IAG Commission X – N.A. Subcommission
NAREF Technical Working Group

The North American Reference Frame

Densification of the ITRF in North America

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Plate Boundary Observatory US/Canada Workshop
Seattle, March 5, 2002

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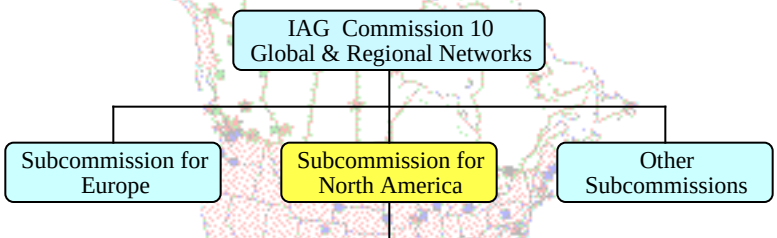

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NAREF Objectives

Densify the ITRF reference frame in NA

- Temporal as well as spatial densification
- Kinematic description of the Earth's shape as it changes

Produce coordinate solutions (IGS SINEX format)

- Produce weekly combinations of regional solutions
- Cumulative solutions with velocity estimates

Make available to public

- Archive results and raw data & forward to IGS
- Scientific applications (crustal motion studies)
- GPS base stations for integrating surveys into ITRF

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Regional Solutions

Station selection criteria

- Dual frequency data: 24 hr/day, min. 5 days/week
- Elevation mask angle ≤ 10°
- Stable and recoverable monumentation (or classify?)
- Complete & up to date station logs

Overlapping networks/solutions desired

- Stations in multiple solutions
- Reliable outlier detection
- Detect/average out software biases

Regional Processing

State-of-the-art GPS software

- Advanced modelling
  - Trop (zenith/gradient)
  - Antenna PCV
  - Ambiguity resolution
  - Earth tides and ocean loading
- E.g., Bernese, GAMIT, GIPSY-OASIS, MicroCosm
- Use fixed IGS orbits & ERPs
- Results in SINEX format

Difficult to impose standards

- Regional solutions from independent organizations
- Objectives different from NAREF

Contributors

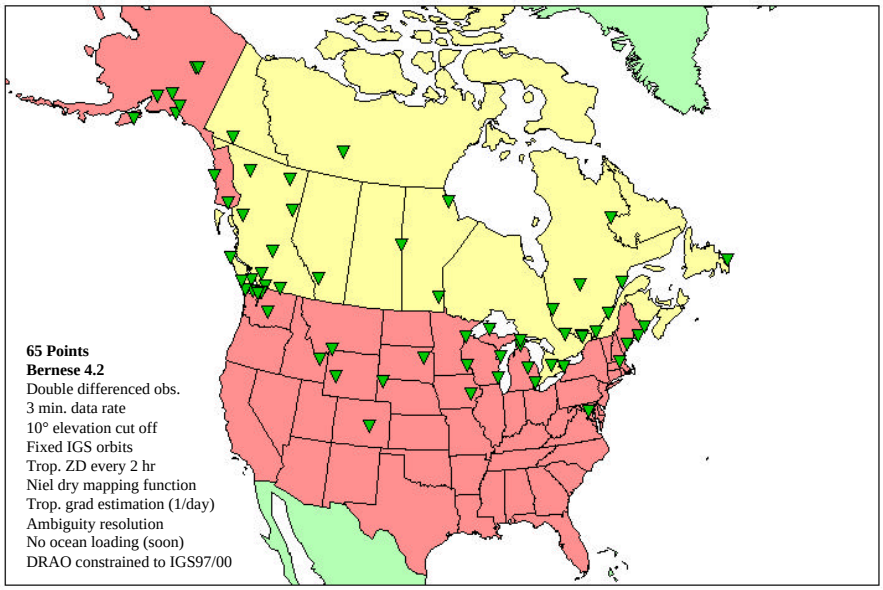
Currently 4 solutions

- ✓ Geodetic Survey Division Bernese Regional Network
- ✓ Geodetic Survey Division GIPSY Regional Network
- ✓ Pacific Geoscience Centre WCDA
- ✓ SIO Plate Boundary Observatory
- ✗ U. Alaska Alaska Deformation Array
  (unable to contribute due to lack of resources)

