Goddard Space Flight Center

Land Information System

Extending High Resolution Modeling of Land-Atmosphere Ammonia Exchanges

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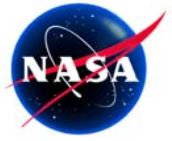
EPA Partners: Donna Schwede, John Walker, and Robin Dennis (EPA/RTP AMSD/NERL)



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Outline

1. **Project Purpose**
2. **Overview**
3. **Technical Aspects**
   - **Background on Ammonia Flux**
   - **Systems Configuration (MLBC-LIS)**
   - **MLBC Model Testing and Validation Results**
4. **Summary (Quad Chart)**
   - **Expected DSS Impact**
   - **Status**
   - **Schedule**
   - **Issues**

1. Purpose of the Project

The Ammonia Exchanges project evaluates the potential of NASA modeling systems and data from TRMM and MODIS to improve the EPA models of ammonia flux exchange in the Community Multiscale Air Quality (CMAQ) system, which is used in air quality forecasting to support public health and NAAQS compliance.

2. Overview:
Extending High Resolution Modeling of Land-Atmosphere Ammonia Exchanges

Models

GSFC: Land Information System (LIS)
EPA: Multi-layer Biochemical Dry deposition Model (MLBC)

Observations

MODIS Land Products (MOD12, MOD15)
GOES Radiation
TRMM Precip Products (3B-42, 3B-43)

Ammonia flux
Carbon Dioxide flux
Surface Temperature
Soil Moisture
Evaporation
Sensible Heat Flux

Decision Support Tools

EPA's Models-3/ Community Multiscale Air Quality (CMAQ) Modeling system

EPA United States Environmental Protection Agency

Value and Benefits to Citizens and Society

Improved Public Notice/Warnings

Improved Air Quality Impact Mitigation

Public Health Benefits:
- Reduced Mortality
- Reduced Illness
- Reduced Hospitalization

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3. Technical Aspects
Background: Flux Equation

- **$F = G (C_i - C_a) = 1/R (C_i - C_a)$, where**
  G=conductance=1/R=1/resistance
  Ci=surface concentration of species
  Ca=atmospheric concentration
- **$F\downarrow \Rightarrow$ G = Deposition velocity**
- **$F\uparrow \Rightarrow$ G = Emission coefficient**

Background: MLBC (1 of 2)

MLBC References: Wu et al, 2003a, 2003b, JGR, V. 108, D1

- **Parameterization of NH3 compensation point=Ci has been added**
- **Aerodynamic Resistance (Ra) based on Monin-Obukhov similarity theory (Wesely and Hicks, 1977)**
- **Boundary layer resistance (Rb) is proportional to the inverse of the Stanton number and in the form for aerodynamically smooth flow (Reisman et al., 1994)**

Background: MLBC (2 of 2)

- **Soil Resistance (Rsoil) from Wu et al., 1995**
- **Stomatal Resistance (Rs) based on Berry et al., 1978**
  - **Applied to sunlit & shaded leaves**
  - **Norman radiation scheme**
  - **C3 & C4 photosynthesis processes**
  - **Water stress index applied to the maximum CO2 uptake rate**
- **Cuticular Resistance (Rcut) based on membrane simple transport theory**

Background: Ammonia Compensation Point

$$[NH_3]_{gas} = \frac{10^{-(0.0897+2729/T)}}{4.7589T} \frac{[NH_4^+]}{[H^+]} \exp\left[41000\left(\frac{1}{T} - \frac{1}{298.0}\right)\right]$$

(Wu et al., 2007, in revision, Agr. For. Met.)

The Equation indicates that ammonia compensation point is a strong function of leaf temperature and the ratio of NH4+ and H+ in the plant apoplast which is a useful indicator of emission and absorption potential of plants.

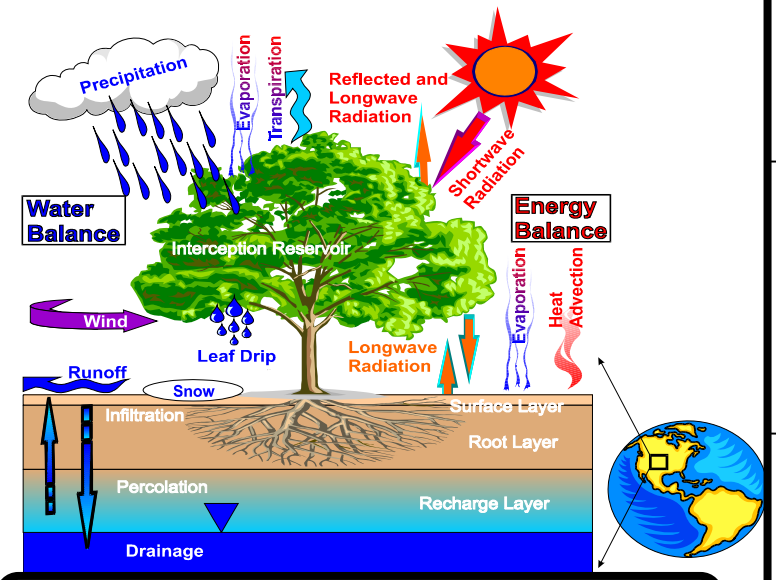
LIS-MLBC Systems Configuration

Inputs

- Topography, Soils (Static)
- Land Cover, Crop Type Leaf Area Index (MODIS)
- Modeled + Observed Meteorology (TRMM)
- Observed Surface States (e.g., Snow, Soil Moisture)

