Initial Development for Simulating Land Surface Change Impacts on Climate in the Northern Plains

Aaron K. Scott (aaron.scott@und.edu) and Aaron Kennedy

University of North Dakota, Grand Forks, ND

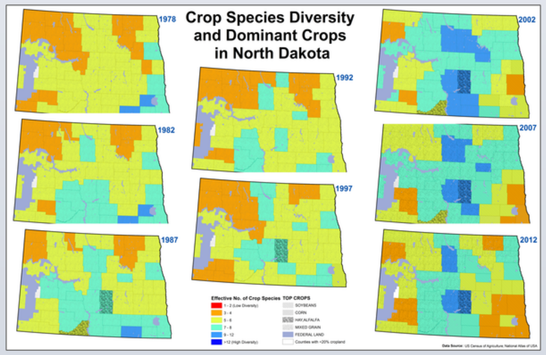
Introduction

Changes in crop type and coverage can have a significant impact on regional weather and climate. Over the Northern Plains (NP), there has been a transition from grains to leafier crops such as corn and soybeans. This should increase the amount of evapotranspiration, which may then lead to other changes in the atmosphere.

For this study, the Weather Research and Forecasting (WRF) model is used to downscale the Community Earth System Model (CESM). Simulations are performed using a standard configuration, and with the Noah-MP Land Surface Model (LSM) with a dynamic crop model such that feedback of crops can be further studied. The Noah-MP-Crop model has been tuned for southern regions of the U.S. Midwest and must be tuned for use in the NP region.

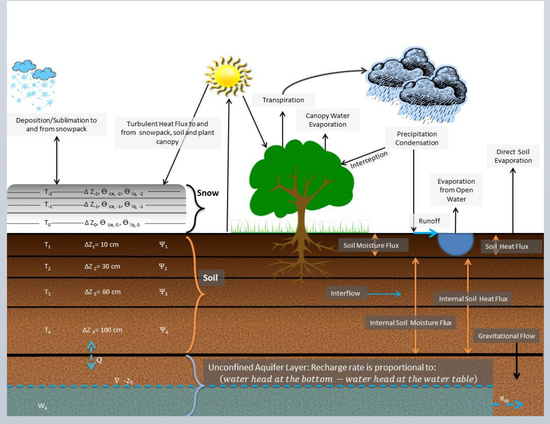
> Goal: Show usefulness of using a coupled Atmosphere/Crop model and tune crop model for NP region.

Vegetation Changes



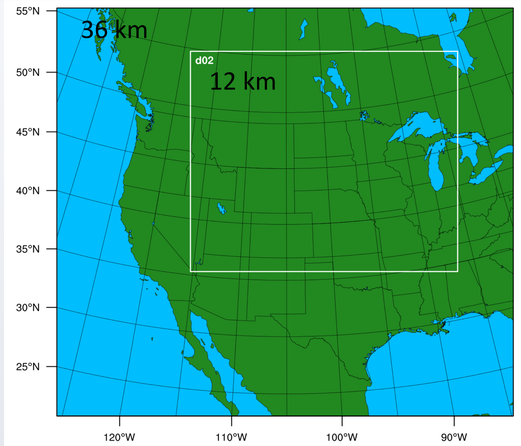
Aguilar J, Gramig GG, Hendrickson JR, Archer DW, Forcella F, et al. (2015) Crop Species Diversity Changes in the United States: 1978–2012. PLOS ONE 10(8): e0136580. https://doi.org/10.1371/journal.pone.0136580

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0136580

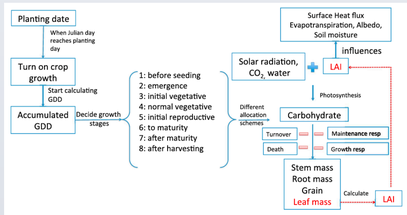


Example of processes in the Noah-MP land surface model. The Noah-MP-Crop model is added onto this model framework. Source: https://www.jsg.utexas.edu/noah-mp

Methodology



- 36 km/12 km grid spacing
- 45 vertical levels
- 2-way nesting
- Spectral nudging on outer domain
- W-Damping for model stability
- 12 month simulation with 1 month spin-up



Noah-MP-Crop model framework.
Source: Liu, X., F. Chen, M. Barlage, G. Zhou, and D. Niyogi (2016), Noah-MP-Crop:Introducing dynamic crop growth in the Noah-MP land surface model,J. Geophys. Res. Atmos., 121,13,953–13,972, doi:10.1002/2016JD025597.