Need more for US & Mexico

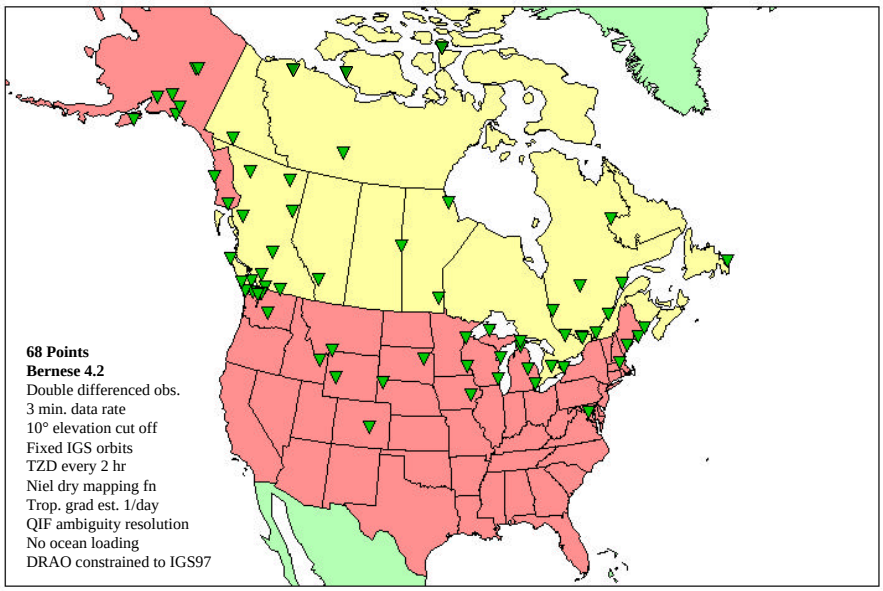
- ➢ NGS (PAGES) solution for CORS – about 150 pts
- ➢ Mexican permanent GPS network – about 10 pts

GSD Bernese Regional Network (GSB)



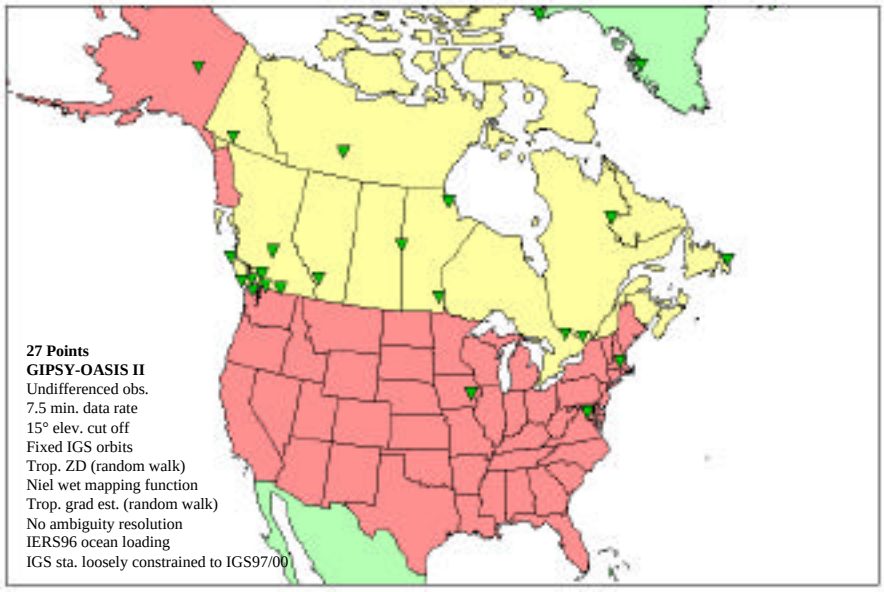
65 Points
Bernese 4.2
Double differenced obs.
3 min. data rate
10° elevation cut off
Fixed IGS orbits
Trop. ZD every 2 hr
Niel dry mapping function
Trop. grad estimation (1/day)
Ambiguity resolution
No ocean loading (soon)
DRAO constrained to IGS97/00

GSD Bernese Regional Network (GSB)



