

# Climate Change Science Institute (CCSI)

## Earth System Modeling (ESM) Theme

*Forrest M. Hoffman*

## CCSI Earth System Modeling (ESM) Workshop / Dr. David J. Erickson III Memorial Lectures



# ESM Theme

## Progress on Strategic Plan Goals

### Projects:



Funding agencies: DOE, EPA, USDA Forest Service

# ESM Theme

## Progress on Strategic Plan Goals

### 2.2.1. Advance understanding of Earth system processes and improve predictions of climate variability and change.

- **Glaciers:**

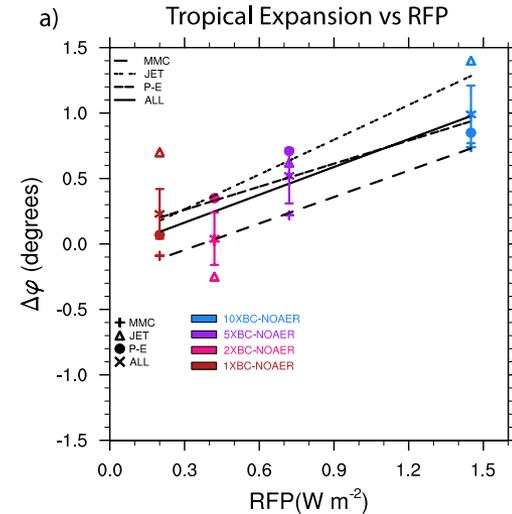
- Kennedy, J. H., and E. C. Pettit (2015), The response of fabric variations to simple shear and migration recrystallization, *J. Glaciology*, 61(227), 537–550, doi:10.3189/2015JoG14J156.

- **Aerosols:**

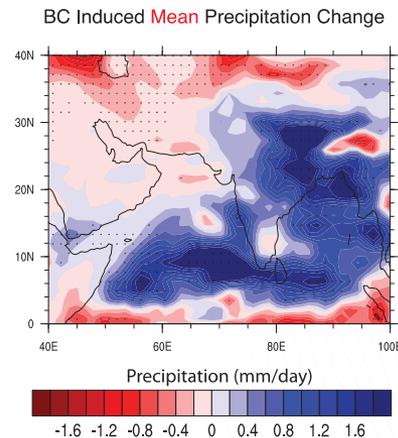
- Kovilakam M. and S. Mahajan (2015): Black Carbon Induced Northern Hemisphere Tropical Expansion, *GRL*.
- Kovilakam M. and S. Mahajan (2016): Confronting “the Indian Monsoon response to black carbon aerosols” with the uncertainty in its radiative forcing. *JGR-Atmospheres* (conditionally accepted).

- **Monsoons:**

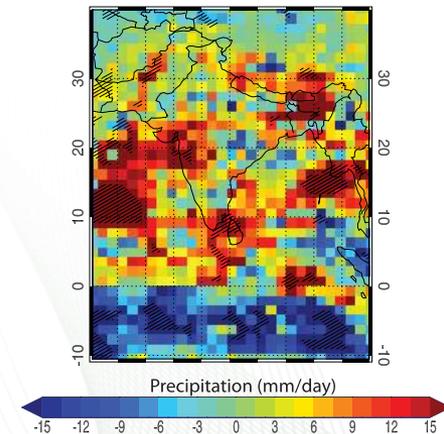
- M. Ashfaq, D. Rastogi, R. Mei, D. Touma and R. Leung, Sources of errors in the simulation of South Asian monsoon in CMIP5 GCMs, *Climate Dynamics* (conditionally accepted)



