DORIS Analysis Strategies:
Analysis Coordination and steps required towards generation of IDS Products

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Outline

• Introduction: Presentation of Position Paper
• Availability of DORIS Products: Review
• Action items from May 2004 IDS Workshop: Status.
• Recommendations for 2006
e.g. Analysis campaigns,
  Refinements to analysis procedures.
• Conclusion

Introduction

• IDS accepted as service of the IAG (July 2003).
• Station renovation is nearing completion (Fagard, this workshop).
• Multiple groups contribute products on a regular basis: IGN/JPL, INASAN, LEGOS/CLS, SSALTO.
• New Analysis Centers: Pecny/CODE; Geoscience Australia.
• Contribution to ITRF2005.
• DORIS has reached a level of maturity and is at a crossroads.

Our challenge is continue to improve the geodetic products and transition to routine delivery of IDS products.
### Current IDS Products (March 2006)

<table>
<thead>
<tr>
<th>Product</th>
<th>Present AC</th>
<th>Previous AC (no recent solution)</th>
<th>Proposed AC</th>
<th>Combined product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative solutions</td>
<td>IGN/JPL LEGOS/CLS*</td>
<td>SOD</td>
<td>Geoscience Australia IAA</td>
<td>No</td>
</tr>
<tr>
<td>(positions/velocities)</td>
<td></td>
<td>LEGOS/CLS</td>
<td>Geoscience Australia IAA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GSFC (1 yr)</td>
<td>IAA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pecny/ICG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly series</td>
<td>IGN/JPL INASAN LEGOS/CLS</td>
<td></td>
<td>Geoscience Australia IAA</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>SSALTO</td>
<td></td>
<td>IAA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pecny/ICG</td>
<td></td>
</tr>
<tr>
<td>Monthly series</td>
<td>IGN/JPL INASAN LEGOS/CLS</td>
<td></td>
<td>Geosciences Australia IAA</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>SSALTO</td>
<td></td>
<td>IAA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geocenter</td>
<td>IGN/JPL INASAN</td>
<td>LEGOS/CLS</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>EOP</td>
<td>IGN/JPL</td>
<td>LEGOS/CLS</td>
<td>INASAN</td>
<td>No</td>
</tr>
<tr>
<td>Orbits</td>
<td></td>
<td>LEGOS</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Ionosphere</td>
<td>SSALTO</td>
<td></td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>

* Not at CDDIS.
DORIS geocenter TZ (time series at NASA/CDDIS)

DORIS TRF scale (time series at NASA/CDDIS)
DORIS Ionosphere product (1)

- Ionosphere correction calculated routinely and part of normal data record.
- Supplementary IONO file contains additional information, including elevation angle & geometry

The format is:-

- for the header (for each satellite pass over a beacon) : s
  satellite, beacon mnemo, number of observations, max of satellite pass elevation,
  local time (deg), meteorological data : Pressure (mb), T (deg), Humidity (%)
  ex: SPOT2 SALB 27 57.954 22.6091012 21 68

- for the data :
  CNES julian date, second in the day of the observation (TAI),
  elimination criteria,
  count interval (2 GHz channel),
  count interval (400 Hz channel),
  Tropospheric correction (2 GHz channel),
  Tropospheric correction (400 MHz channel),
  Ionospheric correction (2 GHz channel),
  Ionospheric correction (400 GHz channel),
  Elevation angle, Azimuth, Station-satellite distance (m),
  Acquisition mode,
  Received power level (400 Mhz), Received power level (2 Ghz),
  Ponderation (0 if eliminated or 1),
  Doppler count (400 Mhz), Doppler count (2 Ghz).
DORIS Ionosphere product (2)

IONO Files Available:
Spot5: from May 2004.

