Association of Ontario Land Surveyors
Eastern Regional Group Meeting

Jan 7, 2009

Datums and the Integration of Cadastral Surveys in Ontario

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Agenda

- *New proposed regulations on integrating surveys*
- *Datum Essentials*
- *Wide Area GPS correction services*
  - *CDGPS, CSRS-PPP*
- *PHASE Differential GPS techniques*
  - *RTK, Baseline Post-Processing*
  - *Network RTK*
- *MSL Heights from GPS and a Geoid model*

White paper – Integrated Cadastral Surveys

Our ability to measure absolute positions has improved a hundred fold since NAD83(Original) was defined. Consequently a new system has been implemented that gives the average surveyor access to geographically referenced positioning that is accurate enough for legal surveys. The current system is the Canadian Spatial Reference System, or NAD83(CSRS). It is now possible to accurately locate and re-locate boundaries using modern positioning systems and equipment.

CSRS positions are no longer concentrated in urban areas and along the corridors connecting them. These positions can be obtained anywhere in Canada using GPS. To aid the surveyor, there are many sources of free data including:

1. A network of Canadian Active Control stations (CACs) established by NRCan that continuously collect satellite data;
2. Canadian Base Network stations (CBNs) established by NRCan, a high precision network of monuments in the ground that surveyors can occupy with GPS;
3. Precise Point Positioning (PPP), a service supplied by NRCan that allows a surveyor to determine an autonomous geographic position accurate to about five centimetres, practically as a by-product of normal GPS surveying;
4. Grid Shift files and software supplied by the Ministry of Natural Resources (MNR) and NRCan to convert NAD27 and NAD83(Original) to NAD83(CSRS).
5. Current and historical monument coordinates are available to surveyors from the MNR "Cosine" database.

Ontario Coordinate System

Reference Datum

2. The Ontario Coordinate System is referenced to the North American Datum of 1983 (NAD83).

3. Every user of the Ontario Coordinate System must specify the reference datum, adjustment epoch and map projection utilized.

Coordinates

4. Coordinates can be expressed as Geographic values, in a Universal Transverse Mercator map projection or Modified Transverse Mercator map projection.

Surveyor's Act

12. If a survey is made for the purpose of defining, locating or describing a line, boundary or corner of a unit of land in relation to the regulated level of a body of water or defining a boundary in reference to an elevation, and no permanent bench mark exists within 300 metres of the site of the survey, a permanent bench mark, defined by a monument referred to in clause 2 (1) (a), (b), (d), (e) or (f) of Ontario Regulation 525/91 or other durable and stable object, shall be established at or near the site. O. Reg. 42/96, s. 8.

(1) When undertaking a survey for a plan to be registered or deposited in the Land Registry System, a licensed member shall integrate the survey with the Ontario Coordinate System and determine the coordinates of every angle or corner on a line or boundary and all topographic information required under section 25

(2) The coordinates required under subsection 12.1shall be accurate to:

(a) in urban areas to 0.05 metres,

(b) in rural areas to 0.2 metres, or

(c) in remote areas to 1 metre,

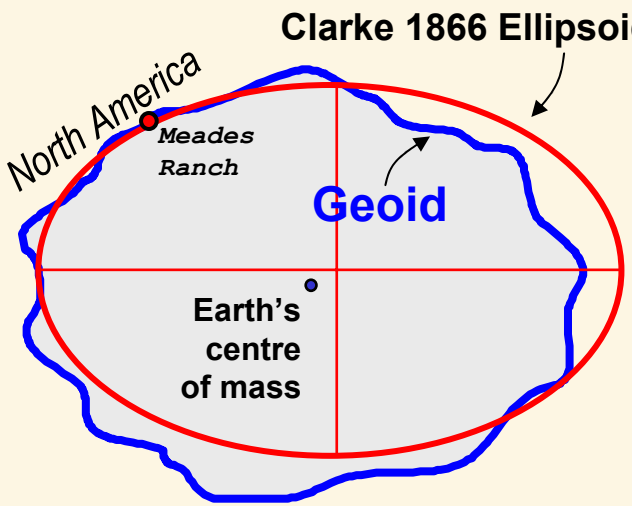
at the 95 percent confidence level.

(j) where a plan has been integrated pursuant to section 12.1, a table containing the Ontario Coordinate System coordinates of at least 2 monumented points related to the survey together with a Note stating 'These coordinates cannot, in themselves, be used to re-establish the corners or boundaries shown on this Plan'.

(c) if bearings have been derived from a coordinate system, a note shall be included on the plan indicating that the bearings are grid bearings, are derived from the stated values for specified known control points or observed reference points, and are referred to the stated map projection, zone datum and adjustment epoch.

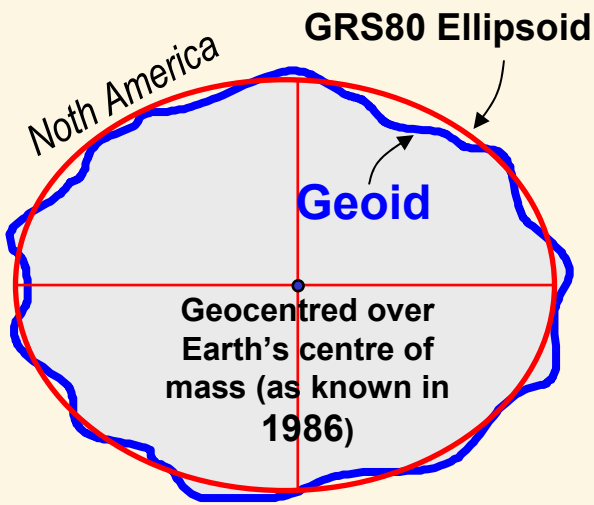
Datums

NAD27



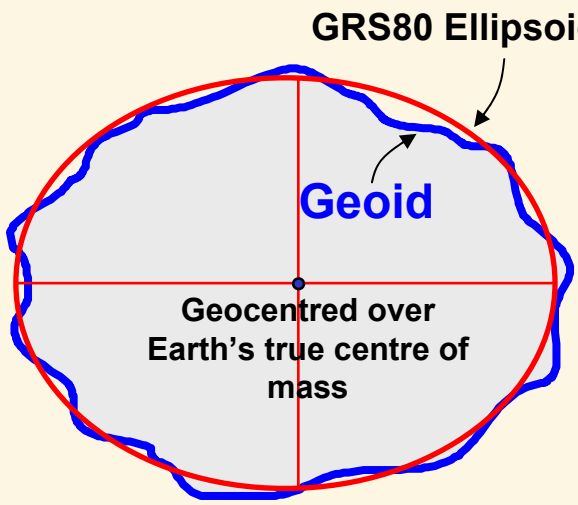
- Datum used before 1986
- Ellipsoid that best represented the geoid in North-America
- Not geocentric
- Origin at Meades Ranch (US)
- From traditional surveys (pre-1927) + local adjustments

NAD83



- Datum officially adopted by Canada and US in 1986
- Full network readjustment
- Fixed to North American tectonic plate
- Before 1994: WGS84 (GPS datum) was the same as NAD83
- NAD83 is (near) geocentric (2m off) + has Axis Orientation error

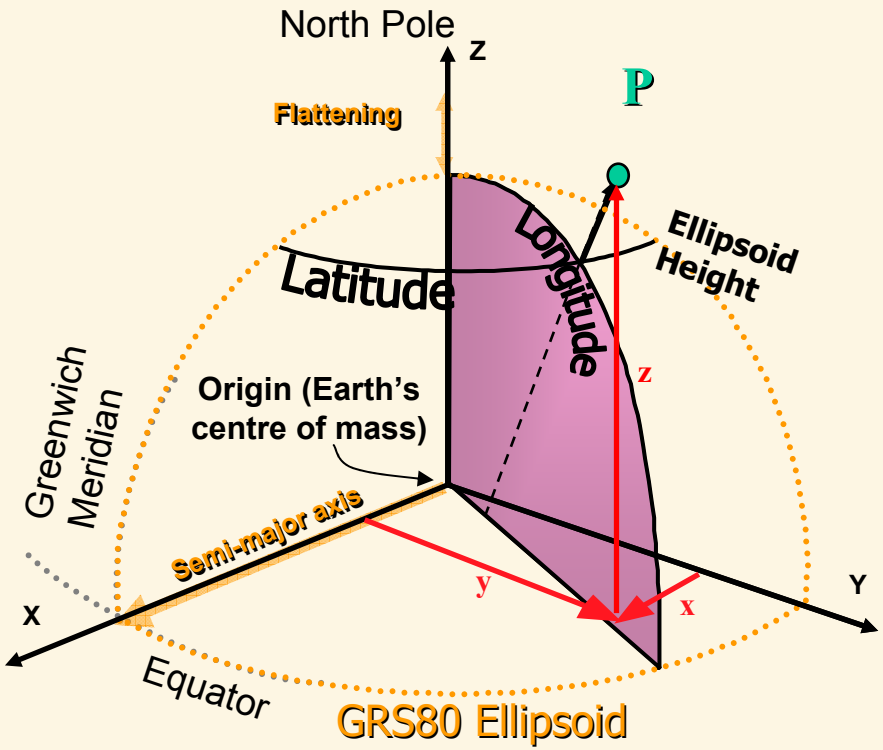
ITRF

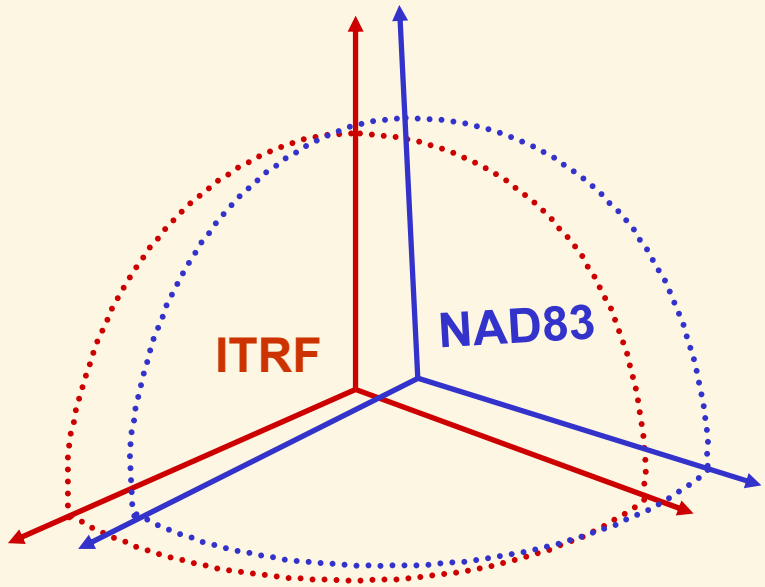


- Since 1988: Dynamic High accuracy International Terrestrial Reference Frame
- In 1994: WGS84 ➢ ITRF

Today: non-geodetic (recreational/mapping) GPS receivers still think NAD83=WGS84

3D position





Expressed in Cartesian Coordinates (XYZ)
or Geographic Coordinates (Lat, Long, Height)
relative to an ellipsoid (GRS80)

Lat/Long can be expressed in
UTM or MTM projections

NAD83

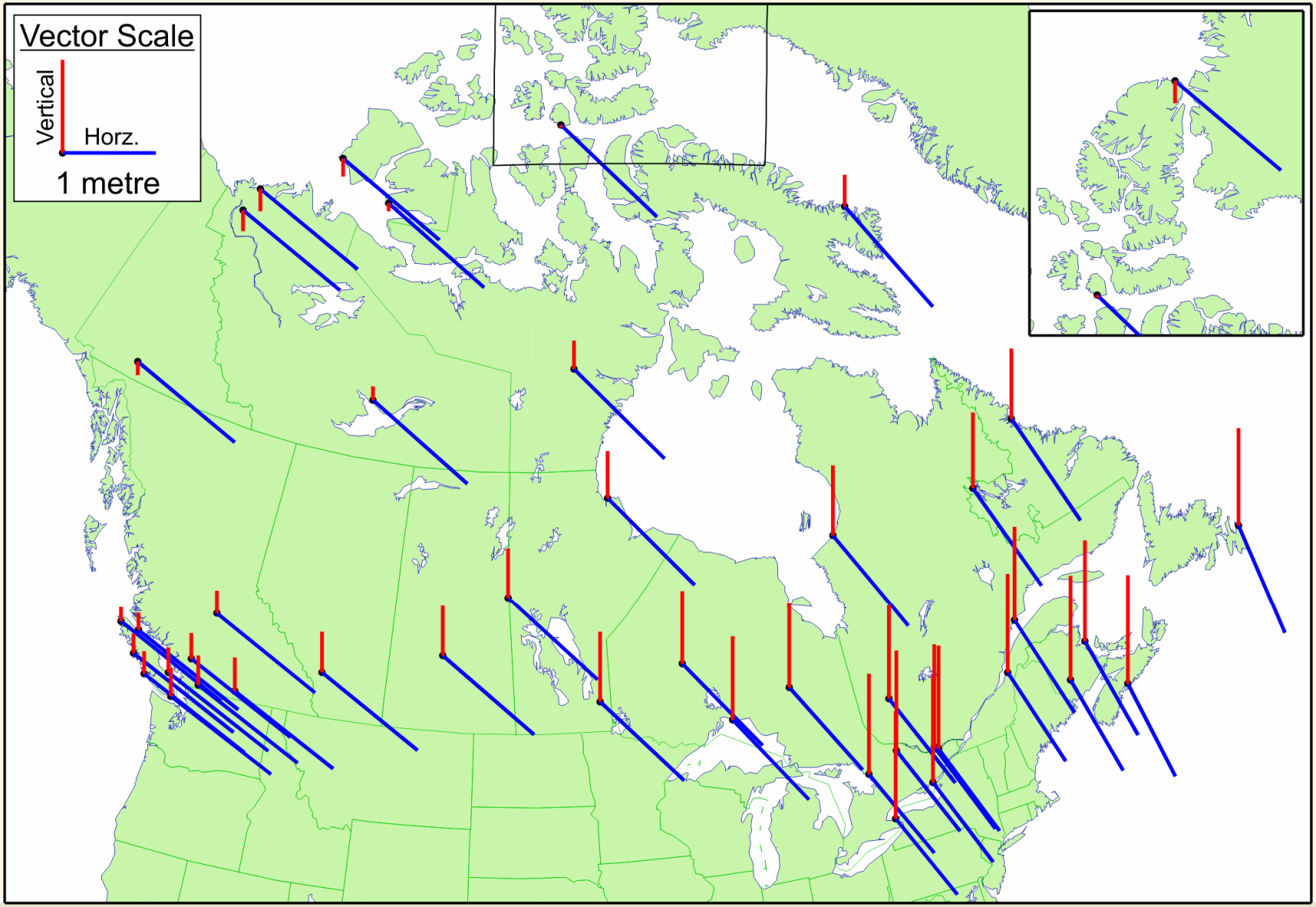
Origin off by 2m
(translations TX, TY, TZ)

Axis Orientation error
(rotations RX, RY, RZ)

