Accuracy Assessment of SRTM, ICESat, and Survey Control Monument elevations of multi-faceted terrain in Alberta, Canada

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Questions asked

- How accurate are the 3 elevation datasets SRTM “unfinished”, ICESat GLA06 and ASCM
- Test regions: Alberta, Quebec, NW-America
- Is SRTM compatible with ICESat/ASCM?
- Are ASCM consistent or are there outliers?
- Can SRTM be used for well-site planning, slope assessment, hydrology, and as a vertical reference?
- What effects have temporal changes of Earth surface systems?

Well Site Elevation Determination in Alberta

- Official regulations for determining elevations of well sites in Alberta is in the *Manual of Standard Practice* by the Alberta Land Surveyors' Association

- Section C,1.5: a minimum of 2 benchmarks with published elevations should be used and the result related to the appropriate vertical datum as specified in Part D, Section 1.3.
  - The recognized vertical datum for spatially referenced data is CVD28

- Typical benchmarks:
  - Alberta Survey Control Markers (ASCM)
  - Geodetic Survey of Canada Benchmarks
  - Irrigation Survey Benchmarks
  - Department of Transportation (Highways) Benchmarks
  - Canadian Pacific Railway Benchmarks
  - Previously surveyed well site corner markers

Well Site Elevation Determination in Alberta

- **Historically**, well site elevations are determined by locating 2 benchmarks with known elevations and creating a level loop between them and the well site of interest
  - Required accuracy: $\pm 50\,mm\sqrt{d}$ where *d* is distance of loop in km
  - Orthometric heights implied, although true reference datum of published benchmarks is always in doubt

Well Site Elevations with GPS

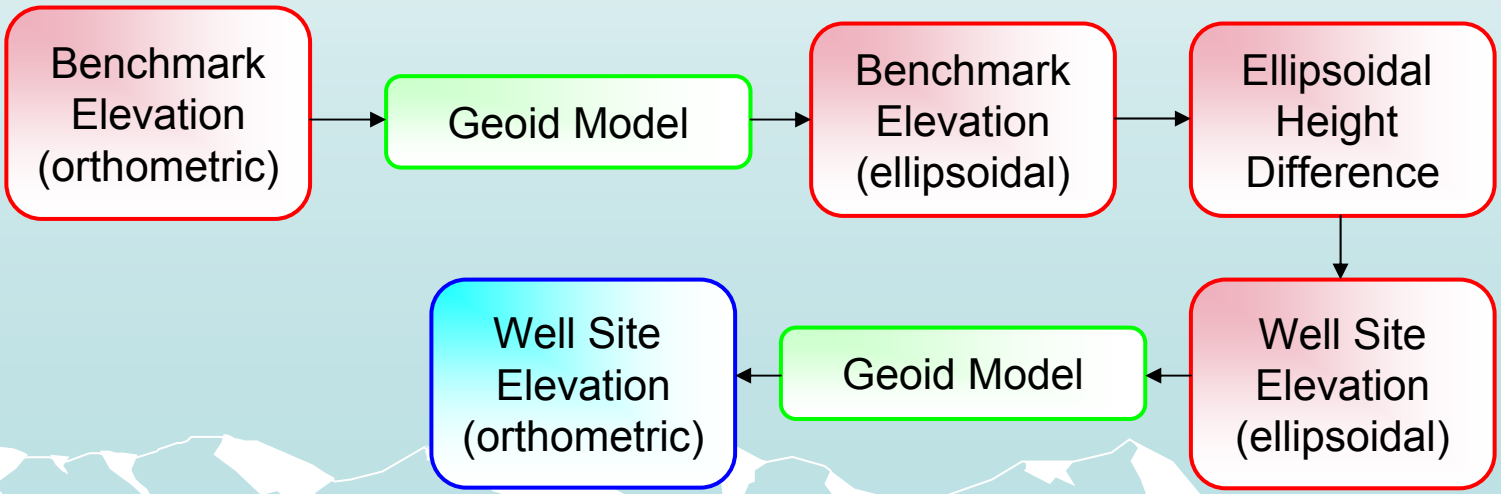
- Advent of GPS and its adoption by the land surveying community significantly improved the accuracy & efficiency of well site elevation determination

- **New typical practice** is to find 2 published benchmarks, and directly tie well site elevations via GPS
  - enhanced accuracy of elevation transfer, although specification required to meet is only 20 *ppm* between known benchmarks

Well Site Elevations with GPS

- Key: to distinguish ellipsoidal height differences & orthometric height differences
  - most GPS processing packages automatically apply geoid model to convert the GPS ellipsoidal height differences to orthometric height differences
- Depending on the geoid model used, resulting well site elevations may ***not*** be referred to CVD28
  - Typically EGM96 is used as default, which may result in errors/inconsistencies
  - Improved results possible via HTv2.0 (NRCAN)
  - These effects are generally below the 20 ppm accuracy requirement!

Schematic Procedure



ASCM Marker Data

SURVEYING AND MAPPING DIVISION
Alberta Survey Control Marker (ASCM) Information
MASCOT DSS-1

Horz Datum NAD83 Updated: 1995-08-17
Latitude 49 13 56.00221 dms
Longitude 113 07 18.02563 dms
Horz Class TRANSFORMED , ORDER U

Vert Datum CVD28 Updated: 1981-08-20
Elevation 1187.755 m
Vert Class INTEGRATED , SPIRIT LEVELS

Marker Installed 79-05

Date Printed 2004-04-23
Last Updated 1996-01-06

For current information call Geodetic Survey
(780) 427-7374 FAX: (780) 422-0973

ASCM 18199D

Tablet Markings 49112.343

Mapsheet Name LETHBRIDGE
Mapsheet Number 49112 82H

Marker Condition GOOD 79-05-01

3TM COORDINATES

Scale Factor 0.999900 At Ref Mer 114

Northing 5455279.370 m
Easting 63962.624 m
Convergence 0 39 54.84 dms
Station Ellipsoid Factor 0.999816
Station Combined Factor 0.999766

GEOID DATA (GSD95) Updated: 96-01-06

Component	Magnitude	Std Dev
Meridian Defl,XI(+N)	7.3 s	2 s
Prime Vert Defl,ETA(+E)	-0.1 s	2 s
Geoid_Ellip Separation	-14.54 m	1 m

COORDINATE HISTORY

	HORZ	VERT
Originating Project	79036	79036
Published	81-08-20	81-08-20
Revising Project	95156	
Published	95-08-17	
Revising Project	95151	
Published	95-05-04	
Revising Project		
Published		

NON COORDINATE REVISIONS

1981-08-20 FIRST MARKER LOCATION DESCRIPTION ENTERED
2003-03-12 "MAPSHEET NAME" AND/OR "MAPSHEET NO" CHANGED

HISTORICAL/OTHER MARKER NAMES

OLD ASC # 493112 343

HISTORY 49112. 343

ADJACENT MARKERS (calculated) Updated:

ASCM Tablet To Markings	Slope Distance (m)	Std Dev (cm)	PPM/ Order	Grid/Slope Factor	Astronomic Azimuth (dms)	Std Dev (s)	T-t Corr (s)

MARKER TYPE Updated: 1981-08-20

ASC CAP ON 6 CM DIA HEAVY WALL STEEL PIPE 2.4 M LONG WITH HELIX BASE

MARKER LOCATION Updated: 1981-08-20

NEAR NE COR SEC 23-3-24-4. 21.7M N & 6.3M W OF FENCE COR.
NOTE: ELEVATION REVISED BY ADA SPIRIT LEVELS, 1982 01 21.

ID PHOTO: NM 89981-21 & 22

MARKER CONDITION COMMENTS Inspected Updated

COORDINATE HISTORY COMMENTS

HORZ 95-08-17 APPROXIMATED VIA NATIONAL TRANSFORMATION V2.0
95-05-04 239 56 02 0.207 m APPROXIMATED VIA NATIONAL TRANSFORMATION V2B
81-08-20 APPROXIMATED VIA NATIONAL TRANSFORMATION V1.1
VERT

SRTM

un

Terrestrial Height Data Descriptions

Alberta Survey Control Monuments (ASCM)

- Original registered data: 33463 points
- Horizontal datum: NAD83(CSRS)
- Vertical datum: CVD28 (ortho.), GSD95 (geoid)
- Surveys conducted over long time-span, periodically updated (spirit levelling, GPS, Doppler, unspecified)
- Marker condition: Destroyed – Anomalous – Good

High Precision Network (HBN)

- Sub-set of ASCM: 1003 points
- Considered more accurate, stable & reliable than ASCM
- Urban & rural control markers

Canadian Base Network (CBN)

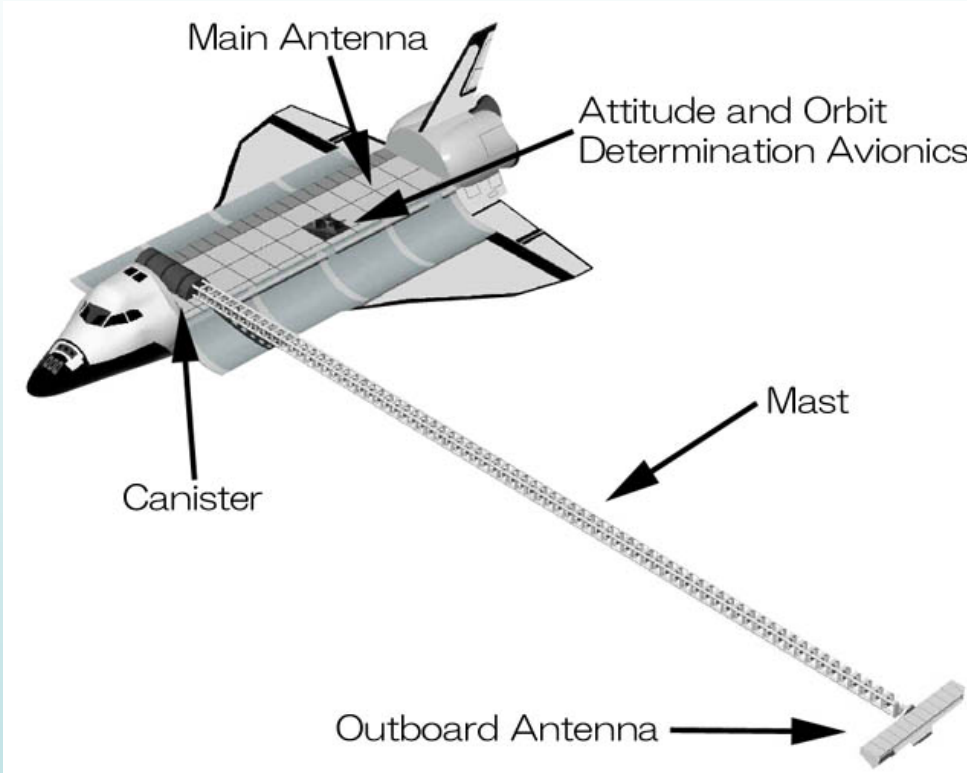
- ground segment of monument control of CSRS
- Pillars positioned 3D with GPS to cm-level accuracy with respect to the CACS, levelling with respect to the primary vertical control network
- 21 CBN pillars in Alberta
- 125 km spacing south of 56°N & at 300 km spacing north of 56°N

