

FIGURE 1 Ten-day average from April 10 to 19, 2010 of **(a)** the BEST daily maximum 2-m temperature anomaly and ERA-I 10-m wind (0600 UTC) **(b)** the BEST daily minimum 2-m temperature and ERA-I 10-m wind (0600 UTC) anomalies. On panel (b), the climatological and 10-day average Inter-Tropical Discontinuity (ITD) at 0600 UTC are indicated with the thin and bold grey lines, respectively. The ITD is defined as the 8 g/kg ERA-I 2-m water vapour mixing ratio isoline. BEST and ERA-I climatologies are computed over the period 1980-2010. The black array emphasises the simulated domain (5°W-3°E, 10°N-18°N). The black dots locate the in-situ measurement sites: Agoufou (15.34°N, 1.48°W), Niamey (13.48°N, 2.17°E) and Ouagadougou (12.35°N, 1.52°W).

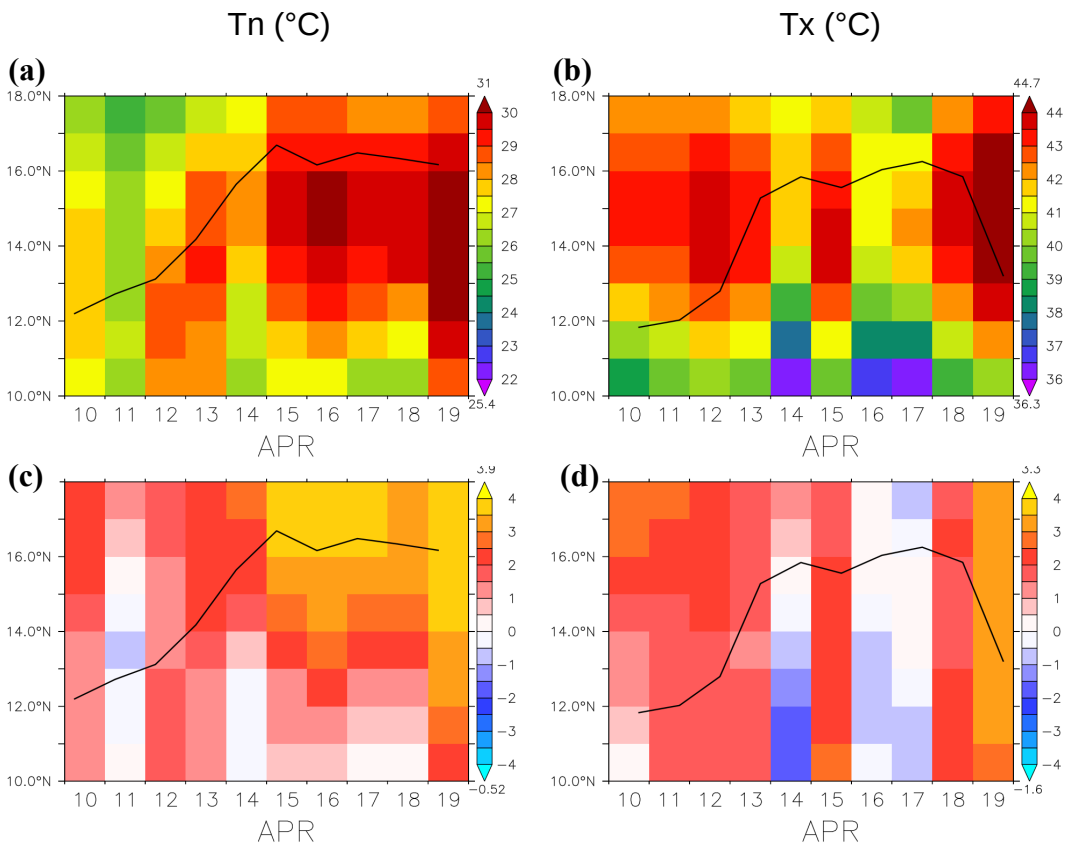


FIGURE 2 Hovmöller diagram from April 10 to 19, 2010 of the BEST daily (a) minimum and (b) maximum air near-surface (2-m) temperatures and (c) and (d) their respective anomalies computed with respect to the BEST 1980-2010 climatology. The ITD location is indicated with the black line (2-m water vapour mixing ratio contour of 8 g/kg), at 0600 UTC in Tn charts and at 1800 UTC in Tx charts, using ECMWF operational analyses. Numbers on the bottom and top of the colour bars are respectively the minimum and the maximum level of the chart. All data are averaged over [4.5°W-2.5°E].

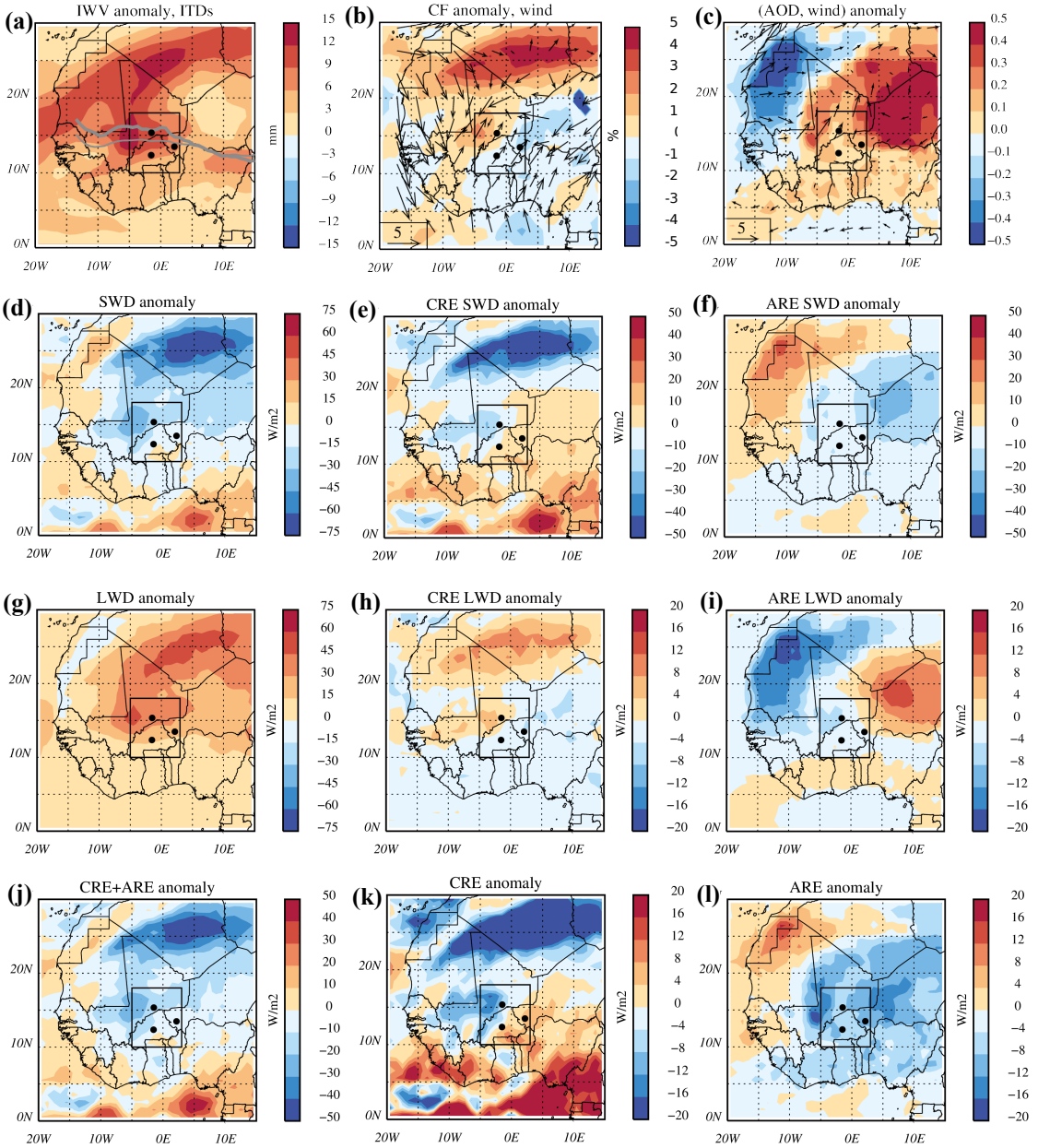


FIGURE 3 Ten-day average from April 10 to 19, 2010 of the CERES **(a)** Integrated Water Vapour **(b)** cloud fraction and **(c)** 55 μm Aerosol Optical Depth anomalies. Subsequent panels indicate various contributions to the surface Downwelling radiative flux anomalies, based on CERES data: **(d)** total ShortWave (SWD) **(e)** SWD cloud radiative effects (CRE) and **(f)** SWD aerosol radiative effects (ARE); **(g)** total LongWave (LWD) **(h)** LWD CRE and **(i)** LWD ARE; **(j)** sum of the CRE and ARE, **(k)** CRE and **(l)** ARE. On panel **(a)**, the climatological and 10-day average Inter-Tropical Discontinuity (ITD) at 0600 UTC are indicated with the thin and bold grey lines, respectively. On panel **(b)** ERA-I 10-m wind and on panel **(c)** wind anomalies (0600 UTC) are computed. The CERES anomalies are computed over the period 2000-2015 and the ITD and wind over the period 1980-2010. See Figure 1 for more details.

