Geologically Useful Reference Frame for North America

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Goal

Use GPS to establish a geologically useful reference frame to estimate motions of the North American rigid plate and hence assess deviations due to tectonic and non-tectonic processes.

Angular Velocities for North America

Author	Frame	Sites	North º	East º	ω º/Myr	σ_{maj} º	σ_{min} º	MRR mm/yr	χ^2
Argus and Gordon, 1996	VLBI	5						2	
Dixon et al., 1996	ITRF94	8	6.3	-81.8	0.202			1.3	
DeMets and Dixon, 1996	ITRF96	18	-0.9	-79.8	0.192				
Larson et al., 1997	ITRF94	7	-0.4	-84.5	0.22	4.3	2.0		
Newmann et al., 1999	ITRF96	18	-1.16	-80.2	0.193			1	
Kogan et al., 2000		10						0.5	0.9
Gan and Prescott, 2002	ITRF97	55	-1.88	-77.67	0.201			3.2	
Sella et al., 2002	ITRF97	64	-2.39	-79.08	0.199	0.8	0.3	0.9	1.05
Beavan et al, 2002	ITRF00	9	-3.86	-83.96	0.199	1.02	0.41	0.6	1.47
Altamimi et al., 2002	ITRF00	16	-5.04	-83.14	0.194				
Fernandes et al., 2003	ITRF00		-4.57	-83.15	0.195	1.69	0.55		
Steblov et al., 2003		14						1	
Sella (no sites near HB)	**ITRF00**	**83**	**-4.96**	**-85.34**	**0.195**	**1.0**	**0.3**	**1.1**	**1.08**
Sella with 46 GIA sites	**ITRF00**	**129**	**-4.72**	**-84.76**	**0.194**	**1.0**	**0.3**	**1.3**	**1.33**

Choice of sites:

Geographically representative distribution of sites

Stable plate:

>100 km from plate boundaries, seismicity, active faults (Avoid seismic cycle effects)

Rigid plate:

Minimize any plate wide effects e.g. GIA, subsidence, intra plate deformation (Recognize area affected)

Avoid any local effects e.g. fluid withdrawal or injection (Need independent info)

Avoid poorly monumented/malfunctioning sites (WRMS?)

Our Approach

Use geologic a priori criteria to exclude any sites not on stable plate. Sites are:

- -East of the Rocky Mountains
- -North of the central Gulf of Mexico Coast
- -No Memphis or Charleston sites
- -Exclude sites within ~1800 km of Hudson Bay

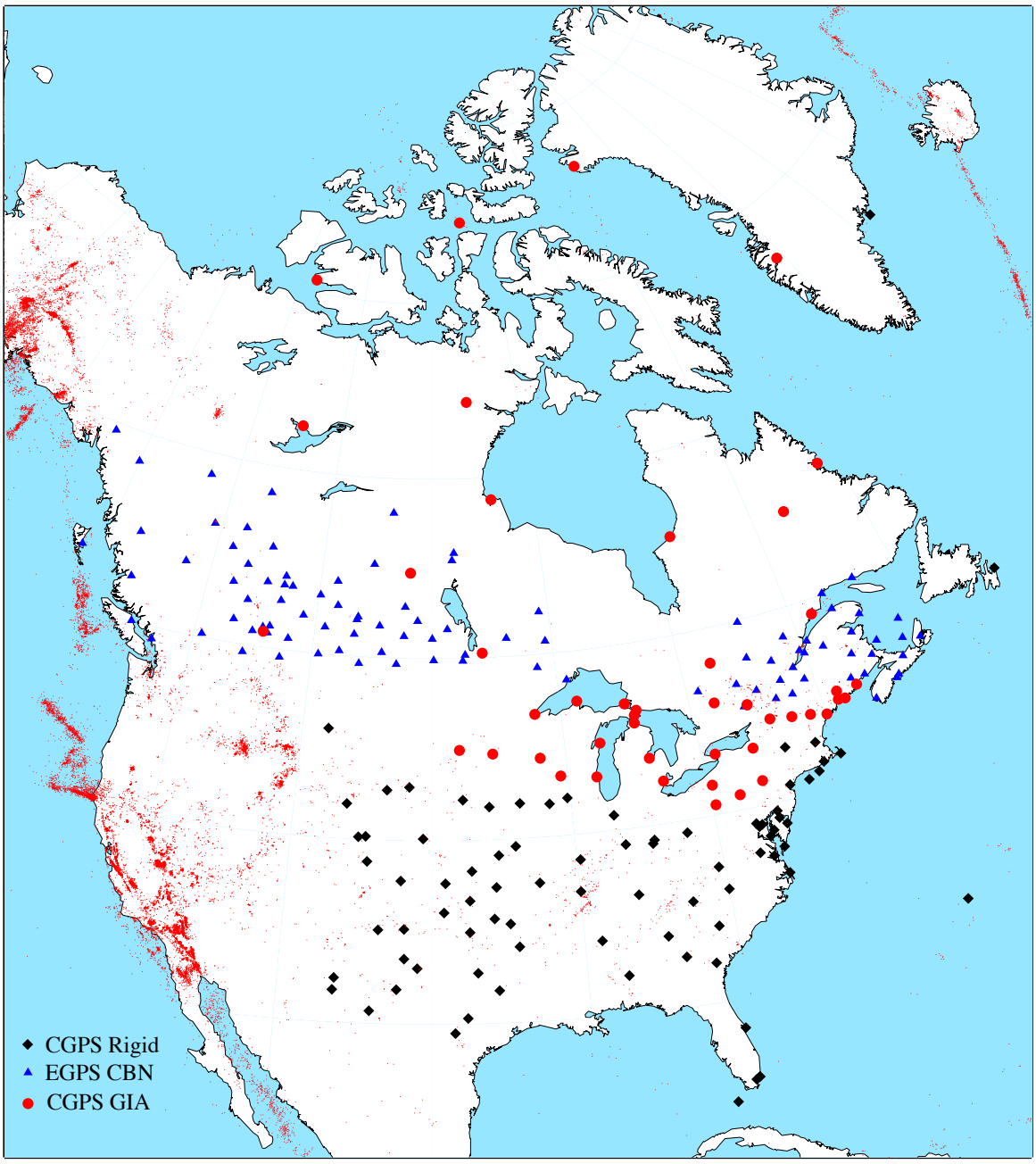
Use a χ^2 test to assess the accuracy of our uncertainties. Should give a value of 1.