~Same Scale

7-parameter transformation

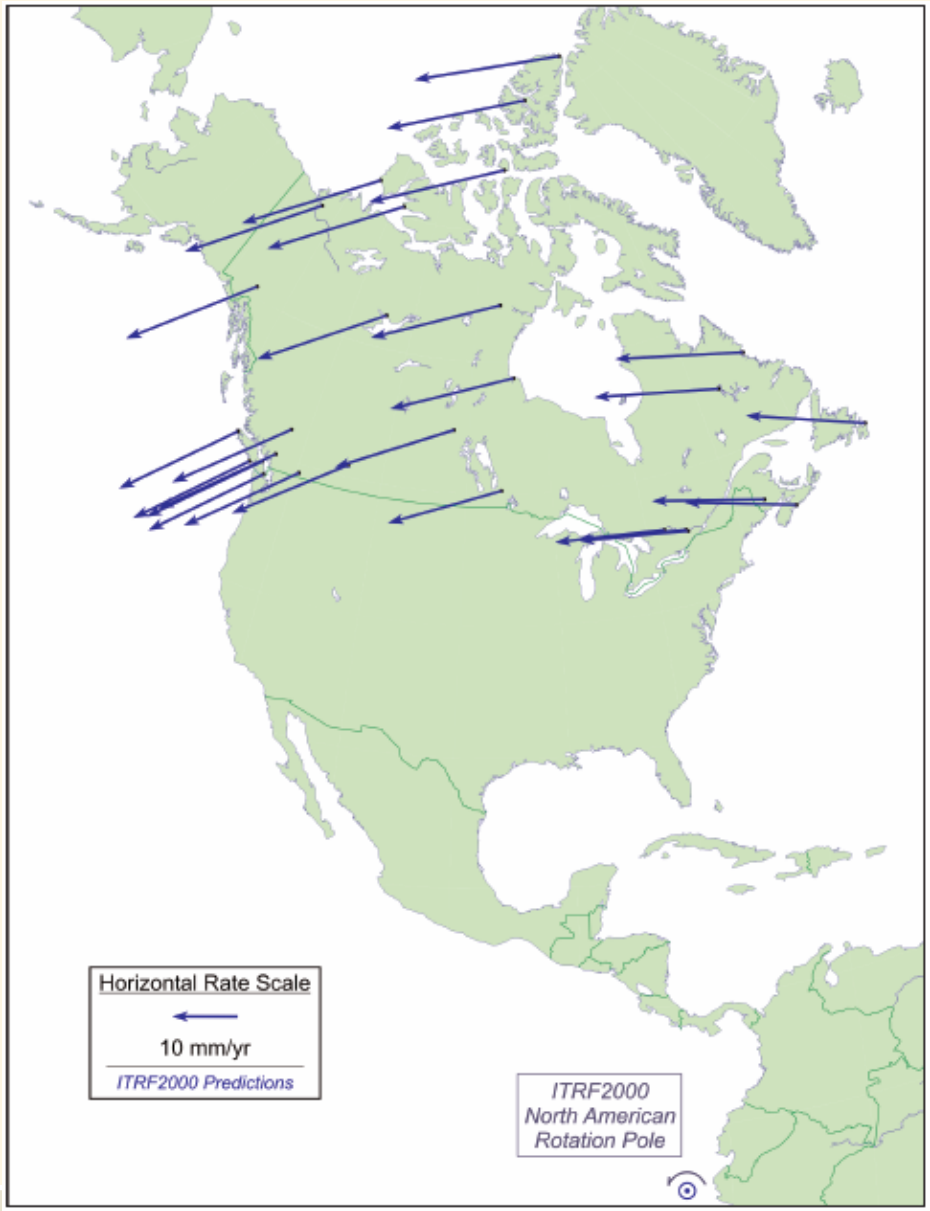
Difference between WGS84/ITRF and NAD83



Movement of North American tectonic plate

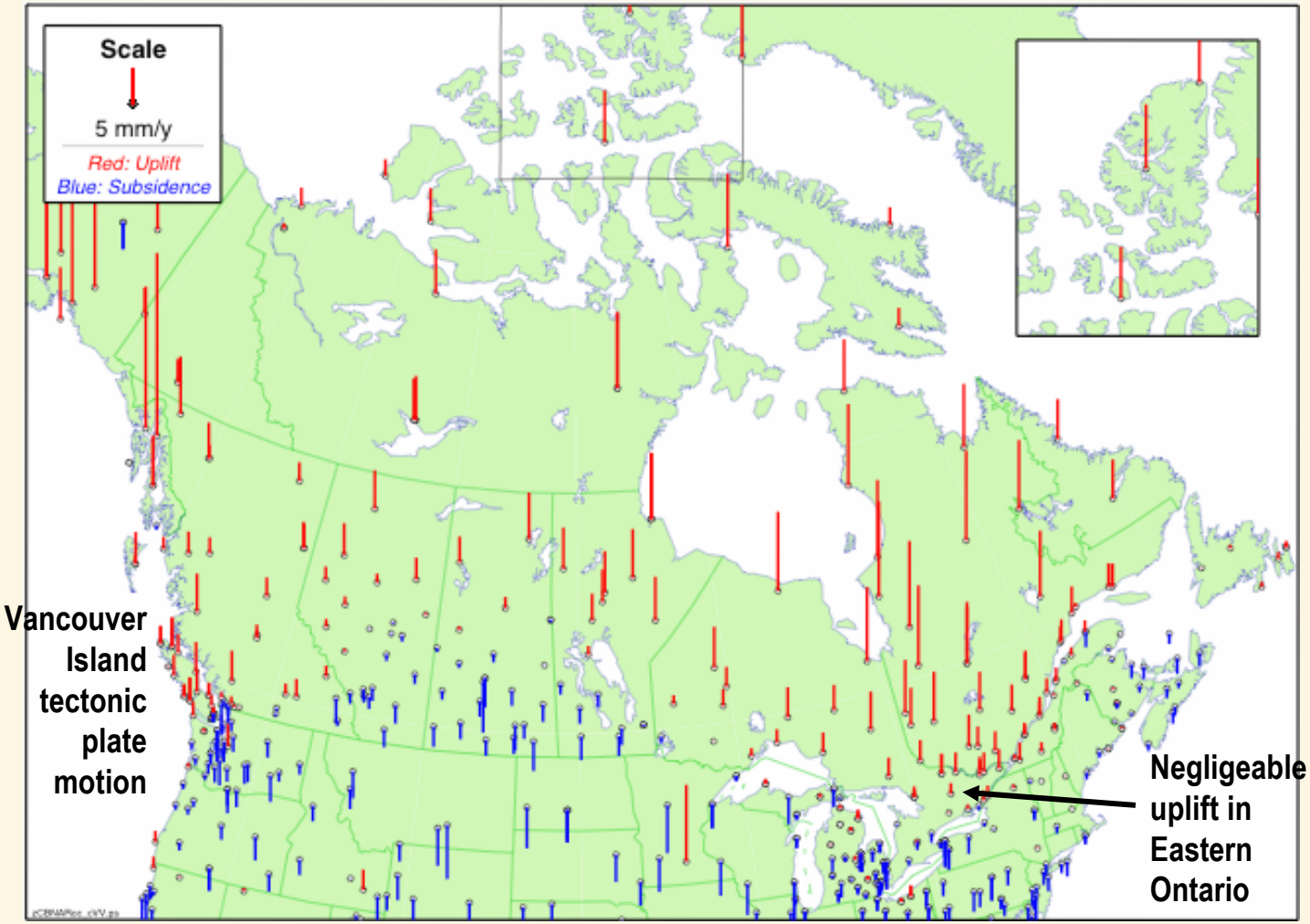
- **Plate moves 2 cm per year counter-clockwise**
- **WGS84/ITRF**
  - dynamic
  - coordinates change over time
- **NAD83**
  - fixed to the North American tectonic plate
  - coordinates will not change over time

except for….



Uplift/Subsidence

Due to post-glacial rebound



NAD83 “4-D” Velocity Grid available soon

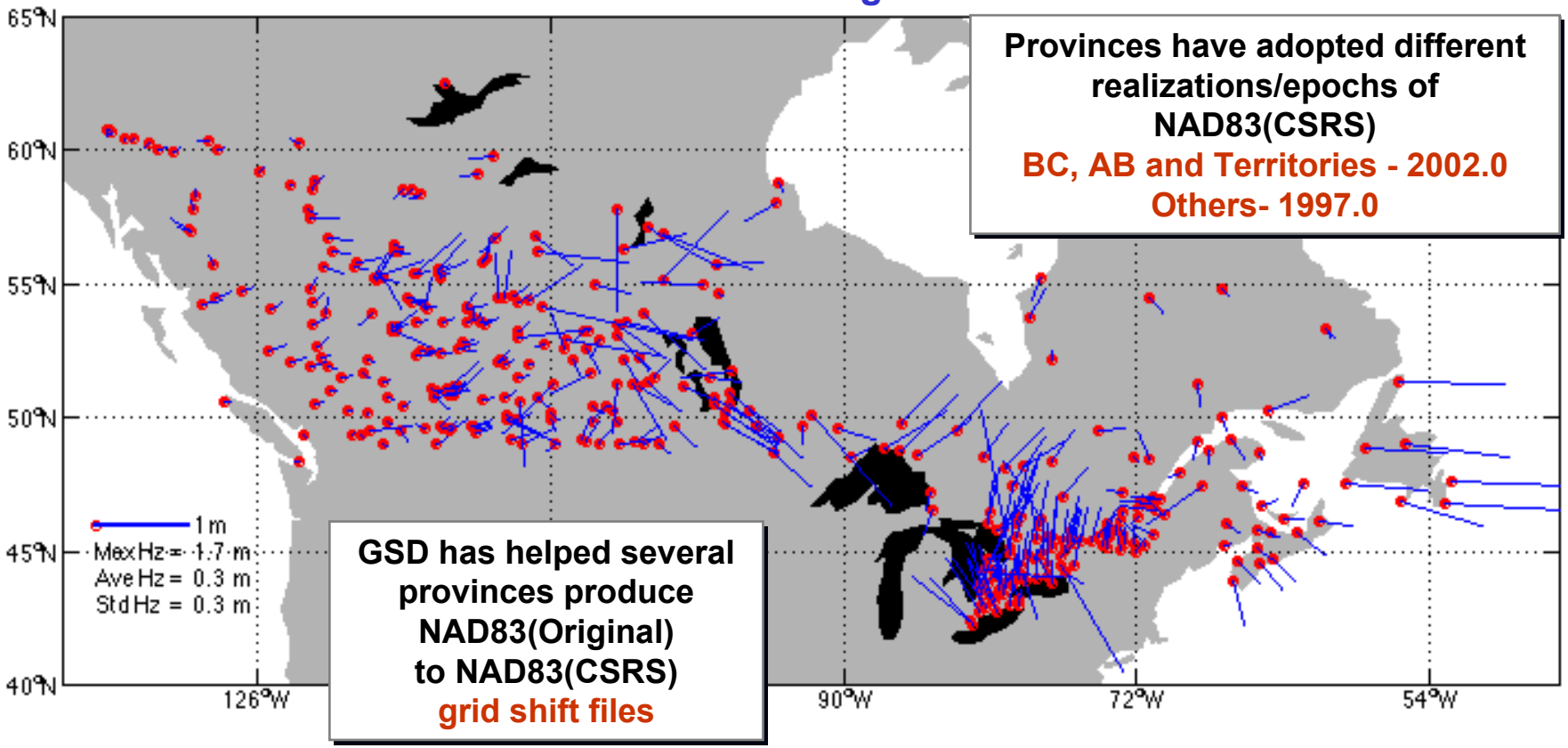
NAD83: One datum, two main realizations

NAD83(Original) and NAD83(CSRS)

From traditional surveys
Adjustment anchored to Doppler (1m)
Variable-accuracy 2D

From high-order GPS surveys
Anchored to VLBI (1cm)
Centimeter-accuracy 3D
Since 1997

NAD83(Orig.) stations re-observed with high-order GPS
Difference between Original and CSRS



Provinces have adopted different realizations/epochs of NAD83(CSRS)
BC, AB and Territories - 2002.0
Others- 1997.0

GSD has helped several provinces produce NAD83(Original) to NAD83(CSRS) grid shift files

Datum transformation software

- **NTv2.0 (National Transformation) software**
  - Available no-charge from GSD *www.geod.nrcan.gc.ca*
    - For use Online
    - Free download
  - Software Licences
    - Several companies are commercially licenced to distribute software packages that include NTv2.
  - Grid shift files available from provincial survey organizations
    - Ontario (MNR) COSINE *www.cosine.mnr.gov.on.ca*

- **TRNOBS software**
  - NAD83(CSRS) ⇔ ITRF
  - Free Online service from GSD *www.geod.nrcan.gc.ca*

Ontario M.N.R. (COSINE)

www.cosine.mnr.gov.on.ca

Download NTv2-Related Files

Next | Prev | Documentation / Canada / Ontario / Toronto | Submit | Cancel | Reset

Ontario NTv2 Files

File Name	Version Date / Length	Datum (1) ↔ Datum (2)	Remarks	Action
ON27CSv1.gsb	2007/03/07 17102016	NAD-1927:1974 ↔ NAD-1983:CSRS	NAD27 ⇔ NAD83(CSRS)	Retrieve
ON76CSv1.gsb	2007/03/07 17102016	NAD-1927:1976 ↔ NAD-1983:CSRS	May'76 ⇔ NAD83(CSRS)	Retrieve
ON83CSv1.gsb	2007/03/07 17102016	NAD-1983:ORIG ↔ NAD-1983:CSRS	NAD83(Orig) ⇔ NAD83(CSRS)	Retrieve

Ontario M.N.R. (COSINE)

www.cosine.mnr.gov.on.ca

Download NTv2-Related Files

Next | Prev | Documentation / Canada / Ontario / Toronto | Submit | Cancel | Reset

Toronto NTv2 Files

File Name	Version Date / Length	Datum (1) ↔ Datum (2)	Remarks	Action
TO27CSv1.gsb	2006/01/11 1337088	NAD-1927:1974 ↔ NAD-1983:CSRS	NAD27 ⇔ NAD83(CSRS)	Retrieve

GPS can answer the questions

- **"Where am I on Earth?"**
  - Techniques:
    - Realtime : **Broadcast GPS (uncorrected), CDGPS, WAAS**
    - Post-processing: **CSRS-PPP**
  - "Absolute" accuracy
    - Relative to a **Spatial Reference System** (**Datum**)

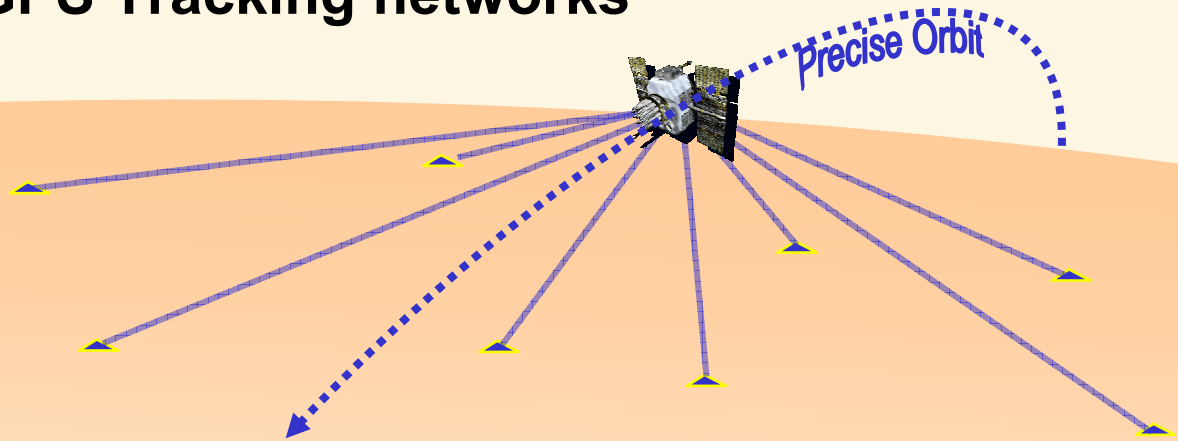
Single Receiver Point Positioning

- **"Where am I relative to a GPS Base Station?"**
  - Techniques:
    - Realtime : **RTK**
    - Post-processing: **Phase Differential**
  - "Relative" precision
    - Precision dependant on **baseline length**

