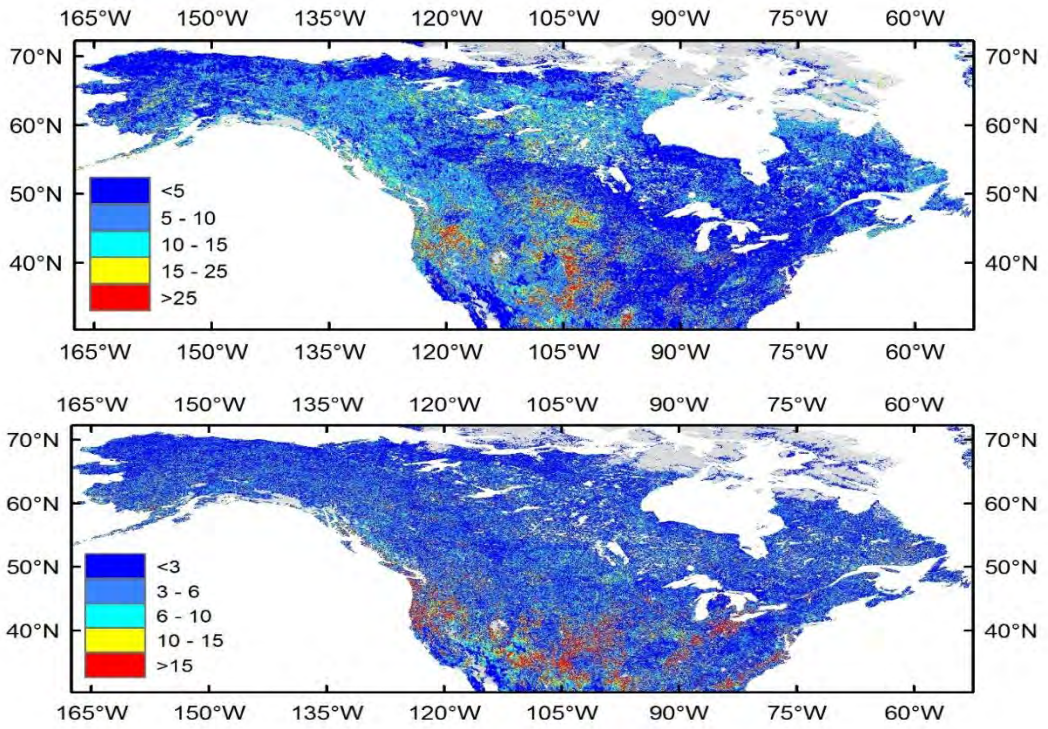


Figure 3. Assessment of the quality of real-time monitoring of spring phenology. The absolute mean difference of days is calculated from the real-time monitoring and regular phenology detection for the greenup onset (upper panel) and maturity onset (lower panel).

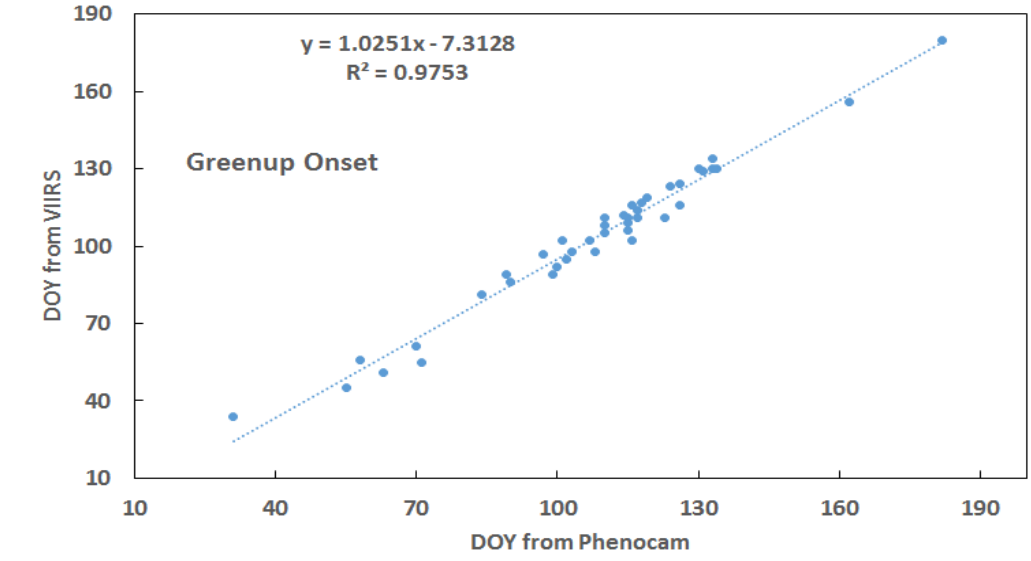


Figure 4. Comparing of real-time monitoring of phenology from VIIRS with PhenoCam observations.

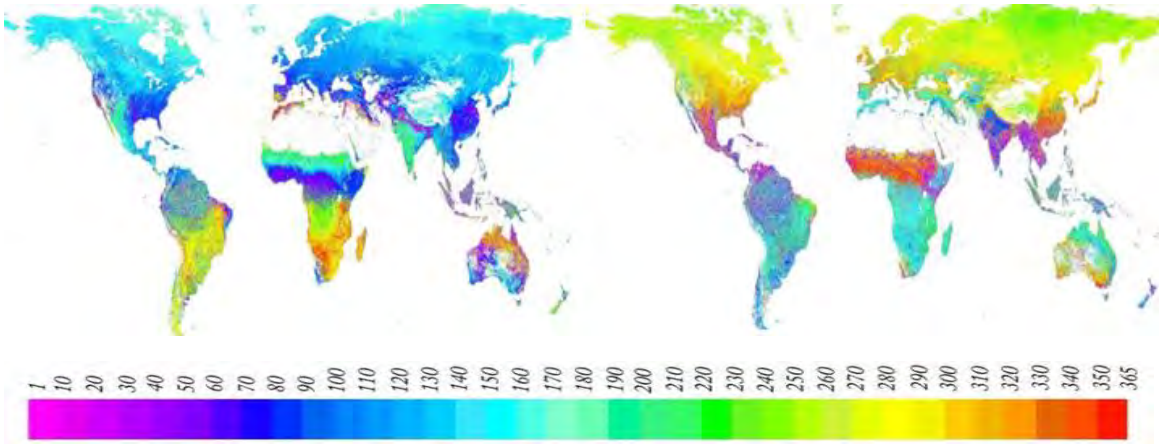


Figure 5. Global VIIRS phenological dates (day of year) at 4km. Left panel is the onset of greenness increase (greenup onset) and right panel is the onset of greenness minimum (dormancy onset) in 2013.

Planned work

- Project completed in September 2016

Publications

1. Yan, D., Zhang, X., Yu, Y. Guo, W., 2017, Characterizing land cover impacts on the responses of land surface phenology to the rainy season in the Congo Basin, *Remote Sensing* (under review).
2. Liu, L., Zhang, X., Yu, Y. Guo, W., 2017, Real-time and short-term predictions of spring phenology in North America from VIIRS data, *Remote Sensing of Environment* (in press).
3. Liu, L. Zhang, X., Yu, Y., and Donnelly, A., 2017. Detecting spatiotemporal changes of peak foliage coloration in deciduous and mixedforests across the Central and Eastern United States, *Environmental Research Letters*, https://doi.org/10.1088/1748-9326/aa5b3a
4. Yan, D., Zhang, X., Yu, Y., Guo, W. and Hanan, N. P., 2016, Characterizing land surface phenology and responses to rainfall in the Sahara Desert, *Journal of Geophysical Research- Biogeosciences*, 121, http://dx.doi.org/10.1002/2016JG003441.
5. Yan, D., Zhang, X., Yu, Y., and Guo, W., 2016, A comparison of tropical rainforest phenology retrieved from geostationary (SEVIRI) and polar-orbiting (MODIS) sensors across the Congo Basin, *IEEE Transactions On Geoscience and Remote Sensing*, http://doi.org/10.1109/TGRS.2016.2552462.

Presentations

1. Wang, J., Zhang, X., 2016, Impacts of Wildfires on Long-term Land Surface Phenology, AGU *Fall Meeting*, 12–16 December, San Francisco, California, USA.
2. Yan, D., Zhang, X., Yu, Y., Guo, W., 2016, Characterizing the Responses of Land Surface Phenology to the Rainy Season in the Congo Basin, *AGU Fall Meeting*, 12–16 December, San Francisco, California, USA.

3. Zhang, X., Yu, Y., Liu, L., Yan, D., 2016, Real-time Monitoring of Land Surface Phenology from Polar-Orbiting and Geostationary Satellites, *US-IALE 2016 Annual Meeting*, 3-7 April 2016, Asheville, North Carolina
4. Liu, L., Zhang, X., Yu, Y., 2016, Evaluating the potential of satellite data to track temporal trend in peak coloration of temperate forest in eastern United States, *2016 AAG Annual Meeting*, March 29 - April 2, San Francisco, California, USA.
5. Zhang, X, Liu, L., Yu, Y., 2016, Assessment of Real Time Land Surface Phenology Retrieved from JPSS VIIRS Observations, *2016 NOAA JPSS Science Team Meeting*, August 8-12, College Park, MD.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	5
# of NOAA technical reports	
# of presentations	5
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Support transition of GSIP LST products to the Enterprise Processing System

Task Leader	Yuling Liu
Task Code	YLYL_GSIP_14 Year 3
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic:	Earth System Monitoring from Satellites
Contribution to NOAA goals (%)	Goal1:20%; Goal 2: 80%;
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

This report summarizes the work of the project entitled "supporting the transition of GOES LST product to the enterprise processing system". Information on land surface temperature (LST) is important for understanding climate change, modeling the hydrological and biogeochemical cycles. Current GOES LST is an independent product running at OSPO. It was proposed to integrate GLST product into the enterprise operational system. This task is a part of the enterprise product development project with the objective of providing support for the transition of GOES LST product to the enterprise system.

Accomplishments

1) Emissivity update

a) The emissivity data used as input for GOES LST retrieval are updated annually. The most recent 10 years of monthly emissivity data is used to generate the average emissivity for GLST use. The emissivity in 2016 has been included in the latest update.

2) Corrected the error in the GLST code for the quality flag related to the snow cover

a) Fixed the error in the software code. Performed the code test in the local environment.
b) Delivered the code package and verified the output from OSPO.

3) Delivered the code package to ASSIST.

4) GLST verification and validation report on the input GSIP V3 update

a) Compared the old and new GLST with different versions of the GSIP V3 data. The GLST image looks very different. It was confirmed that the cloud mask 4-tier classification scheme has been changed in the updated GSIP V3 data. The configuration file has been changed accordingly to adapt for the new cloud mask.
b) Verified the output from OSPO.
c) A verification report has been delivered to summarize the modifications and test results regarding to the new GSIP update.

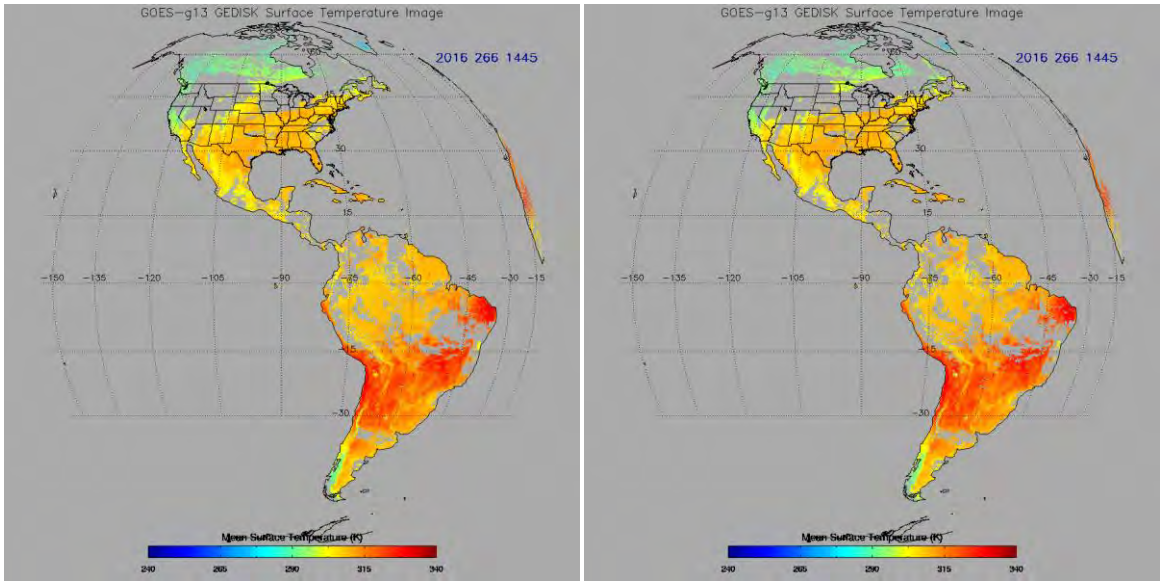


Figure 1. The GLST image generated for visual check: new GLST (left) and old GLST (right)

5) **Provided scientific and technical support on the implementation of the GLST in the framework**. This task took much more time than expected because the input data has been totally changed so as the logic in the LST calculation and quality flag setting has to be changed accordingly. For example, previous required input is GSIP V3 which includes all variables in one single file but in the framework, all input SDR data, cloud data, land mask data, snow cover data, tpw data etc are from different products in the framework chain which have different data structure and data interpretations. The dramatic differences in the input as well as the framework requirements increase the difficulties and complexities in the integration.
   a) Determined the new quality flag list and criteria
   b) Considering that there is no reference GLST to verify if the modified code working correctly, IDL code is written to generate LST, quality flag as well as the metadata.
   c) Verify the output from the framework. GLST in four domains including NHEM and FD for GOES 13 and GOES 15 , respectively are selected as scenarios for the verification. Many inconsistencies have been observed and got solved finally e.g. standard deviation calculation, daynight QC setting, snow flag error, wrong coefficient file for G15 LST calculation etc.
   d) Documentation update. Due to the change in GLST input, the QC logic needs to be updated. An Amendment has been added to the GOES LST ATBD.
   e) Provide materials for the test readiness review(TRR)

Planned work

- Maintenance of the GLST product
- Scientific and technical support on the future update.

