Styrelsen for
Dataforsyning og
Effektivisering

Geodesy – From Science to Society

Integrating InSAR into Future Height Infrastructure

NKG – Science Week
Reykjavík, Iceland
9'th March 2020

On behalf of Spatial References, SDFE
Erik Lysdal

Styrelsen for
Dataforsyning og
Effektivisering

New people, new technology, new direction

Outline of presentation:

- Current Height Infrastructure

- Changing physical height network

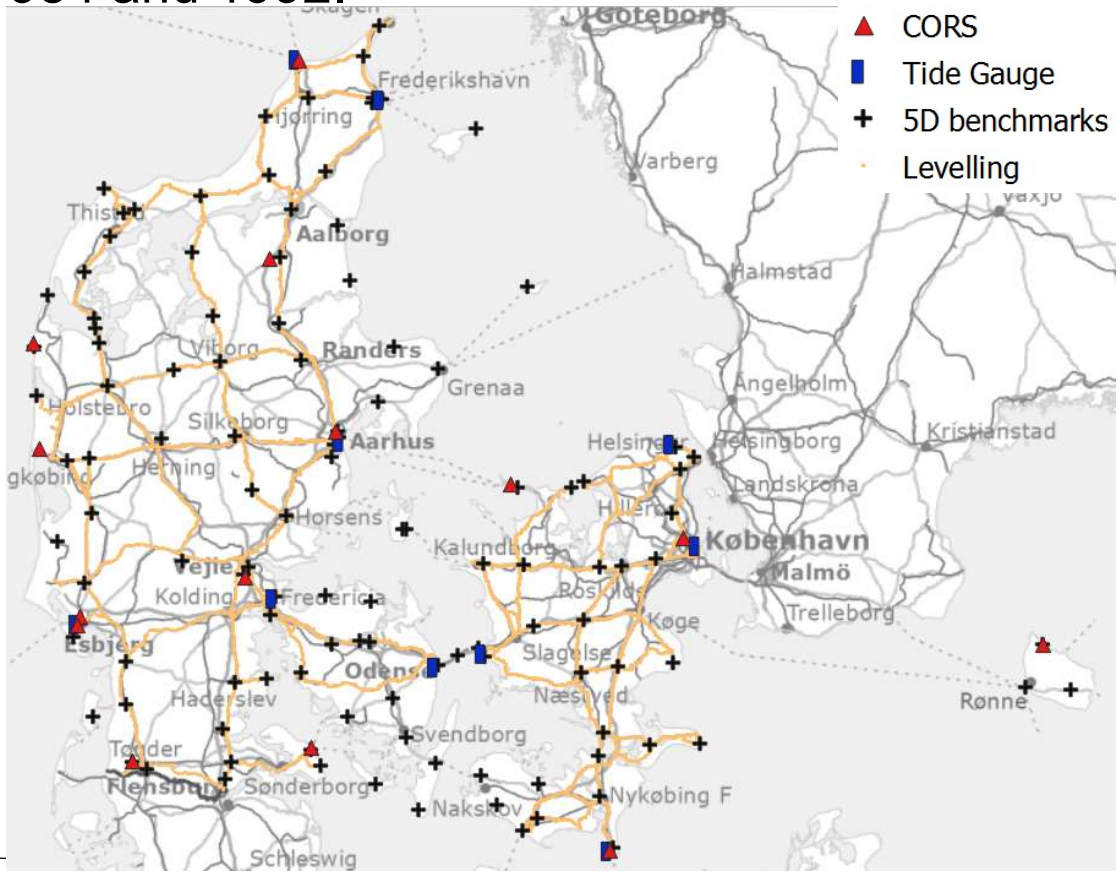
- Integration of InSAR into Height Infrastructure

- Summery

Current Height Infrastructure

DVR90, One height system for entire country:

- DVR90 is defined from 10 tide gauges.
- 3’rd precise levelling between 1984 and 1992.
- 3,000 benchmarks subsurface.
- 120 5D points.
- 14 CORS.
- 5 mm geoid in 2021.
- Height published through “Valdemar”

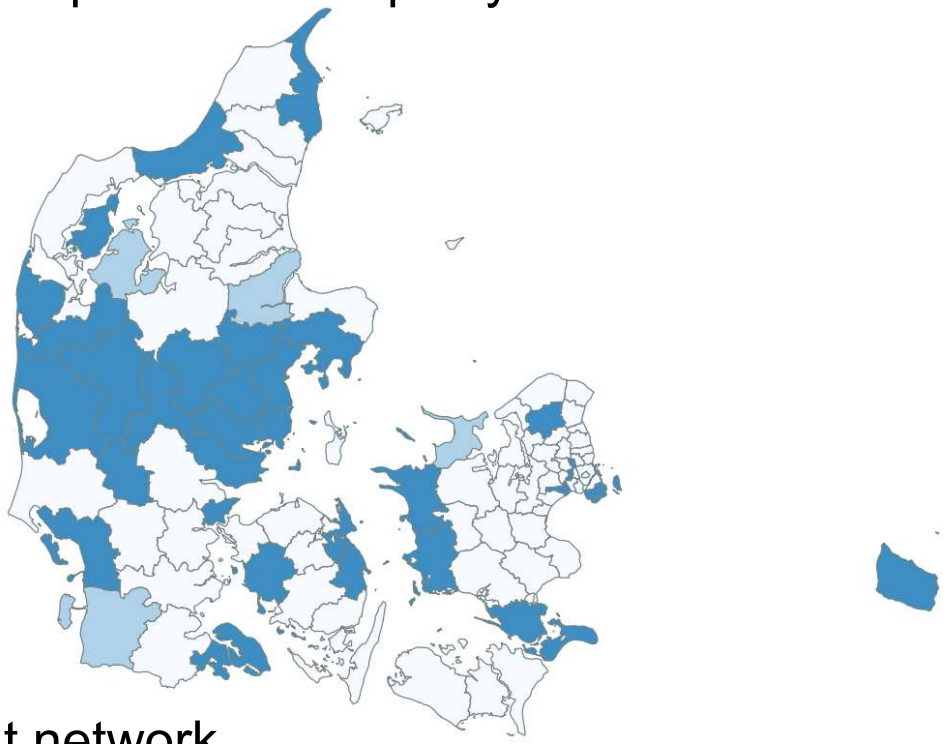


Status of Physical Height Network

Maintenance agreements with municipalities:

Decreasing interest for maintenance agreements, per 1’st Jan. 2020:

- 36 municipalities have agreements for complete municipality
- 4 municipalities have agreements for part of municipality
- 58 have no agreement



Trend:

2018; resignations from 4 municipalities

2019; resignations from 4 municipalities

accession; none

Reasons for resignation:

- Financial priorities
- None application of the physical height network

Status of Physical Height Network

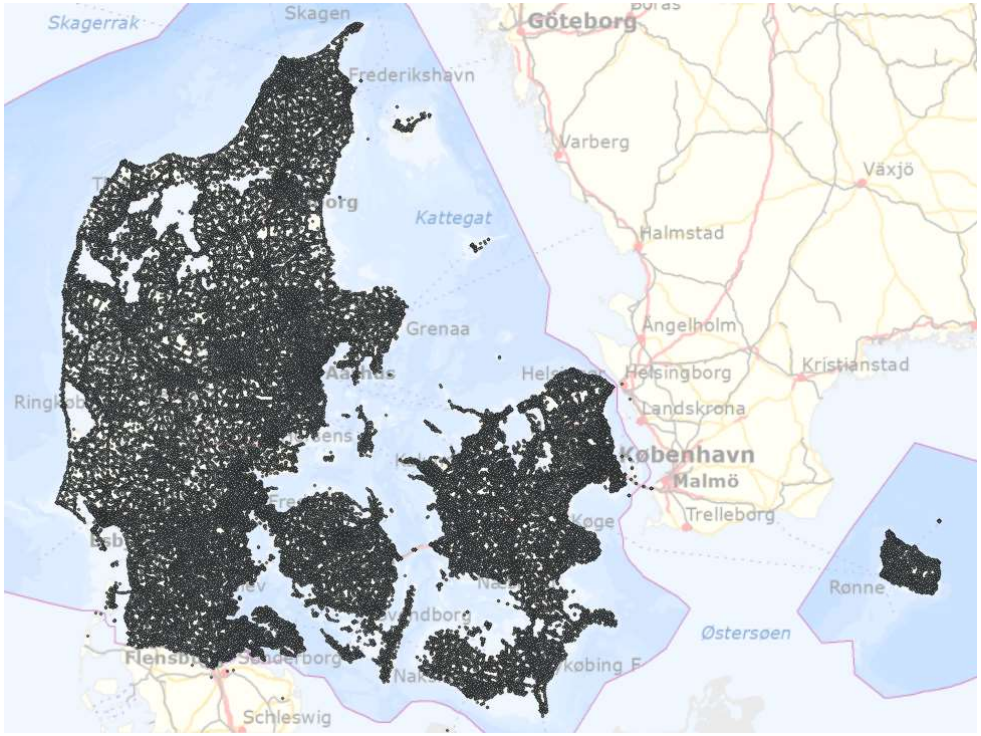
Variation of height accuracy:

Danmarks Fikspunktsregister:

Consist of app. 72,000 physical height benchmarks.

Heights determined in 1940 – without succeeding verification.

Not sufficient resources for maintenance of all the benchmarks to secure valid height information.



Status of Height Network

Evolution within technology:

Status:

- About 100 satellites in orbit round the earth with GPS, GLONASS, Galileo og BeiDou provides higher accessibility GNSS.
- 5 mm geoid for Denmark in 2021 improve the GNSS measurements.
- InSAR for deformation monitoring provide huge amount of potentials within the height infrastructure.

Galileo på Frederiksberg: Nøjagtighed på 3 cm

Høj præcision i arbejdet mellem bygninger og træer på Frederiksbergs veje var hidtil umuligt for Frederiksberg Forsyning. (Illustration: Geoteam)

GPS-pendanterne fra EU, Rusland og Kina bliver nu brugt til at gøre dansk vejarbejde 40 pct. hurtigere.

Ingeniøren, 2017

Feature Height Information

Action required - how and when?

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Change from passive to active network

Proposal: Measurement to physical benchmarks will be replaced with GNSS measurements.

Start in 2022

SDFE draft for Future Height Network

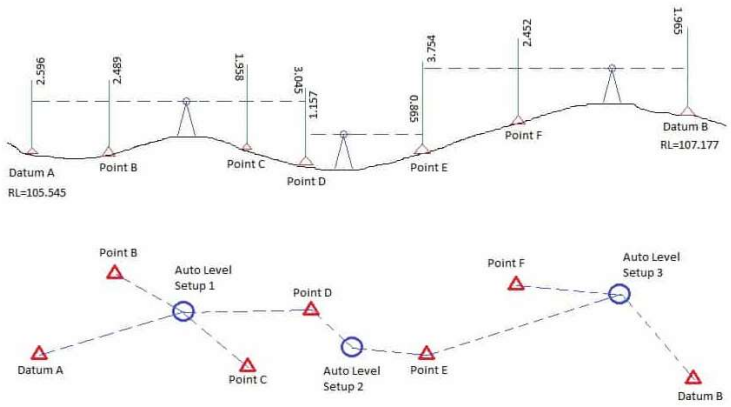
1) Transition to active height network with measurement via GNSS and geoid.

a) Height network becomes nationwide elevation information.

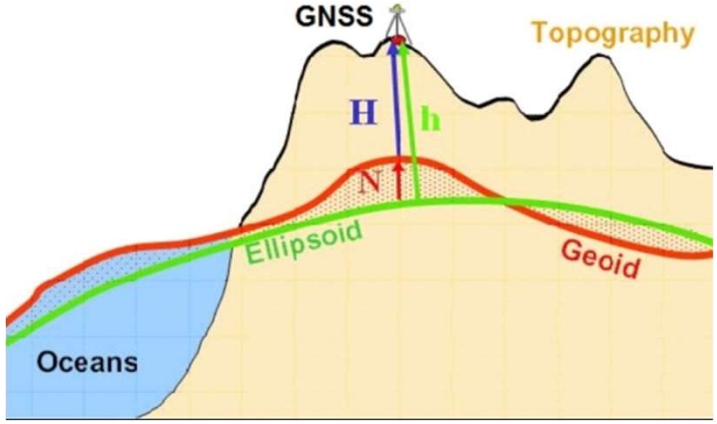
b) Reduce the number of physical benchmarks from 72,000 to approx. 120 maintained.

c) In 2020, GRF will carry out a study of the GNSS accuracy across entire Denmark for verification between orthometric heights and GNSS heights.

