

# NAREF & CBN Velocity Solutions for a New Version of SNARF



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# Outline



## NAREF velocity solution (Continuous GPS)

- Data used
- Weekly solutions
- Cumulative (velocity) solution
- Plate motion estimates

## CBN velocity solution (Episodic GPS)

- Data used
- Epoch solutions
- Cumulative (velocity) solution

## Future plans





# NAREF Data



## Combination of regional continuous GPS solutions

Regional Solutions	Solutions Since	# Stations Used (GPS Week 1399)
GSD (Bernese)	2001.0	112
GSD (GIPSY)	2001.0	43
PGC WCDA (Bernese)	2001.0	55
NGS CORS (PAGES)	2002.0	762
SIO PBO (GAMIT)	2001.0	140
MIT PBO Combination	2006.0	183





# Stations in Multiple Solutions (Stations with Redundant Checks)

GPS Week 1399 – 708 Stations Total

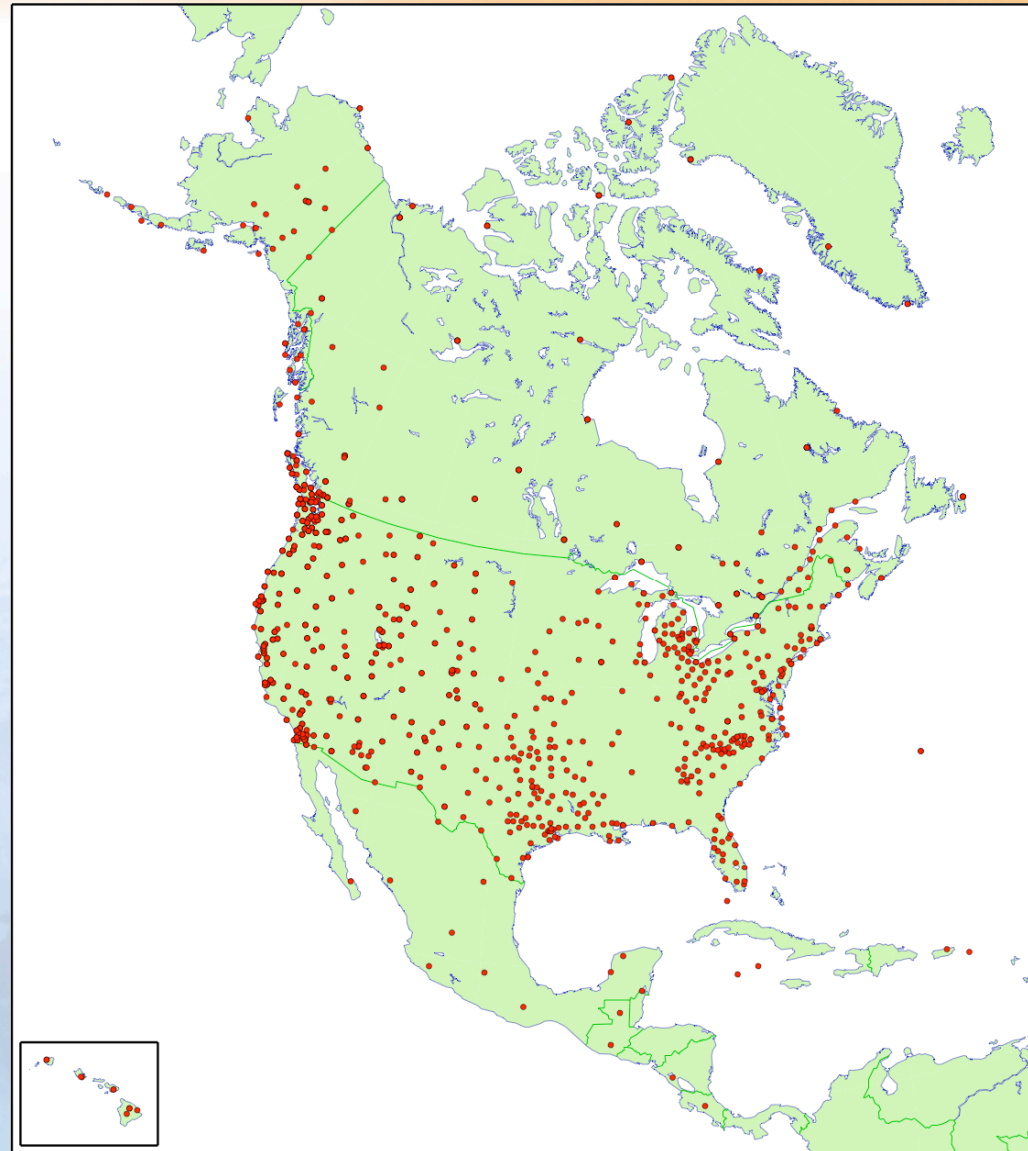
	Number of Stations	Percentage
1 Solution	488	69%
2 Solutions	94	13%
3 Solutions	95	13%
4 Solutions	21	3%
5 Solutions	7	1%
6 Solutions	3	0.4%





