ILRS General Assembly

Agenda

• **Introductory Remarks**	W. Gurtner	5 min
• **ILRS Status Report**	M. Pearlman	15 min
• **Working Group Reports**		
✦ Missions	D. Carter/H. Kunimori	5 min
✦ Networks & Engineering	G. Kirchner/U. Schreiber	5 min
✦ Data Formats & Procedures	W. Seemueller/J. McGarry	10 min
✦ Refraction Study Group	S. Riepl	
✦ Prediction Format	R. Ricklefs	
✦ Analysis	R. Noomen/P. Shelus	5 min
✦ Signal Processing A/H	G. Appleby	5 min
• **Campaign and Mission Reports**	M. Pearlman/P. Shelus	30 min
• **Annual Report for 2002 and 2003/04**	M. Pearlman	5 min
• **ILRS Governing Board Elections**	M. Pearlman	5 min
• **Discussions, Next Meeting**	M. Pearlman	5 min
• **Closing Comments**	W. Gurtner	5 min

ILRS Status Report

10th ILRS General Assembly
June 11, 2004
San Fernando, Spain

ILRS Status

ILRS Central Bureau
NASA GSFC, Greenbelt, MD USA
cb@ilrs.gsfc.nasa.gov

ILRS Status

- **Mission items:**
  - GP-B launched April 20
    - 16 month mission
    - Satellite tracking provided by GPS and SLR; SLR tracking to commence in late June
    - SLR predictions will be generated by two centers
    - Project will generate station pass list and distribute through normal prediction channels
  - GFO re-acquisition achieved early April
  - Awaiting specifications on Galileo retroreflector array
  - Should we approach GPS-III regarding retroreflectors on board?
  - Problem with Meteor-3M data yield; signal strength very low
  - Tracking Support Request forms submitted by JAXA for ETS-VII and ALOS

ILRS Status
(Continued)

- **Station items:**
  - New Mt. Stromlo station in testing; dedication held on April 1, 2004
  - GUTS system installation underway in Tanegashima, Japan
  - SALRO station doing well; GPS receiver installed and awaiting IGS approval
  - Grasse SLR station (7835) closed end of May 2003
  - NASA SLR program being restructured to accommodate budget cut in FY04
  - SLR2000 has received first returns
  - HOLLAS to close by end of 2004
  - Arequipa operations uncertain at this time

ILRS Status
(Continued)

- **Central Bureau Activities:**
  - Significant reduction in HTSI headquarters support
  - Proceedings from 2002 Washington laser ranging workshop (hardcopy and CD) issued in December 2003
  - 2002 ILRS Annual Report posted on website in April 2004; hardcopy to be printed and mailed by end of June
  - Plan to issue combined 2003/2004 annual report
  - Fourth quarter 2003 ILRS station report card issued; first quarter 2004 ILRS report card with performance charts in process at RITSS
  - INDIGO now funded and will support NASA participation in GGOS and IERS

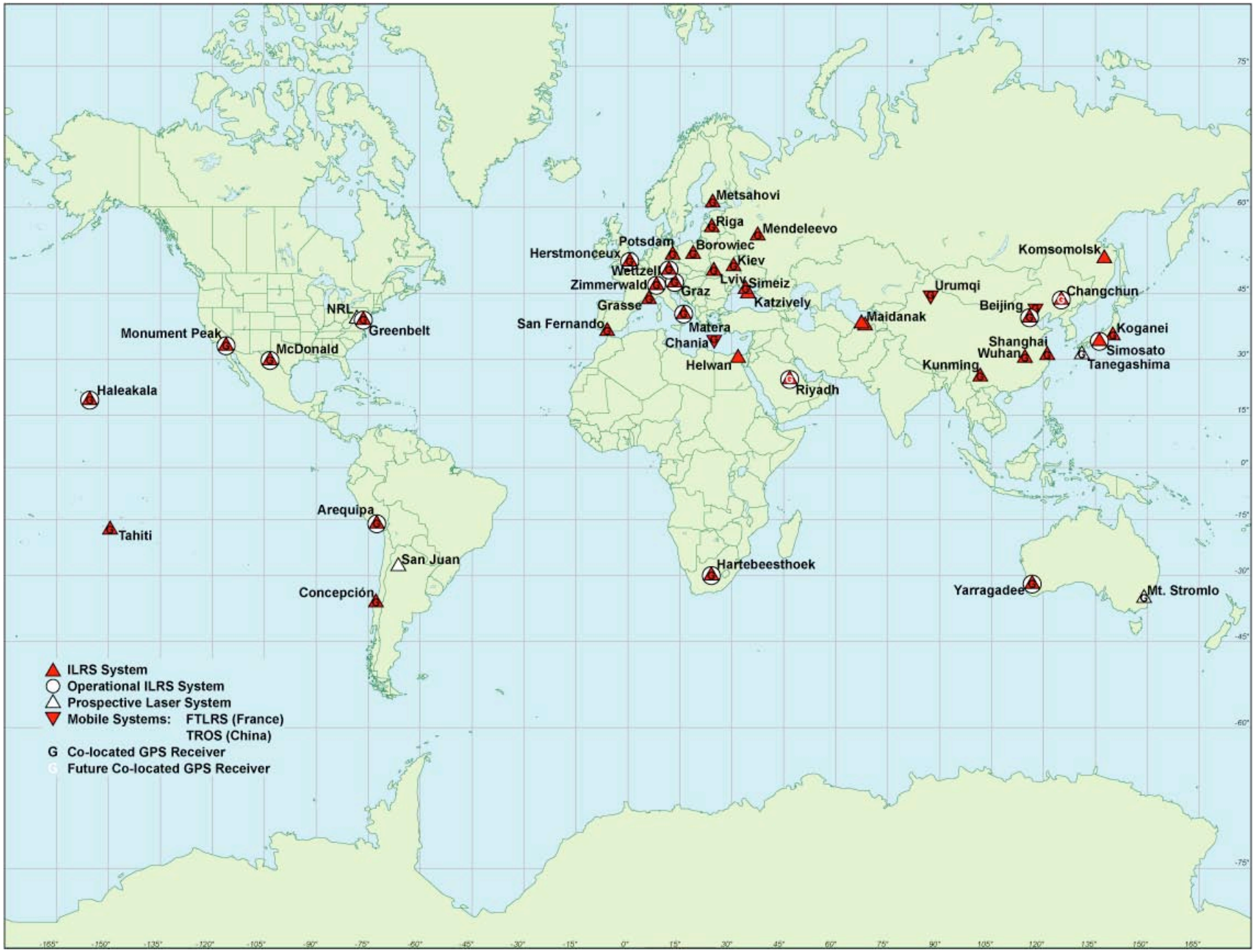
ILRS Status
(Continued)

- **Meeting News:**
  - ILRS Technical Workshop held in Koetzting in October 2003
  - ILRS AWG meeting held in Nice in April 2004
- **Site surveys:**
  - Site surveys conducted at Hartebeesthoek and Shanghai; survey planned for Beijing
  - Analysis of survey data from Hartebeesthoek, Shanghai, Hawaii, Arequipa, and GSFC in process
  - IERS has established a Collocation/Survey Working Group to coordinate ground survey activities for the IAG Space Geodesy activities (ILRS, IVS, IGS, and IDS)

ILRS Status
(Continued)

- **Other items:**
  - ILRS "recognition" in scientific publications:
    - SLRMail sent by ILRS CB
    - Messages on ILRS website (AC and AAC application forms and Mission Support Request form)
    - Message on CDDIS (and EDC?) ftp sites
  - EDC has implemented data format integrity validation software
  - Analysis WG continues to work on development of ILRS standard products
  - NERC assisting in screening of data from stations
  - ILRS data centers providing access to all SLR data files within 5 minutes of receipt
  - CDDIS plans to modify SLR data archive structure to coincide with operation of new server; new archive intended to be more user friendly
  - CRL reorganized into new organization: National Institute of Information and Communications Technology (NICT)

ILRS Network

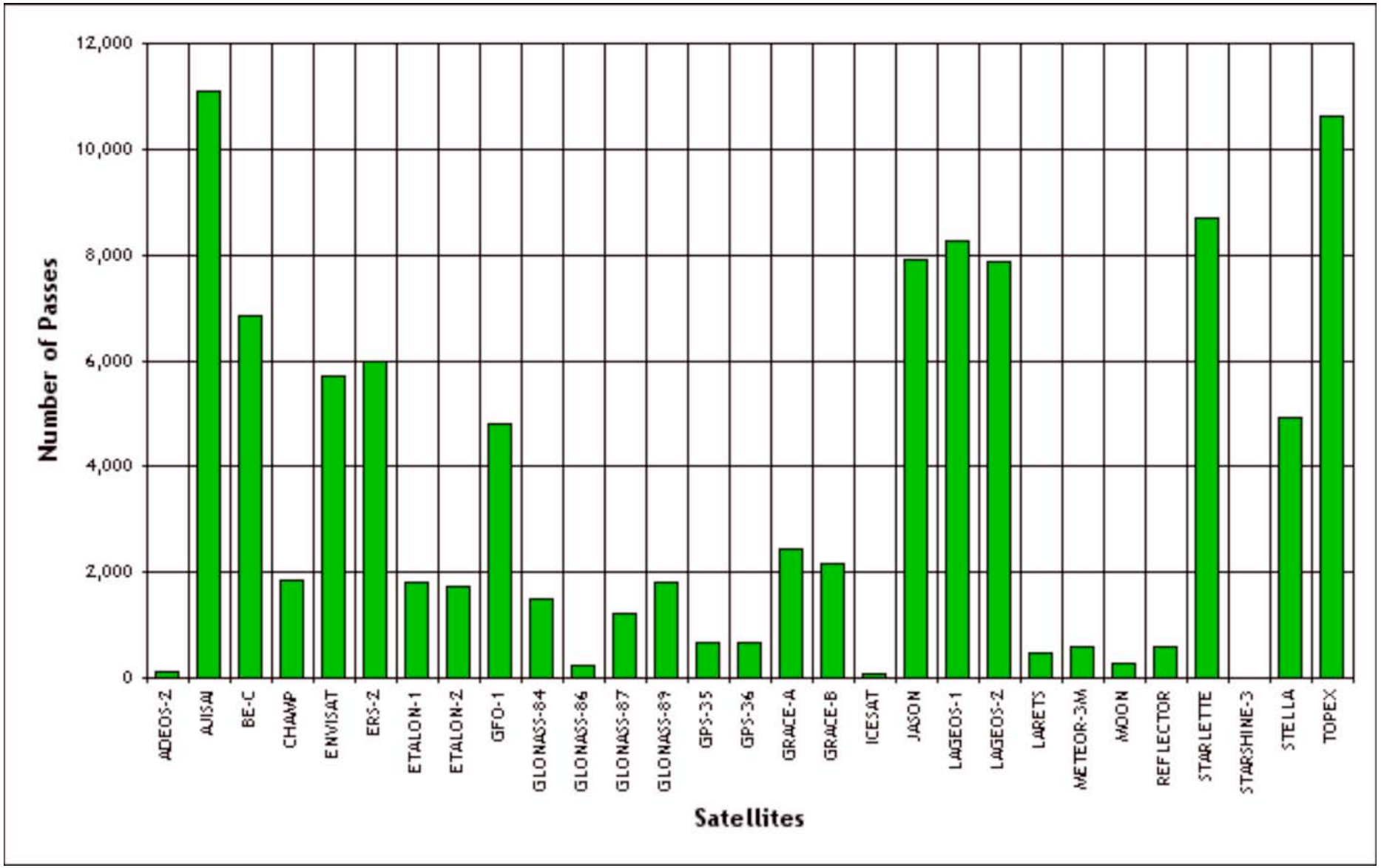


ILRS Station Qualifications

- Began January 1, 2004
- Requirements
  - Data Quantity
    - Within the past 12 months, 50 LAGEOS passes within a consecutive 3 month period
  - Data Quality
    - NP RMS: 1 cm
    - Short term stability: 4 cm
    - Percentage of Good Data: 80%
  - Operational Compliance
    - Completed Site Log
    - Collocated with GPS (grace period until July 1, 2004)

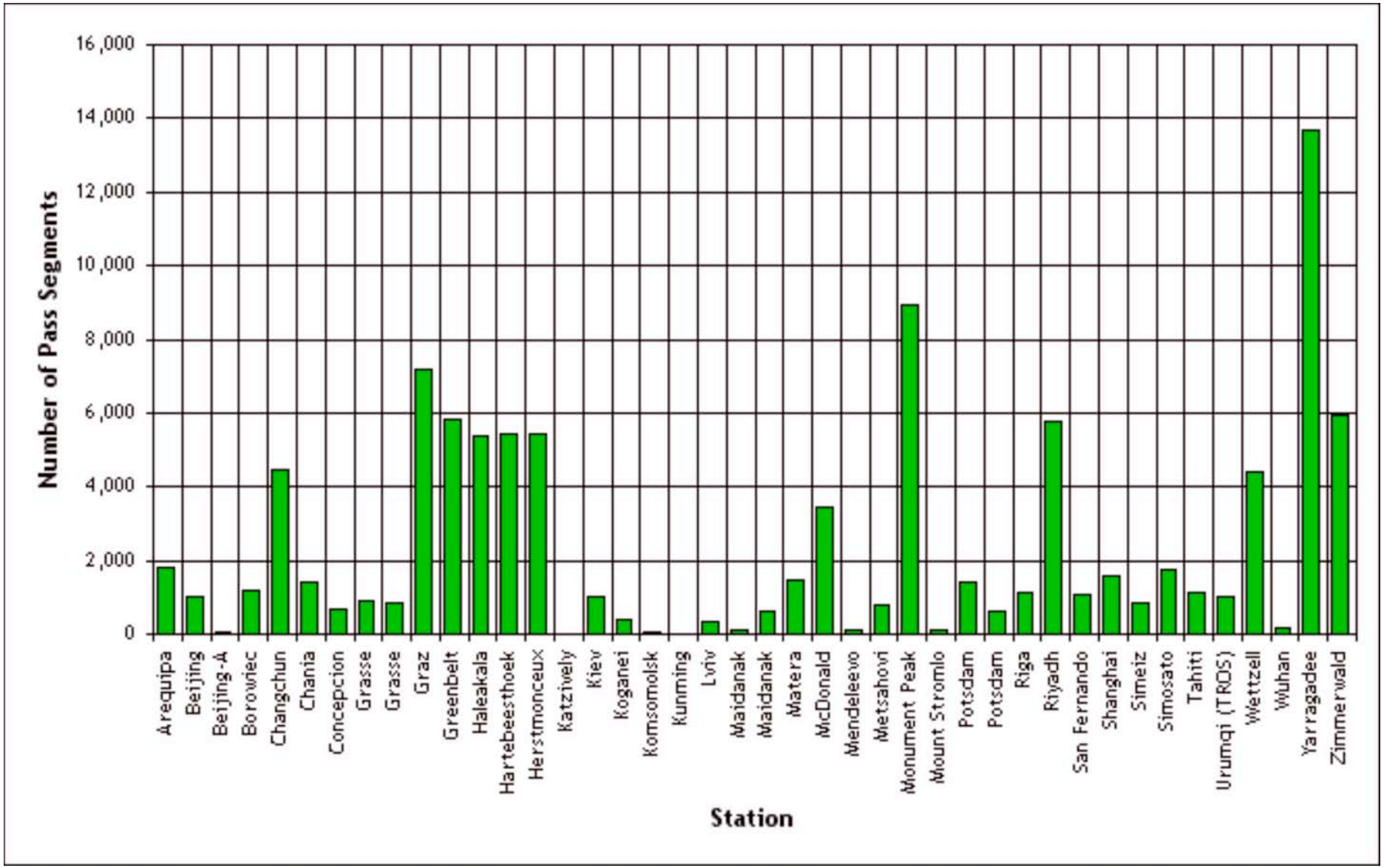
ILRS Tracking Statistics

(2003, by Satellite)



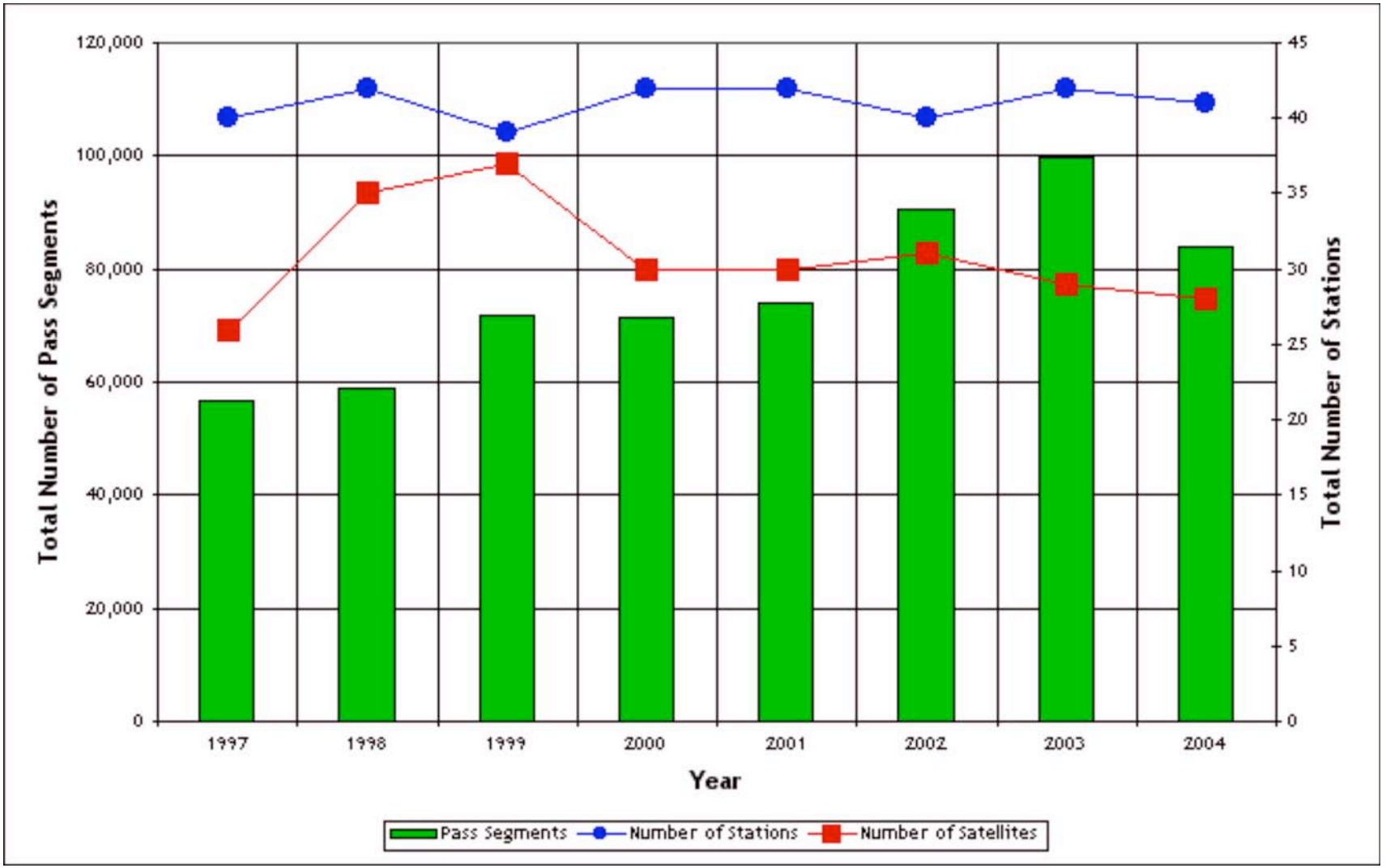
ILRS Tracking Statistics

(2003, by Station)



