Department of Meteorology

Interactions between parameterised diabatic processes in numerical simulations of extratropical cyclones

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1. Introduction

Diabatic processes are critical for the evolution of the atmosphere through the modification of mesoscale circulations and vice versa. Diabatic processes cannot be directly resolved in numerical weather forecast and climate model but have to be parameterised in terms of resolved variables at grid scale. Nevertheless, the parameterised version of diabatic processes plays a similar role in shaping the evolution of a model's atmosphere. Basic research comparing the ways in which diabatic processes interact in numerical models and in the real atmosphere is paramount to improve the quality of weather and climate forecasts.

2. Effects produced by parameterisation differences

Even though different short-range simulations of a single system can lead to broadly-similar results when certain large-scale variables are assessed, important differences can appear in other dynamically meaningful fields. **Figure 1** shows a trajectory analysis of a warm conveyor belt simulated with two models: the Met Office Unified Model (MetUM) and the COnsortium for Small-scale MOdeling (COSMO) model (Martínez-Alvarado et al. 2014).

- The similarity in pressure and specific humidity is remarkable (**Fig. 1a,b**).
- However, there are differences in potential temperature (**Fig. 1c**).
- MetUM trajectories reach higher isentropic levels.
- It can be shown that these differences are mainly due to differences in the convection parameterisation rather than differences in the dynamical core.