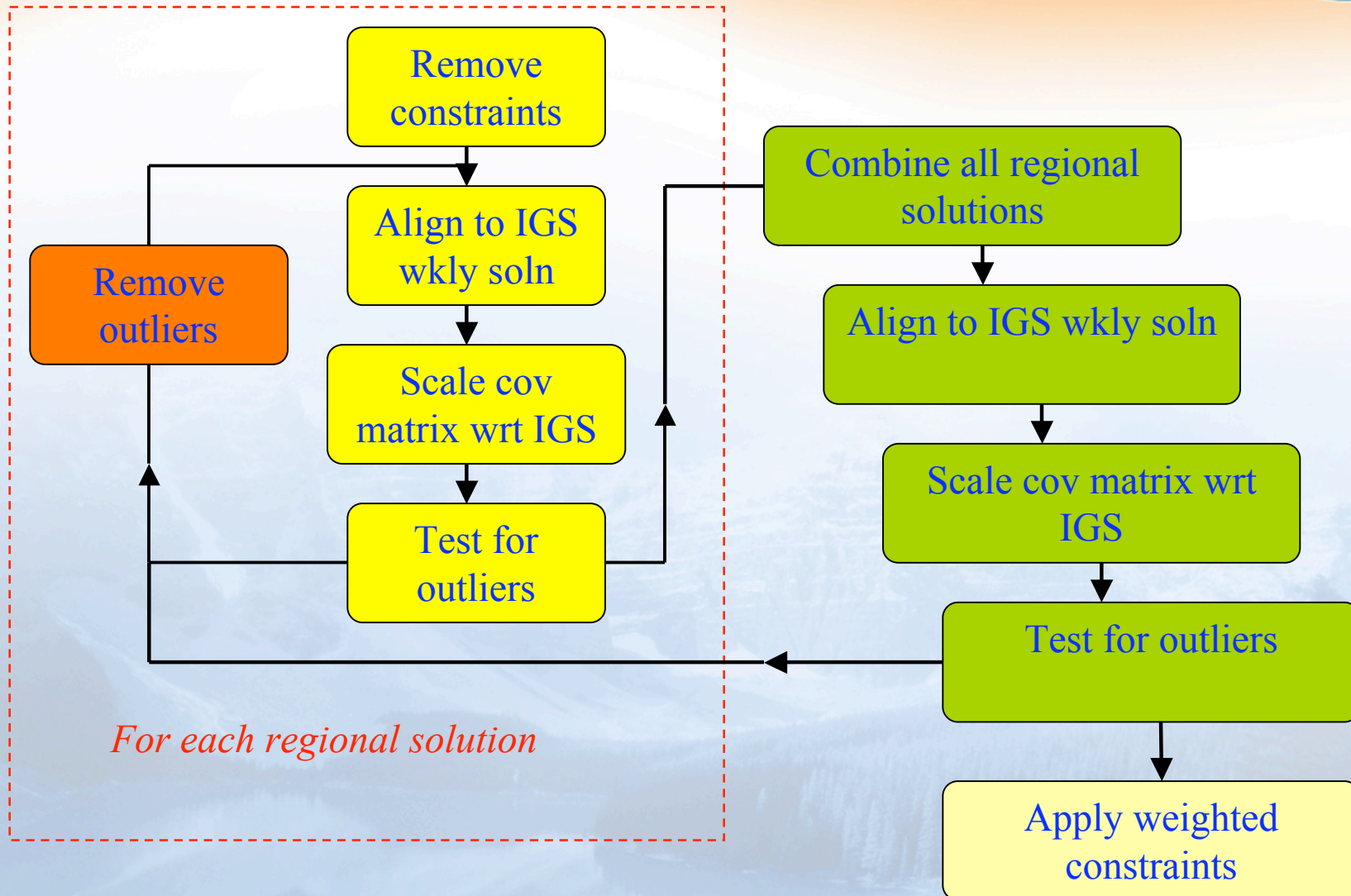
# NAREF Combination Network

GPS Week 1399  
708 stations total  
56 IGS constraint  
stations





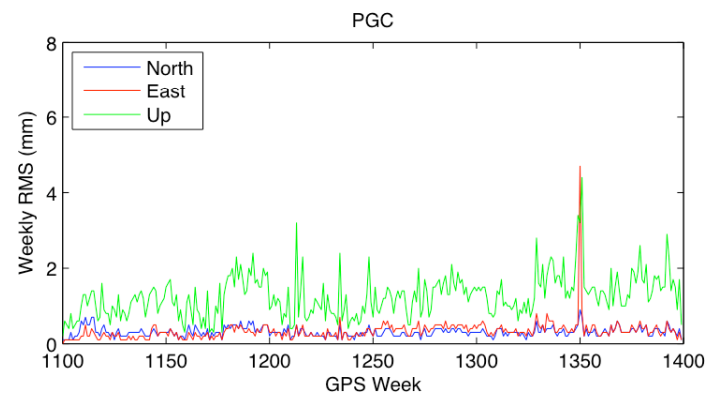
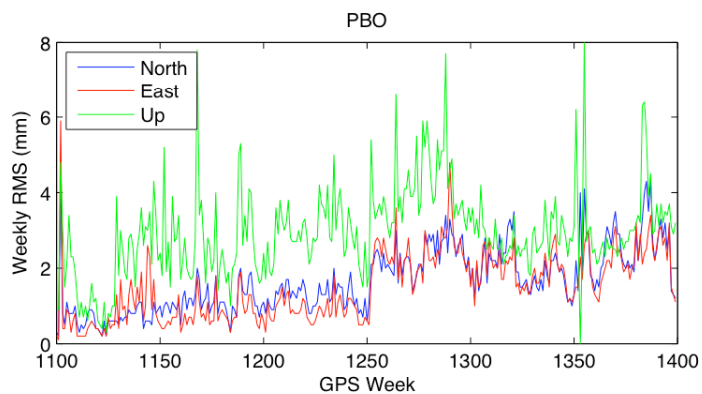
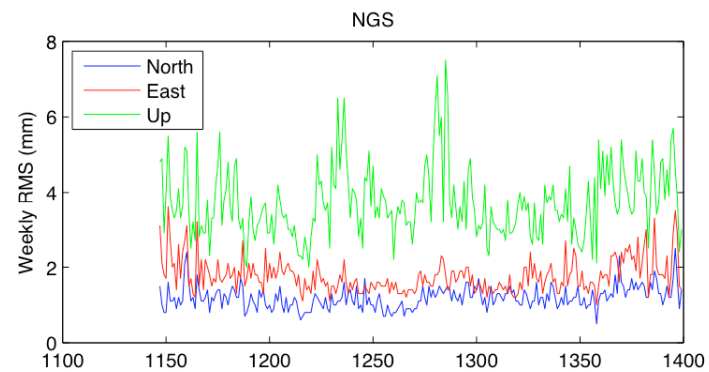
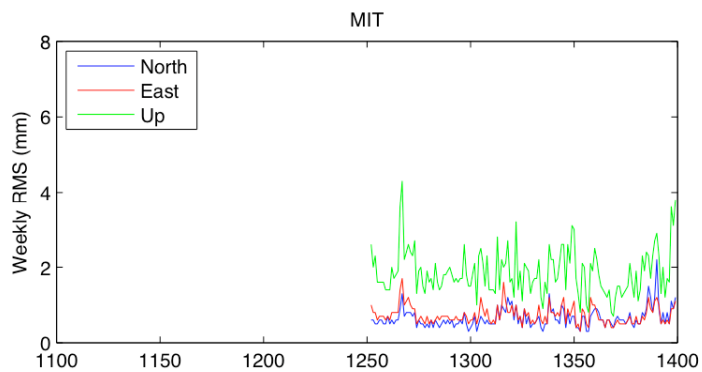
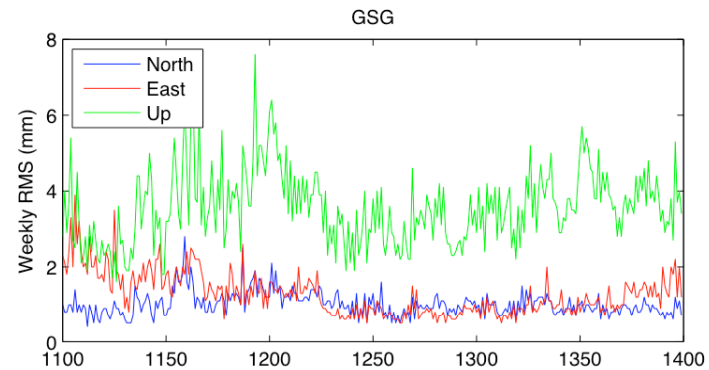
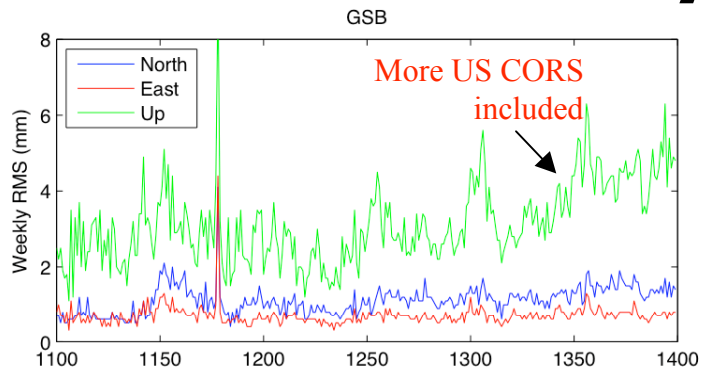
# Weekly Combination Procedure



