P8.132 EVALUATION OF THE MODEL MM5 PERFORMANCE IN AN EXTREME PRECIPITATION EVENT AND A DEEPER ANALYSIS OF ITS METEOROLOGICAL CAUSES

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1. INTRODUCTION

The predictability of adverse meteorological events is one of the most challenging tasks of numerical weather forecast. A good representation of these events by the numerical models is essentially important to the meteorological warnings and the decision making, by the authorities.

According to Arakawa (1993), the understandment of the interactions between the convective and large scales is one of the essential tasks for dynamic meteorology. The cumulus parameterization is one of the most important tools to represent such interaction in numeric weather predition and simulation.

Nicosia et al (1999), while studying a flash flood related to a quasi-stationary system, stated that the complex interaction of different scales forcings was the great responsible for the extreme rainfall. The paper also pointed that the lake effect might have strenghened the precipitation over the region.

Maddox et al (1979) stated that most of the flash flood events occur during the warm season, which demonstrate the convective nature of this type of storm. In these situations, a great amount of water vapour is present in a relatively deep tropospheric layer.

About the quasi-stationary systems, Schumacher (2009) affirmed that the constant formation of new cells upstream the predecessor characterizes the back-building quasi-stationary aspect, and that slow moving mesoscale convective systems are responsible for large precipitation amounts.

An extreme precipitation event occurred in the city of Pelotas, Rio Grande do Sul state, Brazil, in January, 2009, leading to rainfall accumulate greater than 500 mm in less than 12 hours, about four times greater than the climatic mean of January for this region. Some synoptic features were identified by Bainy and Teixeira (2012a), among which are highlighted: low level mass convergence, related to winds coming from the Ocean and the Amazonic region and the approach of an mid-tropospheric trough. Satellite and radar imagery allowed the identification of an cloud cluster in sub-synoptic scale, which remained during all the 28th afternoon. Even though synoptic conditions over the period in which the situation occurred were favourable to severe weather, they do not completely explain the magnitude of the rainfall that affected the region of Pelotas. Beyond this fact, Almeida and others (2009) verified a sub-estimative of the accumulate precipitation of the numerical models forecasts and hidroestimators based in satellite and meteorological radar, whose estimative did not crossed the 111 mm. Aiming to obtain some more information about the event which took place in Pelotas, in January, 2009, experiences were done with the meteorological model MM5, with the following goals: to verify the impact of improving the spatial scale on the representation of accumulate rainfall during the event, to identify with more accuracy the structure and development of the phenomenon and to evaluate the hability of the MM5 model in reproducing the observed rainfall in function of different convection and cloud microphysics parameterization .

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2. DATASETS AND METHODS

This study took two main steps: numerical simulation and model evaluation, and a study on the dynamical forcings which may have led to such event.

The model was run with Final NCEP Analisys, which spatial resolution is 1º and time resolution is 6h. There were run several test simulations, following Bainy and Teixeira (2012b), who, while searching for the most representative cumulus and microphysical parameterization combination capable to reproduce the event by using a simpler model configuration, concluded that the most representative parameterization combination was Grell (cumulus) and Mixed-Phase(microphysics). The test simulations here encompassed several initial times, from the 26th to the 28th of January, with 31 vertical (sigma) levels. The final simulation period extend from the 2009 January 28th 00 UTC (the event day) to the 2009 January 29th 18 UTC (day after the event), in agreement to the most representative simulation. In addition, two more simulations were run: one just setting 35 vertical level (2 more on low levels and 2 more in high levels), and the other one with the same 35 sigma levels, but employing the Kain-Fritsch cumulus parameterization. All the simulations were run with two nested domains: the mother domain, which spatial resolution is 36 km, and dimensions that encompasses most of South America, and a second domain, which spatial resolution of 12 km, and dimensions that encompasses the most southern Brazil, where Pelotas is located. Statistical indexes like BIAS, False Alarm Ratio (FAR) and Threat

Score (TS) will be used to evaluate objectively the representativeness of rainfall by the model.

What is more, the evaluation of the terms of equations of atmospheric dynamics was done, such as vorticity equation, thermodynamic equation and moist conservation equation . Those terms were helpful in the evaluation of the most important dynamic processes that led to the occurrence of such extreme event, and were calculated in each data point, and then a average over an area, defined to be between the latitudes of 31 and 32 S and the longitudes of 52 and 53 W, was procceeded.