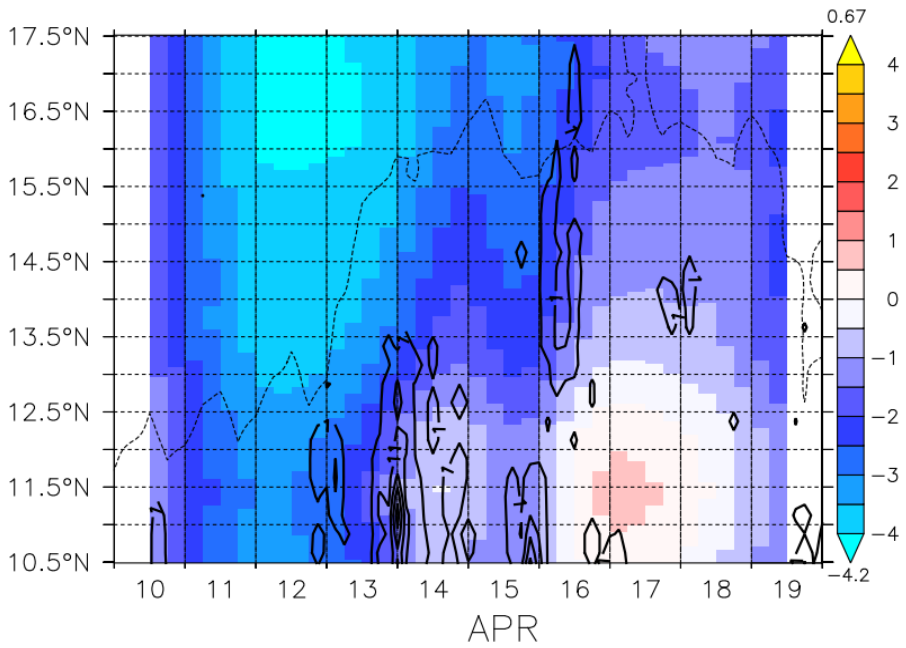


FIGURE 4 Hovmöller diagram from April 10 to 19, 2010 of the 2-m pressure anomalies with respect to the initial state on a sliding average over 24 hours to avoid the barometric tide (shade, hPa) for the ECMWF operational analyses. The surface precipitation from the 3-hourly TRMM 3B42 estimates has been superposed (thick black isolines from 1 to 41 every 10 mm/day). The ITD location is indicated with the dashed black line (2-m water vapour mixing ratio contour of 8 g/kg), using the ECMWF operational analyses. All data are averaged over [4.5°W-2.5°E].

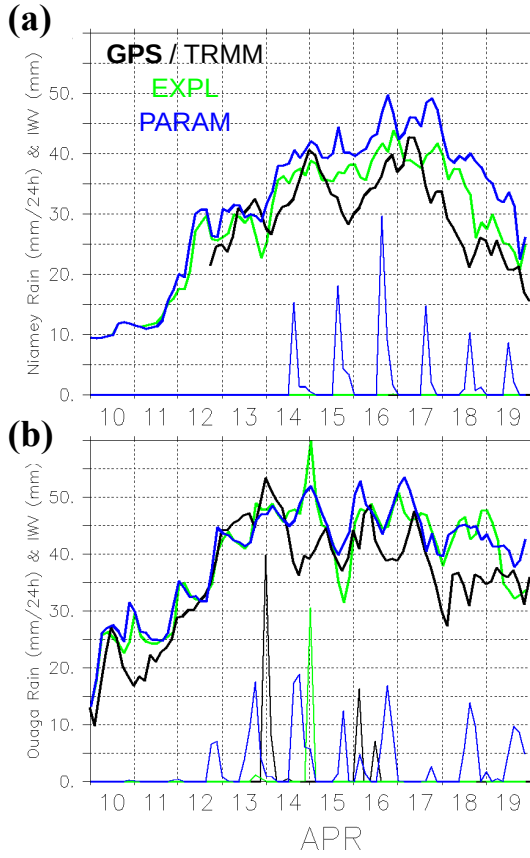


FIGURE 5 Time (UTC) evolution of the 3h-averaged Integrated Water Vapour (IWV, mm, thick lines) and surface precipitation (mm/day, thin lines) at the **(a)** Niamey and **(b)** Ouagadougou sites for the observations (black), and the EXPL (green) and PARAM (blue) simulations. Note that GPS data at Niamey are missing until April 12, 2010 early afternoon.

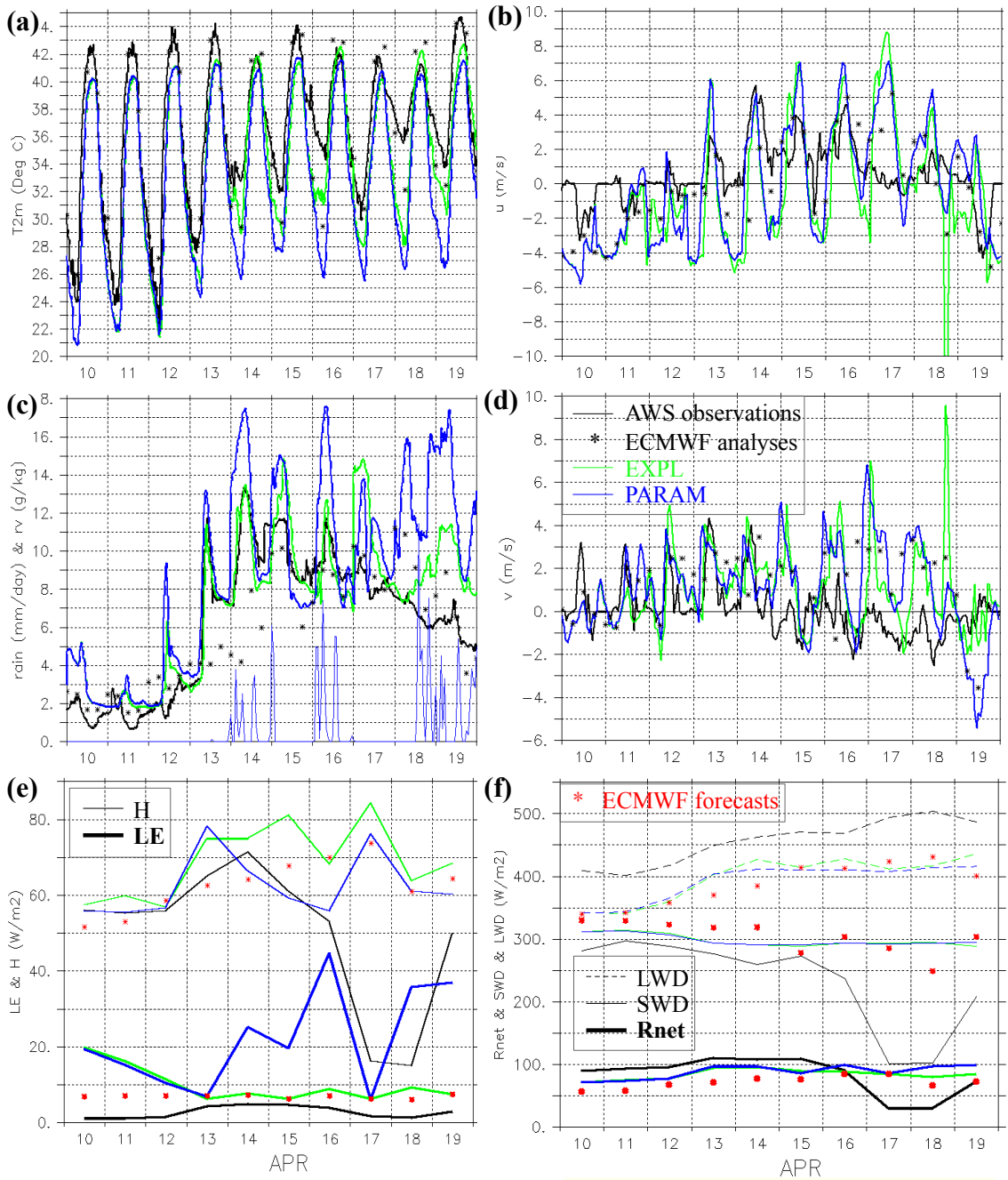


FIGURE 6 Time series in Agoufou for the (a) the 2-m temperature every 15 mn ($^{\circ}\text{C}$) (b) 10-m zonal wind component every hour (m/s) (c) the 2-m water vapour mixing ratio every 15 mn (g/kg) and the precipitation at the surface averaged over 1 hour (mm/day) (d) 10-m meridional wind component every hour (m/s) (e) day-mean of the sensible heat flux (thin line) and of the latent heat flux (thick line) at the surface (W/m^2) (f) day-mean of LWD (dash), SWD (thin line) and net radiation (thick line) at the surface (W/m^2) for the observation Automatic Weather Station (AWS) in black, the explicit run in green and the run with the parameterized convection scheme in blue. The MésoNH and ECMWF data are averaged over the four points surrounding the Agoufou station. ECMWF analyses are every 6 hours (black stars) and ECMWF forecasts every 3 hours (red stars). Note in Figure 6c that no rainfall is observed and only the PARAM simulation makes rain.

