Impact of a non-orographic gravity wave drag parameterization on the middle atmosphere in the Global Spectral Model of the Japan Meteorological Agency

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Introduction

The Japan Meteorological Agency (JMA) has a plan to raise the topmost level of operational Global Spectral Model (GSM) from 0.1hPa to 0.01hPa, which makes GSM include whole stratosphere and place the model lid on the mesopause. The total number of vertical layers will be increased from 60 to 100, with the aim of improving the representation of the middle atmosphere. In the middle atmosphere, gravity waves play key roles as a driving force of meridional circulations and long-term oscillations like QBO (Fritts and Alexander 2003). Because of insufficient vertical resolution of GSM, their effects need to be parameterized.

For this purpose, non-orographic gravity wave drag (NGWD) scheme by Scinocca (2003) (hereafter referred to as S03) was tested in GSM.

Experiment Configurations

As gravity wave drag parameterizations, the operational GSM includes the orographic gravity wave drag scheme by Iwasaki et al. (1989) and the simple non-orographic gravity wave drag scheme as known as Rayleigh friction (RF) by Boville (1986). To study the impact of NGWD scheme, two experiments that one used RF and the other used NGWD instead of RF were conducted using low horizontal resolution GSM (TL95) with the extended vertically resolution (L100) and the GSM with the operational vertical resolution (L60). Parameters of S03 were as follows ; s = 1, p = 1.5, launch level = 450 [hPa], number of azimuths = 4 (N, S, E, W), number of phase speeds = 50, launch E-P flux density = 3.5 x 10^-3 [Pa], m = 2000 [m], c_min = 0.25 [m/s], c_max = 2000 [m/s], gamma = 0.6. Time step was 3600 seconds. Other model descriptions of GSM were as same as described in Nakagawa (2009). The integration period was 6 years for 1995-2000 and initial condtions were JRA-25 (Onogi et al. 2007). Analyzed SST and climatological ICE field were given. The model climatologies of the experiments are compared to the SPARC climatology (Randel et al. 2003) and ERA-Interim (Dee et al. 2011).

Zonal Mean Climatologies

- Winter polar lower stratosphere temperature (50hPa) of L60-RF (Fig. 1a, 3a) is about 10 K colder than SPARC (Fig. 1e, 3e). This bias is alleviated in L60-NGWD (Fig. 1b, 3b), L100-RF (Fig. 1c, 3c) and L100-NGWD (Fig. 1d, 3d). In addition, the summer stratopause temperature in L60-NGWD and L100-NGWD are much closer to SPARC.
- Considering that winter stratopause temperature of L60-NGWD (Fig. 2b, 4b) and L100-NGWD (Fig. 2d, 4d) are much colder than SPARC (Fig. 2e, 4e) and winter mesosphere temperature are much warmer than SPARC, NGWD drag is so weak that meridional circulation is insufficiently represented. Therefore, temperature bias alleviations seen in the summer stratopause in NGWD experiments may be compensating errors between weak heating bias of short wave radiation scheme and lack of upwelling cooling of meridional circulation in NGWD experiments.
- L100-RF and L100-NGWD have less latitudinal temperature gradient in the mesosphere, so that the winter westery jets are too strong and are not closed in the mesosphere. Possibly this may be caused by O3 climatology error and radiation scheme bias (Sekiguchi at JMA/NPD, personal communication) in the mesosphere. Development to tackle the issues is undergoing at JMA/NPD.
- In the summer hemisphere, zonal mean of zonal wind for L100-NGWD (Fig. 2d, 4d) shows good agreement with SPARC (Fig. 2e, 4e), which indicates that RF excessively deaccelerates easterly winds in the region.

