16B.7 MODEL STUDY OF INTERMEDIATE-SCALE TROPICAL INERTIA GRAVITY WAVES AND COMPARISON TO TWP-ICE CAMPAIGN OBSERVATIONS.

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ABSTRACT

A 2-day inertia gravity wave (IGW) was observed in high-resolution radiosonde soundings of horizontal wind and temperature taken during the TWP-ICE experiment in Darwin area (Evan et al., 2008). The wave presented vertical and horizontal wavelengths of around 6 km and 7220 km respectively. The wave was observed to propagate southeastward during the end of the easterly phase of the QBO. A reverse ray-tracing analysis suggests that the source of the wave is located in the maritime continent region. The total vertical momentum flux associated with the wave is estimated to be 1 to 2.2x10^{-3} m^2 s^{-2}. This is of the same order of magnitude as previous observations of 4-10 day Kelvin waves in the lower stratosphere.

A comparison between the characteristics of the IGW derived with the ECMWF analyses to the properties of the wave derived with the radiosonde data shows that the ECMWF model captures similar structure for this 2-day wave event but with a longer vertical wavelength.

The Advanced Research Weather Research and Forecasting (WRF) modeling system is used to study the wave generation mechanisms and propagation dynamics. The model domain configured as a tropical channel encompasses the evolution of the 2-day IGW. The ECMWF analyses provide the north/south boundaries and initial conditions. The model is run from January 18 to February 11 2006 to cover the wave lifecycle. Different simulations have been performed to determine the sensitivity of the wave structure to cumulus schemes and initial conditions. The wave characteristics inferred from WRF simulations are compared to ECMWF analyses and forecasts.

1 INTRODUCTION

Extensive studies of atmospheric waves generated by tropical convection have been carried out over the past decades as these waves play an important role in the dynamics of the tropical middle atmosphere. These different studies suggest that planetary scale waves alone can not explain the dominant circulation patterns in the stratosphere and mesosphere. Mesoscale gravity waves and intermediate-scale inertia-gravity waves can have an important role in the dynamics of this region and thus must be resolved properly in GCMs.

We need to understand the link between convection and the intermediate scale waves. Modelling is needed to assess the sources and mechanisms which lead to the generation of such waves. According to recent studies (e.g., Plougonven et al., 2003; Alexander et al., 2007), ECMWF analyses and forecasts can reproduce some qualities of observed gravity waves. However the vertical resolution of the model in the stratosphere might be insufficient to resolve the wave structure properly. Regional models such as WRF can be used as a complement to ECMWF data to validate and further understand the mechanisms of the intermediate scale wave generation and propagation to the stratosphere. Different papers have evaluated WRF performance in the tropics and its ability to simulate atmospheric waves (Tulich et al, 2009; Kim et al, 2009). These studies give us some confidence that the WRF model may be used to determine the properties of atmospheric waves in the tropics.

2 DATA

2.1 Verification data

We use the Global Precipitation Climatology Project (GPCP) one-degree daily precipitation data set to evaluate the simulated daily mean rainfall. We also use the daily ECMWF analyses at 00, 06, 12, 18UTC and forecasts at 03, 09, 15, 21UTC from 18 January to 11 February 2006. The data are interpolated on a regular latitude/longitude grid with a spatial resolution of 1° with 21 levels from

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the surface to 1hPa. The data set comprises the ECMWF fields of temperature, zonal and meridional winds and geopotential heights.

2.2 Model and experiments

In this study we use the Advanced Research Weather Research and Forecasting modeling system version 3.1. Table 1 summarizes the main physics options used in the simulations. All simulations were performed using a horizontal resolution of 40 km. 84 vertical levels are used from the surface to 1hPa with a damping layer in the uppermost 15 km. The boundary and initial conditions were constructed using the ECMWF analyses and forecasts. Simulations were carried out in a domain covering the tropics with periodic boundary conditions in the West-East direction. The model was run during 24 days (18 January to 11 February 2006) to overlap the period of the wave generation and propagation up to the stratosphere. We focus the analysis of the 2-day wave in the stratosphere on the period from 28 January to 6 February, when the wave is most prominent in the TWP-ICE observations. We did also 4 simulations with different initialization times (20, 22, 24 and 26 January) to evaluate the sensitivity of the wave response to the initial conditions. To compute the wave properties both ECMWF and WRF fields are interpolated to a regular grid with a resolution of 2.5°.

