GGOS Global Space Geodesy Networks and the Role of Laser Ranging

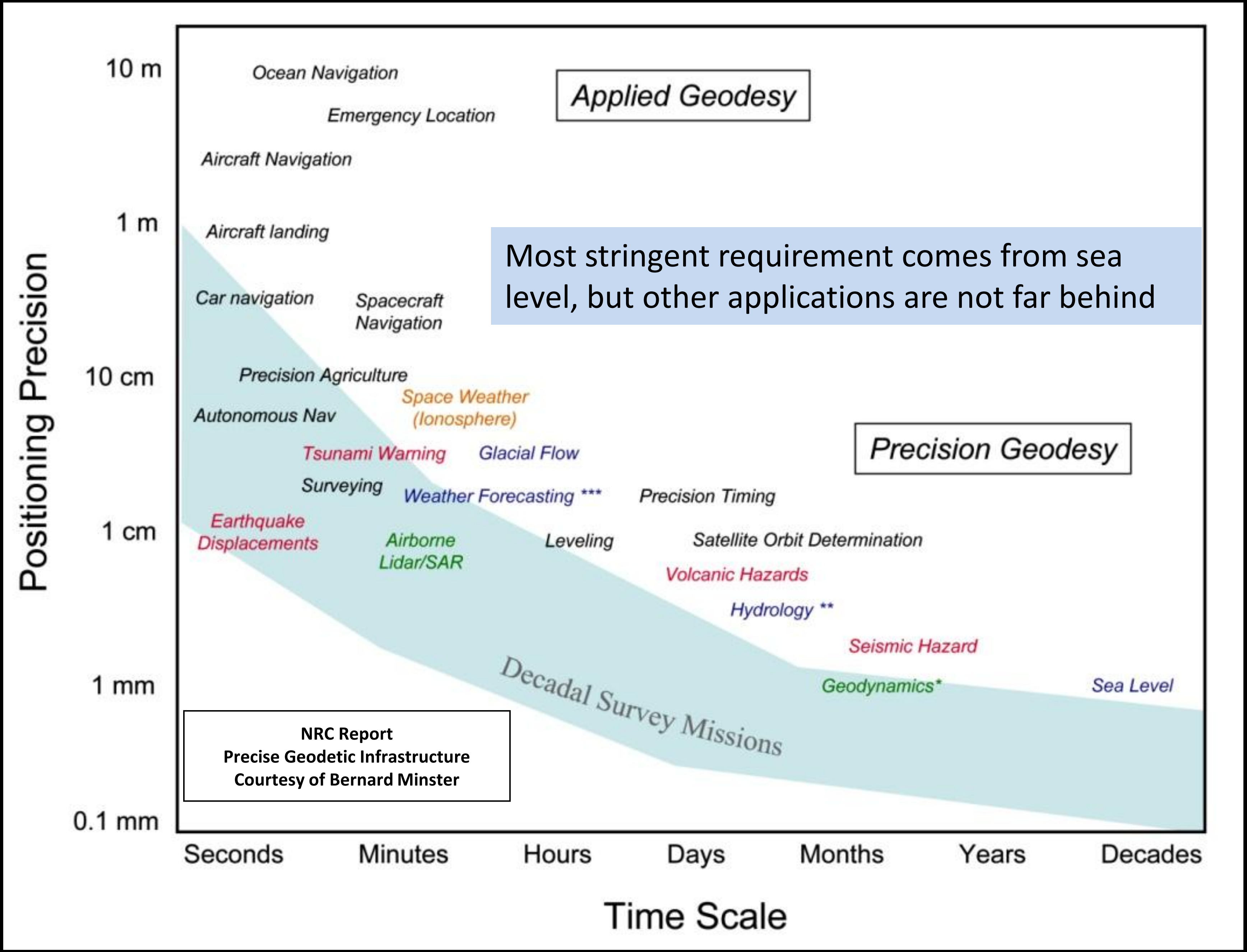
(Article 13-0103)

Michael Pearlman[1], Erricos Pavlis[2], Carey Noll[3], Chopo Ma[3], Scott Wetzel[4], Graham Appleby[5], Ruth Neilan[6]