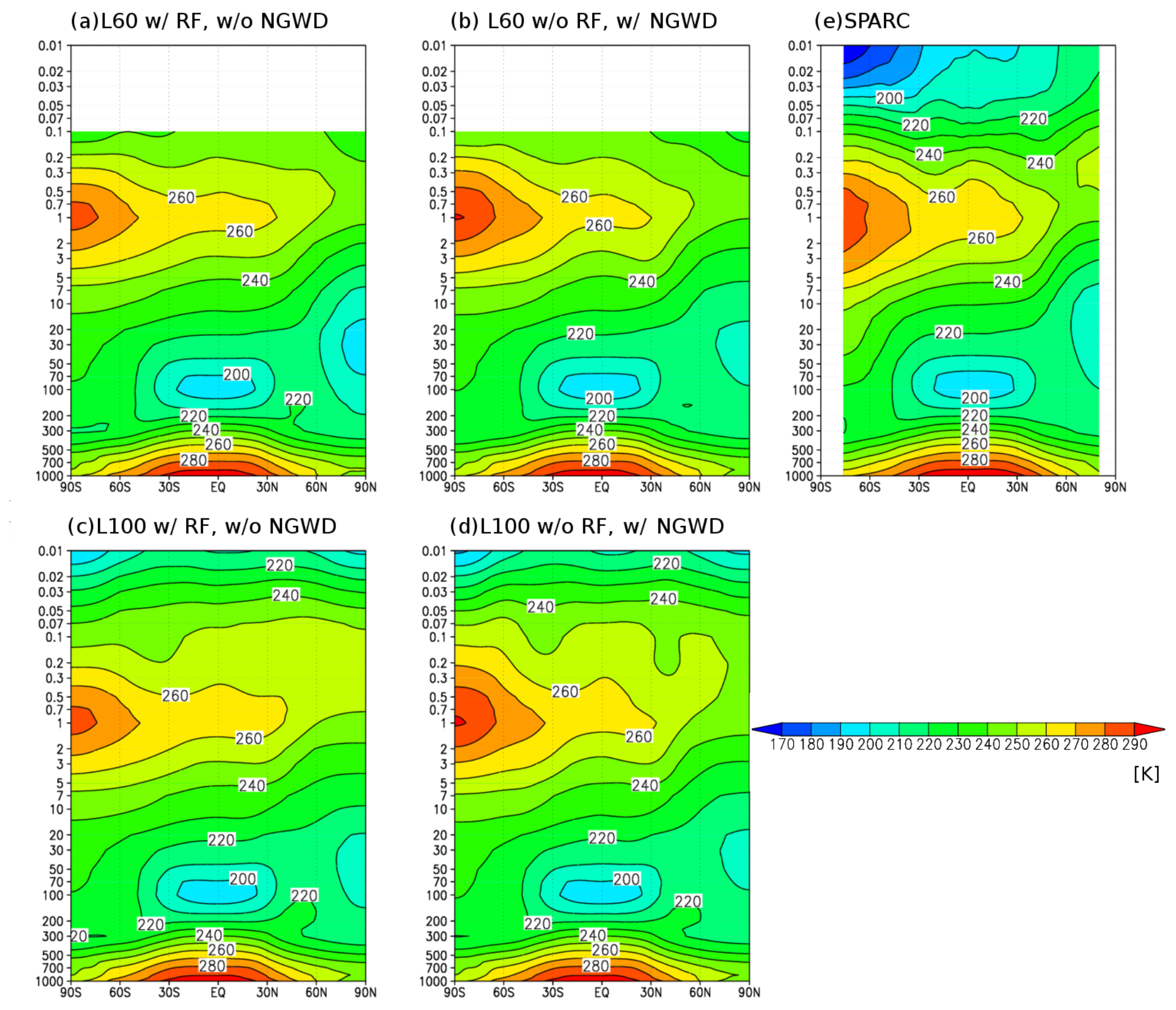

Fig. 1. Zonal mean of temperature in January. (a) L60 with RF, (b) L60 with NGWD, (c) L100 with RF, (d) L100 with NGWD and (e) SPARC.

