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

Defining a Plate-Fixed Regional Reference Frame

The SNARF Experience

The SNARF Working Group

G. Blewitt, D. Argus, R. Bennett, Y. Bock, E. Calais, M. Craymer, J. Davis, T. Dixon, J. Freymueller, T. Herring, D. Johnson, K. Larson, M. Miller, G. Sella, R. Snay, M. Tamisiea

Presented by Mike Craymer
Geodetic Survey Division, Natural Resources Canada

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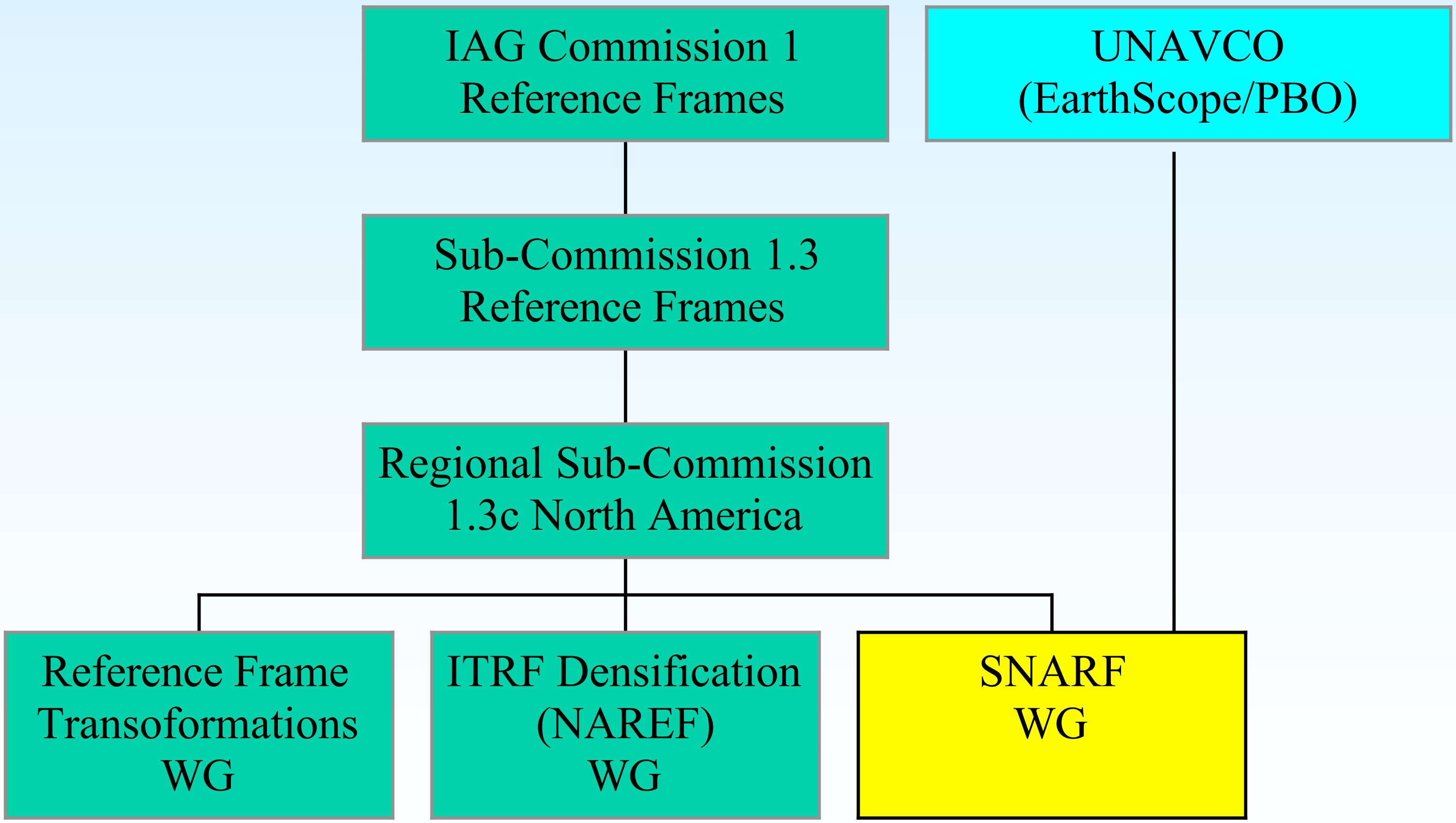
Abstract

