Regional Reference Frames
for North America
Current Status & Future Plans of Sub-commission 1.3c

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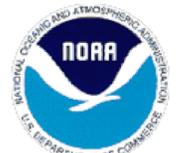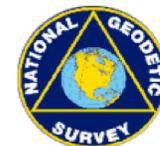
Outline

➢ Regional Sub-commission 1.3c

➢ ITRF/IGS Densification Working Group

➢ Stable N.A. Reference Frame Working Group

➢ Transformations Working Group

Sub-Commission 1.3c Objective

To provide international focus and cooperation for issues involving
the geodetic reference frames of North America

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                    │   IAG Commission 1      │
                    │   Reference Frames      │
                    └─────────────────────────┘
                                │
                    ┌─────────────────────────┐
                    │  Sub-Commission 1.3     │
                    │  Reference Frames       │
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│ Regional Sub-      │ │ Regional Sub-      │ │  Other Regional    │
│ Commission         │ │ Commission         │ │  Sub-Commissions   │
│ 1.3a Europe        │ │ 1.3c North America │ │                    │
│ (EUREF)            │ │ (NAREF)            │ │                    │
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      │ ITRF/IGS     │  │  SNARF       │  │ Reference Frame  │
      │ Densification│  │  WG          │  │ Transformations  │
      │ WG           │  │              │  │ WG               │
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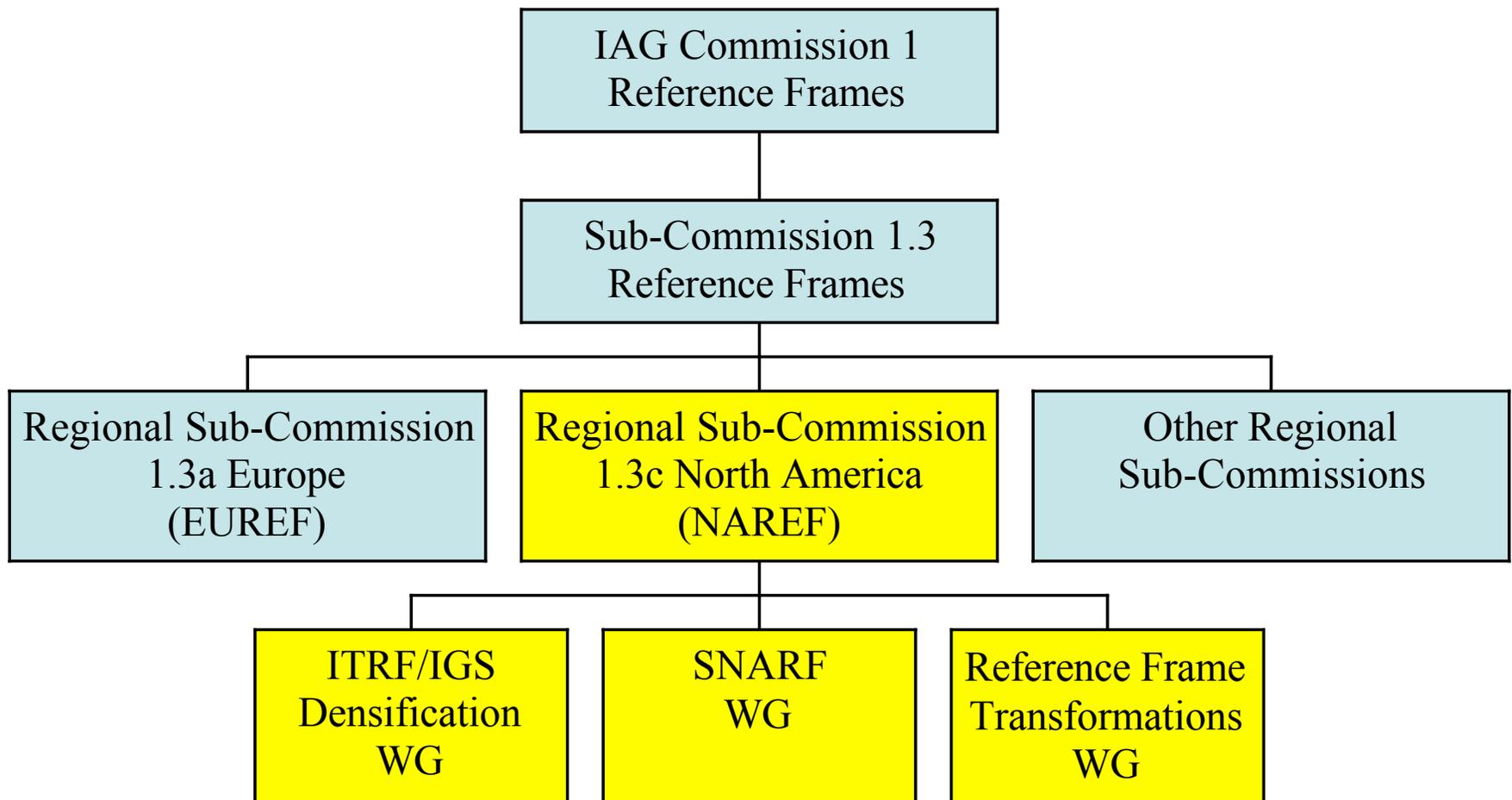
ITRF/IGS Densification Working Group

