Space Geodesy Applications: Altimetry Satellites

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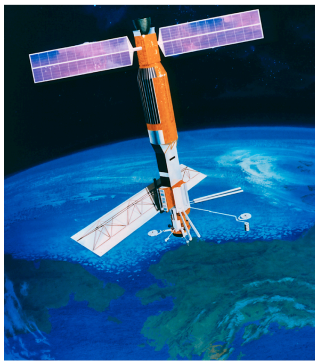
Altimeter Satellites: Pathfinder missions

NASA's involvement with satellite altimetry goes back to the 1970's.

GEOS-3, 1975



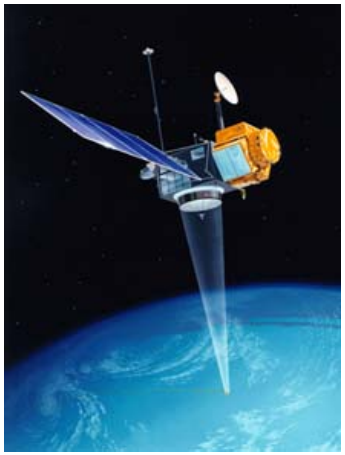
SEASAT, 1978

GEOSAT, 1985

CRYOSAT-2, 2010

Altimeter Satellites

From the launch of the first spaceborne altimeters, Precision Orbit Determination (POD) has been driven by the science goals of the geodetic altimeter missions…