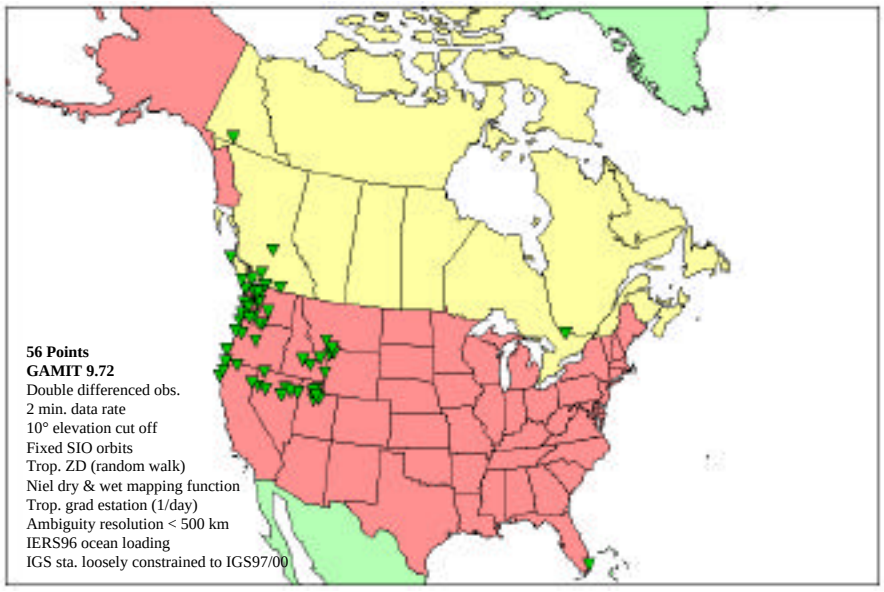
68 Points
Bernese 4.2
Double differenced obs.
3 min. data rate
10° elevation cut off
Fixed IGS orbits
TZD every 2 hr
Niel dry mapping fn
Trop. grad est. 1/day
QIF ambiguity resolution
No ocean loading
DRAO constrained to IGS97

GSD GIPSY Regional Network (GSG)



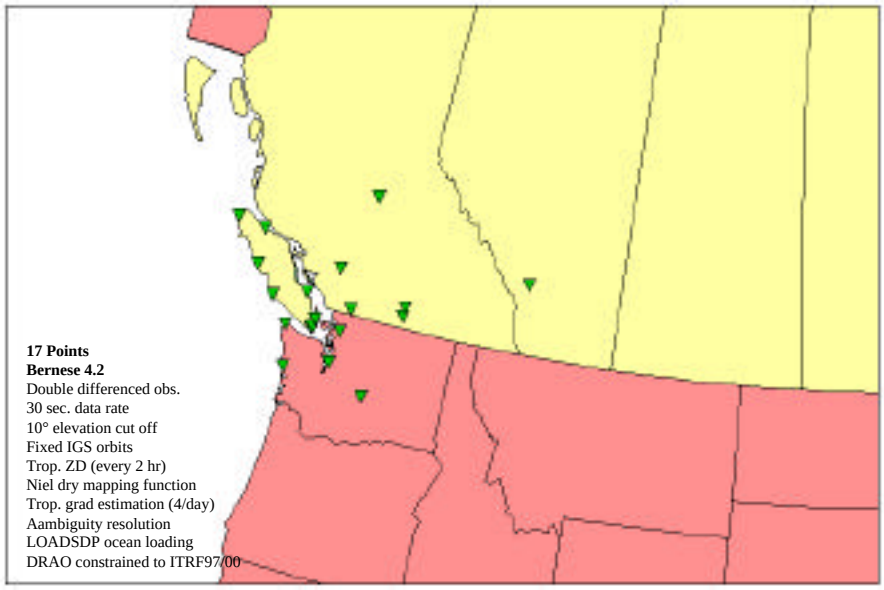
27 Points
GIPSY-OASIS II
Undifferenced obs.
7.5 min. data rate
15° elev. cut off
Fixed IGS orbits
Trop. ZD (random walk)
Niel wet mapping function
Trop. grad est. (random walk)
No ambiguity resolution
IERS96 ocean loading
IGS sta. loosely constrained to IGS97/00

SIO Plate Boundary Observatory (PBO)



