Improving the Image & Visibility of Geodesy

Chris Rizos

The Classical “Pillars” of Geodesy

Geometry of the Earth’s Surface(s)

What is wrong with this image?

Reference Frames (Terrestrial and Celestial)

Earth Rotation and Polar Motion (EOP)

The Earth’s Gravity Field
The Classical Challenges of Geodesy (1)

Geometry of the Earth’s Surface(s)

- National geodetic control networks
- Atmospheric refraction
- Precise angle & distance measurement
- Ellipsoidal calculations & map projections
- Large geometric system LSE & error theory
- Geodetic survey technology

The Classical Challenges of Geodesy (2)

Earth Rotation and Polar Motion

- Positional astronomy
- Earth/mass/inertia & SEMs
- Reference frame transformations
- Ocean-atmosphere-solid earth coupling
- Astronomical & space geodesy technology
The Classical Challenges of Geodesy (3)

- GBVP & potential theory
- Gravity anomalies & DoV
- “Unification” of geometry & gravimetry
- Surface gravity data limitations
- Height datums
- Satellite GFMs
- Astronomical & space geodesy technology
- Satellite altimetry
- Absolute & relative gravimetry

Geodesy has an “image problem”… Concepts and results are difficult to explain to a layperson or decision-maker… who thinks we don’t need it anymore or, worse, that it is an indulgence…
Geodetic Stasis

By the 1970-80s:

- National control networks largely complete in developed countries...but lag in developing countries
- Restrictions on access to surface gravity data...as well as incomplete coverage
- Low quality geoid models...of academic interest only
- Geodesy has “finished”?...BUT

The Beginnings of a Geodetic Renaissance

Yet:

- Geodesy joins the ranks of “big science”...satellite missions: altimetry, laser-tracked spacecraft, etc
- Big, expensive observatories...SLR, VLBI
- Exotic data...restricted access & capability
- SW & analysis expertise concentrated in few centres...GFM, POD, SLR/VLBI, etc.
- Globalisation of geodesy, e.g. WGS84, GEMs
- Widening gap between classical geodesy methods & new space-based techniques
Geodesy in Universities (1)

By the 1970-80-90s:

- Subjects reflect mission of classical geodesy… remember your university education?
- University research focused on theory
- Geodesy subjects considered too “hard”…LSE, GBVP, ellip. comps, map projections, SHMs, orbital mechanics, astronomy & time, and others
- Many geodesy subjects dropped from surveying curricula, and/or names changed, and/or content trimmed/modified

Geodesy in Universities (2)

With implications:

- Geodesy in danger of being considered irrelevant (like astronomy) for UG studies…in favour of land & environmental studies, GIS, remote sensing, etc.
- Few obvious career paths
- Small number of university postgraduate geodesy education centres
- Then, along comes GPS… (more later)
Modern Geodesy’s Capabilities

Geodesy now defined in terms of the following capabilities:

1. Determination of precise global, regional & local 3-D (static or kinematic) positions on or above the Earth’s (solid or aqueous) surface
2. Mapping of land, sea & ice surface geometry
3. Determination of the Earth’s (time & spatially) variable gravity field
4. Measurement of dynamical (4-D) phenomena:
   - Solid Earth (incl. cryosphere): surface deformation, crustal motion, GIA, polar motion, earth rotation, tides, water cycle, mass transport, etc.
   - Atmosphere: refractive index, T/P/H profiles, TEC, circulation, etc.
   - Ocean: sea level, sea state, circulation, etc.

Modern geodesy has an impressive array of space & terrestrial technologies at its disposal
Why Geodesy Matters, Now More Than Ever

Geodesy is a suite of powerful Earth-observation techniques, associated methodologies, and analysis tools, that today are making a vital contribution to science and society. Geodesy is not a new, child-of-technology science. It dates back hundreds of years—some would claim thousands of years, and reasons for its transformation. Firstly, modern geodesy relies on space technology, and accuracies usually have been made in accuracy, resolution, and coverage due to advances in satellite sensors and an expanding portfolio of satellite missions. Secondly, geodesy can measure with precision that no other means-racing technique can, such as the position and velocity of points on the earth’s surface, the shape and changes of the earth’s ocean and land surfaces, and it can map the spatial and temporal features of the gravity field. These geodetic parameters are in effect the “fingerprint” of many dynamic earth phenomena, including these that we now associate with global changes (due to anthropogenic as well as natural causes). The challenge is to invert the outward expressions of these global-change phenomena in order to measure and date over time the underlying physical causes. Finally, what relentlessly drives geodesy users in the future is the massive amount of signals transmitted by GNSSs such as GPS and GLONASS.

