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The crucial representation of deep convection for the cyclogenesis of Medicane Ianos

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S1 Detailed description of the mesoscale models

S1.1 BOLAM and MOLOCH

The modelling system developed at CNR-ISAC consists in the hydrostatic model BOLAM (Bologna Limited Area Model; Buzzi et al., 2003) and the non-hydrostatic, fully compressible, convection-permitting model MOLOCH (Local Model in Hybrid Coordinates; Malguzzi et al., 2006) that in the operational practise are nested in cascade. Both model employ a latitude–longitude rotated grid, a terrain following coordinate and they share numerical characteristics such as the three-dimensional advection scheme based on a second-order, weighted-average flux implementation (Hubbard and Nikiforakis, 2003). The prognostic variables pressure, virtual temperature, specific humidity, horizontal and vertical wind velocity components, turbulent kinetic energy and five water species are defined on the staggered Arakawa C grid. Also parameterization schemes are similar, with some adjustments required to adapt to the different nature and resolution of the models: an E-l, 1.5 order scheme for the boundary layer closure (Trini Castelli et al., 2020), Kain-Fristch parameterization for deep convection (Kain, 2004), a combined application of the Ritter and Geleyn (1992) and the ECMWF (Morcrette et al., 2008) schemes for computing radiation, a 7-layer soil model and a 1-moment microphysical scheme (Buzzi et al., 2014). An update review of models' characteristics and applications can be found in Davolio et al. (2020).

BOLAM is run only at 10 km horizontal grid spacing, with 60 sigma levels in the vertical, relaxing to pressure coordinates with increasing height above the ground, starting at around 15 m. Deep convection is parameterized. MOLOCH is run at both horizontal grid-spacings, 10 and 2 km, using 60 height-based hybrid atmospheric levels, relaxing smoothly to horizontal surfaces away from Earth's surface, the lowest located at about 20 m above the surface. Convection parameterization is activated at both resolutions, because MOLOCH showed a clear improvement with parameterized convection also with 2 km grid spacing.

S1.2 Meso-NH

Meso-NH is the mesoscale non-hydrostatic model of the French research community (Lac et al., 2018). All Meso-NH simulations in this study use a Lambert conformal projection centred on 35.5°N, 17.5°E and height-based terrain-following vertical coordinates. The mass flux scheme for deep convection of Bechtold et al. (2001) is activated in the 10 km runs only, while the eddy-diffusive mass-flux scheme for shallow convection of Pergaud et al. (2009) is activated in all runs. Cloud microphysics are described by the single-moment mixed scheme of Pinty and Jabouille (1998), turbulence by the 1.5 order closure scheme of Cuxart et al. (2000) and radiation by the ECMWF scheme described in Gregory et al. (2000). The piecewise parabolic method advection scheme (PPM; Colella and Woodward, 1984) is used for scalars, while different advection schemes are used for momentum. The surface is described by the Surface Externalisée model (SURFEX; Masson et al., 2013) with various representations of fluxes over sea.

Two variants of Meso-NH are used here and their differences are briefly described in the following. In the configuration run at Centre National de Recherches Météorologiques (MESONH-CNRM), model version 5.5 is used with 88 levels starting at 8 m using vertical coordinates defined by Gal-Chen and Somerville (1975). A fourth order centered advection scheme is preferred for momentum to provide better numerical accuracy, while the operational Exchange Coefficient Unified Multi-campaign Experiments parameterization (ECUME; Belamari, 2005) version 6 is chosen for sea surface fluxes. In the configuration run at Laboratoire d'Aérologie (MESONH-LAERO), model version 5.4 is used with 70 levels starting at 10 m using vertical coordinates defined by Leuenberger et al. (2010). The fifth order weighted essentially non-oscillatory advection scheme (WENO; Shu and Osher, 1988) is preferred for momentum to favour numerical stability, while the well-established Coupled Ocean-Atmosphere Response Experiment parameterization (COARE; Fairall et al., 2003) version 3 is chosen for sea surface fluxes.

