Some features of general circulation atmosphere in Northern Hemisphere under climate changes

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Abstract

An evidence of our understanding of the general circulation is whether we can predict changes in the general circulation that might be associated with past or future climate changes. It would be especially useful to predict changes associated with global warming. Changes in the location, intensity or seasonality of major climatological features of the general circulation could be more important than average temperature changes, particularly where these changes might affect local hydrology, energy balances and etc. This problem has been considered in [1]. Dynamics of General Curculation Atmosphere and Climate. There are important distinctions between tropical and extratropical circulation regimes. The Hadley Cell (HC) is the prominent tropical circulation feature. It extends through the entire depth of the troposphere from the equator to the subtropics (30° latitude) over both hemispheres. The cell develops in response to intense solar heating in the Inter Tropical Convergence Zone (ITCZ) near the equator. The extratropical circulation is dominated by baroclinic turbulence, which are called eddies. These eddies are the product of baroclinic instability, which develops particularly strongly during winter as a consequence of the strong pole-to-equator temperature gradient during that season. The the western parts of the Pacific and Atlantic oceans are the preferred locations for the development of storm-tracks. The poleward of expansion of the tropical circulation (HC). This discussion will focus on the tropical widening phenomenon. We will present some of the mechanisms that have been put forward in the literature to explain the widening. In the works [2] [3] (I. Held, A. Hou, 1980; I. Held, 2000) theory was proposed that establishes a relations between static stability and tropical width. The theory assumes that poleward moving upper branch of the HC is angular momentum conserving. The moving air increases its zonal wind speed until it becomes baroclinically unstable and breaks down under the growing vertical wind shear. This marks the latitude of boundary HC. Global warming related increases in static stability and decay baroclinic unstability in atmosphere. As a consequence, the HC expands towards higher latitudes. The poleward extent of the tropics, therefore, depends on the definition of specific indicators of tropical width. For example, the work [4](T.Reichler, 2009) focused on the structure of the global tropopause as indicator of tropical width. This indictor is based on the well-known distinction between the tropics, where the tropopause is high, and the extratropics, where the tropopause is low. The advantage of this method is that the tropopause is a relatively well observed atmospheric feature that can be easily derived from three-dimensional temperature fields. Using data from radiosondes and reanalysis, it was found that the

tropics have been expanding by about 0.4° latitude per decade since 1979. The same study arrived at very similar results by examining the separation distance between the two subtropical jets. The observed expansion is also reproduced by climate models that are driven with the observed history of forcings over the past decades, for example, twentieth century scenario integrations of IPCC-AR4. We use both the 20th and the 21st century simulations in this study. For the 21st century simulation, we use the data from the A2 and RCP 8.5 scenario. It was revealed the twenty-first century trend in zonal mean tropospheric temperature. It shows a strong upper tropospheric warming in both seasons and an enhanced Arctic warming in northern winter. The tropical upper tropospheric warming is caused by enhanced tropical convection which transports heat trapped by the additional greenhouse gases upward with the tropical atmosphere retaining a moist adiabatic lapse rate under a warmer condition. The large warming located in the Arctic in winter, where the ice-albedo feedback is weak, is largely a result of large atmospheric static stability concentrating the warming at low levels [5] [6] (Hansen J. et al., 1984; Hansen, J., et al., 2005, etc).

Extratropical eddies and jets .

The recent increase in global tropopause heights is closely associated with systematic temperature changes below and above the tropopause temperatures have been warming in the troposphere and cooling in the stratosphere. The pattern of warming and cooling also affects the zonal wind structure in the region of the subtropical upper troposphere and lower stratosphere (UTLS). At intermediate heights of the UTLS region (12-16 km) the tropics warm and the extratropics cool, leading to an increase in meridional temperature gradients, and, by the thermal wind relationship, to an increase of zonal wind speeds above. Extratropical tropospheric eddies play a central role in this mechanism. The eddies tend to move eastward with the zonal flow and equator-ward toward the subtropics until they approach their critical latitudes, where their phase speed equals the speed of the background zonal flow. One question is whether climate change will significantly affect the location and intensity of midlatitude storm tracks and associated jets. Because the wave, mean-flow interaction in midlatitudes produces low-frequency variations in the latitude of the jets, it is reasonable to think that a modest climate change might significantly affect the position of jets and their associated storm tracks. The storm tracks are defined as the region of strong baroclinicity (maximum meridional temperature gradient), which are determined on the basis of eddy statistics like eddy fluxes of angular momentum, energy, and water (with the use of high band pass - filter). In the Northern Hemisphere, there are two major storms in the region Atlantic and Pacific. The role of the storm - tracks in the dynamics of weather and climate: " bring heavy rains and other hazardous weather phenomena in the middle latitudes; " play an important role in the global energy cycle and the hydrological cycle.

