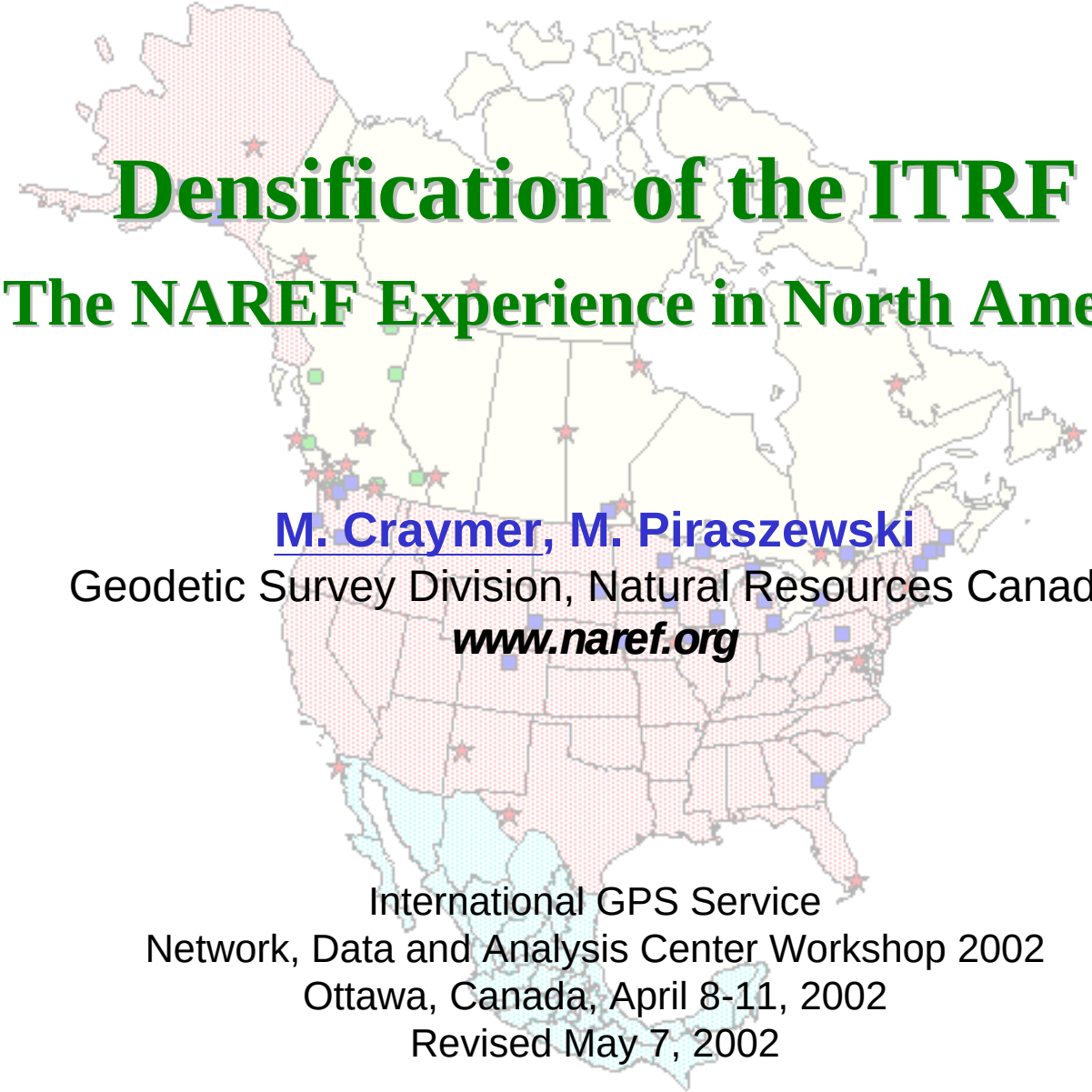


Densification of the ITRF

The NAREF Experience in North America

M. Craymer, M. Piraszewski
Geodetic Survey Division, Natural Resources Canada
www.naref.org

International GPS Service
Network, Data and Analysis Center Workshop 2002
Ottawa, Canada, April 8-11, 2002
Revised May 7, 2002

Outline

- NAREF objectives
- Regional solutions & standards
- Combination of regional solutions
- Integration into IGS global network

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

Make available to public

- Scientific applications (crustal motion studies)
- Reference stations for integrating surveys into ITRF

Standards for Regional Solutions

State-of-the-art GPS software

- Advanced modelling techniques
- Availability of full covariance matrix
- E.g., Bernese, GAMIT, GIPSY-OASIS, MicroCosm

Fixed IGS orbits & ERPs

Ties to IGS global network

- At least 3 IGS global stations
- Preferably all in vicinity of network

Problems

Regional solutions from independent organizations

- Limited resources
- Objectives different from NAREF
- Difficult to impose standards
- Take what we can get

Uneven coverage & redundancy

- Some stations in all solutions
- Many stations in only one solution
- Causes uneven weighting of stations

Standards for Regional Stations

Station selection criteria

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

Overlapping networks/solutions desired

- Stations in multiple solutions
- More reliable outlier detection
- Quantify software “noise” (average out?)

