International Cooperation within IAG's Geodetic Services ILRS and IVS, and the Japanese Contribution

Toshimichi Otsubo (Hitotsubashi Univ),
Shinobu Kurihara (GSI),
Carey E Noll and Dirk Behrend (NASA/GSFC)
Eratosthenes (275BC-194BC) measured the size of the Earth.

Geodesy
= geometrical and gravitational measurement of the Earth
Space Geodesy

**SLR/LLR** (presented by Otsubo), **VLBI** (by Kurihara), **GNSS**, DORIS... based upon ultra-accurate timing measurement by means of artificial satellites and natural objects. → unprecedented **high accuracy & global scale**.

Current target:
1 mm (position) and 0.1 mm/y (velocity)

Applied to:
- Crustal deformation studies
- Reference frame, Mapping
- Sea level rise
- Earth gravity field
- and more (→ Geodesy session on Thu)

http://space-geodesy.nasa.gov/techniques/techOverview.html
What is SLR/LLR?

Satellite/Lunar Laser Ranging

To measure:
• round-trip time (how far)
• epoch (when)
• auxiliary data

http://geo.science.hit-u.ac.jp/education/minilec-slr
Satellites

**Geodesy**
- LAGEOS, ETALON, AJISAI, STARLETTE, STELLA, GFZ-1, BLITS, LARES
- CHAMP, GRACE

**Remote sensing**
- ERS, TOPEX/POSEIDON, ADEOS, JASON, GFO, VCL, ICESAT, ALOS, ENVISAT, ...

**Navigation**
- GPS, GLONASS, GALILEO, COMPASS, ETS-8, QZS
Stations

Tanegashima station (JAXA) 2004-

Koganei station (NICT) 1990-

Shimosato station (Japan Coast Guard) 1982-

Photos: courtesy of each institute
Data Flow

Operational Centers/Data Centers (NASA (USA) and EDC (Germany))

Laser Ranging Station (Japan: Simosato, Koganei & Tanegashima)

Operasonal Centers/Data Centers (NASA (USA) and EDC (Germany))

Observation Data (within 1 hr)

Re-format

Geodetic Products

Quality check

Geodetic analysis

Scientific achievement

Paper

(Associate) Analysis Centers/Mission Centers (Japan: NICT, JAXA & HIT-U)

Orbit analysis

Feedback

prediction
International Laser Ranging Service

Established in 1998.

H Kunimori is a member
H Kunimori served as a chair
T Otsubo serves as a chair of its subWG.
Japan hosts the Int. Workshop this November!

http://ilrs.gsfc.nasa.gov/about/organization/index.html
18th International Workshop on Laser Ranging
- Pursuing Ultimate Accuracy & Creating New Synergies -
11-15 November 2013   Fujiyoshida, Japan

The 18th International Workshop on Laser Ranging is hosted by its Local Organising Committee closely working with International Laser Ranging Service (ILRS) after the unanimous decision made at the previous workshop held in Bad Kötzting.

This workshop is funded by the NICT International Exchange Program, and is supported by the Geodetic Society of Japan and also by the Japan Society for Aeronautical and Space Sciences.

The ILRS group meetings are also planned in and around the week. Email the Local Organising Committee (Z-LW18@jaxa.jp) for inquiries and information.

News:

Wed, 1 May 2013   Mt Fuji to become a World Heritage site (japan times, bbc)

Tue, 23 Apr 2013   First Announcement released

Important Dates:
Consortium Agreement between the International Laser Ranging Service (ILRS) and the International Council for Science (ICSU)

The purpose of this Consortium Agreement is to define the conditions under which the International Laser Ranging Service (hereinafter ILRS) will contribute to the ICSU World Data System (ICSU-WDS) as a Network Member. This document is not legally binding.

1. Laser ranging activities are organized under ILRS, which provides global satellite and lunar laser ranging data and their derived products to support geodetic, geophysical, and fundamental research activities; as well as products important to the maintenance of an accurate International Terrestrial Reference Frame. ILRS is one of the space geodetic services of the International Association of Geodesy and one of the components comprising its Global Geodetic Observing System. ILRS provides free and open access to all its data and product holdings to the general public.

2. It is the intention of ILRS to contribute to ICSU-WDS, and to collaborate with its governing body, the WDS Scientific Committee (WDS-SC), in order to ensure the long-term stewardship and provision of quality-assessed data and/or data services to the international science community and other stakeholders.

3. By joining as a Network Member, ILRS will work towards achieving the following goals and objectives of ICSU-WDS. These are to:
   a. Enable universal and equitable access to quality assured scientific data, data services, products and information
   b. Ensure long-term data stewardship
   c. Foster compliance to agreed-upon data standards and conventions
   d. Provide mechanisms to facilitate and improve access to data

4. ILRS commits to fulfill the ICSU-WDS criteria for membership, including:
   a. Accepting the ICSU-WDS Constitution 2012 (Annex A),
   b. Complying with the ICSU-WDS Data Policy (Annex B), which includes a commitment to full and open exchange of data, metadata, and products deposited within ICSU-WDS.