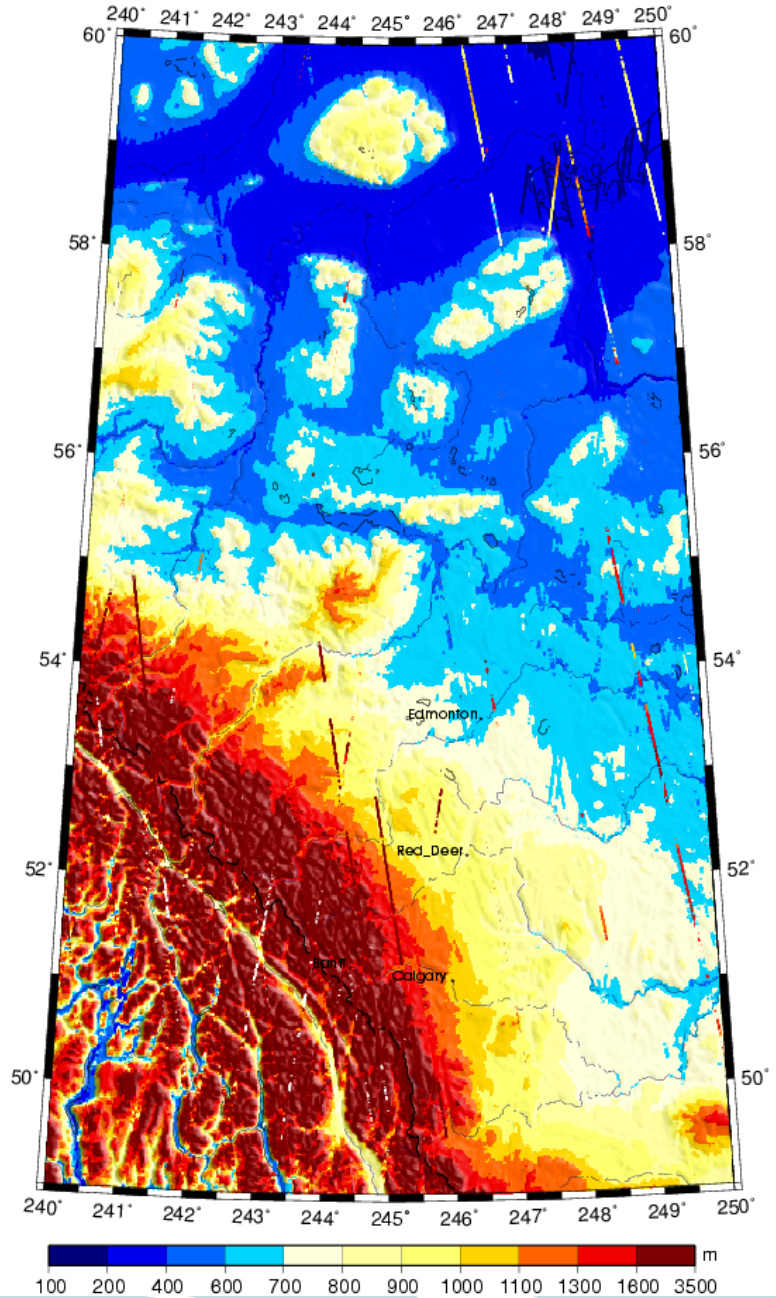
Terrestrial Height Data

- 3 different networks (sub-networks) of vertical control in Alberta

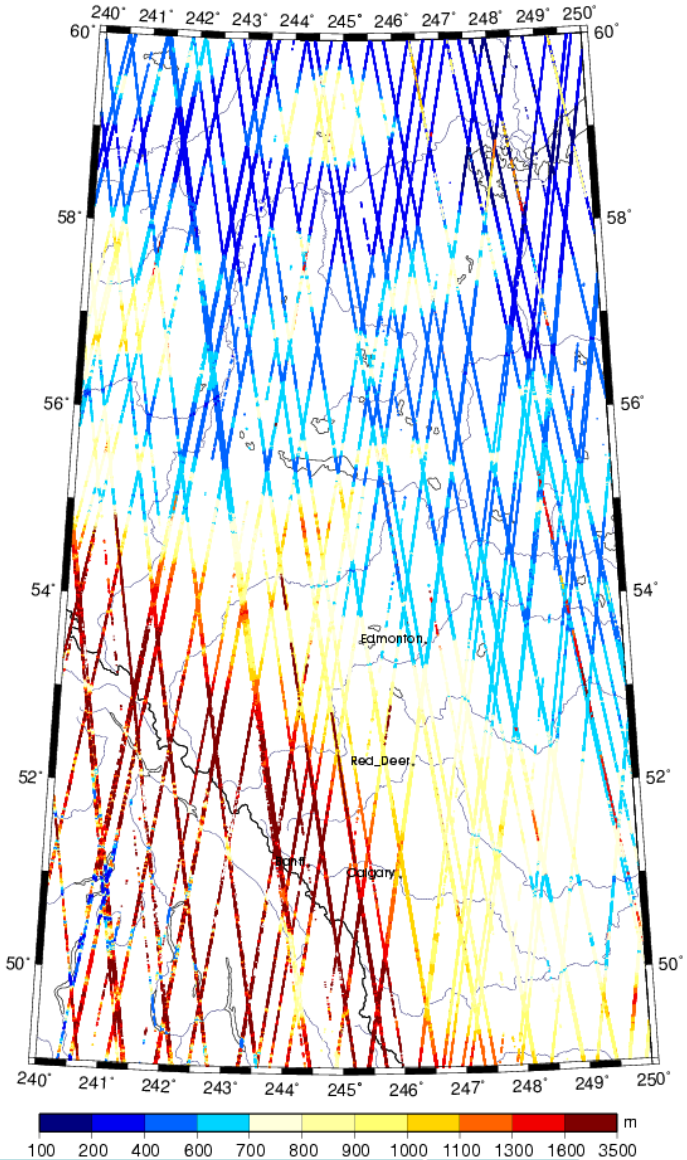
- ASCM - 33463 points
  - Vertical datum: CVD28 (ortho.), GSD95 (geoid)
  - coordinates collected over long periods of time
  - updated periodically
  - mix of spirit levelling and GPS
  - marker conditions unknown in some cases, many disturbed, some destroyed
  - not considered a stable and/or reliable source of information
- HPN
  - more accurate, stable and reliable than ASCM
  - spatial distribution should be improved (only 1003 points for all of Alberta, sparse/uneven distribution)
- CBN
  - very precise
  - consistent & reliable 3D positions from GPS
  - not enough points for survey requirements in Alberta (only 21 points)