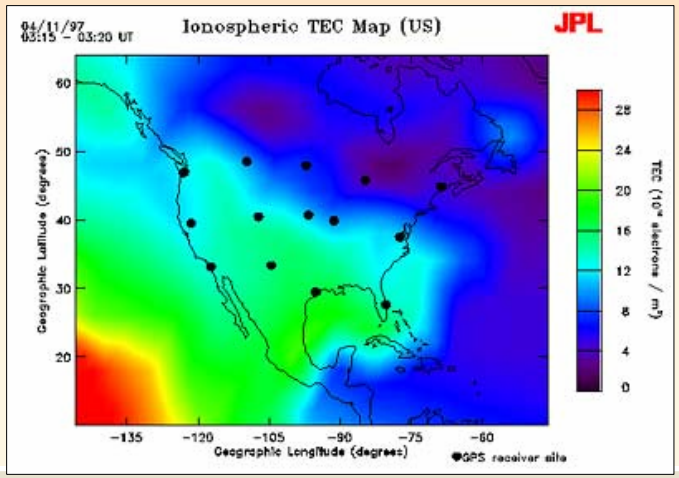
Two receiver 3D Baseline Measurement

Wide Area GPS Corrections

National and Global GPS Tracking networks

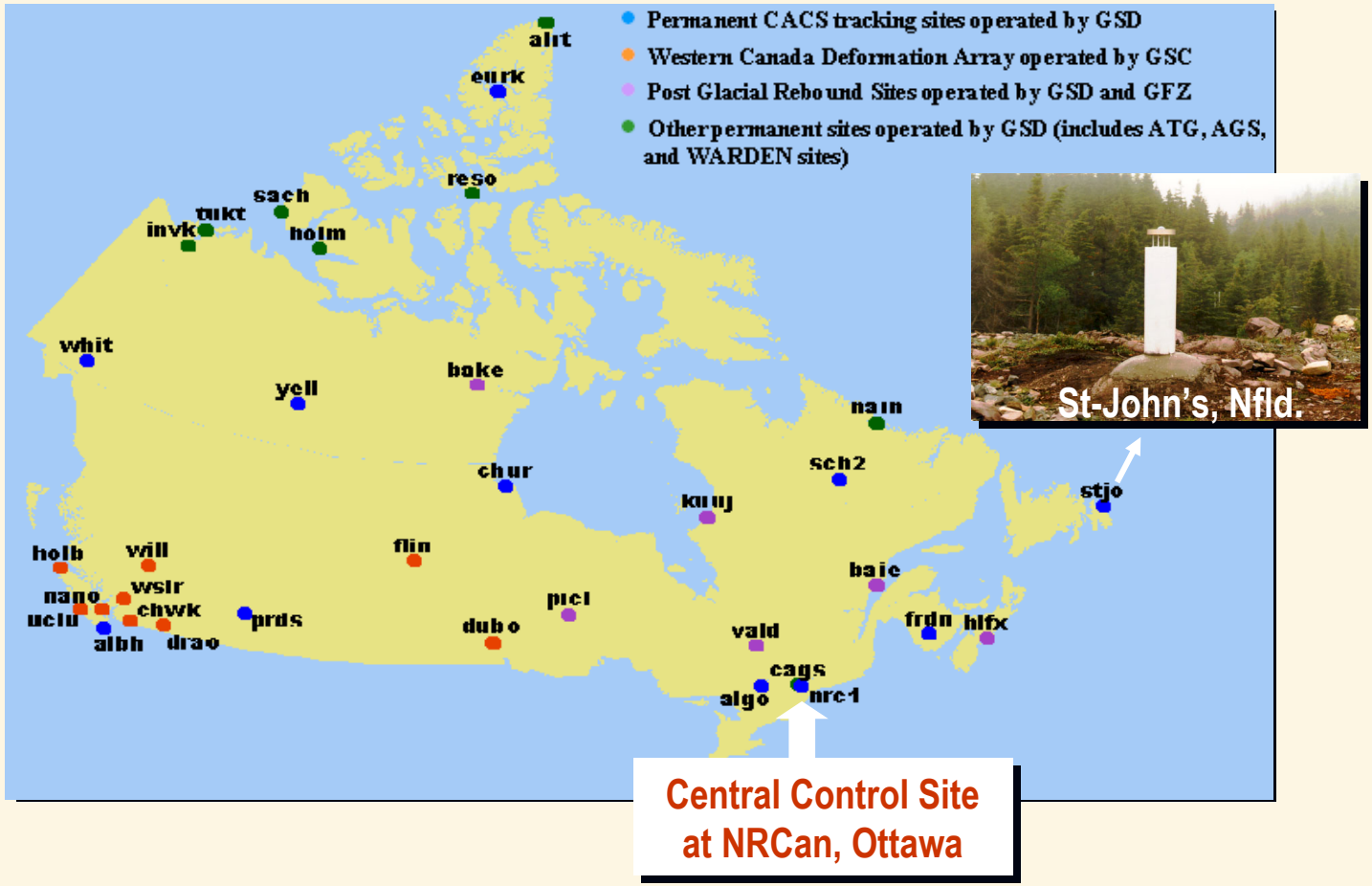


- Continuously-operating **High-End Dual-frequency** GPS reference stations compute:
  - **Precise Ephemerides**
    - Precise Satellite Orbits
    - Precise Satellite Clock Corrections
  - **Ionosphere Model**



CACS
(Canadian Active Control System)

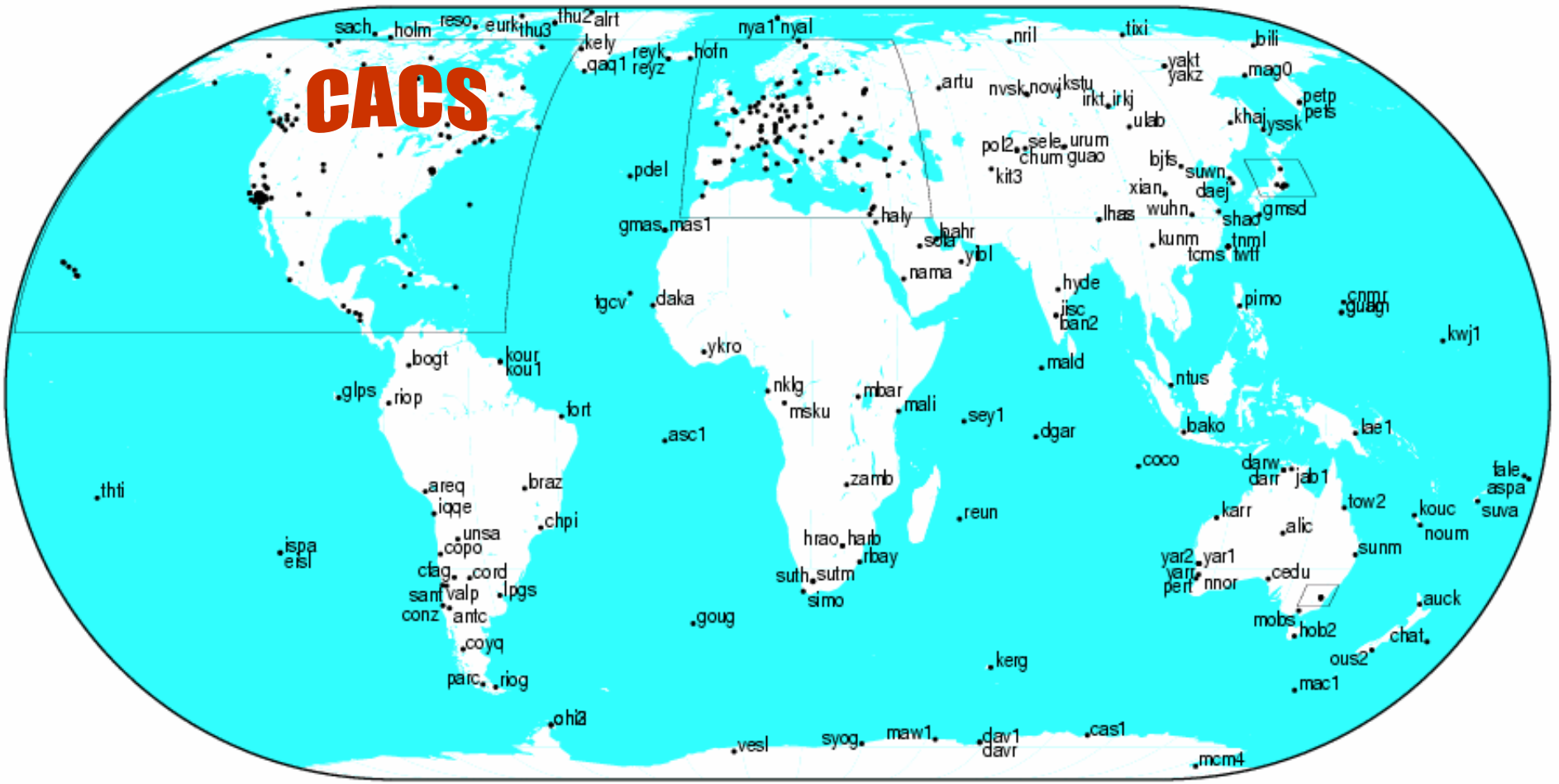
– Canadian GPS Tracking Network



IGS (International GNSS Service)

http://igscb.jpl.nasa.gov/

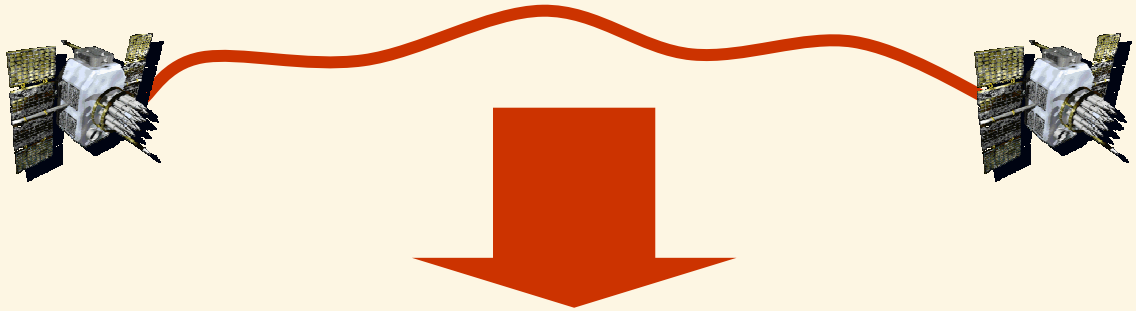
CACS is part of the IGS Global GPS Tracking Network

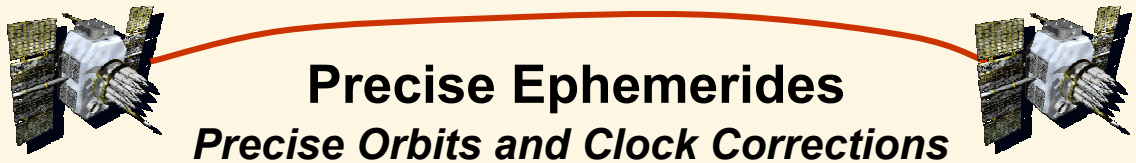


from which are produced GPS Precise Ephemerides

GPS Precise Ephemerides

Broadcast Ephemerides (+/- 1 to 2 m)





Precise Ephemerides

Precise Orbits and Clock Corrections

Used in
CSRS-PPP
Post-Processing

FINAL (+/- 2 cm) available in 13 days

RAPID (+/- 5 cm) available next day

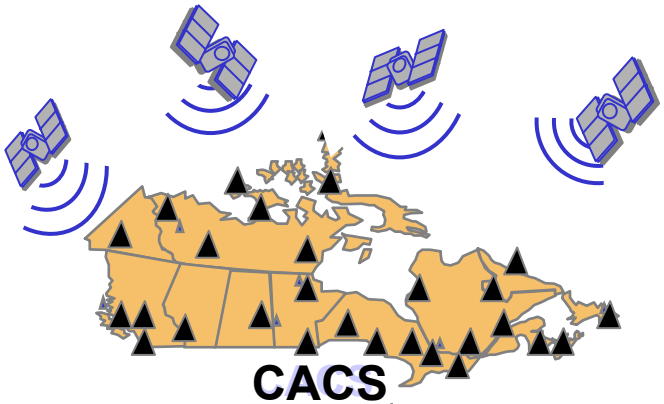
ULTRA RAPID (+/- 15 cm) available 90 min past the hour

→ ***Used to produce GPS-C realtime corrections (currently available via CDGPS service)***

Real-Time

GPS•C Realtime Corrections

Corrected Positions are in NAD83(CSRS)



Central Control Site
RNCan, Ottawa

GPS•C Realtime Corrections from ULTRA RAPID ephemerides

MSAT

CDGPS Radio

Mapping grade GPS

GPS•C

RTCM corrections

MSAT Ottawa

Receivers with integrated CDGPS
Novatel, Raven, BeelineArro, Sokkia, Topcon, GEM magnetometers
(they all use the Novatel GPS/CDGPS chip)