Contributors

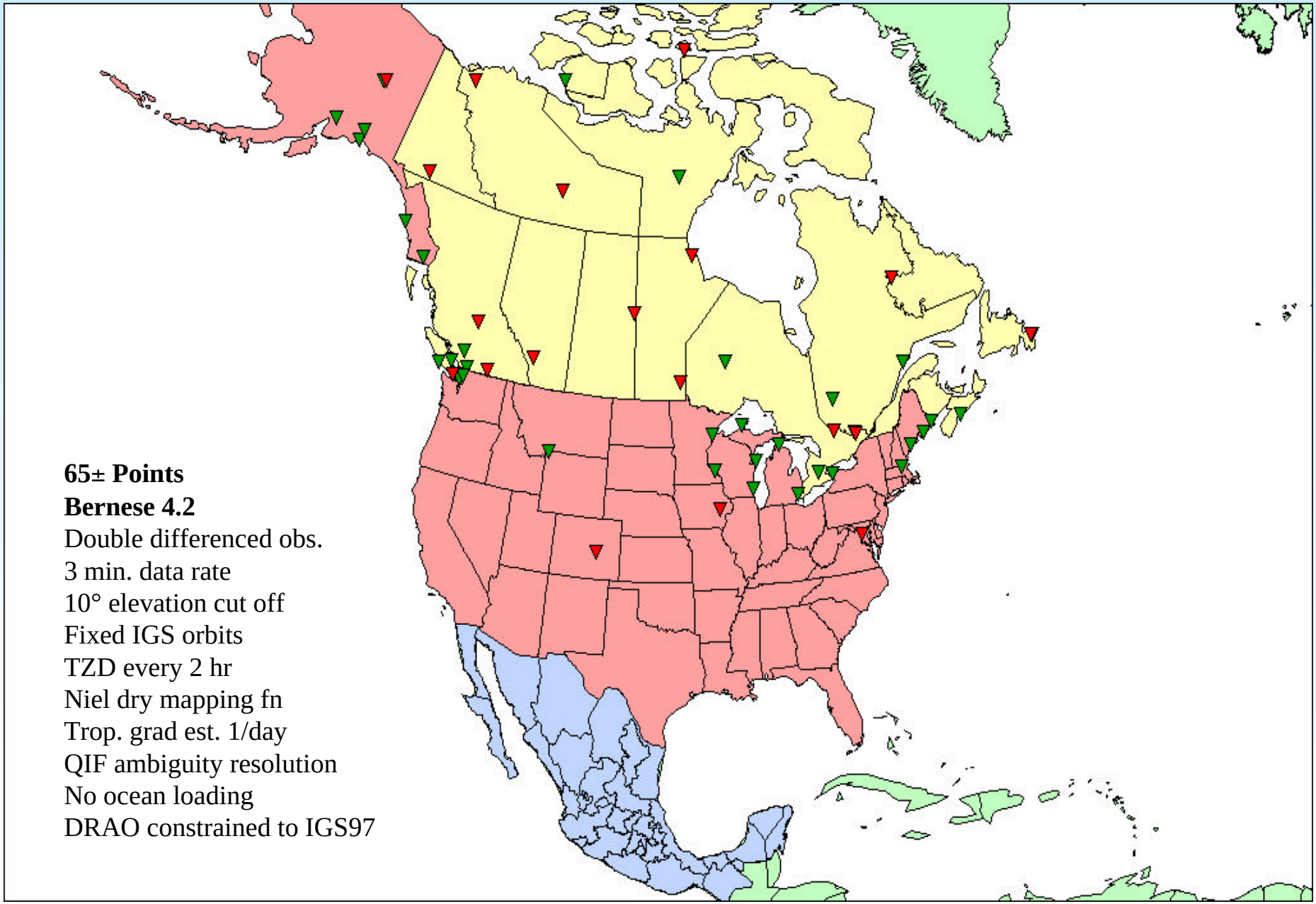
Currently 4 solutions

- ✓ Geodetic Survey Division Bernese Regional Network
- ✓ Geodetic Survey Division GIPSY Regional Network
- ✓ Pacific Geoscience Centre WCDA
- ✓ SIO Plate Boundary Observatory

Need more for US & Mexico

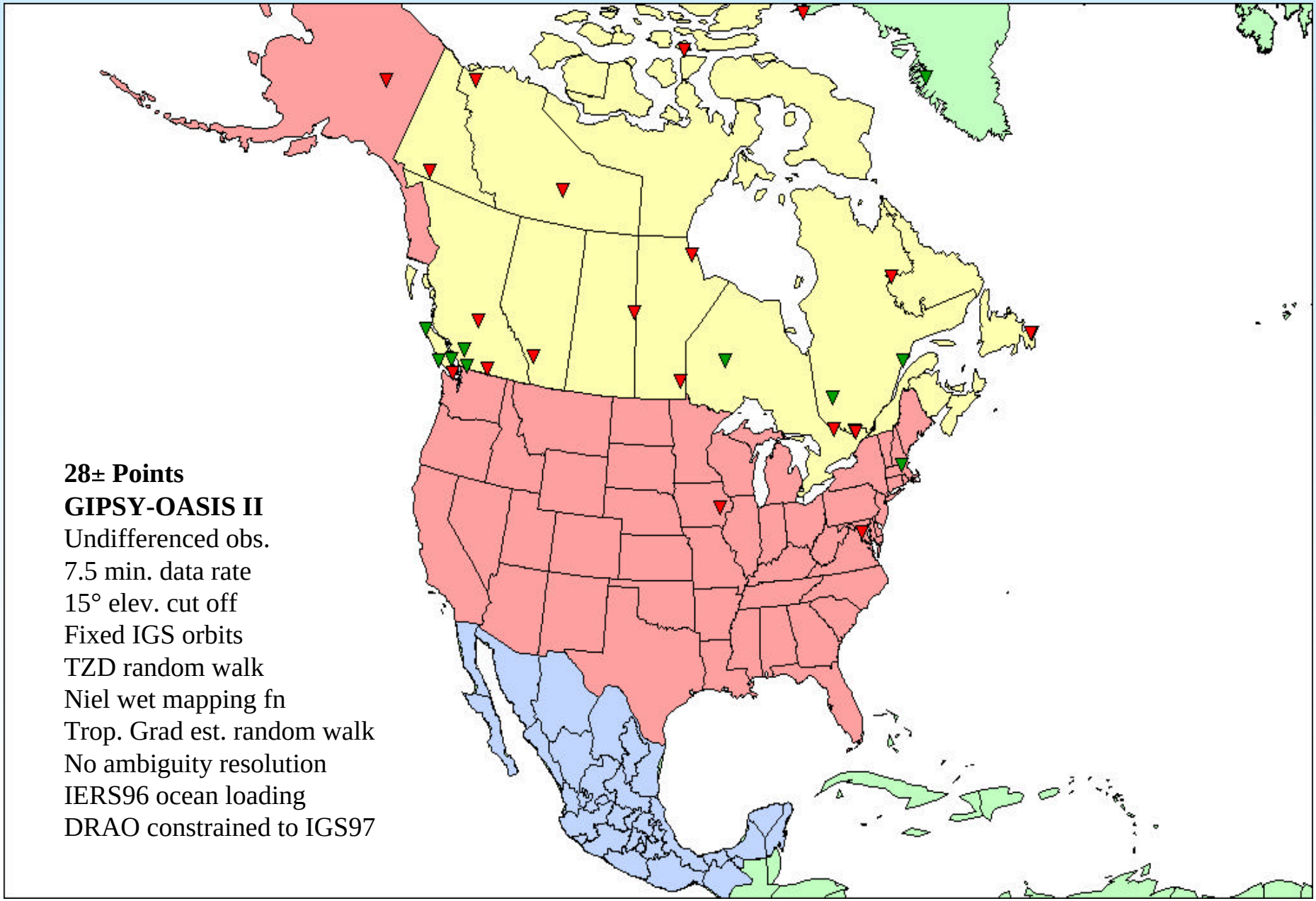
- ➢ CORS network – over 200 pts (NGS ??)
- ➢ Mexican permanent GPS network – about 10 pts

GSD Bernese Regional Network (GSB)



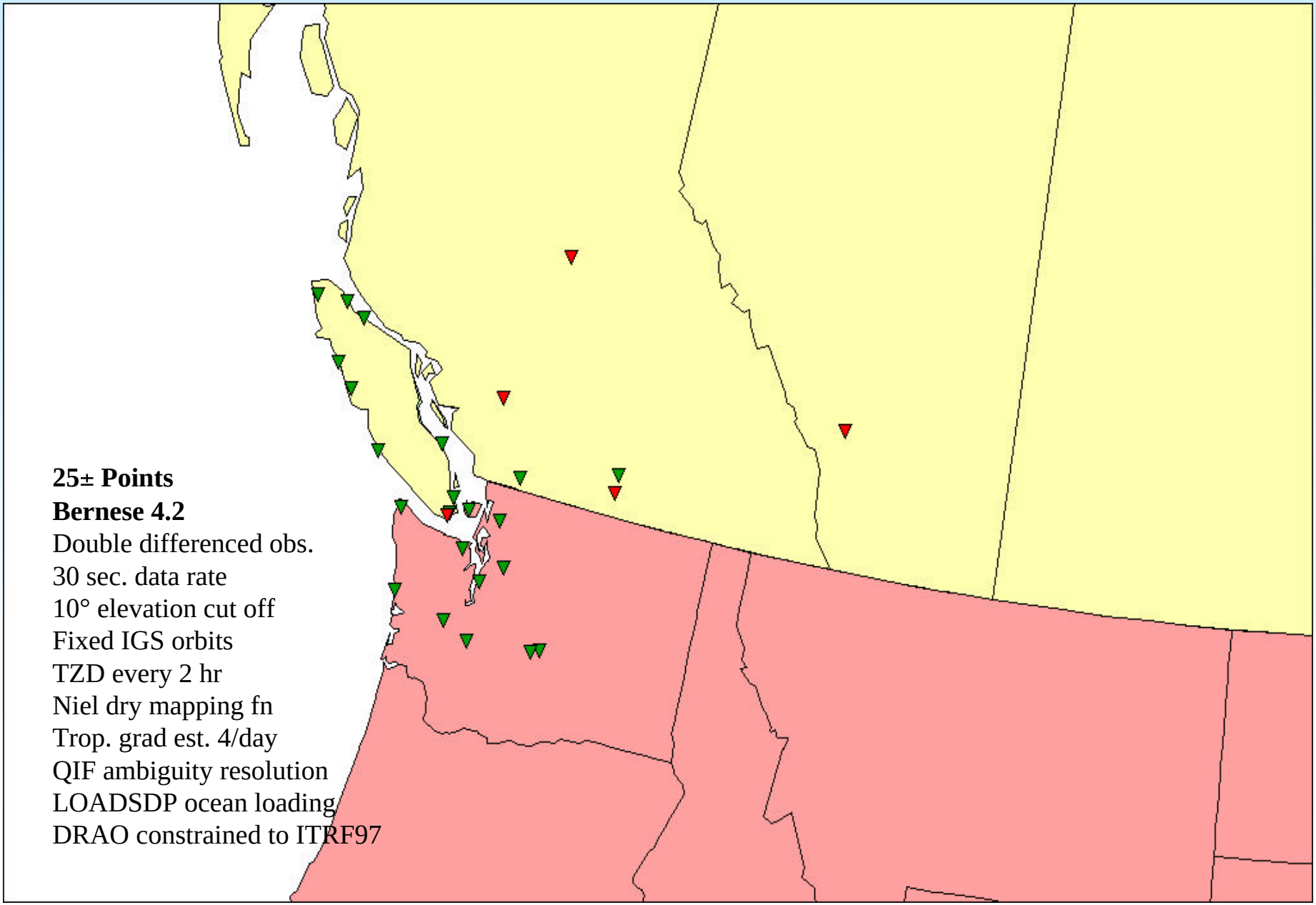
65± Points
Bernese 4.2
Double differenced obs.
3 min. data rate
10° elevation cut off
Fixed IGS orbits
TZD every 2 hr
Niel dry mapping fn
Trop. grad est. 1/day
QIF ambiguity resolution
No ocean loading
DRAO constrained to IGS97

