ACT-America Community Workshop Abstracts

April 27-30, 2020

Day 1: Monday, April 27, 2020

11:00 EDT	**Welcome, Logistics & Opening Remarks**	**Ken Davis, Penn State**
11:10 EDT	**A word from our sponsors**	**Ken Jucks, NASA HQ**
	ACT-America Data	
11:20 EDT	**Plan, gaps, opportunities**	**Yaxing Wei, S Pal, T Gerken**
11:25 EDT	**Data Flags**	**S Pal, T Gerken, L. Campbell**
	Within the Atmospheric Carbon and Transport–America (ACT-America, a NASA Earth Venture Suborbital project), for the first time, we collected measurements of atmospheric GHGs and state variables within the atmospheric boundary layer (ABL) and free troposphere (FT) across many different fronts to capture repeated realizations of fluxes and weather conditions covering all four seasons (summer 2016, winter 2017, fall 2017, spring 2018, and summer 2019) in three regions of the United States (Mid-Atlantic, Mid-West, and South). For the sake of diverse scientific application and straightforward data analyses strategies, we made a unique effort to tag airborne in-situ observations of the ACT-America data sets and classify the measurements among various types. Data sets were categorized based on (1) mission type (e.g. fair weather, frontal environment), (2) the location of sample altitude with respect to the ABL top heights (BL and FT samples), (3) maneuver types (level leg, take off, landing, en route ascent or descent, etc.), and (4) air mass type with respect to the location of frontal boundary (e.g. warm versus cold air mass). After detailed classification, we created harmonized flags (1 or 2) for all four categories and documented in the 5-s merged netCDF files archived on the ORNL data base. For instance, all data collected during the frontal research flights were binned into front-specific categories including the warm versus cold sectors across the frontal boundary on the day of frontal passage. Profiles were also classified into warm and cold sector profiles. Fair weather RFs were identified as prefrontal and postfrontal and similar profiles, and level legs classifications were also performed. For further details, readers are referred to Pal et al. 2020 (JGR-Atmospheres).	
11:35 EDT	**Lidar ABL depth data**	**S Pal, A Nehrir**
11:45 EDT	**Description of the final MFLL XCO2 product**	**J Campbell, B Lin, LaRC**

	We present an evaluation of airborne Intensity-Modulated Continuous-Wave (IM-CW) lidar measurements of atmospheric column CO2 mole fractions during the ACT-America project. This lidar system transmits online and offline wavelengths simultaneously on the 1.57111-μm CO2 absorption line, with each modulated wavelength using orthogonal swept frequency waveforms. After the spectral characteristics of this system were calibrated through short-path measurements, we used the HITRAN spectroscopic database to derive the average-column CO2 mixing ratio (XCO2) from the lidar measured optical depths. Based on in situ measurements of meteorological parameters and CO2 concentrations for calibration data, we demonstrate that our lidar CO2 measurements were consistent from season to season and had an absolute calibration error (standard deviation) of 0.80 ppm when compared to XCO2 values derived from in situ measurements. By using a 10-second or longer moving average, a long-term stability of 1 ppm or better was obtained. The estimated CO2 measurement precision for 0.1-s, 1-s, 10-s, and 60-s averages were determined to be 3.4 ppm (0.84%), 1.2 ppm (0.30%), 0.43 ppm (0.10%), and 0.26 ppm (0.063%), respectively. These correspond to measurement signal-to-noise ratios of 120, 330, 950, and 1600, respectively. The drift in XCO2 over one-hour of flight time was found to be below our detection limit of about 0.1 ppm. These analyses demonstrate that the measurement stability, precision and accuracy are all well below the thresholds needed to study synoptic-scale variations in atmospheric XCO2.	
12:00 EDT	**HALO XCH4 data product**	**Barton-Grimley, LaRC**
	HALO participated as a part of the summer 2019 ACT-America campaign providing measurements of aerosol and clouds optical properties and distributions of mixed layer heights. This campaign also served as an opportunity to demonstrate HALO's new capability in measuring high accuracy methane columns. This presentation will address three main topics: 1) briefly summarize the archived HALO products from the 2019 campaign, 2) describe the HALO XCH4 product development, 3) provide comparisons between in-situ CH4 and HALO XCH, initial comparisons to WRF reanalysis, and discuss future collaborative efforts in the utilization of the HALO aerosol and methane products	
12:15 EDT	Break / Discussion	
12:30 EDT	**ACT data archive overview. Feedback and beta-testing session**	**Yaxing Wei, Rupesh Shrestha, ORNL**
	Four topics will be covered in this presentation and discussion session: 1. Overview of ACT-America datasets published and being published at the ORNL DAAC, their status, and future update plan. 2. Overview of the most recent ACT-America merge data product. Link to access the merged data files will be shared at the beginning of the session. We encourage people to download and try the merged data files and provide comments/feedbacks on how we can further improve them. 3. A live demo of the latest ACT-America Campaign Catalog (https://actamerica.ornl.gov/campaigns.html)	

