Comparison of Topex/Poseidon sea surface heights and Tide Gauge sea levels in the South Indian Ocean

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Abstract

The comparison of Topex/Poseidon sea surface heights and Tide Gauge sea levels was studied in the South Indian Ocean after Topex/Poseidon mission of about 3 years (11- 121 cycles) from January 1993 through December 1995. The user's handbook (AVISO) for sea surface height data process was used in this study. Topex/Poseidon sea surface heights ($\zeta^{T/P}$), satellite data at the point which is very closed to Tide Gauge station, were chosen in the same latitude of Tide Gauge station. These data were re-sampled by a linear interpolation with the interval of about 10 days, and were filtered by the gaussian filter with a 60 day-window. Tide Gauge sea levels (ζ^{Argos}, $\zeta^{In\ situ}$ and ζ^{Model}), were also treated with the same method as satellite data. The main conclusions obtained from the root-mean-square and correlation coefficient were as follows: 1) to produce Tide Gauge sea levels from bottom pressure, in-situ data of METEO-FRANCE showed very good values against to the model data of ECMWF and 2) to compare Topex/Poseidon sea surface heights of Tide Gauge sea levels, the results of the open sea areas were better than those of the coast and island areas.

Key words: Signal treatment, Topex/Poseidon sea surface heights, Tide Gauge sea levels

Introduction

The altimeter radar of Topex/Poseidon satellite measures sea surface height as the distance of difference between altimeter range and orbit height, with the correction of geoid height (Yoon *et al.*, 1998). Altimeter offers sea surface heights with the time interval of about 10 days in any observed points and Tide Gauge observes bottom pressures with the time interval of 1 hour in any considered points.

Until now, many studies used to altimeter data have reported by Tai *et al.* (1989), Wyrtki and Mitchum (1990), Harangozo *et al.* (1993) and Chao *et al.* (1993) for Geosat satellite, and by Topex/Poseidon: Geophysical evaluation (1994) for Topex/Poseidon, respectively.

This study has two objectives as follows: 1) to find the reasons of discordance between Topex/Poseidon sea surface heights and Tide Gauge sea levels, and 2) to understand the mutal relations.

Data and Methods

In order to study the variations of sea levels in the Amsterdam- Crozet- Kerguelen region of the South Indian Ocean (Fig. 1), the comparison of Topex/Poseidon sea surface heights and Tide Gauge sea levels was carried out during 3 years. Firstiy, Topex/Poseidon data were offered by CD-ROM of AVISO (Archivage, Validation et Interpretation des donnees Satellites) according to the user's handbook for sea surface height data process (AVISO, 1994a and 1994b). Secondly, the observed tidal stations were divided of two areas as follows: 1) the bottom pressures were measured by Tide Gauge in the bottom plateau area, and 2) the atmospheric and bottom pressures were obtained by Argos satellite in the coastal area. And finally, the two atmospheric pressures (the in-situ data of METEO-FRANCE and the model data of ECMWF [European Center for Medium- range Weather Forecasting]) were used together in this study, respectively.

The oceanic tide as one of important oceanic factors was especially used in order to obtain accurate sea surface heights (Le provost *et al.*, 1994a and 1994b). Topex/Poseidon data were chosen at the point, with the same latitude, which is very closed to Tide Gauge stations (Mitchum, 1994).

Sea levels were calculated with the hydrostatic equation, then $P_b(t)$ depends on $P_a(t)$ in all the observed periods, as follows:

$$P_b(t) = \rho g H + P_a(t) \quad \text{------------------} \quad (1)$$

$$H = \overline{h} + h_s(t) \quad \text{-----------------------} \quad (2)$$

here, ρ is density (Kg/m^3), g is gravity (m/sec^2), $\overline{h}$ is mean sea height, $h_s(t)$ is variations of sea level with the fonction of times and H is total sea height, respectively. Therefore, $h_s(t)$ and $h_i(t)$ can be described as the next equations,

