A National Crustal Velocity Model For Canada

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Terminology

- CACS (Canadian Active Control System) = CORS
- RACS (Regional Active Control System) = CORS
- CBN (Canadian Base Network) = “Passive” stations/pillars (FBN?)

Velocity Field
- Point velocities at individual stations
- Determined together with coordinates at a reference epoch
- Usually just at the CACS/RACS/CBN stations
- Part of reference frame realization

Velocity Model/Grid
- A model (grid) of velocities derived from the velocity field
- Predicts velocities anywhere within velocity field
- Also considered part of the reference frame

NAD83(CSRS) – NAD83 realizations/versions based on ITRF
- Same as NAD83(CORS96) & NAD83(2011)
The Need for a Velocity Model

- To propagate coordinates to different epochs
  - Significant cm/yr crustal motions throughout Canada
    - Vertical GIA in most of Canada ~ 1-2 cm max
    - Horizontal & vertical eustonic deformation on west coast ~ 1 cm
    - Error in NUVEL-1A plate motion model defining NAD83(CSRS)
  - Different reference epochs adopted by provinces
  - Precise Point Positioning (PPP) gives coordinates at epoch of observations/orbits
  - Need to propagate coordinates to adopted epochs

- For scientific studies
  - Velocity field can be used to improving GIA models – ICE-6G used our GPS to “tune” the model (ice load) in Canada
  - Velocity model needed to estimate crustal motions when predicting relative sea level changes for assessing coastal flooding hazards
  - GPS strain used as additional input to maps of seismic hazards
Current Velocity Field

- Based on CACS/RACS/CORS/CBN in northern half of N.A.
- Data used
  - CACS/RACS/CORS: 2000 – 2011.3 (switch to IGS08)
  - CBN: 1994 – 2011 (4 primary campaigns + “occupations of opportunity”)
- Produced velocity field using repro1 multi-year densification solution
  - Bernese GNSS Software 5.0 to estimate coordinates & velocities
  - IGS05 (repro1) orbits & antenna calibrations
  - Aligned to IGS08 using a global set of 117 ref. frame stations
  - Corrected for IGS08 antenna calibrations using IGS correction model
- Transformed to NAD83(CSRS)
Current Velocity Field Vertical

Depicts mainly GIA

Scale

5 mm/y

Red: Uplift
Blue: Subsidence
Current Velocity Field
Horizontal

Depicts mainly error
In NNR-NUVEL-1A
Current Velocity Model

- Based on only GPS velocity field in NAD83(CSRS)
- Used GMT interpolation to produce a velocity grid (model)
- Removed outlier velocities in an iterative manner
- Separate grid for each coordinate component (lat, lon, h)
- Considered part of NAD83(CSRS) v6 realization
- Used in current CSRS-PPP software to propagate solutions to adopted provincial epochs
- Used in current TRX transformation software
- Good modelling in south where many GPS sites
- Poor modelling in north & west coast where few GPS sites
Current Velocity Model
Vertical

Few GPS stations

Missing GIA uplift dome
New Vertical Velocity Model

- Incorporated a GIA model
  - To improve vertical velocity model where few GPS sites
  - Effectively used as a more intelligent interpolation
- GIA models used
  - ICE-6G as “base” model
  - Added Laur16 elastic model in Ellesmere Island area (more recent deglaciation)
- Method
  - Estimated ICE-6G velocities at GPS sites in velocity field
  - Determined misfit between ICE-6G and GPS velocities
  - Interpolated misfit to a grid = correction to ICE-6G to agree with GPS
  - Added misfit grid to ICE-6G grid to obtain “hybrid grid” constrained to GPS – effectively a GIA interpolation between GPS points
  - Same as distorting geoids to fit levelling datum (“hybrid geoids”)
ICE-6G + Laur16 GIA
Vertical Velocity Model
New Hybrid Vertical Velocity Model

Need to verify/constrain with additional CACS

Doesn’t change much in south
Current GPS-Only Velocity Model
Future Improvements – Velocity Field

- Install new CACS in targeted areas to better constrain GIA model – see map
  - 5 new stations in last few years (not in 2011 solution)
    - DRNG  ENNA  **TKTO (max uplift point)**
    - RNKN  CDOR
  - 5 new stations planned for installation 2016/17
    - MAYO  NORW  TALO
    - QUAQ  **LG-4 (max uplift point)**
- Incorporate selected sites from commercial RTK networks in targeted areas
- Reprocess all data for consistency with current solutions
  - Using Bernese 5.2 and repro2 orbits
  - Aligning to ITRF2014/IGS14
  - 80% done
New/Planned CACS Stations
Future Improvements – Velocity Model

- Investigate more GPS-compatible GIA models
  - LAUR15 (James/Simon) – based on ICE-6G with more GPS information
  - Laur16 elastic rebound model for high Arctic (Ellesmere Island)
  - Little Ice Age velocity model (Freymueller et al.) – Glacier Bay, AK
- Incorporate “block” models of tectonic deformation on west coast
- Improve interpolation method
  - Investigate NTv2-type interpolation
  - Include estimation of uncertainties
Questions?