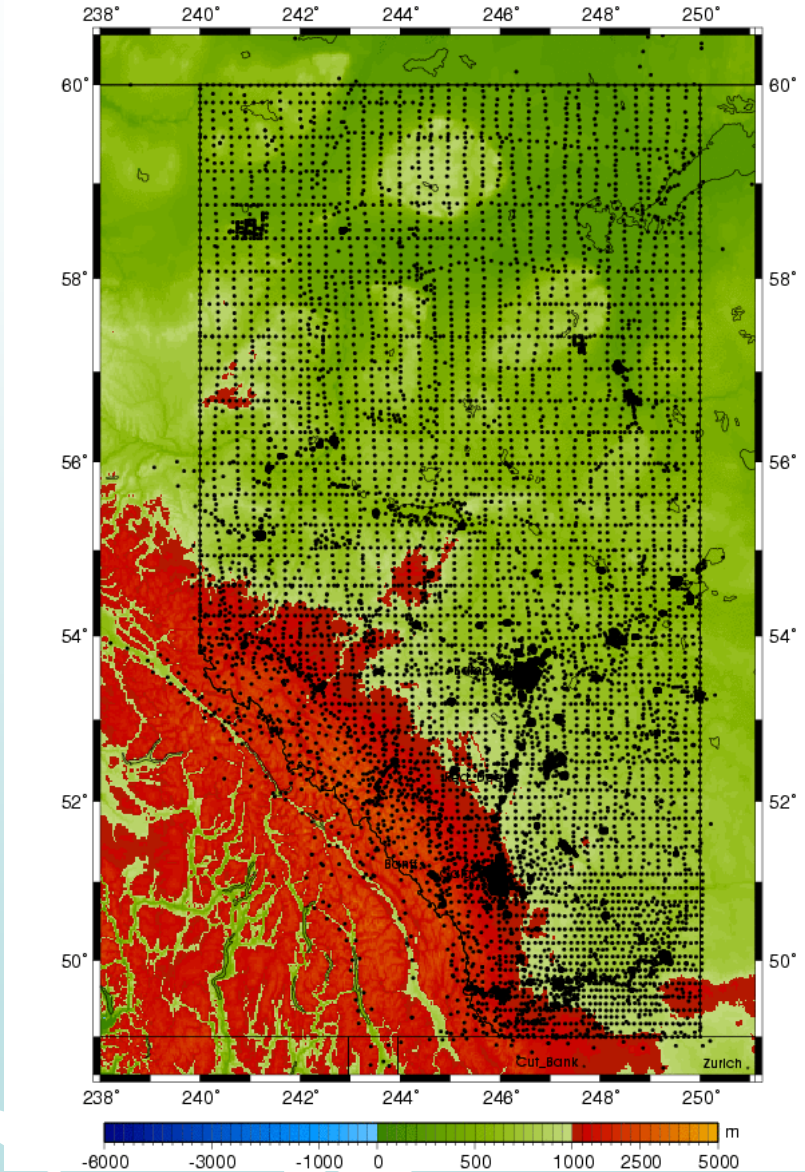
Shuttle Radar Topography Mission DEM



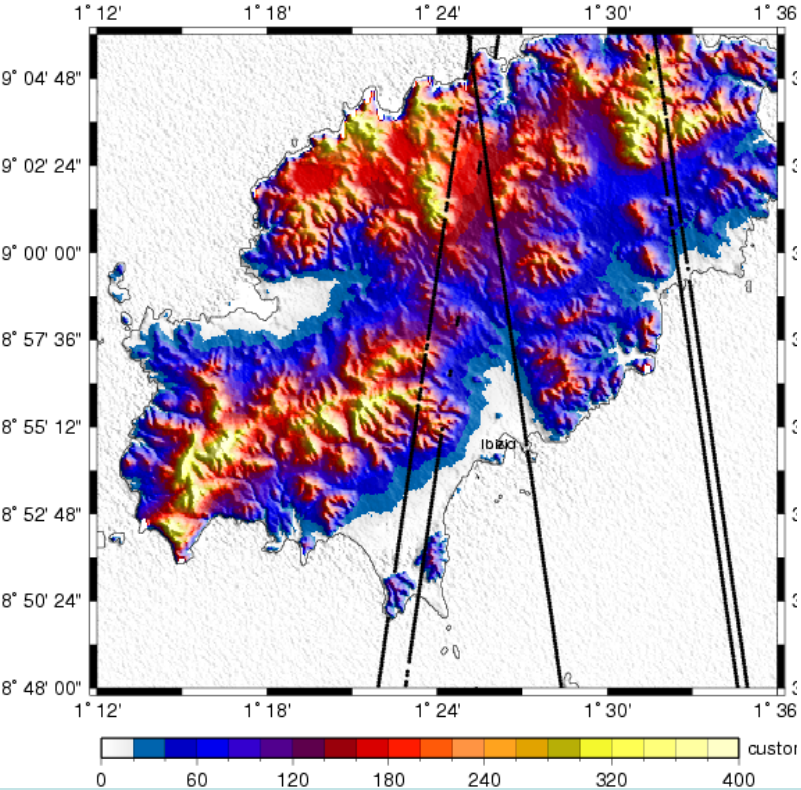


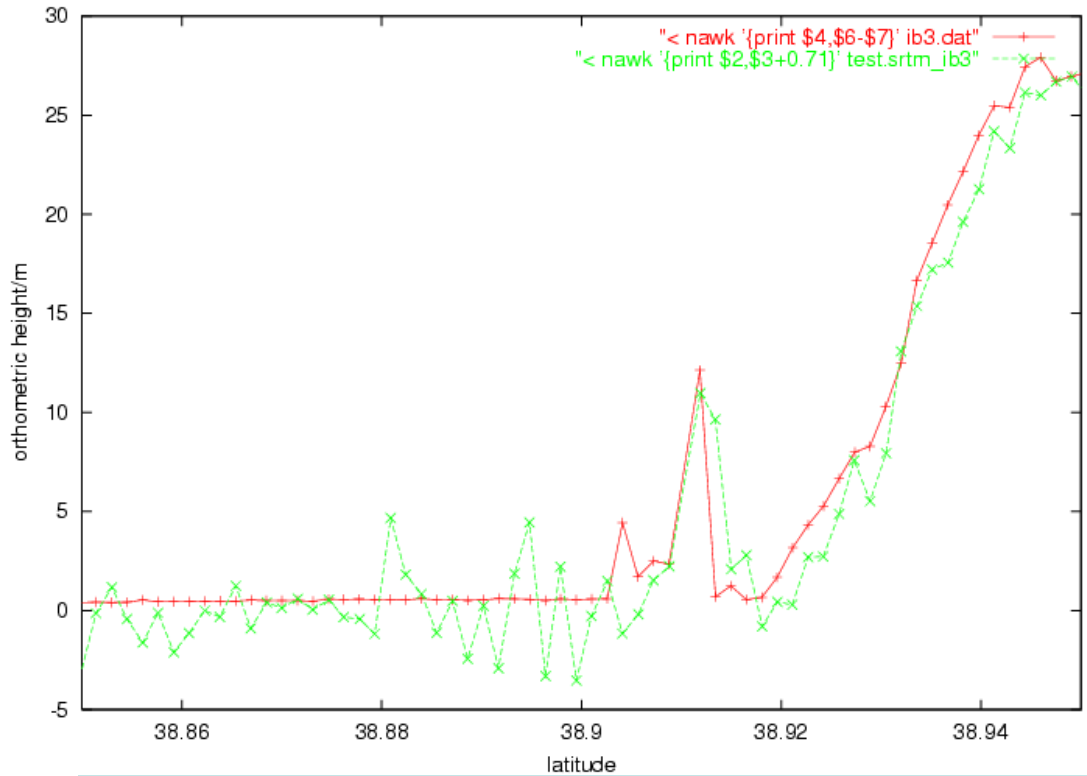
ICESat and ASCM Elevation Data



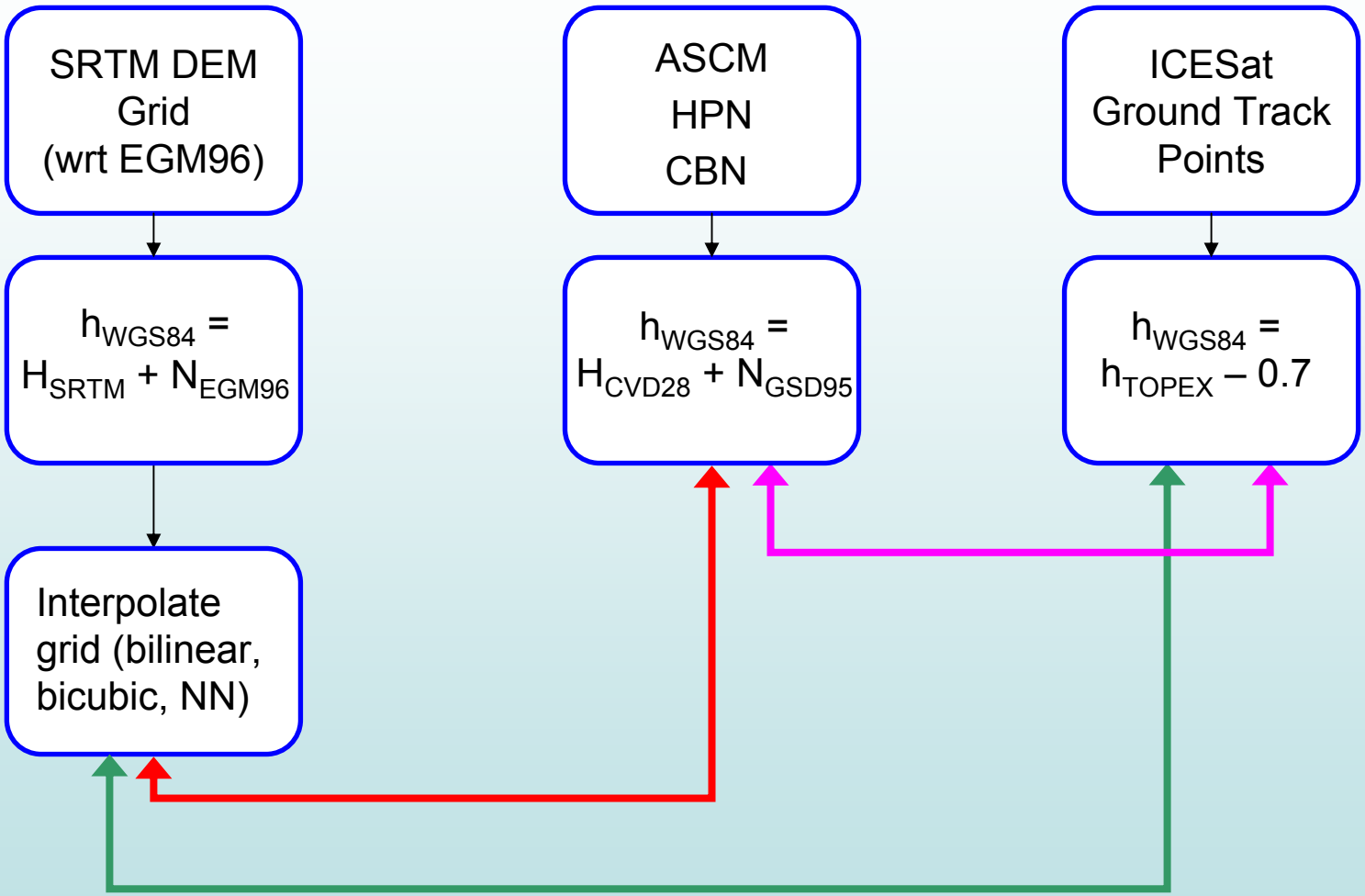


ICESat vs. SRTM over Ibiza

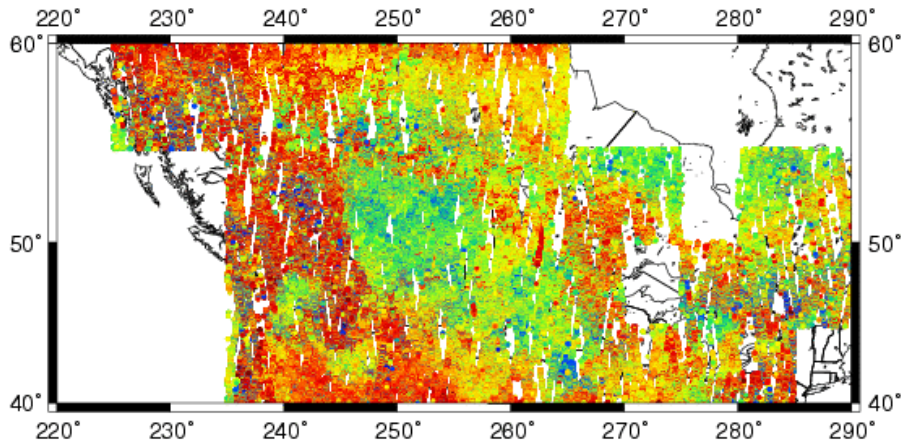


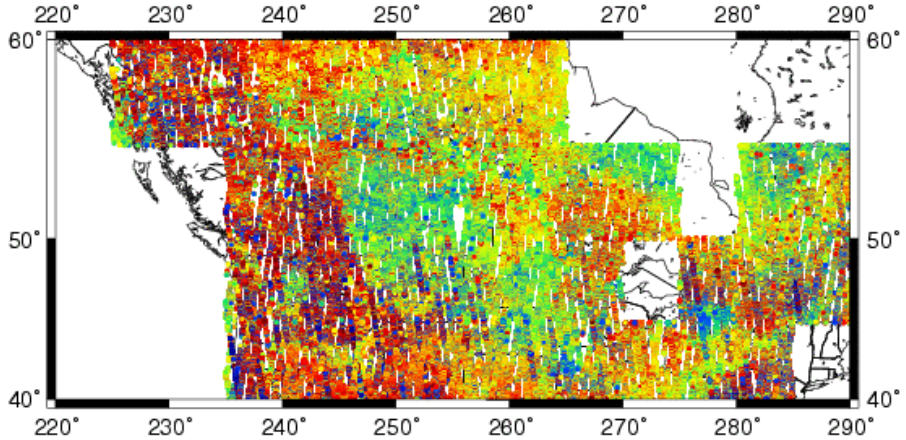


Data Comparison/Calibration Scheme

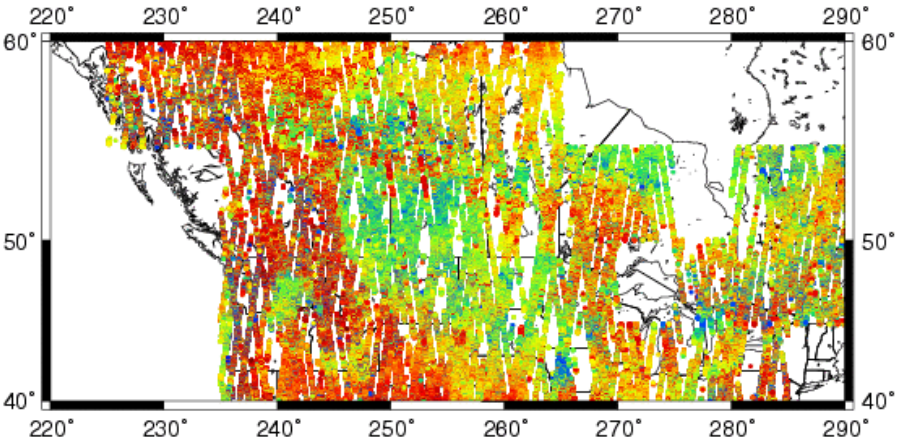


ICESat - SRTM (NW-America)