Uncertainties: white + coloured + RW1.7$\sqrt{t}$

In the rigid part of the plate the residual velocities should be randomly oriented and have a small magnitude.

Outside of this area patterns in the horizontal and/or vertical velocities should be present.

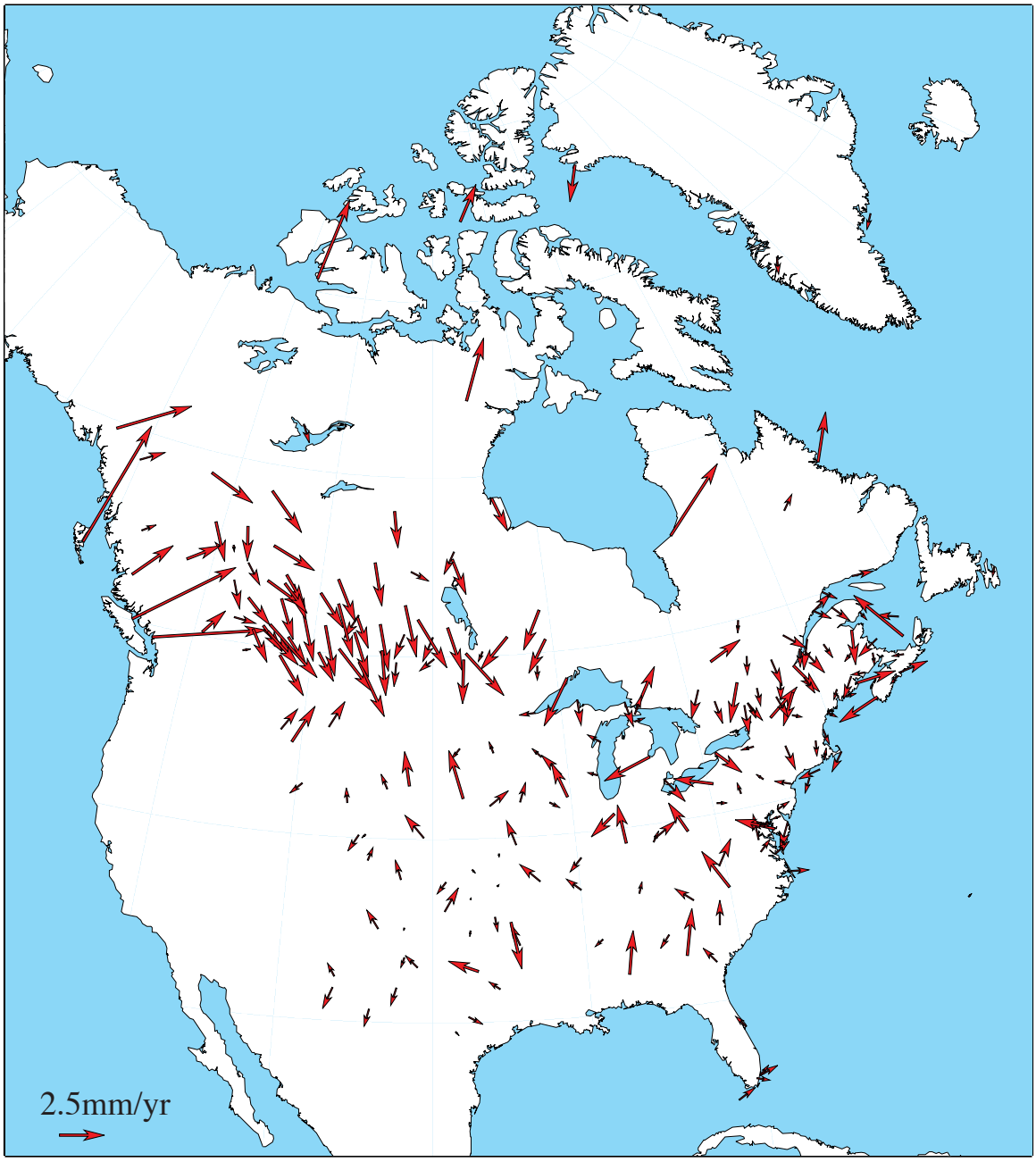
Distribution of GPS sites on North America with seismicity



