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Indications of long-term changes in the lower thermosphere prevailing zonal wind regime

E. S. Kazimirovsky, V. D. Kokourov, and G. V. Vergasova

Institute of Solar-Terrestrial Physics, Irkutsk, Russia

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[1] To take a new approach to the lower thermosphere (80–100 km) long-term behavior, the variations of the dates of the equinoctial rearrangements of the zonal wind circulation were considered. We have evaluated the duration of unstable equinoctial rearrangements periods and duration of rather stable summer and winter circulation periods as well. The identical multiyear radio measurements of the horizontal winds in the lower thermosphere/ionosphere at two midlatitude (52°N) observatories (Irkutsk (Badary Observatory), East Siberia, and Collm, central Europe) during 1981–1996 were used. It is shown that there are significant nonzonality and regional differences in the character of the circulation rearrangements. The duration of the winter circulation in East Siberia is systematically longer than in central Europe. However, the tendency to a decrease of the summer circulation duration for the years under consideration is observed for both regions. *INDEX TERMS:* 0341 Atmospheric Composition and Structure: Middle atmosphere: constituent transport and chemistry; 2437 Ionosphere: Ionospheric dynamics; 2427 Ionosphere: Ionosphere/atmosphere interactions; *KEYWORDS:* Lower thermosphere/ionosphere; Prevailing wind; Long-term changes.

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1. Introduction

[2] Releases of trace gases as a result of human activity have a potential for causing a major change in Earth's climate. There is no doubt that the problem of the global climate change has led to controversy, speculation, and confusion. However, despite the many uncertainties concerning the timing and magnitude of changes that still remain, the consensus of most scientists knowledgeable in these matters is that a global climate change will occur.

[3] The troposphere and stratosphere are expected to warm and cool, respectively. The ozone concentration is expected to decrease. The consequences for the atmosphere above 60 km are considered during the recent years to be very active, and overall results indicate that the global changes caused by trace gases (e.g., by CO_2 and CH_4 doubling) are not only confined to the lower atmosphere but also extend well into the mesosphere, thermosphere, and even the ionosphere [*Golytsin et al.*, 1996; *Roble and Dickinson*, 1989]. The expected changes should also lead to some alterations in global circulation, in distributions of temperature and composition, and in the response of the atmospheric system to solar and auroral variability.

[4] Thus long-term changes in the upper atmosphere present an important and topical subject. Traditionally, the systematic long-term changes are called "trends," meaning the linear correlation of the parameter with time. Of course, it is only a first-order approximation, and actually, the trends often show interruptions or even reversals.

[5] Contemporary studies of the long-term changes (trends) in the upper atmosphere are mainly based on the assumptions that the global warming in the troposphere is accompanied by a "global cooling" of the middle atmosphere and thermosphere, that is, by a thermal contraction which lowers the height of the ionosphere [*Ulich et al.*, 2003]. The results concerning the ionosphere can be masked by solar variability and geomagnetic variations and significantly depend on the region and season.

[6] The systematic long-term changes could be manifested in the upper atmosphere transport and circulation. *Langematz et al.* [2003] recently found that the increase of CO_2 content and the decrease of the ozone concentration are actually able to influence the stratospheric circulation, the winter period of the circulation systematically increasing and

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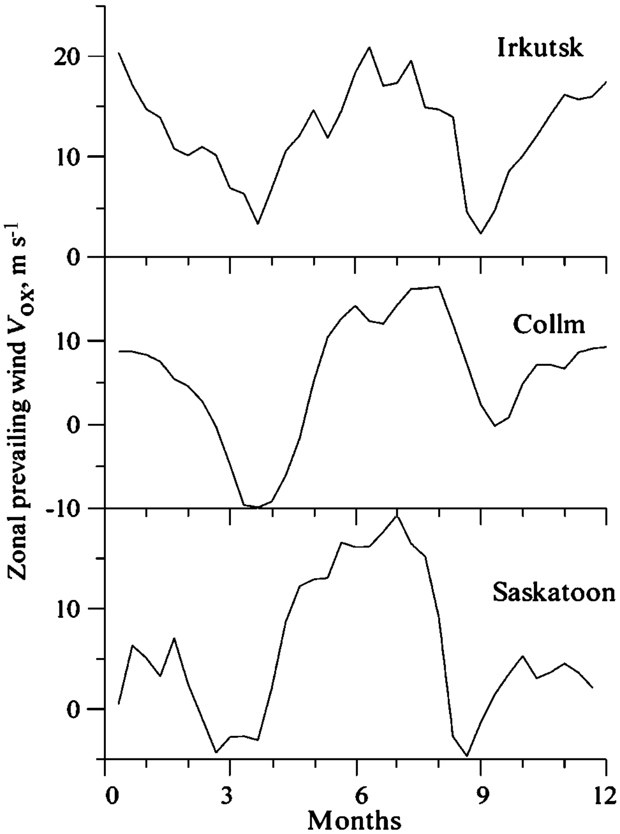