Objective

- ➢ Densify ITRF/IGS global reference frame in N.A.
  - ▪ Combining 6 regional solutions
  - ▪ Includes most continuous GPS sites in N.A. (~800 sta)
- ➢ Following IGS processing standards
 - ▪ Fixed orbits/EOP's used in most regional solutions

Products

- ➢ Weekly coordinate solutions
- ➢ Annual velocity solutions

Contributing Regional Solutions

| Contributor	Since	Software	Region (# stations wk 1367)
GSD/NRCan	2001	Bernese	Northern N.A. (104)
GSD/NRCan	2001	GIPSY	Canada (42)
PGC/NRCan	2001	Bernese	Western Canada (54)
SIO	2001	GAMIT	Western N.A. (149)
NGS	2002	PAGES	USA and Central Am.(706)
MIT	2004	Combination (GIPSY,GAMIT)	Western & Central N.A. (172)

NAREF Densification Network
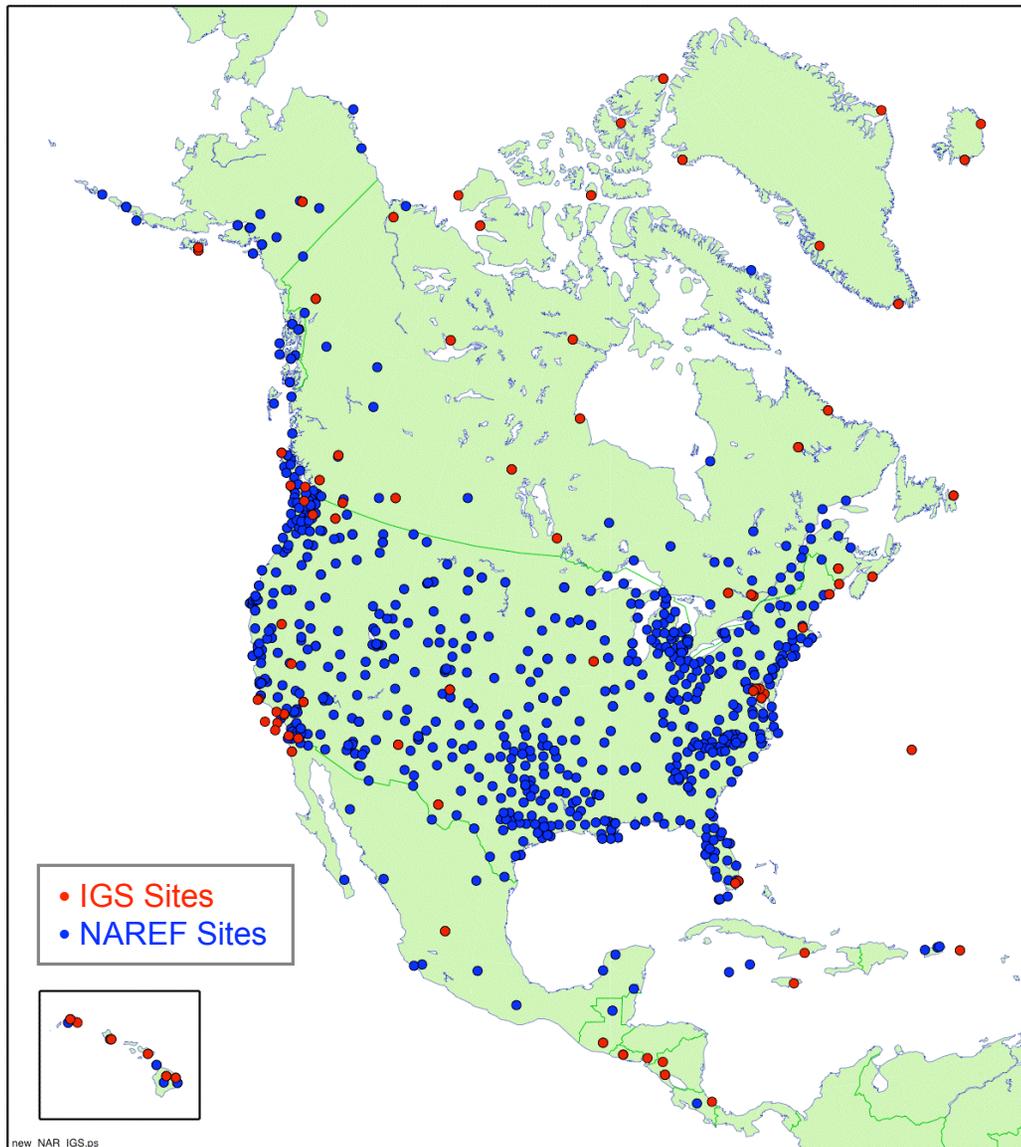
GPS Week 1367

ITRF/IGS Frame Sites	55
NAREF Densification	783
Total	838

Number of Stations in

1 solution	607
2 solutions	105
3 solutions	101
4 solutions	20
5 solutions	3
6 solutions	2