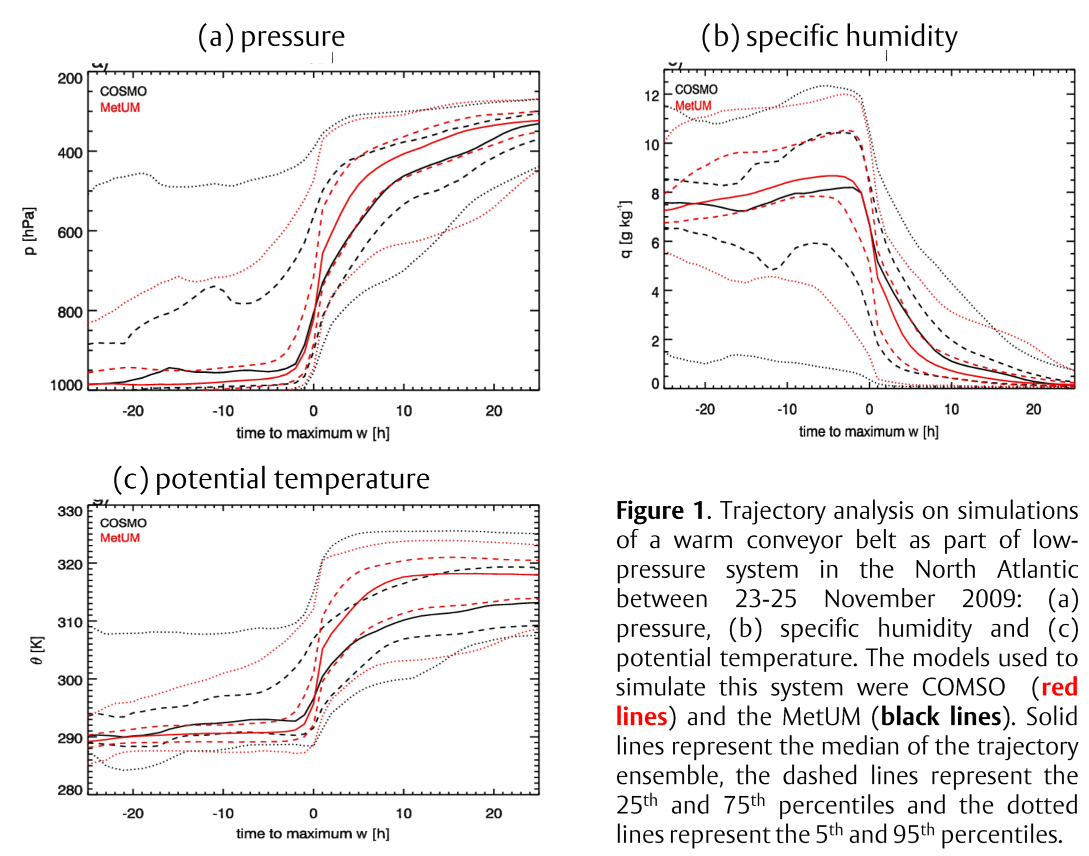


Figure 1. Trajectory analysis on simulations of a warm conveyor belt as part of low-pressure system in the North Atlantic between 23-25 November 2009: (a) pressure, (b) specific humidity and (c) potential temperature. The models used to simulate this system were COMSO (red lines) and the MetUM (**black lines**). Solid lines represent the median of the trajectory ensemble, the dashed lines represent the 25th and 75th percentiles and the dotted lines represent the 5th and 95th percentiles.