Products

- GOES LST product.

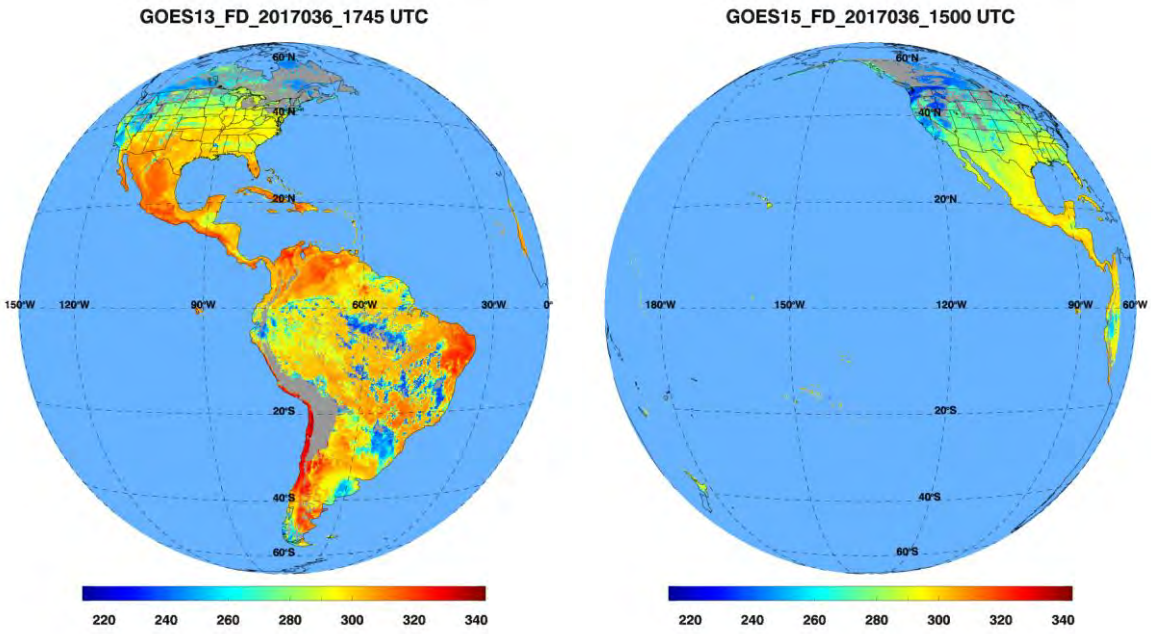


Figure 2. The GLST image generated using the enterprise system input for GOES13 (left) and GOES 15(right)

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

2.9 Education, Training, and Outreach

Climate Outreach, Education, and Community Engagement at the Climate Program Office	
Task Leader	Alison Stevens
Task Code	DBWC_CPO_14 Year 3 & EBAS_CPO_16
NOAA Sponsor	Eric Locklear
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Science to Support Policy and Outreach
Contribution to NOAA goals (%)	Goal 1: 10%; Goal 2: 90%; Goal 3: 0%
Strategic Research Guidance Memorandum:	6. Other: Scientific Outreach and Education

Highlight: Ms. Stevens' accomplishments support more effective dissemination of research results and program accomplishments from NOAA to the broader national and international research and climate-interested communities. Additionally, her efforts help strengthen relationships with funded scientists and increase the visibility of the scientists, their research, and ultimately CPO as a result. Through enhanced access to climate-related information, Ms. Stevens work supports greater opportunities for collaboration and linkages among researchers and other user groups.
Link to a research web page: http://cpo.noaa.gov/MAPP

Background

The Climate Program Office (CPO) works to develop and engage a broad user community for climate products, services, data, and information through communication, education, and outreach efforts. To this end, CPO will benefit from enhanced internal and external partnerships, stakeholder engagement, and development of products that help disseminate information. These efforts require strong communication, writing, and interpersonal skills, which match well with Alison Stevens' experience, education, and background.

Accomplishments

In FY16, Ms. Stevens accomplished several tasks to support communication and outreach efforts of CPO. She developed several internal communication products including Hot Items and Three Things Memos to inform OAR, NOAA, and DOC leadership of research and program accomplishments and upcoming events. To reach the external community, including funded scientists and the climate-interested public, she produced news articles for the CPO website and liaised with the CPO CEE Division and OAR communications to share higher impact items on climate.gov and the NOAA Research website. She also developed concise info sheets, including one about the newly funded NOAA S2S Prediction Task Force, as a handout for conferences, workshops, and as a source of information on the CPO website. Furthermore, she helped edit, format, and print reports developed and organized by CPO and CPO-funded scientists to share and distribute at conferences, workshops, meetings, and on the CPO website. To reach broader and less technical audiences, Ms. Stevens worked with the CEE Division to produce Featured Image Stories for climate.gov highlighting CPO-funded research. These stories include a key image representative

of the research findings. Ms. Stevens applied her data visualization skills to help develop easily digestible and visually pleasing maps to accompany the Featured Image Stories.

To better engage CPO-funded scientists, Ms. Stevens initiated a targeted outreach plan in FY16. With the help of the Program Managers, she identified key scientists to reach out to. She scheduled interviews with the identified scientists to cultivate a personal relationship with each of them, learn more about their research, and inform them of the types of communication support she can provide. Using the information she gathered during the interviews, she began developing Meet Our Scientist profiles highlighting the CPO-funded scientists, their backgrounds, and their currently funded research. These profiles have been published on the NOAA Research website, increasing the visibility of CPO and its funded scientists.

Figure 1. Screenshot of Meet Our Scientist profile highlighting Jason Otkin on the NOAA Research Website.

To help to continue to diversify the communications products used to publicize CPO-funded research and to better engage the external community, Ms. Stevens proposed the idea of developing an Esri Story Map. She published her first story map for CPO in FY16 on drought.gov, which describes the evolution of the recent Texas Drought and highlights CPO-funded research related to drought. This story map was so well received that the NIDIS Program asked to partner with Ms. Stevens and her colleagues to develop a series of additional drought story maps. She will continue to develop these additional story maps with NIDIS in FY17.

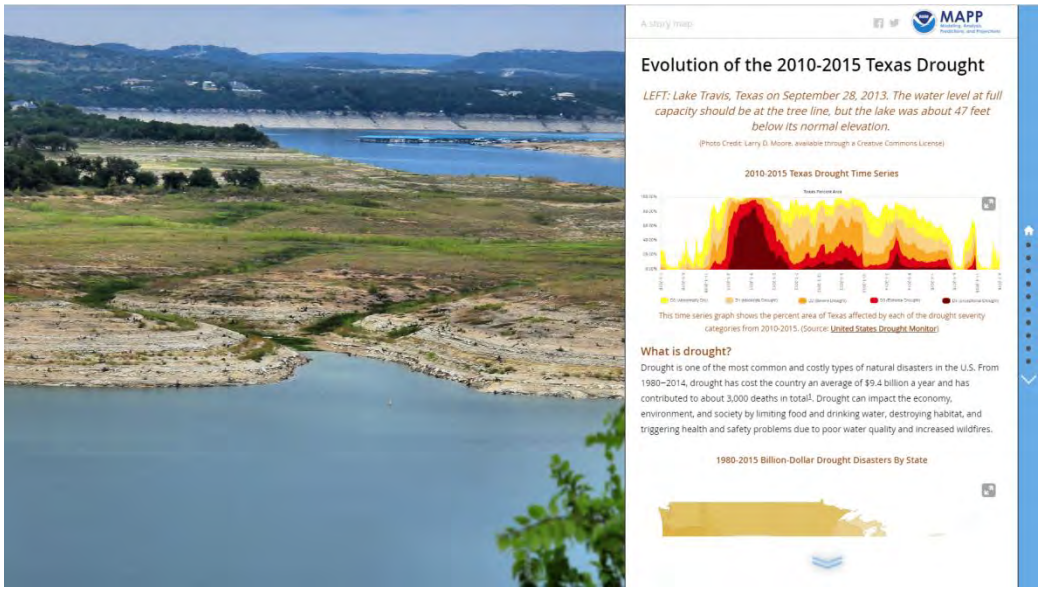


Figure 2. Screenshot of the story map about the evolution of the recent Texas Drought.

To help share the products she developed, Ms. Stevens created new pages for the CPO website and updated the website with news articles, Meet Our Scientist profiles, and other upcoming and recent events and workshops. In addition, she maintained and improved the MAPP Program newsletter, incorporating feedback received and compiling material to include in the quarterly issues. Furthermore, she liaised with the CEE Division and OAR communications to share her news articles and other products and upcoming events on climate.gov and NOAA Research social media.

Ms. Stevens also joined a USGCRP working group, the Indicators Interagency Working Group, in FY16 to improve the look, feel, and utility of the USGCRP National Climate Indicators System. She contributed ideas and provided feedback on the individual indicator pages as well as the website as a whole.

Planned work

- Develop and support pathways for enhanced Climate Program Office/MAPP engagement with Congress, NOAA leadership, and the scientific community by liaising with staff in the CPO Communication, Education and Engagement Division (CEE), and OAR and NOAA public affairs and communications offices.
- Help organize and facilitate communications and engagement with investigators through workshops and other activities.
- Publicize the major accomplishments of the MAPP and Assessments programs and make the community aware of ongoing activities and how to engage in them by liaising with staff in the CEE Division and OAR communications office.
- Work with the CPO Assessments program to establish relationships with NOAA and interagency elements critical to the development and production of the next National Climate Assessment.
- Work with MAPP-funded principal investigators and NCEI staff to better translate and communicate their significant findings and activities to a broader audience via websites, social media, and

other means; facilitate the integration of their research results into useful activities and products.

- Help develop and advance new initiatives and directions related to the National Climate Indicators System, including expanding the stakeholder and producer base for Indicators and involving the external community more actively.
- Work with MAPP, NCEP/NWS (e.g. the Climate Test Bed) and partners in other NOAA Line Offices (NMFS) to improve the flow of research results on prediction systems and models to operations and applications; enhance the communication from operational needs to research.
- Develop materials (written as well as graphical content) for websites to translate and publicize research results.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

See new products and efforts described in the accomplishments section. The metrics listed here are not applicable to this task.

CICS Support for NOAA's GOES-R Training Program	
Task Leader	Jim Gurka
Task Code	EBJG_GOESR_14 Year 3
NOAA Sponsor:	Steve Goodman
NOAA Office :	NESDIS/GOESPO
Contribution to CICS Research Themes (%)	Theme 1: 100%
Main CICS Research Topic	Education, Training, and Outreach
Contribution to NOAA goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	6. Other: Scientific Outreach and Education

Background

NOAA is conducting extensive preparations to ensure user readiness as GOES-16 approaches operational status. NOAA has invested billions of dollars in developing the GOES-R Series of satellites. The recent NAPA report on the NWS recommends significant reinvestment in training for the NWS. A major component of the preparations for GOES-R is user readiness that includes a comprehensive training program for NOAA staff and its partners in the media, academia, private sector and other governmental agencies.

Accomplishments

During the last year, James Gurka:

1. Gave a presentation titled: "Overview of Satellite Short Courses" at **the 3rd NOAA Satellite Proving Ground/User Readiness Meeting** at the National Weather Center in Norman OK, May 9 to 13, 2016. The purpose of the meeting was to focus on what has been done, current efforts, and future actions with respect to infrastructure and training, to ensure the National Weather Service is ready for the receipt and operational use of GOES-R and JPSS-1 data.