[1]Harvard-Smithsonian Center for Astrophysics, Cambridge, USA
(mpearlman@cfa.harvard.edu, 001 617 4960121)
[2]University of Maryland Baltimore County, Baltimore, USA
[3]NASA Goddard Space Flight Center, Greenbelt, USA
[4]Honeywell Technical Solutions, Inc
[5]Natural Environment Research Council
[6]Jet Propulsion Laboratory/Caltech

18th International Workshop on Laser Ranging
Fujiyoshida, Japan
November 11 - 15, 2013

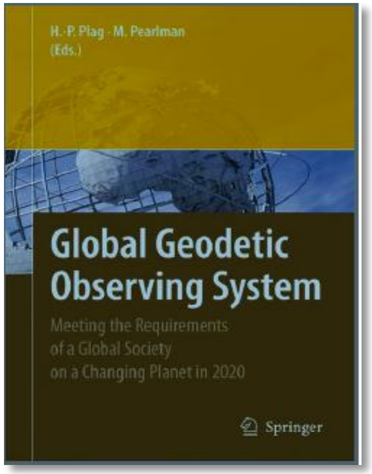
Most stringent requirement comes from sea level, but other applications are not far behind



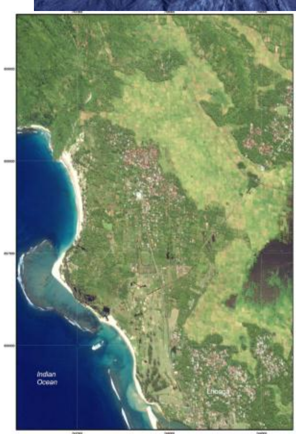
Courtesy of Bernard Minster
http://dels.nas.edu/Report/Precise-Geodetic-Infrastructure-National-Requirements/12954

Global Geodetic Observing System (GGOS)

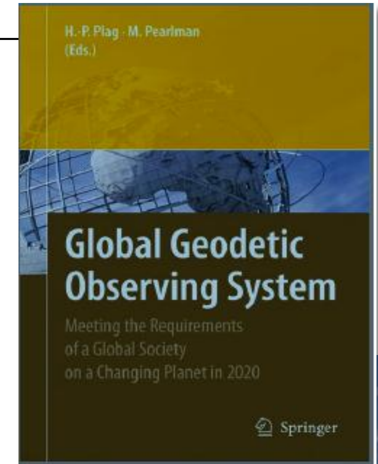
- Established by the IAG to integrate the three fundamental areas of geodesy (Earth's shape, gravity field, and rotation), to monitor geodetic parameters and their temporal variations in a global reference frame with a target relative accuracy of 10E-9 or better.
- Provide products & services with the geodetic accuracy necessary to address important geophysical questions and societal needs, and to provide the robustness and continuity of service which will be required of this system in order to meet future needs and make intelligent decisions
- Constituted mainly from the Services (ILRS, IVS, IGS, IDS, and IERS)
- Main focus at the moment is the International Terrestrial Reference Frame

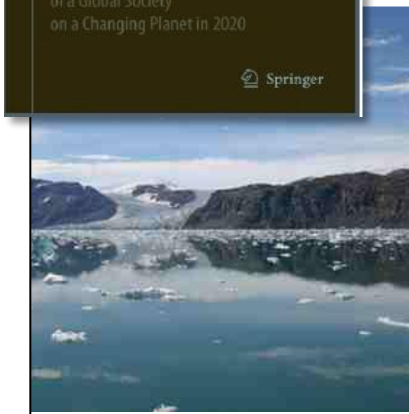


Global Geodetic Observing System (GGOS)



