Agricultural Applications in Weather and Climate Forecast Models

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NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

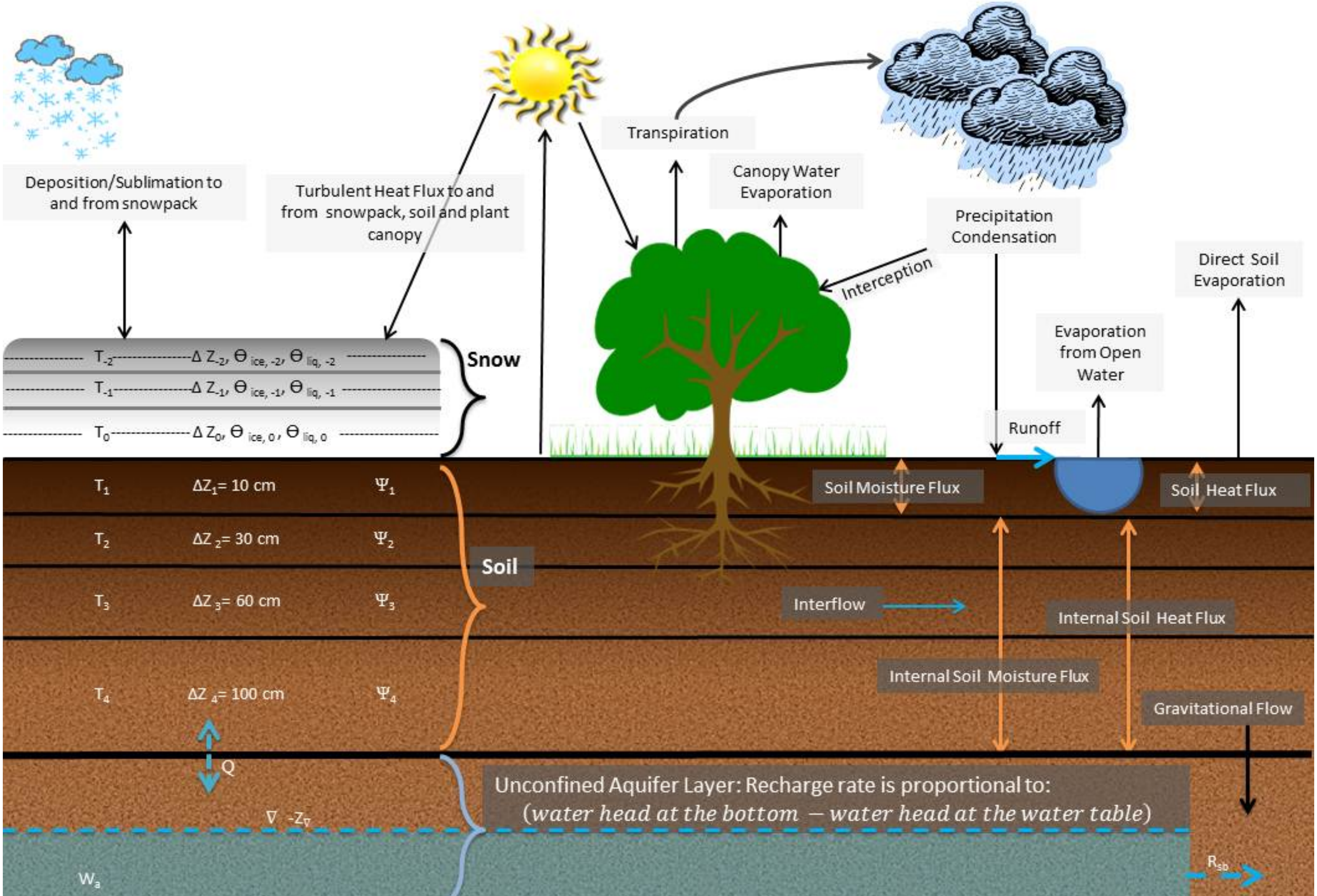
HRLDAS System

NCAR High-Resolution Land Data Assimilation System (HRLDAS) Concept

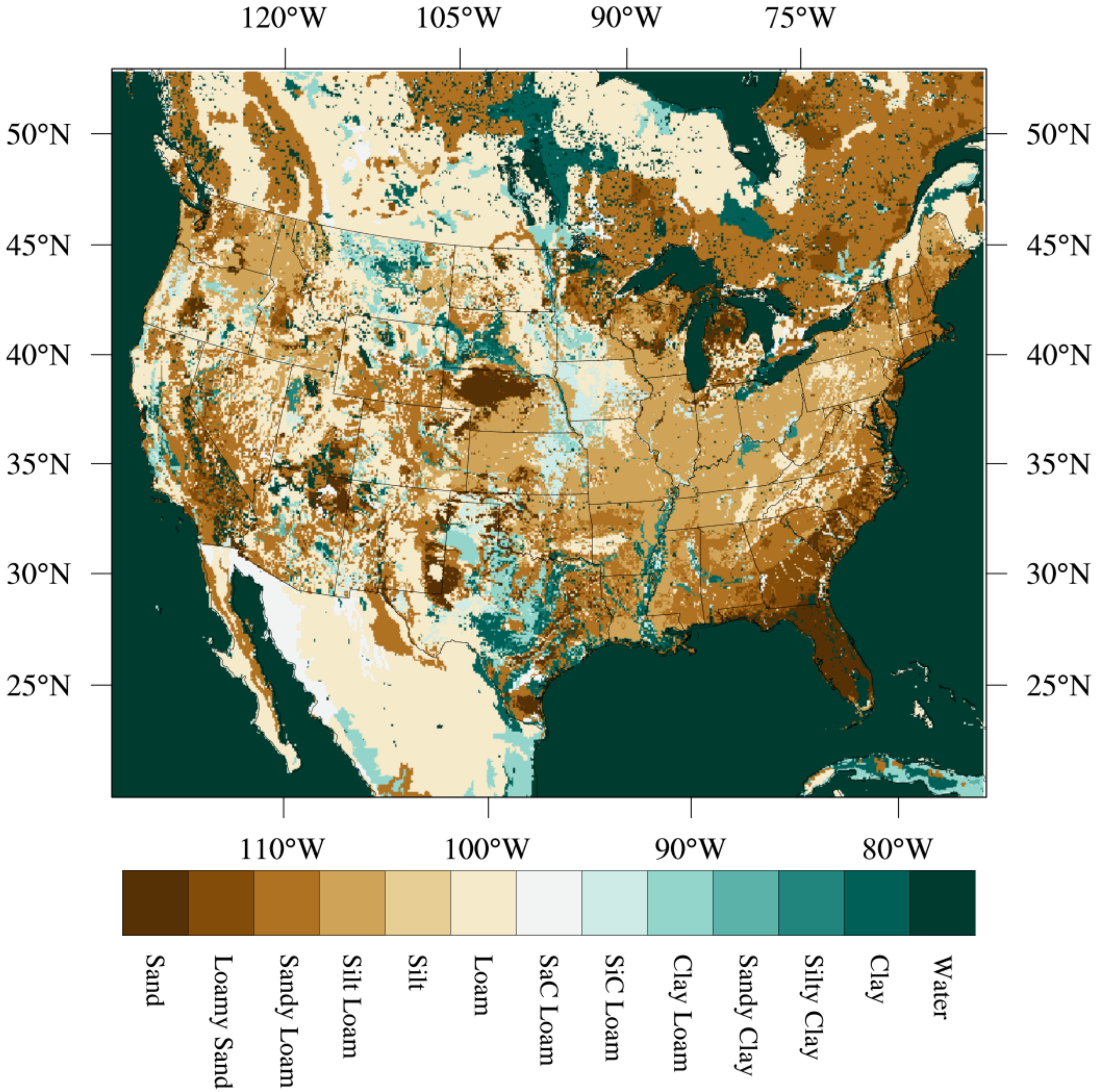
Run uncoupled LSM on the same grid as mesoscale NWP models

- Using the same LSM as in coupled NWP model: same soil moisture climatology
- No mis-match of terrain, land use type, soil texture, physical parameters between sources of soil data and NWP models
- No interpolation and soil moisture conversion

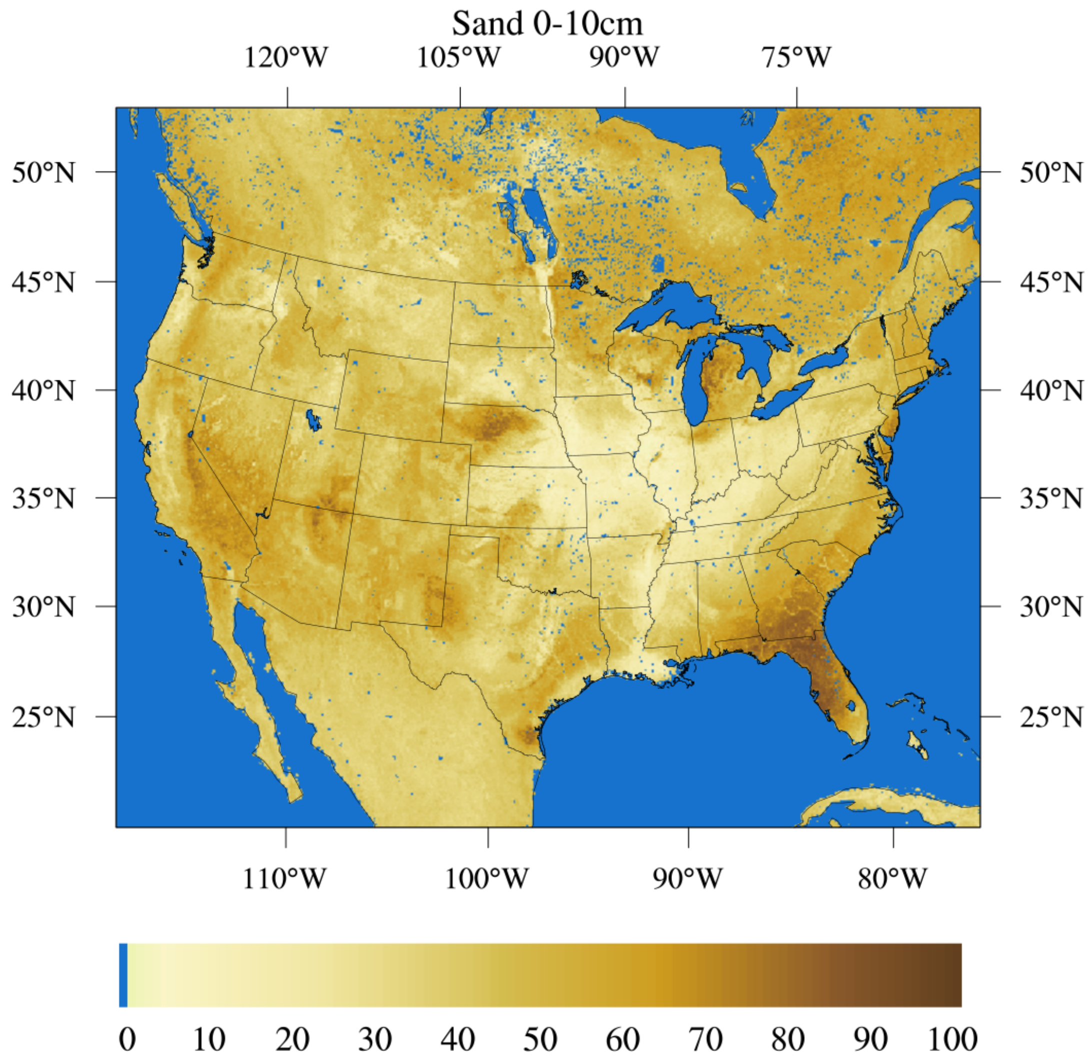
Noah-MP Processes (figure from Zong-Liang Yang)



Datasets: Soil Texture



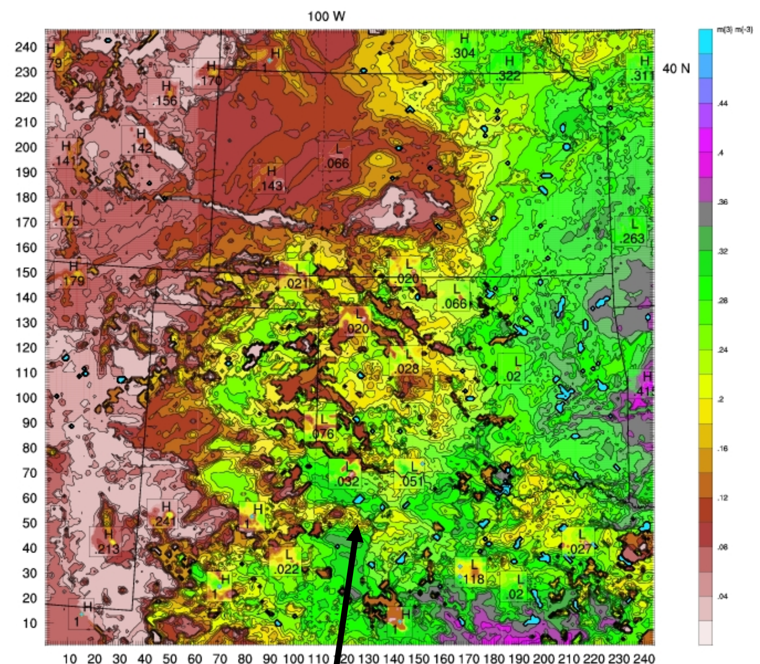
Datasets: Soil Composition from SoilGrids