2. I was a co-organizer, co-chair and presenter for the **American Meteorological Society's (AMS) Short Course: "GOES-R Preview for Broadcasters", held on June 14, 2016, in Austin TX**, preceding the AMS Broadcasters' Conference. My presentation was a 30 minute introduction to the short course and an overview of GOES-R status and capabilities. There was a diverse geographical mix of 20 broadcasters from coast to coast. The goal of the course was to make broadcasters aware of GOES-R capabilities, how they can improve services to the viewing public, where to find additional information on GOES-R, and what equipment upgrades are needed to handle the new data and products. Participants provided lots of positive feedback on the course including the following comments: a) Great overview of the entire GOES-R Program. Good instruction; b) Very good short course; c) Don't change a thing. Great job by the entire staff. I really learned a lot and am excited even more; d) Additional GOES-R sessions post launch; Great Course!; e) Great job continuing to inform AMS attendees with GOES-R information; f) good job; g) Great job by presenters; h) Can't wait for launch; i) It's a great value and opportunity to have actual representatives here in person. Representatives from NOAA, NASA, and CIMSS in particular.

3. I represented the NWS Office of the Chief Learning Officer (OCLO) in giving an oral presentation titled "GOES-R Operational Readiness Review: NWS Training" at the **GOES-R Operational Readiness Review (ORR) at the NOAA Satellite Operations Facility**, in Suitland MD, on July 28, 2016. A NASA ORR examines the actual system characteristics and the procedures used in the system of end product's operations and ensures that all system and support (flight and ground) hardware and software, personnel, procedures, and user documentations accurately reflect the deployed state of the system. As a result of a successful ORR completion, the system is ready to assume normal operation.

4. I gave a poster presentation for the NWS OCLO titled: "GOES-R Training Plan for NOAA/NWS Forecasters" at the **21st AMS Conference on Satellite Meteorology and Oceanography** in Madison WI (Aug 15-18, 2016). I also chaired a session at the conference.

5. I was part of the planning team and an instructor at the "New Generation (GOES-R and JPSS) Satellite Workshop" at the **National Weather Association (NWA) Annual Meeting in Norfolk VA, Sept. 12-15, 2016.** In a displaced real-time hands-on forecast scenario, I provided the "shift change briefing" as the outgoing lead forecaster on the midnight shift, briefing the incoming forecast team for the day shift. I also helped guide the participants through their hands-on forecast activities.

6. I served as a subject matter expert at the **Satellite Training Advisory Team (STAT) meeting in Boulder CO, Sept. 6-9, 2016**. The meeting objectives were to: finalize any remaining SATFC-G issues that required STAT involvement; develop an implementation plan for the SATFC-J (JPSS); Complete an agenda and implementation plan for the SOO/DOH Prep. Course; Develop a plan for GOES-R Level 2 (Applications Training); and Develop a plan for JPSS Level 2 training.

7. I served as a co-organizer and co-chair for the AMS Short Course: "GOES-R Preview for All GOES Users", held on Jan. 22 preceding the **AMS Annual Meeting in Seattle, WA**. There was a diverse mix of about 40 domestic and international participants from government and private industry, ranging from operational forecasters to university researchers. The course goal was to make current and future GOES users aware of the new GOES-R series capabilities and how they will improve environmental observations and forecasts. Participants asked numerous good questions and provided lots of positive feedback on the course. Thirty-two of the participants filled out an AMS evaluation form. Typical responses included: "Excellent learning experience and demonstrations regarding the new GOES-16 features". Another comment: "Wish we had real data to demo, but the hands-on experience was well taught and put together". Also: "Repeat next year using real data". We provided the link to a "one stop shopping" web site which provides the presentations given at the course, plus follow-on information for those desiring additional knowledge on the GOES-R series.

8. I served as a subject matter expert at the **Satellite Training Advisory Team (STAT) meeting in Boulder, CO, March 27-31, 2017**. We reviewed the current breadth of training related to geostationary satellite meteorology to help plan the development on new applications training for NWS operational forecasters. In preparation for the meeting, I updated the inventory of existing GOES related training, and mapped the Satellite User Readiness Team's training objectives to

the existing training. The completion of the foundational training, consisting primarily of online self-paced modules, was a requirement of all NWS meteorologists to ensure first-stage knowledge about the GOES-R series meteorological instruments. The applications training will be targeted to specific meteorologists and operational meteorology in a variety of forms. I was a member of the Integrated Forecast Applications Subgroup for Convection. We identified GOES-16 bands, composites and derived products that can be used to complete specific atmospheric phenomena forecast and decision support tasks. The atmospheric phenomena were mapped to specific NWS programs to support operations. These products will assist NWS field operations by enhancing future products and services, including Impact-based Decision Support Services (IDSS) that support a Weather Ready Nation. The purpose of this exercise was to present a roadmap for the contribution of satellite information into a blended concept for future training, which will include remote sensing, NWP, fused products, and other sources.

9. I accepted an invitation to serve a three year term on the National Weather Association's "Remote Sensing Committee.

10. I participate in the weekly (Thursday) NWS GOES-R training teleconferences that includes all the STAT team members.

Planned work

1. Work with the Cooperative Program for Meteorology Education and Training (COMET) to identify aviation, marine and fire weather modules that need updating with new GOES-R Series information.
2. Work with COMET to update the modules in the Satellite Foundational Course-Geostationary (SATFC-G) with new GOES-16 data and products.
3. Work with COMET to develop applications training for Super Rapid Scan Operations (SRSO) data for the new generation geostationary satellites.
4. Work with the NWS OCLO and the Satellite Training Applications Team (STAT) to develop applications training for GOES-16 data and products.
5. Submitted an abstract for the NWA Annual Meeting (Sept. 2017).

Products

Updated GOES related satellite training inventory with cross reference to training objectives.

Presentations

1) "Overview of Satellite Short Courses" at **the 3rd NOAA Satellite Proving Ground/User Readiness Meeting** at the National Weather Center in Norman OK, May 9 to 13, 2016
2) "Introduction to Short Course and GOES-R Program Overview" **American Meteorological Society's (AMS) Short Course: "GOES-R Preview for Broadcasters", held on June 14, 2016, in Austin TX**
3) "GOES-R Operational Readiness Review: NWS Training" at the **GOES-R Operational Readiness Review (ORR) at the NOAA Satellite Operations Facility**, in Suitland MD, on July 28, 2016.
4) "GOES-R Training Plan for NOAA/NWS Forecasters" at the **21st AMS Conference on Satellite Meteorology and Oceanography** in Madison WI (Aug 15-18, 2016)

5) Presented the "Shift Change Briefing" at the New Generation (GOES-R and JPSS) Satellite Workshop at the **National Weather Association (NWA) Annual Meeting in Norfolk VA, Sept. 12-15, 2016**

Other

I accepted an invitation to serve a three-year term on the National Weather Association's Remote Sensing Committee.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	5
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Climate Outreach and Education at the Climate Program Office

Task Leader	Will Chong
Task Code	DBDB_COEC_14 Year 3 & EBWC_COEC_16
NOAA Sponsor	Eric Locklear
NOAA Office	OAR/CPO/ASD
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Literacy and Outreach
Contribution to NOAA goals (%)	Goal 1: 10%; Goal 2: 90%; Goal 3: 0%
Strategic Research Guidance Memorandum:	6. Other: Scientific Outreach and Education

Highlight: Increased collaboration and cooperation with scientist from NOAA, other agencies, Cooperative Institutes, and the external community fosters the net output of research for the general public. Outreach using web interface and communicative materials has helped maximize the promotion of scientific stewardship of climate related information.

Link to a research web page: http://cpo.noaa.gov/MAPP

Background

The Climate Program Office (CPO) focuses on developing a broader user community for climate products and services, provides NOAA a focal point for climate activities, leads NOAA climate education and outreach activities, and coordinates international climate activities. To achieve these goals, CPO will benefit significantly from a strong partnership with outside investigators. Building this partnership requires the involvement of personnel with computational and organizational skills to assist with program management activities.

Accomplishments

In FY16, the primary scientist continued to manage the website on the web interface content management system (CMS). The old website was structured using basic HyperText Markup Language (HTML), something that limited how much information and the type of information that could be effectively communicated online. The previous migration and creation of the new CMS allowed for a more efficient way to display and communicate climate related research results to the public. This past year, the primary scientist continued to manage and develop new content for the website to better communicate and distribute the program's research outcomes with the public. New pages and sections were created to represent new task forces, providing a space for the public to view descriptions, missions, participants, news items, publications, reports and other resources. Articles were continually developed throughout the year to highlight newsworthy program news and events. This work enabled scientists from NOAA, other agencies, Cooperative Institutes, and the external community to increase their collaboration and improve the public's knowledge of research activities across multiple sectors.

The primary scientist collaborated with the Climate Program Office's Communication and Education division and public sector communities for the development of material for the website and communication materials. Material for the website including images and graphics were used to increase the communication and distribution of research results reflected on the website. Physical materials such as informational business cards and program brochures were co-created by the physical scientist for the distribution at meetings and conferences, such as the American Geophysical Union Fall Meeting and the

American Meteorological Society Annual Meeting. Those materials allowed for more outreach to promote scientific stewardship of climate related information.

In addition to the above materials, a new communication tool was developed this year to highlight MAPP funded research to better monitor, understand, and predict drought. The web application allows users to take a deeper look into this recent multi-year Texas drought and ongoing scientists' efforts to understand it. Called a "Story Map," the web app recounts the phenomena that sparked and busted the drought and describes the ups and downs along the way, through a highly visual and interactive user experience. Key features include explorable U.S. Drought Monitor maps, relevant research highlights, photos of drought impacts, informative images and video clips, and contributions from scientists.

The primary scientist interacted with investigators funded by the grants program to better promote and communicate their research and to facilitate the integration of their research results into NOAA activities and products. A webpage was created on the website that displays the projects in an informal profile for those of the general public who are interested in learning more about current and past NOAA research activities. The primary scientist also archives progress reports and publications submitted by investigators throughout the year for program management to review.

The involvement of the primary scientist with computational and organizational skills to assist with program management activities has been essential to the success of his ability to provide climate outreach and education activities at CPO. The primary scientist has provided logistical and technical support for organized groups of federal, state, non-governmental organizations, and the broader academic research community. Examples of this include successfully scheduling and organizing monthly teleconferencing events, virtual meetings, in-person meetings and workshops to connect and engage research activities across sectors. The primary scientist also provides IT support during meetings to help ensure they run smoothly. Technical support includes running test on computers and software prior to meetings to ensure timely efficiency. Web conferencing tools have been utilized to allow for program management and scientist to more effectively communicate during virtual meetings. This has resulted in improved meeting engagement with participants.

Planned work

- Successful management of the Modeling, Analysis, Predictions, and Projections program's website.
- Continued development of communicative tools for outreach and education.
- Greater opportunities for collaboration and linkages among researchers and other user groups through enhanced access to climate-related information.
- Increased user community and stakeholder engagement through strengthened and additional partnerships.
- Continued support of MAPP Program principal investigators during organized monthly teleconferencing events, virtual meetings, in-person meetings and workshops to connect and engage research activities across sectors.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

No new and improved products were developed for operational use. Developed outreach products are described in the accomplishments section. Papers and graduate students are not applicable to the task.

JPSS-Students Professional and Academic Readiness with Knowledge in Satellites (JPSS-SPARKS)

Task Leader:	Shakila Merchant, Assistant Director, NOAA-CREST, CCNY
Task Co-Leader:	Murthy Divakarla, Senior Program Manager, IMSG, Inc.
Task Code:	SMSM_JPSS_15
NOAA Sponsor:	Mitch Goldberg
NOAA Office:	JPSSO
Contribution to CICS Research Themes (%)	Theme 3: 100%
Main CICS Research Topic	Education, Training, and Outreach
Contribution to NOAA goals (%)	Goal 2: 100%
Strategic Research Guidance Memorandum:	Other–Scientific Outreach and Education

Background

America's COMPETES Act directed NOAA to create a 20-year NOAA Education Strategic Plan that included developing a diverse workforce. NOAA-CREST Center, with major funding from NOAA Educational Partnership Program with Minority Serving Institutions (EPP/MSI), has helped construct a unique research and educational partnership between NOAA and a diverse consortium of schools to help achieve NOAA's educational goals. The JPSS-SPARKS is one of the initiative that NOAA CREST created in strong partnership with NOAA JPSS and NESDIS/STAR, and NOAA contractor IMSG, Inc., and NOAA-Cooperative Institute for Climate Studies (CICS) in 2016-2017. NOAA CREST continues to help NOAA achieve its mission of preparing a diverse STEM workforce that can understand, and engage in NOAA sciences to address environmental problems.