3. RESULTS AND DISCUSSION

a) Numeric simulations

The best simulation (according to the generated rainfall field) was the one which was composed by 35 vertical levels and the Grell and Mixed-Phase parameterization combination. The total rainfall amount for the simulated period is represented on Figure 1.

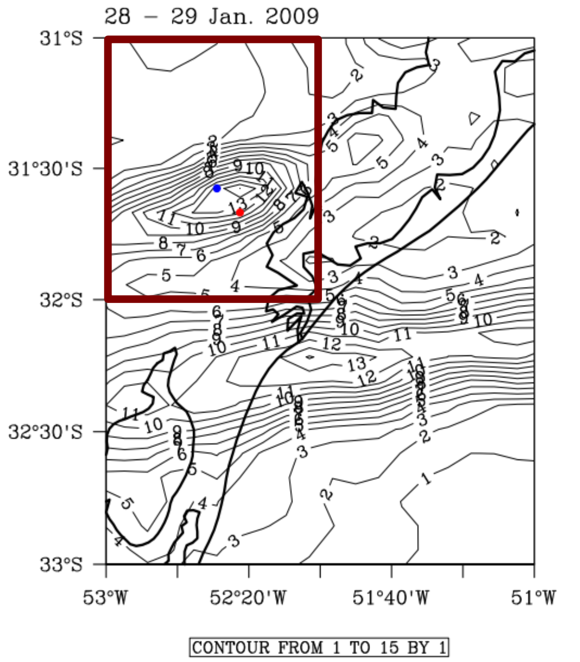


Figure 1: Accumulated simulated rainfall amount (cm) for the whole period. The dots represent the two meteorological stations which belongs to EMBRAPA. The blue and red dots are the location of the Cascata and the Sede stations, respectively.The red square indicates the area over which averagesfor the budget terms were calculated.

The total registered and simulated rainfall amount for the two stations is shown on Table 1.

Table 1: Observed and simulated accumulated rainfall (mm) from the 28th 00 UTC to the 29th 18 UTC of January, 2009.

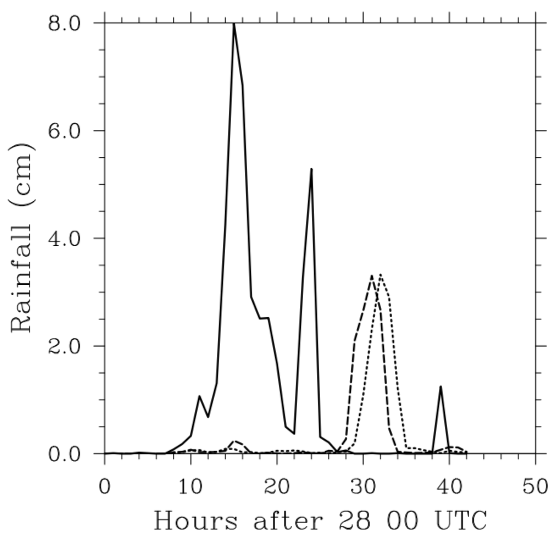
	Cascata	Sede
Observed	590.7	437.1
Simulated	135.4	122.8

It is obvious that the model understimated the rainfall. However, it must be considered that, anyway, the predicted amount would itself charachterize an extreme precipitation event. However, another consideration to be noticed is about the time of maximum precipitation. The model is quite late with respect to the observation, according to Figure 2. The greatest volumes precipitated between the afternoon and evening of the 28th , while the simulation put it on the early hours of the 29th. It is also possible to notice that the model improved considerably the precipitation over Cascata, when it was added four more vertical levels. It is probably due to the improvement of the boundary layer processes representation.

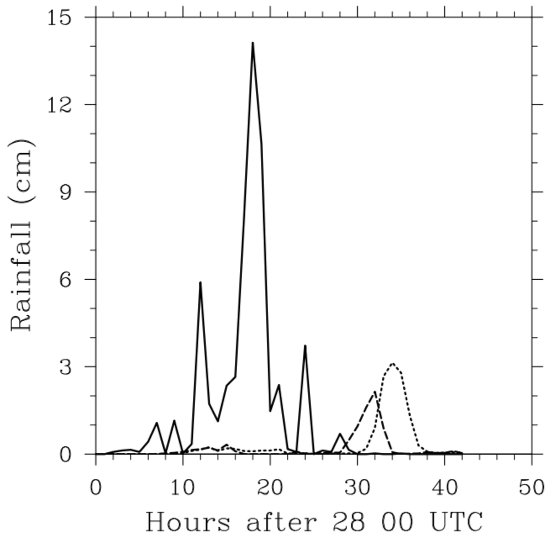
Table 2: Simulated and observed rainfall accumulated (mm) for the 29th (from 12 UTC of the 28th to 12 UTC of the 29th), in some locations.