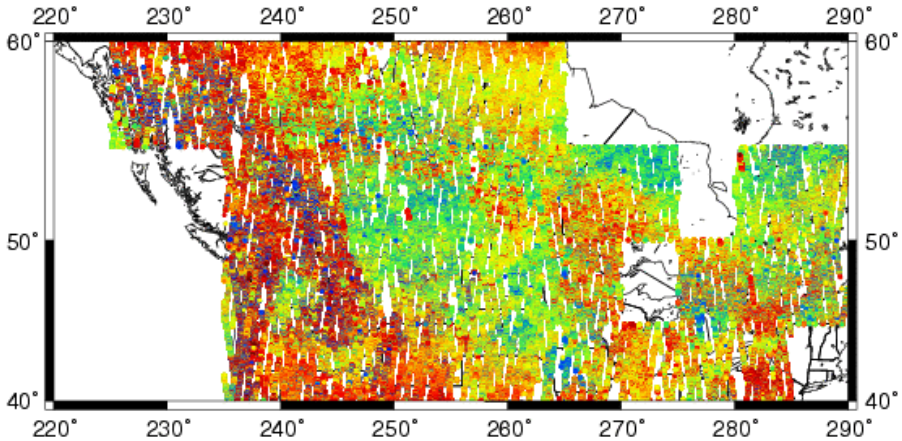




Fall 2004, 2005 Sep-Nov

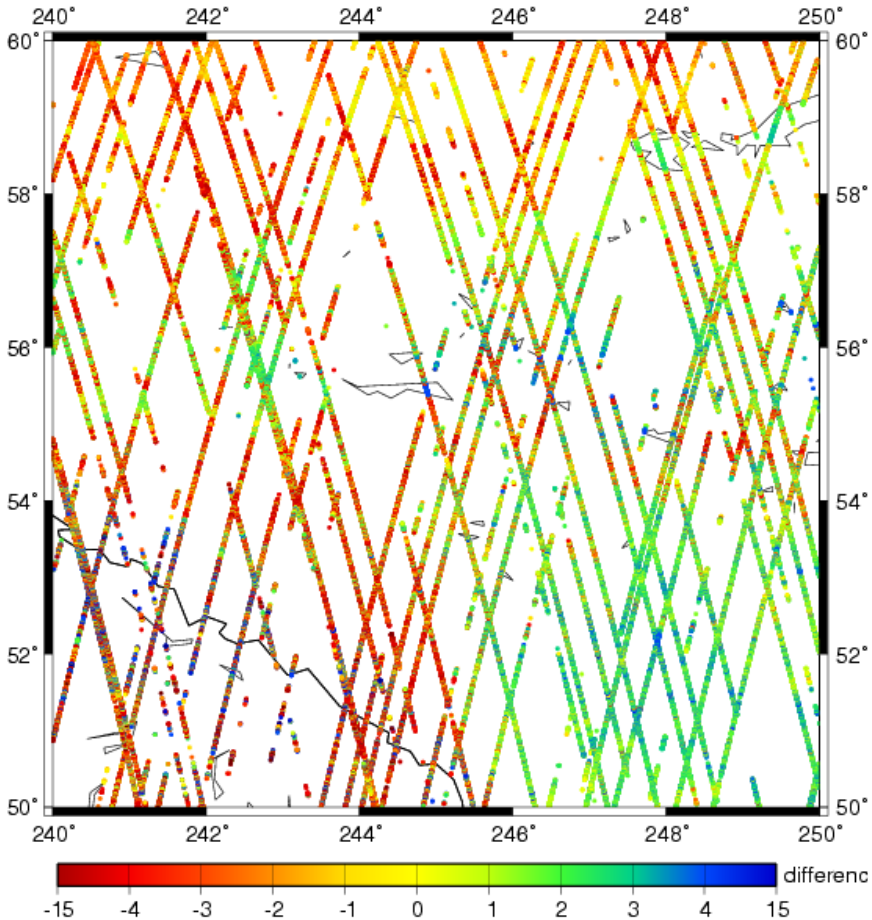


Winter 2004, 2005 Feb-Mar

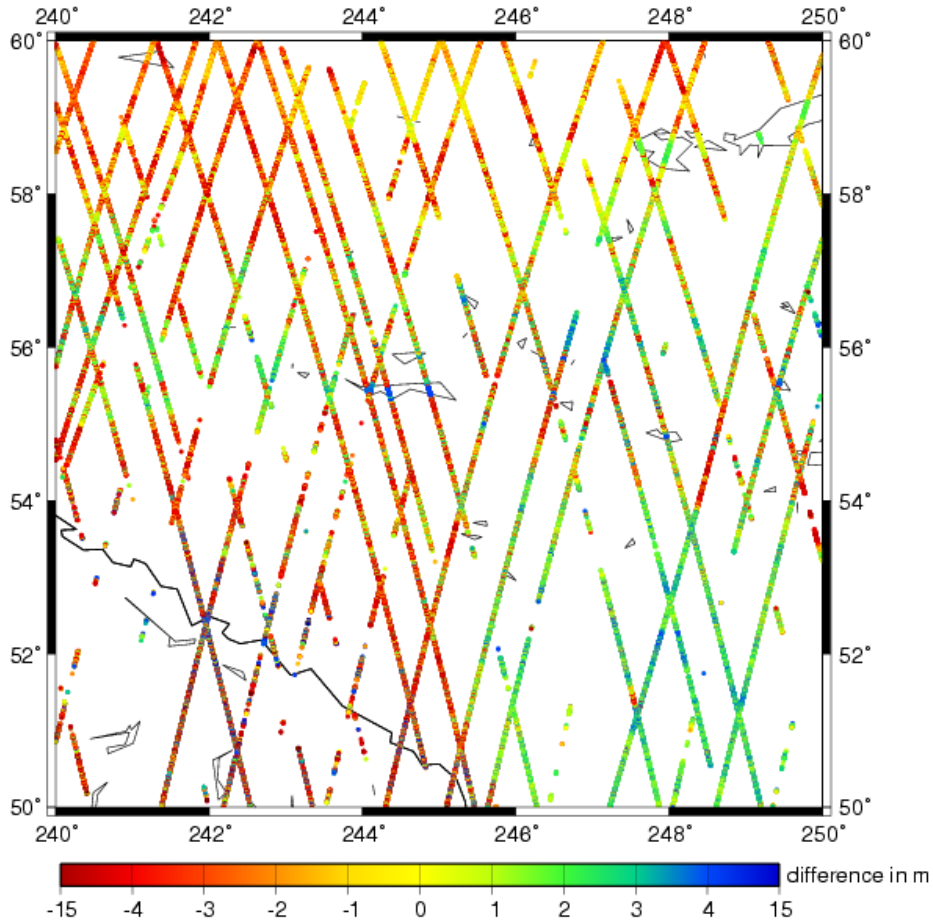


ICESat - SRTM (Alberta)

Oct 2003

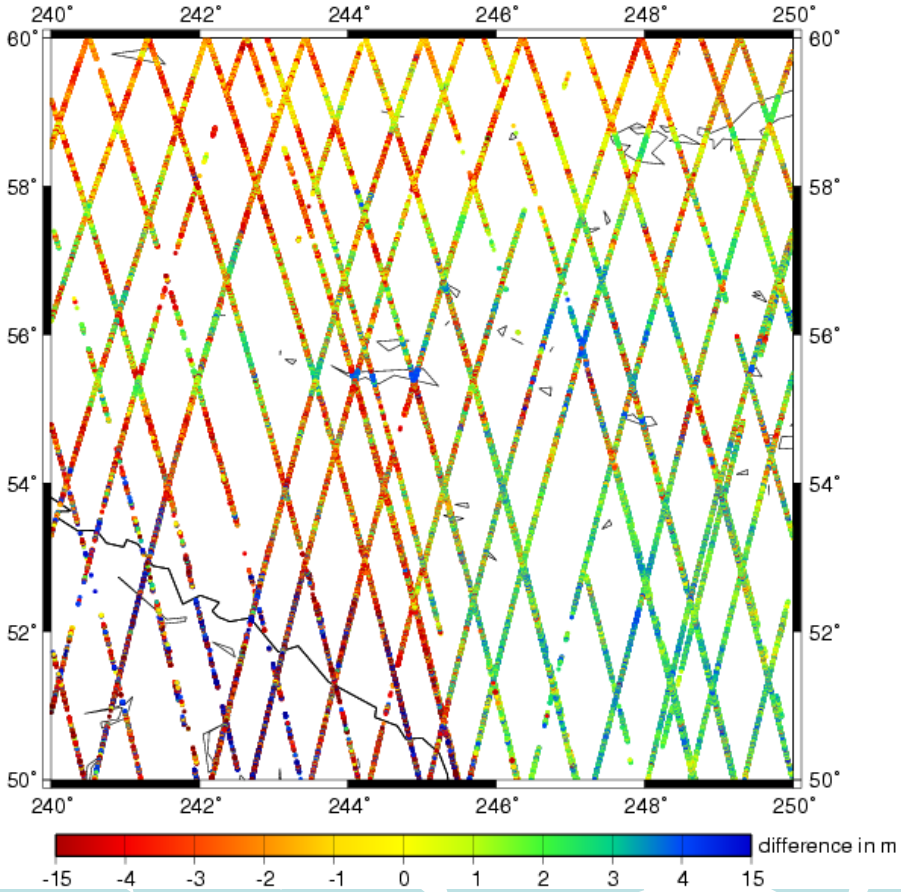


Oct 2004



ICESat - SRTM (Alberta)

Mar 2004



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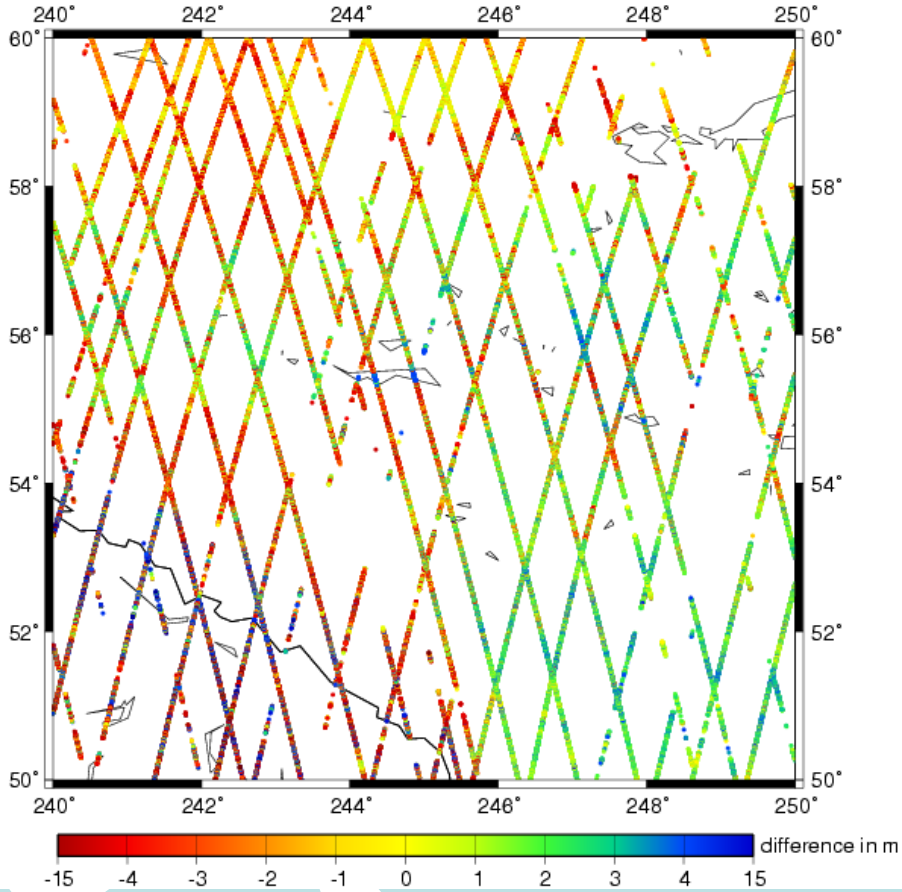
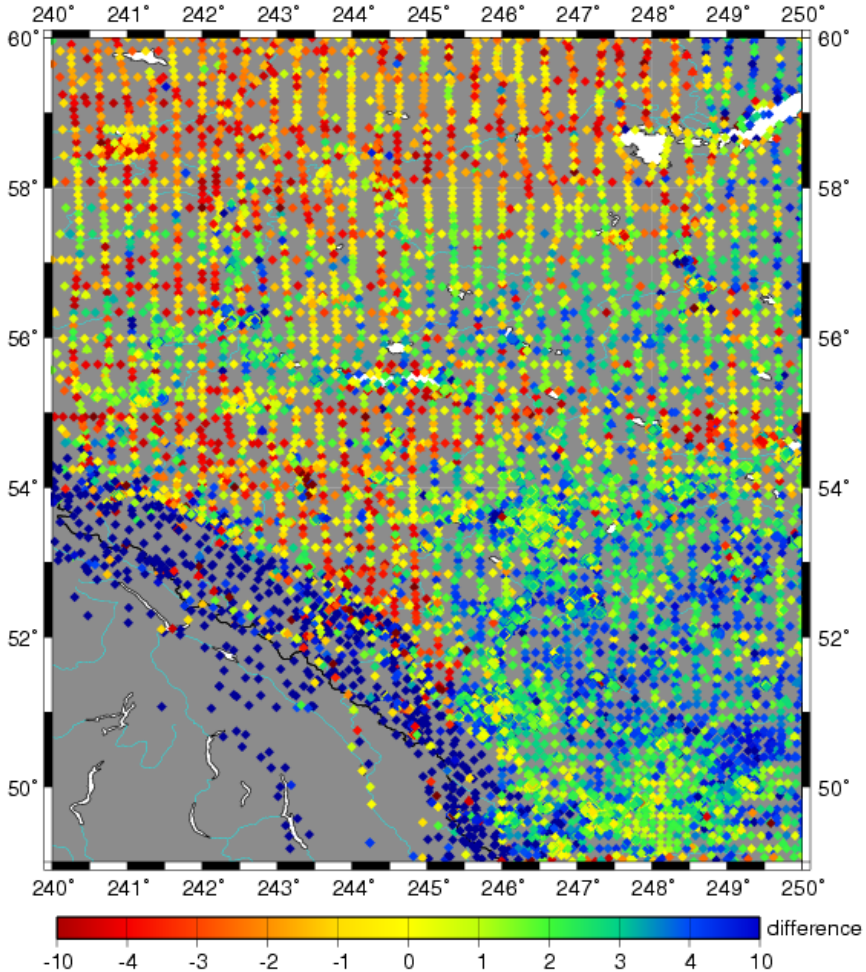
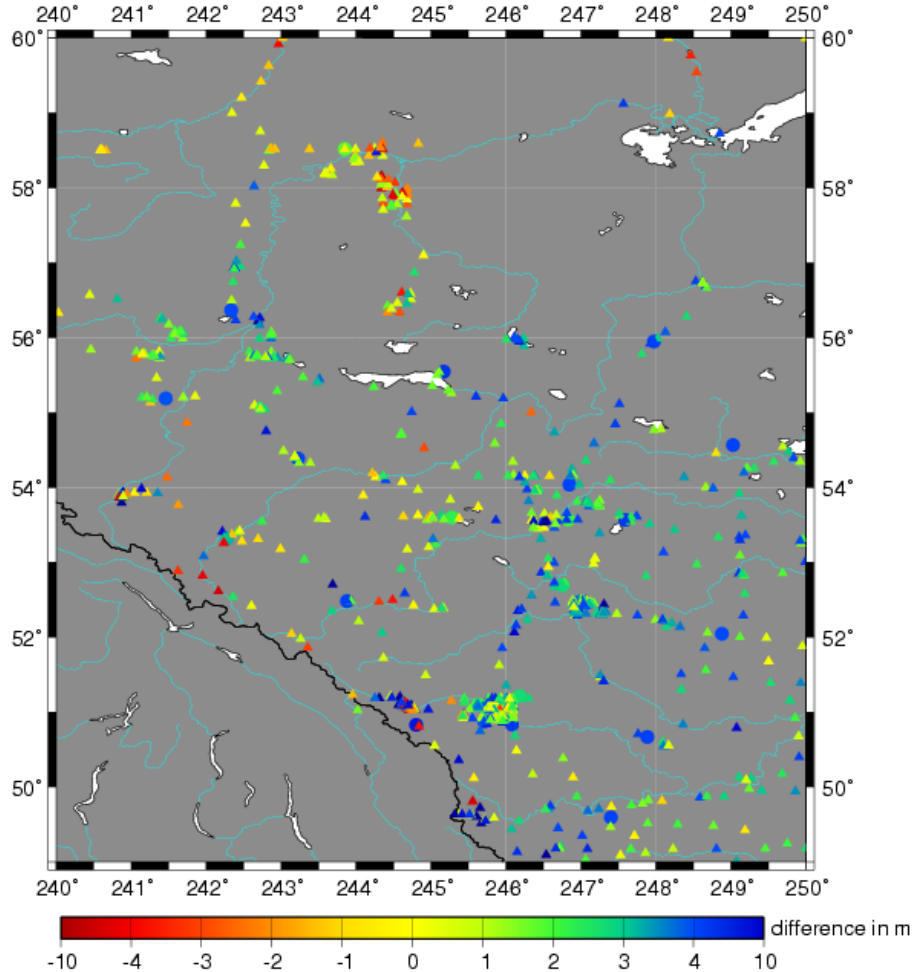


