Limitations and Noise Sources
Future InSAR Missions

- Limitations of current data
  - temporal decorrelation – X, C, and L
  - troposphere and ionosphere (mostly L-band)
  - phase noise and spatial resolution
  - baseline control/topography error
  - second look direction not always available

- Future InSAR missions
  - Sentinel-1, C-band, October, 2013, acquisition plan, data access
  - ALOS-2, L-band, late 2013, acquisition plan, data access
  - US L-band mission possible before end of decade.
X-band – 30 mm

COSMO-SkyMed interferogram using data from 19 February 2009 and 9 April 2009. Perpendicular baseline is 480 m.

Note poor correlation after less than 2 months.
C-band – 56 mm

Envisat interferogram interpretation.

Note decorrelation after 2 months.
On April 6, 2009 (UTC), magnitude 6.3 earthquake occurred in central Italy. The Japan Aerospace Exploration Agency (JAXA) performed an emergency observation on April 22, 2009.

Note the good correlation after more than 1 year.
Decorrelation time of ALOS is sometimes more than 2 years while ERS is less than 6 months over vegetation in California. [Wei and Sandwell, 2010]
Limitations and Noise Sources
Future InSAR Missions

• Limitations of current data
  – temporal decorrelation – X, C, and L
  – troposphere and ionosphere (mostly L-band)
  – phase noise and spatial resolution
  – baseline control/topography error
  – second look direction not always available

• Future InSAR missions
  – Sentinel-1, C-band, October, 2013, acquisition plan, data access
  – ALOS-2, L-band, late 2013, acquisition plan, data access
  – US L-band mission possible before end of decade.
Effects of Ionosphere on Range

index of refraction

\[ n = \sqrt{\varepsilon} = \sqrt{1 - \frac{\lambda^2 e^2 N_e}{4\pi^2 m\varepsilon_0 c^2}} \approx 1 - \frac{1}{2} \frac{\lambda^2 e^2 N_e}{4\pi^2 m\varepsilon_0 c^2} = 1 - K\lambda^2 N_e \]

\[ \Delta \tau = \int_0^H (\frac{1}{v_p} - \frac{1}{c}) dz = -\frac{K\lambda^2}{c} \int_0^H N_e(z) dz = -\frac{K\lambda^2}{c} TEC \]

range change

\[ \Delta \rho = -K\lambda^2 TEC \]

error proportional to wavelength squared

\[ X \ 30 \text{ mm} \ - \ 0.1 \text{ m delay} \]
\[ C \ 56 \text{ mm} \ - \ 0.35 \text{ m} \]
\[ L \ 230 \text{ mm} \ - \ 5.9 \text{ m delay} \]
Can the TECU models be used to correct ionospheric errors in interferograms?

http://www.swpc.noaa.gov/ustec/

http://iono.jpl.nasa.gov/
No because the ionosphere has short wavelength structure not imaged in the global TEC models.

Residual phase for ALOS interferometry over Japan.

11.8 cm/cycle

Significant error at 60 km wavelength.

[Shimada et al., DPRI Workshop, Kyoto September 2009]
Limitations and Noise Sources
Future InSAR Missions

• Limitations of current data
  – temporal decorrelation – X, C, and L
  – troposphere and ionosphere (mostly L-band)
  – phase noise and spatial resolution
  – baseline control/topography error
  – second look direction not always available

• Future InSAR missions
  – Sentinel-1, C-band, October, 2013, acquisition plan, data access
  – ALOS-2, L-band, late 2013, acquisition plan, data access
  – US L-band mission possible before end of decade.
ERS Tandem C-band phase noise

ERS resolution
230 m - range
180 m - azimuth

(note: this is full wavelength resolution)
ALOS L-band phase noise

ALOS resolution
151 - 238 m range
116 - 181 m azimuth

(note: this is full wavelength resolution)
LOS Noise (100 m - 5000 m wavelength band)

ALOS noise 3.3 mm
ERS noise 2.1 mm
Limitations and Noise Sources
Future InSAR Missions

• Limitations of current data
  – temporal decorrelation – X, C, and L
  – troposphere and ionosphere (mostly L-band)
  – phase noise and spatial resolution
  – baseline control/topography error
  – second look direction not always available