Physics

- Land Surface Models (LSM) MBLC



- Data Assimilation Modules

Outputs

- Soil Moisture & Temperature Profiles
- Surface Energy & BC Fluxes (e.g., H,LE)
- Surface Water Fluxes (e.g.,Runoff)
- Surface States: (e.g., Snow, LAI)

Applications

- Mobility Models (e.g.,FCS)
- Atm. Models (e.g.,WRF, CMAQ)
- Water Resources/ Ocean Models
- Carbon Models

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MLBC V&V Sites

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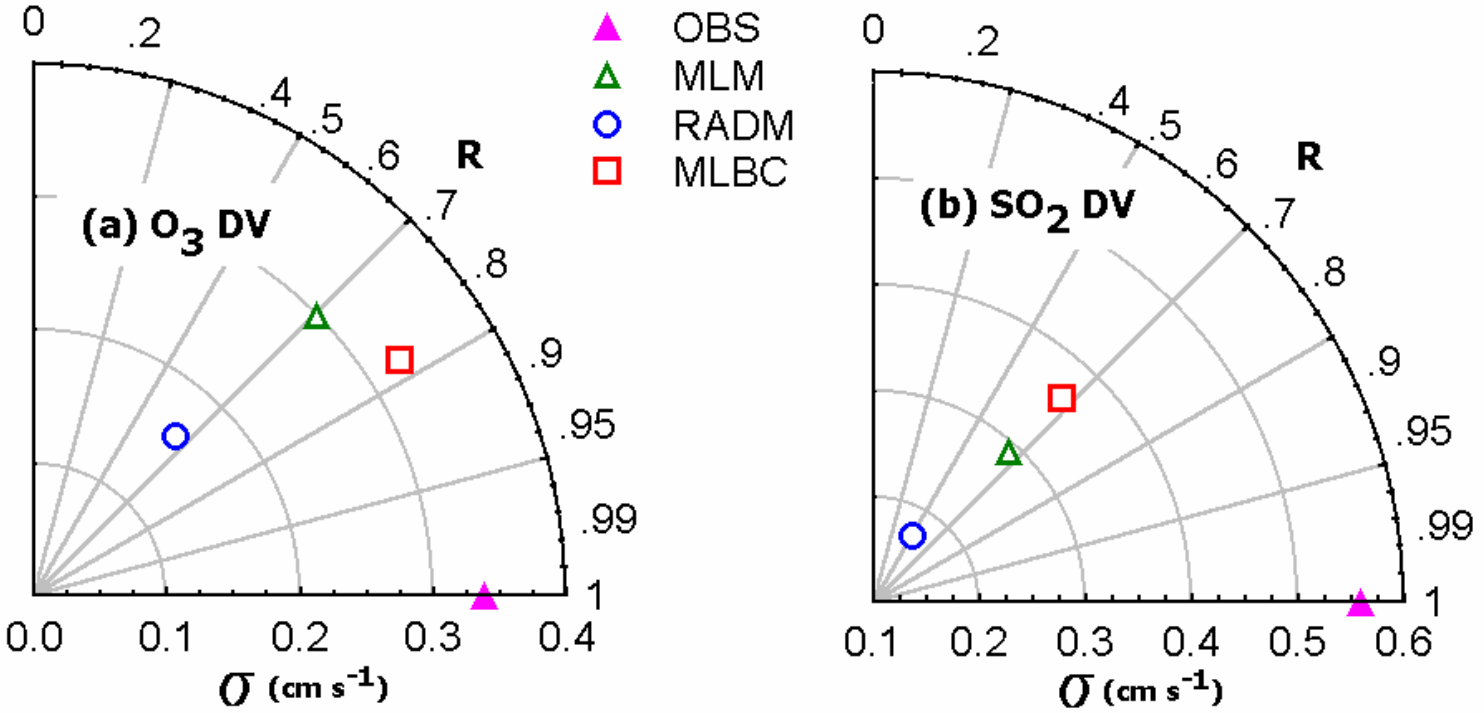
MLBC V&V Sites

Location	Plant (Type)	Period (mo, yr)
Nashville, TN	**Soybean (C3)**	**6--10, 95**
Kane Forest, PA	**Cherry+Maple (C3)**	**4--10, 97**
Bondville, IL	**Corn (C4)**	**8--10, 94**
Plymouth, NC	**Soybean (C3)**	**7--8, 96**
Sand Flats, NY	**Mixed forest (C3)**	**5--10, 98**
Sand Mountain, AL	**Pasture grass (C4)**	**4--6, 95**
Duplin, NC	***Soybean (C3)***	***6--8,04***