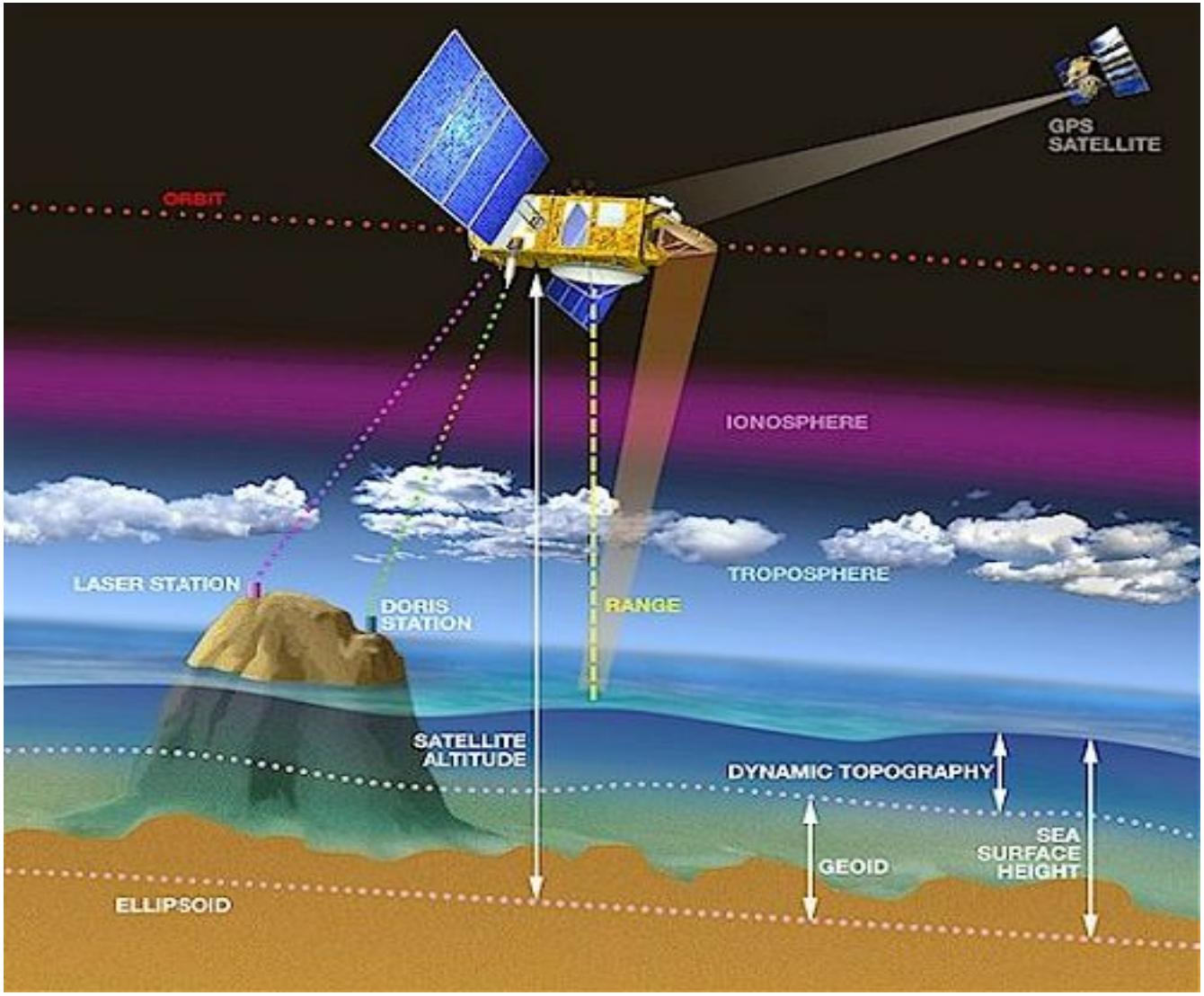
TOPEX/POSEIDON, 1992

Jason-1, 2002
Jason-2, 2008

ENVISAT, 2002

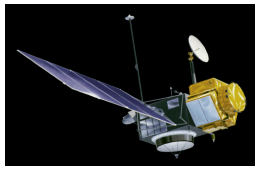
CRYOSAT-2, 2010

POD - Schematic



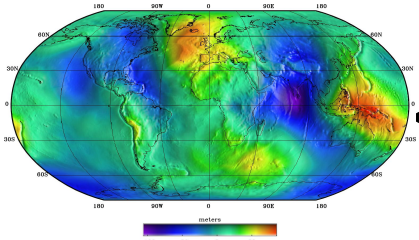
Orbit Determination - Schematic

Onboard Tracking Systems
LRR
DORIS
GPS

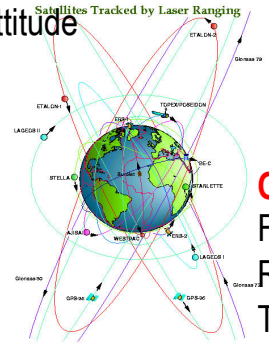


Atmospheric Modeling
Ionospheric Propagation Delay
Tropospheric Refraction
Atmospheric Density

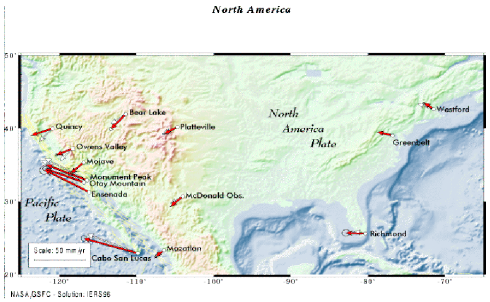
Surface Forces
Modeling
S/C Attitude



Geophysical Models
Gravity Models
Tide Models
Time Variable Gravity

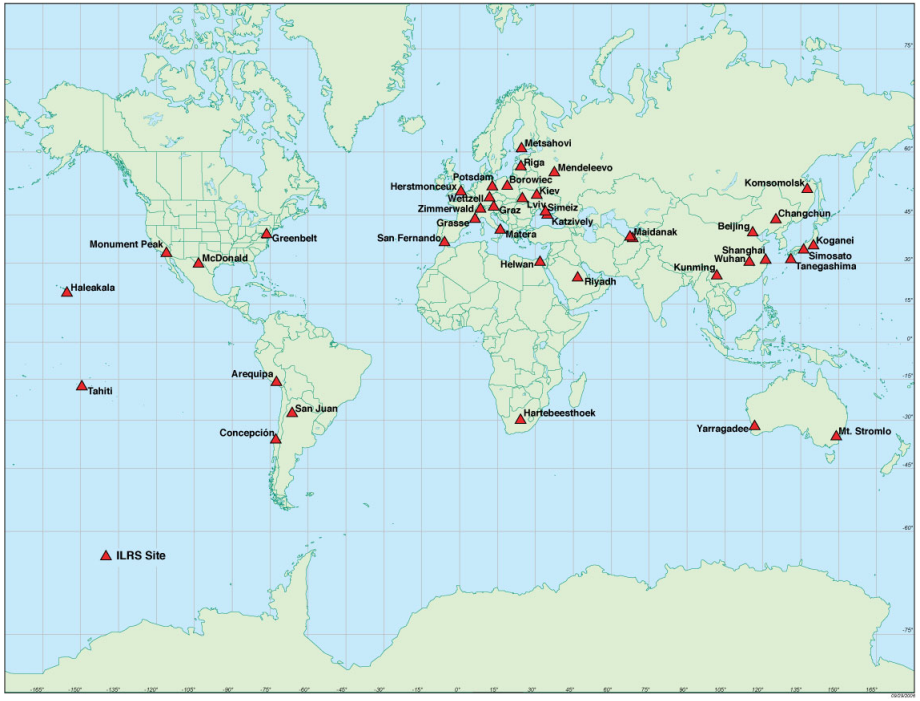


Orbit Determination
Force Modeling
Reference Frame
Tracking Technology



Reference Frame
International Terrestrial Reference Frame
Horizontal plate and vertical site motion
Geocenter motion
Polar Motion and Earth Orientation

