Community Climate System Model

A comparison of dynamical tropopause pressure from WACCM and ERA-40

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Introduction

In the recent years the tropopause region has received increased interest. The tropopause has been studied as an exchange region for mass, moisture, and chemical constituents between the troposphere and the stratosphere, two regions with significantly different aspects: dynamics, radiation and chemistry. Slight changes in the moisture and chemical constituents fluxes across the tropopause may lead to significant changes in the global climate. Therefore precise knowledge of the spatial and temporal structure of the tropopause is at much interest at study of global climate change.

Global circulation models (GCMs) are important tools in the study of past, present and future of climate. Among them, the Whole Atmosphere Community Model (WACCM) has high vertical resolution near the tropopause.

In the present study Reanalisys data (ERA-40) are used to test WACCM's ability to reproduce realistically the tropopause climate.

Annual and seasonal climatology-mean, meridional profiles and trends of the tropopause pressure of reanalysis and simulations of WACCM are compared.

Data

- **Reanalysis data – ERA-40 - “quasi-real data”**
  - **ERA40 project – ECMWF –**
  - **Resolution vertical - 60 levels --- hybrid coordinates---**
  - **Resolution horizontal – 2.5° lat x 2.5° lon –**
  - **Resolution temporal – all days at 00Z, 06Z, 12Z and 18Z –**
  - **Period (1963 -2001)**

- **WACCM data**
  - **Whole Atmosphere Community Climate Model (WACCM) – CCSM -**
  - **Resolution vertical from Earth's surface to the thermosphere (approximately 145 km altitude) – 66 levels ---hybrid coordinates---**
  - **Resolution horizontal – 1.9° lat x 2.5° lon -**
  - **Resolution temporal – one a day -**
  - **Period (1963-2001)**

Methodology and Calculation of Derived Variables

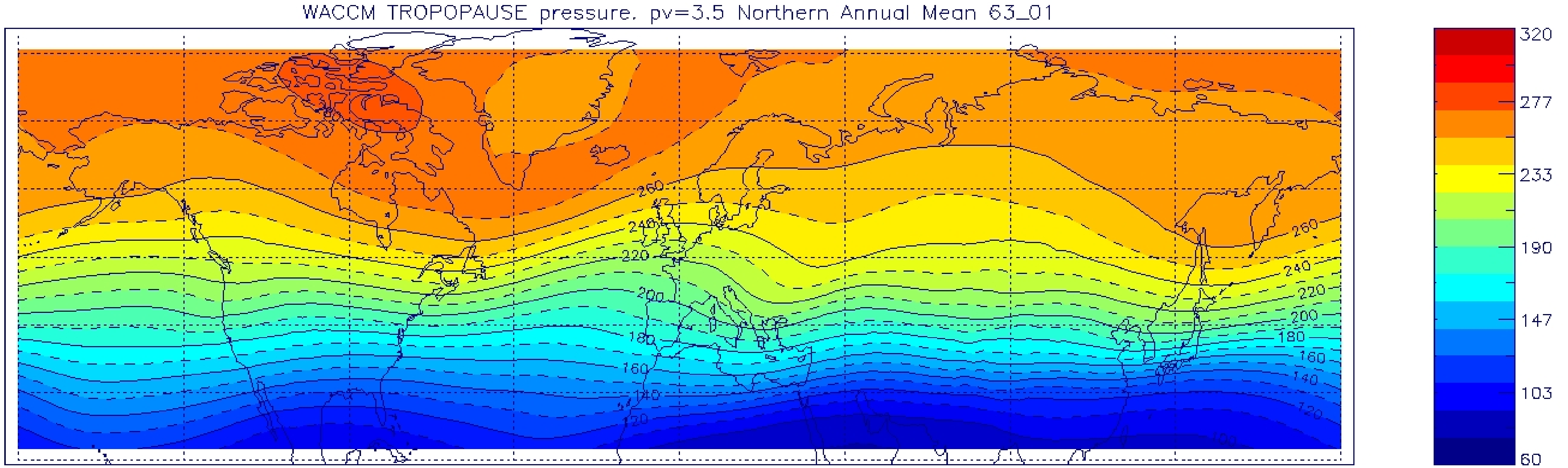
- **<u>Definition dynamical tropopause:</u> A surface of constant isentropic potential vorticity PV_θ expressed in PVU (1PVU = 1 x 10^{-6} m^2 s^{-1} K kg^{-1}), that separates low potential vorticity values in the troposphere from high values in the stratosphere.**

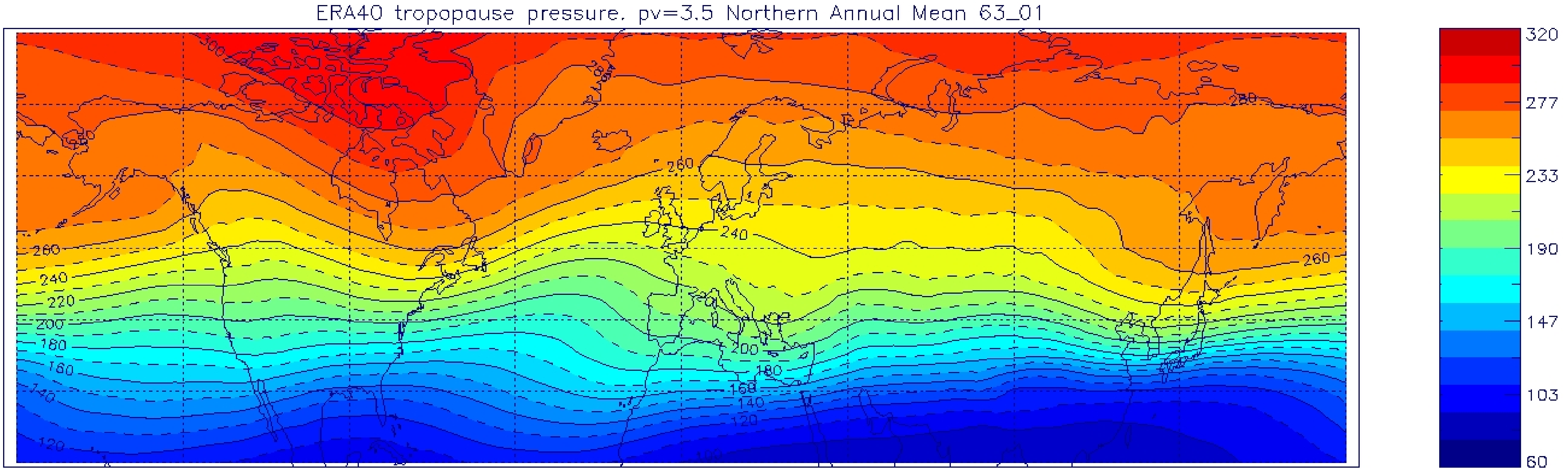
- ***<u>In this work is considered;</u>***
  - **Extratropical latitude – (20°- 80°)**
  - **Tropopause of 3.5PVU – as suggested by Hoerling et al, (1991) for extratropical latitudes -**
  - **Northern Hemisphere**

