DTC Project report I

The Role of Low-Level Jets in the Cold Air Damming Events using high-resolution Advanced Research WRF model

Thara Prabhakaran and Gerrit Hoogenboom

Department of Biological and Agricultural Engineering, The University of Georgia

in collaboration
with

Alan Norton, NCAR

Introduction

Cold-air damming (CAD) is typically associated with high-pressure scenarios that are conductive for the development of the low-level jets and very stable boundary layers. Cold-air damming (CAD) event during 27th Feb – 6rd March 2009 was selected for the study. First half of the study period characterized the passage of the cold front and associated rain events. During the second half, cold air dammed period showed high pressure situations with diurnal oscillation of surface pressure and temperature at higher amplitude. The study is carried out in two parts; focus in first part is on the rainfall verification and the second part is on the prediction of near surface atmospheric variables relevant for frost assessment, where low-level jets associated with cold air damming and its extension southward also play a significant role in the persistence of cold pool. In both situations, jets play a crucial role in the moisture transport

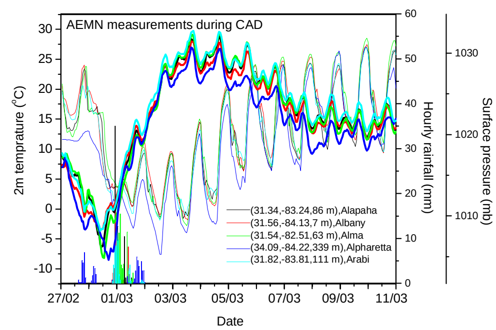


Figure 1. AEMN observations of 2m temperature (thin line), rainfall (vertical bars) and surface pressure (thick lines) Latitude, longitude and elevation are given selected stations

This preliminary report gives an overview of different results and the work that is underway for this case. Data sets used for verification include Georgia automated weather monitoring network (AEMN; www.Georgiaweather.net) with over 75 monitoring stations, and CMORH rainfall dataset.

Model configuration:

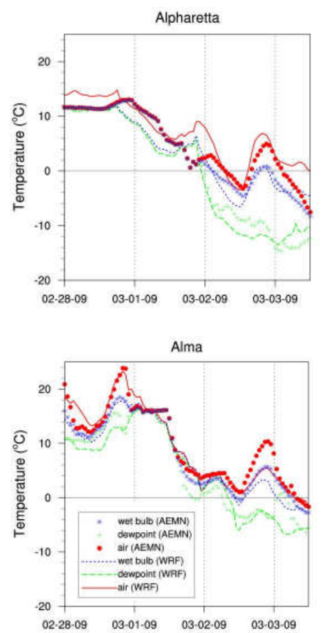
PBL: YSU, MYJ, QNSE, MYNN
Microphysics: Option 16, modified boundary condition, relaxation used at the boundary
Cloud: Kain-Fritsch scheme / CRM
LSM: Noah LSM
Radiation: Dudhia SW scheme, Rapid Radiative Transfer Model for LW
Surface Layer: different for PBL schemes
Domains: 3 km nested inside 9km
Input: NAM 12 km CONUS 3 hourly update for outer boundary
Time: starting time 000 UTC on 28th Feb

a. Model evaluation using AEMN dataset for phase I (02-28-09 to 03-03-09):

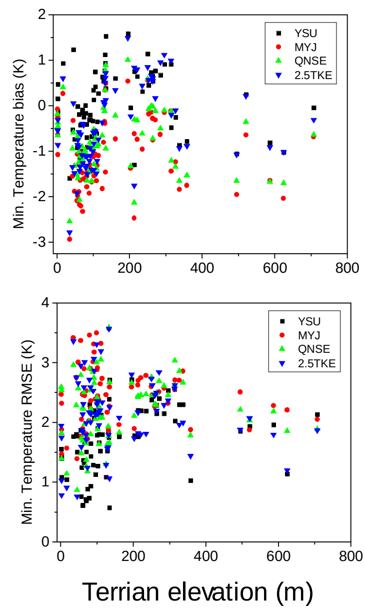
Objective: verification of surface parameters against AEMN observations
Dry bulb, wetbulb and dewpoint temperatures from AEMN and ARW during the frontal passage at Alpharetta (Northern) and Alma (Southern) location showed considerable

resemblance in reproducing their evolution. The northern location (along the slops) has a warm bias.