Regional reference frames fixed to the stable part of a tectonic plate are often required to facilitate geophysical interpretation and inter-comparison of geodetic solutions of crustal motions. In 2003, the Stable North American Reference Frame (SNARF) Working Group was established under the auspices of UNAVCO and the IAG Regional Sub-Commission 1.3c for North America to address such pressing needs for the EarthScope project. The goal is to define a regional reference frame stable at the sub-mm/yr level. The SNARF Working Group identified and addressed several issues that must be dealt with to properly define such regional frames, including (1) the selection of "frame sites" based on geologic and engineering criteria for stability, (2) the selection of a subset of "datum sites" which represent the stable part of the plate and will be used to define a no-net rotation condition, (3) the modeling of any significant intra-plate motions using a relatively dense GPS velocity field, and (4) the generation and distribution of products for general use. In the case of SNARF, the vertical datum is consistent with ITRF2000 in that the center of mass of the whole Earth system is taken to be the origin while the horizontal datum differs by a rotation rate that brings the rotation of the stable part of North America to rest. The first release of SNARF provides a rotation rate vector that transforms ITRF2000 velocities into the SNARF frame, and an initial reference frame defined as a list of selected sites, epoch coordinates and velocities in a Cartesian system. Over the next few years SNARF will be incrementally improved through further research.

Outline

- Objective & rationale
- Issues addressed
- SNARF v1.0 results
- Future improvements
- Long term maintenance