Kovilakam and Mahajan, 2015



BC Induced Extreme Precipitation Change



Kovilakam and Mahajan, 2016

# ESM Theme

## Progress on Strategic Plan Goals

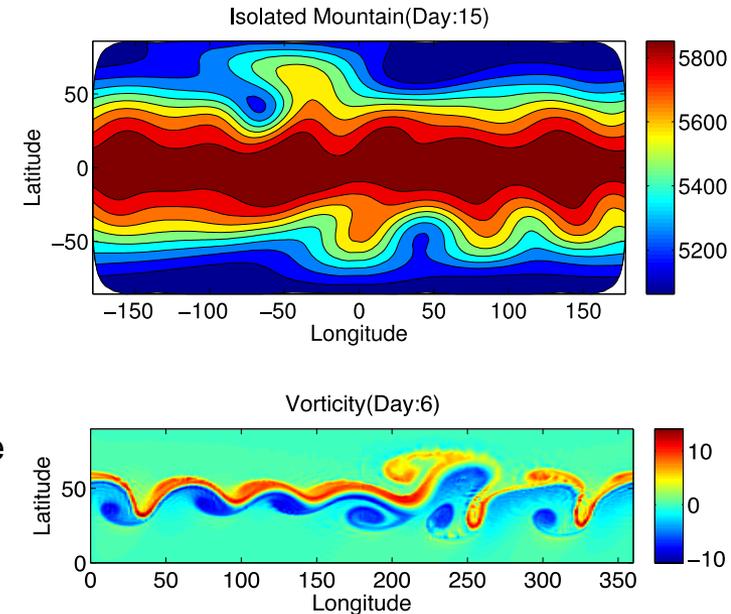
### 2.2.2. Enable application of Earth system models to questions requiring high resolution and high fidelity.

- Algorithms & Methods:

- Woodward, C. S., D. Gardner, and K. J. Evans (2015), On the Use of Finite Difference Matrix-Vector Products in Newton-Krylov Solvers for Implicit Climate Dynamics, *Procedia Computer Science*, 51:2036-2045.
- Collins, W. D., H. Johansen, K. J. Evans, C. Woodward, and P. Caldwell (2015), Progress in Fast, Accurate Multi-scale Climate Simulations, *Procedia Computer Science*, 51:2006-2015.

- Software Engineering & Performance:

- Norman, M. R., J. Larkin, A. Vose, and K. J. Evans (2015). A case study of CUDA FORTRAN and OpenACC for an Atmospheric Climate Kernel, *J. Computat. Sci.*, 9:1-6.
- Archibald, R. K., K. J. Evans, and A. G. Salinger (2015). Accelerating Time Integration for the Shallow Water Equations on the Sphere Using GPUs, *Procedia Computer Science*, 51:2046-2055.
- Wong, D. C., Yang, C. E., Fu, J. S., Wong, K., and Gao, Y. (2015), An approach to enhance pNetCDF performance in environmental modeling applications, *Geosci. Model Dev.*, 8, 1033–1046.



Archibald et al. 2015

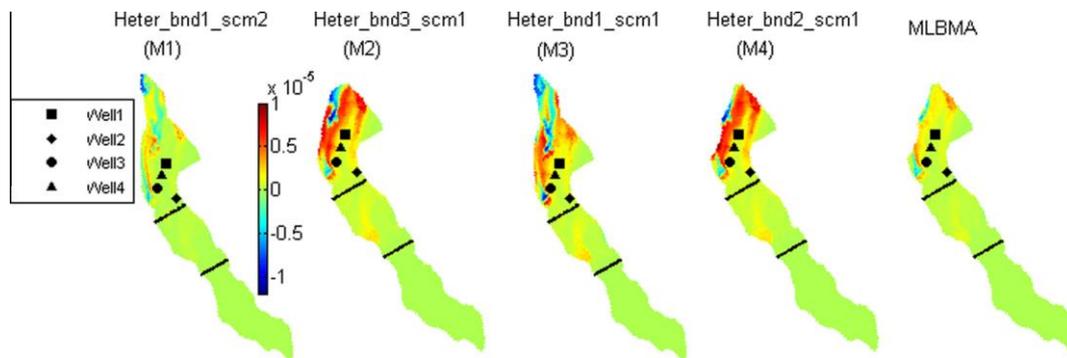
- Workshops:

- Numerical and Computational Developments to Advance Multi-scale Earth System Models – MSES, ICCS 2015

# ESM Theme

## Progress on Strategic Plan Goals

- **2.2.2. Enable application of Earth system models to questions requiring high resolution and high fidelity.**
- **UQ:**
  - Liu, P., A.S. Elshall, M. Ye, P. Beerli, X. Zeng, **D. Lu**, and Y. Tao (2016), Evaluate marginal likelihood with thermodynamic integration method and comparison with several other numerical methods, *Water Resour. Res.*, 52
  - **Lu, D.**, M. Ye, and G.P. Curtis (2015), Maximum Likelihood Bayesian Model Averaging and its Predictive Analysis for Groundwater Reactive Transport Models, *J. Hydrol.*, 529, 1859–1873.
  - Hill, M.C., D. Kavetski, M. Clark, M. Ye, M. Arabi, **D. Lu**, L. Foglia, and S. Mehl (2015), Practical use of computationally frugal model analysis methods, *Ground Water*