Rigid North America defined using 83 CGPS sites shown in black diamonds χ_ν^2=1.08 include 46 GIA (Red) 129 sites χ_ν^2=1.33

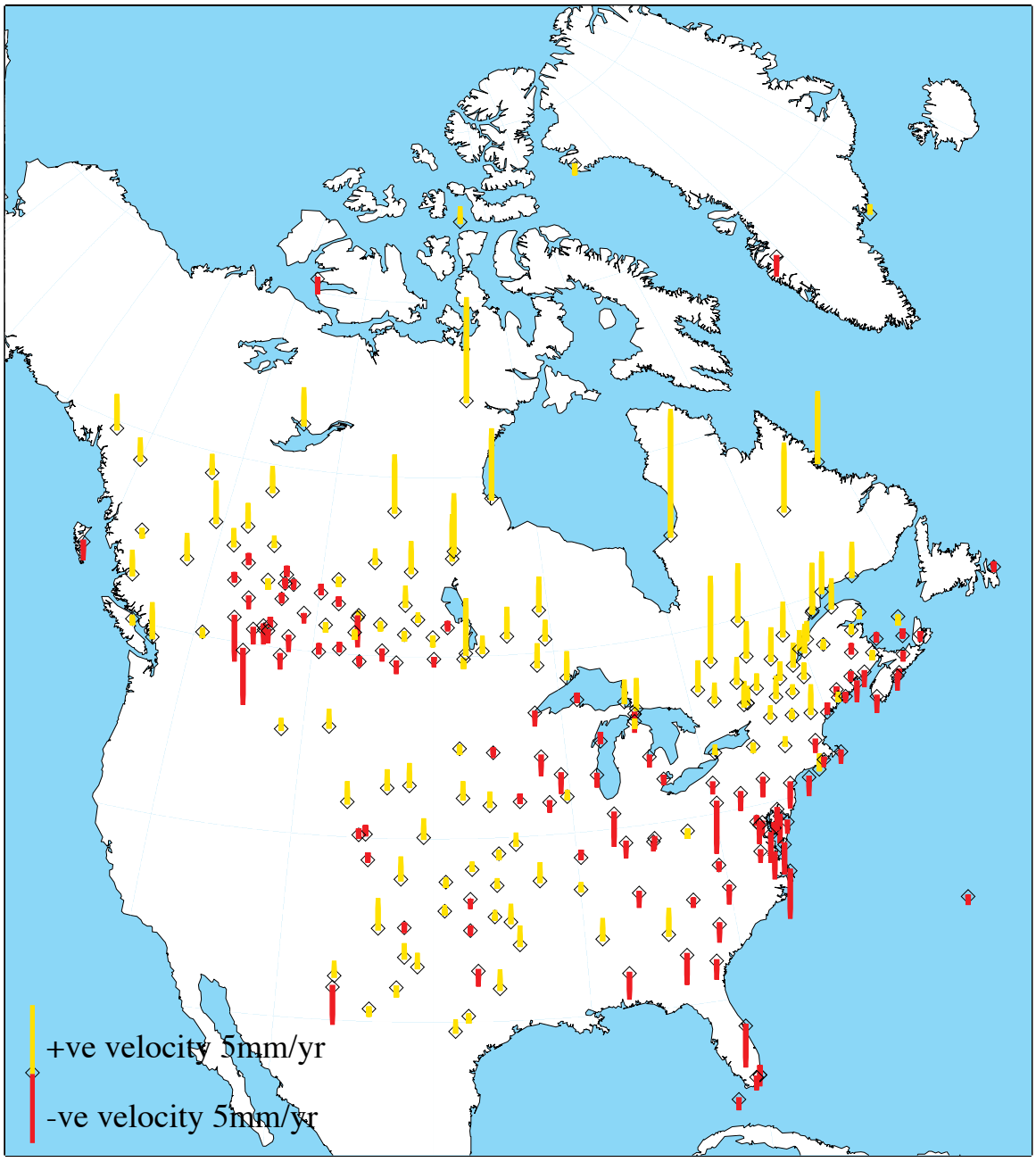
CGPS - Continuous GPS EGPS - Episodic GPS