ILRS Tracking Statistics

(Total Pass Segments 1997-2004*)



Note: 2004 values are projected to end of year based on tracking totals from January 01 through May 31, 2004

ILRS Tracking Priorities

Priority	Mission	Sponsor	Altitude (km)	Inclination (degrees)	Comments
1	GP-B	NASA/Stanford U.	642	90	New mission
2	GRACE (A,B)	GFZ/JPL	485-500	89	Tandem mission
3	CHAMP	GFZ	429-474	87.27	
4	GFO-1	US Navy	790	108.0	Altimetry/no other tracking technique
5	Envisat	ESA	796	98.6	Tandem with ERS-2 tracking to commence 40 days after launch
6	ERS-2	ESA	800	98.6	Tandem with ENVISAT
7	Jason	NASA/CNES	1,350	66.0	Tandem with Topex*
8	TOPEX/Poseidon	NASA/CNES	1,350	66.0	Tandem with Jason*
9	Larets	IPIE	691	98.204	
10	Starlette	CNES	815-1,100	49.8	
11	Stella	CNES	815	98.6	
12	Meteor-3M	IPIE	1000	99.64	
13	Ajisai	NASDA	1,485	50	
14	LAGEOS-2	ASI/NASA	5625	52.6	
15	LAGEOS-1	NASA	5850	109.8	
16	Beacon-C	NASA	950-1300	41	Upgraded from campaign to ongoing mission (Jan-02)
17	Etalon-1	Russian Federation	19,100	65.3	Campaign extended to 01-Oct-02
18	Etalon-2	Russian Federation	19,100	65.2	Campaign extended to 01-Oct-02
19	GLONASS-89	Russian Federation	19,100	65	Replaced GLONASS-86 as of 20-Mar-03
20	GLONASS-87	Russian Federation	19,100	65	Replaced GLONASS-88 as of 20-Feb-02
21	GLONASS-84	Russian Federation	19,100	65	Replaced GLONASS-79 as of 22-Feb-01
22	GPS-35	US DoD	20,100	54.2	
23	GPS-36	US DoD	20,100	55.0	

ILRS Prediction Centers

	Prediction Center						
Satellite	**HTSI**	**GFZ**	**NERC**	**MCC**	**JAXA**	**ESOC**	**G926**
Current Missions							
Ajisai	Dy		My, Dy		Wy		
BE-C	Dy		Dy				
CHAMP		Dy3, SE, MM, DF					
Envisat	Dy					Dy	
ERS-2	Dy	Wy, SE, MM					
Etalon-1,-2	Dy		Dy				
GFO-1	Dy, MM		My, Dy				2/Wy
GLONASS	Dy		Dy, Dy4				
GPS-35, -36	Dy, MM		Dy, Dy4				
GRACE		Dy3, SE, MM, DF					
JASON & TOPEX	Dy, MM		My, Dy				
LAGEOS-1, -2	Dy		Dy		Wy		
Meteor-3M	Dy			Wy			3/Wy
Starlette, Stella	Dy		My, Dy				
Past Missions							
LRE					Wy		
Reflector	Dy			Dy			
Sunsat	Dy, MM		My, Dy				

Notes: Yy=yearly, My=monthly, Wy= weekly, Dy= daily, numbers following code indicate frequency
SE=SAO elements, MM=maneuver messages, DF=drag function

ILRS Annual Report Series

- 2002 ILRS Annual Report on web; hardcopy will be distributed shortly
- A combined report for 2003 and 2004 will be created
- Call for input to this 2003/2004 ILRS Annual Report to be issued in July 2004
- Contributions due to C. Noll by October 31, 2004
- Plans:
  - Longer report (like 1999, 2000, and 2001 reports)
  - Individual AC and AAC reports
  - Individual station reports

2003/2004 ILRS Annual Report

Outline

- Preface, Acknowledgements
- Introduction to the 2003/2004 ILRS Annual Report
- Chairperson's Remarks
- Sections
  - 1 – ILRS Organizations
  - 2 – ILRS Tracking Network
  - 3 – ILRS Missions and Campaigns
  - 4 – Infrastructure
  - 5 – Tracking Procedures and Data Flow
  - 6 – Emerging Technologies
  - 7 – Analysis Pilot Projects
  - 8 – Modeling
  - 9 – Science Coordination
  - 10 – Meetings and Reports
  - 11 – Bibliography
- Appendices
  - A – AC and AAC Reports
  - B – Station Reports
  - C – ILRS Information

ILRS Governing Board Elections

- ILRS Governing Board includes:
  - Three Ex Officio Members
    - President of IAG Commission I
    - Director of Central Bureau
    - Secretary of Central Bureau
  - Six appointed Network Representatives
    - EUROLAS (2)
    - NASA (2)
    - WPLTN (2)
  - One appointed IERS Representative
  - Six elected representatives from:
    - Analysis and Associate Analysis Centers (2)
    - Data Centers (1)
    - LLR community (1)
    - At-large (2)

Current ILRS Governing Board

- **Ex-Officio Members:**
  - President of IAG Commission I: Hermann Drewes
  - Director of Central Bureau: Mike Pearlman
  - Secretary of Central Bureau: Carey Noll
- **Appointed Network Representatives:**
  - EUROLAS: Giuseppe Bianco, Werner Gurtner
  - NASA: David Carter, Jan McGarry
  - WPLTN: Ben Greene, Hiroo Kunimori
- **Appointed IERS Representative:** Bob Schutz
- **Elected Representatives:**
  - Analysis Representatives: Graham Appleby, Ron Noomen
  - Data Center Representative: Wolfgang Seemueller
  - LLR Representative: Peter Shelus
  - At-Large Representatives: Georg Kirchner, Ulrich Schreiber

ILRS Governing Board Elections
(Continued)

- Elections conducted by ILRS Central Bureau Jul.-Oct. 2004
- Proposed schedule
  - Jul. 1: solicit representatives from IERS, EUROLAS, NASA, and WPLTN (due Jul. 30)
  - Aug. 2: solicit nominations for analysis center, data center, and LLR representatives (due Aug. 13)
  - Aug. 16: conduct elections for analysis center, data center, and LLR representatives (due Sep. 17)
  - Sep. 17: solicit nominations for at-large representatives (due Oct. 4)
  - Oct. 4: conduct elections for at-large representatives (due Oct. 15)

Upcoming Meetings

- ILRS General Assembly meetings held in spring
- ILRS meetings held in fall should be of a specialized nature (e.g., Koetzting workshop in October 2003)
- Fall 2004:
  - Topic?
  - Location?
  - Date?
- Meeting with newly elected ILRS Governing Board should be held in conjunction with this fall meeting
- April 25-29, 2005: Full complement of ILRS meetings at EGU in Vienna, Austria
- October 16-20, 2006: 15th International Workshop on Laser Ranging in Canberra, Australia

ILRS Science Coordinator Report

10th ILRS General Assembly
June 11, 2004
San Fernando, Spain

SLR Science

A short list, not comprehensive:

- **Fundamental contribution to the definition of the Earth's reference frame and scale *(ITRF, IERS, GGOS)*.**
- **Extremely important to the determination of long wavelength static and time-varying Earth gravity and tides.**
- **Significant contributions to relativity and Lunar Science.**
- **An important part of orbit determination, calibration, and validation of altimetry satellites (*perhaps for non-Earth missions)*.**
- **Useful "judge" of orbit determination by other tracking technologies (*e.g. GPS*).**
- **Rescued missions with failed space-segment tracking. (*GFO and Meteor-3*)**

SLR Science

So . . .

Keep producing the excellent data pushing toward the (sub?) millimeter level.

SLR Science

A quick reminder:

Send citations for engineering and science publications to the Central Bureau.

Remember to credit the ILRS in publications.

ILRS Working Group Reports

10th ILRS General Assembly
June 11, 2004
San Fernando, Spain

ILRS AWG

R. Noomen

14th International Laser Ranging Workshop

San Fernando, Spain

7-11 June 2004

“POS + EOP” Pilot Project

- Under development since about 1999
  - Initial organizational meeting in Florence
- Proposed Products
  - EOP’s (x-pole, y-pole, LOD)
  - Station Coordinates

Customers

- IERS Bulletin A
- IERS Combination Pilot Project

Current Status

- 7-Day period for accumulating data sets
- Use of LAGEOS 1/2 and ETALON 1/2 data
- Contributing Analysis Centers
  - ASI, DGFI, GFZ, JCET, NSGF
- Products
  - 1-day EOP's (x-pole, y-pole, LOD)
  - Network Coordinates at Central Epoch

AWG Meeting - 5 June 2004

- ASI: Official Primary ILRS Combination Center
- DGFI: Official Back-up ILRS Combination Center
- MCC: ILRS Combination Center in Development
- Effective as of June 1, 2004
- Re-evaluation in October 2006

Missions Working Group Report to GA

ILRS Missions Working Group

San Ferunando , Spain

June 11, 2004

Summary

- **MWG membership coordinator: David Carter (NASA)**
- **Past and Current Activity Since Last Meeting (October 2002 - Washington)**
  - **Mission Status**
    - **Icesat, GP-B by Peter-Shelus**
    - **ALOS, ETS-VIII, by H.Kunimori**
    - **Other satellites information addressed in workshop papers**
  - **Time-restricted operation**
- **Continuing Actions**
  - **Work with satellite organizations to get Mission Request Forms and Support Plans completed and put on Web – ongoing / Mission/Satellite Data Base for Satellite Signature Study/ COM information**
  - **Satellite Tracking Priority List and Dynamic priorities**
- **Upcoming Missions ***
  - **Cryosat (2004 –)**
  - **ALOS (2005)**
  - **ETS-VIII (2006-)**

  *** Mission Tracking Request former**
- **Other Mission News**
- **Other Issues**

ILRS

Summary

NEWG

San Fernando, 2004-06-06, 10:00 – 11:00

- Engineering Data File / EDF
- Daylight Tracking for ALL Stations
- kHz SLR
- NP Checks, Segments vs. Passes etc.

ILRS

EDF

NEWG

- CAL File Data available from: Riga, Potsdam, Graz, RGO, ???
- Infos available at http://www.astr.lu.lv/edf :
  - EDF creation support packages; scripts; examples etc.
  - Link will be added on ILRS Home Page;
- Graz will implement automatic XML CAL File Creation and Upload within next few weeks;
- About 5 other stations expressed interest to join;
  - Will then get all info necessary to start with;
  - Should be easy to implement ….

ILRS

Daylight Tracking

NEWG

- Still missing a number of good stations during daylight …
- Work is going on in many of them for daylight;
- We think it is very important; so:
  - Assistance will be given;
  - Hope that more daylight stations available next year (Shanghai, Beijing, Changchun, ???)

ILRS

kHz Meeting

NEWG

- A small, technical meeting for kHz SLR planned;
- Will be in Graz, October or November 2004; 1-2 days;
- Goal: To have more kHz stations as soon as possible
  - Small (10-20 participants);
  - Details, problems, solutions, assistance, ???

ILRS

NP Issues

NEWG

- A poll for all stations during next weeks:
  - Who is doing which checks on NPS before sending;
  - How are you forming NPs;
- A comparison / check on NP formation is planned;

- Discussion about counting of
  - Number of Passes
  - Or Segments of data
  - Or Minutes of data ???

- YOU SEE: WE ARE BUSY !

NATURAL ENVIRONMENT RESEARCH COUNCIL

NiCT

Signal Processing Working Group Meeting

San Fernando, Spain

Sunday 6th June 2004

Agenda

- **CoM Issues:**
  Request to stations to do variable energy experiments –
  Response and future

- **Laser Array info on ILRS website - xyz of phase centers - update;**

- **Spacecraft Attitude algorithms - status.**

CoM issues (precise geodesy)

- Community (reasonable) expectation is that there exist accurate CoM values for LAGEOS for the main ILRS stations;
- SPWG members have looked at theoretical calculation of values, as functions of detector (MCP, (C)-SPAD), return energy level and particular satellite (Otsubo&Appleby, 2003).
- Message is that for LAGEOS, for **single-photon detectors at single photon return level**, we can model precise CoM correction value.
- For MCP systems, the CoM value is more problematic to compute. Good working-estimate is the ground-based value of 251mm.
- To quantify energy-level effects, SPWG asked ILRS stations to perform some high-low tests for LAGEOS, ENVISAT and AJISAI.
- Ongoing, but some results presented at LW14:
  - Maybe sub-mm level effects at YARR MCP on LAGEOS
  - mm-level effects in C-SPAD stations, if stray from single photons.

Laser Array info on ILRS website

- SPWG gathering info to make and maintain comprehensive collection of data: see current webpage (in collaboration with Mark Torrence)
- Recommend to MWG that all new missions wishing to have ILRS support make that info available via the mission request form.

Documents

- Spacecraft Attitude algorithms for active satellites – gathering reports to reference via ILRS website.

ILRS Data Formats and Procedures Working Group Meeting
June 07, 2004, San Fernando/Spain

Attendees: Werner Gurtner, Stefan Riepl, Maury Dube, David Carter, Jan McGarry, Julie Horvath, Mark Davis, Bud Donavan, Randy Ricklefs, John Luck, Chris Moore, Mike Pearlman, Wolfgang Seemüller

Agenda:
1. Welcome and Introduction
2. Membership
3. Review of CB Activities
4. Refraction Study Group Report
5. Format Study Group Report
6. Full-Rate data delivery
7. Filenaming and directory change at CDDIS
8. Normal Point data format and integrity check
9. Pass list format for gravity Probe – B
10. More frequent ONP data exchange?
11. Urgent Mail/Prediction Exploder satisfying?
12. Working Group Charter/WG Activities

1. Welcome and Introduction

W. Seemüller welcomed the attendees, and gave short remarks about the work done since the last Working Group meeting in Nice, April 2003.

2. Membership

Roger Wood has retired and is withdrawn from the list of WG members. Thanks to him for his excellent work done in this group. Maury Dube was added to the membership list.

3. Review of CB Activities

Mike Pearlman gave a short report on the activities of the Central Bureau. He reports that SLR is not getting proper recognition in papers and reports that are being issued by the analysis and science community. A notification should be put on the ILRS web site and at the EDC web page too. The Station Qualification procedure has been implemented. The recent NASA budget reduction result in closure of the SLR stations Arequipa and Maui, and cutbacks for stations Monument Peak and McDonald. Concerning the satellite predictions some duplications occur. CB will prepare a list of recommended prediction sets. The formerly report cards were produced by Van Husson, who is not working anymore for the ILRS. This work will be replaced by RITSS soon.

4. Refraction Study Group and 5. Format Study Group

The most important work is done in these two Study Groups of the DF&P WG.
See the two special reports by the chairs of these Study Groups Stefan Riepl and Randy Ricklefs.

6. Full-Rate data delivery

Still some problems are existing with some SLR stations due to format, filenaming and delivery errors. Automatic archiving and handling is problematic therefore.

AI: E-mail to the corresponding stations

7. Filenaming and directory change at CDDIS (and EDC)

Carey Noll and Maury Dube presented a poster in San Fernando about these changes. The changes have to be fitted to requests of the ACs

8. Normal point data format and integrity check

Wolfgang Seemueller reports about the normal point data format and integrity check at EDC. It is implemented, and the program and a description is put to the ftp server at EDC/DGFI.

9. Pass list format for Gravity Probe - B

A first format description of the pass list for Gravity Probe – B was given by Werner Gurtner. The final format will be available soon. A similar pass list is necessary for problematic satellites due to damages of other satellite equipments (e.g. ICESAT).

10. More frequent ONP data exchange

The same exchange frequency of ONP data should be at both Global ILRS Data Centers CDDIS and EDC. Wolfgang Seemüller will make the correspondent arrangements for coordination of the equal data exchange at both centers.

11. Urgent Mail/Prediction Exploder satisfying?

After the transition of the Prediction Exploder from CDDIS/HTSI to EDC nobody is blaming, so all seem to be satisfied. No comments were given.

12. Working Group Charter/WG Activities

No changes

Finally our former chair of the DF&P WG John Luck presented his research about the multi-colour normal point generation. He was asked to formulate a recommendation about this item (see attachment). The recommendation is under review by the members of the DF&P WG. Additionally he formulates a workshop resolution (see attachment). Thanks to John for his excellent work.

RECOMMENDATION
From : DATA FORMATS AND PROCEDURES WORKING GROUP
To : ILRS Central Bureau
On: The 1997 ILRS Normal Point (NP) Algorithm

Considering that:
Item (1) of the published algorithm reads:
"Use high precision predictions to generate prediction residuals $PR_j = O_j - P_j$ where j indexes all returns in the pass . ."; and that:
Item (3) of the published algorithm reads:
"Solve for a set of parameters . . . to remove the systematic trends of the prediction residuals, giving the trend function f(PR); and that:
Item (4) of the published algorithm reads:
"Compute fit residuals $FR_j = PR_j - f(PR_j)$ and omit outliers"; and

Noting that:
inappropriate interpolation methods can introduce serious errors in the predictions P_j and therefore in the prediction residuals PR_j leading to errors in Normal Points as great as one-third of the amplitude of the prediction error in any bin,

Recommends that :
1. Interpolations be performed on Cartesian X,Y,Z coordinates, not on azimuth, elevation and range, at each instant of observation. Geocentric X,Y,Z is preferable, but topocentric X,Y,Z (e.g. East, North, Up) is adequate; and
2. The tabular interval used as the basis of interpolations be no larger than the intervals for each satellite recommended by ILRS for its new predictions format, and that orbit integrator step sizes which produce the tabular points for interpolation be no greater than these intervals; and
3. Such tabular intervals be less than the ILRS Normal Point bin sizes; and
4. The interpolation mechanism be at least Lagrangian of order 8 or equivalent (8-point, i.e. degree 7). In particular, cubic splines should never be used; and/or
5. Alternatively, separate trend functions in each NP bin may be computed from observations accepted in steps (3) and (4), from which new fit residuals FR_j are computed for the generation of the Normal Point. Such separate trend functions need only be of low order, e.g. quadratic; and
6. Each station and Operations Centre rigorously examines its own software and ensures that it complies with this recommendation; and
7. Any station that amends its NP generation software to accord with this Recommendation must update its System Change Indicator as of the date of implementation; and
8. The ILRS Central Bureau updates the NP Algorithm document forthwith.

Reference:
http://ilrs.gsfc.nasa.gov/products_formats_procedures/normal_point/np_algo.html

JMcKL, 10 June 2004
Item 7 added 19 June 2004

14th INTERNATIONAL WORKSHOP ON LASER RANGING

San Fernando, Spain, 7-11 June 2004

WORKSHOP RESOLUTION

The 14th International Workshop on Laser Ranging,

- Recognizing that inappropriate interpolation methods into tables of range predictions can introduce significant errors in Normal Point values which may behave as unidentifiable random errors; and that inappropriate interpolation methods into tables of pointing predictions can produce substantial tracking errors leading to unnecessary loss of data; and
- Considering that software for Normal Point generation and for telescope pointing at some stations might still employ such inappropriate interpolation methods as legacies from bygone days when the errors were viewed as less important,
- Implores the people responsible for maintaining operational software at or for each and every ILRS station to examine the interpolation schemes employed for Normal Point generation and for tracking predictions, and to adopt the Recommendation dated 10 June 2004 from the Data Formats and Procedures Working Group to the ILRS Central Bureau.

