Article

Weather Research and Forecasting Model Sensitivity to Choice of Parameterization over Ethiopia

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Abstract: A 3-month (June–August) regime of the year 2002 summer rainfall (JJA2002) was simulated with 30 physics combinations using the Weather Research and Forecasting (WRF) model at 12-km horizontal grid resolution. The objective is to examine summer rainfall sensitivity to parameterization of microphysical, convective, and boundary layer processes and identify an best possible combination of parameterization options that performs relatively better in simulating spatial and temporal distribution of summer rains over Ethiopia. The WRF simulated rainfall was evaluated against station data and satellite rainfall products (CHIRPS and ENACTS) using mean absolute error, Pearson and Pattern correlation coefficients (PCC), pattern correlation and and error in number of rainy days as evaluation metrics. Summer rainfall is found to be most sensitive to choice of cumulus parameterization and least sensitive to cloud microphysics. All simulations captured the spatial distribution of mean seasonal precipitation with PCC ranging from 0.89-0.94. However, all simulations overestimated precipitation amount and number of rainy days. Out of the 30, the simulations that uses a combination of Grell-3D cumulus scheme, ACM2 boundary layer, Lin Microphysics, Dudhai shortwave radiation and RRTM longwave radiation scheme ranked the top and provided the most realistic simulation in terms of amount and spatio-temporal distribution of summer rainfall.

Keywords: RCM, WRF, Downscaling, Parameterization, Sensitivity, Ethiopia

1. Introduction

Advancements in scientific understanding of the climate system and climate modeling have promoted seasonal forecasting to be a well-established operational area at several national centers[1]. As a result, different centres around the world (e.g., the National Center for Environmental Prediction–NCEP, the European Center for Medium Range Weather Forecast-ECMWF, Australian Bureau of Meteorology) run seasonal forecasting systems (e.g., the Climate Forecast System version 2 [CFSV2, 2], seasonal forecast system [SEAS5, 3], and the Australian Ocean-Atmosphere Model for Climate Prediction [POAMA, 4] respectively on a global scale. These seasonal forecast products provide reasonable global perspectives and outlooks of the climate several months in advance. However, despite their potential applications for different socio–economic sectors, the usefulness of these forecasts has been limited because of their coarse spatial resolutions [1,5]. In order for such climate forecasts to be of practical societal value, it is essential for them to be issued at spatial scales appropriate to the decision maker or at the scale needed to exploit them further (e.g., using them as an input for hydrologic or crop simulation models) [5]. To address the scale problem and meet the need for regional information, downscaling seasonal forecast by using regional climate models (RCMs) became an emerging area during the last decade [5–7].

Several studies around the world have demonstrated the potential advantages of using RCMs to downscale coarse resolution climate predictions [e.g., 1,8–15]. Although

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   Operational Flood Forecasting, Warning and Response for Multi-Scale Flood Risks in Developing Cities María Carolina Rogelis,2020-04-22 The aim of this book is to contribute to understanding risk knowledge and to forecasting components of early flood warning particularly in the environment of tropical high mountains in developing cities This research covers a challenge taking into account the persistent lack of data limited resources and often complex climatic hydrologic and hydraulic conditions In this research a regional method is proposed for assessing flash flood susceptibility and for identifying debris flow predisposition at the watershed scale An indication of hazard is obtained from the flash flood susceptibility analysis and continually the vulnerability and an indication of flood risk at watershed scale was obtained Based on risk analyses the research follows the modelling steps for flood forecasting development Input precipitation is addressed in the environment of complex topography commonly found in mountainous tropical areas A distributed model a semi distributed model and a lumped model were all used to simulate the discharges of a tropical high mountain basin with a p ramo upper basin Performance analysis and diagnostics were carried out in order to identify the most appropriate model for the study area for flood early warning Finally the Weather Research and Forecasting WRF model was used to explore the added value of numerical weather models for flood early warning in a p ramo area   *Recent Advances in Intelligent Information Systems and Applied Mathematics* Oscar Castillo,Dipak Kumar Jana,Debasis Giri,Arif Ahmed,2020-01-31 This book describes the latest advances in intelligent techniques such as fuzzy logic neural networks and optimization algorithms and their relevance in building intelligent information systems in combination with applied mathematics The authors also outline the applications of these systems in areas like intelligent control and robotics pattern recognition medical diagnosis time series prediction and optimization of complex problems By sharing fresh ideas and identifying new targets problems it offers young researchers and students new directions for their future research The book is intended for readers from mathematics and computer science in particular professors and students working on theory and applications of intelligent systems for real world applications   **High Performance Computing in Science and Engineering '14** Wolfgang E. Nagel,Dietmar H. Kröner,Michael M. Resch,2015-02-14 This book presents the state of the art in supercomputer simulation It includes the latest findings from leading researchers using systems from the High Performance Computing Center Stuttgart HLRS The reports cover all fields of computational science and engineering ranging from CFD to computational physics and from chemistry to computer science with a special emphasis on industrially relevant applications Presenting findings of one of Europe s leading systems this volume covers a wide variety of applications that deliver a high level of sustained performance The book covers the main methods in high performance computing Its outstanding results in achieving the best performance for production codes are of particular interest for both scientists and engineers The book comes with a wealth of color illustrations and tables of results   *Monitoring and Prediction of Tropical Cyclones in the Indian Ocean and Climate*