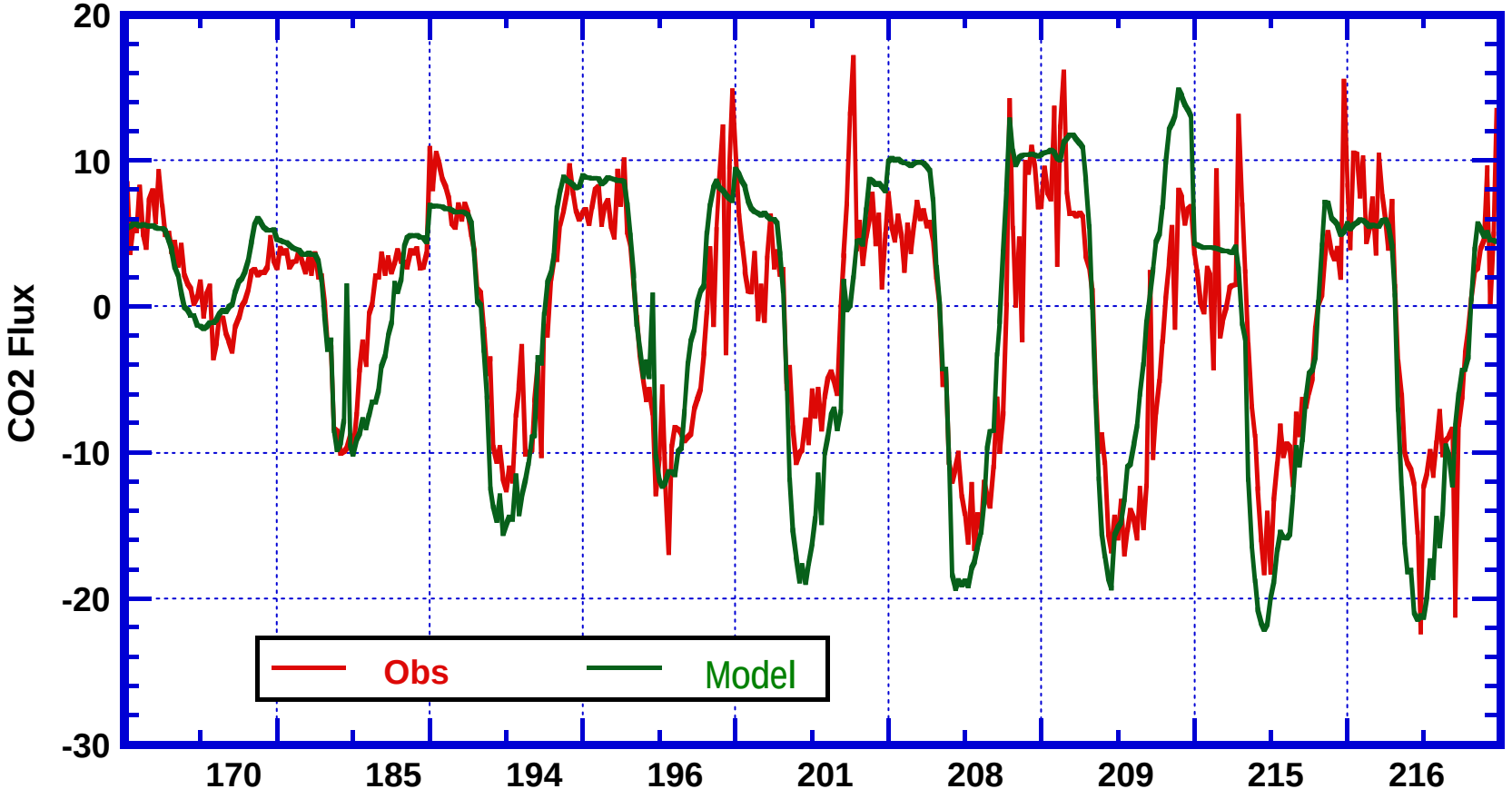
Original MLBC V&V
Nash: Soybean site

RADM (Wesely, 1989)
MLM (Meyers et. al., 1998)
MLBC (Wu et al., 2003a and 2003b)

