Orographic effects on precipitation and atmospheric water cycle in the Weather Research and Forecasting Model

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1. INTRODUCTION

Regional Climate Models (RCM) simulate the effects of local orography on precipitation and clouds much better than Global Climate Models (GCM) thanks to their higher spatio-temporal resolution (see Figure 1). However, a RCM still needs parameterizations for microphysical processes such as the evolution of cloud droplets into rain or snowfall. Sometimes these parameterizations are well suited for short-term forecasts but their effect on long-term climate simulations can introduce large errors[1]. Our objective is to assess the fundamental characteristics of different schemes of microphysics by performing an idealized simulation with the Weather Research and Forecasting (WRF) model[2]. The knowledge of the effects of parameterization on the atmospheric water cycle is required to enhance the quality of long-term RCM simulations.

Figure 1: precipitation rate

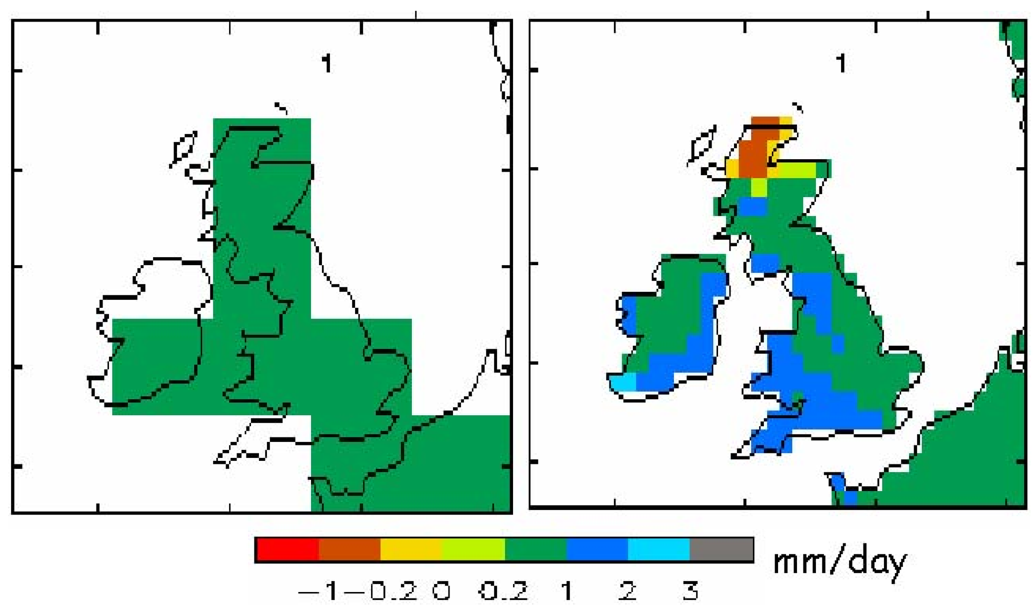


Image source: climateprediction.net

Figure 2: simulation scenario

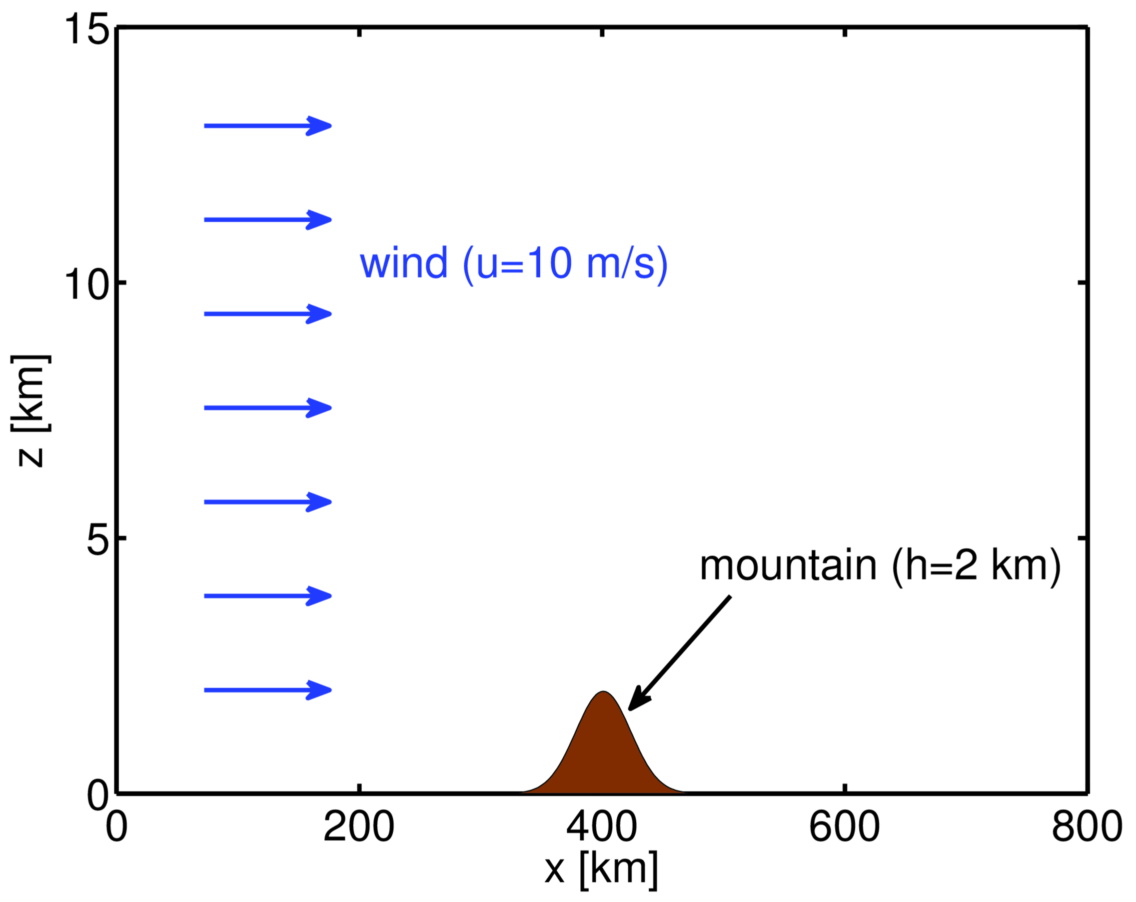
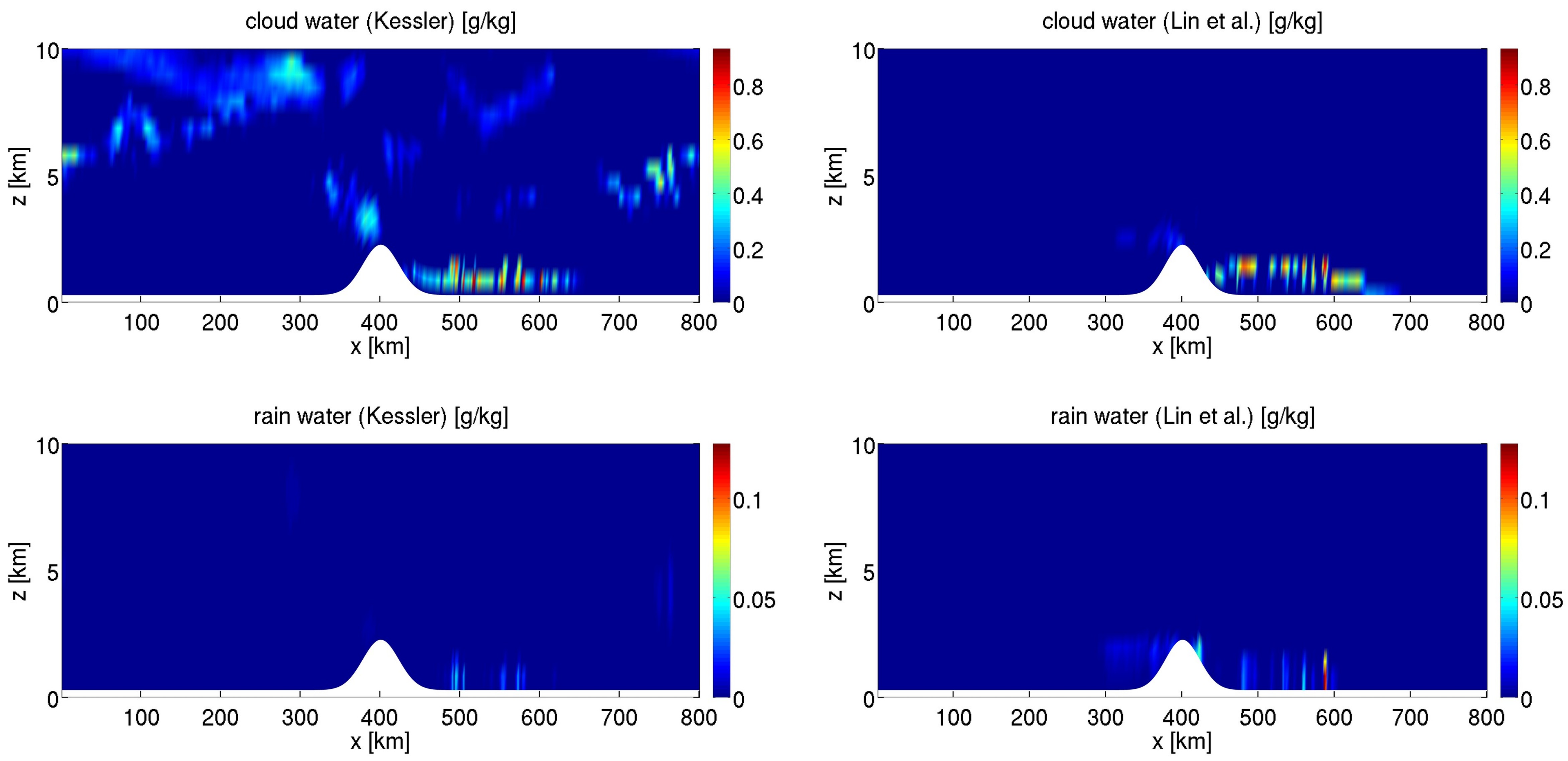


