CICS-MD challenges in the context of the Food-Energy-Water Nexus

The **water, energy and food security nexus** refers to the fact that the three sectors — water security, energy security and food security — are inextricably linked and that actions in one area more often than not have impacts in one or both of the others.

The **nexus approach** integrates management and governance across sectors and scales.

Actions should lead to improved ecosystem management that can provide multiple **ecosystem services** and increase overall benefits derived from them.

Hoff 2011 – Stockholm Environment Institute

CICS-MD challenges in the context of the Food-Energy-Water Nexus

- Increase in food production required to feed a world of 9 billion by 2050
- Increased dependence on food trade exposes countries to water stress impacts abroad

- Trade-offs between water and energy including integrated management of hydro and other renewables
- Regional cooperation needed to optimize hydropower in conjunction with other water uses

- Increased water demand from mushrooming cities
- Growing numbers of people and value of assets at risk from flooding

Courtesy of Fernando Miralles-Wilhelm

CICS-MD Topic areas

- Calibration / Validation
- Data Fusion and Algorithm Development
- Surface Observing Networks
- Future Satellite Programs (JPSS and GOES-R)
- Climate Research, Data Assimilation and Modeling
- Earth System Monitoring from Satellites
- Data Stewardship
- Land and Hydrology
- Climate Science to Support Policy, and Outreach

CICS-MD has demonstrated its capacity to develop reliable satellite products and contribute on each of its topic areas to NOAA's mission.

These products include components of the water, energy, and carbon cycles.

(e.g., precipitation, evapotranspiration, soil moisture, snow cover, vegetation, shortwave and longwave radiation, and much more)

Three questions three…

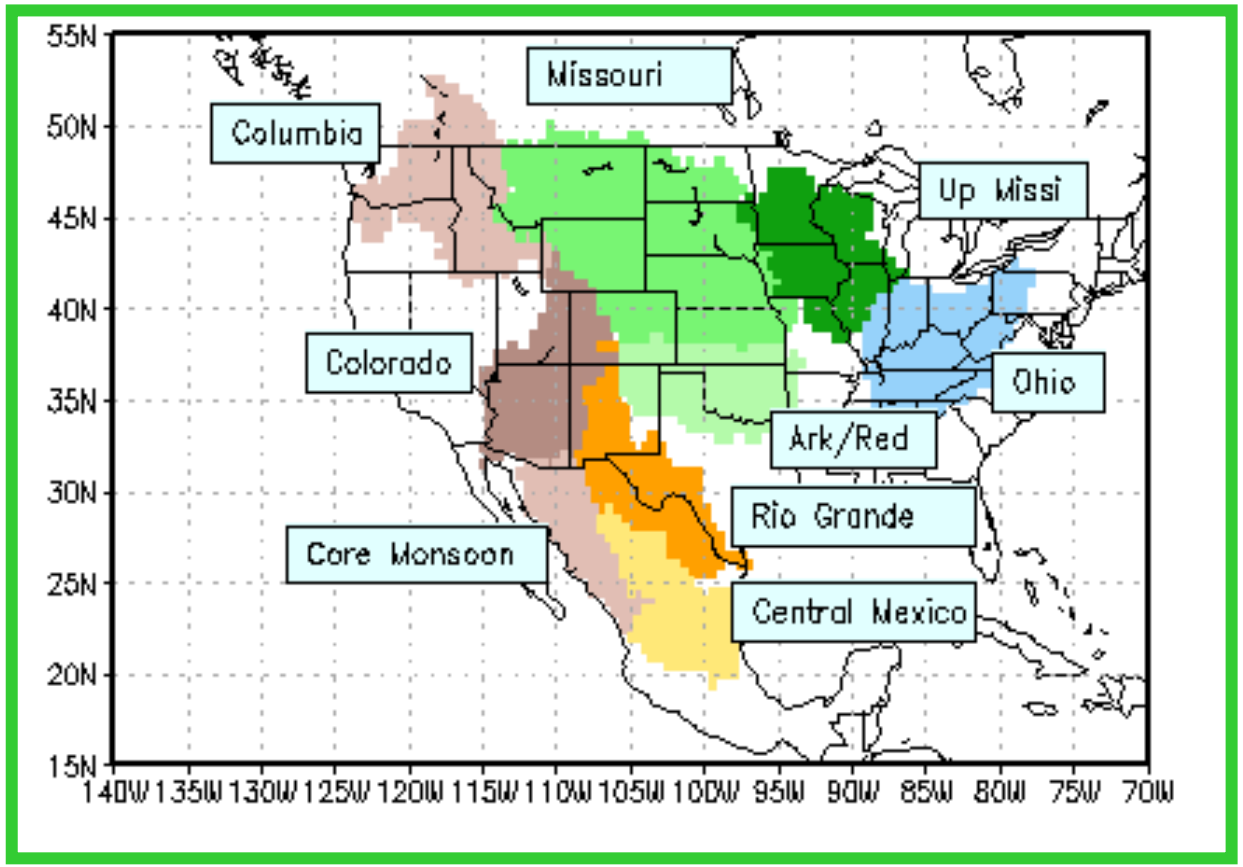
- *What is the **consistency** of our products?*

