Urban Model and Noah-MP

Development and Future Directions

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WRF Workshop

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Recent Model Development Focus

- Efficiency and usability
  - Some schemes, like urban and lake, have poor memory management and therefore can be of limited use
- Code consolidation
  - Model version proliferation
  - Different Noah-MP versions in multiple systems

Urban Memory Cleanup

DESCRIPTION OF CHANGES:

Multi-layer urban models pack 4D, 5D, and 6D arrays into 3D. The old code used one dimension (num_urban_layers) which depends on the largest 6D array. The new code creates separate mapping for the different urban arrays so that the arrays are maximally filled for each urban array.

Compared to the original code, the memory cost (relative to a non-urban run) of using UCM is reduced from 31% to 5%, BEP from 31% to 15% and BEM from 707% to 274%, equivalent to a 20%, 45% and 64% reduction in memory used, respectively.

When users run BEP or BEM and want to change urban model structure, the model will automatically adjust for memory efficiency.

num_urban_ndm: maximum number of street dimensions
num_urban_ng : number of grid levels in the ground
num_urban_nwr: number of grid levels in the walls or roof
num_urban_ngb: number of grid levels in the ground below building
num_urban_nf: number of grid levels in the floors
num_urban_nz: maximum number of vertical levels in the urban grid
num_urban_nbui: maximum number of types of buildings in an urban class

Push NWM Noah-MP mods to WRF

DESCRIPTION OF CHANGES:

Noah-MP code within WRF and the National Water Model has diverged. This pull request feeds NWM development back to WRF.

LIST OF MODIFIED FILES:
M phys/module_sf_noahmpdrv.F
M phys/module_sf_noahmplsm.F
M run/MPTABLE.TBL

- add unpopulated header required by NOAA
- add BATS parameters to data structure and output band snow albedo
- updating MPTABLE for BATS albedo parameters
- add bats albedo local variables to noahmpdrv
- transfer new bats table values to parameters data structure in noahmpdrv
- add RSURF_EXP parameter to data structure and update MPTABLE
- change snow water equivalent limit to 5000mm
- assume LAI is stand LAI and doesn't need to be rescaled by FVEG
- conserve snow pack heat when layer melts completely
- change output messages and Fortran open/read unit numbers to WCOSS

BEM Air Conditioning Flexibility

DESCRIPTION OF CHANGES:

Two urban parameter tables options are added to prescribe the fraction of building (BLDAC_FRC) and fraction of floors in a building (COOLED_FRC) that have air conditioning.

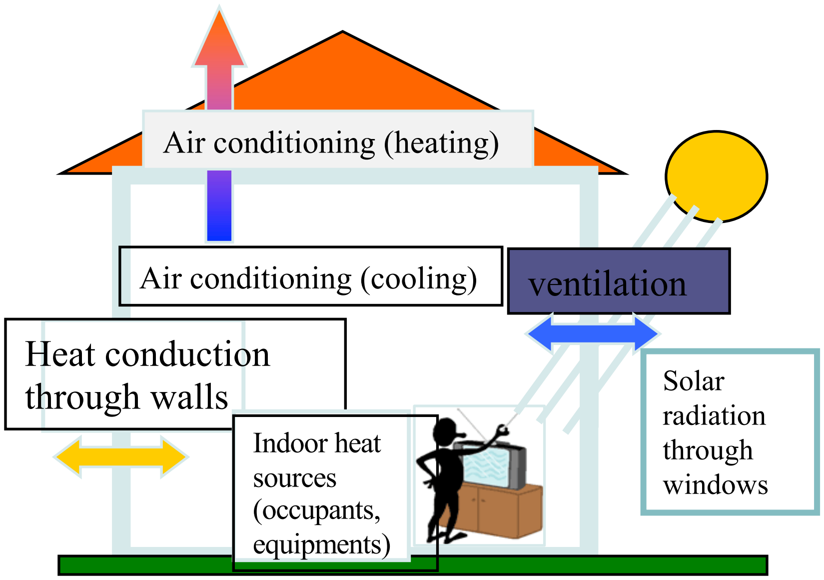
By default, these fractions are set to 1.0 and answers are unchanged.

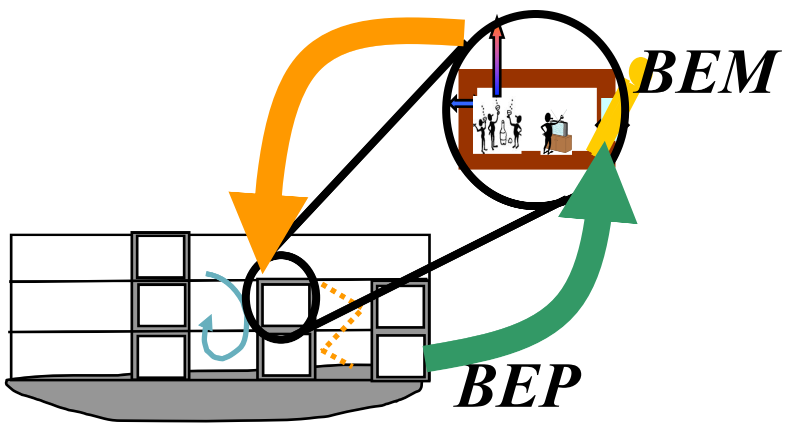
LIST OF MODIFIED FILES:
M phys/module_sf_urban.F
M phys/module_sf_bep_bem.F
M run/URBPARM.TBL

Extending Building Energy Model (BEM)

Representing indoor-outdoor exchange

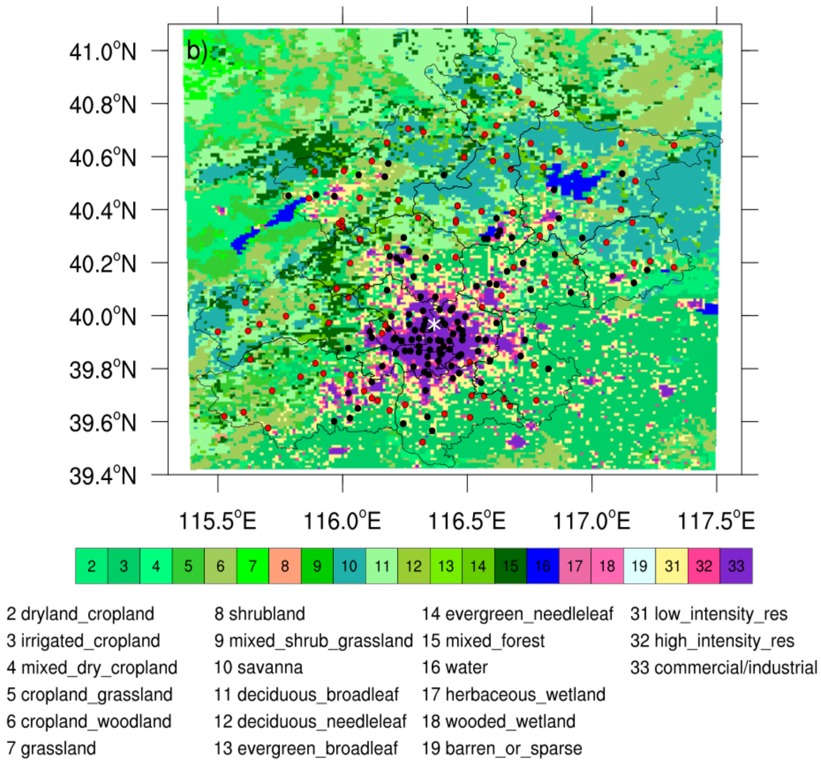
- Improve the estimate of the anthropogenic fluxes.
- Estimate energy consumption related to meteorology (air conditioning and heating).