- **<u>Calculation of tropopause pressure:</u>**
  - **The pressure data in model levels were converted into isentropic coordinates by vertical interpolation at temperature potential levels set (270 to 440, at 5 K increments).**
  - **In this isentropic levels the pressure and potential vorticity were evaluated.**
  - **Finally, tropopause pressure is calculated by interpolation at pressure for first vertical level that exceeds the threshold value of 3.5 PVU.**

Results analysis

Mean annual climatology





- **It reflects a *similar structure*.**

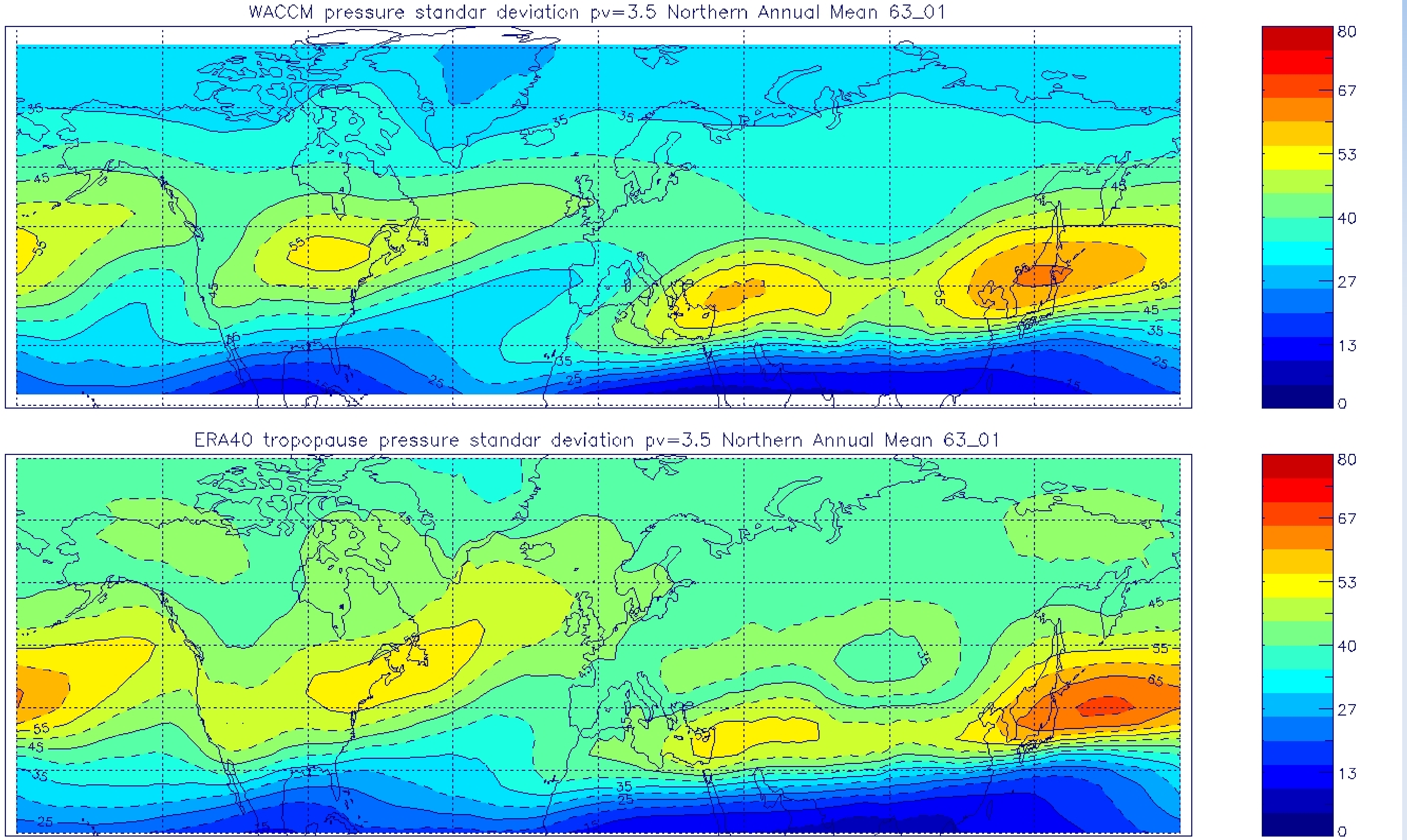
- **It's characterized by *flow patterns with zonal wavenumbers* between one and three for ERA-40 and WACCM, which could be generated by the distribution of continents and oceans.**

- **One *belt with strong meridional gradients* can be seen clearly, which are concentrated around the globe between 30° and 60° latitude for ERA-40 and between 20° and 60° for WACCM, perhaps associated with the subtropical jet stream.**

- **The *isobars converge strongly* above the eastern United States and East Asia, this convergence may result from orographic accidents in these regions, the Rocky Mountains and Himalaya. For WACCM this isobaric convergence is lower than obtained by Reanalysis.**

- **For WACCM the overall structure is softer, the gradient is less pronounced and the pressures are lower for different latitudes.**