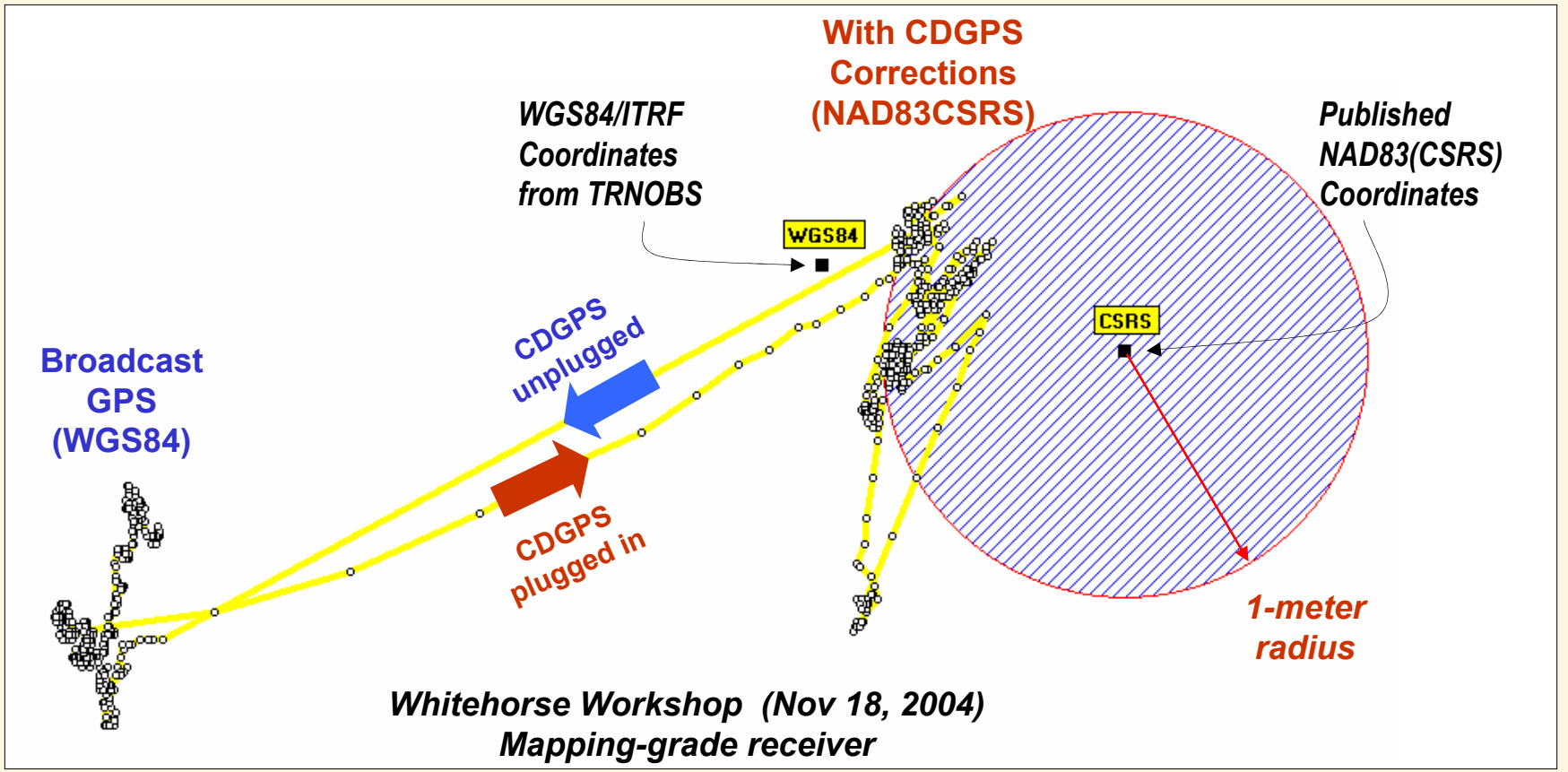
Distribution via CDGPS

Other possible distribution modes (Internet, cellular…)

Real-Time

CDGPS

Metre-level positioning with single frequency receiver



60cm positioning with dual-freqency receiver (Novatel)

Coming…. **Decimetric accuracy PHASE solution with realtime global network**

*GSD is leading the **IGS Realtime Pilot Project***

Post-Processing

CSRS-PPP

http://www.geod.nrcan.gc.ca

FREE for GPS users WORLDWIDE

Natural Resources Canada | Ressources naturelles Canada | Canada

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- CSRS-PPP
- Users' Guide
- Latest News (last updated December 05, 2006)

CSRS-PPP

CSRS-PPP is an on-line application for GPS data post-processing that allows GPS users to submit observation data over the Internet and recover, using precise GPS Orbit and Clock information, enhanced positioning precisions in the Canadian Spatial Reference System (CSRS) and the International Terrestrial Reference Frame (ITRF).

Select one RINEX File: [ ] [Browse...]
(Compression: none or zip (.zip), gzip (.gz) or UNIX Compress (.Z))
(Format: RINEX or Compact RINEX (Hatanaka))

Select Mode of Processing: (•) Static ( ) Kinematic

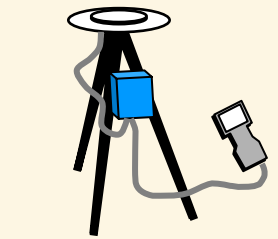
Select Reference System: (•) NAD83-CSRS ( ) ITRF

Enter/Change E-Mail to which results will be sent:
plsauve@nrcan.gc.ca

File Upload/Processing: [START]

(Note: Processing will start once the upload is completed which may take a few minutes)

Precise
Point
Positionning



RINEX

Submit

E-Mail

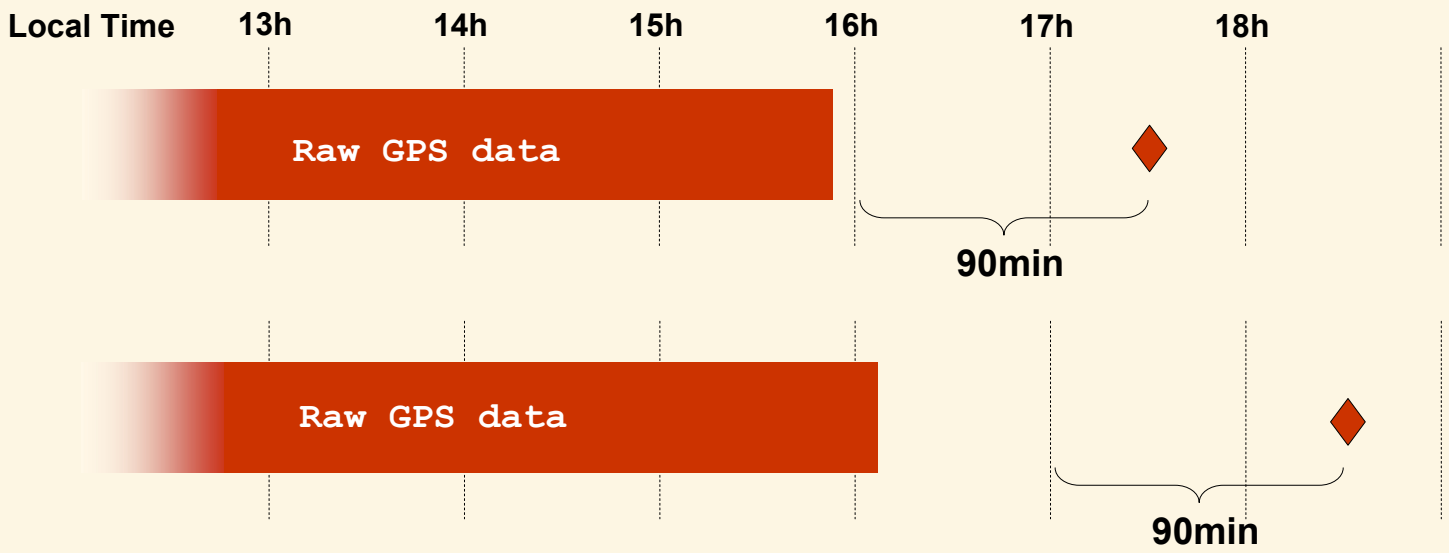
RINEX data

Receiver INdependent EXchange format

```
     2              OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
Convert             NRCan               29-Sep-04 09:09     PGM / RUN BY / DATE
SE corner of deck                                           MARKER NAME
HOME                                                        MARKER NUMBER
PLS                                                         OBSERVER / AGENCY
                    NovAtel GPSCard                         REC # / TYPE / VERS
                                                            ANT # / TYPE
  1110521.8710 -4347973.0600  4517270.4976                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1     7   G 4   G 7   G 8   G 9   G11   G19   G20WAVELENGTH FACT L1/2
     1     1     3   G27   G28   G31                       WAVELENGTH FACT L1/2
     1     1                                               WAVELENGTH FACT L1/2
     1     1                                               WAVELENGTH FACT L1/2
     6    C1    L1    D1    P2    L2    D2                 # / TYPES OF OBSERV
    10                                                      INTERVAL
  2004    09    26    23    54   24.000000      GPS        TIME OF FIRST OBS
  2004    09    27    02    01   40.000000      GPS        TIME OF LAST OBS
                                                            LEAP SECONDS
                                                            END OF HEADER
 04 09 26 23 54 24.0000000  0  6G11G31G27G 7G28G 8
  20682001.694 9 108684654.614 9      -145.893 9  20682001.342 6  84689338.936 6
      -113.683 6
  21647744.359 8 113759673.189 8     -2562.544 8  21647745.201 3  88643787.472 3
     -1996.789 3
  21887796.446 7 115021141.665 7      2825.988 7  21887799.255 4  89626873.419 4
      2202.066 4
  23190091.828 8 121864756.474 8     -2576.065 8  23190091.522 3  94959523.542 3
     -2007.328 3
  21242267.310 9 111628863.734 9     -2001.787 9  21242265.979 4  86983415.213 4
     -1559.832 4
  20821309.709 9 109416712.759 9      1853.006 9  20821309.051 4  85259777.441 4
      1443.900 4
 04 09 26 23 54 30.0000000  0  6G11G31G27G 7G28G 8
  20681837.451 9 108683792.395 9      -141.246 9  20681837.199 6  84688667.077 6
      -110.061 6
```

Delay before submitting data (♦)

- ULTRA-RAPID Ephemerides are available 90 minutes after each hour



- Soon datasets submitted early will be “held” until ULTRA-RAPID ephemerides are available

CSRS-PPP (Static)

Email Return

Results of your CSRS-PPP processing can be downloaded by clicking on the following link:

http://luna.geod.nrcan.gc.ca/ppp_data/20070126_0011_6hrs_oem3onpier13/20070126_0011_6hrs_oem3onpier13_full_output.zip

URL to PDF summary file:
http://luna.geod.nrcan.gc.ca/ppp_data/20070126_0011_6hrs_oem3onpier13/6hrs_oem3onpier13.pdf

The estimated coordinates / standard deviations for the 6hrs_oem3onpier13.05o RINEX file are as follow:

Corrected coordinates in email text

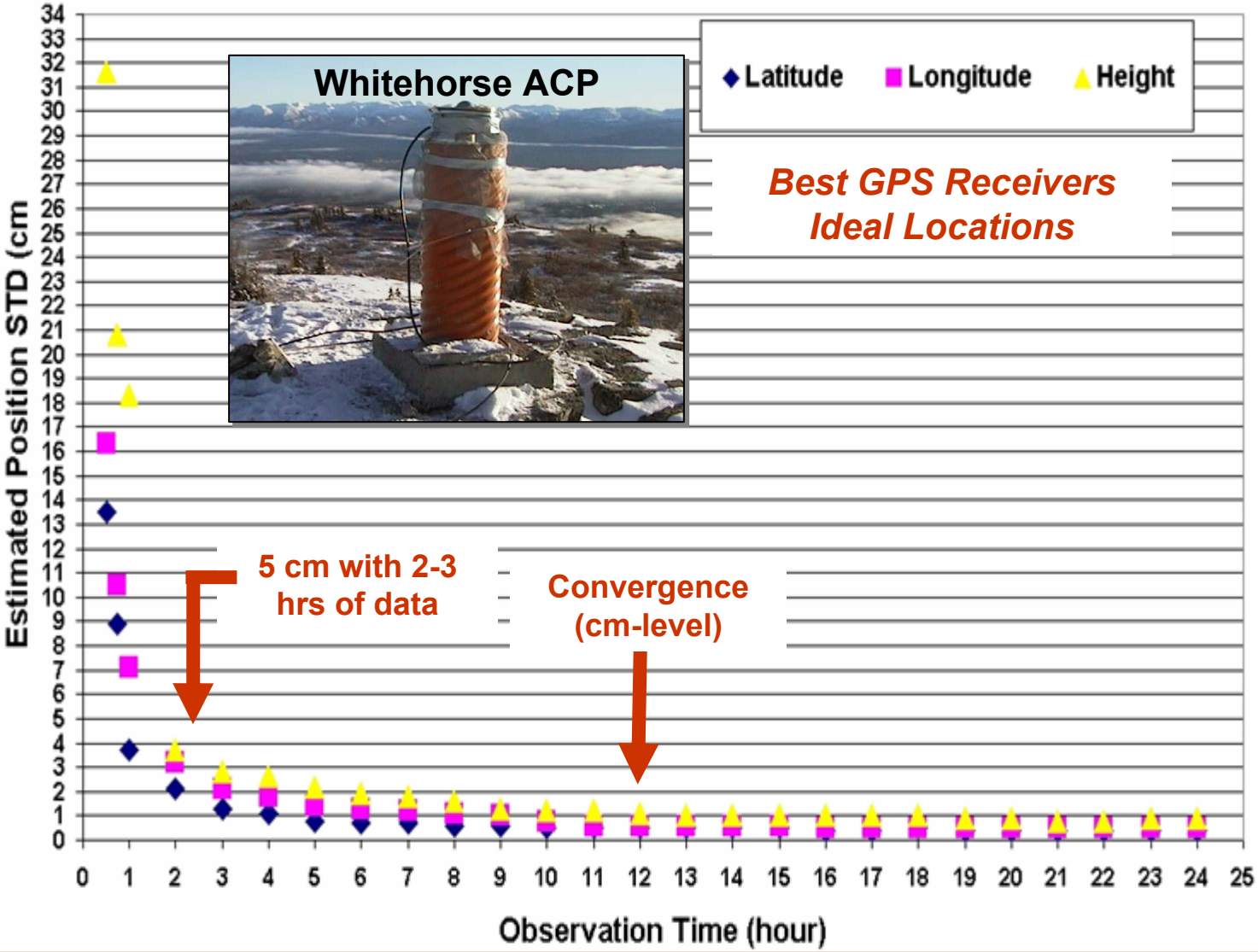
Latitude (NAD83-CSRS): 45 23 59.9769 (dms) / 0.005 (m)
Longitude (NAD83-CSRS): -75 55 08.9965 (dms) / 0.006 (m)
Ellipsoidal Height (NAD83-CSRS): 46.279 (m) / 0.014 (m)

Orthometric Height CGVD28 (HTv2.0): 79.491 m

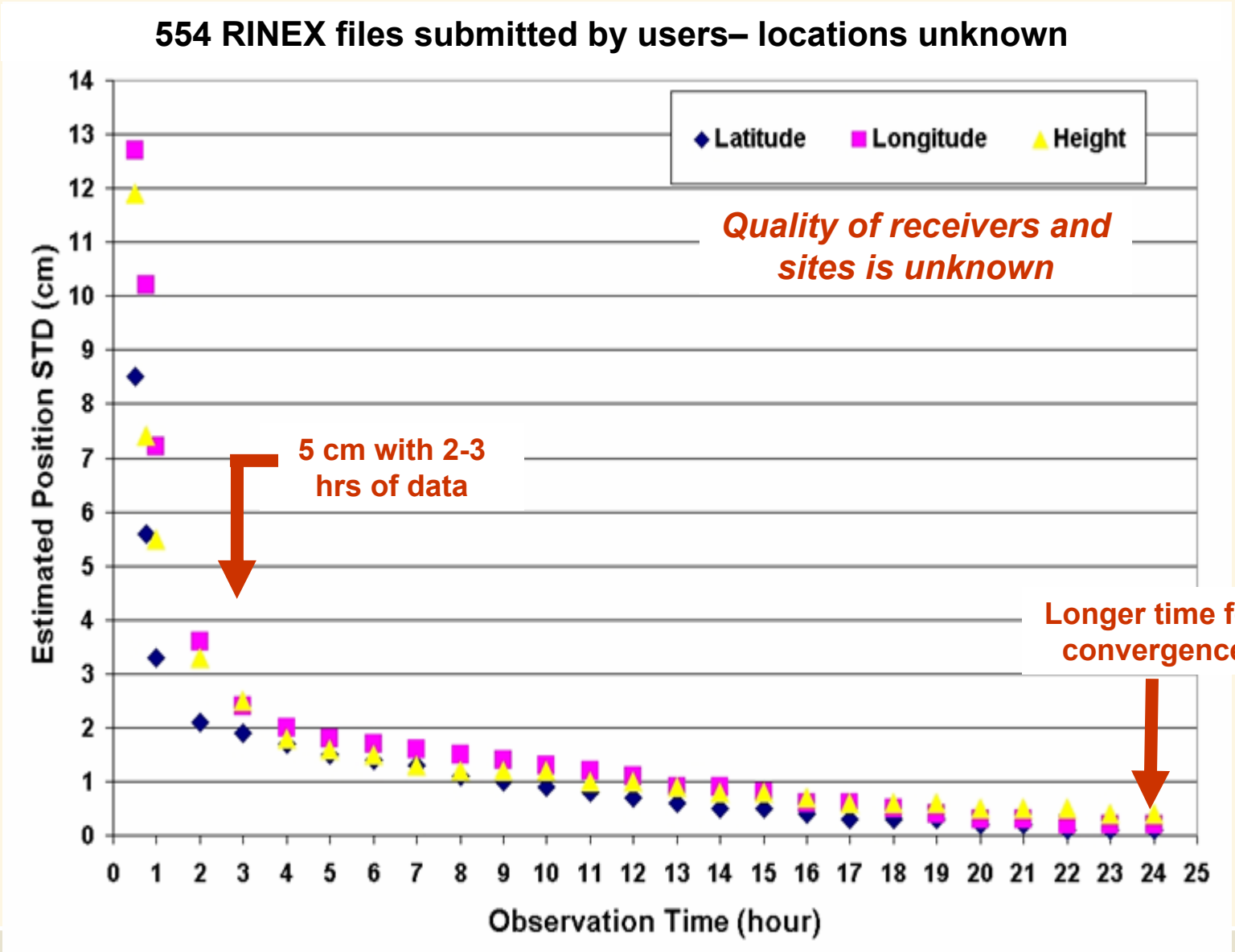
Software Version: 1.04 246

CSRS-PPP (Static)