Lu et al. 2015

# ESM Theme

## Progress on Strategic Plan Goals

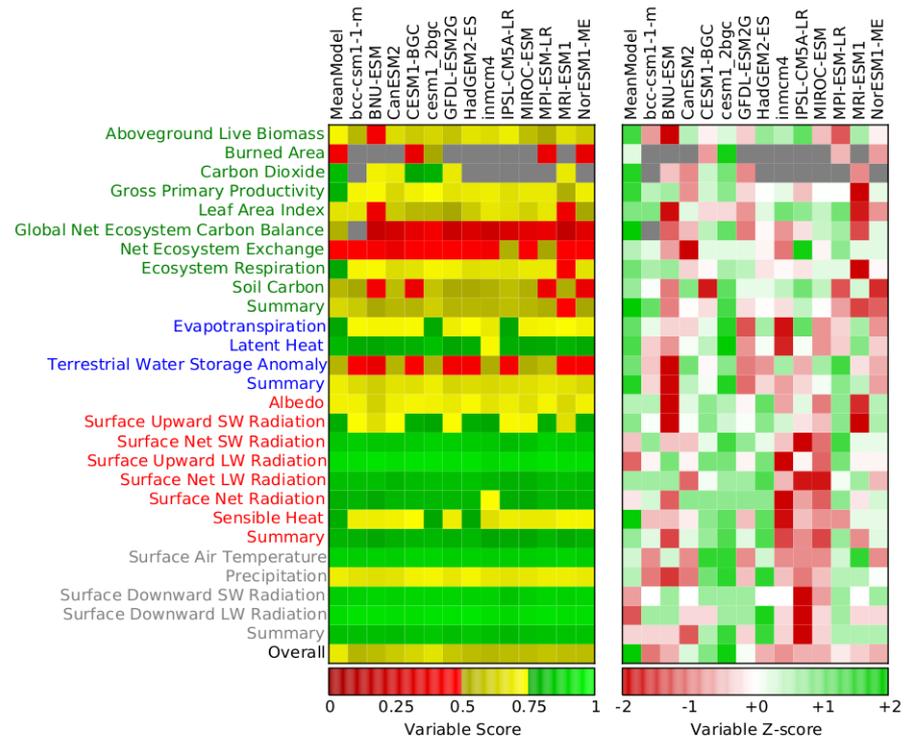
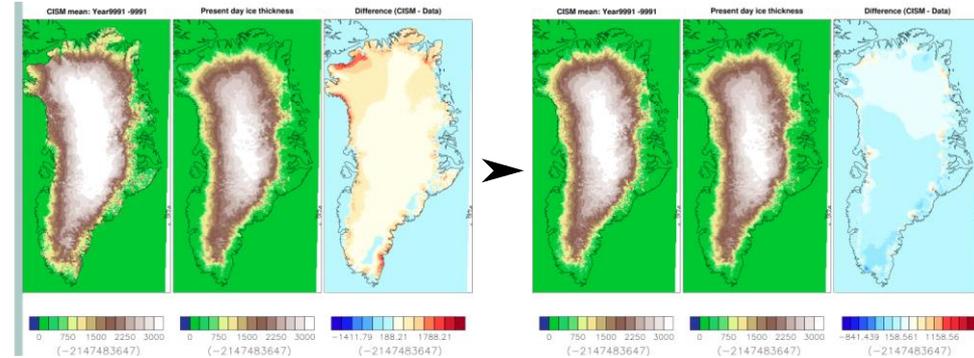
### 2.2.3 Quantify and reduce uncertainties in predictions of ESMs.

- Benchmarking/V&V:

- LIVVkit, the land-ice verification and validation system, was released in July.
- The first ILAMB land model benchmarking package was released at the AGU Fall Meeting in December.

- Biogeochemistry:

- Wang, Y. P., J. Jiang, B. Chen-Charpentier, F. B. Augusto, A. Hastings, [Forrest M. Hoffman](#), M. Rasmussen, M. J. Smith, K. Todd-Brown, Y. Wang, X. Xu, and Y. Q. Luo (2016), Responses of two nonlinear microbial models to warming and increased carbon input, *Biogeosci.*, 13(4):887–902, doi:10.5194/bg-13-887-2016.