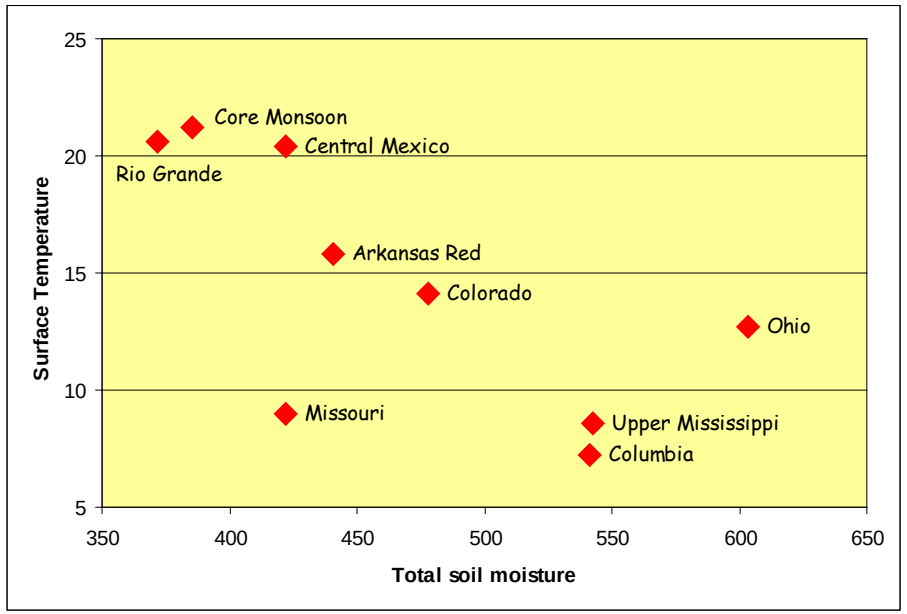
- *What do we need to **monitor** the Earth System?*

- *How can we use our expertise to **train a workforce** that meets NOAA's needs?*

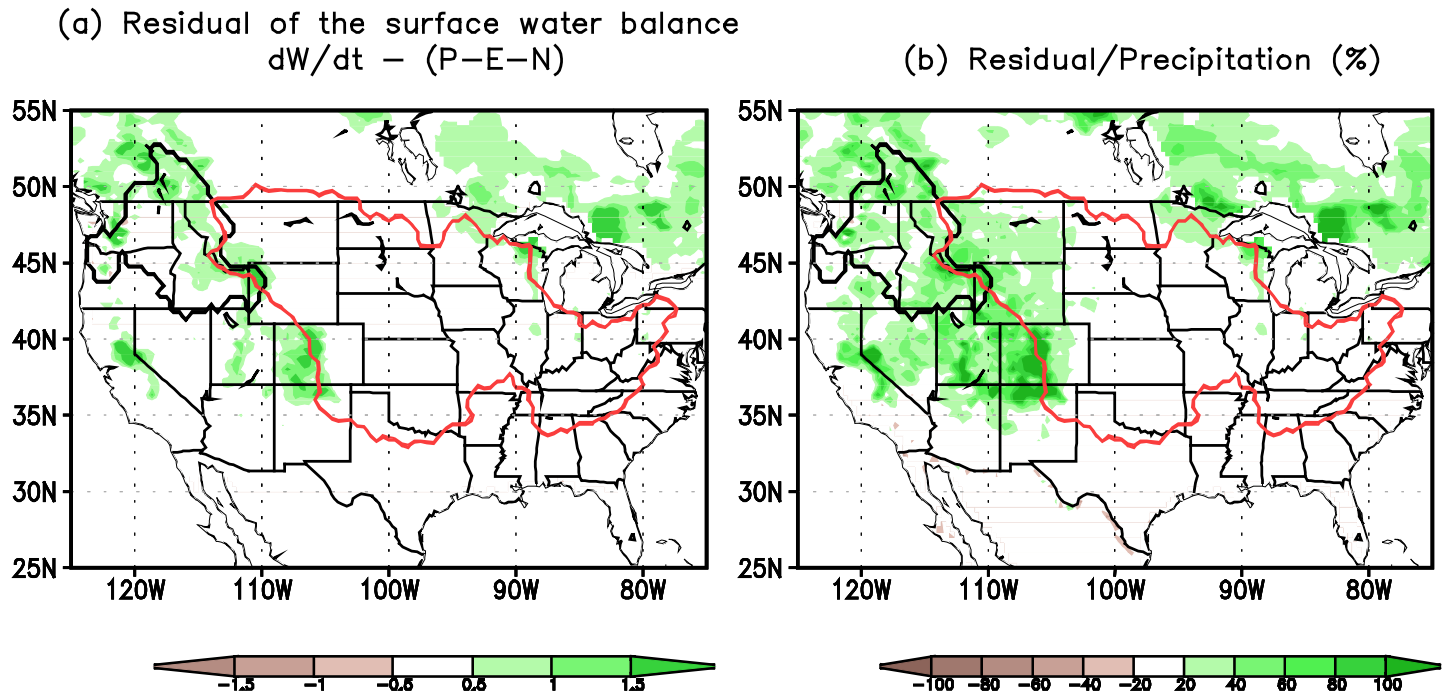
The Surface Water Balance

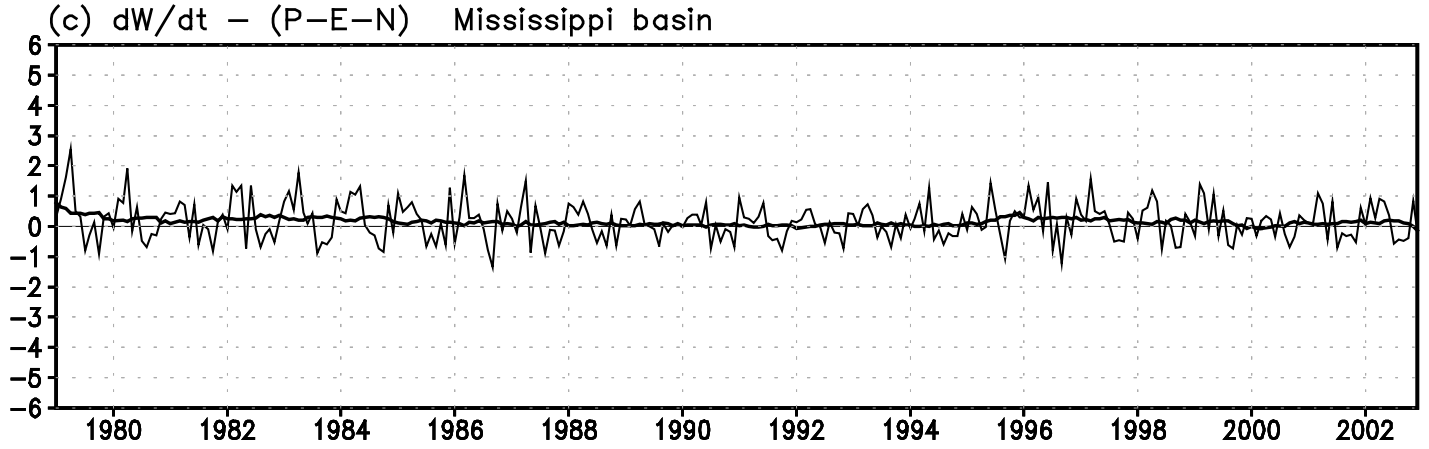
$$\frac{\partial W}{\partial t} = P - E - N + RESW$$