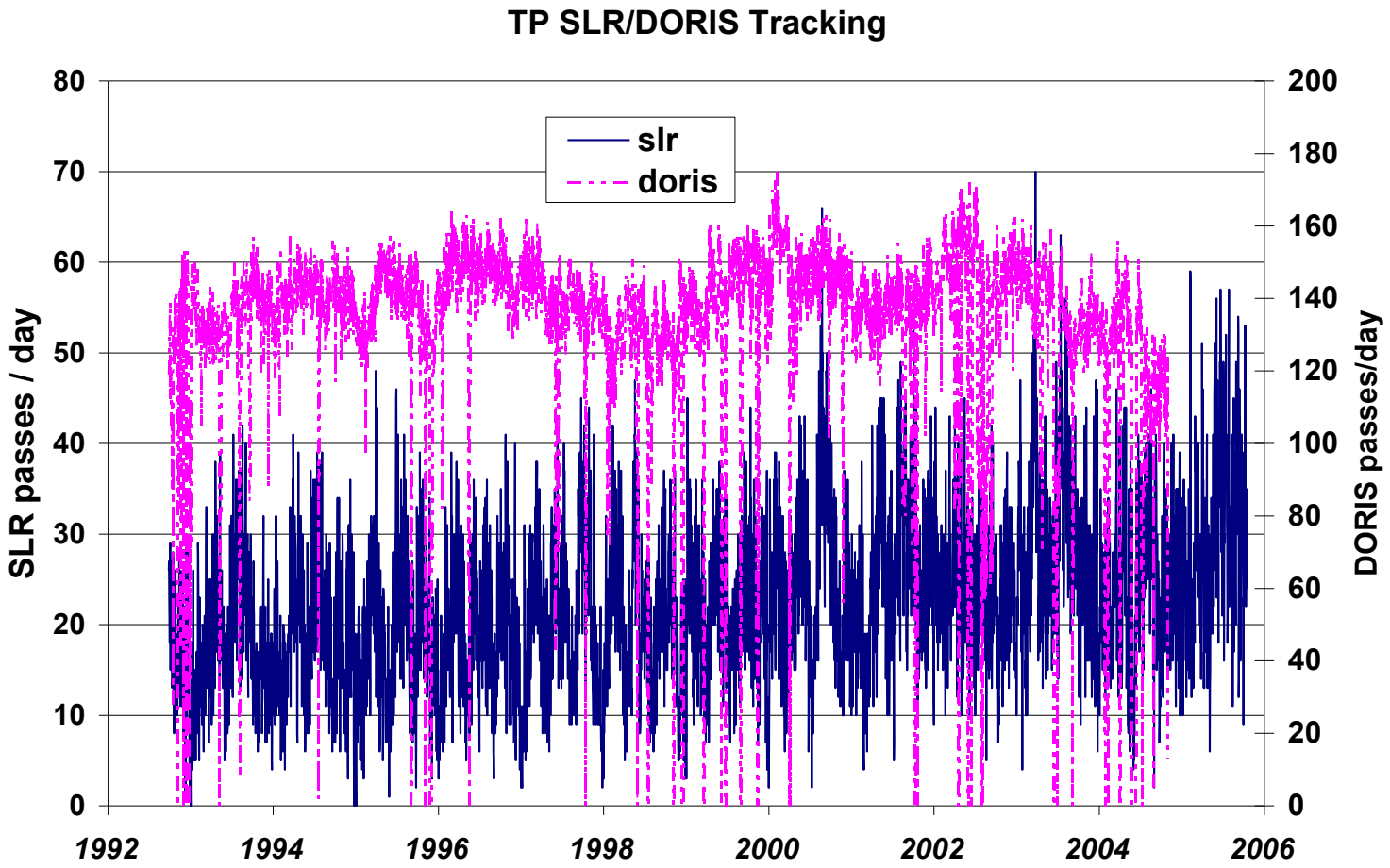
Altimeter satellites - SLR



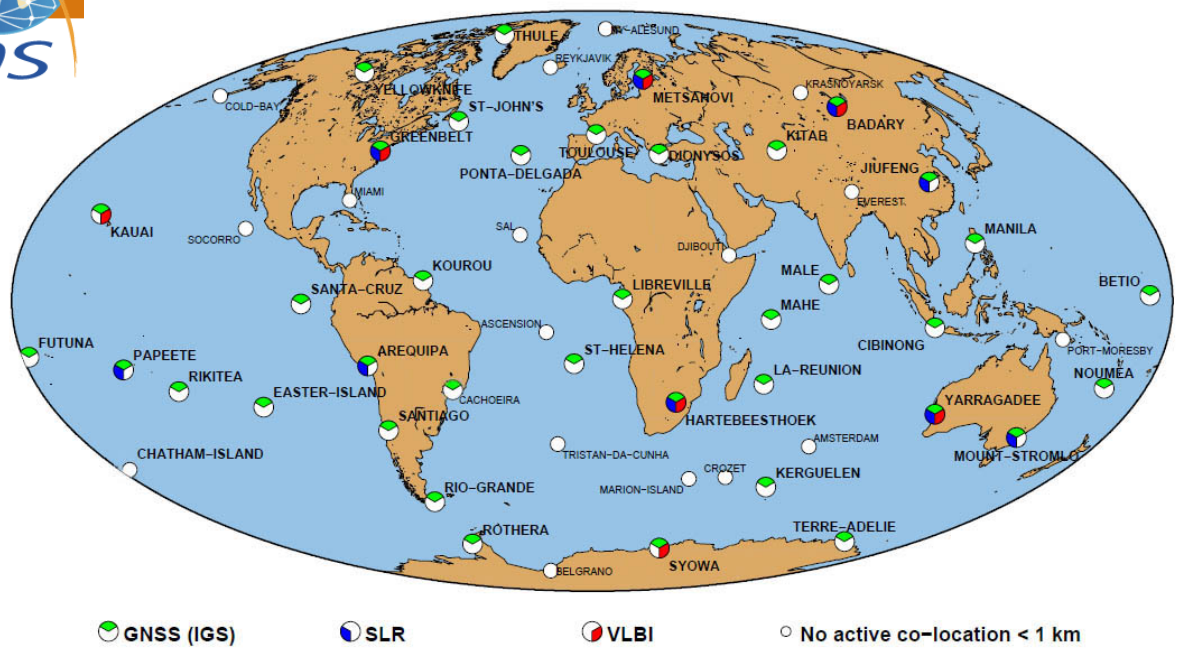
SLR data anchor the altimeter satellite orbits in the ITRF and provide the unambiguous orbit centering. They are essential for orbit validation for all missions.

