DORIS absolute velocities on Sorsdal and Lambert glaciers in Antarctica

JJ. Valette \(^1\), R. Govind\(^2\), FG. Lemoine\(^3\)

\(^1\) CLS, Collecte Localisation Satellites, France
\(^2\) Geoscience Australia, Canberra, Australia
\(^3\) NASA Goddard Space Flight Center, Greenbelt, Maryland, US
Summary

Introduction

Context

IDS Pilot Experiment campaigns
sites & installation
data acquisition (lessons learnt)
processing
velocity results
comparisons

Conclusions
90% of the Antarctic ice sheet is discharged in glaciers & ice stream

In East Antarctica, the Lambert-Amery glacier-ice shelf drainage system is the largest
Ice discharge in Antarctica and Greenland influences the global sea level and climate changes

Ice accumulation rate  MASS BALANCE  Ice thickness changes

Tools for surface velocities:

Altimetry: radar (ERS, Envisat,…), laser (Icesat) > mapping
Geodetic: GPS, DORIS
...

A very difficult task: complex drainage structures, strong local variability (velocity, precipitations…)
IDS Pilot Experiment campaigns

GEOSCIENCE AUSTRALIA
proposition for several weeks DORIS permanent monitoring stations

(From Manson, 2000)
DORIS campaigns: sites & installation

Beacon program:
- Satellite selection (SPOTs)
- Approx. position (few km)
- Sequences of transmission
- IAT clock synchronisation
- Initial training by SIMB/IGN

> Self operating

Power supply:
- 75 ah needed
- 2x60 W solar panel
- Voltage regulator

SSALTO/CNES Control Center:
- 401.25 MHz & 2036.25 MHz signals received at Toulouse, within a few hours
- Signal char. and Doppler obs. systematically checked
- Contact at Davis base in case of anomaly

< Daily control
### Data acquisition & lessons learnt

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Period</th>
<th># days (obser.)</th>
<th>DORIS dataset</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorsdall</td>
<td>12-Nov-2001 - 13-Jan-2002</td>
<td>23</td>
<td>Sat pass./obs.</td>
<td>Power supply deficiency, too many satellites tracked</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td>Spot2 5/13</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spot4 26/685</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Topex 3/61</td>
<td></td>
</tr>
<tr>
<td>Lambert</td>
<td>9-Dec-2002 - 23-Jan-2002</td>
<td>11</td>
<td>Spot4 93/2928</td>
<td>Nominal operations after full beacon initialisation (self-training)</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td></td>
<td>Spot5 74/3621</td>
<td></td>
</tr>
<tr>
<td>Sorsdall</td>
<td>29-Nov-2003 - 02-Jan-2004</td>
<td>9</td>
<td>Spot4 24/653</td>
<td>Interruption due to a big storm and Katabatic wind</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td></td>
<td>Spot5 29/1191</td>
<td></td>
</tr>
<tr>
<td></td>
<td>02-Jan-2004 - 23-Jan-2004</td>
<td>21</td>
<td>Spot4 122/2101</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spot5 147/5130</td>
<td></td>
</tr>
</tbody>
</table>

**Save power:** 2 sat. enough

**Encouraging**

**Meteo risk**
Velocities processing

by Geoscience Australia IDS Analysis Center (R. Govind)

GEODYN software (NASA/GSFC, F. Lemoine)

- Modelling
  - GGM01S gravity field
  - Time varying gravity applied for zonals up to degree 5, C(2,1) and S(2,1)
  - Ocean Tides – GOT99
  - Ocean Loading – from GOT99
  - ITRF2000 apriori coordinates and velocity
- Partially Generated for Each Satellite as follows:
  - **Global Set:**
    - GM, Semi-Major Axis, flattening
    - Gravity coefficients to degree and order 10
    - X-Pole, Y-Pole and A1-UT1
    - Tracking Station Coordinates
  - **Arc Set:**
    - State Vector
    - 8-hourly drag coefficient
    - General Acceleration (4)
      - Once/rev sine and cosine – along and cross track
    - Measurement biases (Doppler) pass-by-pass
    - Tropospheric Scale Bias – pass-by-pass
- Estimated Parameters at the Combination stage (all possible satellites):
  - Tracking Station Coordinates
  - X-Pole, Y-Pole and A1-ut1
  - Gravity Field Coefficients to degree and order 2
  - GM
  - Satellite state vector, General Acceleration, Drag
Results

SORSDLAL: Dec 2003-Jan 2004 (SOSB) / GEODYN

- Latitude: $-4.7 \text{ cm/day} \pm 0.4$
- Longitude: $-9.1 \text{ cm/day} \pm 0.8$
- Height: $-4.1 \text{ cm/day} \pm 0.4$

LAMBERT - Jan. 2003 (LAMB) / GEODYN

- Latitude: $1.071 \text{ m/day} \pm 0.04$
- Longitude: $0.714 \text{ m/day} \pm 0.047$
- Height: $0.0003 \text{ m/day} \pm 0.009$

**Sorsdal (2003) > 10 cm/day**

**Lambert > 130 cm/day**
### DORIS results & GPS comparison

#### DORIS results

<table>
<thead>
<tr>
<th>Site</th>
<th>Velocity (cm/day)</th>
<th>Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorsdal (Dec 2001-Jan 2002) *</td>
<td>31.0</td>
<td>246.4</td>
</tr>
<tr>
<td>Sorsdal (Dec 2003-Jan 2004)</td>
<td>11.0</td>
<td>242.7</td>
</tr>
<tr>
<td>Lambert (Jan 2003)</td>
<td>128.7</td>
<td>56.3</td>
</tr>
</tbody>
</table>

* under refinement

#### Sorsdal (Dec 2001-Jan 2002)

<table>
<thead>
<tr>
<th></th>
<th>DORIS</th>
<th>GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days between obs.</td>
<td>31</td>
<td>65</td>
</tr>
<tr>
<td>Velocity (m/day)</td>
<td>0.31</td>
<td>0.31</td>
</tr>
<tr>
<td>Azimuth (°)</td>
<td>246.37</td>
<td>244.43</td>
</tr>
</tbody>
</table>

(Patrick, Univ. Melbourne, 2003)
Comparisons

DORIS velocities


(from Manson, 2000)
ERS-1. (From Testut, 2003)
5 km digital elevation model > high velocity zones

green dot is Lambert glacier DORIS point
DORIS velocity: > 450 m/yr

DORIS/ERS

IDS Workshop, Venice, 13-15 March 2006
Conclusions

DORIS monitoring of surface displacement
  > self operation of the beacon
  > routine data control at Toulouse, France
  > installation precaution (beacon program, power supply)
  > 2 or 3 polar satellites for high resolution

SORSDL-LAMBERT glaciers dynamics
  > DORIS velocities from 10 to 130 cm/day
  > very strong local variation of ice-flow rates
    (2 to 60 m/day over 2 km at Sorsdal, from Patrick, 2003)

Proposition for a DORIS experiment at International Polar Year?
  > Greenland (retreat of coastal glaciers)
  > ...