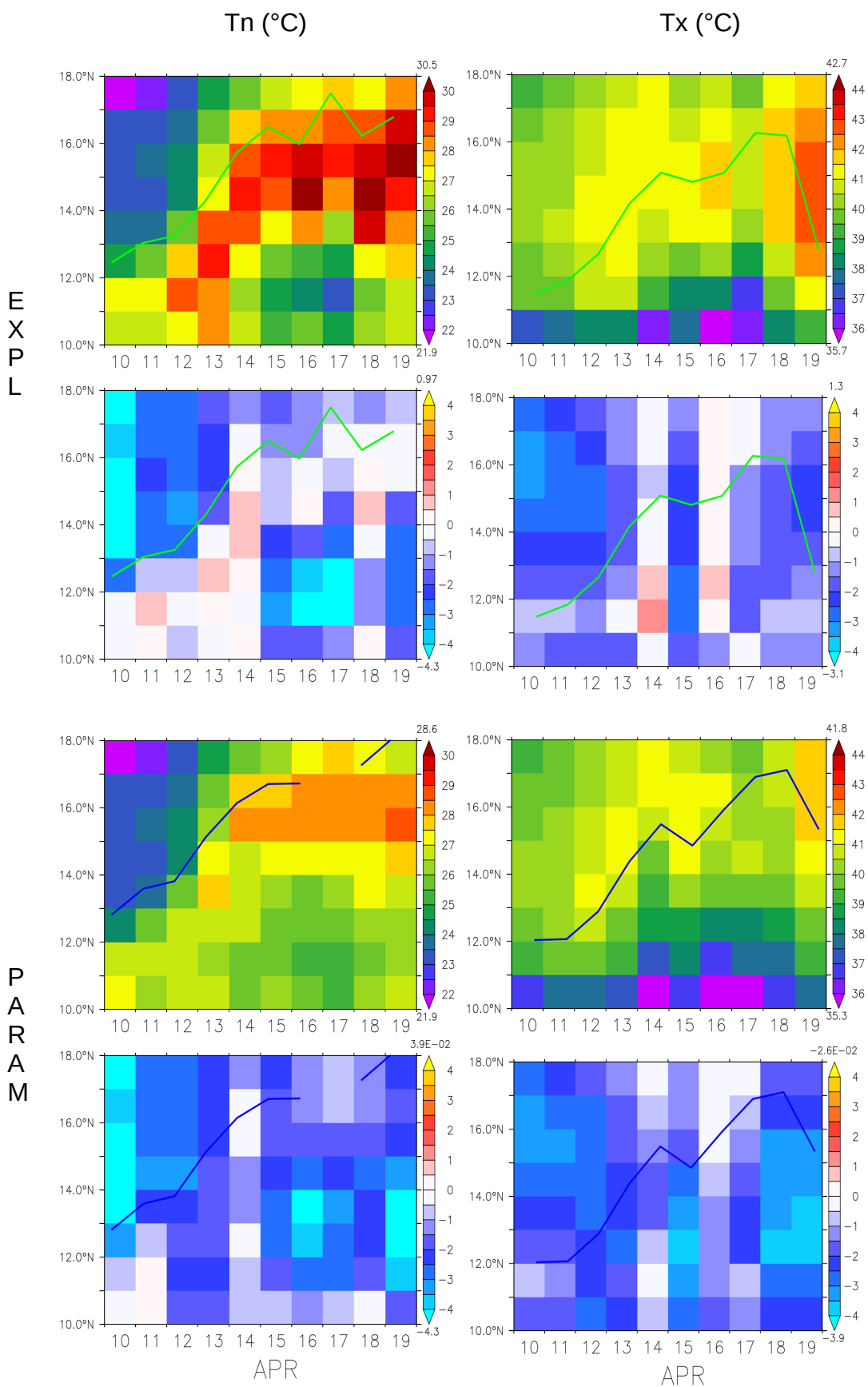


FIGURE 7 Minimum (left) and maximum (right) of the daily 2-m temperatures as a function of the latitude and time from April 10 to 19, 2010 for the explicit run (EXPL, first row), the parameterized deep convection run (PARAM, third row) and for the associated anomalies with respect to BEST from April 10 to 19, 2010 (second and fourth rows). The ITD location (2-m water vapour mixing ratio contour of 8 g/kg) is indicated by the green lines for EXPL and blue lines for PARAM, at 0600 UTC in Tn charts and at 1800 UTC in Tx charts. The PARAM ITD isoline breaks on April 17 0600 UTC because it is located north of 18°N. All figures are averaged over the longitudes [4.5°W-2.5°E]. Numbers on the bottom and top of the colour bars are respectively the minimum and the maximum level of the chart.

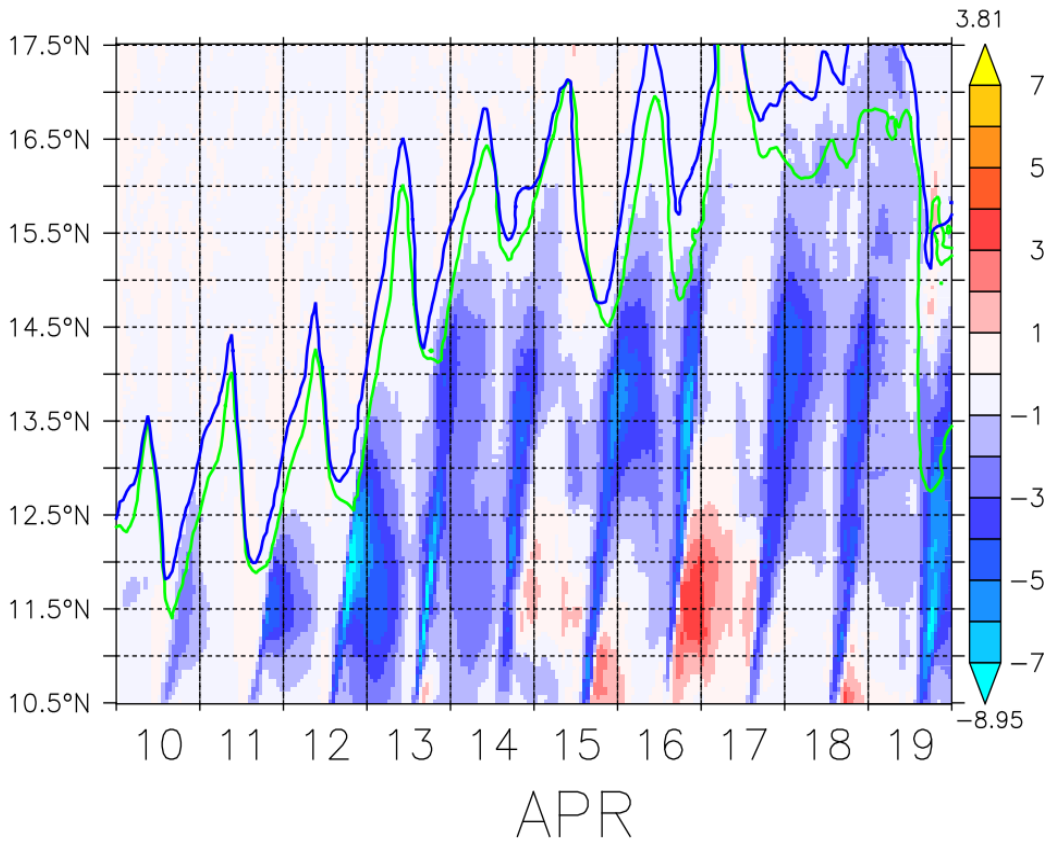


FIGURE 8 Hovmöller diagram of T2m (°C) difference between PARAM and EXPL simulations (PARAM-EXPL) averaged over the longitudes [4.5°W-2.5°E]. The ITD seen as the 8 g/kg water vapour mixing ratio at 2-m above the surface is superimposed (green line for EXPL, blue line for PARAM). Numbers on the bottom and top of the colour bars are respectively the minimum and the maximum level of the chart.