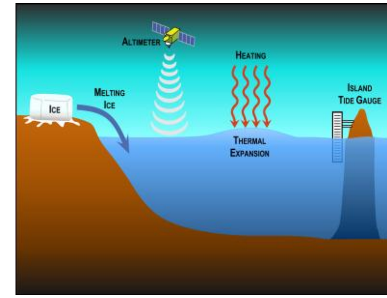
- Established by the IAG to integrate the three fundamental areas of geodesy (Earth's shape, gravity field, and rotation), to monitor geodetic parameters and their temporal variations in a global reference frame with a target relative accuracy of 10E-9 or better.
- Provide products & services with the geodetic accuracy necessary to address important geophysical questions and societal needs, and to provide the robustness and continuity of service which will be required of this system in order to meet future needs and make intelligent decisions
- Constituted mainly from the Services (ILRS, IVS, IGS, IDS, and IERS)
- Main focus at the moment is the International Terrestrial Reference Frame





GGOS Reference Frame Requirement

- Our metric measurements depends on the Reference Fame
- Most stringent requirement from sea level rise:
  - "accuracy of 1 mm, and stability at 0.1 mm/yr"
  - This is a factor 10-20 beyond current capability



- Accessibility: 24 hours/day; worldwide

Users anywhere on the Earth can position their measurements in the reference frame

- Space Segment:
  - LAGEOS, LARES, GNSS, DORIS to define the reference frame
- Ground Segment (Core Sites):
  - Global distributed network of "modern technology", co-located SLR, VLBI, GNSS, DORIS stations locally tied together with accurate site ties
  - Dense network of GNSS ground stations distributes the reference frame globally to the users
  - Co-locate with other measurement techniques including gravity field, tide gauges, leveling, etc.

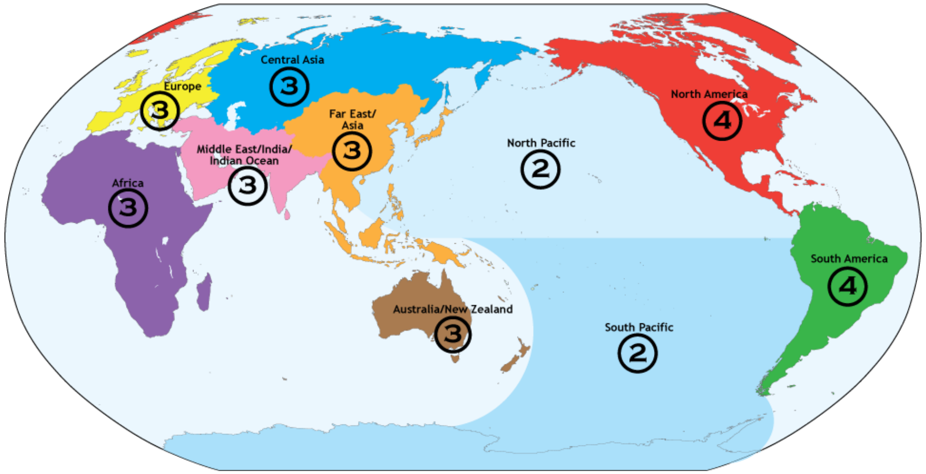
Simulation Studies to Scope the Network

(impact on the Reference Frame)

(Erricos Pavlis)

Simulation studies show:

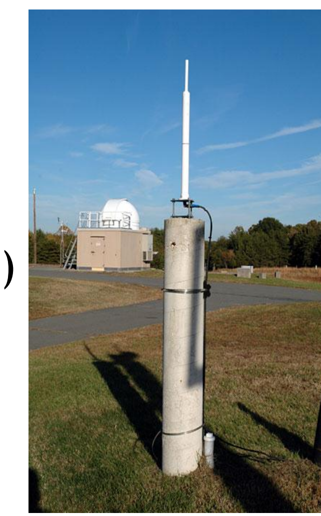
- ~32 globally distributed, well positioned, new technology, co-location sites will be required to define and maintain the reference frame;
- ~16 of these co-location stations must track GNSS satellites with SLR to calibrate the GNSS orbits which are used to distribute the reference frame.