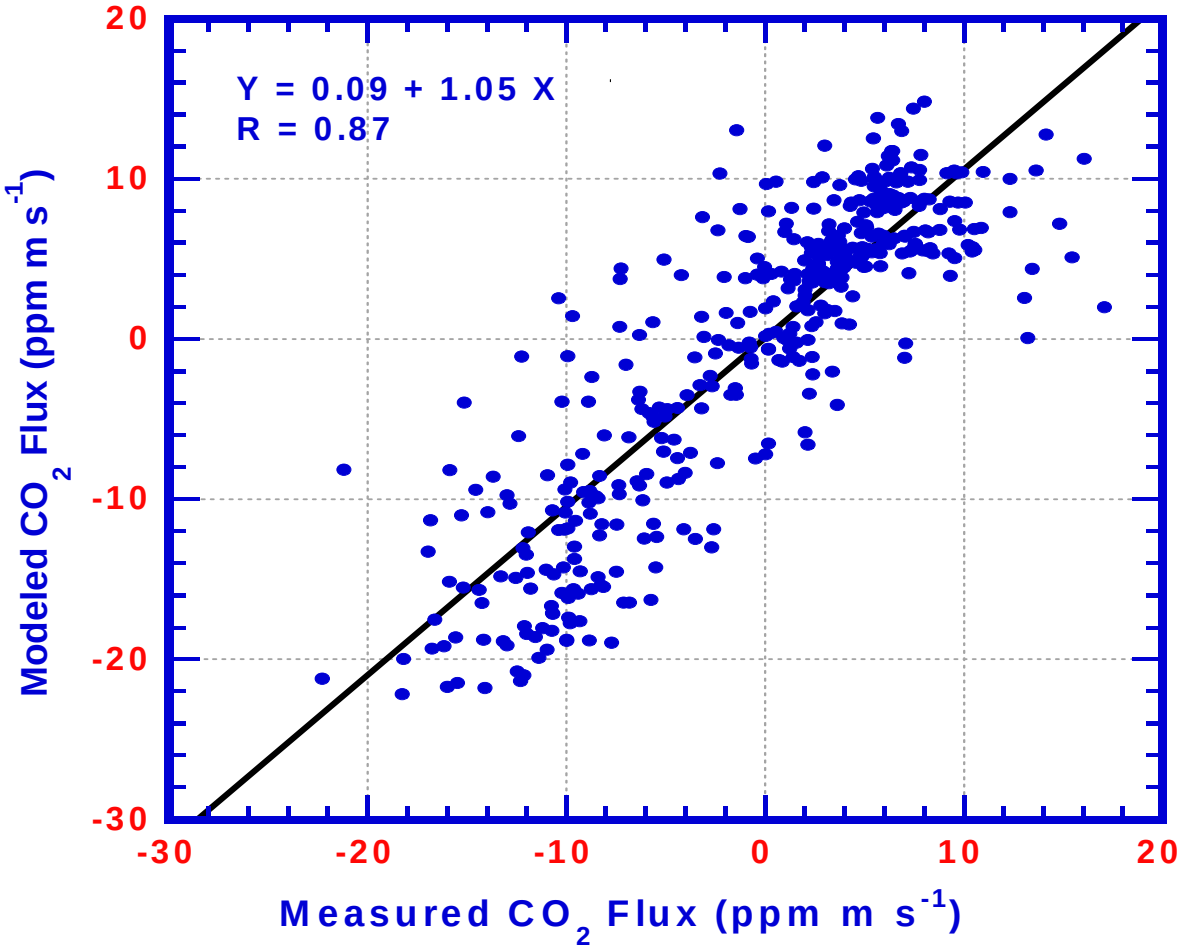


Statistics summary of correlation coefficient (R), standard deviation (σ) and the centered pattern root-mean-square difference (E') at Nash

V&V: CO_2 Flux at Duplin, NC