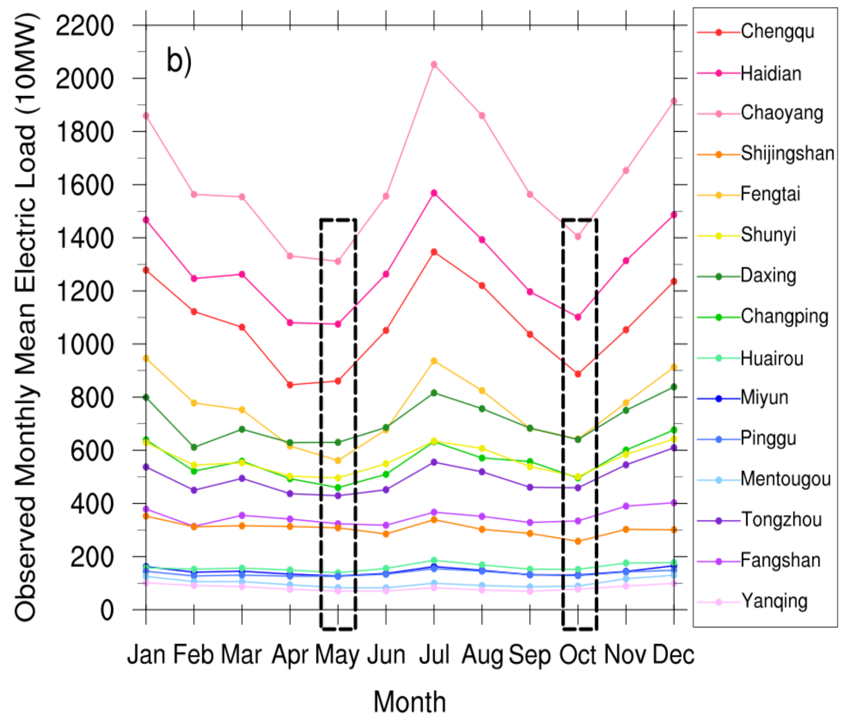




Salamanca and Martilli (2009, *Theoreti. Appli. Climatol.)*

Impacts of air-conditioning energy consumption on local weather





Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2017JD028168

Using WRF-Urban to Assess Summertime Air Conditioning Electric Loads and Their Impacts on Urban Weather in Beijing

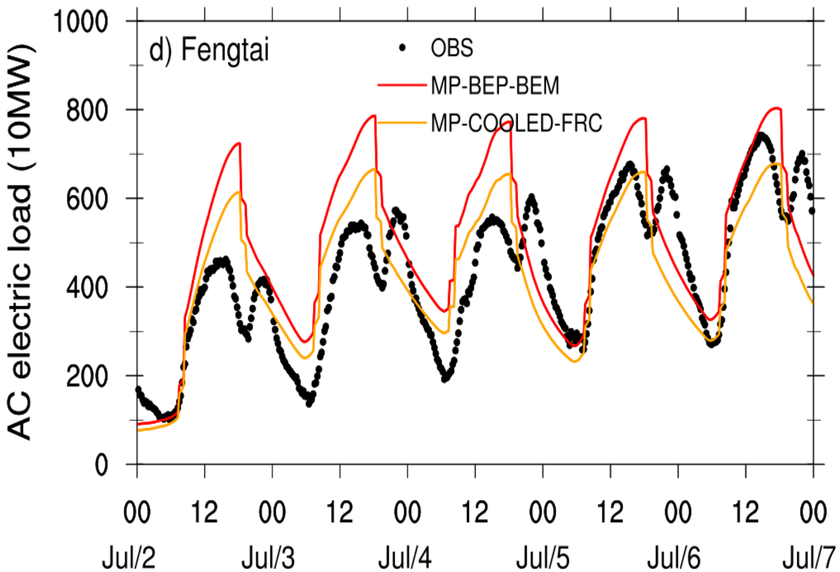
Xiaoyu Xu[1,2,3], Fei Chen[3,4], Shuanghe Shen[1], Shiguang Miao[2], Michael Barlage[3], Wenli Guo[5], and Alex Mahalov[6]

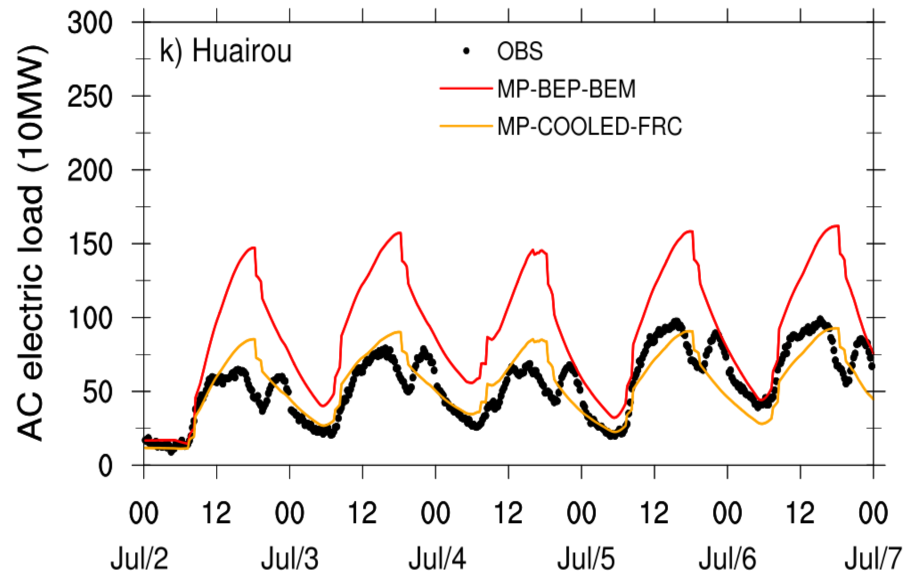
Key Points:

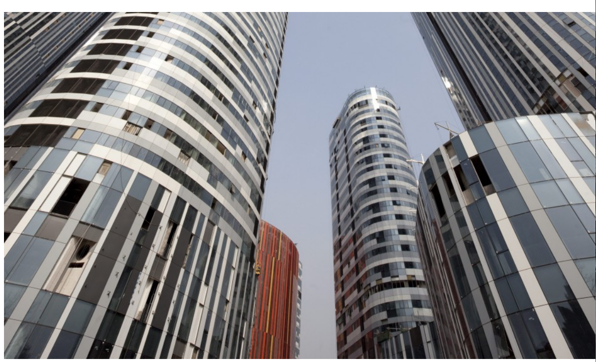
- The WRF-Urban model reasonably produces observed Beijing district-level cooling electric loads by introducing the cooled fraction

