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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Ocean Service
National Geodetic Survey

The NAREF Perspective on a New Plate-Fixed Reference Frame for North America

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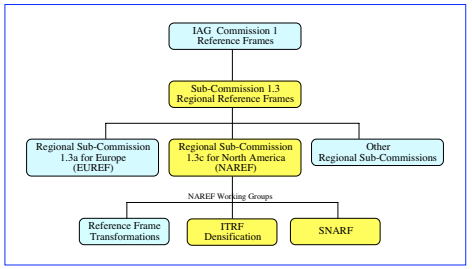
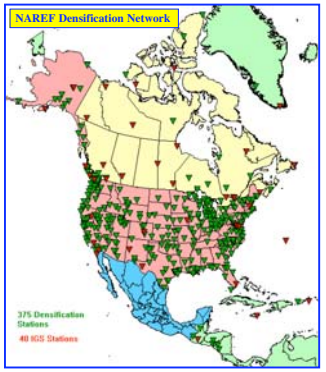
ABSTRACT

In collaboration with the IAG community, its service organizations and the national geodetic organizations of North America, the IAG's Sub-Commission 1.3a on Regional Reference Frames for North America (NAREF) provides international focus, cooperation and coordination for issues involving the geodetic reference frames and control networks of North America. Some of these issues include the maintenance and future evolution of reference frames for North America and the setting of standards and guidelines. To this end, NAREF has coordinated the densification of the ITRF reference frame in North America and has been providing regular weekly coordinate solutions for most of the permanent GPS receivers on the continent since 2001. Work is now progressing on providing regular cumulative solutions with velocities estimates for all stations. More recently, a new initiative has begun, underwritten by UNAVCO, Inc. in support of the Earthscope project, to establish a stable, plate-fixed reference frame for North America that would serve the broad scientific and geomatics communities. The goal is to provide a consistent reference system, including velocity models, procedures and transformations, tied to a "stable" North America in which scientific and geomatics results (e.g., positions in tectonically active areas) can be produced and compared. This paper focuses on the requirements that such a reference frame would need to satisfy from the perspective of NAREF. We also make some suggestions for how such a new reference frame could be implemented for the benefit of the general public and discuss some pitfalls learned from the ITRF densification work.

IAG/NAREF ORGANIZATION





CURRENT REGIONAL CONTRIBUTIONS TO NAREF

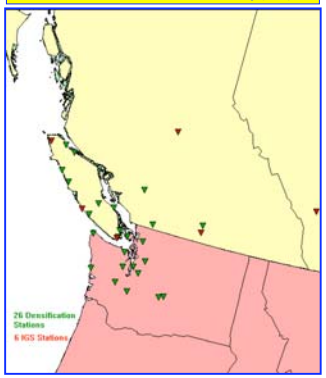
NRCan Bernese Network (GSB)

- From Geodetic Survey Division, NRCan
- Bernese GPS Software Version 4.2
- Double differenced observations
- 3 minutes data sampling
- 10 deg elevation cut off
- Fixed IGS precise orbits & ERP
- Tropospheric zenith delay (every 2 hours)
- Niell mapping function (dry)
- Tropospheric gradient (1/day)
- QIF ambiguity resolution with regional ionosphere model
- LOADSDP v.5.0 ocean loading model
- 1 IGS reference frame station (DRAO) constrained to IGS00

NRCan GIPSY Regional Network (GSG)

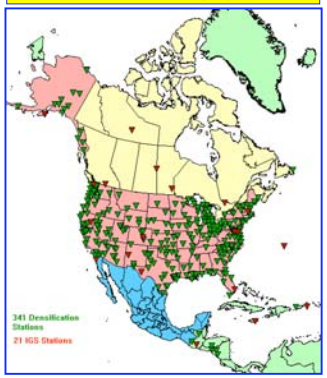
- From Geodetic Survey Division, NRCan
- GIPSY-OASIS II software
- Undifferenced observations
- 7.5 minutes data sampling
- 15 deg elevation cut off
- Fixed IGS precise orbits & ERP
- Tropospheric zenith delay (random walk)
- Niell mapping function (wet)
- Tropospheric gradient (random walk)
- Ambiguity resolution applied
- IERS96 ocean loading model
- 1 IGS reference frame station (DRAO) constrained to IGS00

NRCan Western Canada Deformation Array (PGC)