3. Same parameterisation, different parameters

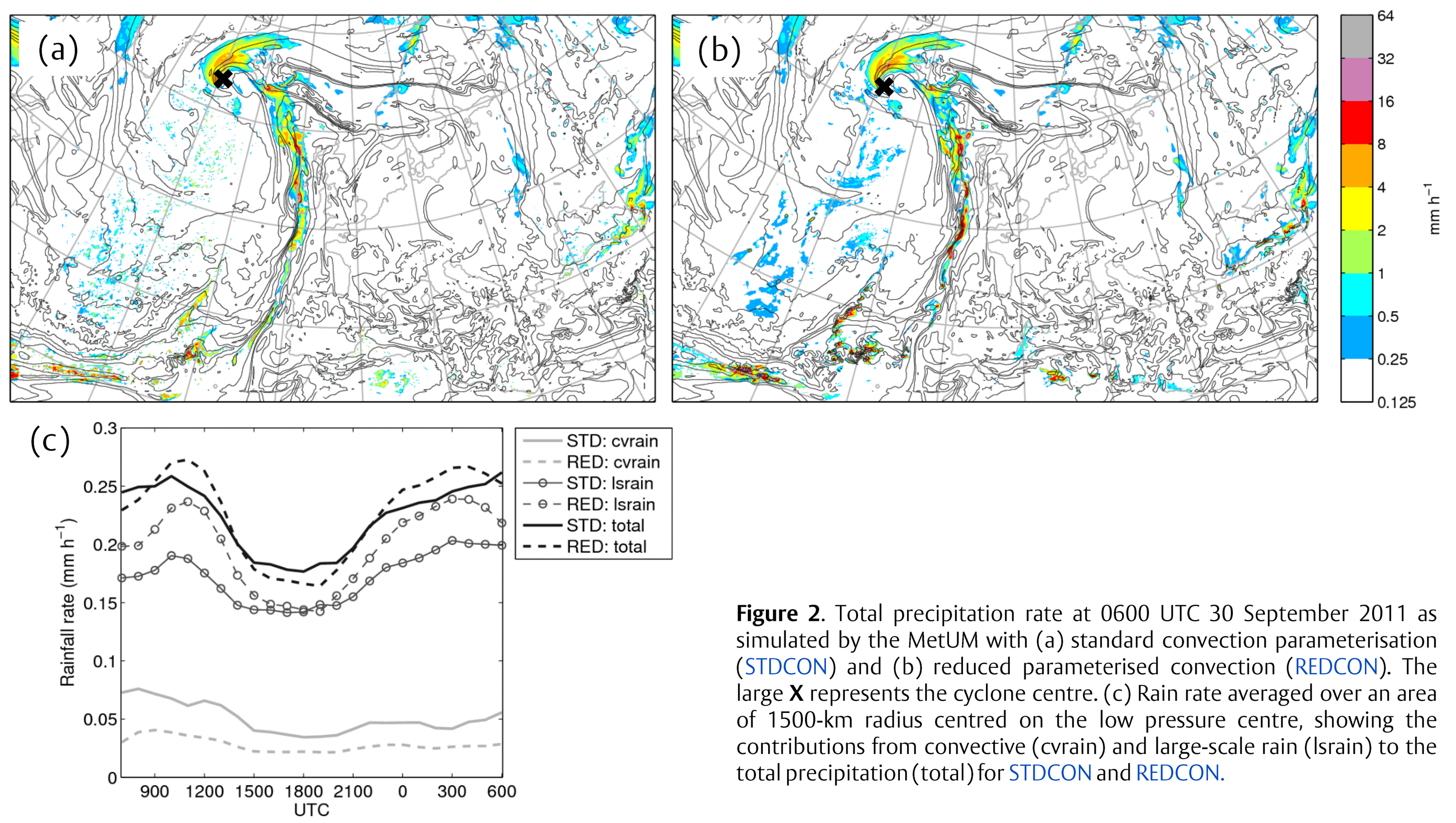
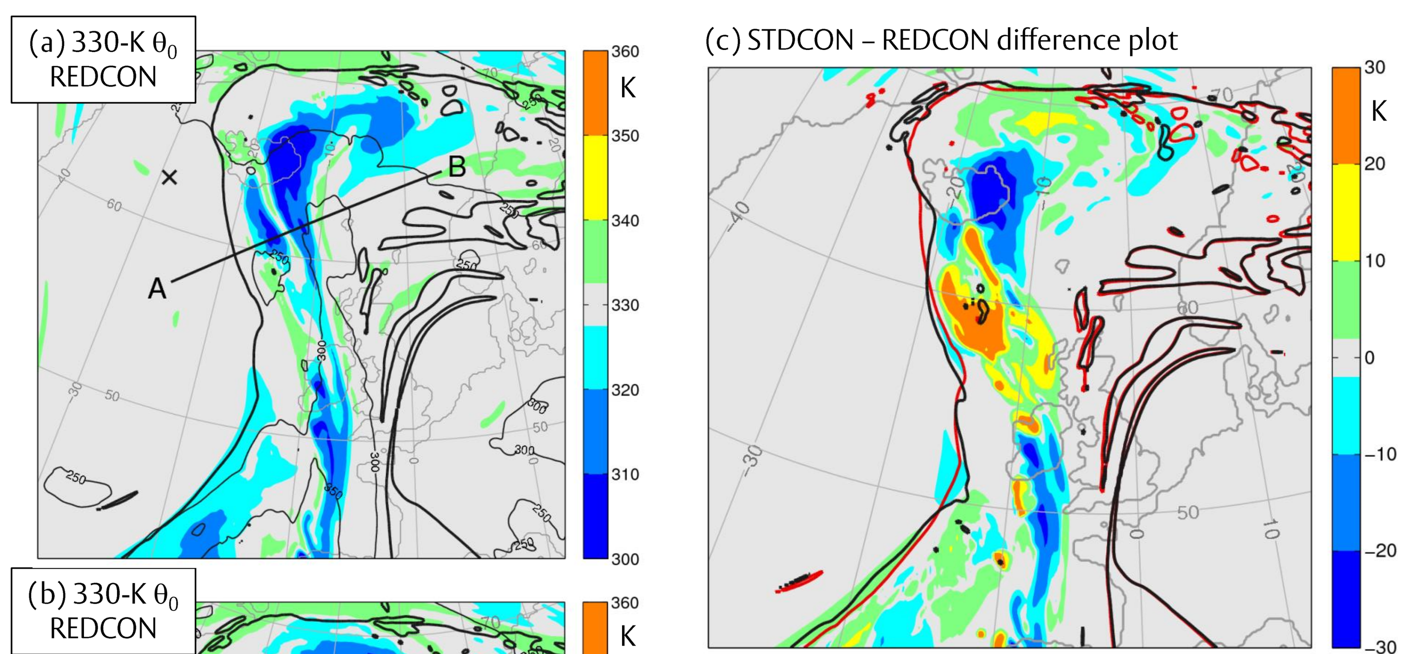


Figure 2. Total precipitation rate at 0600 UTC 30 September 2011 as simulated by the MetUM with (a) standard convection parameterisation (STDCON) and (b) reduced parameterised convection (REDCON). The large **X** represents the cyclone centre. (c) Rain rate averaged over an area of 1500-km radius centred on the low pressure centre, showing the contributions from convective (cvrain) and large-scale rain (lsrain) to the total precipitation (total) for STDCON and REDCON.