Annual standard deviation



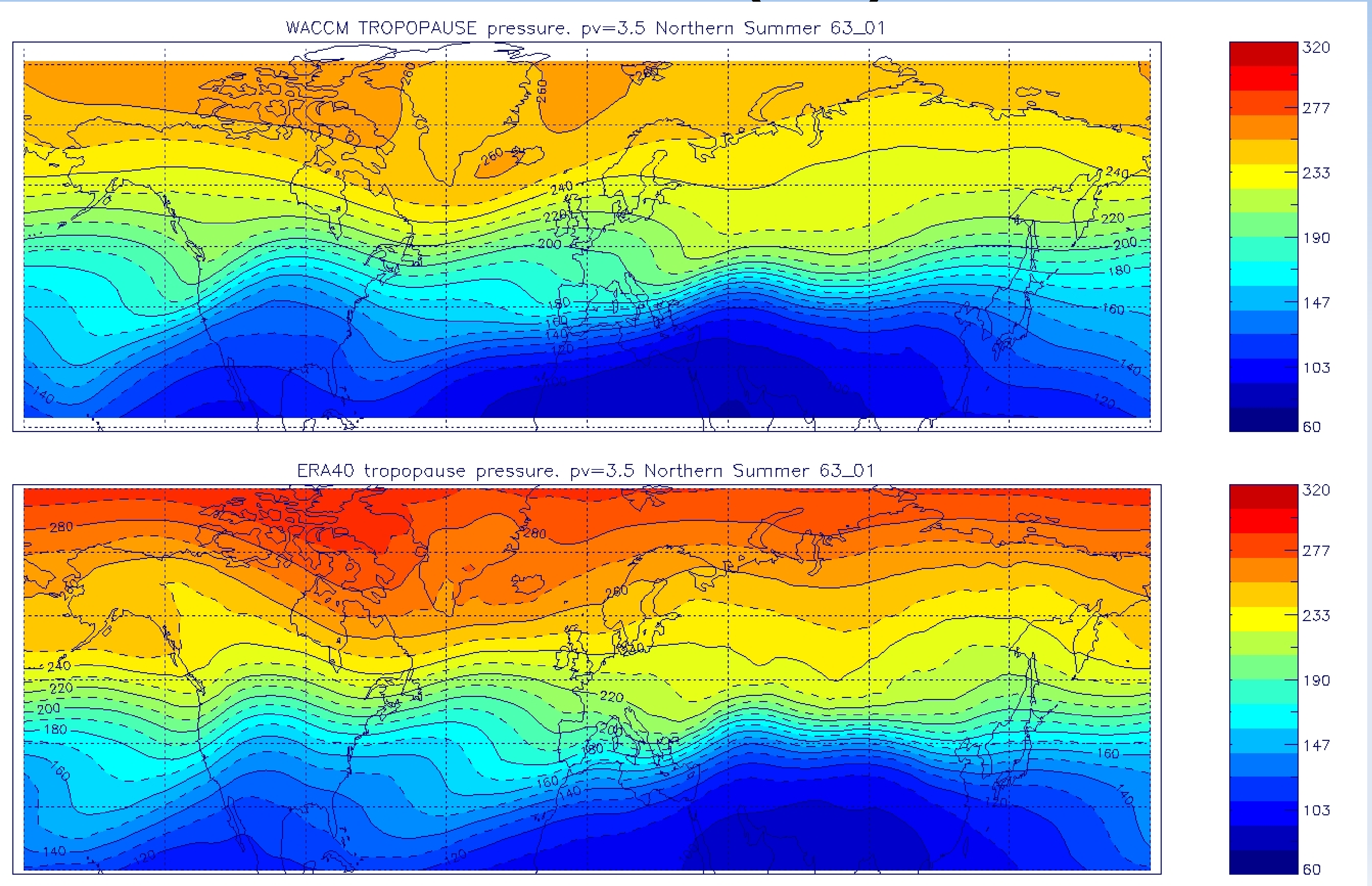
- **There are three *maximums of variability* over the Atlantic Ocean, the Pacific Ocean and the southwestern Europe and Asia, for ERA-40 and WACCM.**

- **ERA-40's data have greater variability than WACCM data.**

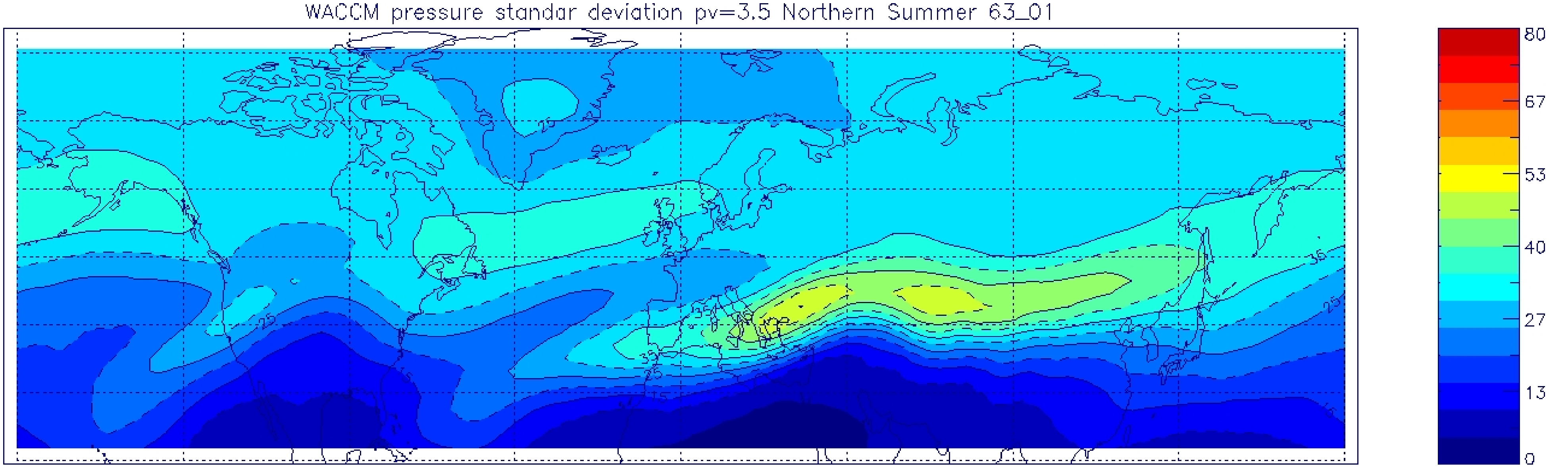
- **The area with high standard deviations above the Atlantic Ocean and Pacific Ocean coincides with the *storm tracks*. This variability patterns may be connected with the baroclinic waves.**