V&V: CO_2 Flux at Duplin, NC



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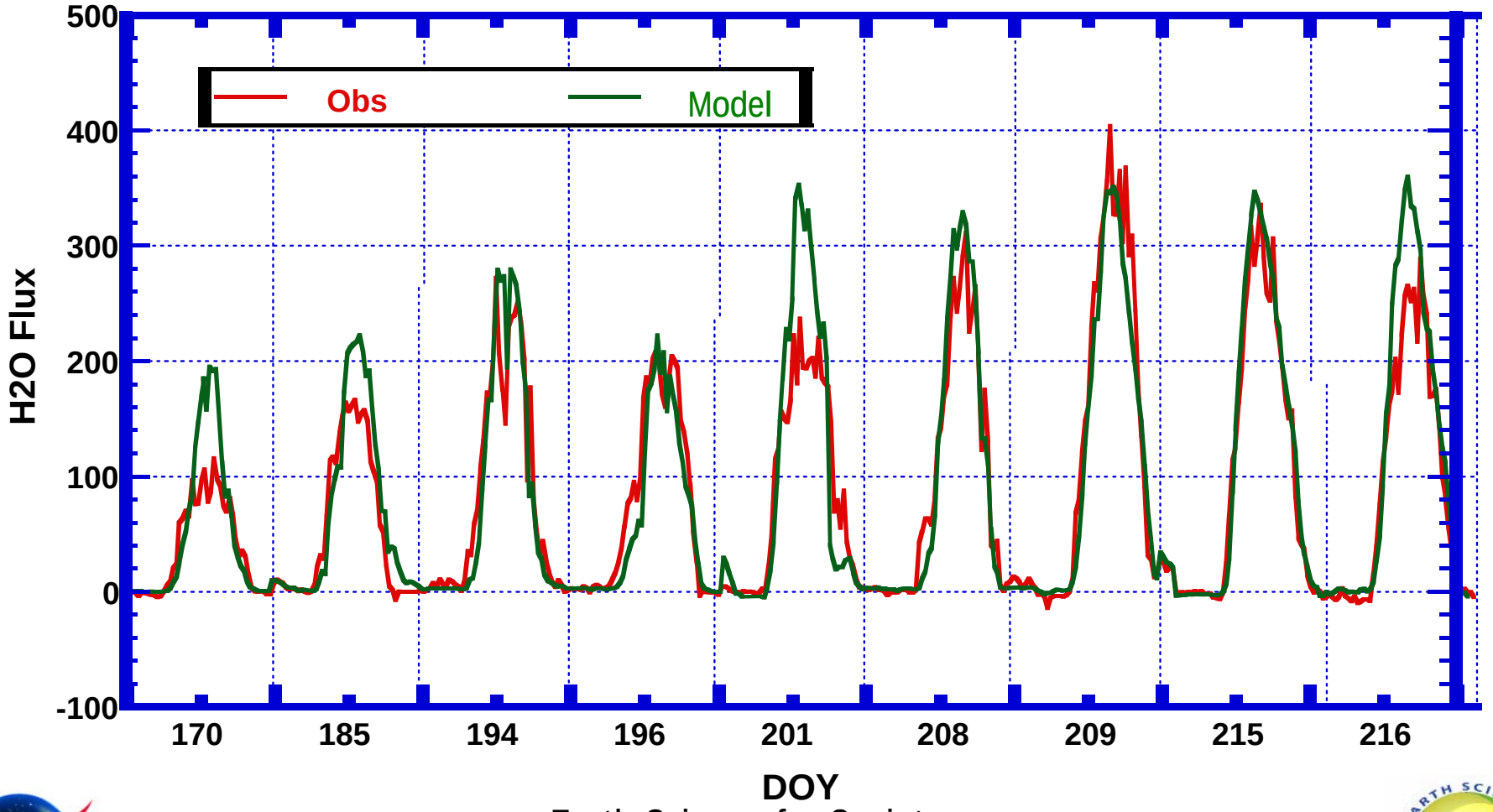
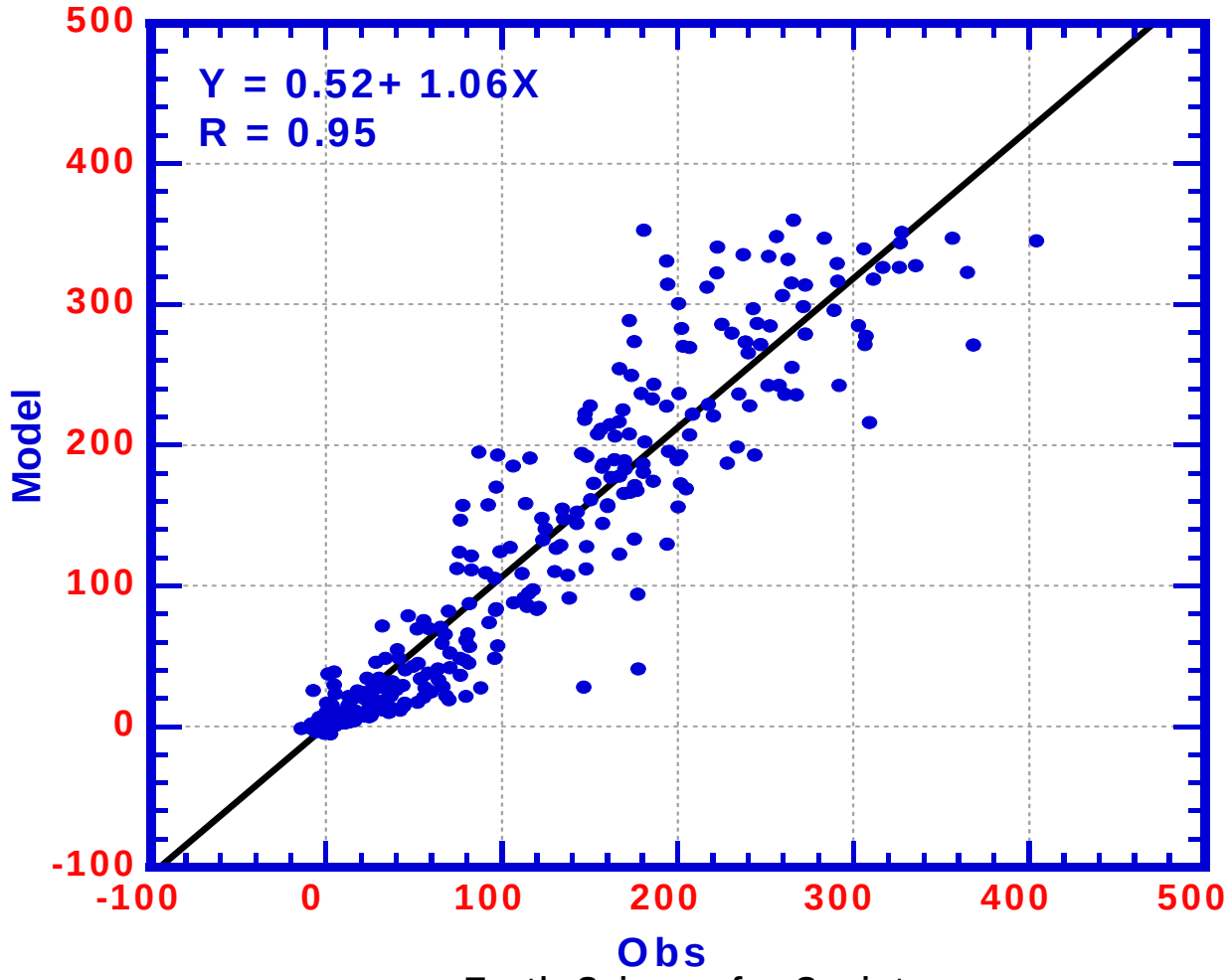
V&V: H_2O Flux at Duplin, NC



