A Method for Precision Differential GPS Data Processing on Moving Sea Ice Floes

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Summary

- A measurement and data processing strategy is presented for GPS surveying with non-stationary reference stations
  - Differential surveying performed on drifting & rotating sea ice floes.
  - Precise solutions generated in a local coordinate system relative to ice floe.

- RTKLIB GPS software is briefly discussed
  - Freeware, extremely versatile, handles a wide range of GPS data operations.
  - Polar researchers may find this software very useful, especially in dealing with oddball datasets that they often collect.

- A few notes about other technical equipment

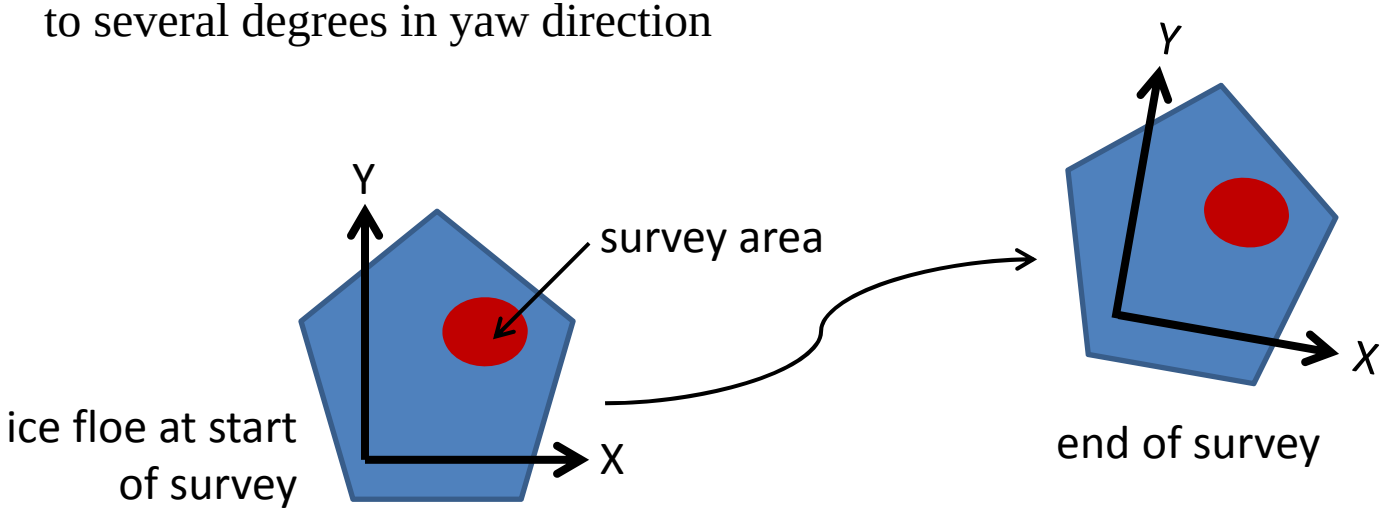
AWECS Research Cruise

Antarctic Winter Ecosystem Climate Study

- Weddell Sea, AWI icebreaker Polarstern, June-August 2013.
- ~20 international science projects, and a bewildering array of equipment onboard.
- Our study focused on the impact of blowing snow on the snow accumulation and mass balance of sea ice
  - Eight “ice stations” with ship parked by ice floe for 1-4 days
  - Measuring of snowflake size distributions
  - Installing a suite of autonomous instrument stations
  - LiDAR scanning of snow surfaces
  - Snow depth measurements across LiDAR scan areas
  - GPS surveying: Locating snow depth measurement points, locating LiDAR optical targets, mapping study sites across entire ice floe

GPS Surveying / Processing Strategy

- However…
  - Far from GPS reference stations. On-ice GPS were only available reference.
  - During study periods, ice floes drift at speeds up to several knots and rotate up to several degrees in yaw direction