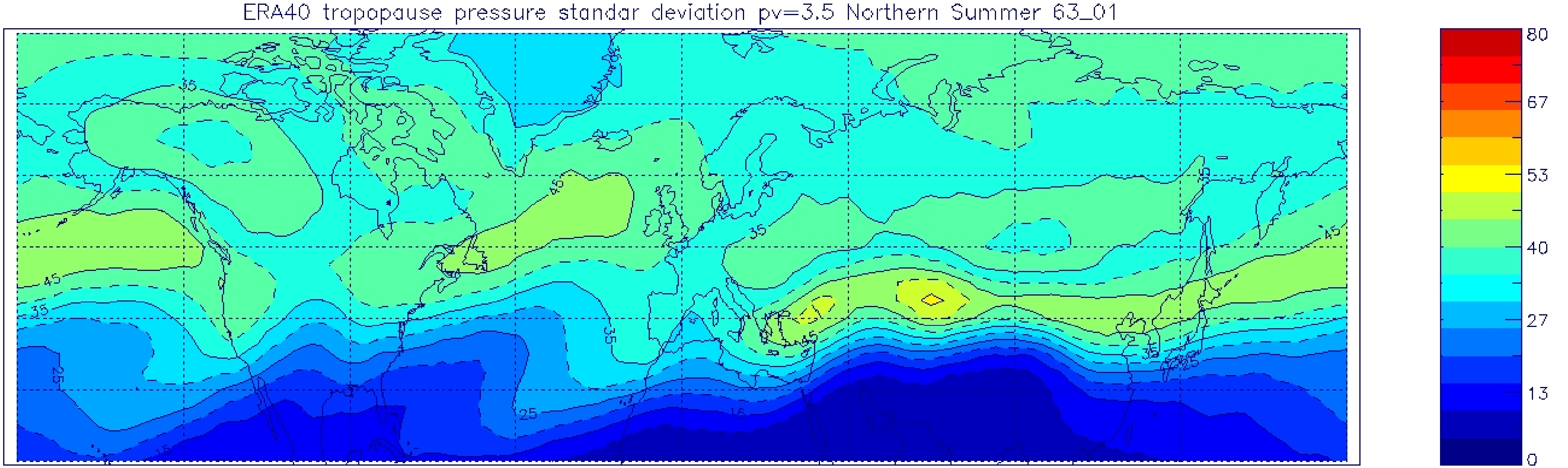
- ***Minimums of variabilitys* extends longitudinally between 20°– 30° latitude (subtropical latitude) and over Greenland.**

Mean seasonal climatology
Summer (JJA)

