

# NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2019

David Skaggs Research Center, Room GC-402  
325 Broadway, Boulder, Colorado 80305 USA

## Tuesday Morning, May 21, 2019 Agenda

(Only presenter's name is given; please refer to abstract for complete author listing.)

**07:30**            **Registration Opens in GC-402 - lunch orders and posters collected at registration table**

**07:45 - 08:30**   **Morning Snacks - coffee, tea, fruit, bagels and donuts served**

	Page No.
<b>Session 1</b> <b>Welcome, Keynote Address &amp; Highlights</b> — Chaired by James H. Butler	
08:30 - 08:45    Welcome and Conference Overview <i>James H. Butler (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))</i>	-
08:45 - 09:15    KEYNOTE: Placeholder - Waiting on Final Abstract Info <i>Guy Brasseur (National Center for Atmospheric Research (NCAR), Distinguished Scholar)</i>	-
09:15 - 09:30    On the Unexpected Increase in CFC-11 Emissions, Are They Still on the Rise? <i>Steve Montzka (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))</i>	1
09:30 - 09:45    Spatial/temporal Patterns in the Atmosphere: The Carbon Cycle Revealed <i>Pieter Tans (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))</i>	2
09:45 - 10:00    Geoengineering for Climate Change: Nature Has Already Demonstrated the Process and Effects <i>Russ Schnell (NOAA Global Monitoring Division)</i>	3
<b>10:00 - 10:30</b> <b>Morning Break &amp; Group Photo on the Stage</b>	
<b>Session 2</b> <b>Global Carbon Cycle</b> — Chaired by Arlyn Andrews	
10:30 - 10:45    First IAGOS-CORE and IAGOS-CARIBIC Greenhouse Gas Observations from Commercial Airliners <i>Christoph Gerbig (Max Planck Institute for Biogeochemistry (MPI-BGC), Jena, Germany)</i>	4
10:45 - 11:00    The SIO O <sub>2</sub> Program: Constraints on Long-term Carbon Cycle Changes Through Measurements of Atmospheric Oxygen <i>Eric Morgan (Scripps Institution of Oceanography, University of California at San Diego)</i>	5
11:00 - 11:15    Regional Attribution of CO <sub>2</sub> Seasonal Amplification in Northern Hemisphere using a Tagged Tracer Transport Model <i>Xin Lin (University of Michigan)</i>	6
11:15 - 11:30    The Prospects for Top-Down Atmospheric Flux Inventories for CO <sub>2</sub> and CH <sub>4</sub> <i>David Crisp (NASA Jet Propulsion Laboratory, California Institute of Technology)</i>	7
11:30 - 11:45    Patterns and Controls on Trace Gas Fluxes of CO <sub>2</sub> and/or CH <sub>4</sub> in Marine and Terrestrial Habitats from Barrow, Alaska to Pago Pago, American Samoa <i>Walter Oechel (San Diego State University, Global Change Research Group)</i>	8
11:45 - 12:00    Simulating International Drought Experiment Field Observations Using The Community Land Model <i>Timothy W. Hilton (University of California at Merced)</i>	9
<b>12:00 - 13:00</b> <b>Catered Lunch - Outreach Classroom GB-124 (pre-payment of \$12.00 at registration)</b>	