GSD GIPSY Regional Network (GSG)

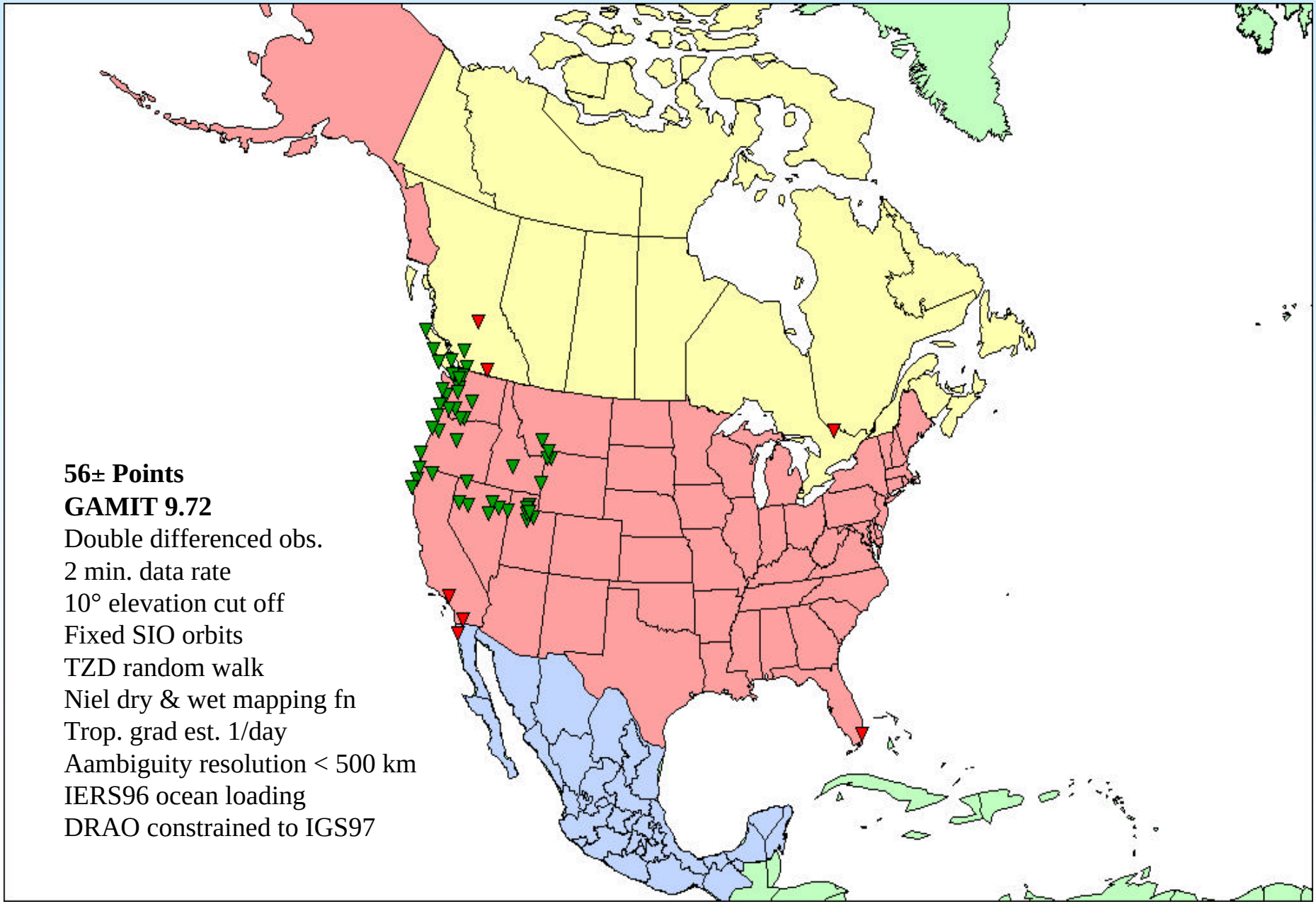


28± Points
GIPSY-OASIS II
Undifferenced obs.
7.5 min. data rate
15° elev. cut off
Fixed IGS orbits
TZD random walk
Niel wet mapping fn
Trop. Grad est. random walk
No ambiguity resolution
IERS96 ocean loading
DRAO constrained to IGS97

PGC Western Canada Deformation Array (PGC)