Figure 1. Seasonal variations of the zonal prevailing wind V_{ox} in the lower thermosphere for observatories Irkutsk, Collm, Saskatoon. The data are heavily averaged for each 10-day interval during all years. Irkutsk, 1975–1994; Collm, 1979–1997; and Saskatoon, 1984–1990.

the summer period of the circulation decreasing. However, contrary to the stratosphere, using the long series of the upper mesosphere temperature data (optical atmospheric emissions), *Offermann et al.* [2003, 2004] detected an increase of the summer duration of about 12% in 20 years.

[7] The aim of our work was to investigate the variability of the dates of the lower thermosphere circulation reversals and to reveal there possible trends in the summer and winter circulation periods. We had at our disposal the database of the regular multiyear lower thermosphere horizontal wind measurements in the Irkutsk/Badary (East Siberia, 52°N, 102°E) and Collm (central Europe, 52°N, 15°E) observatories. The technique of these measurements (space diversity reception method in the LF range) was numerously described [e.g., *Kazimirovsky and Vergasova*, 2001]. The statistical analysis of data and comparison of the results made it possible to establish the mean climatic norms for the seasonal variations of the prevailing (mean, background) wind and to reveal the longitudinal (regional) variability of the lower thermosphere wind regime possibly associated to the external forcing from below [*Kazimirovsky and Vergasova*, 2001; *Kazimirovsky et al.*, 1999, 2003].

2. Results

[8] Contrary to the distinct seasonal reversals in the lower atmosphere circulation for summer and winter, the direction of the prevailing zonal wind in the lower thermosphere climatology remains eastward in winter and in summer as well. As for equinoxes, the wind direction depends on the longitude (region). The eastward wind decreases, and sometimes (e.g., in central Europe) even a wind reversal occurs. Figure 1 demonstrates the multiyear averaged seasonal variations in the zonal prevailing wind V_{ox} at three midlatitude (52°N) observatories: Irkutsk (East Siberia), Collm (central Europe), and Saskatoon (Canada). The 10-day running smoothing was used. This seasonal pattern based on the daily data has a high statistical significance. Also, it is evident that the seasonal variation in the zonal circulation really depends on the longitude: The autumn minimum over Siberia occurs earlier than over Europe, and the spring minimum is accompanied by a reversal of the wind only over Europe and Canada but not over Siberia. During winter the averaged wind over Siberia and over Canada is about twice stronger than over central Europe.

[9] However, if we consider the day-to-day wind variations without statistical averaging and smoothing, we can obtain an extremely high wind variability especially for the periods of equinoctial circulation rearrangements. It is known that in the winter months the wind reversals in the lower thermosphere can be associated with sudden stratospheric warmings and the spring circulation rearrangements there often coincide in time with so-called "final" stratospheric warmings [e.g.,*Kazimirovsky et al.*, 2003]. Principally, strong geomagnetic storms can be also associated with the lower thermosphere wind reversals [e.g., *Kazimirovsky et al.*, 1999]. The variations in daily values of the prevailing zonal wind velocity (V_{ox}) are shown in Figure 2 for two observatories and 10–11 years of observations.

[10] We define "summer" and "winter" periods of circulation as periods with rather stable eastward winds and periods of rearrangement in the circulation as periods of high instability of the wind direction. It is clear that accepting these definitions, the duration of the rearrangement period can vary from some weeks up to some months. The boundaries between the seasonal regimes (dates) were determined as days of an abrupt change of the wind direction or as the days of a significant decrease of the wind with stable direction. Of course, in some situations, there is some arbitrariness in the determination within 2–5 days. The regional and specific features in the character of V_{ox} variations can be seen in Figure 2. For Irkutsk especially, the "nonstandard" year was 1988. In the first half of this year a strong eastward wind was observed. In the middle of July a reversal occurred, and a westward wind was observed during almost 4 months. The winter eastward wind was established only for a short period at the end of November.