$$\begin{aligned} h_s(t) &= \frac{P_b(t) - P_a(t)}{\rho g} - \overline{h} \\ &= \frac{P_b(t) - P_a(t)}{\rho g} - \frac{\overline{P_b}(t) - \overline{P_a}(t)}{\rho g} \quad \text{---} \quad (3) \end{aligned}$$

$$\begin{aligned} \overline{h} &= \frac{\overline{P_b}(t) - \overline{P_a}(t)}{\rho g} \\ &= \frac{dP_b(t) - dP_a(t)}{\rho g} \quad \text{------------------} \quad (4a) \end{aligned}$$

$$dP_b(t) = P_b(t) - \overline{P_b}(t) \quad \text{----------- -------} \quad (4b)$$

$$dP_a(t) = P_a(t) - \overline{P_a}(t) \quad \text{------------------} \quad (4c)$$

$$\begin{aligned} h_i(t) &= -\frac{P_a(t) - \overline{P_a}(t)}{\rho g} \\ &= -\frac{dP_a(t)}{\rho g} \quad \text{---------------------} \quad (5) \end{aligned}$$

i.e., three sea levels [(7), (8) and (9)] were obtain from (3), and they should be comparied with (6),

$$\zeta^{T/P} \quad \text{--------------------------------} \quad (6)$$

$$\zeta^{Argos} = \zeta_b^{Argos} + \zeta_a^{Argos} \quad \text{-------- --------} \quad (7)$$

$$\zeta^{In\text{-}situ} = \zeta_b^{Plateau} + \zeta_a^{In\text{-}situ} \quad \text{----------------} \quad (8)$$

$$\zeta^{Model} = \zeta_b^{Plateau} + \zeta_a^{Model} \quad \text{----------------} \quad (9)$$

here, $\zeta^{T/P}$ is Topex/Poseidon sea surface height, ζ^{Argos} is Argos sea level, $\zeta^{In\text{-}situ}$ is METEO-FRANCE sea level and ζ^{Model} is ECMWF sea level, respectively.

In the comparisons among one another, $\zeta^{T/P}$, ζ^{Argos}, $\zeta^{In\text{-}situ}$ and ζ^{Model} were re-sampled by a linear interpolation with the interval of about 10 days together, and were filtered by the gaussian filter with a 60 day-window in order to remove the incompletely corrected error of oceanic tide (Yoon, 1997).

Results and Consideration

1. Amsterdam plateau

In the comparison $\zeta_{AP}^{T/P}$ of $\zeta_{AP}^{In\ situ}$ [ζ_{AP}^{Model}], RMS (Root-Mean-Square) and r (correlation coefficient) showed 2.96 cm [4.69 cm] and 92% [79%], respectively (Fig. 2b). Generally, the results were satisfied. Only on the atmospheric pressure, $\zeta_{AP}^{In\text{-}situ}$ with METEO-FRANCE data was better than ζ_{AP}^{Model} with ECMWF data. It should be explained that the differece between two results is because METEO-FRANCE data were measured in the field station and ECMWF data has basically the erroneous characteristics as the values of model.

2. Saint-Paul island

Saint-Paul island not showed good results compared with the Amsterdam plateau. In comparison ζ_{SC}^{Argos} of $\zeta_{SC}^{T/P}$ with N°406 [N°115], RMS and r presented 6.06 cm [3.91 cm] and 39% [54%], respectively (Fig. 2c). The discordance of results was essentially caused to the difference of distance; it is 55.4 Km [164.78 Km] from the observed station of Argos to the ground track point of with N°406 [N°115] of Topex/Poseidon. Additionally, the oscillations of ζ_{SC}^{Argos} were faible against to $\zeta_{SC}^{T/P}$. This phenomena should be considered because of the geological characteristics of the coastal area in Saint-Paul island.