3 RESULTS

Figure 1 shows the daily mean rainfall from 18 January to 28 January 2006 (corresponding to the period of the wave generation). We can see that the model can fairly well locate the position of the ITCZ. However excess rainfall is simulated by both cumulus schemes over South America. Precipitation is also understimated over the oceans. WRF using the Kain-Fritsh scheme tends to produce more unrealistic precipition over land compared to WRF using the Betts-Miller scheme.

Figure 2 shows the Taylor diagram of daily mean precipitation. Taylor diagrams are useful tools to help compare different datsets to one reference dataset, in our case GPCP. As expected ECMWF daily mean precipitation has good spatial correlations with GPCP. The simulation using the Betts-Miller scheme shows superior skill in precipitation compared to the simulation using Kain-Fritsch.

Figure 3 corresponds to a latitude-pressure cross section of zonal wind and temperature averaged over 18 January-6 February 2006 for WRF and ECMWF. The structure of the stratospheric zonal-mean zonal wind is important as it influences the vertical propagation of gravity waves. Overall there is good agreement between the temperature and zonal wind structures in ECMWF and WRF. However there is an average difference of 2K between the tropopause temperature in WRF and in ECMWF.

We used a method similar to the one described in Alexander and Barnet (2007) to derive the wave amplitude and horizontal structure. Figure 4 displays the latitude-longitude distribution of magnitudes of quadrature spectrum of filtered perturbations (1.7 to 3 days) of zonal and meridional winds averaged between 30 and 20hPa. We used the quadrature spectrum to highlight waves with strong rotational component including inertia gravity waves (see e.g. Fritts and Alexander, 2003).

In ECMWF the maxima are observed between 80° and 130° and 5 and 15°S. In table 2 this corresponds to planetary wavenumbers 5 to 8.

In the simulation initialized January 18 two peaks appear. The first one over the Atlantic Ocean might be a wave response to the model overestimated precipitation over South America. The second peak over the Western Pacific has a wavenumber 6 and seems to be in agreement with the structure observed in ECMWF.

When iniatialized 2 or 4 days later (20-22 January) the model has less skill to produce the wave structure. This might be due to the fact that the model misses part of the development of the convective sources in the troposphere.

In the simulations initialized the 24th and 26th of January the model simulates a realistic spatial distribution and amplitude of the wave. In these two cases the initial conditions in the stratosphere might be such that the model has enough information to reconstruct the wave structure.

It seems that if the model is initialized soon enough, the model can then develop the convective sources in the troposphere and simulate the wave propagation up to the stratosphere.

Table 2 summarizes the mean horizontal wavelength and propagation direction associated with the amplitudes shown on Figure 4. The values inferred from the radiosonde data are also shown for comparison.

These results confirm WRF ability to reproduce the wave structure in the stratosphere. Further analysis is needed to understand the influence of initialization time and convection on the wave generation and propagation to the stratosphere.

4 REFERENCES

Alexander, M. J., and H. Teitelbaum (2007), Observation and analysis of a large amplitude mountain wave event over the Antarctic peninsula, J. Geophys. Res., 112, D21103, doi:10.1029/2006JD008368.

Evan, S., and M. J. Alexander (2008), Intermediate-scale tropical inertia gravity waves observed during the TWP-ICE campaign, J. Geophys. Res., 113, D14104, doi:10.1029/2007JD009289.

Fritts, D. C., and M. J. Alexander (2003), Gravity wave dynamics and effects in the middle atmosphere, Rev. Geophys., 41(1), 1003, doi:10.1029/2001RG000106.