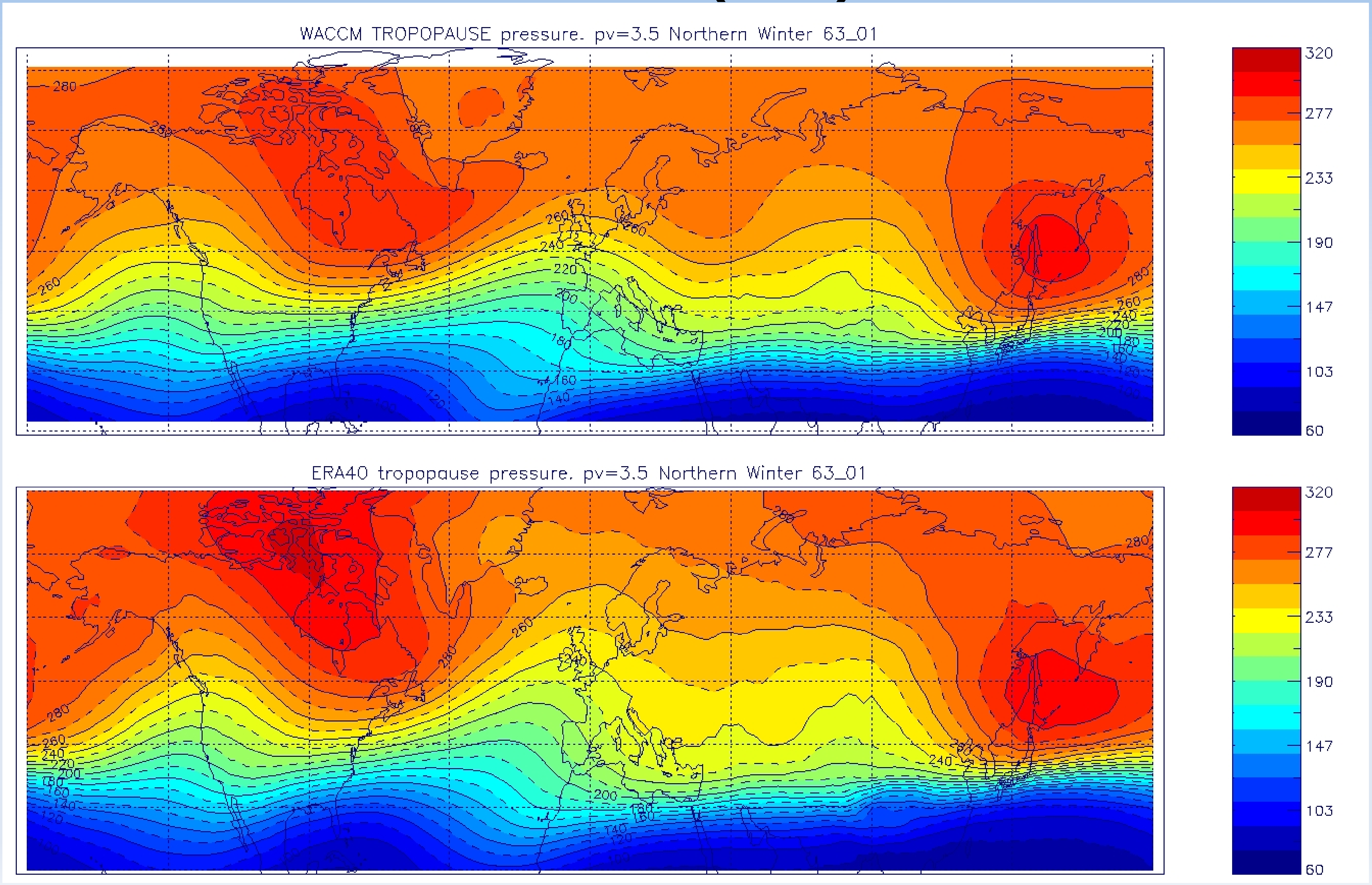


Seasonal standard deviation - Summer -

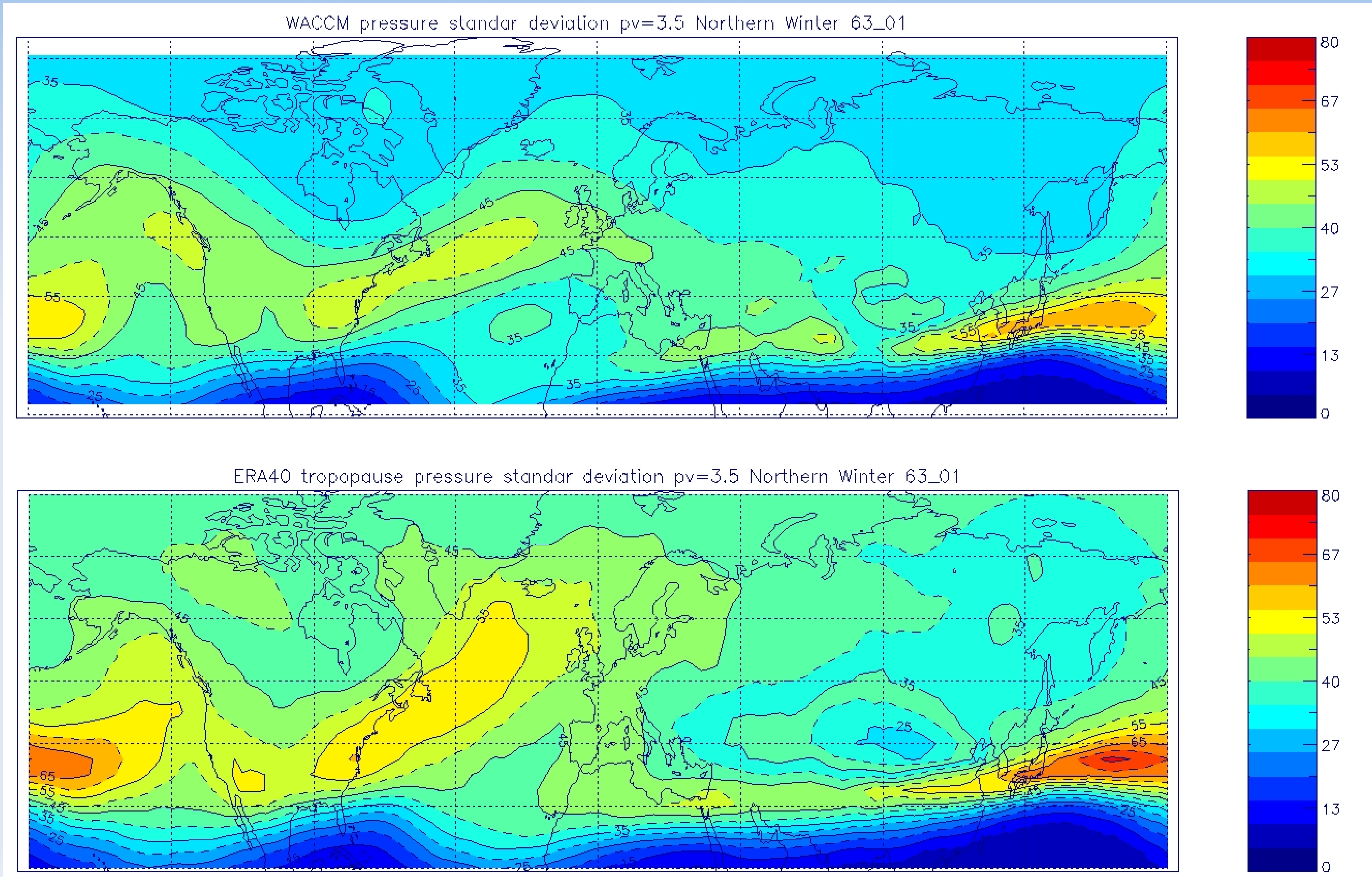




Mean seasonal climatology Winter (DJF)