GPS World, Jan 2011, p.8-10

Space Geodetic Techniques

Gravity Field

- CHAMP
- GRACE-1/2
- GOCE

Ocean Altimetry

- Topex/Pos.
- JASON-1
- JASON-2

Atmosphere

- CHAMP
- COSMIC-1/2
- MetOp

Ice Altimetry

Satellite Tracking

- SLR sats
- DORIS sats

Earth Surface

- Cosmo-Skymed
- TanDEM-X

GNSS Positioning

- a large toolkit...

Geomatics Education & Research: Challenges & Opportunities, HKPU, 29 May 2014
Modern Geodesy is both a geoscience and a geospatial discipline…

Making contributions as an Earth Observation Science and to Society through its services and its identification with Precise GNSS Positioning…
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Making contributions as an Earth Observation Science and to Society through its services and its identification with Precise GNSS Positioning...

The challenge is getting our messages across...

The public needs to hear not only about good science but how geodesy supports society...
How geodesy contributes to strengthen the study of our changing planet

Measuring the planet

Through geodesy, we measure and define the Earth's shape, rotation and gravitational field and changes to these.

Geodesy is fundamental for monitoring changes to the Earth including the continents, ice caps, oceans and the atmosphere. Geodesy is also fundamental for mapping, navigation and universal timing.

EARTH IS A DYNAMIC PLANET and is in constant motion. We monitor the different processes which cause these motions.
Where places and people are

Because the Earth is in constant motion, an accurate point of reference is needed for making measurements. Geodetic provides a very accurate and stable coordinate reference frame for the whole planet: A global geodetic reference frame.

This coordinate system allows us to relate measurements taken anywhere on the Earth with similar measurements taken at a different time or location.

Natural hazard and disaster management

To make good decisions for the future, information is needed about sea level changes, plate movements, land uplift and ice sheet and glacier changes.

The global geodetic reference frame provides the basis for such decisions. Without this system, it would be difficult to identify areas under threat of flooding, earthquakes or drought and to adopt preventive measures to protect them.

The basis for geospatial information

A global geodetic reference frame is in growing demand. Monitoring changes to the Earth is important for environmental studies and for the global economy.

It’s the basis for geospatial information and navigation used in many Earth sciences and societal applications and in a whole series of industries, such as construction, mining, agriculture, financial transactions and transport.
Geodesy as an Earth Observation Science

Many Earth System Effects have either Geometric, Earth Rotation & Gravitational Signatures, or combinations…

Many are coupled in complex ways… with feedbacks…
Geodesy as an Earth Observing Science

Answer questions, such as

- **Climate Change:**
  - How much is sea level changing here?
  - How is the atmospheric circulation changing?
  - How is the Water Cycle changing?
  - How do the Earth, Atmosphere and Oceans exchange energy?

- **Geohazards:**
  - Is stress building on this fault?
  - Has a tsunami wave been detected?
  - Is there an impending volcanic explosion?
  - What is the ground & structural deformation?

- **Environmental:**
  - What is the mesoscale ocean circulation?
  - What is the pattern of the atmospheric water vapour?
  - How is the pattern of ground water & soil moisture changing?
  - What is the volume of ice being lost in the Arctic/Antarctic?

Capability: Geocentre Motion

**SUB-CM EARTH MEASUREMENTS**

The change in the origin of the crust-fixed frame (ITRF) w.r.t. the geocentre due to non-tidal mass transport in the atmosphere and ocean.

Applications: mm/yr tectonic motions, mm/yr rise in global sea level, mm level changes in local geoid (gravity) due to ground water processes...

How? SLR
**Capability: Earth Rotation & Orientation**

*How? GNSS, SLR, VLBI*

**Capability: Earth Surface Motion**

*How? GNSS at fixed ground stations*
Capability: Precision Monitoring

How? GNSS

Capability: Atmospheric Sounding

How? GNSS ground network & spaceborne GNSS
Capability: Gravity Anomalies from Altimetry

How? POD & satellite altimetry

Capability: Monitoring Sea Level Rise

Not just a global average SLR

How? POD & satellite altimetry
**Capability: Sea Ice Thickness Maps**

- **Sea Ice Thickness**
  - Oct 4 – Nov 18, 03
  - Feb 18 – Mar 21, 04
  - May 15 – Jun 24, 04

**How? POD & specialist missions**

**Capability: Land surface deformation**

- Monitoring changes in land surface:
  - “geodetic remote sensing”

**How? SAR missions**
Capability: Remote Sensing of Mass Flux

How? gravity mapping satellites

Measuring the planet

Through geodesy, we measure and define the Earth's shape, rotation and gravitational field and changes to these. Geodesy is fundamental for monitoring changes to the Earth including the continents, ice caps, oceans and the atmosphere. Geodesy is also fundamental for mapping, navigation and universal timing.
The image & visibility of geodesy is enhanced by its status as an EOS...