Passive Height Network



Active Height Network

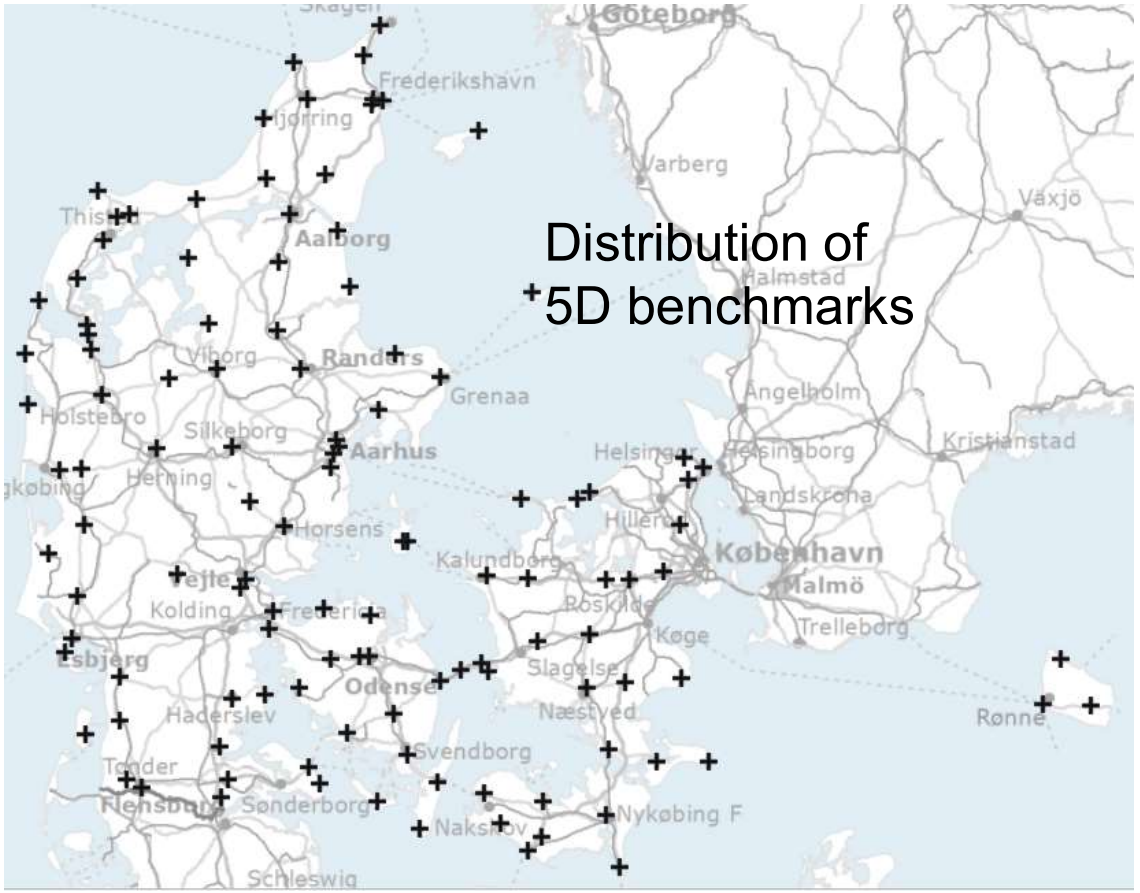


SDFE draft for Future Height Network

2) Accurate benchmark point for each 20. km.

a) Verification of GNSS equipment.

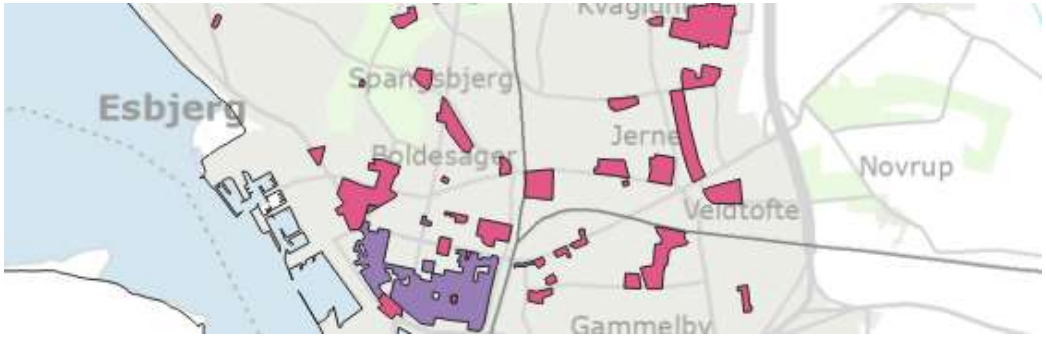
b) SDFE select app. 120 benchmarks – corresponds to 5D benchmarks.



SDFE draft for Future Height Network

3) Physical benchmarks in rural areas are not updated.

Instead, heights are measured with GNSS.



4) Physical benchmarks in urban areas – TBD.

Options are investigated in 2020:

a) RTK – SDFE establish a class B GNSS stations as master.

b) Fast static GNSS measurement where SDFE develops computational service.

c) Retain a reduced passive height network – 1 km between benchmarks and verification of height changes.

SDFE draft for Future Height Network

5) Possibility of including benchmarks acquired by municipalities – IF THERE IS A NATIONAL NEED BETWEEN THE MUNINICALITIES.

a) Benchmarks become more "Real Time". Created when needed and not after maintenance cycle.

b) SDFE's municipal maintenance of the high network are terminated.

c) Passive benchmarks can be established and updated in at request of the municipality, the utility company or the port company (project owner).

d) SDFE contributes with requirement specification for levelling and calculation.

e) New and existing municipal benchmarks gets special status in the DB, to inform that points are acquired externally.

f) Private companies can acquire and update benchmarks on behalf of municipalities, utility companies or port companies.

g) SDFE will prepare an automatically standardized reporting and updating portal for benchmarks.

SDFE draft for Future Height Network

6) No benchmarks are physical removed.

Quality of benchmarks are divided into more strict quality classes, so verified benchmarks are clearly marked.