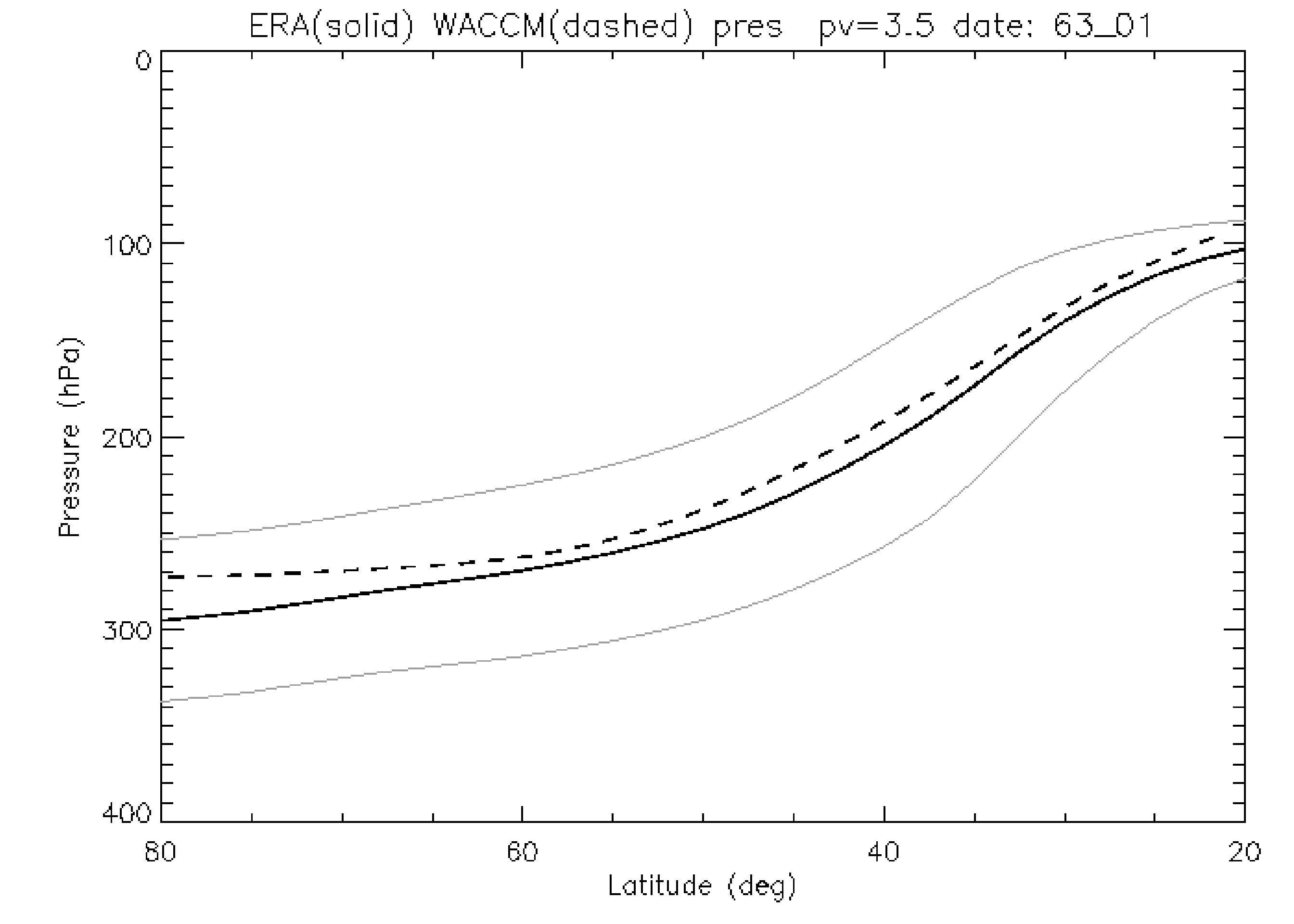


Seasonal standard deviation – Winter -



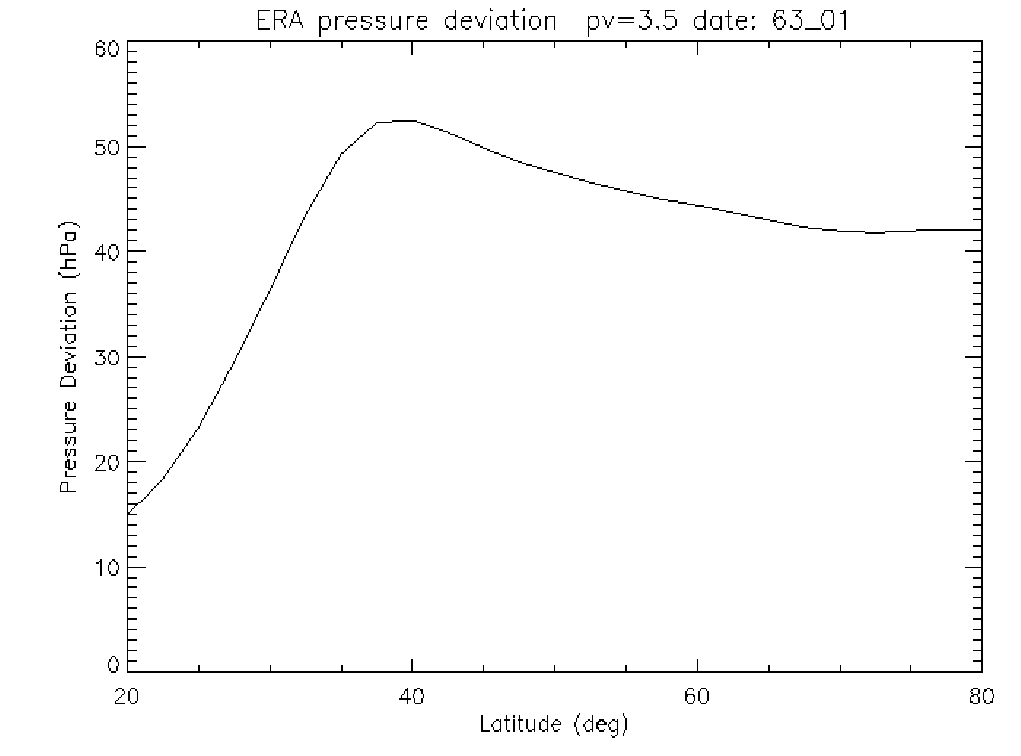
- **The longitudinal gradient is *more intense in winter* and *weaker in summer*, possibly associated with seasonal variations in the intensity of the subtropical jet stream.**
- ***Global movement* of this gradient northward in summer and southward in winter are due probably to seasonal movements of the jet stream.**
- ***Two maximums* pressure for the *winter*, one above Greenland and the northern Canada for ERA-40 and WACCM, and other above the Pacific Ocean for WACCM and ERA-40. The minimum height (maximum pressure) of the tropopause over Greenland also appears in the annual average for both models.**
- ***In winter* there is a *great variability* on the structure associated with the subtropical jet stream, with one maximum probably due to the variation of the position and speed of jet stream (for ERA-40 and WACCM).**
- **In summer the variability is more smoother over the position of jet stream.**
- **The Himalaya region is characterized by one minimum in winter and one maximum during the summer, it moved westward in the summer.**

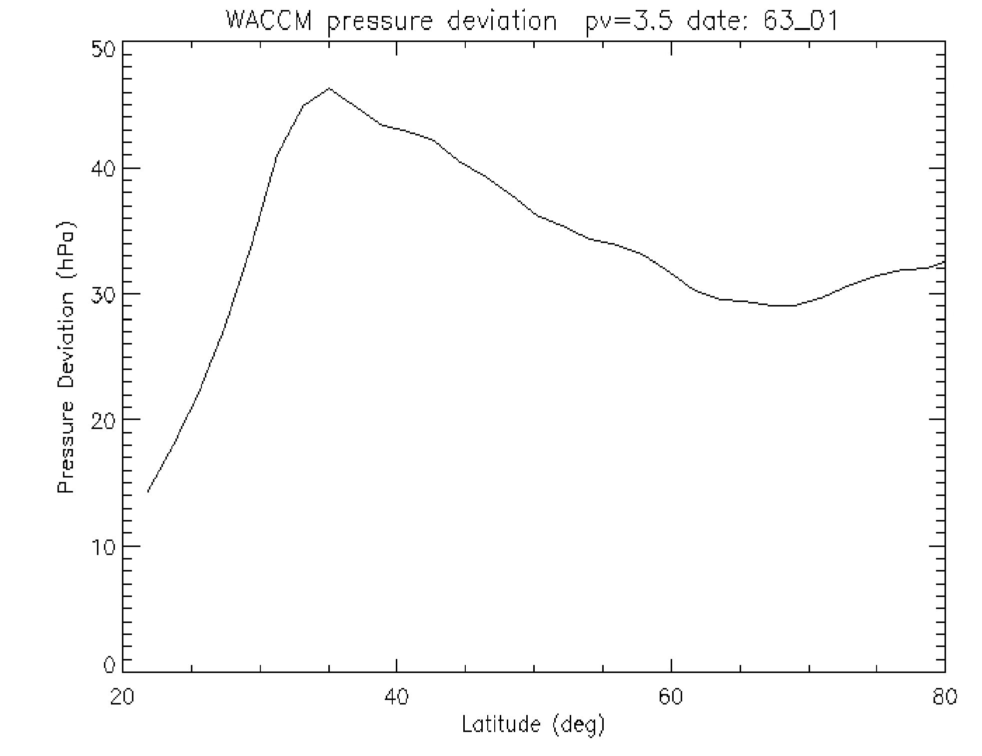
Annual meridional profile



- **High tropopause (low pressure), at 20° latitude.**
- **Low tropopause (high pressure) at 80° latitude.**
- **The height tropopause decreases with increasing latitude.**
- **WACCM's results are within the range of one deviation of the ERA-40's results.**
- **The pressure gradient for WACCM is greater than for ERA-40, for all latitudes.**