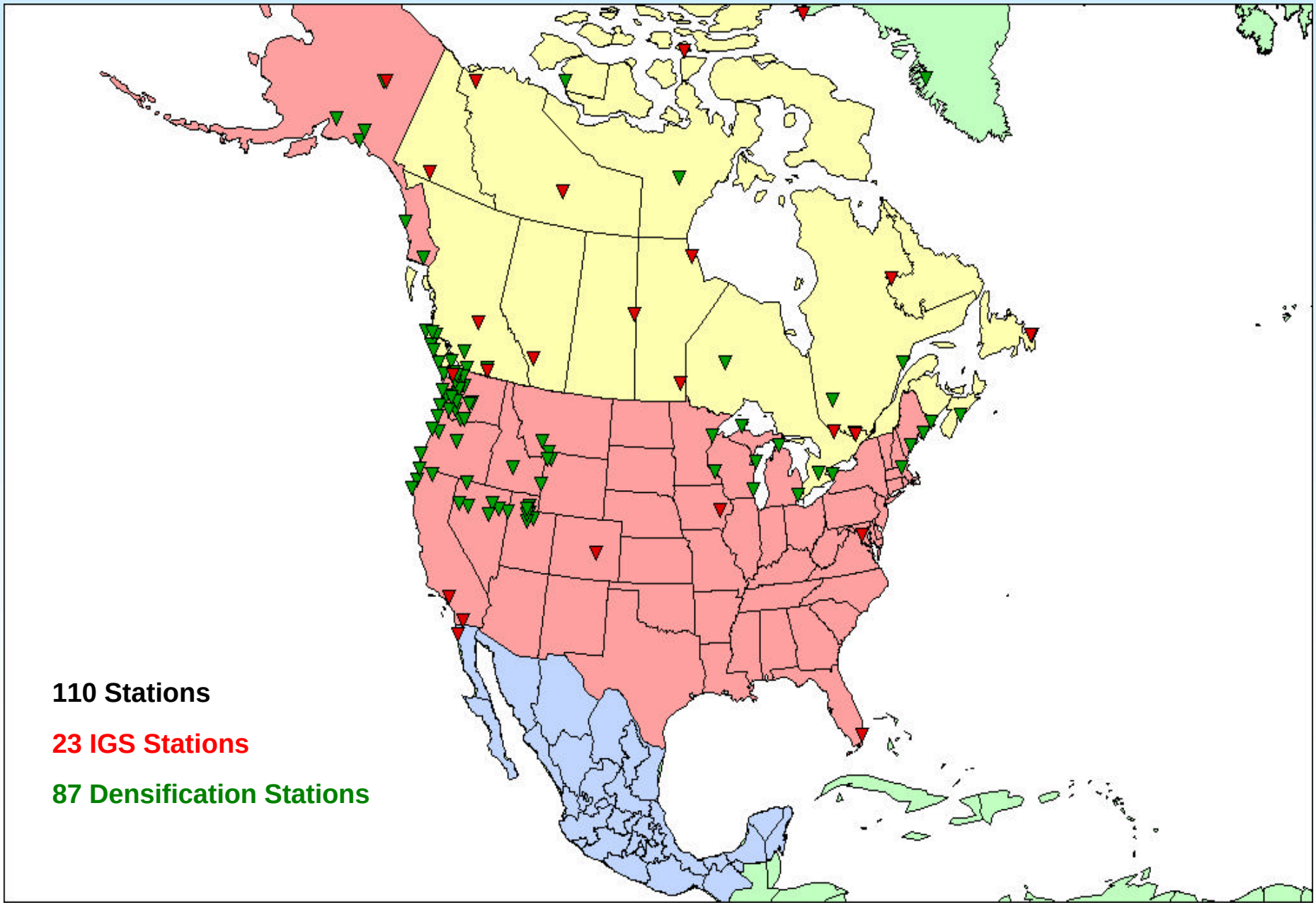


SIO Plate Boundary Observatory (PBO)



56± Points
GAMIT 9.72
Double differenced obs.
2 min. data rate
10° elevation cut off
Fixed SIO orbits
TZD random walk
Niel dry & wet mapping fn
Trop. grad est. 1/day
Aambiguity resolution < 500 km
IERS96 ocean loading
DRAO constrained to IGS97

NAREF Densification Network



Combination of Regional Solutions

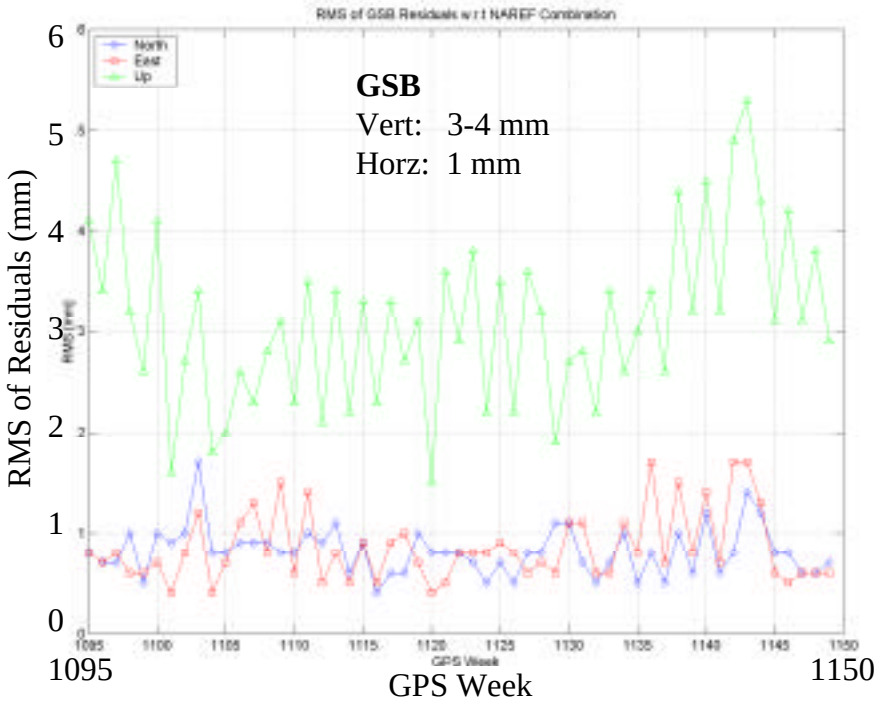
Alignment of Each Regional Solutions

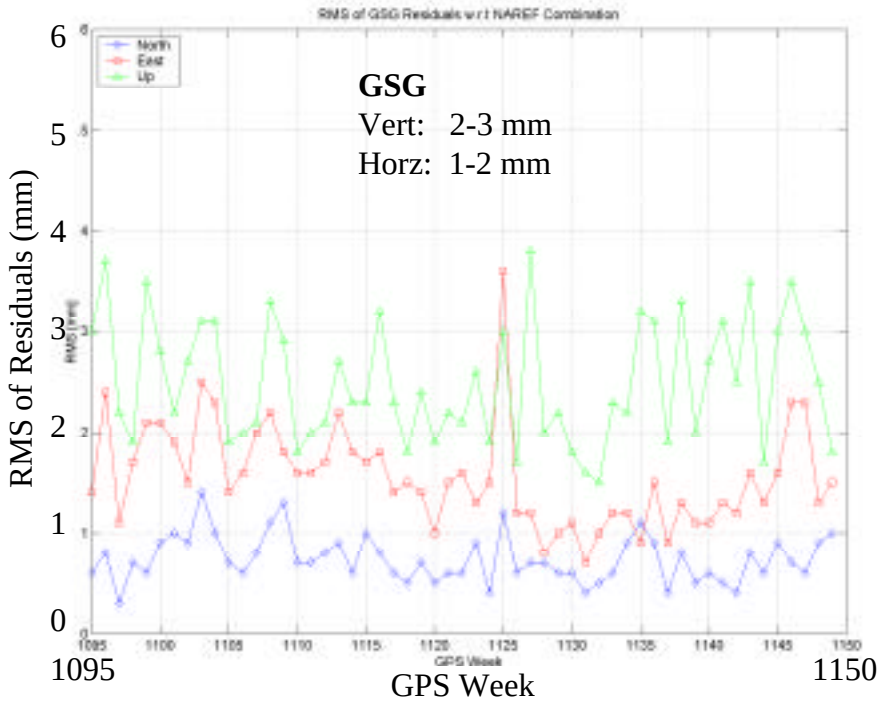
1. A priori datum constraints removed
2. Aligned to IGS weekly solution (3 translations, 3 rotations, scale change)
3. Covariance matrix scaled by WRMS of residuals
4. Residuals tested for outliers (outliers removed –> iterate #2-4)