- A very specific surveying and processing strategy was needed
  - Generate carrier phase solutions with centimeter-level accuracy
  - Results in coordinate system relative to ice floe

GPS Surveying / Processing Strategy

- Two portable survey-grade GPS base stations required
  - Differential GPS instead of Precise Point Positioning (PPP). Subtraction of PPP solutions probably less accurate, and onboard internet was limited
  - First base station: origin for differential processing, tracking floe translation
  - Second base station: >100m away from first, used to track floe rotation
  - Drill through ice near antenna poles, record heights of antennas above sea level

GPS base station

UNAVCO Trimble

NetR9 system

GPS Surveying / Processing Strategy

- Notes about roving GPS survey system
  - Set to same sample rate as both bases. Record data in hour-long files.
  - Hand-held "Survey Controller" units do not work well in extreme cold and darkness (touch screen, backlighting, battery life). Use Garmin-type GPS to record UTC time of each survey point in notebook.
  - Occupy important survey points for at least 15 seconds; average coordinates later during post-processing.
- Straightforward so far, but processing is the tricky part
  - How to generate precision solutions in a local coordinate system when GPS base stations are "rapidly" drifting and rotating?
  - Disclaimers:
    - This type of processing may have been done before, but I haven't heard of it.
    - Other valid approaches certainly exist in addition to what's presented here.
    - All GPS data processing packages have quirks, limitations, and learning curves.

TBC versus RTKLIB

- Try Trimble Business Center (TBC) first
  - Pros: Used with success by myself and many others to process many scientific GPS datasets. Fairly intuitive GUI, available for loan at no cost to NSF-funded researchers through UNAVCO.
  - Cons: Relatively expensive to buy. Large installation size. Heavy with features, mostly for land surveying and not relevant to most scientific GPS datasets. AND: baseline processing fails when base station is moving ~1km/hr.
- Try RTKLIB package (by Tomoji Takasu)
  - Pros: Freeware, open source. Efficient, well designed software. Functional and straightforward GUIs. Processing utility RTKPOST allows user full control over processing parameters. Includes PPP solution capability. AND: able to solve the ice floe problem.
  - Cons: None so far, but admittedly limited usage. Other utilities are available but not tested (plotting, data conversion, etc).

Data Processing Procedure

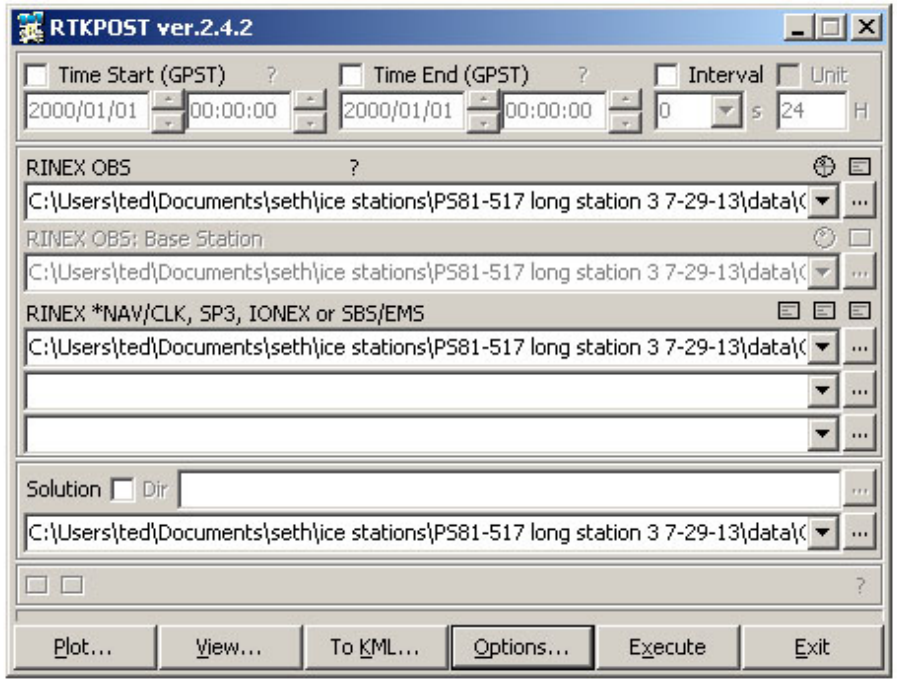
- Process data from first GPS base station
  - Generate time-windowed RINEX files using “teqc” utility. Load OBS and NAV files into RTKPOST, select processing parameters.
  - Generates autonomous “single” solution
    - Solution is for absolute position of first base, epoch-by-epoch (1 sec for our case).
    - Accuracy of absolute positions (lat/lon/height) is meter level.
- Process data from second GPS base station
  - Load RINEX files from first and second bases, select processing parameters.
  - Generate differential “moving baseline” solution from first base to second base.
    - Regenerates first base autonomous solution, then differential solution to second base.
    - Solution is absolute position of second base (lat/lon/height), epoch-by-epoch. Absolute positions are meter level accuracy, but positions relative to first base are centimeter level.
    - Try L1-only and L1+L2 solutions; occasionally one has better solution quality. Also use time-forward and time-backward combined solutions.