Figure 3



2. SIMULATION

The scenario used for our simulations consists of a 2-D atmospheric flow of saturated air interacting with an idealized mountain ridge (Figure 2). In order to conserve the total amount of water in the domain, periodic lateral boundary conditions are applied so that the air exiting at one side is reinserted at the other side. More details about the simulation setup are provided in the table "WRF idealized simulation".

The microphysics schemes tested in our simulations are the Kessler scheme and the Lin et al. scheme (see table "Microphysics schemes"). The high-resolution output of WRF model allows us to resolve clouds and analyze the distribution of the different phases of water (Figure 3).

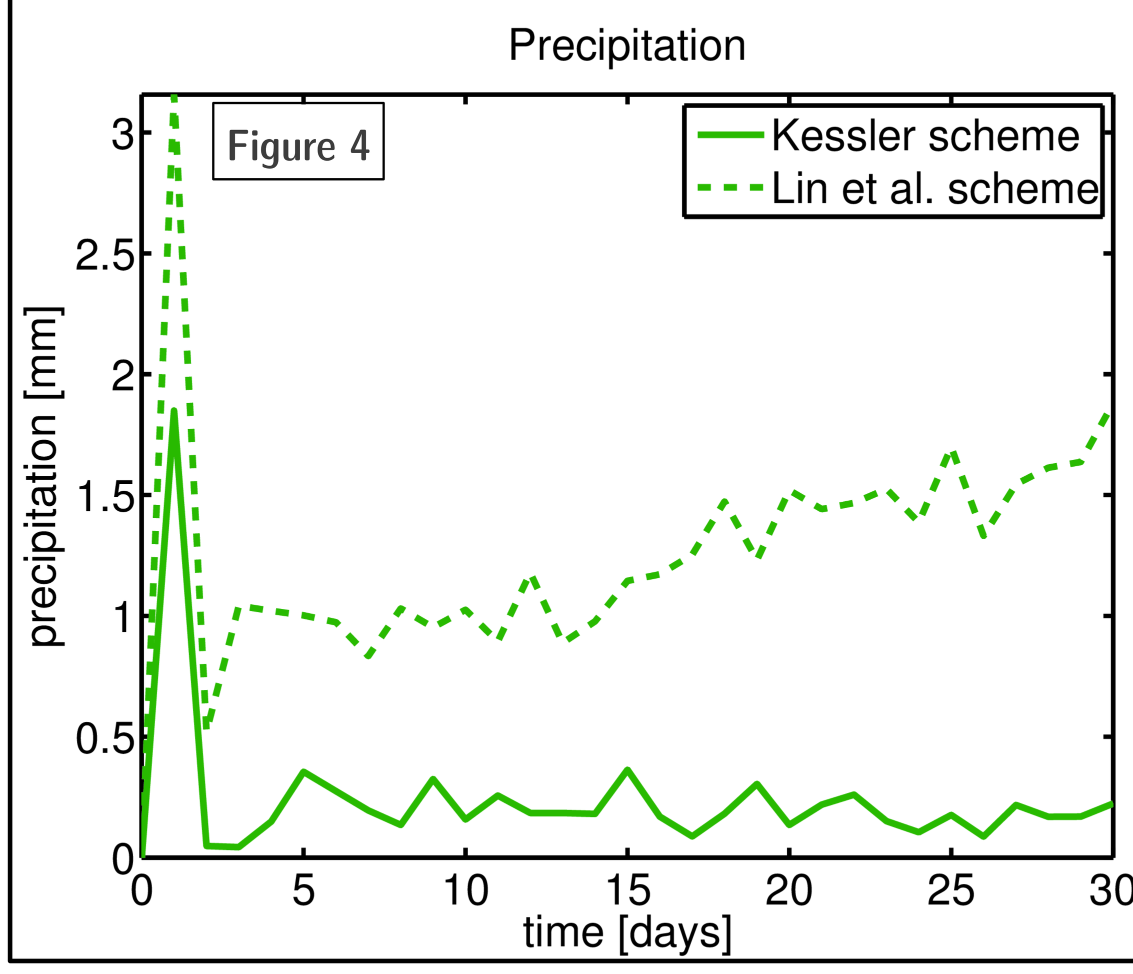
WRF idealized simulation

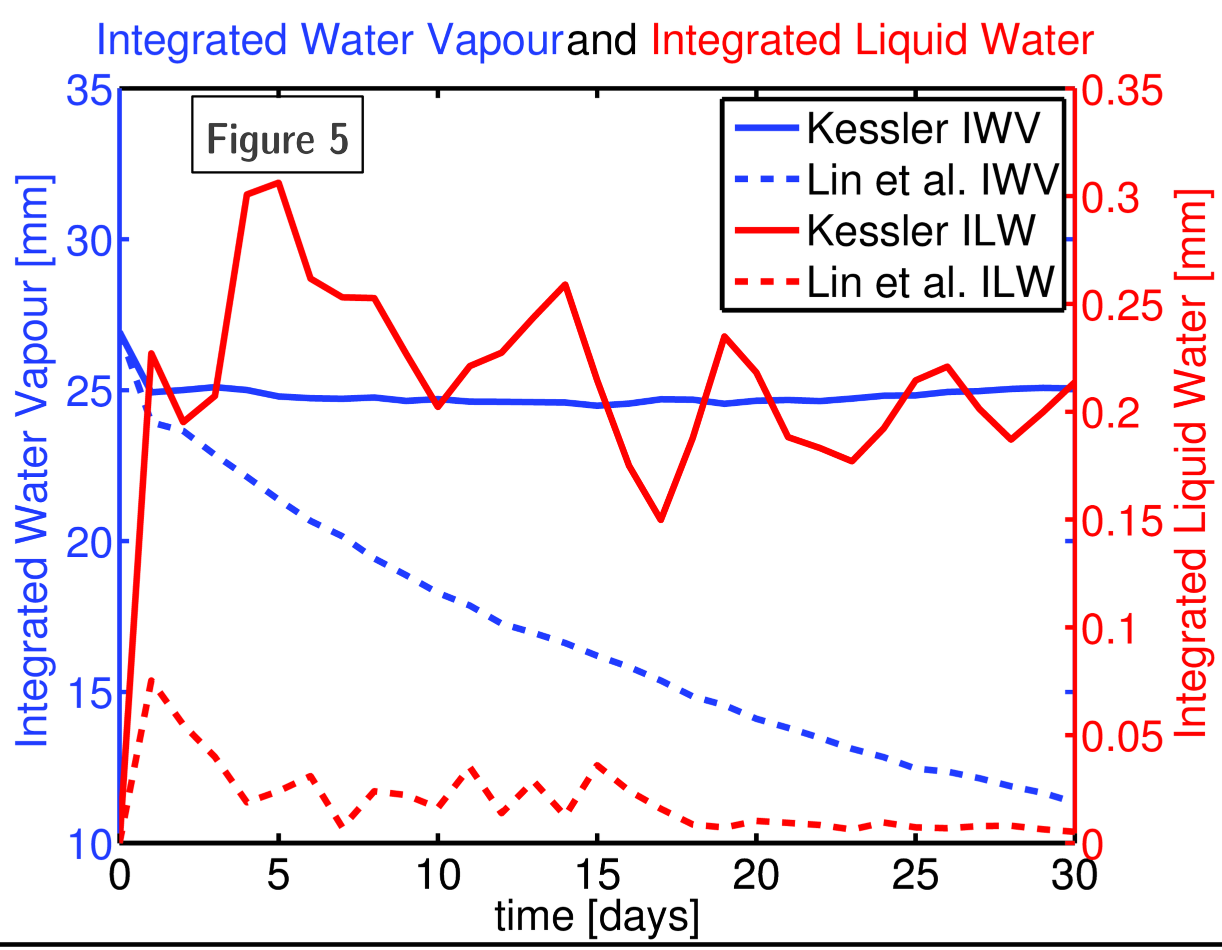
domain size / duration	2-D domain of 800 km x 30 km / 30 days
grid resolution / time step	Δx=2 km, Δz variable (500 m–2.3 km) / Δt=20 s
mountain type	bell-shaped (height=2 km, half-width=16 km)
boundary conditions	periodic lateral boundaries, absorbing upper boundary
initial profiles	T, p and q averaged profiles from ECMWF ERA-Interim
initial wind field	u=10 m/s, w=0 m/s
WRF version	3.3.1

Microphysics schemes

	Kessler scheme	**Lin et al. scheme**
hydrometeors included:	water vapour, cloud water, rain	water vapour, cloud water, rain, cloud ice, snow, graupel
