Dzerdzeevski´s atmospheric circulation classification and it´s applicability to northern-hemispheric climate variations (preliminary results)

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Abstract:

Hemispheric-scale classifications of atmospheric circulation conditions are rarely applied in climatology. This may be related to a comparably weak regional focus, conceptual difficulties and homogeneity issues. Yet, such concepts may be worthy tools for investigating teleconnections and very large-scale circulation changes. The Dzerdzeevski classification (DZc) of non-tropical north-hemispheric atmospheric circulation conditions was developed 70 years ago and is continuously updated. It´s concept is based on the number and location of blockings and the trajectories of cyclones/anticyclones and troughs/ridges.

This short contribution discusses observed frequency variations of circulation classes, compared with trends in the North Atlantic Oscillation (NAO) – the dominating mode of north-hemispheric wintery climate variability. Preliminary results show large frequency fluctuations in all seasons, with a specifically large increase in meridional southerlies in recent decades, which needs to be further verified. Furthermore, the applicability of the DZc to temperature variations is checked, and a potential to use the DZc for exploring high- and central-latitudal climate variations gets visible.

1. Introduction

Ecology, economy and human societies are world-wide affected by climate variability and climatic changes recently observed and projected for the 21st century. It is therefore essential to increase the knowledge about climate variations on different spatio-temporal scales. Large-scale atmospheric circulation is an important component in this context, largely shaping the climate of the extra-tropical areas of the globe (e.g., Hurrell 1995 and Hoy 2013 for the northern hemisphere). Despite the large number of available regional and continental-scale approaches (e.g., Yarnal 1993; Barry and Carleton 2001; Huth et al. 2008), only one truly hemispheric-scale classification of atmospheric circulation conditions was developed for the entire central and northern latitudes of the northern hemisphere: the classification of Boris Lvovich Dzerdzeevskii (1898-1971).

The Dzerdzeevskii classification (thereafter abbreviated as DZc) is still frequently applied mostly in Russia and some of the former Soviet countries (see literature list at http://atmospheric-circulation.ru/stati/). Yet, applied publications in international scientific literature are mainly missing, with very few (recent) exceptions only (e.g., Dzerdzeevskii 1962; Matishov et al. 2014; Brencic et al. 2015; Tursunova 2015). Such a lack may predominantly refer to the underlying language barrier, because detailed descriptions of classification features are available in Russian language only. Other potential reasons for the low popularity of the DZc outside the former Soviet Union are conceptual difficulties, a weak regional focus due to a (necessarily) high level of generalisation and the manual and therefore non-reproducible nature of the classification. In this context, modifications in data quality/availability and changing processors over time are potential sources of inhomogeneities. Yet, the underlying complex and elaborated concept strongly justifies exploring application possibilities of the DZc to improve our knowledge on north-hemispheric climate variations.

2. Classification

The DZc concentrates on very large-scale hemispheric circulation characteristics. It is based on 1) the number and location of blockings of the prevailing westerlies by polar intrusions/southern intrusions to the polar basin and 2) trajectories of cyclones and anticyclones, as well as troughs and ridges. Opposite to the majority of the more regional classifications available for certain areas of the world, the DZc focusses on macro processes instead of individual fronts and disturbances. Upper air data at 500 and 700 hPa levels are utilized to indicate the main mid-tropospheric steering currents.

The DZc dataset starts from 1899. It is continuously updated and currently available until 2015, downloadable via http://atmospheric-circulation.ru/datas/. Here, we focus on 1901–2010. The concept inheres 41 subtypes, so called “elementary circulation mechanisms” (ECM), merged into 13 circulation types (CT) and four circulation groups (CG). For details of the 41 ECM´s see Dzerdzeevskii et al. (1946), Dzerdzeevskii (1962, 1975) or Kononova (2009). The CG´s characteristics are illustrated in fig. 1 and summarized below:

- **Zonal (Z)**: polar anticyclone, no blocking, 5 ECM´s in 2 CT´s [1901–2010 frequency: 7%]
- **Zonal disturbed (ZD)**: polar anticyclone, 1 blocking, 13 ECM´s in 5 CT´s [25%]
- **Meridional north (MN)**: polar anticyclone, 2-4 blockings, 21 ECM´s in 5 CT´s [54%]
- **Meridional south (MS)**: polar cyclone (!), no blocking, 2 ECM´s [13%]

