Evaluation and Adaptation of a Regional Climate Model for the Horn of Africa: Rainfall Climatology and Interannual Variability

Zewdu T. Segele[1], Lance M. Leslie[2], and Peter J. Lamb[1, 2]

[1]Cooperative Institute for Mesoscale Meteorological Studies/[2]School of Meteorology
The University of Oklahoma, Norman, OK 73072 (zewdu@ou.edu)

1. Introduction

Regional climate models (RCMs) increasingly are being applied in various parts of the world to examine regional climate patterns and processes and to downscale seasonal climate predictions. This study evaluates the ability of the Abdus Salam International Center for Theoretical Physics (ICTP) version 3 RCM (RegCM3) to reproduce the observed rainfall amounts and distribution over the topographically varied region of the Horn of Africa.

2. Simulation & Validation Data

- **Design and Data:**
  - 60-km horizontal grid resolution, 18 vertical levels, and 3 minute integration time step
  - NCEP/NCAR Reanalysis and OISST for initial and boundary conditions
  - CMAP, CRU, and Ethiopian station rainfall for verification
- **Simulation:**
  - Two-month integration for Dry (1984) and Wet (1996) seasons for convective scheme adaptation
  - 18 years (June-September, 1982-99) integration using modified Emanuel scheme for climatology

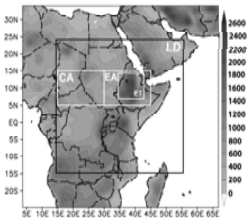

Fig. 1. Model domain showing national boundaries (thick broken lines), surface elevation (m), and subregions for statistical evaluation of model performance.

3. Convective Scheme Dependence

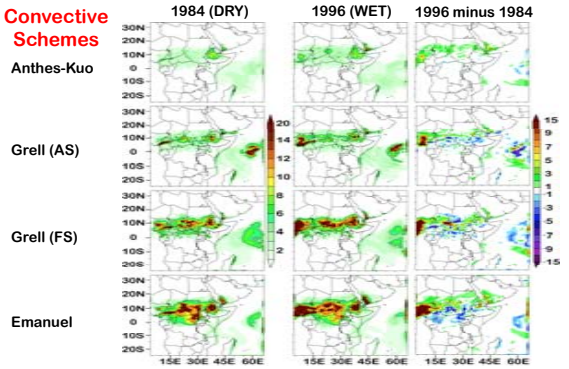

Fig. 2. July–August simulated rainfall rates (mm d^{-1}) using different convective schemes (rows) for dry 1984 (left) and wet 1996 (middle), and their difference (1996 minus 1984; right). AS (Arakawa–Schubert) and FC (Fritsch–Chappell) denote the closure assumptions used in the Grell scheme.

Conclusions

- Default Emanuel convective scheme showed closer correspondence with observations than the Kuo and Grell schemes, but it excessively overestimated rainfall over the Horn of Africa.
- Rate of convective mass flux adjustment, fraction of condensed water, and heating and moistening characteristics of the environment control the amount of simulated rainfall over Ethiopia.
- The correlation between the modified Emanuel-simulated and Ethiopian station rainfall is strong (+0.66).

4. Sensitivity Experiments (Control)

	Ex. I		Ex. II	Ex. III	Ex. IV	
	Σ_d	σ_s	α	l_o	α	l_o
Default	0.05	0.12	0.2	0.0011	0.2	0.0011
Run 1	0.05	0.15	0.0002	0.0001	0.02	0.008
Run 2	0.01	0.015	0.002	0.002	0.02	0.010
Run 3	0.05	0.10	0.02	0.004	0.06	0.004
Run 4	0.01	0.10	0.06	0.008	0.06	0.008
Run 5	-	-	0.8	0.01	0.10	0.010
Run 6	-	-	-	0.05	0.30	0.010

Table I. Values of key Emanuel scheme parameters/processes used in sensitivity experiments. σ_d is fractional area of unperturbed environmental air occupied by unsaturated downdraft, σ_s is fraction of precipitation falling outside of cloud, α is a relaxation rate, and l_o is warm cloud autoconversion threshold.

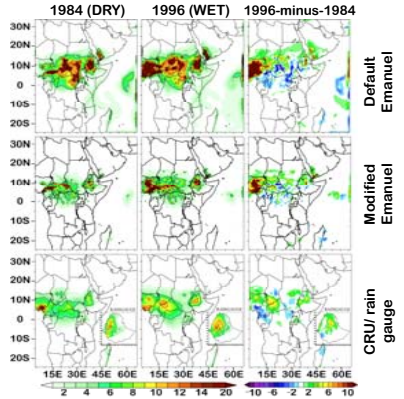

Fig. 3. July–August simulated (top and middle rows) and observed (bottom) rainfall rate (mm d^{-1}) for 1984 (left column), 1996 (middle), and their 1996 minus 1984 difference (right). Domain-wide observed rainfall patterns are from CRU data, with inset giving observed station rainfall rates for the northern two-thirds of Ethiopia.

5. Model Climatology

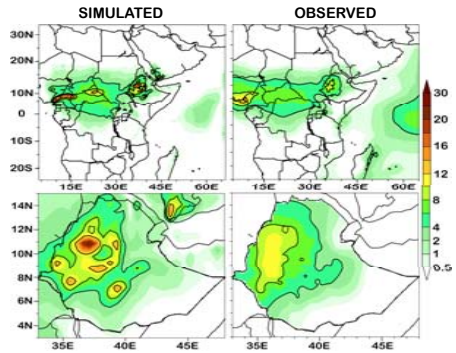

Fig. 4. Average June–September simulated (left, modified Emanuel, Experiment III, run 5) and observed (right) rainfall rates (mm d^{-1}) for 1982–1999 for eastern Africa–western Indian Ocean sector (top) and Ethiopia (bottom). Bottom simulation is an enlargement of top simulation for Ethiopia. Observed patterns are from CRU (land) plus CMAP (ocean) data in top panel, and Ethiopian rain gauge data for entire country (121 stations) in bottom panel.

6. Interannual Variability

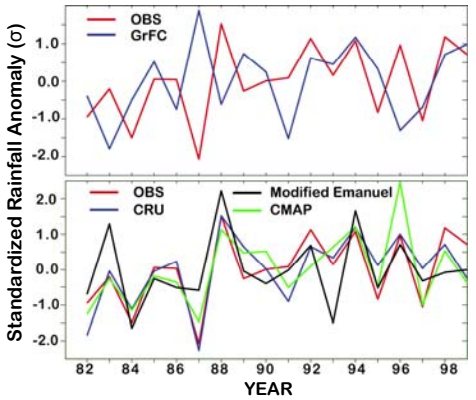

Fig. 5. Interannual variations of Ethiopian June–September standardised rainfall rate anomalies (σ) for 1982–99. (top) Modeled with the standard default Grell convective scheme (GrFC; blue) and rain gauge (red). (bottom) Rain gauge (red), CRU (blue), CMAP (green), and modeled with modified Emanuel convective scheme (Experiment III, Run 5; black).

Reference:
Segele, Z. T., L. M. Leslie, and P. J. Lamb, 2009: Evaluation and adaptation of a regional climate model for the Horn of Africa: Rainfall climatology and interannual variability. International Journal of Climatology, 29, 47-65.

Acknowledgments:
This research was supported by the NOAA Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) and the International Activities Office of the U.S. National Weather Service through NOAA Grant NA17RJ1227.