• IGS Sites
• NAREF Sites

new_NAR_IGS.ps

Network Growth

- • 2003 sites
- • 2007 additional

old_new_NAR.ps
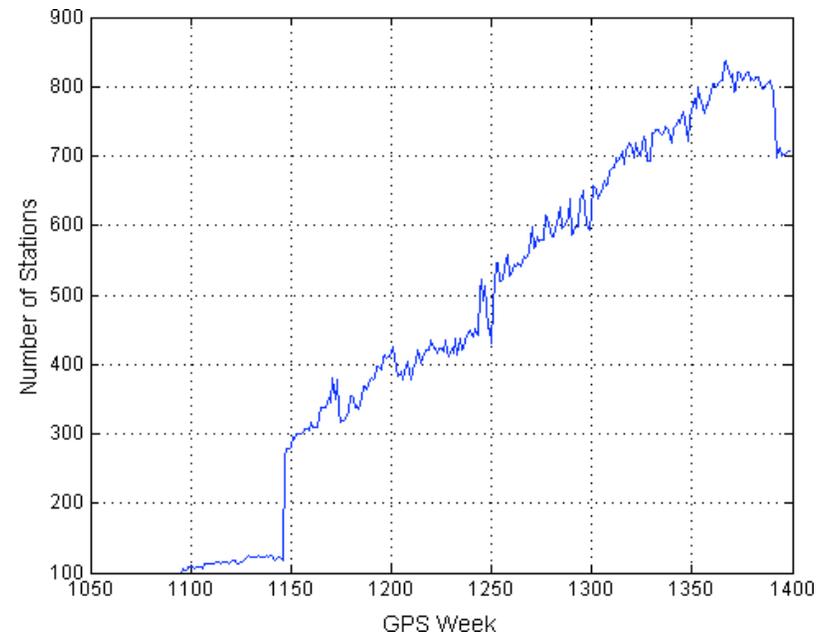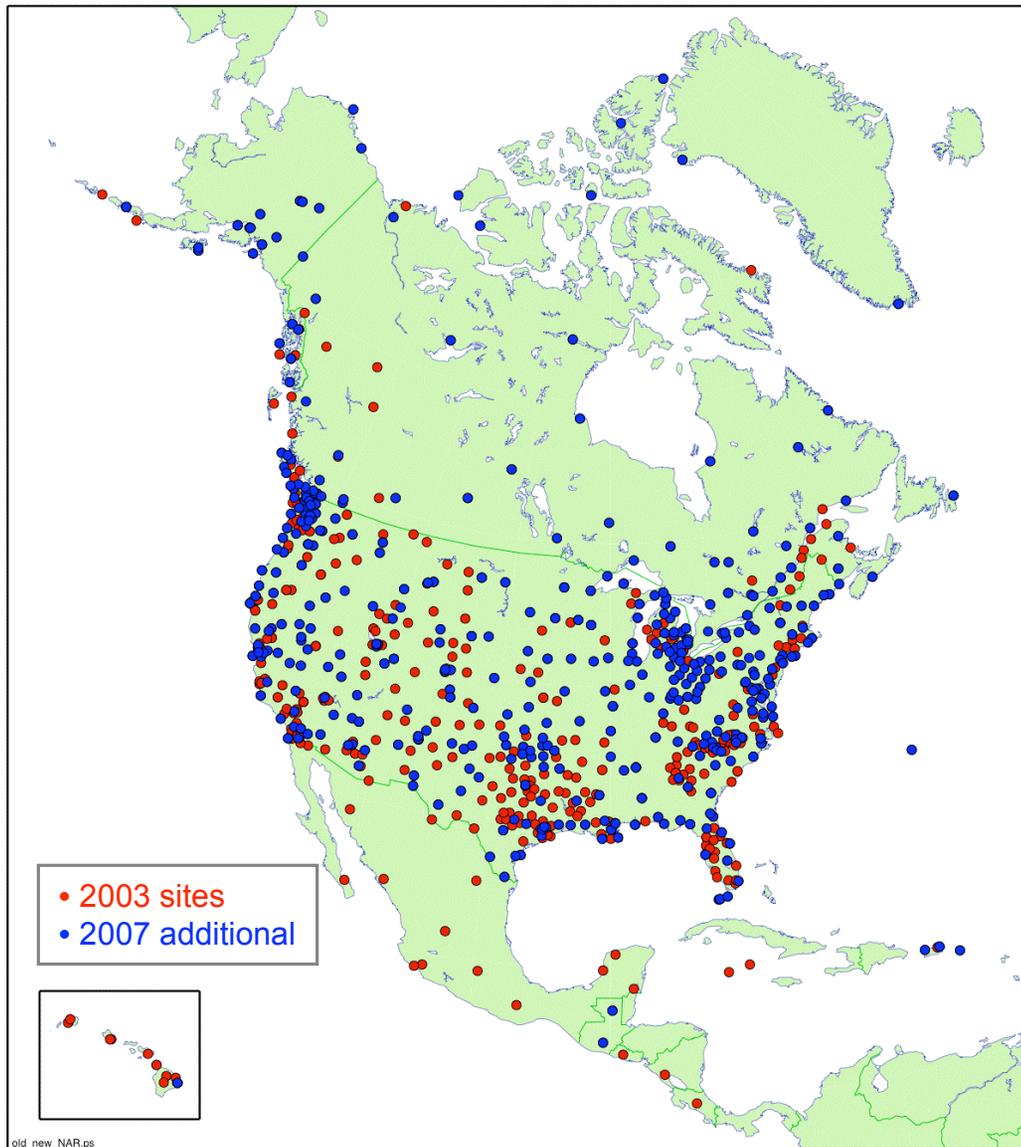
NAREF Velocity Field

