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Subsidence Monitoring in Hampton Roads Using InSAR

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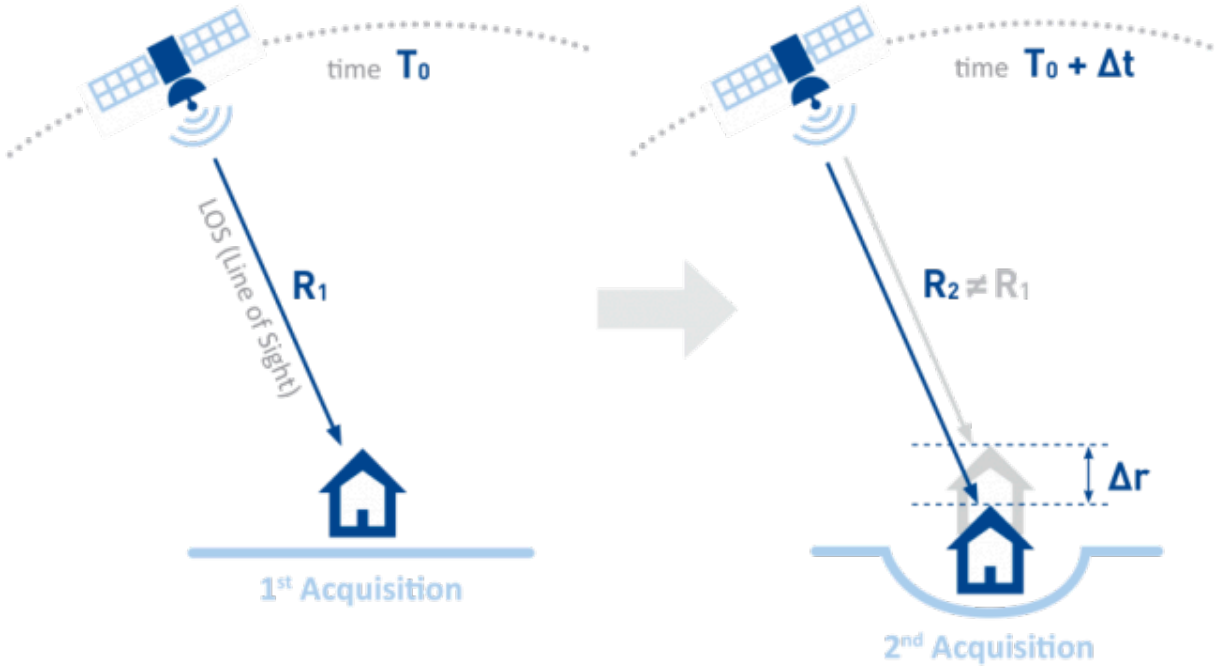
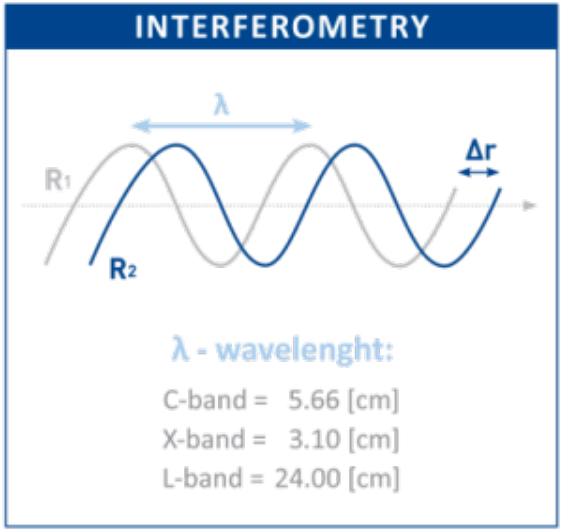
Commonwealth Center for Recurrent Flooding Resiliency (CCRFR)
NASA Jet Propulsion Laboratory
NASA Langley Research Center

What is SAR/InSAR?





What do we need to measure the rate of subsidence?