HRLDAS System

HRLDAS: Capturing Small-Scale Variability
An example over CONUS

- Input:
  - 4-km hourly NCEP Stage-II rainfall
  - 1-km landuse type and soil texture maps
  - 0.5 degree hourly GOES downward solar radiation
  - 0.15 degree AVHRR vegetation fraction
  - T,q, u, v, from model based analysis
- Output: **long term evolution of multi-layer soil moisture and temperature, surface fluxes, and runoff**



4-km HRLDAS surface soil moisture
in IHOP-2002 domain 12 Z May 29 2002

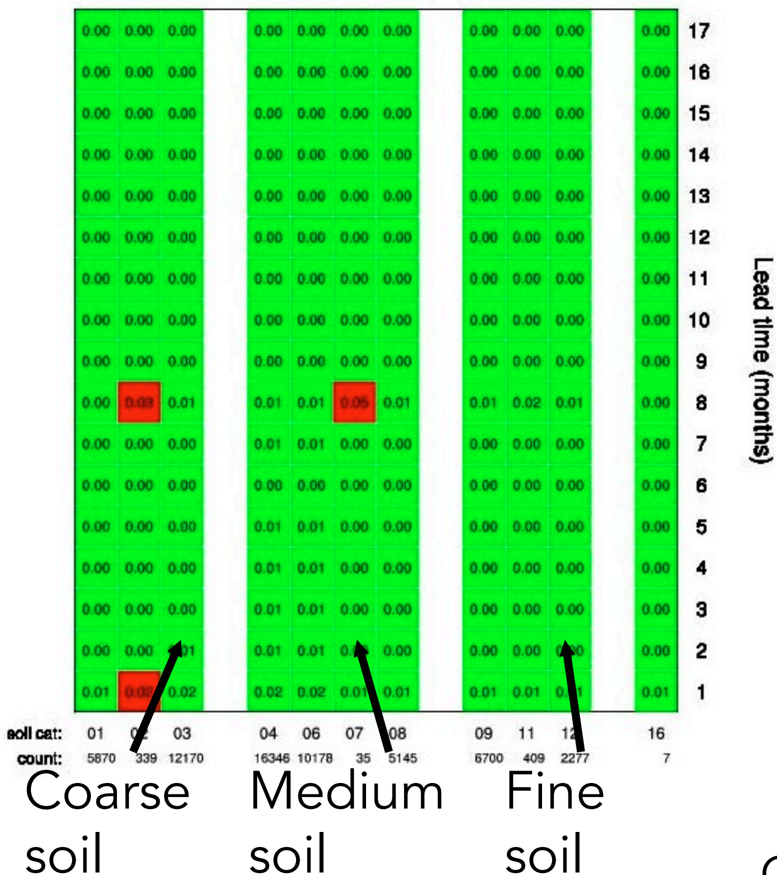
HRLDAS System

Spin-up of Soil Moisture

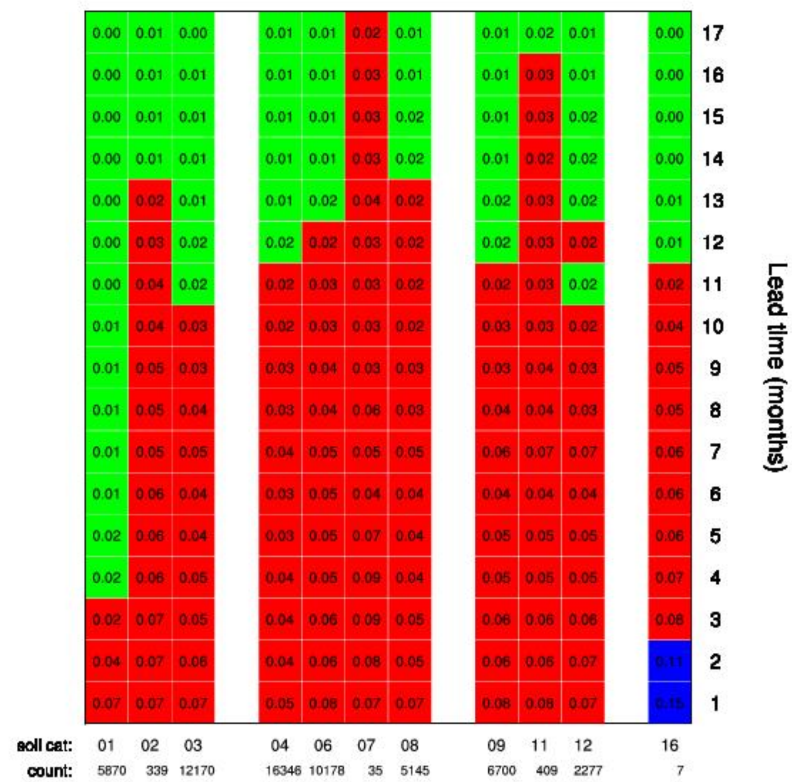
Volumetric soil moisture
RMS difference (m^3m^{-3})

< 0.02 0.02 < < 0.1 >0.1

1st layer soil moisture



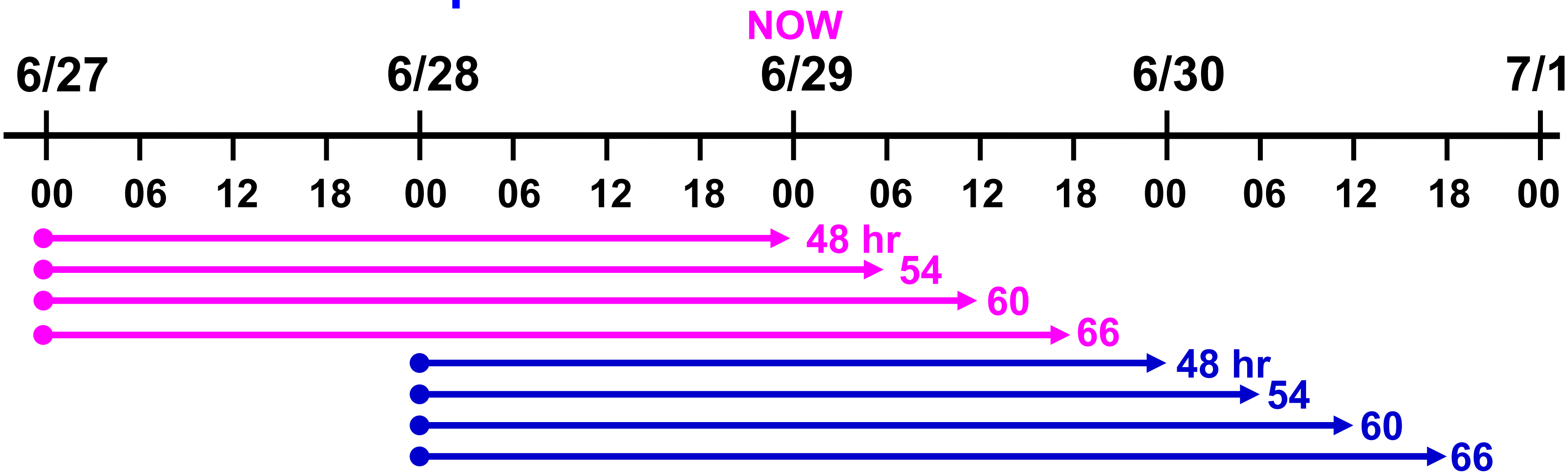
3rd layer soil moisture



Chen et al., *J. Appli. Meteorol. Climate, 2007*

HRLDAS System

Implementation at CWB



	00	06	12	18
1st run	12:02	18:02	00:02	06:02
2nd run	15:02	21:02	03:02	09:02

(~10 min)

Mainly Output：
skin temp、soil temp (4 layers)、soil moist (4 layers)

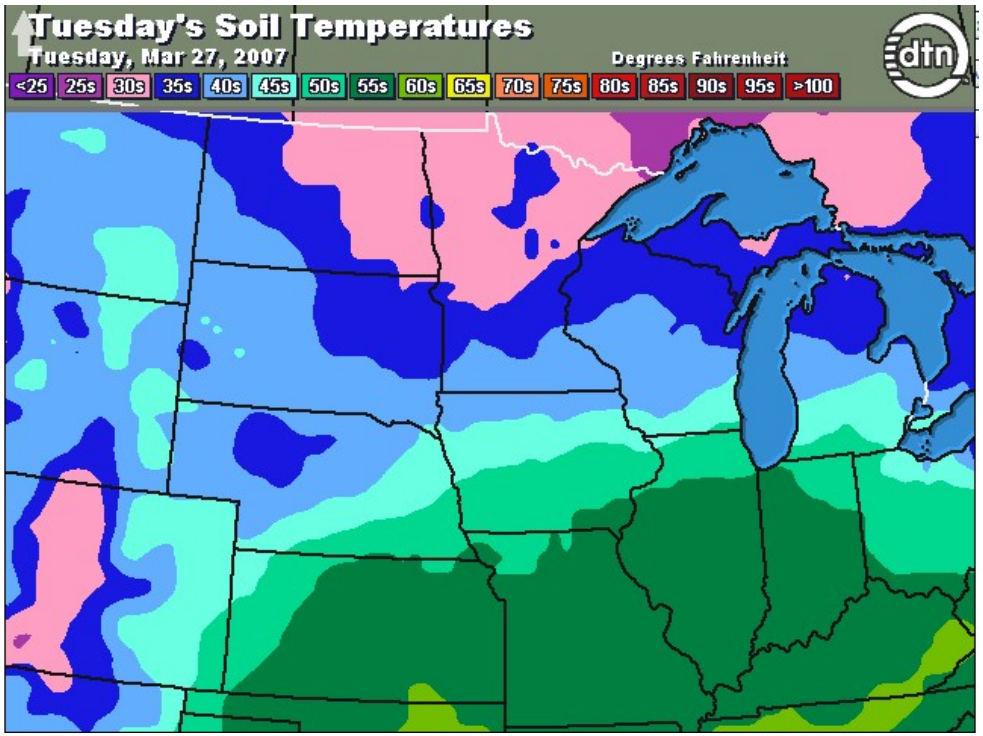
HRLDAS System

Realtime fine-scale soil moisture and temperature prediction system

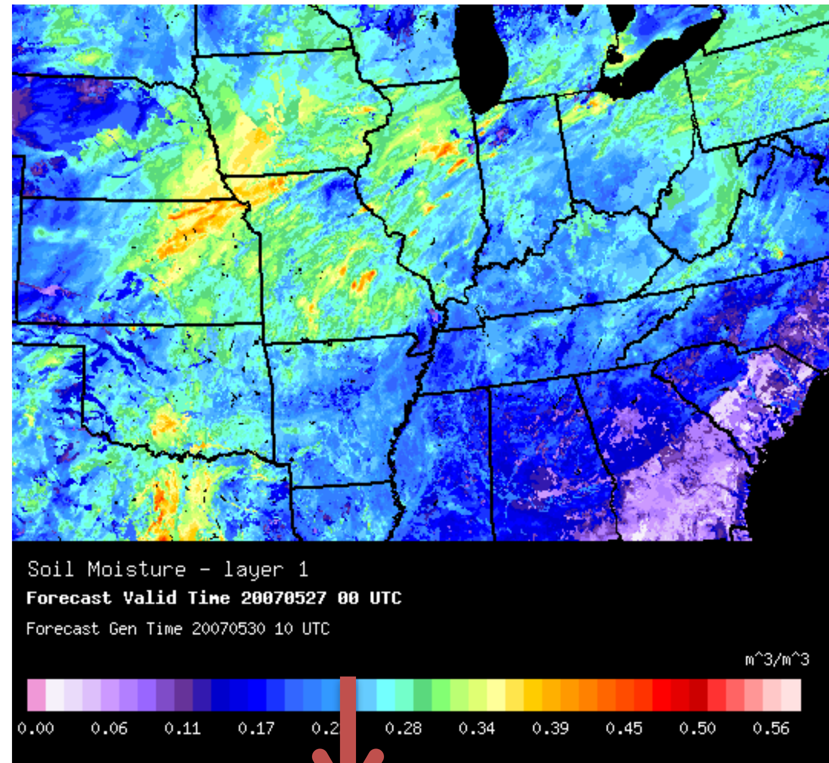
- Combines advanced forecast systems to produce soil forecasts
  - DICast (Dynamic Integrated ForeCast) System
  - HRLDAS (High-Resolution Land Data Assimilation System)
- Soil forecasts will drive Agriculture-specific models (e.g. pest models)
- RAL partnered with Meteorlogix