JMcKL, 19 June 2004

Prediction Formats Study Group

R. Ricklefs, The University of Texas at Austin
For the ILRS Prediction Format Study Group

Introduction

- Consolidated Prediction Format provides method of ranging to disparate targets using one format
- Allows cross-technique ranging attempts
- Does not rely on on-site gravity model, tuning, or separate drag and time bias functions
- Tabular format contains un-tuned state vectors at appropriate intervals
- Typically in true body fixed system of date

Status

- Format is stable except for more obscure fields
- MLRS field tests have begun
  - Data has been acquired on 4 slr passes using the HTSI-derived predictions
  - NSGF predicts are being evaluated
  - LLR changes and predictions are in place awaiting tests

Status - 2

- Transponder predictions tested via simulations
- Additional field tests planned
  - NERC SGF
  - EOS/Mt. Stromlo
- New Format and sample code being worked

Campaign and Mission Reports

10th ILRS General Assembly
June 11, 2004
San Fernando, Spain

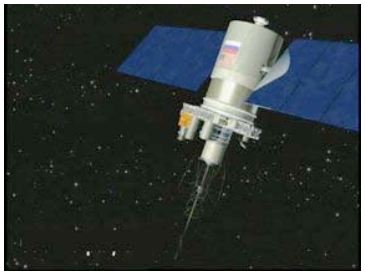
ILRS Mission Support

ILRS Central Bureau
NASA GSFC, Greenbelt, MD USA
cb@ilrs.gsfc.nasa.gov

Meteor-3M

- SAGE III/Meteor3m is a joint partnership of NASA and RASA
- Payload is SAGE III; measures temperature and humidity profiles and Earth Surface Properties (need good along-track orbit accuracy)
- Orbits NEED to be good to 500 meters along track
  - Benefits from improvement to 10s of meters
  - On board GPS receiver failed
  - SLR tracking has saved the mission
- Achievements:
  - Has extended the climate record of ozone aerosol and NO2 profile
  - Ground breaking measurements of NO3 from limb sounding
  - Preparation for next generation ozone monitoring (NPOES)
- SLR Tracking:
  - Has saved mission, but is often tracking is very sparse
  - Only a few stations track
    - Yaragadee (especially consistent)
    - Riyad, Herstmonceux, and Monument Peak

Image from: http://www-sage3.larc.nasa.gov/meteor-3m/

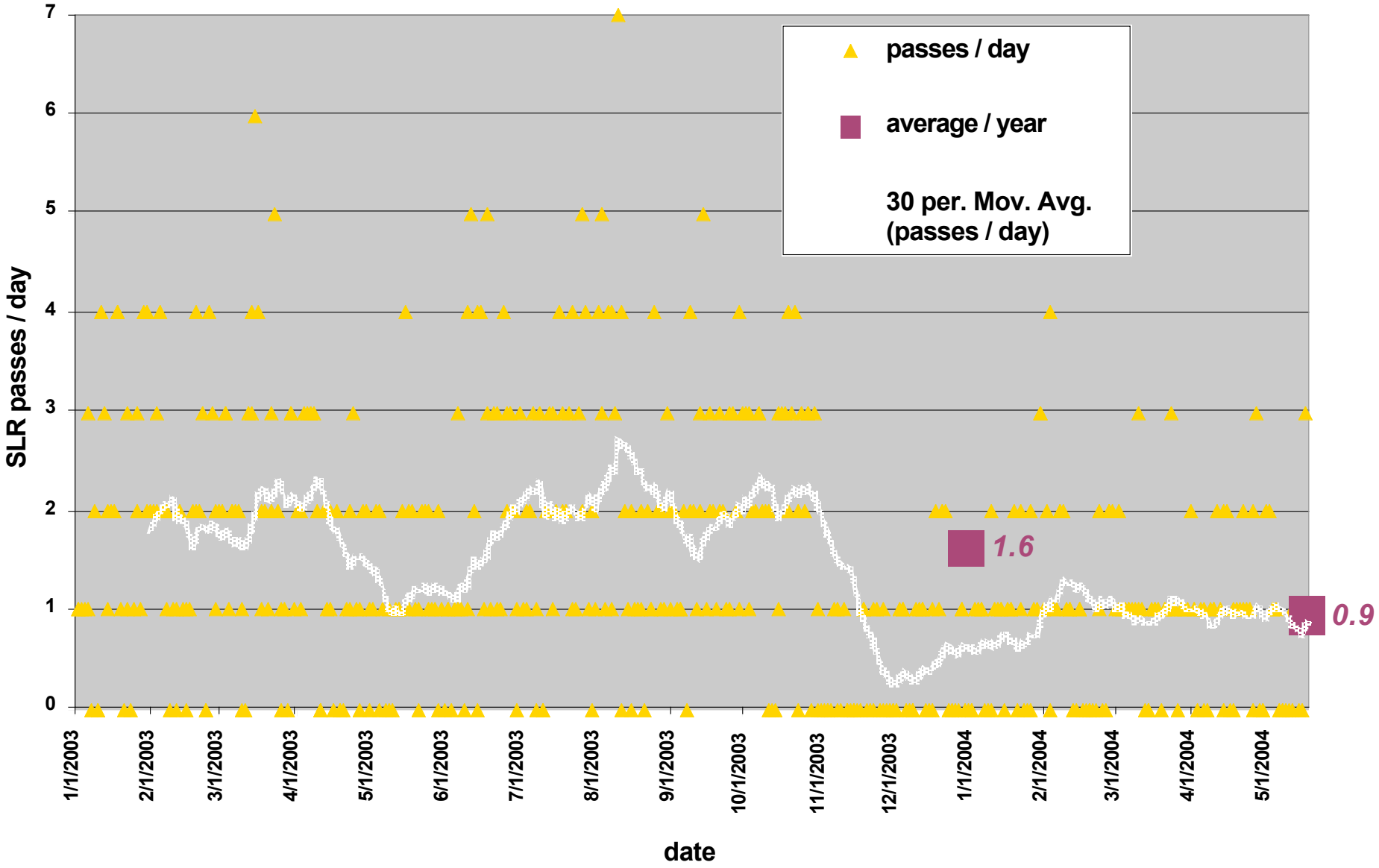


Meteor-3M Status

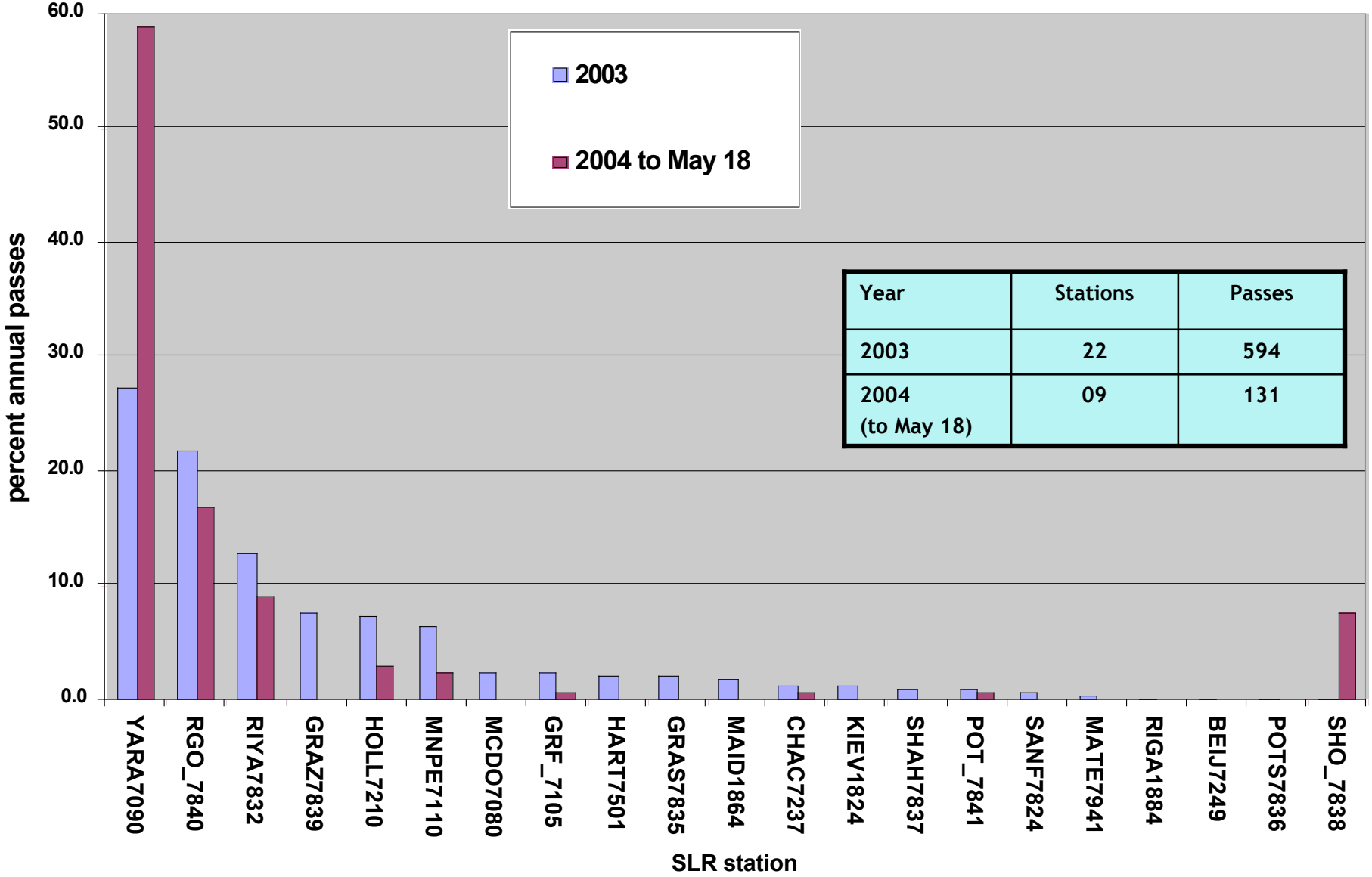
D. D. Rowlands, D. S. Chinn, F. G. Lemoine
NASA Goddard Space Flight Center

- Meteor-3m (with SAGE-III payload) is a joint partnership of NASA and RASA
- SAGE-III measures temperature and humidity profiles
- Meteor-3M mission continues normally (we have no information to the contrary). Precise orbits (good to 500 meters along-track) are required to support an experiment on the spacecraft from NASA/Langley.
- SLR tracking has saved mission since on-board GPS receiver failed
- Tracking of Meteor-3M has been sparse. In the past six months particularly, without the exceptional efforts of Yarragadee, Herstmonceux, and Riyad, we would not be able to compute the orbits for this spacecraft.
- Stations have reported problems obtaining successful returns. The returns are weak. Stations should treat the spacecraft as if it were a "high" satellite and apply appropriate filters. Night tracking has been more successful than daytime tracking.
- Tracking below 30 deg. elevation is not possible.
- GSFC Code 926 supplies predictions three times weekly. Please use these in conjunction with bias functions supplied by NERC. If at all possible, we would appreciate more tracking.

Meteor-3M (M3M)
SLR Tracking / Daily Passes



Meteor-3M (M3M) SLR Tracking by Station



Year	Stations	Passes
2003	22	594
2004 (to May 18)	09	131

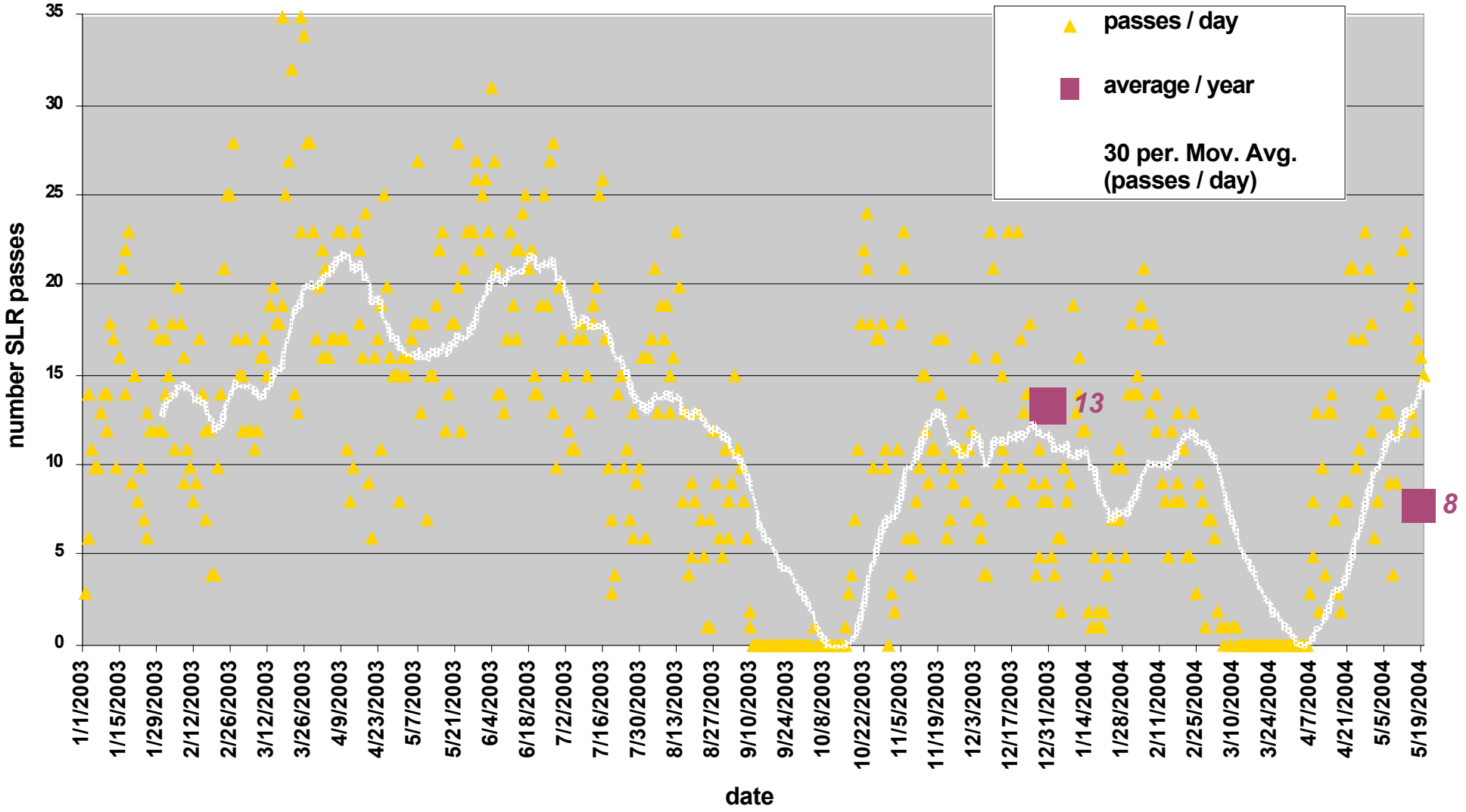
Image from: http://gfo.bmpcoe.org/Gfo/default.htm

GFO Status

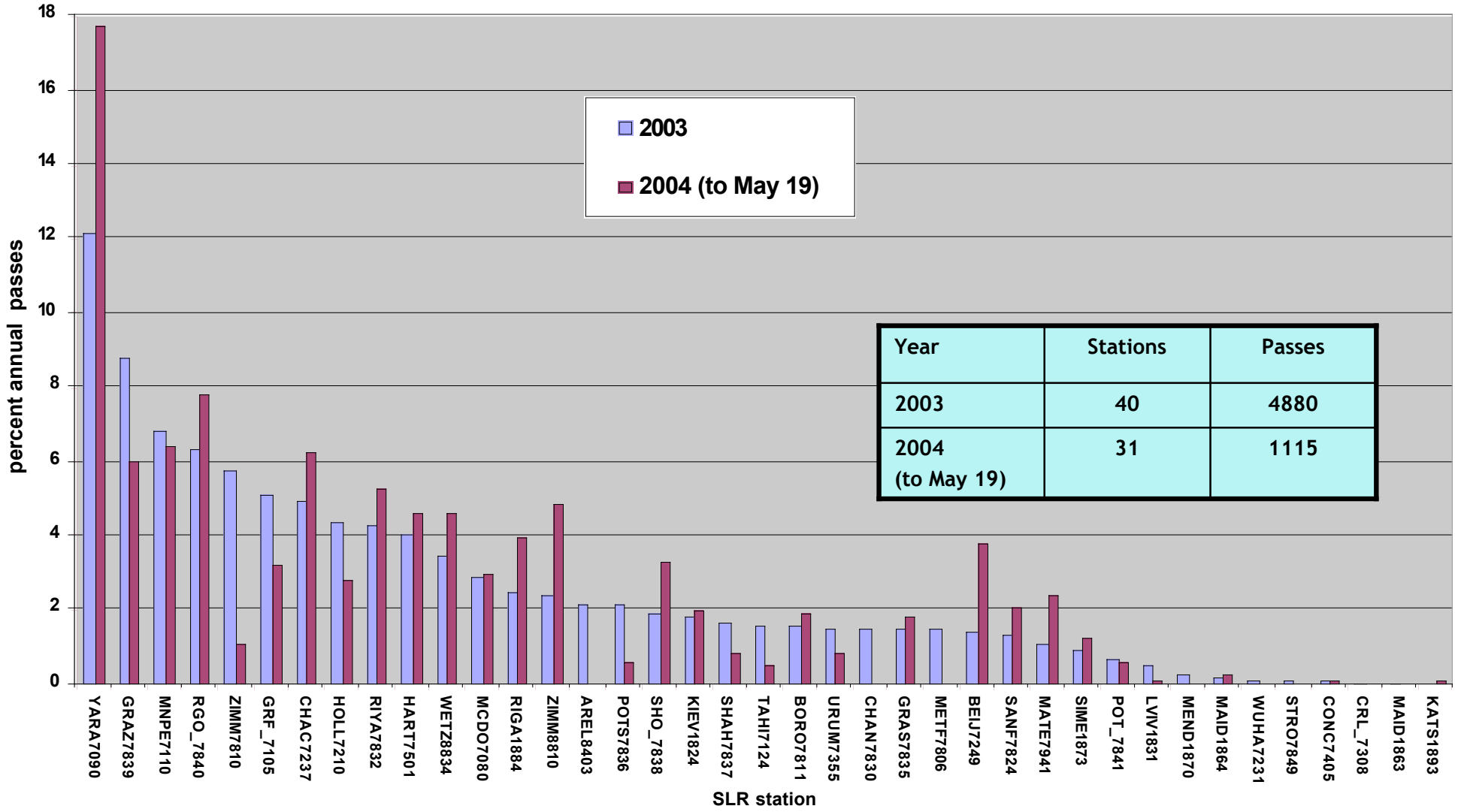
F. G. Lemoine, N. P. Zelensky, D. D. Rowlands
NASA Goddard Space Flight Center
June 2004

- GFO has exited solstice hiatus (Feb-April 2004) and normal operations have resumed.
- GSFC Code 926 now delivers tuned SLR predicts daily (since January 2004). [Thanks to Herstmonceux and Yarragadee for their help in refining our procedures].
- A new set of precise orbit ephemerides have been computed using a tuned CHAMP+GFO+other satellite geopotential model and will be delivered shortly to NOAA. Usable altimeter data now spans four years.
- Both the daily orbits (MOE's) and the precise orbits (POE's) depend heavily on SLR. Altimeter crossovers and Doppler are not enough! SLR continues to assure mission success. More tracking is encouraged.