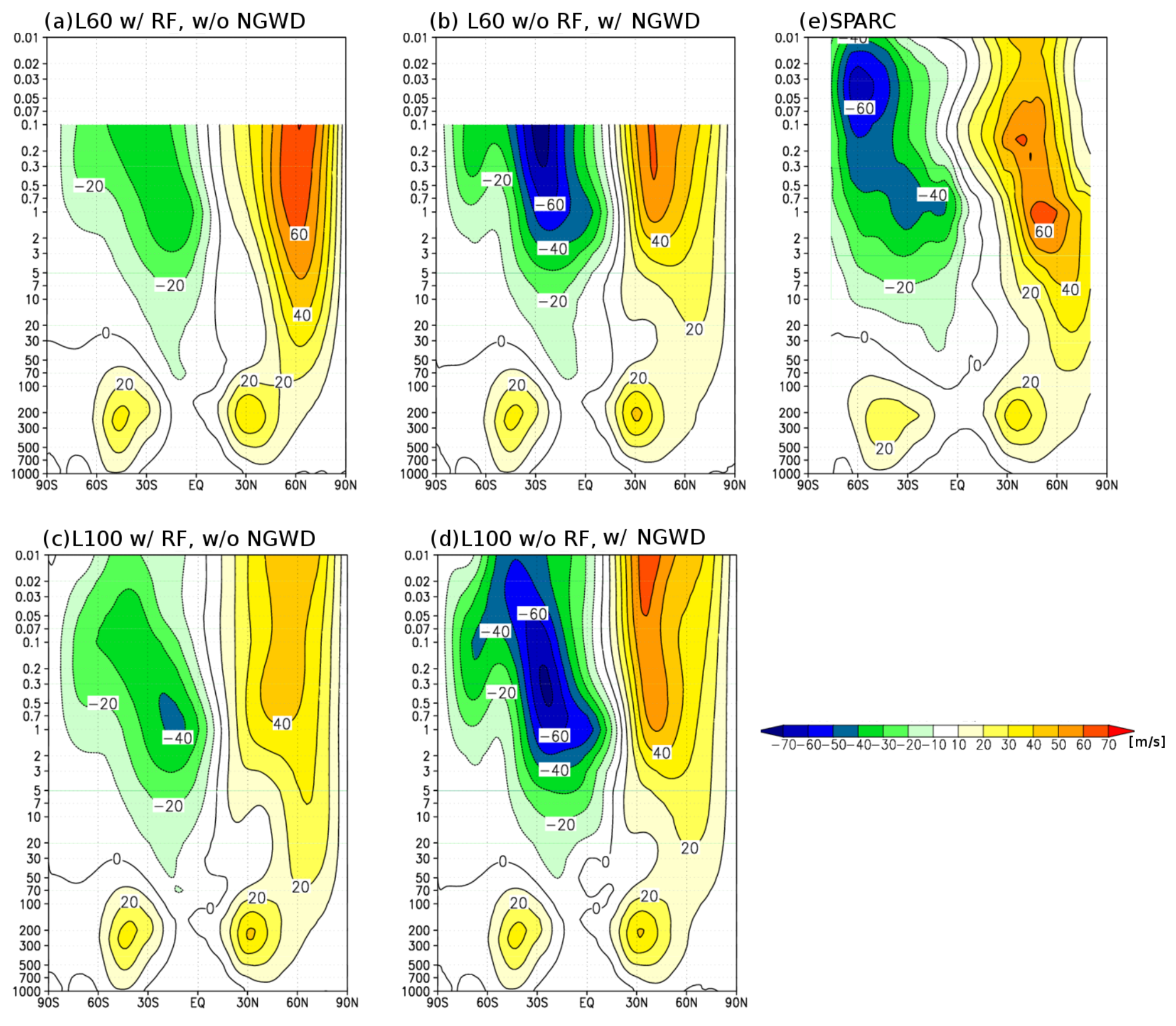

Fig. 2. Zonal mean of zonal wind in January. Other configurations are the same as Fig. 1.