The Surface Water Balance





The Surface Water Balance

Basin	Ohio	Columbia	Colorado	Arkansas/ Red	Missouri	Core Monsoon
TSM	603.23	541.58	478.00	440.47	422.11	385.12
P	3.11	1.83	0.90	1.92	1.35	1.29
E	2.70	1.56	1.09	1.86	1.44	1.51
N	0.46	0.69	0.20	0.12	0.14	0.05
dW/dt	0.00	0.01	-0.01	0.00	0.00	-0.01
Res	**0.05**	**0.42**	**0.39**	**0.06**	**0.23**	**0.26**
E/P (%)	86.8	85.2	121.1	96.9	106.7	117.0
N/P (%)	14.8	37.7	22.2	6.3	10.4	3.5

mm day^{-1}

Our vision for building CICS collaborations

Develop a *consistent, long-term* dataset that fully represents the water cycle and hence facilitates hydro-climate research and applications

Current work

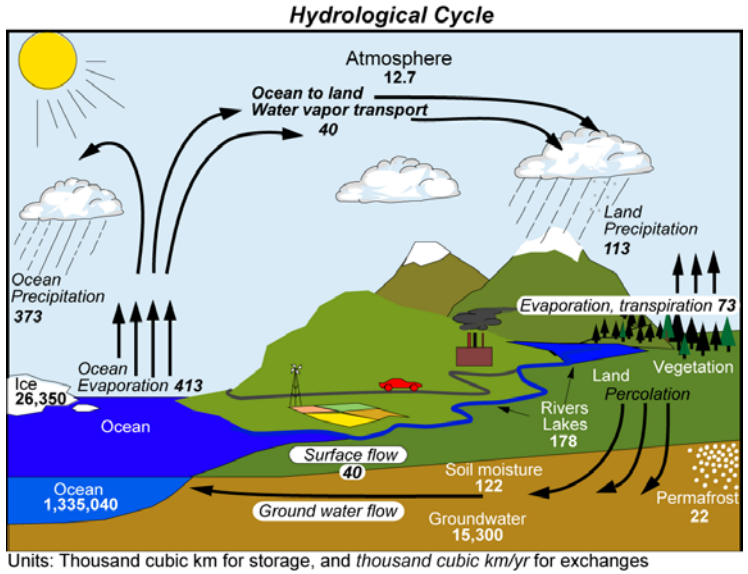
P

EVT

SM

Runoff

…



Vegetation

LCLUC

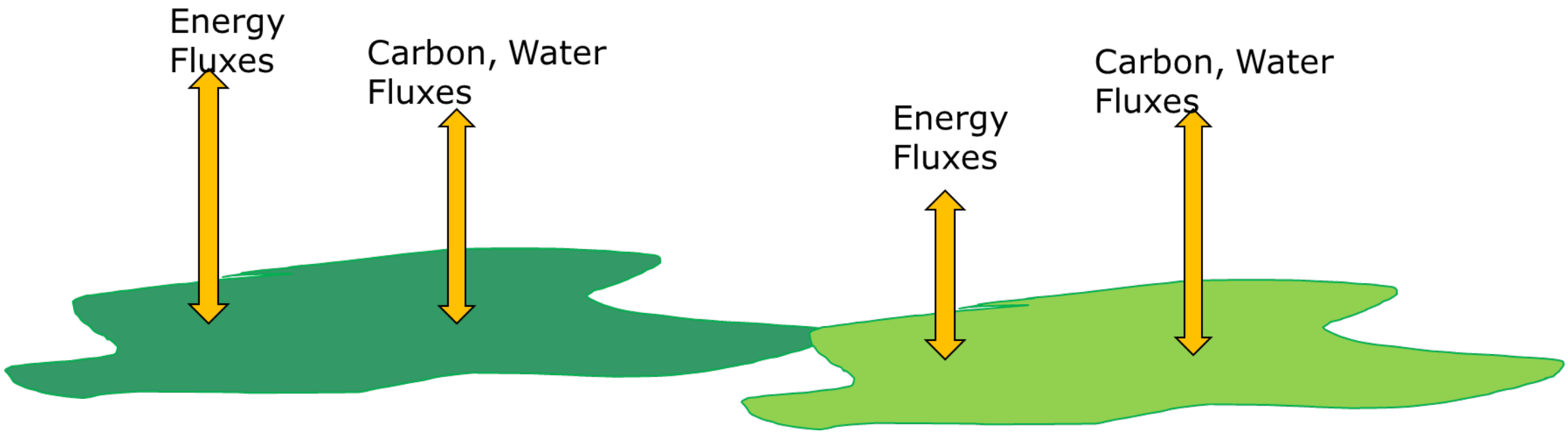
Ecosystems

Earth System

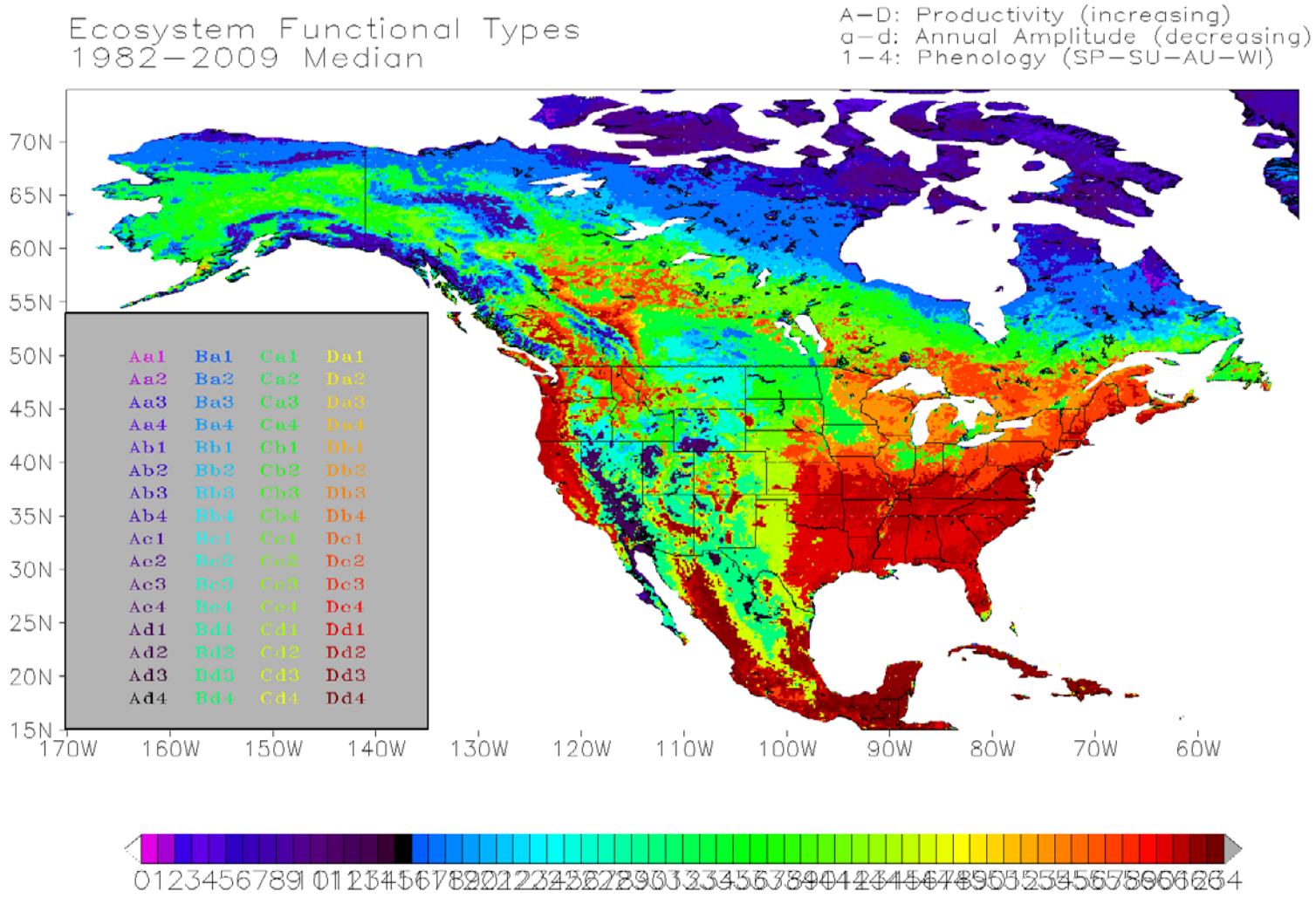