Another example is provided by two simulations of a single case, in which the same convection parameterisation scheme (based on Gregory and Rowntree, 1990) was used (Martínez-Alvarado and Plant 2013). The first simulation (STDCON) uses standard parameter settings while the second (REDCON) has an increased CAPE closure time-scale, effectively reducing the strength of parameterised convection. The total rain rates in both simulations are similar either at a single snapshot (**Fig. 2a,b**) or as an area-average throughout the period of analysis (**Fig. 2c**).



Red: STDCON 330-K 2-PVU isoline
Black: REDCON 330-K 2-PVU isoline

Figure 3. Mass redistribution on the 330-K isentropic level after a 6-hour simulation according to (a) STDCON and (b) REDCON. The coloured field represents the potential temperature at the beginning of the simulations so that warm (cold) colours represent cross-isentropic descending (ascending) air masses. Black bold lines represent the 330-K 2-PVU isoline for the corresponding simulation. The segments A-B indicate the position of the vertical sections shown in **Figure 4**. (c) Difference plot comparing STDCON – REDCON.

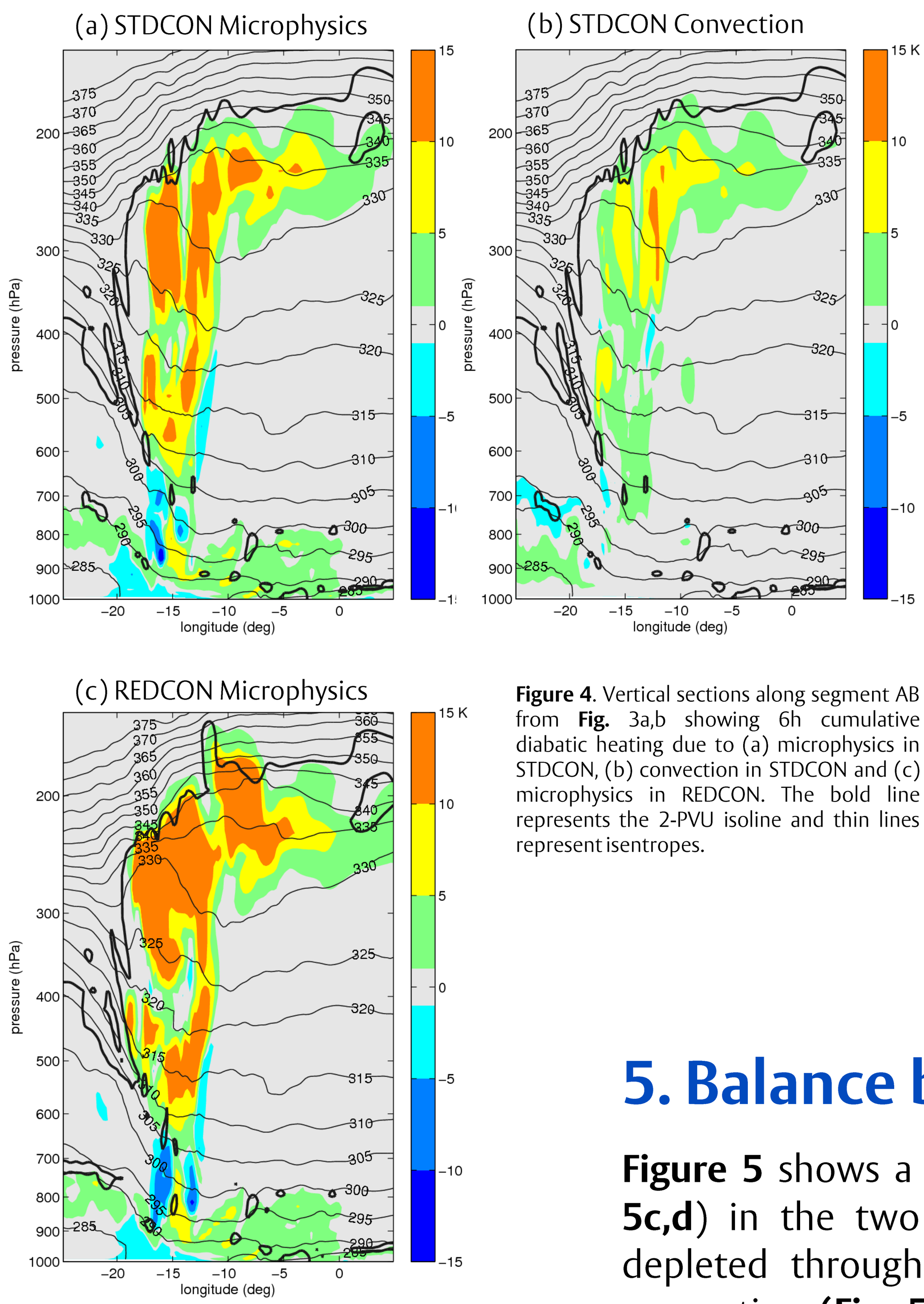


Figure 4. Vertical sections along segment AB from **Fig.** 3a,b showing 6h cumulative diabatic heating due to (a) microphysics in STDCON, (b) convection in STDCON and (c) microphysics in REDCON. The bold line represents the 2-PVU isoline and thin lines represent isentropes.

4. Mass redistribution

Despite similarities in surface fields and in the short-term evolution of the system, there are differences in the way that mass is redistributed vertically. REDCON produces more localised regions of ascent (**Fig. 3a,b**). A comparison of the position of the dynamical tropopause (2-PVU isosurface) shows that there is a wave-like displacement of one simulation with respect to the other (**Fig. 3c**). These differences might appear small. However, they provide a mechanism to generate larger forecast differences of the first kind in the medium- and long-range.

Differences in cross-isentropic motions are caused by differences in the representation of diabatic processes. The convective and microphysics parameterisations are both capable of depleting existing CAPE. In STDCON, microphysics (**Fig. 4a**) and convection (**Fig. 4b**) contribute comparable amounts to total heating. In REDCON total heating is explained almost completely by microphysics (**Fig. 4c**).

