Model estimates of water yield and N yield under alternative N management practices across the Mississippi-Atchafalaya River basin during 1980-2017

Chaoqun Lu (clu@iastate.edu)

Jien Zhang (jienz@iastate.edu)

Department of Ecology, Evolution, and Organismal Biology, Iowa State University, Ames, IA 50010

This documentation includes descriptions of the results of the following publication:

Lu, C. et al. Increased extreme precipitation challenges nitrogen load management to the Gulf of Mexico. *Communications Earth and Environment*. In press. 2020.

Introduction

This folder contains time-series maps of the model-estimated water yield and nitrogen (N) yield, covering the Mississippi/Atchafalaya River Basin (MARB) spanning from 1980 to 2017. These maps show annual total and sum of water yield and N yield in days with extreme precipitation events, which are aggregated from daily estimates of a process-based hydro-ecological model (Dynamic Land Ecosystem Model, DLEM). They are at a spatial resolution of 5-min×5-min (0.08333° Lat × 0.08333° Lon). By using model simulation, we predict water and N yield under alternative N management scenarios across the MARB. There are two subfolders, "TT" and "DT", within this folder. "TT" and "DT" indicate "traditional timing" and "dynamic timing" of nitrogen fertilizer applications, respectively, in regards to the model experiments in the main text. The "TT" folder contains the gridded model estimates of water yield (named by "Runoff") and nitrogen yield (named by "Nleach") at annual bases. TT reflects our best estimate of water and N yields within the context of multi-factor environmental changes, including climate, atmospheric CO_2 concentration, N deposition, land use, and human management history (such as fertilizer use, tillage, tile drainage, etc.). The "DT" folder only contains the model estimates of nitrogen yield (“Nleach”) under an alternative N application timing. More details can be found in Lu et al. (2020).

The DLEM (version 2.0) is an integrated land system model that couples biophysical, biogeochemical, hydrological, vegetation dynamical, and land use processes in an earth system context (Lu et al., 2018; Tian et al., 2010a). This version of DLEM was designed to explicitly model carbon, nitrogen, water balance, and land-to-aquatic mass flows (Chen et al., 2006; Liu et al., 2008; Lu et al., 2018; Tian et al., 2010b). It is capable of simulating N cycling and the flow of water and N from managed and natural land ecosystems (such as crops, grasslands, forests, etc.) to streams and rivers (Liu et al., 2013; Tian et al., 2020). In DLEM, each grid cell is a cohort of up to four natural plant functional types and one cropping system with its annual area percentage prescribed by land use input data. Specifically, we consider the distribution and physiological properties of corn, soybean, winter wheat, spring wheat, rice, and 6 other major crop types across the river basin. This version of DLEM also models the impacts of synthetic N fertilizer and manure applications, tile drainage, tillage, crop rotation, and crop technology innovations on the coupled hydro-biogeochemcial cycle in agricultural systems as well as the effects of climate, CO_2, and nitrogen deposition for non-agricultural ecosystems.

Daily climate data (maximum, minimum and mean temperature, precipitation, and shortwave radiation) used in this study to drive DLEM were generated from high-resolution gridded meteorological data products from station observations by the Climatic Research Unit (CRU) of the University of East Anglia (Mitchell and Jones, 2005) and North America Regional Reanalysis (NARR) dataset from a combination of modeled and observed data (Mesinger et al., 2006). Atmospheric CO_2 was retrieved from IPCC historical CO_2 data and published results (Wei et al., 2014). The gridded N deposition data were developed by interpolating 3-year N deposition data with N emission patterns from EDGAR (Dentener, 2006; Wei et al., 2014). Land use and land cover change data were developed by a recent study (Yu and Lu, 2018), with the annual harvested crop area in each county kept consistent with the county-level survey records provided by USDA NASS. The time-series gridded data of N fertilizer use rate, timing, and types were developed by a recent study (Cao et al., 2018). The details of model input data can be found in the Supplementary Information (Part II) in Lu et al. (2020).

Rule of naming:

DT: dynamic timing of N fertilizer application, fertilizer application timing postponed to meet crop growth demand.

TT: traditional timing of N fertilizer application, according to fertilizer use database developed by Cao et al. (2018)

Runoff: water yield, sum of surface runoff and baseflow, unit in mm/m2/year.

Nleach: nitrogen yield, N leaching loss induced by both surface and sub-surface runoff, unit in g N/m2/year.

AT: annual total summed over all 365 days each year

EP: annual total summed only from extreme precipitation events each year. The EP events are defined as daily precipitation amount above the 90th percentile for each pixel. We use a climatological baseline period 1961–1990 to estimate the thresholds for easy comparison with extreme climate indices (Zhang et al., 2005).