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	Page No.
<b>Session 3</b>	
<b>Global Methane — Chaired by Lori Bruhwiler</b>	
13:00 - 13:15	Recent Increases in the Burden of Atmospheric CH <sub>4</sub> : Implications for the Paris Agreement <i>Edward Dlugokencky (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))</i> 10
13:15 - 13:30	Quantification of Methane Emissions and the Role of Satellites Moving from Global to Local Scales <i>Sander Houweling (Vrije Universiteit Amsterdam, Department of Earth Sciences, Amsterdam, Netherlands)</i> 11
13:30 - 13:45	Recent Acceleration of Methane Growth Rate: Leading Contributions from Tropical Wetlands and China <i>Yi Yin (California Institute of Technology)</i> 12
13:45 - 14:00	High Affinity Methanotrophs Are an Important Overlooked Methane Sink in Arctic and Global Methane Budget <i>Youmi Oh (Purdue University)</i> 13
14:00 - 14:15	Investigation of the Global Methane Budget Based on Improved Measurement Datasets and Prior Emission Information <i>Xin Lan (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i> 14
14:15 - 14:30	Ground-truth Validation of VIIRS Nightfire for Gas Flaring Estimates <i>Mikhail Zhizhin (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i> 15
<b>14:30 - 15:00</b>	<b>Afternoon Break</b>
<b>Session 4</b>	
<b>Ozone and Water Vapor in the Stratosphere — Chaired by Irina Petropavlovskikh</b>	
15:00 - 15:15	NOAA Ozone Sonde Sites from the Tropics to Mid-latitudes: Ozone Variability, Links to Meteorological Conditions, and Validation of NASA Chemical Models <i>Ryan M. Stauffer (Universities Space Research Association (USRA) - NASA Postdoctoral Program (NPP))</i> 16
15:15 - 15:30	Drivers of Variations in the Vertical Profile of Ozone in the Greenland Sector of the Arctic <i>Shima Bahramvash Shams (Laboratory of Atmospheric Research, Department of Civil and Environmental Engineering, Washington State University)</i> 17
15:30 - 15:45	Twenty Years of Observed Tropospheric Ozone Increases Across the Northern Hemisphere <i>Audrey Gaudel (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i> 18
15:45 - 16:00	The Alpha Jet Atmospheric EXperiment (AJAX): Past, Present and Future Airborne Measurements <i>Emma L. Yates (NASA Ames Research Center, Atmospheric Science Branch)</i> 19
16:00 - 16:15	The Importance of Temporally Comprehensive Vertical Ozone Measurements for the Evaluation of Ozone NAAQS Exceedances in California <i>Seyedmorteza Amini (California Air Resources Board)</i> 20
16:15 - 16:30	Observational-based Assessment of Contributions to Southwest U.S. Maximum Ozone Concentrations <i>David D. Parrish (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i> 21
<b>Session 5</b>	
<b>Special Science on a Sphere Presentation — Chaired by</b>	
16:30 - 16:45	HOLOSCENES Presented on Science on a Sphere <i>Shilpi Gupta (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i> 22
<b>16:30 - 19:00</b>	<b>Poster Session (DSRC Cafeteria) with appetizers and refreshments</b>

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**07:30**            **Registration Opens in GC-402 - lunch orders collected at registration table**

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	Page No.
<b>Session 6</b>	<b>Halocarbons and Other Ozone Depleting Substances — Chaired by Bradley Hall</b>
08:30 - 08:45	Western European Emissions of CFC-11 and CFC-12 Inferred from Atmospheric Observations and Inverse Modelling 23 <i>Michela Maione (University of Urbino, Department of Basic Sciences and Foundations, Urbino, Italy)</i>
08:45 - 09:00	What Science Have We Learned from Our Combined Airborne and Ground-based Measurements of Halocarbons and other Trace Atmospheric Species? 24 <i>James W. Elkins (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))</i>
09:00 - 09:15	The Stratospheric Quasi-Biennial Oscillation Influence on Trace Gases at the Earth's Surface 25 <i>Eric A. Ray (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i>
09:15 - 09:30	Iodine Detection in the Lower Stratosphere 26 <i>Rainer Volkamer (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i>
09:30 - 09:45	Atmospheric History of Carbonyl Sulfide During the 20 <sup>th</sup> century from Antarctic and Greenland Firn Air Measurements 27 <i>Murat Aydin (University of California at Irvine, Department of Earth System Science)</i>
09:45 - 10:00	Constraints on Ocean Heat Uptake from the Atmospheric Argon to Nitrogen Ratio 28 <i>Benjamiin Birner (Scripps Institution of Oceanography, University of California at San Diego)</i>
<b>10:00 - 10:30</b>	<b>Morning Break</b>
<b>Session 7</b>	<b>Changes in Surface Radiation, Clouds, and Aerosol Distributions — Chaired by Patrick Sheridan</b>
10:30 - 10:45	Optical Properties of Black Carbon and Brown Carbon and Their Contribution to Aerosol Light Absorption 29 <i>Sang-Woo Kim (Seoul National University, South Korea)</i>
10:45 - 11:00	The Role of Ground-based Aerosol Networks in Evaluating Satellite-retrieved Aerosol Radiative Properties over Mountainous Regions 30 <i>James Patrick Sherman (Appalachian State University, Department of Physics and Astronomy)</i>
11:00 - 11:15	Evaluation of Novel NASA Aerosol Fire Products Over Extreme Fire Events in the Semi-arid Western U.S. 31 <i>S. Marcela Loria-Salazar (University of Oklahoma)</i>
11:15 - 11:30	Application of Solar Aureole for Atmospheric Monitoring 32 <i>Pi-Huan Wang (Taksha Institute)</i>
11:30 - 11:45	Developing Solar Forecasting Model Diagnostics of Cloud Impacts on Solar Variability 33 <i>Laura Riihimaki (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i>
11:45 - 12:00	The Aleutian Low – Beaufort Sea Anticyclone: A Climate Index for Predicting the Timing of Springtime Melt in the Pacific Arctic Cryosphere 34 <i>Christopher J. Cox (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)</i>
<b>12:00 - 13:00</b>	<b>Catered Lunch - Outreach Classroom GB-124 (pre-payment of \$12.00 at registration)</b>