HRLDAS System

Current capability of soil moisture and temperature prediction



New high-resolution realtime soil condition forecast



Input to
pest control management
Crop models

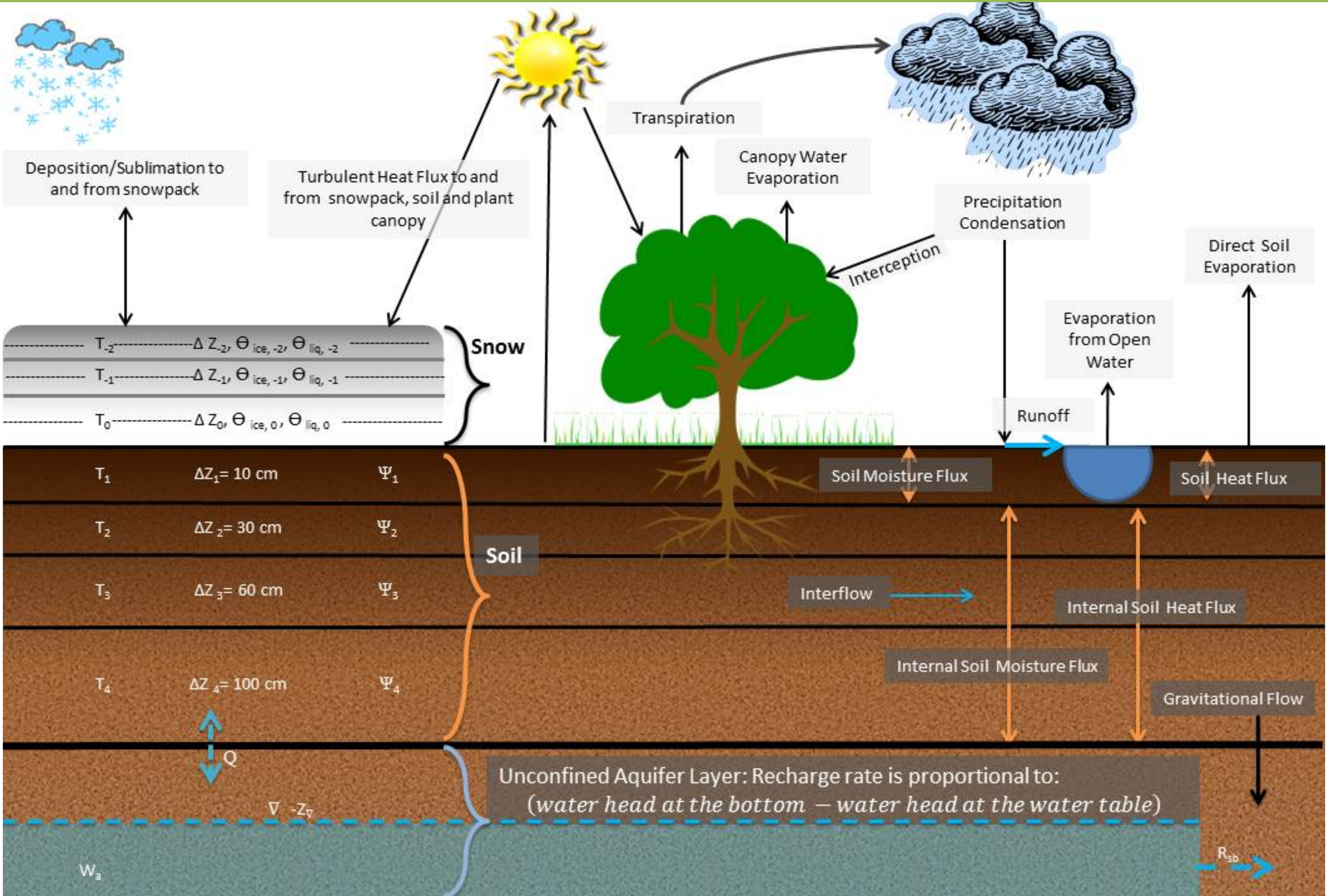
Model framework

LSM: Noah-MP + Crop modeling = Noah-MP-CROP

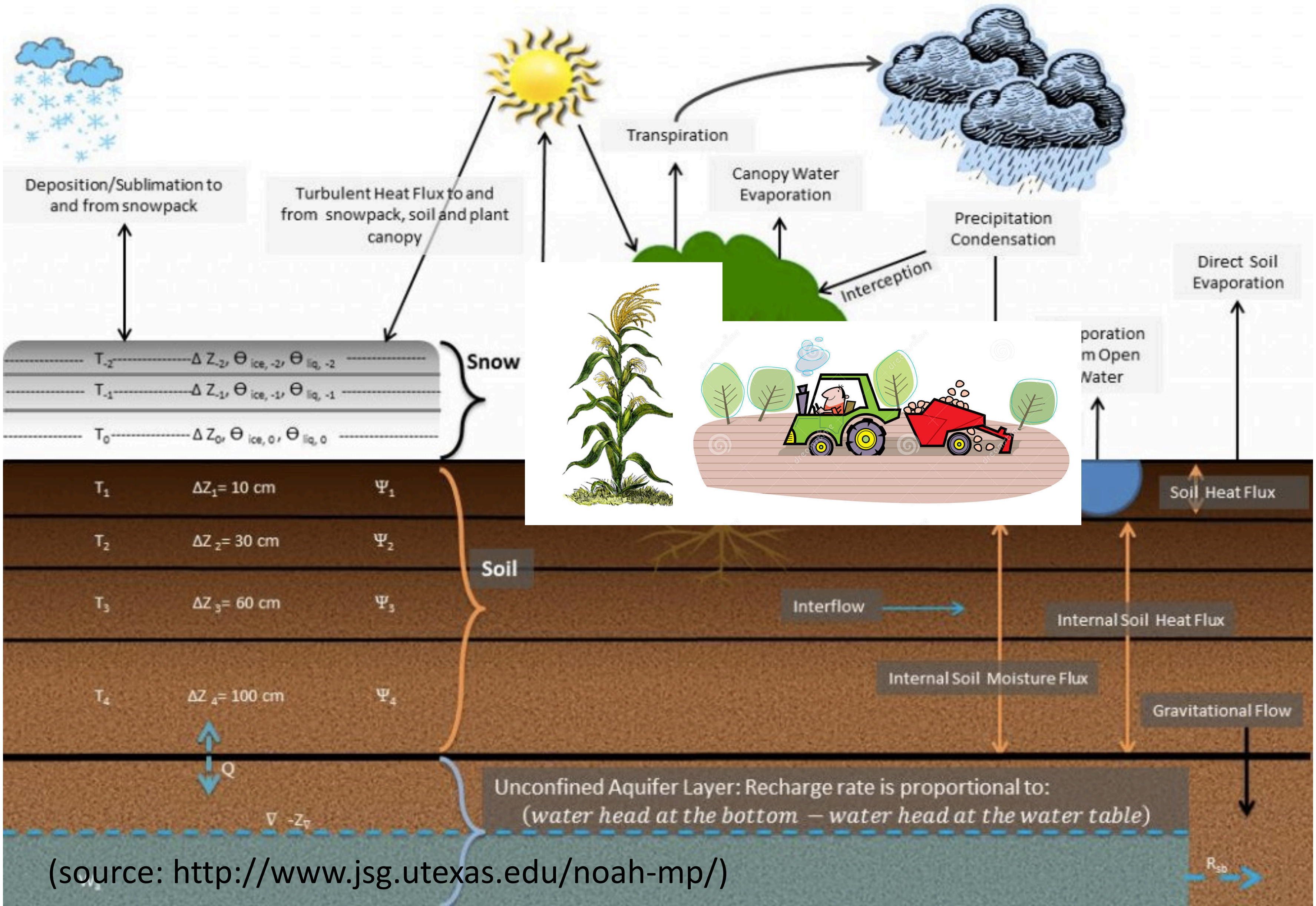
Objective 1. Provide high-resolution regional crop modeling products for agricultural applications and research.

Objective 2. Enhance the performance of Noah-MP in modeling surface fluxes, for coupling with Weather Research and Forecasting (WRF) model in the future study, e.g. seasonal prediction.

Model framework

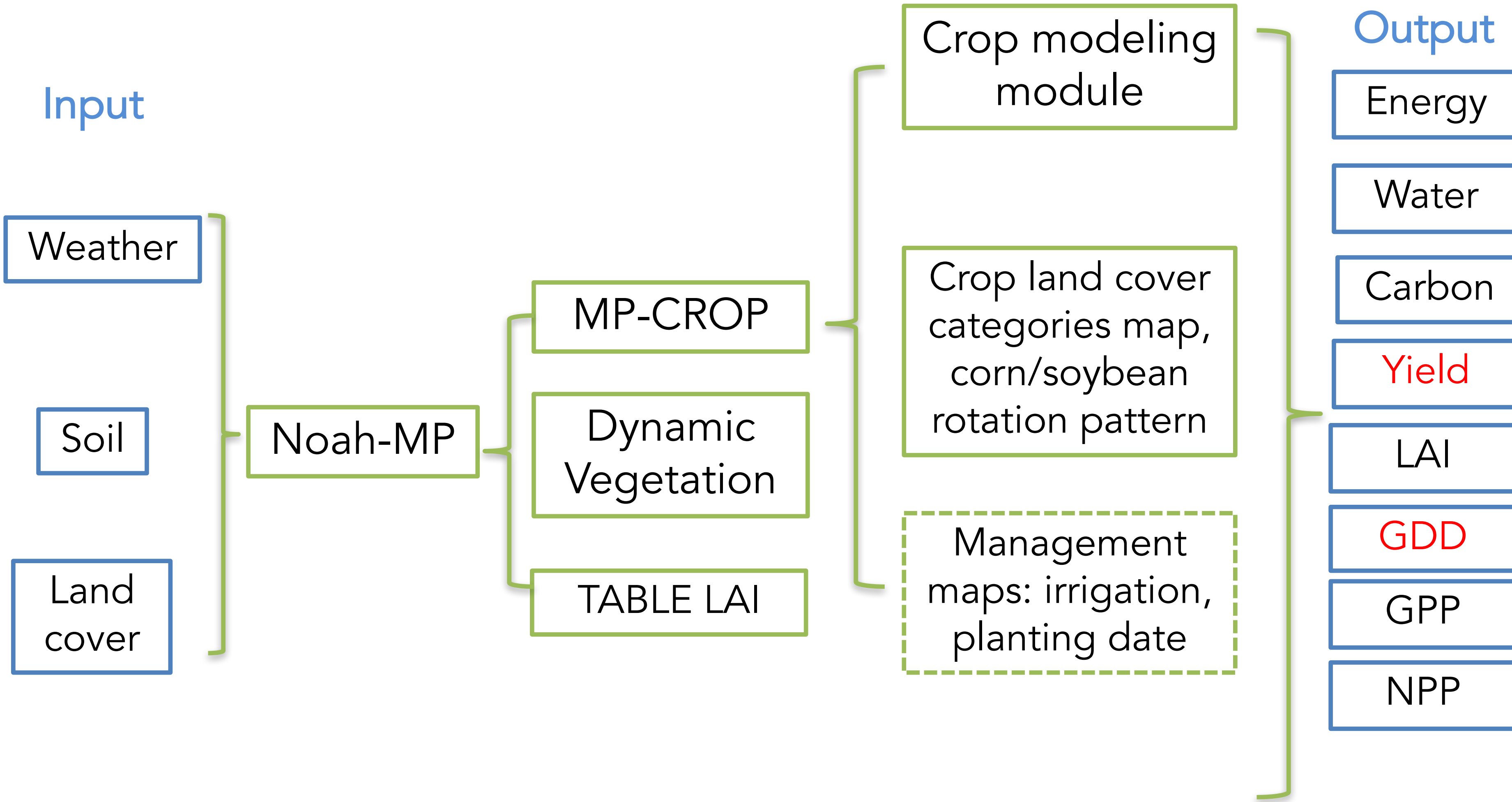


Model framework



(source: http://www.jsg.utexas.edu/noah-mp/)