[11] Using the aforementioned definitions and criteria for the beginning and end of the circulation rearrangements, it is possible to follow how these dates vary between one year and another. Figure 3 demonstrates these variations for spring and autumn. At Collm the duration of the autumn

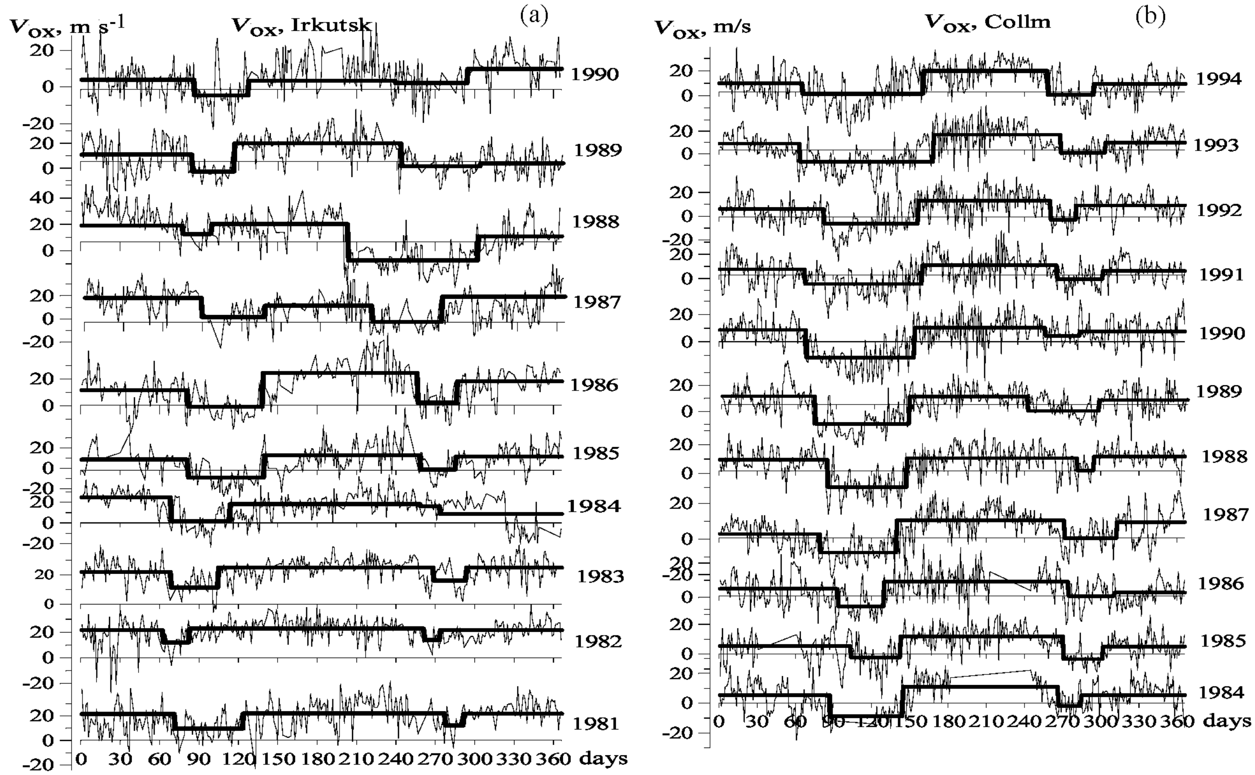

Figure 2. Variations of daily zonal prevailing wind velocity (V_{ox}) for observatories (a) Irkutsk and (b) Collm. The bold horizontal lines show the averaged values for the corresponding time intervals.

rearrangement remains almost constant from year to year, but the duration of the spring rearrangement increases systematically and so summer duration decreases. At Irkutsk, after 1986 the autumn rearrangement begins earlier and its duration increases. The spring rearrangement here during 1981–1992 begins and ends later and later. So, at Irkutsk the duration of the spring rearrangement varies within the 58–20 days interval, and the duration of the autumn rearrangement varies within the 99–12 days interval. At Collm the tendency to increasing of the duration of spring rearrangement is observed. It was minimal (40 days) and maximal (∼100 days) in 1985–1986 and 1993–1995, respectively. It is worth mentioning that the duration of the spring rearrangement at Collm varies within a wider interval than at Irkutsk (36–105 days) but the duration of the autumn rearrangement at Collm varies within a narrower interval than at Irkutsk (13–43 days). Therefore, for both regions the summer circulation period (the interval between the end of

