WORK ON CUMULATIVE GNSS SOLUTIONS AT LANTMÄTERIET

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NKG WG REFERENCE FRAMES

MAY 19-20, 2022

LANTMÄTERIET

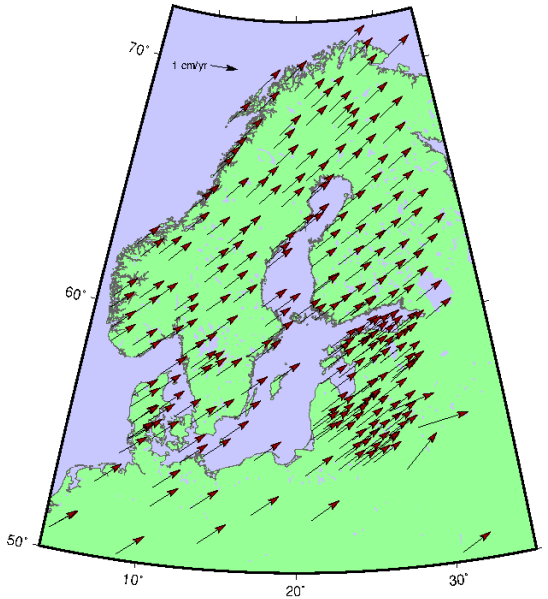
BACKGROUND AND MOTIVATION

- Currently, cumulative solutions (for estimating positions and velocities) using the CATREF software is, within the NKG, performed at FGI
  - NKG Repro 1, *doi:10.1007/s10291-019-0886-3*
  - NKG Repro 1 upd 2020, *doi:10.1007/s10291-021-01194-z*
- Goal to make more regular cumulative solutions in the future
- Would be good to have more institutions within the NKG making cumulative solutions with CATREF
  - As backup
  - For validation
  - Possibility to discuss problems etc. with each other
- At Lantmäteriet we are interested in making cumulative solution, e.g., to get positions and velocities for all SWEPOS stations

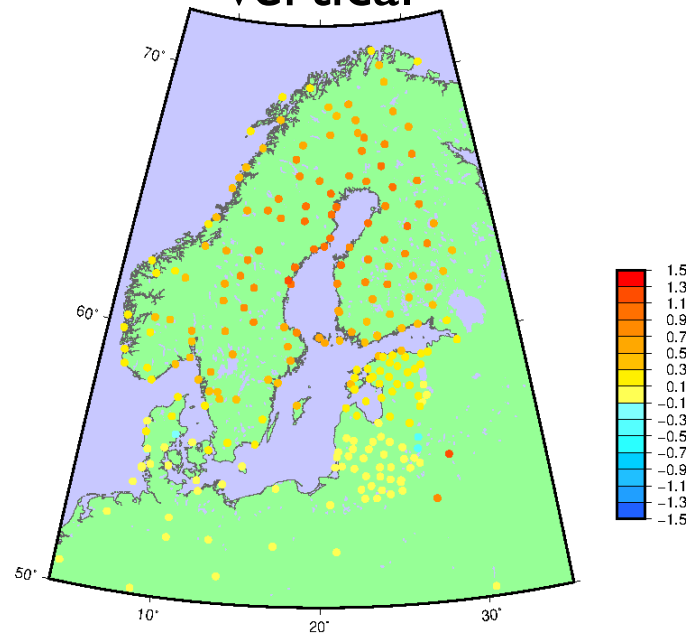
1. LM VERSION OF NKG REPRO1 UPD 2020

- First, a version of NGK Repro1 upd 2020 cumulative solution was calculated:
  - NKG Repro1 (1997-2017) + operational NKG solutions (2017-2020)
  - Official solution by Sonja Lahtinen (FGI), *doi:10.1007/s10291-021-01194-z*
- Goals:
  - Getting started with CATREF
  - See if the obtained results agree with Sonja
- Used (almost) the same setup as Sonja:
  - Same SINEX files (except two)
  - Same datum
  - Same list of breaks
  - Almost the same outliers

Horizontal

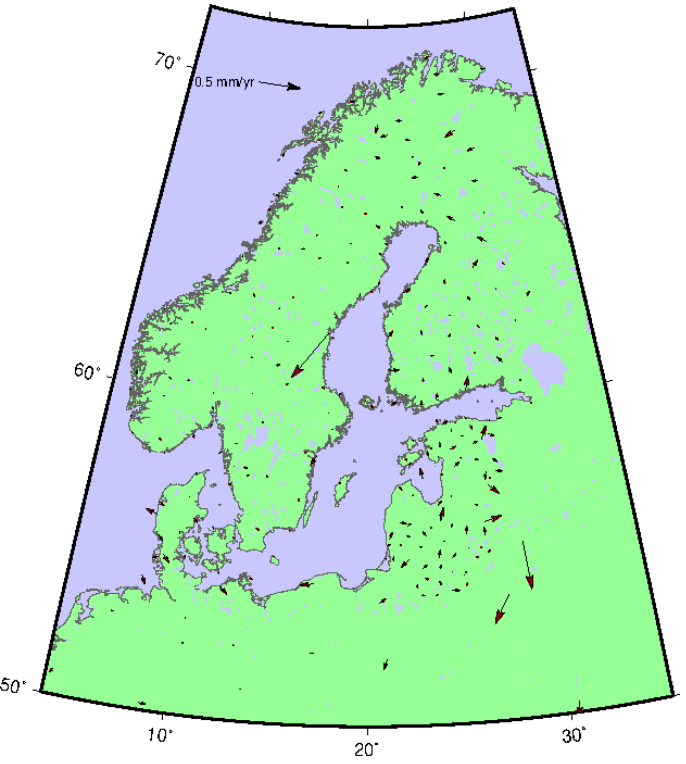


Vertical



COMPARISON WITH NKG REPRO1 UPD2020

Horizontal



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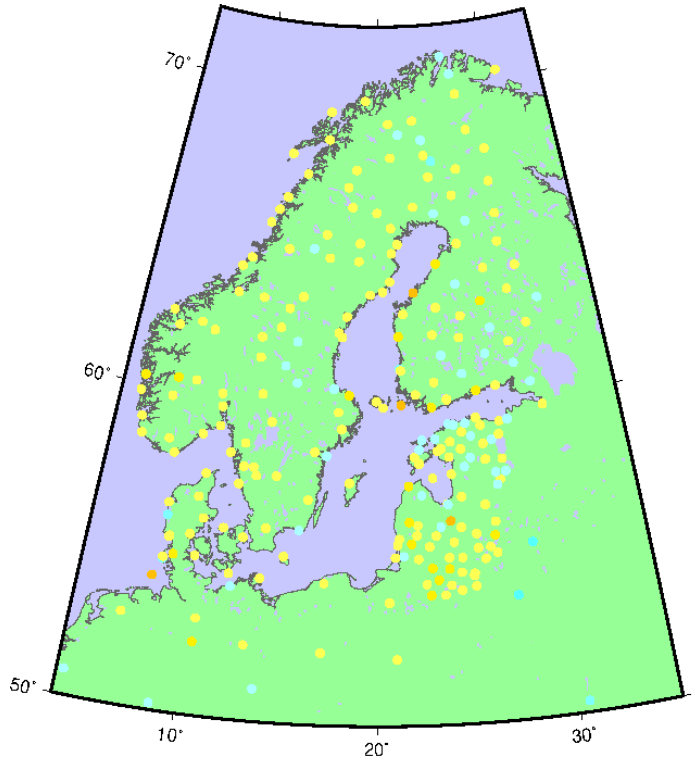
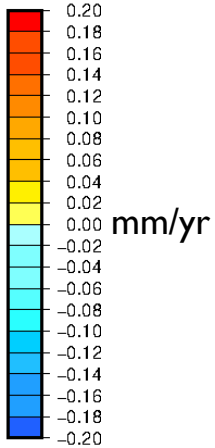
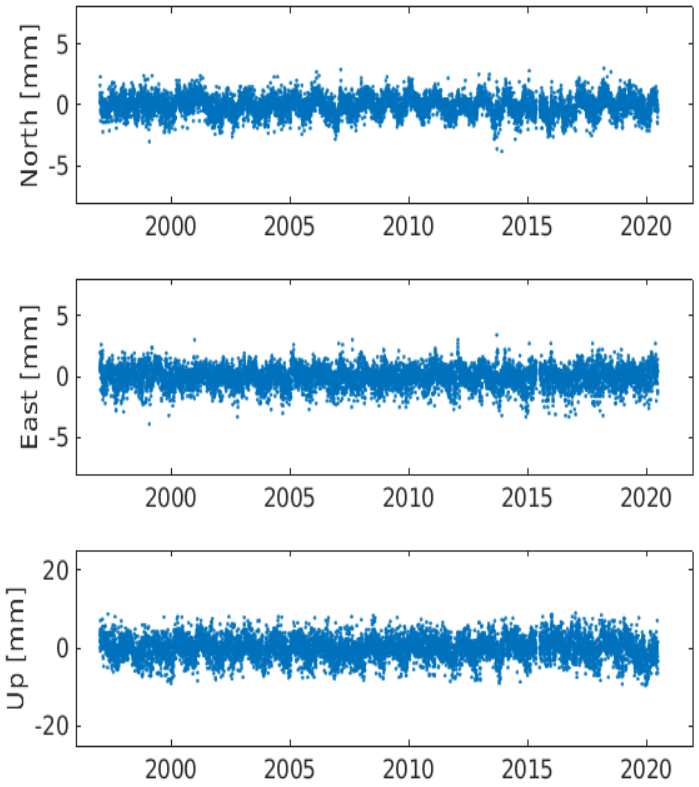