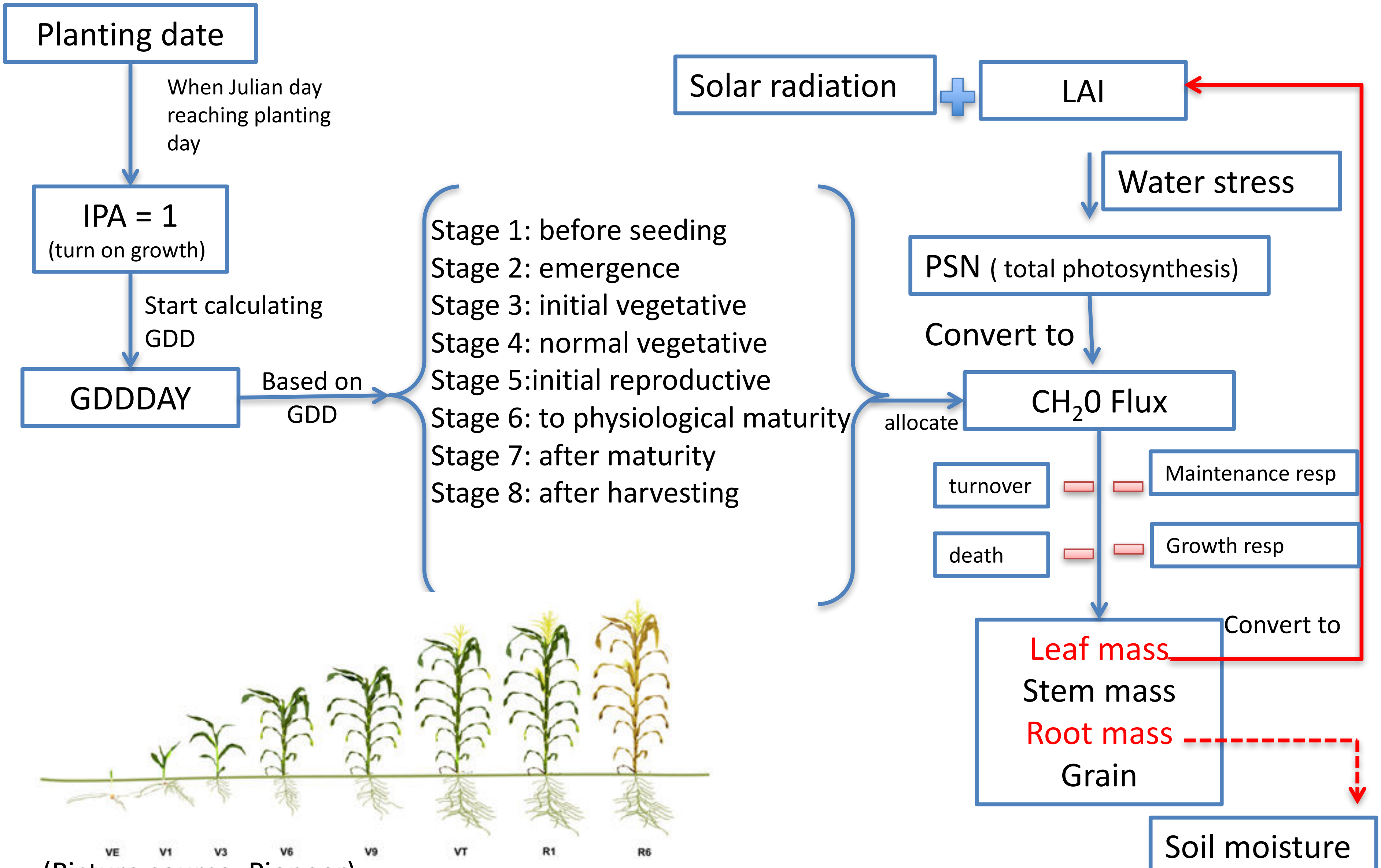
Model framework



Flexible spatio-temporal resolution

(GDD: Growing degree days)

Model framework



(Picture source: Pioneer)

Offline Results

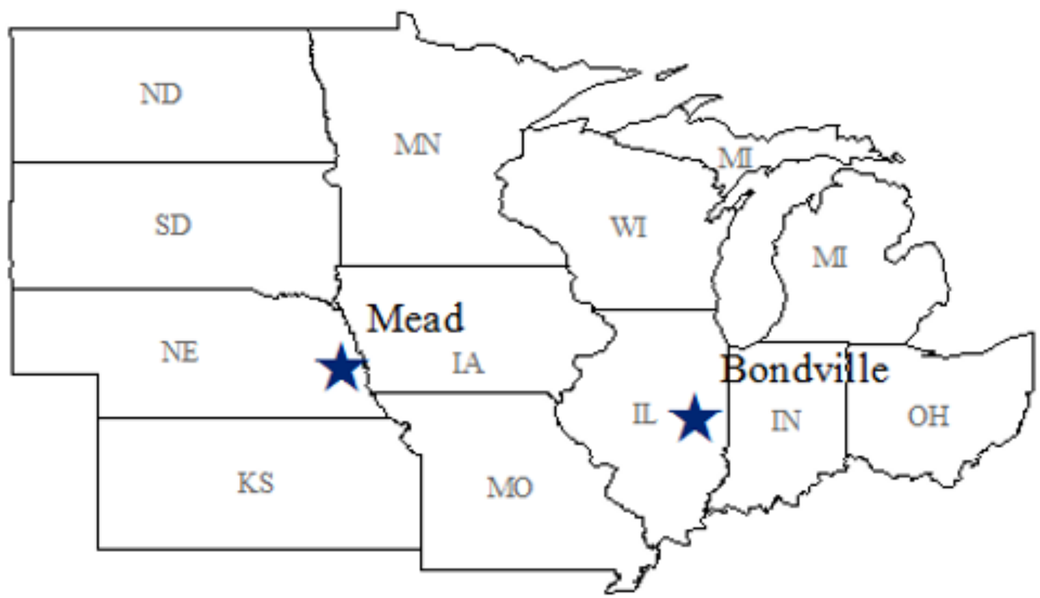
Research area and data source :

1-D offline field-scale:

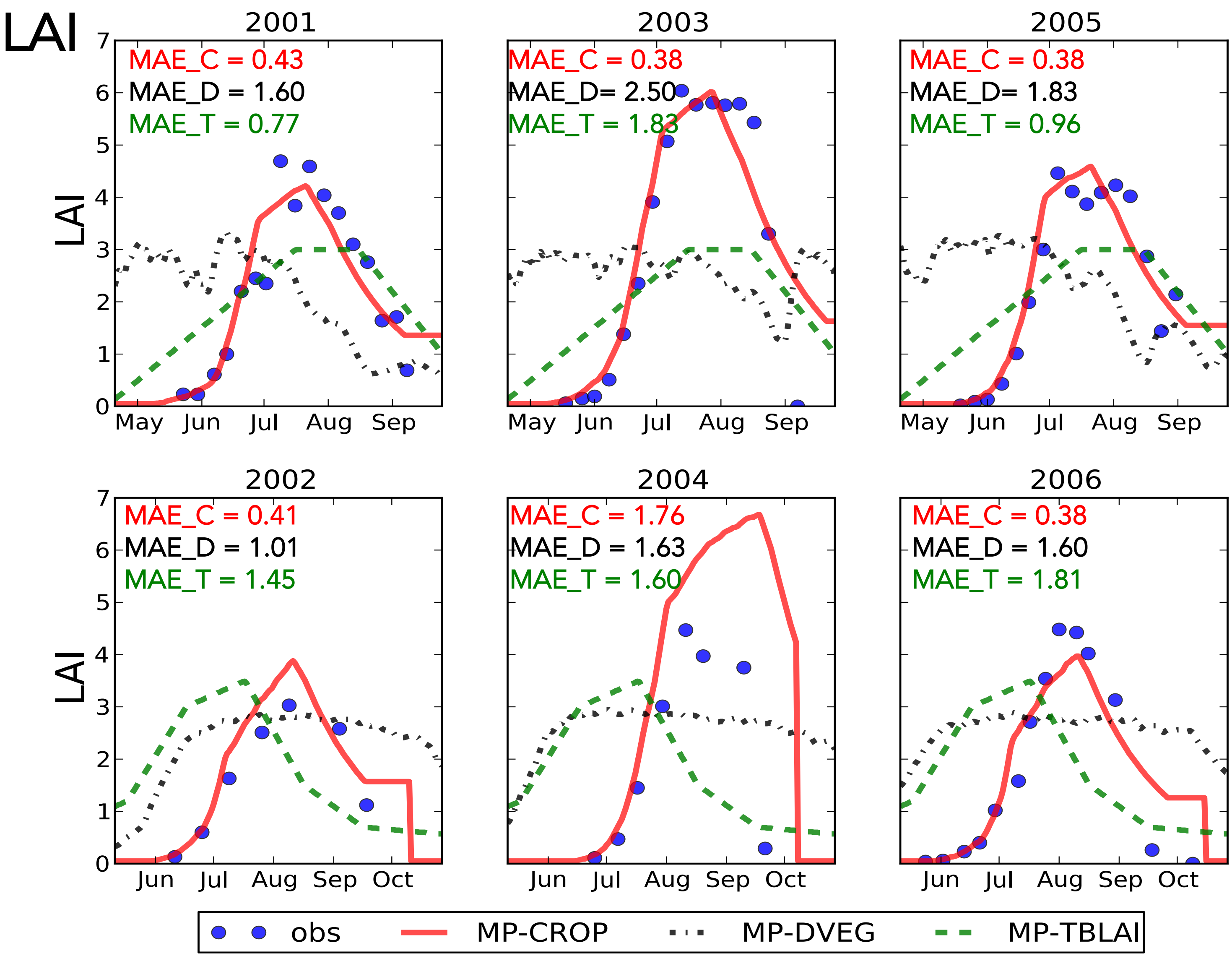
Bondville, IL (2001, 2003, 2005), corn, rainfed, half-hourly weather input.
Mead, NE (2002, 2004, 2006), soybean, rainfed, hourly input.
Data source : Ameriflux

Running model with 3 Vegetation options:

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



Offline Results



Bondville, IL
Corn

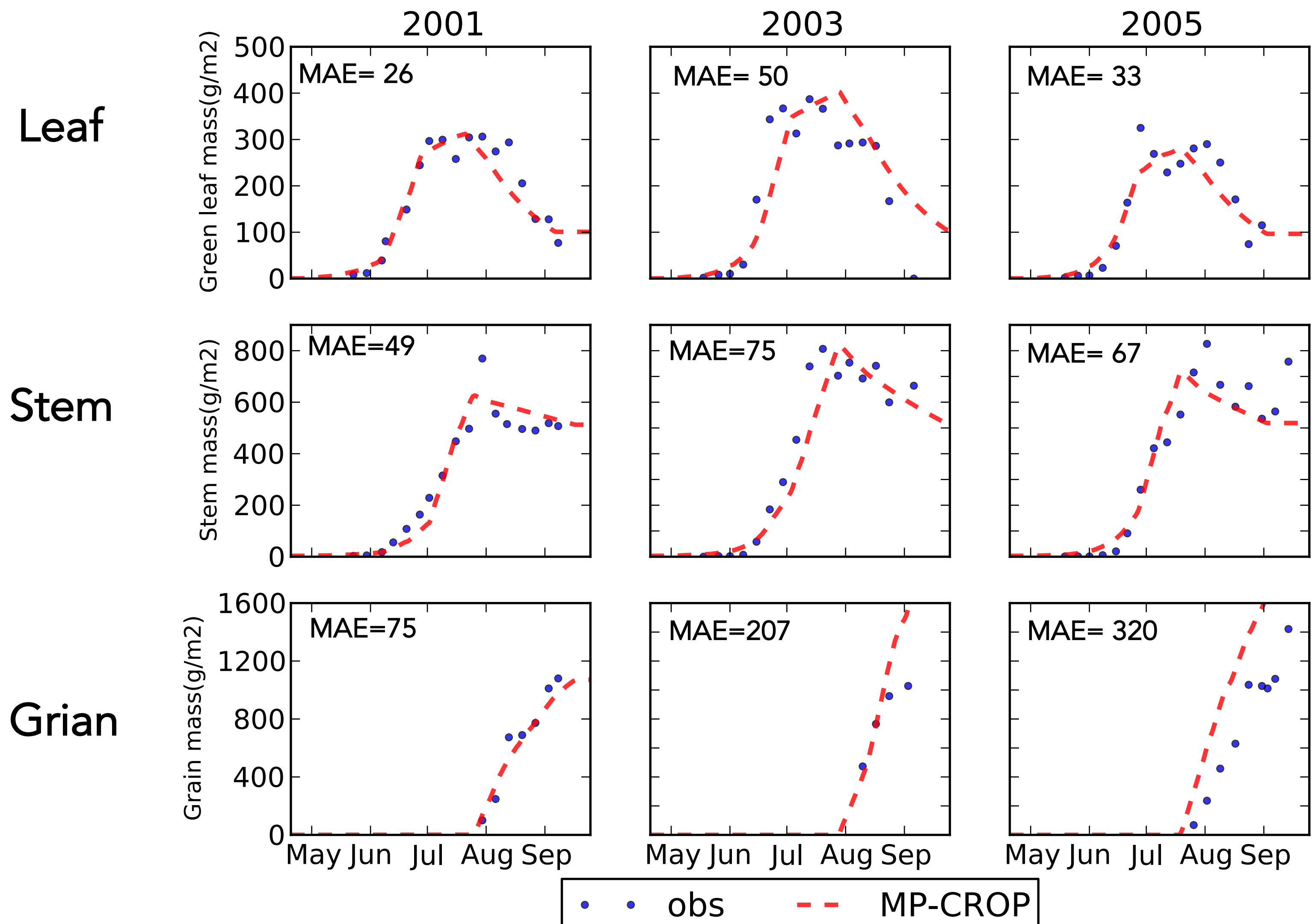
MAE: Mean Absolute Error

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

Mead, NE
Soybean

Offline Results

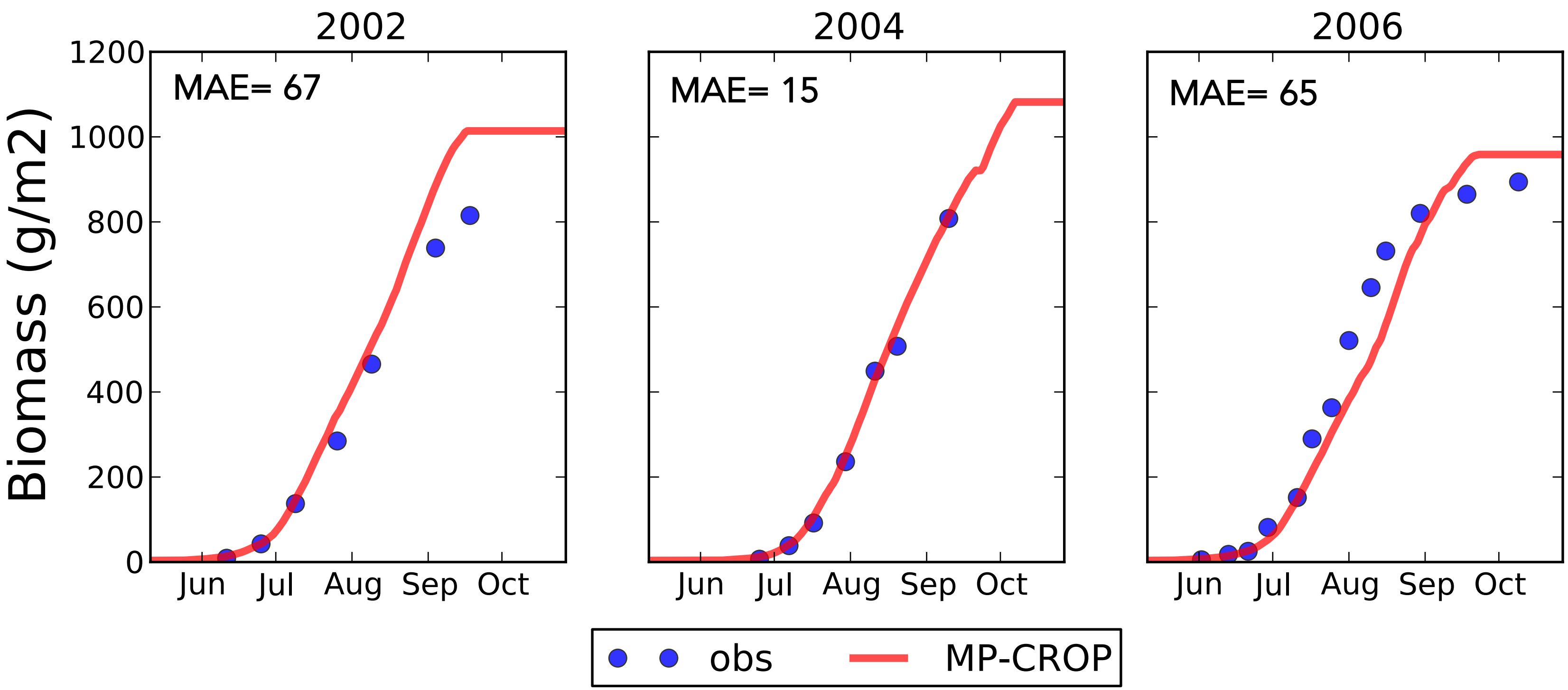
Biomass ---Corn



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

Offline Results

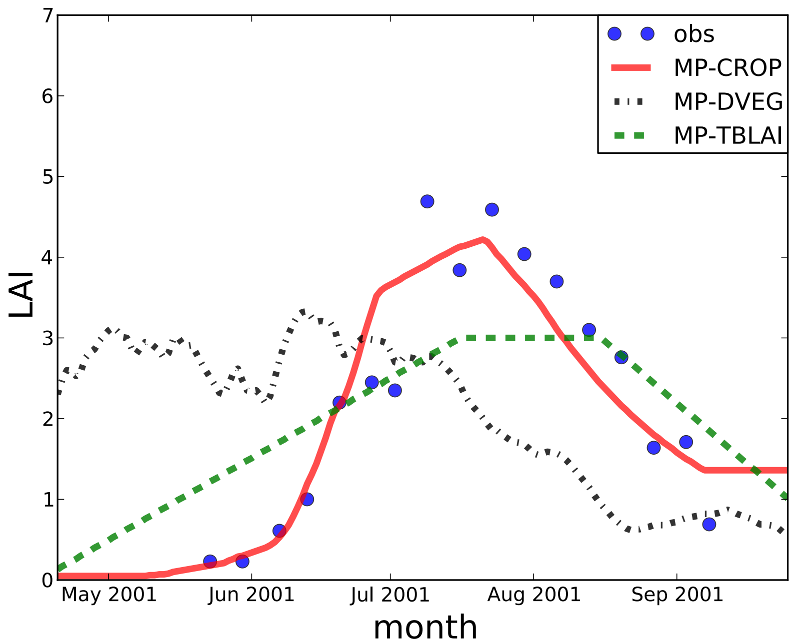
Biomass ---Soybean

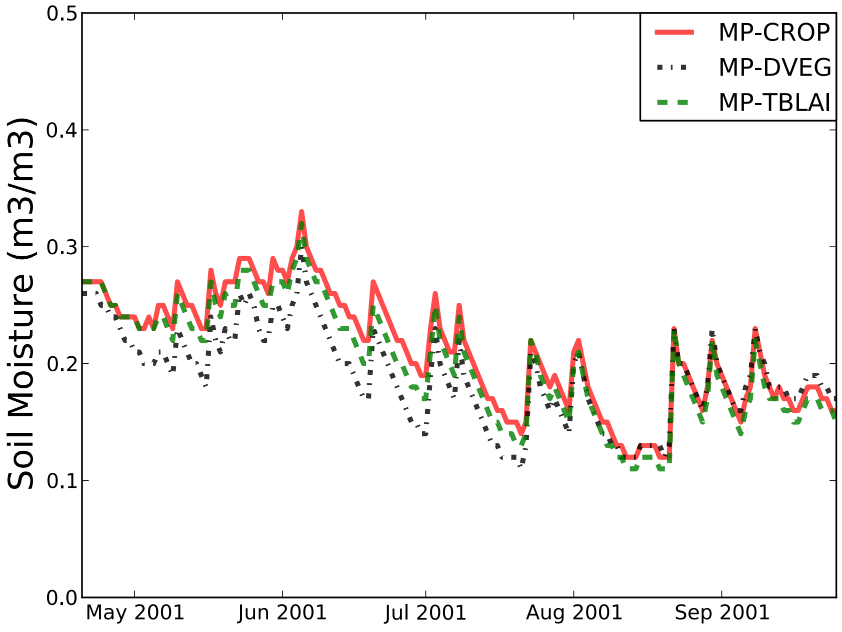


MAE: Mean Absolute Error (Unit: g/m2)

Offline Results

Explicitly modeling crop growth modifies soil-moisture simulation



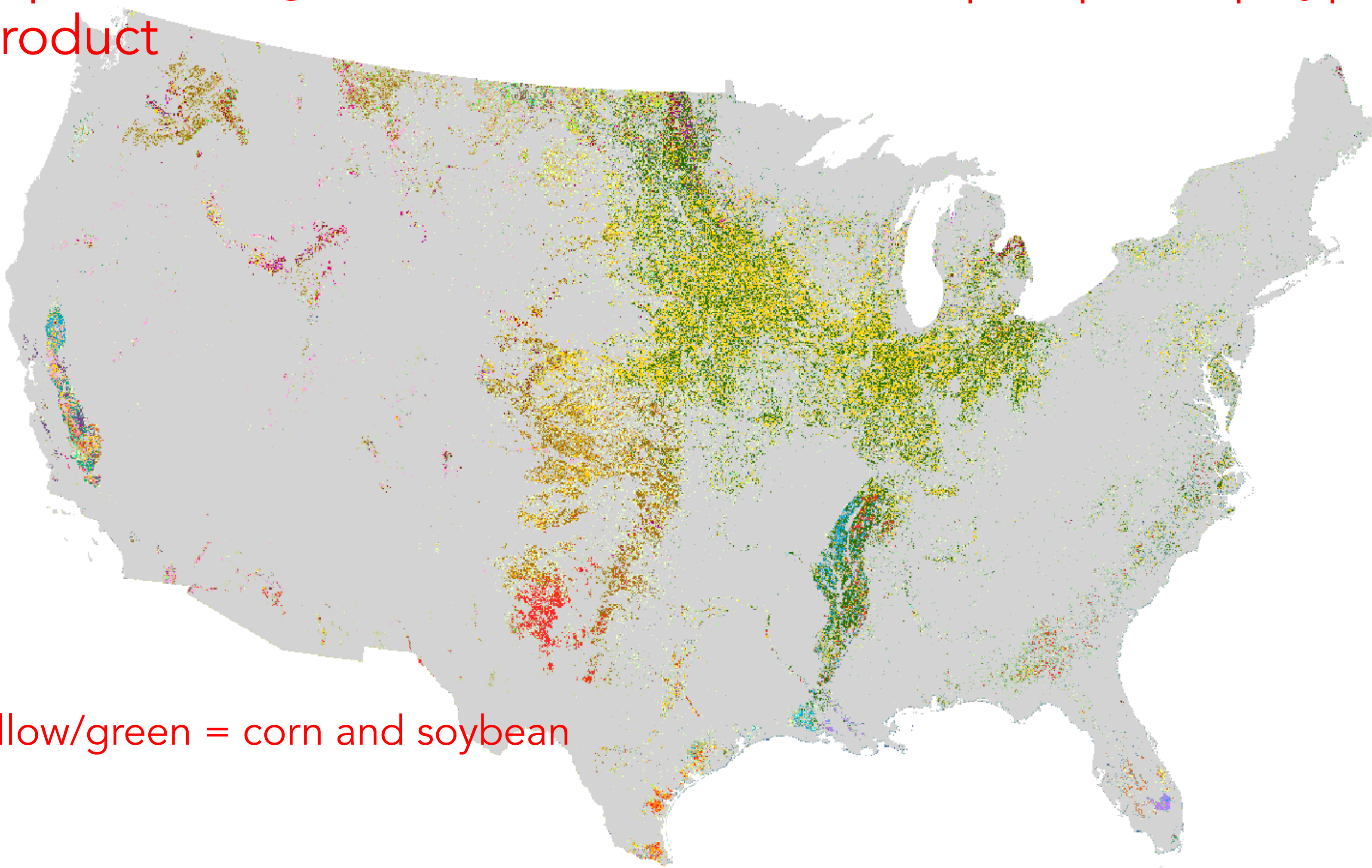


Liu et al (2014, AGU Annual Meeting)

WRF Noah-MP-Crop

Data Requirement for Integrating Noah-MP-Crop with WRF

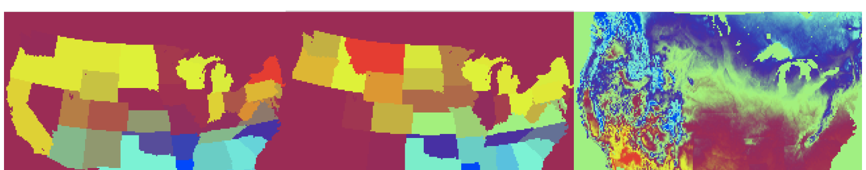
Implementing 30-meter USDA/GMU Cropscape crop type product