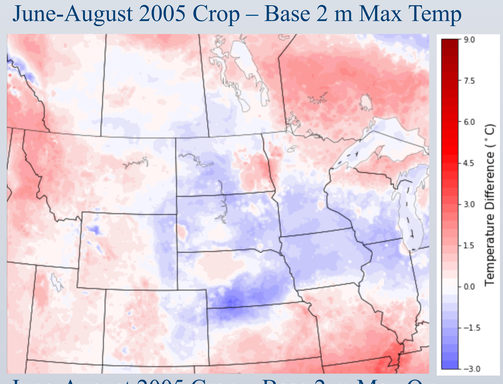
- Baseline Simulations: Standard model settings (5 yearly sims: 2001-2005)
- Crop Simulations: Noah-MP-Crop model coupled with standard WRF (2005 sim.)
- Compare Model differences between Crop and Baseline simulations

Downscale → Couple Crop → Alter Crop Usage

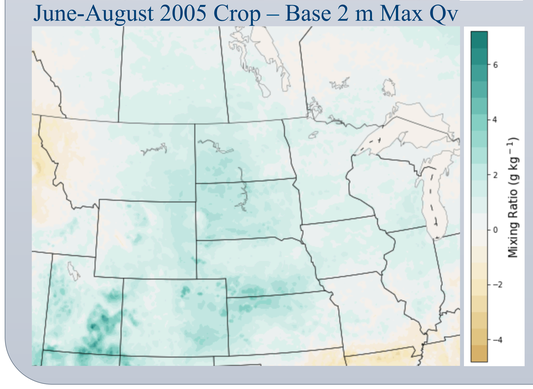
CESM GCM MOAR MEMBER	WRF Model: 5 Year 36/12 km domain Simulation	3 Month Growing Season: WRF 12 km nest domain Simulation	NOAH-MP-Crop: Tune for NP and simulate climatological changes

Initial Results

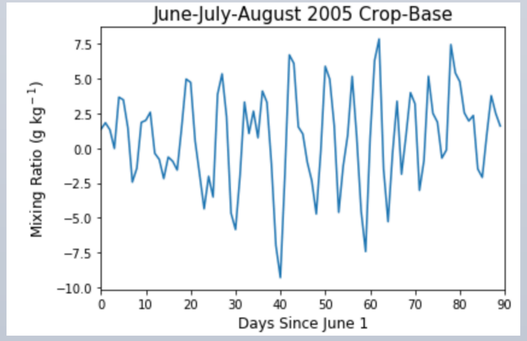
June-August 2005 Crop – Base 2 m Max Temp



June-August 2005 Crop – Base 2 m Max Qv



- 2005 June, July, and August 2-m max temperatures are compared between Crop and Baseline simulations
- The crop model is not tuned for the corn and soybeans in North Dakota. Note the Crop simulation produced warmer average max temps in that region
- Less water vapor mixing ratio was diagnosed from the crop simulation for same area
- Time-series from SE ND shows the largest amount of deviation from the Crop and Baseline simulations in mid-summer



Post Processing

In order to make model data output useful for other groups within CRCS, an effort is being made to convert model output files (netCDF) into GeoTiff files. By using Python and Gdal, variables such as temperature, dew point can be saved to the new format style.

> What model output is useful for other CRCS research groups? What are known best practices for format conversion?

Ongoing Work

- The current Noah-MP-Crop model is tuned for areas outside of the Northern Plains
- The next step is to tune the model for the Northern Plains
- Different parameters must be changed for each crop type with model
- Analyze downscaling performance of Baseline
- Analyze Changes Crop flux has on local climate

> Crop information for NP will be used to tune crop model. What are the most important factors?