*For each regional solution*

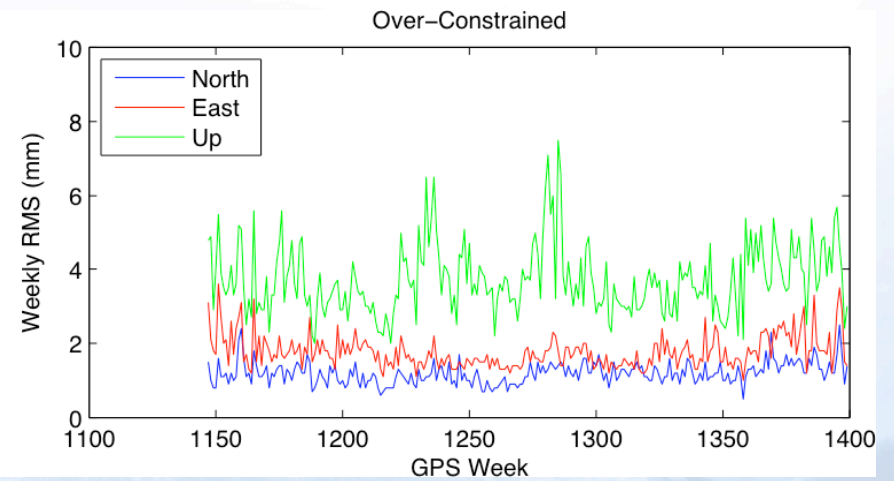
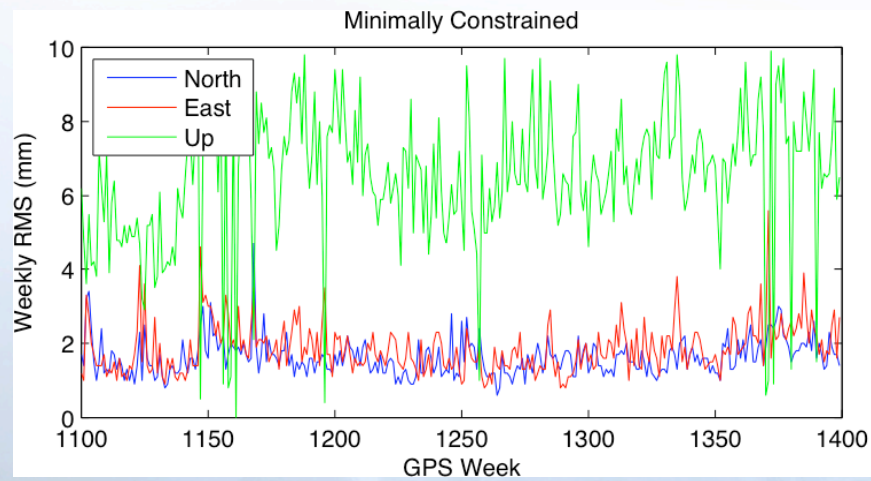


# RMS of Weekly Regional Solutions vs. Weekly Combinations





# RMS of Weekly NAREF Combinations vs. IGS Weekly Reference Frame







# NAREF Cumulative Combination



- 1) Removed a priori constraints from weekly NAREF solutions
- 2) Aligned weekly solutions to IGS05
  - 7 parameter transformation
  - Used 11 N.A. sites in IGS05
  - Propagated IGS05 to epoch of week
- 3) Combined aligned weekly solutions & estimated velocities
  - Used official IGS/ITRF discontinuity table + NAREF discontinuities
- 4) Applied velocity equivalence constraint across discontinuities where appropriate
- 5) Re-aligned cumulative solution to IGS05 (14 parameters)
- 6) Analysed residual time series for additional discontinuities
  - Add to discontinuity table and restart from step (3)
- 7) Optionally included IGS05 solution as a priori constraints





# NAREF Velocity Solution



## Summary statistics

- Time span of weekly solutions 2001-2006 (wks 1195-1399)
- Number of weekly solutions used 305
- Number of stations available 906
- Number of stations used 578 (328 omitted\*)

