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ABSTRACT. The perturbations of geophysical and geodetical measurements caused by the variable load of the oceanic tide and the way to model them are briefly described. Finally, a new approach based on Inverse Theory to model the ocean tides in relation with the loading effects computation is discussed.

## 1. INTRODUCTION

All people are aware of the existence of the ocean tides because of their visible effects. But what are less commonly known are the periodical deformations of the earth caused by the periodical load of the tidal water movements and also the earth tides which are the "direct" deformations of the earth due to the gravitational attraction of the Moon and Sun.

The earth tides effects are far from being negligeable : for example, the tidal vertical displacement at the surface of the earth reach up to 40 cm (Ducarme & Janssen, these Proceedings). Concerning the loading tides, the effects

generally are of an order of magnitude lower than those of the earth tides depending on the component of the deformation (Figure 1). However, in unfavourable locations the loading effects can reach large magnitude : a classic example is the extremety of the Cornwall in the south west of England where the strong oceanic tides in the adjacent Celtic Sea cause a semidiurnal vertical movement of 10 cm range.

Due to the increase of the precision of geophysical and geodetical observing technics, it becomes necessary to take into account the loading tides in the signal processing and to remove them with reliable loading tide models for further investigations. Some works, among many others, have already been done on the loading corrections of Very Long Baseline Interferometry (VLBI)(for instance Schuh & Moehlmann, 1989), of altimeter data (Francis & Mazzega, 1990) and of Baselines Variations with applications to GPS (Ducarme & Janssen, these Proceedings). All these papers make use of the usual procedure developed by Farrell (1972) in order to compute the loading effects which is a convolution integral between the Green's functions (representing the earth's response to a mass point load) and a oceanic tidal model (Schwiderski, 1980 a-b). In addition, all the mentioned papers agree about one point : the accuracy of the loading estimations depends essentially on the accuracy and the resolution of the oceanic tidal model that could be improved.

This paper deals with a new approach to investigate the ocean tide in order to provide better global oceanic tidal models with a chosen resolution and with objective informations on their precision.


## 2. OCEANIC TIDAL MODEL

This section is restricted to the main idea about our approach for modelling the ocean tides and is dedicated to a review of its advantages and of preliminary results.

The models have been computed from harmonic constants of tide gauge and gravity loading measurements. The problem consists in recovering the tides of the global ocean from these heterogeneous sampling of the ocean tide. The optimal interpolation of these data based on the Total Inverse Theory uses a priori covariance functions deduced from a global

hydrodynamical model. More details about the method and a priori informations used can be found in Francis & Mazzega (1989 & 1990). The most important points of these preliminary results are :

1° the solution can be restored on an arbitrary chosen grid,
2° the inverse theory allows to estimate a posteriori errors of the inverse solutions.

The error maps are very important to provide objective estimations of the quality of the solutions but also they are very useful as a priori informations to applications using tidal model like loading computations.

Two models of the principal semidiurnal ocean tide $M_2$ and their a posteriori standard deviation of the in-phase component (ie. A $\cos\varphi$ where A is the amplitude and $\varphi$ the Greenwich phase) are presented (figures 2 to 5). The major features of the $M_2$ tide are surprisingly well recovered even in the middle ocean where data lack. The first model (figures 2 & 3) has been obtained by only inverting tide gauge measurements while the second one (figure 4 & 5) is the result of a joint inversion of tide gauge and gravity loading measurements. In this last case, the weak reduction of the a posteriori errors in comparison to the first model is due to the fact that only "integral" informations (say gravity loading measurements) are added. Nevertheless, the solution seems to be less reliable because the gravity loading measurements contain informations not exclusively on the ocean tides but also on lateral heterogeneities, instrumental errors whose are not modelled in this first attempt.


3. CONCLUSION

Only a brief presentation of a new approach for modelling ocean tides based on inversions of tide gauge and gravity loading measurements has been given. The method presents several advantages (ie. computation of a posteriori errors) and the results are very promissing. In the future, large sets of satellite altimeter data will be included in order to fill region where data lack. Finally, dynamical constrains will be added through a complete assimilation scheme into a finite element hydrodynamical model of ocean tides.