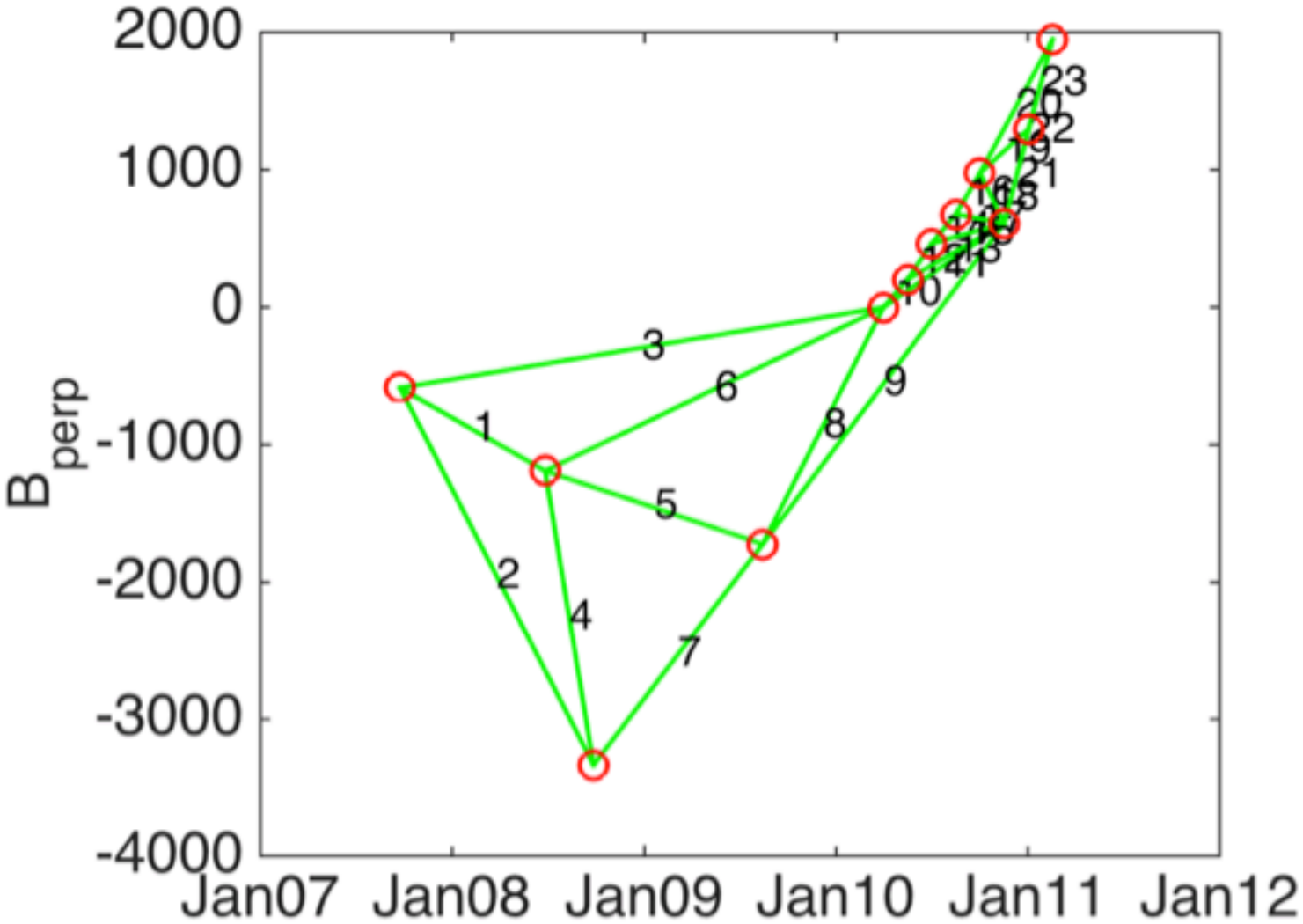
- To get accurate satellite-derived measurements of long-term subsidence in the region, we need:
  - A long record
  - Good sampling within that record (many acquisitions)
  - In situ measurements (GPS) for calibration and ground-truthing/validation, converting from relative to absolute land motion.
  - Ability to correct for sources of error (atmosphere typically biggest source of error).