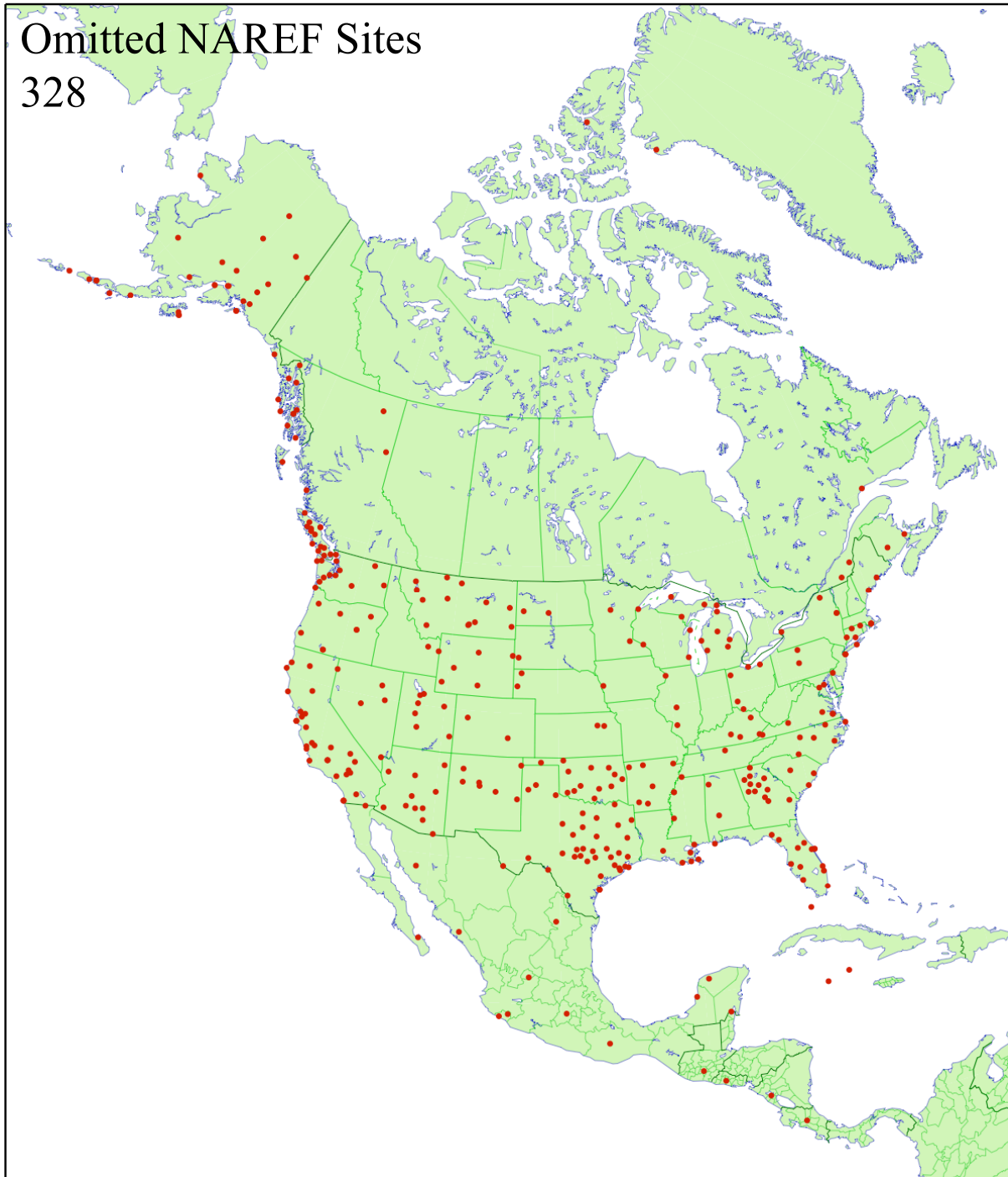
## \*Reasons for omitting sites

- Short time span (less than 2 yr) ~260 sites
- Collocated/redundant sites (mainly USCG sites) ~50 sites
- “Bad” time series (noisy, gaps, multiple offsets) ~20 sites