Horizontal

Vertical

Scale

20 mm/yr

CLNutsrpNARmc_CMBoc11_hvn.ps

Scale

5 mm/yr

Red: Uplift
Blue: Subsidence

CLNutsrpNARmc_CMBoc11_vvn.ps
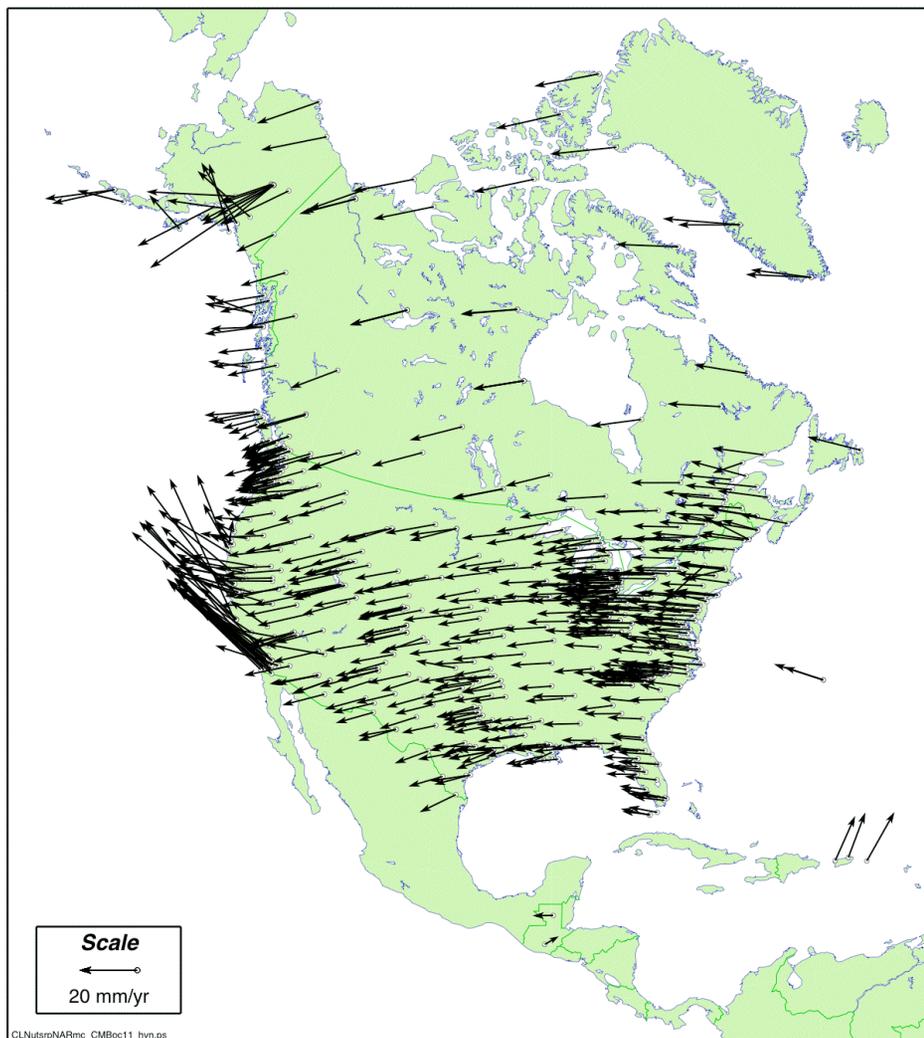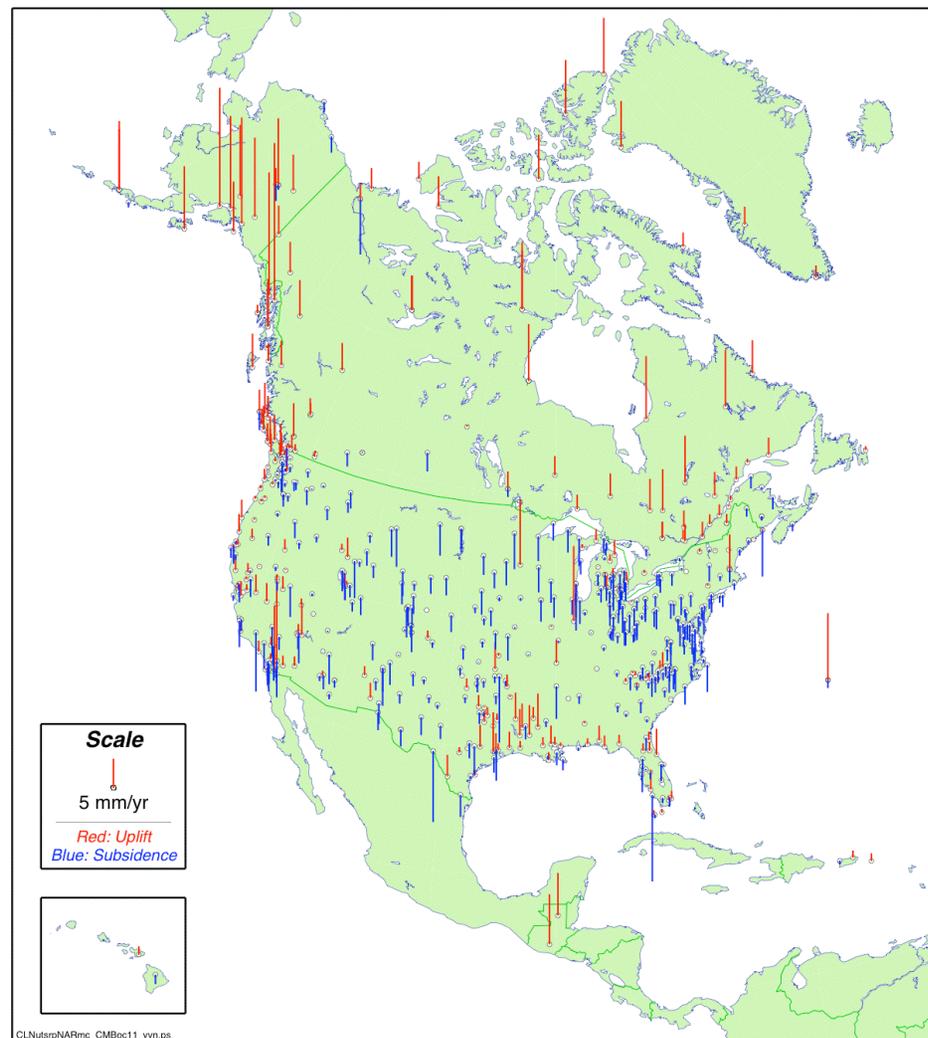
Future Plans

