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EVIDENCE FOR A ZONALLY TRAPPED DIURNAL TIDE IN CRISTA TEMPERATURES

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ABSTRACT

CRISTA temperature data which was taken from 50 to 90 km on 5 November 1994 are discussed. There appears to be evidence for a highly excited, trapped diurnal tidal wave. At 75 km altitude and near the equator the amplitude reaches it's maximum. The amplitude is not zonally symmetrical, but shows a maximum at 30° E. Preliminary analysis of the temperature data from 9 November 1994 indicate the observed tide being a singular event of a lifetime of about one week.

INTRODUCTION

The Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) limb sounding experiment is briefly discussed by Riese *et al.* (this issue). Temperatures at the higher altitudes can be derived from CO_2 emissions around 665 cm^{-1} measured by the center telescope. For this channel the altitude range is from about 40 to 90 km in the stratospheric/mesospheric measuring mode. Altitude scan steps of 1.5 km have been performed. The field of view is of the order of 2 km. The vertical resolution of the current retrieval is 3km. The retrieval has been performed using an optically thin region of the CO_2 band. At 90 km altitude the signal to noise ratio is about 100 in this spectral region. Therfore, the temperatures presented here do not depend on any climatological data. The instrumental noise of the temperature field retrived at 75 km altitude can be estimated to 1.2 K in the present data version. The noise will be significantly reduced in later versions.

CRISTA TEMPERATURE OBSERVATIONS

Figure 1 shows the global temperature distribution at 75 km altitude which was measured for 24 hours on Nov 4 and 5, 1994. The track of the CRISTA orbit can be recognized from the measuring points given in the map. Each CRISTA orbit intersects the equator twice. Measuring points sampled from southwest to northeast are denoted as ascending nodes, others as descending nodes. The local time of ascending nodes measured within one day depends on latitude only. It is almost independent of longitude, because the orbit is nearly sun-synchronous. The same is valid for the descending nodes. Figure 2 shows local time versus latitude. At the equator the ascending nodes are measured at 9 am local time and the descending nodes 12 hours later. In a region between the equator and 20° N and between about 40° W to 90° E a difference of approximately 40 K is observed between the ascending and the descending nodes (see Figure 1).