Impacts of air-conditioning energy consumption on local weather

Specifying fraction of buildings and fraction of floors that use AC improves load forecast







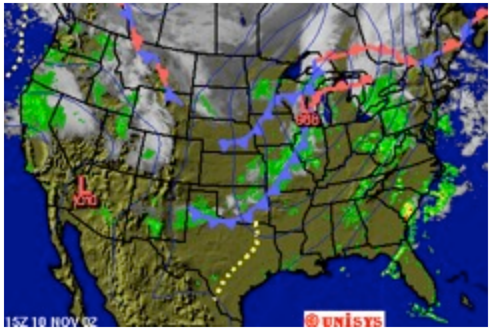
Modeling urban human behavior

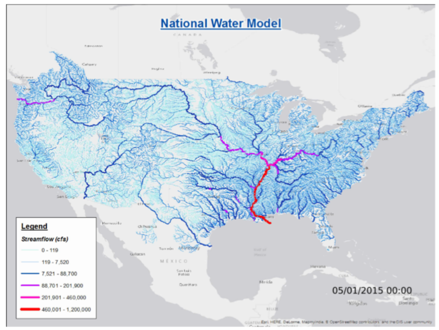
Future Model Development Focus

- Agriculture Modeling
  - Spatial performance of Noah-MP-Crop
  - Irrigation
  - Drainage tiling
- Urban Modeling
  - Solar panel options
  - Parameter tables

Field-scale Agriculture Prediction

Fei Chen, Dev Niyogi, Xing Liu, Xiaoyu Xu, Zhe Zhang, Liping Di





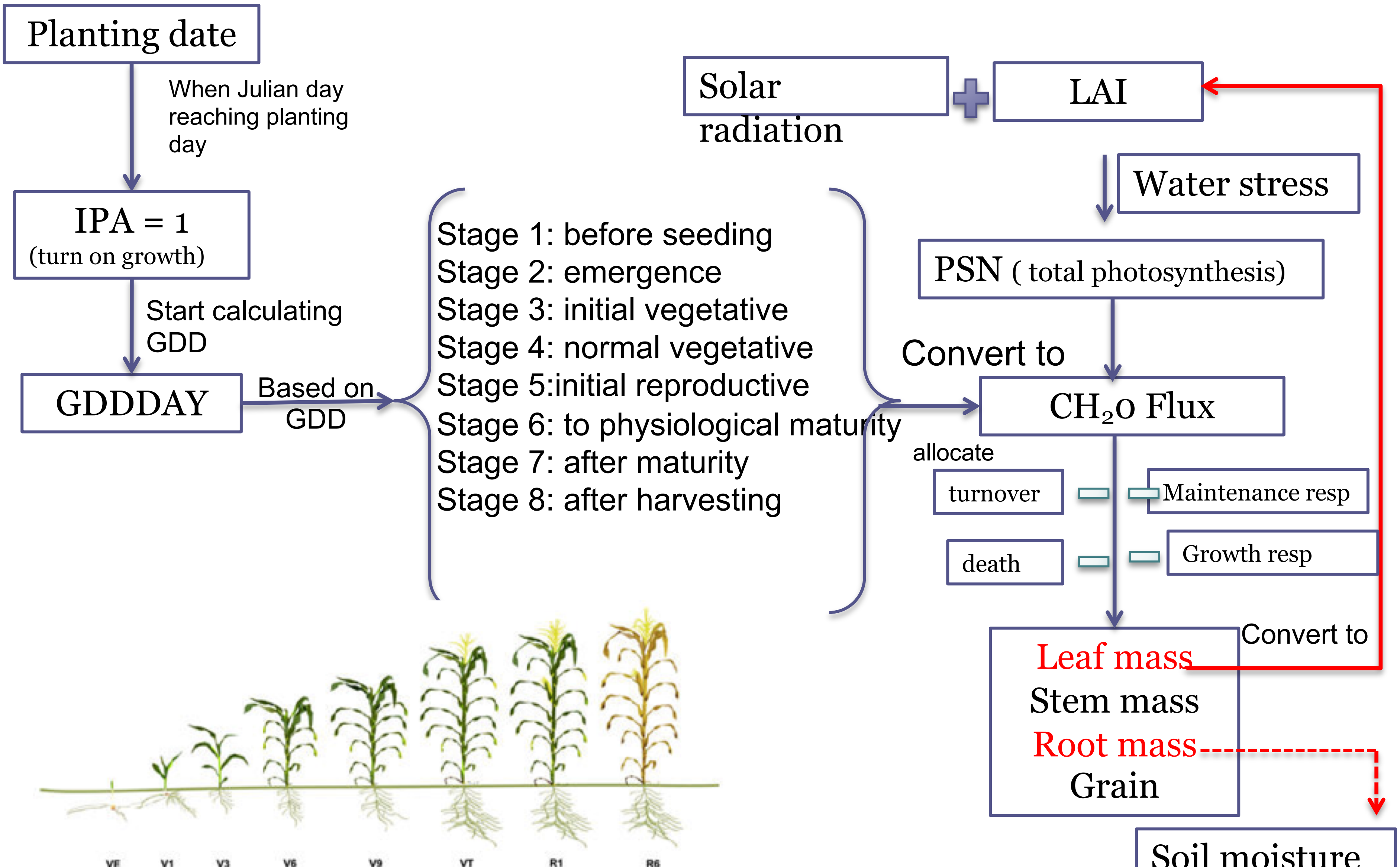
13-km GFS weather and 1-km NWM water forecast at continental scales

Downscale (~7 days) national GFS and NWM forecast to field scales (30-m)

HRLDAS (High-Resolution Land Data Assimilation System) to integrate land-surface, soil, hydrology, crop-growth models; NASA products and ag management data

Field scales

Noah-MP-Crop Model Framework



(Picture source: Pioneer)