IM Systems Group, in collaboration with the City University of New York (CUNY), and Joint Polar Satellite System (JPSS) scientists at the Center for Satellite Applications and Research (STAR) coordinated and conducted its first JPSS education and outreach-training program in the summer of 2016. The training program was sponsored as part of the JPSS educational outreach activities. The objectives of the training program are: (a) introduce graduate students to the JPSS program and provide hands-on training experience towards JPSS science product algorithm research, development, and calibration/validation; (b) expand their understanding of Research to Operations (R2O) protocols, programming languages and standards used in operational implementation of the JPSS science algorithms.

This program was founded in conjunction with the CSC Earth System Science and Remote Sensing Technologies group at CUNY, formerly known as Cooperative Remote Sensing Science and Technology (CREST) center had noted great success in transitioning students to post-graduate careers. However, very few of these students had established careers at NOAA compared to other agencies, private industrial jobs that CREST graduates were able to join after their graduation. JPSS-SPARKS was created because of several discussions and brainstorming with NOAA CREST External Advisory Board chair Mitch Goldberg, and industrial partners including IMSG, Inc., ERT and STC. This disconnect could partially be addressed by first establishing a career at NOAA via a contracting company. A partnership with IM Systems Group could help bridge the gap between current academia and the NOAA workforce. However, IM Systems Group also found that new graduates often did not have all of the skills sought by NOAA. Therefore, in addition to a basic internship to immerse students within NOAA, IM Systems Group

would offer an intensive training period early in the internship to prepare students for the NOAA-JPSS environment.

Accomplishments

The first five weeks of the internship were primarily devoted to extensive IMSG training through programming workshops and JPSS science seminars. Morning sessions were devoted to intensive programming workshops in Fortran 90, C++ and Perl. These programming languages are less commonly offered in current academia, as languages that are more modern have gained favor in other sectors of employment. However, the vast majority of algorithm maintenance and development at NOAA still occurs in FORTRAN 90 and C++, and in operations, these are often wrapped in a shell scripting language such as Perl. The workshops are designed to use the computing logic and structure that students have already acquired from prior programming classes to bridge them into the NOAA algorithm environment. In the Fortran 90 and C++ workshops, students learned to program using sample data in formats common to the JPSS mission (e.g. NetCDF-4 and HDF-5), and then learned how to download their own data from the NOAA Comprehensive Large Array-data Stewardship System (CLASS). The Perl workshops taught students how to create wrapper scripts to run their C++ or Fortran 90 codes, and were designed to help students understand the Perl drivers that are often used in operations to run multiple codes for large sets of data. These workshops were taught in conjunction with guidelines from the Satellite Product and Services Review Board (SPSRB), which encourages safe and robust coding practice.

The afternoon sessions consisted primarily of JPSS science lectures provided on a voluntary basis by members of the JPSS team. The JPSS lecture series began with overview sessions of four of the JPSS instruments (ATMS, CrIS, OMPS, and VIIRS). Lectures then shifted to products available through various JPSS instruments (e.g. atmospheric products, land products, cryosphere products, and atmospheric soundings). Remaining open space in the afternoon lecture series was supplemented with managerial lectures (e.g. product review processes, ground systems, product management), satellite applications (e.g. forecast models, long-term monitoring), and additional programming lectures (e.g. GRIB format, configuration management). These lectures exposed students to many different facets of working in the JPSS community.

During the second half of the program, students shifted to working primarily with their STAR and/or IMSG mentors. Students combined their new knowledge of C++ and Fortran 90 with their analytical skills in other languages to investigate various issues and topics of interest agreed upon by the students and mentors. Mentors gave instruction and background on each topic, offered algorithms and/or satellite data, and often provided ancillary data to aid in their investigations (e.g. rawindsondes, ground truth, etc.). IMSG and CUNY each provided computing resources, compilers, and tools to aid students in their discoveries. Students then presented their topic of interest at the JPSS Annual Science Team meeting. During the Annual Meeting, students presented their work in a one-slide talk on-stage and then presented their work during poster sessions throughout the week. Post-internship feedback from mentors reported students as self-motivated, organized, knowledgeable, and skilled programmers.

This program began with an initial investment of four students as part of CUNY's program. Two more students from the CICS program joined the lecture series, as did a summer intern from a separate program and an IMSG employee. Ultimately, one CUNY student presented on his summer work at the

annual American Meteorological Society meeting, and another CUNY student gained employment at IMSG.

Planned work

JPSS-SPARKS phase II (2017-2018) will expand to include students from other CREST partner institutions (potentially - Hampton University and University of Puerto Rico, Mayaguez). New core competency areas of training and research are being considered for the IMSG training curriculum, including basic radiation, radiative transfer, data visualization, data assimilation, and ocean remote sensing. These adjustments to the curriculum will allow the program to partially address the core curriculum values set forth by the CUNY education program. This not only allows multiple universities to benefit from the internship program, but also benefits NOAA by having IMSG-trained potential future employees that have been educated by universities across the country. This expands the wealth of knowledge available to the community as students gain employment in the NOAA workforce. The plan is also to include other NOAA contractors (such as STC, ERT and SSAI) to provide workforce training in JPSS mission science to CREST students.

Publications

Separate peer reviewed from non-peer reviewed –only for period covered in report:

Presentations

Refereed presentations:

1. Merchant, S*[1], Mitch Goldberg[2], Reza Khanbilvardi[1] (2016). **A Novel Approach to Prepare the Next Generation Cadre of JPSS Scientists through Pragmatic Education and Training**. [1]NOAA CREST Center, the City College of New York, NY 10031. [2]NOAA /JPSS Program Science Office, Joint Polar Satellite System, AMS 96th Annual Meeting, New Orleans Convention Center, LA, January 13, 2016. *Presenting author - smerchant@ccny.cuny.edu.

Other non-refereed presentations:

2. **JPSS-SPARKS success stories** presented at the 8th Biennial EPP/MSI Education and Science Forum, New York, August 28-31, 2016
3. **JPSS Proving Ground Seminar Series presentation:**
   Merchant, S, Divakarla, M and Wilson, M (2016). JPSS-SPARKS: A unique research and training model to create a diverse STEM workforce in NOAA mission-related sciences.

CUNY Program Presentation:

4. Shakila Merchant, M. Divakarla, M. Wilson, "JPSS SPARKS: A Unique Research and Training Model to Create a Diverse STEM Workforce in NOAA Mission-Related Sciences", JPSS Science Seminar, November 2016.

Student External Presentation:

5. David Melecio-Vazqauez, N. Nalli, Q. Liu, and J. E. Gonzalez, "Thermal Boundary Layer Retrievals over the Washington D.C. Metro Area using Satellite-Based NUCAPS-EDRs," 97th American Meteorological Society Annual Meeting, January 2017.

JPSS Annual Presentations:

6. Cassandra Calderella, X. Zhan, T. King, and M. Wilson, "Validation of SMAP Soil Moisture Data using Field Measurements in New York," STAR JPSS Annual Science Team Meeting, August 2016.

7. Elius Ettienne, F. Kogan, and W. Guo, "Detecting Spatiotemporal Changes in Vegetation for the Past 35 Years Using Polar-Orbiting Satellite Data. Case Study: Haiti," STAR JPSS Annual Science Team Meeting, August 2016.

8. David Melecio-Vazqauez, N. Nalli, and Q. Liu, "Thermal Boundary Layer Retrievals over the Washington D.C. Metro Area using Satellite-Based NUCAPS-EDRs," STAR JPSS Annual Science Team Meeting, August 2016.

9. Ivan Valerio and I. Csiszar, "An Evaluation of the VIIRS Radiative Signal from the Fort McMurray Fire," STAR JPSS Annual Science Team Meeting, August 2016.

Other

This effort was originally designed to train four students. Ultimately, eight students and staff benefitted from this program, leading to the direct hire of one student and a professional presentation by another student. In addition, all of the CUNY students presented posters in the JPSS Annual Meeting in 2016, which allowed them to interact directly with JPSS experts.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	4 (JPSS annual) 2 (external)
# of graduate students supported by your CICS task	4
# of graduate students formally advised	4
# of undergraduate students mentored during the year	

2.10 Environmental Decision Support Science

Identifying Users, Diagnosing Understandability Challenges, and Developing Prototype Solutions for NOAA Climate Prediction Center's Seasonal Climate Temperature and Precipitation Outlooks

Task Leader:	Melissa A. Kenney and Michael D. Gerst
Task Code	MKMG_CPC_16
NOAA Sponsor	Dave DeWitt
NOAA Office:	CPC/OSTI/Modeling Branch
Contribution to CICS Research Themes	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic:	Environmental Decision Support Science
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%
Strategic Research Guidance Memo:	3. Decision Science, Risk Assessment and Risk Communication

Highlight: The goals of this research are to understand how climate outlooks are understood and used in decision-making. By assessing both individual visualizations and overall design of the forecast products, we aim to suggest pragmatic improvements that will improve the understandability and use of the products by decision-makers**.**

Link to a research web page: http://indicators.umd.edu

Background

The National Oceanic and Atmospheric Administration (NOAA) National Weather Service Climate Prediction Center (CPC) provides future-oriented scientific information on various climate outcomes in the range from one week out to one year. This information can be viewed as a leading indicator, as it provides predictive, albeit uncertain probabilistic information tracked over time that is intended to be useful for decision-making. Structuring the delivery of this information is challenging for many reasons, foremost being that visualizing uncertainty for geospatial data has been an open area of research for many years (MacEachern, 1992). However, careful attention to delivery of uncertain information is of high importance because incorporating uncertainty into decisions can be challenging, even when uncertainty is small. Larger uncertainties compound this problem because users often conflate larger uncertainty with less utility of the information to decision making (Montibeller and von Winterfeldt, 2015). In addition, CPC publishes predictions for temperature, precipitation, and drought as well as a synopsis of potential hazards. Each type of prediction engenders its own uncertainty characteristics and feeds into decision-making differently. Consequently, web-based information delivery must take into account these aspects so that users can find information efficiently and understand its meaning.

Over the two-year period, research activities that will inform the potential adjustments or revision of CPC's temperature and precipitation outlook visuals shall be conducted by the research group at the Cooperative Institute for Climate Studies (CICS) in order to determine how to better communicate risk and uncertainty associated with the forecasts. The work will be divided into two components: (i) assessment of individual visualization of CPC forecasts and (ii) overall product design.

Accomplishments

Phase 1: Initial Scoping of User Communities

The first phase proposed to assess existing CPC visualizations is to understand CPC's current and aspirational goals of temperature and precipitation outlook images. The Environmental Decision Support Science Lab (indicators.umd.edu), led by Kenney and Gerst, identified the objectives and intended user audiences through semi-structured interviews with eight NOAA experts identified through CPC. In close collaboration with CPC, we developed an interview protocol that focused on participants' perception of how the products are designed and how well they work / their utility. For example, interviewees viewed a variety of CPC precipitation and temperature outlook products, such as the 8-14 Day Precipitation Outlook below. The interviews were conducted from June to August 2016. Of the eight interviews, five were held in-person and three were held via web conference using Adobe Connect. The interviews ranged in length from 40 minutes to 1.5 hours. All interviewed experts were affiliated with Federal agencies. Seven participants were affiliated with NOAA, and one was affiliated with the United States Department of Agriculture. The individual interviews were transcribed and then sent to the interviewee via e-mail where they were provided with the opportunity to amend the transcript. The transcripts were then coded using NVivo software to identify information and themes. The majority of the participants volunteered to connect us to identified user communities, if it would be useful in future research phases. There was also general support for this research and the use of it to improve the outlook products. Key findings from Phase 1 are that boundary organizations and science translators are significant users of CPC outlooks and the current outlook products are not well understood by users.