With great potential uses for water resources, agriculture, GEWEX/WCRP …

Monitoring of the environment: Ecosystem Functions

Ecosystems can be classified by their ***functional characteristics in relation to the amount and timing of the exchanges of matter and energy between the biota and the physical environment***.



Ecosystem Functional Types estimated from NESDIS NDVI (16 km res)



Monitoring of EFTs is useful for:

- land management,

- estimating the anthropogenic influence on ecosystems

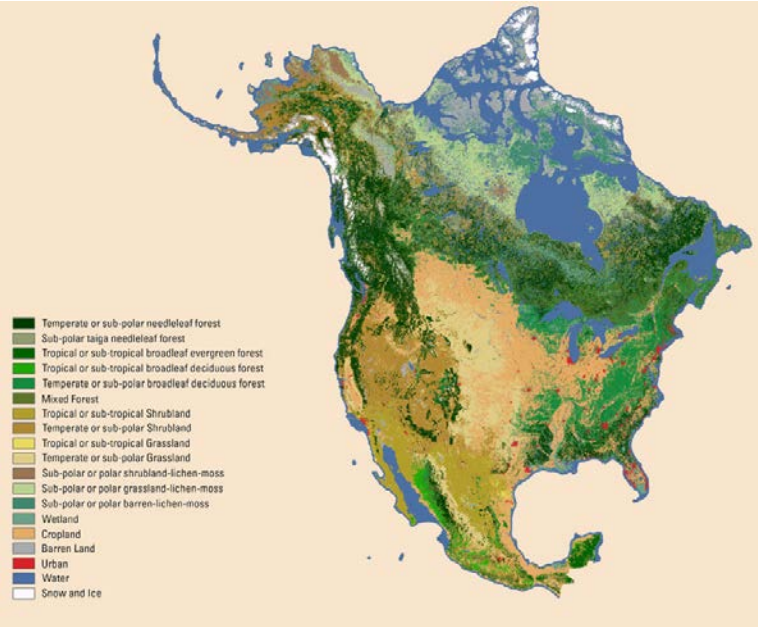
- as an alternative to Land Cover Types to characterize the dynamics of land surface-atmosphere interactions

Conversion from radiances to land cover types involves (Friedl et al. 2010):

- *ensemble decision trees,*
- *sample bias correction, and*
- *training of results*

} (None of these aspects can be easily replicated.)