- The warm bias was consistently seen for minimum temperature, which was more pronounced for non-local PBL scheme and MYNN compared to other (MYJ and QNSE) local schemes with a cold bias. RMSE for YSU scheme was lowest for all locations. The local schemes gave rise to a minimum temperature bias of -1 to -3 K (RMSE of 3 K) at low lying locations.



A comparison (ARW (YSU) and AEMN) of dry bulb, wetbulb and dewpoint temperatures



Minimum temperature bias and RMSE as a function of AEMN station elevation

- Cold biases of -1 to -4.5 K were noticed for maximum temperature at most valley stations with local schemes. However, the non-local scheme provided slight warm biases for these locations. Spatial distribution of maximum temperature also showed warmer temperatures.
- Daily average mean temperature biases were generally less than 1.5 K with YSU scheme for all locations. However, the local schemes have a cold bias (0.5 to 2.5 K) at all locations. Errors were more pronounced for low lying southern locations.
- A maximum RMSE for mixing ratio was 2.5 gkg^{-1} for low lying locations were noticed, irrespective of the schemes. Mixing ratio RMSE reduced to 0.5 gkg^{-1} at higher elevations.

b. Effect of vertical resolution/domain

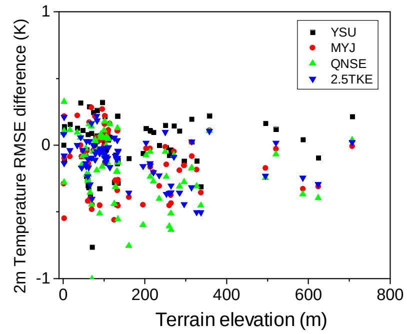
Two model configurations are used in this analysis. The vertical resolution in the boundary layer was kept such that lowest level is at 7 m above the surface and in othercase, lowest level is at 12 m.

- There is a little (0.25 K) reduction in the RMSE of temperature for MYNN scheme while using a higher vertical resolution in a large domain.

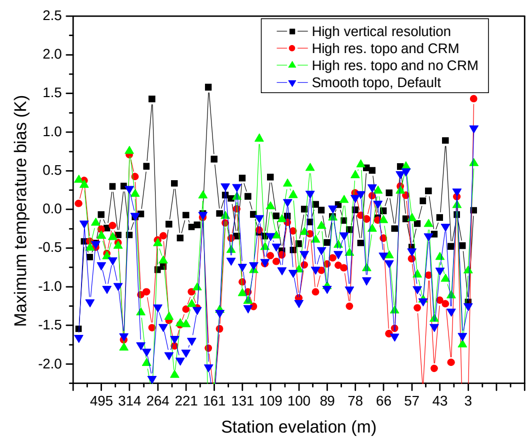
- If vertical resolution is improved in a smaller domain, 2m temperature RMSE for local scheme has decreased (upto 0.5 K). However, errors in 2m level water vapor mixing ratio were not improved.

- Use of higher vertical resolution with YSU PBL (no w damping) has reduced the cold bias in maximum temperature.

- Use of high resolution topography / a CRM simulation did not improve the maximum temperature biases.



RMSE difference (for average temperature) between the high resolution and low resolution runs for different PBL physics

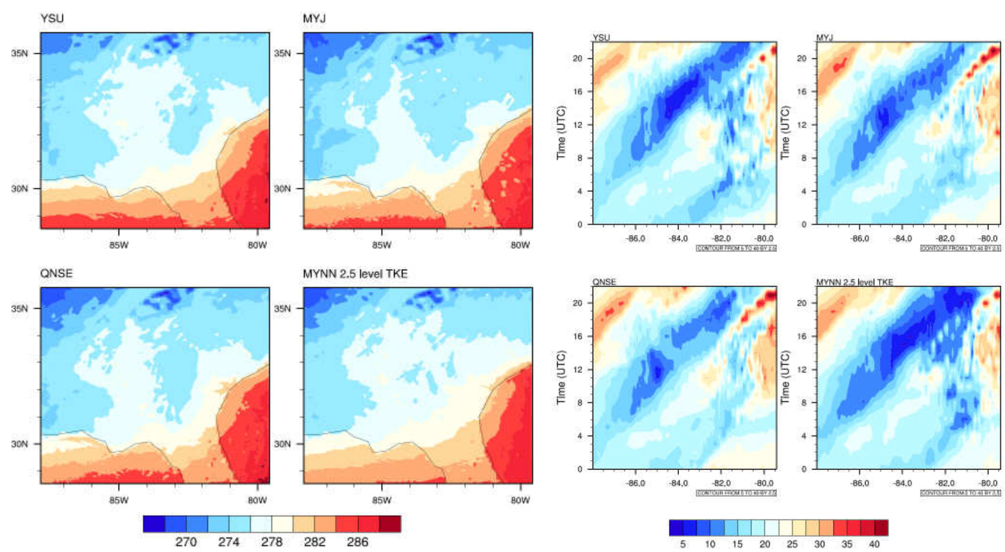


A comparison of maximum temperature bias at different AEMN stations using various model configurations of vertical resolution, topographic height smoothing, all using YSU PBL