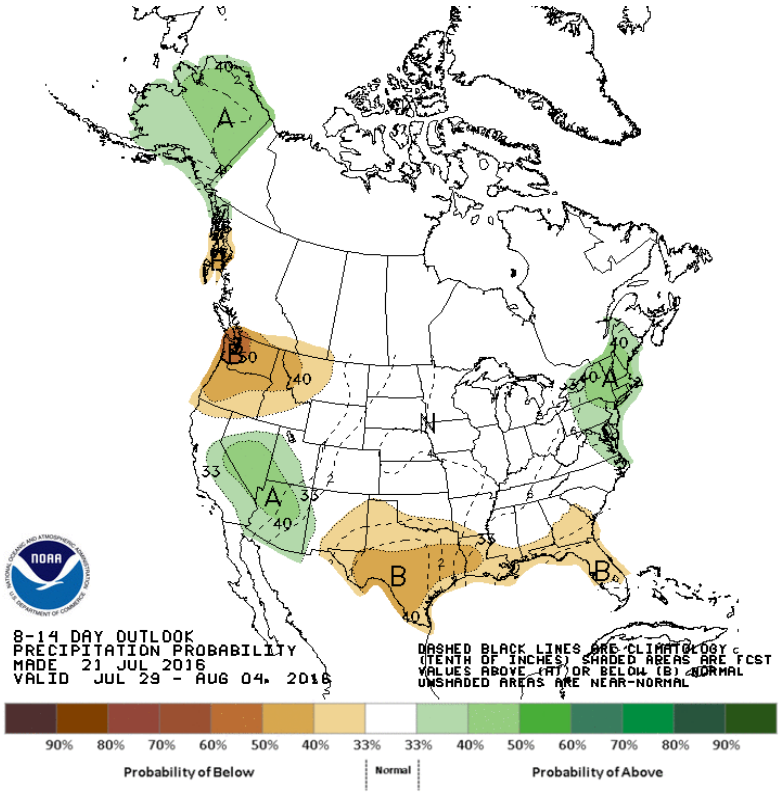


Figure 1: 8–14 Day Precipitation Outlook

Phase 2: Identifying End-user Audiences
Key to improving the climate outlooks is identifying the end-user audiences and the potential or intended uses of the climate outlooks for their own understanding and use in a range of different decision-making contexts. Phase 2 will focus on the target end-users identified by CPC—the organizations that are between the level of the science translator, identified in Phase 1, and the level of the individual user. Specifically, we focused on the target end-users in four sectors identified in close collaboration with CPC. These sectors include emergency management, water resource management, agriculture, and energy. Through the interview processes of Phase 1, we have identified a small set of boundary organizations and science translators within these organizations that will provide initial contacts to the target end-users and their networks. Additional target end-users will be identified through a combination of methods such as: 1) snowball sampling of science translators identified in Phase 1, 2) secondary document analysis and Internet searches where decisions, information needs, or CPC products are presented and discussed or are eluded to. We completed a preliminary build-out of a database for all four sectors. Within all four sectors, we conducted pattern analyses of the identified entities to identify trends and gaps amongst characteristics for the entities including the types of decisions, timescale of decision-making, stakeholders, and point(s) of contact.

Planned work

- Using a short survey (≤15 minutes) distributed widely to target end-users to the four focus sectors (using methods identified in Phase 2), we will assess both ends of this context. In addition to the survey, we will conduct one focus group with target end-users from each of the four sectors. The focus groups will emerge one decision type or decision context of interest to CPC (Phase 3, July 2017).
- The results of the CPC expert and user elicitations will provide the basis on which to diagnose any mismatch between existing visualizations and user needs (Phase 4, July 2017).
- After diagnosing visualization problems for different end-users, the climate outlooks will be redesigned for 1-3 user audiences (Phase 5, November 2017).
- After redesigning the visuals, CICS will test the effectiveness (both in terms of improved understandability and affect) of the redesigned climate outlooks (Phase 6, February 2018).
- We will develop the results both into peer-reviewed papers to be published in journals such as, *Weather, Climate and Society*, and recommendation for CPC in the form of technical reports (Phase 7, April 2018)

Publications *(Publications Relevant or *Funded by this Grant)*

Non peer-reviewed

1. Gerst, M.D., M.A. Kenney, A. Baer, J.F. Wolfinger et al. (2017) Effective Visual Communication of Climate Indicators and Scientific Information: Synthesis, Design Considerations, and Examples. A Technical Input Report to the 4th National Climate Assessment Report. http://www.umdindicators.org/?page_id=1028

Peer-reviewed

2. Gerst, M.D., M.A. Kenney, J.F. Wolfinger, I. Feygina. Increasing understandability of visual climate indicator graphics. *in prep*
3. * Gerst, M.D., M.A. Kenney, A.E. Baer. Identifying Users, Diagnosing Understandability

Challenges, and Developing Prototype Solutions for NOAA Climate Prediction Center's Temperature and Precipitation Outlooks. *in prep during Y2*

Products

1. Phase 1 Initial Scoping Think Aloud Interview Protocol used during semi-structured interviews with NOAA experts identified through CPC.
2. Phase 1: Identifying Users, Diagnosing Understandability Challenges, and Developing Prototype Solutions for NOAA Climate Prediction Center's Temperature and Precipitation Outlooks memo
3. Options for Phases 2-4: Identifying Users, Diagnosing Understandability Challenges, and Developing Prototype Solutions for NOAA Climate Prediction Center's Temperature and Precipitation Outlooks memo
4. Initial database for water, energy, agriculture, and emergency management end-user organizations

Presentations

Invited Presentations

1. Kenney, M.A., M.D. Gerst, A.E. Baer. (2016) Phase 1 Results on the Understandability Challenges for Non-scientific Users of the Climate Temperature and Precipitation Outlooks. *National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center*, College Park, MD.
2. Kenney, M.A. (Fall 2016) Effective Scientific Information Translation to Support Environmental Decision-making. University of Maryland, College Park, MD. College of Information Studies.
3. Kenney, M.A. (Spring 2016) Environmental Decision Support Science to Support Complex Water Resources and Climate Decision-making. Tufts University, Medford, MA. Civil and Environmental Engineering.
4. Gerst, M.D., M.A. Kenney (November 14, 2016) Using visualization science to diagnose and improve global change indicator understandability. *Institute for Operations Research and the Management Sciences (INFORMS)*, Nashville, TN.

Invited Workshop Presentations and Participation

1. Business Case for Resilience Roundtable. (November 2016) Invited Participant. Sponsored by White House Council on Environmental Quality. Washington, DC.
2. Water-Energy-Food Nexus Roundtable. (August 2016) Invited Participant. Sponsored by White House Office of Science, Technology, and Policy. Washington, DC.
3. Public Engagement Training for Leshner Leadership Institute Fellows. (June 2016). Sponsored by American Association for the Advancement of Science (AAAS) Leshner Leadership Institute. Washington, DC. http://www.aaas.org/pes/leshner-fellows

Other

9-2-16 **Kenney Attends White House Roundtable:**

CICS-MD Scientist Melissa Kenney participated in the Water-Energy-Food Nexus Roundtable sponsored by the White House Office of Science and Technology.

It was held on August 25th in Washington, DC. The issues discussed included Alternative Water and Water Reuse, Biofuels, Flexible Grid Technologies, Food Waste, and Wastewater Treatment.

Importance: Decision support science allows NOAA to disseminate its climate, weather, coastal, and marine data directly to policymakers. *POC*: M. Kenney

9-30-16 **Kenney Quoted on Outreach to Students:**

"AAAS Lessner Fellows help their communities to confront climate impact" is a news item in the September 29th issue of *Science*. CICS-MD Scientist Melissa Kenney (supporting OAR/CPO), a 2016 Lessner Fellow, is quoted as saying:

> "Fellow Melissa Kenney, assistant research professor in environmental decision support science at the University of Maryland, worked with undergraduate students this summer to synthesize the challenges and informational needs of community representatives in the Chesapeake Bay by reviewing existing reports and other documents. "We wanted to do our homework so we didn't ask a lot of questions that were already answered," Kenney said. She and her team are looking for "research gaps and science translation opportunities" to approach community leaders with processes and tools that will "facilitate evidence-based decision-making….In a densely populated watershed, climate is amplifying existing impacts on our region," added Kenney. "So we don't have a choice; we have to make decisions to consider current and future climate impacts."

See the full article at http://science.sciencemag.org/content/353/6307/1508. Kenney (OAR/CPO/ASD) Kenney is the Task Leader on the Task entitled "Research, Development and Implementation of Physical, Ecological, and Societal Climate Change, Impact, Vulnerability and Preparedness Indicators for the United States."

Importance: Training NOAA's next generation of scientists helps NOAA sustain a world-class workforce. *POC*: M. Kenney

1-27-17 **Kenney's CICS Research Highlighted in *Decision Analysis Today*:**

CICS-MD Scientist Melissa Kenney (OAR/CPO/ASD) and her NOAA-funded research on Climate Change Indicators were featured In the December 2016 issue of *Decision Analysis Today*, a publication of the INFORMS Decision Analysis Society.

Her work was the first in a new series "to highlight work at the intersection of practice and research, looking at decision analysis research that is impacting other fields or applications, fundamental research that can have an impact on practice, or great work in practice that can stimulate research ideas." Mer-

rick, Jason, 2016: President's Letter, *Decision Analysis Today*, 35(3), 1–2, https://www.informs.org/Community/DAS/Newsletter.

Importance: Applying NOAA's scientific research to policy decision-making is an important element of "climate intelligence." *POC*: M. Kenney

Advising and Mentoring: Graduate Students

1. Stärk, Johanna, Max-Planck Odense Center, 2016-present (dissertation committee)
2. Reyes, Julian, Washington State University, 2014-present (mentored dissertation chapter)
3. Anderson, Sarah, Washington State University, 2013-present (mentored dissertation chapter)
4. Prava, Venkat, Johns Hopkins University, 2010-2016 (co-advisor, dissertation committee, received two awards by the Decision Analysis committee for co-authored paper resulting from dissertation)
5. Salehittal, Akshata, University of Maryland, 2016-present
6. Larger, Eric, University of Maryland, 2015-2016

Advising and Mentoring: Undergraduate Students

1. Cavanagh, Meg, University of Maryland, 2016-present
2. Speciale, Amanda, University of Maryland, 2016-2017
3. Jaffee, Natalia, University of Maryland, 2016
4. Sproul, Dean, University of Maryland, 2016-present
5. Winik, Jason, University of Maryland, 2016-present
6. Veselka, Camille, University of Maryland, 2016
7. Bell, Julia, University of Maryland, 2016
8. O'Connor, Beatrice, University of Maryland, National Socio-Environmental Synthesis Center (SESYNC) Internship, 2016
9. Li, Angelica, University of Maryland, National Socio-Environmental Synthesis Center (SESYNC) Internship, 2016
10. Truitt, Elisabeth, University of Maryland, 2016
11. Sadecki, Nicole, University of Maryland, 2016

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	6
# of undergraduate students mentored during the year	11

Research, Development and Implementation of Physical, Ecological, and Societal Climate Change, Impact, Vulnerability and Preparedness Indicators for the United States

Task Leader:	Melissa Kenney
Task Code	MKMK_RDIP_14 Year 3
NOAA Sponsor	Eric Locklear
NOAA Office:	OAR/CPO
Contribution to CICS Research Themes	Theme 1: 75%; Theme 2: 0%; Theme 3: 25% (estimated)
Main CICS Research Topic:	Environmental Decision Support Science
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memo:	3. Decision Science, Risk Assessment and Risk Communication

Highlight: Kenney's research team is leading the development of prototypes and the evaluation of an interagency climate indicator system to bring together data, observations, and indicator products in innovative ways to better assess climate changes, impacts, vulnerabilities, and preparedness and move the research products into operations for decision support.

Link to a research web page: http://indicators.umd.edu; http://www.globalchange.gov/what-we-do/assessment/indicators

Background

Research activities in Year 3 were marked by a major milestone in producing a guidance document for effective communication of climate indicators and scientific information, which was submitted as Technical Input for the 4th National Climate Assessment. Specific activities include: (1) understandability of indicators by non-scientists; (2) indicators special issue in *Climatic Change*; and (3) review and synthesis of resilience indicators**.** Results from previous years is available in prior annual reports. Finally, we will summarize future research activities in progress.

Accomplishments

1. **Visualization Guidance**

At NOAA's request, we were asked to develop an "understandability guide." Our team synthesized the visualization literature across several disciplinary domains, examples from various climate graphic documents (e.g., National Climate Assessment, EPA Indicators, NOAA visuals), and our own research. The resulting document focused on pragmatic recommendations for improvement of climate and scientific visuals for non-scientific audiences to increase their understandability of the information presented. This visualization report additionally highlighted the results of leveraged seed research funds from the University of Maryland NSF ADVANCE program, which allowed for in-depth exploration of indicators and the Global Change Information System (GCIS) products as a linked boundary object, where the presentation and transparency of metadata is especially important for the indicators to be viewed as trusted and credible by technical audiences.

Version 1 was submitted as a Technical Input report (via URL) for the 4th U.S. National Climate Assessment. Given feedback on version 1 and new research and literature, edits and additions will be ongoing and posted (http://www.umdindicators.org/?page_id=1028). Additionally, a brief visual guidance recommendation fact sheet is being developed as a supplement to this document to provide pragmatic

guidance for the development of visuals for the 4th National Climate Assessment.

2. **Understandability of Indicators by Non-Scientists**

In order for indicators to effectively convey information target audiences must easily understand them. Indicator understandability derives from the abstractness of the indicator, the complexity of the patterns portrayed by the indicator, and visualization techniques. We chose to focus on visualization techniques, as this is often the easiest lever to use in efforts where indicators have been co-produced with experts and stakeholders. The experimental design proceeded in two phases, the first being completed over the last research period. Phase 1 provided useful initial results, which were synthesized and included as part of the 2nd Annual Report produced by the White House Social and Behavioral Sciences Team (SBST) because of our collaboration on this project with former SBST fellow Irina Feygina.