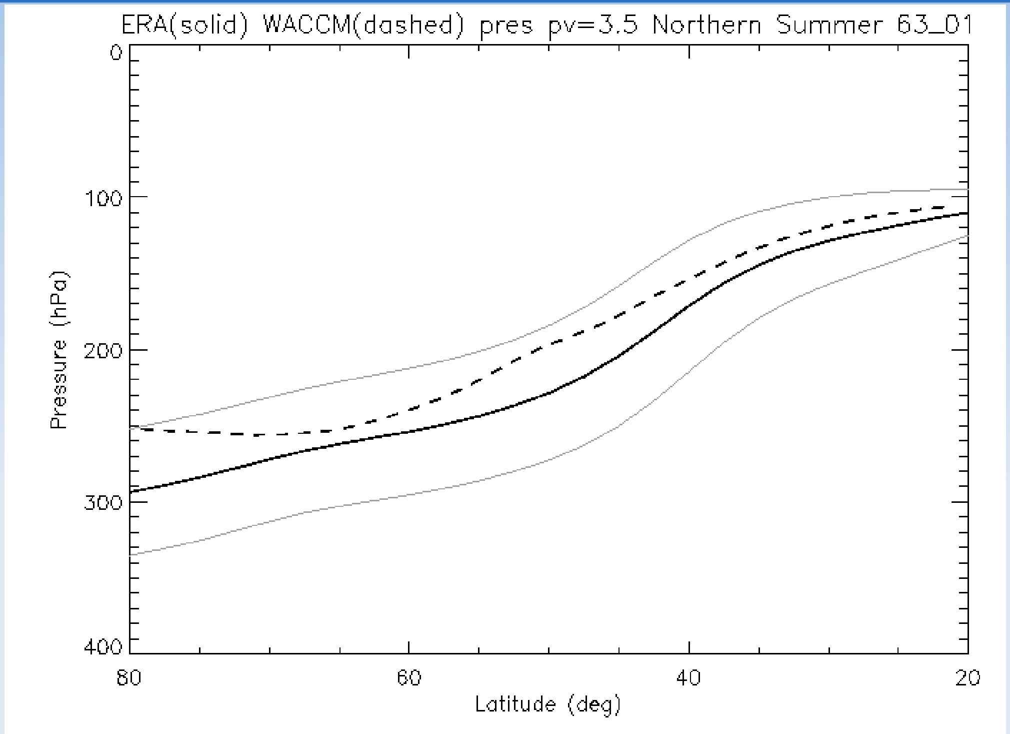
Variability annual meridional profile

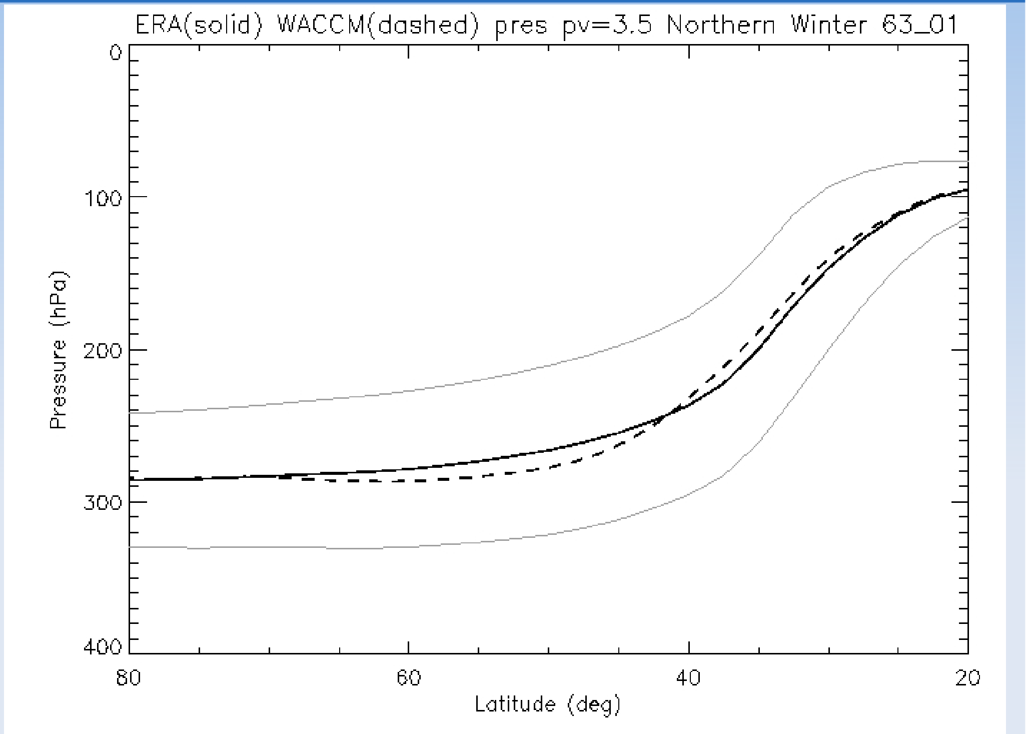




- The variability is lower for subtropical latitude for both models.
- The maximum variability is found between 30° and 50° N, which is due to the variability of the jet stream in this latitudes.
- For WACCM the maximum variability is lower than for ERA-40 and there is lower variability in extratropical latitudes.