Noah-MP-Crop Offline Results

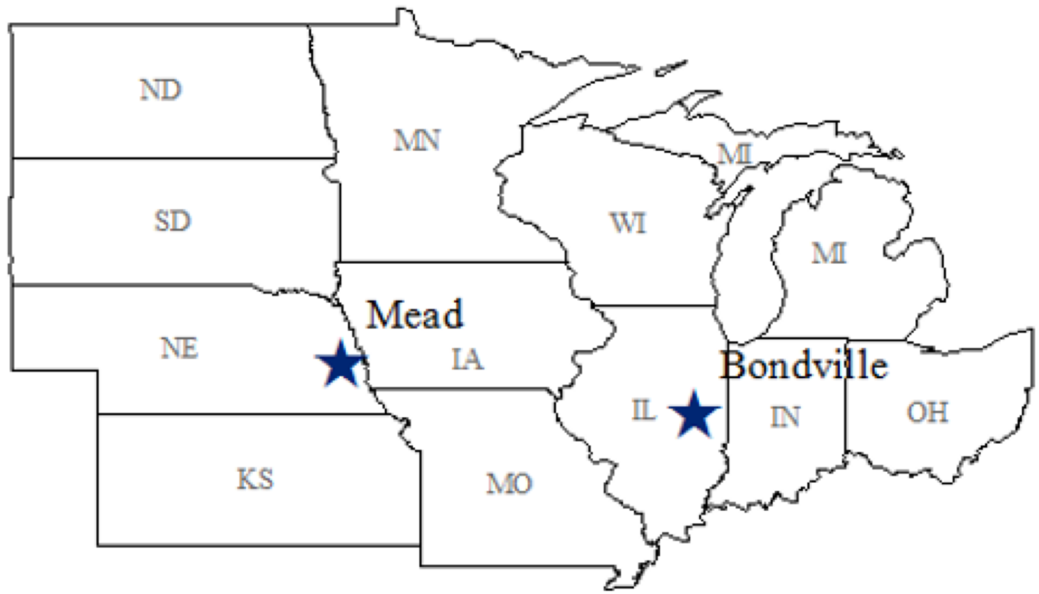
Research area and data source :

1-D offline field-scale:

Bondville, IL (2001, 2003, 2005), corn, rainfed, half-hourly weather input.
Mead, NE (2002, 2004, 2006), soybean, rainfed, hourly input.
Data source : Ameriflux

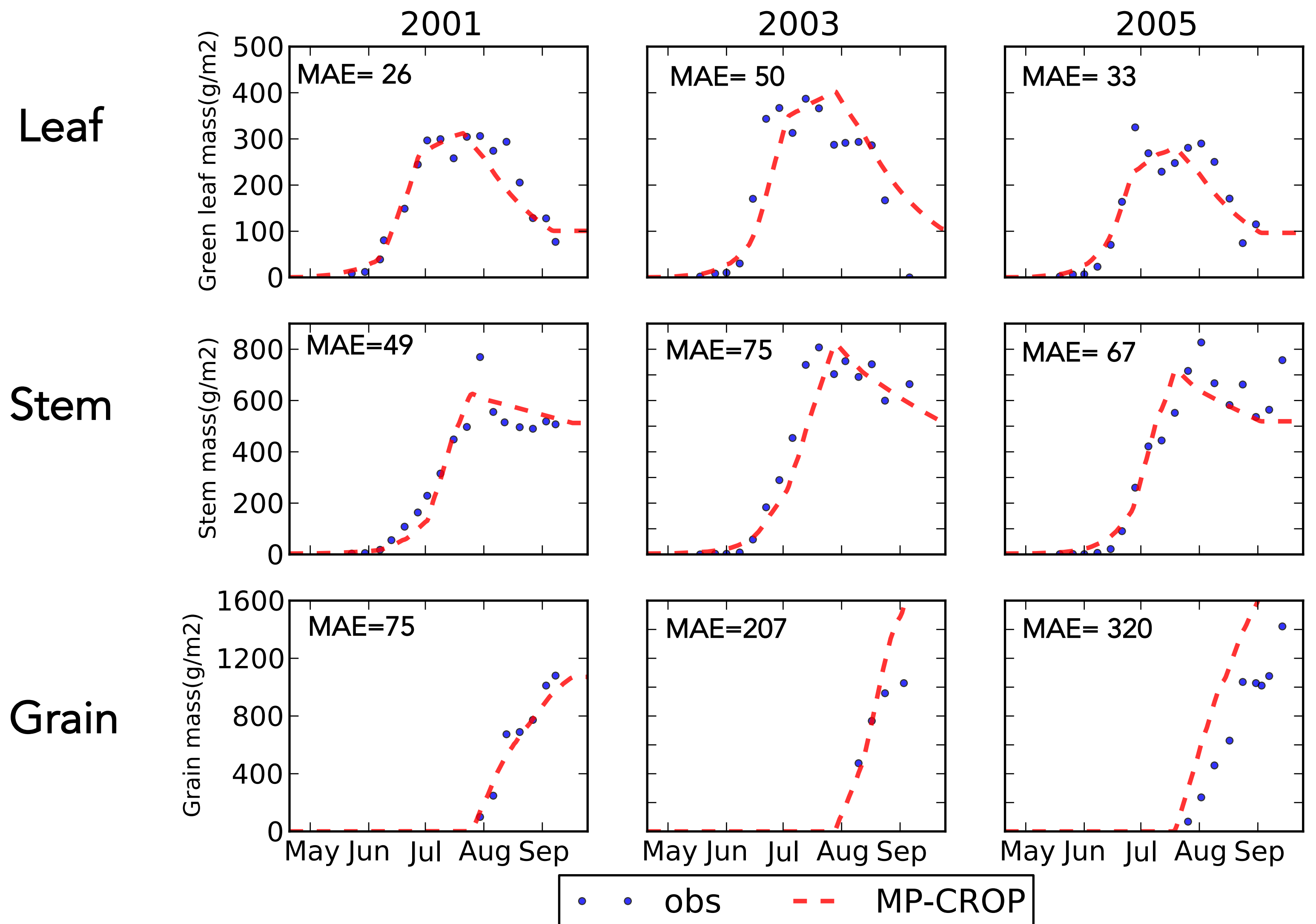
Running model with 3 Vegetation options:

C: MP-CROP
D: Dynamic Vegetation
T: Table LAI



Noah-MP-Crop Offline Results

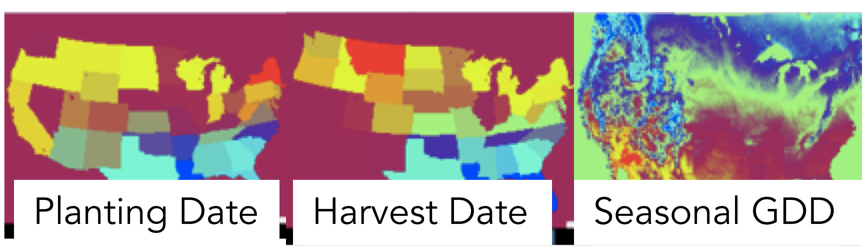
Biomass ---Corn

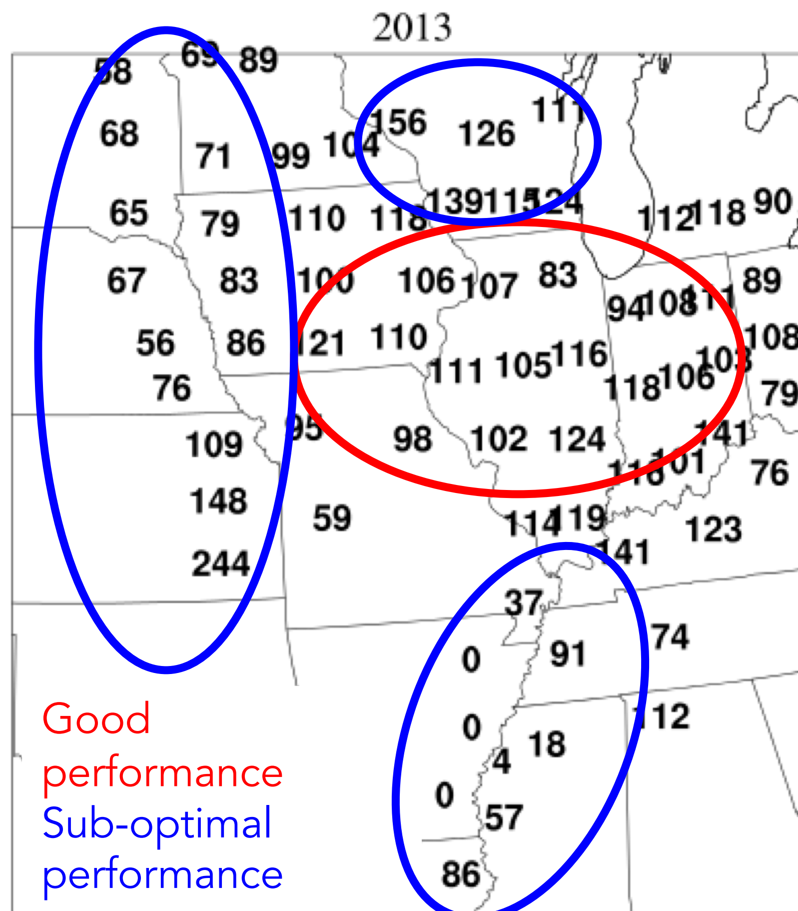


MAE: Mean Absolute Error (Unit: g/m2)

WRF-Noah-MP-Crop Challenges

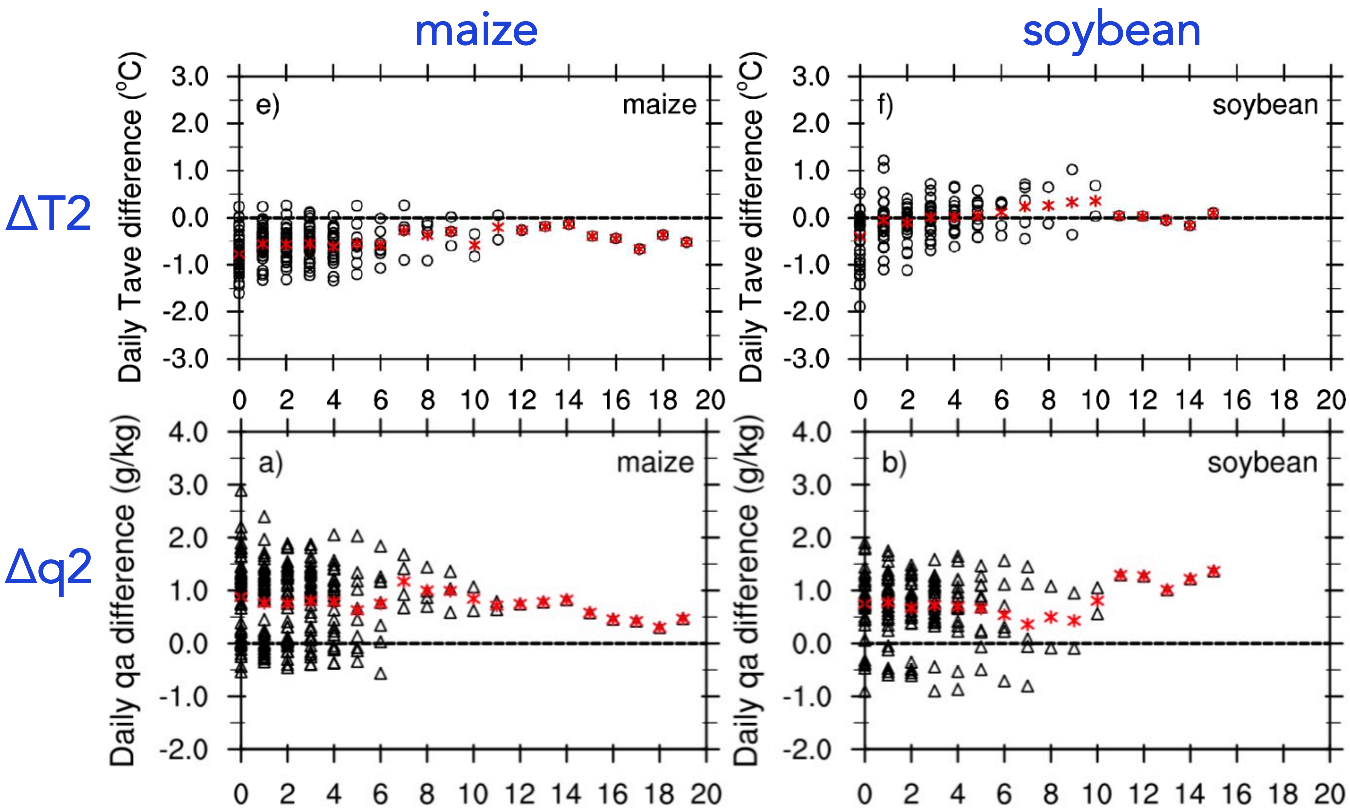
- For a normal year (2013), WRF-Crop predicted crop yield is good in corn dominated regions (Iowa, Illinois, Indiana) near where the model was calibrated (right)
- Challenge: improve model performance beyond calibration region for its global applications using spatially varying parameters





Corn yield ratio (modeled / observed) in % for 73 USDA zones (e.g., <100 implied underprediction)