Data Processing Procedure

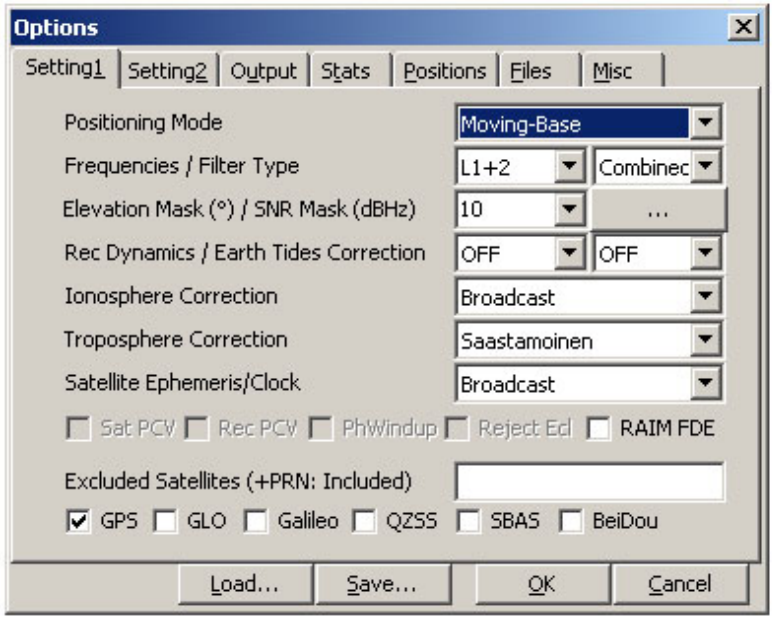
- Process data from roving GPS survey unit
  - Generate “moving baseline” solution from first base to roving unit, i.e. repeat above process as for second GPS base.

- Convert all lat/lon values to projected coordinates (northing/easting)
  - In our case, geodetic coordinates were WGS84 and projected coordinates were UTM. Used “UTMconversions1.xls” spreadsheet from Steven Dutch at U. Wisconsin (no longer available). Another utility is “UTMS” from NGS.