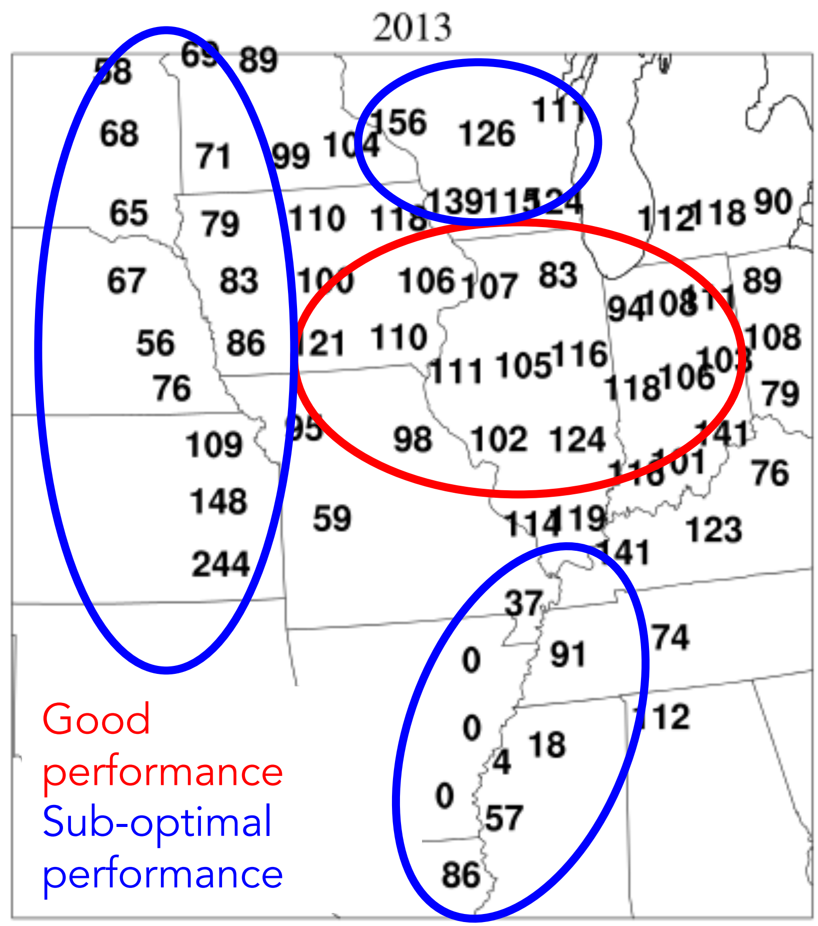
Yellow/green = corn and soybean

WRF Noah-MP-Crop

- 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

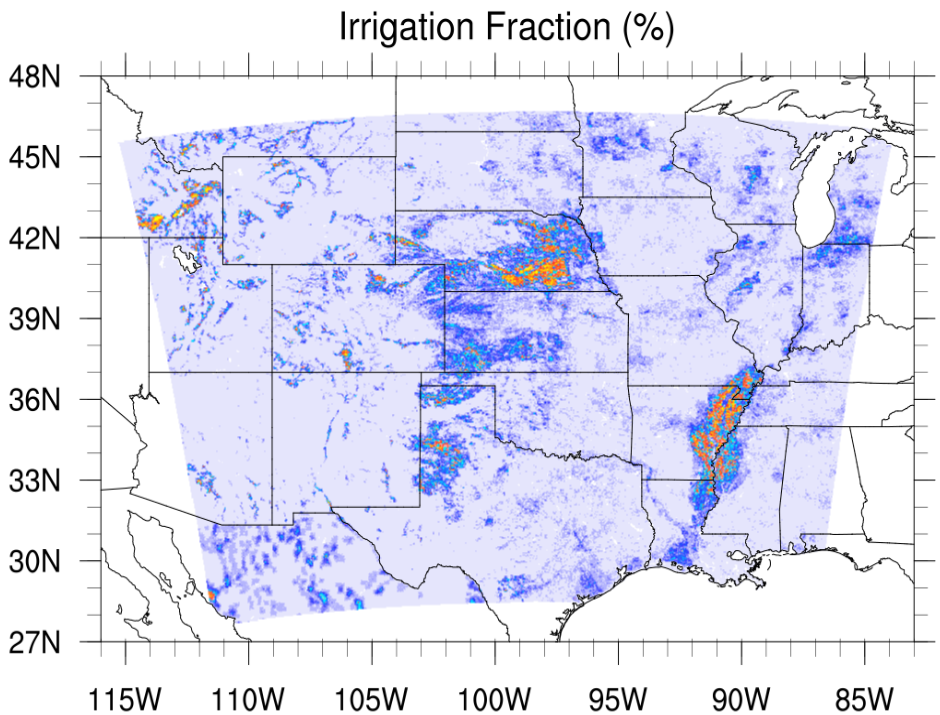


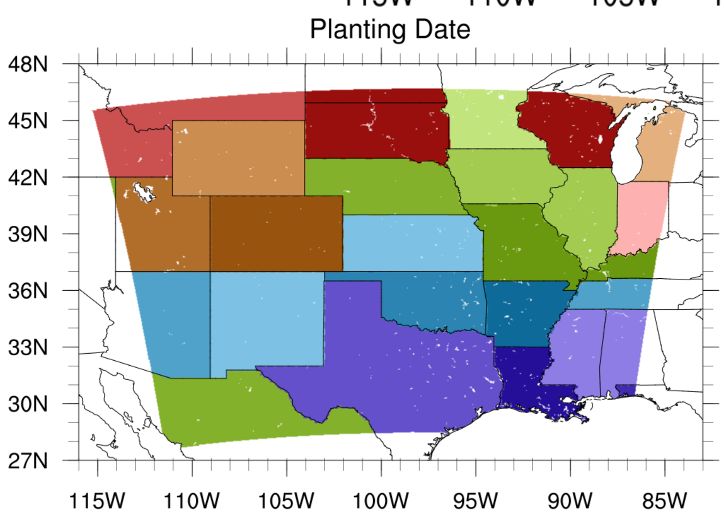
Planting Date Harvest Date Seasonal GDD

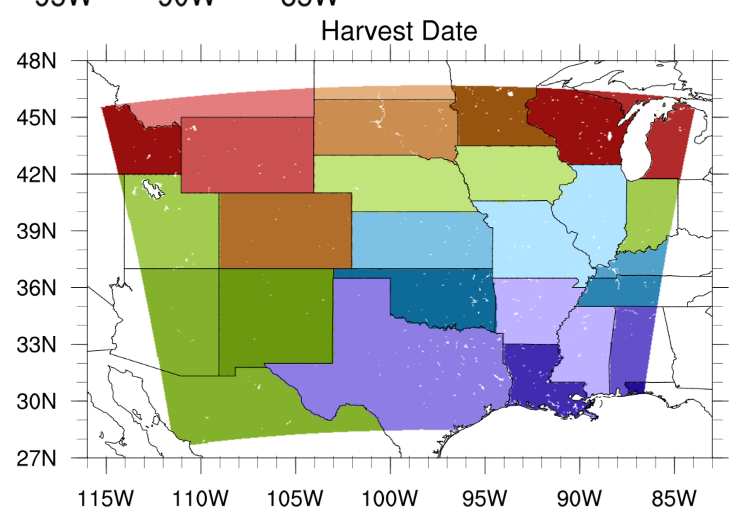


Corn yield ratio (modeled / observed) in % for 73 USDA zones (e.g., <100 implied underprediction)

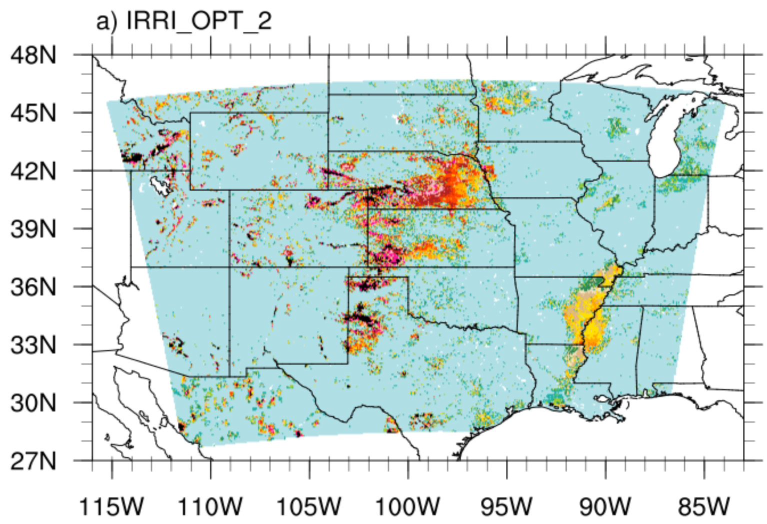
Incorporating Irrigation for WRF-Crop





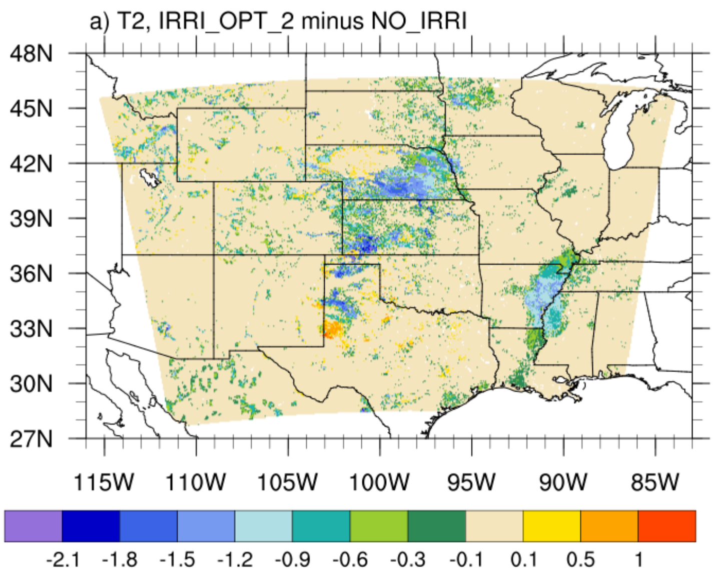


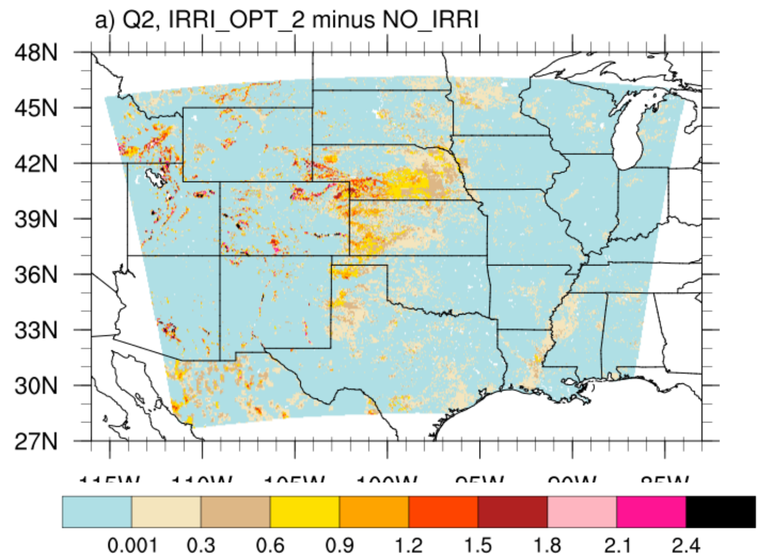
Incorporating Irrigation for WRF-Crop



Annual accumulated irrigation amount (km^3/year)

Impact of irrigation on regional climate





HRLDAS Forcing: DICast

DICast® In a Nutshell

***D**ynamic*
***I**ntegrated*
*fore**Cast***
***S**ystem*

- *Statistical Post-processer of model data*
  - *Removes bias*
- *Optimal Forecast Combiner*
  - *Create best combination of inputs*

HRLDAS Forcing: DICast

History of DICast®

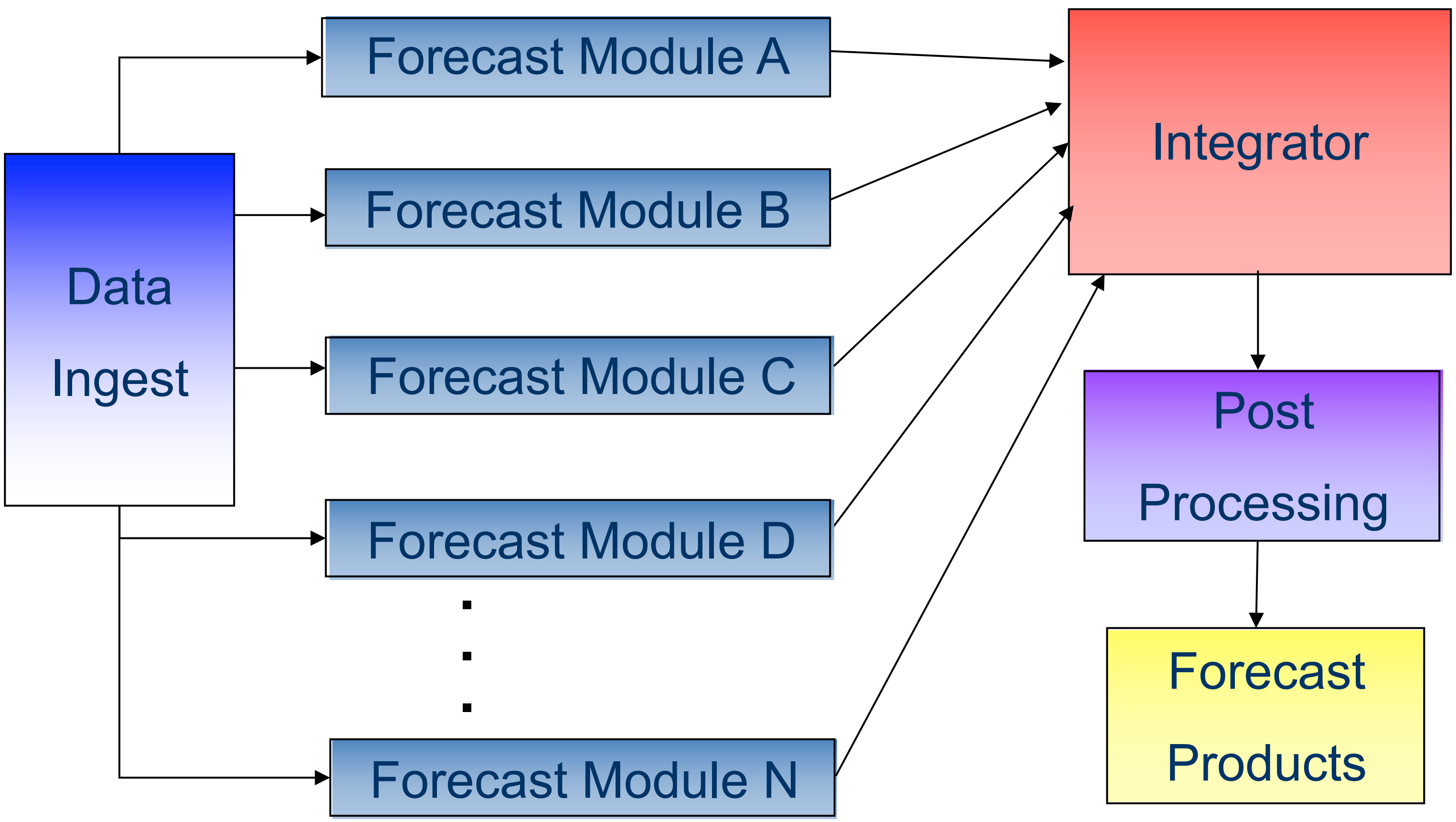
- Originally developed in RAL for The Weather Channel to produce public-oriented forecasts, circa 2000
- Used by Global Weather Corporation (GWC)
- Also by Schneider Electric Corporation (formerly Telvent, formerly DTN, formerly Meteorlogix, formerly Kavouras)
- Just started a new project with Panasonic Avionics Corp
- Used in many other projects (Road Weather, Wind, Solar) as the 'weather engine'

DICast generates the bulk of 'commodity' weather forecasts available on the Internet.