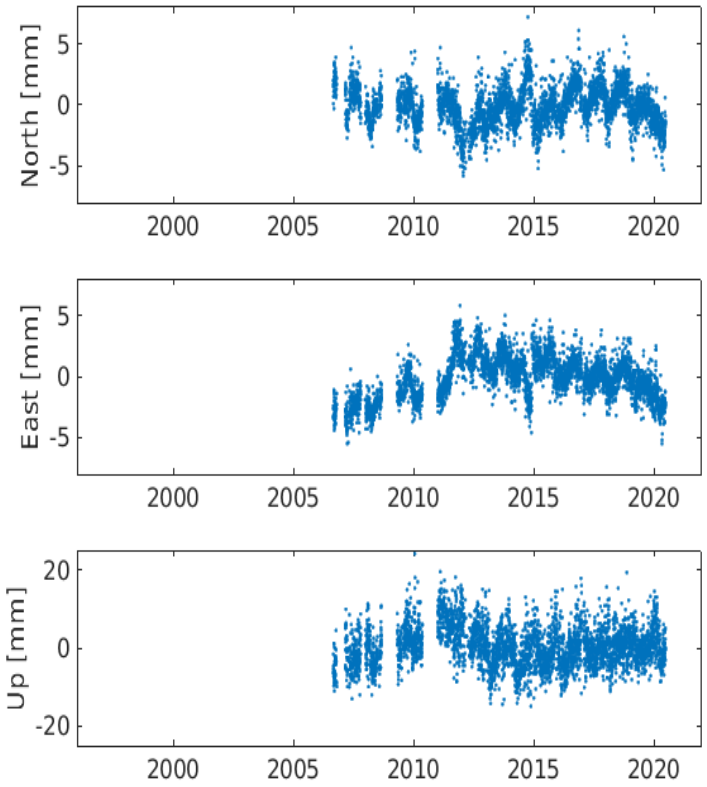
- Velocity differences between LM solution and official solution (FGI)
- Mostly very close to zero
- Occasionally differences of some tenths of mm/year
  - Stations with very short time series (< 1 year)
    - VIB0 (252 days)
    - MNKW (77 days)
    - NOVP (77 days)
    - RIKO (191 days)
    - BAU1 (179 days)