The initial results of Phase 1 indicate that understandability varies across indicators somewhat along expectations. In addition, we found that understandability across beliefs in climate change does not vary widely. In addition to this work, an in-depth literature review of indicator understandability was synthesized into a guidance document for effective visual communication of climate indicators and scientific information (see section on Visualization Guidance above).

A Phase 2 survey was developed to allow for better analysis of changes in understandability resulting from modifications to indicator visualizations. Multiple versions of the survey have been tested and subsequently improved with small sample populations via Amazon Turk. A subset of the USGCRP indicators have been systematically modified in preparation for the survey. The Phase 2 survey instrument is now undergoing additional internal and external review before release to the survey participants. Phase 2 will focus on static graphics with the aim of supporting the development of the fact sheet described in the Visual Guidance section above.

If there is additional grant funding remaining, then the same survey mechanism will be used to provide preliminary results, similar to the preliminary test/re-test Phase 1 results, on interactive graphics for 1-2 indicators such as Heating and Cooling Degree Days. These will specifically test the interactive graphics that were included in the 3rd National Climate Assessment for understandability and perceived user experience.

3. **Special Issue of Climatic Change**

During the summer of 2016, Kenney and Janetos successfully finalized logistics to guest edit a special issue in the journal *Climatic Change.* The special issue is anticipated to include 15 papers and be published in Fall 2017 - Winter 2018.

Seven of the 12 technical teams have submitted their individual articles to *Climatic Change*; 2 additional papers are under agency review, and the remaining papers are ones our team is actively managing to a submitted draft. This special issue will peer-review the system-wide recommendations for a national assessment-focused indicator system, highlight knowledge gaps, and suggest future directions for indicator development. Two non-technical team papers have also been submitted, one additional is anticipated for submission in this month. The technical teams have required very active coordination, conceptual model, research, and graphic design support to finalize their papers for submission, which our team has provided (i.e., more time than estimated).

The summary article – authored by Kenney, Janetos, and Gerst – is planned for submission in the next month. It will provide a built-out version of the overarching conceptual framework for the indicator system, which describes how the various sectors are linked in the broader system, and a synthesis of the comprehensiveness of the indicators chosen by the teams (i.e., technical team results were needed to complete our submission). In addition, discussion will be included on future directions of the system, including leading indicators.

4. **Review and Synthesis of Resilience Indicators**

We found a major gap in the literature for review of indicator efforts. This gap is emphasized by the many Federal indicator workshops requesting indicator inventories, with slightly different emphases. Thus, there is a clear need to better understand the indicator efforts that measure critical metrics and what purposes these indicators are used, from the local to federal government scale.

To develop the method and meet regional needs expressed by stakeholders in the Northeast states, we designed an indicators synthesis process by identifying indicator efforts in urban areas in the Northeast US. A small group of undergraduate research assistants have finalized and coded a dataset of urban resilience indicators in the Northeast US (DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT), which involves a review of efforts for 114 cities. In the Northeast US, we found that few cities' indicator systems are either framed around resilience or contain all of the components (hazard, exposure, sensitivity, capacity, and impact) necessary to be used as a resilience indicator system. However, a significant majority of cities produced indicators for other types of efforts, such as health, sustainability, prosperity, quality-of-life, and well-being. Many of these contain social and economic indicators that would be important in constructing a comprehensive resilience indicator system, especially with respect to sensitivity and capacity.

5. **Other Knowledge Transfer Activities**

The team has actively supported communications and presentations related to the NOAA-funded indicators development and research, much of this is uncredited work reviewing or supporting Federal agency requests. Additionally, over the past several years, as requested by NOAA-funded centers or USGCRP Federal agencies, Kenney has served as an on-call expert on aspects related to decision support and indicators for assessment purposes. These activities are viewed as both the mission of the research team and are often conducted during overtime hours.

Planned work *(remainder of Y3 and no cost extension to complete grant products)*

- **Understandability of Indicators by Non-Scientists:**
    - Generate concise graphical summary of visual communication guidance document (April 2017)
    - Updated baseline survey for USGCRP indicators (April 2017)
    - Survey to test / Re-test study of modified indicator visualizations (April and May 2017)
    - Data analysis and write-up of initial results (June 2017)
    - Write and submit publication of the survey Phases 1 and 2 (Summer / Fall 2017)
    - Fact sheet with pragmatic guidance on design of scientific graphics (June

2017)

- Continuous updates to visual communication guidance document based on feedback as well as ongoing research efforts (as applicable)

- **Special Issue on Indicators in *Climatic Change***
  - Anticipate that all publications will be submitted by early Summer 2017
  - Review and revision of papers is ongoing but is aimed for completion by Fall 2017
  - Publication of papers is as they are accepted; the target for the special issue publication with all papers is targeted Winter 2017-Spring 2018, depending on the journal queue.

- **Review and Synthesis of Resilience Indicators:**
  - A summary of the findings of the resilience indicator effort is drafted and is planned for submission to *Climatic Change* in summer 2017; the results will also be presented at a conference in June 2017. The methods developed as part of this research study are designed to be scalable to larger indicator review efforts.
  - Additional data for the Pacific US Island Region and the Caribbean regions have also been collected and coded but require an additional level of coding before they can be analyzed. We had multiple conversations with the Pacific RISA because of the difficulty of locating sources and developing a comparable dataset; the challenges of conducting such an indicator review within this region were confirmed. After the submission of the Northeast regional paper, we will revisit these datasets, reconnect with the Pacific RISA, and explore the development of an islands focused paper.

- **Leading Indicators, Development, and Implementation:**
  - We are still aiming to develop a leading indicators workshop multi-stressor climate impact leading indicators. The proposed timing aimed for Summer-Fall 2017. Several anticipated sponsors are reticent to make final financial commitments until there is great budget certainty. (New funding sources are currently being explored, such as the National Socio-environmental Synthesis Center (SESYNC) workshop funding.)
  - CPO funds would have supported a modest amount of time (1 week) from the PI for workshop scoping and report writing.
  - Assuming that plans move forward, the anticipated outcome of the workshop is a report and peer-reviewed manuscript on a framework of needs for decision-makers and example indicators in the different typology categories. CPO will be acknowledged in these products.

Publications

Peer-reviewed

1. Hatfield, J.L, J. Antle, K.A. Garrett, R.C. Izaurralde, T. Mader, E. Marshall, M. Nearing, G.P. Robertson, and L. Ziska (submitted). Indicators of Climate Change in Agricultural Systems. For special issue on indicators in *Climatic Change.*

2. Wilbanks T.J., J. Dell, D.J. Arent, M.A. Brown, J.L. Buizer, B. Gough, R.G. Newell, R.G. Richels, M.J. Scott, and J. Williams (submitted). Energy System Indicators of Climate Resilience. For special issue on indicators in *Climatic Change.*
3. Anderson, S.M., L.S. Heath, M.R. Emery, J.A. Hicke, J. Littell, A. Lucier, J.G. Masek, D.L. Peterson, R. Pouyat, K.M. Potter, G. Robertson, and J. Sperry (submitted). Developing a set of indicators to identify, monitor, and track impacts and change in forests of the United States. For special issue on indicators in *Climatic Change.*
4. Ojima, D.S., R.A. Washington-Allen, D.W. Bailey, N. Cavallaro, R. Aicher, S. Archer, S.M. Casby-Horton, J.A. Tanaka, and J.J. Reyes (submitted). Indicators for a changing home on the range. For special issue on indicators in *Climatic Change.*
5. Wilbanks, T., S. Conrad, S. Fernandez, S. Julius, P. Kirshen, M. Matthews, M. Ruth, M. Savonis, L. Scarlett, H. Schwartz Jr., W. Solecki, L. Toole, and R. Zimmerman (submitted). Toward Indicators of the Resilience of U.S. Infrastructures to Climate Change Risks. For special issue on indicators in *Climatic Change.*
6. Peters-Lidard, C.D., K.C. Rose, J. Kiang, M.L. Strobel, M. Anderson, A. Byrd, M. Kolian, L. Brekke, and D. Arndt (submitted). Indicators of climate change impacts on the water cycle and water management. For special issue on indicators in *Climatic Change.*
7. Lorente, M., S. Gauthier, P. Bernier, and C. Ste-Marie. Tracking forest changes: Canadian Forest Service indicators of climate change. For special issue on indicators in *Climatic Change.*
8. Jones, M.O., S.W. Running, J.S. Kimball (submitted). Terrestrial Primary Productivity Indicators for Inclusion in the National Climate Indicators System. For special issue on indicators in *Climatic Change.*
9. Hamin, E.M., M.A. Kenney, Y. Abunnasr, P. Judge, J. Buxton, M. Dilthey, R.L. Ryan, E. Roper, P. Kirshen, B. McAdoo, L. Nurse, E.A. Albright, M. Buchanan, T. Sheahan, D J DeGroot (in revision) Transformational Infrastructure for Coastal Resilience: The Adaptive Gradients Framework. *Nature Climate Change*.
10. Kenney, M.A., J.S. Dukes, K.R. Lips, J.J. Hellmann (2016) Engagement 2.0: increasing our collective impact. *Frontiers in Ecology and the Environment*. 14(8): 403. doi:10.1002/fee.1416
11. Mallampalli, V.R., G. Mavrommati, J. Thompson, M. Duveneck, S. Meyer, A. Ligmann-Zielinska, C. G. Druschk, K. Hychka , M.A. Kenney, K. Kok, M.E. Borsuk (2016) Methods for Translating Narrative Scenarios into Quantitative Assessments of Land Use Change. *Environmental Modelling and Software*. 82: 7-20.

Non Peer-reviewed

1. Gerst, M.D., M.A. Kenney, A. Baer, J.F. Wolfinger et al. (2017) Effective Visual Communication of Climate Indicators and Scientific Information: Synthesis, Design Considerations, and Examples. A Technical Input Report to the 4th National Climate Assessment Report. http://www.umdindicators.org/?page_id=1028
2. Kenney, M.A., M.D. Gerst, and J.F. Wolfinger (2016) Understandability of Indicators for Non-expert Audiences: Increasing their potential value for decision-making. Conference abstract for edited volume for workshop on the Socioeconomic Benefits of Geospatial Information.

Publications in Preparation

1. Prava, V., R.T. Clemen, B.F. Hobbs, and M.A. Kenney. (drafted, available upon request) Modeling and Correcting Over-precision Bias in Elicited Confidence Intervals.

2. Kenney, M.A., A.C. Janetos, M.D. Gerst (drafted) Socio-environmental Assessment Indicators for a Sustainable U.S. For special issue on indicators in *Climatic Change.*

3. Rose, K.C., B. Bierwagen, S.D. Bridgham, D.P. Hawkins, N.L. Poff, J.S. Read, J. Rohr, J.E. Saros, and C.E. Williamson (drafted). Indicators of the effects of climate change on freshwater ecosystems.

4. Clay, P.M., J. Howard, R. Griffis, lead authors; S. Busch, L.L. Colburn, A. Himes-Cornell, S. Rumrill, and S. Zador (drafted). Oceans and Coasts Indicators: Understanding and Coping with Climate Change at the Land-Sea Interface. For special issue on indicators in *Climatic Change.*

5. Solecki, W.D. and C. Rosenzweig (drafted). Indicators and Monitoring Systems for Urban Climate Resiliency. For special issue on indicators in *Climatic Change*.

6. Stanitski, D., M. Druckenmiller, F. Fetterer, M. Gerst, J. Intrieri, M. Kenney, W. Meier, J. Overland, J. Stroeve, S. Trainor (drafted). Indicators for a Changing Arctic. For special issue on indicators in *Climatic Change*.

7. Butler, J., et al. Atmospheric Composition and GHG Mitigation Indicators. For special issue on indicators in *Climatic Change*.

8. Arndt, D., et al. Climate Indicators. For special issue on indicators in *Climatic Change*.

9. Betancourt, J., et al. Phenology Indicators. For special issue on indicators in *Climatic Change.*

10. Lipp, E., Trtanj, J., et al. Human Health Indicators. For special issue on indicators in *Climatic Change.*

11. Kenney, M.A. Stakeholder Information Needs to Enable Climate Solutions in the Chesapeake Bay.

12. Gerst, M.D., M.A. Kenney, J.F. Wolfinger, I. Feygina. Increasing understandability of visual climate indicator graphics.

Products

1. Several prototype indicators were redesigned including:
    a. Heating and Cooling Degree Days
    b. Atmospheric Carbon Dioxide
    c. Global Surface Temperatures
    d. Start of Spring
    e. Annual Greenhouse Gas Index
    f. Sea Surface Temperatures

Presentations

Invited Presentations

1. Kenney, M.A., M.D. Gerst, A.E. Baer, J.F. Wolfinger (2017) Effective Visual Communication of Climate Indicators and Scientific Information: Synthesis, Design Considerations, and Examples. *National Oceanic and Atmospheric Administration (NOAA) Climate Program Office*, Silver Spring, MD.
2. Gerst, M.D., M.A. Kenney (November 14, 2016) Using visualization science to diagnose and improve global change indicator understandability. *Institute for Operations Research and the Management Sciences (INFORMS)*, Nashville, TN.
3. Kenney, M.A. (October 2016) Making Hard Environmental Restoration Decisions. Kent State University 4th Annual Water and Land Symposium. Kent, OH. Invited Speaker.