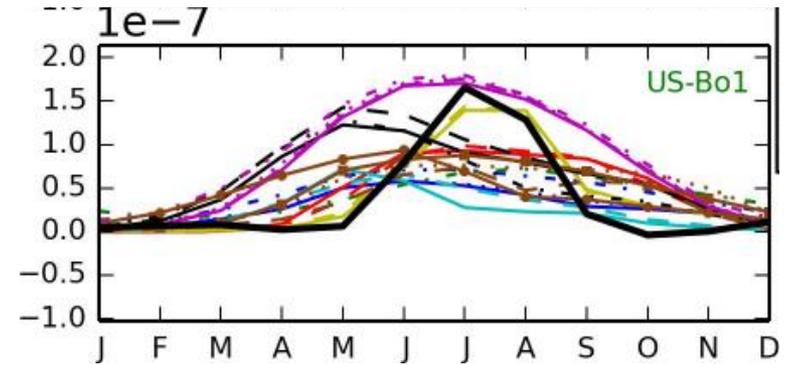
# ESM Theme

## Progress on Strategic Plan Goals

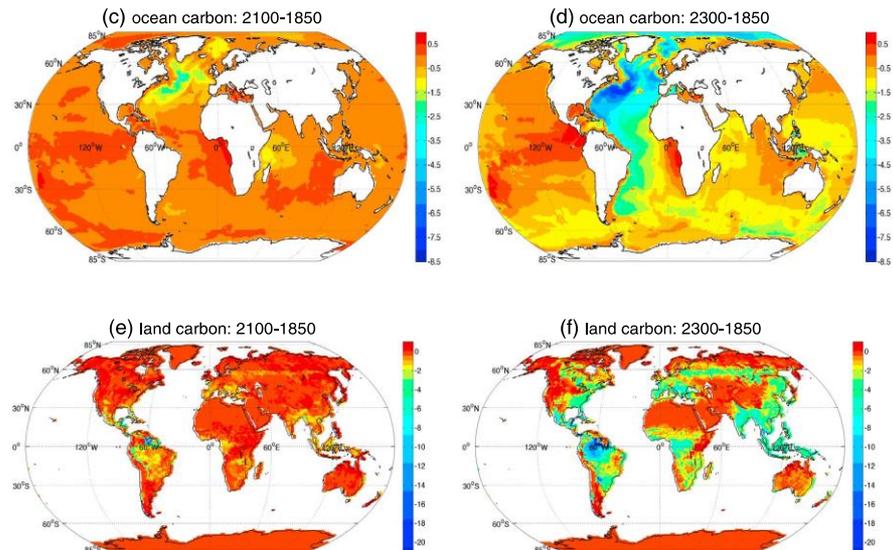
### 2.2.3 Quantify and reduce uncertainties in predictions of ESMs.

- Biogeochemistry:

- Ogunro, Oluwaseun O., Susannah M. Burrows, Scott Elliott, Amanda A. Frossard, [Forrest M. Hoffman](#), Robert T. Letscher, J.Keith Moore, Lynn M. Russell, Shanlin Wang, and Oliver W. Wingenter (2015), Global distribution and surface activity of macromolecules in offline simulations of marine organic chemistry, *Biogeochemistry*, 126(1–2):25–56
- [Xu, Min, and Forrest M. Hoffman](#) (2015), Evaluations of CMIP5 simulations over cropland, *Proc. SPIE*, 9610:961003–961003-15.
- Randerson, James T., Keith Lindsay, Ernesto Muñoz, Weiwei Fu, J. Keith Moore, [Forrest M. Hoffman](#), Natalie M. Mahowald, and Scott C. Doney (2015), Multicentury Changes in Ocean and Land Contributions to the Climate–Carbon Feedback, *Global Biogeochem. Cycles*, 29(6):744–759