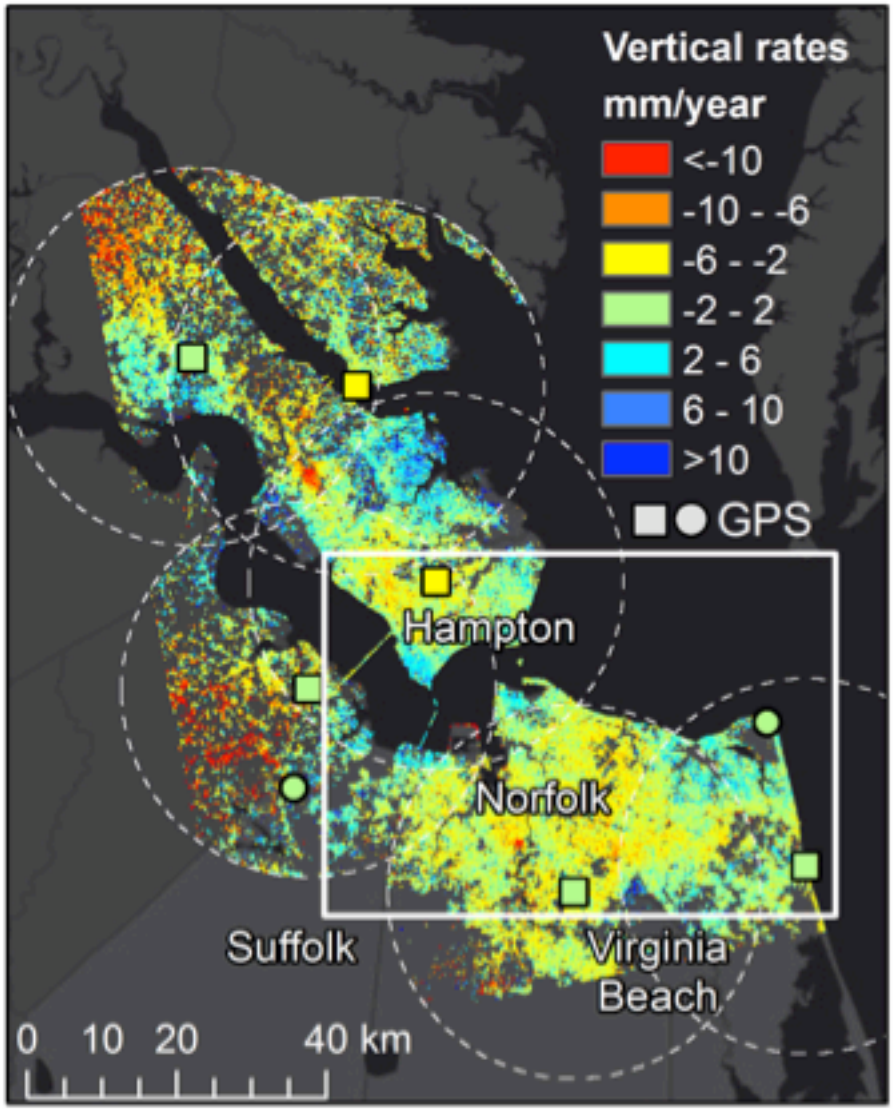
Preliminary InSAR Analysis

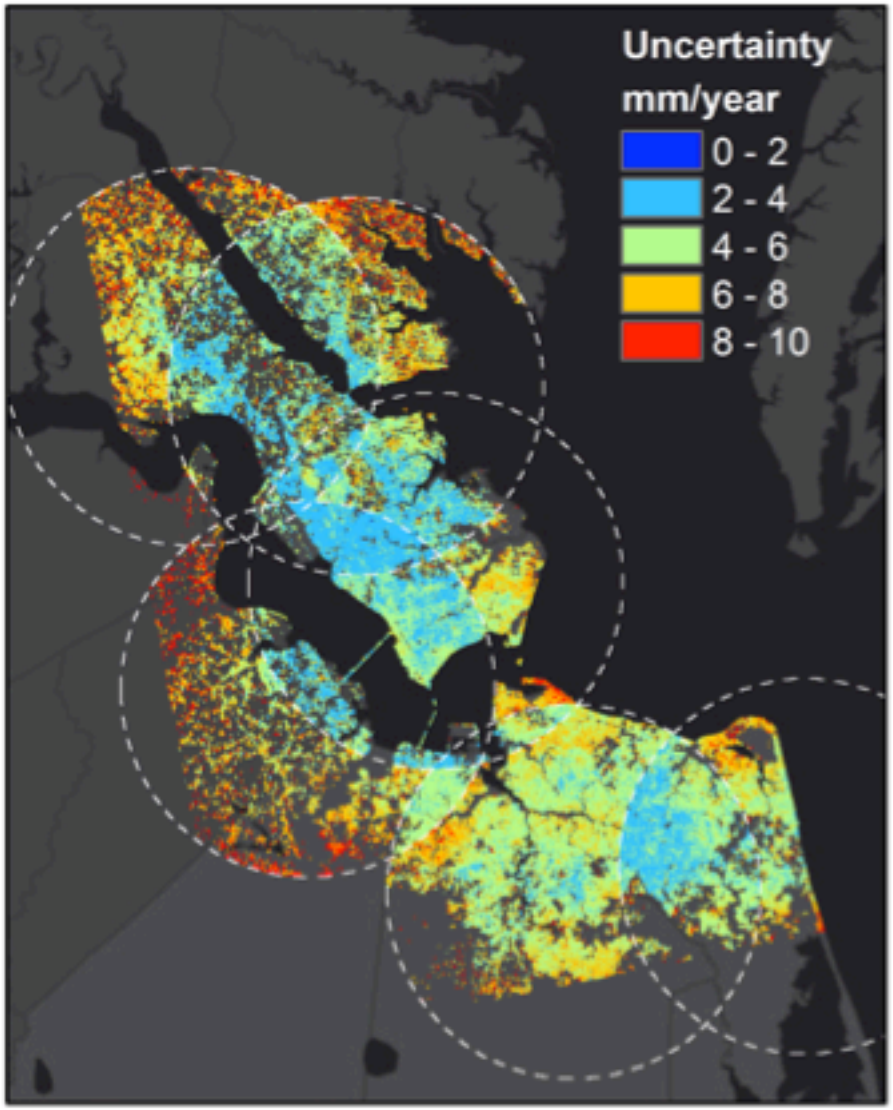
- As a starting point, we have performed a preliminary InSAR analysis for the region.
  - **Goals**:
    - Analyze available (free) historical SAR data with state-of-the-art InSAR techniques to compute an initial subsidence rate map.
    - Understand the uncertainties associated with performing the analysis of our region.
    - Establish a system that provide ongoing subsidence monitoring in the region.
- Using ISCE and StaMPS, we have analyzed two scenes over Hampton Roads using ALOS-1 data from 2007-2011.
  - InSAR provides relative rates – we have gone one step further to compute absolute rates by tying into the available GPS data in the region.