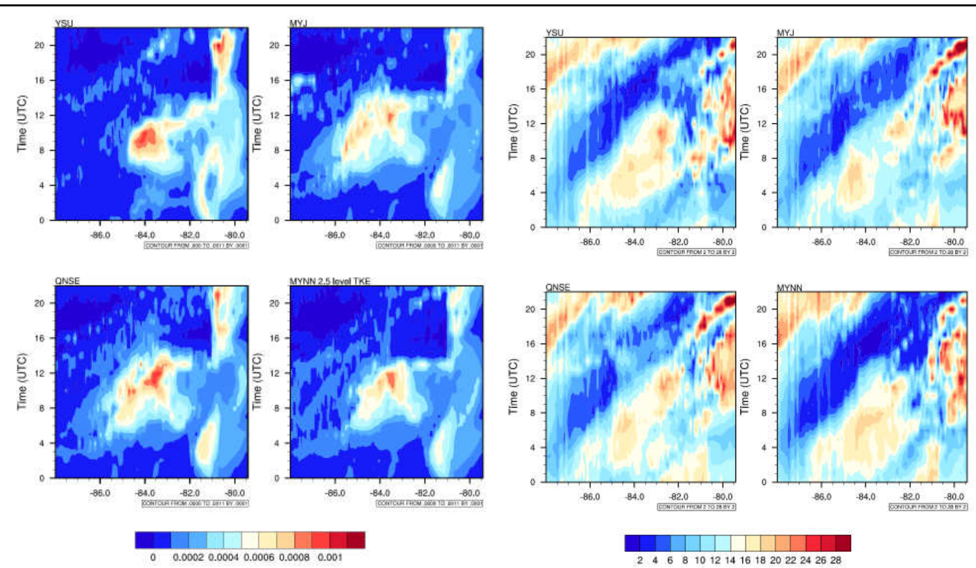
b. Low-level jet

Spatial distribution of minimum temperature on Feb 28th 2009 from four PBL schemes showed differences along the east side of Appalachian mountain, MYNN has much warmer temperatures along the region between the coastal and high mountainous areas. MYNN also characterized a weak low-level jet that was prevalent over the area. The jet propagated eastward along the Appalachian with time

The PBL schemes have a crucial role in the prediction of cold pool as demonstrated here, the dynamics of which is closely related to LLJ evolution in the model.



Distribution of minimum temperature at 1000 UTC and evolution of LLJ from four PBL schemes



Temporal evolution of surface layer stability and jet shear along the transect shows presence of strongly stable conditions and strong shear.

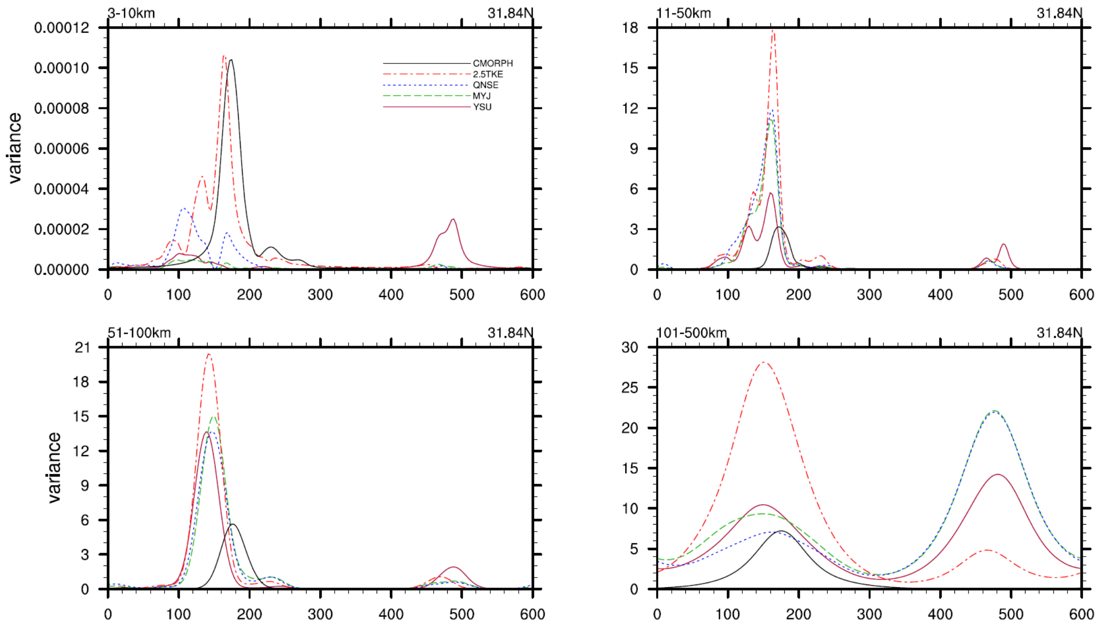
Strongly stable region existed over central Georgia and along coastal areas in all four PBL simulations. The extension of stable region is quite different in the four simulations. YSU scheme showed a much localized area with strong stability, while all local schemes showed wide areas with strong stability.