• Future InSAR missions
  – Sentinel-1, C-band, October, 2013, acquisition plan, data access
  – ALOS-2, L-band, late 2013, acquisition plan, data access
  – US L-band mission possible before end of decade.
Landers EQ
Hector Mine EQ

optimal baseline control

[Lyons and Sandwell, JGR, 2003]
ALOS Interferograms

drifting orbital baseline reduces the number of possible interferograms

- need improved baseline control < 500 m
- need a minimum of two look directions
Annual Time Series in LA-Basin from ERS-1/2

- resolve/remove annual signals
  - > 12 acquisitions/yr.
  - baseline control < 500 m
  - 2 look directions.
  - automated processing of ScanSAR
  - time series software

[Lanari et al., 2004]
Conclusions
Limitations and Noise Sources

• North of LA, non-urban C-band interferograms have poor correlation for time > 6 mo. while L-band has adequate correlation to time > 2-yr.

• L-band and C-band have similar, orbit error and tropospheric error.

• L-band InSAR has 16 times worse ionospheric error than C-band. C-band also contaminated at the ~2 cm level.

• C-band and L-band have similar spatial resolution of 200 m wavelength for a single interferogram. One should filter at 100 m for stacking.
Limitations and Noise Sources
Future InSAR Missions

• Limitations of current data
  – temporal decorrelation – X, C, and L
  – troposphere and ionosphere (mostly L-band)
  – phase noise and spatial resolution
  – baseline control/topography error
  – second look direction not always available

• Future InSAR missions
  – Sentinel-1, C-band, October, 2013, acquisition plan, data access
  – ALOS-2, L-band, late 2013, acquisition plan, data access
  – US L-band mission possible before end of decade.
Sentinel-1 Mission Operations Concept

Pierre Potin
Sentinel-1 Mission Manager, ESA

POLinSAR 2013
ESRIN, Frascati, 28 Jan to 1st Feb 2013
Sentinel–1: C-band SAR mission

- Data continuity of ERS and ENVISAT missions
- GMES radar imaging mission for ocean, land and emergency services

Applications:
- monitoring sea ice zones and the arctic environment
- surveillance of marine environment (e.g. oil spill monitoring)
- maritime security (e.g. ship detection)
- wind, wave, current monitoring
- monitoring of land surface motion (subsidence, landslide, tectonics, volcanoes, etc.) #5.
- support to emergency / risk management (e.g. flooding, etc.) and humanitarian aid in crisis situations
- mapping of land surfaces: forest, water and soil, agriculture, etc.
Sentinel-1 Mission Facts

• C-Band Synthetic Aperture Radar Payload (at 5.405 GHz).
• 7 years design life time with consumables for 12 years.
• Near-Polar sun-synchronous (dawn-dusk) orbit at 698 km.
• 12 days repeat cycle.
• Launch of Sentinel-1A scheduled for October 1<sup>st</sup>, 2013.
• ScanSAR interferometry (IWS) mode over land.
Americas –
EWS and IWS, ascending orbits, 12 days
Americas –
EWS and IWS, descending orbits, 12 days
Sentinel-1 (ESA) Data Availability

Response from: Pierre Potin, Sentinel-1 Mission Manager, ESA

We had an informal discussion with UNAVCO, but nothing is decided yet. The situation on GMES/Sentinels is more complex compared to Envisat.

Programmatically and at political level, cooperation with international partners will be managed by the European Union. ESA will certainly be involved in the implementation of the agreements (technical part). The process is under discussion with the EC.

Most probably, international cooperation on GMES will be made with large public organisations such as space agencies. We are starting discussions with NASA, USGS.