- Major Challenge
- Will require time, significant resources, and strong international participation

Example Fundamental Station

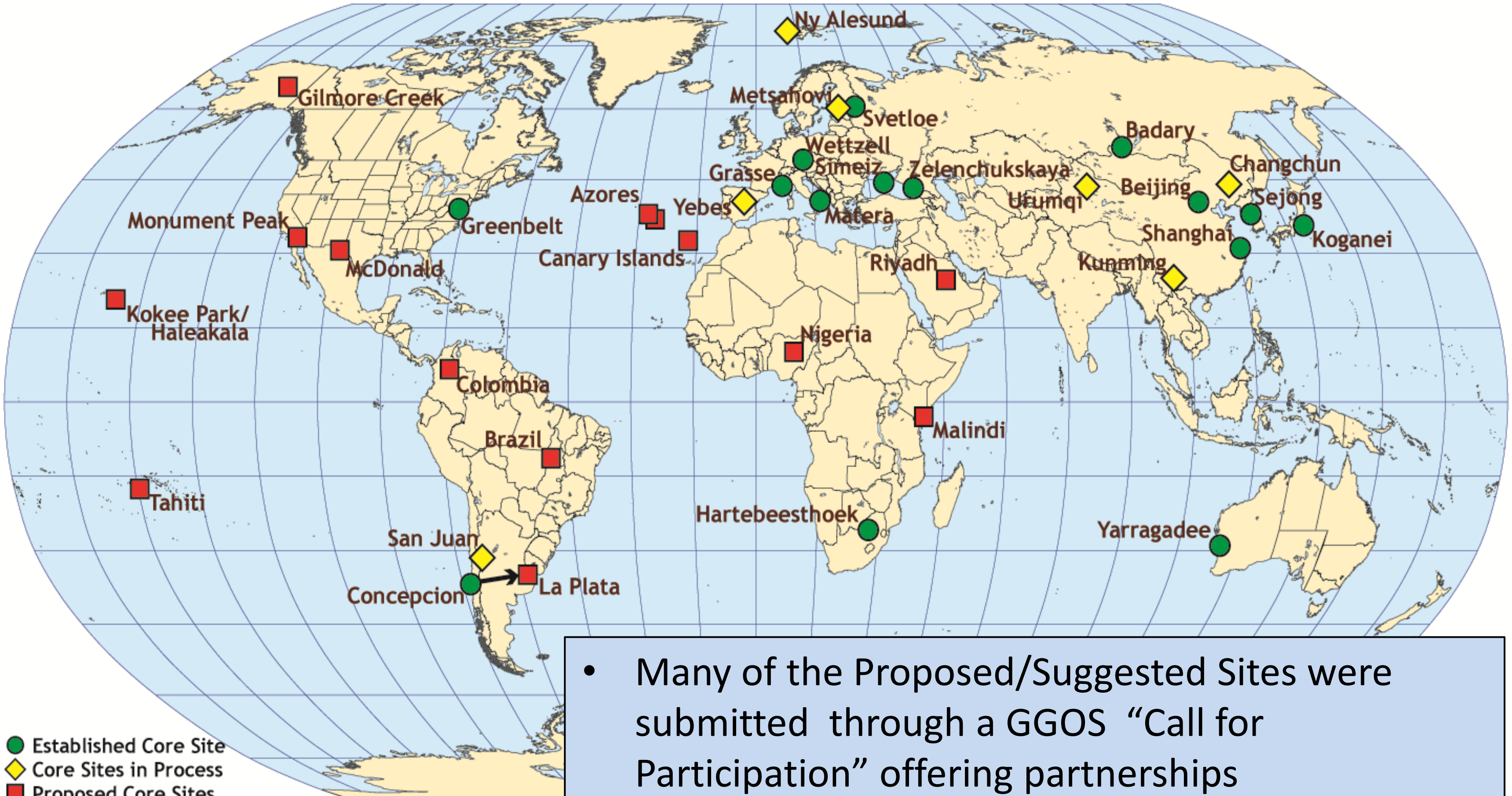
NASA Goddard Space Flight Center, Greenbelt MD, USA



Goddard Geophysical and Astronomical Observatory (GGAO) has four techniques on site:

- Legacy SLR, VLBI, GPS, DORIS
- NGSLR
- VLBI2010
- New generation GNSS

Network of Present, in-Process, and Proposed/Suggested Core Sites



- Many of the Proposed/Suggested Sites were submitted through a GGOS “Call for Participation” offering partnerships