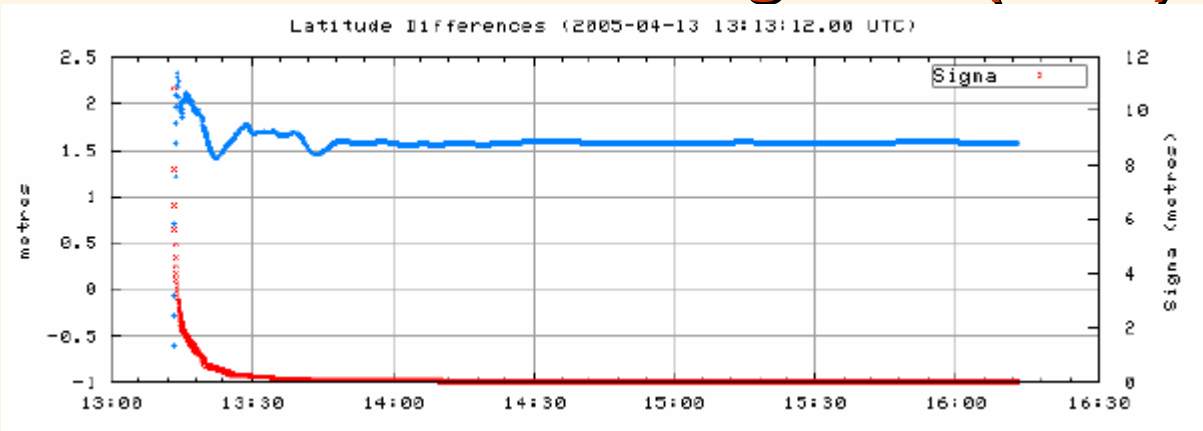
186 RINEX file from CACS stations – known locations

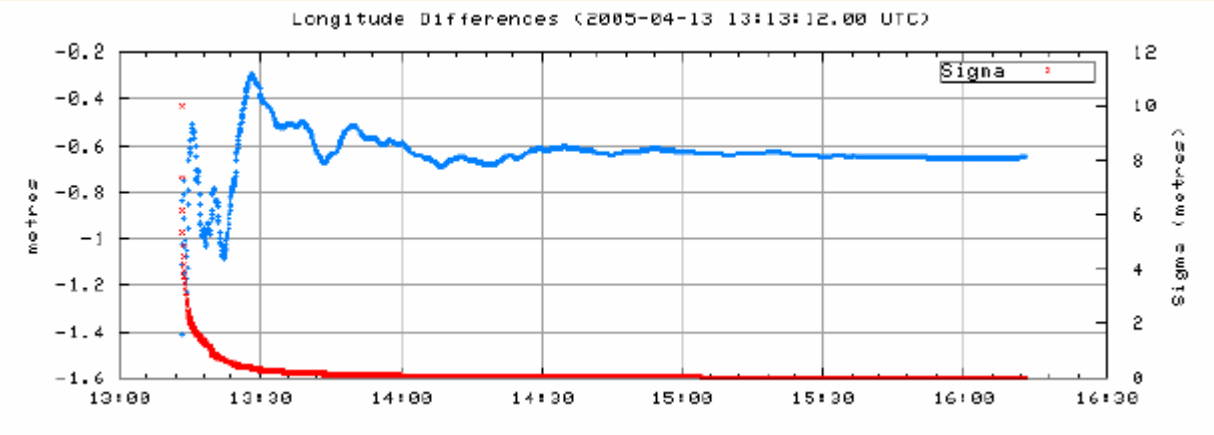


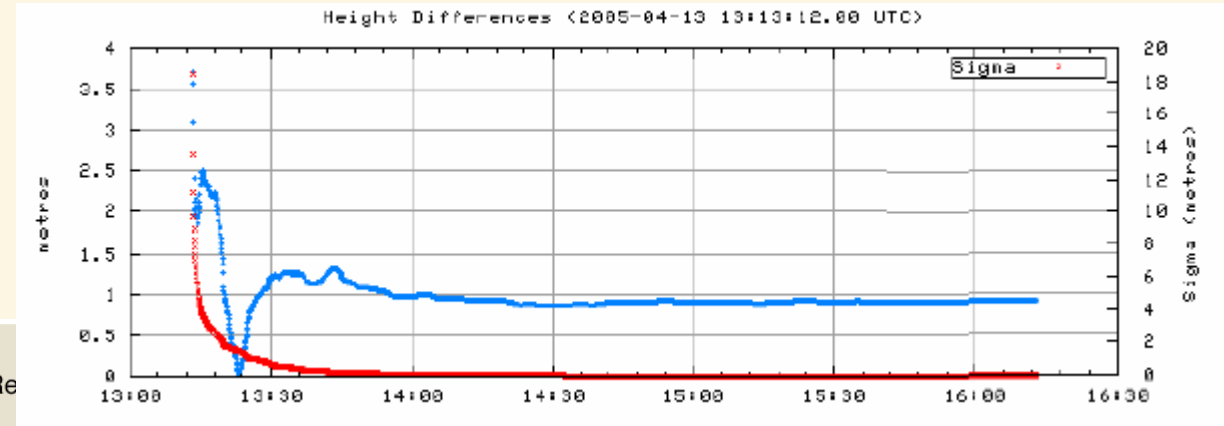
CSRS-PPP (Static)



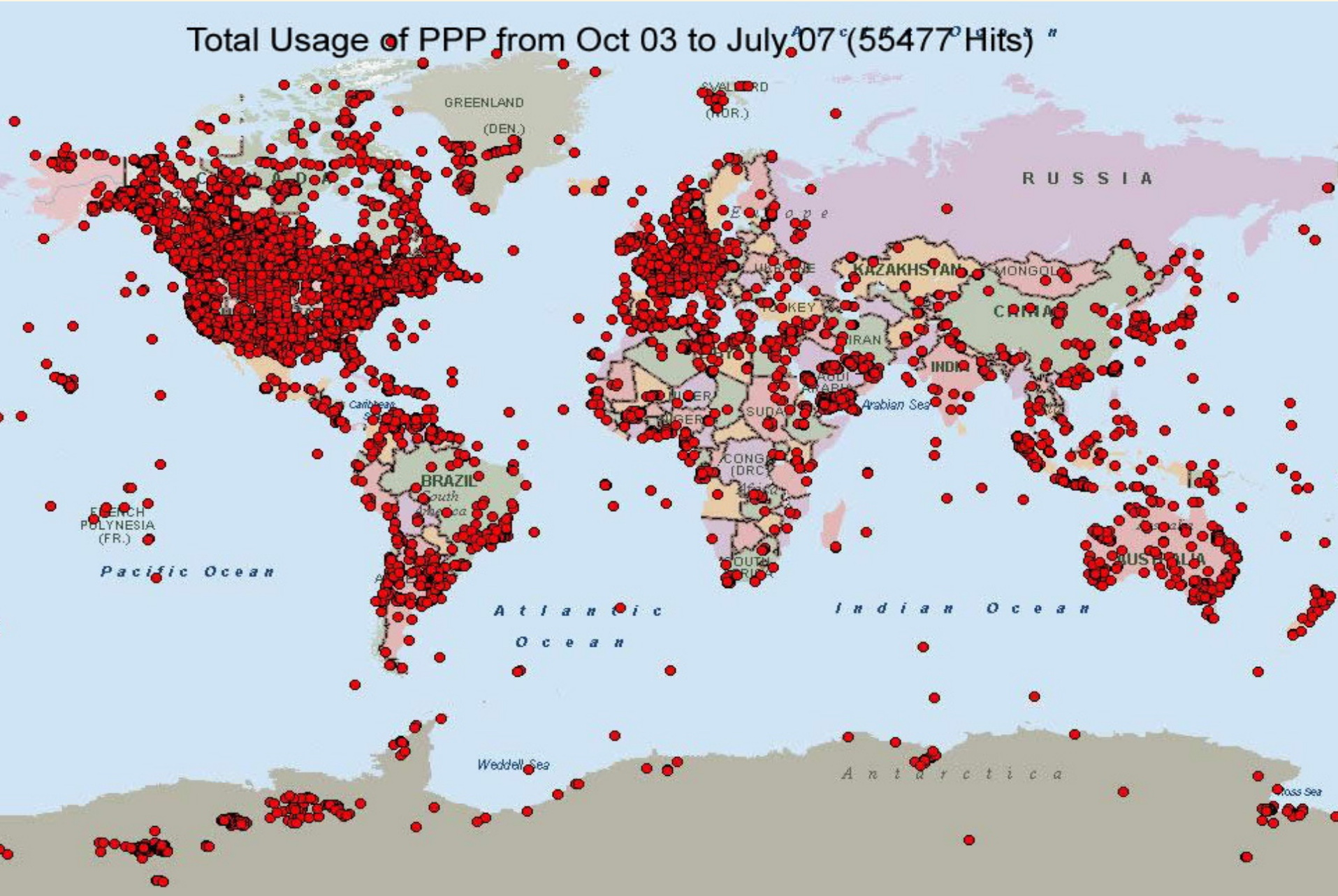
Coordinate convergence (PDF)







CSRS-PPP usage worldwide



CSRS-PPP

Accuracy after Convergence

Receiver	Observation Processed	PPP Mode	Precision (cm)		
			Latitude	Longitude	Height
Dual Frequency	Code & Carrier	Static	1	1	2
		Kinematic	5	4	10
Single Frequency	Code Only (1)	Static	10	10	100
		Kinematic	50	50	150
Single Frequency	Code & Carrier	Static	2	3	4
		Kinematic	25	25	50

80% of users

- Kinematic PPP is ideal for airborne applications
  - LIDAR, airphoto
  - 15 cm accuracy (with inertial system)
  - no need for a base station
- Commercial GPS software using their own "PPP"
  - Leica APIS 10

Static CSRS-PPP

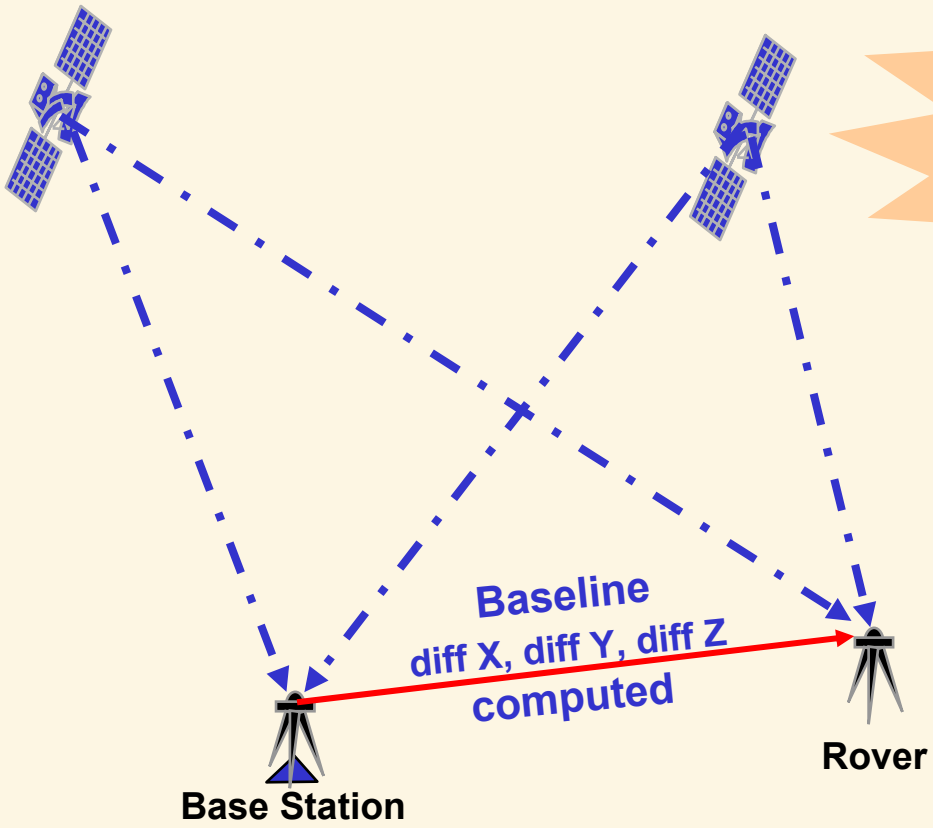
- **Test your equipment at a known geodetic monument**
  - Useful graphs in PDF show coordinate convergence

- **Easy to establish centimetric-accuracy 3D geodetic control**
  - Anywhere on Earth
  - Close to your work area
  - Corrected coordinates in **NAD83(CSRS)** or **ITRF**
    at epoch the data was collected

- **Perfect complement to Baseline PHASE Differential Correction Techniques**
  - Determine base station coordinates (using **CSRS-PPP**)
    - **Absolute accuracy** of a few cm
  - Do survey (**RTK** and/or **Baseline Post-Processing**)
    - Very short baselines
    - **Relative precision** of a few cm

Baseline PHASE Differential

- **Baseline (3D vector) is computed by Double-Differencing**
  - GPS **PHASE** data from Base Station and Rover are combined in such a way as to eliminate all common errors



Accuracy depends on baseline length

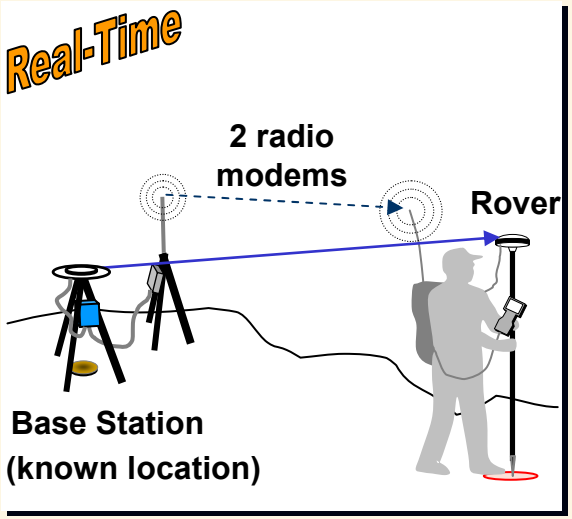
Typical precision (rms)