Styrelsen for Dataforsyning og Effektivisering

Rentemestervej 8, 2400 København
Email:grf@sdfe.dk

Fikspunktsbeskrivelse

For	35-04-09011
Udskrevet	18-11-2019 13:19:54

Koordinater

System	UTM32 ETRS89
Easting	594123 m
Northing	6137102 m
Publiceret	

Koter

System	DVR90
Klasse	3
Kote	16.915 m
Målt år	1944
Publiceret	05-03-2002 11:45:00

Afmærkning

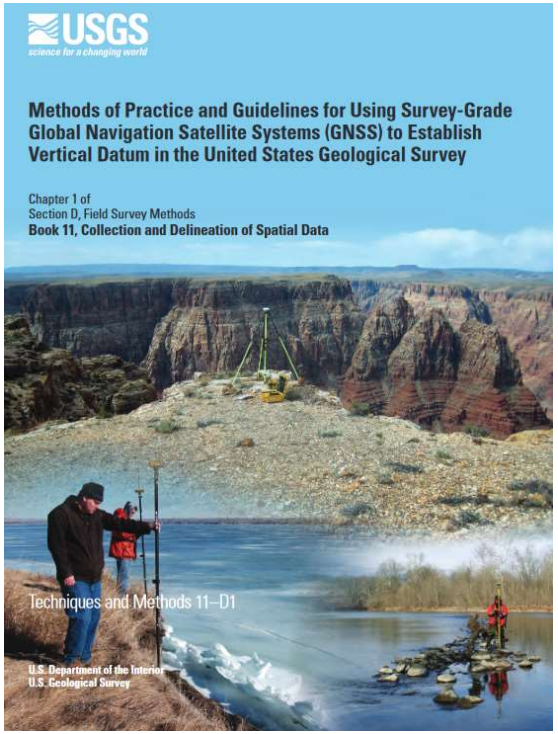
Bolt. 0.20 m over terræn.

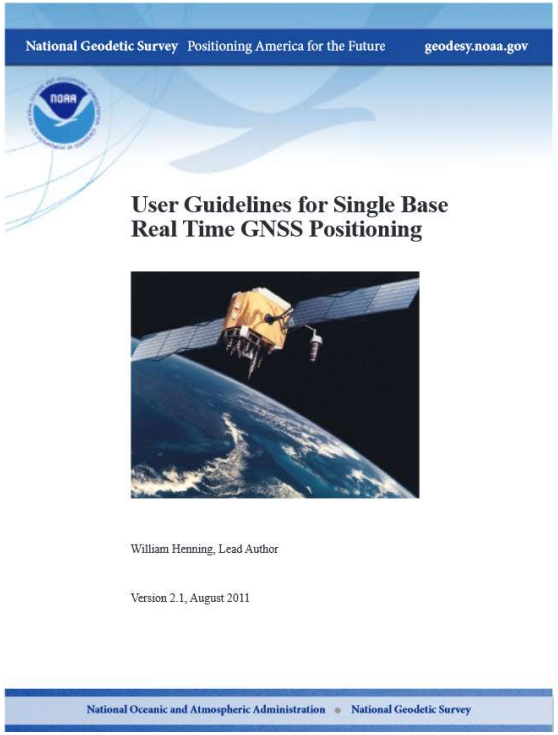
Vejen Fraugde - Åsum, Ø. side.
Ca. 1900 m N. for Fraugde Kirke.
Krogslundvej nr. 167.
Hus, Egely.
Matr.nr. 14 d.
Punkt i S. gavl.
1.42 m fra SV. hjørne.
I overkant af sokkel.
0.20 m over terræn
Beskrivelse udfærdiget 1984

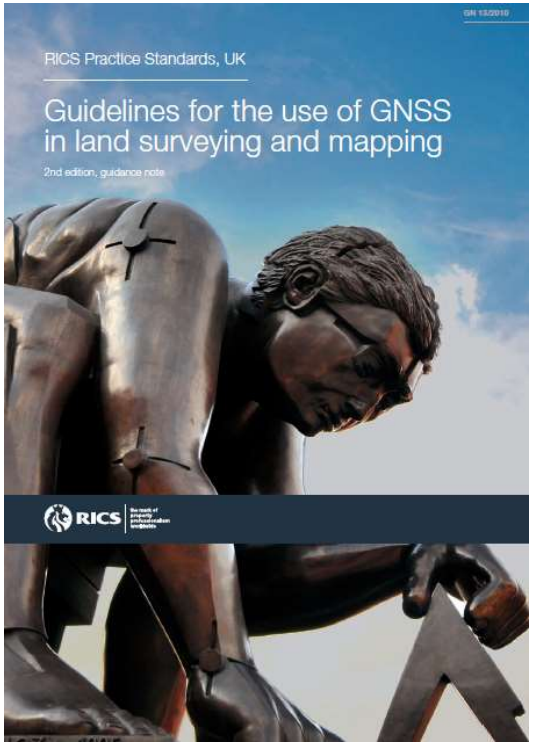
SDFE draft for Future Height Network

7) Elaboration of ”Best Practice” for measurements of height fix points.

SDFE elaborate description for measurements of height fix point with GNSS how to evaluate accuracy.







SDFE draft for Future Height Network

8) Integrate InSAR into geodesy and height infrastructure

a) InSAR is capable for deformation maps

b) See a lot of potentials within geodesy and height infrastructure

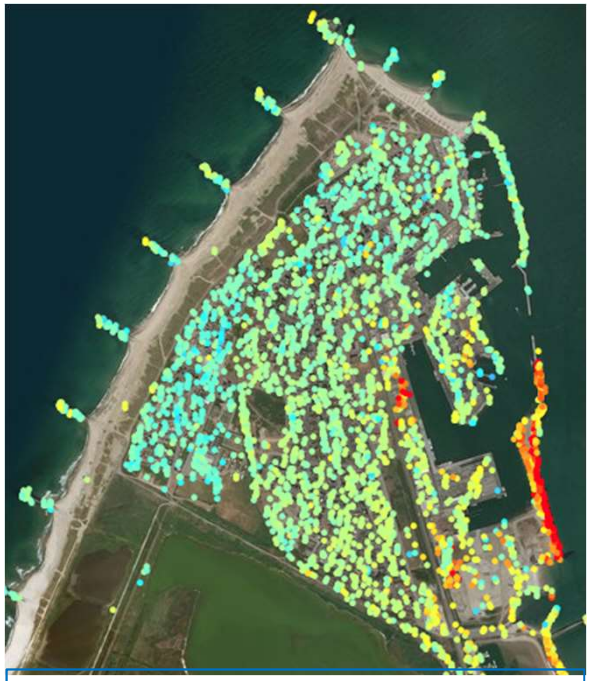
Integration of InSAR

Prior project: Thyborøn (levelling vs InSAR)

- Several years aware of subsidence of up to 7 mm/year.
- Compare InSAR with levelling of benchmarks.

