#### Simulation of the West African Monsoon using the MIT RCM & Its Application to Irrigation Sensitivity Study

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#### **RegCM3 Upgraded by MIT Eltahir Group**

	New Features	Key References
New Land Surface Scheme	Integrated Biosphere Simulator (IBIS)	Winter et al. (2009)
	New surface albedo assignment	Marcella (2012), Marcella and Eltahir (2012)
<b>Modified Emanuel</b> <b>Convection Scheme</b>	New convective cloud scheme	Gianotti (2012), Gianotti and Eltahir (2013a)
	New convective rainfall autoconversion scheme	Gianotti (2012), Gianotti and Eltahir (2013b)
	Modified boundary layer height and boundary layer cloud scheme	Gianotti (2012), Gianotti and Eltahir (2013c)

MIT Regional Climate Model (MRCM)

#### Simulation of the West African Monsoon

: Focus on the effect of land surface & convection schemes

- Resolution: 50km
- Integration Period: 1989-2008 (20yr)
- Initial & Boundary Condition
  - : ERAInterim (1.5deg)
- Sub-domain for area-average validation
  - A: Guinea Coast
  - ▷ B: Sahel
  - C: Northern Africa



	Land surface scheme	Convection scheme
IGF	IBIS	Grell FC
BSE	BATS	Standard Emanuel
ISE	IBIS	Standard Emanuel
IME	IBIS	Modified Emanuel
MIT Regional Climate Model (MRCM)		

# **JJA Rainfall Spatial Pattern**



# **Rainfall Monthly Variation**





#### Latitude-Time Cross-section of Rainfall



#### Latitude-Time Cross-section of Net Radiation











#### **Surface Albedo**



SRB



ISE



IME



# Summary

- The simulation of the WAM exhibits a strong sensitivity to the choice of both land surface scheme and convection scheme.
- The improvement in the spatial and temporal distribution of rainfall in simulations using IBIS, rather than the default BATS scheme, is significant.
- In addition, the modifications incorporated within MRCM with respect to convective cloud cover, autoconversion and boundary layer characteristics significantly improved the simulation of rainfall.

- The MRCM represents a significant improvement over previous versions of this model that attempted to simulation the West African Monsoon.
  - The MRCM is capable of reproducing the major features of the rainfall and dynamics of the West African monsoon.

#### Impact of Irrigation on the West African Monsoon

: Focus on the location dependency



# **Irrigation Module in IBIS**

- Static irrigated cropland biome added to IBIS
- Root zone soil moisture is forced to relative field capacity
- "Negative runoff" to supply water and conserve water balance
- Irrigation forcing
  - : Anomalous wet soil condition
- More details are in Marcella (2012)
   & Marcella and Eltahir (2013)



[Adapted by Marcella (2012)]

#### **Experiment Design**



desert open shrubland dense shrubland grassland savanna tropical evergreen tropical deciduous cropland temperate evergreen

### Rainfall Change (May-Sep)



### **Mechanism of Local Response**



#### **Convective Activity**

 Significant reduction of days with moist convection are found in the irrigated area.



# Rainfall Change (May-Sep)



#### Local vs. Remote Response



### **Remote Effect**

# Black arrow : CONT monsoon flow Red gradient arrow: Anomalous flow



#### Schematic Diagram of Remote Mechanism



# Rainfall Change (May-Sep)



# Summary

- Using the MIT Regional Climate Model (MRCM) and its new scheme for irrigation in Integrated Biosphere Simulator (IBIS), we estimate the potential impact of irrigation on the West African Monsoon based on a control simulation with no irrigation and several simulations varying locations of irrigation.
- The local effect induced by strong surface cooling tends to decrease the rainfall over the irrigated fields itself. In spite of enhanced moist static energy and resultant higher CAPE, convective inhibition also occurs because the suppression of PBL height hinders strong enough updraft for the triggering of convection.
- In contrast, the remote effect shows a large sensitivity of rainfall change over the Guinean coast and Sahel region. The determinant is the geographical location of northeasterly outflows blowing off anti-cyclonic circulation induced by the anomalous descending motion over irrigated area.

This study highlights the sensitivity of induced land-atmosphere interactions in West Africa to the location and timing of the perturbations in land surface condition.



The ultimate goal is to gain further insight of the potential role of irrigation in shaping rainfall patterns over West Africa.

#### Thank you for your attention!!

E.-S. Im, R.L. Gianotti, and E.A.B. Eltahir, 2013: Simulation of the West African Monsoon using a Regional Climate Model. *J. Climate*, Under Review.

E.-S. Im, M.P. Marcella, and E.A.B. Eltahir, 2013: Impact of potential irrigation on the West African Monsoon and its dependence on location of irrigate area. *J. Climate*, Under Review.

# Latitudinal Dependency

- The latitudinal distribution of the zonally-averaged rainfall along 15W-0.
- The rainfall distribution shows a strong latitudinal dependency rather than longitudinal position.



# Geo. Height & Wind at 925hPa



 Higher pressure centered at irrigated area is associated with anomalous descending motion, leading to low-level divergence over the irrigated region. Theses low-level outflows result in anomalous anti-cyclonic circulation.

# **CAPE & CIN**

- The wet soil moisture is expected to lead to the higher moist static energy (as described θe) due to the increase of the total flux of heat from the land surface, and this results in an increase of the CAPE.
- Enhanced soil moisture simultaneously reduces PBL height due to evaporative cooling. The simulated reduction of the PBL height tends to inhibit convective triggering. Indeed, in spite of the higher moist static energy and CAPE, EXP4 results are dominated by the enhanced inhibition of convective triggering.