Table 2. Parameters in New User Customized Table in the Noah-MP-Crop Model[a]

Parameters	Description	Values for Corn (Soybean)	Equations
PLTDAY	Planting day (in Julian day format)	111 (131)	(A3)
HSDAY	Harvesting day (in Julian day format)	300 (280)	(A3)
GDDTBASE	Base temperature for GDD accumulation (c)	10 (10)	(A1)
GDDTCUT	Upper temperature for GDD accumulation (c)	30 (30)	(A1)
GDDS1	GDD from seeding to emergence	50 (60)	(A3)
GDDS2	GDD from seeding to initial vegetative	625 (675)	(A3)
GDDS3	GDD from seeding to normal vegetative	933 (1183)	(A3)
GDDS4	GDD from seeding to initial reproductive	1103 (1253)	(A3)
GDDS5	GDD from seeding to physical maturity	1555 (1605)	(A3)
Q10MR	Q10 for maintenance respiration	2.0 (2.0)	(A5)
FOLN_MX	Foliage nitrogen concentration (%)	1.5 (1.5)	(A5)
LEFREEZ	Characteristic T for leaf freezing (K)	268 (268)	(A7)
BIO21AI	Leaf area per living leaf biomass (SLA)	0.015 (0.030)	(A9)
LFMR25	Leaf maintenance respiration at 25c (μmol co2/m**2/s)	1.0 (1.0)	(A5)
STMR25	Stem maintenance respiration at 25c (μmol co2/kg bio/s)	0.05 (0.05)	(A5)
RTMR25	Root maintenance respiration at 25c (μmol co2/kg bio/s)	0.05 (0.05)	(A5)
GRAINMR25	Grain maintenance respiration at 25c (μmol co2/kg bio/s)	0 (0)	(A5)
FRA_GR	Fraction of growth respiration	0.2 (0.2)	(A6)
DILE_FC(PGS)	Coefficient for leaf temperature stress death (1/s)	PGS = 5: 0.5 (0.5) PGS = 6: 0.5 (0.5)	(A7)
DILE_FW(PGS)	Coefficient for leaf water stress death (1/s)	PGS = 5: 0.2 (0.2) PGS = 6: 0.2 (0.2)	(A7)
LF_OVRC(PGS)	Leaf turnover coefficient (1/s)	PGS = 5: 0.2 (0.2) PGS = 6: 0.3 (0.3)	(A7)
ST_OVRC(PGS)	Stem turnover coefficient (1/s)	PGS = 5: 0.2 (0.12) PGS = 6: 0.3 (0.06)	(A7)
RT_OVRC(PGS)	Root turnover coefficient (1/s)	PGS = 5: 0.12 (0.12) PGS = 6: 0.06 (0.06)	(A7)
LFPT(PGS)	Fraction of carbohydrate flux to leaf	PGS = 3: 0.36 (0.4) PGS = 4: 0.1 (0.2)	(A6) and (A8)
STPT(PGS)	Fraction of carbohydrate flux to stem	PGS = 3: 0.24 (0.2) PGS = 4: 0.6 (0.5)	(A6) and (A8)
RTPT(PGS)	Fraction of carbohydrate flux to root	PGS = 3: 0.4 (0.4) PGS = 4: 0.3 (0.3) PGS = 5: 0.05 (0.05)	(A6) and (A8)
GRAINPT(PGS)	Fraction of carbohydrate flux to grain	PGS = 5: 0.95 (0.95) PGS = 6: 1 (1)	(A6) and (A8)

[a]PGS means plant growth stage; some parameters have different values for each growth stages.

Table of parameters for Noah-MP-Crop Model. Currently tuned for Mid-West region.
Source: Liu, X., F. Chen, M. Barlage, G. Zhou, and D. Niyogi (2016), Noah-MP-Crop:Introducing dynamic crop growth in the Noah-MP land surface model,J. Geophys. Res. Atmos., 121,13,953–13,972, doi:10.1002/2016JD025597.

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