Precise levelling: ~70 points.
Cyklus: 3 years (2006 →)

Subsidence
(single track: 139D)



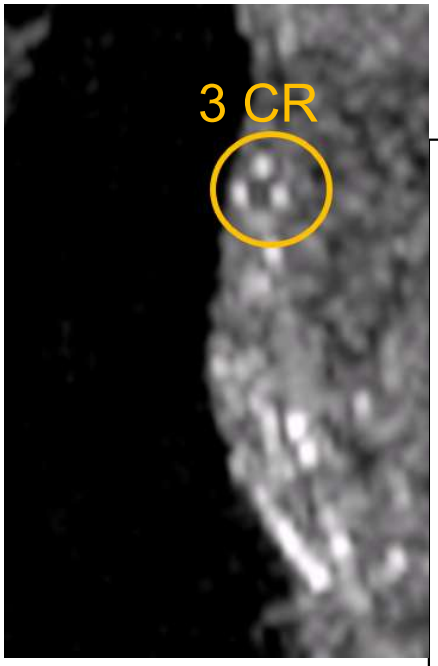
Subsidence
(track: 37D, 139D, 15A, 117A)

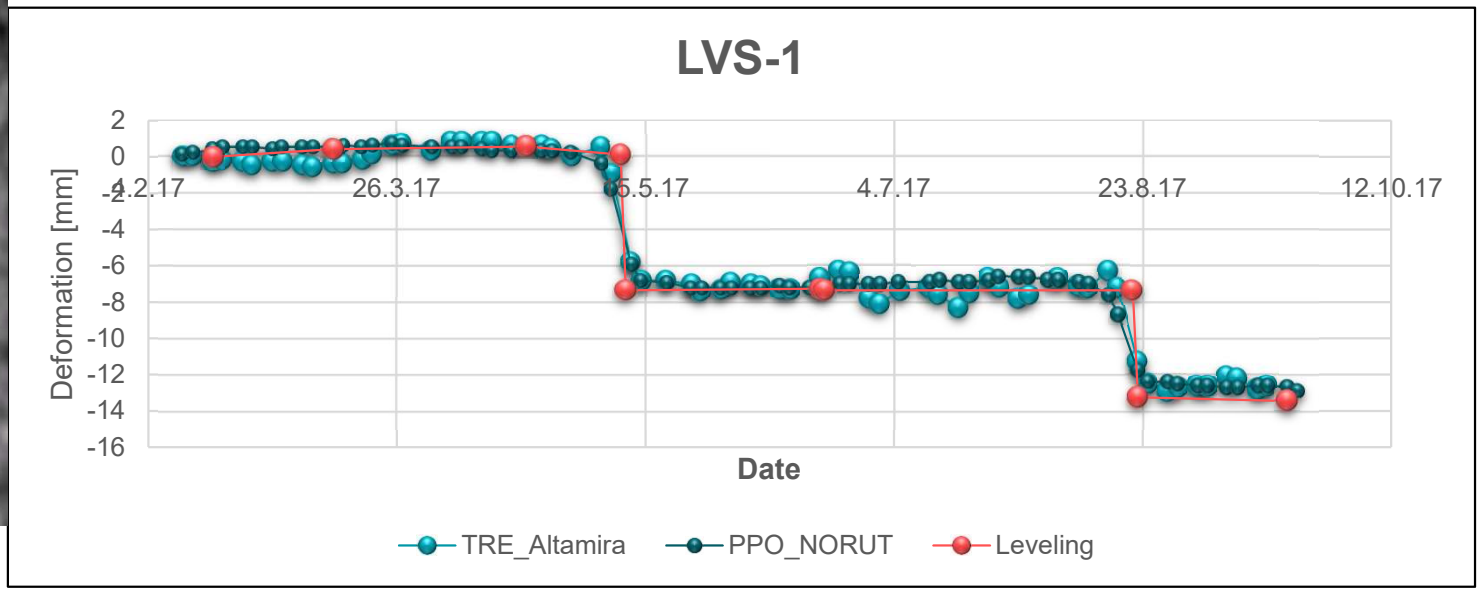
- Conclusion: Complete conformity between levelling and InSAR calculation.

Integration of InSAR

Prior project: Thyborøn (levelling vs InSAR) – continued

- Test of Corner Reflector by adding deformation to CRs





- Two companies have verified the deformation for the CRs
- InSAR calculations follows the levelling closely.
- **Unambiguous Conclusion: Consistency between InSAR and levelling**

Integration of InSAR

Scaling InSAR into national level

- SDFE ordered in 2018 a national calculation of “Deformation Maps” covering the period from October 2014 to June 2018.
- Next national calculation performed in 2019 with period from April 2015 to June 2019.