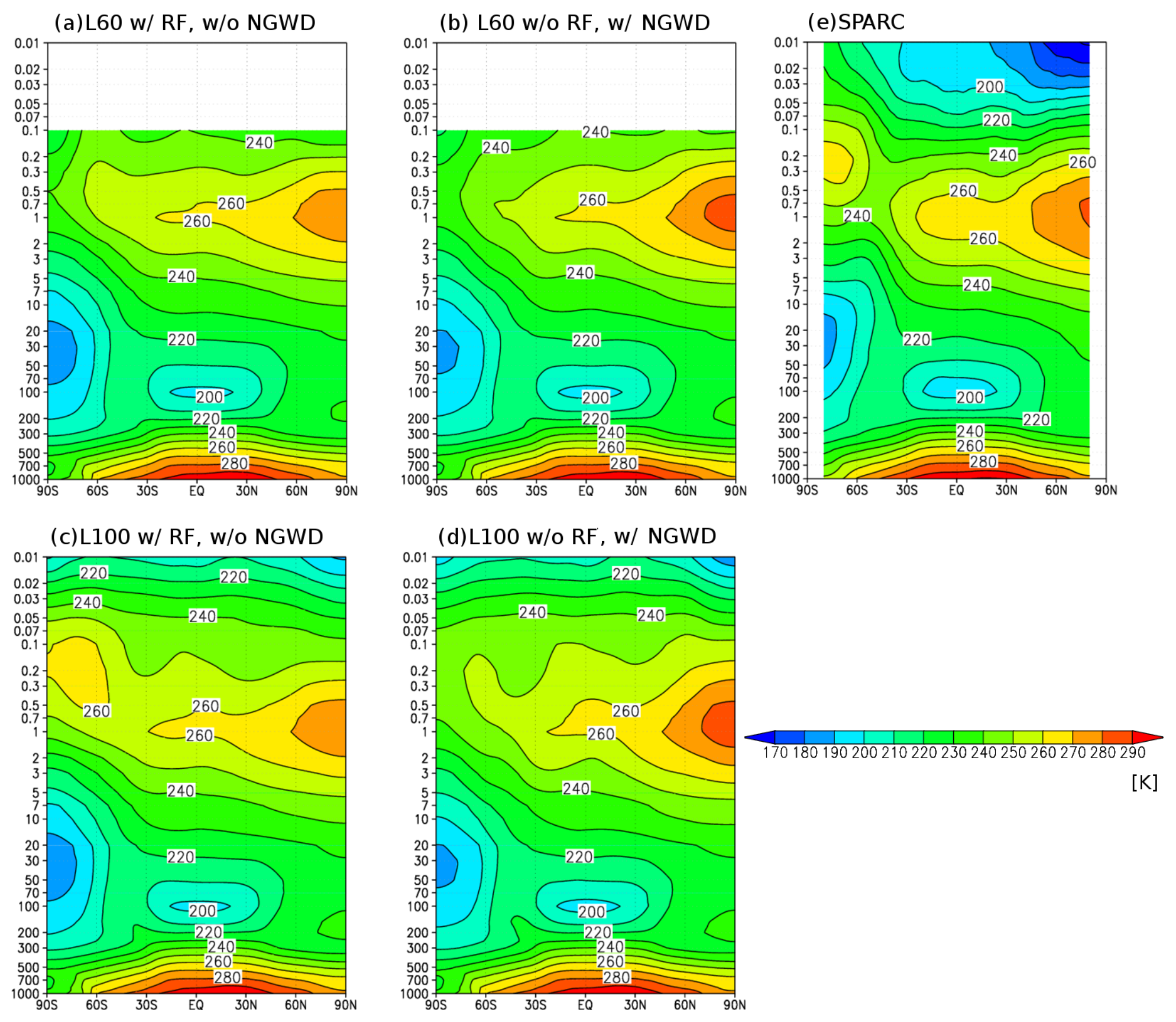

Fig. 3. Same as Fig. 1, but for July.