RESIDULAS FOR SOME STATIONS

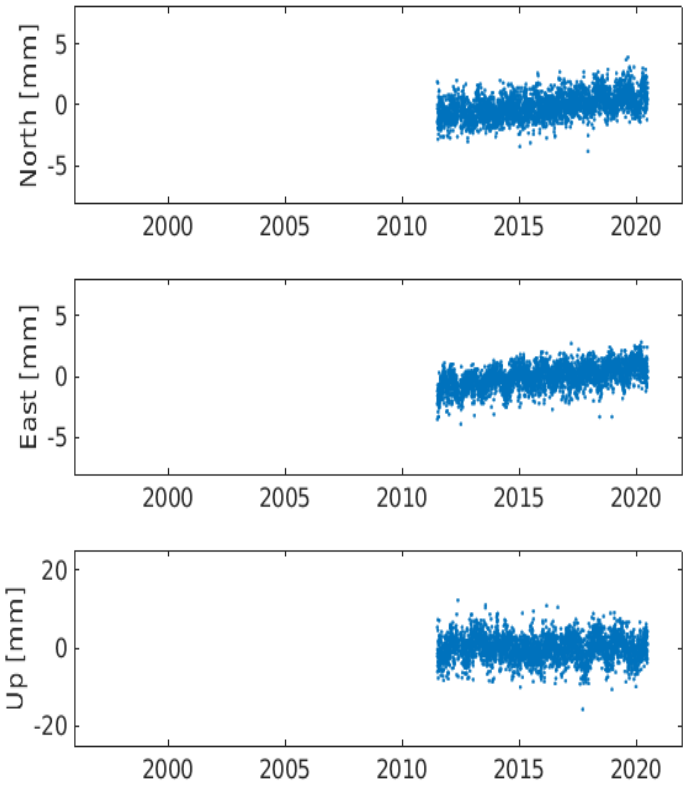
ONSA



MYVA



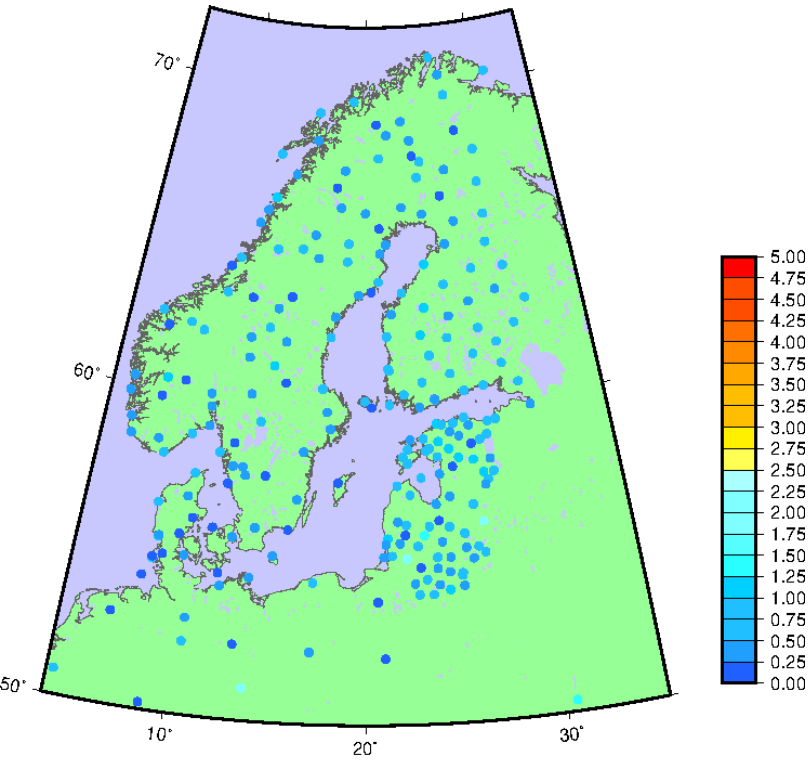
SUL5



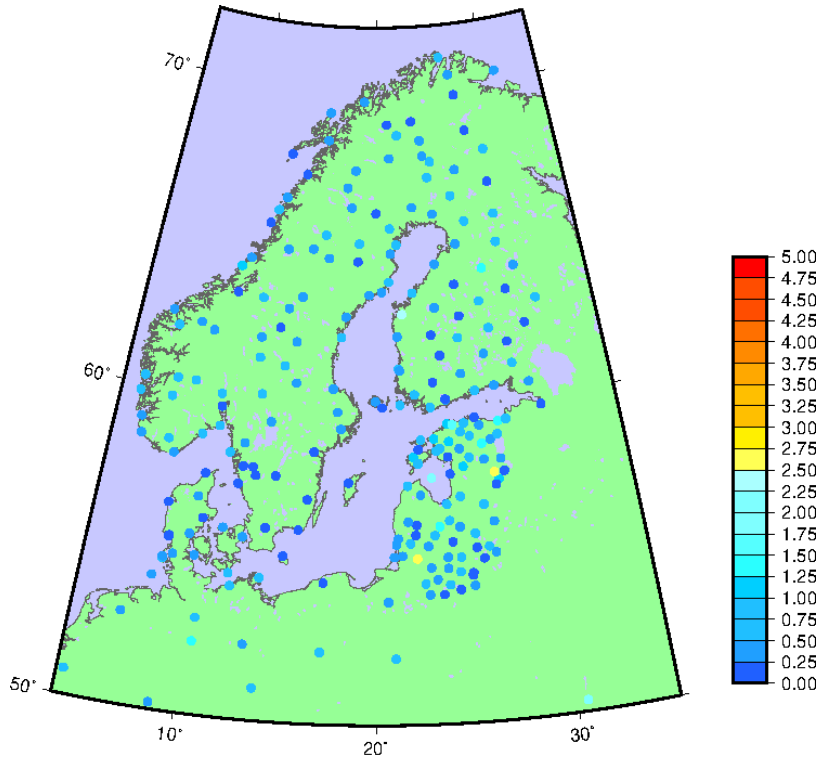
SEASONAL VARIATIONS

- A test was made also estimating seasonal signals (365.25 days)
- Figures below shows the estimated amplitudes (in mm)

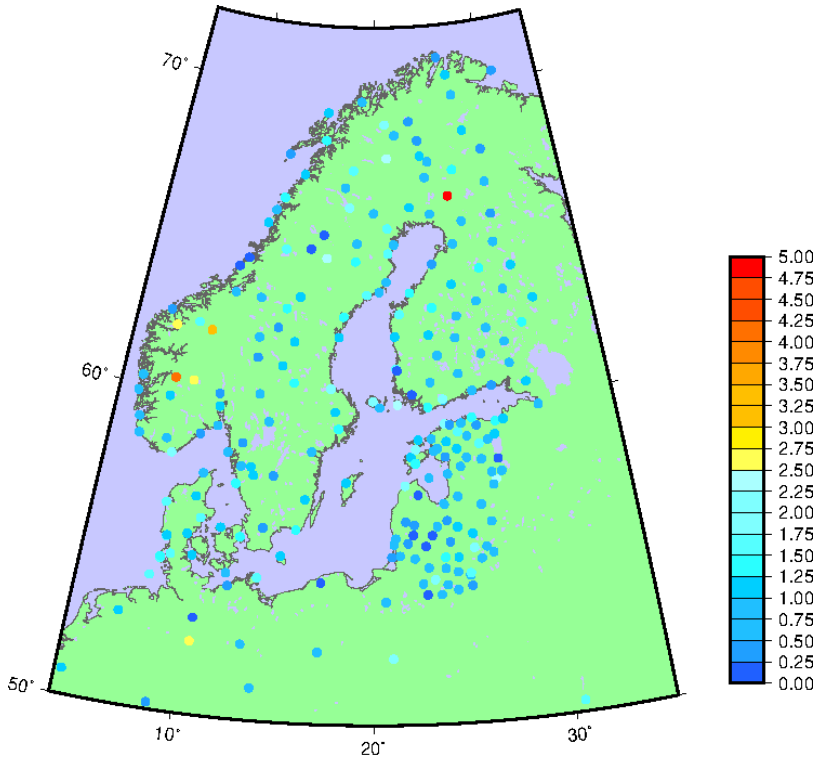
East



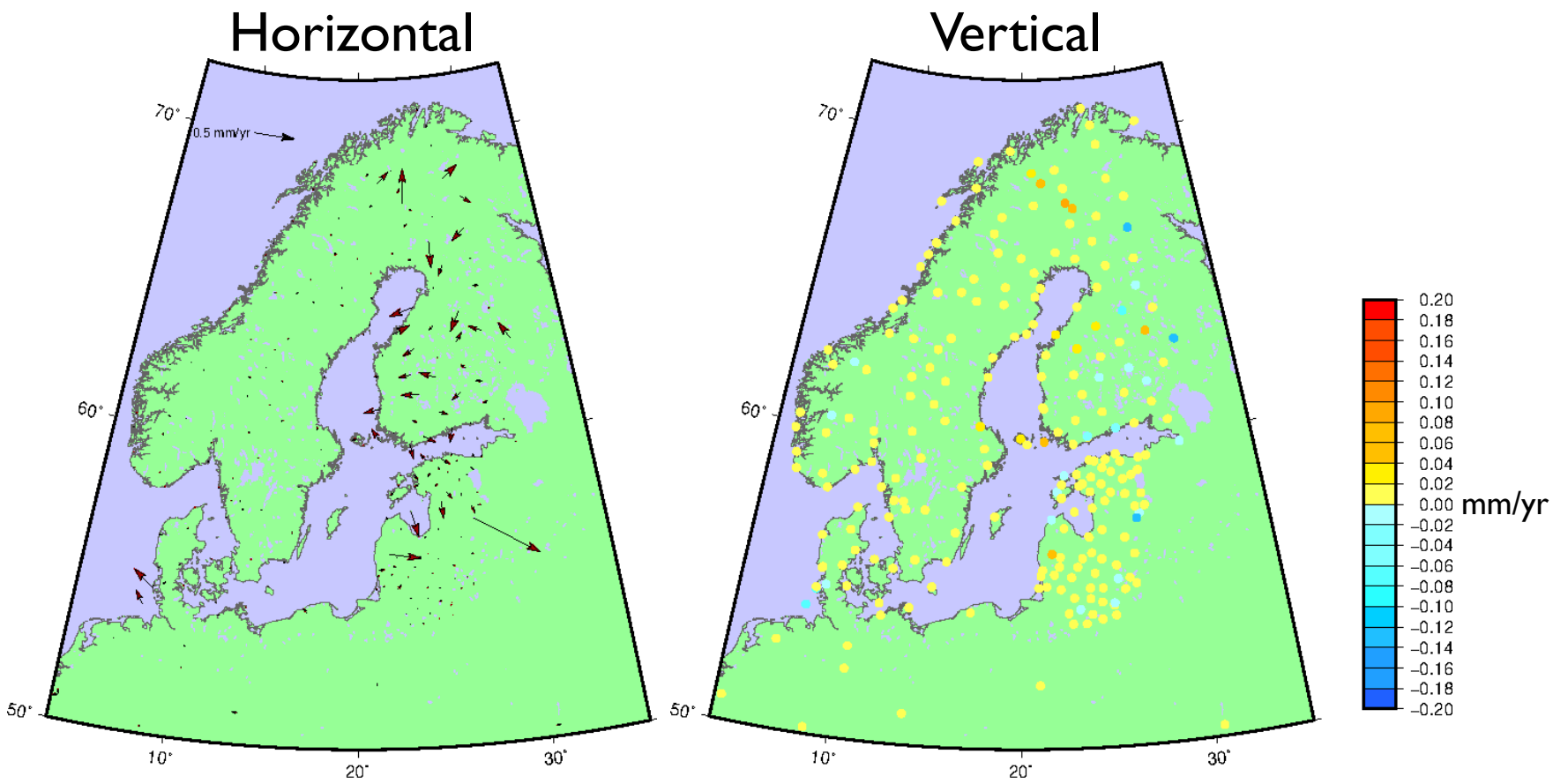
North



Up



EFFECT OF INCLUDING SEASONAL VARIATIONS

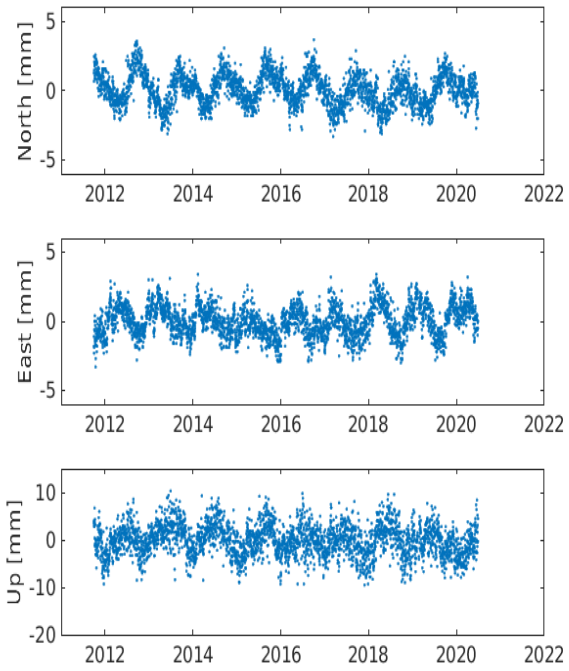


- Figure show difference between velocities estimated in solutions with and without seasonal signals
- Mostly minor differences
- Lager differences for a few stations:
  - Relatively short time span (a few years)
  - Variable amplitude of seasonal signal