Kim, S.-Y., H.-Y. Chun, and D. L. Wu (2009), A study on stratospheric gravity waves generated by Typhoon Ewiniar: Numerical simulations and satellite observations, J. Geophys. Res., 114, D22104, doi:10.1029/2009JD011971.

R. Plougonven and H. Teitelbaum (2003), Comparison of a large-scale inertia-gravity wave as seen in the ECMWF analyses and from radiosondes, Geophys. Res. Lett., 30, 1954, doi:10.1029/2003GL017716.

Tulich, S. N., G. N. Kiladis, and A. S. Parker (2010), Convectively-coupled Kelvin and easterly waves in a regional climate simulation of the tropics. Climate Dyn., DOI 10.1007/s00382-009-0697-2.

5 ILLUSTRATIONS AND TABLES

Table 1: Configuration and parameterization used in WRF experiments.

WRF options	**Configuration (Parameterization)**
Shortwave radiation	Goddard SW radiation
Longwave radiation	RRTMG LW radiation
Land surface scheme	Unified Noah land-surface
Planetary Boundary Layer scheme	Mellor-Yamada-Janjic
Cumulus scheme	Kain-Fritsch scheme (Mass flux scheme) or Betts-Miller-Janjic scheme (Adjustment scheme)
Vertical layers	84 ($\Delta z = 500m$ between 20 and 30km)
Model top	1hPa
Damping layer depth	15km

Table 2: Mean horizontal wavelength and direction of propagation.

Data	λ_h **(km)**	α **(degree from east)**
Radiosondes	7220	-47.3 to -74
ECMWF	5650	-42.5
WRF 18 January	4175	-39
WRF 20 January	3622	-46
WRF 22 January	4372	-29
WRF 24 January	5294	-49
WRF 26 January	4655	-32