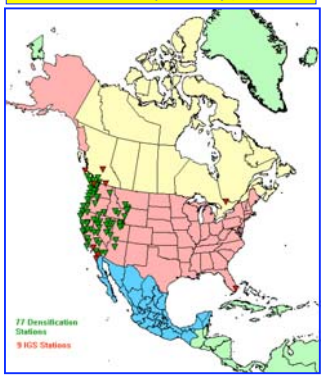
- From Herb Dragert, Pacific Geoscience Centre (PGC), NRCan
- Bernese GPS Software Version 4.2
- Double differenced observations
- 30 second data sampling
- 10 deg elevation cut off
- Fixed IGS precise orbits & ERP
- Tropospheric zenith delay (every 2 hours)
- Niell mapping function (dry)
- Tropospheric gradient (4/day)
- QIF ambiguity resolution
- LOADSDP v5.02 ocean loading model
- 1 IGS reference frame station (DRAO) constrained to ITRF97

NGS CORS Network (NGS)



- From U.S. National Geodetic Survey (NGS)
- PAGES, v0205.22
- Double differenced observations (iono-free combination)
- 30 second data sampling
- 15 deg elevation cut off
- Fixed IGS rapid orbits & ERP
- Tropospheric zenith delay (every 2 hours)
- Niell mapping function (dry & wet)
- No tropospheric gradient estimation
- No integer ambiguity resolution
- IERS 96 ocean loading model
- 8 IGS stations constrained to ITRF2000 values

SIO Plate Boundary Observatory (GSB)



- From Scripps Institution of Oceanography (SIO)
- GAMIT v9.72 software
- Double differenced observations
- 2 minute data sampling for final solution
- 10 deg elevation cut off
- Fixed SIO precise orbits & ERP
- Tropospheric zenith delay (random walk)
- Niell mapping function (dry & wet)
- Tropospheric gradient (1/day)
- Ambiguities resolved for lines < 500 km
- IERS 96 ocean loading model
- IGS reference frame stations loosely constrained to IGS00

OBJECTIVES

- To densify the ITRF and IGS reference frames in North America and Caribbean
- Consolidate regional networks into a single continental one
- Integrate into IGS global network (ITRF)
- Produce coordinate solutions
  - Weekly solutions/combinations
  - Cumulative solutions with velocity estimates
- Provide transformations between references frames used in North America (NAD83, ITRF, IGS)

STANDARDS

- ***Site Selection***
  - 24 hr data, 10 deg. elev. mask angle
  - Continuous operation (min. 5 days/week?)
  - Stable & recoverable monumentation
- ***Data Archiving***
  - Most regional data already archived at CDDIS or SOPAC
  - Ensure complete/consistent meta-data in RINEX, SINEX, and log files
- ***Regional Processing***
  - Follow IGS & EUREF standards as much as possible
  - Fixed IGS orbits & ERPs (preferably "final")
  - Redundant solutions for quality control
- ***Combination of Solutions***
  - Accumulate normals of each solution
  - Realistic scaling of covariance matrices – *difficult*
  - Two independent combinations for quality control
- ***Problem***
  - Regional centers operate independently
  - Difficult and sometimes impossible to enforce standards