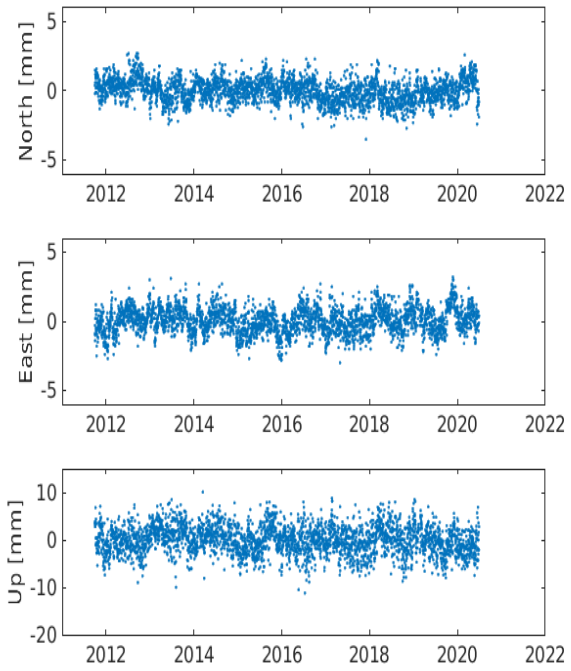
RESIDUALS WITH AND WITHOUT SEASONAL SIGNALS

SUR4

Without seasonals

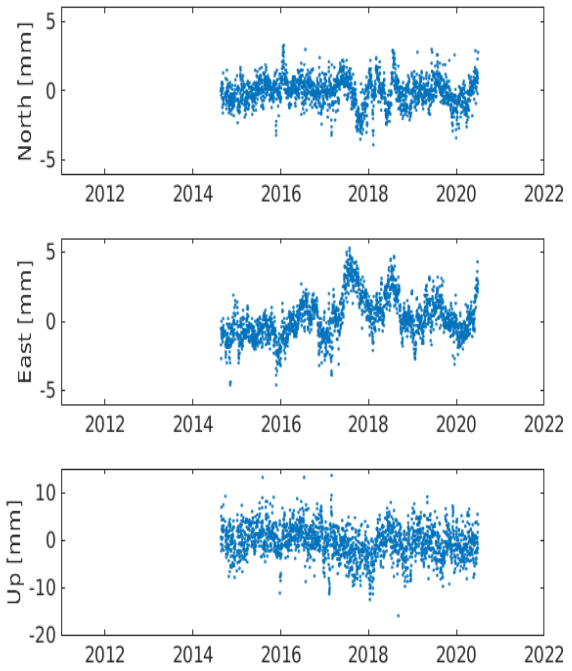


With seasonals

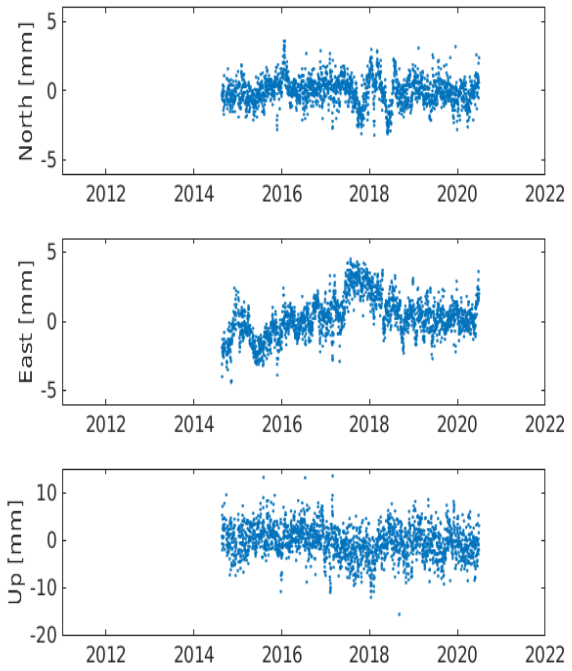


PYHA

Without seasonals

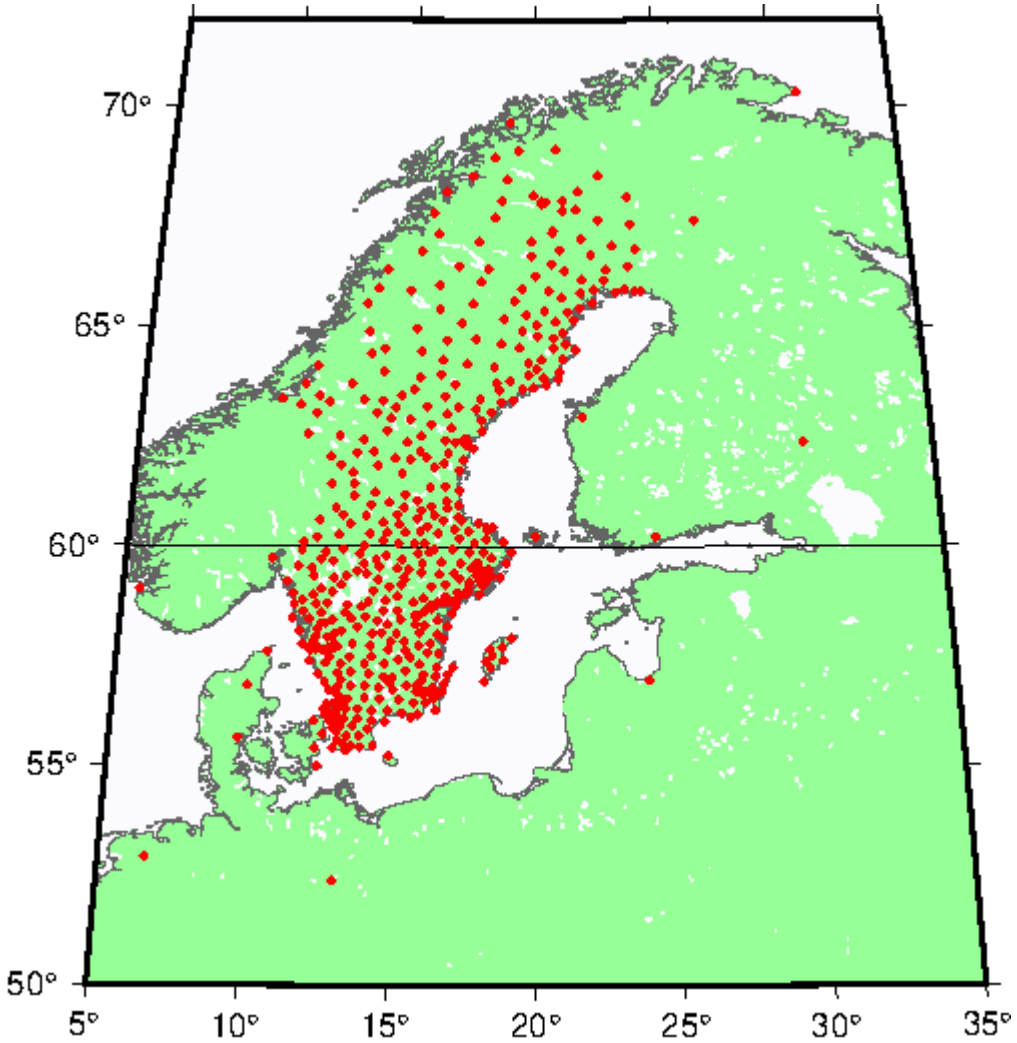


With seasonals



2. PLANS FOR A CUMULATIVE SOLUTION FOR SWEPOS

- Would be nice to estimate positions and velocities of all SWEPOS sites (including important sites in neighboring countries)
- > 500 sites
- All stations operationally processed daily since 2011
- Issues:
  - Need to estimate breaks (preferable automatically)
  - Need to detect outliers (preferably automatically)