Incorporating Irrigation for WRF-Crop



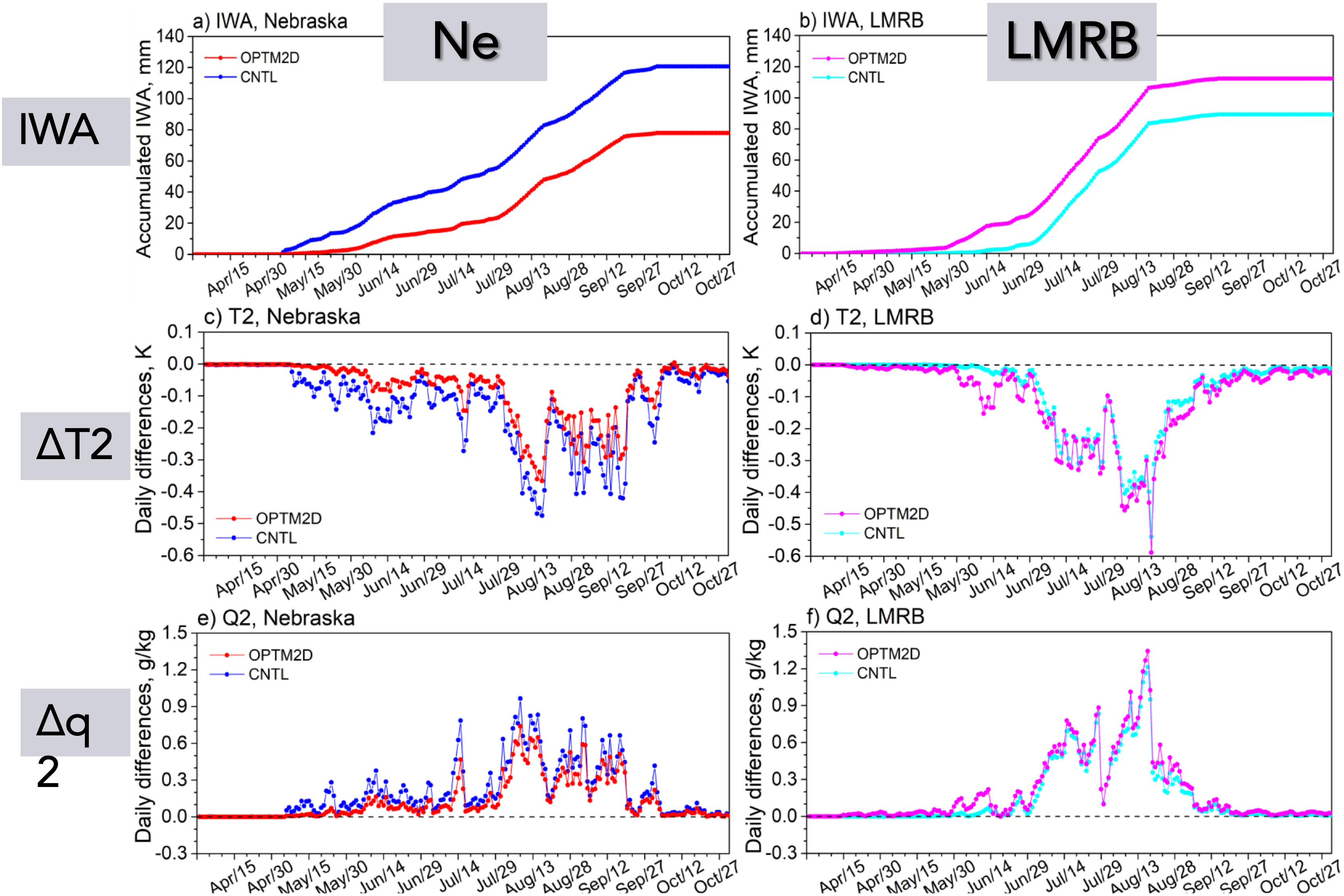
x-axis: days from an irrigation application;

y-axis: differences in daily T2 and q2 between irrigated (USNe2) and rain-fed (USNe3) sites for 2001-2012.

Chen et al. (2018, ERL)

- Irrigation significantly modifies land surface water/energy states and local/regional climate.
- The irrigation cooling **varies with crop species**.
- The irrigation application is not only determined by **soil-moisture deficit**, but also by **crop growth stages**.
- **Q:** How to represent **crop-specifc irrigation** (**both timing and amount**) in LSMs?

Irrigation Effects on Atmosphere

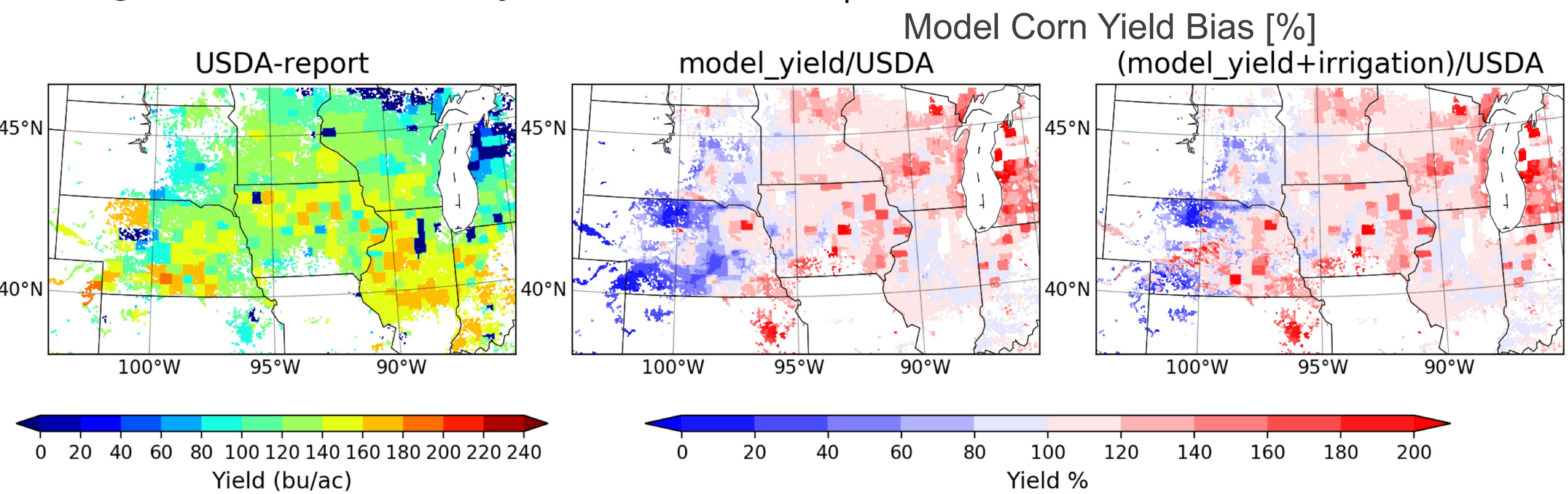


- The land surface hydrometeorological conditions over Nebraska and LMRB were greatly modified by irrigation.

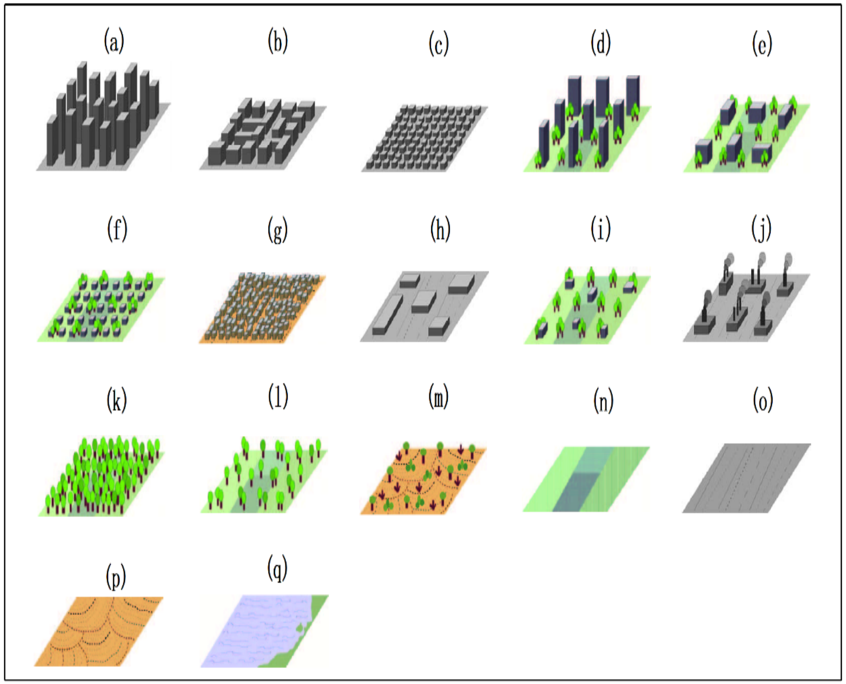
Expanding Input Data for Improved Spatial Performance