USA
0 10 20 40 km
LOYX
VAGP
Epes
LOY1
Hampton
Sewell's Point
Craney Island
DRV5/6
CHR1
LOYZ
Norfolk
LS03
Vsat
Suffolk
Virginia Beach
LOY2
LOS
Naval Shipyard

Name	East Vel. (mm/yr)	North Vel. (mm/yr)	Vert. Vel. (mm/yr)	Uncert. Vert. Vel (mm/yr)	Time Period	Used as Ref.
LOYX	-0.4	0.01	-1.89	0.93	20090509 - 20170408	Yes
VAGP	-0.4	0.01	-2.24	1.21	20071001 - 20160419	Yes
LOY1	-0.22	0.06	-2.42	1.45	20090206 - 20120321	Yes
DRV5 DRV6	-0.32	0.07	-1.86	0.48	20060310 - 20160818	Yes
LOYZ	-0.14	0.36	-1.80	0.82	20090220 - 20170408	No
LOY2	-0.28	-0.01	-1.77	0.86	20090206 - 20170408	Yes
LSO3	-0.14	-0.13	-0.98	0.90	20090255 - 20170408	Yes
CHR1	-0.14	-0.62	1.40	1.53	19960114 - 19990618	No


2000
1000
0
-1000
-2000
-3000
-4000
B perp
Jan07
Jan08
Jan09
Jan10
Jan11
Jan12
1
2
3
4
5
6
7
8
9
10
23
20
22
19
21


Vertical rates
mm/year
<-10
-10 - -6
-6 - -2
-2 - 2
2 - 6
6 - 10
>10
GPS
Hampton
Norfolk
Suffolk
Virginia Beach
0 10 20 40 km