S1.3 MetUM

Simulations with the MetOffice Unified Model (MetUM) at version 12.0 are carried out with horizontal grid spacings of 10 km and 2.2 km, using a rotated-pole grid with the pole at 35.5°S and 197.5°E. MetUM has got two different scientific configurations, one for global convective-parametrized and second for regional convective-resolving resolutions. The 10 km simulations use the Global Atmosphere and Land v7 science configuration (GAL7; Walters et al., 2019), developed for 10–200 km numerical weather prediction and climate global models, whereas the 2.2 km simulations use the Regional Atmosphere and Land configuration version 2 for mid-latitudes (RAL2M; Bush et al., 2023), developed for km and sub-km scale limited area models over the mid-latitudes. The major difference between the GAL7 and RAL2M configuration is the absence of a convection scheme in the latter, where it is entirely switched off, including the shallow convection. The vertical discretization is similar in the 10 km and 2.2 km simulations, with terrain-following levels, but the 10 km simulations use 70 levels with a model lid at 80 km and the 2.2 km 90 levels with a model lid at 40 km. The timestep is 300 seconds in the 10 km and 75 seconds in the 2.2 km simulations.

Both GAL7 and RAL2 MetUM configurations share the Even Newer Dynamics for the General Atmospheric Modelling of the Environment (ENDGAME) dynamical core (Wood et al., 2014), the Joint community land surface model (JULES; Best et al., 2011), and a microphysics scheme based on Wilson and Ballard (1999) with the particle size distribution for rain from the rain-rate-dependent distribution of Abel and Boutle (2012). The convection scheme in GAL7 uses a mass-flux scheme based on Gregory and Rowntree (1990). GAL7 includes the orographic drag scheme described in Lott and Miller (1997) with improvements detailed in Vosper (2015), and the non-orographic scheme of Scaife et al. (2002). Both schemes have got the 1-D boundary layer scheme described in Lock et al. (2000), but the RAL2M blends it with a subgrid turbulence scheme (Boutle et al., 2014). The cloud parametrization in RAL2M is based on Smith (1990) with empirical adjustments to cloud fraction based on Boutle and Morcrette (2010), and GAL7 uses the prognostic cloud fraction and prognostic condensate (PC2) scheme (Wilson et al., 2008). The radiation scheme is the “Suite Of Community RAdiative Transfer codes based on Edwards and Slingo” (SOCRATES) radiation scheme (Manners et al., 2018), GAL7 includes several improvements to the radiation scheme described in sections 3.3 and 3.2 of Walters et al. (2017) and Walters et al. (2019).

S1.4 WRF

The WRF (Weather Research and Forecasting) model (Skamarock et al., 2008) is a numerical weather prediction system that solves the fully compressible, non-hydrostatic Euler equations. In the latest versions, it uses hybrid vertical coordinates that are terrain-following near the surface and become isobaric at higher levels. Five variants of WRF are tested in this study to assess the impact of using different model versions, vertical levels, microphysics and physical parameterizations. Their key characteristics are summarized in Table S1.

In terms of microphysics (MP), 4 formulations are tested: (a) the Thompson scheme (Thompson et al., 2008), (b) the Single Moment 6-class with graupel (WSM6; Hong and Lim, 2006), (c) the Single Moment 6-class adding hail category (WSM7; Bae et al., 2019) and (d) the Double Moment for cloud droplets, rain drops, ice crystals, snow, graupel, and hail (NSSL-2; Mansell et al., 2010). WRF simulations are performed at both 2 km and 10 km grid spacings. At 2 km, cumulus (CU) parameterizations are turned off, while two main cumulus parameterizations are used at 10 km: (a) the Kain-Fritsch (KF; Kain, 2004) and (b) the Betts-Miller-Janjic (BMJ; Janjic, 1994) schemes. To account for turbulence effects, 3 different Planetary Boundary Layer (PBL) parameterizations are tested: (a) the Yonsei University scheme (YSU; Hong et al., 2006), (b) the Mellor-Yamada-Janjić scheme (MYJ; Janjic, 2001), and (c) the non-local Asymmetric Convective Model with upward mixing and local downward mixing scheme (ACM2; Pleim, 2007). To account for both short-wave and long-wave (SW/LW) radiation, three different schemes are used: (a) the Rapid Radiative transfer Model (RRTM; Mlawer et al., 1997), (b) the newer version of the Rapid Radiative Transfer Model application for Global climate models (RRTMG; Iacono et al., 2008) and (c) the Dudhia short-wave radiation scheme (Dudhia, 1989). Regarding the Land-Surface (SFC) model, the 5 WRF variants share the same Unified Noah model (Chen and Dudhia, 2001).