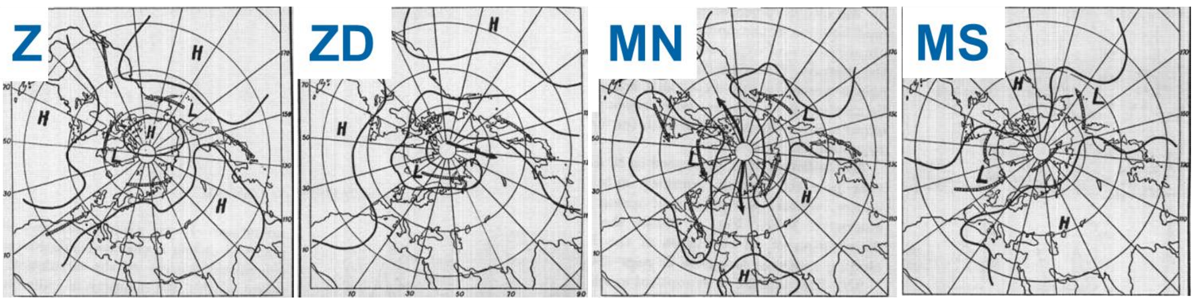

Fig. 1: Synoptic characteristics of the four DZc circulation groups

3. Results

Frequency variations: The inner-annual frequency distribution of the 41 ECM´s conceptually accounts for the pronounced seasonal climatic differences of central and high northern latitudes. Most ECM´s appear in either the cold or warm part of the year only; merely a few quite equally year-round. The CG´s show large frequency variations over time (fig. 2), which are described as circulation epochs in Russian literature (e.g., Kononova 2009, 2010). The inherent strong increase of MS/polar cyclonicity from the 1950s and especially 1980s is the dominating temporal development within the DZc. The Arctic warming of recent decades could be physically connected to that rise, but the nearly absence of MS during the previous warming from the 1920s to the 1940s (e.g., Wood and Overland 2010; Yamanouchi 2011) is illogic. Thus, the observed variability is likely biased by homogeneity issues and needs to be verified by other (automated) classification approaches or well-documented indices as the North Atlantic Oscillation (NAO), to justify using the DZc for explaining climate variability.

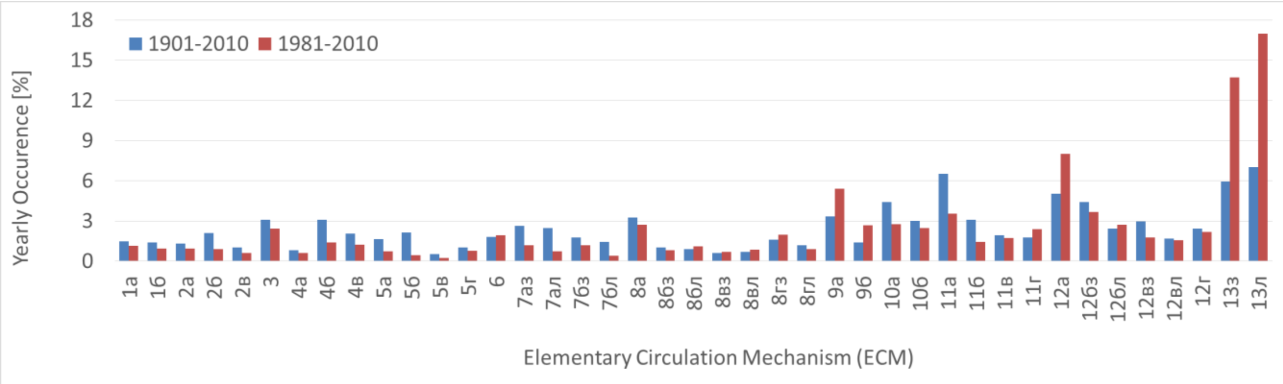

Fig. 2: Frequency of the 41 ECMs, comparing 1901–2010 with 1981–2010

Temperature signals: CG´s – consisting of many CT´s/ECM´s – yield little information on air temperature due to the necessarily large generalisation. They focus on similar processes, like the number of blockings, instead of a similar spatial blocking location – resulting in very different climate impacts in one and the same region. Some individual CT´s and ECM´s include pronounced and meaningful signals, especially in the polar region, Siberia and Northern America – yet, they often have a low frequency or large within-type variability.