ASCM, HPN, CBN - SRTM

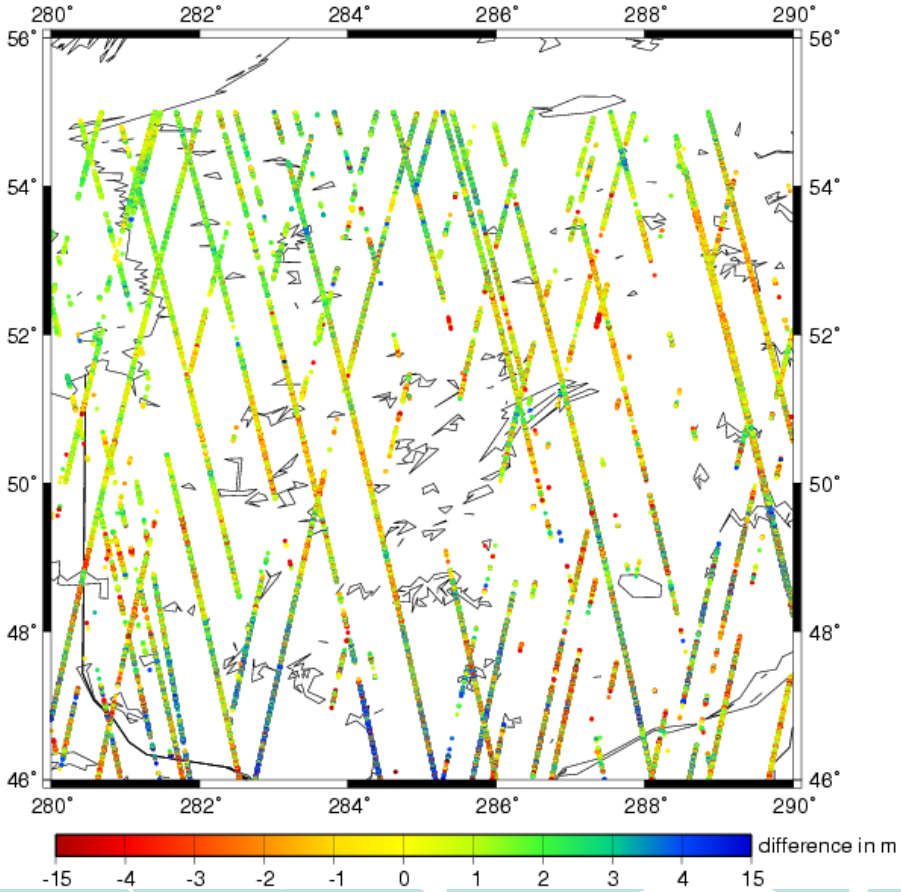
ASCM 1.74 +- 7.03 m **HPN 2.29 +- 4.13** **CBN 4.08 +- 1.47**





ICESat - SRTM (Quebec)

Oct 2003



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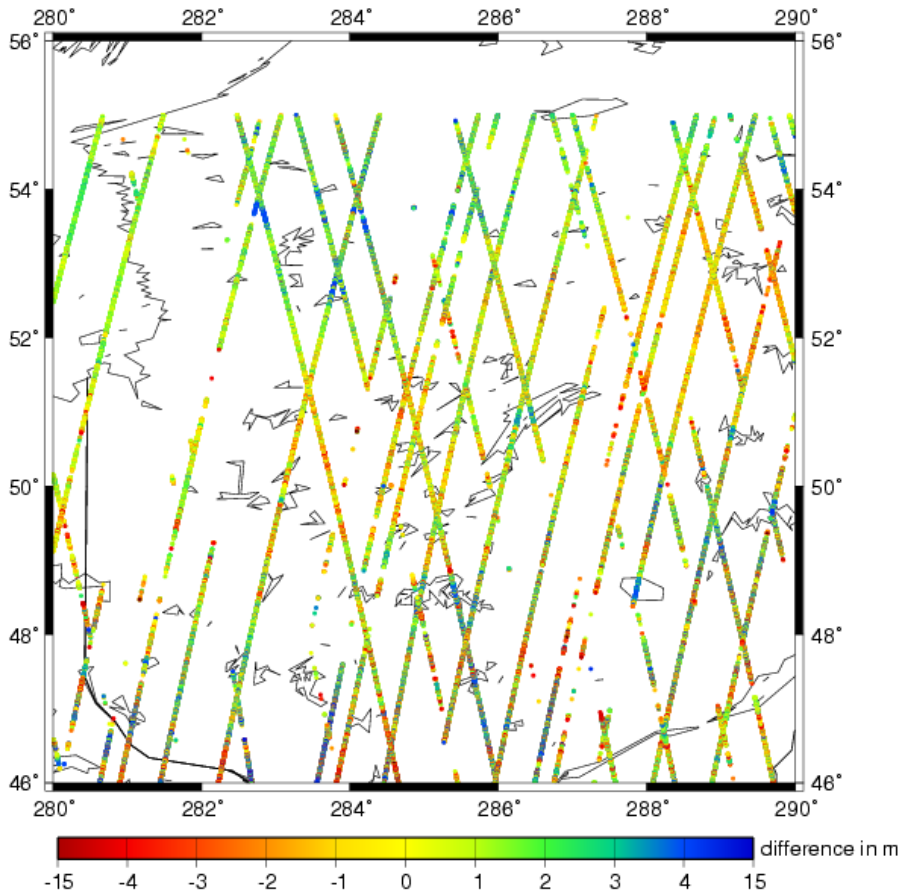
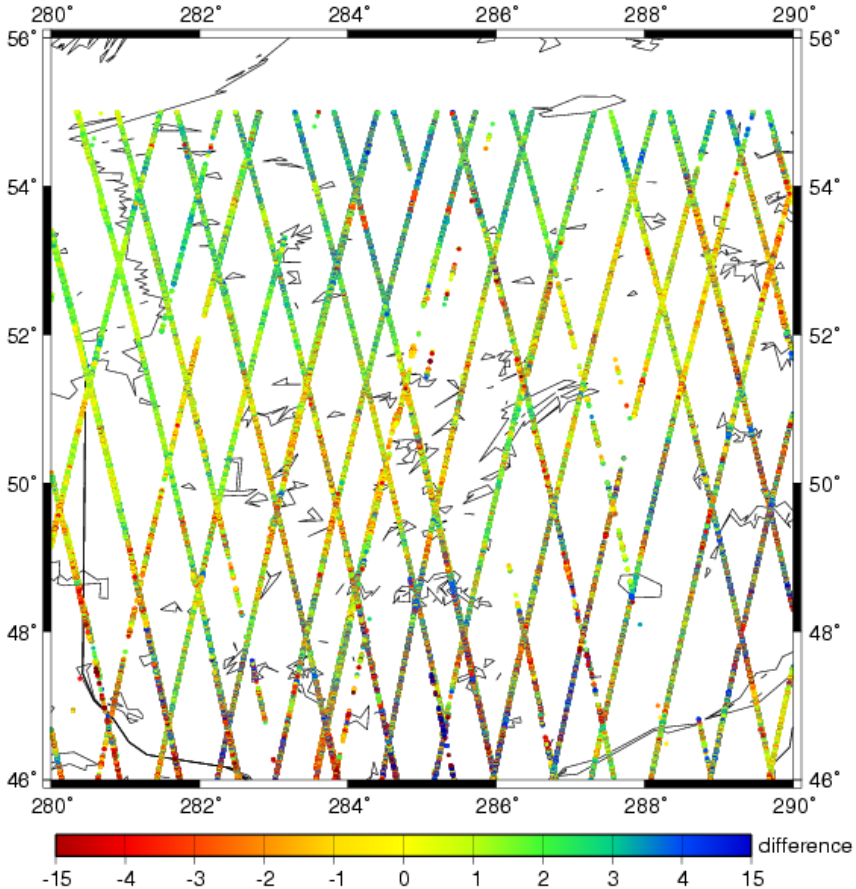
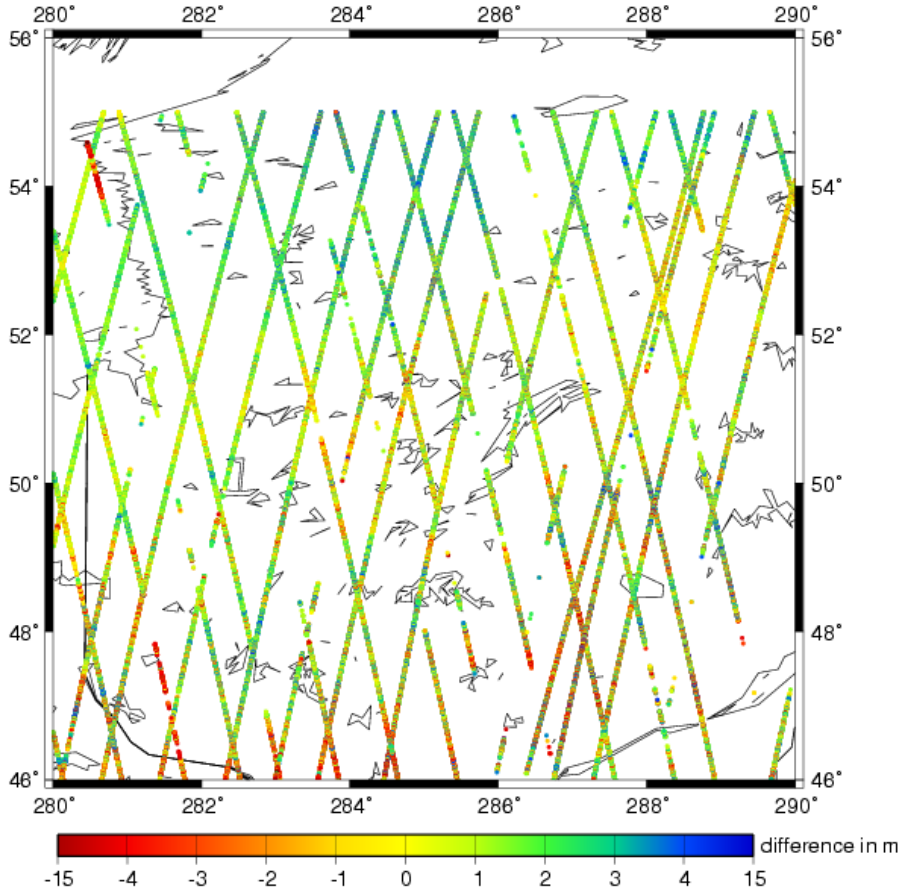


ICESat - SRTM (Quebec)