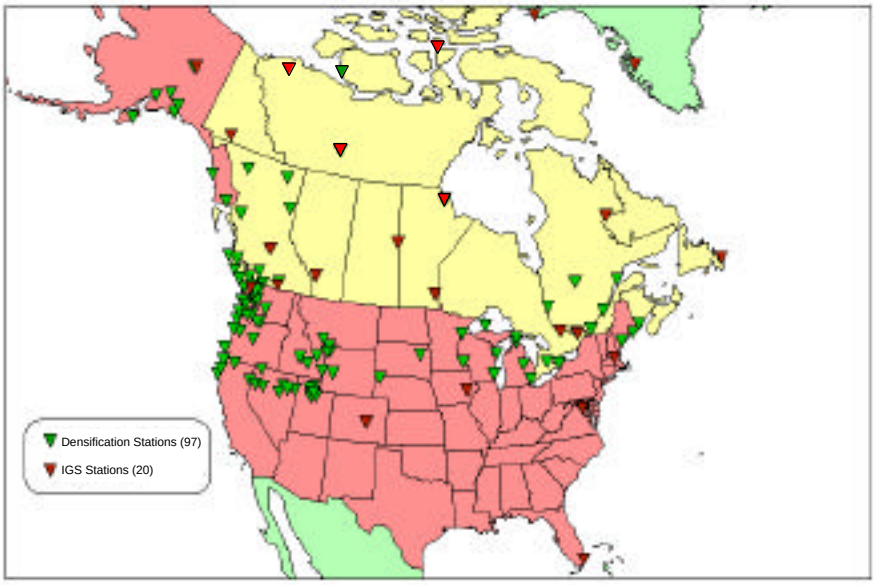
56 Points
GAMIT 9.72
Double differenced obs.
2 min. data rate
10° elevation cut off
Fixed SIO orbits
Trop. ZD (random walk)
Niel dry & wet mapping function
Trop. grad estation (1/day)
Ambiguity resolution < 500 km
IERS96 ocean loading
IGS sta. loosely constrained to IGS97/00

PGC Western Canada Deformation Array (PGC)



17 Points
Bernese 4.2
Double differenced obs.
30 sec. data rate
10° elevation cut off
Fixed IGS orbits
Trop. ZD (every 2 hr)
Niel dry mapping function
Trop. grad estimation (4/day)
Aambiguity resolution
LOADSDP ocean loading
DRAO constrained to ITRF97/00

NAREF Densification Network



Combination Procedure

Alignment of Each Regional Solutions

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. Combine scaled regional solutions (summation of normals)
6. Align 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. Minimum constraint: Station DRAO constrained to IGS97/00

Combination Software

SINEX Software v1.0

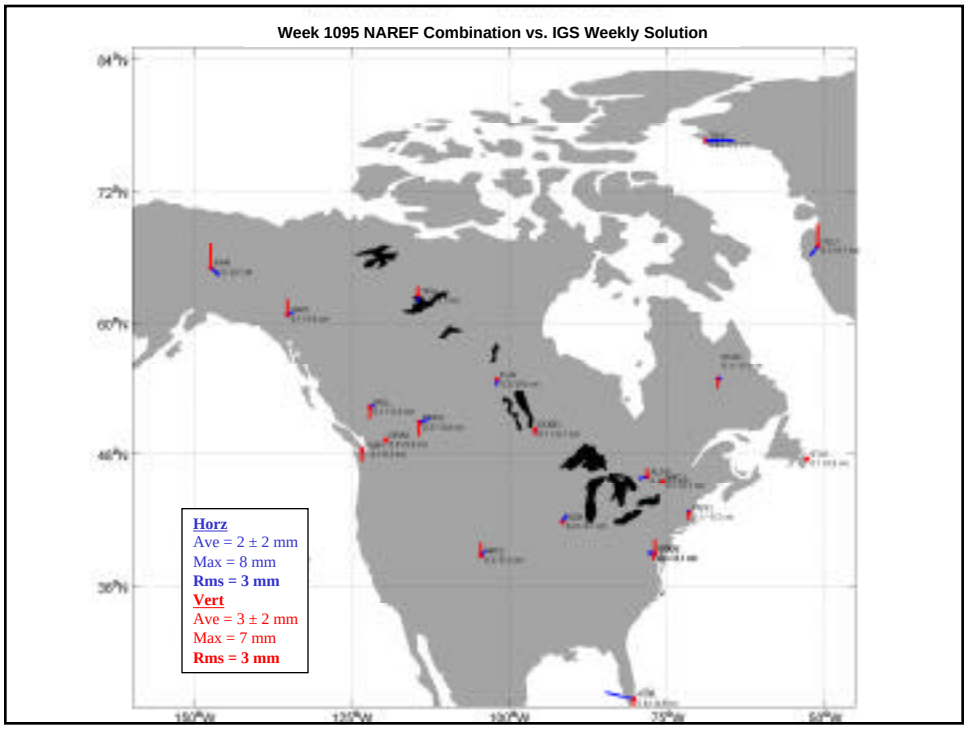
- Developed by Remi Ferland (IGS RF Coordinator)
- Used to produce official IGS global combinations