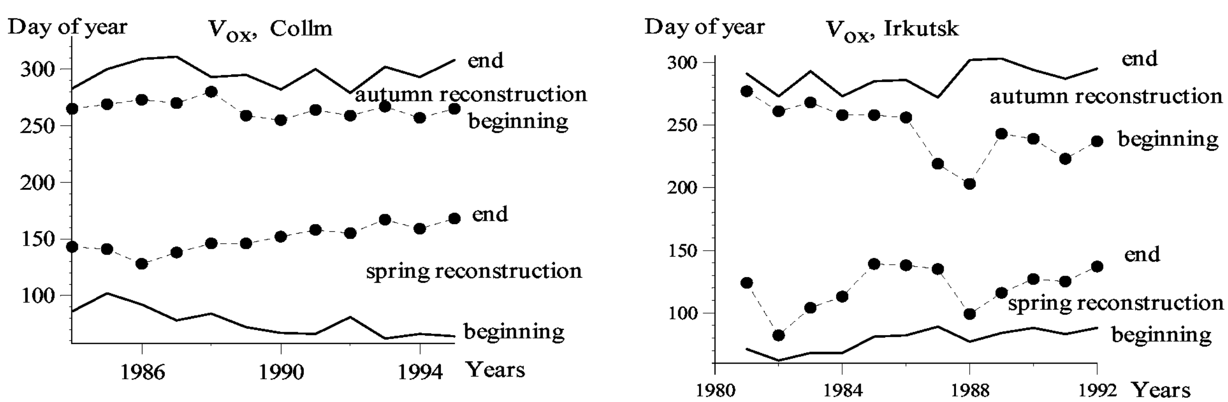

Figure 3. Variability of dates of the beginning and end of the spring and autumn circulation rearrangements.

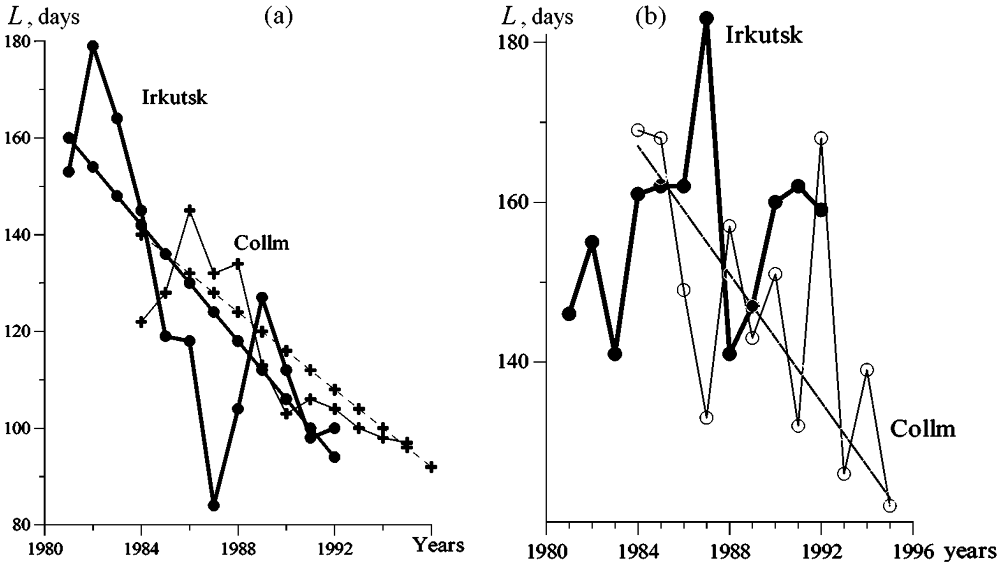

Figure 4. Variations of the duration L of the winter and summer circulation for observatories (a) Irkutsk and (b) Collm.

the spring rearrangement and the beginning of the autumn rearrangement) demonstrates the tendency to a systematic decrease.

[12] The variations of the winter (Figure 4a) and summer (Figure 4b) are presented for both observatories. At Irkutsk the winter duration vary from 141 days in 1983 up to 183 days (~6 months) in 1987 what is longer than at Collm (122–169 days). Also, contrary to Irkutsk, at Collm the winter circulation duration decreases from 169 days in 1984 down to 122 days in 1996. The summer circulation duration at Irkutsk was maximal in 1982 (179 days) and minimal in 1987 (84 days). At Collm a systematic decrease of the summer circulation duration from 1984 to 1996 (145 days and 97 days, respectively) is pronounced more clearly than at Irkutsk.

3. Conclusion

[13] Thus, investigating the temporal variations of the dates of equinoctial circulation rearrangements and winter/summer circulation periods duration in the midlatitude lower thermosphere, we have revealed their high variability and some regional (longitudinal) differences. Nevertheless, the tendency to a systematic increase of the autumn rearrangement duration in East Siberia and of the spring rearrangement duration in central Europe should be mentioned. As a rule, the duration of the winter circulation over Siberia is longer than over Europe. Also, the most interesting result is that the summer circulation duration has a tendency (trend) to a systematic decrease in the both regions.

[14] Comparing these results for the lower thermosphere with the results for the stratosphere [*Langematz et al.*, 2003] and for the mesosphere [*Offermann et al.*, 2003, 2004], we may conclude that the trends of the "summer duration" can depend on the height and can be reversed. It is still not clear whether these trends are related to an anthropogenic influence. The only appropriate way to check this suggestion is via further investigations of multiyear temperature and wind data and study of physical mechanisms.

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E. S. Kazimirovsky, V. D. Kokourov, and G. V. Vergasova, Institute of Solar-Terrestrial Physics, 664033, Post Box 4026, Irkutsk, Russia. (ekazimirovsky@hotmail.com)