GEOSAT Follow-On (GFO) SLR tracking / daily passes

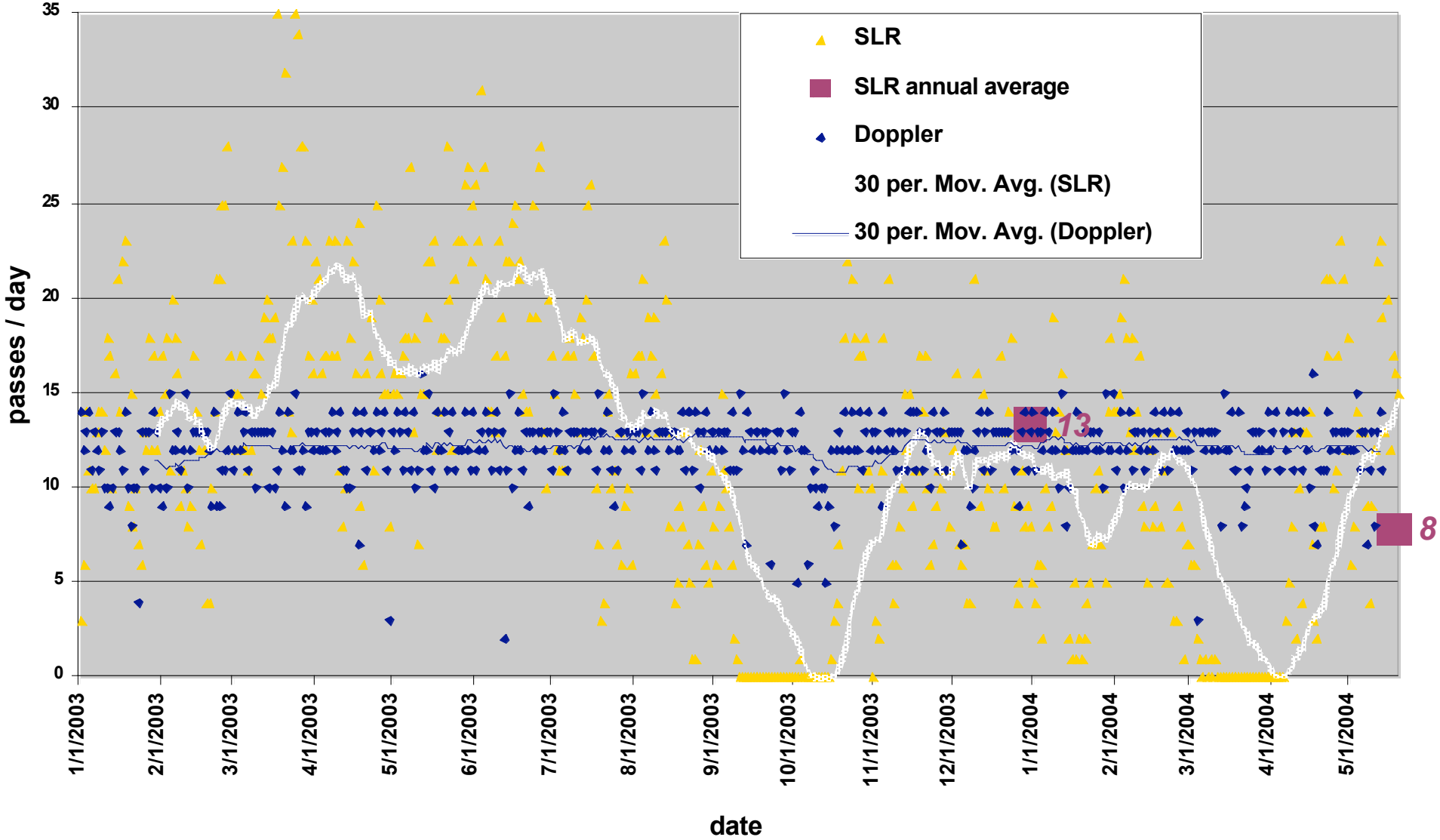


GEOSAT Follow-On (GFO) SLR Tracking by Station



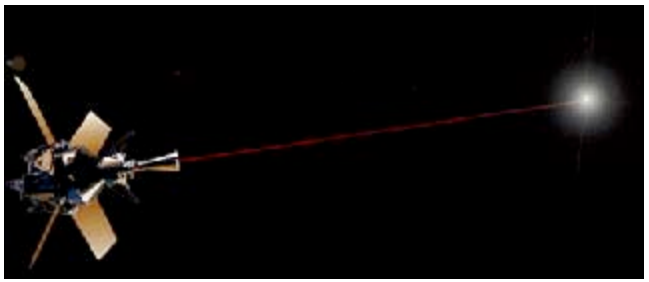
Year	Stations	Passes
2003	40	4880
2004 (to May 19)	31	1115

GEOSAT Follow-On (GFO) Tracking Data / Daily Passes

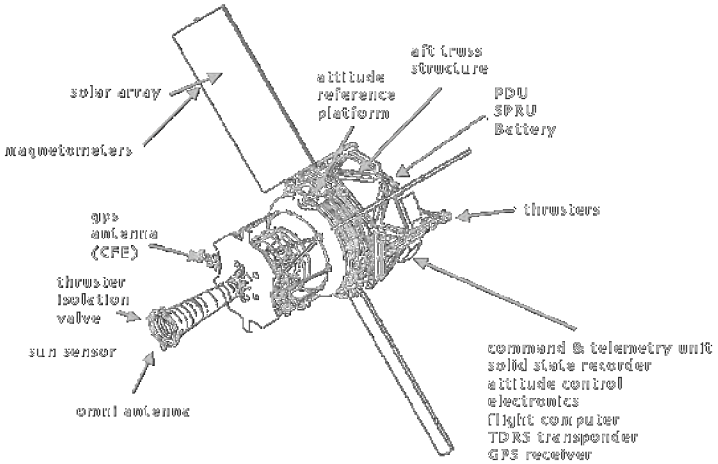


Gravity Probe B (GP-B)

- Launch on April 20 at 9:57:24 a.m. PDT
- Relativity gyroscope experiment developed by NASA and Stanford University to test two unverified predictions of Einstein's general theory of relativity
- Satellite consists of 4 gyroscopes, quartz telescope, GPS receiver, and retroreflector array
- 16 month mission; tracking will commence 5-6 weeks following launch
- Satellite tracking provided by GPS and SLR
- SLR predictions will be generated by two centers
- Project will generate station pass list distributed through normal prediction channels



Photos and background information from http://einstein.stanford.edu/



Engineering Test Satellite - VIII

(ETS-VIII, Future Mission)

- JAXA mission scheduled for launch winter 2004
- Communications experiment using cutting-edge, deployable antenna (largest in the world)
- High-precision clock for satellite positioning experiments; satellite orbits and clocks to be estimated in real-time
- 3 year mission
- Satellite tracking provided by GPS and SLR
- Array consists of 36 cubes, each 4.1 cm in diameter

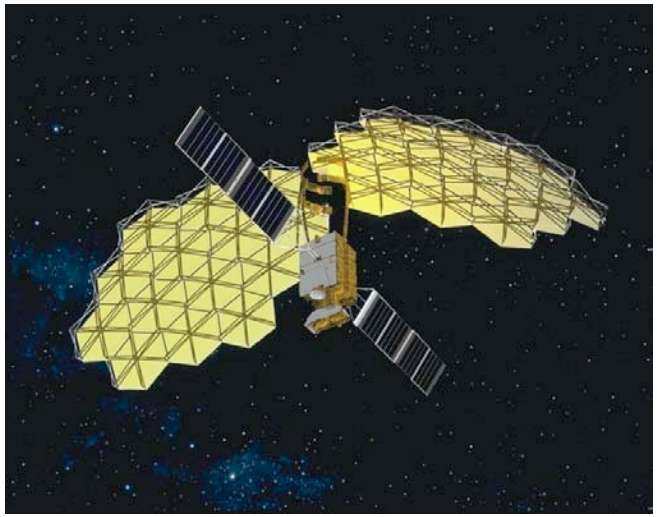


Photo and background information from http://god.tksc.jaxa.jp

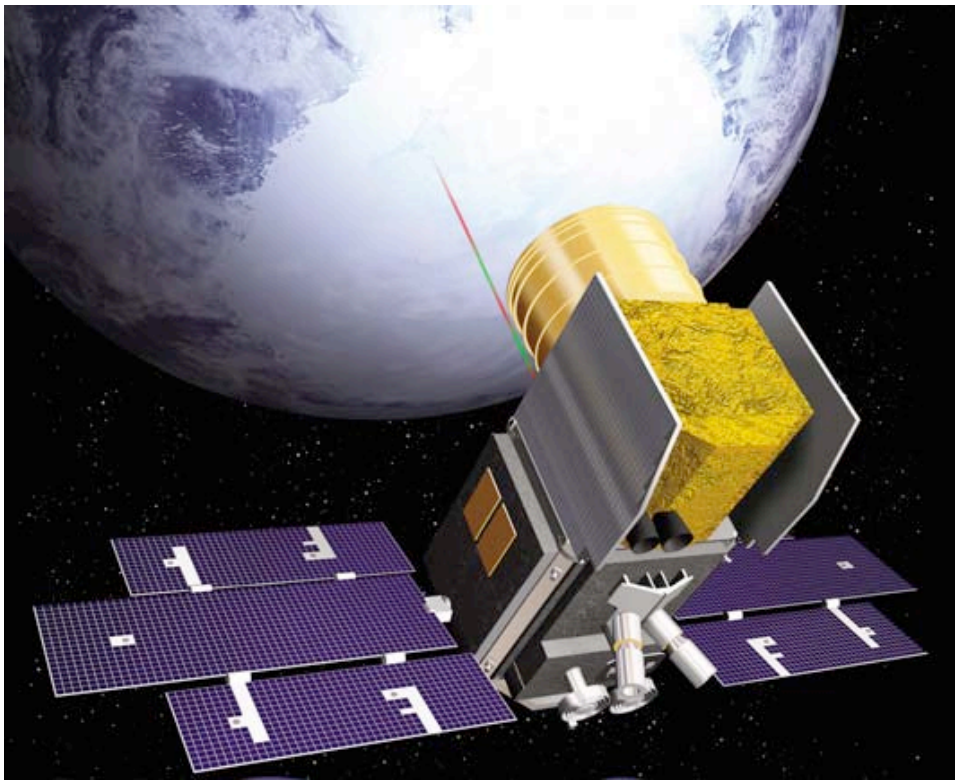
Advanced Land Observing Satellite

(ALOS, Future Mission)

- JAXA mission scheduled for launch Sept. 10, 2004
- Mission objectives:
  - Provide maps for Asia-Pacific region
  - Perform regional observations for "sustainable development"
  - Conduct disaster monitoring
  - Survey natural resources
  - Technology development for future missions
- 5 year mission
- Satellite tracking provided by GPS and SLR; SLR used for calibration of GPS positioning
- Array consists of an annulus of 9 retroreflectors located on body of satellite

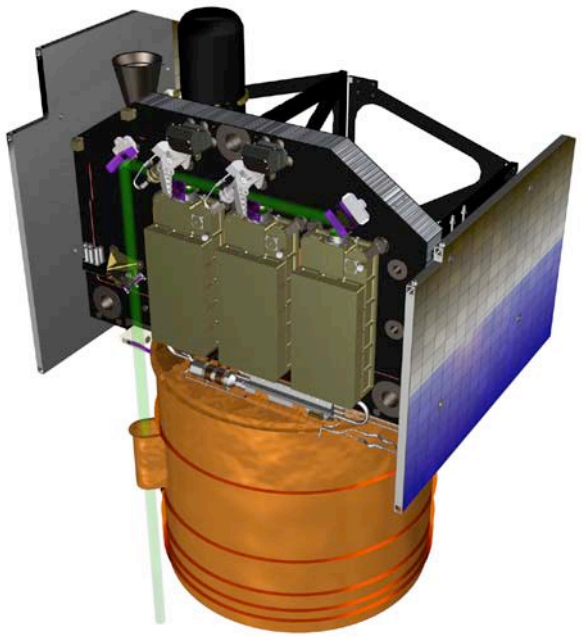
Photo and background information from http://god.tksc.jaxa.jp

ICESat



- NASA mission
- New geodetic tool to support multidisciplinary studies, including cyrosphere, atmosphere, hydrology
- ICESat operated in near repeat ground track
  - Orbit maneuvers ~ 8-10 days
  - Off-nadir pointing at reference ground track in polar regions

Geoscience Laser Altimeter System



- Three lasers to meet mission lifetime
- 1064 nm surface altimetry; 532 nm atmospheric backscatter
- Laser characteristics
  - Divergence illuminates ~70 meter spot on surface
  - 40 Hz pulse repetition rate
  - 170 meter spot separation
- Laser #1
  - 36 days in Feb-Mar 2003 (8-day repeat orbit; 4+ cycles completed)
- Laser #2
  - 56 days in Sept-Nov 2004
    - One 8-day repeat cycle
    - 48 days of 91-day repeat cycle
  - 33 days in Feb-Mar 2004 (91-day repeat)
  - 33 days started May 18 (91-day repeat)
- Laser #3
  - Operate in Fall 2004
- As of May 20, 2004:
  - 125 days of laser operation
  - 425 million laser shots
- SLR
  - measurements from: MLRS, GSFC, Zimmerwald
  - Tracking restrictions (track when elevation is <70°)

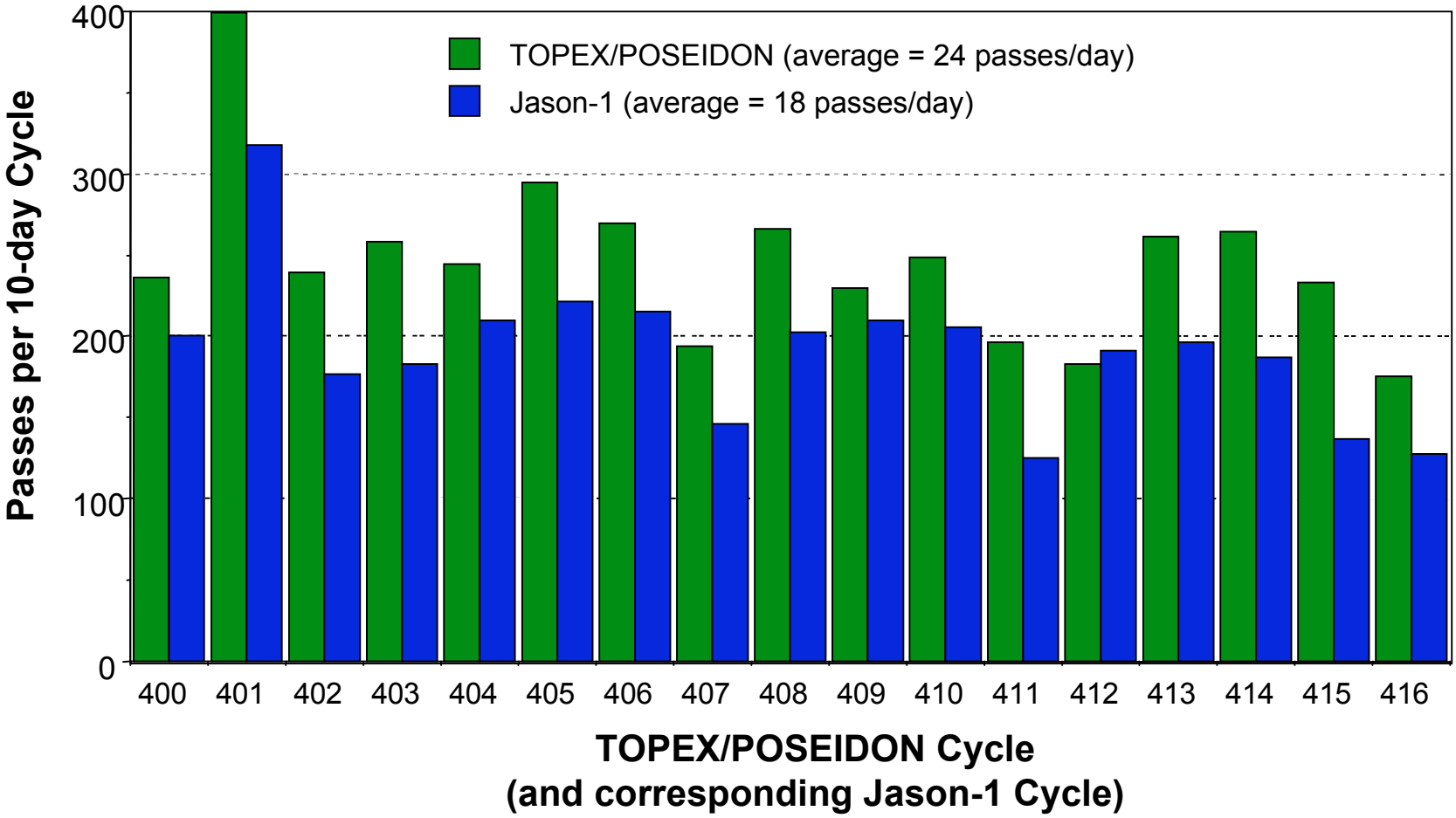
SLR Performance on TOPEX/Poseidon and Jason-1

- **Tracking of T/P and Jason-1 continues to meet mission goal of 15 good passes/day**

TOPEX/Poseidon		Jason-1	
Average number of passes/day	Fit RMS (mm)	Average number of passes/day	Fit RMS (mm)
24	22	18	17

- **Coverage is good in spite of close proximity of T/P and Jason-1**
  - **No significant change from previous report**
- **Tracking bias in favor of T/P likely due to much larger LRA**
  - **However, Jason-1 LRA design supports higher precision ranging**