Temperature signals based on daily average temperature values (for methods see Hoy 2013) are shown in fig. 3, comparing days with classified MS and positive index values of the NAO during the winter half year (October to March). Here, synoptic-scale processes exhibit a much larger relevance than during the summer time. Signal patterns and strength, as well as the location of pressure centres and according air mass movements are surprisingly similar, confirming a potential use of the DZc for climatologists. While NAO signals are more dominant in the mid-latitudes, strongest MS signals appear in the polar region. Typical NAO patterns (like the cold Greenland, Black Sea and Aleutes areas) get visible. Yet, MS signals may be biased by the observed strong recent Arctic warming and thus need to be interpreted with caution.

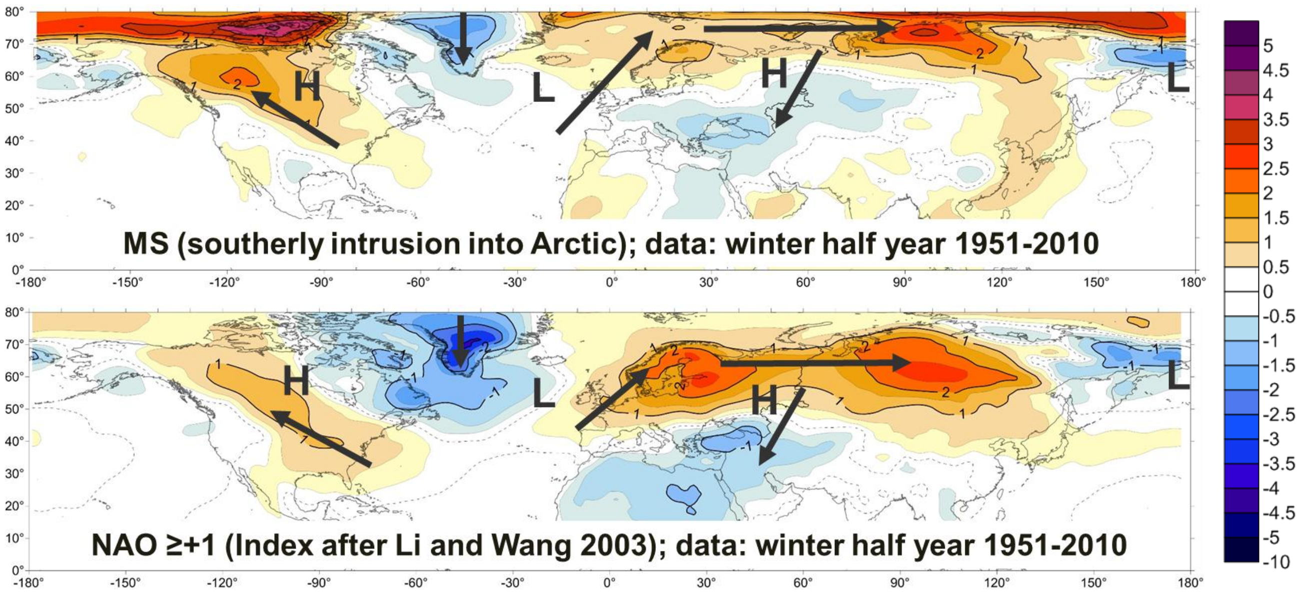

Fig. 3: Temperature signals for MS and high NAO index values ≥1, complemented by the location of major pressure centers (L = low; H = high) and direction of air mass movement

4. Summary and conclusions

A large fluctuation of DZc circulation forms (so-called circulation epochs) gets visible since the 20th century, with a specifically striking increase in MS. Such fluctuations need to be verified by more objective indices/classifications of atmospheric circulation to ensure their robustness and homogeneity. Large-scale air temperature variability is only weakly explained by using existing CG´s due to their large generalisation. Meaningful signals appear within some CT´s/ECM´s, but they often coincide with a rare incidence. Temperature signals of MS and NAO reveal similar spatial patterns – this connection needs to be further explored. Further works to verify DZc signals of temperature and precipitation patterns for northern-hemispheric non-tropical latitudes (30-90°N) are ongoing and will further reveal prospects and value of integrating the DZc into evaluations of north-hemispheric climate variations.

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