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	Page No.
<b>Session 8</b>	<b><i>Regional Carbon Cycle Feedbacks and Observations</i> — Chaired by Kathryn McKain</b>
13:00 - 13:15	Airborne <i>in situ</i> Measurement of CO <sub>2</sub> and CH <sub>4</sub> in South Korea <i>Shanlan Li (National Institute of Meteorological Sciences, Seogwipo-si, South Korea)</i> 35
13:15 - 13:30	Trace Gas Observations from Small Research Aircraft over the Mid Atlantic States and Hebei, China <i>Russell R. Dickerson (University of Maryland, Department of Oceanic and Atmospheric Science)</i> 36
13:30 - 13:45	Characteristics and Mechanisms of Atmospheric CO <sub>2</sub> Variations during Summer Frontal Passages <i>Sha Feng (The Pennsylvania State University, Department of Meteorology and Atmospheric Science)</i> 37
13:45 - 14:00	The Potential for Public-transit Based Atmospheric Monitoring to Advance Air Quality and Atmospheric Chemistry Research and to Engage Urban Stakeholders <i>Logan E. Mitchell (University of Utah)</i> 38
14:00 - 14:15	Fire Emissions in California: Analysis of Airborne Measurements of Trace Gases from Thirteen Fires <i>Caroline Parworth (NASA Ames Research Center, Atmospheric Science Branch)</i> 39
14:15 - 14:30	Commissioning of High Precision <i>in situ</i> Measurements of N <sub>2</sub> O and CO at Cape Grim <i>Elise-Andree Guerette (Commonwealth Scientific and Industrial Research Organisation (CSIRO), Oceans and Atmosphere, Aspendale, Australia)</i> 40
<b>14:30 - 15:00</b>	<b><i>Afternoon Break</i></b>
<b>Session 9</b>	<b><i>Regional Methane Monitoring</i> — Chaired by Gabrielle Petron</b>
15:00 - 15:15	Large Fugitive Methane Emissions from Urban Centers Along the U.S. East Coast <i>Genevieve Plant (University of Michigan)</i> 41
15:15 - 15:30	A Multi-platform Inversion Estimation of Statewide and Regional Methane Emissions in California during 2014-2016 <i>Yu Yan Cui (California Air Resources Board)</i> 42
15:30 - 15:45	Optimization of Methane Emissions in the United States Gulf Region Using Aircraft-based Measurements Across Frontal Boundaries <i>Zachary Barkley (The Pennsylvania State University, Department of Meteorology and Atmospheric Science)</i> 43
15:45 - 16:00	Importance of Super-emitter Natural Gas Well Pads in the Marcellus Shale <i>Dana Caulton (University of Wyoming)</i> 44
16:00 - 16:15	Characterization of Methane Emissions in Los Angeles with Airborne Hyperspectral Imaging <i>Katherine M. Saad (The Aerospace Corporation)</i> 45
16:15 - 16:30	Could O&G Wastewater Be a Significant Source of Air Toxics in the Northern Colorado Front Range? <i>Rachel Edie (University of Wyoming)</i> 46
<b>16:30</b>	<b><i>Closing Remarks - Dr. James Butler, Director (NOAA/ESRL Global Monitoring Division)</i></b>

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### 2019 GMAC Poster Session - Carbon Cycle Greenhouse Gases