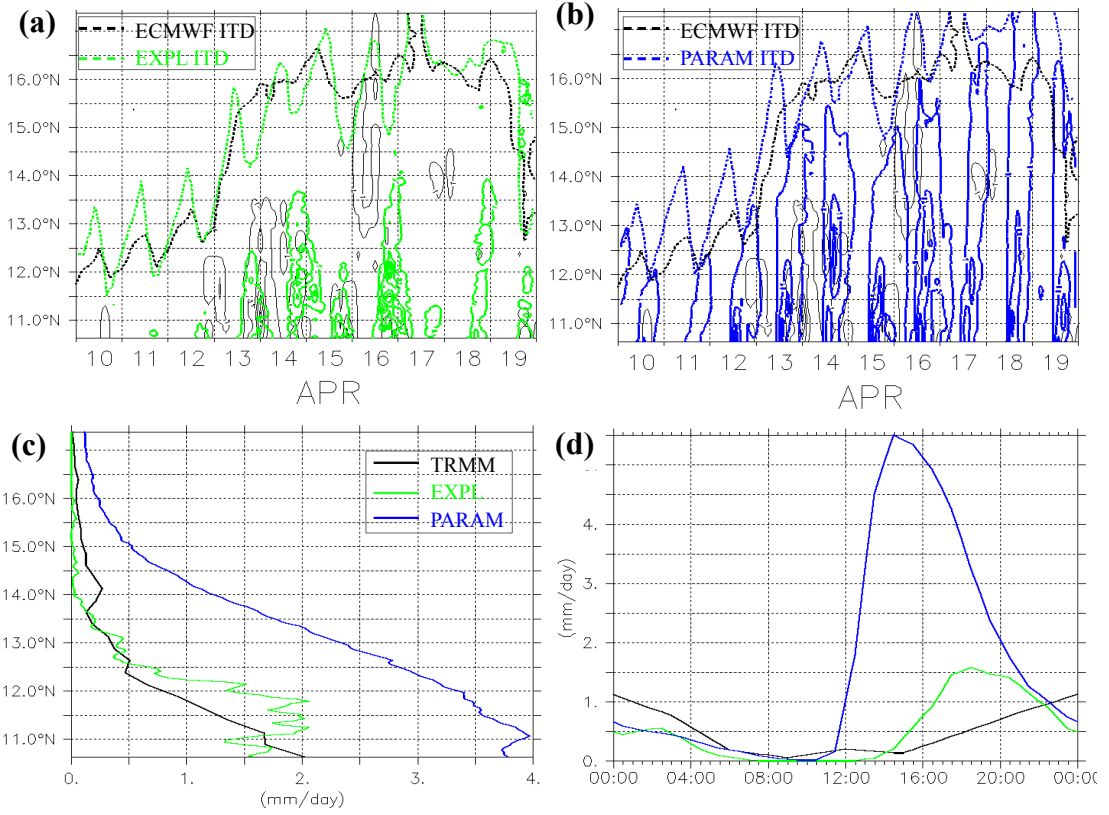


FIGURE 9 Surface precipitation (isolines from 1 to 41 every 10 mm/day) as a function of the latitude and time for April 10 to 19, 2010 **(a)** for the EXPL simulation (green) and **(b)** for the PARAM simulation (blue), averaged over 3 hours. Their respective ITD location is also indicated with the dashed line, averaged over 3 hours. To ease the comparison, the TRMM B42 precipitation observation product (also drawn in Figure 4) and the ITD using ECMWF operational analyses every 6 hours are superimposed in black on the panels (a) and (b). The ITD location is computed from the 2-m water vapour mixing ratio contour of 8 g/kg. **(c)** presents the 10-day surface precipitation as a function of the latitude and **(d)** the surface precipitation diurnal composite averaged over the 10 days and the whole domain [4.5°W-2.5°E, 10.5°N-17.5°N]. All data are averaged over [4.5°W-2.5°E].

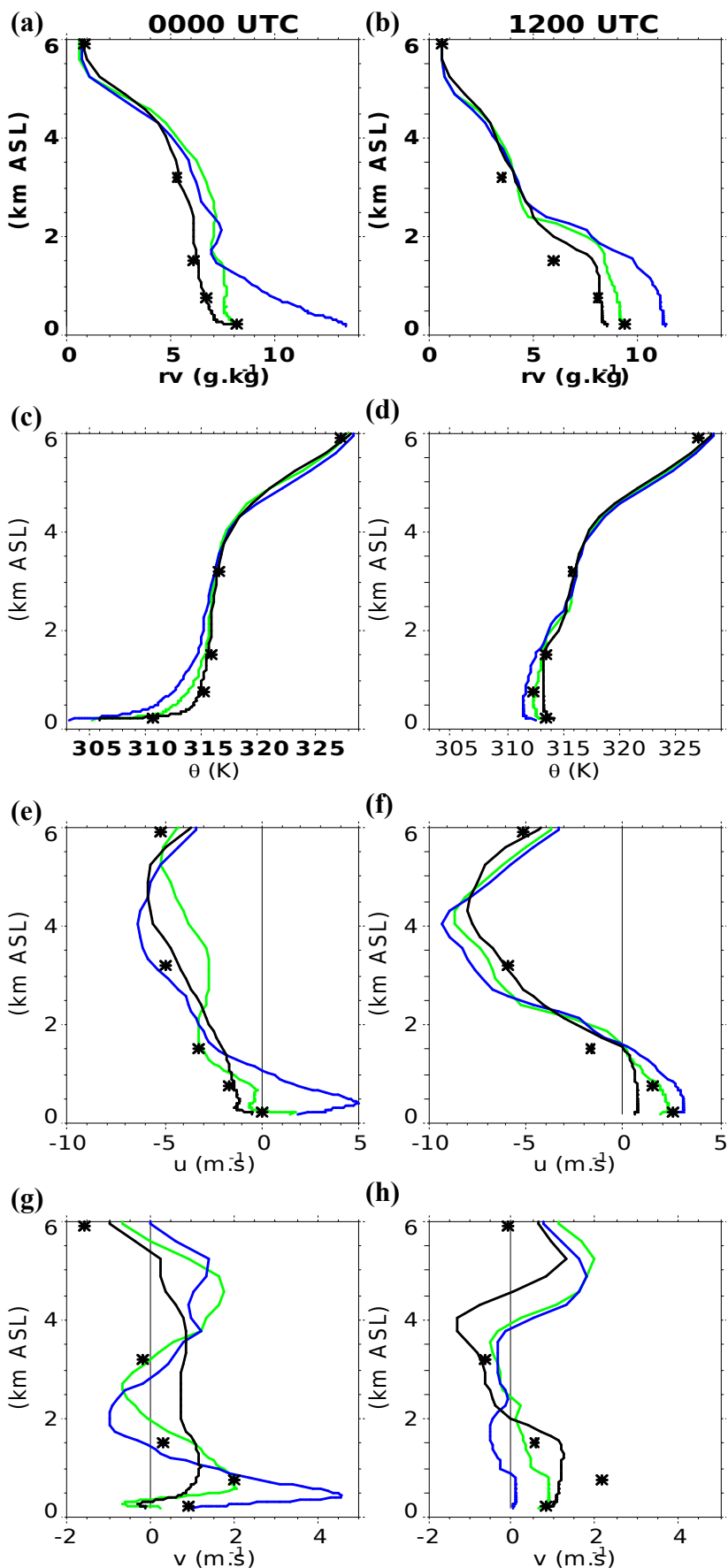


FIGURE 10 Vertical profile at Niamey (Local Time=UTC+1) between the April 10, 2010 1200 UTC and April 20, 0000 UTC except the April 13&16, 1200 UTC. Composites at 0000 UTC for the left column and at 1200 UTC for the right column of the water vapour mixing ratio, the potential temperature, the zonal and meridional wind. Stars refer to the radiosoundings, black lines to the ECMWF reanalyses, green lines to the explicit MésNH run and blue lines to the run with the deep parameterized convection scheme. For the simulation, the closest grid point to observations has been used.

