ERS – ENVISAT TANDEM DATA OVER SEA AND SHELF ICE

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Repeat-pass SAR data well suited for displacement mapping

Techniques used:
→ InSAR
→ offset tracking
→ split-beam interferometry

Different sensors, wavelengths, repeat intervals:
→ different sensitivities
→ different applicability

ERS-ENVISAT Tandem (EET) pairs provide 28´ intervals:
→ suited for fast displacements
→ e.g. sea ice: - drifts
             - tidal effects
We processed EET pairs over Northern latitudes and observed “interesting phase” over sea ice.

We found that it may be of interest to apply offset tracking to EET pairs over sea ice.

We applied split-band interferometry to EET pairs to estimate the coherence over areas with high phase gradients and found that the technique is applicable over sea ice.

Feasibility: yes
Sensitivities: ?
Precisions:  ?
Applicability:  ?
ERS–ENVISAT cross interferometry

The ENVISAT satellite is on the same orbit of ERS-2 (35 days repeat cycle) with a very short temporal separation of 28 minutes.

However, the radar center frequency of ENVISAT ASAR (5.331 GHz) has been slightly changed compared to ERS-2 (5.300 GHz).

At perpendicular baselines around 2 km the baseline effect can composite the frequency difference effect on the reflectivity spectrum allowing to get coherent interferograms.

→ 28 minute interval and 2km perpendicular baseline
ERS–ENVISAT cross interferometry

\[ \phi = \phi_{orb} + \frac{4\pi}{\lambda} B_{\perp} h + \frac{4\pi}{\lambda} r_{\text{disp}} + \phi_{\text{path}} + \phi_{\text{noise}} \]

- Ambiguity height 4.7m (2km perp. baseline) → very sensitive to elevation
- 2.8 cm displacement per phase cycle
  but displacement is for a short 28 minute interval
  → suited for relatively fast displacements
ERS–ENVISAT CInSAR Franz-Joseph-Land

7 Dec. 2007

$B_\parallel = 2066\, \text{m}$

size 53km x 56km
ERS–ASAR CInSAR, Kugmallit Bay, Canada

10-Mar-2009, $dt=28\,\text{min.}$, $B_\perp=2247\,\text{m}$
ERS–ENVISAT cross interferometry

- Precision of EET ClnSAR displacement mapping:

\[
\sigma_\phi = \frac{1}{\sqrt{2N_L}} \frac{\sqrt{1 - \gamma^2}}{\gamma}
\]

\(\gamma = 0.5, \ N_L = 20 \) looks

→ phase noise \(\sigma_\phi = 0.2\) radian

→ 0.9mm LOS displacement precision (per 28´ interval)
  
  (= 4.5cm/day = 16.7m/y)
ERS–ENVISAT cross interferometry

- Applicability range (maximum rate?):

  Assumption: a maximum of 10 phase cycles can be observed
  (high phase gradients and unwrapping problems may prevent
  interpretation of higher values)

  → 28.0cm/28´ = 14.4m/day = 5260m/y maximum LOS
  displacement observable with CInSAR
ERS–ENVISAT offset tracking Franz-Joseph-Land

7 Dec. 2007, $B_\perp=2066\text{m}$, $dt=28\text{min.}$

displacements up to more than $100\text{m}$
ERS–ENVISAT offset tracking Franz-Joseph-Land

- Slant range and along-track components mapped
- Precision of EET offset tracking:
  - 0.05 slc pixel accuracy for offsets (conservative estimate)
  - → 40cm displacement precision in slant range component
  - → 20cm displacement precision in along-track component
- Applicability range (maximum rate?):
  - 10 slc range pixels, 50 slc azimuth pixels
  - → 80m displacement maximum in slant range component
  - → 200m displacement maximum along-track component

→ Offset tracking is well suited for fast displacements
ERS–ENVISAT split-beam interferometry

- Used in EET CInSAR to improve coherence estimation by avoiding the high phase gradients (see Wegmüller et al., IGARSS 2009)

→ Phase also interesting
ERS–ENVISAT split-beam interferometry


- 2 interferometric scenes
- Azimuth band pass filtering of both SLCs
- Calculate 2 interferograms with slightly different DC
- Complex combination of these two interferograms
- Multi-looking
  \[ \rightarrow \text{split-beam interferogram} \]

Phase: \[ \phi = \frac{2\pi d_{az}}{l} \]
ERS–ENVISAT split-beam interferometry

Franz-Joseph Land
7 Dec. 2007,
$B_\perp=2066\text{m}$,
d$t=28\text{min.}$

1 fringe $\rightarrow$ 10m azimuth displacement
ERS–ENVISAT split-beam interferometry

- Along-track displacement component only
- Precision of EET split-beam interferometry:
  \[ \gamma = 0.5, \ N_L = 100 \text{ looks} \]
  \[ \Rightarrow \text{phase noise } \sigma_\phi = 0.09 \text{ radian} \]
  \[ \Rightarrow 0.14\text{m along-track displacement precision (per 28}^{\prime} \text{ interval)} (\Rightarrow 7.2\text{m/day, } \Rightarrow 2.6\text{km/y}) \]

- Applicability range (maximum rate?):
  5 fringes
  \[ \Rightarrow 50\text{m displacement maximum} \]

- “most accurate technique for along-track component”
**Conclusions: Precision and applicability summary**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Displacement rate precision</th>
<th>Displacement rate maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slant range</td>
<td>Along-track</td>
</tr>
<tr>
<td>InSAR</td>
<td>0.9mm/28′</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>4.5cm/day</td>
<td>16.7m/y</td>
</tr>
<tr>
<td>Split-band InSAR</td>
<td>NA</td>
<td>0.14m/28′</td>
</tr>
<tr>
<td>Offset tracking</td>
<td>0.40m/28′</td>
<td>0.20m/28′</td>
</tr>
<tr>
<td></td>
<td>20.6m/day</td>
<td>10.3m/day</td>
</tr>
<tr>
<td></td>
<td>7.5km/y</td>
<td>3.8km/y</td>
</tr>
</tbody>
</table>

- EET interval (28′) is about 50 times shorter as for ERS-1/2 Tandem pairs (1day)
- InSAR and split-band InSAR provide only one component
- No coherence required for offset tracking
- mm to 200m displacements over 28′ interval covered
Homework until next Fringe meeting

Kugmallit Bay
10-Mar-2009,
$dt = 28\text{ min.}$,
$B_\perp = 2247\text{ m}$

Salinity?
Tides?
Penetration?
Ice thickness?
Coherence?

Deformation or topography?
What other data might help?

EET CI nSAR

Please explain!

GAMMA REMOTE SENSING