5. There are currently no data activities of ILRS that fall outside of the scope of ICSU-WDS. If such data activities arise, this Consortium Agreement shall be amended.

6. If ILRS, for any reason, is unable to continue its long-term commitment, then it should endeavour to find a mechanism to secure its data activities by transferring them to another ICSU-WDS facility or other suitable host organization.

7. The resources required for the data activities of the ILRS are the responsibility of its constituent organizations. To ensure continuity, the constituent organizations will provide these resources on a long-term basis as their ability and funding allow.

8. ILRS, as a Network Member of ICSU-WDS, refrains from using the WDS logo and trademarks to make direct financial profit without explicit authorization from the WDS-SC.

9. This Consortium Agreement will enter into force upon signature by both parties. It is valid from the date of signature until one of the parties expresses its willingness to terminate it. This shall not occur prior to a five-year period from the date of signature.

10. This Consortium Agreement is to be signed between ICSU and ILRS by the respective heads of organizations or their authorized delegates.

SIGNED (On behalf of ICSU)
Date: 04/03/2013
Name: Steven Wilson
Position: Executive Director

SIGNED (On behalf of the ILRS)
Date: 15/2/2013
Name: Graham Appleby
Position: Chair, ILRS Governing Board
Data-related issues

- "Full-rate" vs "Normal-point"
  - 5 to 10 Hz → kHz laser
  - Satellite attitude →

- Expanding applications
  - Time transfer
  - Deep space
  - One-way ranging
  → New "CRD" format implemented in 2012.

Kucharski, ASR, 2013.
VLBI Observing System

- **Radio signals of quasars or radio galaxies**
  - 8 channels X-Band/8 GHz
  - 6 channels S-Band/2 GHz
  - Data 1 - 1.5 TByte/day·site
  - Time & Frequency
    - $\Delta F/F \sim 10e^{-15}$ (Hydrogen Maser)
  - Data recording
    - HDD
    - e-transfer

- **Correlation (data processing)**
  - $\sigma_\tau \sim 10$ to 30 ps
Clean map. Array: BFGGHKLMNOOPSW BFGGHKKLMM
CTA102 at 2.292 GHz 1997 Jan 30

Clean map. Array: BFHLMNOPS
0059+581 at 8.106 GHz 1995 Jul 24
Geodetic VLBI Stations in Japan

Shintotsukawa 3.8m
Tsukuba 32m
Aira 10m
Chichijima 10m

Geospatial Information Authority of Japan
IVS Network Stations

52 stations, 16 countries observed in 2012.
Established in 1999.
81 components, representing 41 institutions in 20 countries

Japanese Contribution

GSI, NICT, NAOJ, NIPR

Correlators

Coordination Center
- Publications
- Web Site
- Master Schedule

Data Centers

Analysis Centers

Analyzed results and products

Users

Products for EOP, TRF, CRF

Network Stations

Network Coordinator

Network Development Centers

Operation Centers

Technology Coordinator

Technology Development Centers

WDS (ICSU)
Typical results of VLBI (1)

Plate Tectonics, Crustal movement

Global VLBI Solution 2011d
Data Span: 1980 - 2011
Geospatial Information Authority of Japan
Typical results of VLBI (1)

Plate Tectonics, Crustal movement

March 11, 2011
Tohoku earthquake

24.6 +/- 1.8 cm East

65.2 +/- 0.3 cm East

749 days

2.3 +/- 0.3 cm North

6.4 +/- 0.6 cm Down

10 cm
Typical results of VLBI (2)

Earth Orientation Parameter (EOP)

• The EOP varies from moment to moment, difficult to predict.
• Actual observation is needed. Essential parameter for satellite, and space prove, time keeping as well.
• VLBI is the unique technique to measure the full-set of EOP.
• Latency from observation to deriving a result (rapid-turnaround) is significant. A few minutes is available!
• Real-time data transfer with Tsunami UDP protocol (~600 Mbps).
Big data in VLBI

How big amount of row data do we deal with in VLBI?

- **Row data** from quasar A/D-sampled with 256 MHz.
- 1-day observation:
  - 1 - 1.5 (TB) $\times$ 8-10 (sites) $\sim$ 15 (TB/day)
- 10 - 20 HDDs are needed if 2TB/HDD. Nowadays, **e-transfer** is a state-of-the-art way.
  - $15$ (TB) $\times$ 8 (bit) / 500 (Mbps) $\sim$ 7(hours/site)

- 170 days in a year
  - $\sim$ 2.5 (Pbyte) total amount of data
  - $\sim$ 50 (days) required time to transfer
Consortium Agreement between the International VLBI Service for Geodesy and Astrometry (IVS) and the International Council for Science (ICSU)

The purpose of this Consortium Agreement is to define the conditions under which the International VLBI Service for Geodesy and Astrometry (hereinafter IVS) will contribute to the ICSU World Data System (ICSU-WDS) as a Network Member. This document is not legally binding.