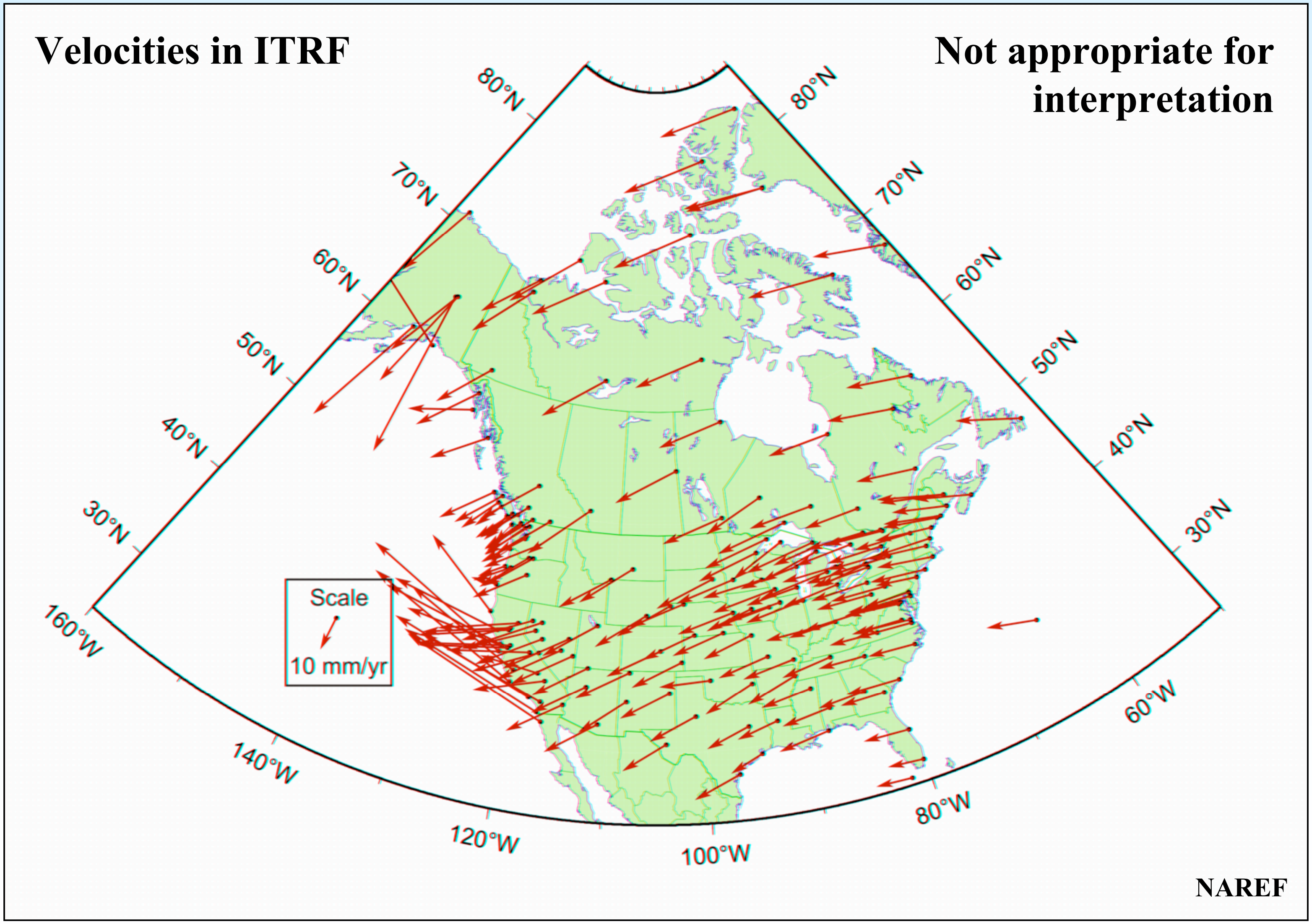
Working Group



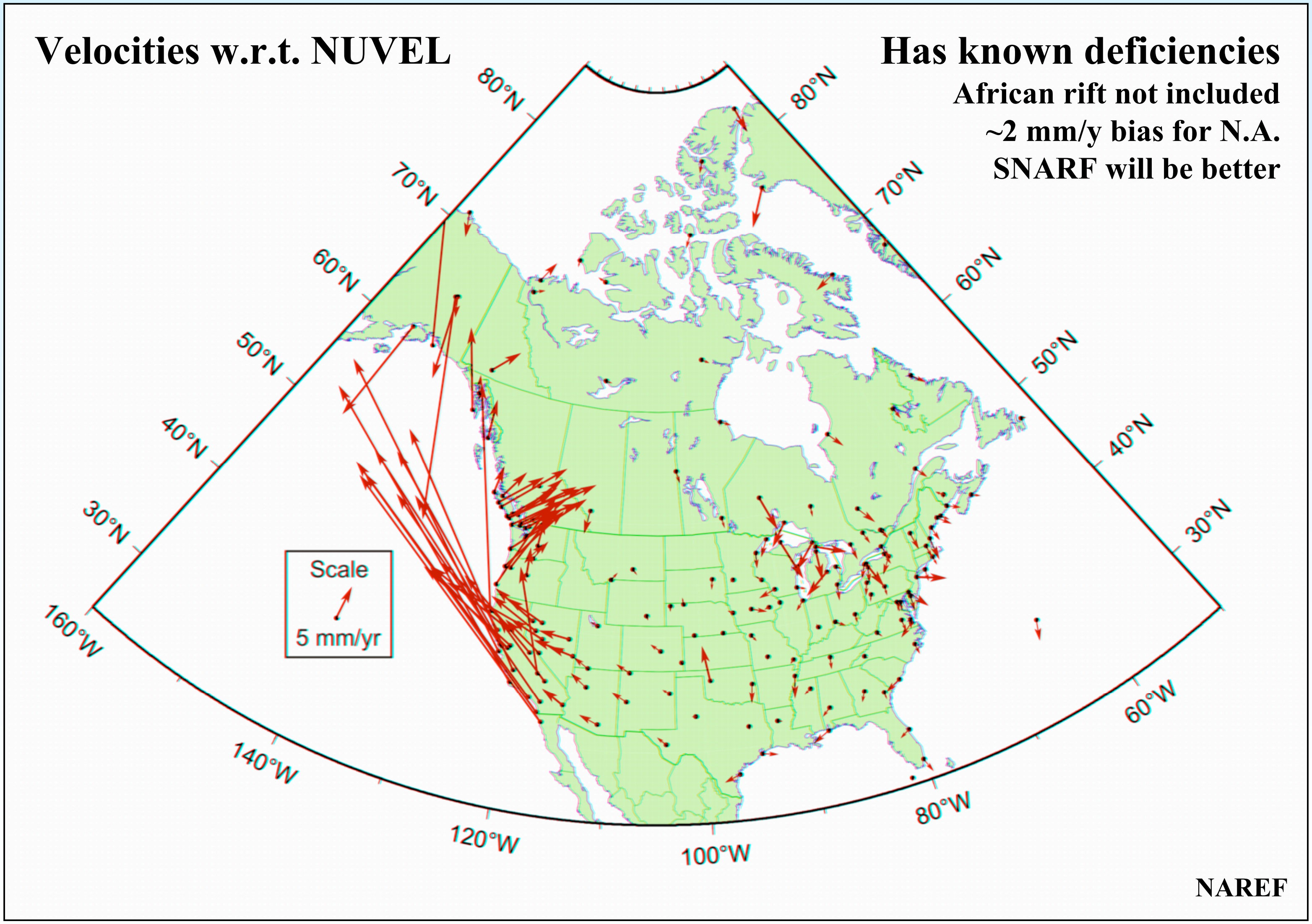
Objective & Rationale

- SNARF -- Stable North American Reference Frame
- Define a reference frame that represents the stable interior of North America
- Why?
  - More appropriate frame to describe relative motions of
    - Sites in N.A.
    - Sites spanning adjacent plate boundaries
  - Provides standardization to facilitate
    - Geophysical interpretation
    - Inter-comparison of solutions
    - Primarily for EarthScope/PBO studies

Why Not Use ITRF?