	Baseline length		
	1km	10 km	30 km
Dual-freq	~1cm	~2cm	~4 cm
Single- freq	~2cm	~4cm	

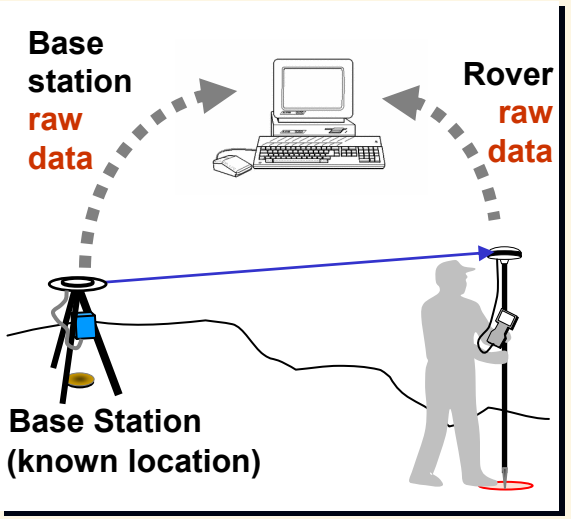
Baseline PHASE Differential

Real Time Kinematic

RTK



Post-Processing



- **Base Station can be**
  - **setup by survey crew at a control point**
    - **existing geodetic control (Fed/Prov/Municipal)**
    - **established using Static CSRS-PPP**
  - **operated by a Public Agency**
    - **NRCan: CACS raw data**
    - **Community base stations: raw data or RTK**
  - **operated by Private Industry**
    - **GPS Manufacturer/dealer or Survey firm: raw data or RTK**

Centimetric-accuracy RELATIVE positioning

Real-Time

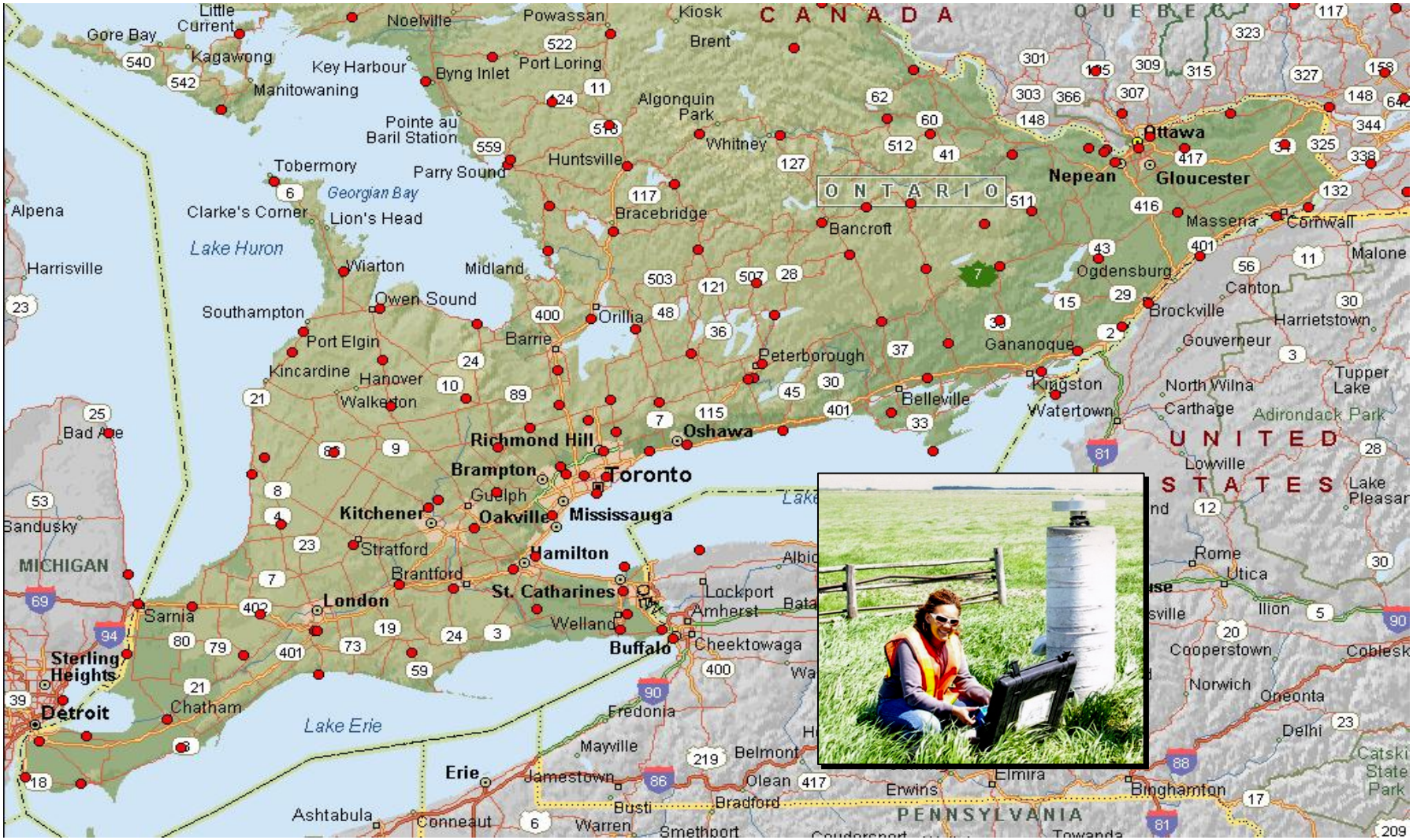
RTK Methodology

- **Base Station**
  - Clear view of sky
  - Set it to log raw data
- **First initialization (solving ambiguities)**
  - usually takes 10 minutes
- **Rover will have centimetric precision**
  - **Fixed Solution**
  - Continuous (on the fly) initialization
- **When insufficient # of common satellites**
  - Problem is usually at the Rover
  - **Float solution** (precision of +/- 2-3 cycles) until re-initialization
- **When loss of radio-communication**
  - **Collect raw data:** see manufacturers suggested times (typically 5 minutes + 1 minute per km over 5km)
  - **Baseline PHASE differential post-processing**
- **Baseline length**
  - Dual-Freq: Max. **30 km** (recommended **< 10km**)
  - Single freq: Max. **10km** (licence-free radio range of 1 to 4 km)

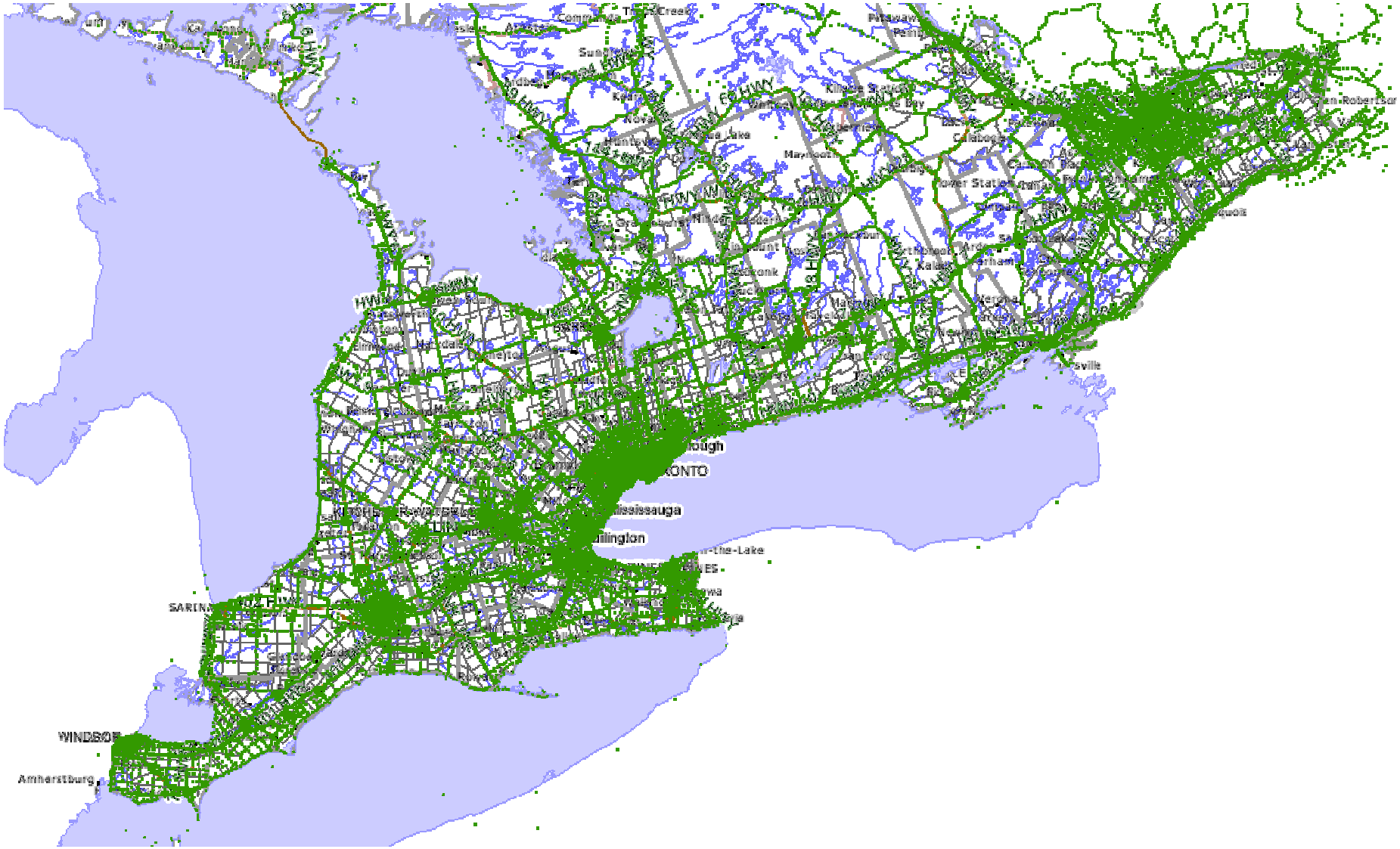

50 ACP stations
CHAIN (10)
CSRS Real-Time (15 stations)
Western Canada Deformation Array (12 Statio
Great Lakes CORS Program (5 Stations)
Post Glacial Rebound (6 Stations)
Arctic Tide Guages (5 Stations)
Climate Change (6 Stations)
Canadian Base Network (CBN)
Arctic Ocean
Greenland Sea
Beaufort Sea
Baffin Bay
Davis Strait
Labrador Sea
Hudson Strait
Hudson Bay
Atlantic Ocean
EUR3
WHIT
YELL
CHUR
SCH3
ALBH
DRAO
PRDS
WINN
ALGO
PRDV
HLFX
STJO
NRC1
NRC3
CANADA
UNITED STATES
YUKON TERRITORY
NORTHWEST TERRITORIES
NUNAVUT
BRITISH COLUMBIA
SASKATCHEWAN
MANITOBA
ONTARIO
QUÉBEC
NEWFOUNDLAND
Whitehorse
Yellowknife
Baker Lake
Rankin Inlet
Arviat
Taloyoak
Iqaluit
Nuuk
Happy Valley Goose Bay
St. John's
Prince George
Calgary
Regina
Winnipeg
Thunder Bay
Ottawa
Montreal
Toronto
Fredericton
Charlottetown
Moncton
Fairbanks
Anchorage
Juneau
Seattle
Portland
Boise
Helena
Bismarck
Sheridan
Duluth
Minneapolis
Sioux Falls
Milwaukee
Detroit
Reno
Concord
Boston
Hartford
Natural Resources Canada
Ressources naturelles Canada
Canada

NAD83(CSRS)

CBN and Ontario HPN (High Precision Network)



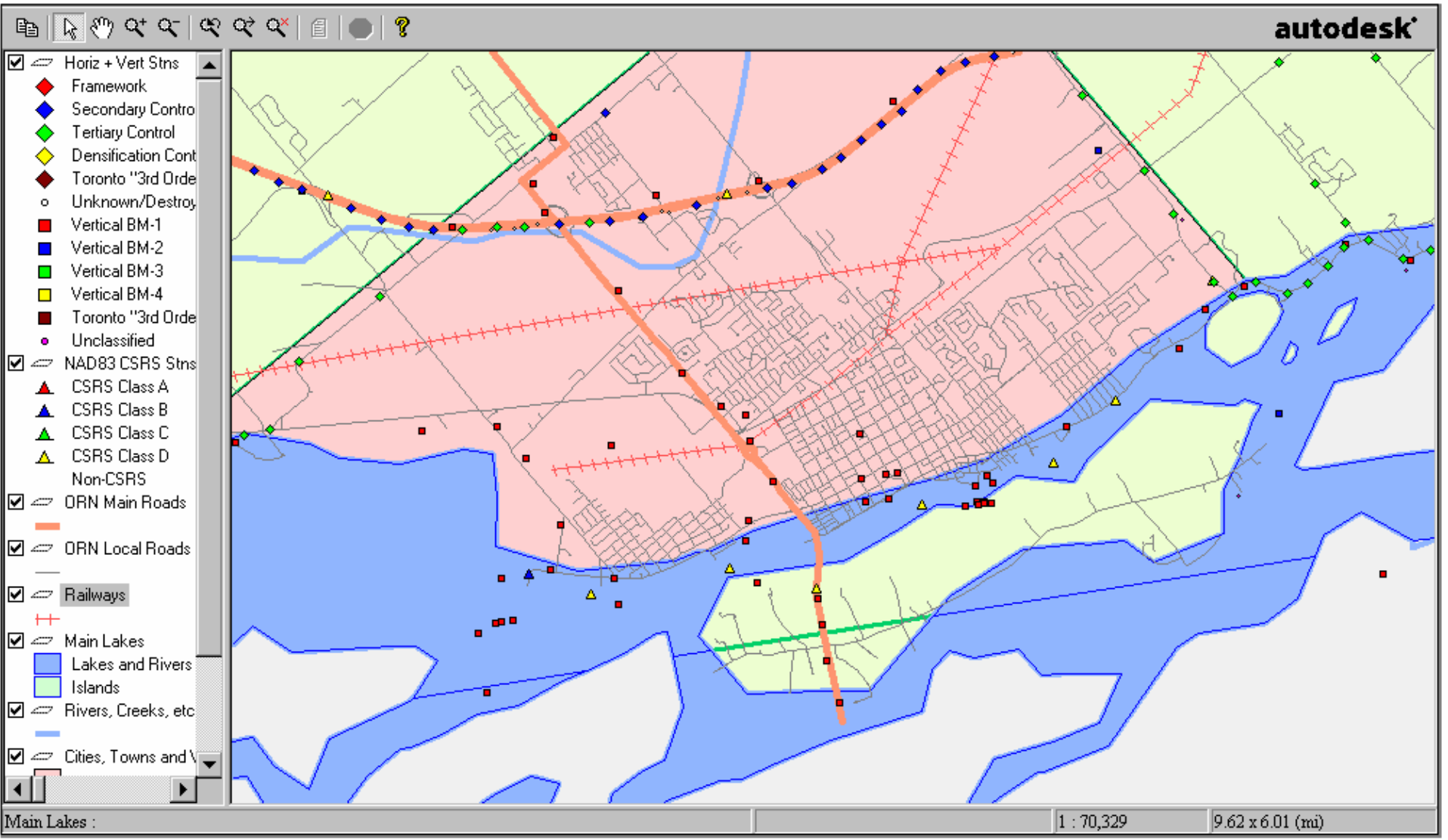
NAD83(Orig)