1. IVS is an international collaboration of organizations that operate or support Very Long Baseline Interferometry (VLBI) components. IVS provides a service that supports geodetic and astrometric work on reference systems, Earth science research, and operational activities. IVS is a Service of the International Association of Geodesy and the International Astronomical Union.

2. It is the intention of IVS to contribute to ICSU-WDS, and to collaborate with its governing body, the WDS Scientific Committee (WDS-SC), in order to ensure the long-term stewardship and provision of quality-assessed data and/or data services to the international science community and other stakeholders.

3. By joining as a Network member, IVS will work towards achieving the following goals and objectives of ICSU-WDS. These are to:
   a. Enable universal and equitable access to quality assured scientific data, data services, products and information
   b. Ensure long-term data stewardship
   c. Foster compliance to agreed-upon data standards and conventions
   d. Provide mechanisms to facilitate and improve access to data

4. IVS commits to fulfill the ICSU-WDS criteria for membership, including:
   b. Complying with the ICSU-WDS Data Policy (Annex B), which includes a commitment to full and open exchange of data, metadata, and products deposited within ICSU-WDS.

5. There are currently no data activities of the IVS that fall outside of the scope of ICSU-WDS. If such data activities arise, this Consortium Agreement shall be amended

6. If IVS, for any reason, is unable to continue its long-term commitment, then it should endeavour to find a mechanism to secure its data activities by transferring them to another ICSU-WDS facility or other suitable host organization.

7. The resources required for the data activities of IVS are the responsibility of its constituent organizations. To ensure continuity, the constituent organizations will provide these resources on a long-term basis.

8. IVS, as a Network Member of ICSU-WDS, refrains from using the WDS logo and trademarks to make direct financial profit without explicit authorization from the WDS-SC.

9. This Consortium Agreement will enter into force upon signature by both parties. It is valid from the date of signature until one of the parties expresses its willingness to terminate it. This shall not occur prior to a five-year period from the date of signature.

10. This Consortium Agreement is to be signed between ICSU and IVS by the respective heads of organizations or their authorised delegates.

SIGNED (On behalf of ICSU)  
Date: 4/3/13  
Name: Steven Wilson  
Position: Executive Director

SIGNED (On behalf of IVS)  
Date: 15.02.2013  
Name: Harald Schuh  
Position: Chair, IVS Directing Board
Contributes to several environmental problems; sea level rise, climate change, and natural hazards; megaquake, typhoon.

Permanent service of the International Association of Geodesy (IAG).

Contributes to GEOSS and GEO.
The Reference Frame and the sustainable observations are necessary for considering these environmental problems.

Accuracy:

- < 1 mm (site positions)
- < 0.1 mm/yr (velocities)

Continuous observation:

- 24-hour, 365-day

↓

Data size definitely increases!
Summary

- Two IAG’s services **ILRS** and **IVS**
  - deal with massive amount of data,
  - recently **signed the agreement with ICSU** relating to the service’s contribution to the **WDS**.

- **SLR:**
  - Data flow coordination and growing application area.

- **VLBI:**
  - Real-time data transfer and rapid turnaround of EOP.

- **GGOS**: Geodetic Observation in Future
  - Contribution to **environmental problems and natural hazards**.
  - Sustainable and long-term observation is needed.
  - The amount of data should **increase definitely**.
IGS : International GNSS Service

- Established in 1994 under the International Association of Geodesy

- Voluntary Federation
  - More than 200 worldwide agencies participate
    (Japan: GSI, JAXA, NICT, NAOJ, JCG, ENRI)
  - Pool resources and GNSS data to generate precise products

- Purposes
  - Support the earth science research
  - Develop the Standard format of GNSS products
  - Provide high quality data and products of GNSS (e.g. Precise ephemeris and Clock info of Satellites, Observation data and Coordinate of IGS stations)
• **IGS Tracking Network**
  - 427 stations and 360 stations are active (6\textsuperscript{th}/May./2013)
  - 12 stations are in Japan (aira, ccj2, gmsd, kgni, ksmv, mcil, mizu, smst, stk2, tsk2, tskb, usud)

• **IGS Activities for WDS**
  - IGS is WDS regular member
  - **IGS benefits:** ICSU level accredited, Visibility and recognition as a model of international community cooperation as a scientific service, Partnerships with global data services, Emphasis on data sharing principles

(Ruth E. Neilan (2012), The IGS as a Member of ICSU World Data System, *IGS 2012 Workshop*)