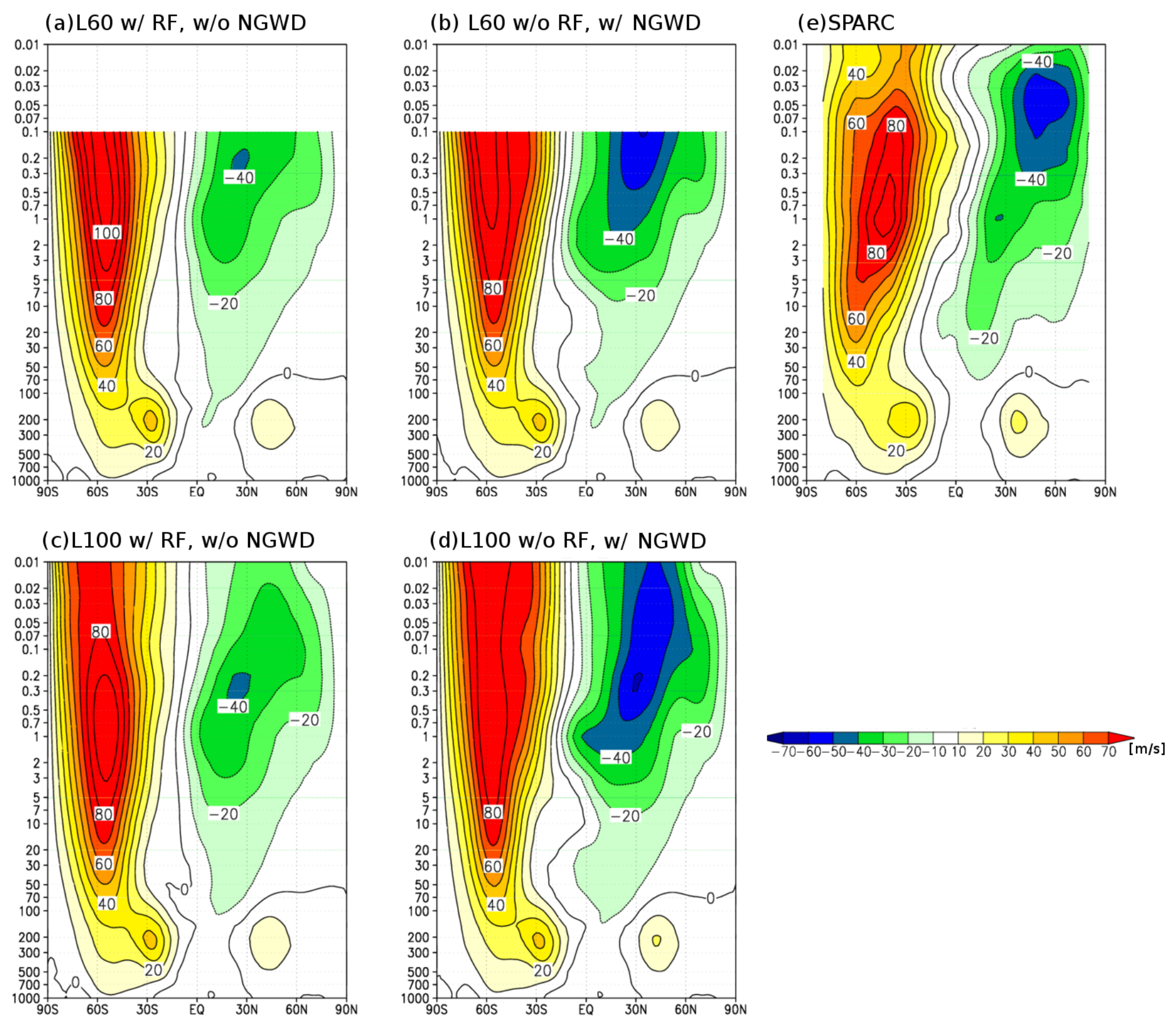

Fig. 4. Same as Fig. 2, but for July.

Tropical Winds

- L60-NGWD (Fig. 5b) and L100-NGWD (Fig. 5d) have zonal wind oscillations, but the amplitudes and periods are weaker and shorter than ERA-Interim. In contrast, L60-RF (Fig. 5a) and L100-RF (Fig. 5c) do not show such periodic oscillation.
- Comparing L60-NGWD with L100-NGWD, NGWD scheme impacts are not identical for L60 and L100 with the same parameters. This suggests the need of different optimal tunings depending on the model levels and the layer thicknesses. Vertical resolution is thought as a key factor of QBO modeling since model resolved waves depend on it.