Change U.C. Mohanty,M. Mohapatra,O.P. Singh,B.K. Bandyopadhyay,L.S. Rathore,2013-10-12 This book deals with recent advances in our understanding and prediction of tropical cyclogenesis intensification and movement as well as landfall processes like heavy rainfall gale wind and storm surge based on the latest observational and numerical weather prediction NWP modeling platforms It also includes tropical cyclone TC management issues like early warning systems recent high impact TC events disaster preparedness assessment of risk and vulnerability including construction archiving and retrieval of the best tracking and historical data sets policy decision etc in view of recent findings on climate change aspects and their impact on TC activity The chapters are authored by leading experts both from research and operational environments This book is relevant to cyclone forecasters and researchers managers policy makers graduate and undergraduate students It intends to stimulate thinking and hence further research in the field of TCs and climate change especially over the Indian Ocean region and provides high quality reference materials for all the users mentioned above for the management of TCs over this region **Meteorological Tsunamis: The U.S. East Coast and Other Coastal Regions** Ivica Vilibić,Sebastian Monserrat,Alexander B. Rabinovich,2014-11-16 The book encompasses a set of papers on meteorological tsunamis covering various aspects on this rare but potentially destructive multiresonant phenomenon Altogether an editorial and 15 contributions are part of this book eight of the contributions deal with different aspects of meteotsunamis along the U S East Coast and in the region of the Great Lakes including one paper introducing a new methodology in meteotsunami research Seven more papers are documenting meteotsunamis in various coastal areas of the world oceans All continents except Antarctica have been covered with the authors representing 11 countries Previously Published in Natural Hazards Volume 74 No 1 2014 Encyclopedia of Atmospheric Sciences ,2025-11-15 Encyclopedia of Atmospheric Sciences Third Edition offers comprehensive insights into the role of the atmosphere in weather climate and life It covers all principal processes and phenomena including intensive measurement and simulation techniques used to predict weather project climate change and assess human impacts on the atmospheric environment The past decade has seen rapid advancements in the atmospheric sciences necessitating the inclusion of several new topics in this updated edition The book highlights key areas of progress such as anthropogenic climate change high resolution numerical modeling and the use of machine learning and AI in forecasting and climate simulation It also covers advances in observational technologies and the study of planetary atmospheres providing multimedia animations of weather phenomena and model simulations to enhance understanding Geoengineering as a controversial yet significant subject is also addressed within the broader scope of climate change topics With over 280 chapters written by world experts in the field Encyclopedia of Atmospheric Sciences 3rd edition once again provides students and researchers with a comprehensive one stop reference work covering the entire field Around 280 chapters written by world leading experts in atmospheric sciences Provides current and comprehensive treatment of all aspects of the atmospheric sciences linking fundamental science to applications Presents in depth coverage of topics relating