Mar 2005



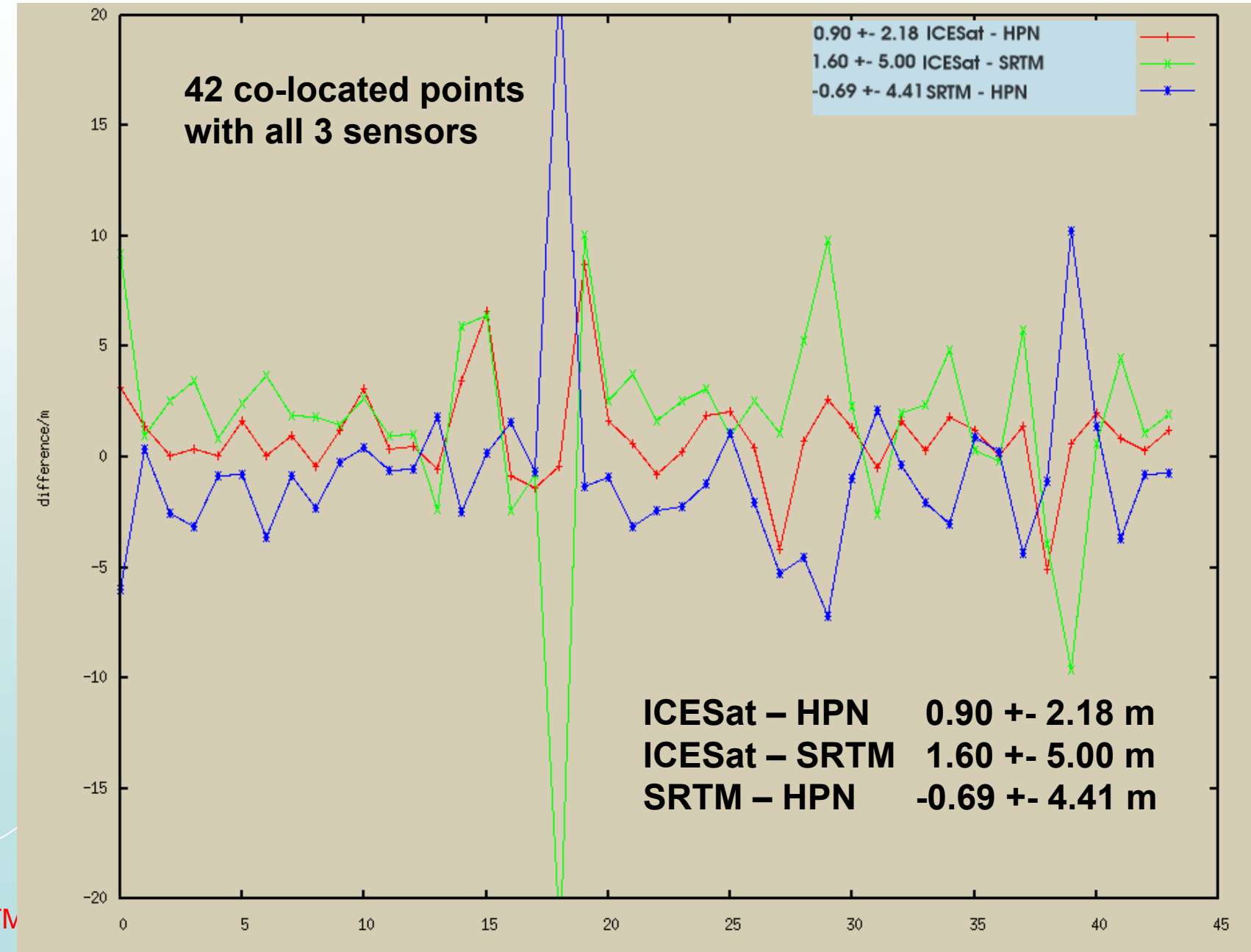
Mar 2005



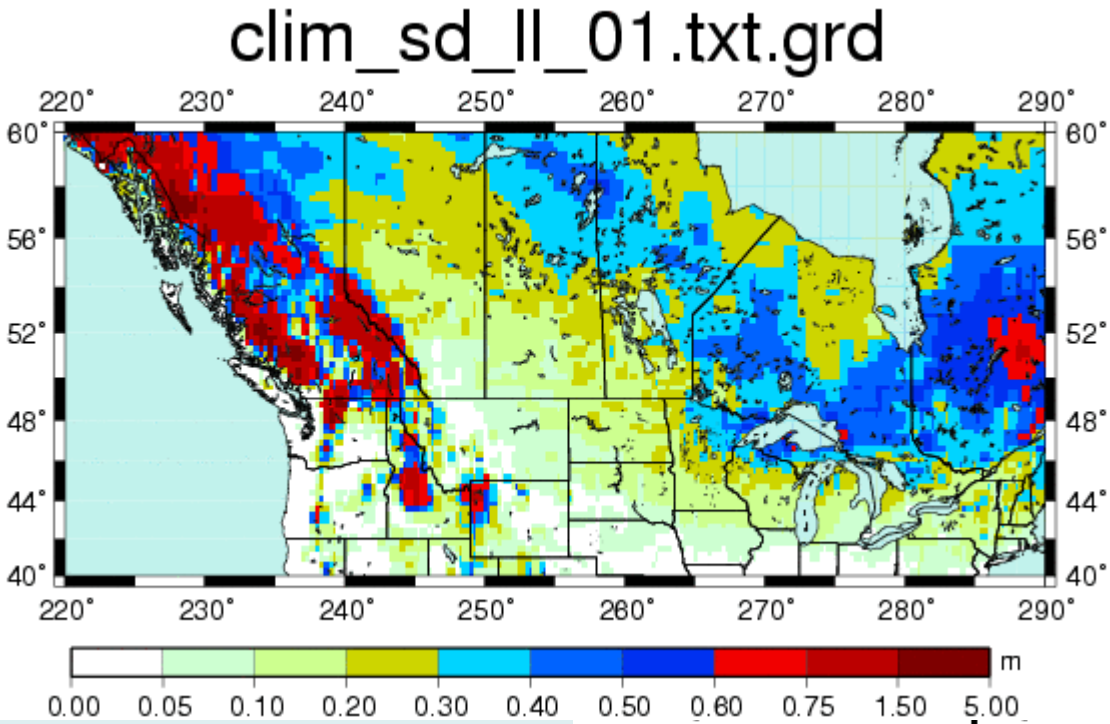
ICESat – SRTM (ellipsoidal height diff)

fa03	-0.52 +- 4.22	NW-America
fa04	-1.02 +- 4.56	7 Million footprints
sp03	-0.54 +- 4.23	
sp04	-0.56 +- 5.59	
sp05	-0.81 +- 4.90	
fa03ab	-1.06 +- 4.44	Alberta
fa04ab	-1.46 +- 4.61	700.000 footprints
sp03ab	-0.86 +- 4.41	
sp04ab	-0.50 +- 5.39	
sp05ab	-0.91 +- 5.13	
fa03qb	0.20 +- 3.44	Quebec
fa04qb	0.21 +- 3.25	
sp03qb	0.59 +- 3.33	
sp04qb	0.46 +- 4.18	
sp05qb	0.44 +- 3.12	