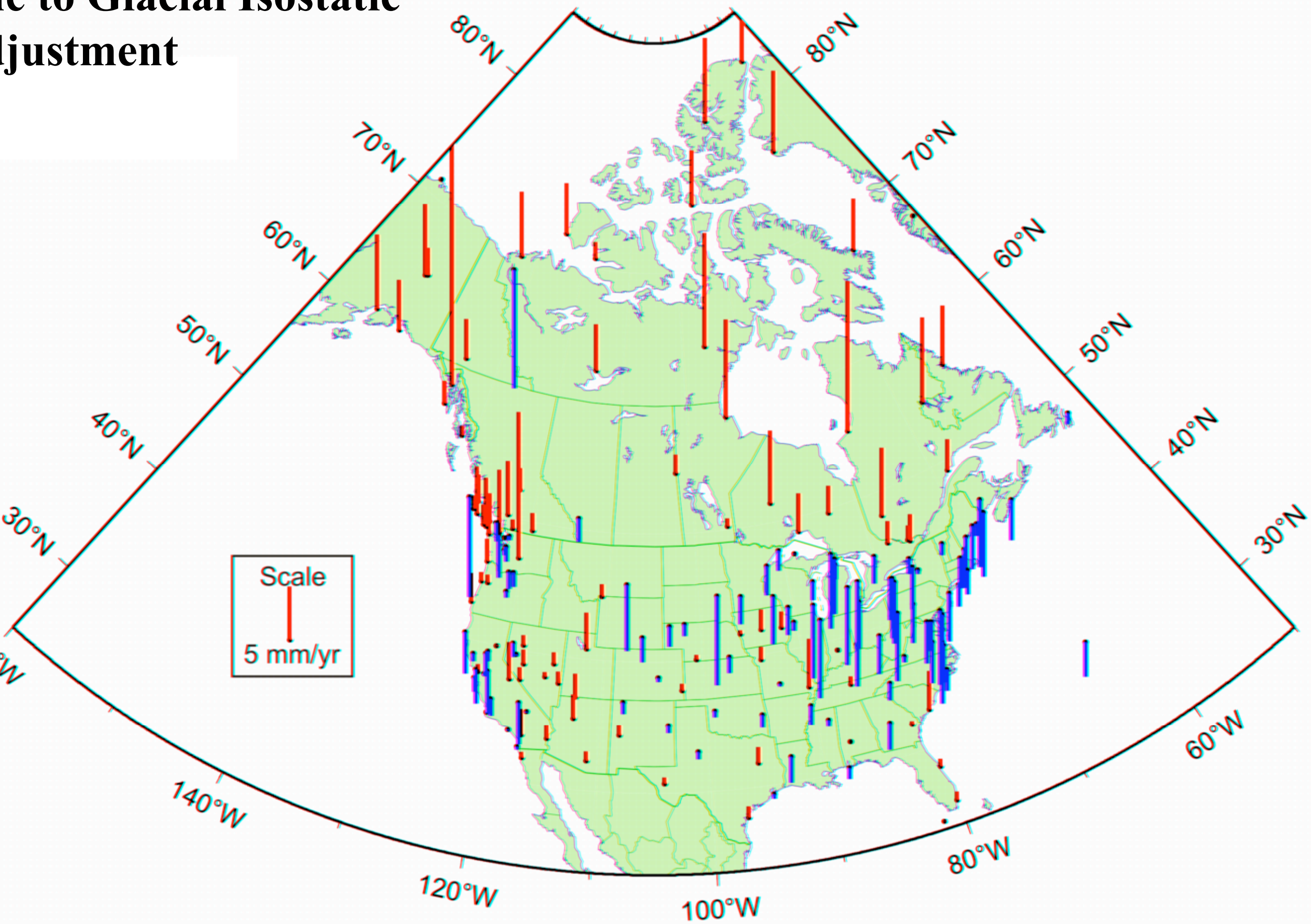


Why Not Use NNR NUVEL-1A?



Significant Vertical Velocities

Due to Glacial Isostatic Adjustment



NAREF

Issues Addressed

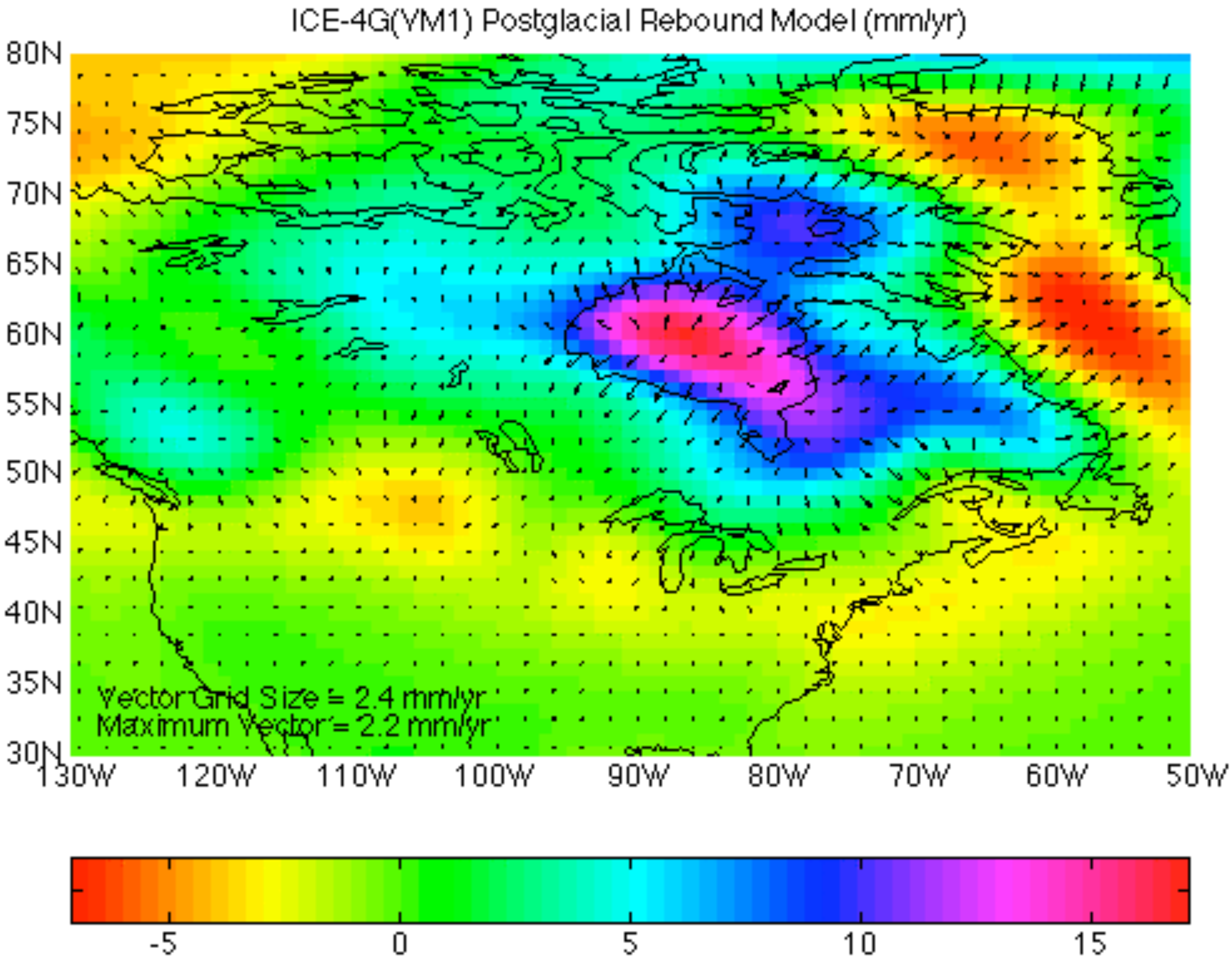
1) Selection of “frame” sites
2) Selection of “datum” sites
3) Intra-plate motions
4) Products to be distributed
5) Product use