4. Kenney, M.A. and M.D. Gerst (2016) Indicators Research, Development and Implementation: Results from Year 2 Cooperative Institute for Climate and Satellite-Maryland Funding. *National Oceanic and Atmospheric Administration (NOAA) Climate Program Office*, Silver Spring, MD.
5. Kenney, M.A. (Fall 2016) Effective Scientific Information Translation to Support Environmental Decision-making. University of Maryland, College Park, MD. College of Information Studies.
6. Kenney, M.A. (Spring 2016) Environmental Decision Support Science to Support Complex Water Resources and Climate Decision-making. Tufts University, Medford, MA. Civil and Environmental Engineering.
7. Kenney, M.A., A. Wiggins, and M.D. Gerst (Spring 2016) Evaluating Coupled Climate-related Indicators and Data Provenance as Boundary Objects with Undergraduate Research Assistants. University of Maryland, College Park, MD. College of Information Studies.

Invited Workshop Presentations and Participation

1. Business Case for Resilience Roundtable. (November 2016) Invited Participant. Sponsored by White House Council on Environmental Quality. Washington, DC.
2. Genetic Rescue of Species Work Group (October 2016) Sponsored by International Union for Conservation of Nature (IUCN) Conservation Breeding Specialist Group. Invited Facilitator in support of Structured Decision-making Process. Puebla, Mexico.
3. Social and Behavioral Sciences Team (September 2016) Invited Participant and Research Featured in Report and Fact Sheet. Sponsored by White House Office of Science, Technology, and Policy. Washington, DC.
4. Water-Energy-Food Nexus Roundtable. (August 2016) Invited Participant. Sponsored by White House Office of Science, Technology, and Policy. Washington, DC.
5. Public Engagement Training for Leshner Leadership Institute Fellows. (June 2016). Sponsored by American Association for the Advancement of Sciences (AAAS) Leshner Leadership Institute. Washington, DC. http://www.aaas.org/pes/leshner-fellows
6. Sustainable Adaptive Gradients in the Coastal Environment (SAGE): Developing the Theory of SAGE. (June 2016) Co-led Writing Workshop by Haimin, E., D. DeGroot, M.A. Kenney, T. Sheahan. Sponsored by SAGE RCN. Boston, MA http://www.resilient-infrastructure.org/
7. University of Maryland Earth Day Forum on Climate – A Hot Topic. (May 2016) Invited speaker and panelist. Presentation entitled, Decision Support Science to Inform Climate Adaptation and Mitigation Decisions. Sponsored by TERP Climate. College Park, MD.
8. Coastal Adaptation Planning, Implementation and Policy. (April 2016) Invited speaker for training workshop for practitioners organized by T. Sheahan. Sponsored by SAGE RCN and offered at Local Solutions: Eastern Regional Climate Preparedness Conference. Baltimore, MD http://www.resilient-infrastructure.org/

Other Presentations

1. Stanitski, D., J. Liou-Mark, S. Trainor, J.E. Overland, M. Druckenmiller, F. Fetterer, J. Stroeve, W.N. Meier, M.D. Gerst, M.A. Kenney. (2017) Indicators of a Changing Arctic. *American Meteorological Society*, Seattle, WA.
2. Druckenmiller, M., F.M. Fetterer, M.D. Gerst, J.M. Intrieri, M.A. Kenney, W. Meier, J.E. Overland, J.C. Stroeve, and S. Trainor. 2016. Arctic indicators of change. *American Geophysical Union Fall Meeting 2016.*
3. Kenney, M.A., M.D. Gerst, J.F. Wolfinger. (2016) Using Visualization Science to Diagnose

and Improve Global Change Indicator Understandability. *Society of Risk Analysis*, San Diego, CA.

4. Kenney, M.A. with the socioeconomic benefit community (2016) A Tribute to the Life and Accomplishments of Molly K. Macauley. *American Geophysical Union*, San Francisco, CA.

Other

Honors to Kenney

- American Association for the Advancement of Sciences Leshner Leadership Institute for Public Engagement with Science Fellow, 2016-2017
- INFORMS *Decision Analysis* Special Recognition Award Runner-up (second best paper in 2016), 2017
- INFORMS Decision Analysis Society Student Paper Award Finalist, 2016

Public Summaries, Outreach, and Media

1. Jarvis, M. (September 30, 2016) AAAS Leshner Fellows help confront climate impacts. *Science*. 353(6307): 1508. DOI: 10.1126/science.353.6307.1508 http://science.sciencemag.org/content/353/6307/1508
2. Platts, E. and C. Sabel. (September 21, 2016) Collaborating with scientists for climate justice. openDemocracy https://www.opendemocracy.net/openglobalrights/ellen-platts-claire-sabel/collaborating-with-scientists-for-climate-justice
3. The White House (September 15, 2016) Fact Sheet: New Progress on Using Behavioral Science Insights to Better Serve the American People. https://sbst.gov/assets/files/2016 Behavioral-Science-EO-Anniversary-Fact-Sheet.pdf
4. Executive Office of the President, National Science and Technology Council. (September 15, 2016) Social and Behavioral Sciences Team Annual Report. pp. x and 19 (includes summary of research conducted by my team) https://sbst.gov/assets/files/2016 SBST Annual Report.pdf

CICS-MD Summaries of Our Work

7-22-16 **Kenney Accepts Position on the ESA Public Affairs Committee:**

CICS-MD Scientist Melissa Kenney has agreed to serve on the Public Affairs Committee of the Ecological Society of America (ESA). The Public Affairs Committee helps the ESA Public Affairs staff and Governing Board to better understand emerging policy issues and how ecological science can inform those issues. As a member of the committee, Kenney will

- o Attend meetings
- o Advise ESA staff on policy news and communications to ESA members,
- o Provide input and approve yearly policy priority guidelines,
- o Propose the Rapid Response Team luncheon speaker, and
- o Choose the Regional Policy Award winner and Opening Plenary speaker for the Annual Meeting.

Importance: Promotes public education and assists decision-makers considering environmental issues to incorporate NOAA data in their policy decisions. POC: M. Kenney

8-19-16 **Climate Change and Human Rights:**

CICS-MD Scientist Melissa Kenney (OAR/CPO) spoke at the Science and Human Rights Coalition Meeting hosted by the American Association for the Advancement of Sciences on July 25 to 26 in Washington, D.C. She moderated the first plenary session on Actionable Climate Science for Human Rights.

It featured a panel of scientists and policymakers who discussed their current work as well as opportunities for preventing and mitigating the human rights impacts of climate change. Melissa Kenney moderated the session. A videotape of highlights from the session can be found at http://www.aaas.org/event/science-and-human-rights-coalition-meeting-climate-change-and-human-rights .

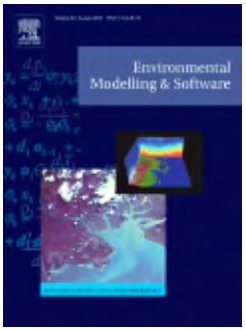
Importance: NOAA mission includes addressing the impact of climate change on communities and individuals. POC: M. Kenney

9-2-16 **Kenney Attends White House Roundtable:**

CICS-MD Scientist Melissa Kenney participated in the Water-Energy-Food Nexus Roundtable sponsored by the White House Office of Science and Technology.

Importance: Decision support science allows NOAA to disseminate its climate, weather, coastal, and marine data directly to policymakers. *POC*: M. Kenney

9-9-16 **Methods to Improve Decision-Making based on Land Use:**



CICS-MD Scientist Melissa Kenney (OAR/CPO) has published a paper on using "translational methods" for land use and land cover scenarios in the August 2016 issue of *Environmental Modelling and Software*. The goal of these methods is to take qualitative descriptions of the land's characteristics and translate them into numbers that can be used by numerical models to predict future societal and ecological impacts and conditions. Mallampalli, Varun Rao , Georgia Mavrommati , Jonathan Thompson, Matthew Duveneck , Spencer Meyer , Arika Ligmann-Zielinska , Caroline Gottschealk Druschke , Kristen Hychka , Melissa A. Kenney , Kasper Kok , and Mark E. Borsuk, Methods for Translating Narrative Scenarios into Quantitative Assessments of Land Use Change, *Environ. Modell. Software*, **82**, 7-20, http://dx.doi.org/10.1016/j.envsoft.2016.04.011 .

Importance: Land use and land cover is a central consideration in policy decisions to prevent and/or adapt to climate change. POC: M. Kenney

9-30-16 **Kenney Quoted on Outreach to Students:**

"AAAS Lessner Fellows help their communities to confront climate impact" is a news item in the September 29th issue of *Science*. CICS-MD Scientist Melissa Kenney (supporting OAR/CPO), a 2016 Lessner Fellow, is quoted as saying:

> "Fellow Melissa Kenney, assistant research professor in environmental decision support science at the University of Maryland, worked with undergraduate students this summer to synthesize the challenges and informational needs of community representatives in the Chesapeake Bay by reviewing existing reports and other documents. "We wanted to do our homework so we didn't ask a lot of questions that were already answered," Kenney said. She and her team are looking for "research gaps and science translation opportunities" to approach community leaders with processes and tools that will "facilitate evidence-based decision-making….In a densely populated watershed, climate is amplifying existing impacts on our region," added Kenney. "So we don't have a choice; we have to make decisions to consider current and future climate impacts."

See the full article at http://science.sciencemag.org/content/353/6307/1508. Kenney (OAR/CPO/ASD) Kenney is the Task Leader on the Task entitled "Research, Development and Implementation of Physical, Ecological, and Societal Climate Change, Impact, Vulnerability and Preparedness Indicators for the United States."

Importance: Training NOAA's next generation of scientists helps NOAA sustain a world-class workforce. *POC*: M. Kenney

1-27-17 **Kenney's CICS Research Highlighted in *Decision Analysis Today*:**

CICS-MD Scientist Melissa Kenney (OAR/CPO/ASD) and her NOAA-funded research on Climate Change Indicators were featured In the December 2016 issue of *Decision Analysis Today*, a publication of the INFORMS Decision Analysis Society.

Her work was the first in a new series "to highlight work at the intersection of practice and research, looking at decision analysis research that is impacting other fields or applications, fundamental research that can have an impact on practice, or great work in practice that can stimulate research ideas." Merrick, Jason, 2016: President's Letter, *Decision Analysis Today*, 35(3), 1–2,

https://www.informs.org/Community/DAS/Newsletter.

Importance: Applying NOAA's scientific research to policy decision-making is an important element of "climate intelligence." *POC*: M. Kenney

Advising and Mentoring: Graduate Students

1. Stärk, Johanna, Max-Planck Odense Center, 2016-present (dissertation committee)
2. Reyes, Julian, Washington State University, 2014-present (mentored dissertation chapter)
3. Anderson, Sarah, Washington State University, 2013-present (mentored dissertation chapter)
4. Prava, Venkat, Johns Hopkins University, 2010-2016 (co-advisor, dissertation committee, received two awards by the Decision Analysis committee for co-authored paper resulting from dissertation)
5. Salehittal, Akshata, University of Maryland, 2016-present
6. Larger, Eric, University of Maryland, 2015-2016

Advising and Mentoring: Undergraduate Students

1. Cavanagh, Meg, University of Maryland, 2016-present
2. Speciale, Amanda, University of Maryland, 2016-2017
3. Jaffee, Natalia, University of Maryland, 2016
4. Sproul, Dean, University of Maryland, 2016-present
5. Winik, Jason, University of Maryland, 2016-present
6. Veselka, Camille, University of Maryland, 2016
7. Bell, Julia, University of Maryland, 2016
8. O'Connor, Beatrice, University of Maryland, National Socio-Environmental Synthesis Center (SESYNC) Internship, 2016
9. Li, Angelica, University of Maryland, National Socio-Environmental Synthesis Center (SESYNC) Internship, 2016
10. Truitt, Elisabeth, University of Maryland, 2016
11. Sadecki, Nicole, University of Maryland, 2016

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	11
# of NOAA technical reports	1
# of presentations	17
# of graduate students supported by your CICS task	2
# of graduate students formally advised	6
# of undergraduate students mentored during the year	11

Strengthening Coastal Community Resilience in the face of Climate Change: Science to Better Understand, Measure, and Value Coastal Ecosystem

Task Leader	Ariana Sutton-Grier
Task Code	ASAS_SCCR_14 Year 3
NOAA Sponsor	Paul Sandifer
NOAA Office:	National Ocean Service Headquarters
Contribution to CICS Research Themes	Theme 1: 5%; Theme 2: 0% ; Theme 3: 95%
Main CICS Research Topic 100%	Environmental Decision Support Science
Contribution to NOAA goals (%)	Goal 3: 100% .
Strategic Research Guidance Memo:	3. Decision Science, Risk Assessment and Risk Communication

Highlight The third year of this project has resulted in the publication of 4 papers on aspects of coastal blue carbon, the incorporation of ecosystem services into federal policy and decision making, and the connections between ecosystem services and human health, and has also contributed to significant progress in natural resource policy and climate policy goals for the U.S.