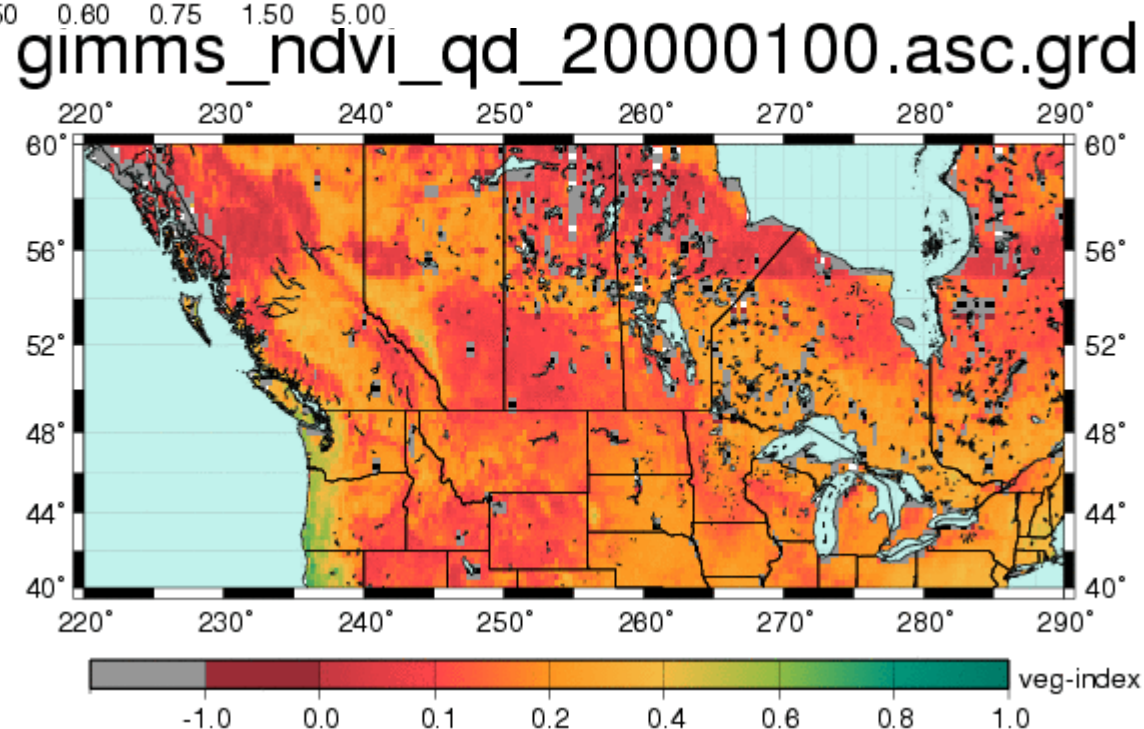
ICESat – SRTM, ASCM, HPN, CBN



Potential causes for bias change



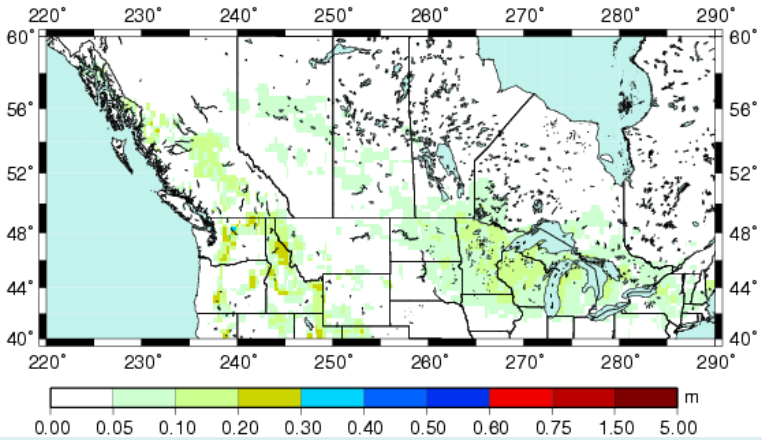
Snow depth



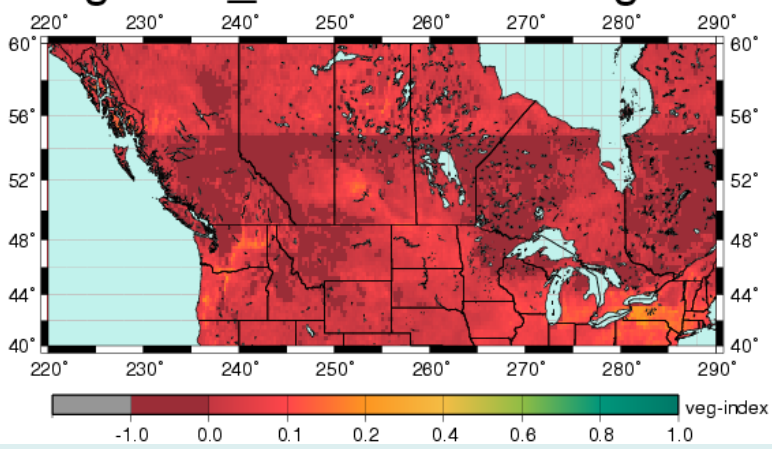
Vegetation index

Differences in vegetation index and snow depths between Feb, Mar and Oct

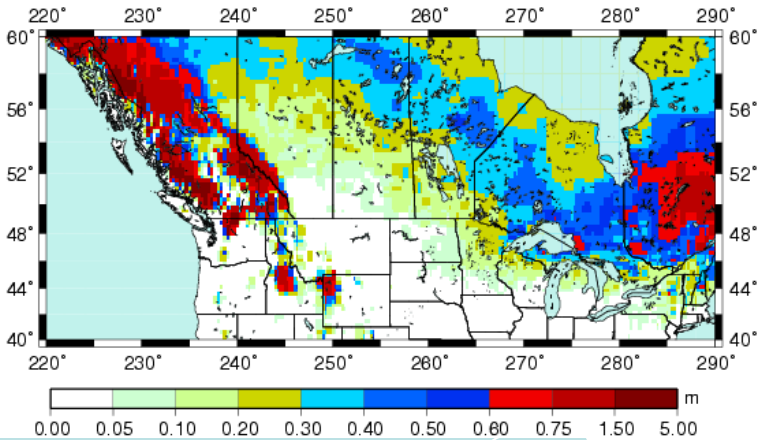
clim_sd_03-02.grd



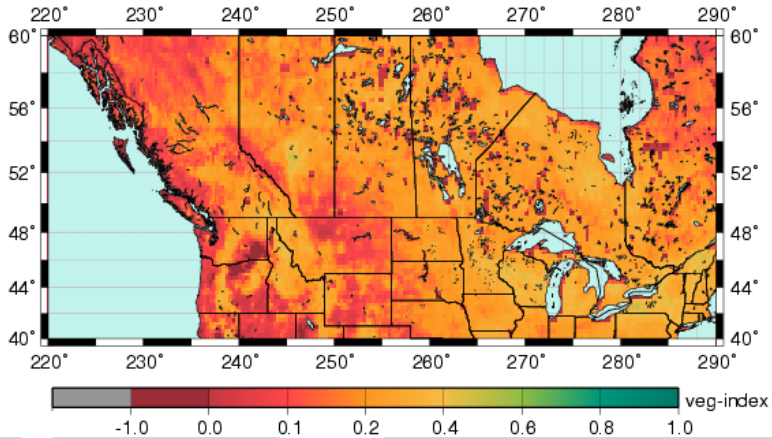
gimms_200203-200002.grd



clim_sd_03-1011.grd



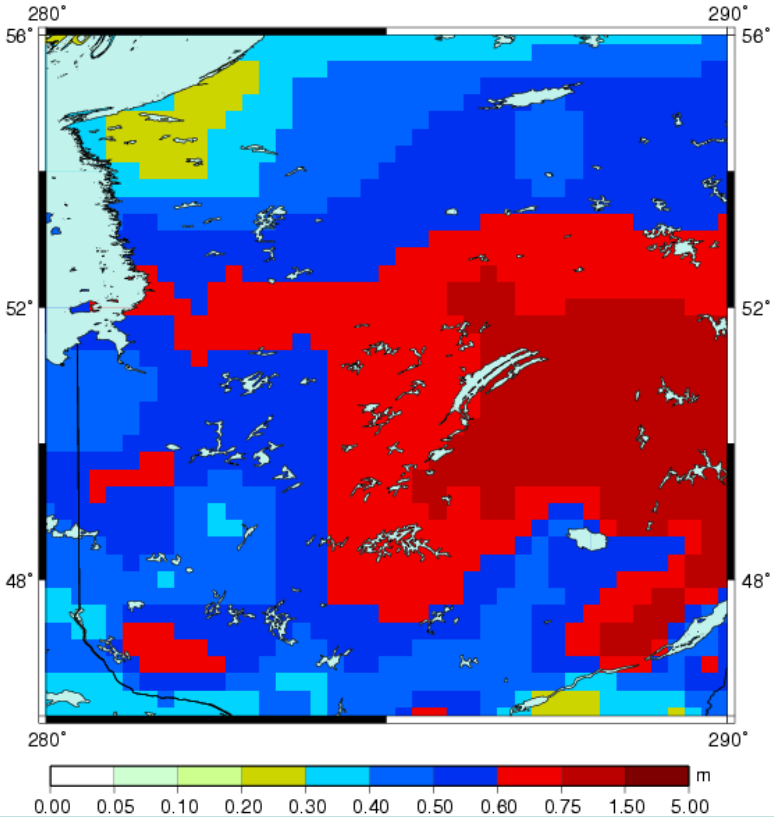
gimms_200110-200002.grd



Differences in snow depths between Mar and Oct

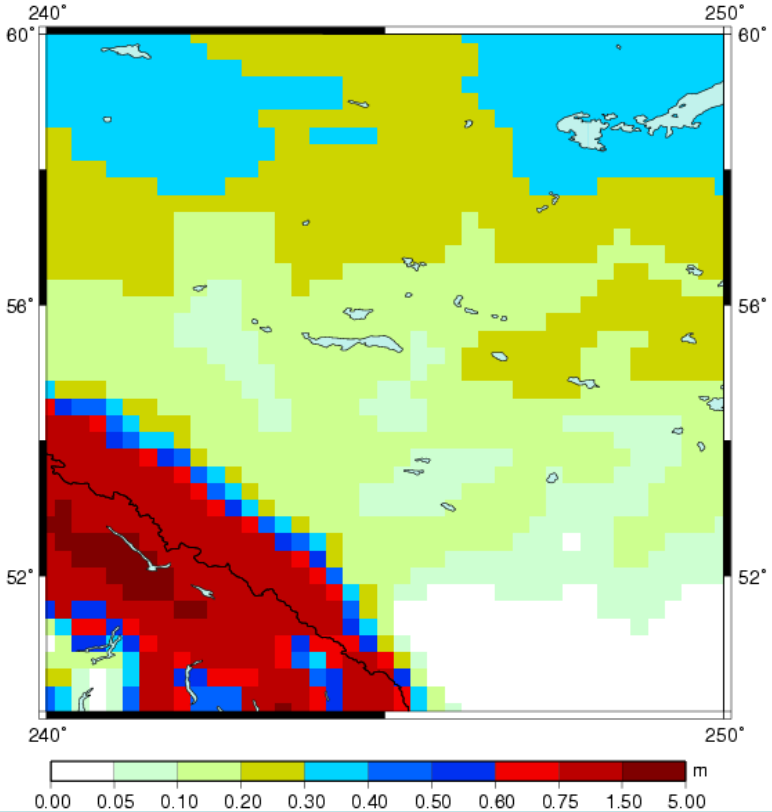
Quebec

clim_sd_03-1011.grd

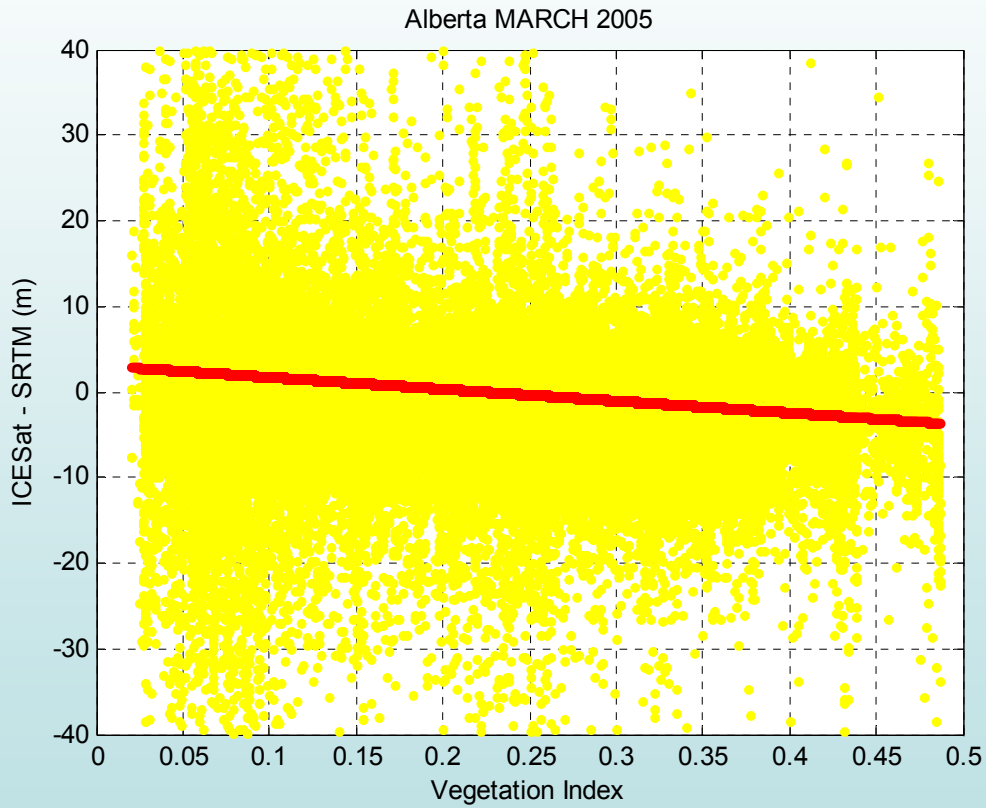


Alberta

clim_sd_03-1011.grd

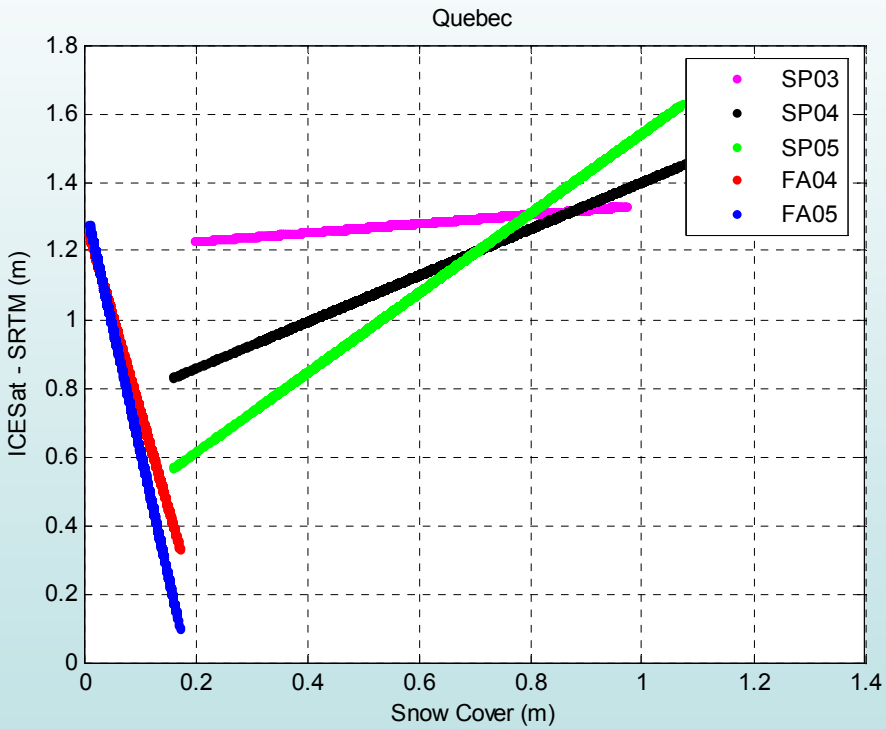


Least square fits vs vegetation index, snow depth and terrain elevation

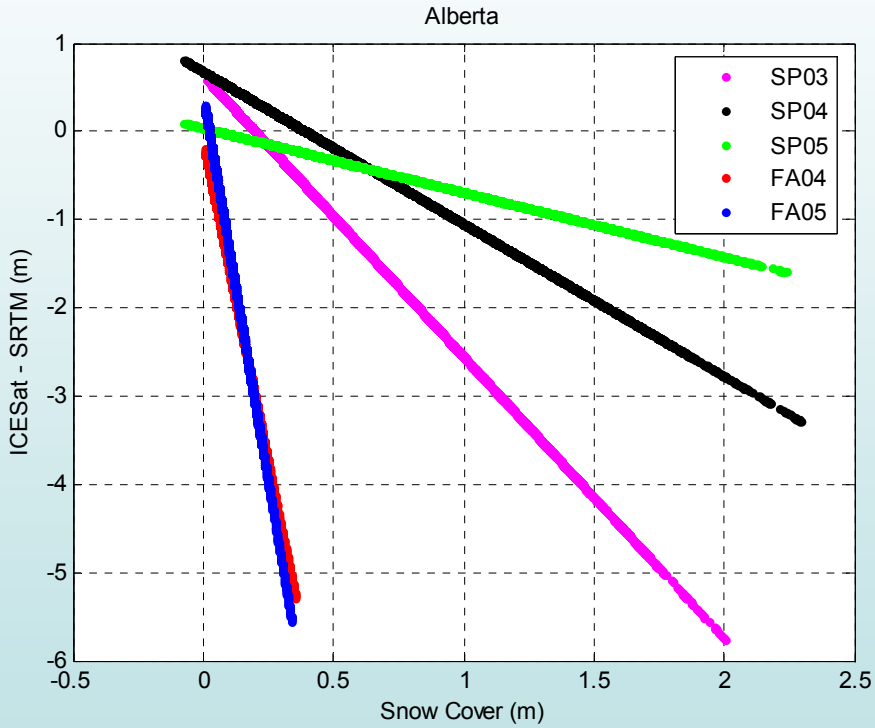


Difference as a function of snow depth

Quebec

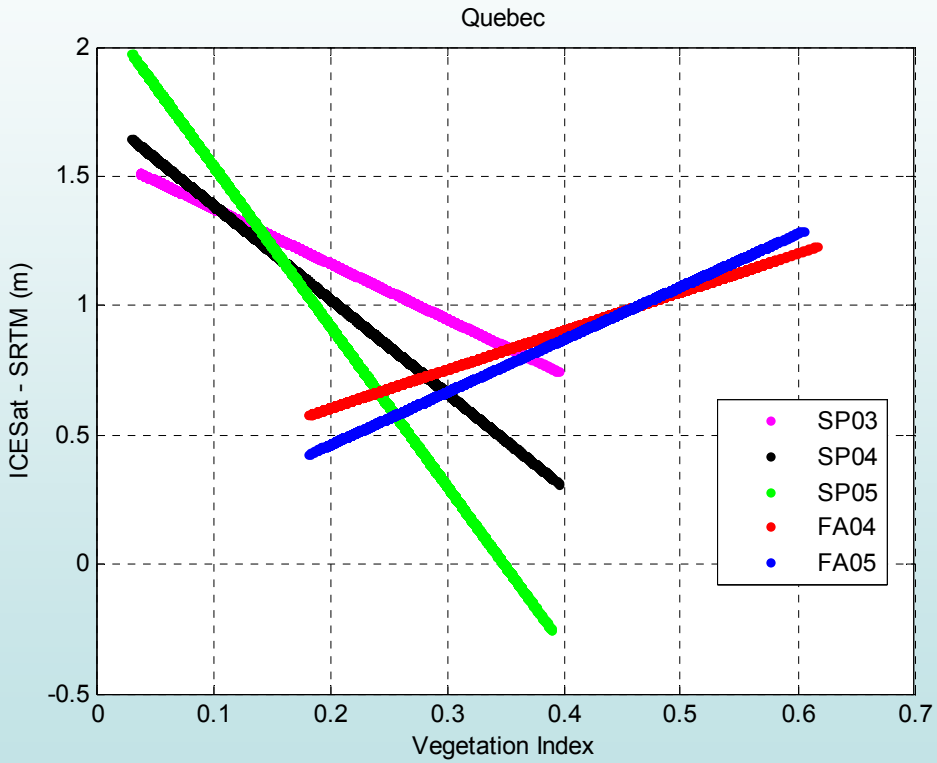


Alberta

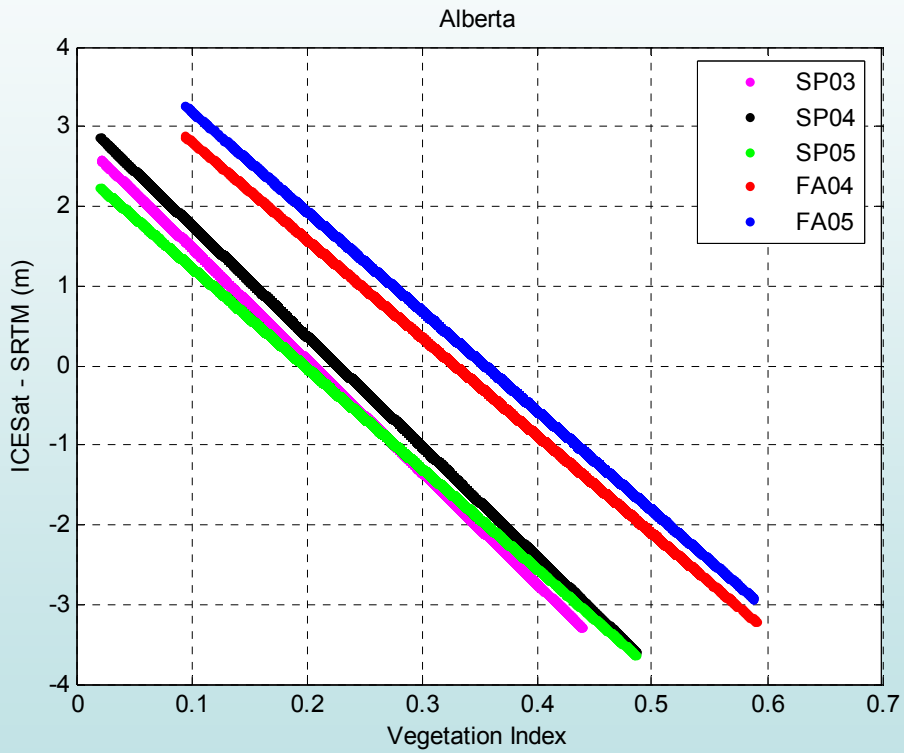


Difference as a function of vegetation index

Quebec

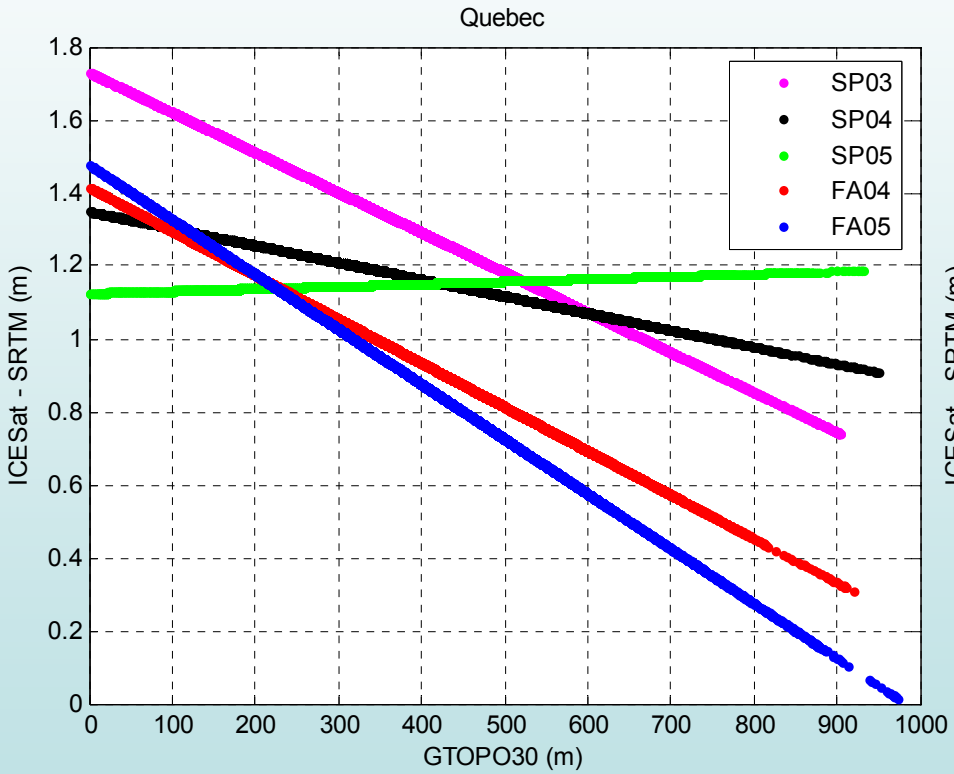