Potentials of InSAR within geodesy and future height infrastructure

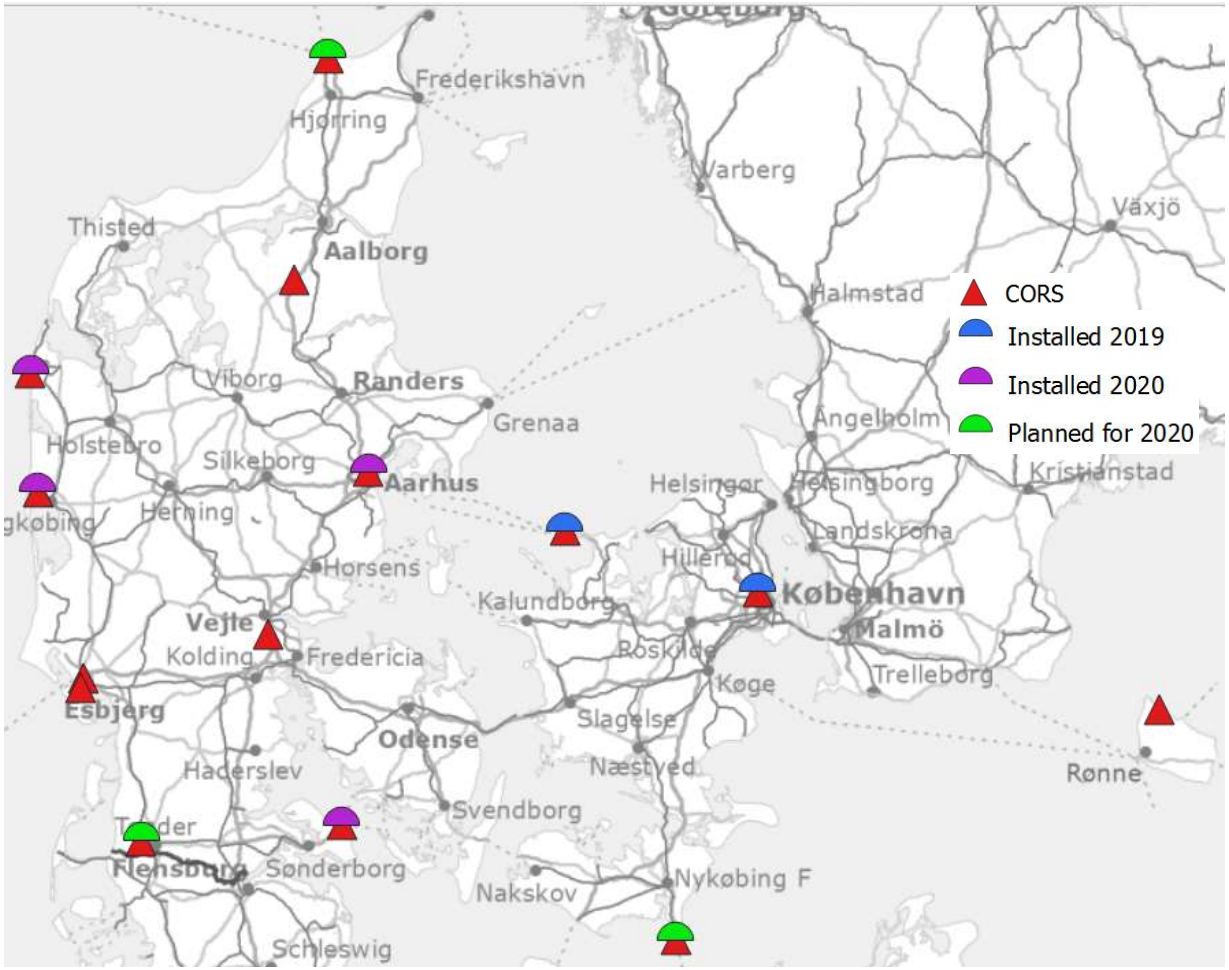
Expect lot of potential within geodesy and height infrastructure if deformations are change from relative to absolute values:

- Verification of stability of CORS stations
- Verification of tide gauges in a more cost efficient way
- Identification of minor subsidence areas
- Identification of deformation within infrastructure
- Etc.

Integration of InSAR

Changing from relative to absolute reference system

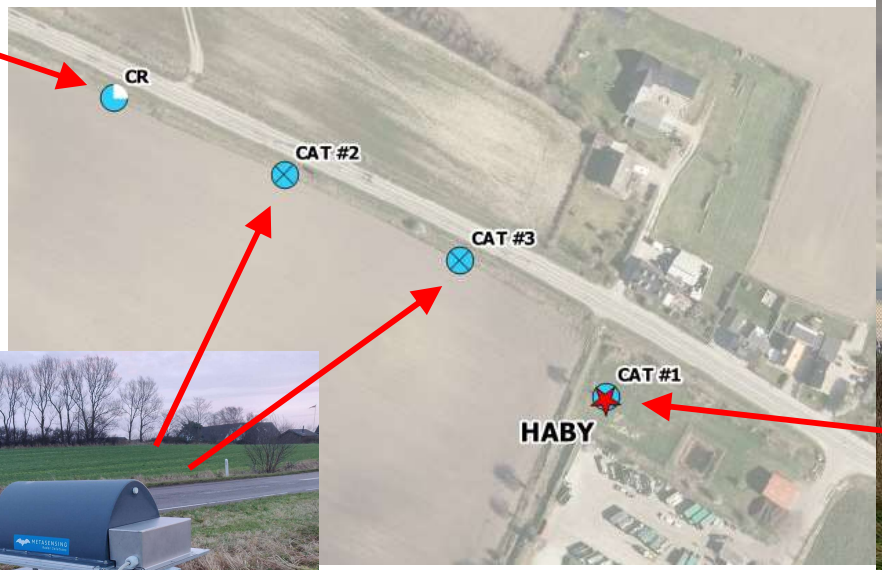
- December 2018 ordered 17 CATs.
- Installation of CATs at CORS stations;
  - 2 CATs installed in 2019
  - 4 CATs installed in 2020 and further
  - 3 CATs to be installed in 2020



Integration of InSAR

Relative to absolute deformation, test 1

HABY test; Test on CATs stability and performance



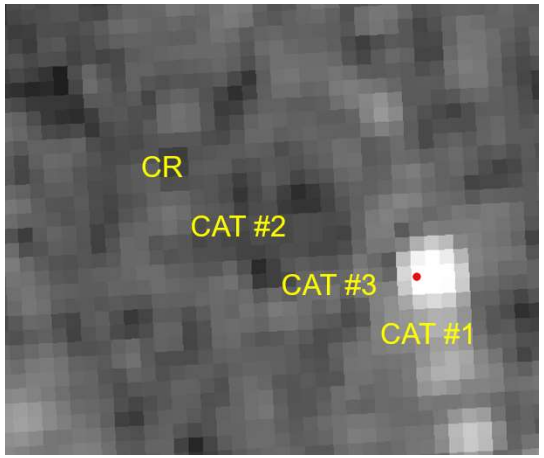
Integration of InSAR

Relative to absolute deformation, test 1 - continued

HABY Outline:

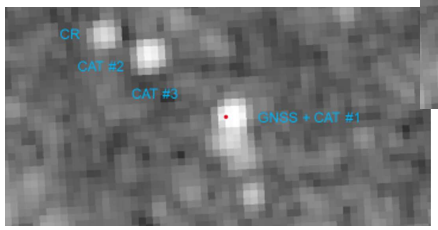
- CATs under realistic conditions.
- Stability of return signal.
- Stability of phase over time.
- Seasonal motion of transponders.
- Test period of at least one year.