Uncertainty
mm/year
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10

Name	East Vel. (mm/yr)	North Vel. (mm/yr)	Vert. Vel. (mm/yr)	Uncert. Vert. Vel (mm/yr)	Time Period	Used as Ref.
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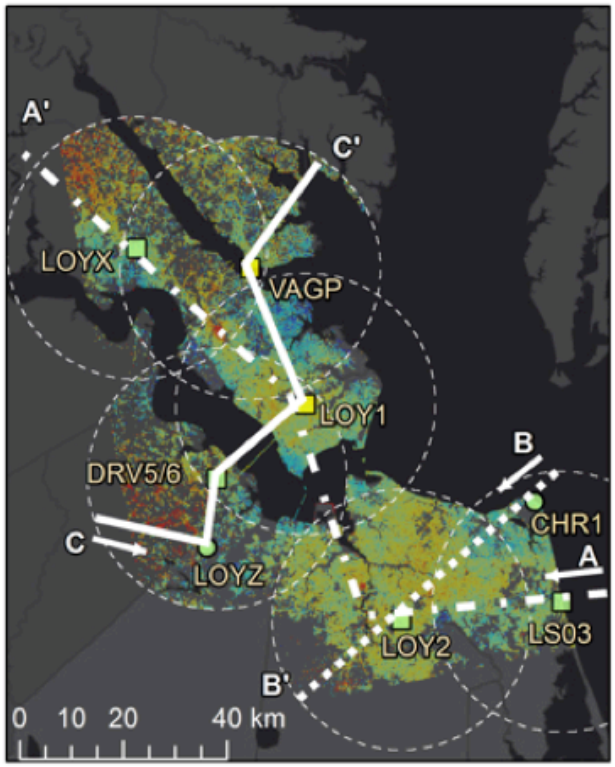
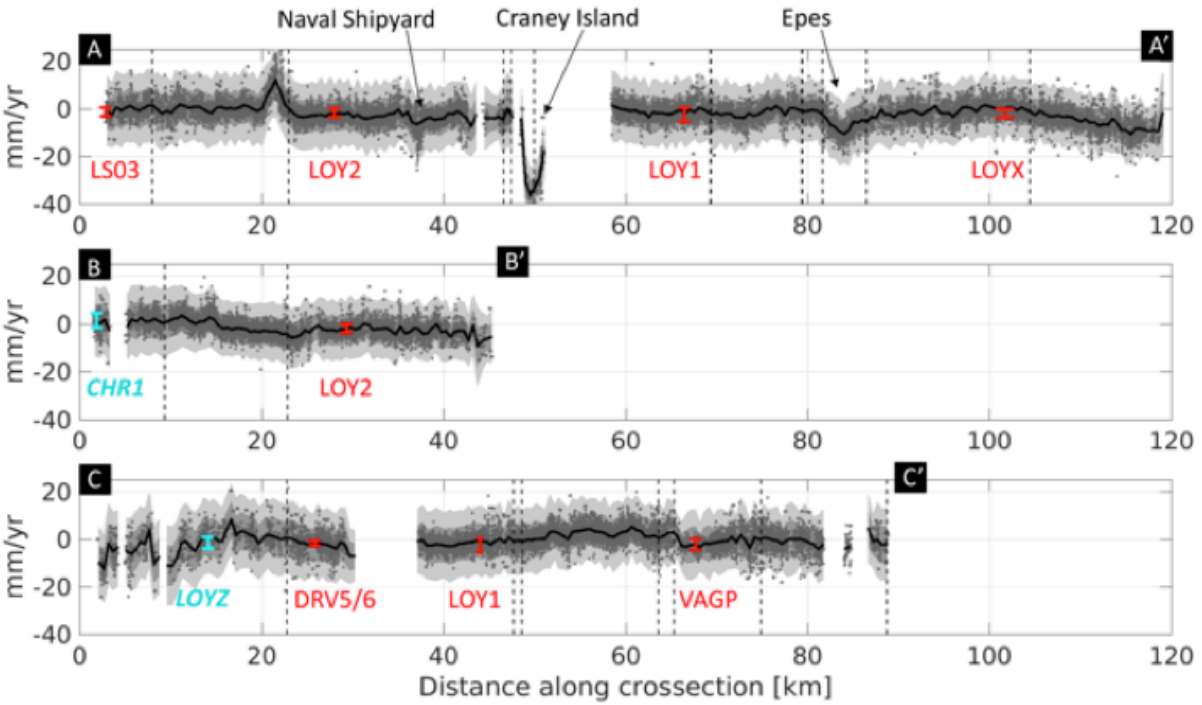
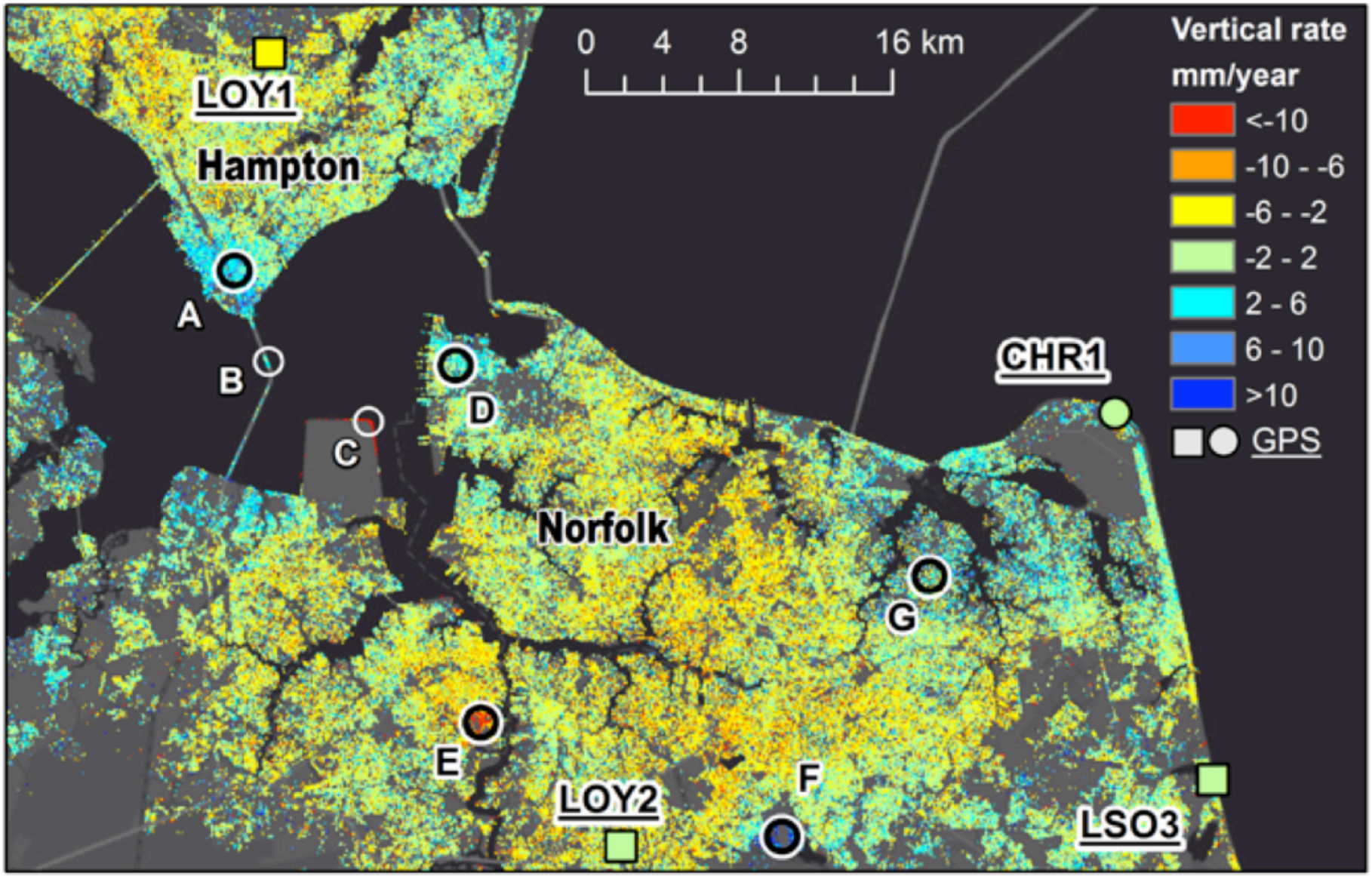
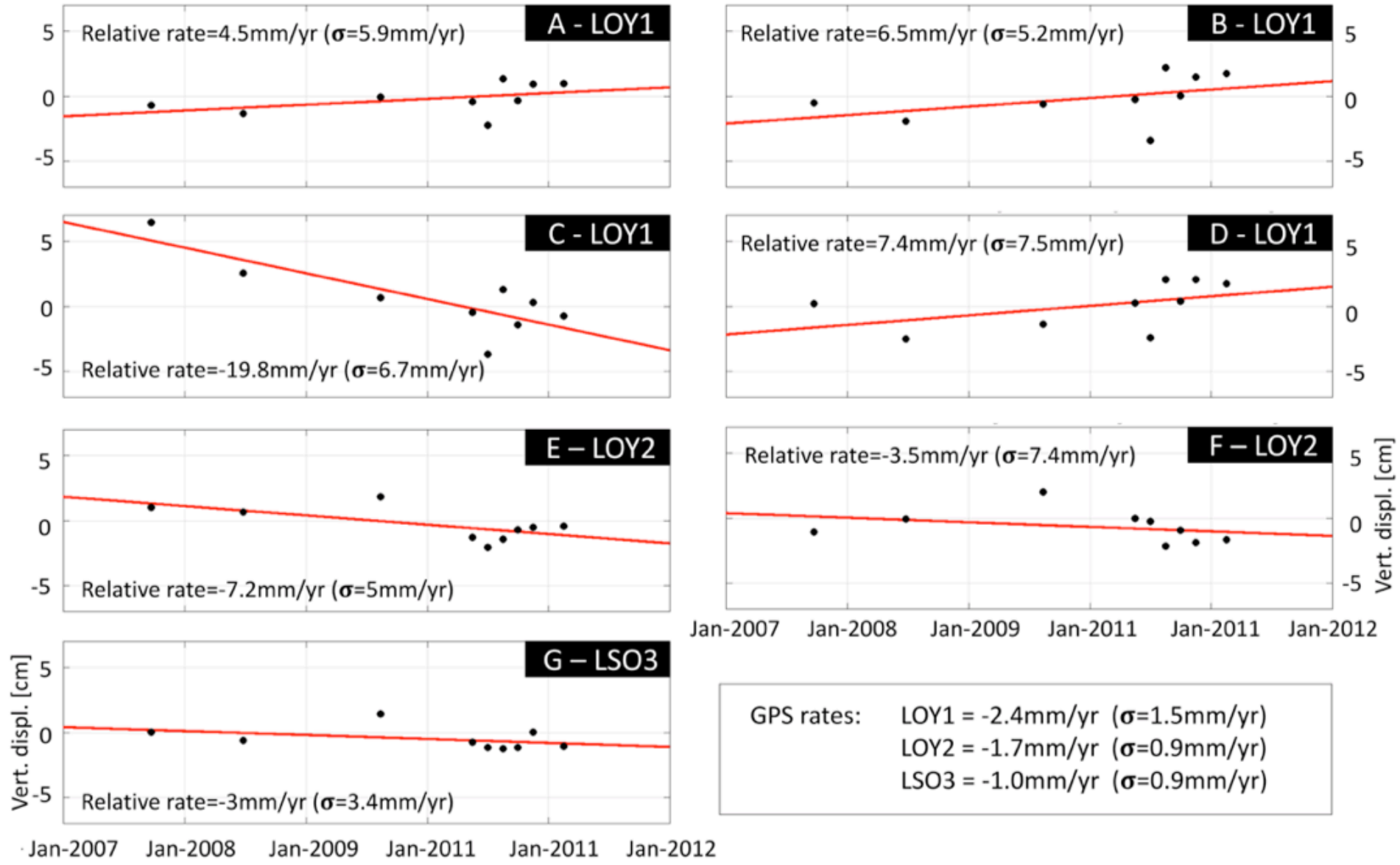