GGOS Site Requirements Document

(http://cddis.gsfc.nasa.gov/docs/GGOS_SiteReqDoc.pdf)

- Introduction and Justification
  - What is a Fundamental Station?
  - Why do we need the Reference Frame?
  - Why do we need a global network?
  - What is the current situation?
  - What do we need?
- Site Conditions
  - Global consideration for the location
  - Geology
  - Site area
  - Weather and sky conditions
  - Radio frequency and optical Interference
  - Horizon conditions
  - Air traffic and aircraft Protection
  - Communications
  - Land ownership
  - Local ground geodetic networks
  - Site Accessibility
  - Local infrastructure and accommodations
  - Electric power
  - Site security and safety
  - Local commitment


Global Geodetic Observing System (GGOS)

Site Requirements
for
GGOS Core Sites
(Revision 1a)

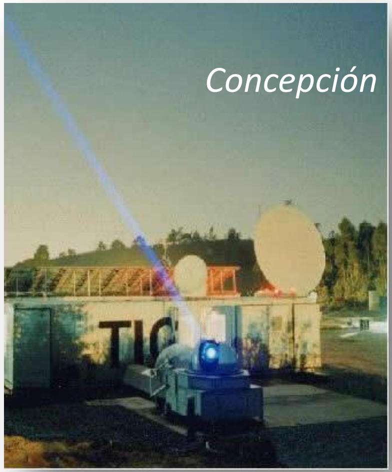
July 18, 2012

Contributors:

Howard Donovan	HTSI
Scott Wetzel	HTSI
Chopo Ma	NASA GSFC
Hayo Hase	TIGO BKG
Dirk Behrend	NASA GSFC
Michael Pearlman	CfA
Carey Noll	NASA GSFC
Erricos Pavlis	UMBC
Jim Long	NASA GSFC
David Stowers	JPL
David McCormick	NASA GSFC
Curtis Emerson	NASA GSFC

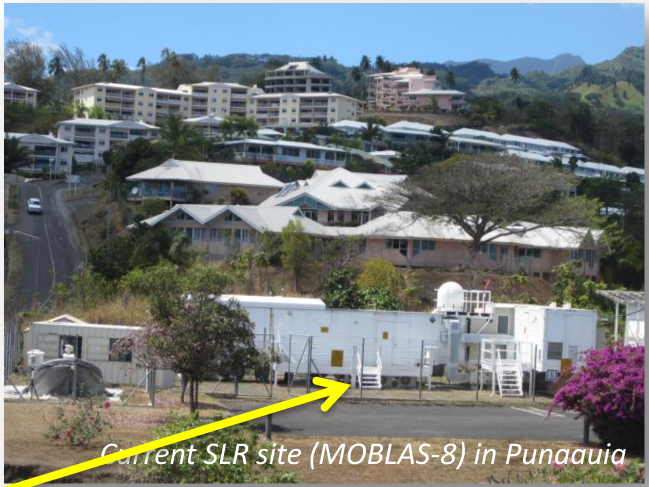
Activities Underway in South America

- Discussions underway with:
  - Colombia: Instituto Geográfico Agustín Codazzi (IGAC)
  - Brazil: National Institute For Space Research (INPE)
- TIGO to move from Concepción to La Plata
- San Juan (NAOC):
  - Planning 40m VLBI2010 compatible system in 2015



Core Site Location Under Consideration French Polynesia

- Cooperation between NASA, CNES, and UFP
- SLR:
  - MOBLAS-8 operational since 1997
  - Co-located GNSS and DORIS
- VLBI:
  - Discussions underway

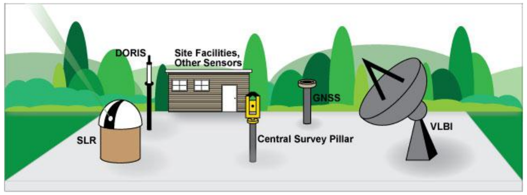


Core Site Locations Under Consideration
Malindi, Kenya and Toto, Nigeria
(speculative)