Friedl et al. (2010) report that the MODIS land cover data set has an overall accuracy of about 75% but ***"the range in class specific accuracies is large."***



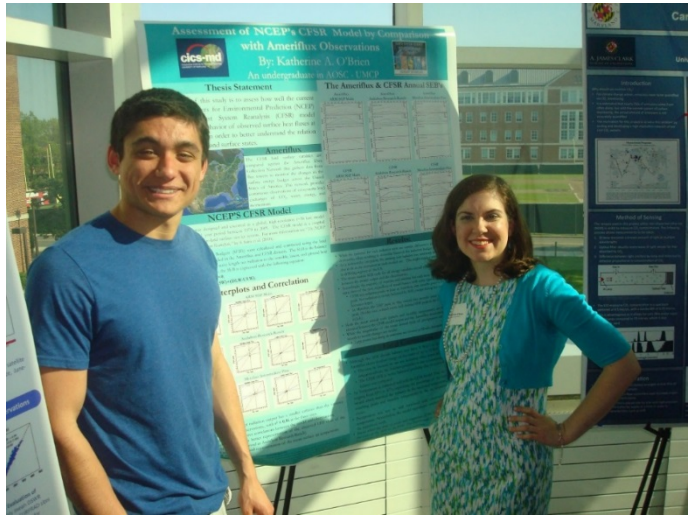
CICS-MD Summer Research Initiative

The CICS-MD Summer Initiative series provides training and outreach opportunities for both graduate and undergraduate students.

It pairs students with mentors to conduct original scientific research and help train future NOAA scientists.

Students not only learn new tools but are already contributing to generate products with value to NOAA

- About 20-25 students each summer; most UG
- 15 on-site; 9 off-site
- Also hosted a visit from the Howard University NCAS Weather Camp
- Two Hollings Scholars



Dustin Shea

- Began as a summer intern
- Continued at CICS-MD
- Graduated with a Masters degree
- Hired by Farmers Insurance as a natural catastrophe analyst

Evaluating WWLLN performance relative to TRMM/LIS

Scott D. Rudlosky[1] and Dustin T. Shea[2]

Received 8 March 2013; revised 27 March 2013; accepted 27 March 2013; published 28 May 2013.

[1] This study evaluates 4 years (2009–2012) of World Wide Lightning Location Network (WWLLN) data relative to the Tropical Rainfall Measuring Mission Lightning Imaging Sensor (LIS). In the Western Hemisphere, between 38°N and 38°S, the WWLLN detection efficiency (DE) (of LIS flashes) steadily improves from 6% during 2009 to 9.2% during 2012. The WWLLN is approximately three times more likely to detect a LIS flash over the ocean (17.3%) than over land (6.4%), and DE values greater than 20% only occur over the oceans. An average of 1.5 WWLLN strokes occurs during each matched LIS flash, but 71.5% of matched flashes are single stroke. Matched LIS flashes have more events/groups, longer durations, and larger areas than non-matched flashes. The close spatial proximity (11 km) and temporal proximity (+62 ms) between matched WWLLN and LIS flashes are important for Geostationary Lighting Mapper risk reduction studies that use existing networks to develop proxy data sets.
Citation: Rudlosky, S. D., and D. T. Shea (2013), Evaluating WWLLN Performance Relative to TRMM/LIS, *Geophys. Res. Lett.*, *40*, 2344–2348, doi:10.1002/grl.50428.

1. Introduction

[2] Ground-based lightning detection networks are continuously improving and growing in importance to scientists and operational weather forecasters. As the variety of users expands, it becomes increasingly important to understand the detection capabilities of these networks. The ground-based World Wide Lightning Location Network (WWLLN) detects very low frequency (VLF) radio waves emitted by lightning [*Dowden et al.*, 2002; *Rodger et al.*, 2004]. It is most sensitive to cloud-to-ground (CG) flashes since they radiate strongest in the VLF range. This study evaluates the detection efficiency (DE), location and timing differences, and multiplicity of WWLLN strokes relative to total lightning observations from the satellite-based Tropical Rainfall Measuring Mission (TRMM) Lightning Imaging Sensor (LIS).

[3] The LIS is an optical transient detector that identifies lightning flashes by detecting the discrete optical pulses associated with changes in cloud brightness at each pixel [*Christian et al.*, 1992]. It reports the time, location, and radiant energy of total lightning events (e.g., CG and intracloud (IC) [*Christian et al.*, 1999]. IC and CG flashes emit very similar optical pulses, so both types are readily observed from above [*Christian et al.*, 1992]. Individual lightning events (illuminated pixels) are combined into groups, flashes, and areas using optical pulse-to-flash and flash-to-cell clustering algorithms [*Bocippio et al.*, 2002]. LIS observations have been cross-calibrated with ground-based lightning detection networks [e.g., *Thomas et al.*, 2000; *Ushio et al.*, 2002] and used to create global lightning climatologies [e.g., *Christian et al.*, 1999; *Cecil et al.*, 2012].

[4] This study compares 4 years (2009–2012) of WWLLN and LIS data within the LIS field of view (38°N and 38°S) in the Western Hemisphere (0° to −180°W). This domain represents overlapping coverage between the LIS and the planned operational Geostationary Lighting Mapper (GLM) [*Goodman et al.*, 2013]. We document the present WWLLN performance and illustrate how it varies in space and time. Improved understanding of WWLLN detection capabilities will enhance its use in research and operations. This study aims to provide valuable information on the relationship between ground-based and satellite-based lightning observations, which will become more important as the GLM launch approaches.

2. Data and Methods

2.1. Data

[5] Four years (2009–2012) of WWLLN and LIS data were gathered. Note that the WWLLN (sferics) and LIS (optics) detect different aspects of a lightning flash and that this study compares WWLLN "strokes" with LIS "flashes." WWLLN strokes occur at a discrete time and place, while LIS flashes have durations (tens to hundreds of milliseconds) and areal extents (tens to hundreds of square kilometers). Furthermore, the WWLLN continuously detects mainly CG lightning, whereas the polar-orbiting LIS provides ~90 s snapshots of all types of lightning within its field of view (600 × 600 km) [*Christian et al.*, 1999]. Despite these differences, the LIS is used as a benchmark because it has provided consistent lightning observations with high DE since its launch in 1997.