Xu and Hoffman, 2016

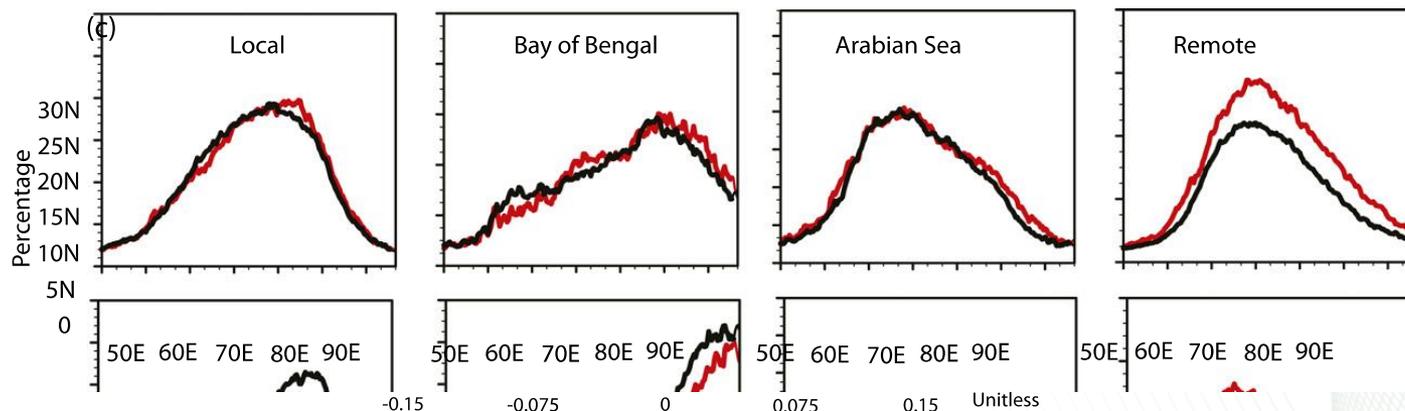


Randerson et al. 2015

# ESM Theme

## Progress on Strategic Plan Goals

- **2.2.3 Quantify and reduce uncertainties in predictions of ESMs.**
- **Hydrology:**
  - Naz, B. S-C. Kao, M. Ashfaq, D. Rastogi, R. Mei, Regional hydrological response to climate change in the conterminous United States using high-resolution hydro-climate change simulations (*in review*)
  - Touma, D., M. Ashfaq, M. Nayak, S-C. Kao, N.S. Diffenbaugh (2015), A Multi-model and Multi-index Evaluation of CMIP5 Drought Characteristics in the 21st Century, *Journal of Hydrology*, 526, 196-207, doi:10.1016/j.jhydrol.2014.12.011
  - R. Mei, M. Ashfaq, D. Rastogi, R. Leung, F. Dominguez (2015), Dominating Controls for Wetter South Asian Summer Monsoon in the 21st Century, *Journal of Climate*, 28, 3400–3419, doi: 10.1175/JCLI-D-14-00355.1
- **Invited Talks:**
  - Moet Ashfaq (*AGU 2015, Monsoon Workshop, Yale 2015*)



Mei et al. 2015

# ESM Theme

## Progress on Strategic Plan Goals

### 2.2.4 Provide usable model products to the impacts research community.

- Health & Disease

- P. Parham, J. Waldock, D. Hemming, K. Evans et al. (2015), Climate, Environmental, and Socioeconomic Change - Weighing up the Balance in Vector-Bourne Disease Transmission. *Phil. Trans. B*, 370:20130551. doi: 10.1098/rstb.2013.0551.
- T. Yankeelov, V. Quaranta, K. Evans, and E. Rericha (2015), Towards a Science of Tumor Forecast for Clinical Oncology, *Cancer Research* , 75:918-23, doi:10.1158/0008-5472.CAN-14-2233.
- Paull. S.H., D. Horton, M. Ashfaq, D. Rastogi, N. S. Diffenbaugh, A. M. Kilpatrick, Immunity dampens climate change impacts on West Nile virus epidemics across North America (in review)



Cover image from Parham et al., review article for special issue on Climate Change and Vector Borne Diseases of Humans: The mosquito *Aedes japonicus japonicus* is native to northern Japan, but has been introduced to the US and Europe and is adapting to warmer climates in Hawaii and the Southern USA. Image: Ary Faraji

# ESM Theme

## Progress on Strategic Plan Goals

### 2.2.4 Provide usable model products to the impacts research community.

- Hydropower:

- Kao, S-C., M. Sale, M. Ashfaq, R. U. Martinez, D. Kaiser, Y. Wei, N. S. Diffenbaugh (2015), Projecting changes in annual hydropower generation using regional runoff data: an assessment of the United States federal hydropower plants, *Energy*, 80, 239-250, doi:10.1016/j.energy.2014.11.066
- Kao, S-C, M. Ashfaq, B. S. Naz, R. Martinez, D. Rastogi, R. Mei, J. Yetta, N. M. Samu, M. J. Sale, The Second Assessment of the Effects of Climate Change on Federal Hydropower, ORNL Technical Report (in review)

- Floods

- Jing, L., T.W. Hurtle, N. S. Diffenbaugh, M. S. Delgado, M. Ashfaq (2015), Future property damage from flooding: sensitivities to economy and climate change, *Climatic Change*, doi:10. 1007/ s10584-015-1478-z