to climate change arguably the most important environmental issue confronting humanity Helps readers navigate the breadth of atmospheric science ranging from physics and fluid dynamics to chemistry and interactions with biological and human systems Includes new topics on anthropogenic climate change high resolution numerical modeling new observational technologies and planetary atmospheres **The Adaptation to and Mitigation of Climate-Sensitive Natural Hazards** Diandong Ren,Gen Li,Mervyn Lynch,Anning Huang,Bo Lu,2022-11-29 *Meetings Abstracts* ,2006 Abstracts from the ... Conference on Great Lakes Research ,2007 Journal of Hydrometeorology ,2007 **Lagrangian Modeling of the Atmosphere** John Lin,Dominik Brunner,Christoph Gerbig,Andreas Stohl,Ashok Luhar,Peter Webley,2013-05-28 Published by the American Geophysical Union as part of the Geophysical Monograph Series Volume 200 Trajectory based Lagrangian atmospheric transport and dispersion modeling has gained in popularity and sophistication over the previous several decades It is common practice now for researchers around the world to apply Lagrangian models to a wide spectrum of issues Lagrangian Modeling of the Atmosphere is a comprehensive volume that includes sections on Lagrangian modeling theory model applications and tests against observations Published by the American Geophysical Union as part of the Geophysical Monograph Series Comprehensive coverage of trajectory based atmospheric dispersion modeling Important overview of a widely used modeling tool Sections look at modeling theory application of models and tests against observations *Mausam* ,2006 *2005 Joint Assembly* American Geophysical Union. Joint Assembly,2005 Quantitative Precipitation Forecast Sensitivity to Microphysics Parameterization and Sea Surface Temperature Source Over North Carolina During Two Cold Season Events ,2004 In the southeastern United States some of the most dramatic model quantitative precipitation forecast QPF failures in recent years have been associated with winter precipitation events For example the Eta model predicted nearly three inches of total liquid equivalent precipitation over most of central and eastern North Carolina for 2 3 December 2000 while less than 0 10 in 2 54 mm of liquid equivalent precipitation actually fell over the majority of central North Carolina While the over prediction of precipitation for the 21 22 January 2003 event was not as significant the predicted precipitation nevertheless might have led to a higher impact case if it had verified Despite a forecasted liquid cloud with cloud top temperatures warmer than 15 C the Eta model produced excessive QPF for both cold season events The purposes of this study are i to determine whether sea surface temperature data source 1 by 1 weekly Reynolds SST vs 1 27 km CoastWatch daily SST could have significantly impacted the 2 3 December 2000 QPF ii to test sensitivities associated with the Ferrier microphysics scheme by studying the effects of various ice nucleation and total glaciation temperatures on QPF and iii to investigate sensitivity of QPF to sea surface temperature data and to choice of microphysics scheme to determine which change yields a more significant contribution to QPF differences In an effort to understand why the Eta model over predicted precipitation in the 2 3 December 2000 and 21 22 January 2003 winter events sensitivity tests were conducted using the Weather Research and Forecasting model WRF These sensitivity studies included testing the QPF differences due

to choice of microphysics parameterization scheme and to choice of sea surface temperature SST data source for the 2 3 December 2000 case while only the sensitivity of QPF to choice of microphysics parameterization scheme was tested for the 21 22 January 2003 case It was hy **New Permafrost and Glacier Research** Max I. Krugger,2009 In geology permafrost or permafrost soil is soil at or below the freezing point of water 0 C or 32 F for two or more years Ice is not always present as may be in the case of nonporous bedrock but it frequently occurs and it may be in amounts exceeding the potential hydraulic saturation of the ground material Most permafrost is located in high latitudes i e land in close proximity to the North and South poles but alpine permafrost may exist at high altitudes in much lower latitudes The extent of permafrost can vary as the climate changes Today approximately 20% of the Earth s land mass is covered by permafrost including discontinuous permafrost or glacial ice A glacier is a large slow moving mass of ice formed from compacted layers of snow that slowly deforms and flows in response to gravity and high pressure The word glacier comes from French via the Vulgar Latin glacia and ultimately from Latin glacies meaning ice Glacier ice is the largest reservoir of fresh water on Earth and second only to oceans as the largest reservoir of total water Glaciers cover vast areas of polar regions are found in mountain ranges of every continent and are restricted to the highest mountains in the tropics The processes and landforms caused by glaciers and related to them are referred to as glacial The process of glacier growth and establishment is called glaciation Glaciers are sensitive monitors of climate conditions and are crucial to both world water resources and sea level variation This book presents the latest research on both permafrost and glaciers *The Sensitivity of Tropical Cyclone Simulations in the WRF Model to Surface Layer and Planetary Boundary Layer Parameterization* ,2003 The high wind speeds found in tropical cyclones fundamentally change the physical processes by which heat moisture and momentum are transferred between the ocean and the lower atmosphere Despite this fact surface and boundary layer parameterization schemes in many numerical models that are frequently used for tropical cyclone simulations are based on assumptions made in more tranquil atmospheric conditions Limited observations in the high wind speed conditions found in strong tropical cyclones suggest that spray and foam can enhance the transfer of heat and moisture from the ocean to the atmosphere while reducing drag Inclusion of the effects due to sea spray in a numerical model leads to stronger tropical cyclones Wang et al 2001 Perrie et al 2005 Based upon the absence of sea spray effects and the values of the exchange coefficients in the WRF model it was anticipated that simulations using an idealized vortex and ambient environment would not reach the thermodynamically estimated theoretical maximum intensity MPI limit of Emanuel 1986 In addition it was expected that simulations of Hurricane Ivan would not reach the intensity of the observed storm The sensitivity of the model results to surface layer and PBL parameterization and model grid spacing was tested with the hypothesis that the simulated tropical cyclones would remain weaker than MPI theory for the idealized simulations or observations for the Hurricane Ivan studies regardless of the model physical parameterization choice Grid spacing was also hypothesized to impact the simulated TC intensity with the