Table S1. Key parameterizations of WRF model variants: cloud microphysics (MP), cumulus (CU), planetary boundary layer (PBL), land surface (SFC) and short- and long-wave radiation (SW/LW).

Variant	Version	Levels	MP	CU	PBL	SFC	SW/LW
WRF-AUTH	4.2.1	50	WSM6	KF	YSU	Noah	RRTMG/RRTMG
WRF-ISAC	4.3	57	Thompson	KF	MYJ	Noah	Dudhia/RRTM
WRF-ISAC2	4.3	50	WSM7	BMJ	ACM2	Noah	RRTMG/RRTMG
WRF-NOA	4.0	50	NSSL-2	KF	YSU	Noah	RRTMG/RRTMG
WRF-UIB	3.9.1.1	50	Thompson	KF	YSU	Noah	RRTMG/RRTMG

References

Abel, S. J. and Boutle, I. A.: An improved representation of the raindrop size distribution for single-moment microphysics schemes, Quart. J. Roy. Meteorol. Soc., 138, 2151–2162, https://doi.org/10.1002/qj.1949, 2012.

Bae, S. Y., Hong, S.-Y., and Tao, W.-K.: Development of a Single-Moment Cloud Microphysics Scheme with Prognostic Hail for the Weather Research and Forecasting (WRF) Model, Asia-Pacific J. Atmos. Sci., 55, 233 – 245, https://doi.org/10.1007/s13143-018-0066-3, 2019.

Bechtold, P., Bazile, E., Guichard, F., Mascart, P., and Richard, E.: A mass-flux convection scheme for regional and global models, Quart. J. Roy. Meteorol. Soc., 127, 869–886, https://doi.org/10.1002/qj.49712757309, 2001.

Belamari, S.: Report on uncertainty estimates of an optimal bulk formulation for surface turbulent fluxes, MERSEA IP Deliverable 412, p. 1–29, 2005.

Best, M. J., Pryor, M., Clark, D. B., Rooney, G. G., Essery, R. L. H., Ménard, C. B., Edwards, J. M., Hendry, M. A., Porson, A., Gedney, N., Mercado, L. M., Sitch, S., Blyth, E., Boucher, O., Cox, P. M., Grimmond, C. S. B., and Harding, R. J.: The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes, Geosci. Model Dev., 4, 677–699, https://doi.org/10.5194/gmd-4-677-2011, 2011.

Boutle, I. A. and Morcrette, C. J.: Parametrization of area cloud fraction, Atm. Sci. Lett., 11, 283–289, https://doi.org/10.1002/asl.293, 2010.

Boutle, I. A., Eyre, J. E. J., and Lock, A. P.: Seamless Stratocumulus Simulation across the Turbulent Gray Zone, Mon. Weather Rev., 142, 1655 – 1668, https://doi.org/10.1175/MWR-D-13-00229.1, 2014.

Bush, M., Boutle, I., Edwards, J., Finnenkoetter, A., Franklin, C., Hanley, K., Jayakumar, A., Lewis, H., Lock, A., Mittermaier, M., Mohandas, S., North, R., Porson, A., Roux, B., Webster, S., and Weeks, M.: The second Met Office Unified Model–JULES Regional Atmosphere and Land configuration, RAL2, Geosci. Model Dev., 16, 1713–1734, https://doi.org/10.5194/gmd-16-1713-2023, 2023.