Alberta

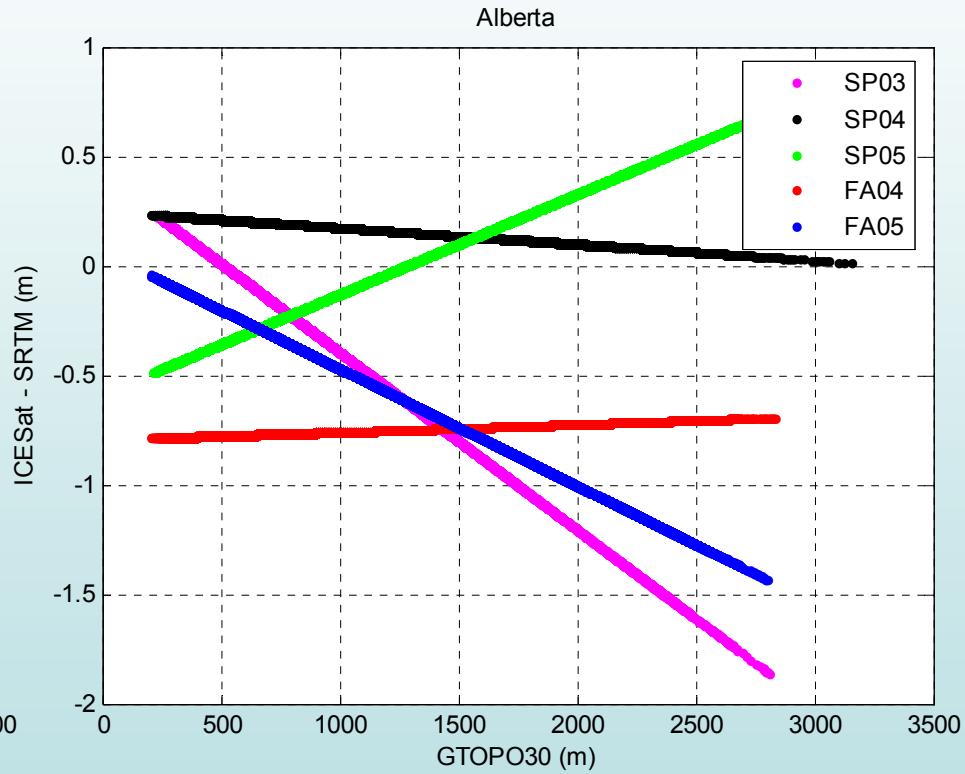


Difference as a function of terrain elevation

Quebec

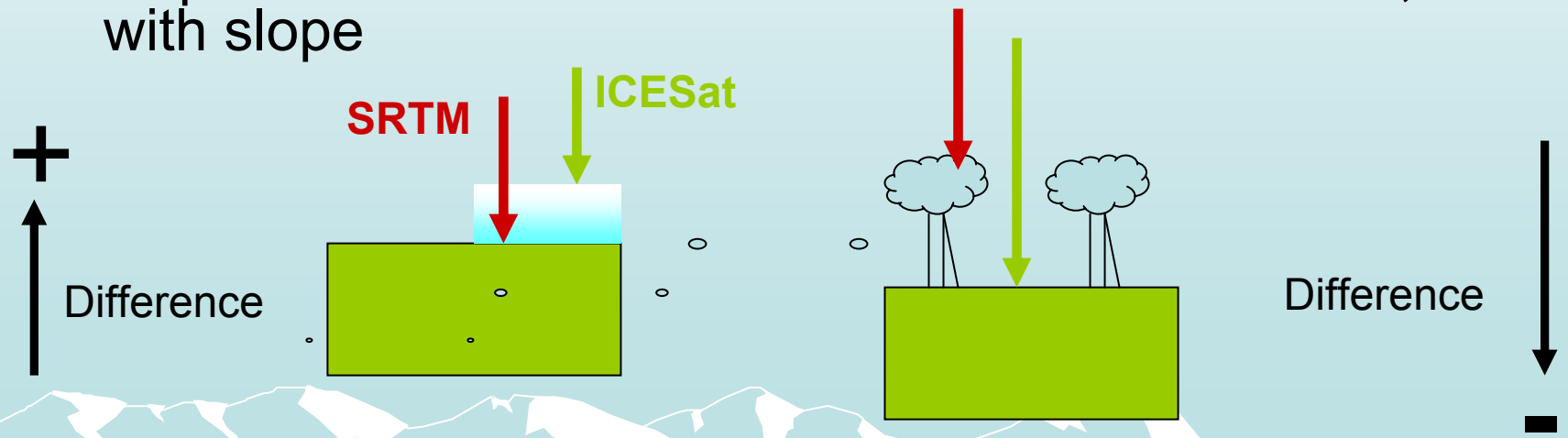


Alberta



Results

- SRTM wrt ICESat -0.5 to -1 m +- 3-5 m Std
- SRTM wrt ASCM 1 to 4 m +- 4-7 m Std
- ICESat and ASCM 0.9 m +- 2.2 m Std
- Vegetation change affects the comparison in Alberta. Higher veg. index leads to higher SRTM elevations and decreasing differences wrt ICESat
- Snow depths change affects comparison in Quebec. Higher snow depth leads to higher ICESat elevations and increasing differences wrt SRTM.
- Dependence on terrain elevation is not conclusive, same with slope



Conclusions and Future Work

- ASCM is in good agreement with ICESat, although local terrain effects have not been considered.
- SRTM can not replace ASCM for well site surveying
- SRTM shows spatio-temporal variations wrt ICESat elevations
- Effects of snow depth, vegetation, slope needs to be studied in more detail
- Statistical test for least square fits
- !!! Go for SRTM-2 on the Shuttle !!!

Thanks to the ICESat Team