The concept of Sentinel data mirror site with one or more US partners will certainly materialize, but it is still to be decided who will be the partners. All or a set of Sentinel data would be redistributed by these partners to US users.
ALOS - 2

Continuity of ALOS PALSAR with
- Systematic acquisition strategy (BOS)
- Improved spatial resolution
- Improved observation frequency
- dual-polarization ScanSAR

Life time: 5 years (target 7 years)
Launch: Late 2013

<table>
<thead>
<tr>
<th>Duty cycle</th>
<th>xx min average/orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>204 orbits/cycle</td>
</tr>
<tr>
<td>Altitude (Nominal)</td>
<td>628 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>97.9 degrees</td>
</tr>
<tr>
<td>Period</td>
<td>97.4 minutes</td>
</tr>
<tr>
<td>Orbit LST</td>
<td>12:00 ± 15 min</td>
</tr>
<tr>
<td>Sun-Synchronous</td>
<td>15-3/14 orbits/day</td>
</tr>
<tr>
<td>Repeat cycle</td>
<td>14 days</td>
</tr>
</tbody>
</table>

Applications:
- Disaster Monitoring #1
- Forest Monitoring
- Information update for land and infrastructure
- Monitoring of cultivated areas
ALOS-2 Basic Observation Scenario

Crustal Deformation

Temporal repeat: 2-6 cov/year & 9 cov/year (42 days)
Mode: Dual-pol (HH+HV) & WB-350km (HH+HV)
Pass dir.: 4*Asc+ 9*Desc + 2*Desc (14-day InSAR)
GSD: 10 m & 100 m
ALOS-2 (JAXA) Data Availability

• First science AO from JAXA November, 2012.

• WInSAR (Fielding et al.) organized co-investigator strategy to optimize data sharing in US.

• At least 50 US investigators approved for limited data access (50/yr.).

• First ALOS-2 investigator meeting scheduled for September, 2013.

• Launch scheduled for November 2013.

• Can WInSAR and PIXEL (Japan) share PI data among their members?

• Can UNAVCO purchase large quantities of data for WInSAR members?

• Data access may depend on US participation in JAXA meetings.
L-band SAR Mission (LSM) for Deformation, Ecosystem Structure and Dynamics of Ice

Proposed Mission Overview
May 4, 2013

Paul A. Rosen
Jet Propulsion Laboratory

This document has been reviewed and determined not to contain export controlled technical data.
Level 1 LSM Science Requirements

- For a minimum of 3 years:

  #1  Measure displacements over Earth’s land and ice covered surfaces with an accuracy of 20 mm with an average sampling capability of 6 days at hectare scale.

  - Measure sea ice displacements at 100 m/day accuracy on a 5 km grid every 3-days

  - Measure global woody aboveground biomass below 100 Mg/ha at 20 Mg/ha accuracy, and disturbance/recovery, at hectare scale, annually.

  - Acquire targeted data sets to characterize wetlands inundation, agricultural systems, aquifers, hydrocarbon reservoirs, permafrost, and coastal winds

  - In the event of a major natural or anthropogenic disaster anywhere in the world, data shall be made available for rapid response
LSM Synthetic Aperture Radar Concept

- Dual Frequency: L- and S-band
- 3 primary modes:
  - Solid earth deformation, ice sheets and glaciers: Single pol (HH or VV)
  - Ecosystems: Quad, Quasi-Quad pol
  - Sea-ice: Low BW single pol
- Data acquired Left or Right of spacecraft track, ascending and descending
  - Wide swath in all modes allows for 12 day repeat with overlap at equator (2-5 passes over a site depending upon latitude)
  - Mode used over any given area selected based on science need
  - Mode conflicts resolved through plan optimization

See export compliance restrictions on cover
LSM (NASA) Data Availability

• Science definition team selected 2012 (Solid Earth members: Brad Hager, Gerald Bawden, Kurt Feigl, Matt Pritchard, Paul Rosen, Mark Simons).

• “mission is still in pre-formulation, and things can change, but the partnership with India seems to be maturing well”

• “launch date before the end of the decade”

• L-band data **completely open** to everyone.

• April, 2012 - EarthScope Steering Committee sent a letter endorsing the critical role of DESDynI (now LSM) for advancing EarthScope Science Objectives.
To do list for US InSAR community

- Work with ESA to ensure EarthScope science targets are included in Sentinel-1 acquisition plan.
- Work with JAXA on ALOS-2 data sharing agreement.
- Promote a NASA L-band mission to provide data later in decade.
- Develop integrated GPS/InSAR deformation models at 200 m spatial resolution and better than seasonal temporal resolution.
- Continue to develop open-source software tools for automated processing of the new ScanSAR data streams coming soon.