- Water Supply:

- Pagan , B. R., J. S. Pal, C. Gao, J. Reichenberger, D. R. Kendall, M. Ashfaq, D. Rastogi, S-C. Kao, B. Naz, J. Schubel, Long Beach Climate Resiliency Study: Impacts on Water Supply and Demand (*submitted for review*)
- Pagan, B. R, M. Ashfaq, D. Rastogi, S-C. Kao, B. Naz, D. R. Kendall, J. S. Pal, Extreme hydrological events drive reduction in water supply in the southwestern United States (*in review*)

# ESM Theme

## Progress on Strategic Plan Goals

### NEW! 2.2.5 Develop, analyze, and manage very large Earth science data.

#### • Publications:

- Kumar, Jitendra, Forrest M. Hoffman et al. (2015), Characterization and classification of vegetation canopy structure and distribution within the Great Smoky Mountains National Park using LiDAR, *Proceedings of the 15<sup>th</sup> IEEE International Conference on Data Mining Workshops (ICDMW 2015)*, pages 1478–1485. Institute of Electrical and Electronics Engineers (IEEE)
- Mahajan, S., K. J. Evans, M. Branstetter and V. Anantharaj (2015): Fidelity of climate extremes in high resolution climate models, *Procedia Computer Science*.

#### • Invited Talks:

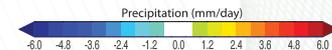
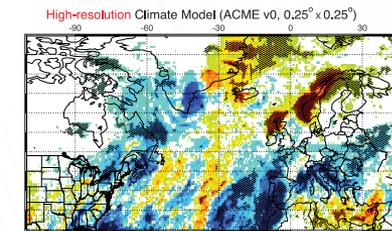
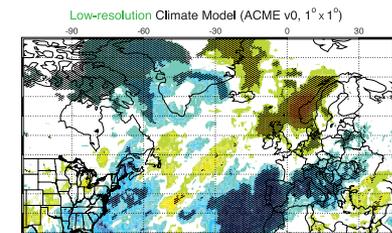
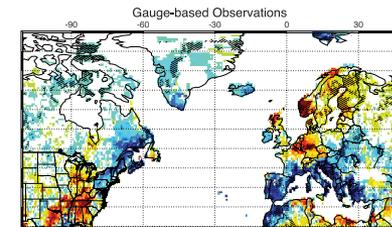
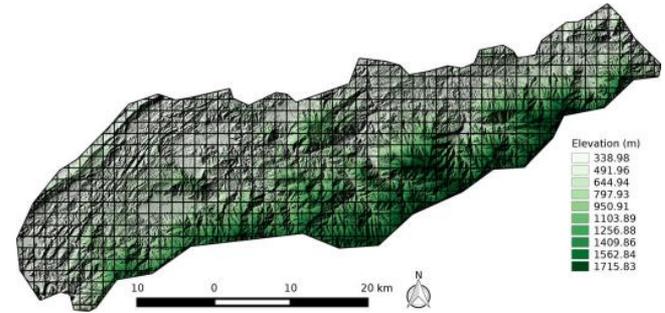
- Mayer, B. (2015): DOE Climate Process flow Overview, NOAA GFDL.

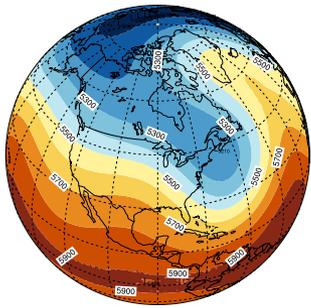
#### • Workshops/Sessions Organized:

- Sixth Workshop on Data Mining in Earth System Science (DMESS 2015) at ICCS 2015
- AGU Fall Meeting Session on Big Data in the Geosciences: New Analytics Methods and Parallel Algorithms

#### • New LDRD SEED project:

- Mahajan, S. (2016–2018): Ensemble based multivariate approach for verification of climate models





# Climate Change Science Institute Earth System Modeling Workshop June 9, 2015

**Objective:** Educate students and stakeholders about the basics and importance of ESM research in contributing to advances in climate change science and the variety of work going on within the ESM theme of the CCSI

## Workshop details and lessons learned:

- 75 registrants, 1 keynote speech, 2 science motivation talks, ~3 tutorials, ~15 highlights speakers, good food and excellent logistics thanks to Teresa and Tonya.