Pre-installation:

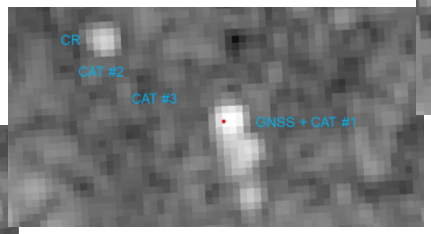


Intermediate response:

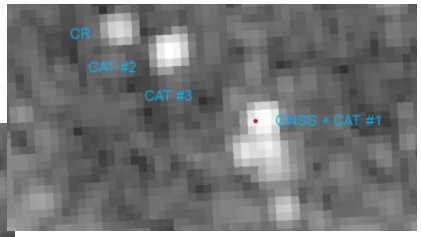
6'th Dec. 2019



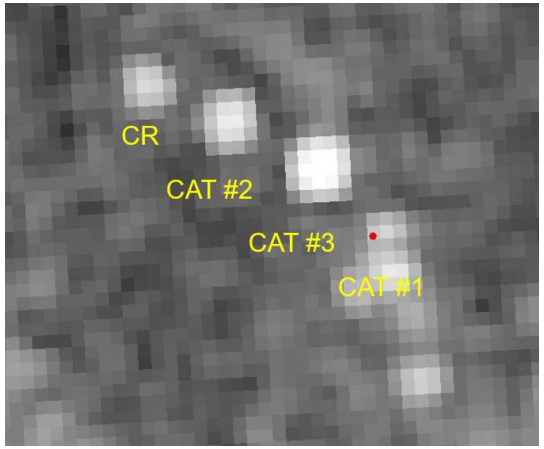
12'th Dec. 2019



30'th Dec. 2019



Post-installation:



Integration of InSAR

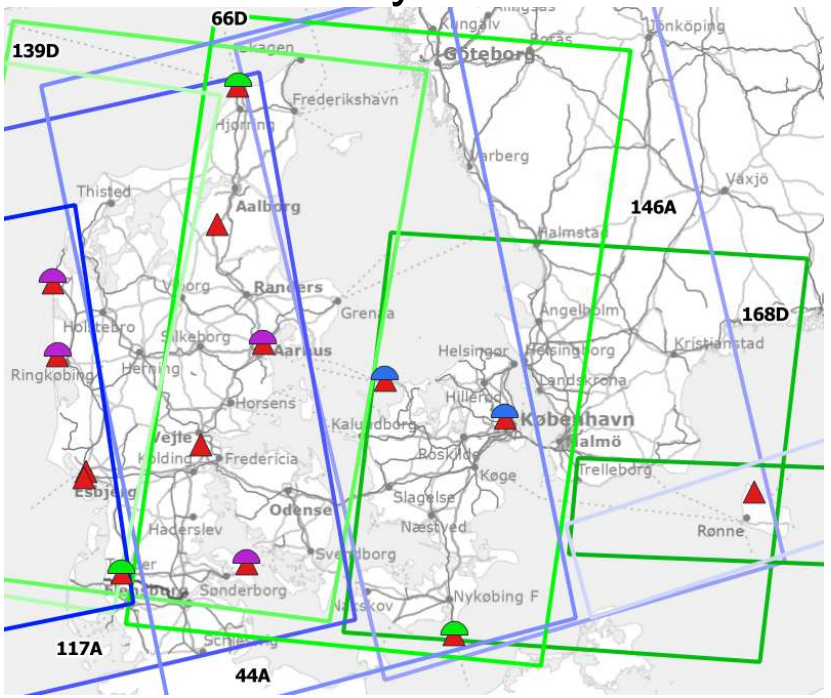
Relative to absolute deformation, test 2

Distance between reflectors / transponders:

- Accuracy of deformation model decrease with distance from reference point.
- How much does the accuracy decrease?
- How many CORS are needed?
- How many reflectors / transponders are needed countrywide?

Relative to absolute deformation, test 3

Tide gauges. Can we replace yearly levelling with InSAR?

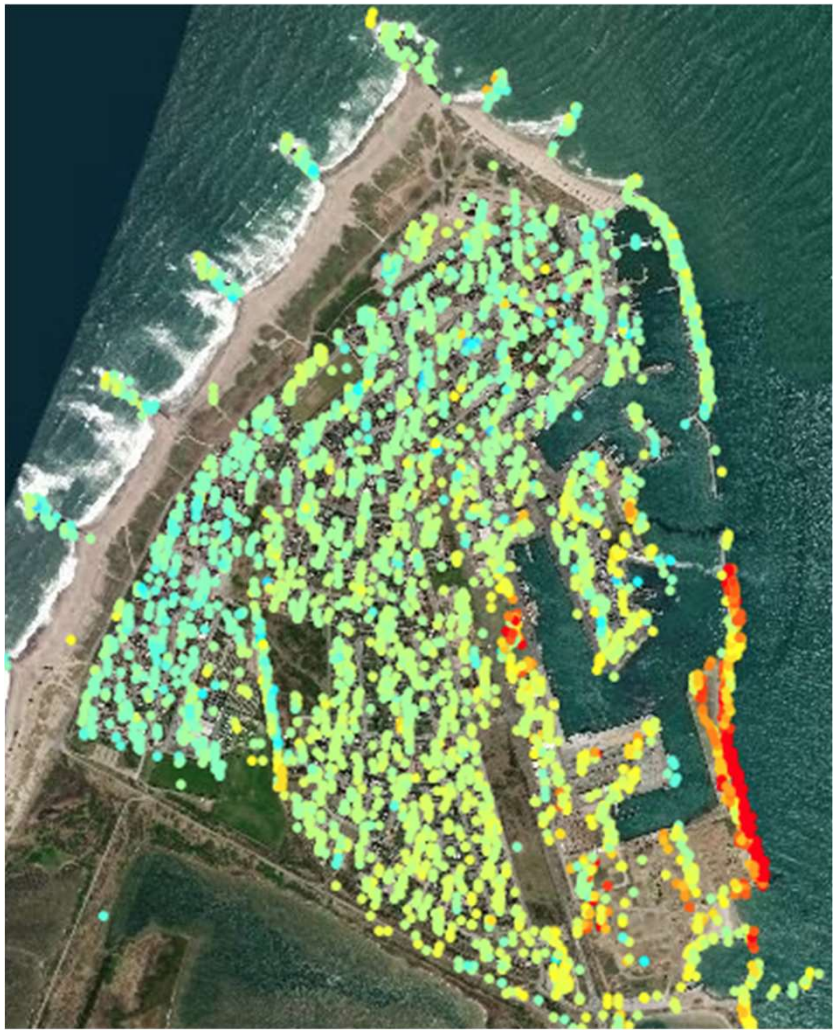


Case-study:

Levmig Vand og Spildevand

- Have 1,200 km sub-surface utility pipes.