Residual horizontal velocities after removing North American plate motion defined using an 83 site solution



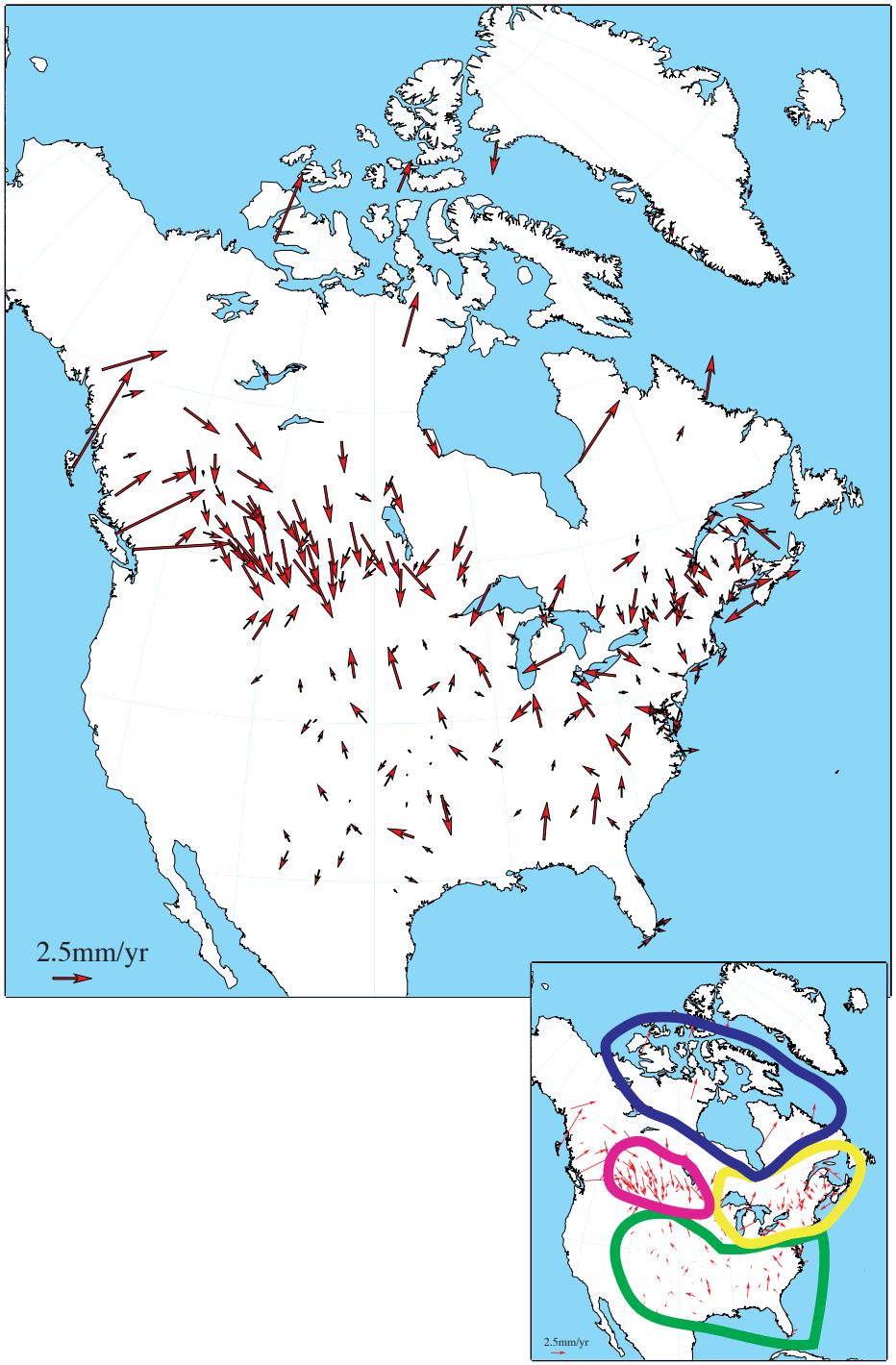
Note the random pattern of velocities across the central eastern US (83 sites that define the motion of North America). To the north patterns of velocities moving southwards and northwards are present