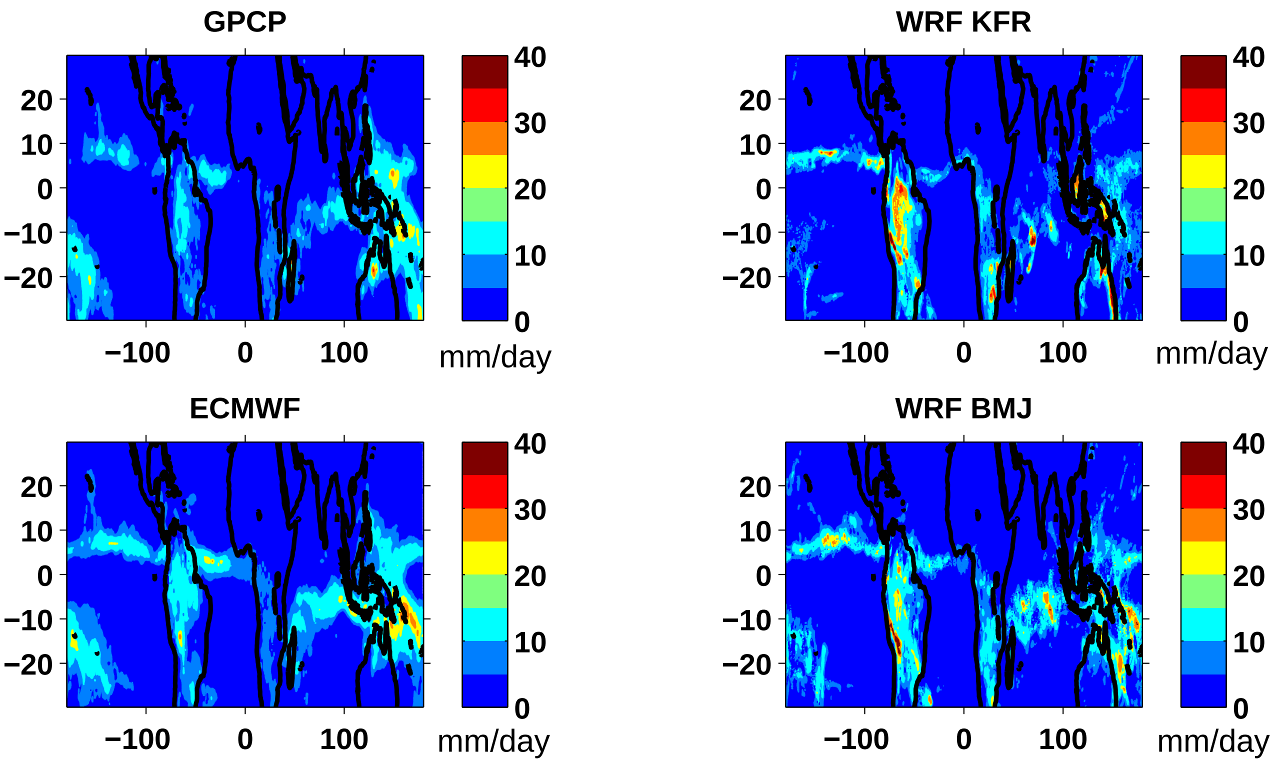

Figure 1: Comparison of simulated (right) versus GPCP and ECMWF (left) daily mean rainfall (mm/day) from 18 January to 28 January 2006.

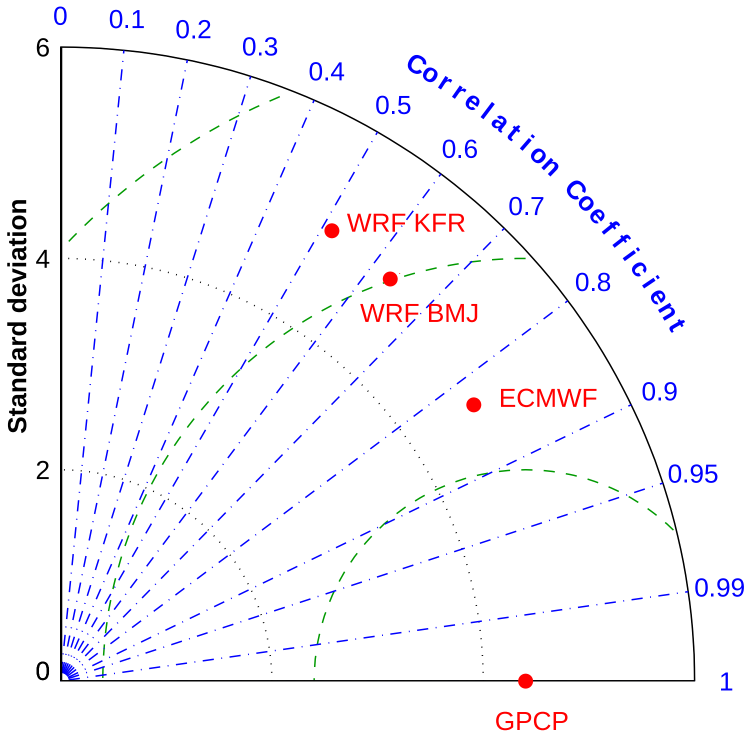

Figure 2: Taylor diagram of daily mean precipitation. Each dot represents a 10-day average from 01/18 to 01/28. The position of each dot represents the correlation between observations (GPCP) and model (WRF, ECMWF). The standard deviation of the simulated rainfall is proportional to the radial distance from the origin. The green contours indicate the root-mean-square difference between the simulated and observed rainfall.