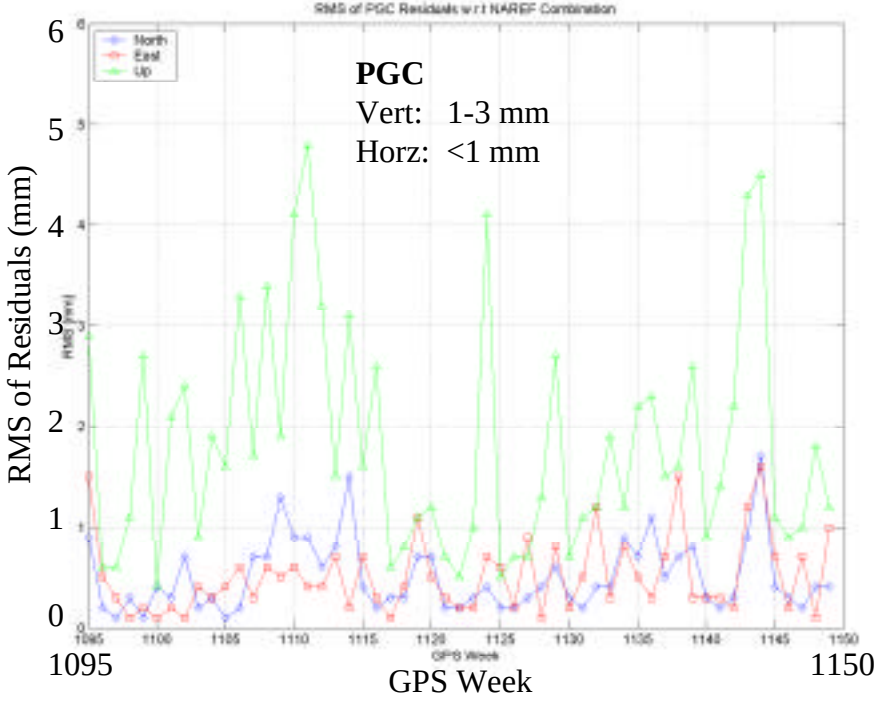
Combination of Regional Solutions

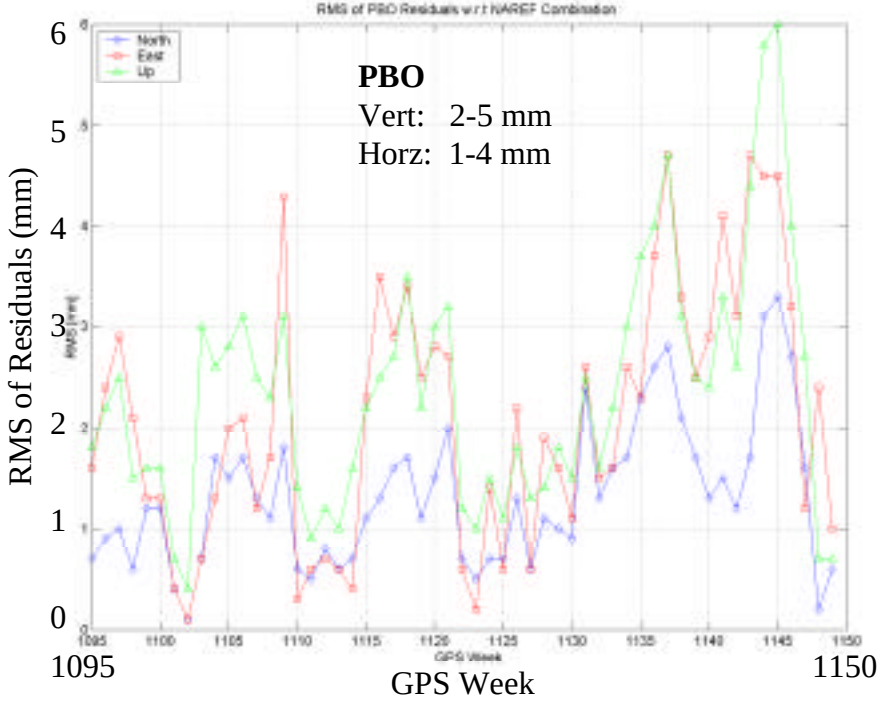
5. Summation of normals of (scaled) regional solutions
6. Aligned to IGS weekly solution (3 translations., 3 rotations, scale change)
7. Covariance matrix scaled by WRMS of residuals
8. Residuals tested for outliers (outliers removed –> iterate #2-8)
9. Minimum constraint: One IGS reference frame station (DRAO) constrained to IGS97

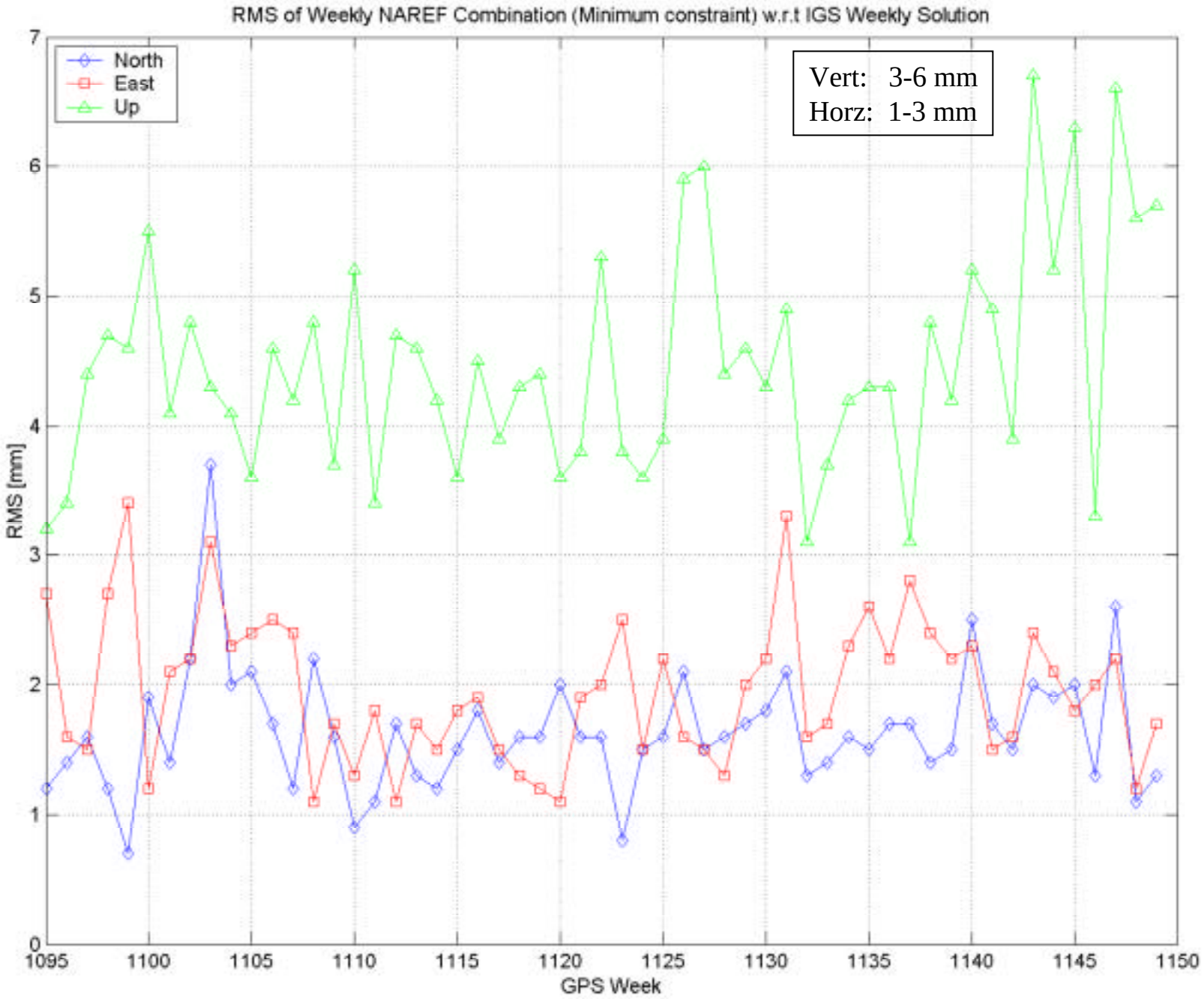
Software: SINEX Software v1.0 by Remi Ferland (used for IGS)