	Cascata	Sede	Rio Grande	Bage
Observed	496.5	421.5	42.6	24.6
Simulated	126.2	118.5	14.3	9.1

	Pelotas	Sta Vitoria	Porto Alegre	Santa Maria
Observed	134.4	47.6	8.7	8.2
Simulated	60.8	10.1	12.7	4.6



(a)



(b)

Figure 2: Pluviograms comparing the observed (solid lines) and the simulated rainfall with 31 (dashed lines) and 35 (dotted lines) vertical levels, for: (a)Sede and (b) Cascata.

The Table 2 compares the observed and simulated precipitation in eight different sites. The model subestimated the amount for almost all stations, except for Porto Alegre, where it overpredicted in about 50%.

Table 3: Statistical indexes calculated for simulated 2m temperature: Threat Score (TS), Bias and False Alarm Ratio (FAR), for the most representative classes.

Indexes\Intervals	20 – 22° C	22 – 24° C
TS	0.357	0.304
Bias	1	0.765
FAR	0.474	0.461

The Table 3 gives some skill indexes for the simulated temperature. The other classes (containing the lowest and highest temperatures), which were not representatives, were ommitted. For the classes indicated on Table 3, it is noticeable that the bias shows that the model was not likely to present strong trends to over- or underforecast. On the other hand, the TS indicates that the simulation presented not few misses to represent temperature. However, the FAR index may suggest that the output temperature was slightly reliable. With respect to rainfall, the simulation did not respond properly, in neither quantitatively nor in time. It subestimated verily the amount and was several hours late in time.

b) Dynamic analysis

Since the model did not simulated properly the rainfall amount, nor the main period of occurrence of the event, it was chosen to analyse the dynamic equations through the NCEP Final Analysis, the same employed as input data to the model. The 1 degree spacial resolution was considered to be small enough to capture some main features of atmospheric environment associated with the event. However, since the storm scale was smaller than the data scale, some suavization may have occurred on the average calculation, but it is not quantitatively known.

Figure 3 gives the moisture budget terms for a huge vertical extension of troposphere and its evolution in time. The first term, local variation, indicates an increase on the moist concentration just before the event, in low to middle levels (considering the event itself the huge rainfall between 12 UTC of the 28th and 00 UTC of the 29th). The advection (b) does not seems to play an important role, though it appears to dry somewhat the lower troposphere. But the most important contribution both before and within the event period was the low level convergence. This may have been the most important mechanism that contributed to the maintenance of the active system, by supplying it with moisture. This term reached also the greatest values, more than twice as the other ones. The vertical transport term reveals the vertical troposphere moisturizing, due to convective activity during the event. The residual term shows also relatively high values, in module. This term is kown as *apparent moisture sink* (Arakawa,1993), and may be understood as the result of the condensation process (Cotton and Anthes, 1989).

Figure 4 gives the heat budget terms. The local variation (a) seems to respond veryly to the diurnal temperature variation. However, in the middle-upper-troposphere, it seems to have a warming, probably due to the latent heat release in the condensation process. The horizontal advection (b), seems also to respond to surface forcings on low levels. The third term, temperature convergence, likely to moist convergence, seems to play a much more important role, since it is one or two orders of magnitude greater than the former ones. It shows that from low to middle levels there was a important temperature convergence, which might have enhanced convection, by making air more unstable.

Vorticity budget is given on Figure 5. The local variation (a) indicates a negative growth tendency on vorticity. In southern hemisphere, this favours vertical ascent of the air, and thus, convection. The relative vorticity horizontal advection term (b) reveals a relatively strong negative (cyclonic) advection during the most intense rainfall period, in middle and higher troposphere . This is associated to the approach of ans upper level trough (Bainy and Teixeira, 2012a), and is often related to the development of storms.

