# GEODETIC REFERENCE SYSTEMS FOR ALTIMETER MISSIONS

P. Willis, C. Boucher, P. Sillard, G. Wöppelmann
(IGN/LAREG, France)

**Space oceanography missions such as the U.S./French TOPEX/POSEIDON (T/P) mission have significantly increased our understanding of mean sea level, ocean circulation, tides, and so on.**

**Ocean data from assimilation models are coming close to geometric precision on the order of a few millimeters, and even tenths of a millimetre for secular variations. These results imply that, as well as ocean measurements, we also need a very-high-accuracy orbit, about 2 cm for T/P. They also mean that all geodetic data products must be supplied in a single reference frame. This requirement may seem obvious to the non-specialist, but it has not really been met for current ocean products.**

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# Introduction

For practical reasons, each orbit is linked to a different tracking network: SLR, DORIS , GPS for T/P; SLR and PRARE for ERS-2. Each orbit is, naturally, in a different geodetic reference system. At the centimetre level, the two origins practically never coincide. The scale factor (linked to the definition of the metre) itself can differ to within an order of a few $10^{-9}$, equivalent to a spurious increase of 0.6 mm in height across the ocean. Also, for a given orbit product, it is still difficult to harmonise these references: the tracking stations are subject to horizontal and vertical motions which can be difficult to predict over long periods.

IGN, in collaboration with the CNES orbit determination department, has begun an in-depth analysis of the use of geodetic reference systems for space oceanography. The work comprises various complementary studies:

- accurate location of orbit determination stations: analysing the quality of the station coordinates, temporal consistency of references, transforms, etc.,
- production of extra geodetic control points, and fixing tide-gauges in the same geodetic reference system,
- studying the current status and the scope for a posteriori correction of operational orbits, without orbit recalculation, to overcome certain systematic errors.

# Accurate location of orbit determination stations

Four space geodesy tracking systems can currently determine an operational low-earth-orbit accurately enough for space oceanography: laser telemetry, SLR, DORIS , GPS and PRARE. These permanent networks are shown in Figure 1.

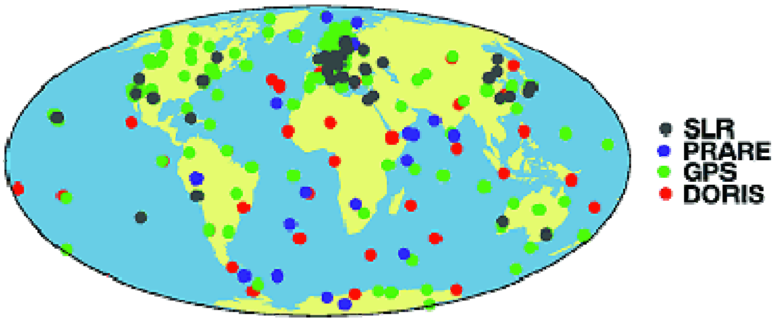


***Figure 1***
*oceanography-related orbitography networks*

Every year IGN produces a terrestrial reference frame, within the International Earth Rotation Service (IERS), based on calculations at various space geodesy analysis centres worldwide [Boucher et al., 1996]. The coordinates (and velocities) from the tracking stations, currently with the exception of PRARE, are supplied within the IERS.

The solutions are constantly improved by enhanced computational methods at the space geodesy centres and by the new modelling approaches used for reference systems (Sillard et al., to appear).

Figure 2 shows the improvement in internal precision of two recent solutions: ITRF94 [Boucher et al., 1996a] and ITRF96 [Boucher et al., 1997]. The coordinates of many geodetic points are now defined within a few mm in a terrestrial reference frame.