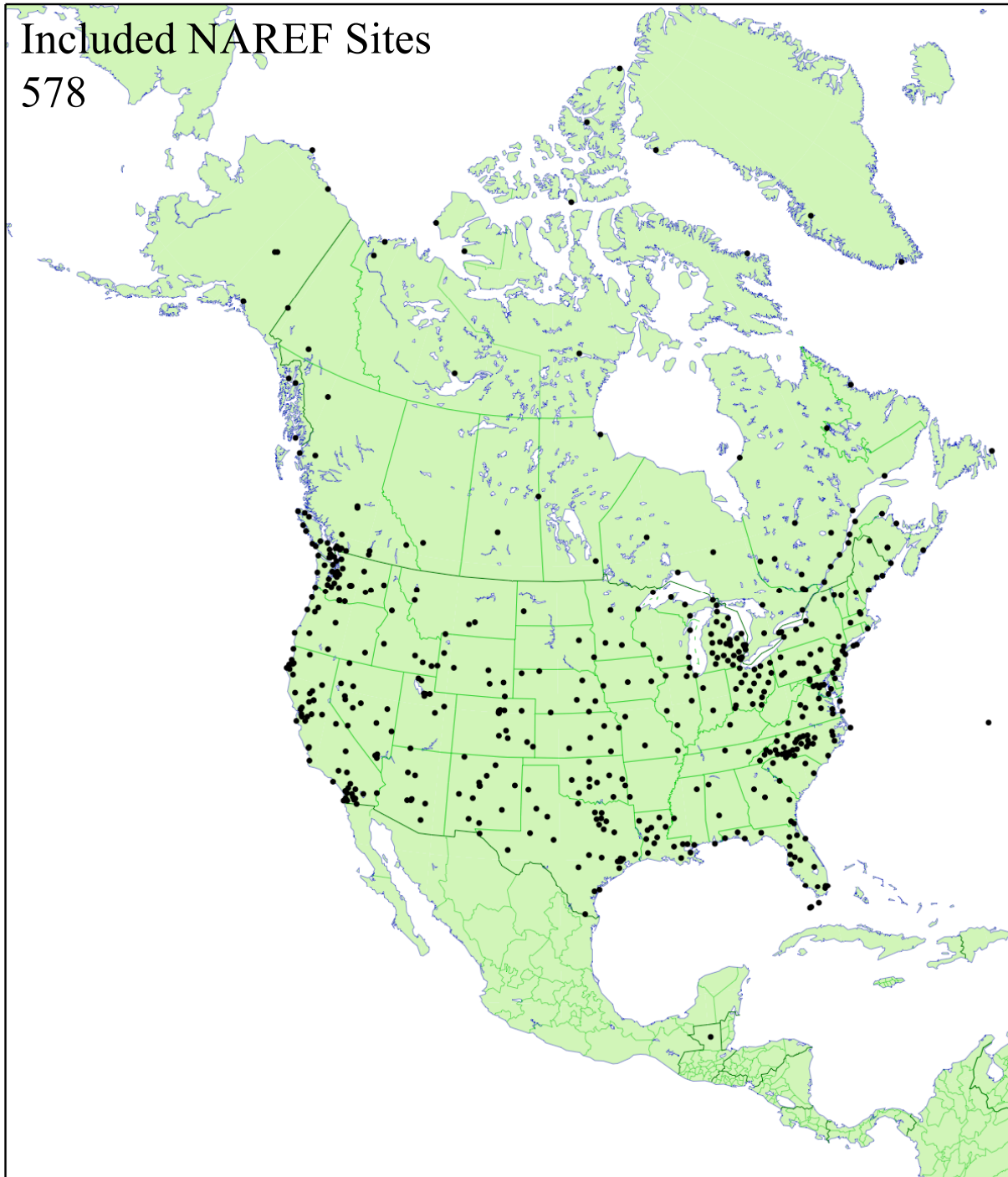
# Omitted NAREF Sites

328

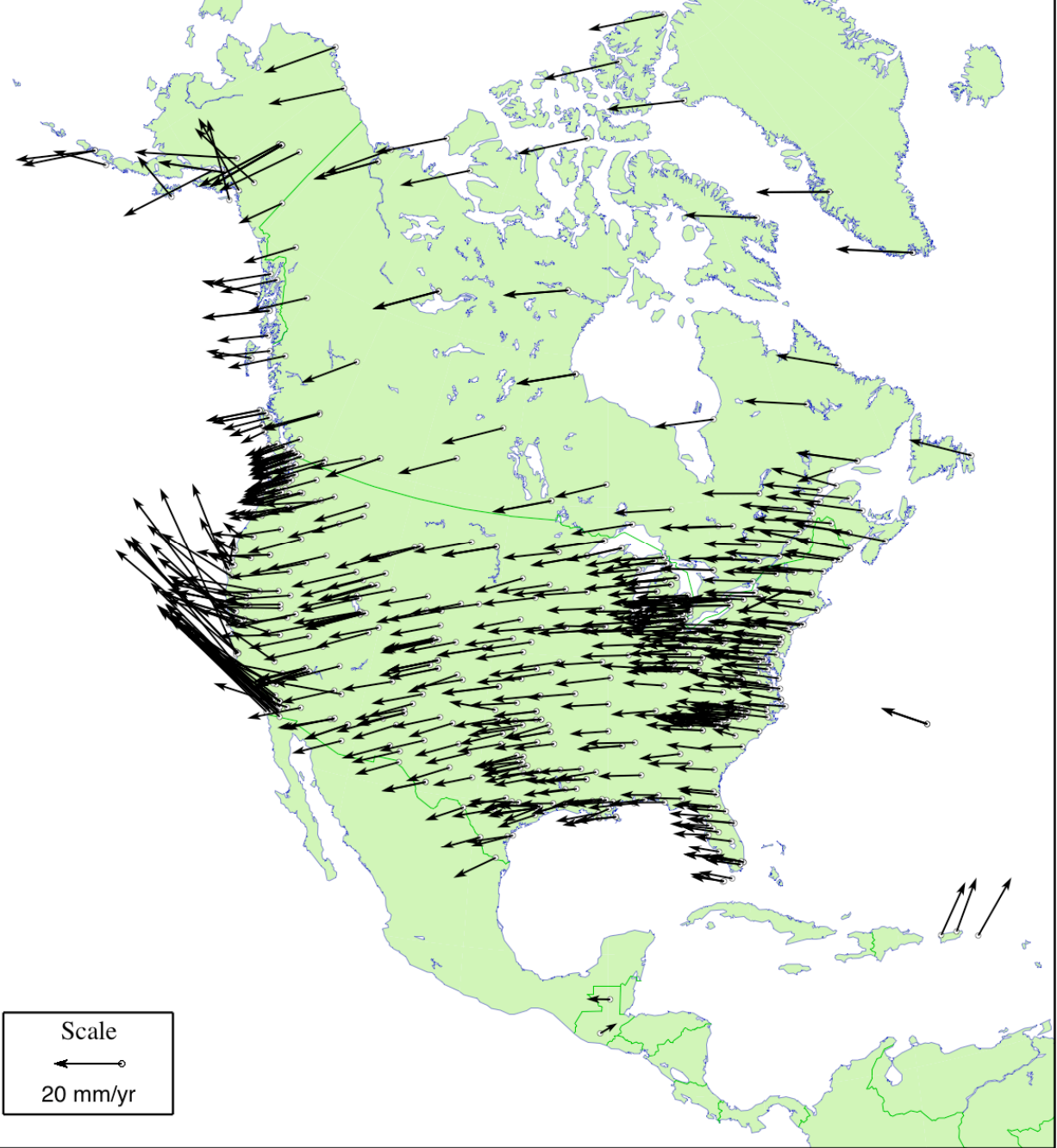


# Included NAREF Sites

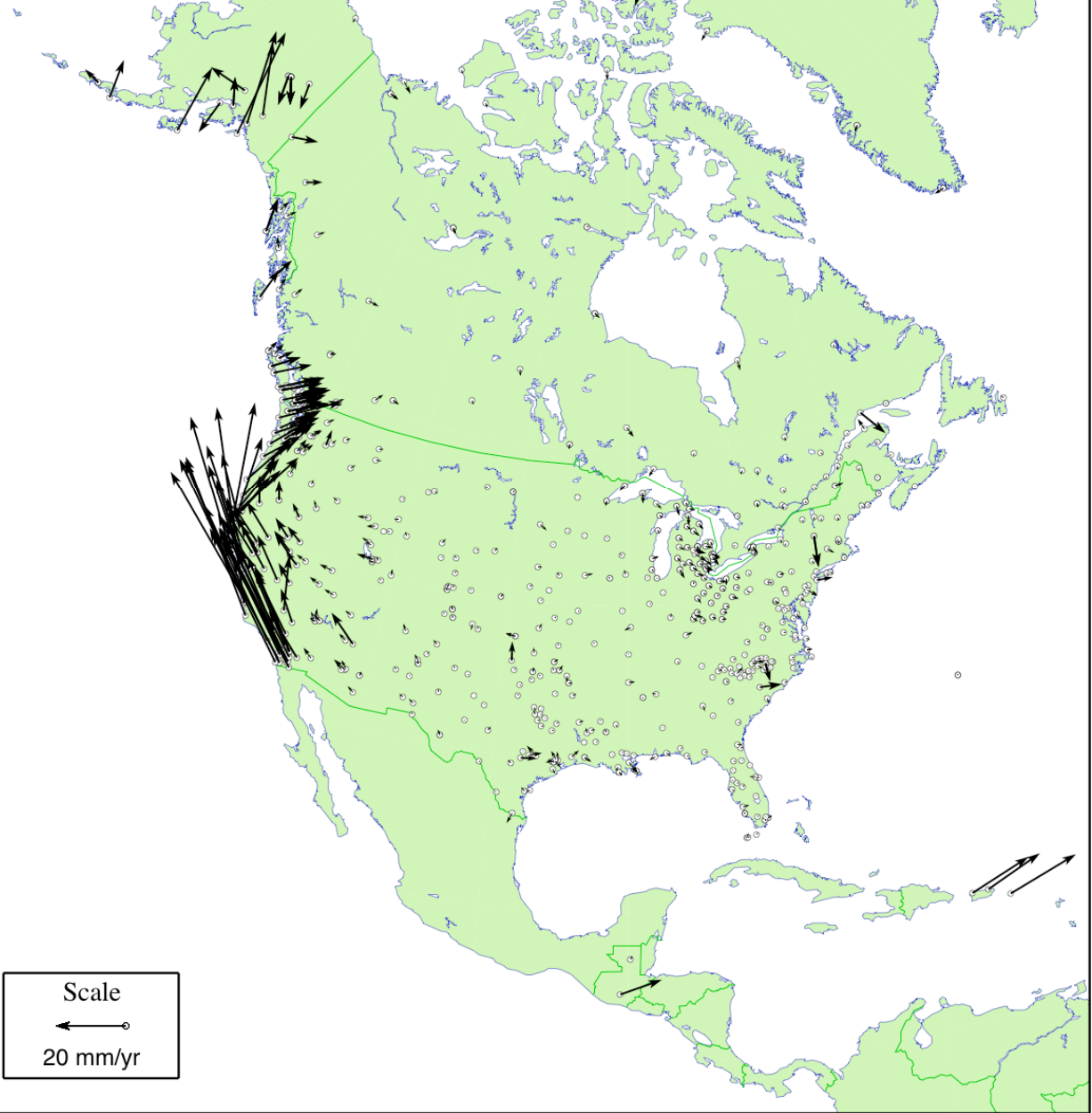
578



# NAREF Horizontal Velocities

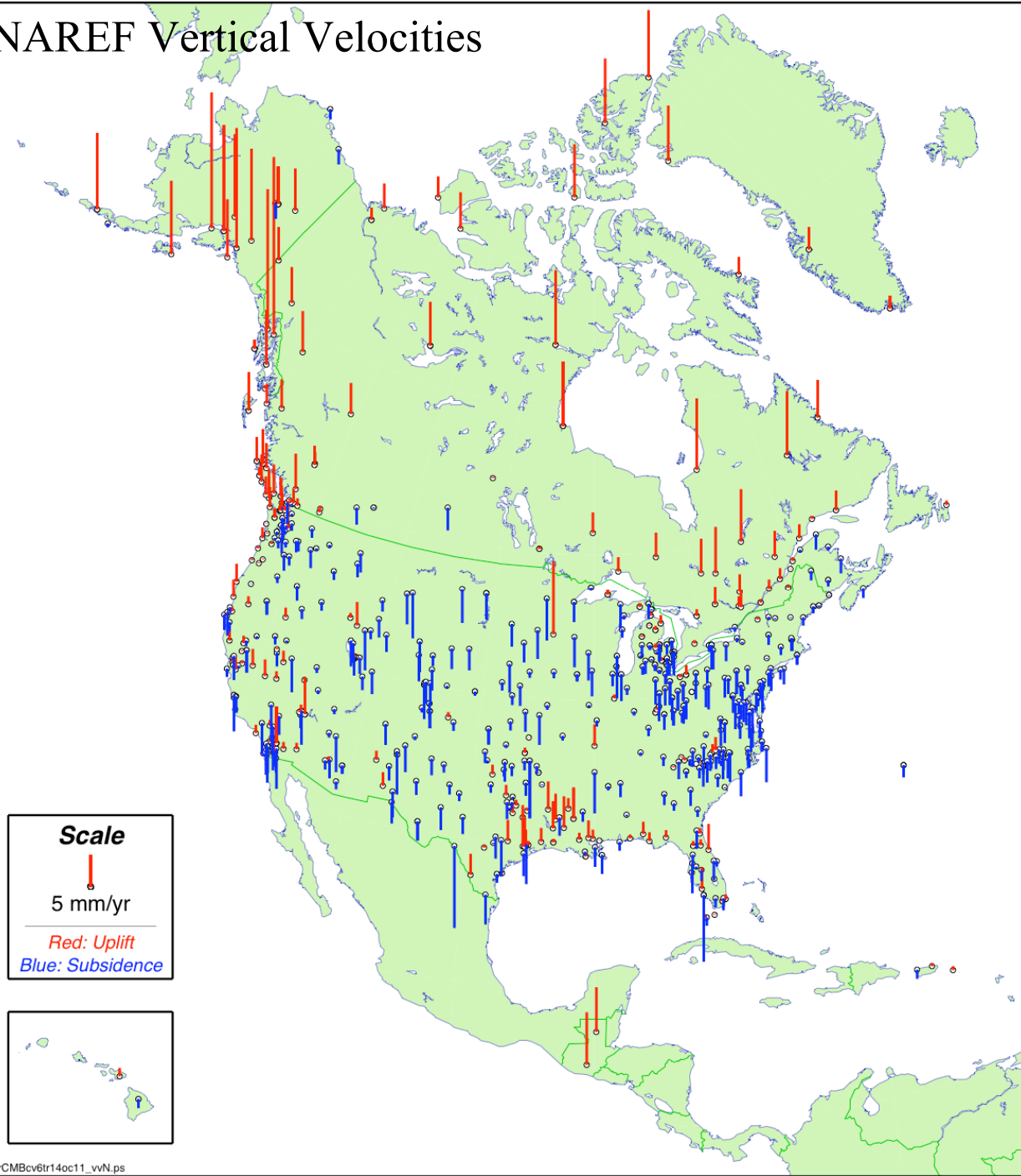
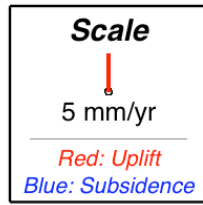


# NAREF Horizontal Velocities w.r.t. ITRF2005 plate motion



Scale  
←→  
20 mm/yr

# NAREF Vertical Velocities





# Plate Motion Estimates



Based on same 29 sites used by UNR

	RY (mas/y)	RY (mas/y)	RZ (mas/y)
ITRF2005	0.0314	-0.6685	-0.0517
UNR (7 t+r+s)	0.0871	-0.7242	-0.1160
NAR (3 r)	0.0263	-0.7079	-0.0524
NAR (6 t+r)	0.4313	-0.5739	-0.0137
NAR (3 t+r+s)	0.4533	-0.5996	-0.0367