Vertical Velocities Observed by GPS with respect to IGS-2000

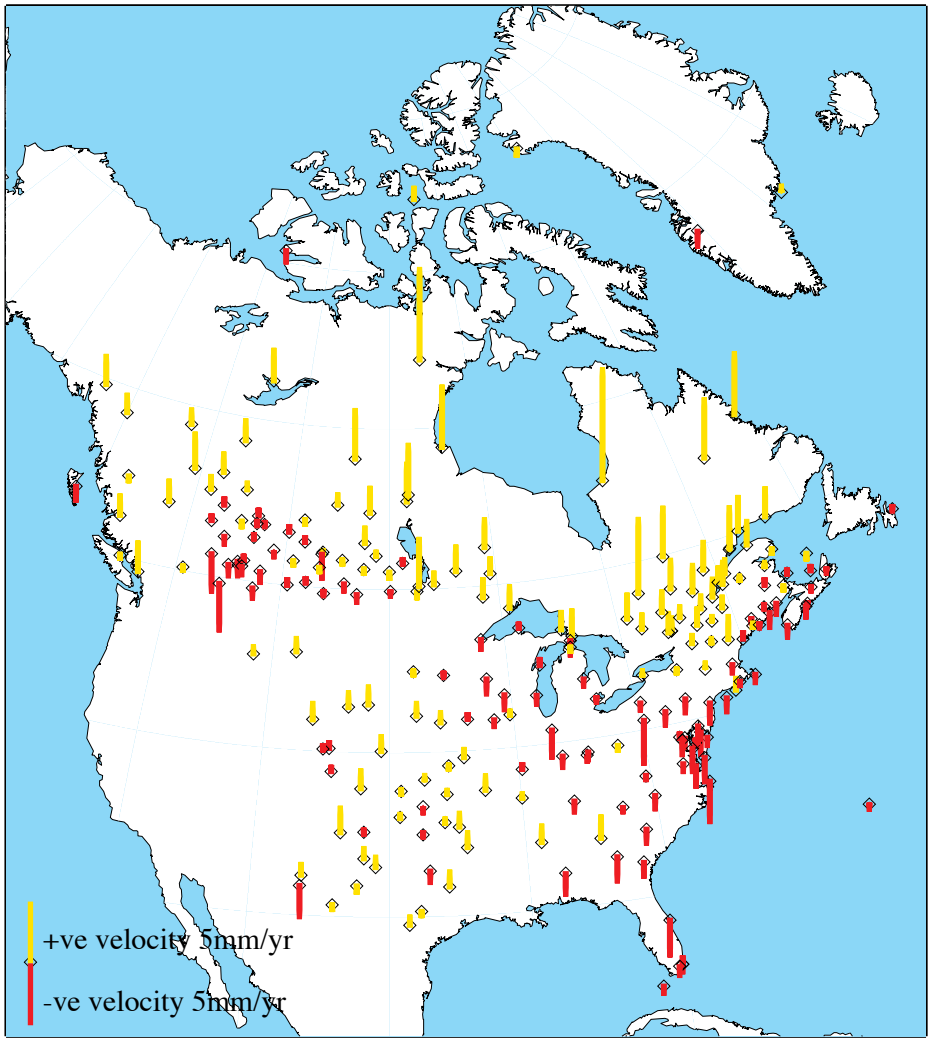


Note the large +ve (yellow) velocites in and around Hudson Bay that decrease southward to zero and then remain very small