3. Crozet plateau

Crozet plateau presented that RMS and r are 3.45 cm [6.39 cm] and 39% [49%] in the comparison $\zeta_{CP}^{T/P}$ of $\zeta_{CP}^{In\text{-}situ}$ [ζ_{CP}^{Model}], respectively (Fig. 3b). Although it is long distance with 57.3 Km from $\zeta_{CP}^{T/P}$ to $\zeta_{CP}^{In\text{-}situ}$, r showed generally the satisfied result. It should be explained that the oceanic phenomena (the dynamical characteristics) will be conserved within the distance of about 1° (≈ 110 Km) at the same latitude.

4. Kerguelen plateau and island

In the Kerguelen plateau, the comparison $\zeta_{KP}^{T/P}$ of ζ_{KP}^{Model} showed RMS=3.28 cm and r=54% (Fig. 4b). Then, the distance between two points is very short as about 4.33 Km.

Although the distance between two compared points ($\zeta_{KC}^{T/P}$ with N°173 and ζ_{KC}^{ARGOS}) is very approched, RMS and r presented 5.71 cm and 38% in the Kerguelen island (Fig. 5b). That is to say, this area showed bad results against to another areas, and it means that the incorrected and deficient data were usually produced within off shore of about 4 Km limits because many oceanic phenomena have locally a great influence with the observed data in the coast and island areas. Somewhat, in order to more improve the former results, $\zeta_{KC}^{T/Pmean}$ was compared with ζ_{KC}^{Argos} after all $\zeta_{KC}^{T/P}$ which is very closed to Kerguelen island were averaged. The later results were better than the former results, then RMS and r presented 3.15 cm and 46%.

Conclusion

As have discussed in the previous results, the main results obtained from the root- mean-square and correlation coefficient were summarized as follows: 1) in the Amsterdam plateau, on the atmospheric pressure, the in-situ data of METEO- FRANCE showed very useful results against to the model data of ECMWF, 2) in the Saint-Paul island, there existed the differences of phase between the oscilation of free surface with the westward propagation of Rossby waves, 3) in the Crozet plateau, this area presented the same results as the Amsterdam plateau, and 4) in the Kerguelen plateau and island, the results of plateau were better than those of island, respectively. Finally, we can have two conclusions; 1) to produce Tide Gauge sea levels from bottom pressure, the in-situ data of METEO-FRANCE showed very good values against to the model data of ECMWF and 2) to compare between Topex/Poseidon sea surface heights and Tide Gauge sea levels, the results of the open sea areas were better than those of the coast and island areas.

Hereafter, with Topex/Poseidon satellite data, we will study on 1) the validation between Topex/Poseidon surface heights and Tide Gauge sea levels, 2) the variations of sea levels on the long term, 3) the circulation of oceans, 4) the response of sea levels to atmospheric pressure, and 5) the extraction of Rossby waves, etc.