A'
C'
LOYX
VAGP
LOY1
DRV5/6
B
CHR1
C
LOYZ
A
LS03
LOY2
B'
0 10 20 40 km


Naval Shipyard
Craney Island
Epes
A
A'
mm/yr
LS03
LOY2
LOY1
LOYX
B
B'
CHR1
LOY2
C
C'
LOYZ
DRV5/6
LOY1
VAGP
Distance along crossection [km]


0 4 8 16 km
Vertical rate
mm/year
<-10
-10 - -6
-6 - -2
-2 - 2
2 - 6
6 - 10
>10
GPS
LOY1
Hampton
A
B
C
D
CHR1
Norfolk
G
E
F
LOY2
LSO3

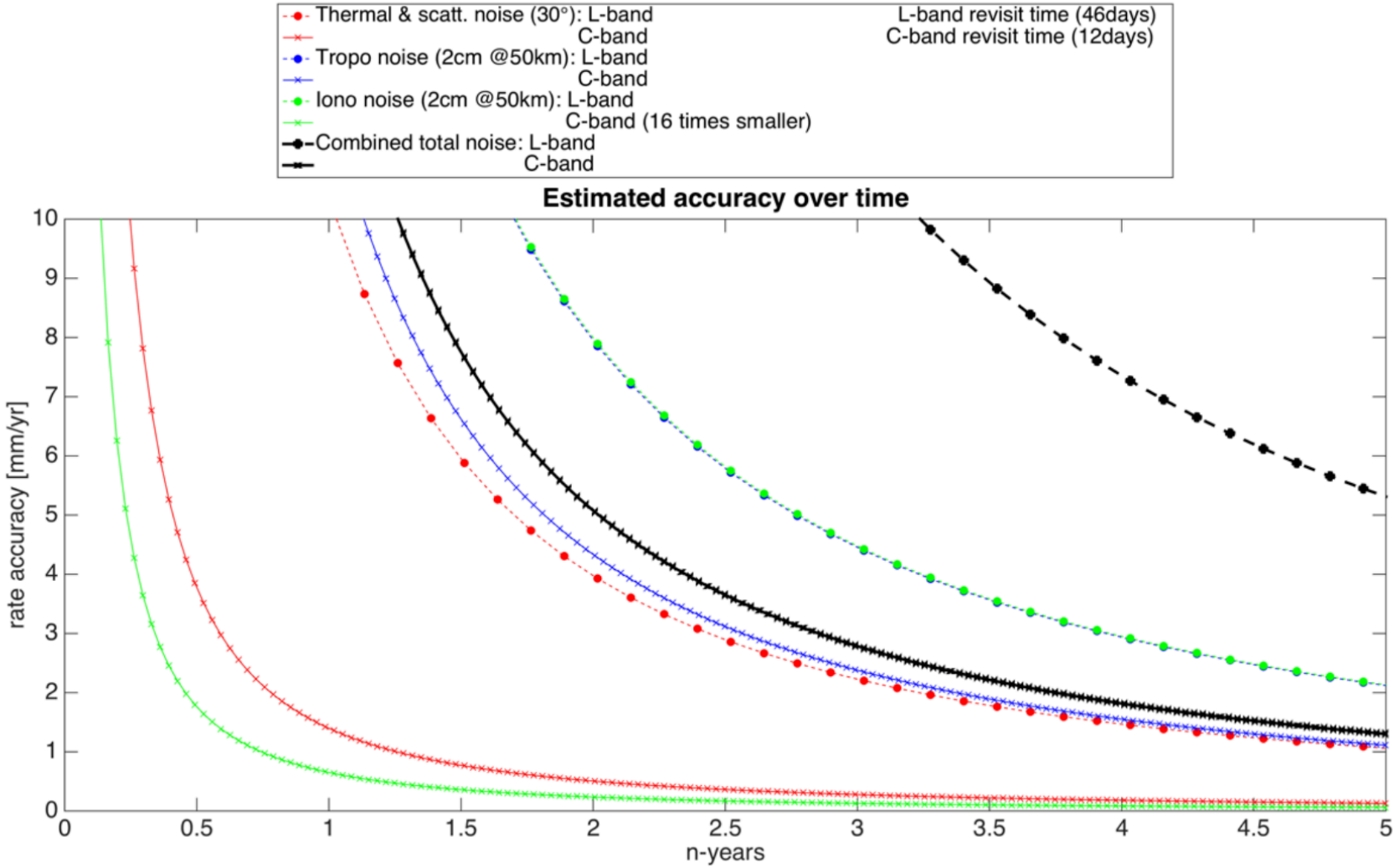


GPS rates: LOY1 = -2.4mm/yr (σ=1.5mm/yr)
LOY2 = -1.7mm/yr (σ=0.9mm/yr)
LSO3 = -1.0mm/yr (σ=0.9mm/yr)

