Impact of Irrigation on Land Surface States and Fluxes

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Motivation

• Improved surface parameterization (skill)
  – Accurate soil moisture improves prediction skill of atmospheric models (Koster et al 2005)
  – River-GW withdrawals (Lohmann et al 2004)

• Surface-atmosphere feedback (impact)
  – Increased ET (Haddeland et al 2005)
  – Roughness and wind effects (Ozdogan et al 2006)
  – Precipitation (Moore and Rojstaczer, 2002)

• BUT, irrigation is rarely incorporated into LSMs
  – Lack of information on irrigation
  – Human impacts play secondary role
New Approach

• Implemented in Noah LSM
• Uses observed irrigated area and crop type datasets
• Based on the deficit irrigation concept
  – Compute irrigation requirements
  – Add to soil column
• Irrigation at sub-daily time step
• Improve land surface states
  – Soil moisture
  – Land surface temperature
• Fluxes
Irrigation Scheme

- **Trigger**: when to irrigate
- **Amount**: how much to irrigate
- **Method**: such as rain, spray, drip; & rate

**Moisture Availability**

\[
MA = \frac{(SM - SMWP)}{(SMFC - SMWP)}
\]

- SM: current root zone* soil moisture
- SMWP: wilting point
- SMFC: field capacity

- Threshold of 50% MA used
- *Current root zone varies based on greenness fraction
Irrigation Module

NLDAS forcing

crop types
& irrigated area

Noah LSM

SMD = PAW - SM

SMD > MA

Irrigate

yes

no

LC soils greenness albedo

crop types

irrigated area

Tile checks

MA <= Threshold

Compute the amount

Compute the rate and add to the precipitation between 6-10 AM

- 6 AM local time
- Non-forest, non-baresoil/urban tile
- Irrigation intensity > 0
- Growing season

Scale down the amount when irrigation % < Crop %

Expand irrigation to non-crop tile when irrigation % > Crop %

First to Grassland, then other tiles

50 % crop

20 % other

30 % forest

60 % irrigation

Irrigation Module
Crop type data

US Irrigation map

Developed at 500m resolution ca. 2002/2003

http://www.sage.wisc.edu/pages/datamodels.html

Ozdogan and Gutman (2008)
Experiments

- One year simulation (2003) - four runs
  - control (no crops) and explicit crop types
  - control (no irrigation+crops) and irrigated (with crops)

- Noah LSM
- NLDAS forcing
- 6 year spin-up (1996-2002)
- Sub-daily irrigation requirements
- Modified Noah vegetation parameter
  - Root and roughness length for crops
- Irrigation in the form artificial precipitation
  - No routing or GW negative discharge
- Irrigate only between 6 - 10 am local
  - Spread irrigation over time don’t allow runoff
Regions

West  Central  Eastern
Irrigation amount/timing

Area total irrigation amount (mm/day)

- Us total
- Eastern
- Central
- Western

2003

1/1 2/1 3/1 4/1 5/1 6/1 7/1 8/1 9/1 10/1 11/1 12/1
Annual Irrigation Amount

RMSE = 0.299 km³
bias = 0.012 km³

modeled irrigation [km³/year]

observed irrigation [km³/year]
Crop Experiment Results

19 Crops - No crop types Evapotranspiration % diff: Aug-Sep

19 Crops - No crop types Base Flow % diff: Aug-Sep

19 Crops - No crop types Sfc Runoff % diff: Aug-Sep

19 Crops - No crop types Soil Moist Layer 4 (kg/m²): Aug-Sep
Water balance components

Total irrigation amount (3) [mm/year]: 2003

Irrigation - Control Evapotranspiration (mm/day): Aug-Sep

Irrigation - Control Total Soil Moist % diff: Aug-Sep

Irrigation - Control Sfc Runoff (mm/day): Aug-Sep
Energy balance components

Irrigation - Control Latent heat flux (W/m²²) : Aug-Sep

Irrigation - Control Sensible heat flux (W/m²²) : Aug-Sep

Irrigation - Control Ground heat flux (W/m²²) : Aug-Sep

Irrigation - Control Net Radiation (W/m²²) : Aug-Sep
Point comparisons

- AMERIFLUX site at University of Nebraska Agricultural Research and Development Center @ 41.165N, 96.477W
- Irrigated with a center pivot system, continuous maize
- Temperate climate, annual total precipitation: 810-880 mm, mean temperature: 11.1 °C
- Elevation 361m
Point comparison-diurnal

Mead, NE

![Graph of Latent Heat Flux (LE) and Sensible Heat Flux (H) for Mead, NE in August 2003. The graphs show the diurnal variation of LE and H under control, irrigation, and observation conditions.](image)
Five Points, CA

- USDA research facility in the Southern San Joaquin Valley @ 36.34N, 120.11W
- Irrigated Grassland
- Elevation 87 m
- Lysimeter ET measurement

Latent Heat Flux (W/m²)

ET (mm/hr)

August, 2004

August, 2005
LST comparisons
California (above) &
Nebraska (left)

Irrigation improves predictions

GOES data courtesy of
Martha Anderson USDA
LST comparison

abs(model_irr - GOES) - abs(model_control - GOES)
Conclusions

• Irrigation changes soil moisture status that is not accounted for in current LSMs
• Irrigation can lead up to 100% increase in ET
• Similar reduction in sensible heat flux
• Presence of irrigation leads to improved surface temperature predictions
• The impact of these changes in SM, LST and fluxes on prediction skill of atmospheric models and boundary layer processes is not well known
• Irrigation should be incorporated in coupled models.
• LSM differences and how to tease out irrigation effects
• Source of water
  – Artificial precipitation
    • Assume water is available in the environment
  – Negative GW discharge
  – River withdrawals
    • Routing is still rudimentary
  – Irrigation canal routing
• irrigation \( \neq \) rate of infiltration
• Water source database (UNH)
• How to incorporate RS inputs
  – Transition dates
What is next?

- Irrigation module in other LSMs
- Use of observed (dynamic) crop parameters
- Water source issue
  - Use river routing and/or GW
- Global extent
- Coupled atmosphere-land runs to understand improvement/feedbacks
Thank you

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