HRLDAS Forcing: DICast

Basic DICast® System Diagram

Designed to emulate the human forecaster process



HRLDAS Forcing: DICast

DICast® Inputs

- Predictors
  - National Weather Service NAM, HRRR, RAP, GFS, GFS & CMC Ensembles, MOS (LAMP, MAV, MET)
  - Community models - WRF
  - Canadian GEM
  - European ECMWF, UKMET
  - Australian BOM ACCESS, OCF MOS
  - Netherlands HIRLAM
- Observations
  - METARs
  - Synopic reports
  - MADIS & custom observations

HRLDAS Forcing: DICast

DICast® Forecast Variables

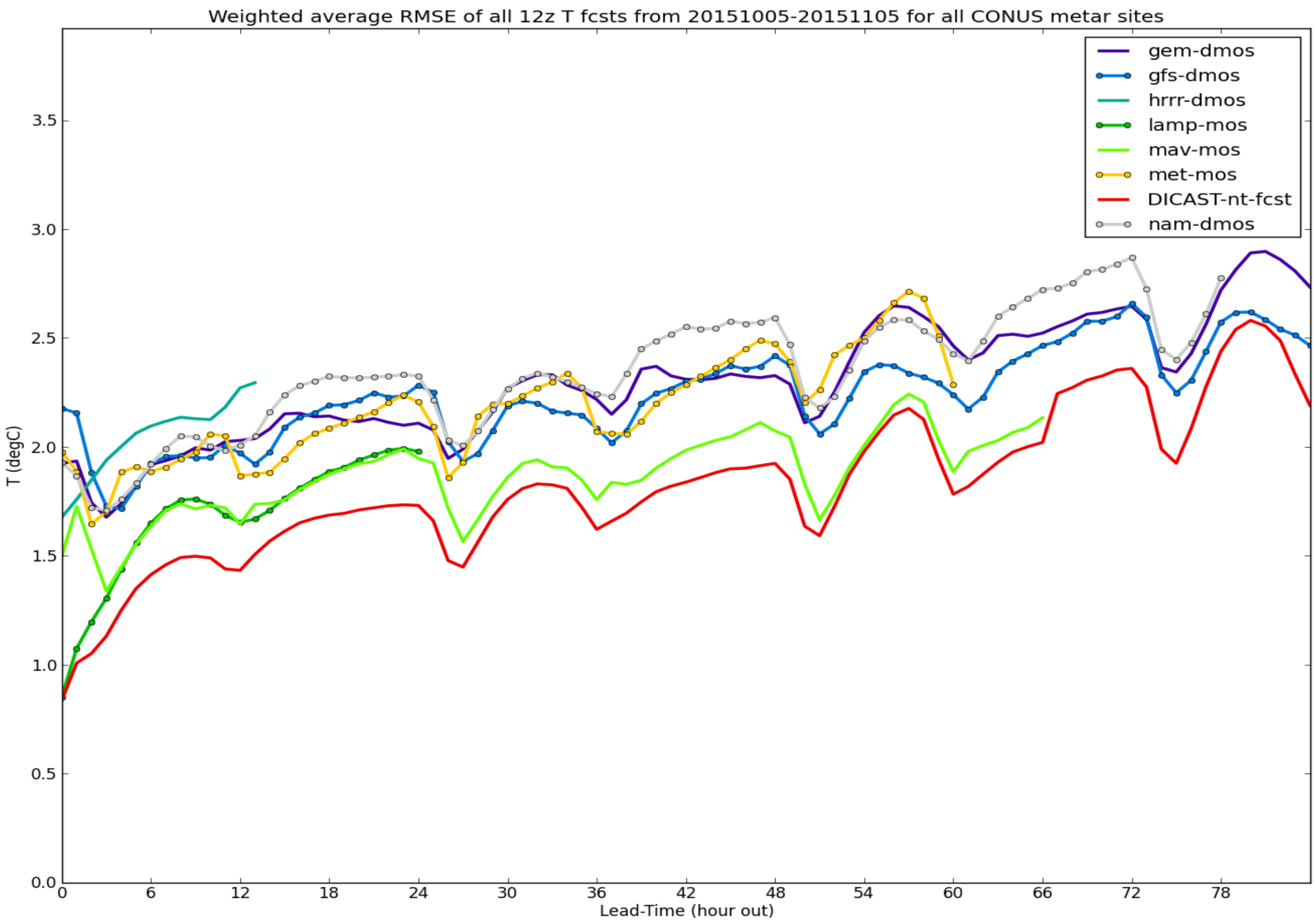
- Daily Max/Min Temp
- Probability of Precip
- Precip amount
- Cond Prob (Rain/Snow/Ice)
- Temp & Dew point
- Wind u-, v-, speed

Cloudiness
Probability of Thunder
Probability of Fog
Visibility
Irradiance

Continuous variables work best, good observations are key!