expectation that simulations with smaller grid spacing would produce more intense TCs based on the results of previous studies Simulated TC intensity is found to be highly sensitive to model grid spacing in experiments with Hurricane Ivan or with an idealized initial vortex Simulations using 4 km grid spacing were able to produce TCs that exceeded the MPI of the idealized envi   A Comprehensive Sensitivity Analysis of the Weather Research and Forecasting Modeling System Over Southern Ontario, Canada Md Mostofa Kamal,2017 Every year weather events cause billions of dollars property damage and take many lives globally Preventing as much damage as possible is crucial and one way to help is through having the most accurate advance warning of extreme weather events Therefore this thesis investigates the sensitivity of precipitation temperatures and surface energy fluxes i e sensible heat flux SHF latent heat flux LHF and ground heat flux GHF in four cumulus cloud CU five cloud microphysics MP and four planetary boundary layer PBL parameterization schemes over five years 2002 2007 2008 2014 and 2015 with significantly different climatological atmospheric conditions horizontal grid spacing two seasons winter and summer and feedback between the nest and its parent domain using the dynamical downscaling technique of the Weather Research and Forecasting WRF model The main objectives are 1 to identify a combination of physics schemes that realistically reproduce observed atmospheric conditions and 2 to improve current understanding of factors influencing the micro climate of southern Ontario a region of complex land water atmosphere interactions Ontario is also the most populous province and the largest manufacturing hub of Canada WRF simulated precipitation and temperature agree well with DAYMET model gridded observations with correlation coefficients of nearly 0 3 to 0 8 and 0 9 respectively Precipitation showed an average systematic bias for July of 50 to 30 mm and for January of 10 to 30 mm The simulated precipitation was more sensitive to CU and PBL schemes WRF simulated temperatures showed good reproducing skill with biases within the range of 1 0 C to 1 0 C in most parts of the domain Model predicted temperature was quite sensitive to PBL and MP schemes Model simulated precipitation variability increased when the horizontal grid resolution was refined from 8 0 to 2 67 km However simulated temperature variability decreased Overall the model performed better in the 2 67 km resolution simulation than in the highest resolution simulations with grid spacing of 0 888 km an unexpected finding that suggests the need for carefully designed high resolution dynamical downscaling experiments WRF s limitation to capture all variation that may occur at a resolution of 1 km particularly of precipitation in mountainous areas may result from uncertainties in our understanding of the climate and our inability to parameterize sub grid scale processes realistically WRF reproduced the diurnal variability of the SHF very well but systematically overestimated LHF compared to eddy covariance EC tower measurements for June of 2007 and 2008 For the interior of all three domains in July 2002 spatial distribution was overestimated for SHF and underestimated for LHF with biases ranging from 30 to 30 W m2 over most of the area when compared to the North America Land Data Assimilation System NLDAS model gridded analysis WRF showed little sensitivity to the choice of PBL scheme except for January 2002 s LHF the hottest January of the five

studied If forced with distinctively different annual climatological boundary conditions such as extreme cold in January 2014 and below average temperatures in January 2015 the model s simulated spatial distribution of energy flux bias indicates behavior that clearly differs from NLDAS analysis A large energy flux bias occurs over the smaller shallow northern lakes perhaps due to incorrect representation of their water temperatures Overall the Kain Fritsch KF CU Yonsei University YSU PBL and WRF Single Moment 6 class WSM6 microphysics parameterization schemes exhibit superior results over the domain studied The WRF model shows a high skill score over southern Ontario while reproducing observed climate means and statistics Nevertheless the model s performance depends on the meteorological variables season and synoptic conditions The Great Lakes strongly influence atmospheric conditions in southern Ontario by affecting precipitation and surface temperatures ranging from the diurnal to the seasonal timescales These results affirm the need for extensive sensitivity analysis for both research and operational applications However the findings are limited by the shorter spin up time and by having only one month simulation although WRF ran for a month in both the winter and summer over multiple years