- Using 30-meter USDA/George Mason University crop frequency data
- Using 500-meter MODIS irrigated area data
- Using state-level planting and harvest data
- Using ⅛° climate data to determine spatially-varying GDD for crop growth in 8 stages

- Compared to county-level yield estimates, model generally produces yield within 20% of observed values
- Irrigation, most notably in Nebraska, improves model estimates



Improving Urban Representation



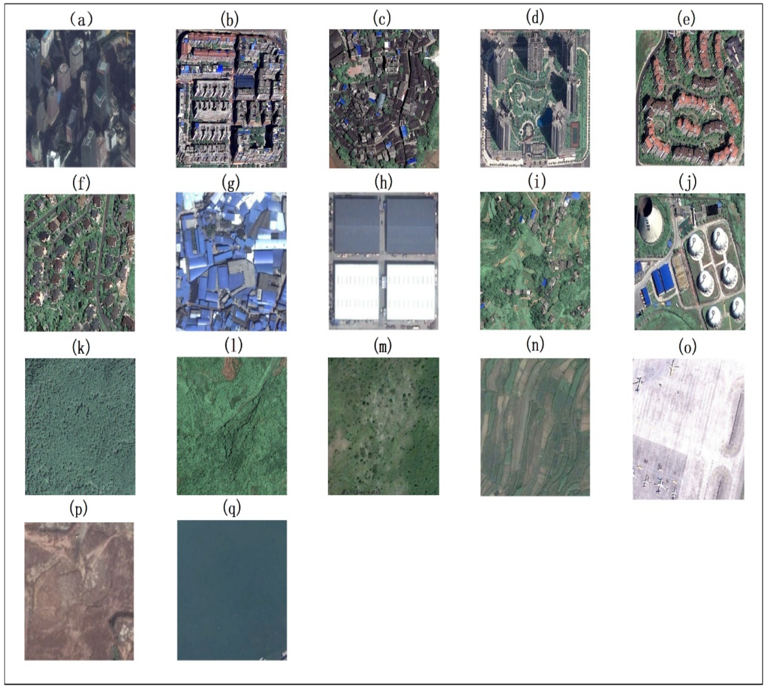


Fig 1 LCZ classes. (a) LCZ1 compact high rise; (b) LCZ 2: Compact mid-rise; (c) LCZ 3: Compact low-rise; (d) LCZ 4: Open high-rise; (e) LCZ 5: Open mid-rise; (f) LCZ 6: Open low-rise; (g) LCZ 7: Light weight low-rise; (h) LCZ 8: Large low-rise; (i) LCZ 9: Sparsely built; (j) LCZ 10: Heavy industry; (k) LCZ A: Dense trees; (l) LCZ B: Scattered trees; (m) LCZ C: Bush, scrub; (n) LCZ D: Low plants; (o) LCZ E: Bare rock or paved; (p) LCZ F: Bare soil or sand; (q) LCZ G: Water

from Yongwei Wang

How to Make LCZ land use types?

According to the guide on this page http://www.wudapt.org/

Improving Urban Representation

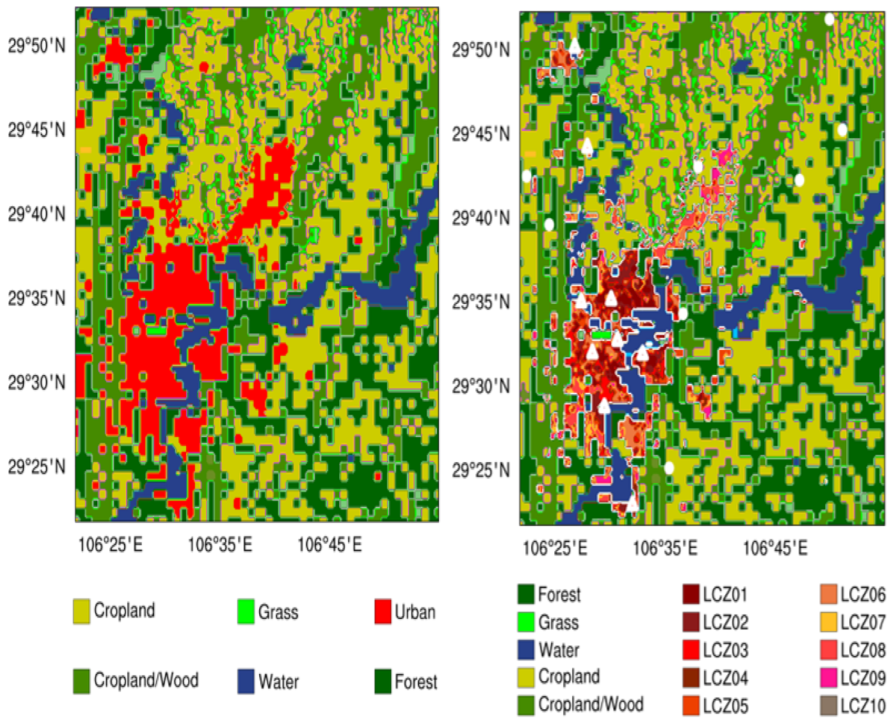


Fig 2 land use types in the D04 domain (a) Classification based on survey data (b) LCZ classification. LCZ1 compact high rise; LCZ 2: Compact mid-rise; LCZ 3: Compact low-rise; LCZ 4: Open high-rise; LCZ 5: Open mid-rise; LCZ 6: Open low-rise; LCZ 7: Light weight low-rise; LCZ 8: Large low-rise; LCZ 9: Sparsely built; LCZ 10: Heavy industry;, Urban sites ▲, suburban sites ●.

LCZ classifications: building height and impervious area

LCZ classification	1	2	3	4	5	6	7	8	9
Building height （m）	25.5	18.5	9.5	25.5	18.5	9.5	3.5	2.5	2.5
impervious （%）	80	80	90	75	60	65	40	50	55

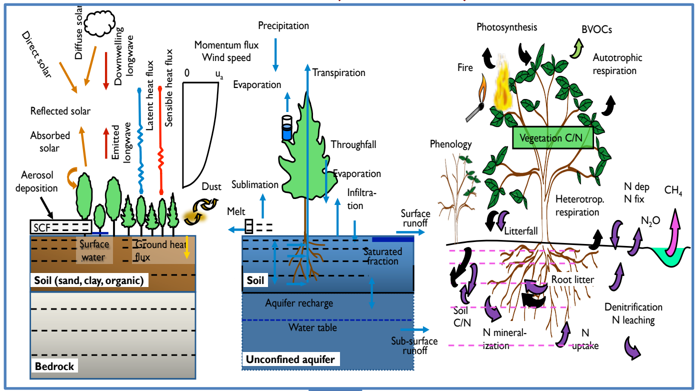
Moving Forward in a Modular Framework

- Expectation for major refactoring of Noah-MP code in the near future
  - Enhance/facilitate collaboration
  - Ease pressure on implementation
- Need coordination and communication for model development
  - Multiple irrigation efforts
  - Multiple agriculture efforts
  - Multiple dynamic root efforts
  - Multiple solar panel efforts
- Limit isolated development