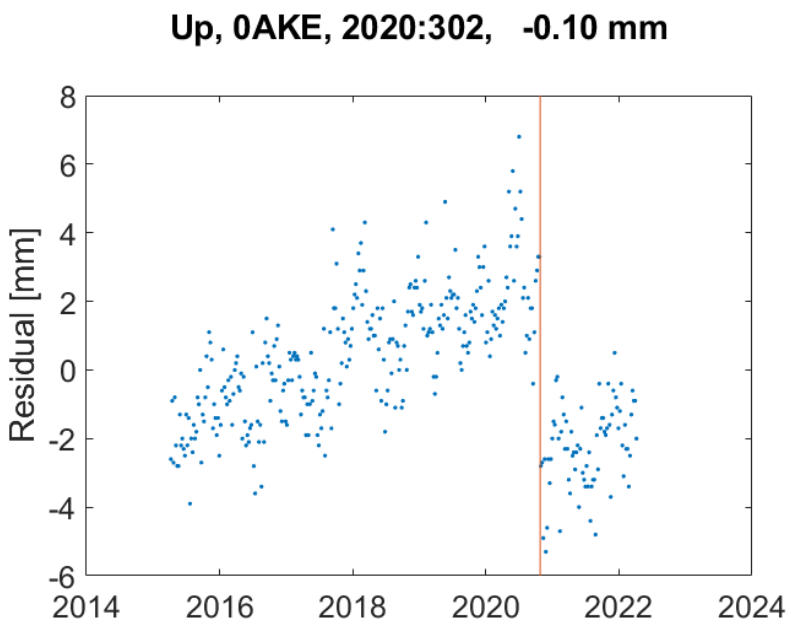


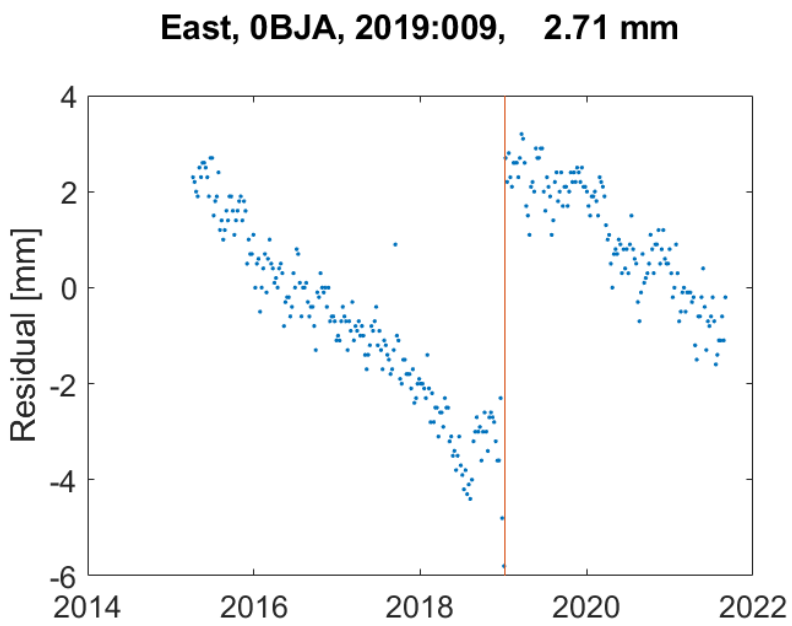
Sites in the SWEPOS daily solutions

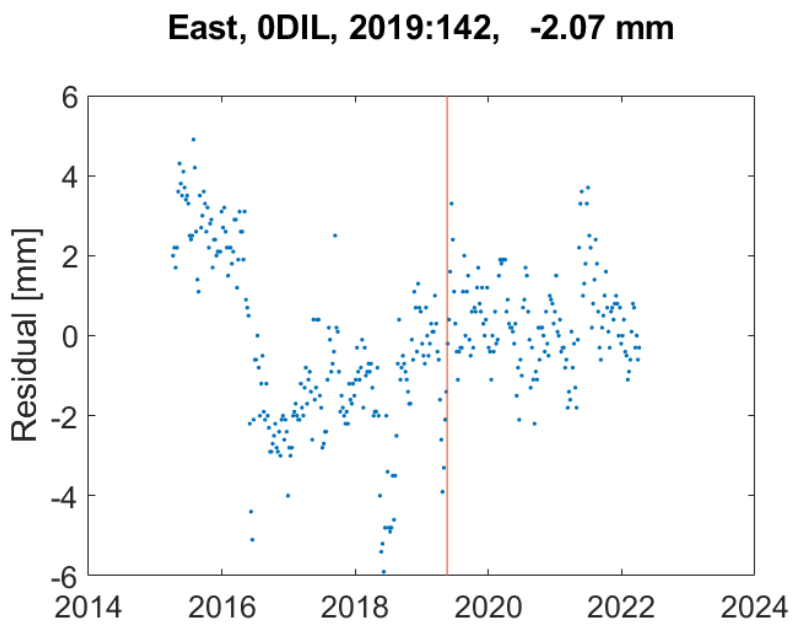
INITIAL SOLUTION

- A first test has been made based on the weekly SWEPOS solutions 2015-2022
- Included stations with time series longer than three years (544 stations)
- Breaks:
  - From NKG Repro1 upd2020 (for overlappning stations)
  - Semi-automatic break detection algorithm implemented. Run iteratively
- Outliers:
  - Automatic outlier detection (5-sigma outlier test with some other conditions). Run iteratively
- Datum:
  - NNT/NNR/NNS relative to the NKG Repro1 updat2020 coordinates/velocities for selected stations
- Seasonal signals estimated (365.25 days and 182.625 days)