Impacts of Physical Parameterization Schemes and Soil Moisture Initialization on Boundary Layer Evolution in the Weather Research and Forecasting (WRF) Model Grace M. Cutting,2022 Numerical weather prediction NWP models have become a necessary addition to the atmospheric research community over the last several decades and atmospheric modeling has been used internationally for numerous operational and research purposes NWP models contain a vast number of combinations of physical and dynamical parameterization schemes however they are not always accurate in forecasting weather phenomena at a particular location as different combinations of parameterization schemes represent differing conditions Weather Research and Forecasting WRF model simulations were run to explore which of the commonly used planetary boundary layer PBL schemes best represented upper air data as well as PBL evolution over northeastern Colorado southeastern Wyoming southwestern Nebraska and northwestern Kansas Additionally errors in soil moisture initialization were investigated to determine if there was an impact on boundary layer evolution Based on model soundings the Grenier Bretherton McCaa GBM scheme was the most representative of this region in terms of the overall PBL structure and there was no evidence to suggest that errors in soil moisture initialization impacted boundary layer evolution but rather the choice in surface layer scheme tended to influence the modeled boundary layer when paired with specific PBL schemes

Modeling the Sensitivity of the February 22-23, 2017 Winter Storm to Microphysics Parameterization and Microphysics Processes Over Colorado and Wyoming Ethan Collins,2019 Accurate weather forecasts are crucial to the profitability of industry in the United States such as the transportation of goods across the country via semi trailer trucks air travel recreation activities etc This topic is of particular concern over the state of Wyoming as wintertime weather forecasts are often prone to error Wyoming not only has a sparse network of surface and upper air observations but also complex terrain that cannot be properly represented in regional numerical models Model forecast errors can have a substantial impact on the

ability to issue advisories and close highways if necessary We focus on improving our understanding of why regional numerical weather prediction NWP models often fall short of predicting accurate snow totals via a case study of an event that occurred on February 22 24 2017 High resolution simulations are run using the Weather Research and Forecasting WRF model Four different microphysics parameterizations are utilized in this study Thompson Morrison two moment Predicted Particle Properties P3 and the WRF Single Moment 6 Class Scheme The coupling between cloud properties and radiation as well as the role of latent heat release due to individual microphysical processes are also explored The simulated precipitation is compared with both Snow Telemetry SNOTEL and Parameter elevation Relationships on Independent Slopes Model PRISM to quantify model errors and improvements using higher resolution simulations and advanced microphysical parameterizations The results support past studies that suggest a dependency exists regarding the choice of microphysics parameterization and resolution over this region All of the parameterizations utilized in this study overpredict snowfall accumulation no clear bias as a function of altitude is identified The coupling between the cloud microphysics and radiation is also found to have a minimal impact on storm strength storm track and snowfall amounts Lastly certain microphysical processes and the resultant latent heating are found to affect the storm characteristics No cooling due to sublimation and no warming due to deposition have the largest influences on snowfall accumulation and cyclone track No cooling due to sublimation was found to decrease negative buoyancy production resulting in deeper clouds and more snowfall accumulation While no warming due to deposition was found to reduce buoyancy production deeper clouds and thus less snowfall accumulation Furthermore reducing ice fall speeds by 50 % was found to increase snowfall accumulation while increasing ice fall speeds by 50 % was found to decrease snowfall accumulation   *Characterizing the Effect of Increasing Albedo on Urban Meteorology and Air Quality in Cold Climates, a Case Study for Montreal* Ali Gholizadeh Touchaei,2015 The higher temperature of urban areas compared to their surrounding rural areas is called urban heat island UHI UHI during summer may harm inhabitants and aggravate cooling energy demand Increasing urban albedo is proposed to counter the undesirable impacts of UHI To analyze the effect of albedo enhancement on urban climate land atmosphere interactions and various physical processes in the atmosphere and on the land should be modeled Weather Research and Forecasting WRF model urban canopy model UCM building energy model BEM and chemical transport model CHEM are coupled to accurately investigate the effect of an increase in the urban albedo To select appropriate models sensitivity of near surface air temperature and near surface wind velocity to the choice of parameterization is evaluated Montreal and Toronto as the two most populated Canadian cities are selected for evaluation of UCMs and an increase in the urban albedo Seasonal performance of the increase in albedo of roofs walls and road by 0 45 0 4 and 0 25 respectively results in an average decrease of 0 25 C during summer and a negligible effect during winter

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