Solutions since GPS week 1400

- ➢ Based on absolute antenna phase centers (APCV's)
- ➢ SIO to expand solution to cover entire N.A.
  - ▪ More stations in 2 or more solutions
- ➢ **Combinations currently on hold**
  - ▪ NGS & PGC still updating to new IGS procedures
  - ▪ SIO waiting for selection of sub-set of CORS sites (can't include all)

Reprocessing with updated IGS orbits (w/ APCV's)

- ➢ Waiting for IGS reprocessing to begin
- ➢ Contributors expected to reprocess all data
- ➢ Some will reprocess data back to 1994

Stable North American Reference Frame (SNARF) Working Group

Objective

- ➢ Define a reference frame that represents the stable interior of North America (plate-fixed)
- ➢ To provide a standard to facilitate
  - ▪ Inter-comparison of velocity solutions
  - ▪ Geophysical interpretation (easier to interpret intra-plate motions)
- ➢ Primarily for EarthScope/PBO studies in U.S.
- ➢ Joint Working Group with UNAVCO, Inc.

Possible successor to NAD 83

- ➢ NAD 83 offset from geocenter (ITRF/WGS) ~2 m

SNARF Approach

Determine a velocity model that brings stable North America to rest

Velocity model includes

- ➢ Rotation rates (plate motion)
- ➢ Translation rates (bias in GPS velocities?)
- ➢ GIA Motion (largest intra-plate motions)

$$\vec{V}_{\text{GPS}}(\lambda, \phi) = \vec{V}_{\text{GIA}}(\lambda, \phi) + \delta\vec{\Omega} \times \hat{r}(\lambda, \phi) + \delta\vec{T}$$

Based on ITRF/IGS reference frame

A Priori GIA Model

Average of a suite of GIA models

- ➢ No consensus on Earth models so using a suite of Earth models
- ➢ Initially using ICE-1 as basis of GIA (Peltier & Andrews, 1976)
    - ▪ Easier to work with for proof-of-concept
    - ▪ Will be attempt to use ICE-3G in future version but …
    - ▪ Some Earth model parameters hard-wired into ICE-3G
- ➢ Using a range of Earth model parameters for ICE-1G
    - ▪ Lithospheric thickness
    - ▪ Upper & lower mantle viscosities
    - ▪ Based on commonly used values

Full covariance matrix used

- ➢ Constructed empirically from variation of suite of models

GPS Velocities

Combination of 3 solutions in IGb00 frame

- ➢ NAREF velocity solution for N.A.
    - ▪ Combination of 6 regional solutions
- ➢ Purdue solution for eastern N.A. (Calais et al, JGR 2006)
- ➢ Canadian Base Network (CBN) densification solution for Canada
    - ▪ ~180 stations with 28 repeated GPS campaigns (2004-2002)

Combined solution

- ➢ Origin and orientation loosely constrained
- ➢ SNARF frame defined by best "datum" points (118)
    - ▪ Stable monumentation
    - ▪ > 3 year time span

Assimilation of GPS & GIA

Based on a novel technique by Jim Davis
- ➢ Weighted assimilation of GPS and a priori GIA model
- ➢ Using full covariance matrices for each

Simultaneously estimating
- ➢ GIA velocities at GPS points
- ➢ GIA velocities on a 2°x2° grid (for user interpolation)
  - ▪ Adjusted through correlations with GPS points
- ➢ Translation & rotation rates from ITRF/IGb00 that minimize motion of "datum" sites

RMS of misfit
- ➢ Horizontal   0.71 mm/y
- ➢ Vertical   1.30 mm/y

SNARF v1.0 GIA Model

SNARF Products

Positions & velocities of all GPS sites

➢ If velocity of a site matches GIA velocity, it is on stable N.A.

➢ Differences represent non-GIA motion

➢ Official PBO solutions provided in SNARF v1.0

GIA model velocities

➢ Give at GPS sites & on 2°x2° grid for interpolation

SNARF plate motion estimate (Euler rotations)

	ω_X	ω_Y	ω_Z	
SNARF (wrt IGb00)	**0.06588**	**-0.66708**	**-0.08676**	(mas/y)
ITRF2000	0.08316	-0.69084	-0.06120	
NNR NUVEL-1A	0.0532	-0.7423	-0.0316	

Future Plans

SNARF v2

- ➢ Expand list of "datum" sites
  - ▪ 60 more, if monumentation can be verified)
- ➢ Incorporate new/updated regional solutions
  - ▪ Latest NAREF solution
  - ▪ Alaska & N.W Canada GIPSY solution (Freymueller)
  - ▪ North American GIPSY solution (Blewitt et al.)
  - ▪ Updated CBN solution with 2005/6 campaigns

Transition from research mode to operational mode

- ➢ National geodetic agencies in US & Can expected to assume responsibility for maintaining SNARF
- ➢ *SNARF may possibly supercede NAD 83 in future*

Transformations Working Group

Objective

➢ To determine consistent relationships between international, regional and national reference frames, and to update these relationships as needed

NAD83-ITRF relationship

➢ NAD83 still the primary horizontal/3D reference frame for N.A.

➢ Now defined by 14-parameter transformations from/to ITRF

  ▪ Originally a 7-parameter transformation w.r.t. ITRF97

  ▪ Updated to other ITRF's using official IERS 14-parameter transformations between ITRF's

  ▪ NNR NUVEL-1A used for N.A. plate motion (biased ~ 2 mm/y)

➢ Transformation recently updated for ITRF2005

For More Information

www.naref.org

Thank you Giovanni !