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# An Updated GPS Velocity Field for Canada

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## ABSTRACT

In an effort to improve previous continental-scale GPS velocity fields for North America and Canada in particular, we have reprocessed data from nearly all continuous GPS sites in Canada, the northern portions of the US including Alaska, Greenland as well as a set of global sites used to define the reference frame. In addition, repeated high accuracy campaign surveys of the Canadian Base Network were included. Previous velocity fields were derived from coordinate time series of somewhat inhomogeneous GPS results due to: (1) the use of relative antenna calibrations that did not include satellite antennas or account for the presence of antenna radomes, (2) the use of different reference frames, (3) the use of IGS precise orbits based on these calibrations and reference frames, and (4) the use of different (evolving) versions of GPS processing software and procedures. This reprocessing effort of all previous data since 2000 is based on more consistent and accurate absolute antenna calibrations of both station and satellite antennas, the ITRF2005 reference frame and the latest versions of the Bernese GPS Software and IGS processing procedures with their so-called "repro1" reprocessed orbits. Also, more than four additional years of continuous data and a new CBN survey campaign have been included in this velocity field estimation. The new velocity solution is compared with our previous solution and also with some recent model predictions of glacial isostatic adjustment. We have begun to process all the data with NRCan's Precise Point Positioning (PPP) software using the same IGS repro1 orbits, precise clocks and absolute antenna calibrations together with the Vienna Mapping Function (VMF1) for the tropospheric model. The PPP software has proven to be highly efficient for processing such large networks and the additional solutions will provide complete redundancy for the Bernese results.

## 1. CONTINUOUS GPS BERNESE SOLUTION (GSB)

### Data Used

- 568 high accuracy GPS sites in Canada, northern US (Great Lakes) & Alaska, and Greenland
- Set of 117 global IGS sites to define reference frame
- Data spanning 2000 to 2011.29 (until IGS08 adopted)

### GPS Processing

- Latest version of Bernese GPS Software v5.0
- Used IGS "repro1" products
  - More consistent throughout time series
  - Common IGS05 reference frame for precise orbits
  - Common absolute antenna calibrations
  - Absolute calibrations account for effect of radomes
- Stacked daily solutions into weekly files

### Multi-Year Combination

- Combined 589 weekly solutions
- Aligned each unconstrained weekly solution to a global set of 117 ITRF2008 sites at epoch of week
- Scaled weekly covariance matrix with respect to ITRF2008
- Using ITRF2008 set of time series discontinuities for ITRF sites
- Examined time series of all sites for additional discontinuities

## 2.CAMPAIGN GPS SOLUTION (CBN)

### Data Used

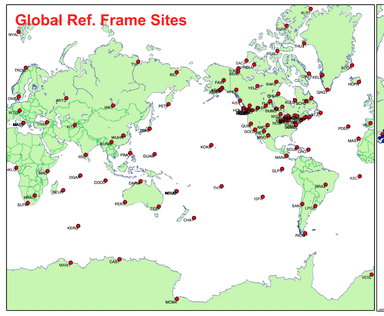
- Repeated survey campaigns of the Canadian Base Network (CBN)
  - Network of stable pillar monuments
  - Forced centering antenna mounts
  - Covers mainly southern half of Canada (sparser in north)
  - Multiple (3-4) 24 hr occupations of each site
- 58 survey campaigns from 1994 to 2011
  - 1st national campaign 1994 – 2000 (no 1998)
  - 2nd national campaign 2001(east) – 2002(west)
  - 3rd national campaign 2005(east) – 2006(west)
  - 4th national campaign 2010(east) – 2011(west)
  - Many smaller campaigns occupied a few CBN sites

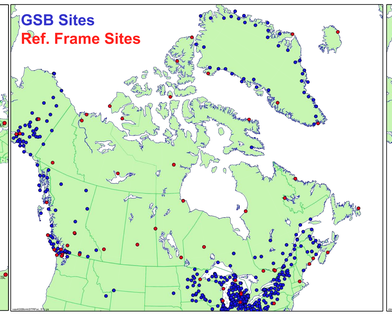
### GPS Processing

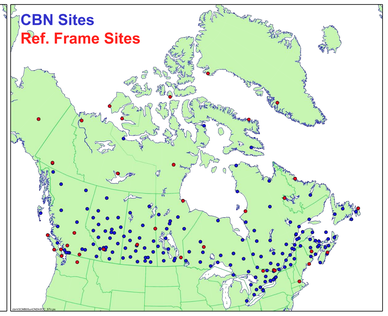
- Identical procedures & software as for GSB continuous processing
- Stacked daily solutions into campaign solutions

### Multi-Year Combination

- Aligned each unconstrained campaign solution to a North American set of 39 ITRF2008
- Scaled campaign covariance matrices with respect to ITRF2008