SEMI-AUTOMATIC BREAK DETECTION

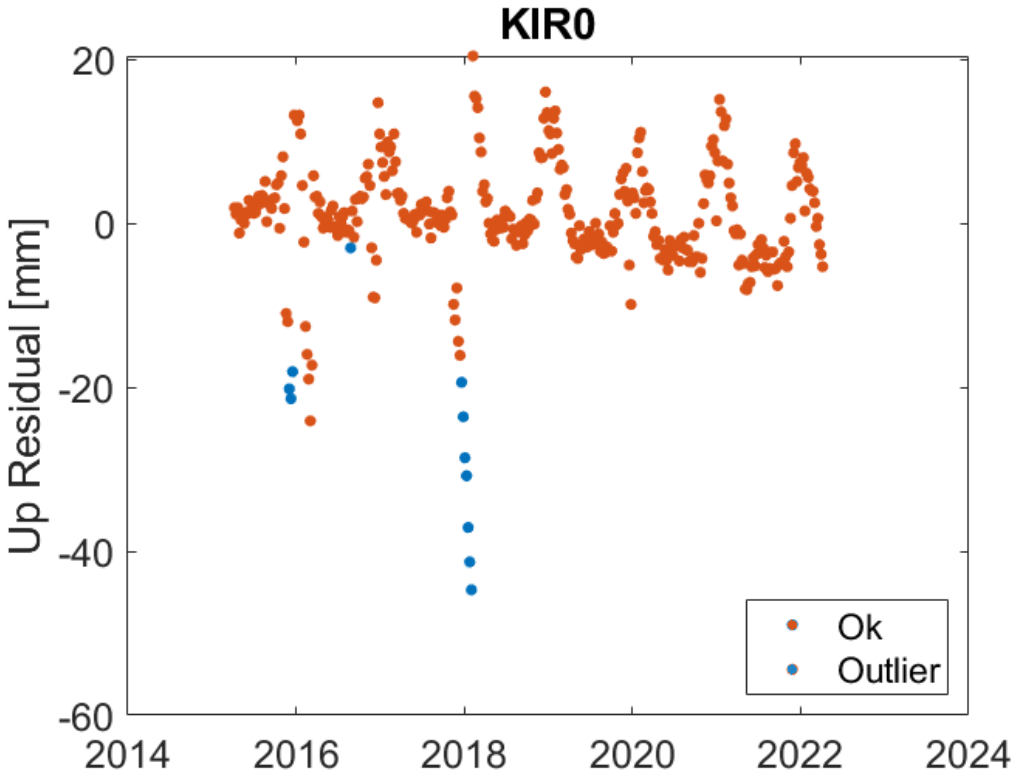


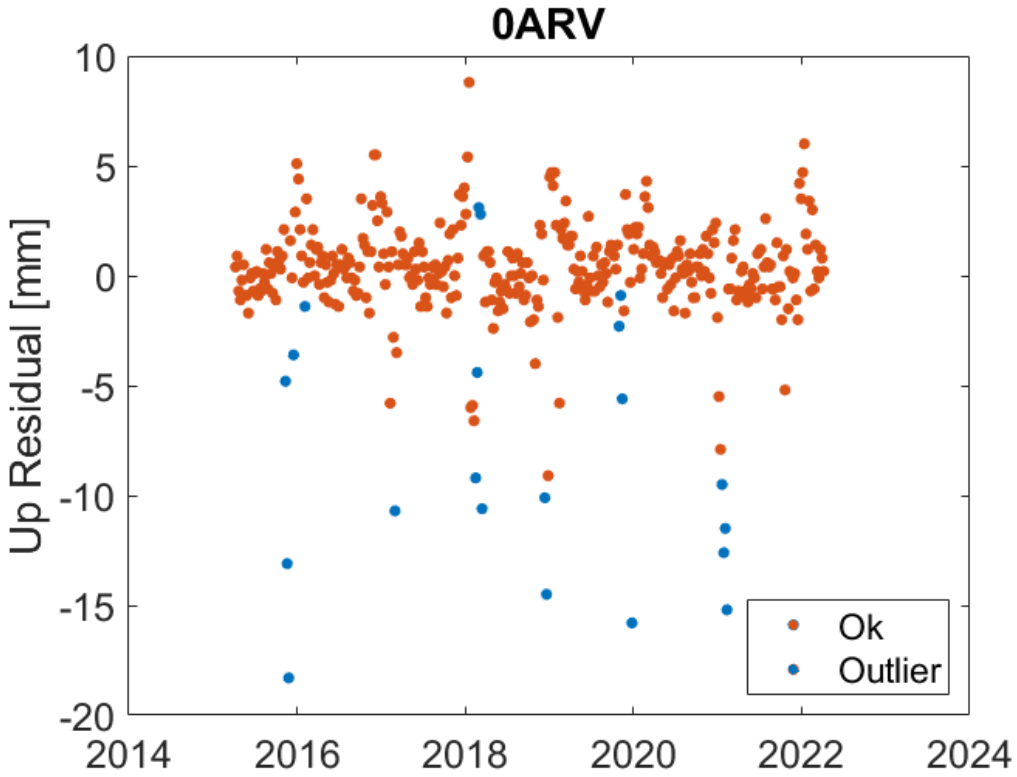




- Gives suggestions where there can be a break. Need to manually decide if it should be used or not
- Not perfect, sometimes it fails
- Need to iterate

OUTLIER DETECTION

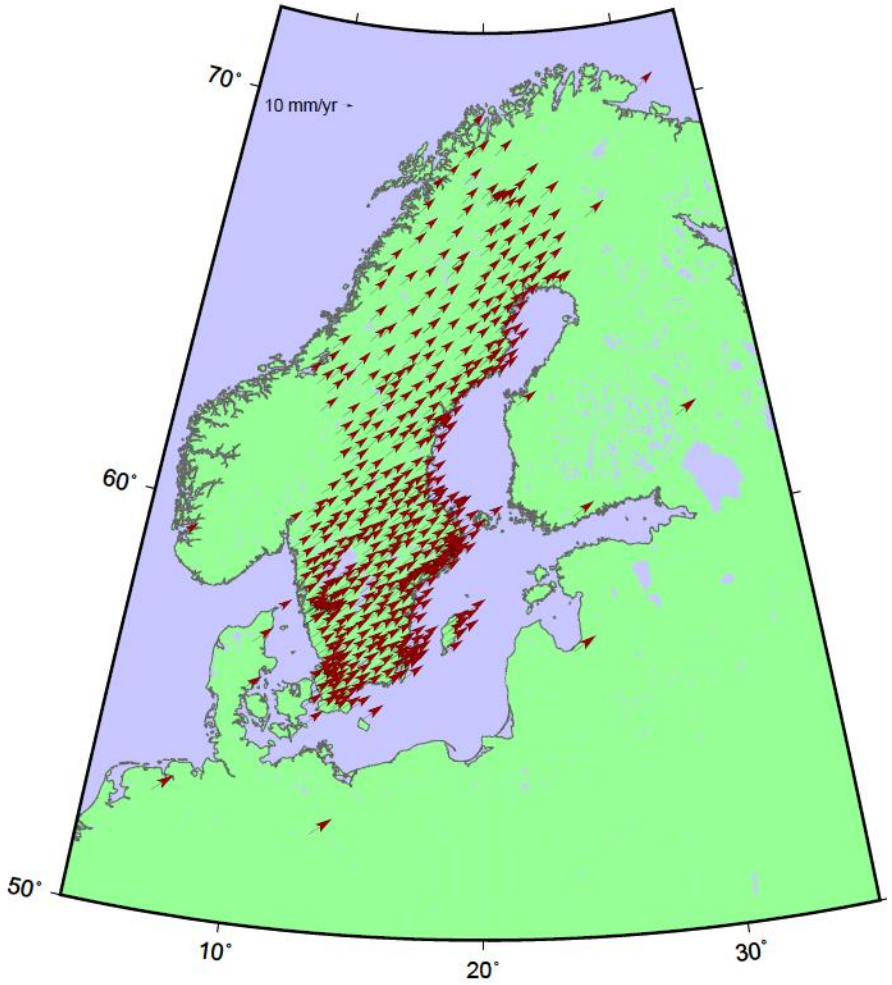




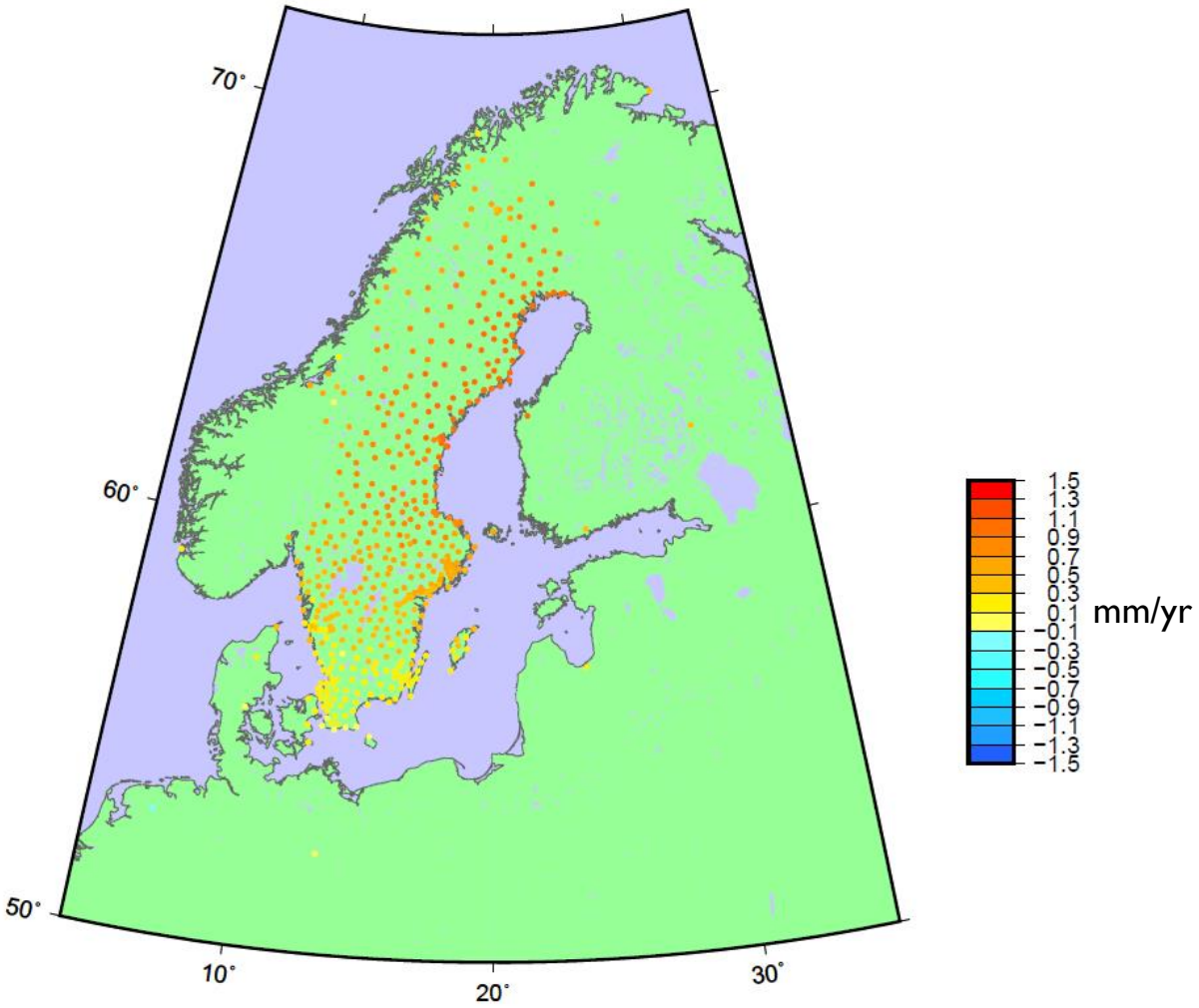
- Outlier after first iterations, more iterations needed