International Laser Ranging Service

SLR – TOPEX tracking summary



Altimeter satellites - DORIS

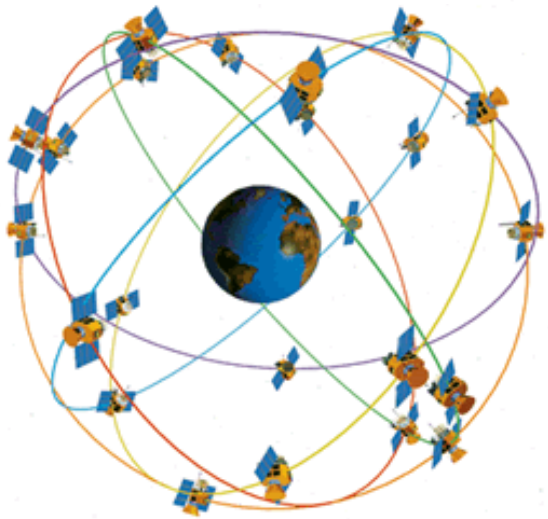


e,g. Rothera,
Antarctica
- **ROTA 1993-2005**
- **ROTB 2005-2007**
- **ROUB 2007-present**

- Global network of ~55 stations (dual-frequency beacons).
- Constellation of Low Earth Orbit (LEO) satellites with DORIS receivers; main users are altimeter satellites (e.g. TOPEX, Jason, Cryosat2, SARAL) and remote sensing satellites (e.g SPOT 2,3,4,5).