[6] The WWLLN began with 11 sensors during 2003 [*Lay et al.*, 2004] and steadily increased to more than 70 sensors by January 2013 [*Hutchins et al.*, 2013]. It monitors the VLF radio waves (sferics) emitted by lightning and uses a time of group arrival technique to locate lightning strokes [*Dowden et al.*, 2002]. Global coverage requires relatively few sensors because VLF radio waves travel through the earth ionosphere waveguide with minimal attenuation [*Crombie*, 1964; *Dowden et al.*, 2002; *Rodger et al.*, 2004]. WWLLN performance has improved over time due to an increase in the number of sensors [*Abarca et al.*, 2010] and improvements in waveform processing algorithms [*Rodger et al.*, 2009]. *Abarca et al.* [2010] evaluated WWLLN performance relative to the National Lightning

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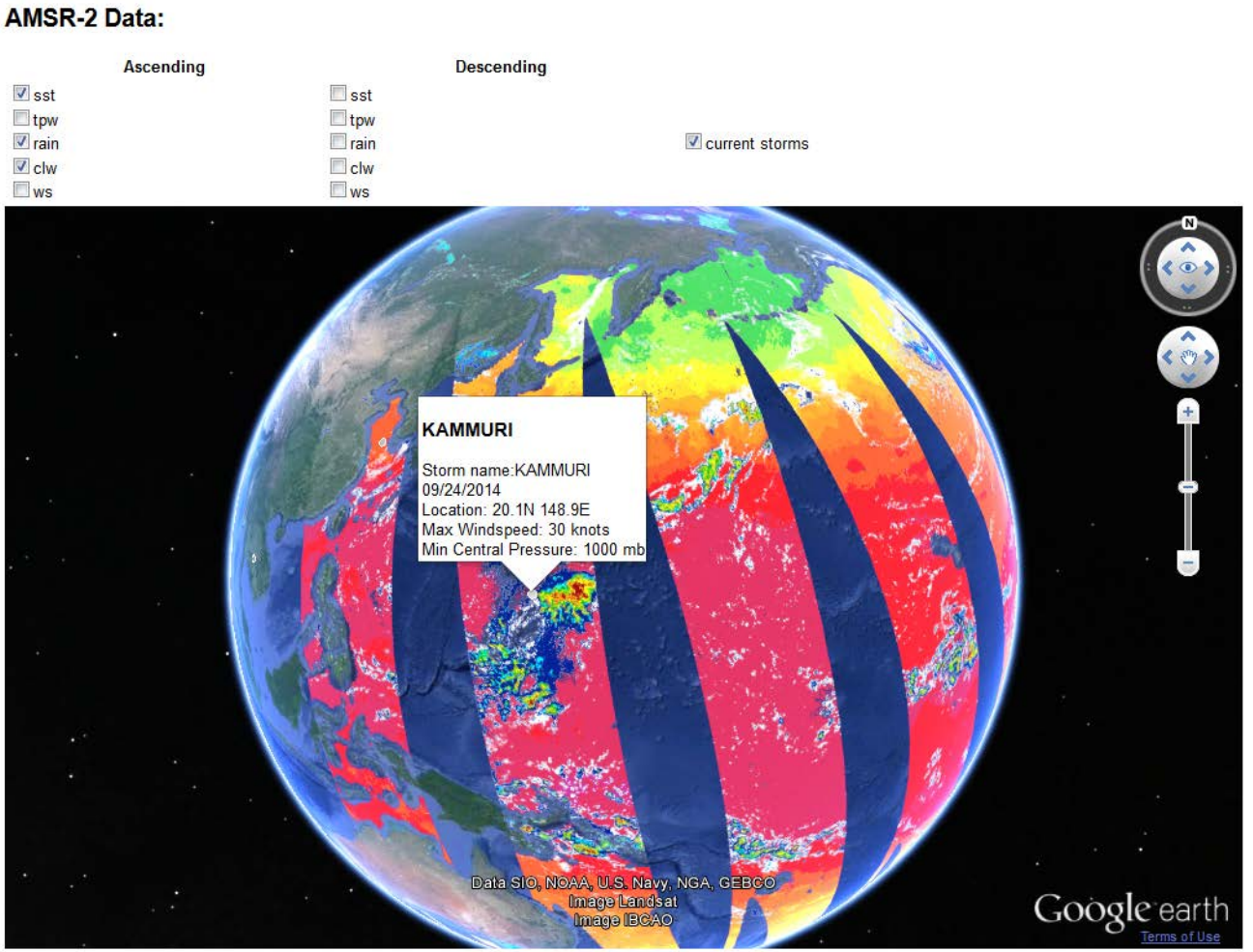
0094-8276/13/10.1002/grl.50428