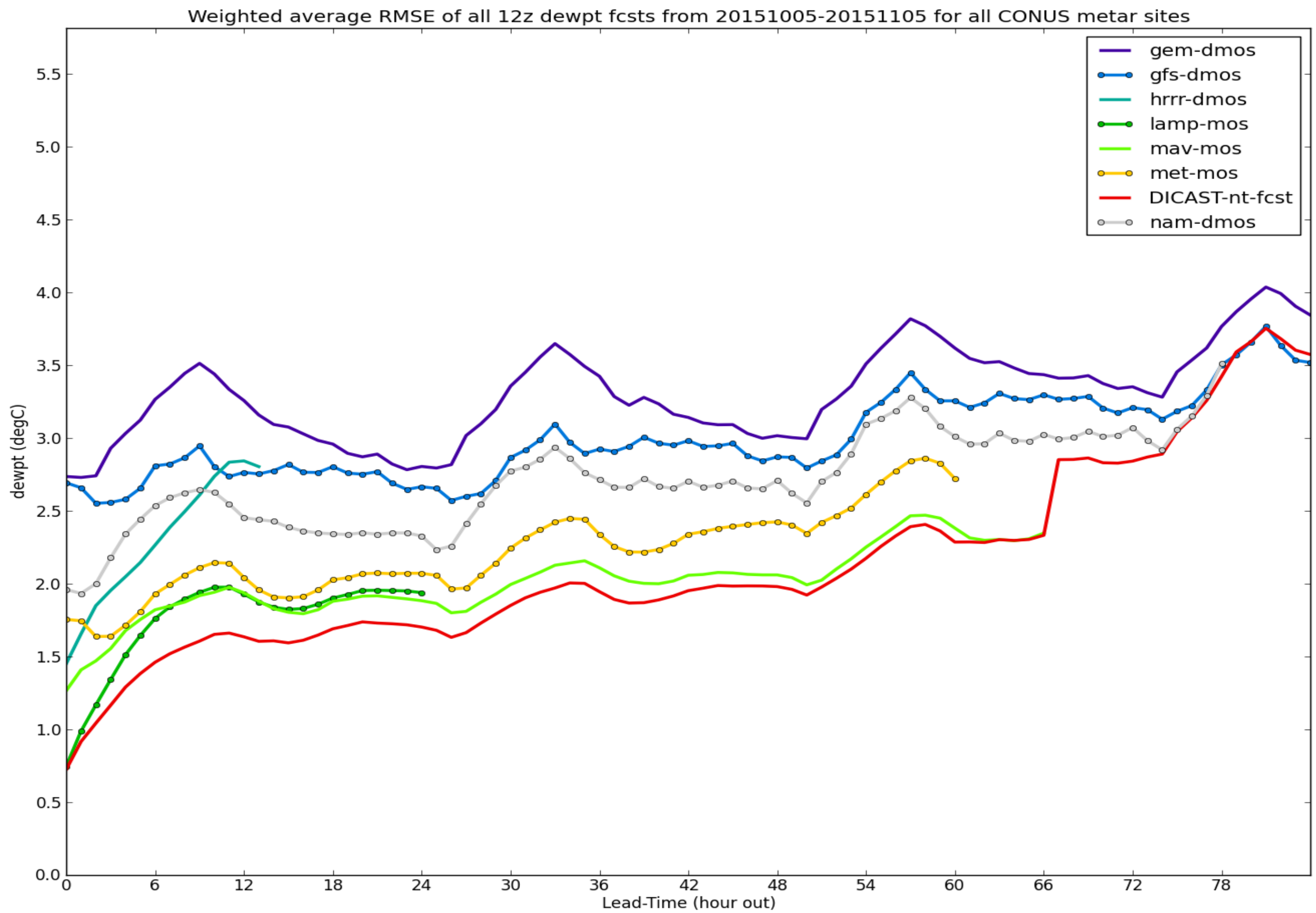
HRLDAS Forcing: DICast

DICast® Performance



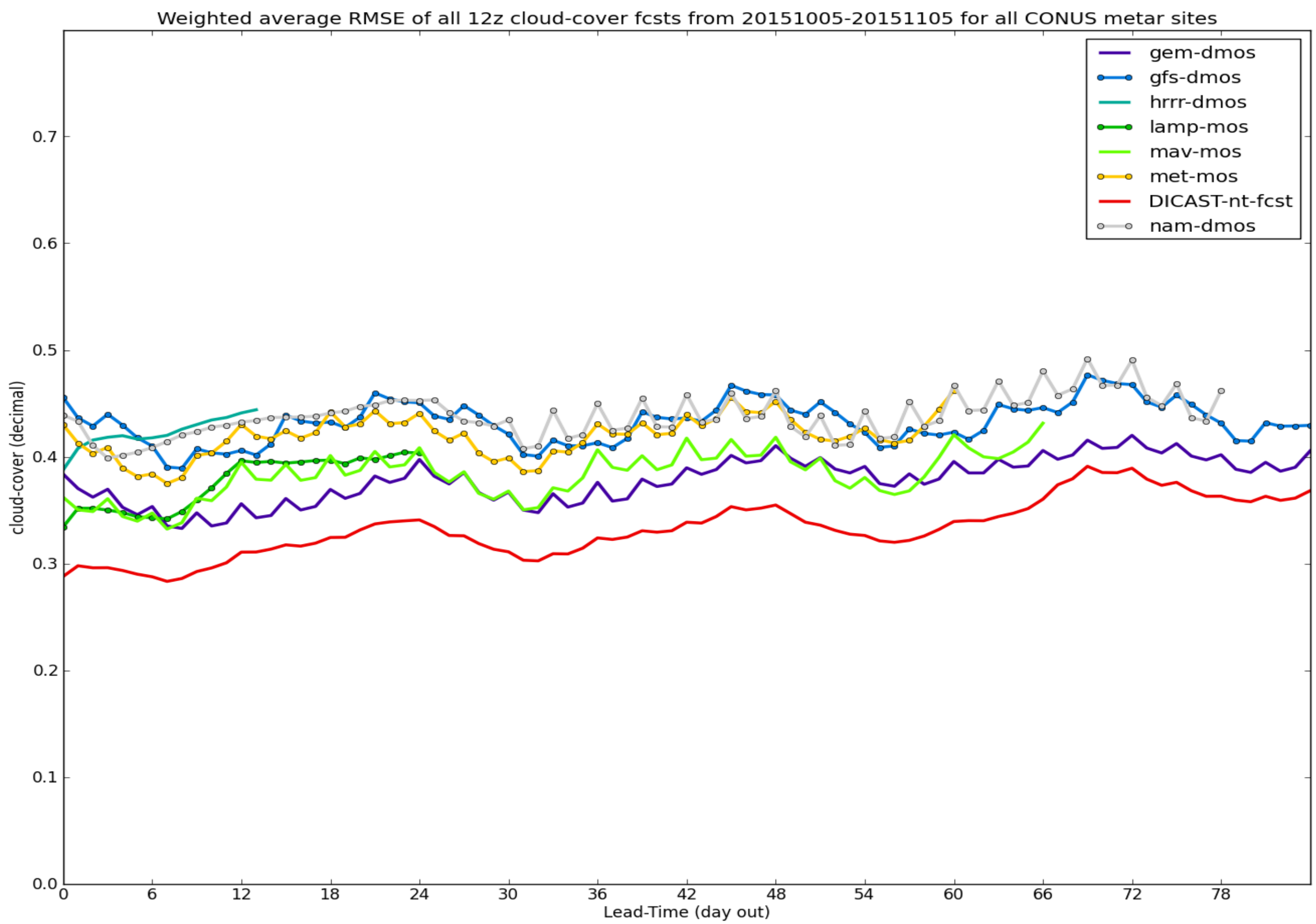
HRLDAS Forcing: DICast

DICast® Performance



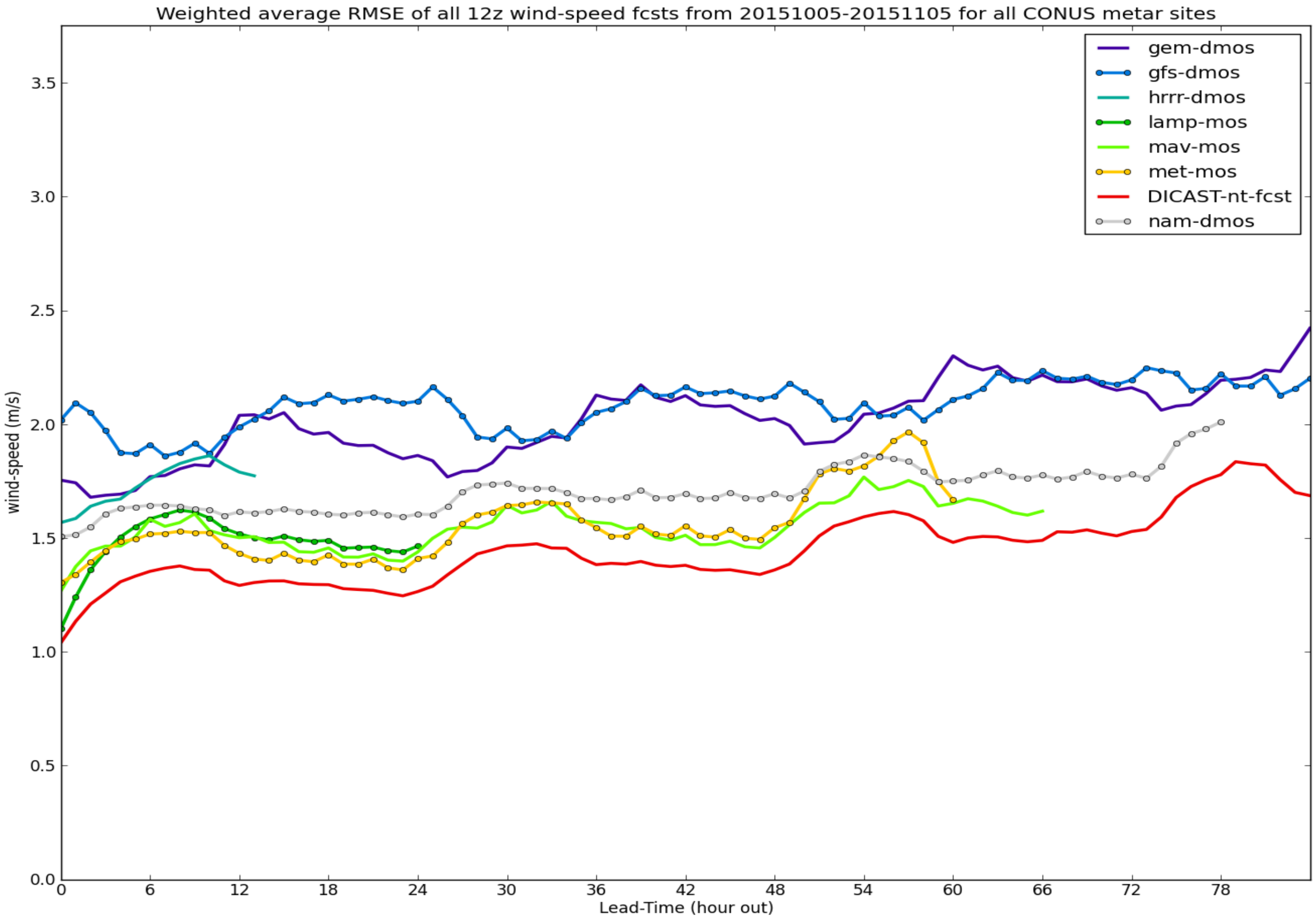
HRLDAS Forcing: DICast

DICast® Performance



HRLDAS Forcing: DICast

DICast® Performance



NWM Operational Configuration

Running Continuously on WCOSS since May 9th

	Analysis & Assimilation	Short-Range	Medium-Range	Long-Range
Cycling Frequency	Hourly	Hourly	Daily at 06Z	Daily Ens (16 mem)
Forecast Duration	- 3 hours	0-15 hours	0-10 days	0-30 days
Forecast Latency (latency of external forcing data accounts for most of delay)	1 hour	1 hour 45 mins	6 hours	19 hours
Meteorological Forcing	MRMS blend/ HRRR/RAP bkgnd.	Downscaled HRRR/RAP blend	Downscaled GFS	Downscaled & bias-corrected CFS
Spatial Discretization & Routing	1km/250m/NHDPlus Reach	1km/250m/NHDPlus Reach	1km/250m/NHDPlus Reach	1 km/NHDPlus Reach

Assimilation of USGS Obs

Reservoirs (1260 water bodies parameterized with level pool scheme)

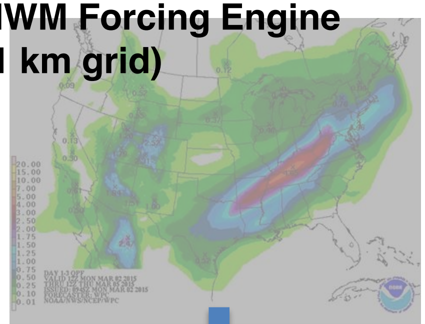
National Water Model Version 1.0: Model Chain

NWM uses NCAR supported community WRF-Hydro system

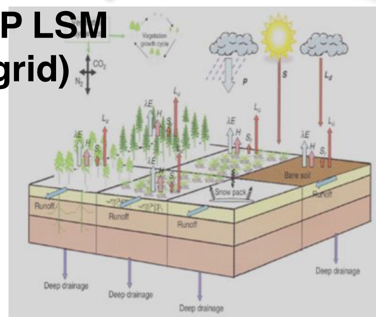
NWM: http://water.noaa.gov/about/nwm

WRF-Hydro: https://www.ral.ucar.edu/projects/wrf_hydro

1. NWM Forcing Engine (1 km grid)

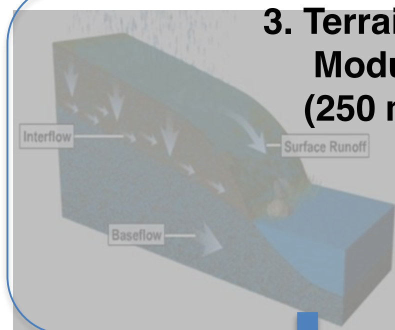


2. NoahMP LSM (1 km grid)

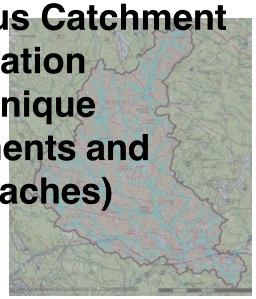


2-way coupling

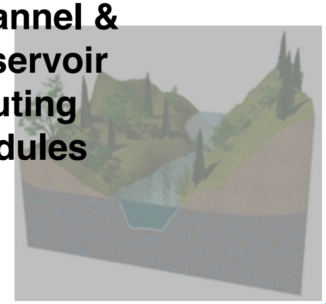
3. Terrain Routing Module (250 m grid)



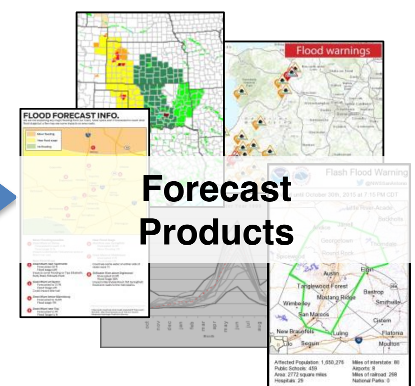
4. NHDPlus Catchment Aggregation (2.7M unique catchments and river reaches)



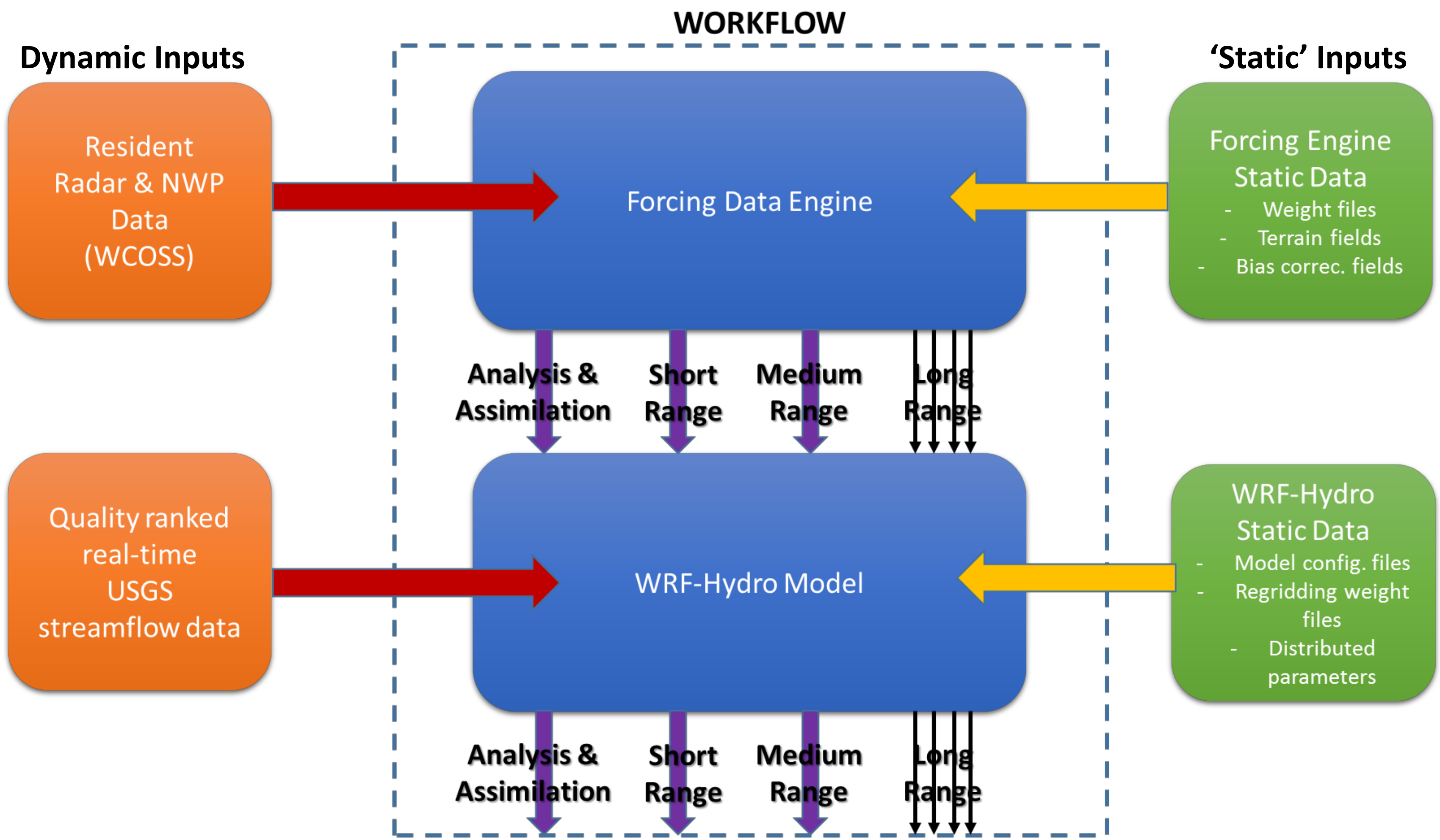
5. Channel & Reservoir Routing Modules



Forecast Products



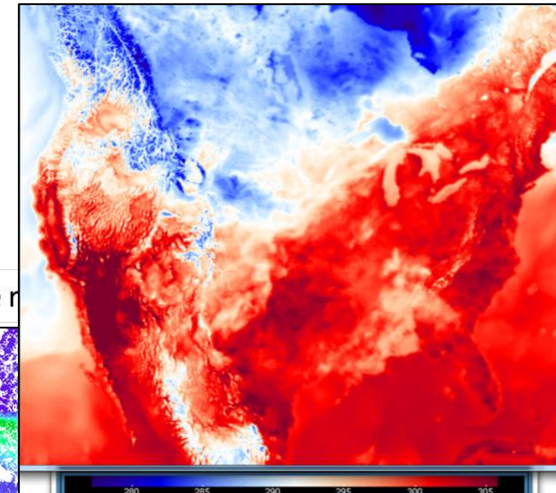
Operational Cycling of the National Water Model



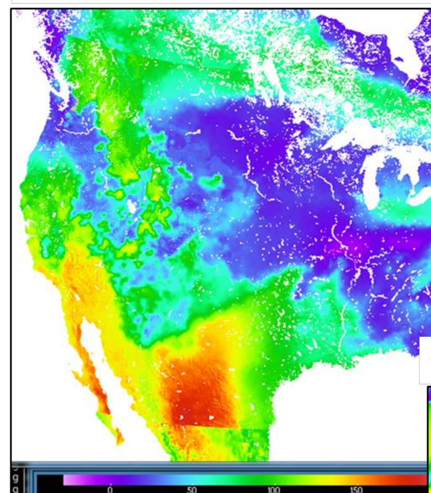
National Water Model Meteorological Forcing Engine

1. Create national 1km gridded fields of:
   - Temperature, mixing ratio, surface pressure, u-, v-windspeed, longwave and shortwave radiation, precipitation rate
2. Terrain Downscaling of:
   - Temperature (NARR distributed climatological lapse rate)
   - Mixing ratio (conserve RH)
   - Surface pressure
   - Incoming shortwave radiation (terrain slope and aspect)
3. Open source ncl/bash scripted workflow utilizing ESMF regridding tools,
4. Rwrfhydro-ESMF regridding used for evaluation

HRRR-RAP 2m Air Temperature



HRRR-RAP incoming longwave r



GFS – derived incoming shortwave radiation