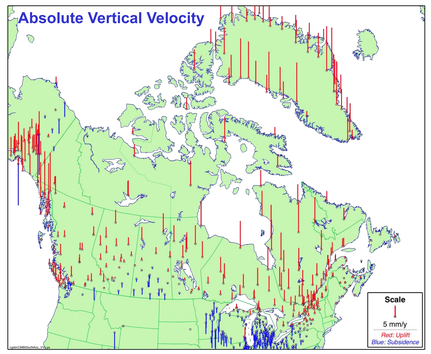



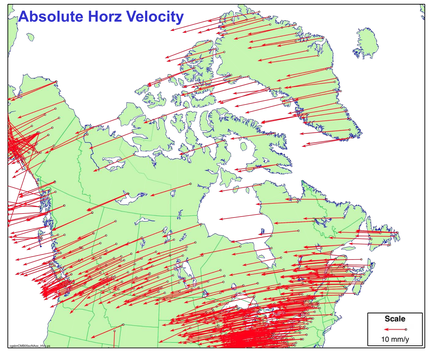



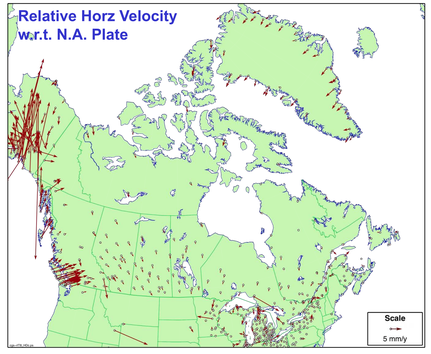

## 4. COMBINED GSB+CBN VELOCITY FIELD

- Vertical velocity field depicts GIA throughout most of Canada and the Great Lakes Region
- Greenland sites exhibiting higher vertical rates (present day ice loss?)
- Horizontal velocities dominated by motion of the N.A. plate
- Relative horizontal velocities represent residual rates after removing preliminary estimate of ITRF2008 plate motion (Altamimi et al., 2011 AGU Fall Meeting, G13B-08)

RX = 0.0275 RY = -0.6752 RZ = -0.0729 mas/y



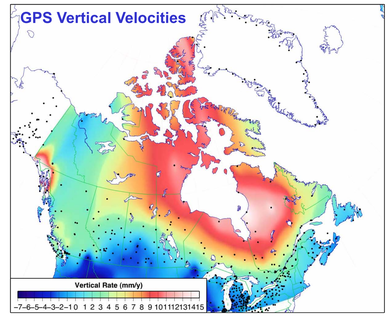



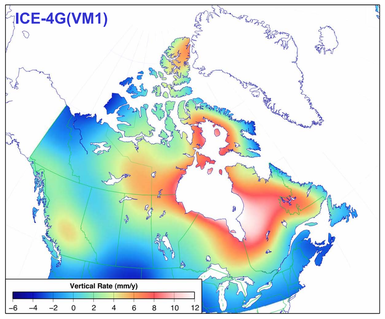

## 5. COMPARISON WITH ICE-4G & 5G

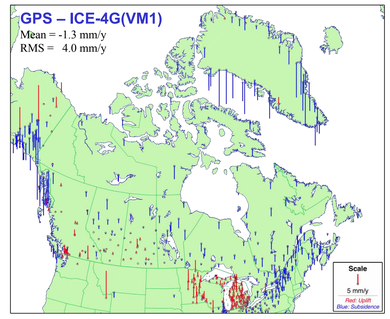
- GPS velocity contour map produced with GMT *(Wessel & Smith, EOS Trans. AGU, 72, 441, 1991)*

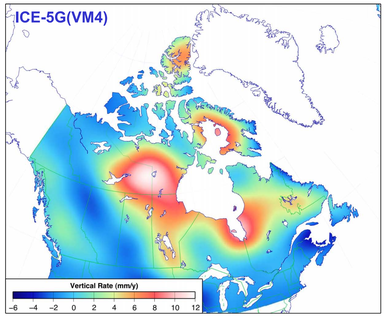
| Diff w.r.t. GPS | Mean | RMS | |
|---|---|---|---|
| ICE-4G(VM1) | -1.3 | 4.0 | mm/y |
| ICE-4G(VM2) | -0.6 | 4.1 | mm/y |
| ICE-5G(VM2) | -1.8 | 4.6 | mm/y |
| ICE-5G(VM4) | -2.0 | 4.5 | mm/y |

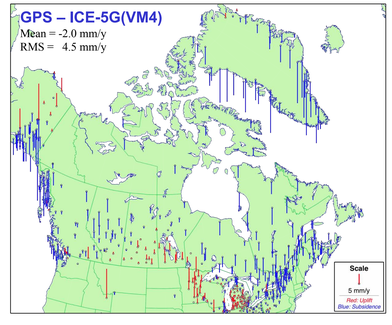
- ICE-4G fits best with GPS
- VM2 better fit with ICE4G but only marginally with ICE5G
- Fits worse than previous velocity field because anomalous velocities not removed




## 6. FURTHER WORK

- Identify & investigate anomalous velocities (mainly due to shorter time series)
- Generate a velocity grid (w/o anomalous velocities) for interpolation to any point
- Transform to NAD83(CSRS) for reconciling different realizations of NAD83(CSRS) at different epochs
- Complete PPP processing and integrate with GSB & CBN solutions for increased redundancy
- Add additional GPS sites west of Hudson Bay

## 7. ACKNOWLEDGEMENTS

- GSD and provincial geodetic agencies for installation of highly stable CBN monumentation
- GSD field survey personnel for consistently highly accurate GPS survey campaigns
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- Zuheir Altamimi (IGN) for providing preliminary ITRF2008 plate motion estimate for North America