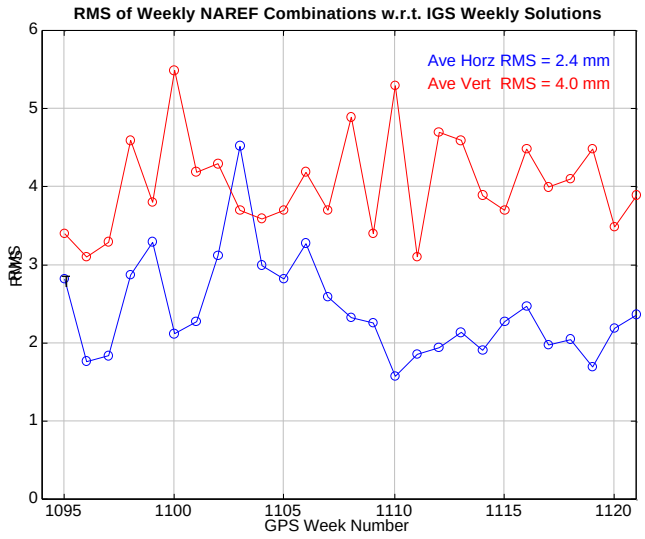
Limitations

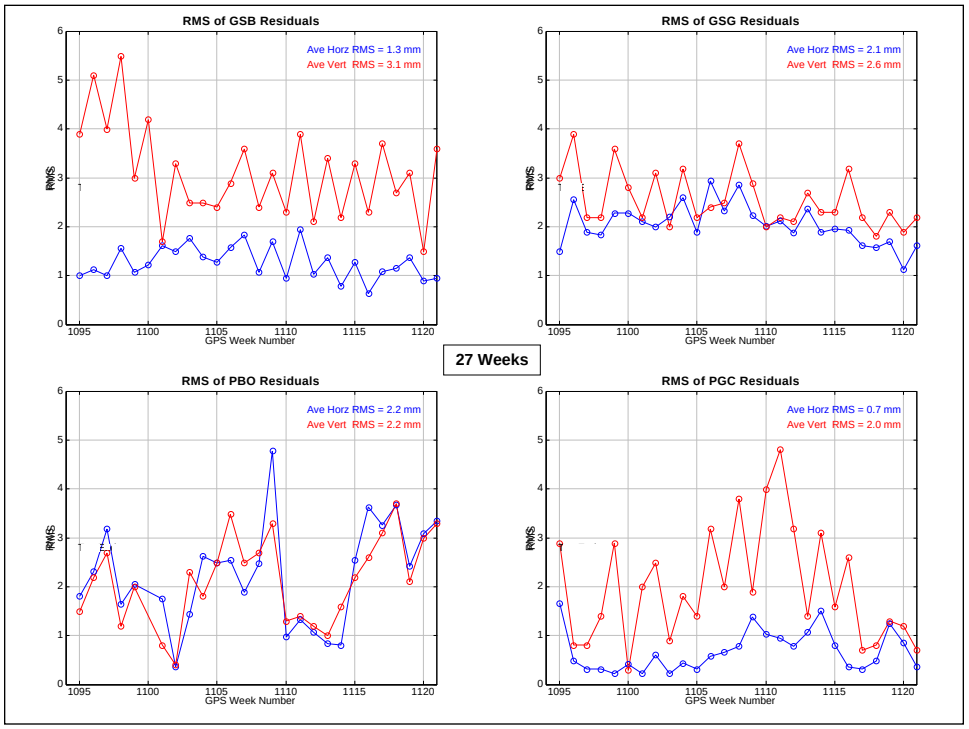
- Uses GIPSY math routines (unable to distribute)
- Limited to about 100 stations per individual solution (bug)

Further development

- Replace GIPSY routines with LAPACK
- Fix bug to handle more stations
- Support for SINEX v2


Week 1095 NAREF Combination vs. IGS Weekly Solution
Horz
Ave = 2 ± 2 mm
Max = 8 mm
Rms = 3 mm
Vert
Ave = 3 ± 2 mm
Max = 7 mm
Rms = 3 mm


RMS of Weekly NAREF Combinations w.r.t. IGS Weekly Solutions
Ave Horz RMS = 2.4 mm
Ave Vert RMS = 4.0 mm
RMS
GPS Week Number



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Future Work

- Incorporate other regional solutions
  - Post-Glacial Rebound monitoring network (6 stations) – 2001
  - GPS at Arctic tide gauges (4 stations) – 2002
  - Great Lakes CORS network (21 stations, 5 in Canada) – 2002
  - NGS CORS network (to cover entire US) – 2002 ?
  - Mexican permanent GPS network (about 10 stations) – ??
  - Campaign surveys ?? – CFI ??
- Regular cumulative solutions with velocities
- Strategy for integration into ITRF/IGS network
- Software modifications/enhancements

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NAREF Densification Network