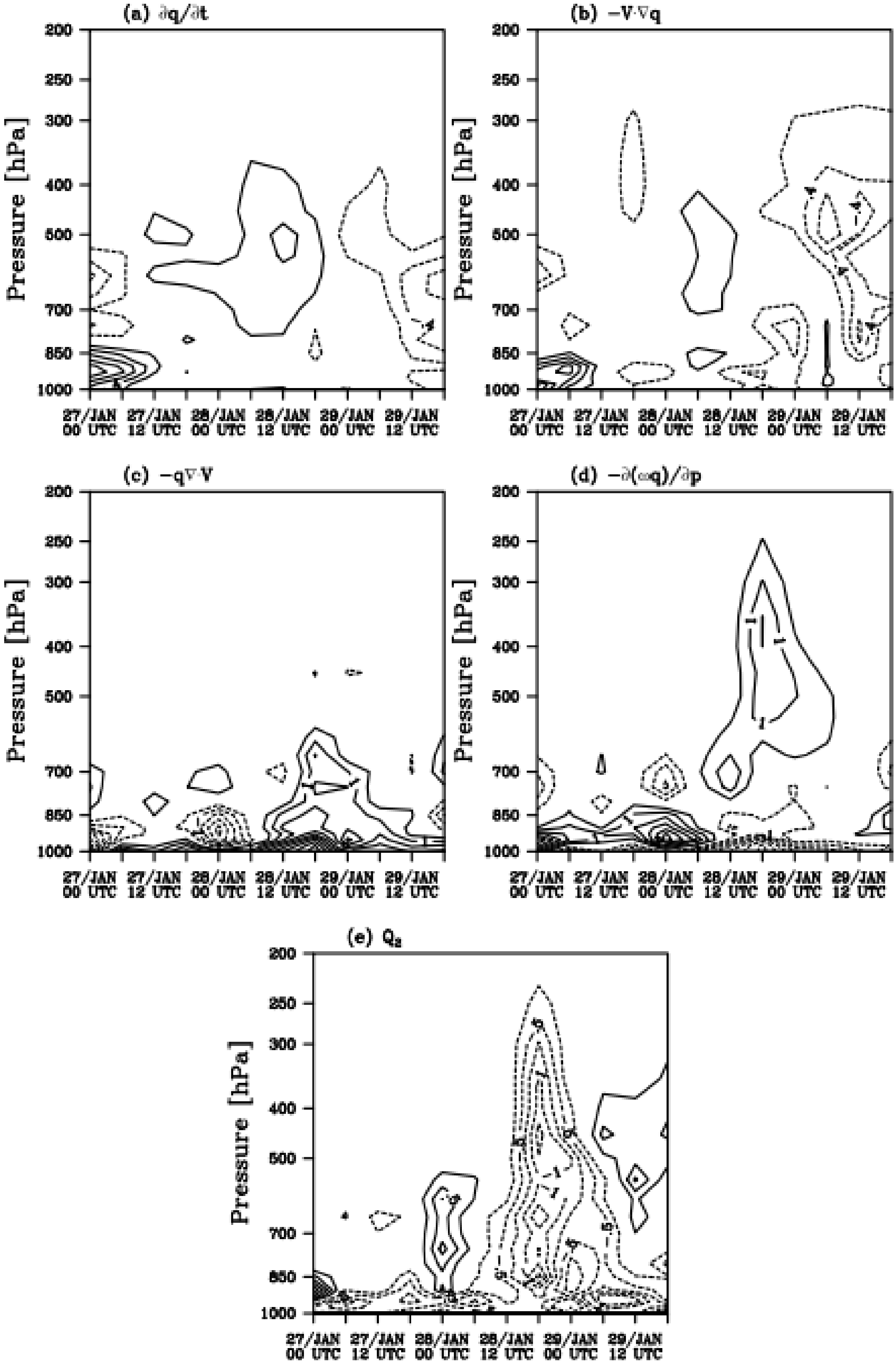


*Figure 3: Heigh – time cross section for area averaged moisture budget (10^{-7} kg/kg*s) terms: local variation (a), horizontal advection (b), horizontal convergence (c), vertical convergence (d) and the residual term (e)*