Horizontal Residual Velocties



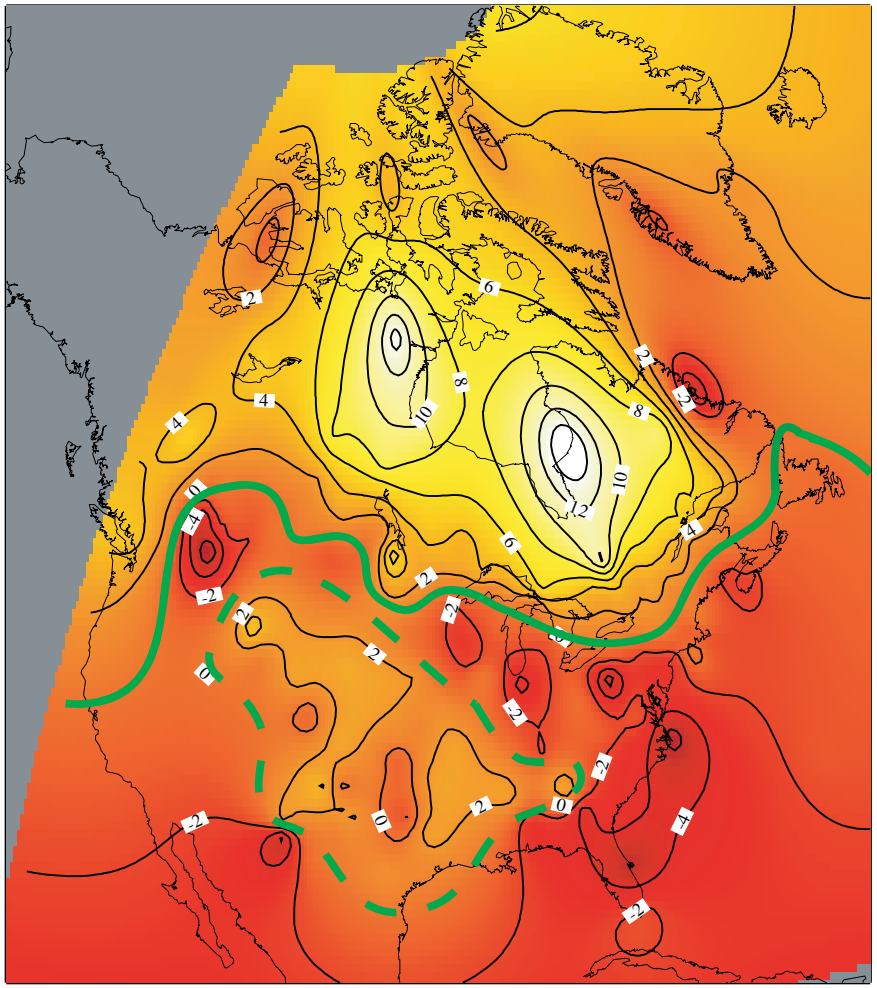
Vertical Velocities w.r.t IGS-2000

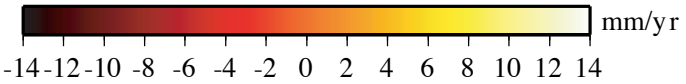


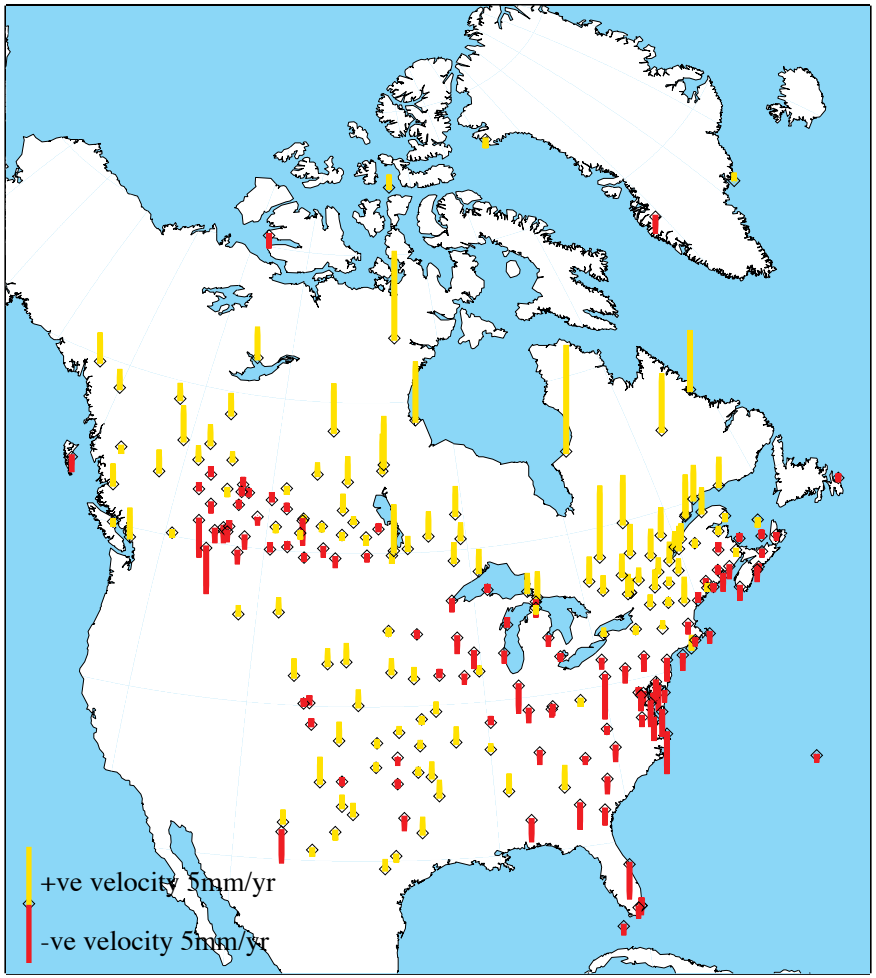
Note the consistent pattern in both horizontal and vertical velocities (large maps) within each of the coloured areas shown in the inset map.