Example: The winter climate of Europe and the Mediterranean is dominated by the weather systems of the midlatitude storm tracks. The behavior of the storm tracks is highly variable, particularly in the eastern North Atlantic, and has a profound impact on the climate of the Mediterranean region [7] (D. J.

Brayshaw et al., 2011).

The Role of SST Forcing.

Surface temperatures over the tropical oceans undergo changes over time, which have been shown to have important consequences for the global atmospheric circulation. These SST changes are primarily related to the natural ENSO phenomenon and to anthropogenic climate change. ENSO related SST fluctuations are periodic in nature and mainly affect the equatorial Pacific. Besides, global SSTs exhibit significant long-term trends that are associated with anthropogenic climate change. Various studies have demonstrated that the tropics are contracting during the warm phase of ENSO (ElNino), as indicated by equator-ward displacements of the jet, storm track, eddy momentum divergence, and edge of the HC. One way to understand the contraction is the intensification of the thermally driven Hadley circulation as the equatorial SSTs become warmer. The stronger HC leads to a westerly acceleration in its upper, poleward moving branch and thus to a strengthening of the subtropical jet, this moves the critical latitude for extratropical wave propagation equator-ward, allowing the extratropical eddies to penetrate deeper into the tropics than during normal or cold ENSO conditions. As a result, elements of the circulation, including the tropical edge, shift equator-ward. Sea ice extent. The Northern Hemisphere sea ice cover has decreased in recent years and is projected to continue to decrease in the future. The observed changes can be compared with the global warming projections from atmosphere-ocean general circulation models that were carried out for the Coupled Model Intercomparison Project phase 3 (CMIP3), the results of which were used for the IPCC AR4 [8] (Solomon et al. 2007). GCM projections vary widely in terms of the rate of Arctic sea ice loss. We have discussed here some problems about that. Water vapor and climate changes. Through radiative forcing by increased atmospheric carbon dioxide and water vapor and increased solar absorption due to less low cloud cover in the subtropics, more energy is gained within the tropics and subtropics, while in the middle and high latitudes energy is reduced through increased outgoing terrestrial radiation in the Northern Hemisphere and increased ocean heat uptake in the Southern Hemisphere. This enhanced energy imbalance in the future climate requires larger poleward atmospheric energy transports in the midlatitudes which are partially accomplished by the intensified storm tracks. This strong connection between intensified storm track energy transports and intensified energy imbalance in the atmosphere is also confirmed in CMIP3/IPCC AR4 models. Recent studies have indicated a poleward shift of the storm tracks and midlatitude precipitation zone in the warming world that will contribute to subtropical drying and higher latitude moistening. In our study we have examined the future projections of some feature general circulation, in particularly, location and amplitude of the storm tracks, sea - ice cover, from the global coupled climate model simulations. The RCP8.5 and other scenarios are used. We have identified a poleward expansion, and intensification on the poleward flank, of storm tracks in the future climate from band-pass filtered transient eddy statistics. The future projections in transient eddy activity and its heat transport well correspond to the changes in baroclinic instability.

Experiments. Model.

We provide our study using the idealized climatic system model [9] (Fraedrich K., Jansen H., et al., 2005).

Experimental design.