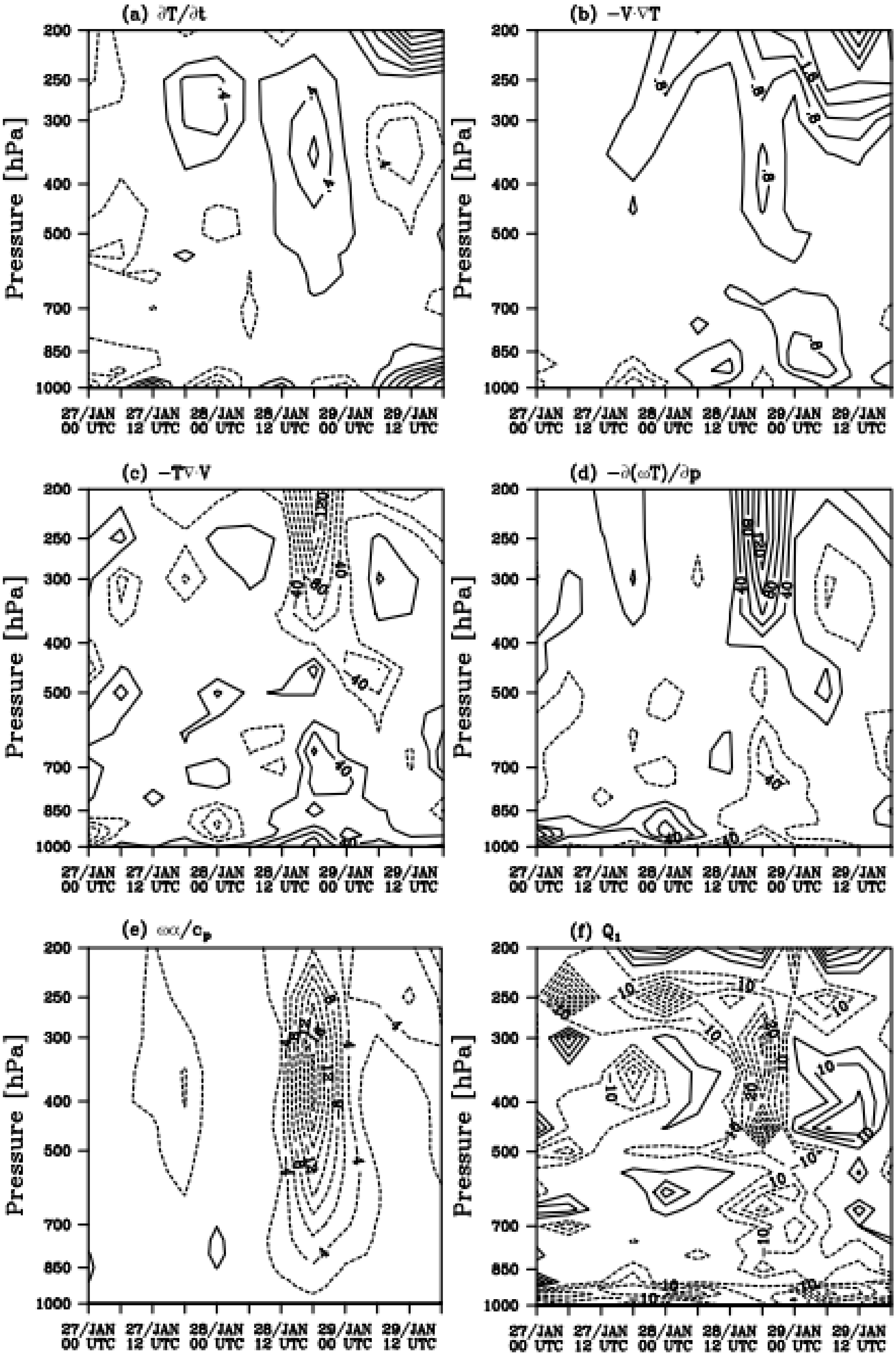


Figure 4: Same as Fig. 3, but for the heat budget terms (10^{-4} K/s): local variation (a), horizontal advection (b), horizontal convergence (c), vertical transport (d), thickness advection (e) and residuals (f).