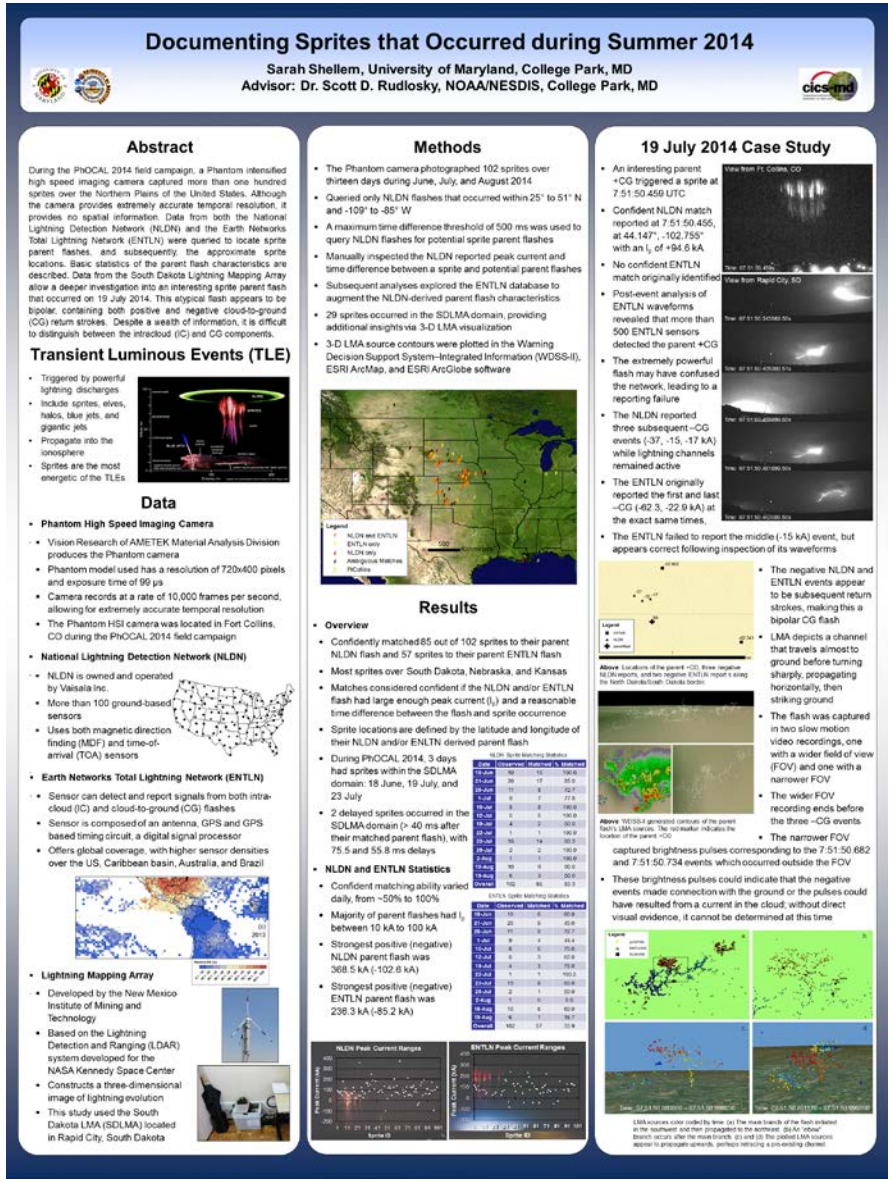
Angelena Bohman

- Math student from Boston College.
- Created web displays of model/satellite data
- Recent graduate and now a DOD contractor



Sarah Shellem

- Began as a summer intern
- Continued working at CICS-MD on her senior thesis
- Graduated with a Bachelors degree during Spring 2015



Documenting Sprites that Occurred during Summer 2014

Sarah Shellem, University of Maryland, College Park, MD
Advisor: Dr. Scott D. Rudlosky, NOAA/NESDIS, College Park, MD

Abstract

During the PhOCAL 2014 field campaign, a Phantom intensified high speed imaging camera captured more than one hundred sprites over the Northern Plains of the United States. Although the camera provides extremely accurate temporal resolution, it provides no spatial information. Data from both the National Lightning Detection Network (NLDN) and the Earth Networks Total Lightning Network (ENTLN) were queried to locate sprite parent flashes, and subsequently, the approximate sprite locations. Basic statistics of the parent flash characteristics are described. Data from the South Dakota Lightning Mapping Array allow a deeper investigation into an interesting sprite parent flash that occurred on 19 July 2014. This atypical flash appears to be bipolar, containing both positive and negative cloud-to-ground (CG) return strokes. Despite a wealth of information, it is difficult to distinguish between the intracloud (IC) and CG components.

Transient Luminous Events (TLE)

- Triggered by powerful lightning discharges
- Include sprites, elves, halos, blue jets, and gigantic jets
- Propagate into the ionosphere
- Sprites are the most energetic of the TLEs

Data

- Phantom High Speed Imaging Camera
  - Vision Research of AMETEK Material Analysis Division produces the Phantom camera
  - Phantom model used has a resolution of 720x400 pixels and exposure time of 99 µs
  - Camera records at a rate of 10,000 frames per second, allowing for extremely accurate temporal resolution
  - The Phantom HSI camera was located in Fort Collins, CO during the PhOCAL 2014 field campaign
- National Lightning Detection Network (NLDN)
  - NLDN is owned and operated by Vaisala Inc.
  - More than 100 ground-based sensors
  - Uses both magnetic direction finding (MDF) and time-of-arrival (TOA) sensors
- Earth Networks Total Lightning Network (ENTLN)
  - Sensor can detect and report signals from both intra-cloud (IC) and cloud-to-ground (CG) flashes
  - Sensor is composed of an antenna, GPS and GPS based timing circuit, a digital signal processor
  - Offers global coverage, with higher sensor densities over the US, Caribbean basin, Australia, and Brazil
- Lightning Mapping Array
  - Developed by the New Mexico Institute of Mining and Technology
  - Based on the Lightning Detection and Ranging (LDAR) system developed for the NASA Kennedy Space Center
  - Constructs a three-dimensional image of lightning evolution
  - This study used the South Dakota LMA (SDLMA) located in Rapid City, South Dakota

Methods

- The Phantom camera photographed 102 sprites over thirteen days during June, July, and August 2014
- Queried only NLDN flashes that occurred within 25° to 51° N and -109° to -85° W
- A maximum time difference threshold of 500 ms was used to query NLDN flashes for potential sprite parent flashes
- Manually inspected the NLDN reported peak current and time difference between a sprite and potential parent flashes
- Subsequent analyses explored the ENTLN database to augment the NLDN-derived parent flash characteristics
- 29 sprites occurred in the SDLMA domain, providing additional insights via 3-D LMA visualization
- 3-D LMA source contours were plotted in the Warning Decision Support System–Integrated Information (WDSS-II), ESRI ArcMap, and ESRI ArcGlobe software