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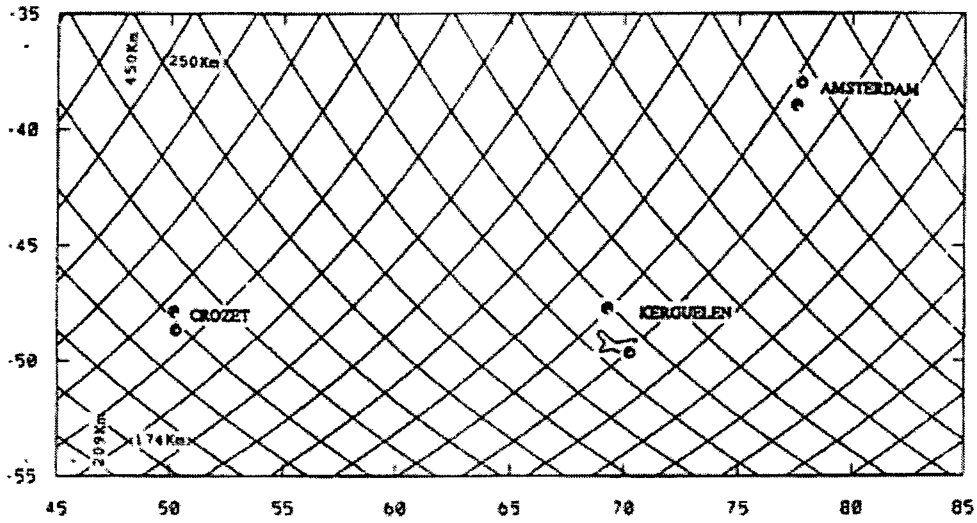
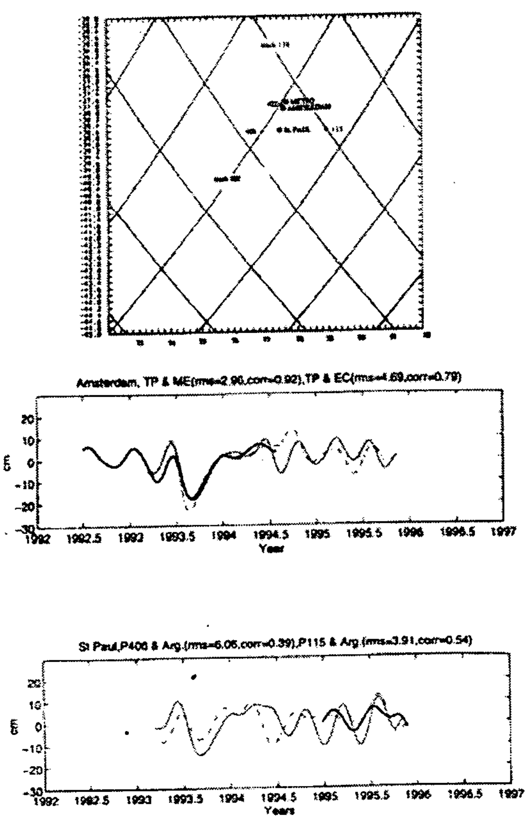


Figure 1



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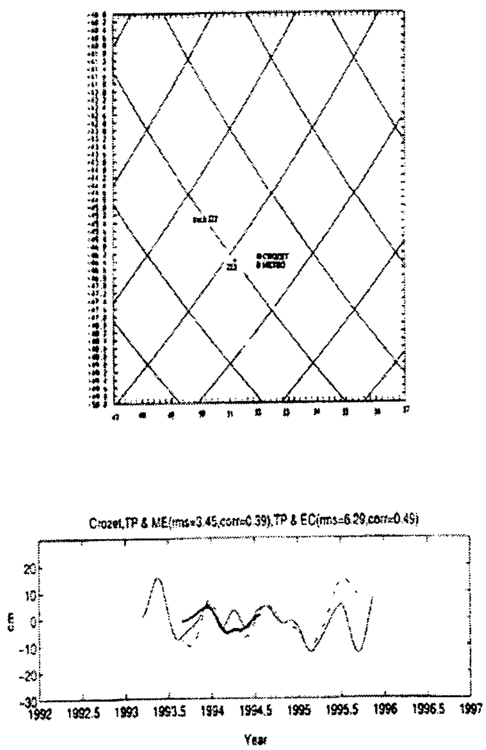

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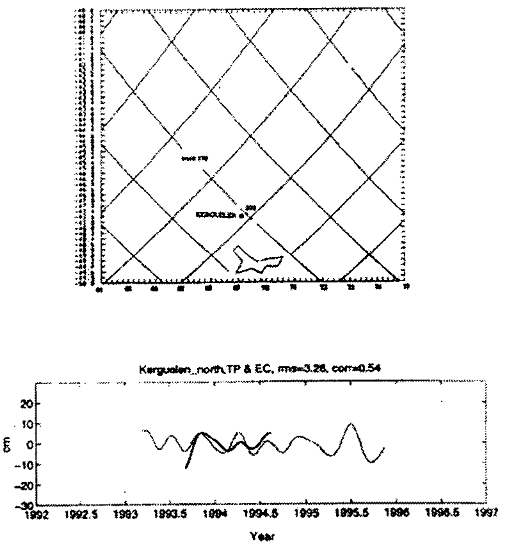