Domain (the North America)

Image size: 1404 columns, 924 rows

All grids: 0.08333° Lat × 0.08333° Lon

Projection: GCS_WGS_1984

Top Left gridcell: 84.0 N, 169.0 W

Bottom Right gridcell: 7.0 N, 52.0 W

Note: Black grid cells outside of the MARB region do not have values and are assigned as “NoData”. These .tif files can be opened in ArcMAP directly or red in any language-based software such as R.

Reference:

Cao, P., Lu, C. and Yu, Z.: Historical Nitrogen Fertilizer Use in Agricultural Ecosystems of The Contiguous United States during 1850–2015: Application Rate, Timing, and Fertilizer Types, Earth Syst. Sci. Data, 10(2), 969, 2018.

Chen, G., Tian, H., Liu, M., Ren, W., Zhang, C. and Pan, S.: Climate impacts on China’s terrestrial carbon cycle: an assessment with the dynamic land ecosystem model, Environ.

Model. Simul., 56–70, 2006.

Dentener, F. J.: Global Maps of Atmospheric Nitrogen Deposition, 1860, 1993, and 2050, Data set. Available on-line (http//daac. ornl. gov/) from Oak Ridge Natl. Lab. Distrib. Act. Arch. Center, Oak Ridge, TN, USA, doi:10.1016/j.ridd.2011.06.019, 2006.

Liu, M., Tian, H., Chen, G., Ren, W., Zhang, C. and Liu, J.: Effects of Land-Use and Land-Cover Change on Evapotranspiration and Water Yield in China During 1900-2000 1, J. Am. Water Resour. Assoc., 44(5), 1193–1207, 2008.

Liu, M., Tian, H., Yang, Q., Yang, J., Song, X., Lohrenz, S. E. and Cai, W. J.: Long-term trends in evapotranspiration and runoff over the drainage basins of the Gulf of Mexico during 1901-2008, Water Resour. Res., 49(4), 1988–2012, doi:10.1002/wrcr.20180, 2013.

Lu, C., Yu, Z., Tian, H., Hennessy, D. A., Feng, H., Al-Kaisi, M., Zhou, Y., Sauer, T. and Arritt, R.: Increasing carbon footprint of grain crop production in the US Western Corn Belt, Environ. Res. Lett., 13(12), 124007, 2018.

Mesinger, F., DiMego, G., Kalnay, E., Mitchell, K., Shafran, P. C., Ebisuzaki, W., Jović, D., Woollen, J., Rogers, E. and Berbery, E. H.: North American regional reanalysis, Bull. Am. Meteorol. Soc., 87(3), 343–360, 2006.

Mitchell, T. D. and Jones, P. D.: An improved method of constructing a database of monthly climate observations and associated high-resolution grids, Int. J. Climatol., 25(6), 693–712, doi:10.1002/joc.1181, 2005.

Tian, H., Xu, X., Miao, S., Sindhoj, E., Beltran, B. J. and Pan, Z.: Modeling ecosystem responses to prescribed fires in a phosphorus-enriched Everglades wetland: I. Phosphorus dynamics and cattail recovery, Ecol. Modell., 221(9), 1252–1266, 2010a.

Tian, H., Xu, X., Liu, M., Ren, W., Zhang, C., Chen, G. and Lu, C.: Spatial and temporal patterns of CH4 and N2O fluxes in terrestrial ecosystems of North America during 1979–2008: application of a global biogeochemistry model, Biogeosciences, 7(9), 2673–2694, 2010b.

Tian, H., Xu, R., Pan, S., Yao, Y., Bian, Z., Cai, W., Hopkinson, C. S., Justic, D., Lohrenz, S. and Lu, C.: Long-Term Trajectory of Nitrogen Loading and Delivery From Mississippi River Basin to the Gulf of Mexico, Global Biogeochem. Cycles, 34(5), e2019GB006475, 2020.

Wei, Y., Liu, S., Huntzinger, D. N., Michalak, A. M., Viovy, N., Post, W. M., Schwalm, C. R., Schaefer, K., Jacobson, A. R., Lu, C., Tian, H., Ricciuto, D. M., Cook, R. B., Mao, J. and Shi, X.: The north american carbon program multi-scale synthesis and terrestrial model intercomparison project - Part 2: Environmental driver data, Geosci. Model Dev., 7(6), 2875–2893, doi:10.5194/gmd-7-2875-2014, 2014.

Yu, Z. and Lu, C.: Historical cropland expansion and abandonment in the continental US during 1850 to 2016, Glob. Ecol. Biogeogr., 27(3), 322–333, 2018.

Zhang, X., Hegerl, G., Zwiers, F. W. and Kenyon, J.: Avoiding inhomogeneity in percentile-based indices of temperature extremes, J. Clim., 18(11), 1641–1651, 2005.