- Discussions initiated with the Italian Space Agency (ASI) for a partnership site
- GGOS CfP site offered in Toro, Nigeria

Reality

- If we do achieve the full complement of core sites in the right places, it will take a long time;
- Even if we have sufficient resources, its very unlikely that we will find the full compliment of ideal sites; Some sites will have less than ideal conditions;
- Aside from core sites we will always need co-location sites (2 techniques or more) to help link the techniques and enhance global coverage
- We expect a mix of new technology and legacy sites for a long time (maybe forever)
- Data products will depend on this mix of sites and technology indefinitely

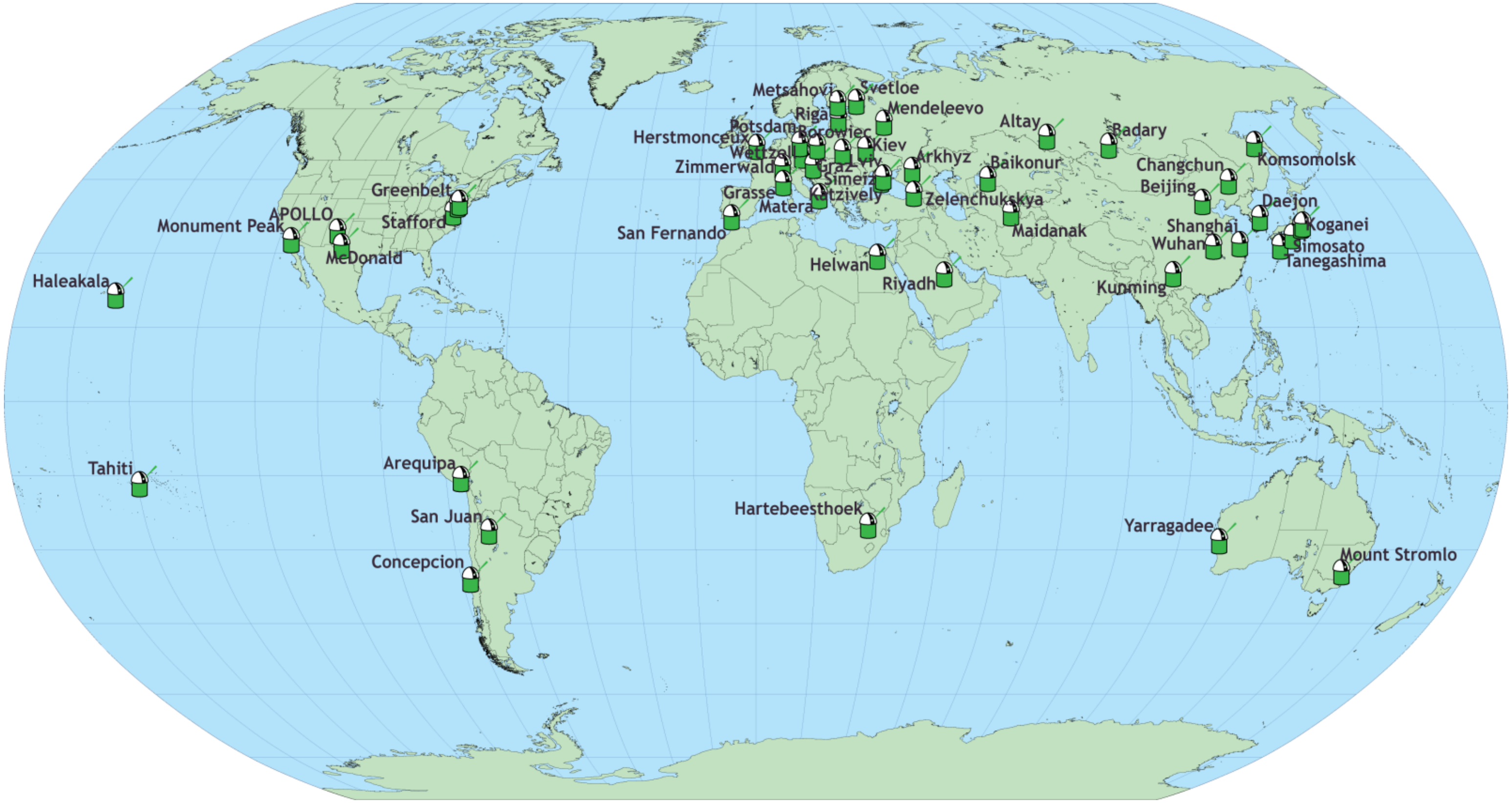


Current Situation with SLR

- Giant steps improvements:
  - High repetition system are populating NP's faster enhancing satellite pass interleaving