V&V: H_2O Flux at Duplin, NC



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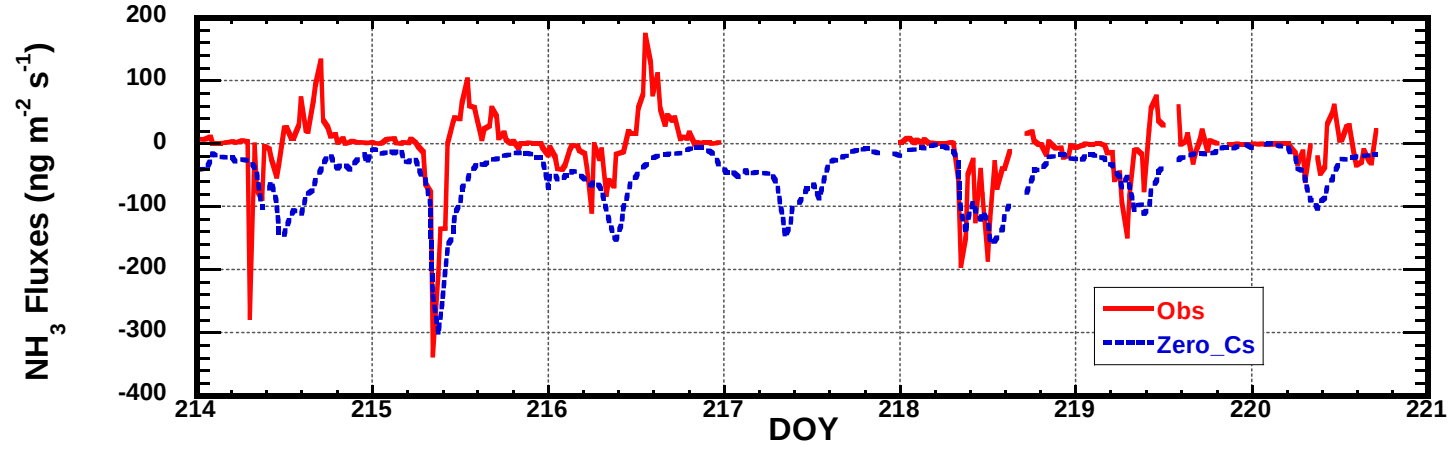
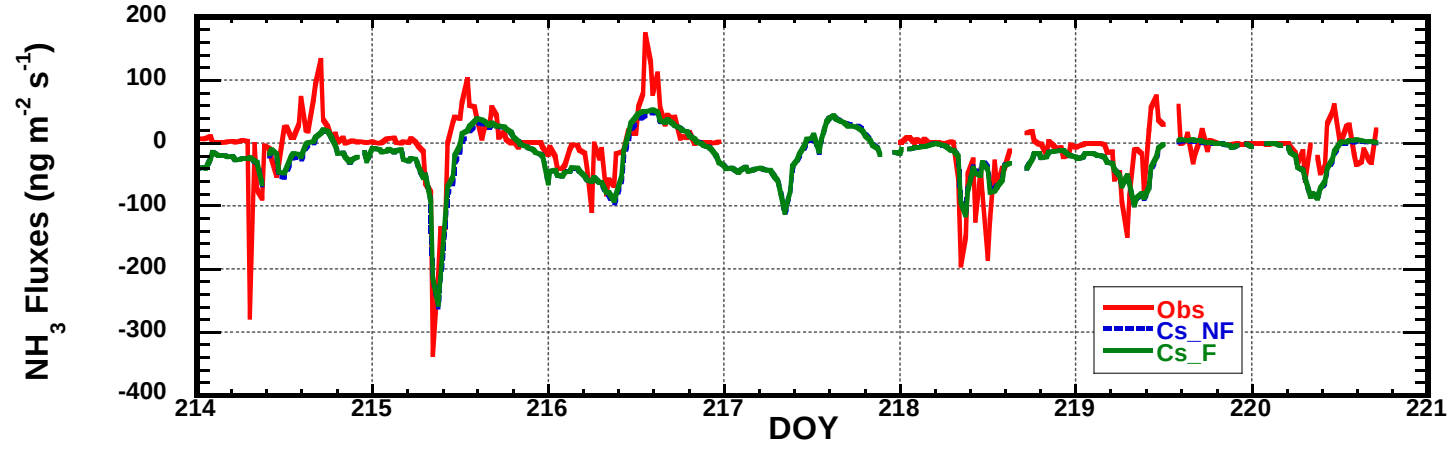
V&V: NH3 Flux at Duplin, NC



RADM/ CMAQ Approach



New MLBC Approach

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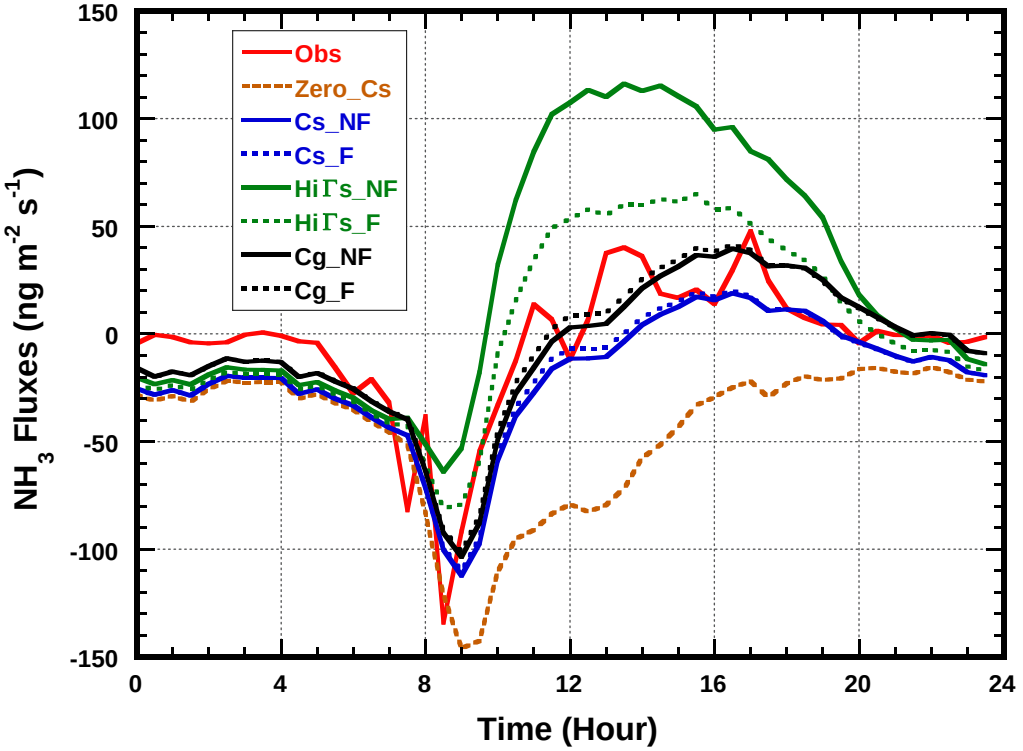
V&V: Sensitivity to Feedback and Soil Emission

In Zero_Cs run, C_c, C_g and C_s were all set to zero so that this run is very similar to the run of current US EPA CMAQ model.