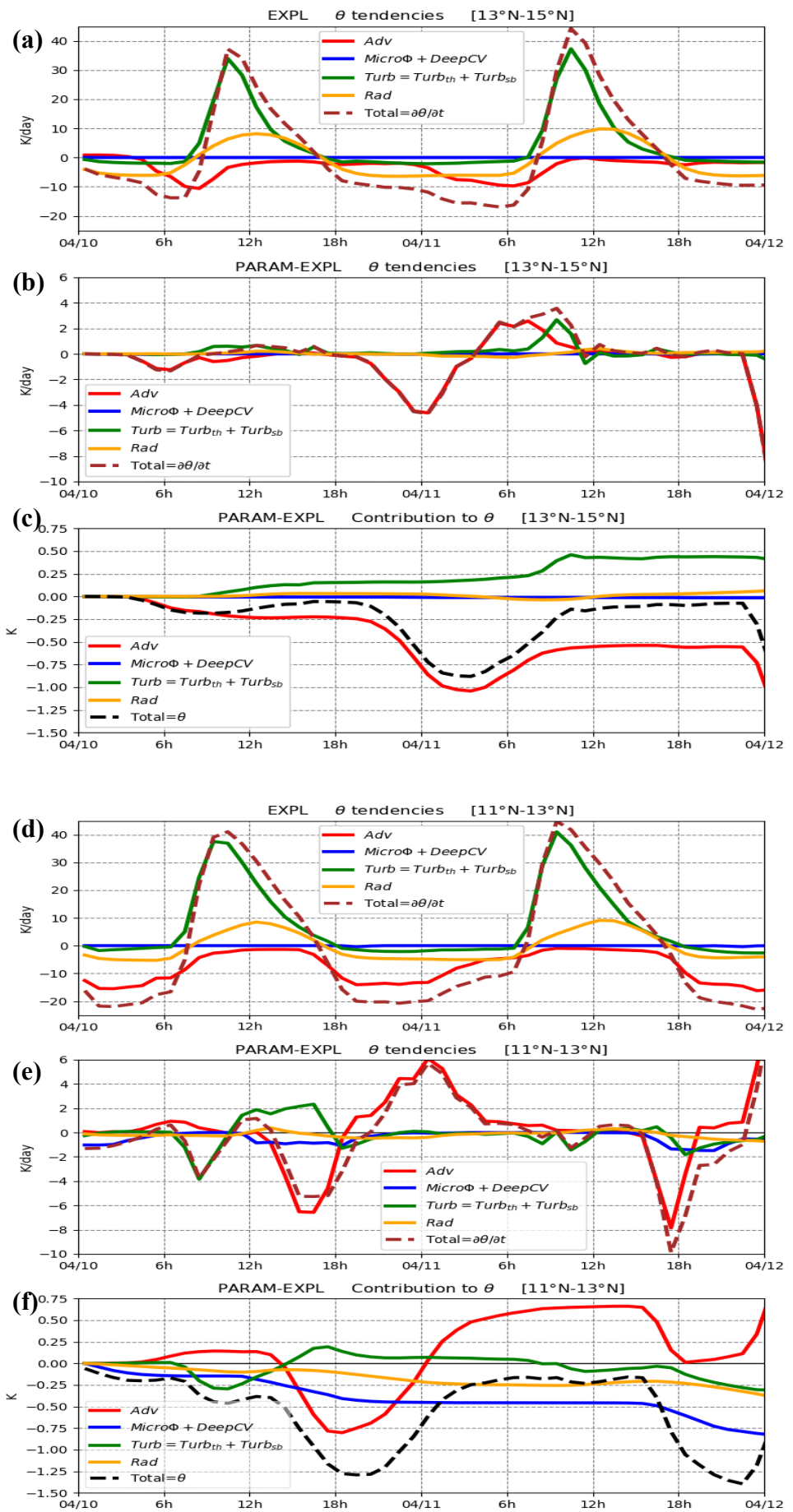


FIGURE 11 Time-evolution during the first two days of the potential temperature budget for the averaged latitudes [13°N-15°N] **(a)** for EXPL tendencies (K/day), **(b)** for PARAM-EXPL tendencies (K/day), **(c)** for PARAM-EXPL time integrated tendencies (K). **(d to f)** the same as (a to c) but for [11°N-13°N]. On each panel, the dashed lines are the sum of the solid lines. All terms are averaged over the 500 lowest metres and longitudes [4.5°W-2.5°E]. See Equation (1),(2),(5)&(6) in Appendix A2 for more details on the different terms.

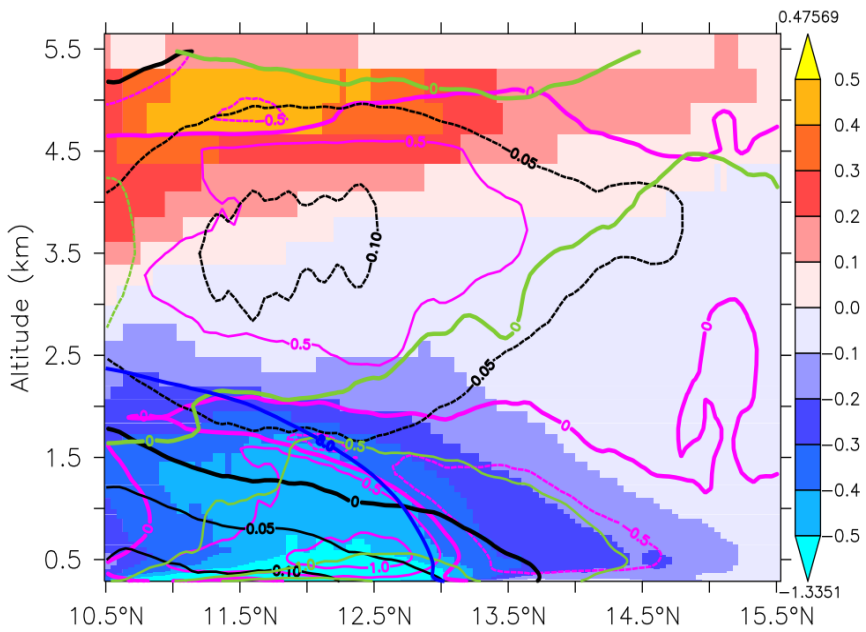


FIGURE 12 First two days' average difference PARAM-EXPL for the potential temperature (shade, K), pressure (black contours, hPa), water vapour mixing ratio (green contours, r_v , g/kg) and horizontal wind speed (purple contours, m/s) as a function of the latitude and altitude. The PARAM 8 g/kg of r_v symbolising its ITD is also drawn in thick dark blue line. All variables are averaged over longitudes [4.5°W-2.5°E]. Numbers on the bottom and top of the colour bars are respectively the minimum and the maximum level of the chart.

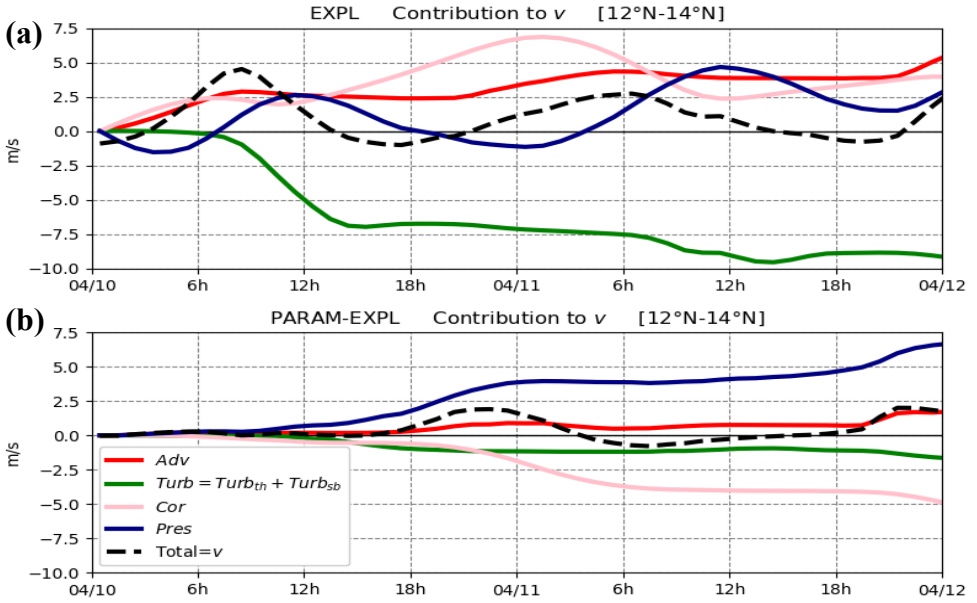


FIGURE 13 Meridional wind budgets first two days' evolution of the main time integrated tendencies (m/s) for the averaged latitudes [12°N-14°N] for **(a)** EXPL and **(b)** PARAM-EXPL. On each panel, the dashed lines are the sum of the solid lines. All figures are averaged over the 500 lowest metres and longitudes [4.5°W-2.5°E]. See Equation (1),(3),(5)&(6) in Appendix A2 for more details on the different terms.