Vertical Velocities with respect to ITRF2000

Cubic spline fit to vertical velocities on right





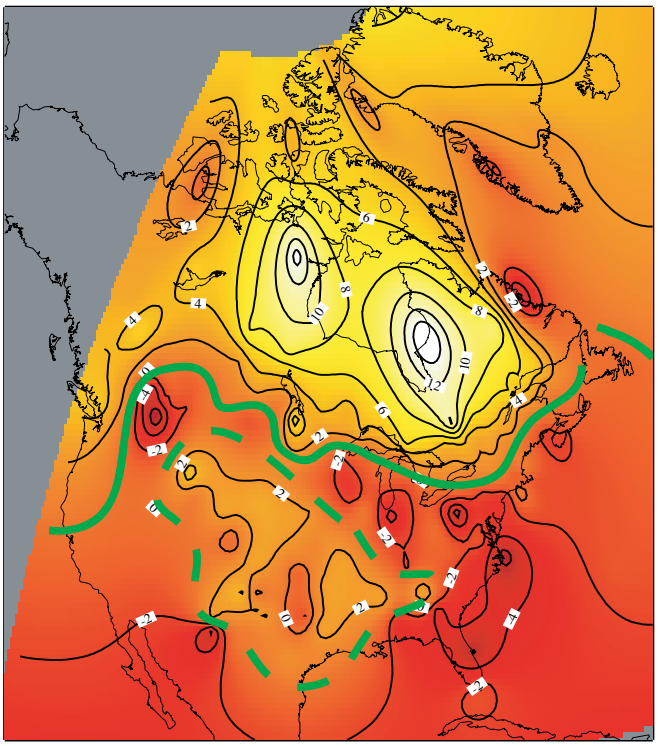


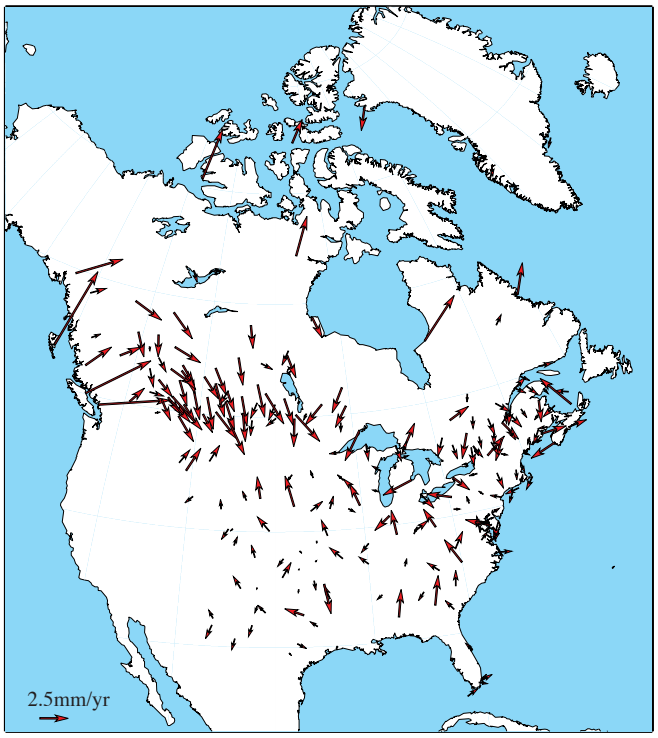
Note the double peak near Hudson Bay is not real. Solid green line shows the hinge line 0 mm/yr. Dashed green line surrounds area of slight +ve uplift