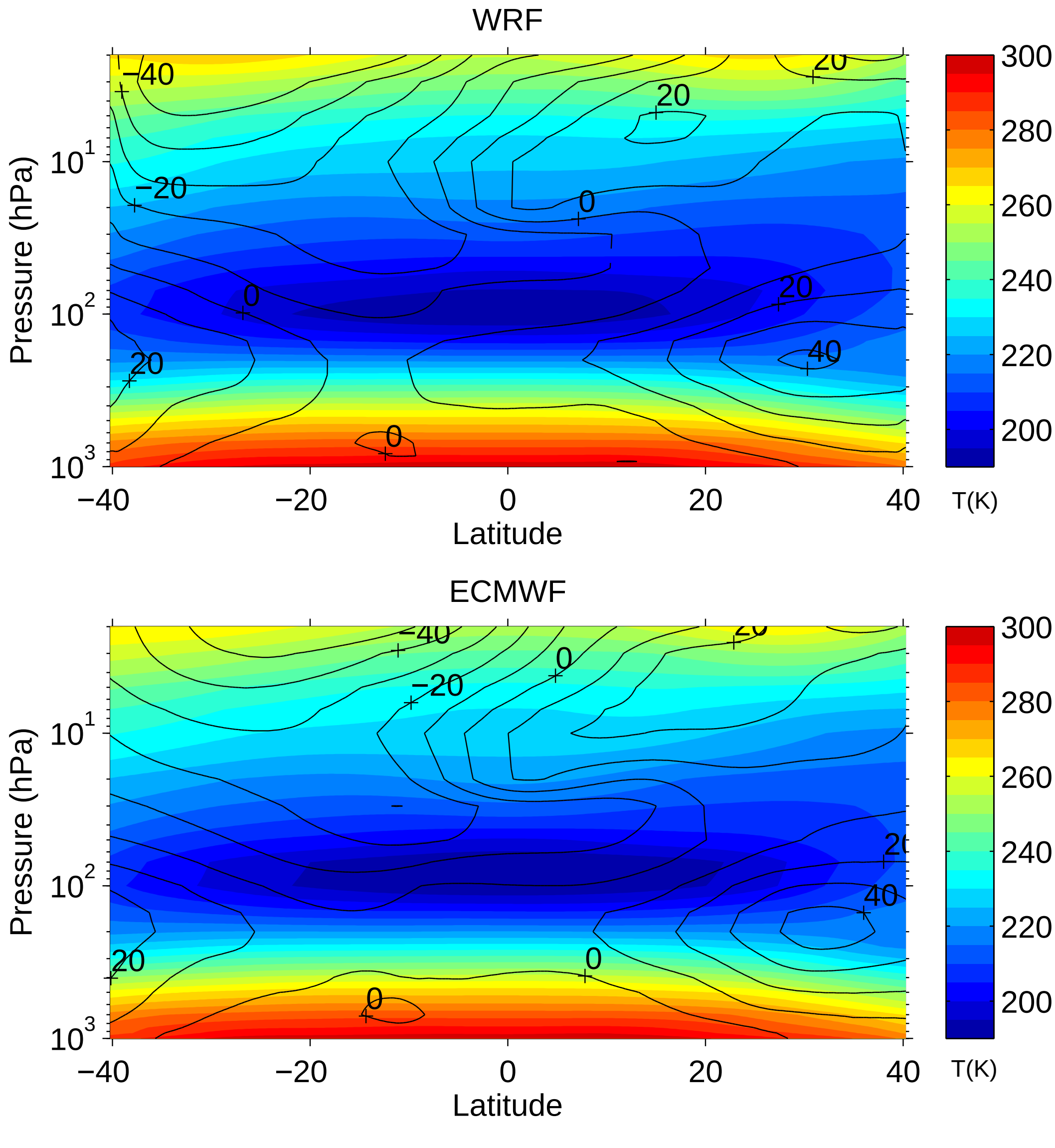

Figure 3: Latitude-pressure cross section of zonal wind and temperature averaged over 18 January-6 February 2006. The vertical grid-spacing for WRF is 500m in the stratosphere. WRF zonal wind and temperature are interpolated to ECMWF pressure levels.

