Changes in reference frames
  - Confusing to users if not explicitly identified (see plot)
  - No reference frame ID block in SINEX format
  - Obtained elevated noise levels at some IGS stations after change from IGS97 to IGS00 (see plot)

MIL1 (Milwaukee) Time Series

ITRF97/IGS97 ◄ ► ITRF2000/IGS00

Shift in coordinates due to change in reference frame.

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ALGO (Algonquin, Ontario) Time Series

Access to Reference Frames

- Three basic methods of integrating survey into a reference frame:
- Constrain to reference frame stations
  - Fix reference frame stations (least desirable)
  - Weight reference frame stations (use full cov matrix)
- Align/transform to reference frame stations using:
  - Known transformation parameters, or
  - Estimated best fitting parameters
- Combined alignment and weighted constraint
- Results depend on:
  - Method used (see plots)
  - Number of ref. Frame stations used to align or constrain (see plots)

Method 1 (Fixed) vs Method 3 (Aligned+Wtd)
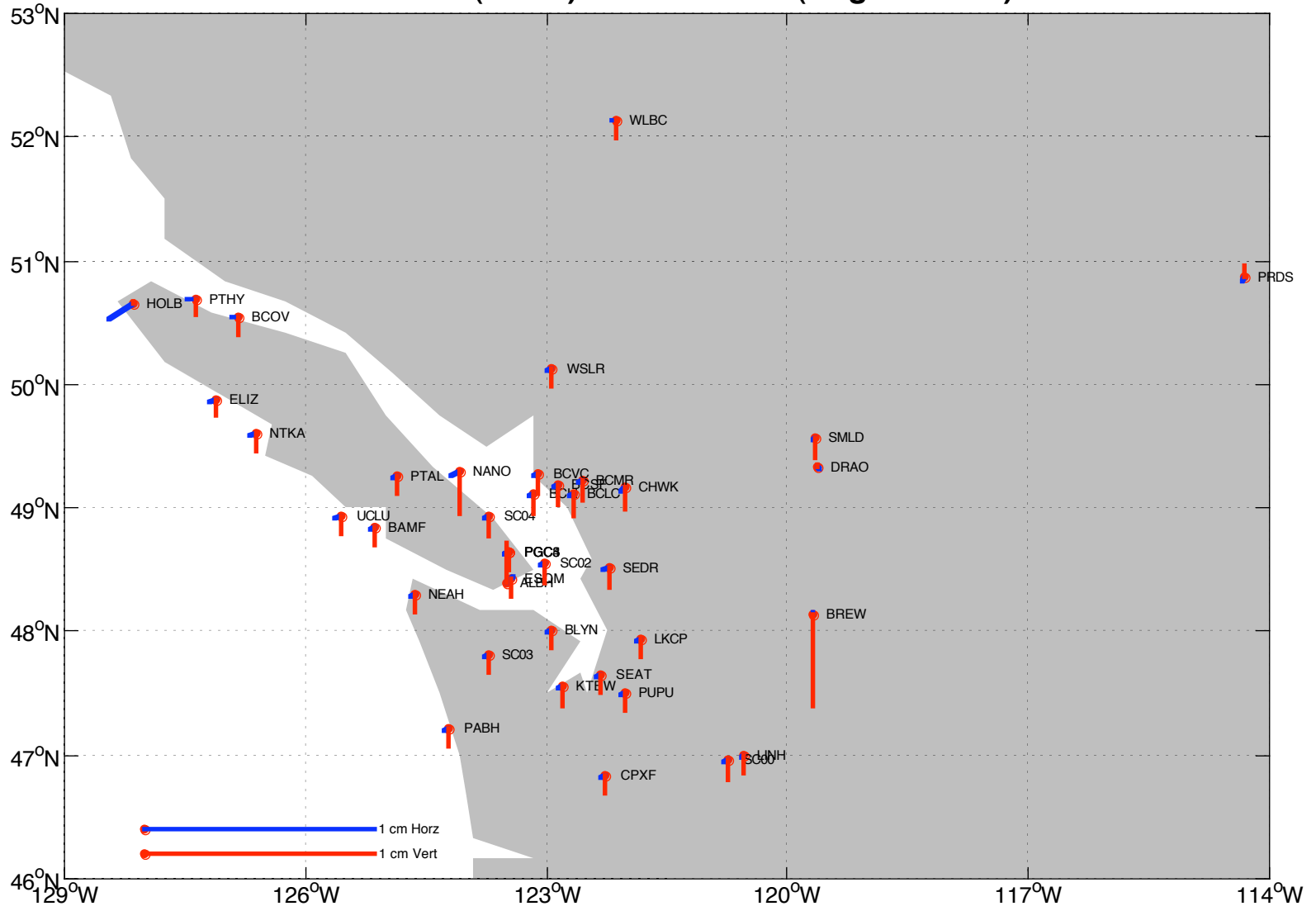
Method 3: 6 vs 4 Reference Frame Sites
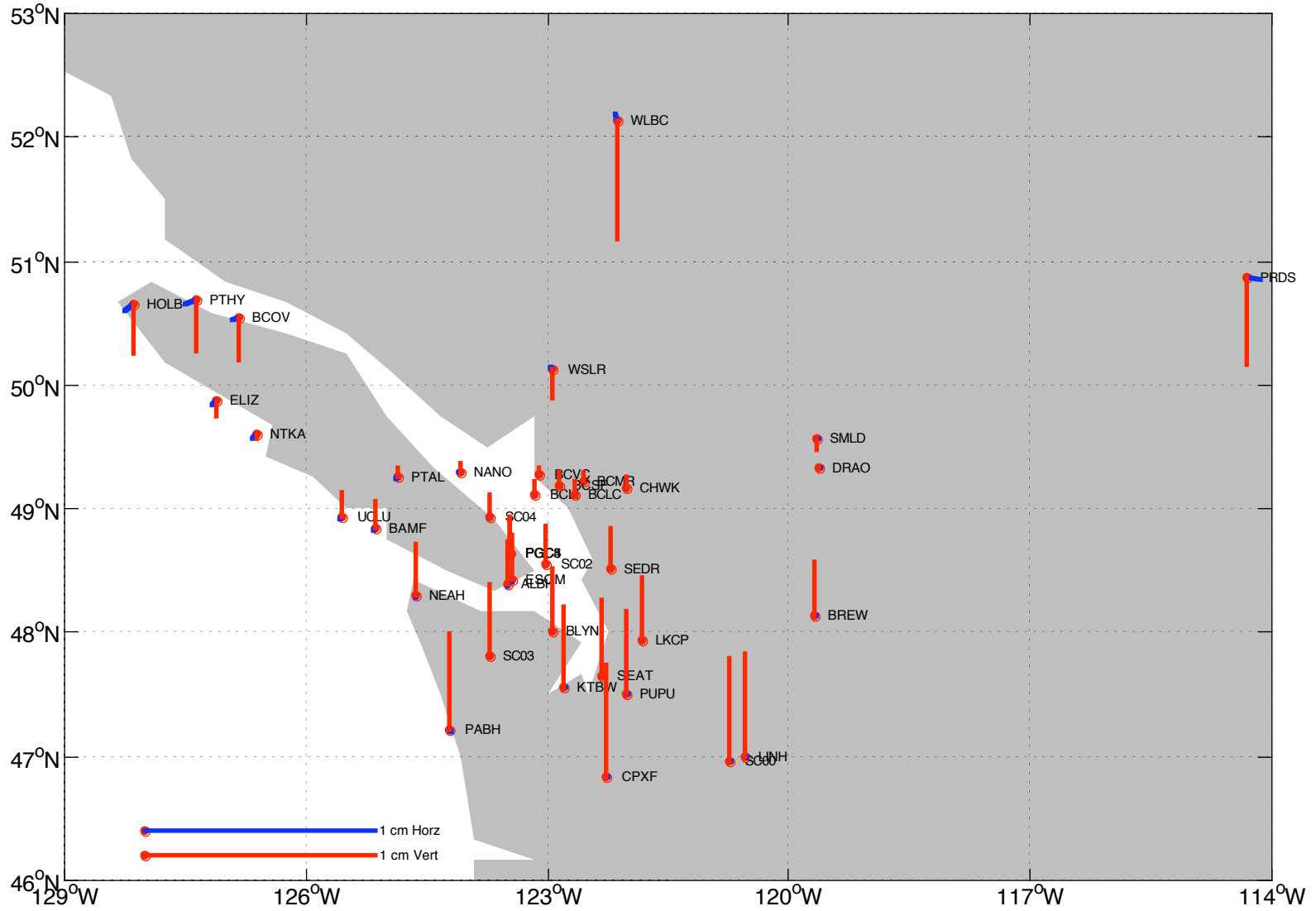
Proposed Contributions to SNARF

- Vehicle for
  - Providing & maintaining official SNARF products
  - Wider use under auspices of IAG & national geodetic agencies

- Combined regional solutions in SNARF

- Transformations between SNARF and
  - NAD83
  - ITRF/IGS