b. Rainfall during the cold front associated with CAD

-Develop wavelet based verification for spatial/temporal evaluations

-Evaluate the impact of PBL schemes on rainrates with and without a Cloud Resolving Model

-evaluate the impact of high resolution terrain and vertical spacing.



A wavelet spectral decomposition of rainfall variance using four PBL schemes in domain 2 at 3 km resolution, compared with CMORPH rainfall variance for respective close to a southern station Arabi.

A wavelet transform is used to develop a scale-dependant, spatio-temporal evaluation of the rainfall forecast against observations from the CMORPH dataset.

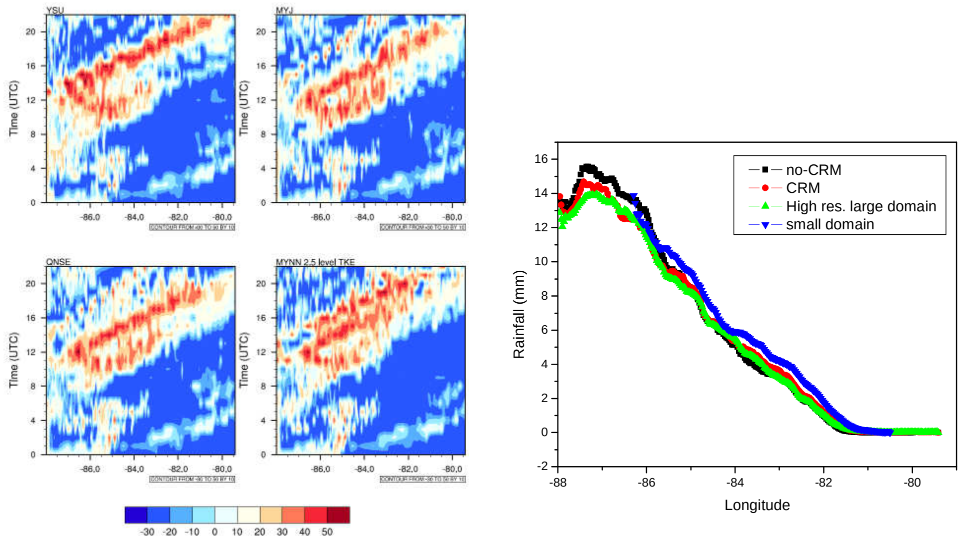
The analysis showed two main findings

1) All models have predicted small scale rain events that were not observed. This seems to be associated with shallow convection, but needs further analysis based on the cloud characteristics and intercomparisons.

2) Large scale variance in YSU is lowest, like in the observations and all local schemes produced more variance at small scale, which is closer to observations.

A rainfall verification using MET Wavelet tool is underway.

The radar reflectivity echoes from the model during 4 UTC were very similar between four PBL schemes. However, the main patterns of reflectivity associated with the front and high rainrate (>30 dB) appeared earlier (12 UTC) in all local PBL schemes



Radar reflectivity (dB) calculated for a transect over Georgia showed the propagation of the frontal system. Average rainfall along E-W transects at 1200 UTC.

- Local schemes produced more rainfall compared with YSU and a significant difference between the convective complexes is noted.
- CRM simulation produced more rainfall compared to a similar YSU PBL configuration without CRM. The difference between the (CRM-noCRM) was maximum while QNSE PBL was used.