COSINE

COSINE Retrieval Form

Help | Options | Datum | Map | Primary | Secondary | Other | Feedback | Submit



Popular methodology in remote areas

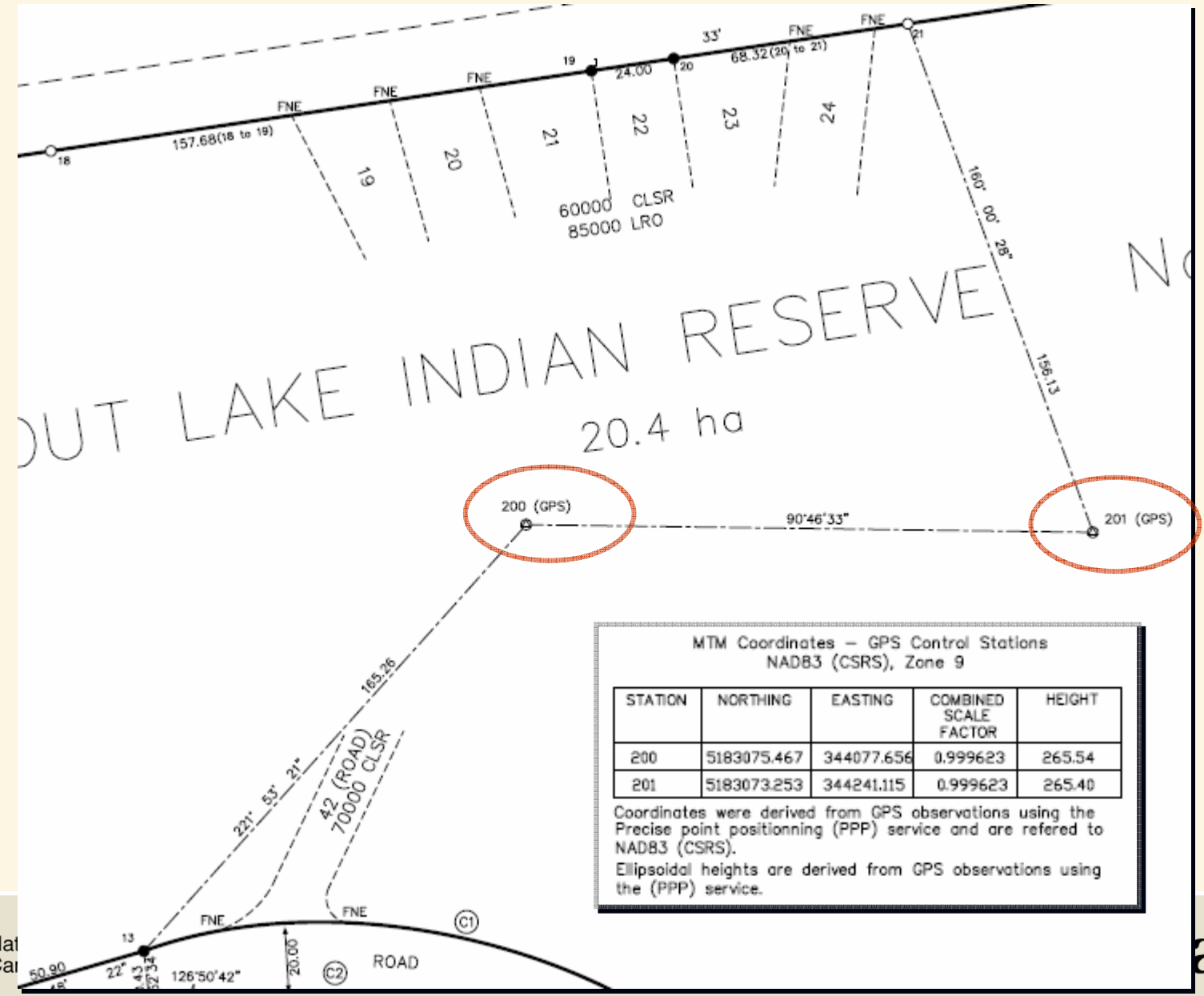
- **Equipment: 2 receivers (dual or single-frequency)**

- **Select 2 (intervisible) points and collect raw GPS data at both simultaneously**
  - Run ***Static CSRS-PPP*** on both datasets
    - Compute distance and azimuth (GSD's ***INDIR*** software)
  - Do ***baseline PHASE post-processing*** and compare with CSRS-PPP results
    - Confirms the CSRS-PPP results
  - You now have 2 geodetic control points
    - One point can serve as backsight for the other (for conventional surveys)

- **Select one of the two points as the base station**
  - Perform your survey (RTK and/or baseline PHASE post-processing)
    - Tie-in the second point for additional verification

Canada Centre for Cadastral Management

Now itegrating Canada Lands to 20cm or better



MTM Coordinates – GPS Control Stations
NAD83 (CSRS), Zone 9

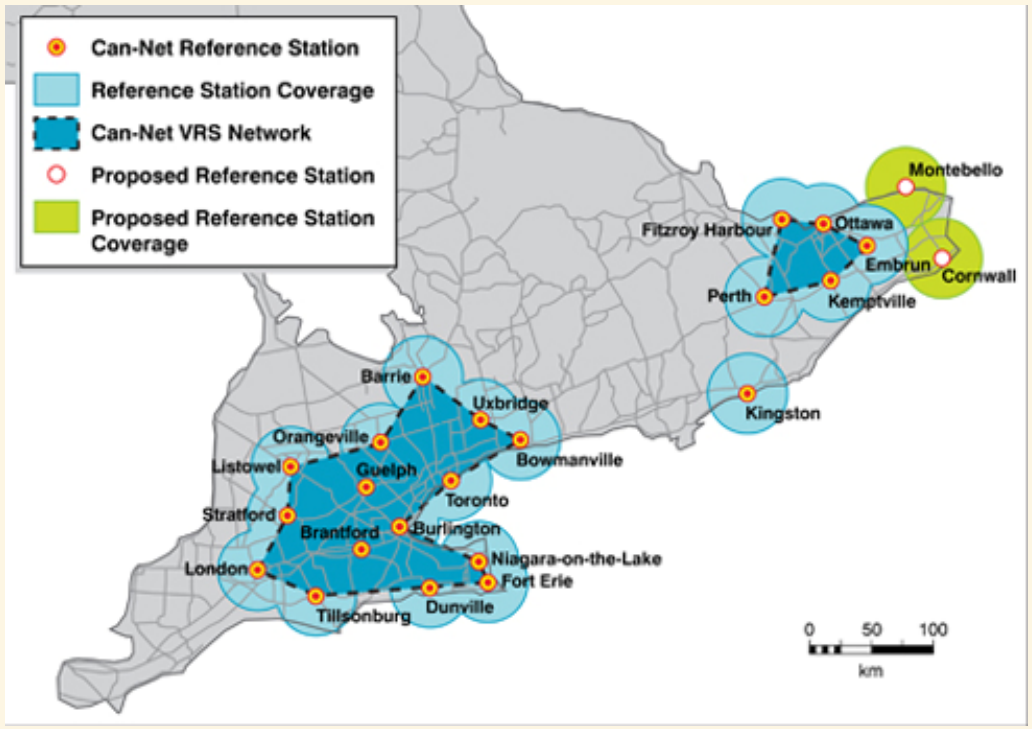
STATION	NORTHING	EASTING	COMBINED SCALE FACTOR	HEIGHT
200	5183075.467	344077.656	0.999623	265.54
201	5183073.253	344241.115	0.999623	265.40

Coordinates were derived from GPS observations using the Precise point positionning (PPP) service and are refered to NAD83 (CSRS).

Ellipsoidal heights are derived from GPS observations using the (PPP) service.

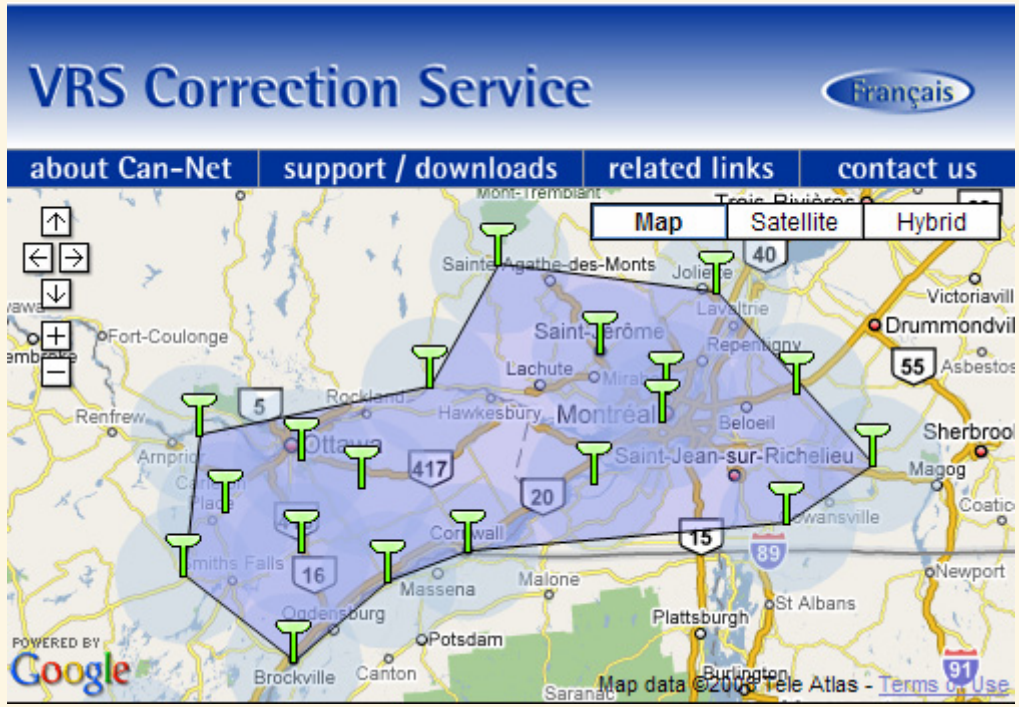
Network RTK (Can-Net)

- **Reference station coordinates are NAD83(CSRS)**
  - Checked using CSRS-PPP?
- **Rover uses cellular wireless**
- **Single baseline RTK**
- **Network RTK using VRS (Virtual Reference Station) concept**
- **RINEX raw data *(for post-processing)***



VRS (Virtual Reference Station) concept

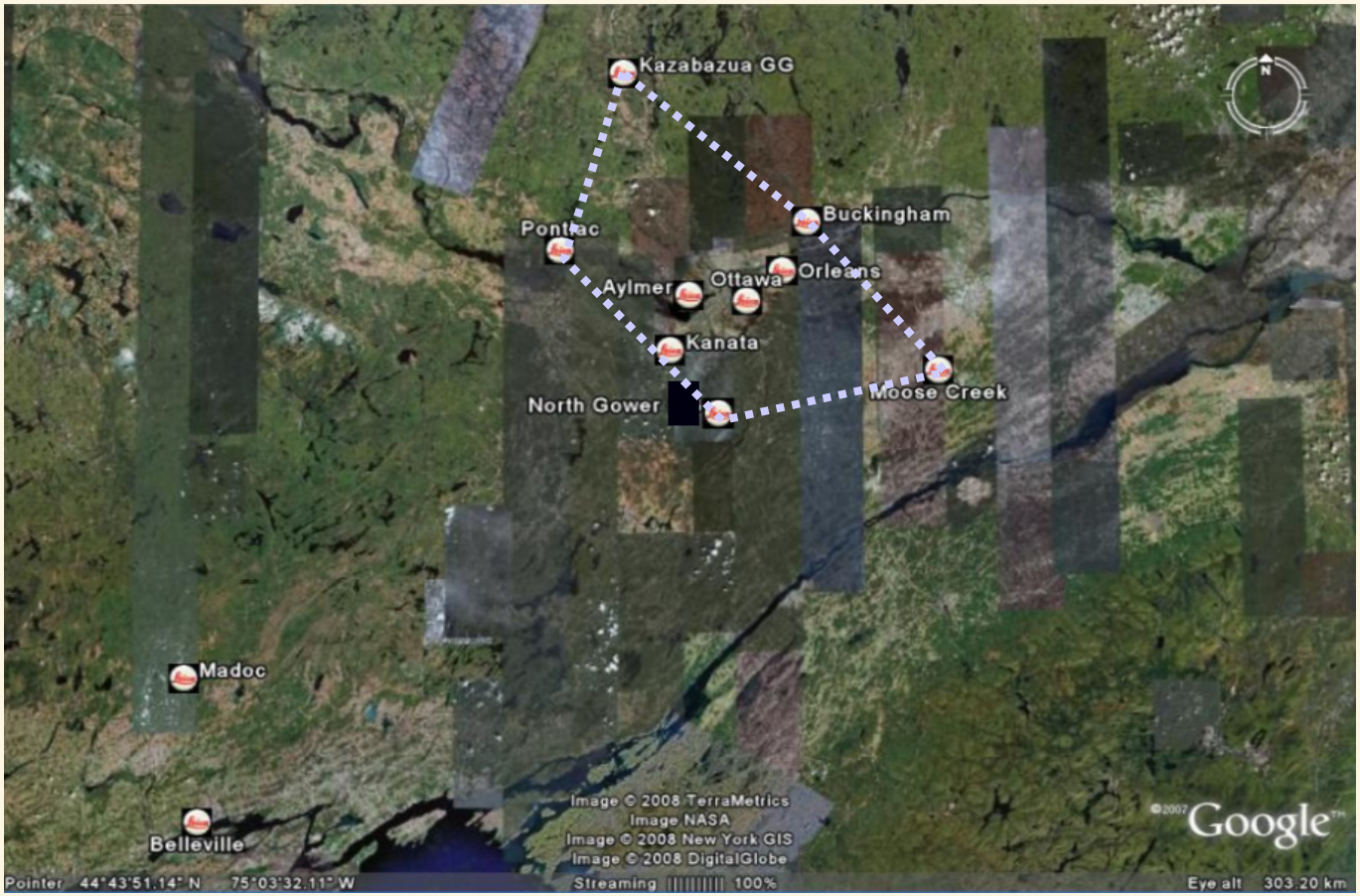
- **Control centre**
  - Continuously gathers information from all reference stations
  - Performs integrity checks on all observables
  - Computes ionospheric, tropospheric and ephemeris errors (by double-differencing)
  - Creates a living database of regional area corrections
- **Rover**
  - send its approx. position to control centre
  - NMEA $GPGGA string



- **Control centre**
  - Creates a “localized” set of corrections
  - Sends it to Rover as pseudorange corrections (RTCM format)
- **Rover**
  - applies these as if they came from an invisible reference station located approx. 1-2 m away

Network RTK (Leica SmartNet)

- Single baseline RTK
- Network RTK using **MAC** (Master Auxilliary Concept)
- RINEX raw data *(for post-processing)*



Network RTK

- **How good are the reference station coordinates?**
  - CGRSC (Canadian Geodetic Reference System Committee) currently looking into regulation of Network RTK
- **Can your GPS/GIS software use Ontario grid shift files?**
  - Some manufacturers offer their own NAD83(CSRS) – NAD83(Orig.) grid shift file
- **Methodology recommends Site Calibration**