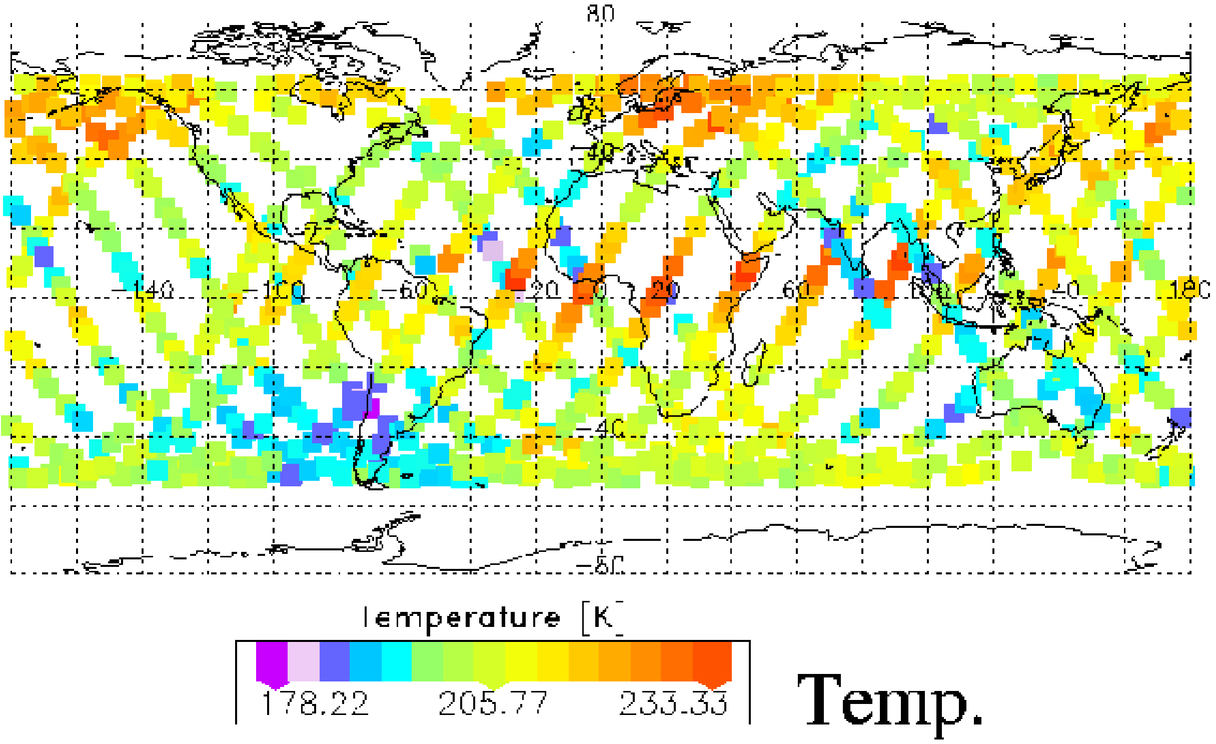

Fig. 1. Temperature distribution at 75 km altitude measured on Nov 4 and 5, 1994 within 24 hours. Each value given is interpolated from a complete height profile. The difference in local time from descending to ascending nodes is nearly twelve hours at the equator. Data are preliminary.

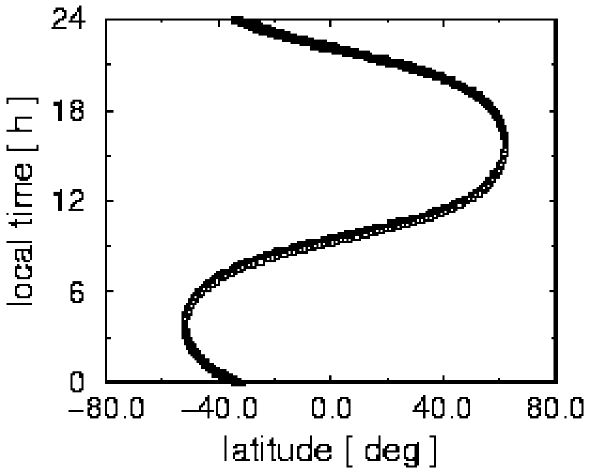

Fig. 2. Dependence of the local time from the latitude. Each latitude is measured on two different local times. The difference is nearly twelve hours at the equator and vanishes at the northern and southern turning points of the satellite orbit.

Figure 3 shows two height profiles measured at 5° N and 25° W at different local times. A wave structure with a vertical wavelength of about 20 km can be recognized. Thus we interprete the observed day-night variation as a diurnal tide. The amplitude is defined as 0.5 times the day-night difference. To verify this interpretation, it has to be confirmed that other waves cannot cause a temperature distribution as shown in Figure 1. A greater influence of local fluctuations like gravity waves on the derived amplitudes can be excluded by considering a large area of consistent day-night differences. Mixed Rossby gravity waves are antisymmetric to the equator and have therefore not to be taken into account. The period of Kelvin waves is several days. This is not compatible to Figure 3. Salby and Roper (1980) have analysed prominent modes of planetary waves. Considering these modes of planetary waves, it can be seen, that only the superposition of several planetary waves could cause a pattern like that seen in Figure 1. These waves should be seen at higher latitudes, too. A single planetary wave with short period, sampled by CRISTA, would exhibit several periods along a latitude circle. None have been recognized in the CRISTA data at the higher altitudes.

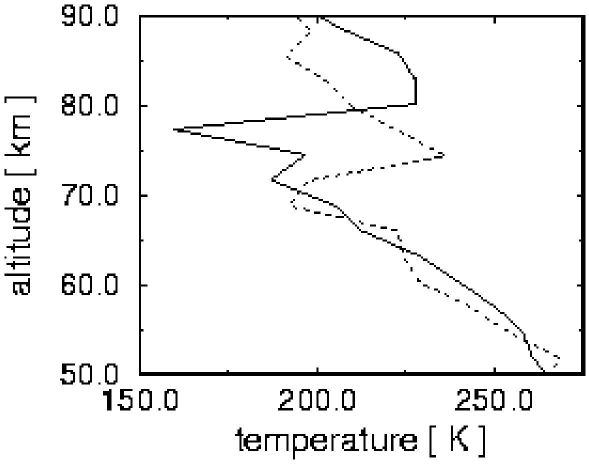

Fig. 3. Two height profiles measured at the same location but at different local times. The two profiles are measured at about 5° N and 25° W. The profile given by the dashed line was sampled at 10 am local time. Twelve hours later CRISTA measured the profile, which is given as a solid line.

Figure 4 shows the zonal structure of the tidal wave. We find that the wave is highly excited with a maximum amplitude of 20 K. Because the local time is nearly constant for all day measurements (respectively night measurements) in a given latitude interval, the phase of the tidal wave is the same for all CRISTA day (night) measurements. Generally the assumption of a westward migrating tide is made. Imagining a wave crest (respectively a wave trough) running around a latitude circle, where the CRISTA sampling points are always coincident with the wave crest (trough), implies there should be no zonal structure in the day-night differences. But a strong zonal structure is observed. Therefore, the data suggest, that the dominant contribution is a zonally trapped tidal wave.