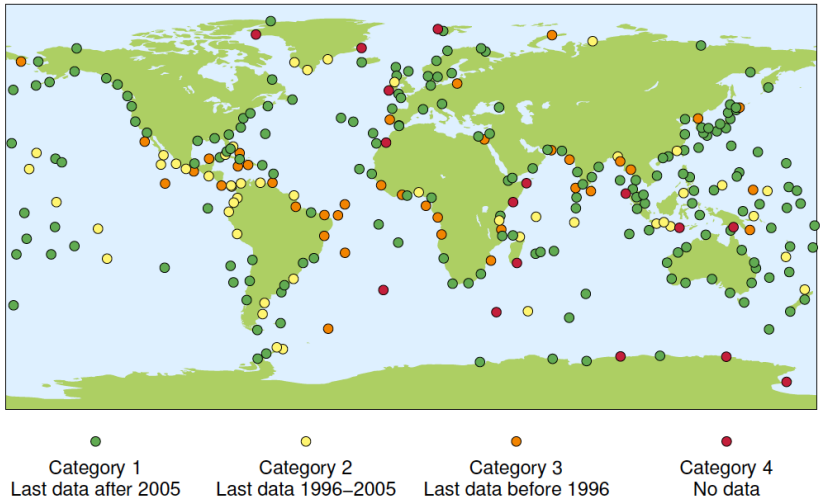
Altimeter satellites - GNSS

GPS Satellite Constellation



JASON GPS Receiver

GLOSS network Tide Gauges

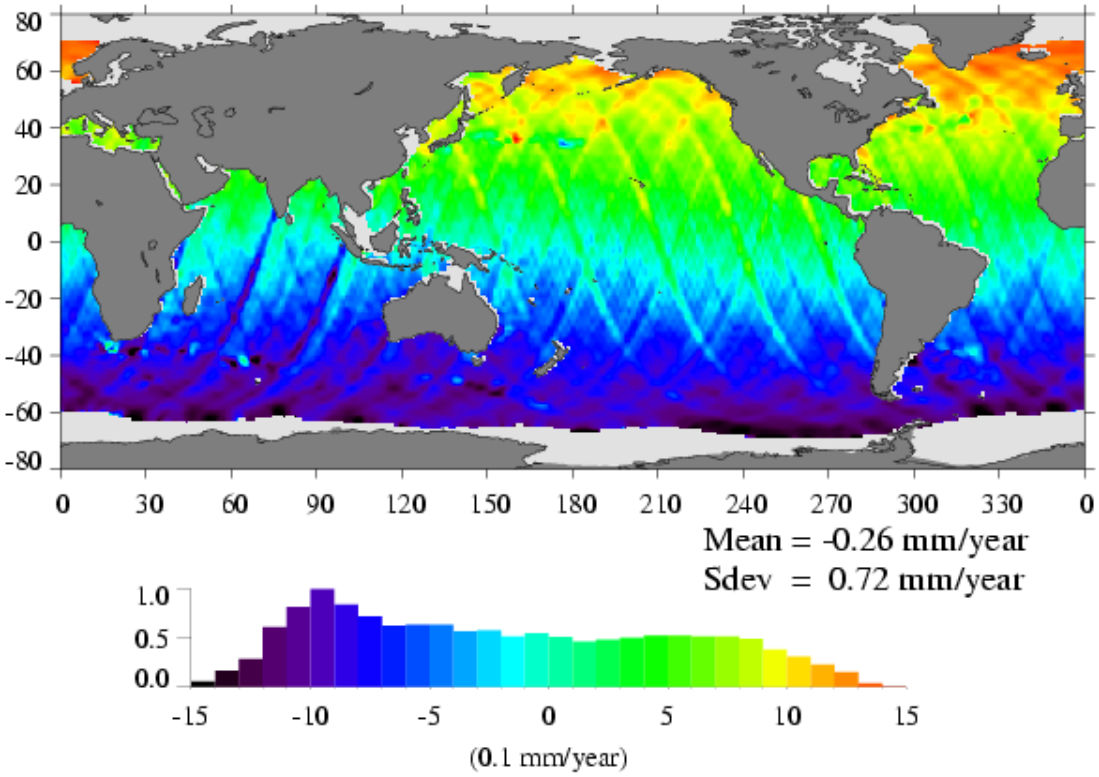


Caveat: Not all GLOSS stations have geodetic measurements of vertical velocity (e.g. from GNSS or DORIS).

IGS International GNSS Service
Formerly the International GPS Service

- Some (not all!) Altimeter satellites depend on GNSS directly (*with a GNSS receiver: e.g. Jason 1-2, SENTINEL-3*); They are linked to the GNSS ground network via the GNSS satellite orbits and IGS ground stations that track the GNSS satellites.
- GNSS stations provide vertical velocities at tide gauge sites used for altimeter calibration.

Altimeter satellites & TRF error



Regional **TOPEX** (**1993-2002**) Sea Surface Height Trend differences from direct impact of the **ITRF2005** (GGM02C) minus **CSR95** (JGM3) orbit differences. **(from Beckley et al.,** *Geophys. Res. Lett.*, **2007).**

Errors in the Z component of the TRF can produce large regional errors in MSL rate determination.

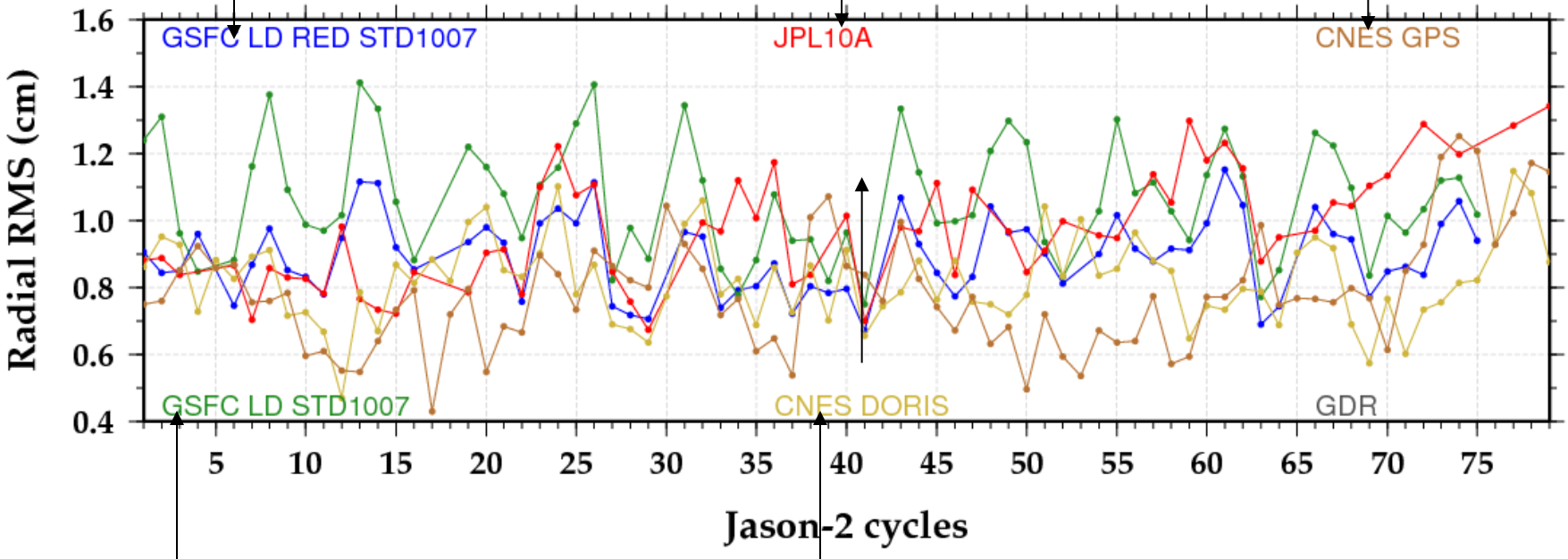
Altimeter satellites – The 1 cm orbit

Orbit intercomparisons for **Jason-2** between techniques and groups (e.g. GSFC SLR/DORIS, vs. JPL GPS-only vs. **CNES SLR/DORIS/GPS**) help to verify the altimeter satellite orbit quality (RMS radial ~1 cm).