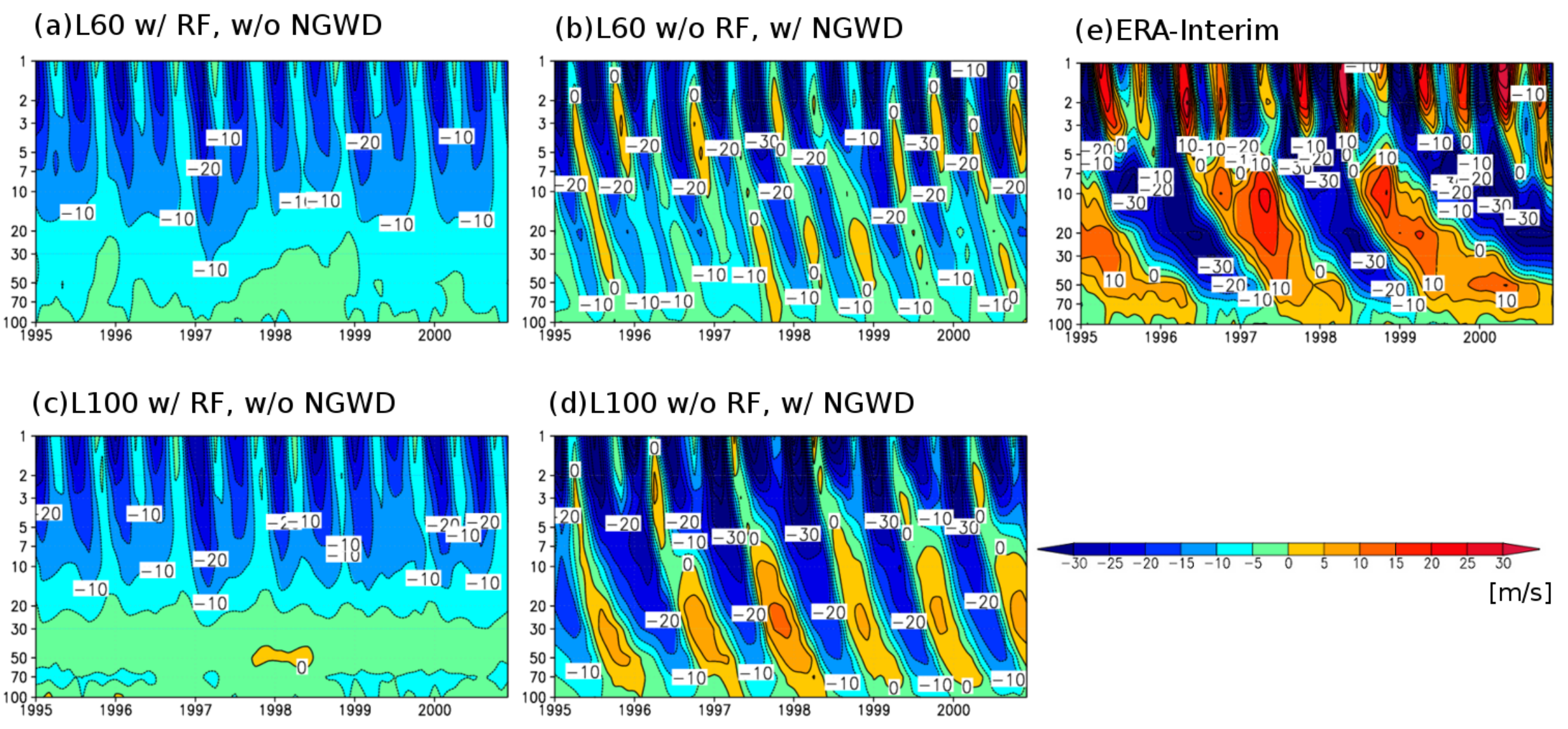

Fig. 5. Zonal mean of zonal wind averaged over 5S-5N for (a) L60 with RF, (b) L60 with NGWD, (c) L100 with RF (d) L100 with NGWD and (e) ERA-Interim.

Planetary Waves

- An amplitude and spatial structure of planetary waves in terms of zonal wind anomaly for L100-NGWD (Fig. 6d, 7d) show good agreements with ERA Interim (Fig. 6e, 7e) in both winter hemisphere. Possibly this is the result of changes in the zonal mean flow induced by non-orographic gravity wave drags since the zonal mean flow affects planetary wave propagation and dissipation.