Buzzi, A., D'Isidoro, M., and Davolio, S.: A case study of an orographic cyclone formation south of the Alps during the MAP-SOP, Quart. J. Roy. Meteorol. Soc., 129, 1795–1818, https://doi.org/10.1256/qj.02.112, 2003.

Buzzi, A., Davolio, S., Malguzzi, P., Drofa, O., and Mastrangelo, D.: Heavy rainfall episodes over Liguria of autumn 2011: numerical forecasting experiments, Nat. Hazards Earth Syst. Sci., 14, 1325–1340, https://doi.org/10.5194/nhess-14-1325-2014, 2014.

Chen, F. and Dudhia, J.: Coupling an Advanced Land Surface–Hydrology Model with the Penn State–NCAR MM5 Modeling System. Part I: Model Implementation and Sensitivity, Mon. Weather Rev., 129, 569 – 585, https://doi.org/10.1175/1520-0493(2001)129<0569:CAALSH>2.0.CO;2, 2001.

Colella, P. and Woodward, P. R.: The Piecewise Parabolic Method (PPM) for gas-dynamical simulations, J. Comput. Phys., 54, 174–201, https://doi.org/10.1016/0021-9991(84)90143-8, 1984.

Cuxart, J., Bougeault, P., and Redelsperger, J.-L.: A turbulence scheme allowing for mesoscale and large-eddy simulations, Quart. J. Roy. Meteorol. Soc., 126, 1–30, https://doi.org/10.1002/qj.49712656202, 2000.

Davolio, S., Malguzzi, P., Drofa, O., Mastrangelo, D., and Buzzi, A.: The Piedmont flood of November 1994: a test-bed of forecasting capabilities of the CNR-ISAC meteorological model suite, Bull. Atmos. Sci. Technol., 1, 263–282, https://doi.org/10.1007/s42865-020-00015-4, 2020.

Dudhia, J.: Numerical Study of Convection Observed during the Winter Monsoon Experiment Using a Mesoscale Two-Dimensional Model, J. Atmos. Sci., 46, 3077 – 3107, https://doi.org/10.1175/1520-0469(1989)046<3077:NSOCOD>2.0.CO;2, 1989.

Fairall, C. W., Bradley, E. F., Hare, J. E., Grachev, A. A., and Edson, J. B.: Bulk Parameterization of Air–Sea Fluxes: Updates and Verification for the COARE Algorithm, J. Climate, 16, 571–591, https://doi.org/10.1175/1520-0442(2003)0162.0.CO;2, 2003.

Gal-Chen, T. and Somerville, R. C. J.: On the use of a coordinate transformation for the solution of the Navier-Stokes equations, Journal of Computational Physics, 17, 209–228, https://doi.org/10.1016/0021-9991(75)90037-6, 1975.

Gregory, D. and Rowntree, P. R.: A Mass Flux Convection Scheme with Representation of Cloud Ensemble Characteristics and Stability-Dependent Closure, Mon. Weather Rev., 118, 1483–1506, https://doi.org/10.1175/1520-0493(1990)118<1483:AMFCSW>2.0.CO;2, 1990.

Gregory, D., Morcrette, J.-J., Jakob, C., Beljaars, A. M., and Stockdale, T.: Revision of convection, radiation and cloud schemes in the ECMWF model, Quart. J. Roy. Meteorol. Soc., 126, 1685–1710, https://doi.org/10.1002/qj.49712656607, 2000.

Hong, S.-Y. and Lim, J.-O.: The WRF single-moment 6-class microphysics scheme (WSM6), J. Korean Meteor. Soc., 42, 129–151, 2006.

Hong, S.-Y., Noh, Y., and Dudhia, J.: A new vertical diffusion package with an explicit treatment of entrainment processes, Mon. Weather Rev., 134, 2318–2341, https://doi.org/10.1175/MWR3199.1, 2006.

Hubbard, M. E. and Nikiforakis, N.: A Three-Dimensional, Adaptive, Godunov-Type Model for Global Atmospheric Flows, Mon. Weather Rev., 131, 1848 – 1864, https://doi.org/10.1175//2568.1, 2003.