microphysical processes included:	production, fall, and evaporation of rain; accretion and autoconversion of cloud water; production of cloud water from condensation	evaporation/sublimation, deposition/condensation, aggregation, accretion, Bergeron processes, freezing, melting, melting evaporation

3. WRF model run over 30 days





4. CONCLUSIONS

The simulations with the Kessler and the Lin et al. schemes produced quite different results in terms of accumulated daily total mean precipitation, integrated water vapour (IWV) and integrated cloud liquid water (ILW). The scheme by Lin et al. produced on average 8 times more precipitation than the Kessler scheme (Figure 4) and thus removed more water vapour from the atmosphere (Figure 5, blue lines). On the other hand, the Kessler scheme has the characteristic of generating more clouds (Figure 5, red lines). Both features are of great importance for the hydrological cycle and for the radiation energy balance of the Earth.

The Kessler and the Lin et al. parameterizations are just two of the available microphysics schemes in WRF model. In the future more schemes will be tested and characterized.

REFERENCES

1. N. K. Awan et al., Parameterization-Induced Error Characteristics of MM5 and WRF Operated in Climate Mode over the Alpine Region: An Ensemble-Based Analysis, J. Climate, 24, 3107 (2011), 10.1175/2011JCLI3674.1

2. W. C. Skamarock et al., A Description of the Advanced Research WRF Version 3, NCAR Technical Note, NCAR/TN−475+STR (2008)