1) Selection of Frame Sites

- Sites that will be used to define the frame
- Sites for which velocity can be reliably estimated
- Selection criteria
  - Geologic considerations (mainly for datum sites)
  - Stable monumentation
  - Geodetic-quality equipment
  - Data quality
  - Duration of data (>3 yr)

2) Selection of Datum Sites

- Subset of frame sites
- Represents the stable part of North America
- Sites affected by GIA not included initially
  - GIA has a horizontal component (see figure)
  - Affects estimation of plate rotation vector
  - May be included in future versions once a reliable GIA model can be determined
    - Will improve the estimation of plate rotation vector
    - Using sites further from rotation pole


ICE-4G(YM1) Postglacial Rebound Model (mm/yr)
80N
75N
70N
65N
60N
55N
50N
45N
40N
35N
30N
130W
120W
110W
100W
90W
80W
70W
60W
50W
Vector Grid Size = 2.4 mm/yr
Maximum Vector = 2.2 mm/yr
-5
0
5
10
15

3) Intra-Plate Motions

- Examples:
  - Tectonically induced deformations
  - Loading effects
  - Glacial Isostatic Adjustment (GIA) -- the dominate signal
- Difficult to select a particular GIA model
  - No consensus on Earth's viscosity structure
  - No consensus on ice history

4) SNARF Products

- Transformation from ITRF2000 to SNARF
  - Rotation between ITRF2000/IGb00 and SNARF velocity vectors
  - *Effectively defines the SNARF frame*
- Positions & velocities of frame sites
  - If velocity of site matches GIA motion, it is on stable part of N.A.
  - Differences represent non-GIA deformations
- GIA model velocities (horizontal & vertical)
  - Given on a grid and at frame sites

5) Product Use

- GPS data processing
  - Use IGS products (orbits & polar motion/UT1)
  - In IGb00 realization of ITRF2000; soon ITRF2004?
- To obtain SNARF coordinates/velocities
  - Rotate results into SNARF using adopted rotation vector
  - Could instead align results to SNARF frame -- but
    - Need to incorporate many SNARF frame sites in solution
    - Need to cover a large portion of North America
  - Optionally remove adopted GIA model velocities
    - To study non-GIA motions

SNARF v1.0 Results

- Just completed
- Positions & velocities estimated by Tom Herring
  - Based on weekly IGS densification solutions
- Estimated plate rotation vector from velocities of SNARF "datum" sites (~120?)

	ω_X	ω_Y	ω_Z	
SNARF	**0.0223**	**-0.1981**	**-0.0083**	**(deg/Myr)**
ITRF2000	0.0231	-0.1919	-0.0170	

- Close agreement as expected

GIA Model (1/2)

- Based on a novel technique by Jim Davis
  - Incorporates GPS velocities into an a priori GIA model
  - Using a Kalman filter
- GPS velocities
  - From a NAREF densification solution
    - Combines 5 different weekly solutions from 2001-2004