- P-1 One-step Preparation of Gravimetric CO<sub>2</sub>-in-air Standards  
*Brad Hall (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))*
- P-2 Development of a New Flask-air Analysis System for the Global Greenhouse Gas Reference Network  
*Andrew Croftwell (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-3 Laboratory Identification and Testing of Sources of Bias in Carbon Dioxide Measurements of Atmospheric Air Collected and Stored in Glass Flasks  
*Don Neff (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-4 Tower *in situ* and Flask CO<sub>2</sub> Comparisons  
*Jonathan Kofler (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-5 High Humidity-induced Bias in Aircraft Network CO<sub>2</sub> Data Due to Water Condensation in Flasks  
*Kathryn McKain (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-6 Stable Carbon Isotope Analysis of Airborne Particulate Matter Using a Carbon Aerosol Analyzer and a Cavity Ringdown Spectrometer  
*Jonathan Bent (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-7 Standoff Measurements of CO<sub>2</sub> and H<sub>2</sub>O in Boulder using DIAL And IPDA Techniques  
*David Plusquellic (National Institute of Standards and Technology (NIST), Physical Measurement Laboratory, Quantum Electromagnetics Division)*
- P-8 Combining *in situ* and Satellite Observations of CO<sub>2</sub> in a Synthesis Inversion Framework for the U.S. Corn Belt  
*Bharat Rastogi (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-9 Partitioning Sources of CO<sub>2</sub> Atmospheric Signal in an Urban Site Using Carbon Monoxide as a Tracer  
*Wilson K. Gichuhi (Department of Chemistry, Tennessee Tech University)*
- P-10 Utilization of CH<sub>4</sub>:CO<sub>2</sub> and CO:CO<sub>2</sub> Correlations in Deciphering Temporal Changes in Urban CH<sub>4</sub> and CO Emissions  
*Lahiru P. Gamage (School of Environmental Studies, Tennessee Technological University)*
- P-11 Utilizing Public Transit for Urban Atmospheric Monitoring in Denver, CO  
*Isaac Vimont (National Research Council Post-Doc)*
- P-12 Creating an Emissions Map for Benzene Based on Fossil Fuel CO<sub>2</sub> emissions: "HESTIA Benzene"  
*Isaac Vimont (National Research Council Post-Doc)*
- P-13 Characterization and Quantification of Benzene Emissions from a New Multi-well Pad in a Colorado Front Range Residential Community  
*Ingrid Mielke-Maday (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-14 Measuring BTEX with a Commercial GC-PID System in an Oil and Gas Field  
*Monica Madronich (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-15 Open-path Mid-infrared Dual Comb Spectroscopy for Measurement of Ambient Ethane and Propane  
*Kevin Cossel (National Institute of Standards and Technology (NIST))*
- P-16 Continuous Methane Leak Detection in Oil and Gas: Recent Progress Toward a Regional Approach with Dual Frequency Comb Spectroscopy and Inversions  
*Caroline Alden (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-17 Measurement Capabilities of the CU SOF Instrument: Separation of Methane Emissions from Agricultural and Natural Gas Sources & Developing Techniques to Quantify Wildfire Emissions  
*Rainer Volkamer (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-18 Modeling Ground- and Aircraft-based Methane Monitoring Systems for Natural Gas Storage Facilities using LPDM-LES  
*Alex Rybchuk (University of Colorado, Department of Mechanical Engineering)*

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### 2019 GMAC Poster Session - Carbon Cycle Greenhouse Gases (continued)

- P-19 How Useful Are Carbon Stable Isotopes of Methane? Improvements in Analysis and Quality Controls at the INSTAAR Stable Isotope Lab  
*Sylvia Englund Michel (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado)*
- P-20 Sensitivity of the Isotopic Composition of Atmospheric Methane to Oxidant Fields in the GEOS Model  
*Sarah Strobe (Universities Space Research Association (USRA))*
- P-21 Quantification of Transport Error Using a Coupled Meteorological and Constituent Transport Model Within an Ensemble Kalman Filter (EnKF)  
*Vikram Khade (University of Toronto, Department of Physics, Toronto, Canada)*

### 2019 GMAC Poster Session - Halocarbons and Other Ozone Depleting Substances

- P-22 Two Years of MAX-DOAS Data from Remote Tropical Marine Mountaintops  
*Theodore K. Koening (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-23 Improving the Sampling and Analysis of Atmospheric Carbonyl Sulfide (OCS) in the GMD Networks  
*Benjamin R. Miller (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-24 SO<sub>2</sub> Profiles during the Kilauea Eruption  
*Paul J. Walter (St. Edward's University)*