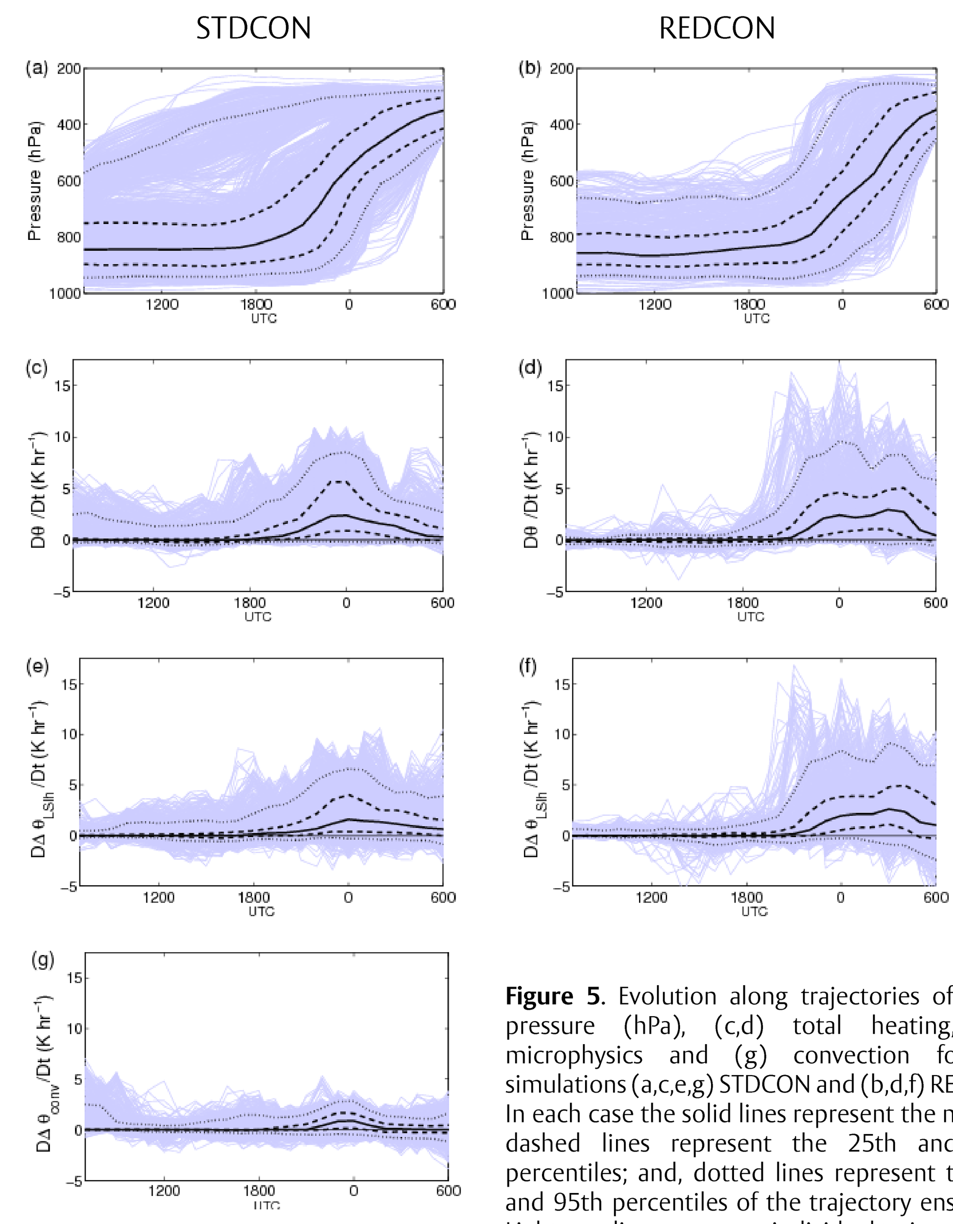


Figure 5. Evolution along trajectories of (a, b) pressure (hPa), (c,d) total heating, (e,f) microphysics and (g) convection for the simulations (a,c,e,g) STDCON and (b,d,f) REDCON. In each case the solid lines represent the median; dashed lines represent the 25th and 75th percentiles; and, dotted lines represent the 5th and 95th percentiles of the trajectory ensemble. Light grey lines represent individual trajectories.

5. Balance between parameterisations

Figure 5 shows a comparison of ascent **(Fig. 5a,b)** and total heating (**Fig. 5c,d**) in the two simulations. In both simulations the existing CAPE is depleted through the joint action of the microphysics **(Fig. 5e,f)** and convection (**Fig. 5g**), but in the case of REDCON the heating along each trajectory occurs in a more abrupt manner.

6. Conclusions and final remarks

- Different NWP models often produce approximately equivalent short-term forecasts for extratropical cyclones.
- This is despite the fact that different parameterisation schemes and their interactions show some different responses to the large-scale conditions.
- The differences are manifest in the diabatic modifications to air masses passing along the warm conveyor belt.
- Modest short-range differences generated there might have important impacts for longer-term integrations.

Acknowledgements
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