  - Narrow pulse widths are reducing rms
  - Near mm precision being demonstrated
  - Addition of LARES to the Reference Frame constellation
  - Improved arrays on GNSS and synchronous satellites
  - Improved data yield and daytime ranging to GNSS and synchronous satellites
  - Improved onsite data preprocessing
  - Increased automation for improved temporal coverage
  - Improved analysis and modeling are improving
  - New groups/new sites joining the network

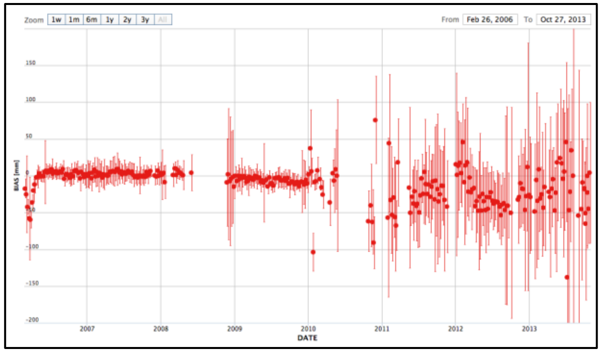
But there are still major challenges even in our current mode of operation

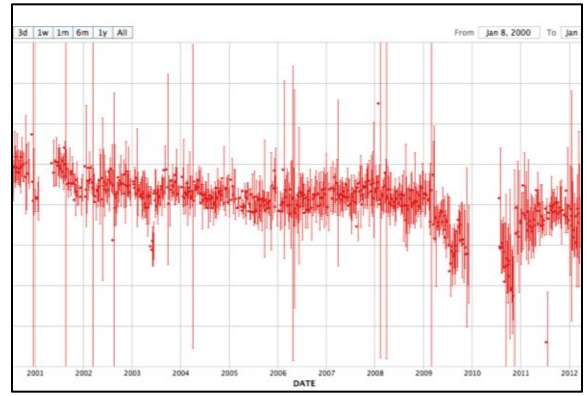
ILRS Network

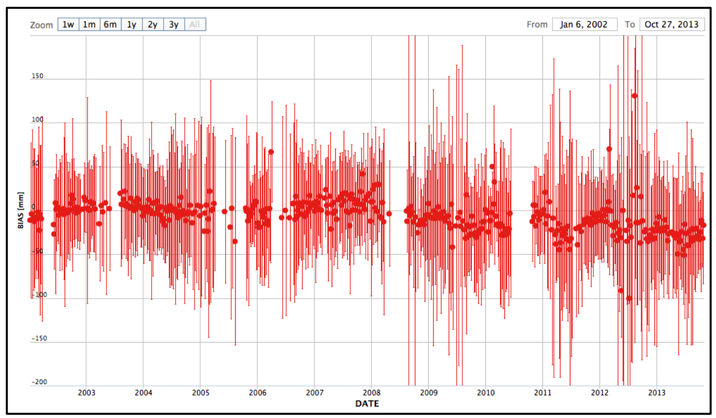


- Large gaps in geographic coverage
- Mix of legacy and new technologies
- Location issues (weather, ground stability, etc.)
- Operational issues