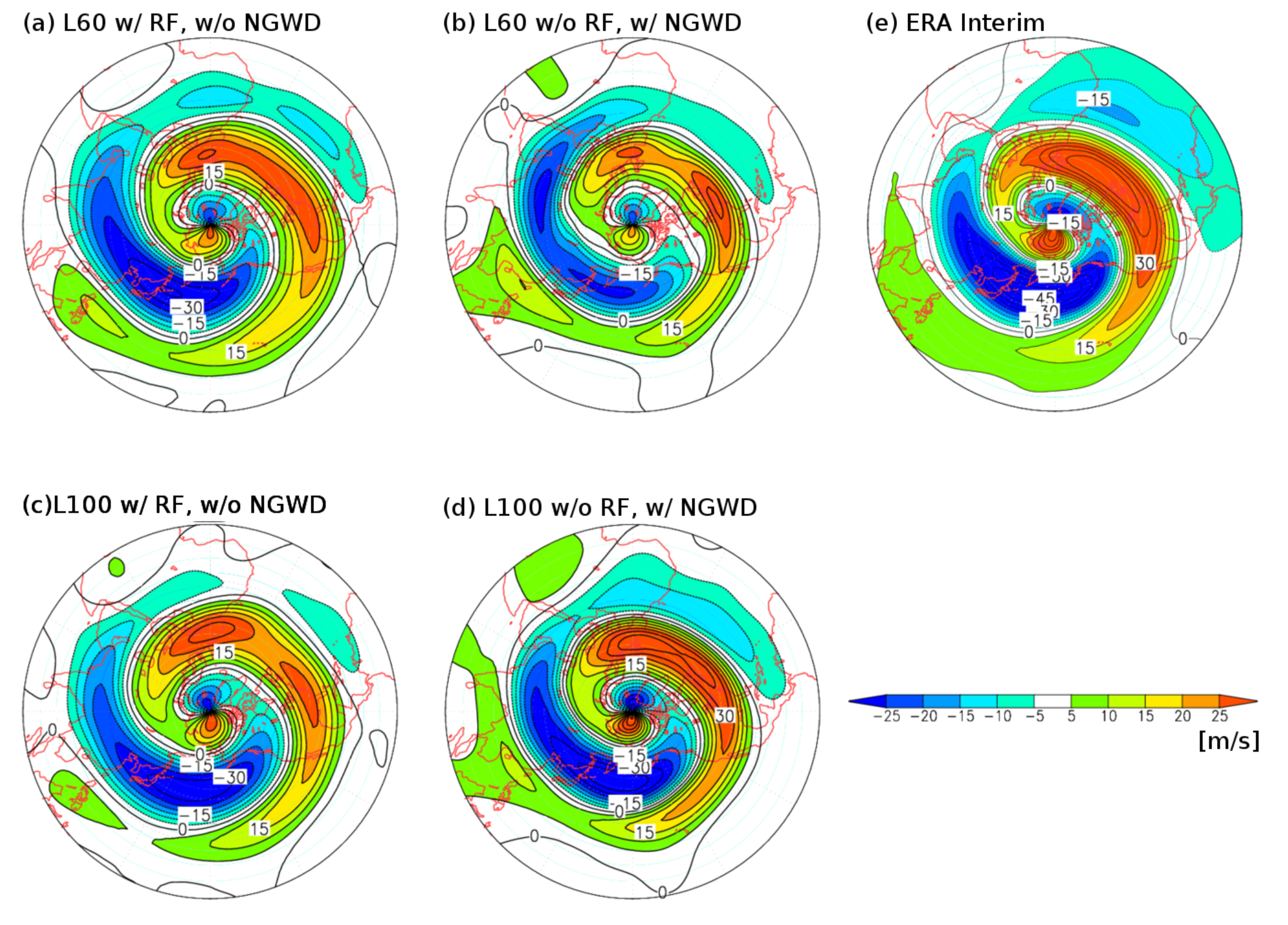

Fig. 6. Zonal wind anomaly from zonal mean at 1hPa in January in northern hemisphere, following the approach of Manzini and McFarlane (1998). (a) L60 with RF, (b) L60 with NGWD, (c) L100 with RF, (d) L100 with NGWD and (e) ERA-Interim.