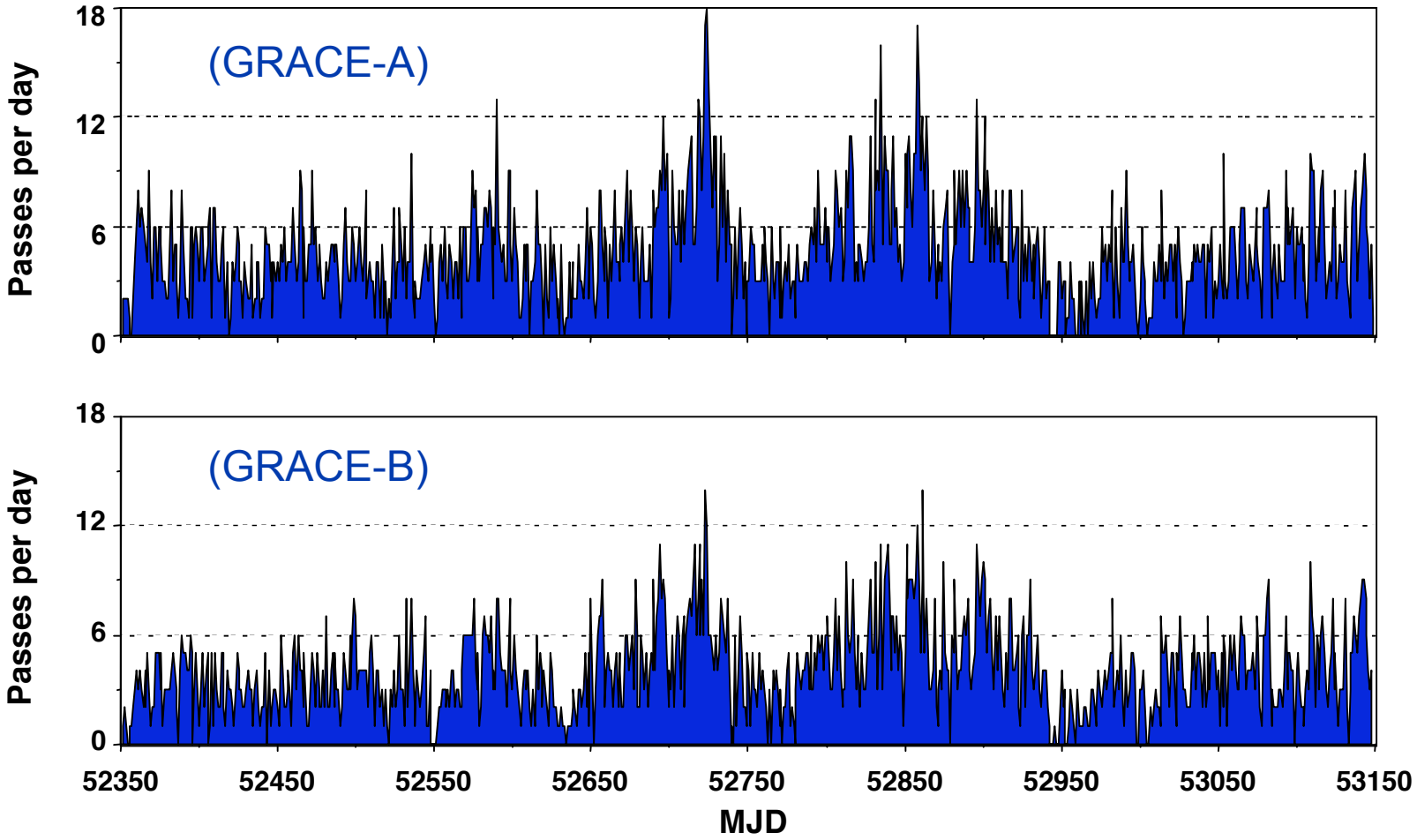
Most Recent SLR Tracking of T/P and Jason-1



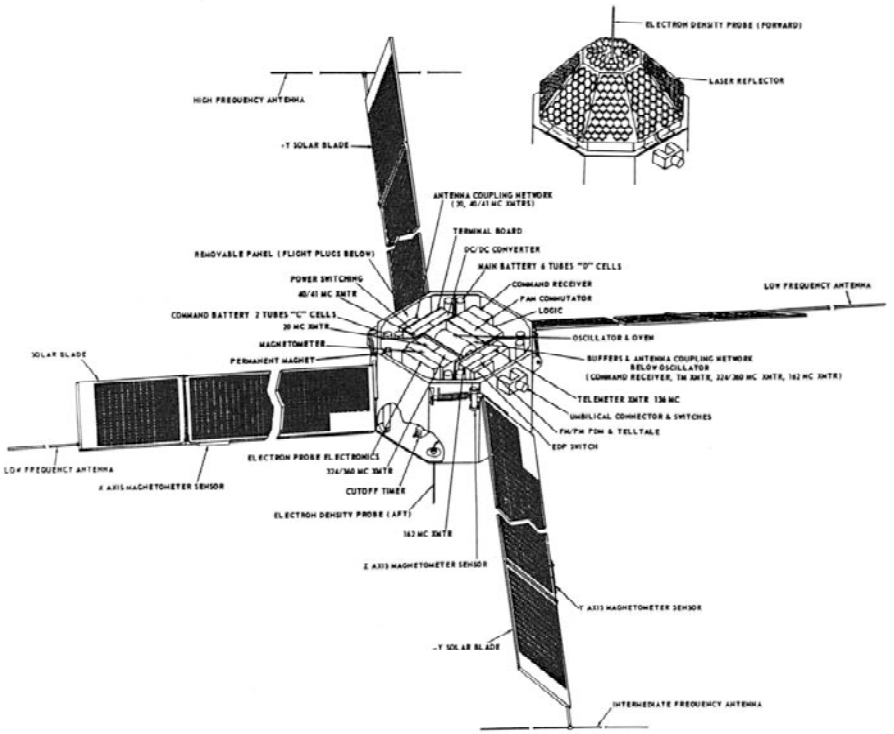
SLR Performance on GRACE

- GRACE-A and GRACE-B tracked ~4-5 times per day on average
  - GRACE-A tracked about 15% more often than GRACE-B
- 6-7 cm SLR RMS consistent with expected orbit error
    - Adequate for initial orbit quality assessment
- Z-bias in center-of-mass offset correction not fully resolved yet

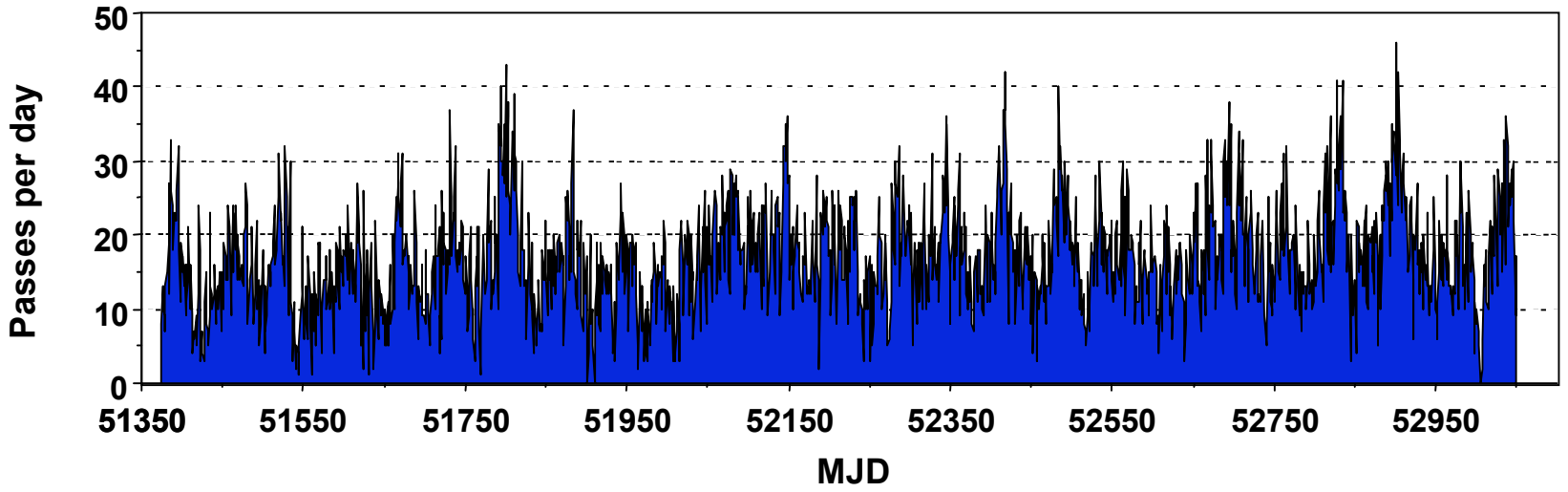
Gravity Recover and Climate Experiment (GRACE)



Beacon Explorer-C

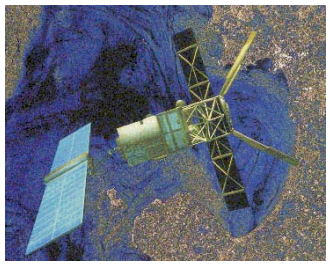


- BEC tracking used with Lageos-1 and 2, Starlette, Ajisai, and Stella for temporal gravity variability studies (Cheng et al., 2002)
- Average of 17 passes per day from 42 stations (after editing)
  - Weighted RMS of fit ~9.5 cm, ranging from 4 to 26 cm



Summary

- SLR remains a important component of radar altimeter satellite POD, for accurate orbit centering (when used for orbit determination) and radial orbit accuracy assessment
  - Tracking on T/P and Jason-1 remains adequate
- Long-term long-wavelength temporal gravity variations can only come from SLR tracking of geodetic satellites
  - GRACE will determine higher resolution gravity variations but only for the duration of its mission
- Orbit accuracy assessment is particularly critical for missions such as GRACE and ICESat where no other independent, absolute orbit error assessment is available
- GP-B will be first SLR-tracked fully drag-free satellite
  - Should provide interesting analysis opportunities



E R S - 2

Status SLR-Tracking ERS-2 Mission

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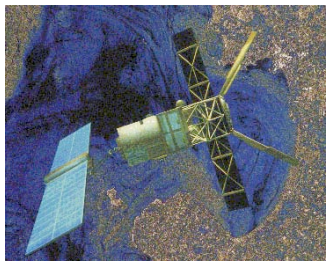


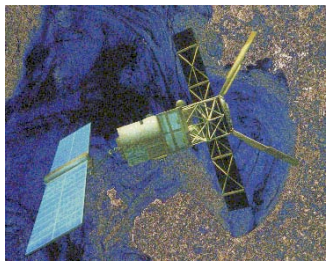
E R S - 2

Mission Status

- ERS-2 is now in orbit for more than 9.0 years and operating longer than ERS-1.
- In general the satellite and the payload are in good condition.
- ESA plans to operate ERS-2 throughout 2005 (funding till mid 2005).

Role of SLR

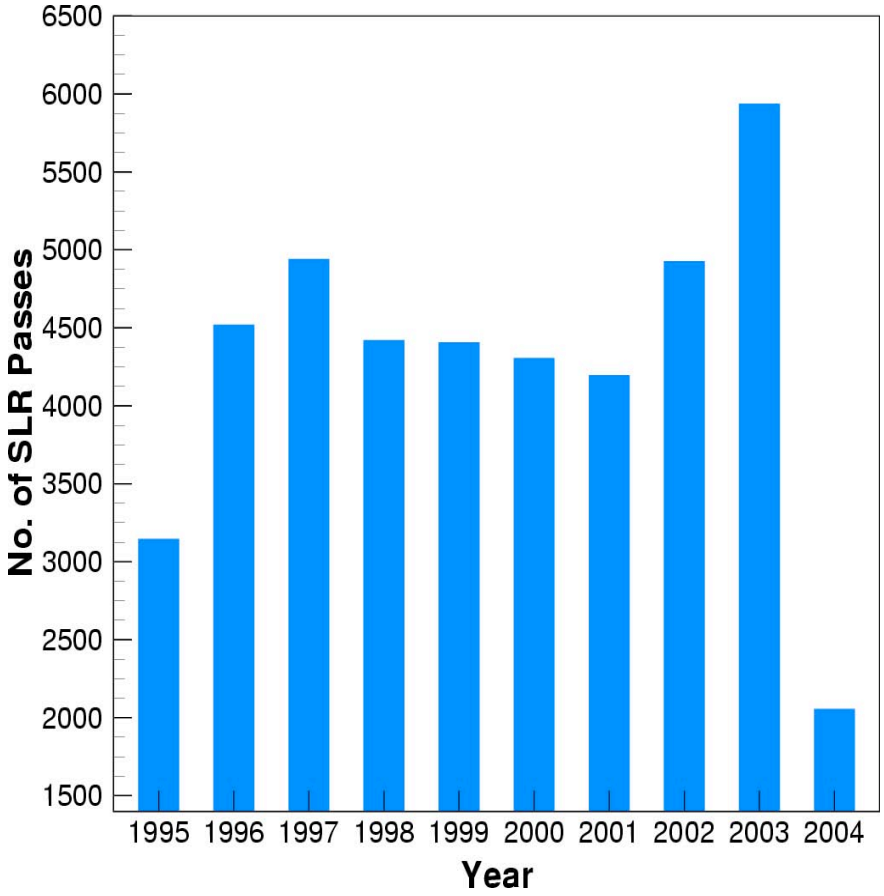
- SLR is the secondary tracking system, while PRARE is the primary one.
- Since 2003 the PRARE system is operated by GFZ on best effort basis due to stop of funding by DLR. This results in an increasing importance of SLR.
- Intensive ERS-2 SLR tracking will be required throughout 2005.

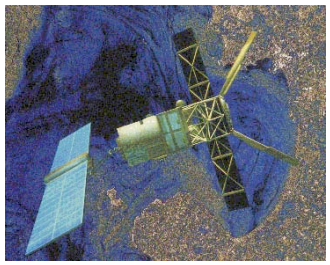


E R S - 2

SLR Data Quantity and Quality

- Since 2001 the SLR tracking steadily increased, 2001 showing the lowest, 2003 the best since start of the mission
- The data quality is in general very good
- Still sometimes large outliers when the normal point has been formed from one full-rate observation only





E R S - 2

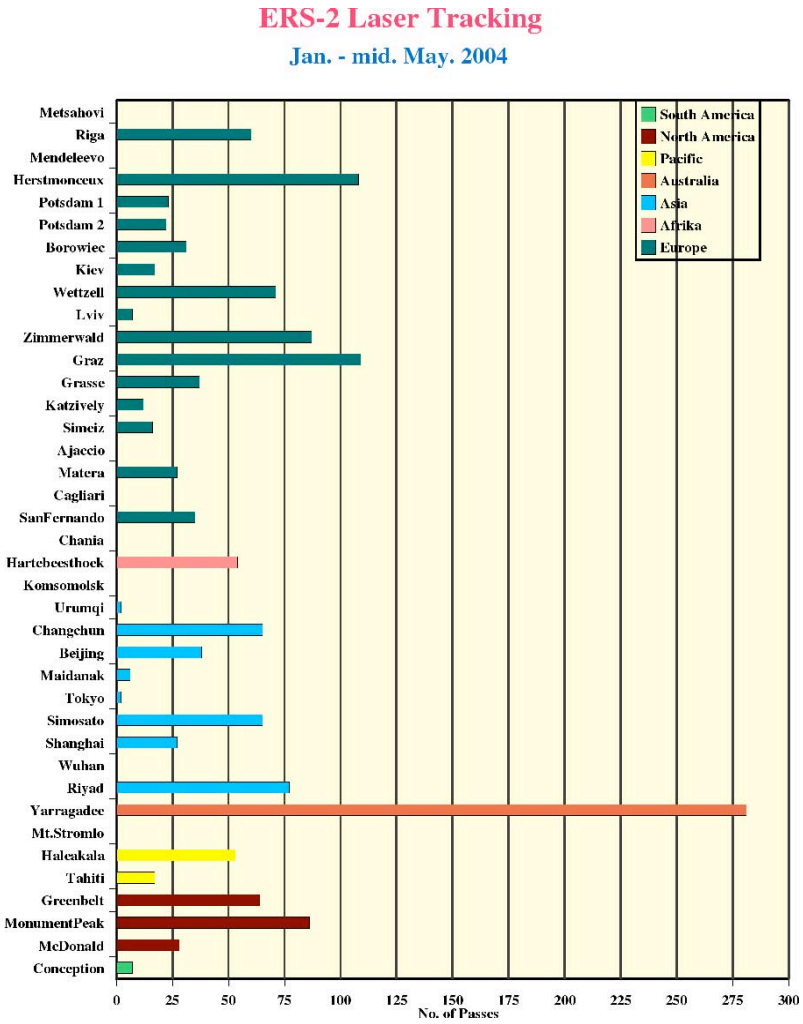
SLR Data Quantity and Results

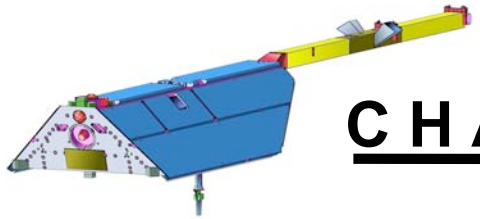
SLR Quantity per Station

- The contributions of the SLR stations are very different, depending on their hardware, weather etc.
- An outstanding contribution is provided by Yarragadee.

Results

- Routine usage for different precision orbit products (predictions, preliminary, precise)
- The orbit forms the basis for other analyses (geolocation, deformation analysis, sea surface and ice mass monitoring, gravity modelling)





CHAMP

Status SLR-Tracking CHAMP Mission

R. Schmidt, R. König, F.-H. Massmann, Ch. Ackermann, Ch. Reigber

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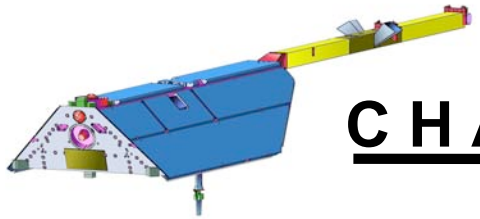


CHAMP

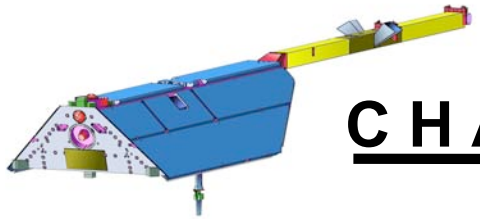
Status

- CHAMP is 1425 days in space on 09-May-2004. The satellite is an excellent condition. The scientific instruments - except the radial channel of the accelerometer - perform nominally. All scientific instruments are in almost continuous science data collection mode (> 98%). No aging effects visible.

- Continued computation of static long-wavelength gravity field (EIGEN models) based on data from the onboard GPS receiver and the precision accelerometer. Investigations of the temporal variability of the long-wavelength part of the gravity field are made from subset solutions and integrated solutions with GPS and SLR ground data. Intercomparison and combination of CHAMP-only and GRACE-only gravity models and combination with terrestrial gravity data .