Iacono, M., Delamere, J., Mlawer, E., Shephard, M., Clough, S., and Collins, W.: Radiative forcing by long-lived greenhouse gases: calculations with the AER radiative transfer models, J. Geophys. Res., 113, D13 103, https://doi.org/10.1029/2008JD009944, 2008.

Janjic, Z.: The step-mountain eta coordinate model: further developments of the convection, viscous sublayer, and turbulence closure schemes, Mon. Weather Rev., 122, 927 – 945, https://doi.org/10.1175/1520-0493(1994)122<0927:TSMECM>2.0.CO;2, 1994.

Janjic, Z.: Nonsingular implementation of the Mellor-Yamada Level 2.5 Scheme in the NCEP Meso model, National Centers for Environmental Prediction, Tech. rep., Office Note, 2001.

Kain, J.: The Kain-Fritsch convective parameterization: an update, J. Appl. Meteorol., 43, 170–181, https://doi.org/10.1175/1520-0450(2004)043<0170:TKCPAU>2.0.CO;2, 2004.

Lac, C., Chaboureau, J.-P., Masson, V., Pinty, J.-P., Tulet, P., Escobar, J., Leriche, M., Barthe, C., Aouizerats, B., Augros, C., Aumond, P., Auguste, F., Bechtold, P., Berthet, S., Bielli, S., Bosseur, F., Caumont, O., Cohard, J.-M., Colin, J., Couvreux, F., Cuxart, J., Delautier, G., Dauhut, T., Ducrocq, V., Filippi, J.-B., Gazen, D., Geoffroy, O., Gheusi, F., Honnert, R., Lafore, J.-P., Lebeaupin Brossier, C., Libois, Q., Lunet, T., Mari, C., Maric, T., Mascart, P., Mogé, M., Molinié, G., Nuissier, O., Pantillon, F., Peyrillé, P., Pergaud, J., Perraud, E., Pianezze, J., Redelsperger, J.-L., Ricard, D., Richard, E., Riette, S., Rodier, Q., Schoetter, R., Seyfried, L., Stein, J., Suhre, K., Taufour, M., Thouron, O., Turner, S., Verrelle, A., Vié, B., Visentin, F., Vionnet, V., and Wautelet, P.: Overview of the Meso-NH model version 5.4 and its applications, Geosci. Model Dev., 11, 1929–1969, https://doi.org/10.5194/gmd-11-1929-2018, 2018.

Leuenberger, D., Koller, M., Fuhrer, O., and Schär, C.: A Generalization of the SLEVE Vertical Coordinate, Mon. Weather Rev., 138, 3683–3689, https://doi.org/10.1175/2010MWR3307.1, 2010.

Lock, A. P., Brown, A. R., Bush, M. R., Martin, G. M., and Smith, R. N. B.: A New Boundary Layer Mixing Scheme. Part I: Scheme Description and Single-Column Model Tests, Mon. Weather Rev., 128, 3187–3199, https://doi.org/10.1175/1520-0493(2000)128<3187:ANBLMS>2.0.CO;2, 2000.

Lott, F. and Miller, M. J.: A new subgrid-scale orographic drag parametrization: Its formulation and testing, Quart. J. Roy. Meteorol. Soc., 123, 101–127, https://doi.org/10.1002/qj.49712353704, 1997.

Malguzzi, P., Grossi, G., Buzzi, A., Ranzi, R., and Buizza, R.: The 1966 'century' flood in Italy: a meteorological and hydrological revisitation, J. Geophys. Res., 111, D24 106, https://doi.org/10.1029/2006JD007111, 2006.

Manners, J., Edwards, J. M., Hill, P., and Thelen, J.-C.: SOCRATES (Suite Of Community RAdiative Transfer codes based on Edwards and Slingo) Technical Guide, https://code.metoffice.gov.uk/trac/socrates, 2018.