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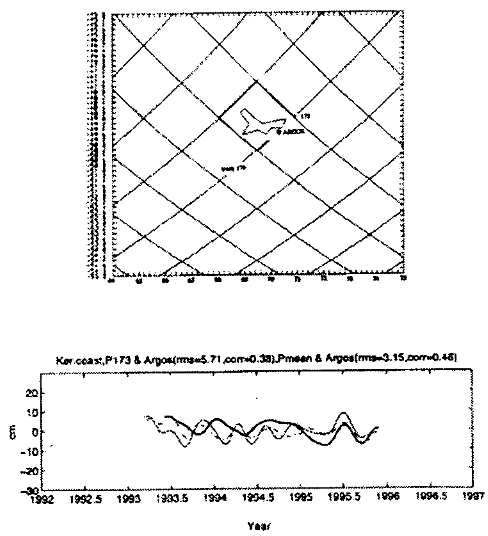

Figure 5

Figure captions

Figure 1. Ground tracks of Topex/Poseidon and positions of observed stations. (c) and (p) present tide gauge in the coast areas and the plateau areas, respectively.

Figure 2. (a) Positions of observed points in Topex/Poseidon (N°422 and 406 of ascending ground track N°103, and N°115 of descending ground track N°118), plateau station (AMS) and coast station (METEO and St Paul-ARGOS), respectively. (b) Comparison of Topex/Poseidon sea surface heights ($\zeta_{AP}^{T/P}$, ___) and Tide Gauge sea levels ($\zeta_{AP}^{In\text{-}situ}$, _ _; ζ_{AP}^{Model}, _._) in the Amsterdam plateau. (c) Comparison of Topex/Poseidon sea surface heights ($\zeta_{SC}^{T/P406}$, ___; $\zeta_{SC}^{T/P115}$, _ _) and Tide Gauge sea levels ($\zeta_{SC}^{T/P406}$, ___; $\zeta_{SC}^{T/P115}$, _ _) and Tide Gauge sea levels (ζ_{SC}^{Argos}, _._) in the Saint Paul island. Here, TP, ME and EC are T/P as satellite data, METEO as in-situ data and ECMWF as model data.

Figure 3. (a) Positions of observed points in Topex/Poseidon (N°223 of descending ground track N°222), plateau station (CRO) and coast station (METEO), respectively. (b) Comparison of Topex/Poseidon sea surface heights ($\zeta_{CP}^{T/P}$, ___) and Tide Gauge sea levels($\zeta_{CP}^{In\text{-}situ}$, _ _; ζ_{CP}^{Model}, _._) in the Crozet plateau. Here, TP, ME and EC are T/P as satellite data, METEO as in-situ data and ECMWF as model data.

Figure 4. (a) Positions of observed points in Topex/Poseidon(N°302 of descending ground track N°170) and plateau station(KER), respectively. (b) Comparison of Topex/Poseidon sea surface heights($\zeta_{KP}^{T/P}$, ___) and Tide Gauge sea levels(ζ_{KP}^{Model}, _ _) in the Kerguelen plateau. Here, TP and EC are T/P as satellite data and ECMWF as model data.

Figure 5. (a) Positions of observed points in Topex/Poseidon(N°173 of ascending ground track N°179) and coast station(METEO and KER-ARGOS), respectively. (b) Comparison of Topex/Poseidon sea surface heights($\zeta_{KC}^{T/P173}$, ___; $\zeta_{KC}^{T/Pmean}$) and Tide Gauge sea levels(ζ_{KC}^{Argos}, _ _) in the Kerguelen island. Here, P173 and Pmean are $\zeta_{KC}^{T/P173}$ and $\zeta_{KC}^{T/Pmean}$.