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E.W. Schwiderski, 1980 a-b. ' Ocean tides, Part I : Global ocean tidal equations; Part II : A hydrodynamical interpolation model', *Marine Geodesy*, 3, 161-217, 219-255.

H. Schuh & L. Moehlmann , 1989 . ' Ocean loading station displacements observed by VLBI', *Geophysical Research Letters*, vol. 16, N°10, 1105-1108.

FIGURE   1   :   M $_2$   loading   tide   :   amplitude of the vertical
displacement in mm.

FIGURE   2 : Inverse solution of the M$_2$ oceanic tide using tide
gauge measurements. Amplitudes are in cm and phase
in degrees (with respect to Greenwich).

FIGURE   3   :   Standard   deviation   (in   cm)   of   the   in-phase
component  of the  M$_2$ oceanic tide corresponding
to the inverse solution in figure 2.

FIGURE   4 : Inverse solution of the M$_2$ oceanic tide using tide
gauge and gravity loading measurements. Amplitudes
are  in cm  and phases in degrees (with respect to
Greenwich).

FIGURE   5   :   Standard   deviation   (in   cm)   of   the   in-phase
component  of the  M$_2$ oceanic tide corresponding
to the inverse solution in figure 4.

FIGURE 1

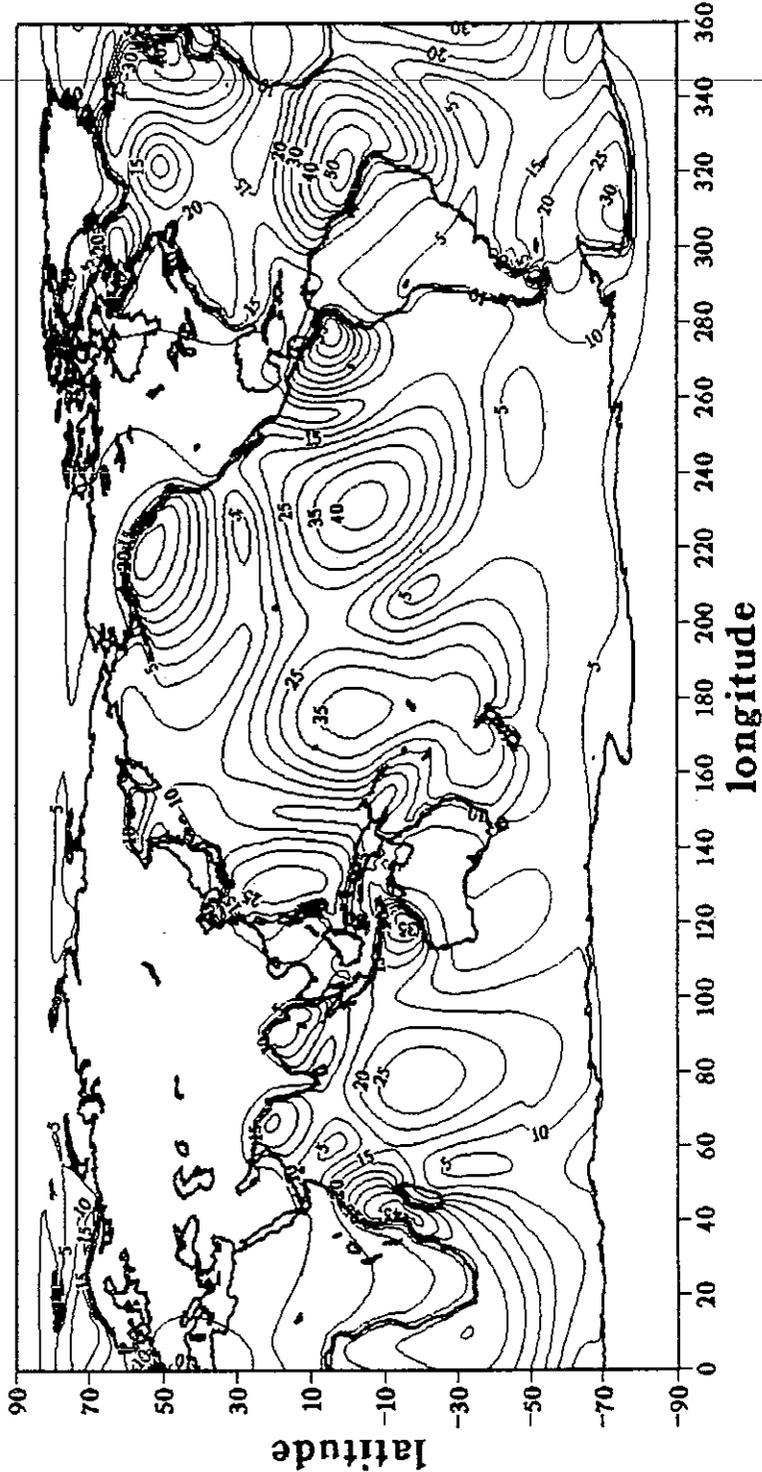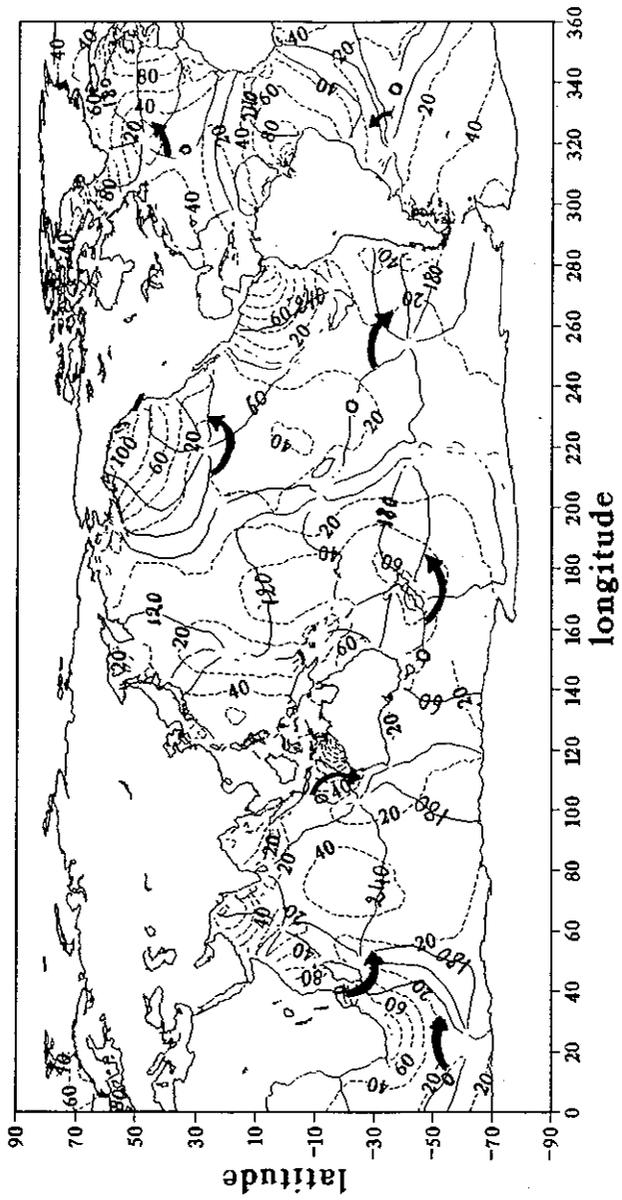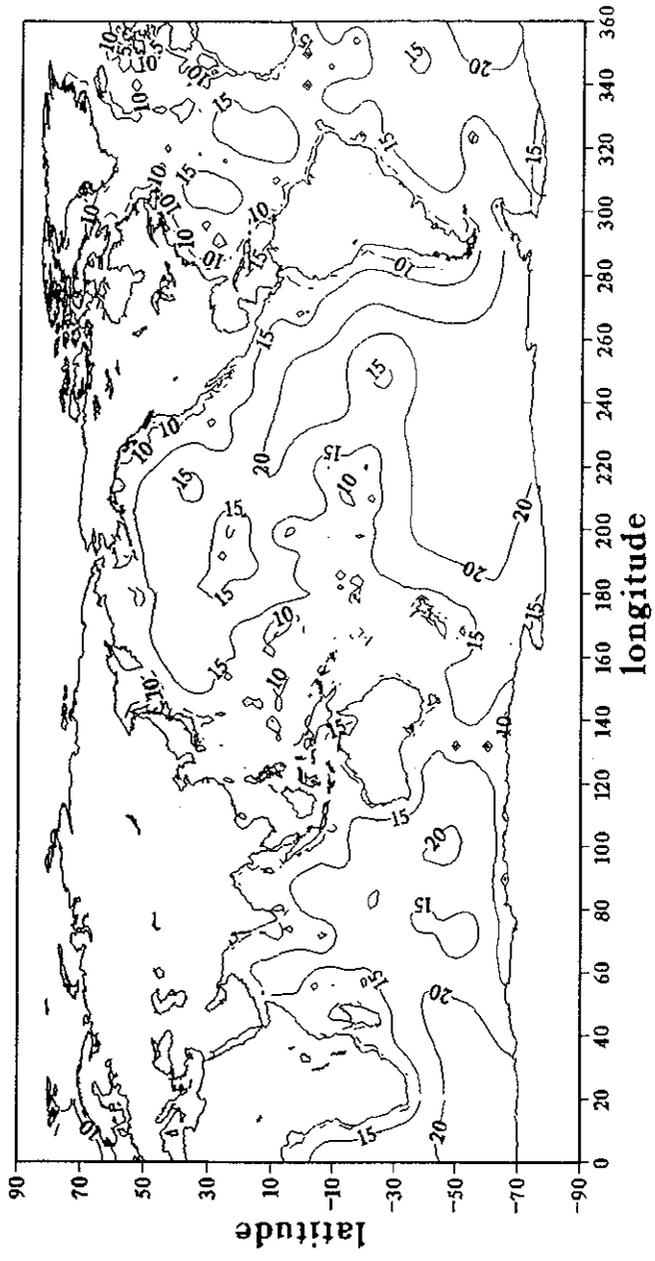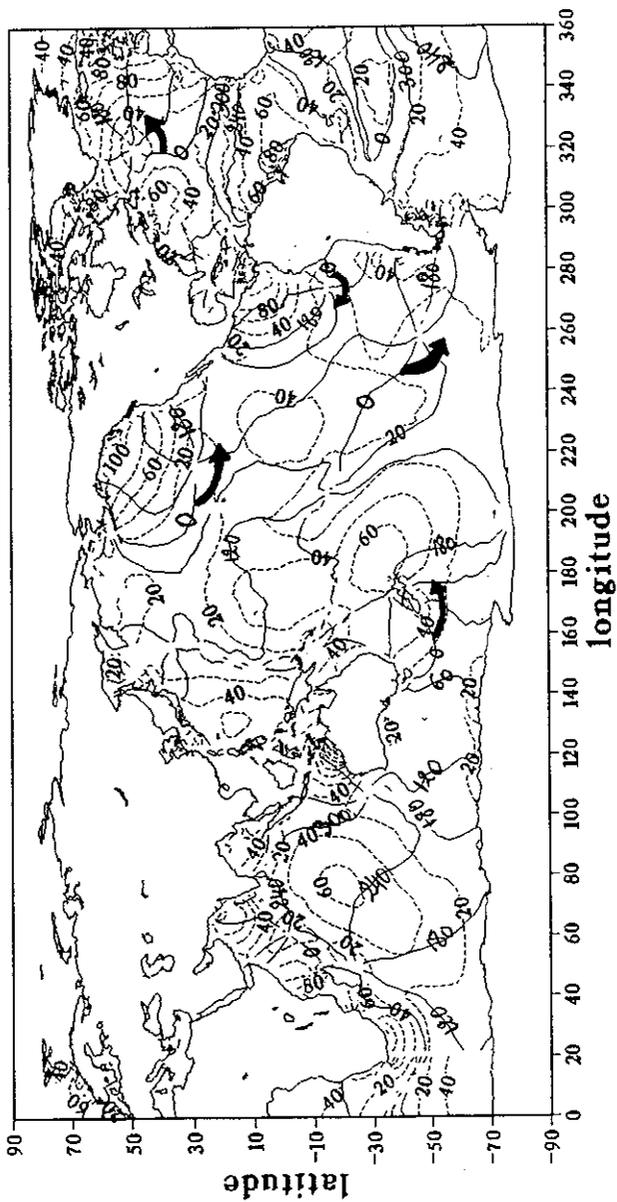## M2 LOAD : Radial Displacement in mm

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5