Since CRISTA measures at fixed local times, the time development of the diurnal tidal wave is covered only by two points. As a result, the day-night differences are a lower limit for the amplitude of the tidal wave at lower latitudes. Semidiurnal tides, which are excited at higher latitudes, cannot be resolved by our measurements. (They can be derived at lower altitudes and higher latitudes considering all three viewing directions.) Near the equator this oscillation is measured at daytime and nighttime at the same phase. However, as Figure 2 shows, the time difference between ascending and descending nodes becomes smaller at higher latitudes. Therefore the semidiurnal tides might influence the analysis at latitudes higher than 20° N and 4° S. Figure 5 shows the meridional structure of the tidal wave derived from the values between 40° W and 80° E. Every amplitude given represents a latitude interval of 4°. Lower and upper limits are determined by the variation of the temperatures inside one latitude interval. The tidal wave is not exactly symmetrical to the equator.

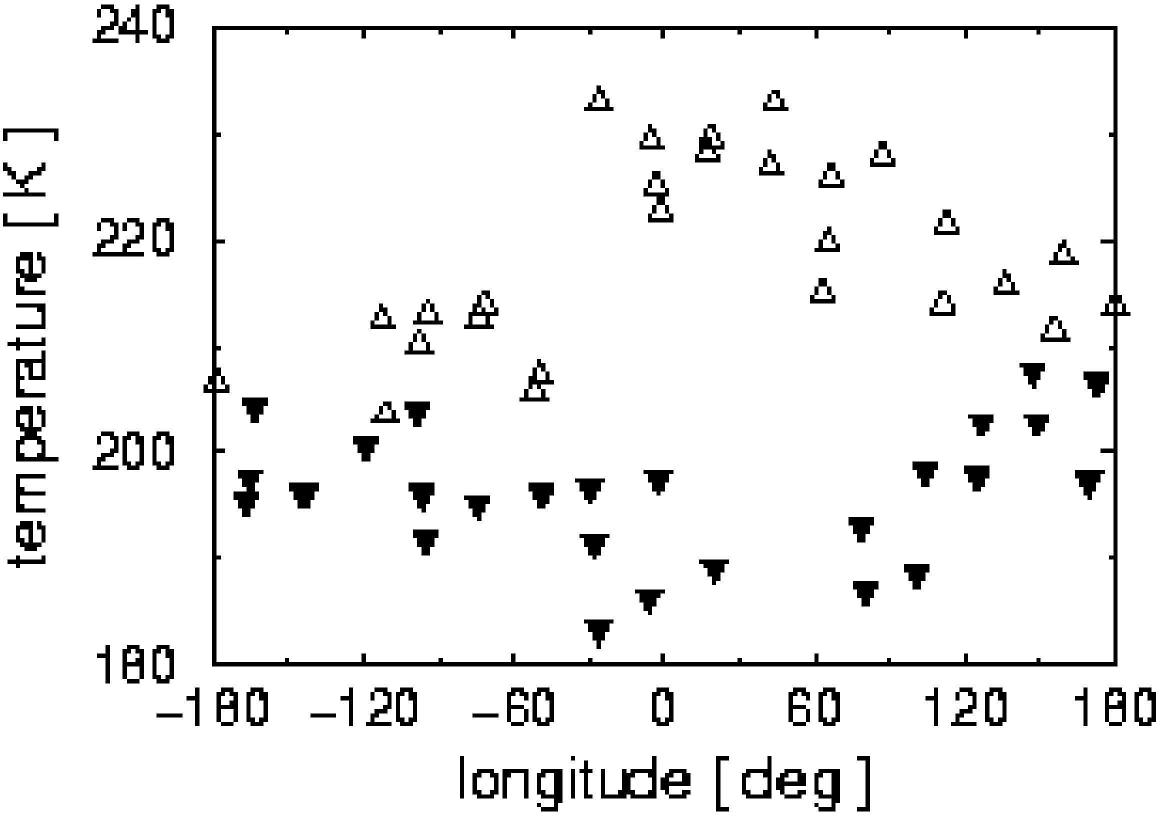

Fig. 4. Temperatures in the latitude interval from the equator to 8° N at the 75 km altitude level. The day values are given by light triangles, the night values by dark triangles. The picture shows that there is a strong zonal structure in the day-night difference and thus in the amplitude of the tidal wave.