SLR+DORIS red-dyn (GSFC)

GPS-only red-dyn (JPL)

GPS-only (CNES)



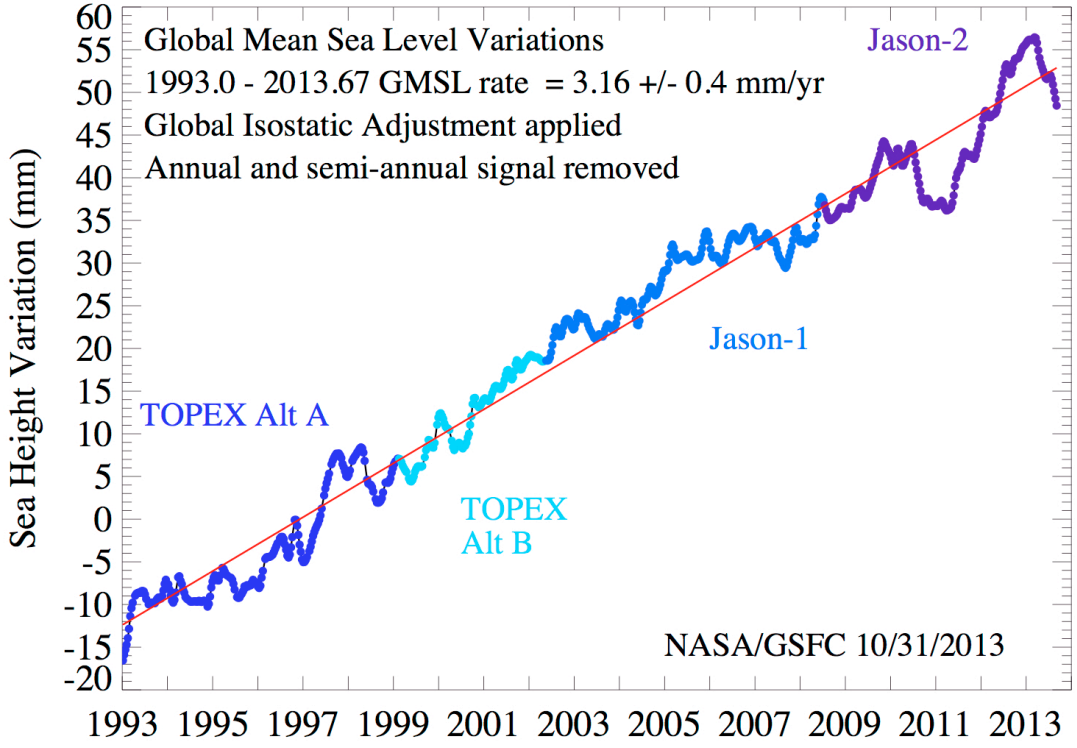
SLR DORIS dyn. (GSFC)

DORIS-only (CNES)

(from **Cerri et al, *Marine Geodesy*, 2010**)

Altimeter satellites – MSL determination

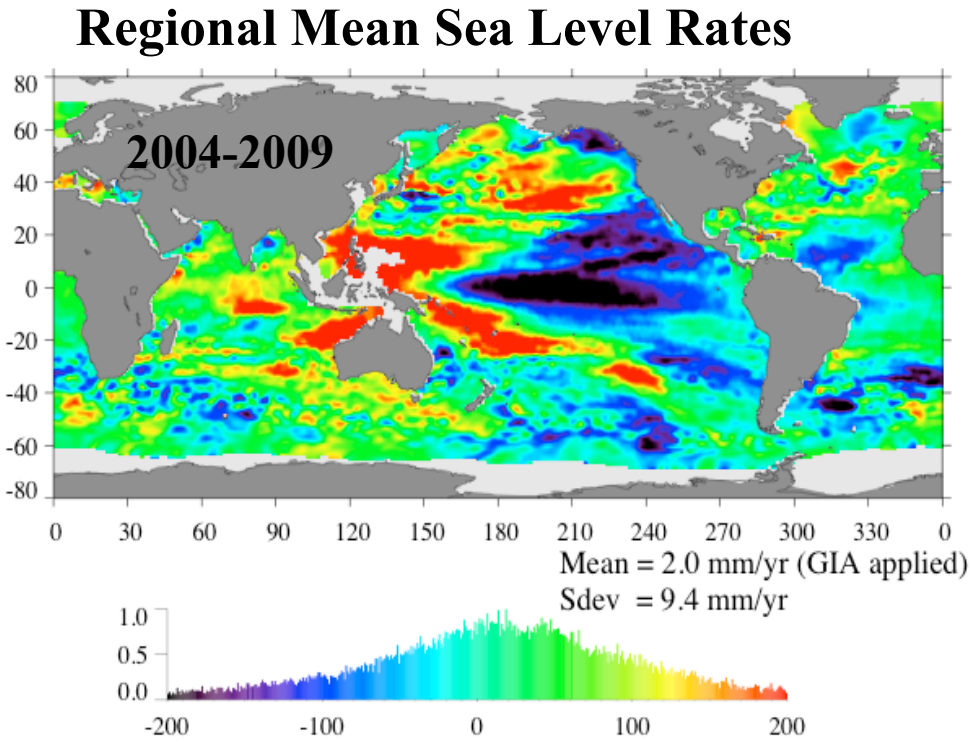
The precise orbits for TOPEX/Poseidon, Jason-1, Jason-2, all computed in a consistent reference frame (ITRF2008) are used to compute the global change in mean sea level from satellite ocean radar altimeter data.