The Community Terrestrial Systems Model

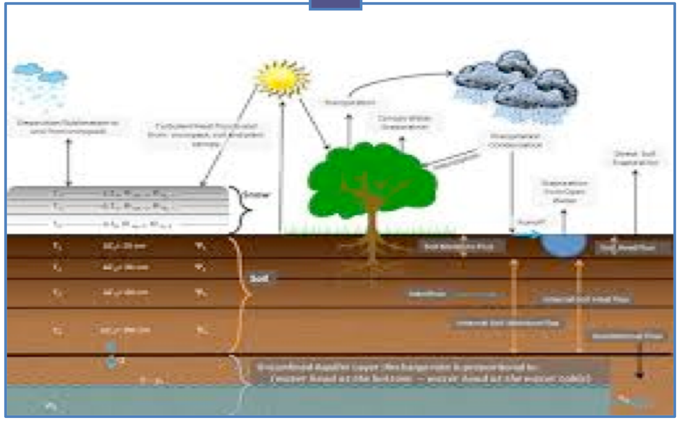
a unified model for research and prediction in climate, weather, water, and ecosystems

CLM (CGD)



- **CLM user community:**
  - climate focus: CESM
  - national and international universities and labs
  - plant hydrodynamics, carbon-nitrogen dynamics, ecosystem demography

CTSM + user communities

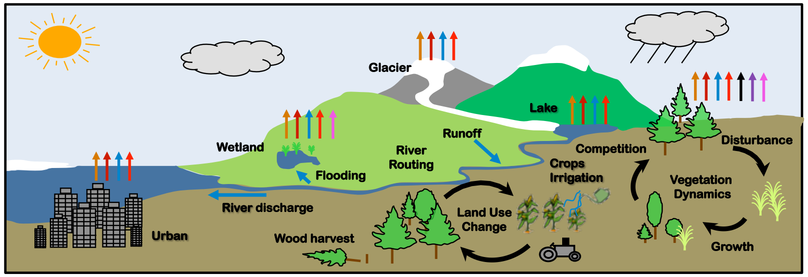


Noah-MP, WRF-Hydro (RAL)

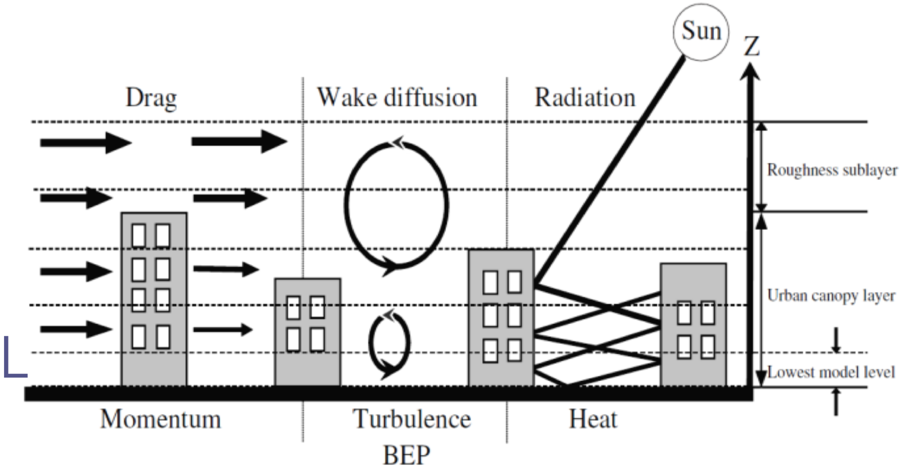
- **Noah-MP user community:**
  - NWP focus: WRF, WRF-Hydro, NOAA NWC/EMC
  - national and international universities and labs
  - higher spatial resolution and temporal coupling frequency

Key Challenges

- Parallel development
  - Existing models currently used across multiple projects
  - Initially the effort is diffuse - partners developing code for both Noah-MP and CTSM (complicated by funding)

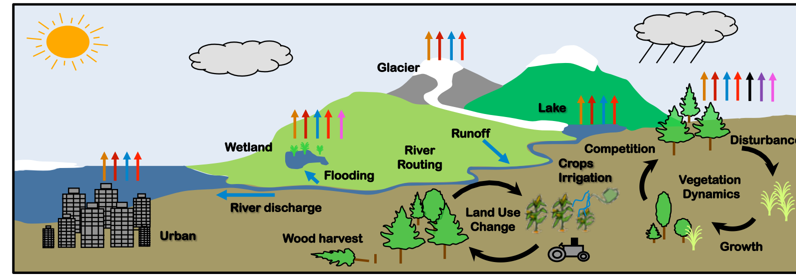


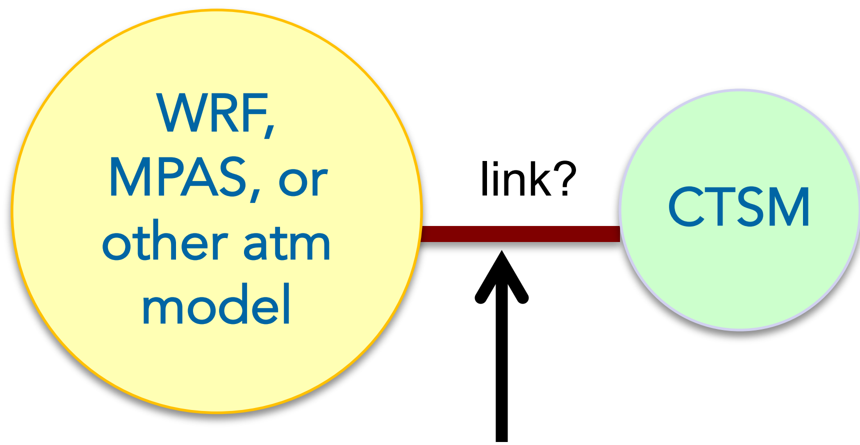
- Diverse Modeling Problems
  - Climate needs vs. NWP needs
  - Land coupling with other components
    - frequency of coupling
    - location of coupling
    - strong coupling, e.g., urban, ML canopy



Key Challenges

- Adoption
  - Target for feature branch in v4.2
  - Development of common test cases to demonstrate performance/capabilities (e.g., NWP configuration)
    - Potential user defined?
  - Expand verification packages
    - Expansion of ILAMB, MET
  - Simplify coupling/ease of use across multiple communities





LILAC
Lightweight Infrastructure for Land-Atmosphere Coupling
Funded NSF Infrastructure project

Extension to CTSM-NWP

- expanding CTSM interest
- CTSM as a viable option for NOAA operational models (NAM,GFS,CFS,HRRR,NWM), WRF (-Hydro) [or any weather model], LIS/NLDAS/GLDAS
- Original results show CLM expensive relative to Noah-MP; makes CTSM a hard(er) sell for the resource limited