———— EXPL - - - - - PARAM

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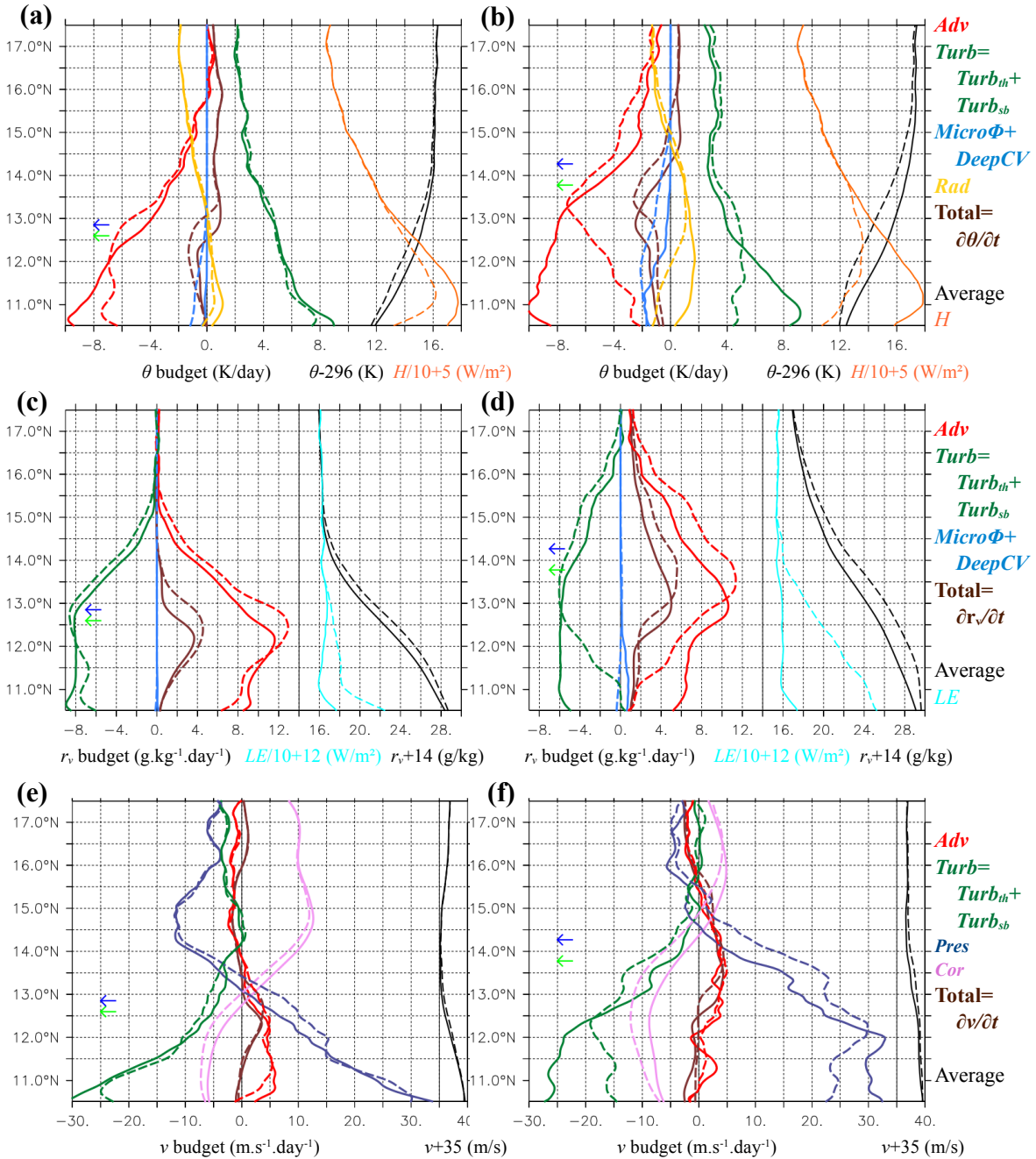


FIGURE 14 From top to bottom, budgets of the (a&b) 2-m potential temperature (K/day), (c&d) 2-m water vapour mixing ratio (r_v , $\text{g.kg}^{-1}.\text{day}^{-1}$) and (e&f) 10-m meridional wind ($\text{m.s}^{-1}.\text{day}^{-1}$) for the PARAM (dashed line) and EXPL (solid line) simulations as a function of latitude averaged over (left) the first 2 days (April 10 0000 UTC to 12 0000 UTC) and (right) the next 2 days (April 12 0000 UTC to 14 0000 UTC). In brown the tendency, in red the total advection budget, in green the turbulence term, in blue the addition of the microphysical terms and the deep convection scheme, in yellow the radiation, in dark blue the pressure force, in pink the Coriolis force. Each variable is also plotted in black (where 296 K has been subtracted from the temperature, $14 \text{ g.kg}^{-1}.\text{day}^{-1}$ has been added to r_v and 35 m/s has been added to the wind). The surface heat flux (H) is added in (a) in orange (divided by 10 then shifted of 5 W/m^2). The surface latent heat flux (LE) is added in (b) in cyan (divided by 10 then shifted of 12 W/m^2). To symbolise the mean ITD, an arrow at the latitude where $r_v=8 \text{ g/kg}$ is added on the left hand side of each graph in green for EXPL and blue for PARAM. All variables are averaged over the 500 lowest metres and longitudes $[4.5^\circ\text{W}-2.5^\circ\text{E}]$ and smoothed on 10 points of latitude (i.e. around 0.5°) to ease the visualisation.

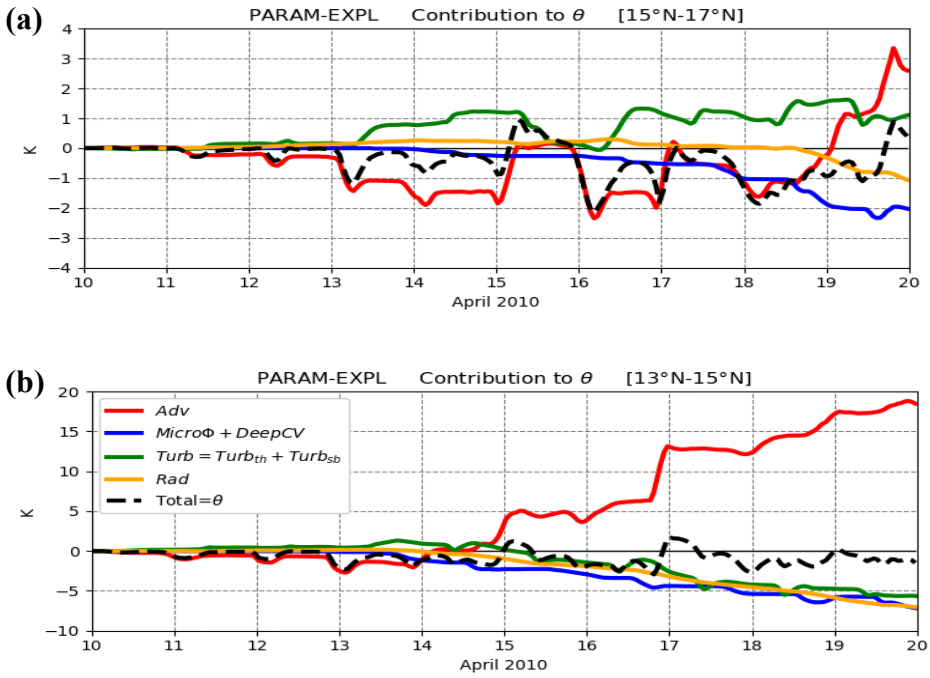


FIGURE 15 Ten-day evolution of the potential temperature hourly tendencies time integrated for the difference PARAM-EXPL and the averaged latitudes **(a)** [15°N-17°N] **(b)** [13°N-15°N]. On each panel, the dashed lines are the sum of the solid lines. Figures are averaged over the 500 lowest metres and longitudes [4.5°W-2.5°E]. See Equation (1),(2),(5)&(6) in Appendix A2 for more details on the different terms.