Results

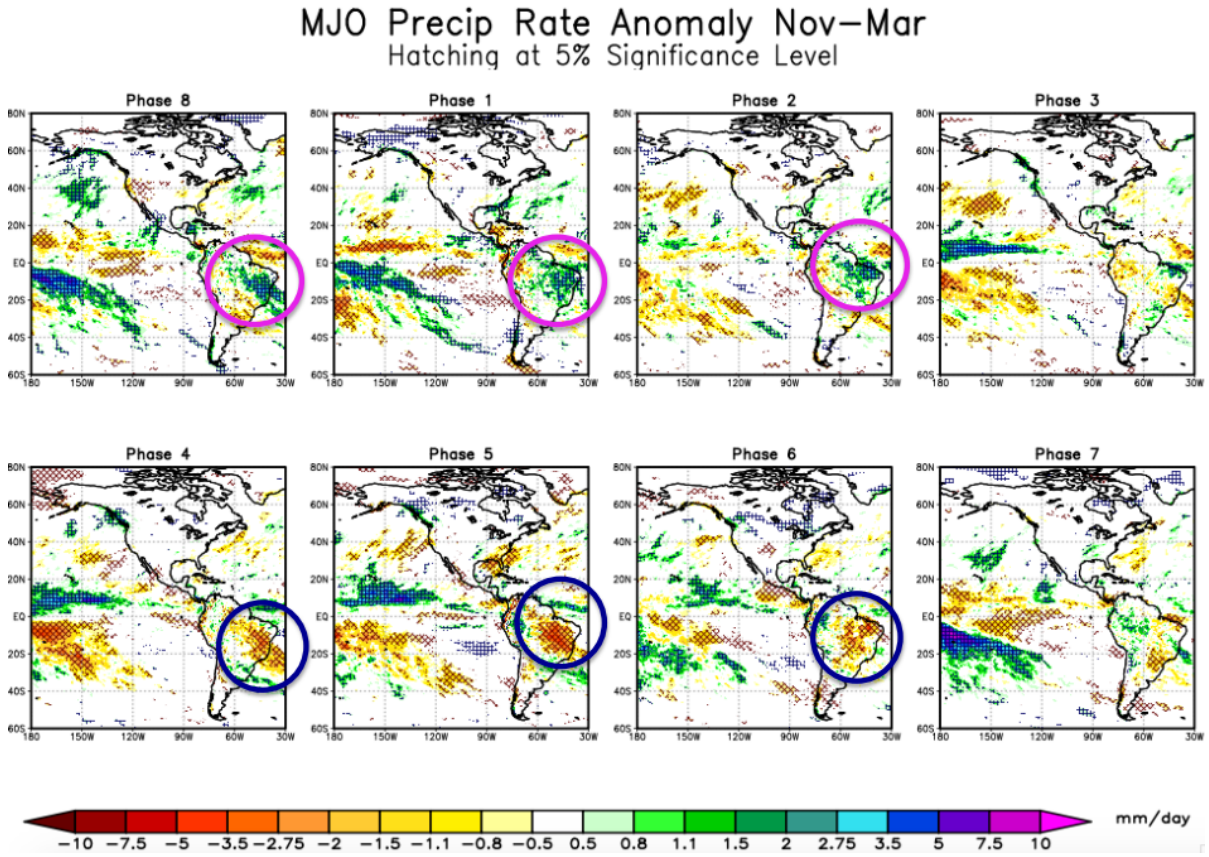
- Overview
  - Confidently matched 85 out of 102 sprites to their parent NLDN flash and 57 sprites to their parent ENTLN flash
  - Most sprites over South Dakota, Nebraska, and Kansas
  - Matches considered confident if the NLDN and/or ENTLN flash had large enough peak current (I_p) and a reasonable time difference between the flash and sprite occurrence
  - Sprite locations are defined by the latitude and longitude of their NLDN and/or ENLTN derived parent flash
  - During PhOCAL 2014, 3 days had sprites within the SDLMA domain: 18 June, 19 July, and 23 July
  - 2 delayed sprites occurred in the SDLMA domain (> 40 ms after their matched parent flash), with 75.5 and 55.8 ms delays
- NLDN and ENTLN Statistics
  - Confident matching ability varied daily, from ~50% to 100%
  - Majority of parent flashes had I_p between 10 kA to 100 kA
  - Strongest positive (negative) NLDN parent flash was 368.5 kA (-102.6 kA)
  - Strongest positive (negative) ENTLN parent flash was 236.3 kA (-85.2 kA)

19 July 2014 Case Study

- An interesting parent +CG triggered a sprite at 7:51:50.459 UTC
- Confident NLDN match reported at 7:51:50.455, at 44.147°, -102.755° with an I_p of +94.6 kA
- No confident ENTLN match originally identified
- Post-event analysis of ENTLN waveforms revealed that more than 500 ENTLN sensors detected the parent +CG
- The extremely powerful flash may have confused the network, leading to a reporting failure
- The NLDN reported three subsequent –CG events (-37, -15, -17 kA) while lightning channels remained active
- The ENTLN originally reported the first and last –CG (-62.3, -22.9 kA) at the exact same times,
- The ENTLN failed to report the middle (-15 kA) event, but appears correct following inspection of its waveforms
- The negative NLDN and ENTLN events appear to be subsequent return strokes, making this a bipolar CG flash
- LMA depicts a channel that travels almost to ground before turning sharply, propagating horizontally, then striking ground
- The flash was captured in two slow motion video recordings, one with a wider field of view (FOV) and one with a narrower FOV
- The wider FOV recording ends before the three –CG events
- The narrower FOV captured brightness pulses corresponding to the 7:51:50.682 and 7:51:50.734 events which occurred outside the FOV
- These brightness pulses could indicate that the negative events made connection with the ground or the pulses could have resulted from a current in the cloud; without direct visual evidence, it cannot be determined at this time

Michael Natoli

- Has interned at UMD for 3 years
- Studies MJO mechanisms for modulating P and T over the Americas.
- Won several awards; last summer he was a Hollings Scholar in Boulder, CO.
- Currently in Barcelona finishing his studies, and applying for Graduate Schools.



CICS-MD Proving Ground and Training Center (PGTC)

Scott Rudlosky and Pat Meyers

*NOAA's **proving grounds** facilitate pre-deployment testing and operational readiness/suitability evaluation in operational proving grounds.*

- *Planned Activities*
  - Receive National Weather Service feeds
  - Send and receive experimental products
  - Implement AWIPS-2, McIDAS-X, and WDSS-II
  - Train Students and Scientists on this software
  - Develop New Products and Visualizations

- *Support*
  - Support from GOES-R and JPSS Programs
  - University of Maryland Campus Visualization Partnership (CVP) Grant (Patrick Myers)

Three questions three…

- *What is the **consistency** of our products?*
- *What do we need to **monitor** the Earth System?*
- *How can we use our expertize to **train a workforce** that meets NOAA's needs?*