### 2019 GMAC Poster Session - Ozone and Water Vapor

- P-25 Optimizing Umkehr Ozone Profile Retrievals during the Mt. Pinatubo Volcanic Eruption  
*Koji Miyagawa (Guest Scientist at NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))*
- P-26 South American Dobson Intercomparison Campaign for RA-III  
*Glen McConville (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-27 New Volumetric Flow Rate Tests of Ozonesonde Pumps at Reduced Pressures  
*Bryan Johnson (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))*
- P-28 Ozonesonde Observations at South Pole Station During the 2018 Ozone Hole  
*Patrick Cullis (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-29 The Role of Convection in Tropical Ozone Variability Inferred from Profiles at NOAA's SHADOZ Stations (1998-2017)  
*Anne M. Thompson (NASA Goddard Space Flight Center (GSFC), Atmospheric Chemistry and Dynamics Laboratory)*
- P-30 OCTAV-UTLS (Observed Composition Trends and Variability in the UTLS) SPARC Activity - Jet-relevant Data Analyses of NOAA Ozonesonde Records  
*Irina Petropavlovskikh (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-31 Measured and Modeled Ozone Distributions over the Atlantic and Pacific Oceans from the ATom Mission  
*Eric Hintsa (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-32 Comparison of Vertical Distribution of Ozone Profiles between Ozonesondes and the GMI Merra II Model  
*Emrys Hall (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-33 Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGE III/ISS) Science Data Products: Preliminary Validation Results  
*Susan Kizer (Science Systems and Applications, Inc. (SSAI))*
- P-34 Seasonal Trends in Observed Surface Ozone Conditions in the Arctic  
*Audra McClure-Begley (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*

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### 2019 GMAC Poster Session - Surface Radiation, Clouds, and Aerosol Distributions

- P-35 Overview and Selected Results from the NOAA Federated Aerosol Network  
*Patrick Sheridan (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))*
- P-36 An Overview of the Effect of Water Uptake on Aerosol Particle Light Scattering: Observations, Evaluation of Proxies, and Comparison with Global Models  
*Elisabeth Andrews (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-37 Seasonal Dependence of Column-averaged and Near-surface Aerosol Optical Properties Measured at Appalachian State University (APP)  
*Taylor Foote (Appalachian State University, Department of Physics and Astronomy)*
- P-38 Variability of Aerosol Optical Properties at Mauna Loa and its Characteristics According to Source Regions  
*Jong-Uk Park (Seoul National University, South Korea)*
- P-39 Case Study of Air Quality during Winter Season over Northeastern Pakistan during 2007 to 2015  
*Muhammad Zeeshan Shahid (College of Earth & Environmental Sciences University of the Punjab, Lahore, Pakistan)*
- P-40 34-year Trends in Aerosol Chemistry in Relation to Aerosol Acidity at Alert, NU, Canada  
*Sangeeta Sharma (Environment and Climate Change Canada, Toronto, Canada)*
- P-41 Variation of Carbonaceous Aerosols in Foggy Days in and Around Special Episodic Events  
*Pallavi Saxena (University of Delhi, Hindu College, Department of Environmental Sciences, Delhi, India)*
- P-42 Two Centuries of Volcanic Aerosols Derived from Lunar Eclipse Records, 1805-2019  
*Richard A. Keen (University of Colorado, Emeritus, Department of Atmospheric and Oceanic Sciences)*
- P-43 Holographic Cloud Particle Imager (HCPI) for Unmanned Aircraft Systems (UASs)  
*Daniel R. McAdams (Radiation Monitoring Devices, Inc.)*
- P-44 The De-Icing Comparison Experiment (D-ICE): A Study of Broadband Radiometric Measurements Under Icing Conditions in the Arctic  
*Christopher J. Cox (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*
- P-45 The Need for a Surface Energy Budget Network and Increased Surface Radiation Measurements to Improve Weather and Climate Forecasting  
*John A. Augustine (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))*

### 2019 GMAC Poster Session - Other

- P-46 Curating a Multi-agency Set of Federal Climate Indicators  
*Laura Stevens (North Carolina State University (NCSU))*
- P-47 The New Barrow Atmospheric Baseline Observatory  
*Brian Vasel (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))*
- P-48 Opportunity to Plan and Develop a Comprehensive U.S. Arctic Research Infrastructure Network Hub at Oliktok Point, Alaska  
*Jasper Hardesty (Sandia National Laboratories)*
- P-49 Soil Respiration Response To *Adenostoma Sparsifolium* Microsites Among Seasons in Semiarid Shrubland  
*Jessica Montes (San Diego State University, Global Change Research Group)*
- P-50 The Acquisition of Fog in Montane California Chaparral: Ecosystem Inputs and Use by Plants  
*Brahma Gillespie (San Diego State University, Global Change Research Group)*
- P-51 A Bibliometric Analysis of GMD Publications, 2010-2018  
*Sue Visser (FedWriters)*

Notes:

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