Figure 2: Comparison of DORIS derived vertical total electron content (VTEC) for JASON in 2004 with VTEC results from different IGS analysis centers. The display indicates the RMS difference between each IGS center and DORIS for 2004. The units are TEC units (TECU). At the Jason altimeter frequency of 13.6 Ghz, 1 cm of range corresponds to 4.6 TECU. (from M. Pajares, April 2004-2005, IGS working group report)
## Station Coordinate Differences (STCD)

**FILE/REFERENCE**
- **DESCRIPTION**: SSALTO (ALTIMETRY LOCATION MULTI-MISSION GROUND SEGMENT)
- **OUTPUT**: Weekly routine solutions
- **CONTACT**: Jean-Jacques.Valette@cls.fr info.doris@cls.fr
- **SOFTWARE**: CLS/IGN
- **HARDWARE**: DIGITAL ALPHA/VMS
- **INPUT**: All satellite DORIS data, MCO 48h delay orbits from CNES/500

**FILE/REFERENCE**

**FILE/COMMENT**
- Solutions have been transformed into ITRF2000

**FILE/COMMENT**
- Fields: MJD dx dy dz dNorth dEast dUp
- **MJD**: Modified Julian Day
- **Decimal Year**: 2000.0000 + (MJD - 51544.05)/365.2422
- **Earth Ellipsoid Reference**: ITRF2000
- **Equatorial Radius (m)**: 6378136.3000
- **Flattening Factor**: 298.2570

**SITE/ID**

*CODE PT DOMES APPROX LAT_APP HEI YEBL A 201275008 D Yellowknife 245 31 12.5 62 28 51.9 182.7*

**SITE/ID**

**SOLUTION/APRIORI**

<table>
<thead>
<tr>
<th>INDEX</th>
<th>TYPE</th>
<th>CODE</th>
<th>PT</th>
<th>SOLVIN</th>
<th>REF</th>
<th>EPOCH</th>
<th>UNIT</th>
<th>S</th>
<th>ESTIMATE</th>
<th>VALUE</th>
<th>STD_DEV</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>STA1</td>
<td>YEBL</td>
<td>A</td>
<td>101:000:0000</td>
<td>m</td>
<td>2</td>
<td>1.22440518731400*E+07</td>
<td>0.0000000+00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>STAY</td>
<td>YEBL</td>
<td>A</td>
<td>101:000:0000</td>
<td>m</td>
<td>2</td>
<td>-2.20821646062410*E+07</td>
<td>0.0000000+00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>STAZ</td>
<td>YEBL</td>
<td>A</td>
<td>101:000:0000</td>
<td>m</td>
<td>2</td>
<td>0.56356490118510*E+07</td>
<td>0.0000000+00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SOLUTION/APRIORI**

| 53739.5000 | -0.015 0.006 -0.001 0.004 0.022 0.005 0.004 0.005 -0.013 0.006 0.023 0.00 |
| 53746.5000 | -0.018 0.006 -0.004 0.004 0.007 0.004 -0.007 0.004 -0.015 0.005 0.011 0.00 |
| 53753.5000 | -0.026 0.006 -0.009 0.004 0.007 0.004 -0.013 0.004 -0.020 0.005 0.015 0.00 |
| 53760.5000 | -0.011 0.006 -0.009 0.004 0.010 0.004 -0.007 0.004 -0.006 0.005 0.015 0.00 |
| 53767.5000 | -0.038 0.006 -0.010 0.004 0.050 0.004 -0.003 0.004 -0.030 0.006 0.040 0.00 |
| 53774.5000 | -0.033 0.007 0.002 0.005 0.021 0.005 -0.001 0.005 -0.031 0.006 0.024 0.00 |
Station Position Residuals (STCD)

DORIS (IGN/JPL, 2006/0303)
Weekly series
ftp://cddis.gsfc.nasa.gov/pub/doris/products/stcd/ign03wd01/ign03wd01.stcd.paqb.gif - Updated weekly.