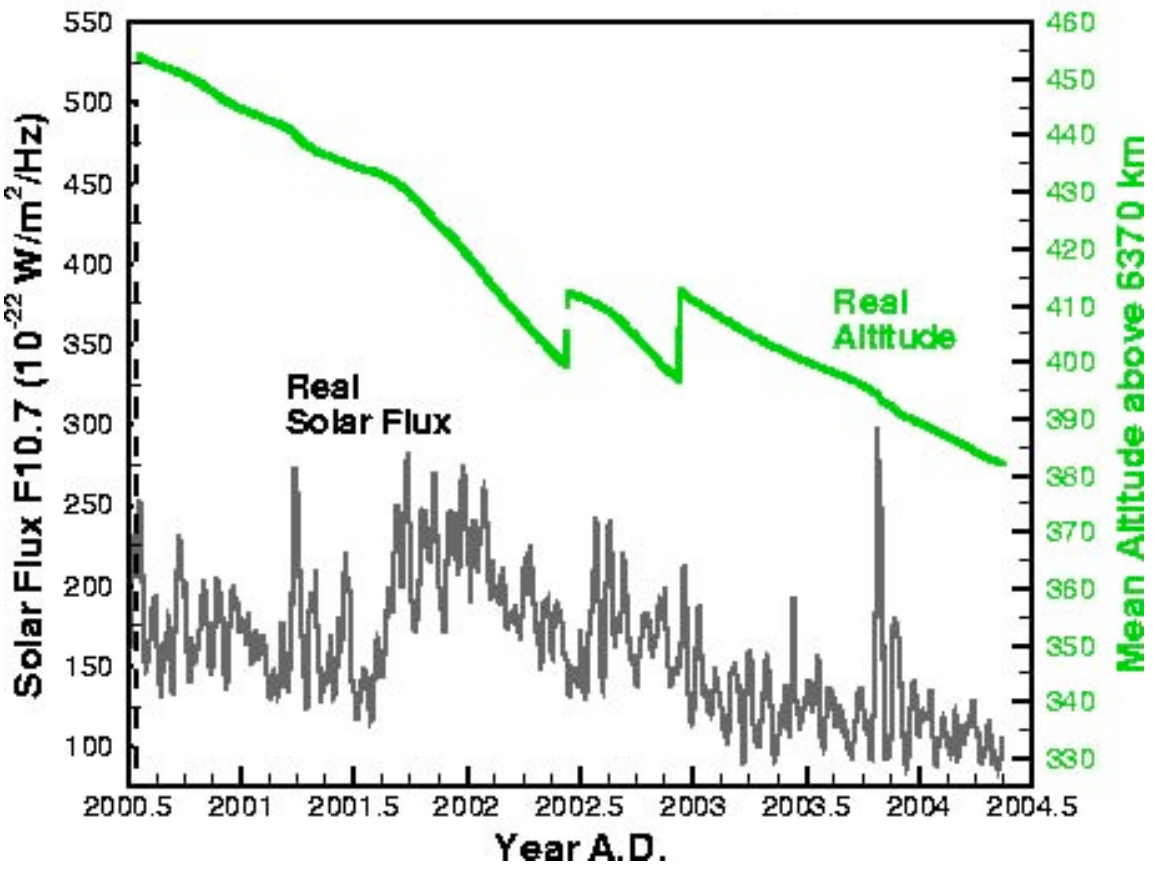
- Accurate globally distributed atmospheric profiles (temperature, humidity) are routinely generated from the GPS-SST data for numerical weather prediction.

- Based on the data from the magnetometer instruments onboard CHAMP accurate and homogeneous maps of the Earth‘s magnetic field are generated.

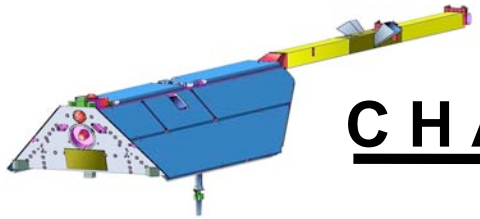


CHAMP

CHAMP Decay Scenario (End May 2004)



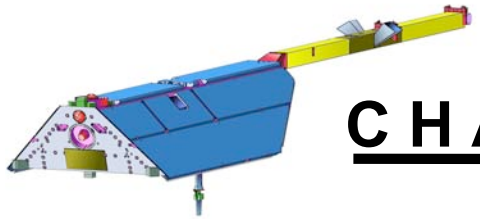
- Current altitude ~ 380 km.
- Two apogee thruster burns (Mid 2002, End 2003) to rise altitude by 20 km each.
- No further apogee burn manoeuvres planned.
- Nominal lifetime of 5 years only 1 year ahead.
- Current decay scenario even predicts extended lifetime to 2007/2008.



CHAMP

Role of SLR Data

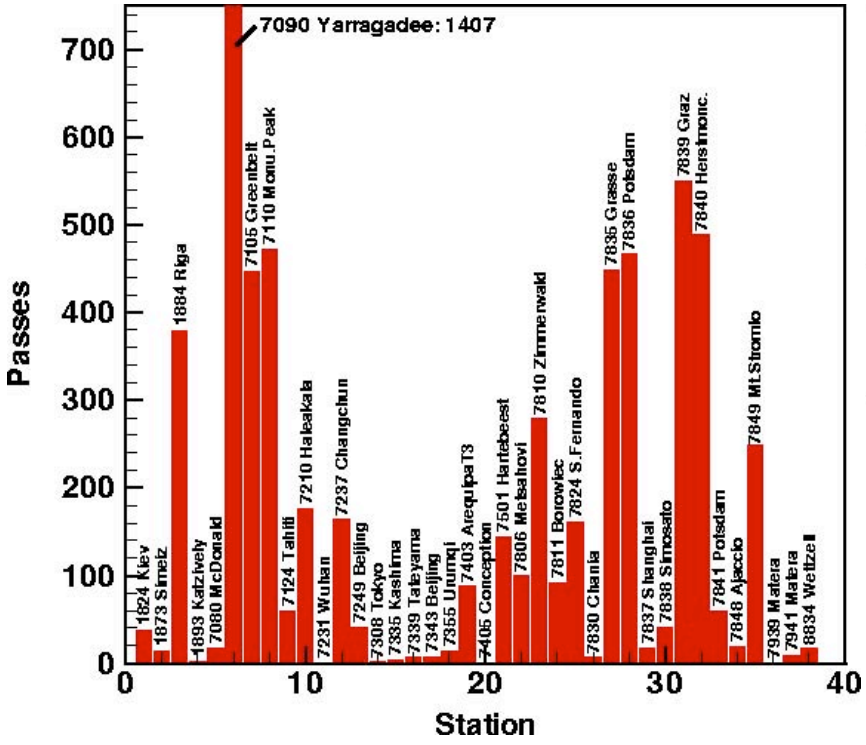
- GFZ orbit predictions are based on ephemeris from GPS navigation solution **and** the more accurate SLR data.
- Routinely used for the validation of the data of the onboard GPS receiver in POD.
- SLR data serve as independent quality measure of gravity field models derived from CHAMP microwave tracking data.
- CHAMP SLR data are combined with GPS ground and space-borne observations for studies of temporal variations of the long wavelength part of the gravity field and the reference frame.



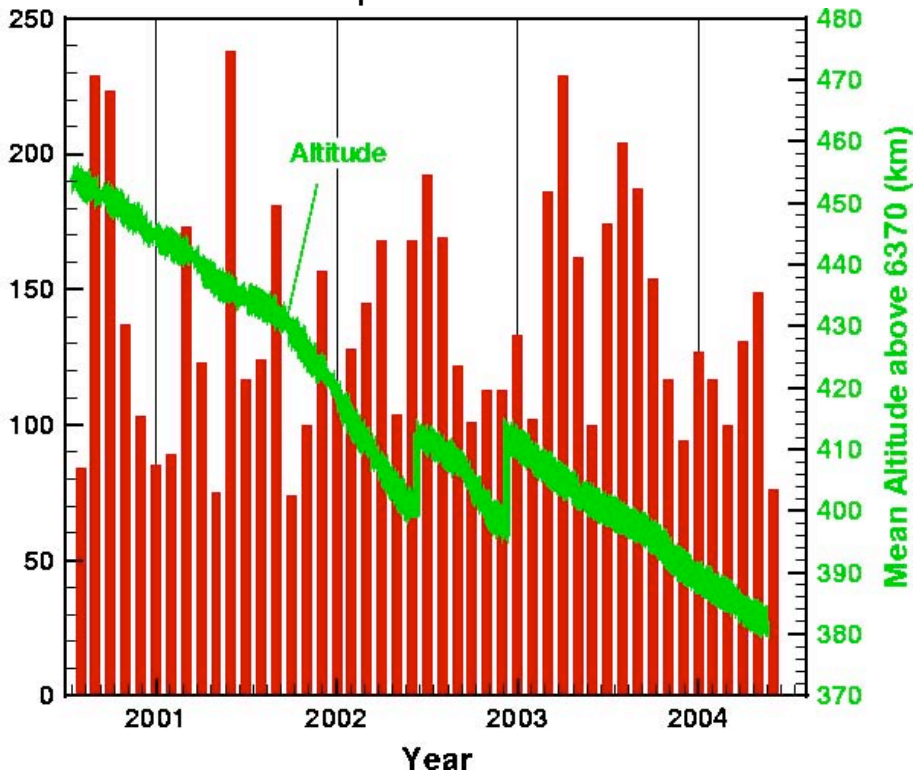
CHAMP

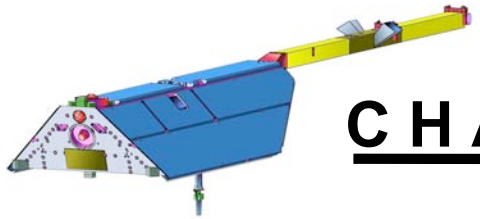
SLR-Tracking Jul. 2000 - May 25, 2004

Total per ILRS station



Total per Month





CHAMP

Summary

- Overall tracking statistics are quite satisfactory for the CHAMP mission - in particular in view of the low altitude of CHAMP.

- Recent statistics (first half of 2004) indicate that current procedure of 3 predictions/day is still sufficient. However, in view of the decreasing altitude an increase to 4-5 predictions/day might become necessary in future.

- SLR data plays an important role:

  - for the generation of accurate orbit predictions,
  - for the continuous validation of the microwave tracking systems onboard the CHAMP satellite,
  - for the quality control of gravity field modeling, and
  - for the combination with GPS data for reference frame and temporal gravity issues

= > continued intensive SLR support is requested

Status SLR Tracking GRACE Mission

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Status

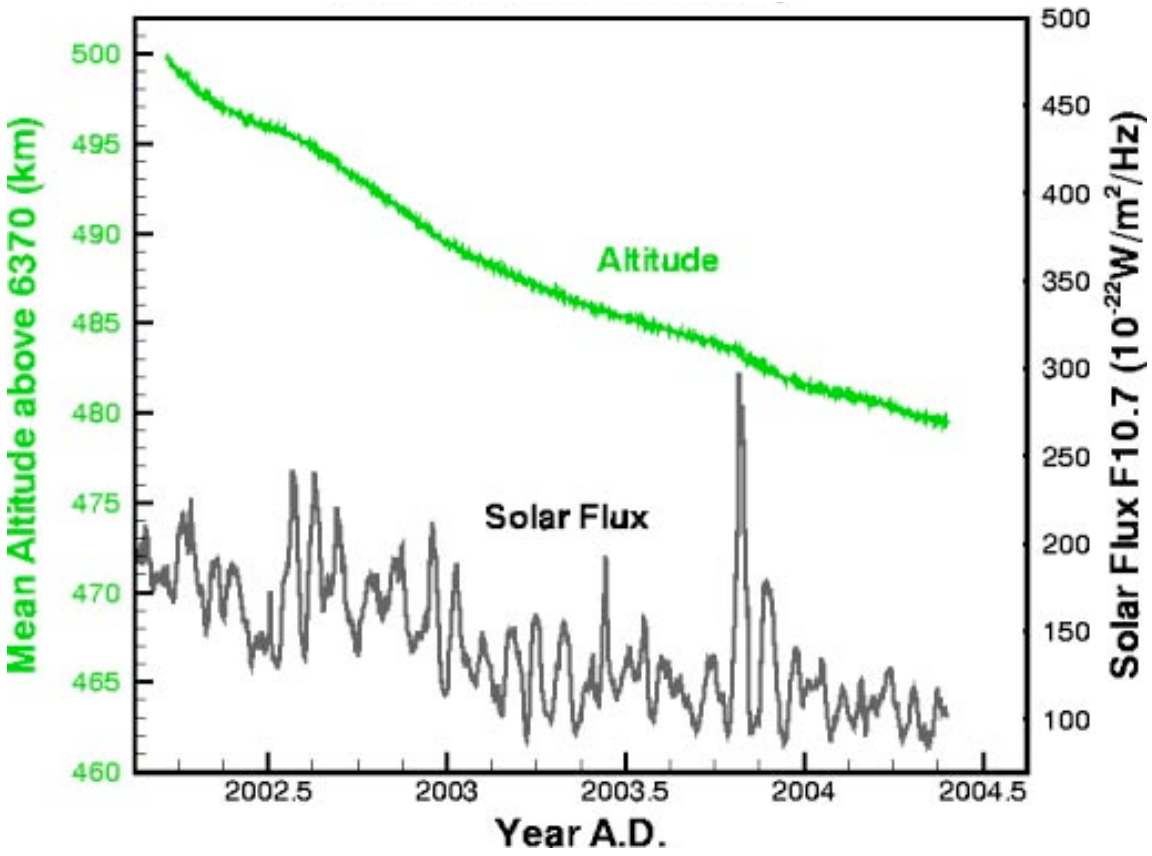
- The twin GRACE satellites are more than two years in space. All sensors and instruments are operating in the science data collection mode. All scientific instruments (accelerometers, star cameras, GPS receivers, K-Band-Ranging system, Laser Ranging Reflector) are performing nominally. On GRACE-1 some instrument redundancy has been lost.

- Current results of the Science Data System teams at JPL, UT-CSR and GFZ reveal the capability of the GRACE data for high resolution and high accurate recovery of the Earth‘s static and temporal gravity field:

  - From multi-months of GRACE data static gravity field models are derived that are about two orders of magnitude (at a resolution of 1000 km) more accurate than state-of-the-art models of the pre-CHAMP/GRACE era.

  - Investigations of recent monthly GRACE-only gravity fields reveal sensitivity to seasonal time-variable gravity induced by mass redistribution in the global hydrological cycle.

GRACE Decay Scenario (End May 2004)

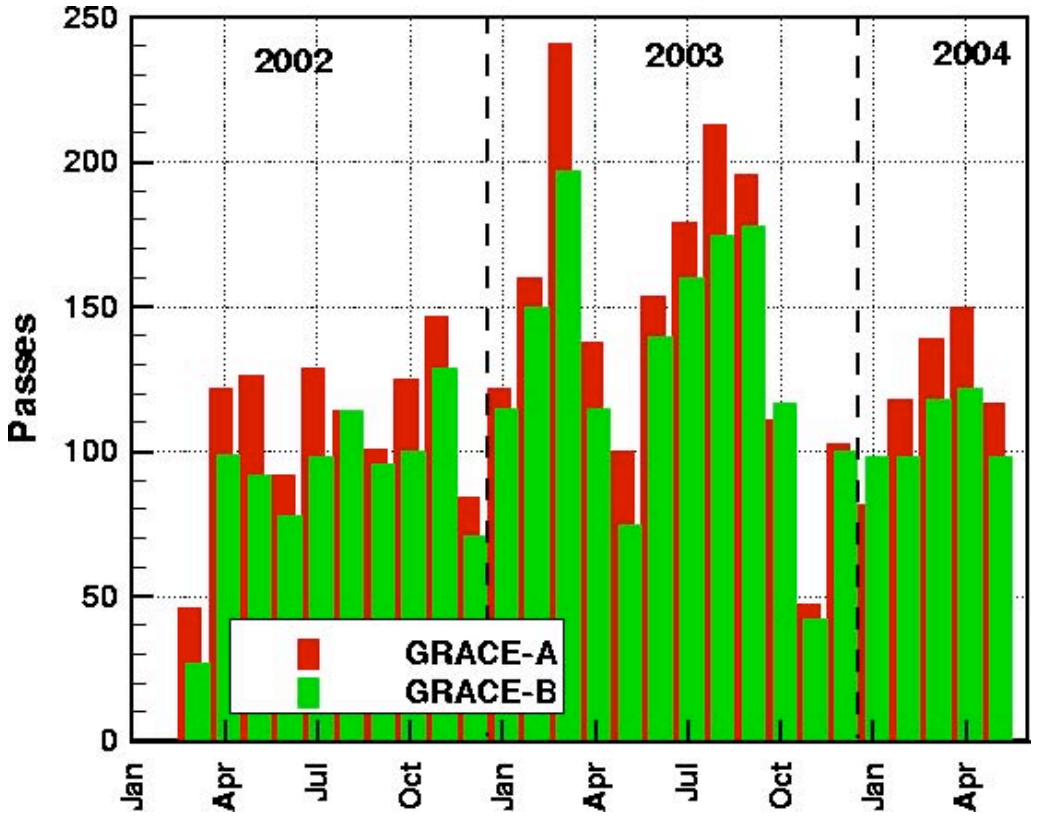


- Current altitude ~ 480 km.
- Current separation of the twin satellites about 225 km.
- With the current decay of about 13 km/year nominal mission lifetime of 5 years in reach.
- From time to time (some months) orbit manoeuvres in order to keep separation distance at 220 km ± 50 km.

Role of SLR data

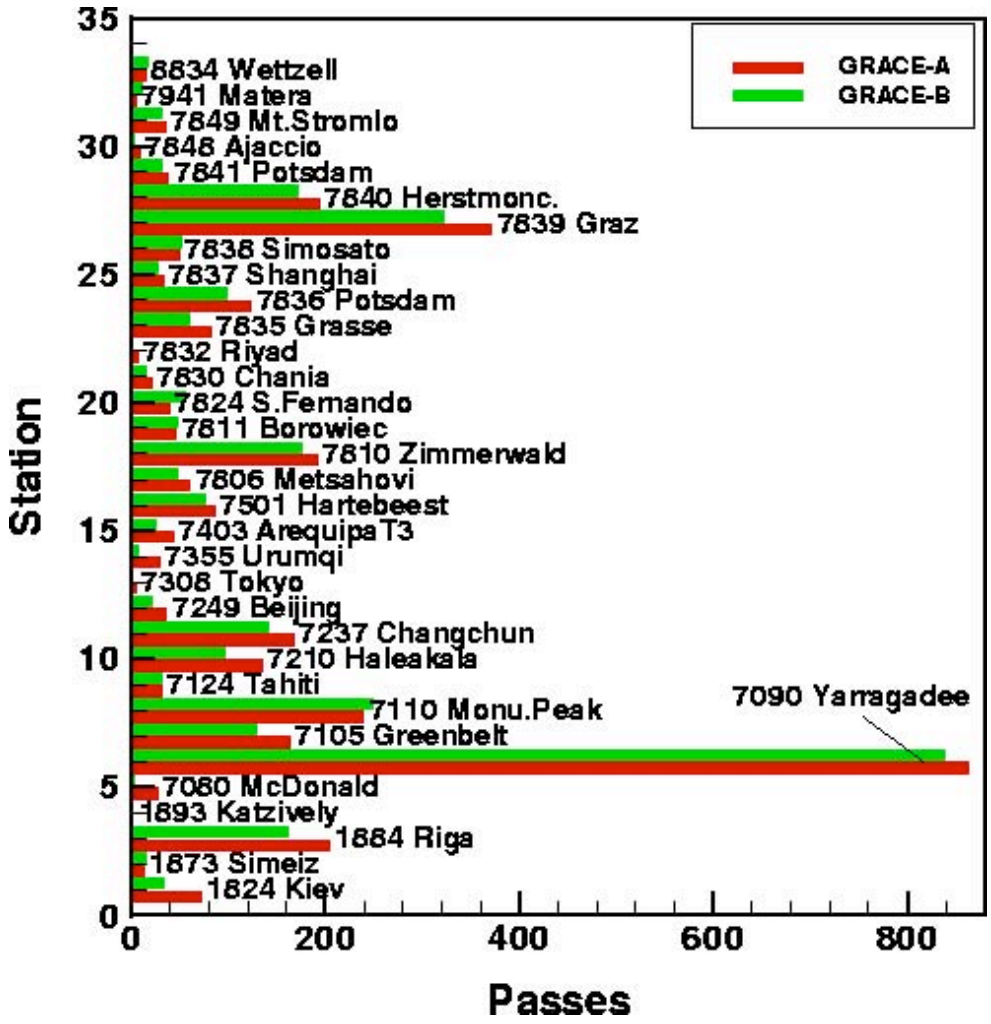
- At GFZ precise orbit predictions are generated from GPS navigation solution **and** the more accurate SLR data.
- Routinely used for the validation of the data of the onboard GPS receivers and K-Band-Ranging instrument in POD.
- SLR data is valuable data for the quality control of gravity field recovery from GRACE microwave satellite-to-satellite tracking data.
- GRACE SLR observations are integrated with GPS ground and on-board data for strengthening reference frame and long-wavelength part of the gravity field solutions.