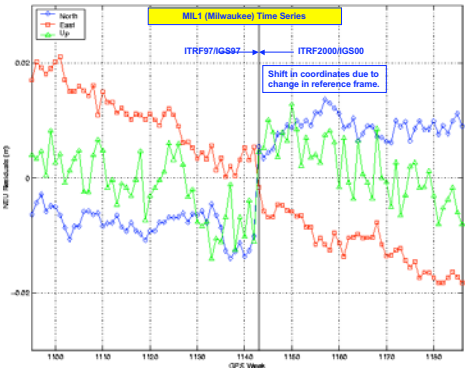
COMBINATION PROCEDURE

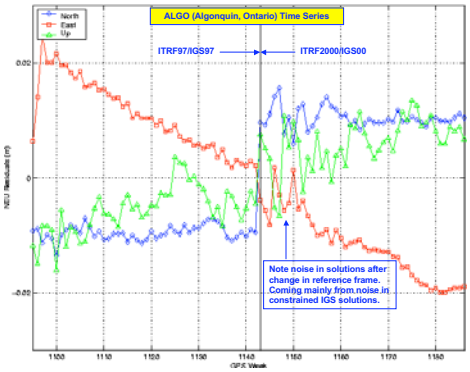
- Using SINEX Software v1.0 by R. Ferland (used for official IGS global combinations)
- A priori datum constraints removed from each regional solution
- Each regional solution aligned to IGS weekly solution (3 translations, 3 rotations & scale change)
- Residuals tested for outliers (removed)
- Covariance matrix of each regional solution scaled by WRMS of residuals
- All (scaled) regional solutions combined (summation of normals)
- Combined solution aligned to IGS weekly solution (3 translations, 3 rotations & scale change)
- Covariance matrix for combined solution scaled by WRMS of residuals
- Residuals tested for outliers (removed)
- 1 IGS reference frame station (DRAO) constrained to IGS00 (min constraint)
- Generated SINEX file for combined solution (NAREF solution)

Joint AGU-CGU Meeting
Montreal, May 17-21, 2004

LESSONS LEARNED FROM NAREF

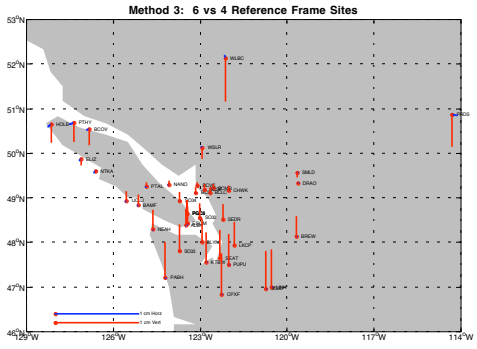
- ***Meta-Data (site logs, etc)***
  - Often incomplete & sometimes contradictory
  - Sometimes not updated on a timely basis
  - Verification an on-going & time consuming task
- ***Reference Frames***
  - Changes and updates in reference frames can be confusing to users if not clearly identified (see plots)
  - SINEX format does not provide a data block for identifying the reference frame (must remember to identify the frame in a comment block)
  - Obtained elevated noise levels in weekly solutions after change from IGS97 to IGS00 (see plot below)
- ***Combinations***
  - Need a basic set of standards for regional networks and solutions but difficult or impossible to impose on independent analysis centers
  - Independent solutions using different software essential for validating results and averaging out "software noise" (stations not in multiple solutions have no check)
  - Common stations between independent regional solutions can be artificially over-weighted in combinations
  - Use only a single combined batch solution for all networks? (use regional solutions/combinations for validation)
  - Need more automated procedures for reliably identifying outlier stations and epochs

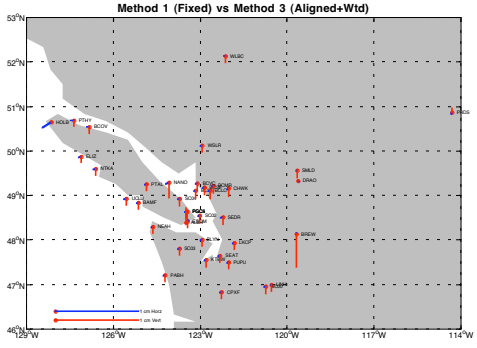




ACCESS TO REFERENCE FRAMES

- ***Constraining to Reference Frame Stations***
  - Fix the reference frame stations (least desireable but easy)
  - Weight the reference frame stations using the full covariance matrix for the reference frame stations)
- ***Aligning to Reference Frame Stations***
  - Transform local solution to fit reference frame stations using either
    1) Known/adopted transformation or
    2) Transformation estimated from best fit of min. constraint solution with reference frame stations (used for IGS realization of ITRF)
- ***Combined Constraining & Aligning***
  - Estimate transformation while combining with weighted reference frame constraints (preferred)
  - Propagates uncertainties from reference frame
  - Used by IGS and NAREF for weekly combinations
- ***Results Dependent On***
  - Number of stations used to constrain or align (see plots)
  - Method used





PROPOSED NAREF CONTRIBUTIONS TO SNARF

- "Vehicle" for providing and maintaining official SNARF products (wider use under auspices of IAG and national geodetic agencies)
- Regional solutions in SNARF (Canadian solutions in Bernese & GIPSY, U.S. CORS solutions in PAGES)
- Combinations of regional solutions using IGS software
- Transformations between SNARF and NAD83, ITRF, IGS, etc.

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