http://podaac.jpl.nasa.gov/highlights/MEaSUREs_TPJAOSv1.0_SSH

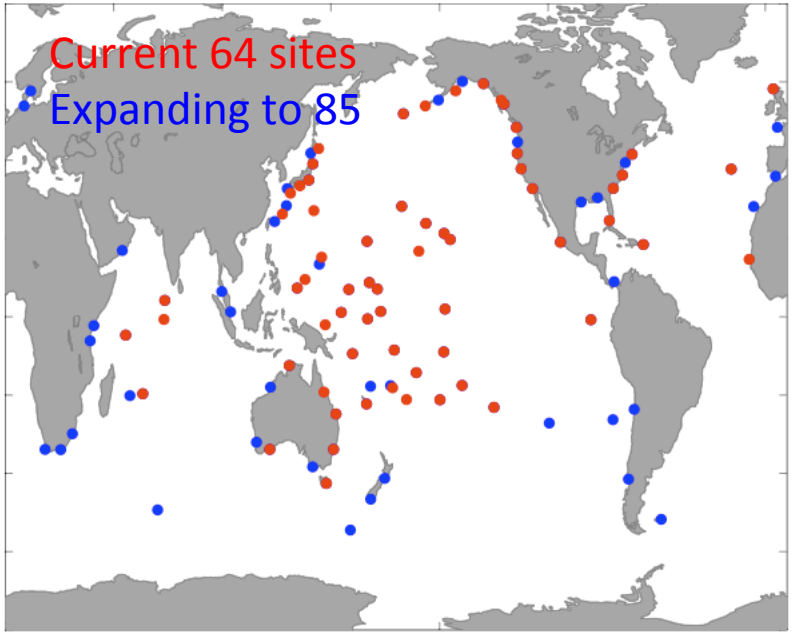
Altimeter satellites – Regional Sea Levels

The precise orbits for TOPEX/Poseidon, Jason-1, Jason-2, in combination with the altimeter data allow us to isolate regional and shorter period changes in mean sea level.



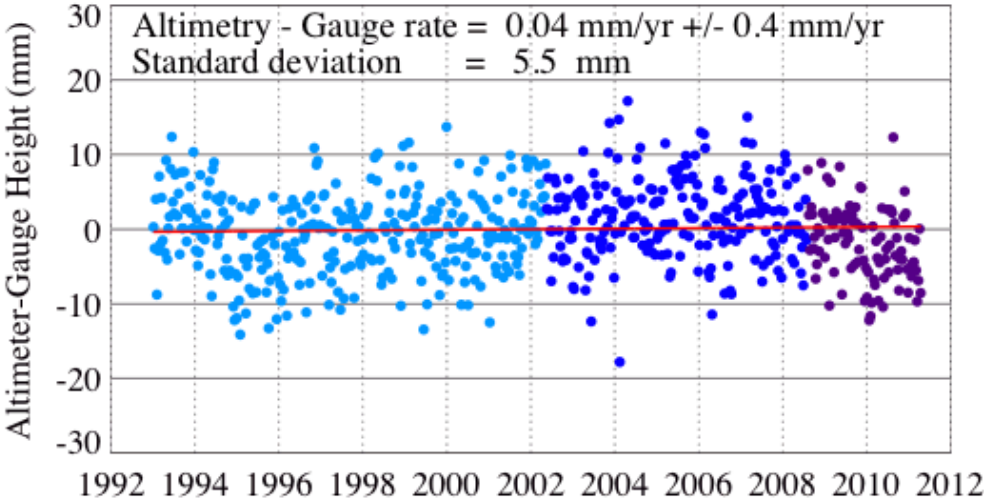
(Beckley et al., *Marine Geodesy*, 2010)