RMS of GSB Residuals w.r.t NAREF Combination
North
East
Up
GSB
Vert: 3-4 mm
Horz: 1 mm
RMS of Residuals (mm)
GPS Week
1095
1150


RMS of GSG Residuals w.r.t NAREF Combination
North
East
Up
GSG
Vert: 2-3 mm
Horz: 1-2 mm
RMS of Residuals (mm)
GPS Week
1095
1150


RMS of PGC Residuals w.r.t NAREF Combination
North
East
Up
PGC
Vert: 1-3 mm
Horz: <1 mm
RMS of Residuals (mm)
GPS Week
1095
1150


RMS of PBO Residuals w.r.t NAREF Combination
North
East
Up
PBO
Vert: 2-5 mm
Horz: 1-4 mm
RMS of Residuals (mm)
GPS Week
1095
1150


RMS of Weekly NAREF Combination (Minimum constraint) w.r.t IGS Weekly Solution
North
East
Up
Vert: 3-6 mm
Horz: 1-3 mm
RMS [mm]
GPS Week
0
1
2
3
4
5
6
7
1095
1100
1105
1110
1115
1120
1125
1130
1135
1140
1145
1150

Integration into Global Network (1)

Fixed constraints (or tightly weighted)

- IGS station coordinates don't change
- But distorts regional covariance matrix in both absolute and relative sense

Weighted constraints

- Equivalent to rigorous sequential adjustment of global & regional
- Summation of normals
- IGS station coordinates change

Integration into Global Network (2)

Transformation

- Align regional solution with global
- Usually done with an inner constraint solution
- IGS station coordinates change

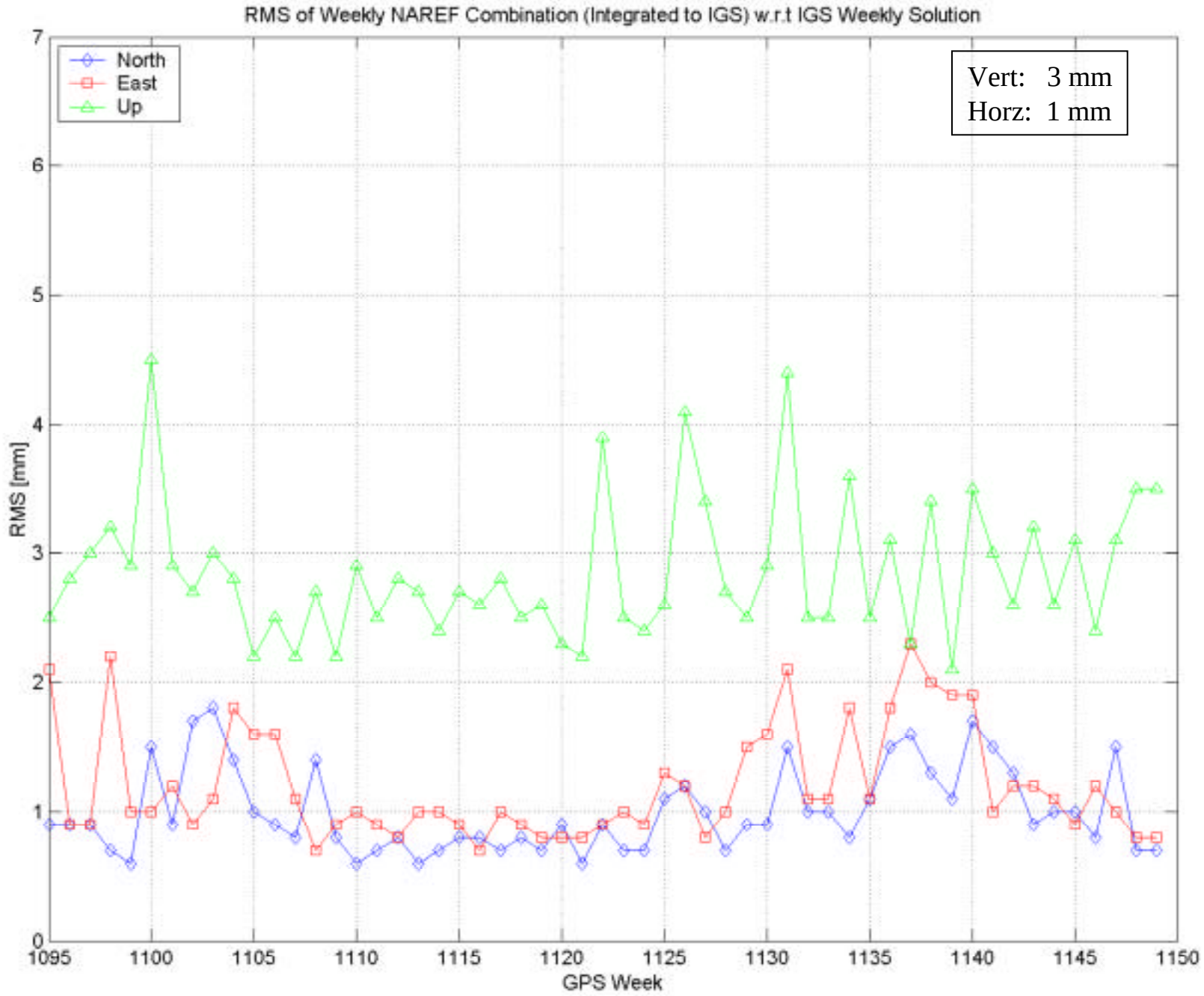
Blaha approach

- Similar to weighted station method
- Additional condition that IGS coordinates don’t change
- Difficult (impossible?) to specify constraint in SINEX APRIORI blocks – can’t remove?

Integration into IGS Global Network

NAREF Approach

- Transformation + weighted constraints
- Transformation/alignment to IGS global network (already done priori to min constraint)
- Remove minimum constraint
- Apply weighted constraints (IGS weekly solution + covariance matrix of common stations)
- Constraints specified in “APRIORI” blocks of SINEX file – can be removed


RMS of Weekly NAREF Combination (Integrated to IGS) w.r.t IGS Weekly Solution
North
East
Up
Vert: 3 mm
Horz: 1 mm
RMS [mm]
GPS Week
0
1
2
3
4
5
6
7
1095
1100
1105
1110
1115
1120
1125
1130
1135
1140
1145
1150