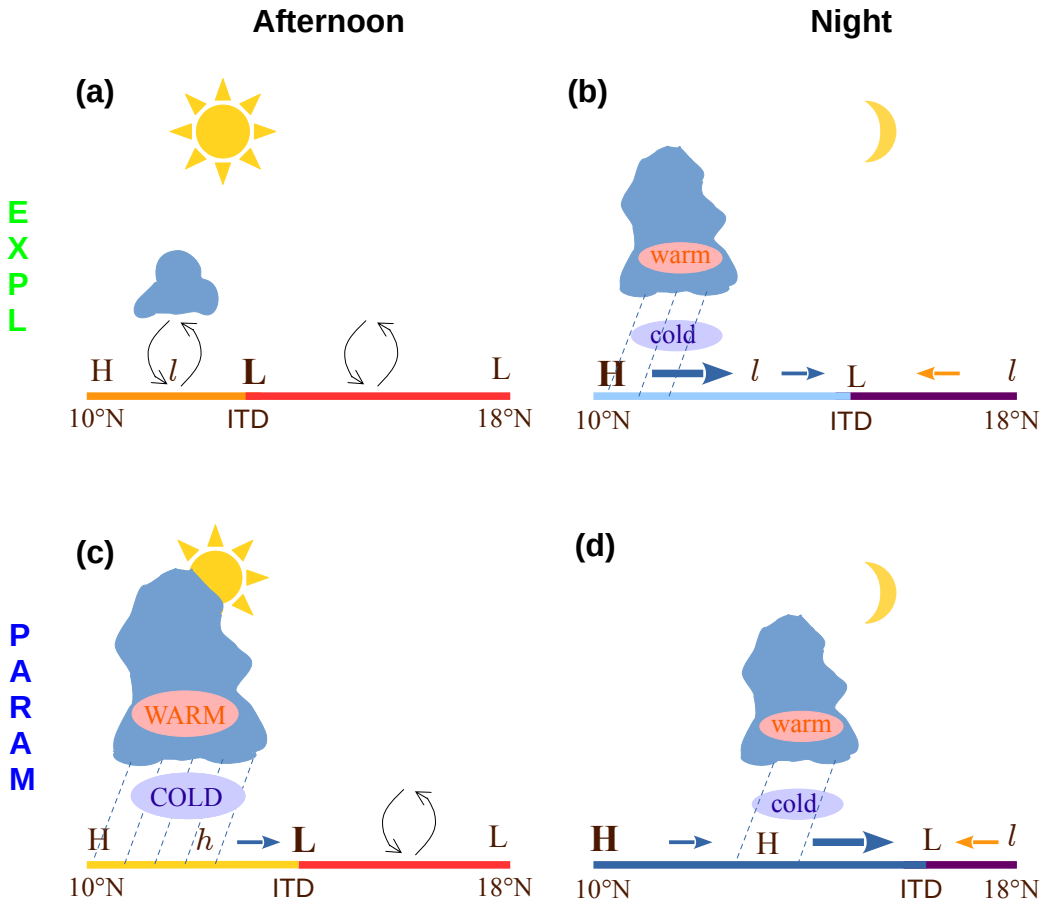
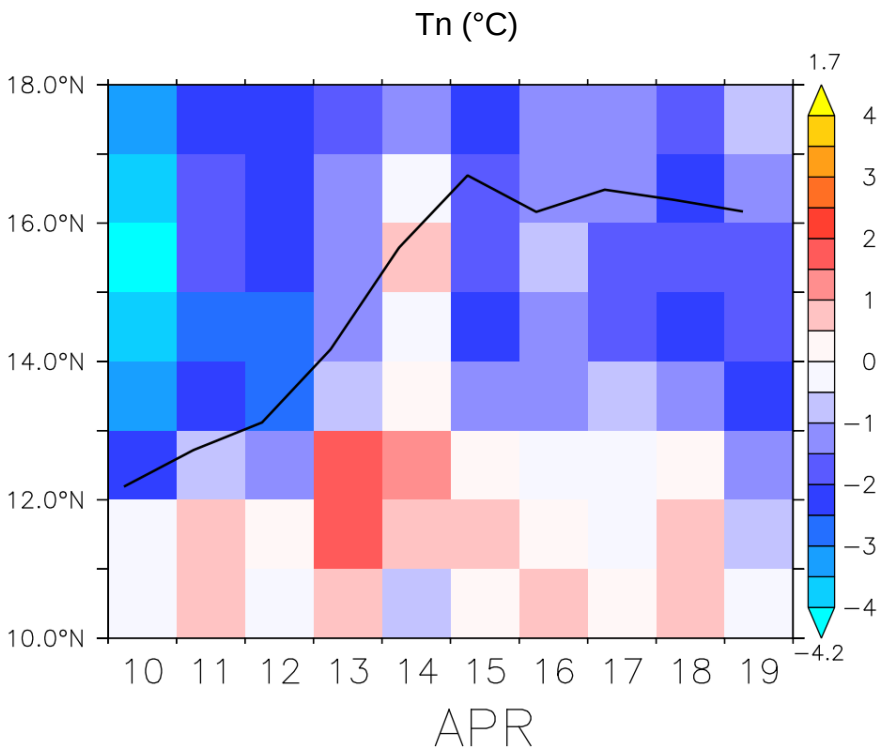
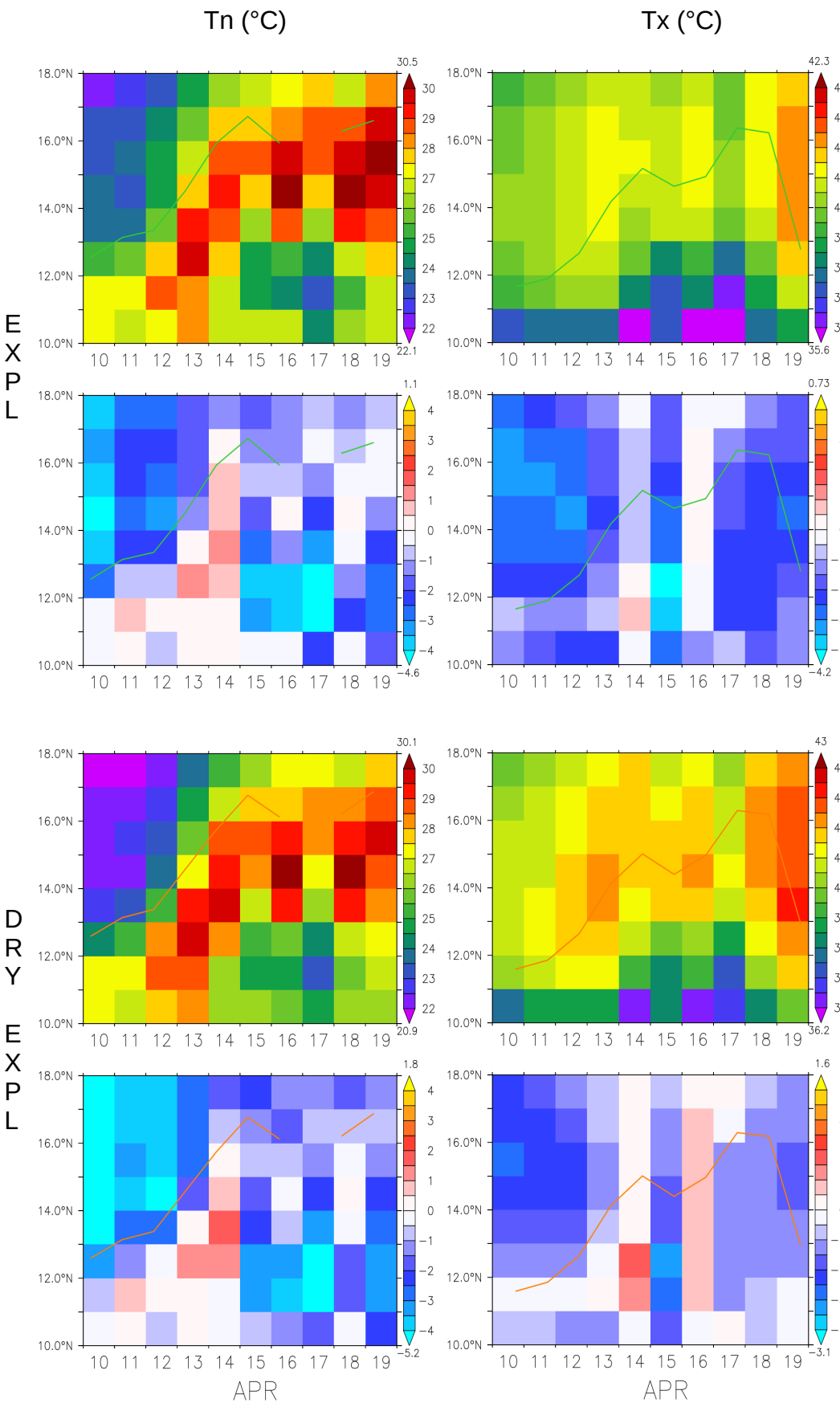


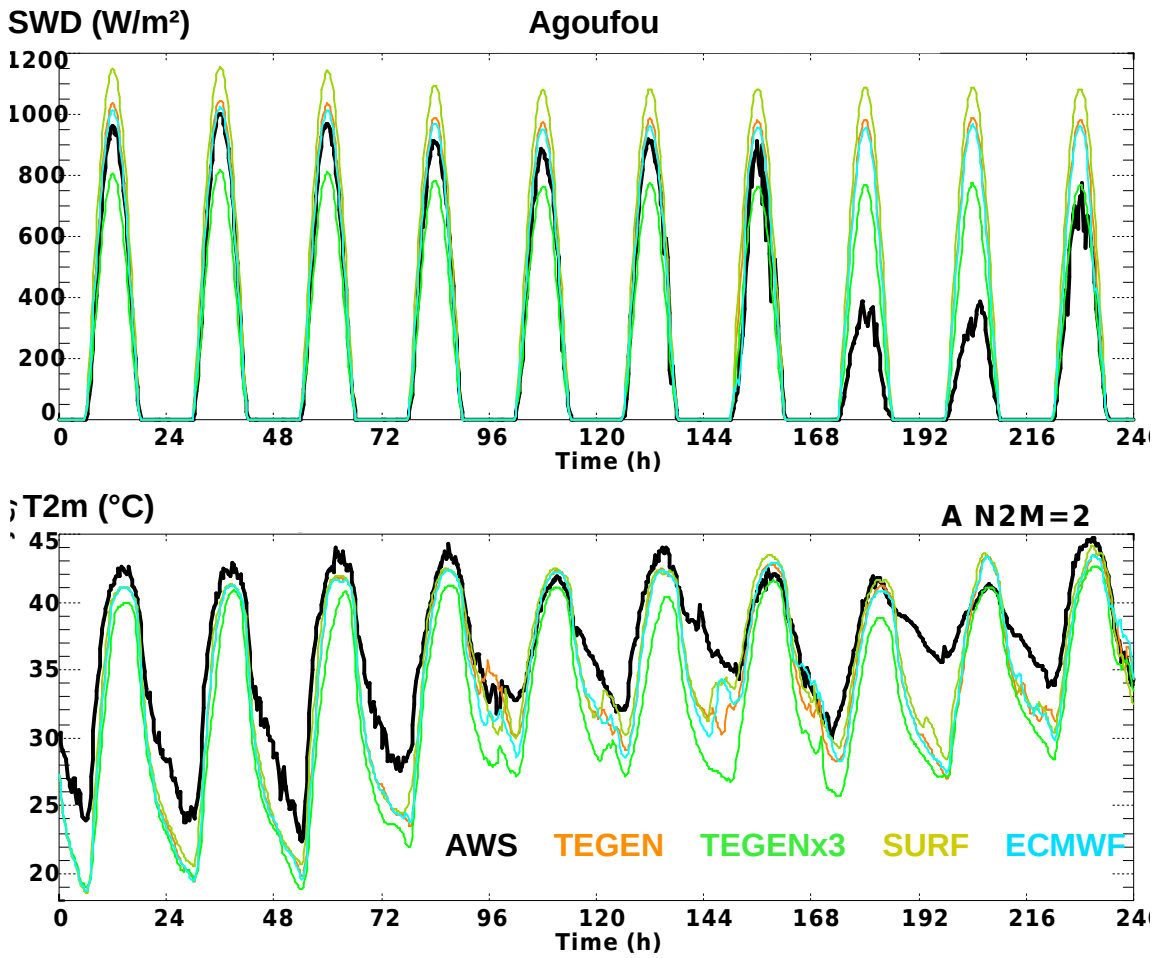
FIGURE 16 Schema illustrating the main differences between EXPL (upper line) and PARAM (lower line) on average over the period, differentiating afternoon/night situation. Here, EXPL is taken as the reference. The pressures at the south and north borders are fixed by the ECMWF coupling and then are the same for both simulations. The schematic pressure strength varies from the lowest to the highest following the rank: **L L l h H H**, identical for both simulations, making it possible to compare latitude for a given simulation or values between both simulations. The low level temperature varies from the cooler to the warmer following the colours from the dark violet, dark blue, blue, yellow, orange to red. The horizontal arrows width and length are proportional to the low-level advection strength cooling and moistening in blue and heating and drying in orange. The vertical arrows represent the turbulent mixing in the boundary layer. The latent heat release is identified by a red ellipse and the evaporative cooling by a blue ellipse. These latent heats are larger when the ellipses are bigger.