ESTIMATED VELOCITIES IN ITRF2014

Horizontal

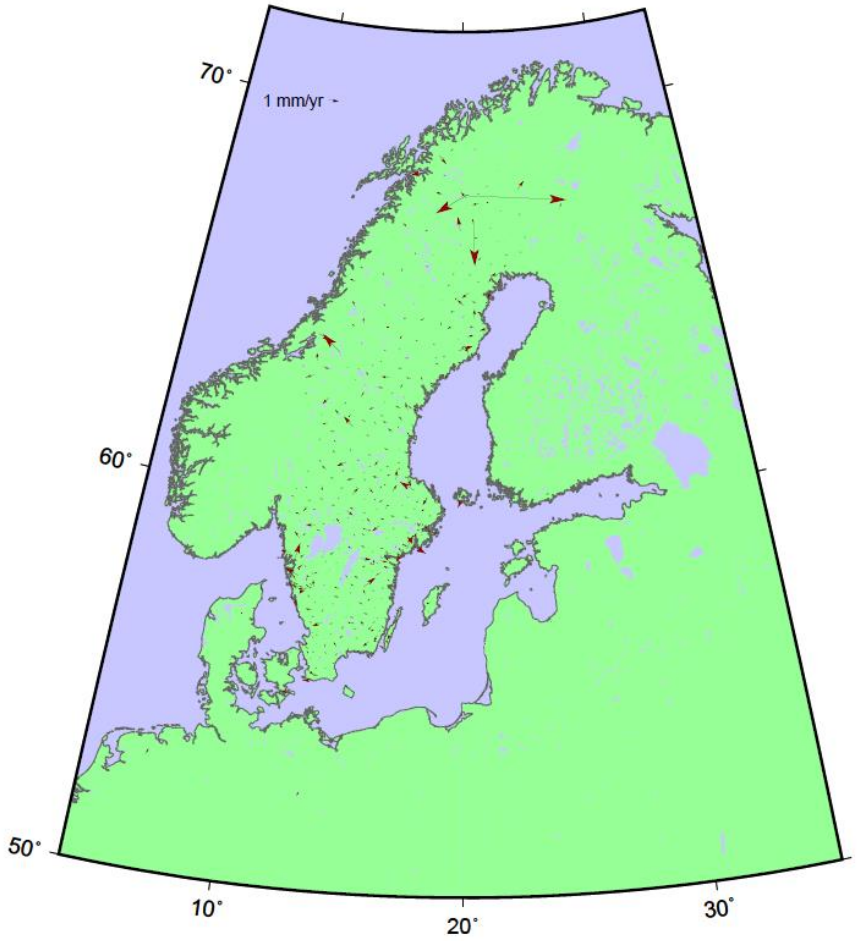


Vertical

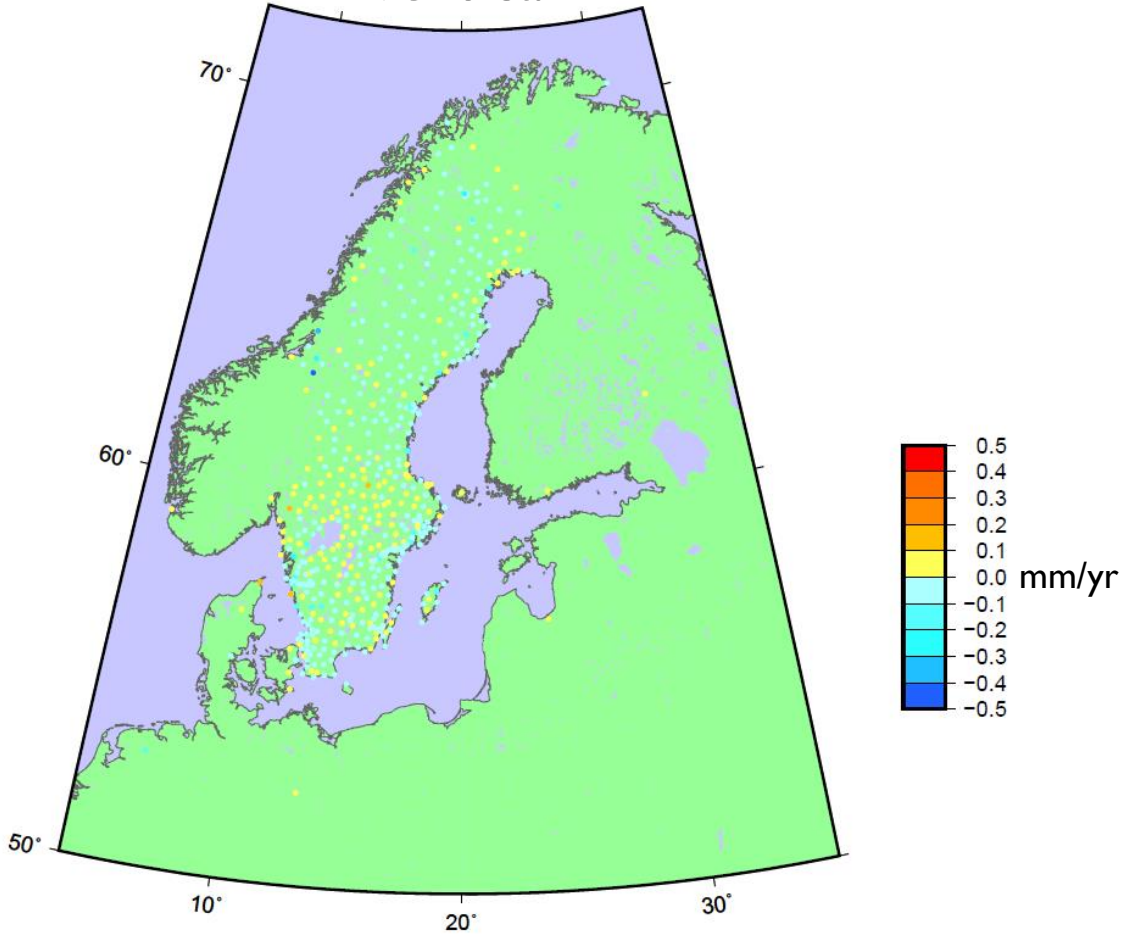


VELOCITIES IN SWEREF99

Horizontal



Vertical



- Transformed to SWEREF99 using the NKG 2020 transformations
- Significant local motions at some stations in Kiruna and Malmberget due to mining

