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Intercomparison of the seasonal cycle of Titan's and Earth's surface climatology

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Abstract

The characteristics of the seasonal cycle of Titan's surface temperature, surface pressure and surface wind and their implication for weather are compared with the terrestrial counterpart. The surface climatology of Titan predicted by a GCM and partly observed by Cassini is presented side by side with the well-known Earth's climatology. Even though the surface temperature varies only by a few K in the course of a Titan year, the seasonality of Titan's surface climate is partly more pronounced than on Earth in a qualitative sense. The seasonal forcing can completely reverse the global circulation and precipitation pattern on almost entire Titan in a monsoon-like fashion. This high sensitivity of Titan's climate to small seasonal temperature variations can be mainly ascribed to Titan's slow rotation.

1. Introduction

The latitudinal and seasonal variations in the surface meteorological variables represent important characteristics of the climate of a planet. On Earth the seasonality of the climate manifests itself e.g. in the sunshine duration, temperature, wind direction and amount and type of precipitation. Titan experiences a seasonal cycle of insolation, which is qualitatively similar to that of the Earth, with a perihelion passage in southern summer, but Titan's surface receives 2 orders of magnitude less solar flux than Earth's surface. Therefore, one might expect a much reduced seasonality on Titan at a glance. Yet several lines of evidence, especially the global cloud distribution, indicate that this is not the case.

In the context of comparative planetology, this study compares the seasonal and latitudinal pattern of the surface meteorological data on Titan and Earth with each other to elucidate the mechanisms and parameters that may be responsible for the qualitative and quantitative difference between the climates.

2. Methods

The seasonal cycle in Earth's climate can be quantitatively described using data bases such as ERA-40 Atlas [1] or NCEP/NCAR reanalysis data [2]. Not surprisingly, such complete data sets do not exist for Titan. This study mainly makes use of the prediction of the surface climatology by the Cologne Titan general circulation model (GCM) [3], whose output can be compared with the Earth's climatology. Observations of the surface temperature by Cassini [4,5] and global cloud distribution [6,7] complement the survey.

3. Results

The Titan-Earth comparison is exemplified by Figs. 1 and 2. The most obvious difference between Titan's and Earth's surface climatology concerns the latitudinal temperature gradient. The average surface temperature on Earth decreases by 50-70 K from equator to pole. Even though the polar temperature in summer is 30 K warmer than in winter, the poles can never get as warm as the equator and the mid-latitude baroclinicity is being maintained year-around. Therefore, the seasonality on Earth is characterized by a latitudinal migration between warm and cold or wet and dry climates. There are also many regions with little seasonal variability in temperature, wind, pressure and precipitation.

By contrast, the average surface temperature on Titan decreases from equator to pole only by 3 K, but Cassini observed a small increase/decrease of the surface temperature in the north/south during the last years. The small latitudinal temperature gradient is a result of both weak sunlight and efficient horizontal heat transport due Titan's slow rotation. Unlike on Earth, the annual maximum surface temperature is predicted to occur at the south pole in southern summer (Fig. 1). There are several reasons for this pattern: 1) the mean equator-to-pole temperature contrast is so small that warming by a few K is sufficient to drastically change the latitudinal temperature profile, 2) polar albedo is low. The global distribution of surface pressure and convective cloud activity is strongly controlled by the surface temperature in the absence of baroclinic instability. The low pressure area (convergence zone) migrates seasonally between the hemispheres much in excess of Earth's monsoon. Consequently, the global circulation pattern radically changes in the course of a Titan year. Both the zonal and meridional component of the surface wind changes direction with season. While the static stability in most parts of Titan's lower troposphere is conditionally unstable, a decrease of the surface temperature by 2 K in winter is sufficient to suppress any convective clouds by increasing the static stability. Virtually every area on Titan may experience distinct dry and wet seasons.

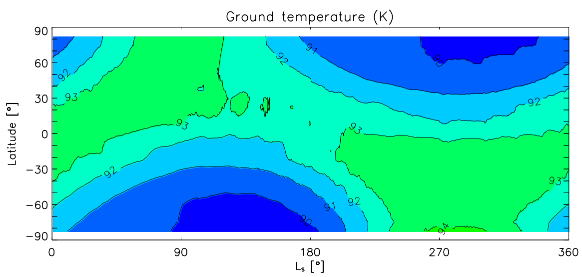

Figure 1. Seasonal and latitudinal variation in the zonal-mean diurnal-mean surface temperature of Titan predicted by a GCM [3]. L_S=0° is northern vernal equinox.

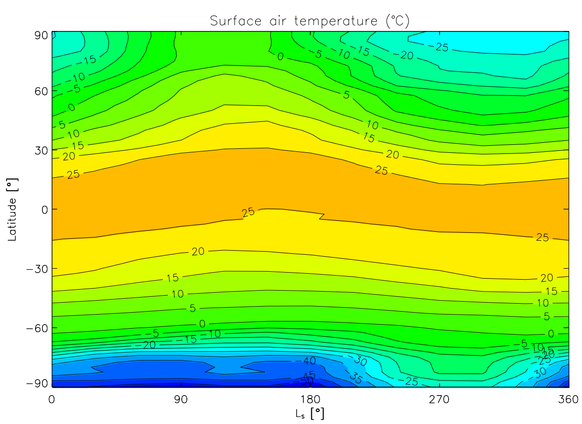

Figure 2. Seasonal and latitudinal variation in the zonal-mean diurnal-mean surface air temperature of Earth from the NCEP/NCAR reanalysis data [2].

Acknowledgements

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