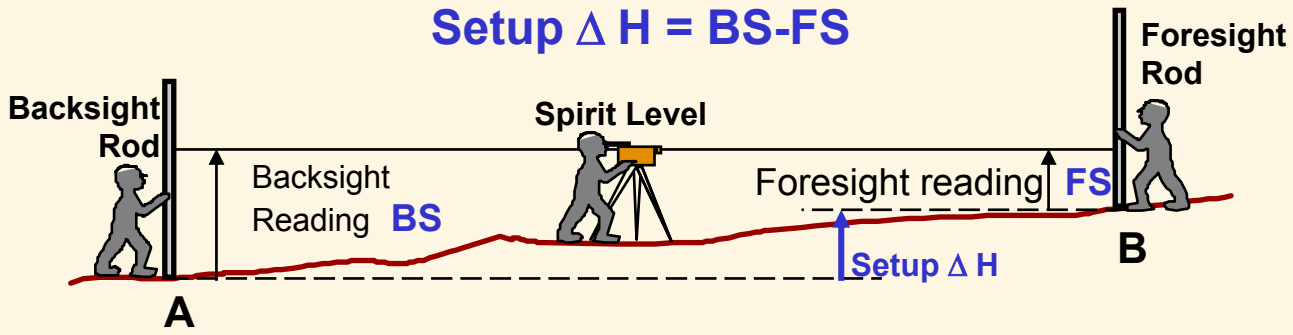
Site Calibration Notes

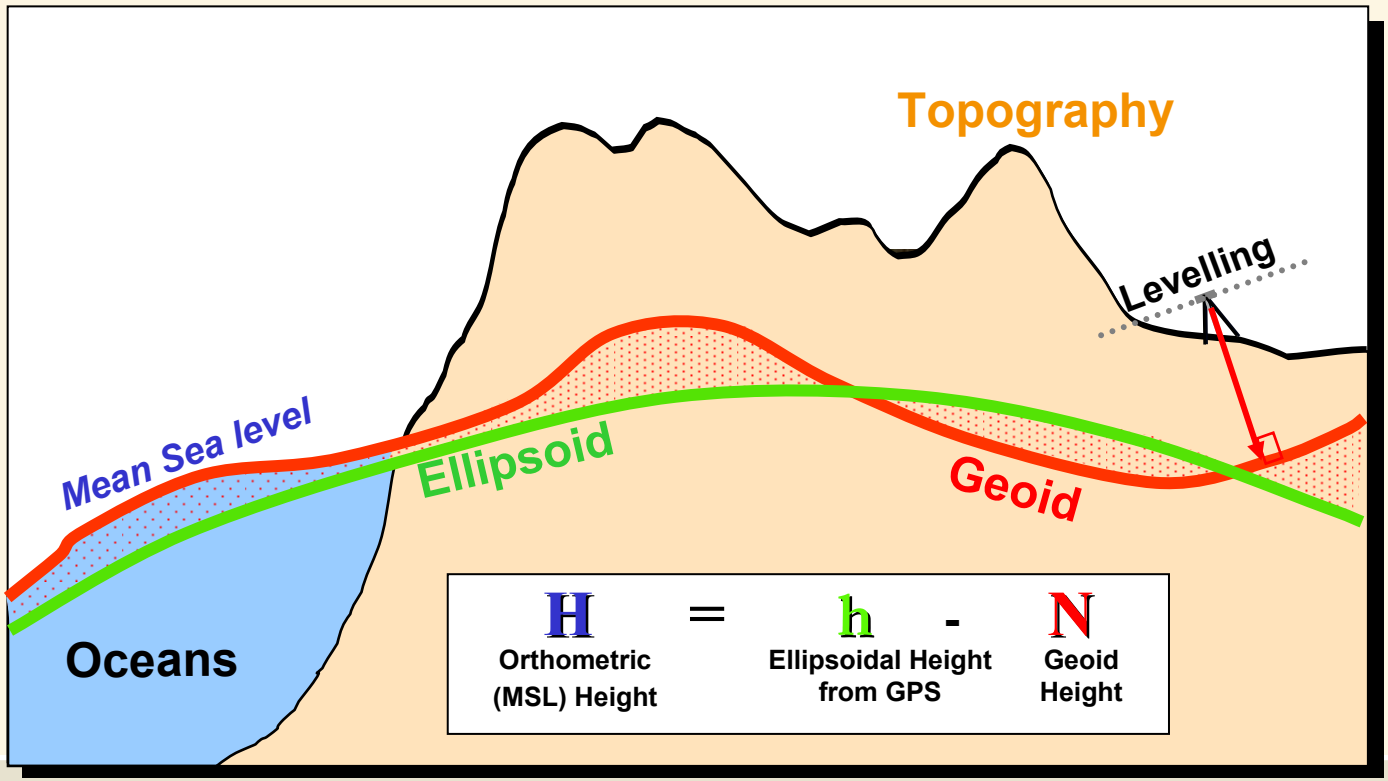
It is highly recommended that a site calibration be performed for every field survey the uses CanNet. The CanNet reference stations are tied to the national reference system NAD83(CSRS) and thus may not fit the local coordinate reference system of your work area. Thus a site calibration is recommended to ensure ties to the local/provincial control network. If the map projection and datum transformation are known they should be entered into the project properties prior to a site calibration.

  - Important to **not to lose the tie to CSRS**

Orthometric Height Differences (ΔH)

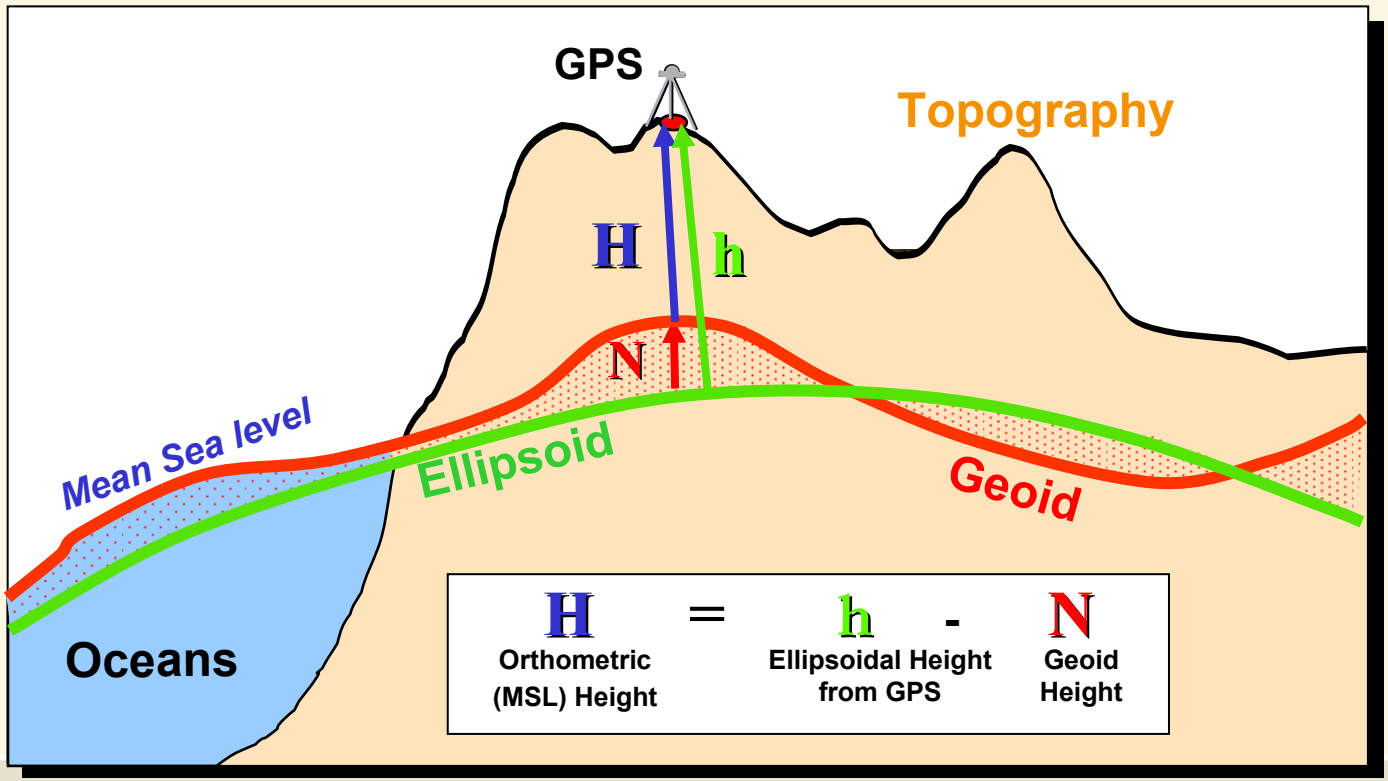
- **Most accurately obtained using Spirit Levelling**
  - Costly and laborious but still the **best method over short distances**





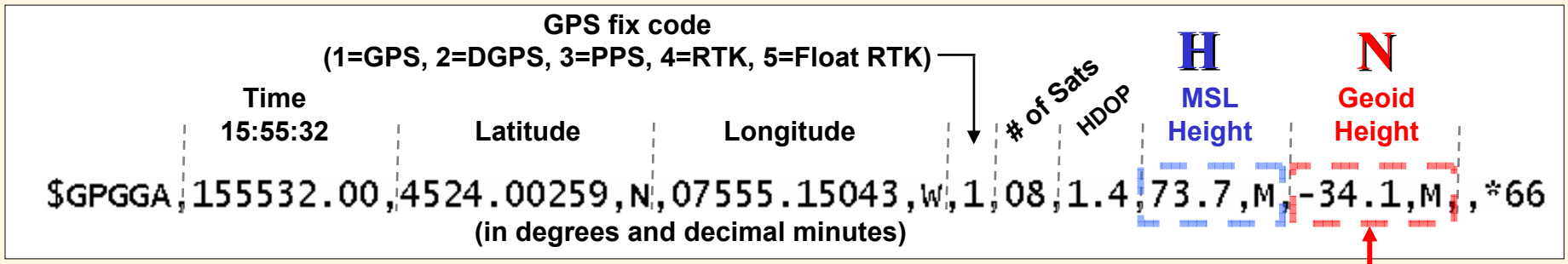
GPS and the Geoid

- **GPS determines 3D positions with respect to an Ellipsoid**
  - Ellipsoid heights **h** are <u>not</u> consistent with Mean-Sea-Level **(MSL)**
- **The Geoid** *(derived from gravimetric measurements)*
  - Equipotential surface that best represents **global Mean-Sea-Level**
  - Expressed practically through **Geoid Heights** (**N**)



NMEA (National Marine Electronic Association) format

- **Ellipsoidal heights h computed by the receiver are not included in the data stream (NMEA)**



- **Your GPS/GIS software should**
  - **recover the ellipsoidal height h**

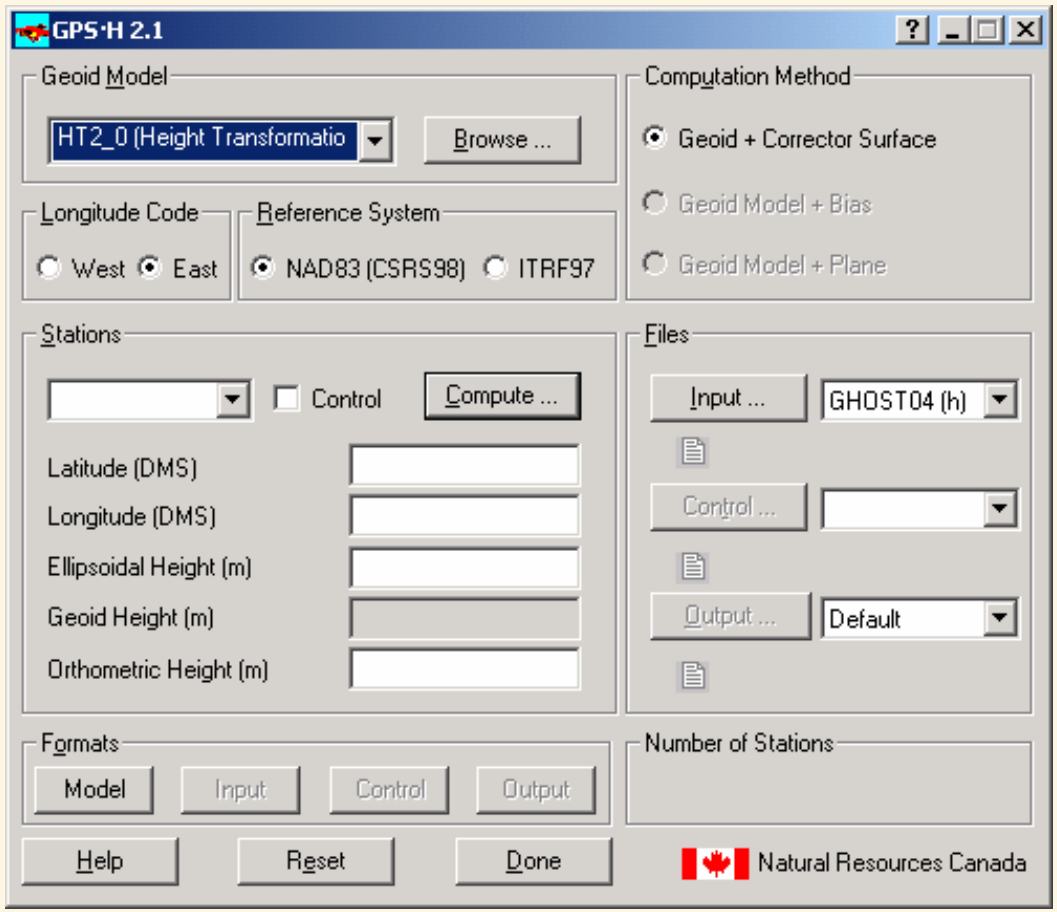
$$H = h - N$$ **H is *always in the same datum as the Lat/Long***

$$h = H + N = 73.7\text{m} - 34.1\text{m} = 39.6\text{ m}$$

  - **produce accurate MSL heights $H = h - N$**
    - by letting you enter one Geoid Height value N (get it using **GPS-H**)
    - and/or by applying a geoid model (**HT2.0**, **CGG2000**, **CGG05**)

GPS•Hv2.1 Software

- **Geoid models available**
  - Most recent Geoid model **CGG05** (Canadian Gravity Geoid 2005)
  - **HT2.0** height transformation (Geoid "adjusted" to the levelling network)



Formats

Absolute accuracy: **+/- 5 cm** in southern Canada and a **few decimeters** in remote or **northern regions**

Relative accuracy (local geoid height differences) at **1-2 cm**

GPS•H v2.1 Online Transform ellipoidal heights to MSL

using the HT2.0 height transformation

Longitude Code		◉ west ○ east				
Reference System		◉ NAD83 ○ ITRF				
Latitude:	degrees	45	minutes	19	seconds	43.4927
Longitude:	degrees	75	minutes	52	seconds	01.2046
Ellipsoidal Height (*m*)		83.49				
Compute					Help	

Results

Input Data

Longitude Code:	west
Reference System:	NAD83
Latitude:	45 degrees 19 minutes 43.4927 seconds
Longitude:	75 degrees 52 minutes 01.2046 seconds
Ellipsoidal Height (m):	83.49

Output Data

Geoid Height (m): -33.120
Orthometric Height (m): 116.610