Ongoing Monitoring

- One of the primary goals of this project is to create the capacity within Hampton Roads to conduct ongoing subsidence monitoring as needed or requested.
- Many different SAR satellites have been launched or are being launched to dramatically improve the coverage.
  - Sentinel-1 (C-band) is a European Space Agency (ESA) mission that was launched in 2014.
  - The NASA-ISRO (NISAR) satellite will launch in 2019.
  - Providing near global coverage of world's coastlines, including Hampton Roads.
- We have begun processing the Sentinel-1 data with the aim of constructing a system that can be updated on a regular basis and provide user-friendly output.

Improvement with Sentinel-1 (C-band)



NASA Sea Level Change Team (N-SLCT)

New N-SLCT was selected recently (objectives below).

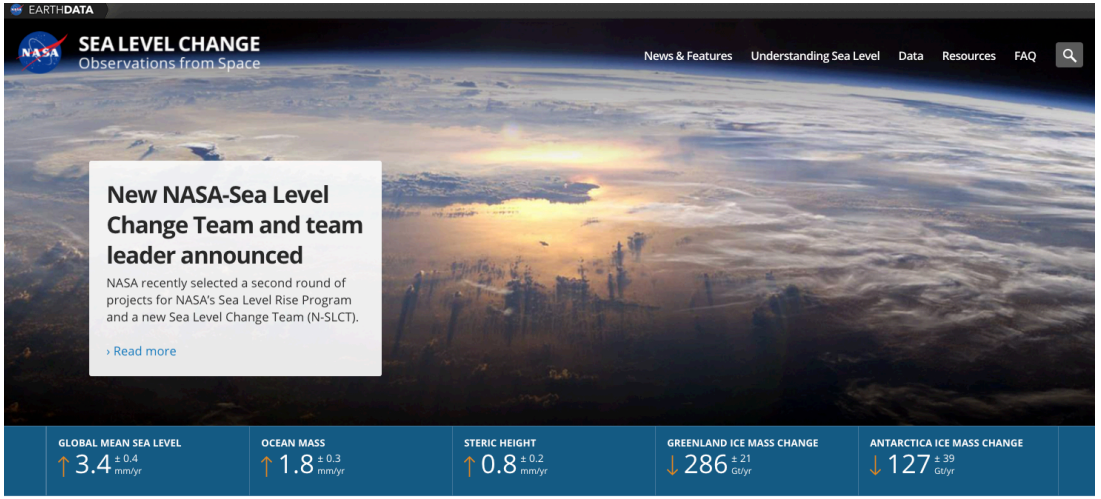
1. Characterizing current changes in sea level: Global and regional sea level projections that extrapolate from satellite and contemporary observations
2. Characterizing underlying processes and improving predictions of regional variations in sea level
3. Improving knowledge of ice mass change that specifically improves estimates of current and future sea level rise
4. Integrating these results into better forecasts of sea level rise.

NASA Sea Level Change Team (N-SLCT)

Focus will be on using satellite data to improve regional relative sea level projections.

Part of this includes identifying ways to perform InSAR analysis on very large spatial scales very quickly and how tie this in with ocean variability.

Hampton Roads is going to serve as one of the test cases.



Web portal with output from team at: sealevel.nasa.gov

Summary

- Initial analysis of the ALOS data indicates spatial variability in vertical land motion → needs further investigation due to uncertainties.
  - InSAR is constraining the short spatial scales (<20 km) well, show large localized subsidence signals larger than the uncertainty (Craney Island: -18 +/- 8 mm/year).
  - Problems:
    - Significant atmospheric noise super-imposed on subsidence signal.
    - Too few acquisitions to reduce long-wavelength noise.
    - **If interested in absolute rates, lack of GPS coverage in the area.**
- We have started analyzing the available Sentinel-1 data.
  - Additional year of the project being supported by NASA and CCRFR at ODU.
  - Significantly reduced uncertainty/noise in the generated subsidence maps.
  - To generate absolute velocities with low uncertainty, improved GPS coverage is needed.
  - With Sentinel-1 still on orbit, new subsidence maps can be generated each month, leading to ongoing monitoring of subsidence in the region.
  - This effort will be tied into the broader NASA effort.