Data Processing Procedure



RTKPOST main window



Options window

Data Processing Procedure

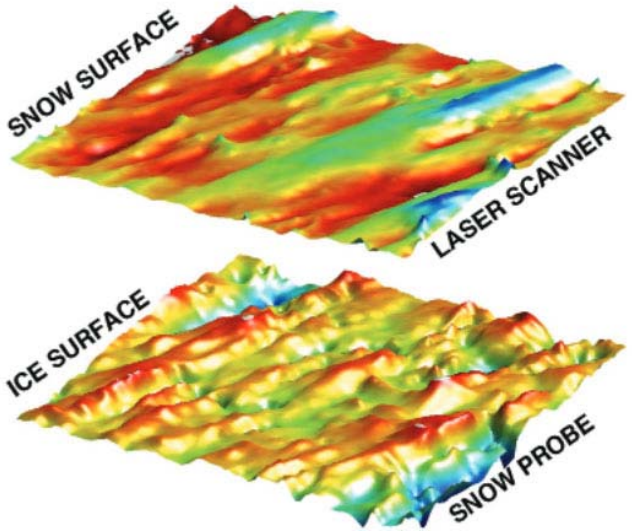
- Calculate ice floe rotation
  - Subtract first base autonomous solution, epoch-by-epoch, from second base moving baseline solution. Yields precise baselines between first and second bases. Change in azimuth of these baselines is ice floe rotation.
- Calculate corrected positions for roving GPS unit
  - Subtract first base autonomous solution from roving unit moving baseline solution, epoch-by-epoch. Yields precise baselines between first base and roving unit, but includes errors due to floe rotation.
  - Subtract floe rotation information, epoch-by-epoch, to correct northing and easting values for roving GPS baselines.
- Correct height values to mean sea level
  - Use true height of first GPS base antenna above mean sea level, as well as antenna height vertical offsets of roving GPS unit, to correct all vertical coordinates to mean sea level.

Other Equipment

- GPS Snow Depth Probe “aka magnaprobe”
  - Backpack-mounted, Campbell datalogger based, hand-held snow depth probe.
  - Also records autonomous GPS positions with each sample (we corrected these with simultaneous survey-grade GPS measurements).
  - Excellent performance during the AWECS cruise. Made by Snow Hydro.

Other Equipment

- Campbell dataloggers and Trimble GPS units operated well
  - Campbell CR1000 and CR800 models
  - Trimble NetR9 receivers and Zephyr 2 GPS antennas
- LiDAR scanners
  - Faro Focus 3d-120 worked well during entire cruise.
  - Reigl LMP-321 (better resolution/range) “got by” at -20C, required heating at lower temps. With generator, heat gun, and light plastic hood, scanned at -30C.

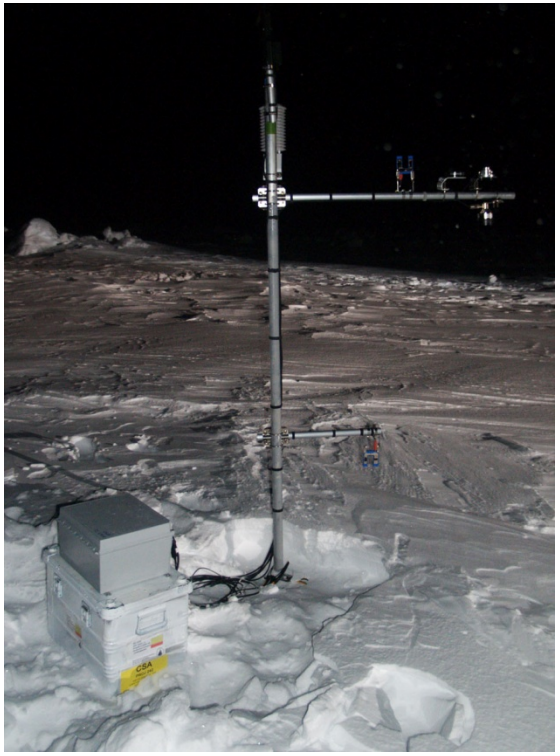


Other Equipment

Blowing Snow Mast (CU)

snow particle counters, met sensors

temporary installation on ice floes



Automated Weather Station Buoy (WHOI)

met, GPS, radiation, and snow height sensors,

particle counters, left to drift on ice floes

Other Equipment

Snow Height Buoy (WHOI)

snow height sensor, left to drift on floes

Ice Mass Balance Buoy (SAMS)

thermistor string to measure snow and ice thickness, left to drift on ice floes