The feedback mechanism is off in "NF" runs, but is on in "F" runs. In Cs_NF and Cs_F runs, C_c and C_g were set to zero.

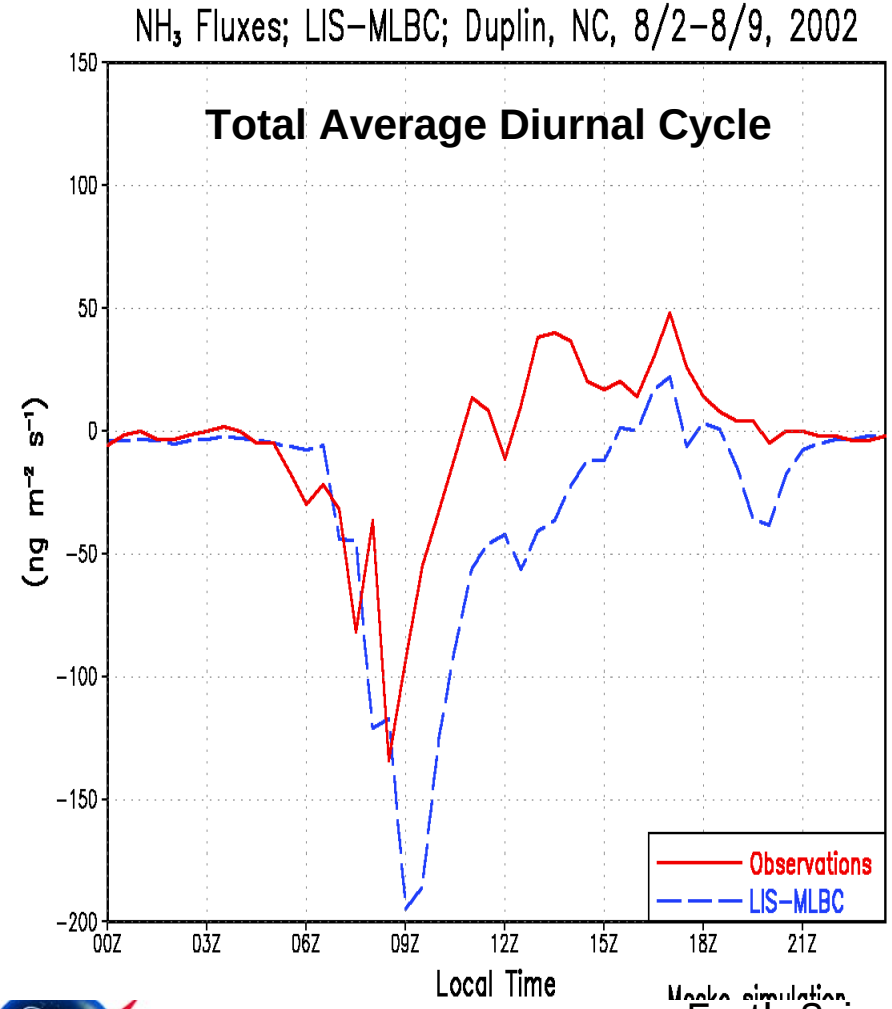
HiΓs_NF and HiΓs_F runs are the same as Cs_NF and Cs_F runs except that the initial value of Γ was set to 2550 (the ratio of $[NH_4^+]/[H^+]$ is denoted as as Γ_s).

In Cg_NF and Cg_F runs, C_c was set to zero.

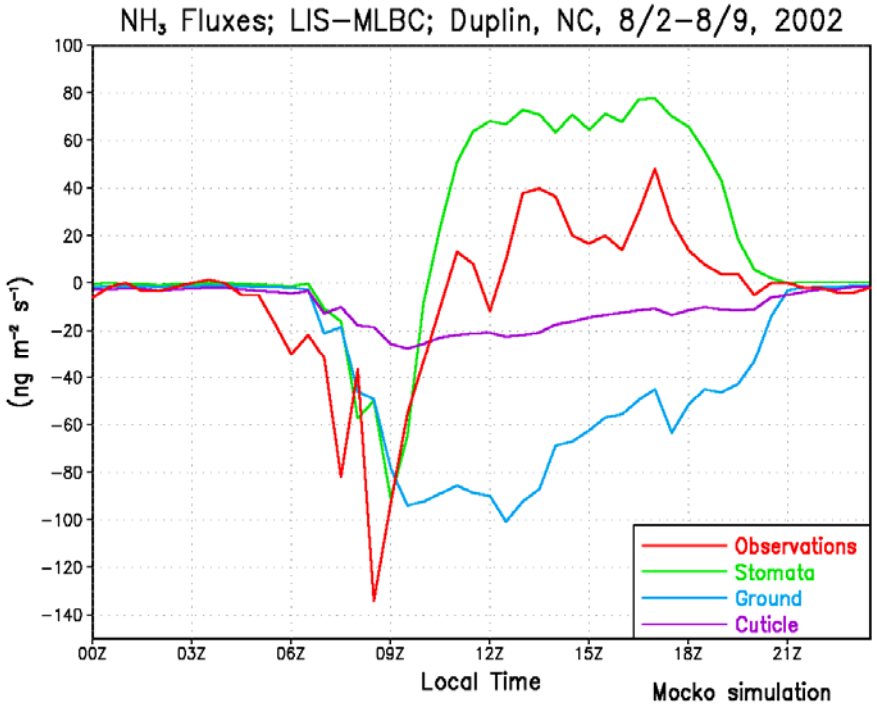


Average daily cycles of NH_3 fluxes for DOY 214 through 221, 2002 at Duplin County, North Carolina.