# NAREF Horizontal Velocities w.r.t. NAR (3 r)

Scale  
←→  
10 mm/yr



# NAREF Horizontal Velocities w.r.t. NAR (6 t+r)





# Canadian Base Network (CBN)





# CBN Data & Episodic Solutions



## CBN (Canadian Base Network) episodic data

- Using 27 repeated campaign surveys from 1994 to 2006
  - 1st campaign 1994-1999 (no 1998)
  - 2nd campaign 2001/2002
  - 3rd campaign 2005/2006
  - Several other smaller campaigns
- Each stations occupied multiple times in each campaign
  - 3-5 independent occupations
  - 24 hr observation sessions

## All epochs processed with Bernese GPS Software v5.0

- Same processing strategy as for continuous GPS





# CBN Cumulative Combination



- 1) Removed a priori constraints from individual CBN solutions
- 2) Aligned solutions to common sites in IGS05
  - 7 parameter transformation
  - IGS05 propagated to epoch of each CBN solution
- 3) Each CBN covariance matrix scaled by WRMS of residual from alignment
- 4) Combined all aligned/scaled CBN solutions (summation of normals) & estimated velocities
  - Used official IGS/ITRF discontinuity table for IGS sites
  - Optionally included translations for each solution
- 5) Applied velocity equivalence constraint across discontinuities where appropriate
- 6) Re-aligned cumulative solution to IGS05 (14 parameters)
- 7) Optionally included IGS05 solution as a priori constraints



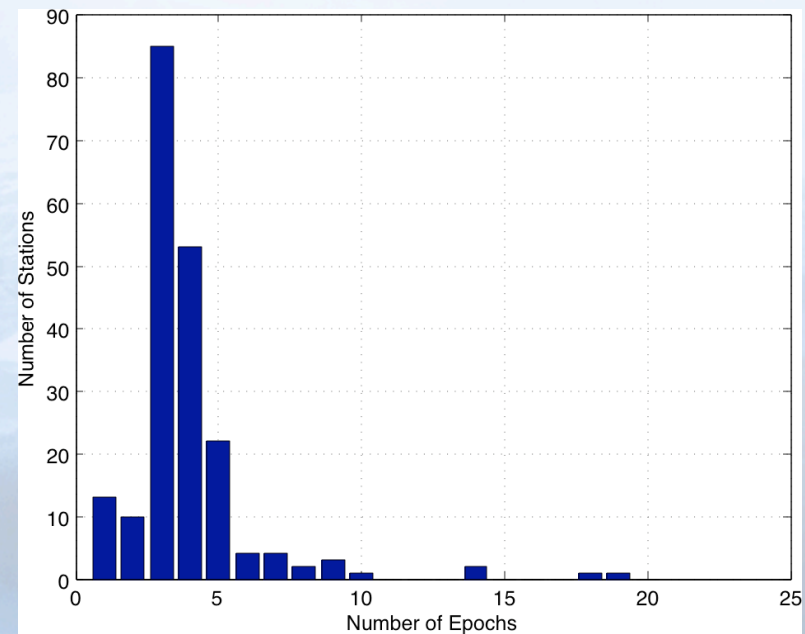
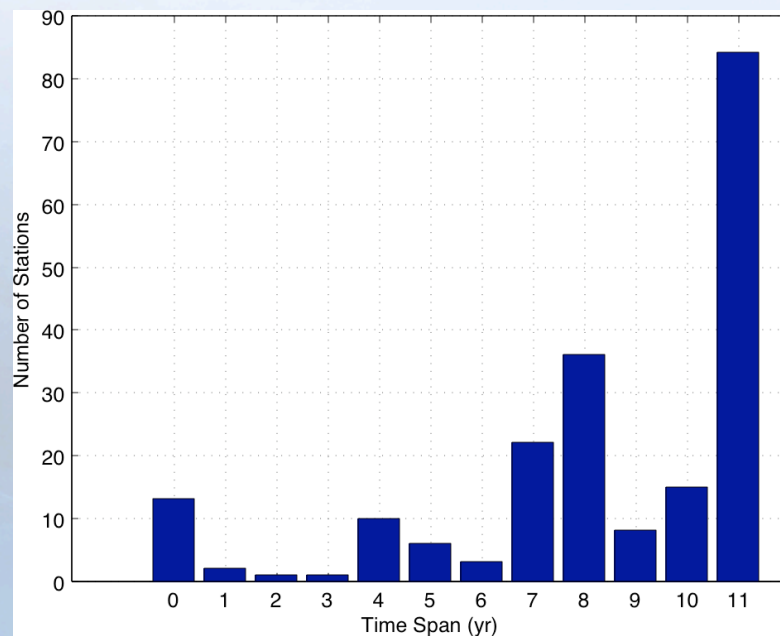