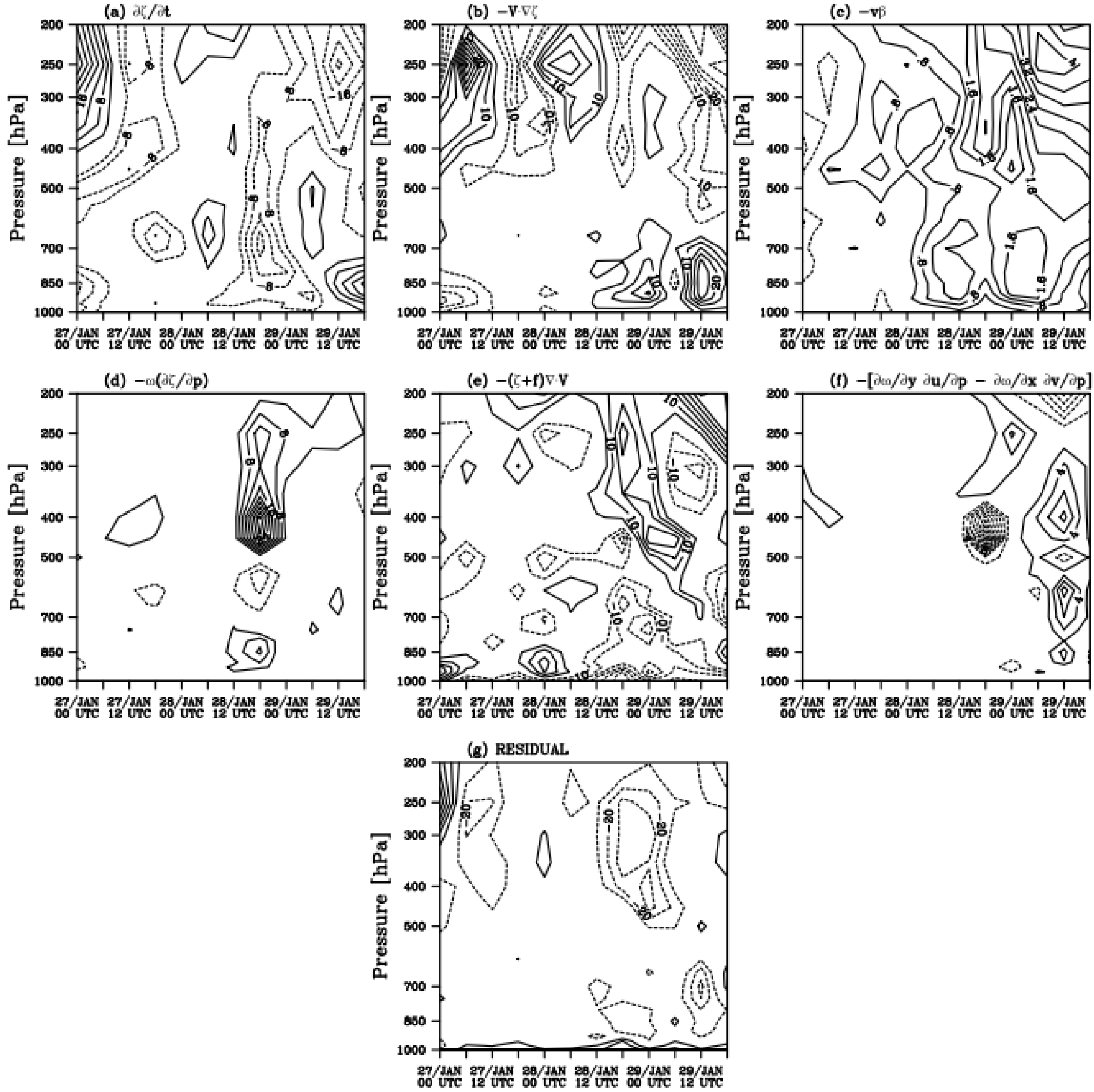


Figure 5: same as Fig. 3, but for vorticity budget terms ($10^{-10}s^{-2}$): local variation (a), relative vorticity advection (b), planetary vorticity advection (c), vertical transport of relative vorticity (d), convergence of absolute vorticity (e), tilting term (f), and residual term (g).

4. CONCLUSIONS

The magnitude of the event that hitted southern Brazil on the 28th and the 29th of January in 2009 was remarkable. It undoubtely reveals how tricky atmospheric motions may be, and that, despite the recent advances in atmospheric modelling and computational improvements, we still are catch by surprise.

However, some important issues can be learnd with this particular event. In summary:

- Numeric weather prediction is a important tool for operational forecasts. Nevertheless, it should not be a substitute for personal and professional skills. Some sorts of meteorological phenomena are hardly reproduced by models, even in several tries.
- Some important features concernin this particular event were identified, as follows: i) strong low level moisture convergence, supplying the system

with water vapour; ii) low level heat convergence, unstabilyzing the atmsphere; iii) contribution of large scale motions, enhancing convective activity; iv) contribution of vorticity on the vertical movements;

- The important contribution of divergence on the flow over the area, which supplied the system with a substantial moisture and heat input and the generation of cyclonic vorticity on the lower atmospheric layers. The magnitude of these convergence may have been a essential factor to the high rainfall amounts observed in this event;
- The latent heat release might also have played an important role in this process, enhancing the low leve convergence effects.

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