The International Geodesy Services
Monitoring Geometric & Gravimetric Signatures

IAG Services

IGS: International GNSS Service (1994)
IVS: International VLBI Service (1999)
BGI: Bureau Gravimetric International (1951)
IGeS: International Geoid Service (1992)
ICET: International Centre for Earth Tides (1956)
PSMSL: Permanent Service for Mean Sea Level (1933)
IAS: International Altimetry Service (2008)
BIPM: Bureau International des Poids et Mesures (Time 1875)
IBS: IAG Bibliographic Service (1889)
Input Data: Station Position Time Series

Global Geodetic Reference Frame ITRF

ITRF2008 Velocity Field

Major plate boundaries are shown in green

Zuhair Attamimi

http://itrf.ensg.ign.fr

ITRF2013 is coming
The potential of GPS for geodesy & geodynamics was realised by the mid-to-late 1980s:

- An official service of the IAG since January 1994
- From 1999 known simply as the *International GPS Service*
- Renamed the *International GNSS Service* in March 2005

The IGS Tracking Network

- ~450 stations
- ~150 real-time
- ~90 multi-GNSS

http://igs.org/network/netindex.html
**IGS Products**

- **Primary products**
  - global tracking data
  - GPS and GLONASS orbits
  - station coords, contribution to global terrestrial reference frame ITRF

- **Related products**
  - clock corrections for satellites and selected stations
  - daily Earth rotation parameters
  - global ionosphere maps
  - station troposphere parameters
  - Standards (site guidelines, RINEX, ANTEX, IONEX, SP3, RTCM, ...)
  - GNSS system monitoring (constellation status, DCB, ...)

http://igs.org/components/prods.html
The image & visibility of geodesy is enhanced through its provision of critical “geometric” & “gravimetric” services for science & society...

Precise GNSS Positioning: More than just Geodesy
From GPS to Multi-GNSS...

- **GNSS:**
  - GPS (32) (32)
  - GLONASS (24) (30)
  - Galileo (4) (30)
  - BeiDou (14) (35)

- **RNSS:**
  - QZSS (1) (5-7)
  - IRNSS (2) (7)

- **SBAS:**
  - WAAS
  - MSAS
  - EGNOS
  - GAGAN
  - SDCM

Number of satellites: (Current) (Planned)

Geomatics Education & Research: Challenges & Opportunities, HKPU, 29 May 2014

Precise Positioning GNSS Applications

- Surveying & mapping
- Precise kinematic apps, such as machine guidance/control
- Define/monitor datum, geodesy applications, etc.
- Precise georeferencing of airborne or terrestrial scanning/imaging sensors

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Relative (Differential) Positioning

- GNSS Constellation(s)
- Local CORS Network
- GNSS User
- DGNSS corrs or raw CORS PR/CPH data

Precise Point Positioning

- GNSS Constellation(s)
- CORS Network
- GNSS User
- CPH measurements
- GNSS Satellite Orbit and Clock Corrections (Real-time or post-processed)
But do these numbers tell the whole story?

No, the economic & social benefits to society of accurate & reliable PNT are estimated to be greater than the mass market “size”
Some Benefits of PP GNSS in Australia

- 2008 study found productivity gains with potential cumulative benefit $73B to $134B over next 20 years in agriculture, construction and mining alone.
- Additional cumulative economic benefit $32B to $58B from a coordinated rollout of NPI.
- Also, significant environmental benefits, such as reduced carbon footprint, through greatly improved fuel efficiency.
- But current market uptake in A-C-M is about 10%!


Advanced ITS Applications...

Positioning in vehicles is going from Passive to Active... from simple navigation to information about traffic to warnings about hazards to actively avoiding hazards
The image & visibility of geodesy is enhanced through its identification with cutting-edge GNSS positioning technology & applications...
Concluding Remarks: The Value of Geodesy

- Fundamental geoscience… solid earth geophysics, atmospheric, cryospheric & oceanographic processes, hydrology...
- Global Change studies… climate change, water cycle & mass transport, sea level rise, mesoscale circulation, GIA, slow deformation… long-term monitoring
- Geohazard research & disaster response… seismic, volcanic, landslip, subsidence, storms, flooding, tsunami, space weather… early warning systems
- Geodetic reference frames… ITRF, national datums, SDI, gravity, timing… supports national mapping & precise positioning
- Engineering… PNT, atmospheric remote sensing, georeferencing sensor platforms, POD… operational & engineering geodesy

Geodesy has an “visibility problem”… Much of what geodesy does remains unseen & under appreciated… That can change, but universities must modernise their geodesy education…