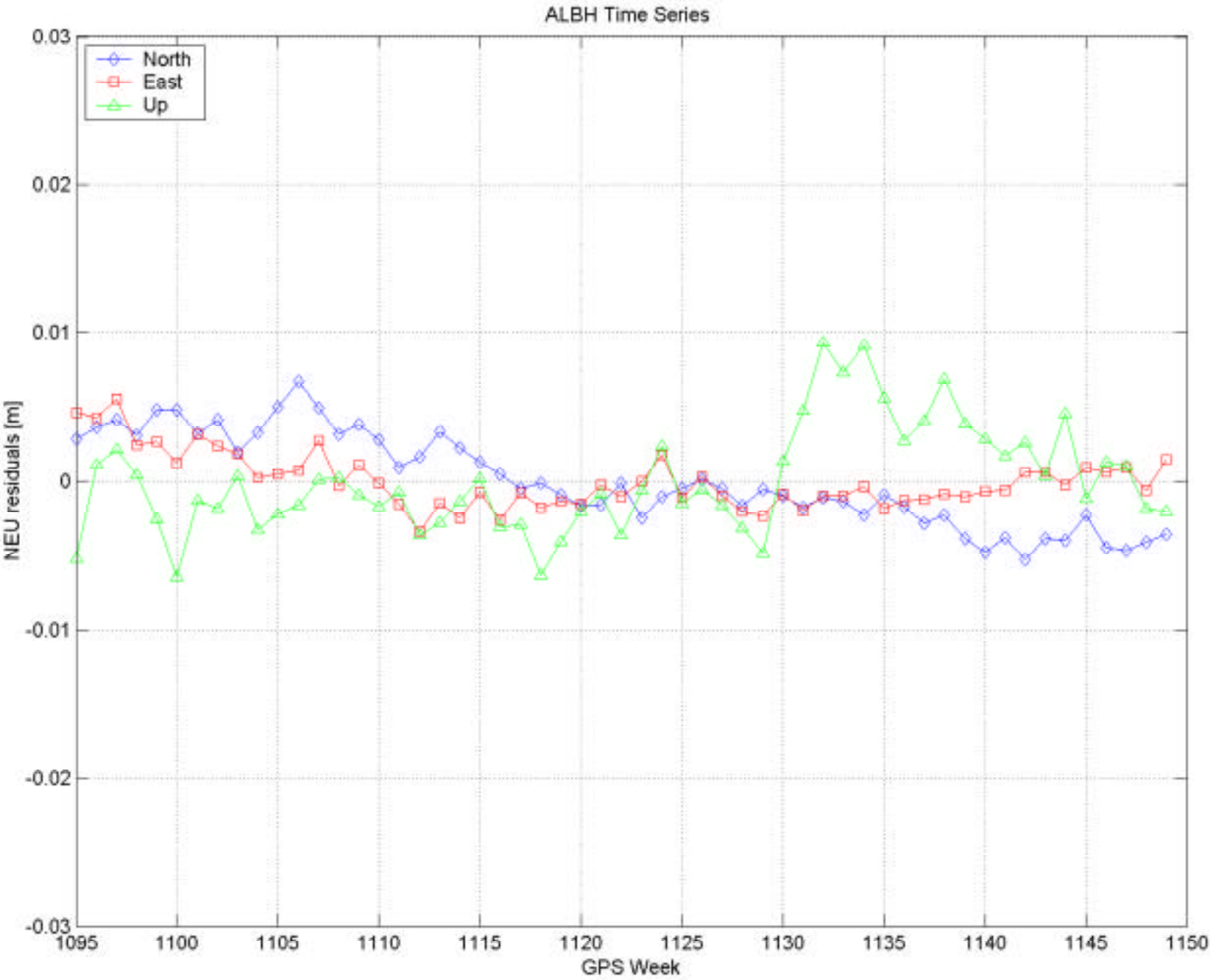
Coordinate Time Series

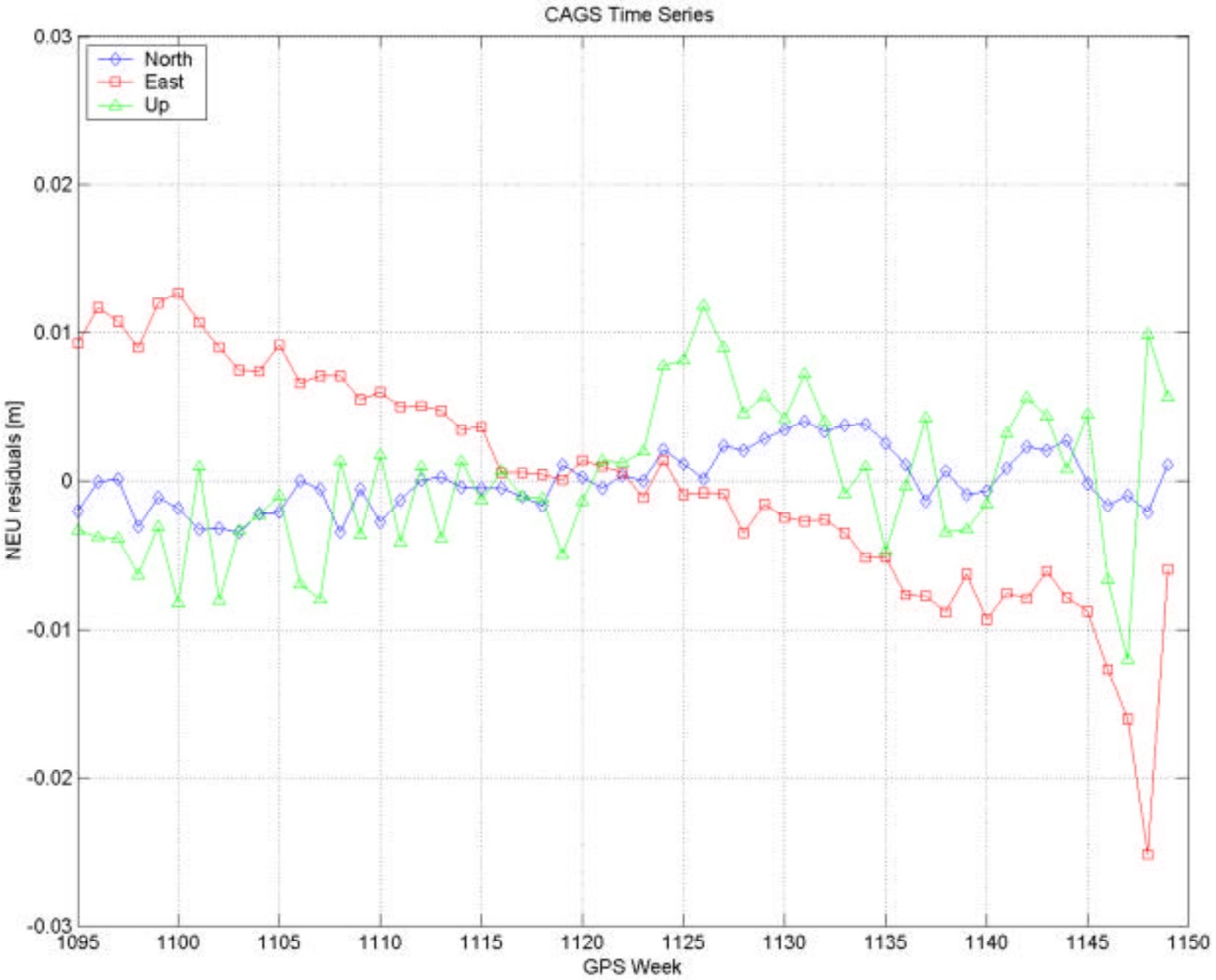
Coordinate Time Series

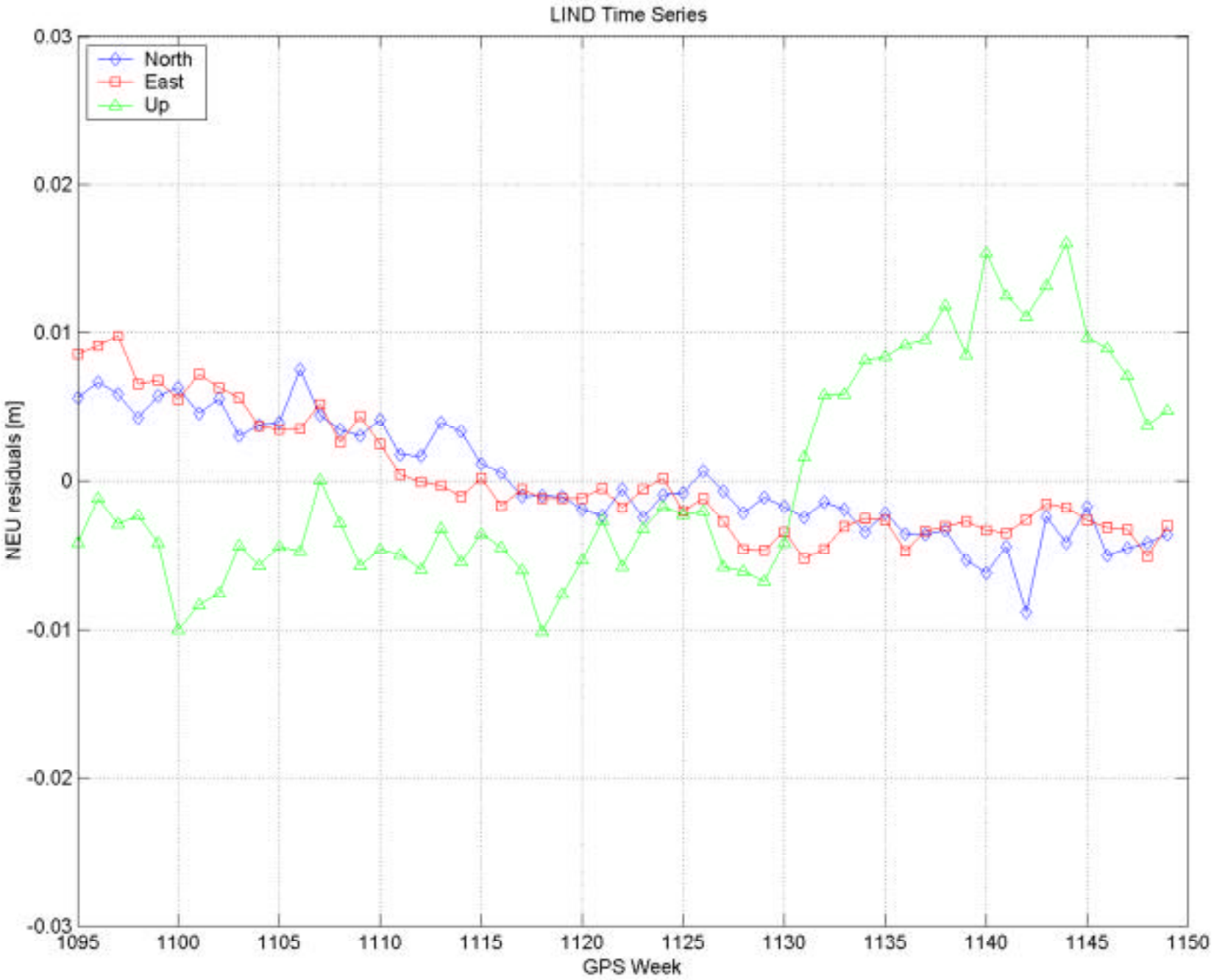
- From weekly NAREF combinations
- Integrated into IGS global network
- For GPS weeks 1095 to 1150 (56 weeks)

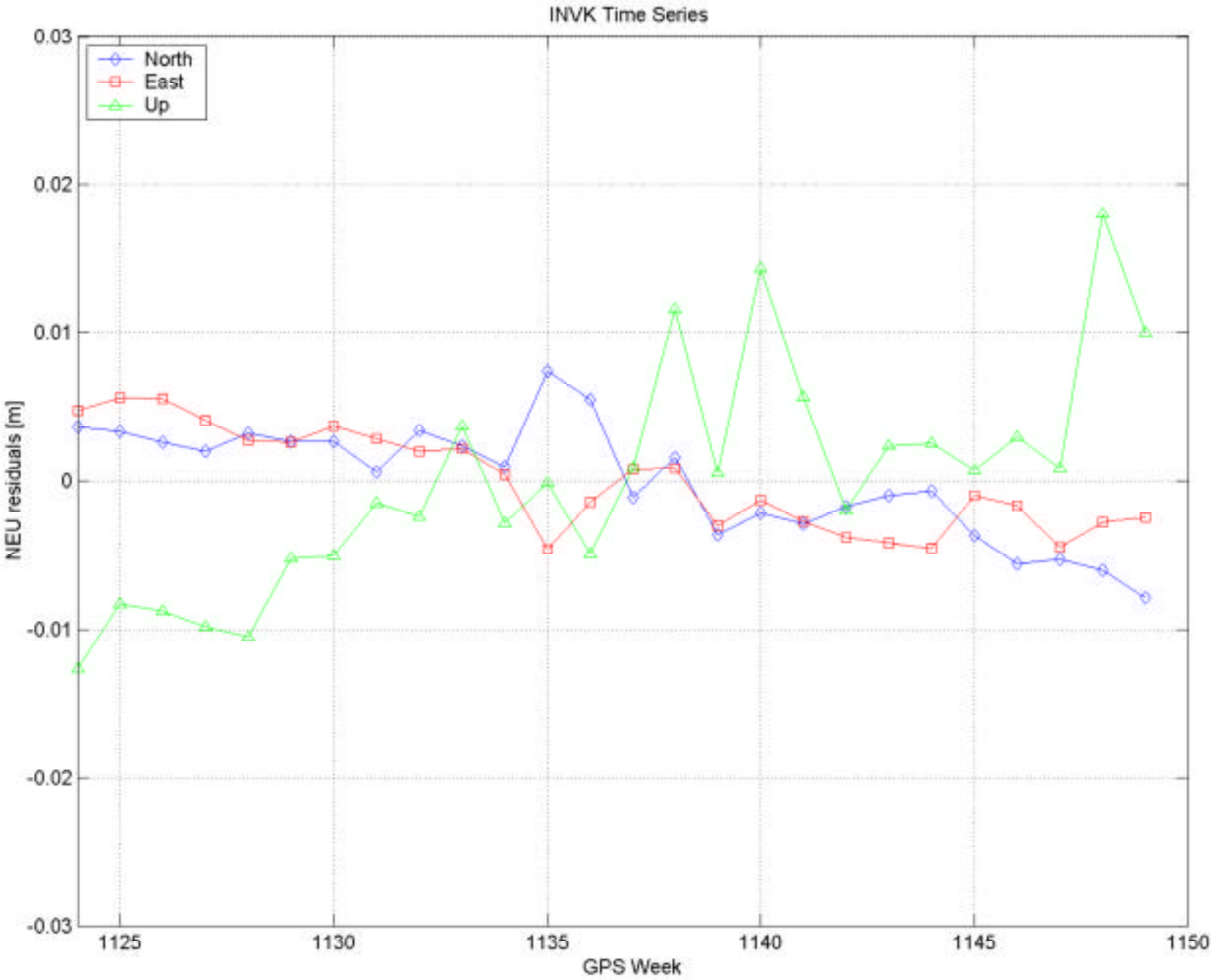
Time Series Plots

- For selected densification points
- Show typical variations in weekly solutions
- In terms of NEU (north, east, up) components
- Coordinate “residuals” are with respect to mean


ALBH Time Series
North
East
Up
NEU residuals [m]
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
1095
1100
1105
1110
1115
1120
1125
1130
1135
1140
1145
1150
GPS Week


CAGS Time Series
North
East
Up
NEU residuals [m]
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
1095
1100
1105
1110
1115
1120
1125
1130
1135
1140
1145
1150
GPS Week


LIND Time Series
North
East
Up
NEU residuals [m]
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
1095
1100
1105
1110
1115
1120
1125
1130
1135
1140
1145
1150
GPS Week


INVK Time Series
North
East
Up
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
NEU residuals [m]
1125
1130
1135
1140
1145
1150
GPS Week

Future Work

Incorporate other regional networks/solutions

- OSU/NGS Great Lakes CORS network (21 Stations) – in progress
- GPS at Arctic Tide Gauges (4 stations) – Summer 2002
- CORS network (would cover entire US) – ??
- Mexican GPS network (about 10 stations) – ??

Submissions to CDDIS to begin next week

- Weekly solutions since beginning of 2001

Regular cumulative solutions with velocities