V&V: LIS-MLBC Diurnal Cycles and Components



Components: Stomata, Ground, Cuticle



Air Quality Applications:

Extending High Resolution Modeling of Land-Atmosphere Ammonia Exchanges

Project Goal: *Evaluate EPA's ability to predict ammonia fluxes, and enable prediction of land-atmosphere ammonia exchange*

Overview: DSSs, Partners, ES Products

Primary Partners: U.S. EPA Atmospheric Sciences Modeling Division

- DSS: EPA's Models-3/ Community Multiscale Air Quality (CMAQ) Modeling system
- Models:
  - -GSFC: Land Information System (LIS)
  - -EPA: Multi-layer Biochemical Dry deposition Model (MLBC)
- NASA Observational Products:
  - -MODIS Land Products (LAI, Vegetation)
  - -TRMM Precipitation Products (3B-42, 3B-43)

Performance, Schedule, Milestones

- √ EPA funded work provided unique ammonia flux dataset in Duplin, North Carolina
- √ Ammonia compensation point parameterization developed and evaluated with good results
- √ MLBC with Ammonia integrated with LIS
- ➢ V&V with MODIS and TRMM due July, 2007.
- ➢ Final Benchmark due September 2007. CMAQ partner?

Start date *(05/01/04)* — Anticipated completion date (09/30/07)

Status and Issues

- CMAQ (and RADM) represent only unidirectional ammonia flux (deposition), contrary to observations
- Ammonia compensation point and resistances must be generalized to be applicable for operational air quality forecasting, but few observations available. Sensitivity to crop type, leaf water needs research.
- NASA's LIS and products provide framework for generalizing and benchmarking at continental scale

Expected benefit if project is successful

- Benefit to EPA: Improved Public Notice/Warnings and Improved Air Quality Impact Mitigation
- Benefit to NASA Earth science: Demonstrate value of NASA LIS and Observations from MODIS and TRMM
- Benefit to Public Health
  - -Reduced Mortality
  - -Reduced Illness
  - -Reduced Hospitalization

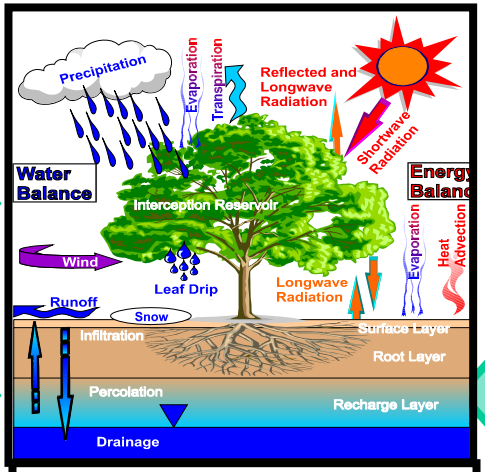
Future Research: Coupling LIS-MLBC to WRF-CHEM

Uncoupled or Analysis Mode

Station Data

Global, Regional Forecasts and (Re-)Analyses

Satellite Products

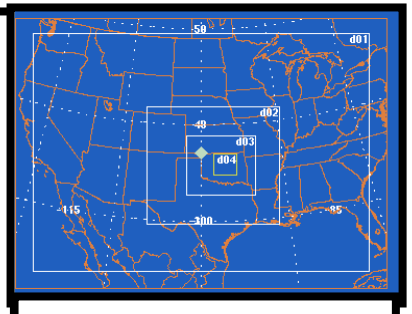


LSM Physics (MLBC,Noah, Mosaic, CLM2, Catchment, VIC, HySSiB)

ESMF

Coupled or Forecast Mode

WRF



MYJ, YSU, MRF PBL Schemes

GCE, LIN, WSM Microphysics Schemes

LSM Initial Conditions

Kumar, Peters-Lidard et al, EMS, 2006; 2007.

Publications/Conferences

- **Publications**

Walker, J., Wayne P. Robarge, Yihua Wu, Tilden Meyers, 2006: Measurement of bi-directional ammonia fluxes over soybean using the modified Bowen-ratio technique, *Agricultural and Forest Meteorology*, **138**, (2006), 54-68.

Wu, Y., J. Walker, C. Peters-Lidard, Donna Schwede, Robin Dennis and Wayne Robarge, 2007: Modeling Bi-directional ammonia gas exchanges between the atmosphere and biosphere, I. Parameterization of ammonia compensation point, *Agricultural and Forest Meteorology*, (in revision).

Wu, Y., J. Walker, C. Peters-Lidard, Donna Schwede, Robin Dennis and Wayne Robarge, 2006: Modeling Bi-directional ammonia gas exchanges between the atmosphere and biosphere, II. Role of leaf surface water (draft).

- **Conference Papers**

Yihua Wu, John Walker, Donna Schwede, Christa Peters-Lidard, Modeling the bi-directional exchanges of ammonia between the atmosphere and terrestrial biosphere, Jan. 20-26, 2006, ILEAPS conference, Boulder, Colorado.

Yihua Wu, John Walker, Christa Peters-Lidard, Donna Schwede, Robin Dennis, Wayne Robarge, Role of leaf surface water in the bi-directional ammonia exchange between the atmosphere and terrestrial biosphere, USDA Workshop on Agricultural Air Quality, June 5-8, 2006, Potomac, MD.

Yihua Wu, Christa Peters-Lidard, Application of satellite data to estimating land-air ammonia exchanges, IGARSS conference, July 31-August 4, 2006, Denver, Colorado.