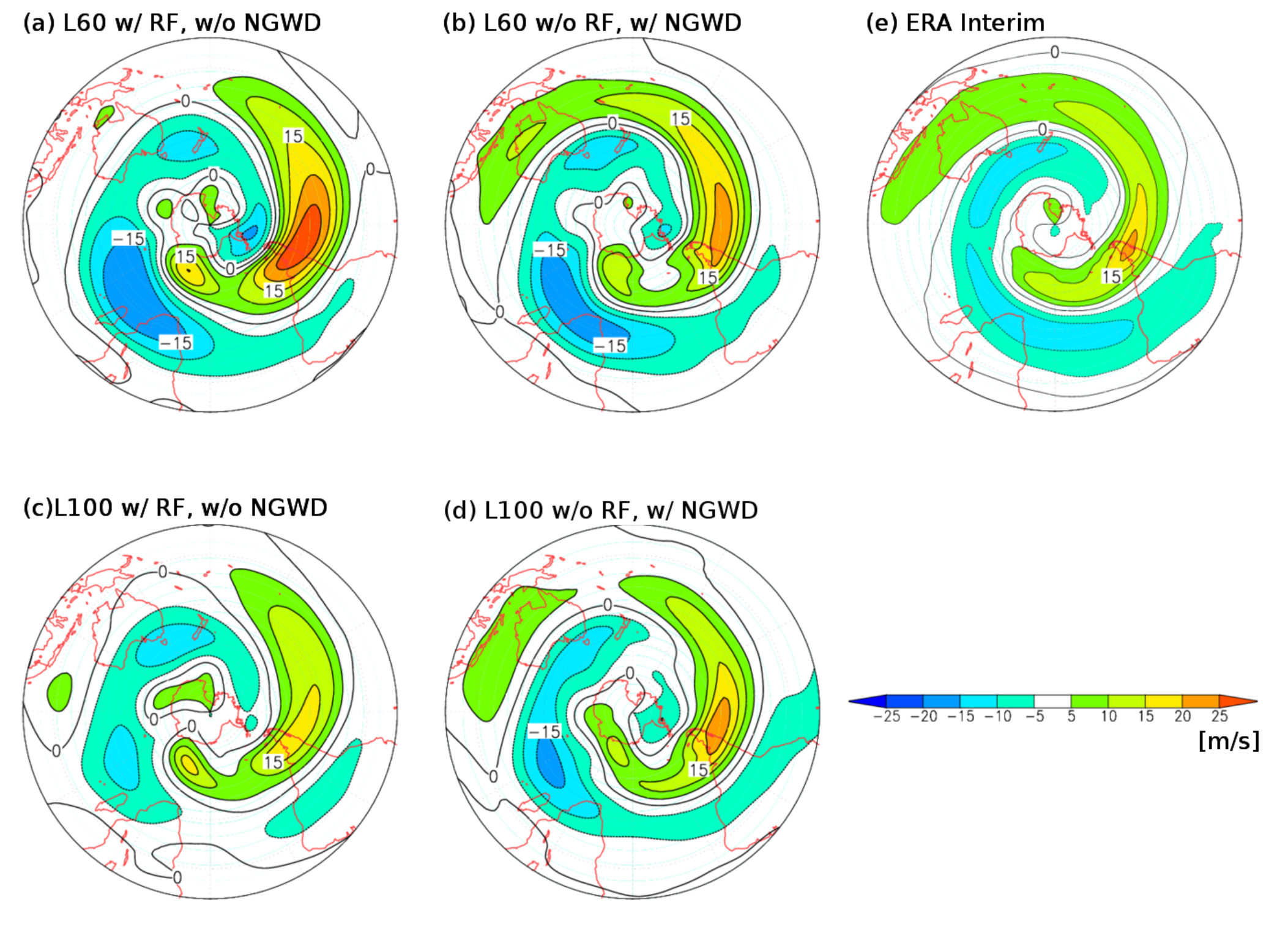

Fig. 7. Same as Fig. 6, but for July and in the southern hemisphere.

References

Boville (1986), JAS ; Dee et al. (2011), QJRMS ; Fritts and Alexander (2003), R. Geophysics ; Iwasaki et al., (1989), JMSJ ; Nakagawa (2009), RSMC Tokyo-Typhoon Center Technical Review ; Manzini and McFarlane (1998), JGR ; Onogi et al. (2007), JMSJ ; Randel et al. (2003), J. Clim ; Scinocca (2003), JAS

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S03 scheme used in this study was downloaded from the website (http://www.cccma.bc.ec.gc.ca/~jscinocca/) published by Dr. John F. Scinocca at the Canadian Centre for Climate Modelling and Analysis, University of Victoria.

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