EVALUATION OF GEODETIC MEASUREMENT IN THE DETERMINATION OF MARTIAN GLOBAL-SCALE SEASONAL CO_2 CHANGE.

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Introduction:

Carbon dioxide is the major ingredient of the Martian atmosphere. The atmosphere exhibits an annual cycle in the CO_2 concentration; as much as 30% of the atmosphere takes part in seasonal exchange of mass between the atmosphere and the seasonal polar caps. This large-scale movement results in changes in the distribution of atmospheric mass. The CO_2 that sublimates in one polar cap is migrated to the other hemisphere and condensed. The signature of this global-scale annual cycle can be found in the variation of gravitational field as well as in the variation of planet's orientation parameters such as polar motion and length of day.

As a part of Mars Premier mission of CNES, the NEtlander Ionosphere and Geodesy Experiment NEIGE aims to measure the variations in the orientation parameters of Mars (Barriot J.-P. et al., [2001]) and in the Martian gravitational field. It is planned that positions of Netlanders on the surface of Mars will be measured with respect to a spacecraft in orbit around the planet, during at least one Martian year. Along with accurate orbiter tracking from the Earth, these measurements will allow for estimates of the variations in gravitational field as well as in the orientation parameters of the planet simultaneously.

At Royal Observatory of Belgium, a significant amount of efforts has been devoted on the determination of Mars rotation parameters, for more than two years (Dehant et al, [2000], Yseboodt et al. [2001], Van Hoolst et al., [2000]). In this context, the influence of the atmosphere on the determination of rotation parameters has been studied in detail (Defraigne et al. [2000], Van den Acker et al., [2002]). Recently, we have been investigating the possibility of using these future measurements to help for understanding global atmospheric dynamics, especially the seasonal exchange of $C0_2$.

Within the NEIGE experiment, geodetic measurements will be used to observe:

1- Variations in the gravitation field ($\Delta J2$).

2- Variations of the planet's rotation parameters (LOD).

As shown by Smith et al. [2001] both of these parameters are related to global-scale annual CO_2 change. In NEIGE experiment, we expect to decorrelate the rotation parameters and seasonal variations in the gravitation field that are measured simultaneously. However, these measurements alone are not sufficient to determine the amount CO_2 mass exchange and its distribution. Nevertheless, by combining these measurements with additional information originated from either observations or numerical methods, one can look forward to obtain global-scale seasonal CO_2 exchange.

Variations in Gravitational Field

The atmospheric pressure and precipitation during the seasonal cycle are directly related to the changes in global mass distribution, hence to the gravity field variations. Global gravity fields are commonly represented as a spherical harmonic expansion, which is the solution of Laplace's equation for the gravitational potential on a sphere. In this expansion, the time variations of the long wavelength signals represent the global changes in the mass distribution. The largest term in a planetary gravity field is the term that represents the planetary geoid flattening. It is commonly referred as J_2. Recently, Smith et al., [2001] estimated the annual variation of J_2 on Mars.

Variations in Rotation Parameters

The interaction between the atmosphere and the underlying solid Mars is one of the most important sources of changes in all three components of the planet's rotation vector on different time scales. It is known that for time scales changing between months and 3-5 years, perturbations in Earth rotation are excited by large-scale motion of geophysical fluids (Brzezinski et al., [2002]). Changes in the pattern of winds and variations in the distribution of mass within the atmosphere produce fluctuations in the atmospheric angular momentum that are well correlated with the orientation parameters of the planet through angular momentum exchanges between the solid Earth and its fluid environment (Volland, [2000]). A similar phenomenon is true also for Mars (Defraigne et al., [2000], Cazenave and Balmino, [1981]). Monitoring and interpreting the variations in Mars rotation can enable us to constrain various parameters related to the global dynamics of geophysical fluids. Moreover, time series of rotation variations can provide additional information on the low frequency variability (2-3 weeks to 6 months) of the atmosphere (Kang and Lau, [1994]). Within the context of NEIGE experiment, rotational parameters of Mars will be determined with typical frequencies representative of seasonal changes associated with global scale mass exchange between the caps and the atmosphere.

Calculations of $C0_2$ Seasonal Cycle

As mentioned above, geodetic measurements alone are not sufficient to determine the amount mass exchange and its distribution. Therefore, it is necessary to have additional information from observations or atmospheric models. The possibility of combining the ΔJ_2 and LOD with observations such as, those will be obtained by the Netlanders (atmospheric pressure) and orbiter (Variation of polar cap boundaries), as well as with the numerical methods is studied. This approach can help to better understand the energy cycle associated with the condensation-sublimation of annual CO_2 and to constrain some of the relatively poorly determined quantities such as the annual variations of CO_2 ice albedo and emissivity.

Calculation of Zonal Winds

Besides studying the global-scale CO2 cycle it would be also possible to estimate the strength of global-scale zonal wind systems along a Martian year. Thanks to the simultaneous measurements of gravity variations and rotation parameters, the amplitude of zonal winds can be estimated if their contribution to global atmospheric angular momentum is sufficiently high with respect to the precision of the measurement.

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