Altimeter vs. tide gauge calibration



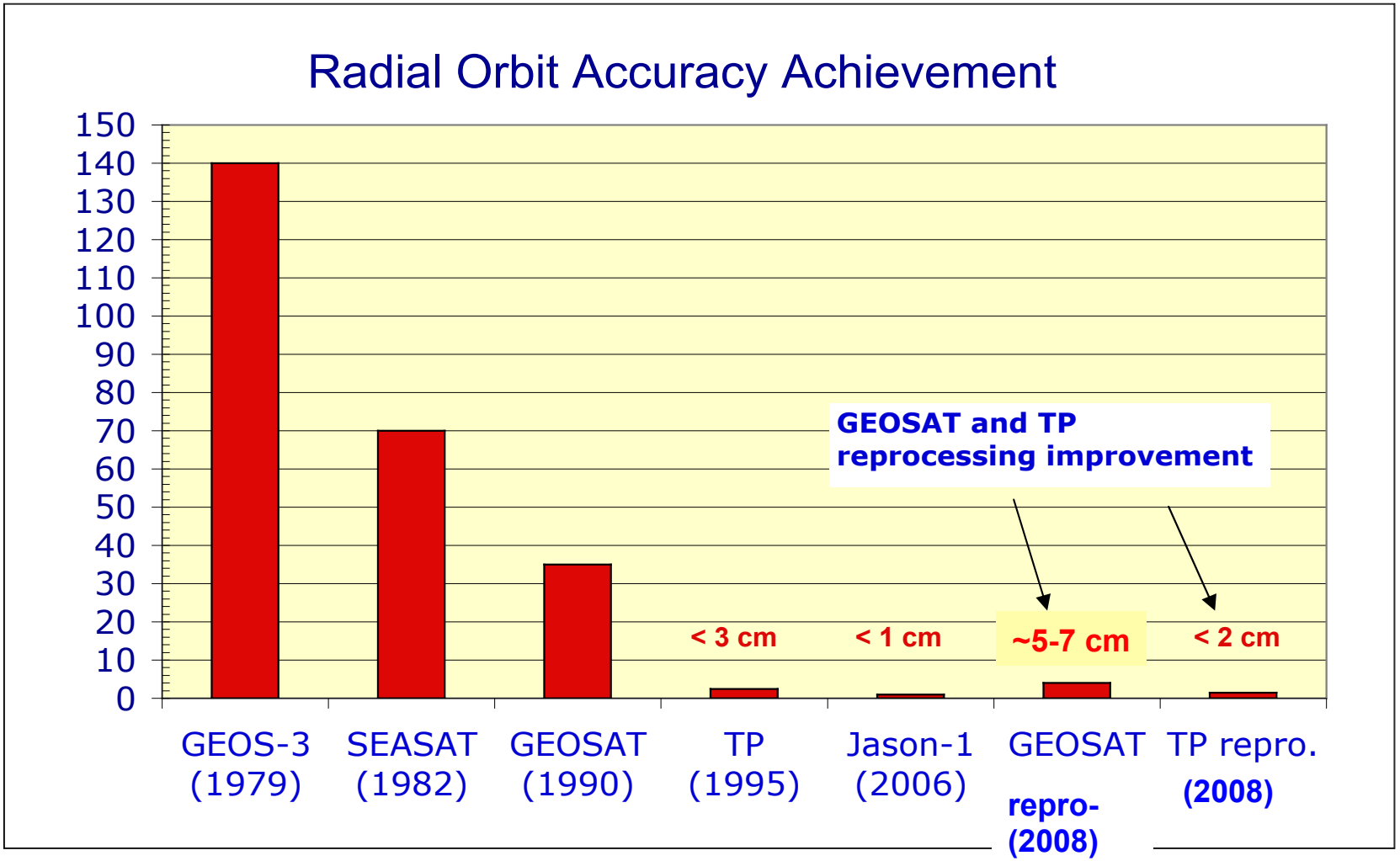
Tide Gauge "ground truth" Network

- Largest uncertainty in estimated rates arises from land motion at tide gauge sites.



(Beckley et al., *Marine Geodesy,* 2010; Mitchum, *Marine Geodesy*, 2000)

Altimeter Satellite POD Summary



Altimeter Satellite Status and Future Missions

Satellite	Agencies	Dates	Alt (km)	Inc. (deg)	Tracking
TOPEX	NASA/CNES	1992-2006	1336	66	SLR + DORIS
Jason-1	CNES/NASA	2002-2013	1336	66	SLR + DORIS + (GPS)
Jason-2	CNES/NASA/ NOAA/Eumetsat	2008-	1336	66	SLR + DORIS¶ + GPS
Cryosat-2	ESA	2010-	717	92	SLR + DORIS¶
Envisat	ESA	2002 - 2012	800	98.5	SLR + DORIS
HY2A	CSA	2011-	963	99.3	SLR + DORIS¶ + GPS
SARAL	ISRO/CNES	2013-	880	98.5	SLR + DORIS¶
SENTINEL-3A	ESA	2015	814	98.6	SLR + DORIS¶ + GPS
Jason-3	NASA/NOAA/ CNES/Eumetsat	2015	1336	66	SLR + DORIS¶ + GPS
SWOT	NASA/CNES	2020	970	78	SLR + DORIS¶ + GPS

¶ DGXX DORIS Receiver (7 channels; can track seven stations at one time).