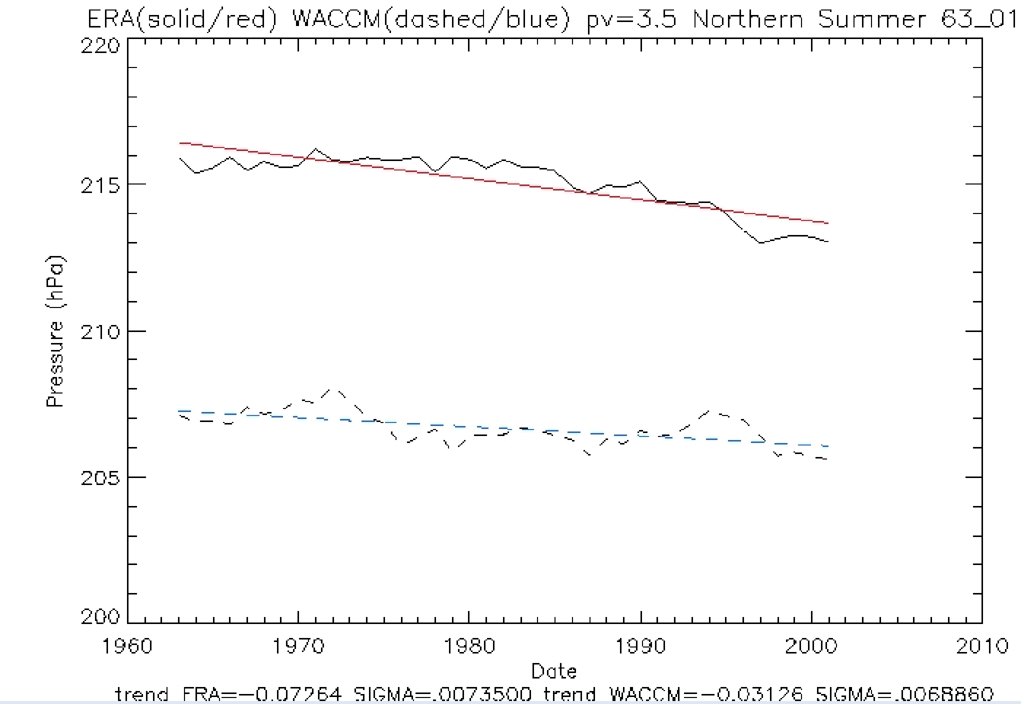
Seasonal meridional profiles

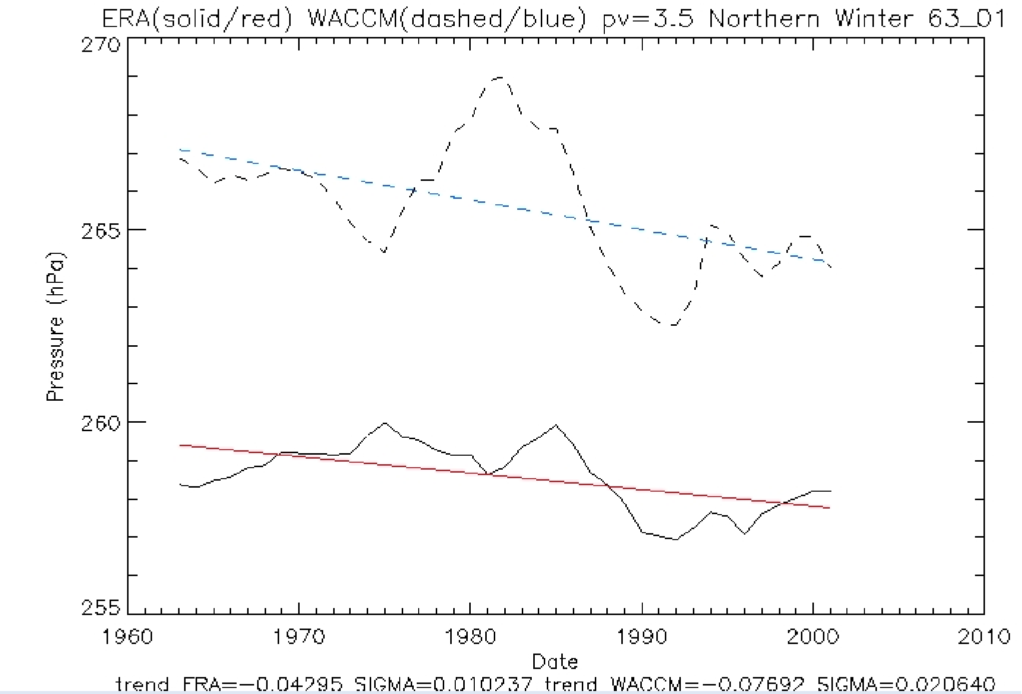




- **In summer, WACCM's tropopause height is higher than in ERA.**
- **In winter tropopause height is almost constant between 50° and 80° latitude .**
- **In winter the model's results match better than reanalysis's results.**
- **There is a good relationship between the meridional profiles for ERA and WACCM.**

Trends





Interannual variability of tropopause pressure for the region between 40° and 60° North. The trends is given with the slope of the linear fit. The data have been smoothed through moving average.

- **The tropopause pressure (height) decrease (increase) on the entire period, with a trend of -0.073 ± 0.007 (summer) and -0.04 ± 0.01 (winter) for ERA and -0.031 ± 0.007 (summer) and -0.077 ± 0.002 (winter) for WACCM.**
- **The interannual variability is more strong for WACCM.**

Summary

- **The following features of the tropopause pressure are reproduced by WACCM:**
  - **It reflects a *similar structure*.**
  - **Above the Northern Hemisphere the continents generate a pattern with wavenumbers between two and three.**
  - **One *belt with strong meridional gradients* concentrated around the globe between 20° and 60° latitude, perhaps associated with the subtropical jet stream.**
  - **Strong standard deviations in the tropopause pressure are associated with the Atlantic and Pacific storm track regions. This variability patterns may be connected with the baroclinic waves.**
  - **The longitudinal gradient is *more intense in winter* and *weaker in summer*, possibly associated with seasonal variations in the intensity of the subtropical jet stream.**
- **Meridional profiles reflect a high tropopause for low latitude and low tropopause for high latitude.**
- **For WACCM, the maximum variability between (30°-60°N) is lower than in ERA-40 and also there is lower variability in extratropical latitudes .**
- **In summer, WACCM's tropopause height is higher than in ERA40, while tropopause height is equal for both models.**
- **WACCM's results are within the range of one deviation of the ERA's results.**
- **For the past recent, the tropopause pressure (height) has decreased (has increased) ,for WACCM and ERA40.**

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