DORIS (LCA 2005.0603)
Monthly series
ftp://cddis.gsfc.nasa.gov/pub/doris/products/stcd/lca05md01/lca05md01.stcd.paqb.gif - Last updated 2005.0603
Station Coordinate Differences (STCD)  
(PAQB comparison with GPS for collocated site, THTI, Tahiti)

<table>
<thead>
<tr>
<th>Series</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGN/JPL ign03wd01</td>
<td>37.5 mm/yr</td>
<td>-63.5 mm/yr</td>
<td>-1.9 mm/yr</td>
</tr>
<tr>
<td>LCA lca05md01</td>
<td>35.1 mm/yr</td>
<td>-69.3 mm/yr</td>
<td>2.4 mm/yr</td>
</tr>
<tr>
<td>GPS Heflin 2004.0</td>
<td>33.40 ± 0.04 mm/yr</td>
<td>-66.78 ± 0.10 mm/yr</td>
<td>-0.47 ± 0.21 mm/yr</td>
</tr>
</tbody>
</table>

GPS (Heflin, 2004.0)  
Not updated since MBH left JPL.
DORIS Data Delivery to NASA CDDIS

DORIS data delivery
(March 8, 2006)
DORIS Product Delivery to NASA CDDIS

Start of IERS CPP Campaign

SINEX delivery delay at CDDIS (days)

Year

- IERS deadlines
- GSFC (WD02)
- IGN/JPL (WD05)
- INASAN (WD03)
- LEGOS/CLS (WD13)
DORIS Data Downloads by Source
ftp://cddis.gsfc.nasa.gov/pub/doris/data
DORIS Product Downloads by Source
ftp://cddis.gsfc.nasa.gov/pub/doris/products
DORIS Evolution from TOPEX analysis

NASA GSFC TOPEX DORIS RMS
(GDR vs GGM02C TVG Reprocessing)
DORIS Evolution from Spot2 analysis

**NASA GSFC Spot-2 DORIS RMS (GGM01S, ITRF2000)**

![Graph showing RMS vs Modified Julian Date](image)
Figure 9. Weighted RMS of the individual weekly time series combinations (Tavernier et al., 2006).
DORIS TRF Scale Differences

Weekly scale factor determination towards ITRF2000 using multi-satellite SINEX solutions. GSFC (circles); IGN/JPL(squares); LEGOS/CLS (crosses), Jan. - Dec. 2004. Left (all satellites); Right (Spot5 only). (Willis et al., 2006 in press; presented at Cairns IAG, August 2005).
DORIS TRF Scale Differences

Figure 11: Scale factor of the individual weekly time series combinations from Tavernier et al. (2006). IGN/JPL (diamonds); LEGOS/CLS (black dots); GSFC (crosses).
DORIS constellation evolution
DORIS Special Issue -
Journal of Geodesy
(status report, March 10, 2006)

Guest Editor: P. Willis (+ W. Featherstone when co-author)

18 papers submitted in total (Oct 2005 - Feb 2006.)

3 with a decision:
   2 accepted (soon on Springer Website with DOI)
   1 refused

15 currently in review:
   6 in 1st review cycle
   8 sent back to authors for corrections
   1 in 2nd review cycle

Expected end of edition = May - June 2006

Authors from 8 different countries
Reviewers from +9 different countries
### Status of 2004 IDS Workshop Recommendations

<table>
<thead>
<tr>
<th>Action</th>
<th>Status</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1. Survey of current uses of IDS products</td>
<td>Open</td>
<td>Rejected during meeting.</td>
</tr>
<tr>
<td>2.2 Define procedure to accept an IDS product</td>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>2.3 Split DORISMail and create DORISReports</td>
<td>Closed</td>
<td></td>
</tr>
<tr>
<td>2.4 Understand why some AC’s have stopped</td>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>3.1 Request data delivery &lt; 6 weeks</td>
<td>Closed.</td>
<td>Done, but SAA problem remains.</td>
</tr>
<tr>
<td>3.2 Change to backup DORIS receiver on Jason</td>
<td>Closed</td>
<td></td>
</tr>
<tr>
<td>3.3 List of IDS Stations (network + campaigns)</td>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>3.4 Test data delivery for campaign stations</td>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>3.5 Define new format (raw data)</td>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>3.6 Request data from Pleiades (+NPOESS)</td>
<td>Open</td>
<td>Done, but unsuccessful.</td>
</tr>
<tr>
<td>4.1 Improve products but keep continuity.</td>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>4.2 Compare AC’s analysis strategies.</td>
<td>Open</td>
<td>Some documentation online.</td>
</tr>
<tr>
<td>5.1 Define validation procedures</td>
<td>Open</td>
<td></td>
</tr>
</tbody>
</table>
2006 IDS Workshop Recommendations
(to be discussed & decided during workshop)