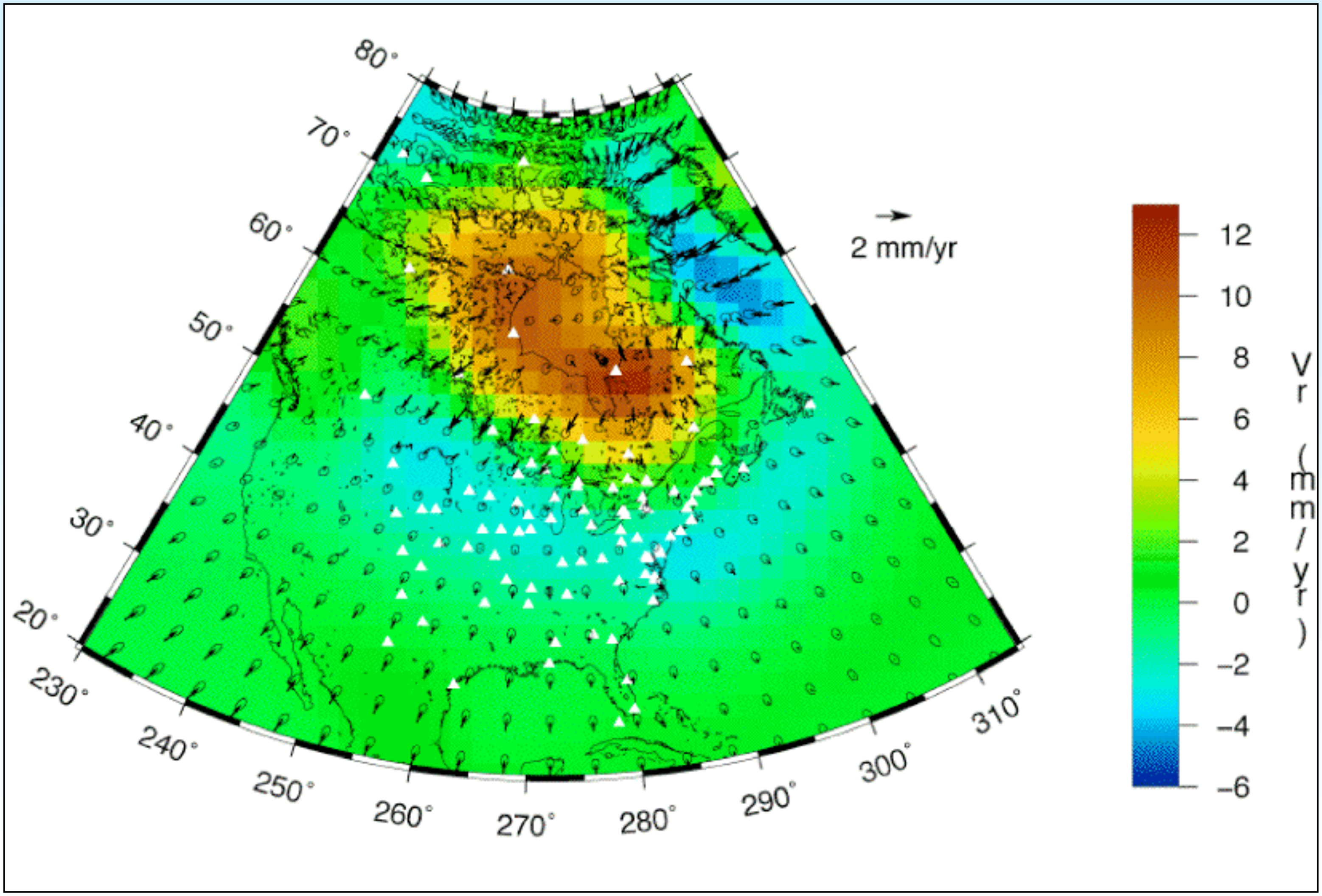
      NGS SIO NRCan/PGC

      NRCan/GSD (Bernese & GIPSY)
    - Velocities shown at beginning of presentation
  - Using only sites east of Rocky Mountains

GIA Model (2/2)

- A priori GIA model
  - Average of a suite of GIA models based on ICE-1
    - ICE-1 more appropriate than ICE-3G (Tushingham & Peltier, 1991)
  - Spanning a range of Earth model parameters
    - Lithospheric thicknesses
    - Upper & lower mantle viscosities
  - Variability of models used to construct a covariance matrix for the average model
- Details of technique to be published soon

