Monitoring of I-77 Slopes Using Satellite Remote Sensing

17th Forum – Geohazards Impacting Transportation in the Appalachian Region
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Edward Hoppe
Acknowledgements

Daniele Perissin, Ph.D.
Assistant Professor
Lyles School of Civil Engineering
Purdue University

Yuxiao Qin
Graduate Research Assistant
Lyles School of Civil Engineering
Purdue University
I-77 Site Location

Carroll County
I-77 Corridor Challenges - Traffic

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<tr>
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<tr>
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<td>21%</td>
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<tr>
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I-77 Corridor Challenges – Steep Grades
I-77 Corridor Challenges – Fog
I-77 Corridor Challenges – Rockfalls

Blue Ridge Physiographic Province

Slope angles: 0.25:1 to 1:1
Principal rock type: metagraywacke
I-77 Rockfall History
Area of Interest

Elevations:
450 m @ MP 0.0
850 m @ MP 8.0
The Benefits of Radar Sensors For Change Detection

- Radar has excellent capabilities for routine global change monitoring
  - 24/7 imaging capabilities: due to weather and illumination independence
  - Advanced change detection performance: due to stable image geometry and own signal source
  - Complementary to optical sensors: provides independent information about surface

Radar Signals
- Visible light observable from Earth, with some atmospheric distortion.
- Radio waves observable from Earth.

Optical and Infrared Signals
- Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).

Atmospheric Opacity
- Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).

Wavelength
- 0.1 nm, 1 nm, 10 nm, 100 nm, 1 μm, 10 μm, 100 μm, 1 mm, 1 cm, 10 cm, 1 m, 10 m, 100 m, 1 km

NASA Earth Observatory images by Robert Simmon, using Suomi NPP VIIRS data from Chris Elvidge (NOAA National Geophysical Data Center)
Radar – Amplitude and Phase

With every radar acquisition, we record both Amplitude and Phase of the reflected polarized microwave signals.

- **Amplitude forms SAR Image**
- **Phase measures the range to objects on ground**
Remote Sensing with Radar Satellite

- Active system, not affected by solar illumination or weather
- Images are formed by radar signals reflected off the Earth’s surface
- Millimeter accuracy
Scanning the Earth
InSAR – Interferometric Synthetic Aperture Radar
Multi-Interferogram Techniques

Principle: Image Stacking

- Identifies coherent points in every image
- Measurements have mm accuracy
- Produce time series of deformation

Minimum 15 images

www.trecanada.com
SAR vs LiDAR

- Millimeter vs centimeter precision in displacement monitoring
- Regular acquisition schedule, typically every 8-14 days
- No field work required
- Works in all weather conditions
- Access to historical data – look back in time
- Point density much higher for LiDAR
Big Sur Landslide – Highway 1 at Mud Creek, Monterey County, California

More than 5 million cubic yards of soil and rock. 1,000 feet of highway affected.
(Civil Engineering, July/August 2017)
Big Sur Landslide – Highway 1, California

Sentinel radar data processed by TRE Altamira
Remote Sensing of I-77 Using COSMO-SkyMed

<table>
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<tr>
<th>Band</th>
<th>Wavelength</th>
<th>Resolution</th>
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<tr>
<td>X</td>
<td>31mm</td>
<td>2m*2m</td>
<td>Descending</td>
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<td>03/14/2017</td>
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Reflectivity Map
I-77 Study Area

Legend
- Footprint of SAR image
- Persistent Scatterers

Area C: MP3.6~4.0
Area D: MP5.4~5.6
Area E: MP6.2~6.5

Area A: MP1.3~1.9
Area B: MP2.7~3.2

North Carolina - Virginia state borderline

Google Earth 2017
I-77 Area A
I-77 Area B
I-77 Area C
I-77 Area D
I-77 Area E
I-77 Area E
I-77 Area C – MP 3.6~MP 4.0
Current and Future SAR Satellites

TerraSAR-X &
TanDEM-X
Cosmo-SkyMed 1st and 2nd generation

PAZ SAR

Sentinel

RADARSAT-2

RCM

ALOS2

SAOCOM

NISAR https://nisar.jpl.nasa.gov

BIOMASS

Revisit time (days)

2000

Present Day

Future

Historical Analysis

Monitoring

X-band

C-band

L-band

P-band

 Courtesy: A. Ferretti, TRE; modified version
Transportation Applications of InSAR Technology

- Roads
- Bridges
- Railways
- Tunnels
- Rapid transit
- Airports
- Marine facilities
- Landslides
VDOT Network

57,867 miles of roads
21,090 bridges and large culverts
7 tunnels

How can we monitor transportation assets?
More Information

http://viva-lab.ece.virginia.edu/foswiki/InSAR/WebHome