**Recommendation 2006.1.0**: (1) Request Release of Pleiades satellite data; (2) Seek other missions of opportunity.

**Recommendation 2006.2.0**: Conduct measurement and force model inventory. Ascertain if AC’s can follow IERS2003 recommendations.

**Recommendation 2006.2.1**: Analysis centers should update their analysis description forms on file at the CDDIS, IGN data centers.

**Recommendation 2006.3.0**: New POD Standards for the IDS. Form subcommittee to examine standards used for GRACE, Topex, Jason, Envisat, and recommend models IDS might/should use. Be up to date but not arbitrary (e.g. Use Grace gravity models, but do not specify exact one to use).
2006 IDS Workshop Recommendations
(to be discussed & decided during workshop)

<table>
<thead>
<tr>
<th>Recommendation 2006.4.0:</th>
<th>Decide orbit format for analysis campaigns. (sp1, sp3, POE).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommendation 2006.4.1:</td>
<td>Conduct analysis campaigns for TRF scale and geocenter. Use updated common standards (from previous recommendations). Perform single-satellite and multi-satellite solutions as well as multi-technique solutions; Compare where possible with external data (SLR, Altimeter Crossovers). Systematically compare orbits produced by AC’s for this campaign as well as final products. 1-2 years (2003-2004?).</td>
</tr>
<tr>
<td>Recommendation 2006.5.0:</td>
<td>Analysis campaign to validate SAA model (JM Lemoine and Capdeville, this workshop). What is impact on orbits, stations, EOP, scale?</td>
</tr>
</tbody>
</table>
2006 IDS Workshop Recommendations
(to be discussed & decided during workshop)

**Recommendation 2006.6.0**: Evolve IDS to an operational service. Request AC’s to submit solutions within X weeks of receipt of data. Request combination center to perform combination with Y weeks of receipt of AC solutions.

**Recommendation 2006.7.0**: Request submission of ionosphere files for years prior to 2000-2001.

**Recommendation 2006.7.1**: Publicize availability of ionosphere data.

**Recommendation 2006.8.0**: Ask analysis centers to define arcs so that overlaps are available. Conduct overlap analyses on a routine basis and make results available to IDS on routine basis in tabular and plot form.

*Comment: Orbit overlaps are a vital statistic to measure internal consistency and should be available for analysis (like the IGS).*

**Recommendation 2006.8.1**: Submit orbits to IDS so all AC orbits can be intercompared on a routine basis on same schedule as in Rec. 2006.6.0.*
2006 IDS Workshop Recommendations
(to be discussed & decided during workshop)

Recommendation 2006.9.0: Harmonize *a priori* positions in all STCD files.

Recommendation 2006.9.1: Ensure that all AC’s can create STCD files and associated plots. Update web site to include results from all AC’s.

Recommendation 2006.9.2: Publicize availability of STCD files and plots in geophysics community (e.g., IGSMAIL, SLRMAIL, other means).
Other Issues

- Analysis campaign for time-variable gravity estimation.
- EOP & EOP-rates (proposal of P. Willis).
- Do we continue monthly series or only do weekly series?
- International Polar Year.
- Encouragement of new AC’s.
Conclusion

DORIS as a geodetic observing system is at a crossroads. It has achieved a level of maturity in the quality of the products that it produces. We must focus on the technical issues (e.g. modelling differences between centers) and operational issues in order to continue to refine and improve the contribution DORIS makes to satellite geodesy.