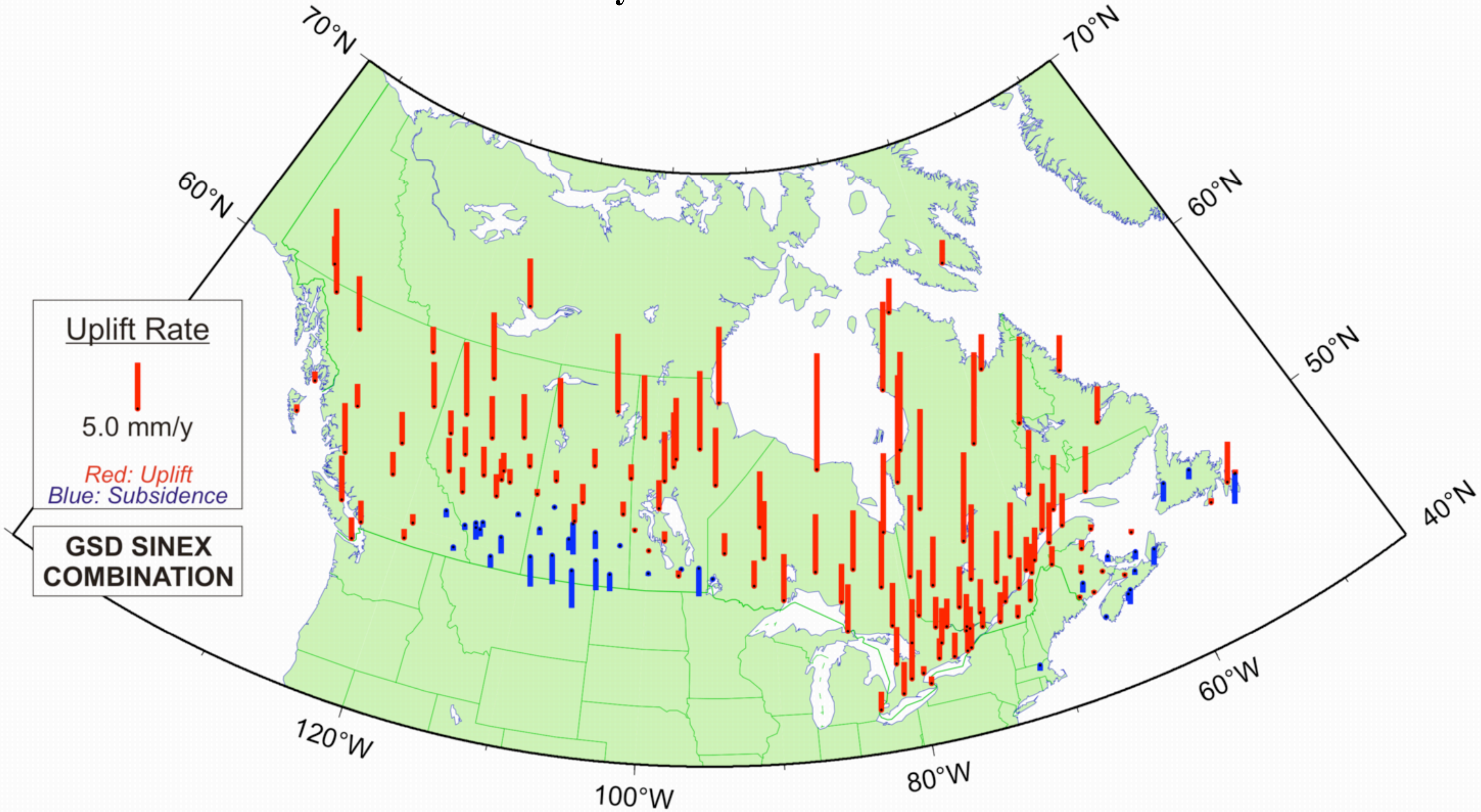
SNARF v1.0 GIA Model



Future Improvements

- Refine list of "datum" sites -- biggest task
  - Another 60 available if monumentation can be verified
  - GIA-affected sites may be suitable if GIA model is used (bootstrap approach)
- Densify GPS solutions for GIA modelling
  - Consider incorporating Canadian Base Network
- Consider modelling other intra-plate motions
  - Seasonal variations
  - Hydrologic and atmospheric loading (for day to day realization of SNARF)

Preliminary CBN Vertical Velocities



Long Term Maintenance

- Transition from research to operational mode by 2008
- National geodetic agencies in Canada & U.S.A.
  - Will continue to produce SNARF products
  - Will continue to improve & update the frame
  - Will produce NAREF regional combinations (weekly & cumulative) in both ITRF/IGS and SNARF
- SNARF expected to eventually supercede NAD83
  - NAD 83 offset by 2 m from geocenter
  - Presently defined in terms of NUVEL-1A plate motion

End

NAREF Densification Network

- **Solutions included:**
  GSD Can (Bernese)
  GSD Can (GIPSY)
  NGS CORS (PAGES)
  SIO PBO (GAMIT)
  PGC WCDA (Bernese)

- **Now over 600 stations**