Link to a research web page suttongrier.org

Background

This report summarizes the third year of the NOAA project entitled, "Strengthening Coastal Community Resilience in the face of Climate Change." This project's goal is to provide science to support coastal resilience efforts with a particular focus on ecosystem services such as coastal blue carbon and the storm protection benefits provided by natural infrastructure (i.e., healthy coastal ecosystems), as well as the connections between ecosystems and human health.

Accomplishments

This project has had a very productive third year. Four publications about ecosystem services were published (one is in press), and I gave nine talks (all of which were invited presentations including 2 webinars and 1 Capitol Hill briefing). This project has also advised 2 graduate student research projects (one doctoral student at the Universite de Bretagne Occidentale, in the Ecole Doctorale des Sciences de la Mer in France, and one Master's student at the College of Charleston) and 1 undergraduate project (1 Socio-Environmental Synthesis Center (SESYNC) summer intern at UMD). The research articles published from all three years of this project have been cited 167 times already.

I also was an invited participant in the SESYNC Workshop on how to improve teaching of socioenvironmental synthesis. As part of that workshop I created a summary of the Jigsaw method for teaching about SE synthesis. (See: https://www.sesync.org/the-jigsaw-method-and-cooperative-learning).

This project has also contributed to significant natural resource policy and climate policy goals for the U.S. federal government including climate policy as well as U.S. coastal resilience efforts. One publication from this project that has had a particularly important policy impact was the "Future of Our Coasts" publication in the journal Environmental Science and Policy. This publication won the 2016 Ecological Society of America's "Innovations in Sustainability Science" Award. The publication also garnered me an invitation to speak at a Capitol Hill briefing organized by Pew on the role of natural infrastructure in

coastal resilience. See more info: http://www.esa.org/esablog/ecology-in-the-news/news-events/2016-innovation-sustainability-science-award/

In addition, my research and expertise on coastal blue carbon at NOAA has also had important policy outcomes. I was part of the NOAA-led Coastal Wetlands Carbon Work Group (CWCWG) which was led by NOAA in order to include coastal wetlands into the U.S. national greenhouse gas inventory. This was a 2 year effort begun in 2015 and completed in 2017 with the inclusion for the first time of coastal wetlands in the US submission to the United Nations Framework Convention on Climate Change (UNFCCC) which is out for public review until March 17. (see: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks). This is a big step forward because now that coastal wetlands are included, they need to be included every year which means the U.S. will need to continue to track the management, restoration, and loss of coastal wetlands every year into the foreseeable future. Hopefully this tracking will result in opportunities for better management and more restoration and it sets an example for the rest of the world about the importance of tracking and managing coastal wetlands.

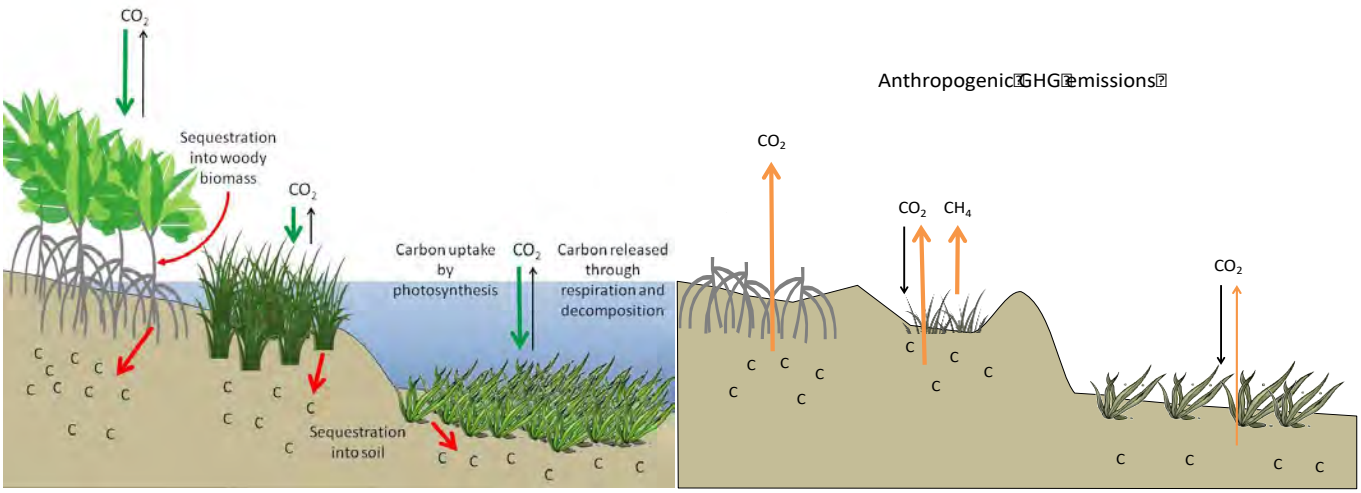


Figure 1: Graphics from the Howard and Sutton-Grier et al. (2017) showing the carbon dynamics in healthy coastal wetlands that sequester carbon long-term in their soils, and how they become additional anthropogenic sources of carbon when these ecosystems are degraded.

I co-led an article on coastal ecosystems and climate mitigation in Frontiers in Ecology and Environment which was also featured in a Restore America's Estuaries webinar (See Figure 1 and Howard and Sutton-Grier et al., 2017). This article clarifies why climate mitigation efforts should focus on protecting and restoring coastal wetland ecosystems and why other coastal and marine ecosystems (including corals, kelp, phytoplankton, and marine fauna) are not good candidates to help with natural climate mitigation opportunities.

I also was invited to participate in the National Center for Ecological Analysis and Synthesis (NCEAS) Science for Nature and People Partnership (SNAPP) work group on coastal restoration which is running 2016-2018. (See website: https://www.nceas.ucsb.edu/projects/12721). This group has met twice (May 2016 and Jan 2017) and we will meet 1-2 more times to complete the publications and projects we are

jointly working on related to assessing the state of coastal restoration in the U.S., identifying barriers to more restoration and suggesting ways to overcome those hurdles. It has been a very exciting and productive third year of this project.

Planned work

- Submit manuscript on storm protection services in the Natural Resources and Damage Assessment (NRDA) process (with colleagues from NOS OR&R); the manuscript has gone through NOAA review and we are just waiting for final approval to submit to Marine Policy (this was submitted 3/22/17 and is in review now)
- Complete final revisions on a book chapter on how blue carbon can be incorporated into national policies
- Complete two publications on the process of doing the incorporation of coastal wetlands into the U.S. national greenhouse gas inventory
- Continue participation in the Science for Nature and People Partnership (SNAPP) team out of the National Center for Ecological Analysis and Synthesis (NCEAS) (Spring 2016-Spring 2018)
- Present on blue carbon at the Society of Wetlands Scientists meeting (June, 2017) and on the impacts of disasters on ecosystem services and subsequently on human health at the annual Ecological Society of America conference (August, 2017) in a session I organized on the links between biodiversity and ecosystem services in coastal environments
- Finish up the research project effort to connect U.S. policy opportunities to the NASA-funded research project linking satellites to field measurements of coastal carbon
- Co-mentor 2 Hollings Scholars to work on coastal resilience science policy and blue carbon (Summer, 2017)

Publications

+Denotes co-first authored publication

Sandifer, P., L. Knapp, T. Collier, A. Jones, R. Juster, C. Kelble, R. Kwok, J. Miglarese, L. Palinkas, D. Porter, G. Scott, L. Smith, W. Sullivan, and **A. Sutton-Grier**. 2017. A conceptual model to assess stress-associated health effects of multiple ecosystem services degraded by disaster events in the Gulf of Mexico and elsewhere. Geohealth 1:1-20. doi:10.1002/2016GH000038.

Howard, J., A.E. **Sutton-Grier**+, D. Herr, J. Kleypas, E. Landis, E. Mcleod, E. Pidgeon, S. Simpson. 2017. Clarifying the role of coastal and marine systems in climate mitigation. Frontiers in Ecology and Environment. 15(1):42-50. DOI: 10.1002/fee.1451.

Polefka, S. and **A.E. Sutton-Grier**+. 2016. Making ecosystem services part of business as usual in federal governance. Frontiers in Ecology and Environment. 14(4):175. DOI: 10.1002/fee.1267.

Sutton-Grier, A.E. and A. Moore. 2016. Leveraging Carbon Services of Coastal Ecosystems for Habitat Protection and Restoration. Coastal Management. Coastal Management. 44(3):259-277. DOI: 10.1080/08920753.2016.1160206.

Presentations (all invited)

Sutton-Grier, A.E. 2017. "Blue Carbon: The Climate Mitigation Opportunity You've Never Heard Of." NOAA Science Workshop Series, From the Surface of the Sun to the Depths of the Ocean. March 3, 2017.

Howard, J. and A. Sutton-Grier. 2017. "Blue Carbon- What's in, what's not, and why." Webinar for Restore America's Estuaries. Feb 8, 2017.

Sutton-Grier, A.E. 2017. "Direct Links Between Biodiversity and Human Health." National Council for Science and the Environment Conference Annual Meeting, Washington,D.C.

Sutton-Grier, A.E. 2016. "The Potential for Managing Coastal Ecosystems to Provide Ecosystem Services and Enhance Resilience." A Community on Ecosystem Services (ACES) conference, Jacksonville, Florida.

Sutton-Grier, A.E., P. Sandifer, K. Wowk, and H. Bamford. 2016. "Global Change Impacts on Coastal and Ocean Ecosystem Services and Human Health and What We Can Do About It." Webinar for the Sustainable Adaptive Gradients in Coastal Environments (SAGE) NSF Research Coordination Network.

Sutton-Grier, A.E. 2016. "Policy Opportunities for Promoting Wetland Conservation and Coastal Community Resilience." Society of Wetland Scientists Annual Meeting, Corpus Christi, Texas.

Sutton-Grier.A.E. 2016. "Advancing Nature-Based Solutions to Coastal Erosion" Capitol Hill briefing, July 6, 2016. Washington, D.C.

Sutton-Grier, A.E. 2016. "Making Your Science Count: Science to Inform Policy and Decision Making." Society of Wetland Scientists Annual Meeting, Corpus Christi, Texas.

Sutton-Grier, A.E. 2016. "Future of our coasts: Potential for natural and hybrid infrastructure to calm troubled waters." Part of the session "Bridging Architecture: Extreme Weather and Troubled Waters in Coastal Cities" at the American Institute for Architecture Annual Conference, Philadelphia, Pennsylvania.

Other

- Recipient of the 2016 Ecological Society of America "Innovations in Sustainability Science" Award for the paper, "Future of Our Coasts…"
- Summer 2016 I co-mentored a Socio-Environmental Synthesis Center (SESYNC) undergraduate fellow, Beatrice O'Connor, Summer of 2016 on her project about natural infrastructure for coastal resilience.
- I am currently on the committee of a Master's student, Rachel Piker, at the College of Charleston.
- I am currently on the Ph.D. advisory committee for Dorothee Herr, at Universite de Bretagne Occidentale, in the Ecole Doctorale des Sciences de la Mer in France
- I was invited to guest lecture as part of a NOAA Science Workshop Series for educators entitled, From the Surface of the Sun to the Depths of the Ocean. I was invited to speak about my work on blue carbon and natural infrastructure. March 2017.
- I was invited for an interview on the radio show "Ocean Currents" out in California on Oct 3, 2016. I spoke about blue carbon. More info: http://cordellbank.noaa.gov/education/radiopodcast2016.html
- I was on the planning committee for the A Community on Ecosystem Services (ACES) bi-annual meeting in Florida. This involved reviewing all the abstracts for acceptance, placing them into themed-sessions, and also reviewing the student travel grant awards.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	4
# of NOAA technical reports	
# of presentations	9
# of graduate students supported by your CICS task	
# of graduate students formally advised	2
# of undergraduate students mentored during the year	1

My grant does not involve the generation of new products or techniques for NOAA. The focus of my project is on science to support policy so the papers and presentations are the two most important ways I make that contribution as well as my participation in key works groups and efforts to incorporate science into policy (such as the incorporation for the first time ever of coastal wetlands into the U.S. national greenhouse gas inventory which was completed for the first time this spring 2017).