- Operation and investment savings:
  - Without information: Replacement utility pipes (Cost: 3,2 mill DKK)
  - With information: Problem solved on-site (Cost: <20K DKK)

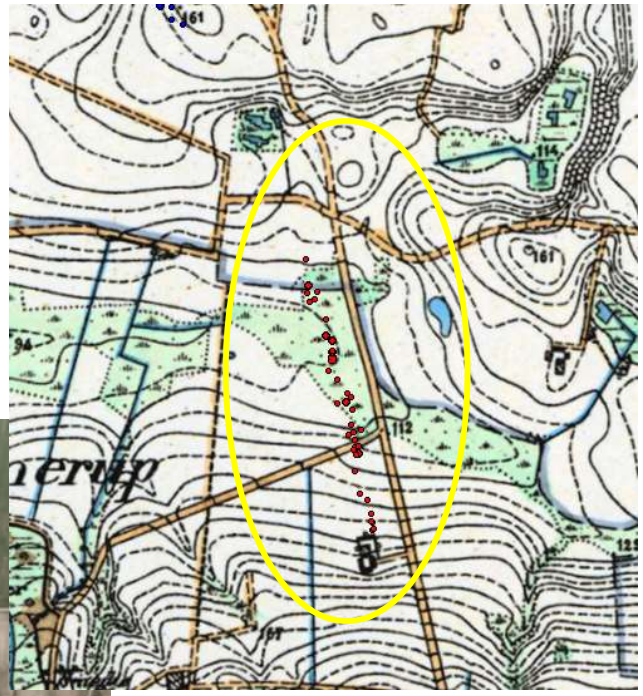


Case-study:

National Road Authority

Input for improved basis of decision:

- Support for new infrastructure
- Improved planning of field campaigns
- Detection of risk for landslide.



Case-study:

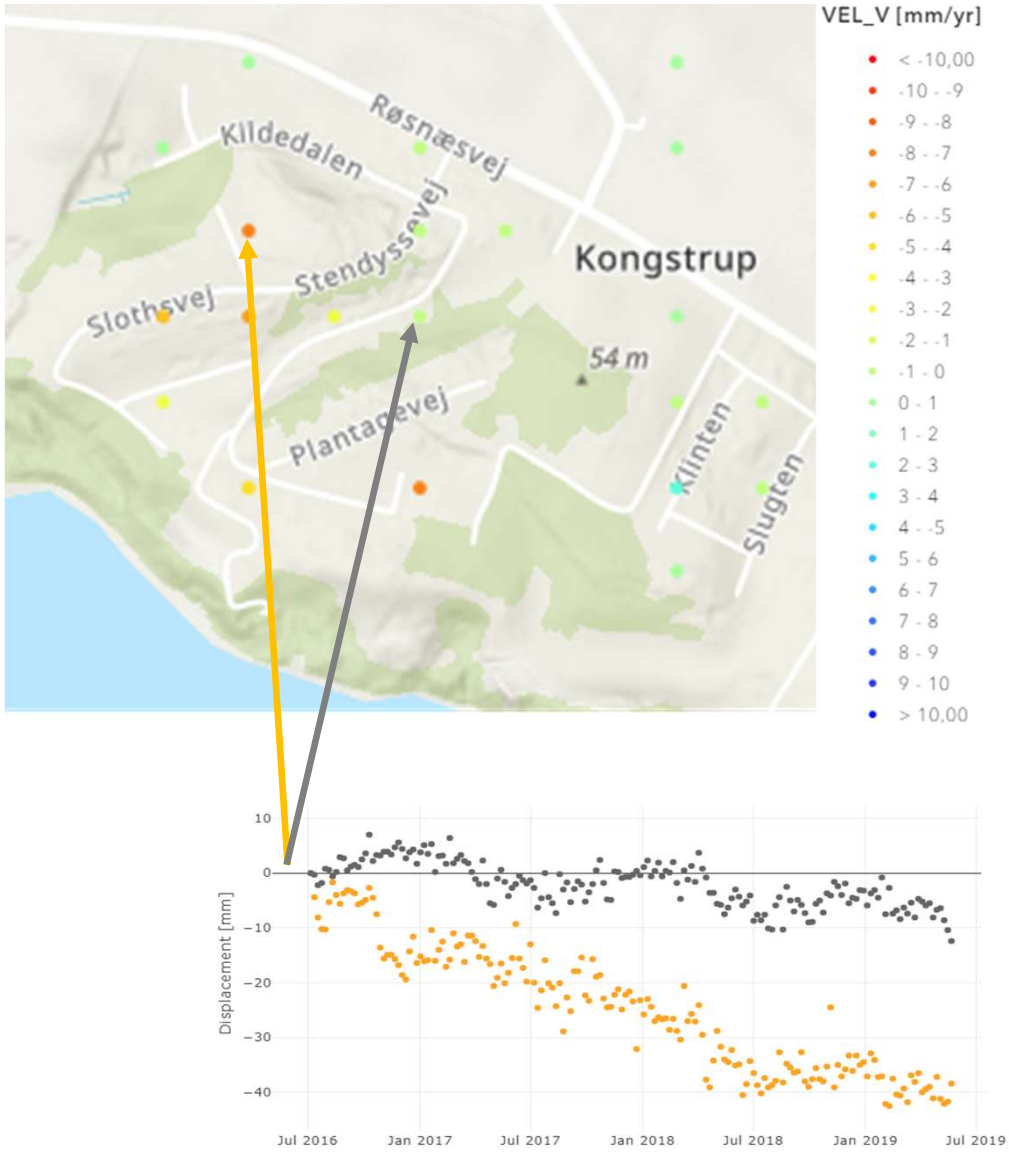
Geology

Area with subsidence and east-west movement.

Surrounding area is stable.

Clay in subsurface (Røsnæs clay / Lillebælt clay)

Seasonal variation.



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Geodesy – From Science to Society

Summery:

a) Transition within applied GNSS. Measuring of benchmarks is not a science, but everyone can perform it. Every day utility and not just with military, geodesy and land surveying.

b) InSAR is also a geodetic science, but main focus is within other fields.

c) Investigation of InSAR with geodesy has started, but still long way to go. SDFE has knowledge exchange with other National Mapping Authorities.