Mansell, E. R., Ziegler, C. L., and Bruning, E. C.: Simulated Electrification of a Small Thunderstorm with Two-Moment Bulk Microphysics, J. Atmos. Sci., 67, 171 – 194, https://doi.org/10.1175/2009JAS2965.1, 2010.

Masson, V., Le Moigne, P., Martin, E., Faroux, S., Alias, A., Alkama, R., Belamari, S., Barbu, A., Boone, A., Bouyssel, F., Brousseau, P., Brun, E., Calvet, J.-C., Carrer, D., Decharme, B., Delire, C., Donier, S., Essaouini, K., Gibelin, A.-L., Giordani, H., Habets, F., Jidane, M., Kerdraon, G., Kourzeneva, E., Lafaysse, M., Lafont, S., Lebeaupin Brossier, C., Lemonsu, A., Mahfouf, J.-F., Marguinaud, P., Mokhtari, M., Morin, S., Pigeon, G., Salgado, R., Seity, Y., Taillefer, F., Tanguy, G., Tulet, P., Vincendon, B., Vionnet, V., and Voldoire, A.: The SURFEXv7.2 land and ocean surface platform for coupled or offline simulation of earth surface variables and fluxes, Geosci. Model Dev., 6, 929–960, https://doi.org/10.5194/gmd-6-929-2013, 2013.

Mlawer, E. J., Taubman, S. J., Brown, P. D., Iacono, M. J., and Clough, S. A.: Radiative transfer for inhomogeneous atmospheres: RRTM, a validated correlated-k model for the longwave, J. Geophys. Res., 102, 16 663–16 682, https://doi.org/10.1029/97JD00237, 1997.

Morcrette, J. J., Barker, H. W., Cole, J. N. S., Iacono, M. J., and Pincus, R.: Impact of a new radiation package, McRad, in the ECMWF integrated forecasting system, Mon. Weather Rev., 136, 4773–4798, https://doi.org/10.1175/2008MWR2363.1, 2008.

Pergaud, J., Masson, V., Malardel, S., and Couvreux, F.: A Parameterization of Dry Thermals and Shallow Cumuli for Mesoscale Numerical Weather Prediction, Bound.-Lay. Meteorol., 132, 83–106, https://doi.org/10.1007/s10546-009-9388-0, 2009.

Pinty, J.-P. and Jabouille, P.: A mixed-phase cloud parameterization for use in a mesoscale non-hydrostatic model: simulations of a squall line and of orographic precipitations, in: Conf. on cloud physics, Everett, WA, Amer. Meteor. Soc., pp. 217–220, 1998.

Pleim, J. E.: A combined local and nonlocal closure model for the atmospheric boundary layer. Part I: Model description and testing, J. Appl. Meteorol. Climatol., 46, 1383 – 1395, https://doi.org/10.1175/JAM2539.1, 2007.

Ritter, B. and Geleyn, J. F.: A comprehensive radiation scheme for numerical weather prediction models with potential applications in climate simulations, Mon. Weather Rev., 120, 303–325, https://doi.org/10.1175/1520-0493(1992)120<0303:ACRSFN>2.0.CO;2, 1992.

Scaife, A. A., Butchart, N., Warner, C. D., and Swinbank, R.: Impact of a Spectral Gravity Wave Parameterization on the Stratosphere in the Met Office Unified Model, J. Atmos. Sci., 59, 1473–1489, https://doi.org/10.1175/1520-0469(2002)059<1473:IOASGW>2.0.CO;2, 2002.

Shu, C.-W. and Osher, S.: Efficient implementation of essentially non-oscillatory shock-capturing schemes, J. Comput. Phys., 77, 439–471, https://doi.org/10.1016/0021-9991(88)90177-5, 1988.

Skamarock, W. C., Klemp, J. B., Dudhia, J., Gill, D. O., Barker, D. M., Duda, M. G., Huang, X.-Y., Wang, W., Powers, J. G., et al.: A description of the advanced research WRF version 3, NCAR technical note, 475, 113, https://doi.org/10.5065/D68S4MVH, 2008.