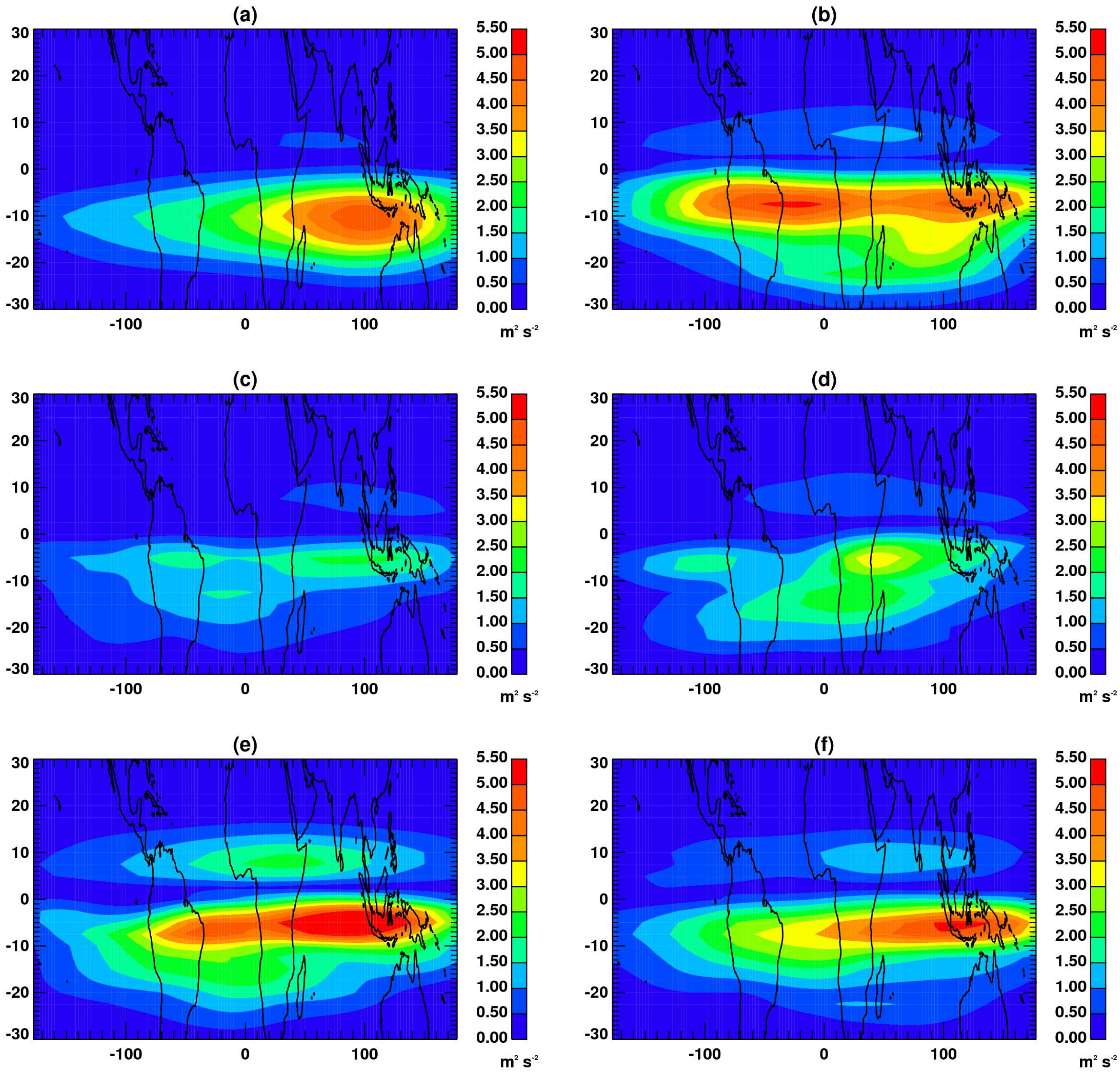

Figure 4: Squared amplitude of the 2-day wave inferred from the quadrature spectrum of meridional and zonal wind perturbations averaged between 30 and 20hPa. (a) ECMWF, (b) WRF simulation beginning 01/18, (c) 01/20, (d) 01/22, (e) 01/24, (f) 01/26. The amplitudes correspond to an average value over 28 January to 6 February.