# CBN Velocity Solution

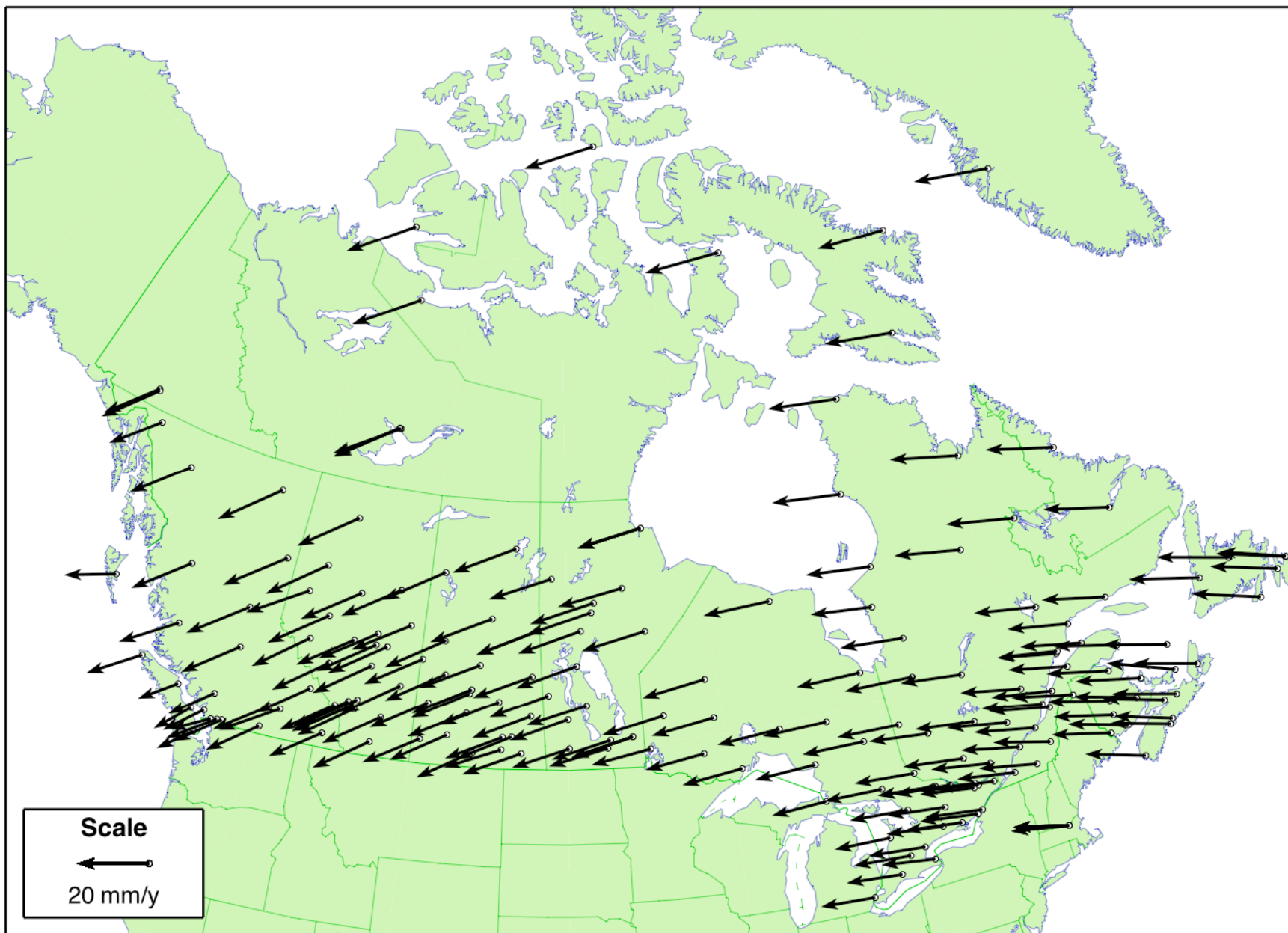


## Summary statistics

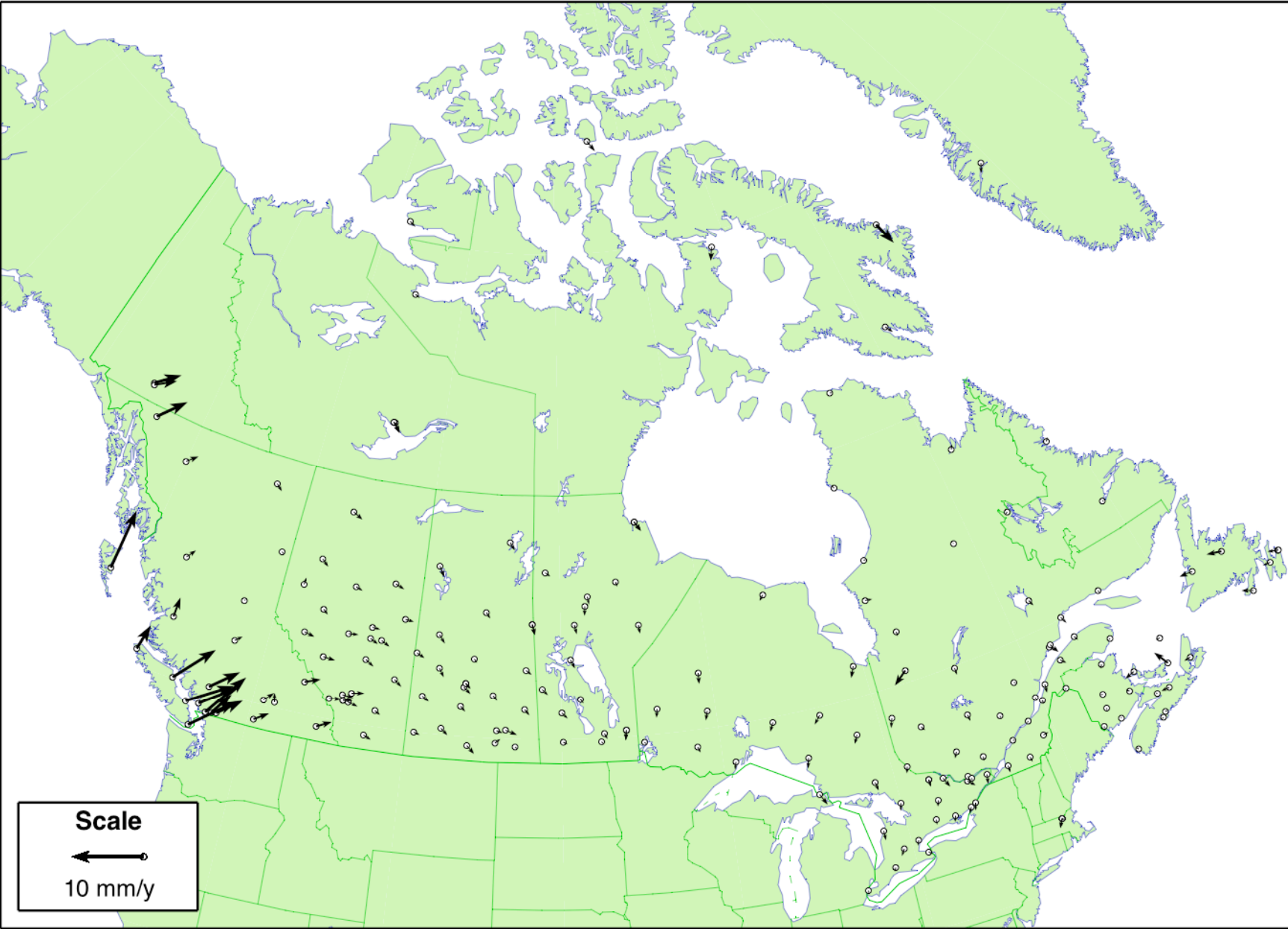
- Time span of episodic solutions 1994-2006 (12 yr)
- Number of episodic solutions 27
- Number of stations (incl. IGS sites) 206
- Total number of parameters 1,170



# CBN Horizontal Velocities

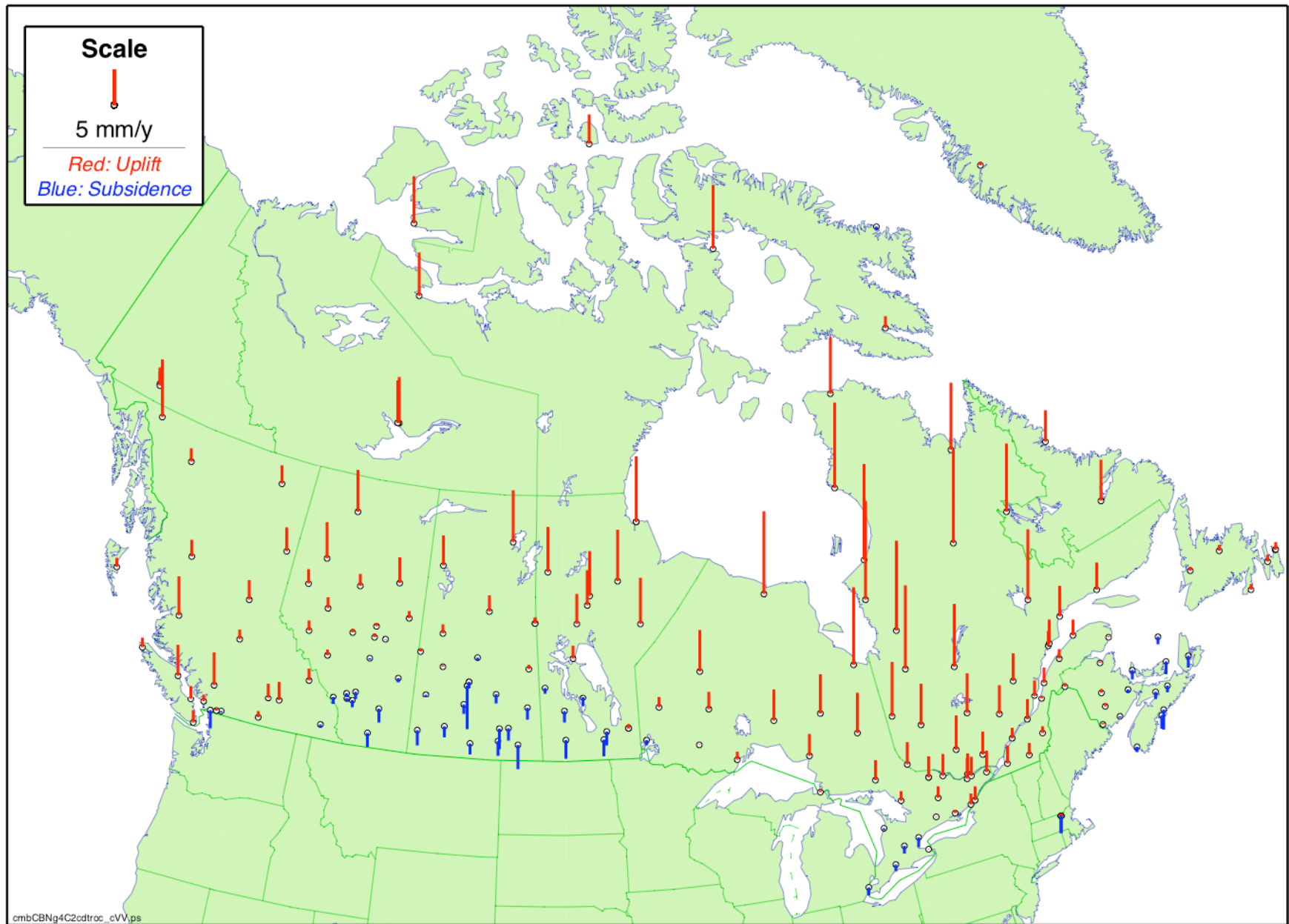


# CBN Horizontal Velocities w.r.t. ITRF2005 Plate Motion





# CBN Vertical Velocities





# Future Solutions

*Need to reprocess all data again due to...*

IGS adoption of absolute PCV since week 1400

- Solutions since 1400 incompatible with older ones
- Need reprocessed older IGS orbits with absolute PCV

Including more NAREF stations

- Upgrading SINEX software to handle >2000 stations
- Will include all sites submitted by contributors
- Will include more global stations for better frame realization

Additional redundancy in NAREF combination

- SIO will process all Canadian & many more CORS stations
- Will provide more redundancy for CORS stations

No new CBN surveys planned until after 2010

- Only eastern part in support of new IGLD





# Acknowledgements

## NAREF regional solution contributors

- NGS – Mike Cline et al.
- SIO – Peng Fang & Yehuda Bock
- PGC – Herb Dragert
- MIT – Tom Herring
- GSD GIPSY solution – Caroline Huot & Brian Donahue

## SINEX combination software

- Remi Ferland





# Time Series Offsets