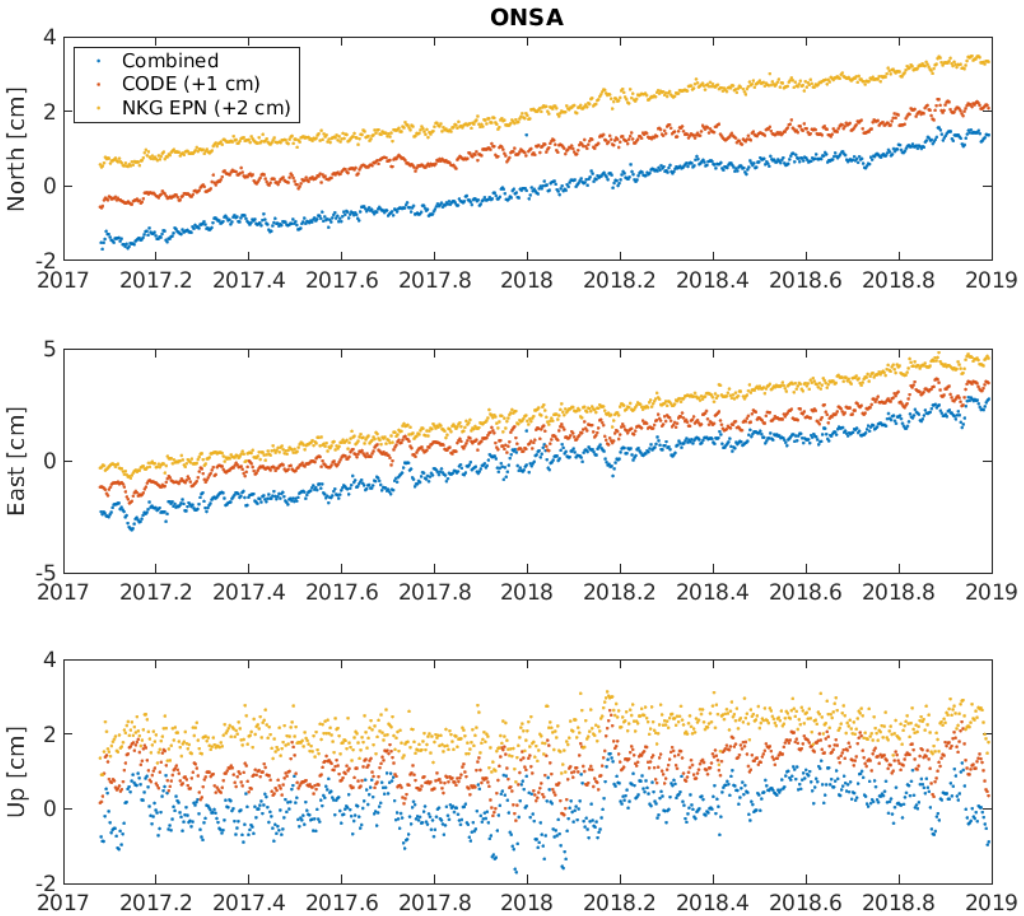
3. GLOBAL ALIGNMENT

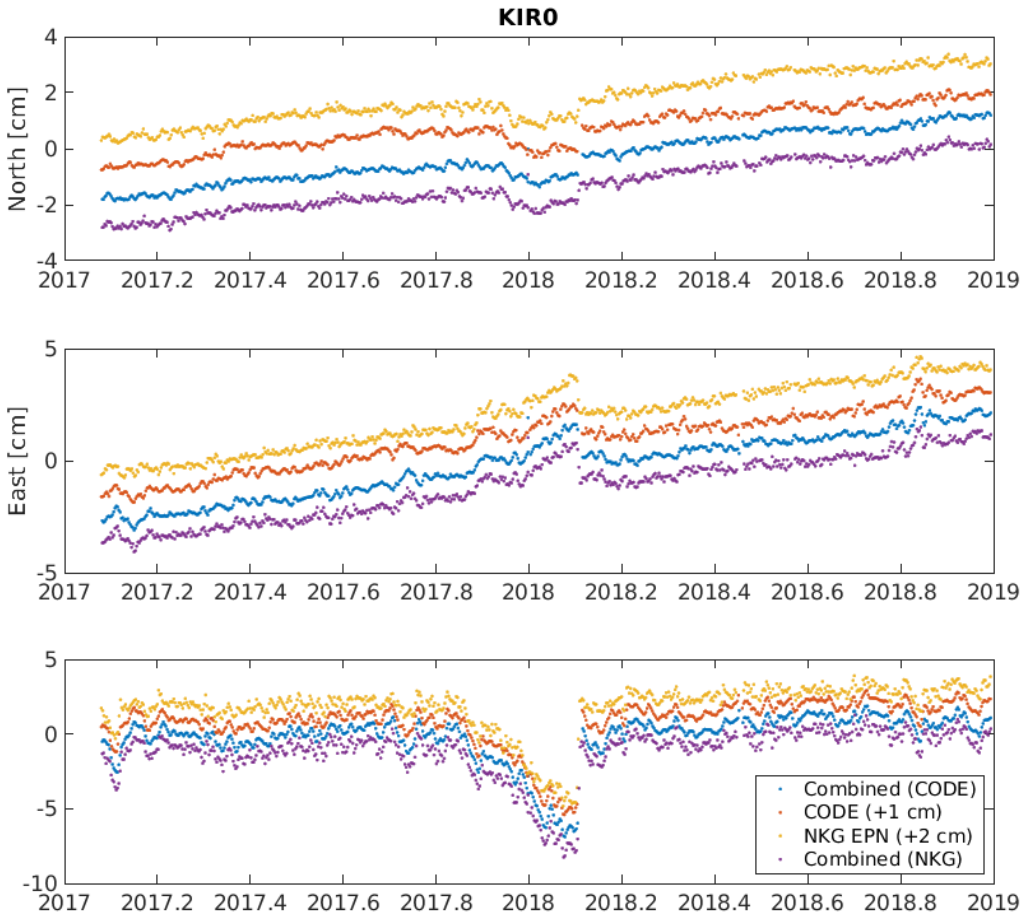
- In many cases it would be nice to have a global GNSS solution (i.e., including stations from all around the world)
- Allows the datum to be defined globally instead of regionally
  - Avoids border effects, i.e., that the datum realization gets worse close to the border of the regional network
- Setting up a complete global solution is a huge effort
  - Needs to include a lot of new sites from different parts of the world and learn about their behavior
- Shortcut: global alignment
  - Take a global GNSS solution (e.g., from CODE or IGS) and combine it with a regional solution
  - Datum can be defined globally, avoid border effects
  - Requires using the same analysis setup for the regional solution as for the global one

FIRST TEST

- A Lantmäteriet, we have started investigating global alignment
- As a test, we want to combine the NKG EPN solution with the global CODE solution
- Main issue:
  - CODE uses type mean antenna models (IGS14.atx)
  - NKG EPN solution uses individual antenna models (where available)
- First test:
  - Combine daily solutions from CODE and NKG EPN using CATREF
  - GPS week 1934-2033 (Jan 29 2017 – Jan 12, 2019, both solutions uses GPS/GLONASS)
  - Only stations with type mean antenna models in both solutions combined (others considered as two different stations)
  - Datum based on 47 globally distributed sites (from IGb14_core.txt list)
- Later we plan to reprocess the NKG EPN solution using type mean models for some time period

FIRST RESULTS





- Two estimates for KIR0 in combined solution because it has an individually calibrated antenna

SUMMARY AND CONCLUSIONS

- At Lantmäteriet we have started calculating cumulative solutions using CATREF
- Our version of NKG Repro1 upd2020 agree well with the official solution
  - Our CATREF installation and setup seems to work well
- Stated making a cumulative solution for all SWEPOS stations
  - First very preliminary results look ok, but some things need to be checked
  - Need to improve break detection and outlier detection algorithms
  - Should switch to using daily solutions instead of weekly, and extend the time period
- Started work on global alignment
  - Seems to be working
  - Final results of this investigation will hopefully be presented at the NKG GA