GRACE SLR-Tracking March 2002- May 2004



- Total 6458 passes (GRACE-A: 3456, GRACE-B: 3002).
- Good amount of data per month and per satellite (as of Apr. 2002 in general >= 100 pass/month).
- In general stronger tracking of GRACE-A (except Aug. 2002, October 2003). Differences vary from month to month. Some part is due to degraded predicts during orbit maintenance manoeuvres mostly performed on GRACE-B

GRACE SLR-Tracking March 2003- May 2004



- Summary per stations also reveal stronger tracking of GRACE-A.
- However, majority of contributing ILRS stations show almost balanced statistics.
- The observed variations in the amount of tracking between GRACE-A and GRACE-B are acceptable.

Summary

- Overall SLR tracking statistics quite satisfactory for the GRACE mission. Current statistics show almost balanced values for the majority of contributing ILRS stations. The deviations in tracking between GRACE-A/B are acceptable. The efforts taken for the twin-tracking are highly appreciated.

- The quality of GFZ orbit predictions and the update rate of 2 predicts/day seems to be sufficient. Therefore no increased update rate is planned in the near future.

- SLR data (for both satellites) play an important role:

  - for the generation of accurate orbit predictions,
  - for the calibration/validation of the microwave tracking systems onboard the GRACE satellites,
  - for the quality control of gravity field recovery,
  - for the combination with GPS observations for gravity variation recovery

= > continued intensive SLR support is requested

Envisat Mission Status

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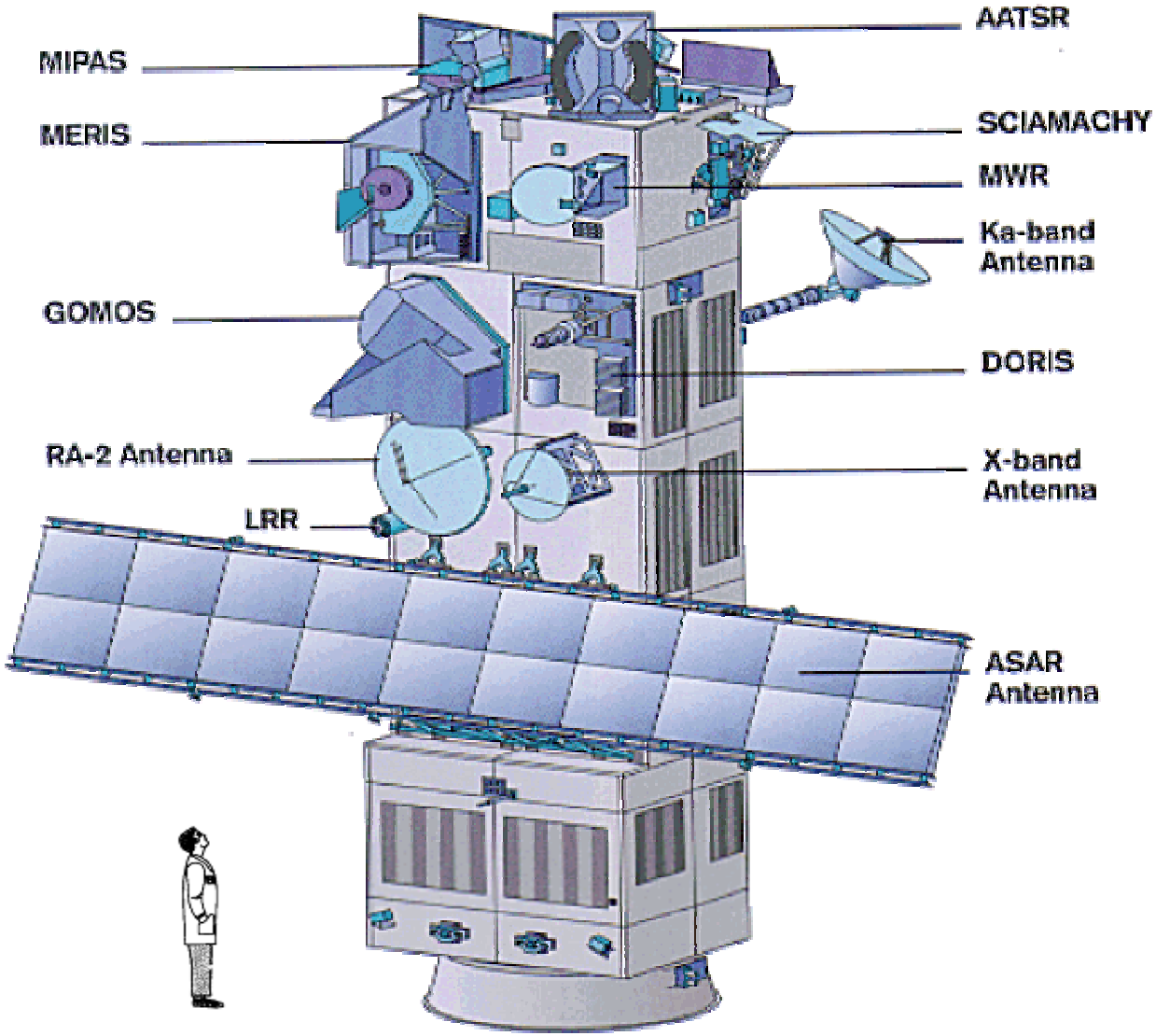
ENVISAT: the most powerful tool for monitoring the state of our planet



- ***Dimensions***

  Launch configuration:
  length 10.5 m
  envelope diameter 4.6 m
  In-Orbit configuration:
  26m x 10m x 5m

- ***Mass***

  Total satellite **8140 Kg**
  Payload 2050 Kg

- ***Power***

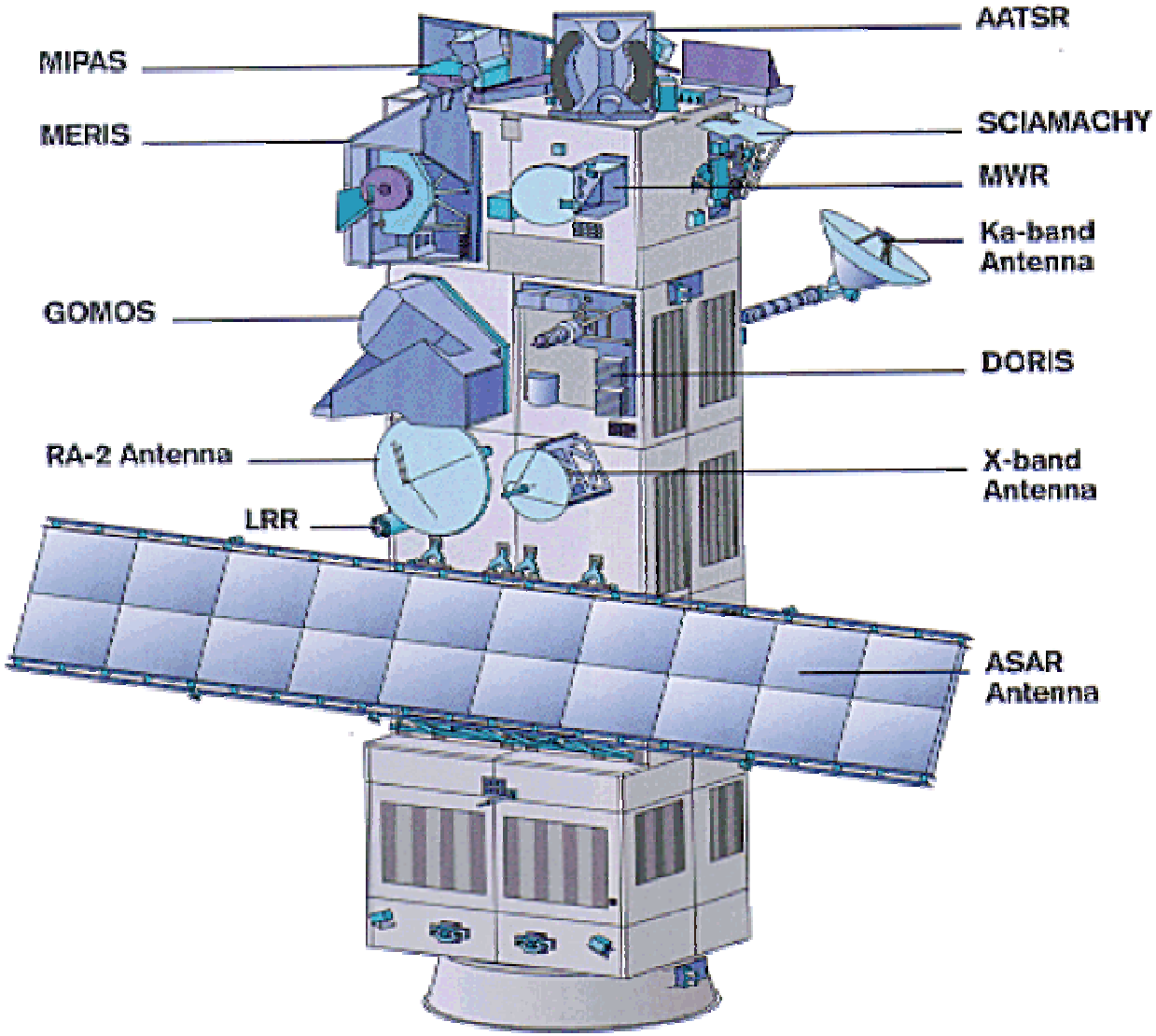
  Solar array power:
  6.5 kW (EOL)
  Average power demand:

	Sun (watts)	Eclipse (watts)
Payload	1700	1750
Satellite	3275	2870

- ***Orbit***

  800 km as ERS, sun synchronous 10:00, i.e. 30 minutes before ERS-2

ENVISAT: 10 ways to monitor the Earth



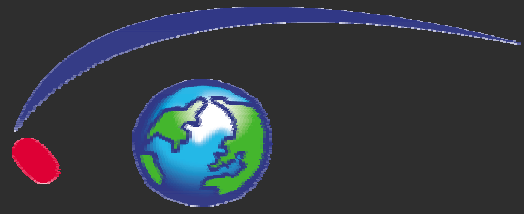
ESA Developed Instruments

ASAR
[Advanced Synthetic Aperture Radar]
MERIS
[Medium Resolution Imaging Spectrometer]
GOMOS
[Global Ozone Monitoring by Occultation of Stars]
MIPAS
[Michelson Interferometric Passive Atmospheric Sounder]
RA-2 [Radar Altimeter 2]
MWR [Microwave Radiometer]
LRR [Laser Retro Reflector]

Announcement of Opportunity Instruments

AATSR
[Advanced Along Track Scanning Radiometer]
SCIAMACHY
[Scanning Imaging Absorption Spectrometer for Atmospheric Cartography]
DORIS
[Doppler Orbitography and Radio-positioning Integrated by Satellite]

ENVISAT Mission
Some numbers



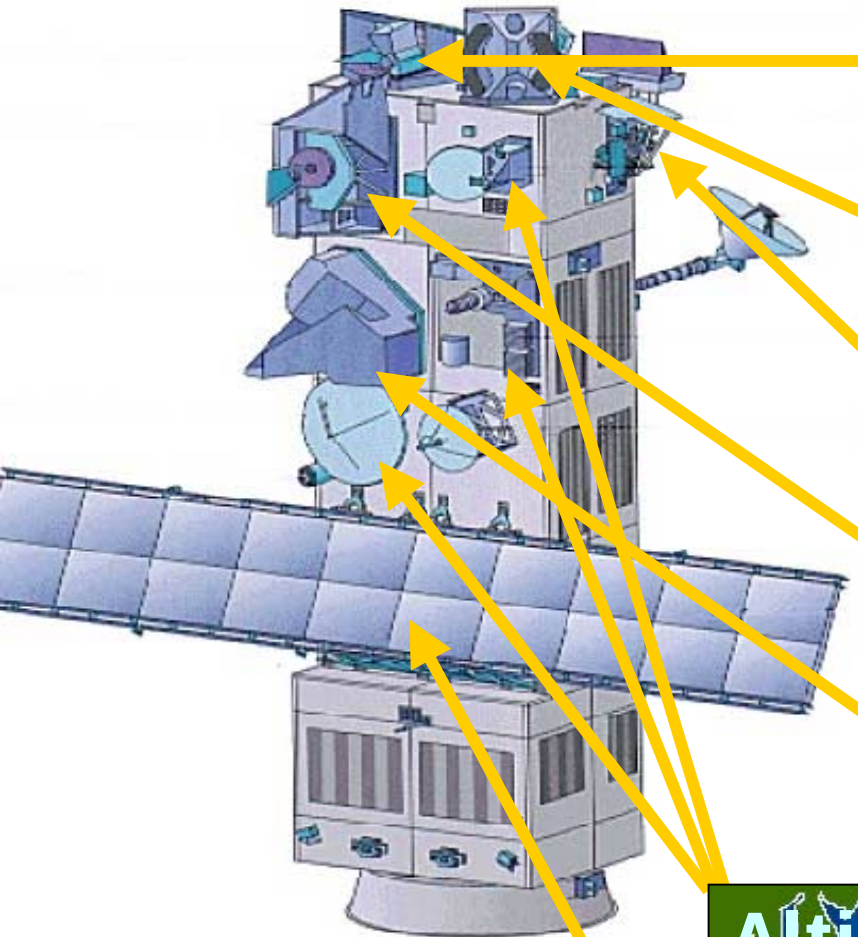
- Largest European satellite & largest worldwide EO satellite:
  - unique combination of 10 instruments ,
  - all instruments working nominally,
  - however recent anomalies with MIPAS instrument led to the suspension of the instrument operations on 26 March

- Satellite OK with long-term operations capabilities:
  - 75 % of fuel available

- 77 different types of data products

- 140 Gigabytes of data products generated per day

ENVISAT: the most powerful tool for monitoring the state of our planet



MIPAS

AATSR

SCIAMACHY

MERIS

GOMOS

Altimetry

ASAR

ENVISAT mission phases since launch

Commissioning Phase

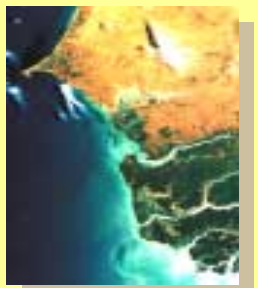
Initial Operations Phase

Gradual opening of services and products to users

Routine Operations Phase

470 served projects

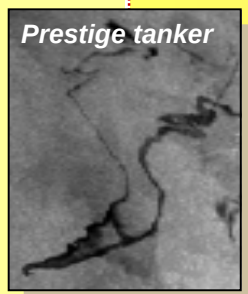
First images

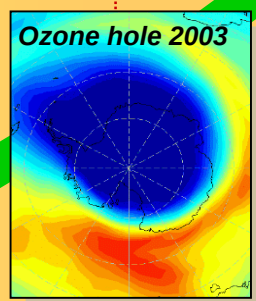


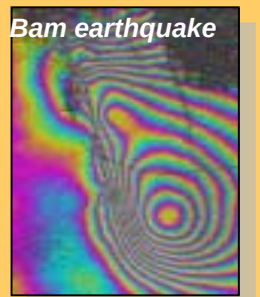
Release of ASAR products

Release of RA2 / AATSR / MERIS Level 2 products

Release of Atm. Chemistry L2 products







Data distribution to Cal/Val teams

Launch

Calibration Review

Validation Workshop

MERIS User Workshop

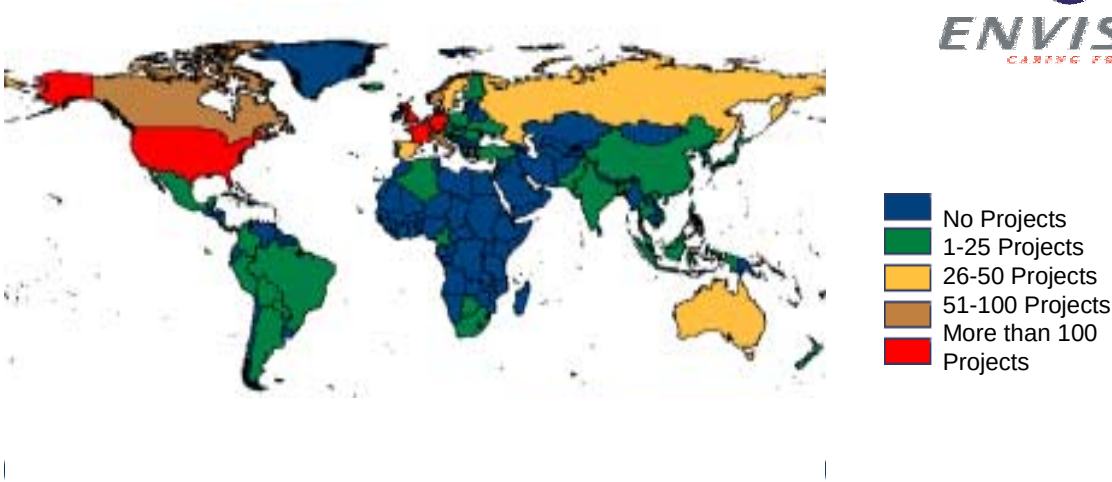
SAR Interferometry Workshop

2nd Atm. Chemistry Validation Workshop

Mar 02 | Sep 02 | Dec 02 | Sep 03 | Nov 03 | Dec 03 | Apr 04

Science

Worldwide scientific community
(more than 3000 scientists)



Public sector

Some examples:

Treaty conventions

Weather forecast

Sea ice services

Civil protections

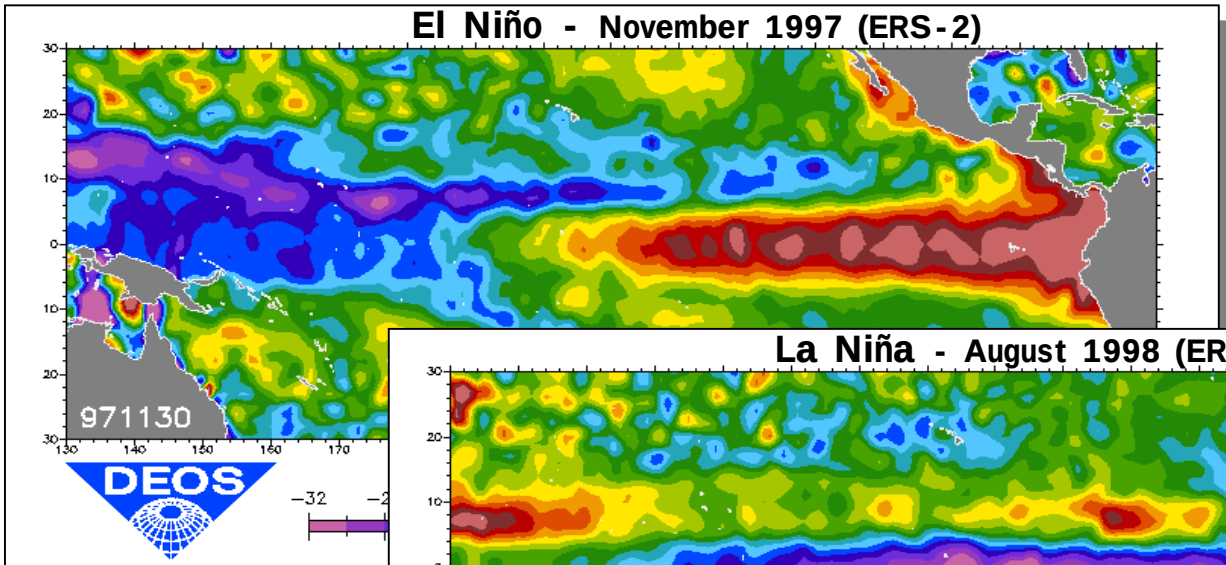
Commercial

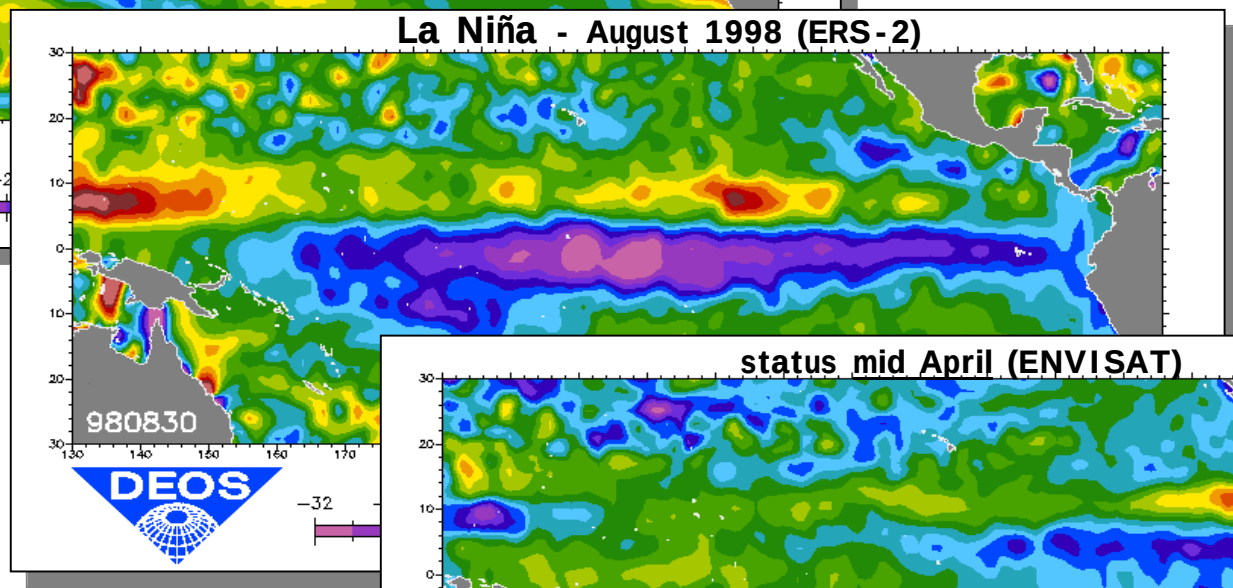
2 Distributing Entities:

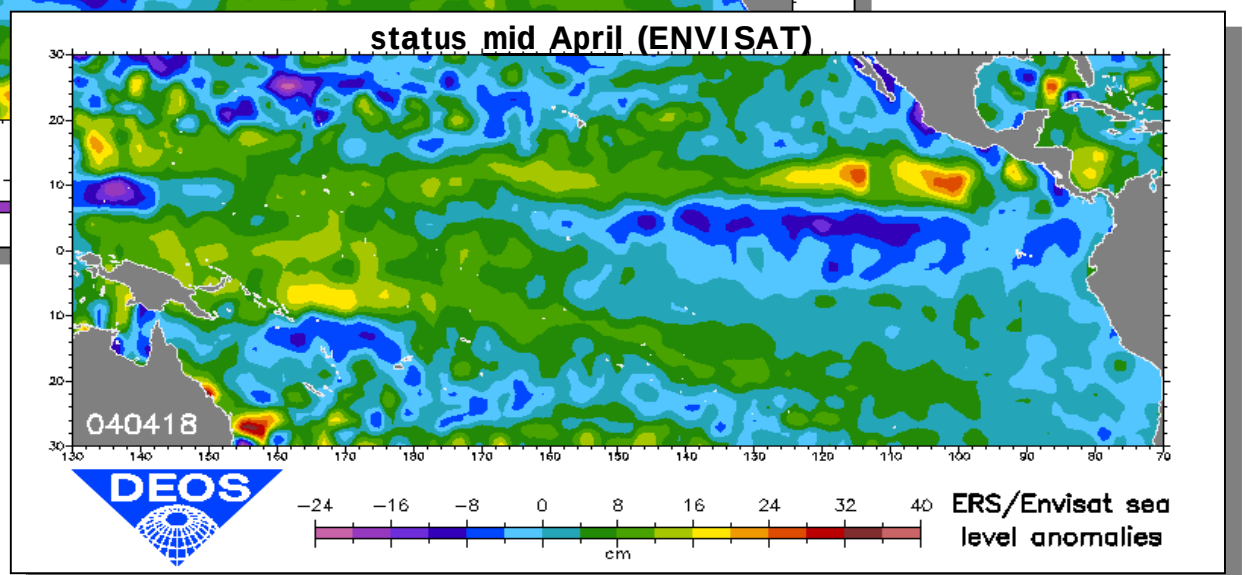
& network of value adding companies

Altimetry

ENVISAT
CARING FOR THE EARTH





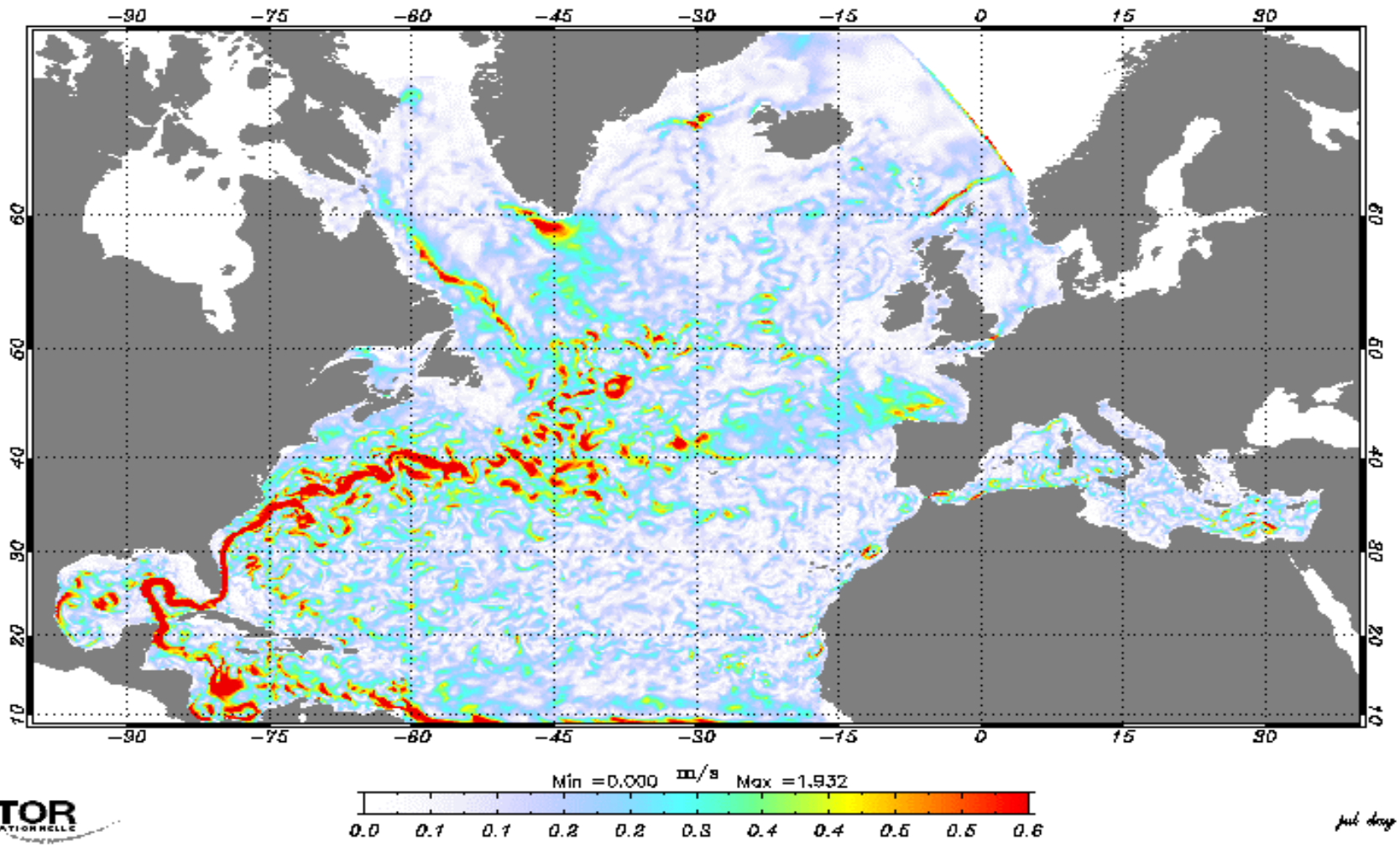


ENVISAT RA-2 has taken over the observations started with the ERS altimeters

esa

ENVISAT
CARING FOR THE EARTH

ENVISAT RA-2 observing the Gulf Stream current velocity (mid-April)



MERCATOR
OCEANOGRAPHIC OPERATIONNELLE

ENVISAT Altimetry System

- Outstanding RA-2, MWR and DORIS sensor availability

- RA2 Sensor continues to perform at a very high level, delivering unprecedented coverage
- High levels of tracker performance reported at Commissioning Phase Review are maintained

- MWR performance nominal (despite 36Ghz drift)

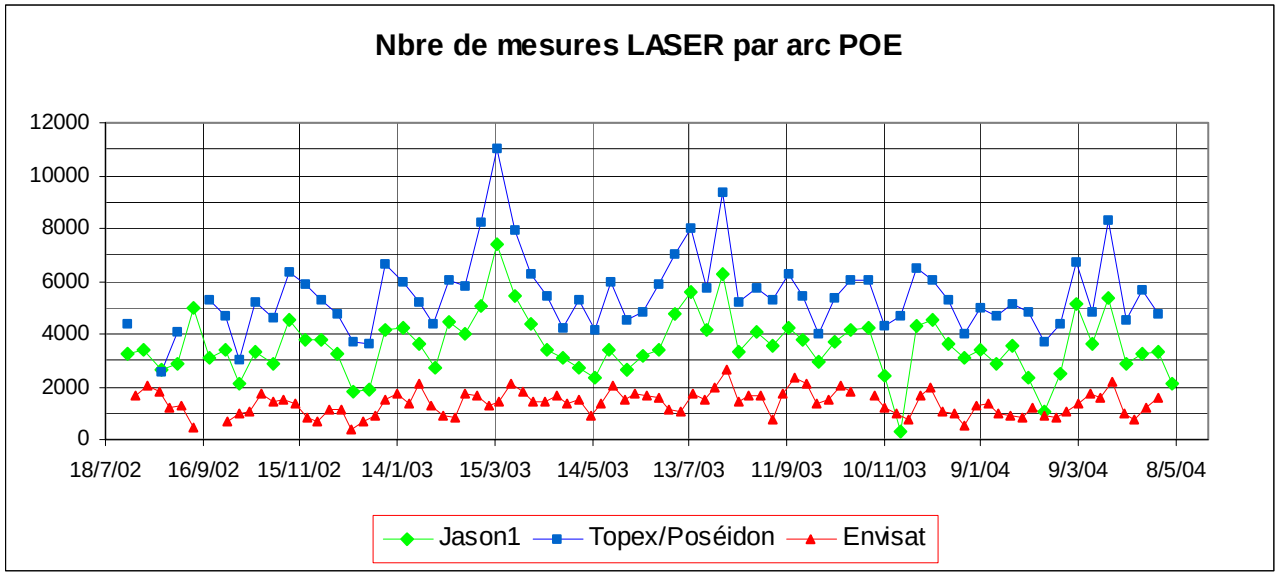
- DORIS instrument performances are excellent

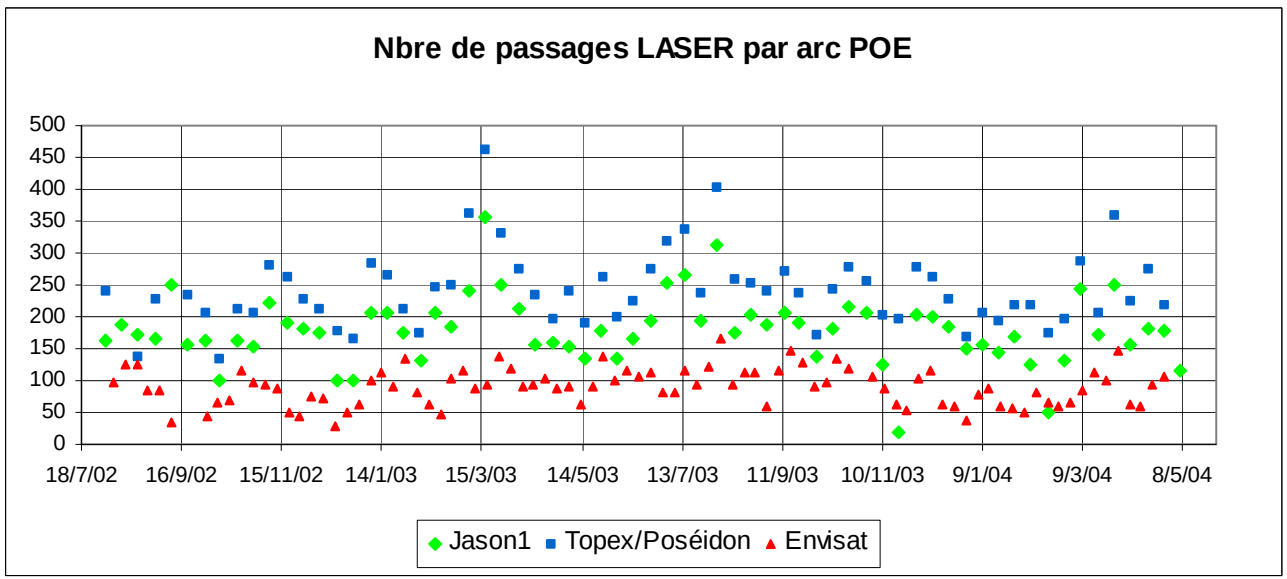
- The quality of products NAV, MOE, POE are also very good

ALTIMETRY MISSION IN PERFECT SHAPE
MORE PARAMETERS AVAILABLE WRT ERS

ENVISAT Laser measurements

- General elements
  - There is a significant decrease in SLR tracking (mainly because of the closure and reduced schedule of some NASA stations) since beginning of 2004
  - The SLR+DORIS orbits for Envisat are anyway still doing quite good
  - There is nothing critical at the present time, in terms of orbit performance
  - The situation has to be carefully and continuously monitored in order to verify if any additional decrease in laser tracking impacts the accuracy of the orbit


Nbre de mesures LASER par arc POE
12000
10000
8000
6000
4000
2000
0
18/7/02
16/9/02
15/11/02
14/1/03
15/3/03
14/5/03
13/7/03
11/9/03
10/11/03
9/1/04
9/3/04
8/5/04
Jason1
Topex/Poséidon
Envisat

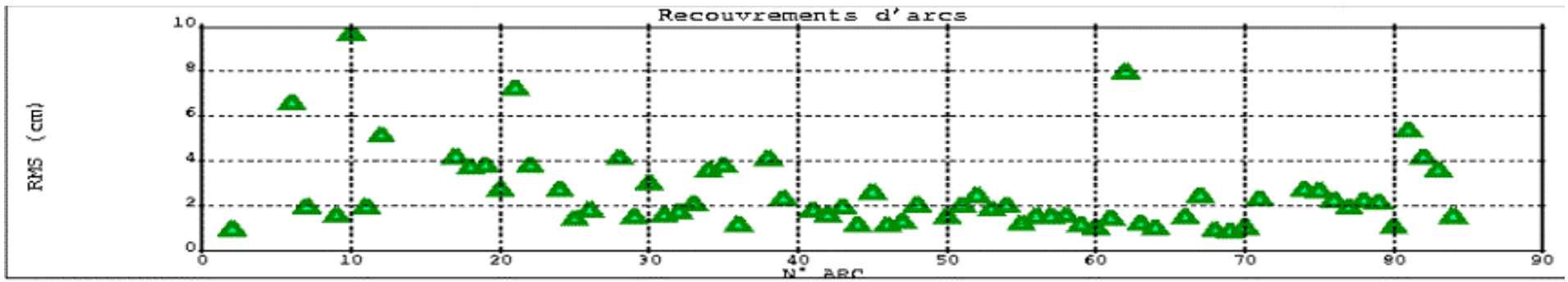

Nbre de passages LASER par arc POE
500
450
400
350
300
250
200
150
100
50
0
18/7/02
16/9/02
15/11/02
14/1/03
15/3/03
14/5/03
13/7/03
11/9/03
10/11/03
9/1/04
9/3/04
8/5/04
Jason1
Topex/Poséidon
Envisat

Preliminary (MOE) & Precise (POE) Orbit Restitution

- MOE accuracy is better than 5 cm RMS radial (when no ground TM data gaps at PDS or satellite event).

- POE laser residuals are about 2 cm RMS radial, this is stable (when no TM data gaps at PDS or satellite event) and very good.
  - Less Laser passes during maneuvers (half the mean value for a 5 day window on maneuver, typically 6/day instead of 12/day)

- POE overall comparison on the radial axis in centimeters:



Conclusions

- **ENVISAT POD activity based on DORIS + Laser**

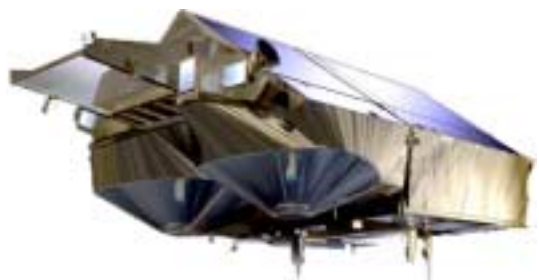
  => laser data are fundamental for the orbit computation and validation

  => Decrease in laser tracking but not critical at present time

- **Continuation of the laser measurements (as denser as possible) over the entire mission duration is confirmed to be necessary to ensure highest level science return**

ESA is thankful to all laser stations for their essential contribution to the ENVISAT scientific success

NEXT ESA MISSION: CRYOSAT (Dec 2004)



CRYOSAT

A Mission to Determine Fluctuations in the Mass of the Earth's Land and Marine Ice Fields.

- ERS 1 and ERS 2 demonstrated the capability of radar altimetry to measure the cryosphere:
    - mass balance of Antarctica;
    - thickness of Arctic sea ice.
- CryoSat was conceived …
    - to continue the measurement series;
    - to rectify limitations of the ERS altimeters.
    - The CryoSat mission will measure long term fluctuations in the mass of the Earths major land and marine ice fields.

Orbit Definition - Science Phase

- 92˚ inclination
- 720 km altitude
- NON sun-synchronous
- 369 days repeat cycle
- 30 days sub-cycle (shown)