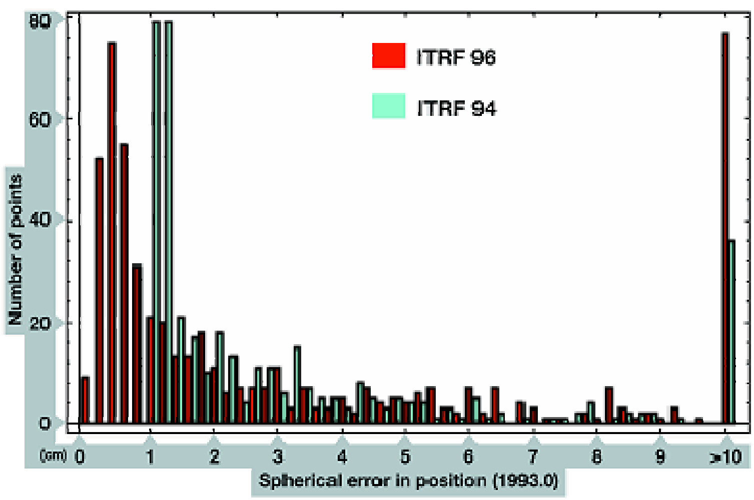


***Figure 2***
*formal standard deviations, ITRF94 and ITRF96*

# Tide-gauge fixing

For many years, various geodesy-oriented organisations have been aware of the usefulness of fixing tide-gauges geodetically. This makes it possible to monitor sea level not only relative to the shoreline but also in absolute terms relative to a centre of mass, or, in fact, relative to the conventional origin of the reference system [Woodworth et al, 1997, Baker et al, 1997; IOC, 1997].

IGN started this type of work in 1986, in collaboration with many other geodetic organisations. The table below summarises the status of field campaigns conducted since that time.

| **Field campaign** | **Space technology** | **Year** | **Region** | **Tide-gauges** |
|---|---|---|---|---|
| EUVN | GPS | 1997 | Europe | 75 |
| EUROGAUGE | GPS<br>GPS | 1993<br>1994 | U.K., Spain, France, Portugal<br>U.K., Spain, France, Portugal | 16 |
| NIVMER | GPS | 1994<br>1995 | Kerguelen | Kerguelen |
| SELF | GPS | 1992<br>1993 | Mediterranean | 20 |
| Channel | GPS | 1986 | English Channel (France and U.K.) | 12 |
| Mediterranean | GPS | 1986<br>1988<br>1990 | Mediterranean | 13 |
| DORIS SIMB | DORIS | 1998 | New Caledonia | Noumea |
| DORIS SIMB | DORIS | 1997 | Tahiti | Papeete |
| DORIS SIMB | DORIS | 1995 | Argentina (Rio Grande) | Ushuaia |
| DORIS SIMB | DORIS | 1997 | Ascension | Ascension |
| NIVMER | DORIS | 1994 | Kerguelen | Kerguelen |

*Table 1: tide-gauge fixing, by IGN or in collaboration with IGN*

The work was conducted either during international GPS observations or as part of field campaigns on the DORIS tracking network, for which IGN is doing the installation and maintenance for the French space agency (CNES).

However, these field campaigns are still difficult to make use of, particularly as the information needed to get the most from them is often missing [Wöppelmann, 1997].

# Future prospects

We expect eventually to calculate reference coordinates for oceanographers, based on the tracking stations (SLR, DORIS , GPS and PRARE) as well as points of interest for space oceanographers (tide-gauges and calibration points). This would make it possible to use old TOPEX/POSEIDON orbits, unmodified, as well as orbits from other satellites such as ERS-2.

We are now closely examining systematic effects induced by geodetic reference problems in ocean data products, e.g. amplitude, spatial and temporal correlations, and how to characterise them.

# Conclusions

The ITRF96 results are considerably better than those of ITRF94. And geodetic problems are tending to diminish. Also, the various international campaigns to fix tide-gauges will make it possible, within a few years, to supply scientific users with positions and velocities from tracking stations and tide-gauges in the same geodetic reference system, known with certainty and maintained over time for several decades. ***References :***


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