COMPARISONS

The vertical wavelength of around 20 km is comparable to the vertical wavelength of the diurnal tide of 20 to 25 km, which has been found by Khattatov *et al.* (1996) in wind measurements of the HRDI instrument on board the UARS satellite and MF radars. The meridional structure of the tidal wave is in qualitative agreement with observations of the ISAMS instrument on board the UARS satellite published by Dudhia *et al.* (1993). Their observations were made from Dec. 5, 1991 to Jan. 13, 1992. They found an amplitude of more than 3 K at 75 km altitude under the assumption of a zonally symmetrical tidal wave. To cover the complete phase of the wave, they evaluated a time period of 40 days to fit amplitudes and phases of the diurnal and semidiurnal tides. The zonal mean amplitude of CRISTA data is 11.4 K on Nov. 5, but decreases to 7.8 K on Nov. 9 1994. Therefore, there is evidence that CRISTA has measured a singular event of a highly excited tide with a lifetime of about a week. This also indicates a comparison with the Kwajalein Model Atmosphere (KMA), where Cole *et al.* (1979) have found an amplitude of 1.8 K at 70 km and 4.5 K at 80 km altitude. So the KMA value seems to be about one fourth of the amplitude measured by CRISTA. But Kwajalein is located at 167.4° E and 8.4° N, where the amplitude derived from the CRISTA data is 7.8 K with a scatter of 4.0 K. This is nearly compatible with the Kwajalein value. Therefore the zonal structure of the tidal wave is important for the comparison of the amplitudes.

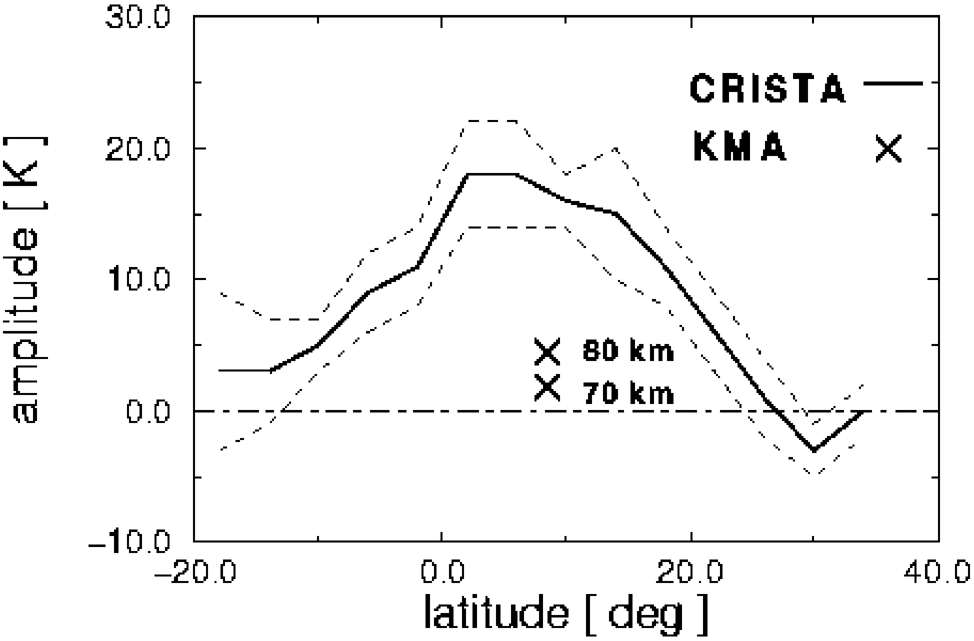

Fig. 5. Meridional structure of the tidal wave derived by CRISTA measurements.

Upper and lower limits are derived from the temperature fluctuations in the evaluated longitude-latitude intervals. The amplitude of the tidal wave seen by CRISTA is much larger than that by the Kwajalein Model Atmosphere (KMA). This also results from the zonal structure of the trapped tidal wave. At 30° N a phase shift of 180° is observed. Nevertheless values at these latitudes might be highly influenced by the semidiurnal tide.

CONCLUSIONS

Data taken at the 4th of November 1994 were discussed. A wave structure was identified, which is most likely a diurnal tidal wave. This tidal wave is highly excited and has its maximum amplitude at 75 km. This wave appears to be a singular event with a lifetime of about one week. The meridional structure is slightly asymmetric to the equator, and the maximum amplitude is shifted northward. In contrast to the general assumption of a zonally symmetric westward migrating tide, CRISTA data suggests evidence of a trapped tidal wave. The comparison of the Kwajalein model atmosphere with the CRISTA data indicates that this asymmetry has to be taken into account for comparison of these two data sets. This could be of general applicability, if such singular events should occur more frequently. In this case the zonally averaged tidal amplitude derived from a satellite experiment could be significantly different from measurements taken at one fixed geographic site.

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