Smith, R. N. B.: A scheme for predicting layer clouds and their water content in a general circulation model, Quart. J. Roy. Meteorol. Soc., 116, 435–460, https://doi.org/10.1002/qj.49711649210, 1990.

Thompson, G., Field, P. R., Rasmussen, R. M., and Hall, W. D.: Explicit forecasts of winter precipitation using an improved bulk microphysics scheme. Part II: Implementation of a new snow parameterization, Mon. Weather Rev., 136, 5095–5115, https://doi.org/10.1175/2008MWR2387.1, 2008.

Trini Castelli, S., Bisignano, A., Donateo, A., Landi, T. C., Martano, P., and Malguzzi, P.: Evaluation of the turbulence parametrization in the MOLOCH meteorological model, Quart. J. Roy. Meteorol. Soc., 146, 124–140, https://doi.org/10.1002/qj.3661, 2020.

Vosper, S. B.: Mountain waves and wakes generated by South Georgia: implications for drag parametrization, Quart. J. Roy. Meteorol. Soc., 141, 2813–2827, https://doi.org/10.1002/qj.2566, 2015.

Walters, D., Brooks, M., Boutle, I., Melvin, T., Stratton, R., Vosper, S., Wells, H., Williams, K., Wood, N., Allen, T., Bushell, A., Copsey, D., Earnshaw, P., Edwards, J., Gross, M., Hardiman, S., Harris, C., Heming, J., Klingaman, N., Levine, R., Manners, J., Martin, G., Milton, S., Mittermaier, M., Morcrette, C., Riddick, T., Roberts, M., Sanchez, C., Selwood, P., Stirling, A., Smith, C., Suri, D., Tennant, W., Vidale, P. L., Wilkinson, J., Willett, M., Woolnough, S., and Xavier, P.: The Met Office Unified Model Global Atmosphere 6.0/6.1 and JULES Global Land 6.0/6.1 configurations, Geosci. Model Dev., 10, 1487–1520, https://doi.org/10.5194/gmd-10-1487-2017, 2017.

Walters, D., Baran, A. J., Boutle, I., Brooks, M., Earnshaw, P., Edwards, J., Furtado, K., Hill, P., Lock, A., Manners, J., Morcrette, C., Mulcahy, J., Sanchez, C., Smith, C., Stratton, R., Tennant, W., Tomassini, L., Van Weverberg, K., Vosper, S., Willett, M., Browse, J., Bushell, A., Carslaw, K., Dalvi, M., Essery, R., Gedney, N., Hardiman, S., Johnson, B., Johnson, C., Jones, A., Jones, C., Mann, G., Milton, S., Rumbold, H., Sellar, A., Ujiie, M., Whitall, M., Williams, K., and Zerroukat, M.: The Met Office Unified Model Global Atmosphere 7.0/7.1 and JULES Global Land 7.0 configurations, Geosci. Model Dev., 12, 1909–1963, https://doi.org/10.5194/gmd-12-1909-2019, 2019.

Wilson, D. R. and Ballard, S. P.: A microphysically based precipitation scheme for the UK meteorological office unified model, Quart. J. Roy. Meteorol. Soc., 125, 1607–1636, https://doi.org/10.1002/qj.49712555707, 1999.

Wilson, D. R., Bushell, A. C., Kerr-Munslow, A. M., Price, J. D., and Morcrette, C. J.: PC2: A prognostic cloud fraction and condensation scheme. I: Scheme description, Quart. J. Roy. Meteorol. Soc., 134, 2093–2107, https://doi.org/10.1002/qj.333, 2008.

Wood, N., Staniforth, A., White, A., Allen, T., Diamantakis, M., Gross, M., Melvin, T., Smith, C., Vosper, S., Zerroukat, M., and Thuburn, J.: An inherently mass-conserving semi-implicit semi-Lagrangian discretization of the deep-atmosphere global non-hydrostatic equations, Quart. J. Roy. Meteorol. Soc., 140, 1505–1520, https://doi.org/10.1002/qj.2235, 2014.