Vertical

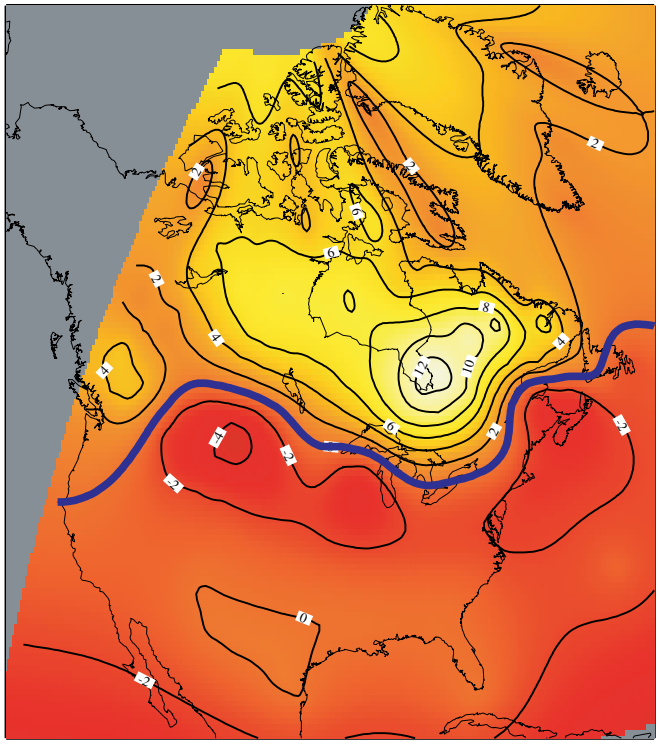
Horizontal

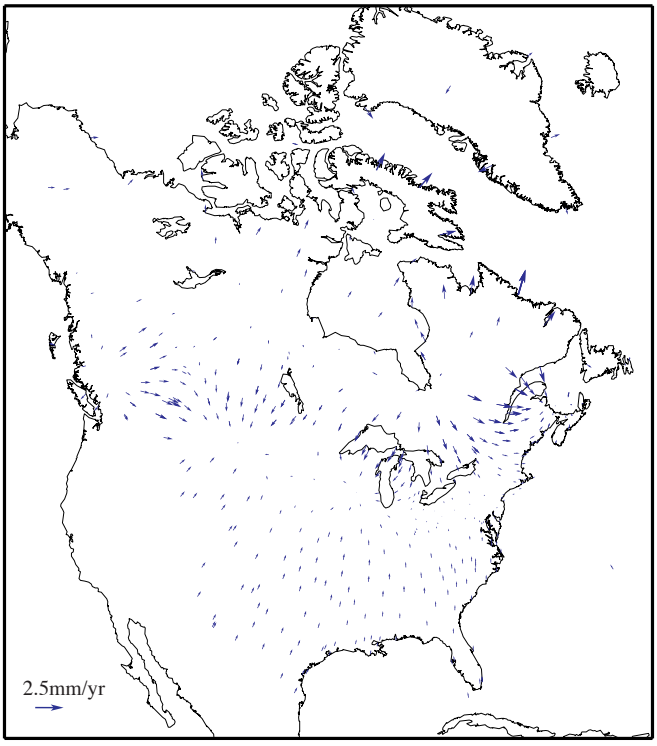
GPS Observed Velocities

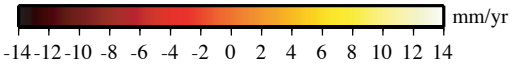




Predicted (ICE-3G loading history) Velocities







Lower mantle viscosity = 4.5 x 10^{21} Pa s

Conclusions

Rigid North American reference frame is well constrained. Most of the deviations seem to be GIA signal rather than other noise.

GIA is a major effect within ~ 1800 km from the center of Hudson Bay both in the vertical and horizontal.

Observing GIA using only CGPS sites is difficult. EGPS sites are important.

GIA models show a large variation in velocity predictions and so constraints from GPS would be helpful. Once this is done GIA predictions could be used to “correct” GPS velocities.

Future work

We plan to improve the velocity field for North America by:

A) Increasing the number of CGPS sites included in our rigid plate definition.

B) Re-occupying EGPS sites of the Canadian Base Network (CBN) in collaboration with Geodetic Survey Division of Canada and the Geologic Survey of Canada will improve our constraints on GIA.