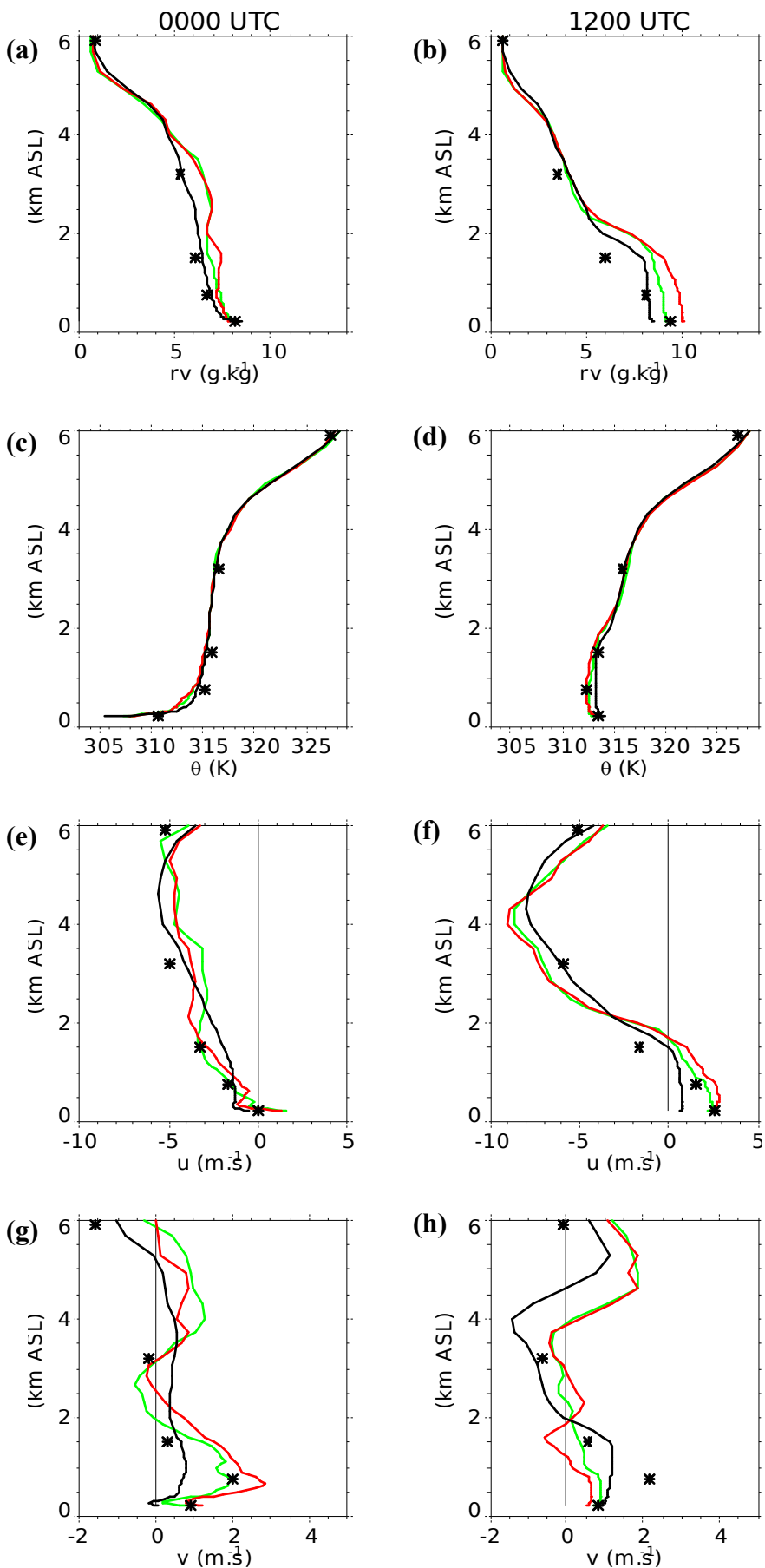
Appendix A1: 2-m air temperatures as a function of the latitude and time from the April 10 to 19, 2010 for the anomalies of the ECMWF analyses compared to BEST (ECMWF-BEST). The ITD location is indicated with the black line (2-m water vapour mixing ratio contour of 8 g/kg). Values are at 0600 UTC typical of the hour of the daily minimum. All data are averaged over the longitudes [4.5°W-2.5°E]. Numbers on the bottom and top of the colour bars are respectively the minimum and the maximum level of the chart.



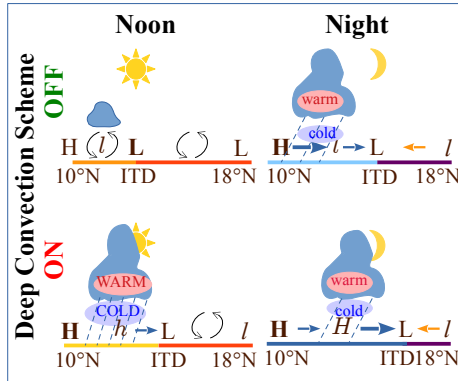
Supporting Information Figure S1 Minimum (left) and maximum (right) of the daily 2-m temperatures as a function of the latitude and the time from April 10 to 19, 2010 for the reference explicit run (EXPL, first row), the explicit run for which the three ground tanks have been drying (DRY EXPL, third row) and for the associated anomalies with respect to BEST from April 10 to 19, 2010 (second and fourth rows). The ITD location (2-m water vapour mixing ratio contour of 8 g/kg) is indicated by the green lines for EXPL and orange lines for DRY EXPL, at 0600 UTC in Tn charts and at 1800 UTC in Tx charts. The ITD isolines break on April 17 0600 UTC because they are located north of 18°N. Outputs every 3 hours. All figures are averaged over the longitudes [4.5°W-2.5°E].



Supporting Information Figure S2 Time series from April 10 to 19, 2010 (in hours) in Agoufou of the short wave down flux (W/m^2 , first row) and the near-surface temperature (T_{2m} in $^{\circ}\text{C}$, second row) for the reference simulation EXPL with the Aerosol Optical Depth (AOD) of Tegen et al. (1997) (named TEGEN), EXPL where the AOD has been tripled (named TEGENx3), EXPL with the climatological AOD of the ECMWF (named ECMWF), EXPL with the AOD deducted from the soil types of Méso-NH (named SURF) and the Automatic Weather Station observations. 2m-temperature has been interpolated between the ISBA surface temperature and the temperature at the first model level (10 m). Outputs every 3 hours.



Supporting Information Figure S3 Vertical profile in Niamey (Local Time=UTC+1) between the April 10, 2010 1200 UTC and April 20, 0000 UTC except the April 13&16, 1200 UTC. Composites at 0000 UTC for the left column and at 1200 UTC for the right column of the water vapour mixing ratio, the potential temperature, the zonal and meridional wind. Stars refer to the radiosoundings, black lines to the ECMWF reanalyses, color lines to the explicit MésosNH reference run with the shallow convection scheme EDKF switched on (green lines) and off (red lines). For the simulation, the closest grid point to observations has been used.



GRAPHICAL ABSTRACT:

Spurious effects of the deep convection parametrization on the simulation of a Sahelian heatwave

Tomasini M. Guichard F. Couvreur F. Roehrig R. Barbier J.*

A severe heatwave in April 2010 over West Africa is simulated with a mesoscale model that is evaluated with different observational datasets and budget analyses. The convection-permitting simulation captures relatively well the water vapour advection by the north and south-west and the associated rise of 2m-temperature in particular of the daily minima. Conversely, when the deep convection scheme is activated, the too early and too strong diurnal precipitation leads to too cold low-layer-temperatures by evaporative cooling and to a shift too north of the monsoon flow.