To identify the response of the storm tracks to climate change we consider two different climatic situation. For the first situation we construct a complex scenario with the total length of 200 years. Here during the first 90 years atmospheric CO2 concentration was set according to SRES A2. For the next 20 years CO2 concentration was fixed on the level of 90th year. During the third part CO2 concentration was declined with same speed like it grew up in the first part of this complex scenario. We compare storm track behavior obtained in this complex scenario and in a reference scenario, where CO2 concentration was constant (360 ppm). We analysed changes in storm track behavior using spatial distribution of mean values and trends of some transient eddy statistics. Climatic scenario we used for the second situation is reproduce both the atmospheric CO2 concentration increase due the anthropogenic effect and following its decrease with the return it to preindustrial value (http://climate.uvic.ca/EMICAR5). Thus, the scenario of the atmospheric CO2 concentration change is consists of four parts: for a time period from 850 to 2005 CO2 concentration was set according to the protocol "Historical simulations" of CMIP5; during the 21-23 century CO2 concentration was set according to the most aggressive scenario RCP 8.5; then for the period 24-29 century CO2 was fixed on the level of the year 2300; and during 30-31 century CO2 was returned to the preindustrial value. At this last period during the first 100 years CO2 concentration was decrease linearly to preindustrial value and then fixed. For the study of storm-track dynamics we selected following 9 time periods. First period (1751-1760) is characterized by the equilibrium state of the climate system before the CO2 increase. Second period (1991-2000) was selected at the beginning of CO2 concentration increase time period, third (2101-2110) was in the middle of this period, fourth (2191-2200) was at the end of this period. Next fifth period (2691-2700) was selected for the conditions of equilibrium state of climate system with the extremely high CO2 concentration. Sixth (3011-3020), seventh (3051-3060) and eighth (3111-3120) periods were selected for the atmospheric conditions at the beginning of CO2 concentration decrease, in the middle of this period and at the end of this period, respectively. The last, ninth, period (3191-3200) was selected for the climate system conditions at the end of the simulation when CO2 concentration has returned to the preindustrial state. We analysed storm track dynamics using Hovmoller diagrams of some transient eddy statistics. A standard band-pass filter is applied to daily data to retain the variability on synoptic time scales of 2-8 days [10] (Blackmon, 1976). All transient eddy statistics computed in this study are based on band-pass filtered data. Results

Storm tracks:

On a basis of simulation using climatic scenario RCP8.5, we constructed Hovmoller diagrams of 10-years mean variance of meridional velocity (v). In these diagrams X axes presents the numbers of our time-slices, Y axes is the latitude. The diagrams show for a both seasons area of maximal storm track activity shifts to high latitudes when CO2 concentration increases, and returns back when CO2 concentration decreases. But there is a feature for a winter season at the end of simulation. Here CO2 concentration has returned to preindustrial value, but storm-track activity has not and it continues to decline. Also diagrams show maximal strom-track activity occurs between 51 and 57 latitudes. we constructed another Hovmoller diagrams of 10-years mean v-variance for 3 different latitudes. X axes presents the longitudes, Y axes is the numbers of the time-slices. It was shown response of Atlantic storm-track to CO2 concentration change more then response of Pacific storm-track. For a winter season Atlantic storm-track amplitude raises with the increase of CO2 concentration, and it reduces with the decrease of CO2 concentration. Here the feature appeared again. Atlantic storm-track amplitude doesn't return back to preindustrial value, and it continues to decline. Pacific storm-track amplitude reduces with the CO2 concentration increase and it raises with the CO2 concentration decrease. And like Atlantic storm-track, Pacific storm-track amplitude doesn't return to preindustrial value. For a summer season both Atlantic and Pacific storm-track amplitude reduces with the CO2 concentration increase and it raises with the CO2 concentration decrease. Hovmoller diagrams of eddies momentum flux was demonstrated that the influence of the CO2 concentration change to these fluxes for a winter season stronger then for a summer. Absolute value of these fluxes raises with the CO2 concentration increase and it reduces with the CO2 concentration decrease.

Sea ice extent.

The decline in Arctic sea ice can be best explained from a combination of natural climate variability, such as variability in air temperature, atmospheric and oceanic circulation, and from external forcing due to rising concentrations of atmospheric greenhouse gases. Global climate models have predicted the rise in atmospheric air temperatures as CO2 concentrations in the atmosphere increase (in Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), 2007) and simulations from the coupled GCMs that incorporate the observed record of CO2 show that the increase in global temperature results in a decline in the Arctic sea ice cover. While the qualitative agreement between the simulations and the observations provides evidence for a role of CO2 radiative forcing on the observed decline ice cover, the disagreement on the rate of decline could indicate a natural variability component. We finds that model loses of its Arctic sea ice in near linear manner and we also find no evidence of summer Arctic sea ice tipping points.

Summary

In this report demonstrates that there exists considerable evidence that key-elements of the atmospheric circulation have been moving poleward during the last few decades. Current theories as well as model experiments indicate that greenhouse gas increases and stratospheric ozone depletion is the most likely cause for the trends. However, there are many other aspects of these shifts that are not well understood. Experiments revealed little effect of hysteresis in the dynamics of the storm track. We find also that sea ice loss is reversible in climate system model over a range of CO2 concentrations in RCP-8.5 scenario.

We find no evidence of possibility sea ice hysteresis between difference states in climate regimes with ice cover.

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