Examples of Unstable Performance

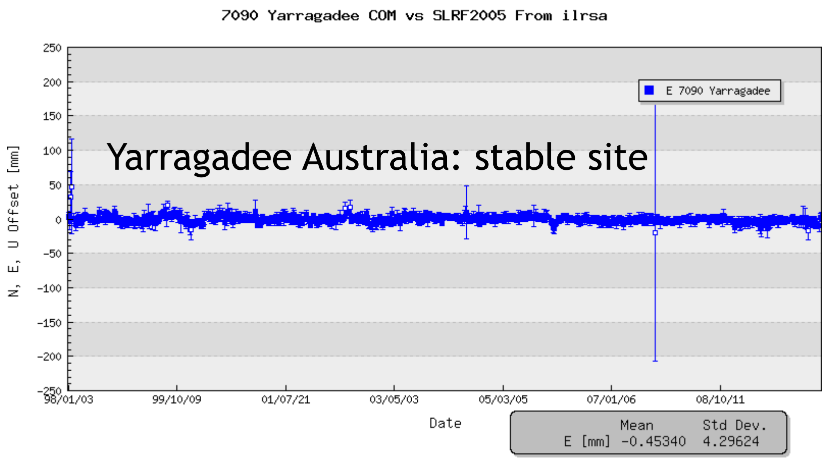






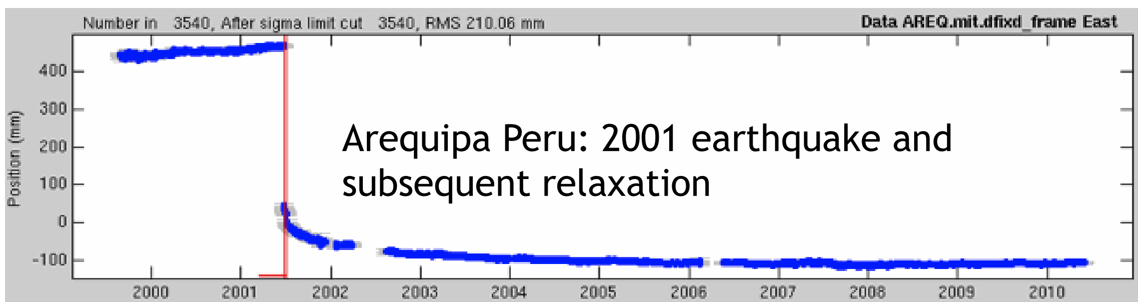
- System biases are corrupting our data products
- Some data and even some stations must be discarded
- Some are engineering and operational issues
- Some are lack of properly reporting systems changes

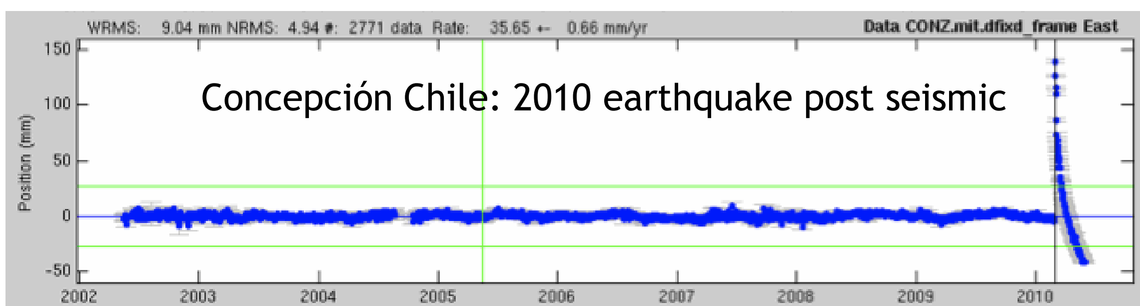
Examples of Local Site Stability
(time history of GPS)



Avoid large dislocations with long relaxation times

Arequipa and Concepción plots courtesy Tom Herring/MIT





Summary

- We have made very significant progress
- We still have many challenges ahead
- We need to put greater care in our data quality through careful station procedures, data scrutiny, and reporting
- We need to use local diagnostics and engineering procedures to examine the data
- We may need better formatted diagnostics from the AWG
- We need to respond promptly to diagnostics from the analysts (data that is corrupted can be wasted)
- Do we have your correct email address?

There are great challenges and there are great opportunities