	4. A live demo of the latest ACT-America Data Visualizer (https://actamerica.ornl.gov/visualize/)	
13:30 EDT	Break	
13:45 EDT	**ACT numerical modeling products. (WRF-Chem, TM5/GEOS, CASA, CarbonTracker, OCO2MIP, influence functions)**	**S Feng, A Schuh, C Williams, T Lauvaux, A Jacobson, Y Cui**
	ACT-America numerical modeling products will be listed in four groups, including regional Eulerian and Lagrangian transport simulations, flux products, and global model output, with brief descriptions. Potential application and collaboration will be discussed.	
14:30 EDT	Break / Discussion	
	XCO2	
14:45 EDT	**Total column measurements of GHGs from ground-based low-resolution remote sensing instruments and their comparison to TCCON**	**Mahesh Kumar Sha**
	Mahesh Kumar Sha*1, Martine De Mazière1, Justus Notholt2, Thomas Blumenstock3, Huilin Chen4, Angelika Dehn5, David W T Griffith6, Frank Hase3, Pauli Heikkinen7, Christian Hermans1, Nicholas Jones6, Rigel Kivi7, Bavo Langerock1, Neil Macleod8, Christof Petri2, Qiansi Tu3, Damien Weidmann8 1. Royal Belgian Institute for Space Aeronomy, Belgium 2. University of Bremen, Germany 3. Karlsruhe Institute of Technology, IMK-ASF, Germany 4. University of Groningen, Netherlands 5. European Space Agency (ESA)/ESRIN 6. University of Wollongong, Australia 7. Finnish Meteorological Institute, Finland 8. Rutherford Appleton Laboratory, United Kingdom The Total Carbon Column Observing Network (TCCON) has been the baseline ground-based network for measuring accurate and precise column-averaged dry air mole fractions of CO2, CH4 and CO amongst other gases. However, the number of stations (currently ~25) is limited and has a very uneven geographical coverage. To improve the satellite validation and better contribute to the carbon cycle science studies, a denser distribution of ground-based solar absorption measurement is needed to cover geographical gaps for various atmospheric conditions (humid, dry, polluted, presence of aerosol, varying surface albedo) and to create a large latitudinal distribution. For this reason, several groups are investigating portable low-cost instruments, which can complement the existing networks and thus enhance the validation of satellite measurements.The “Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations (FRM4GHG; http://frm4ghg.aeronomie.be/)” campaign	

	has been funded by the European Space Agency (ESA) to characterize the performance of several low-cost portable spectrometers for precise solar absorption measurements of CO_2, CH_4 and CO. These measurements were performed next to the TCCON instrument at Sodankylä for three years since 2017 and one of the instruments performed measurements at the TCCON sites in Australia during the last year. In addition, regular AirCore launches were performed from the Sodankylä site to provide in-situ reference profiles of these gases; this is useful for the verification of the instrument calibration. The intercomparison results show that the tested low-resolution instruments provide high quality data comparable to that of TCCON. The data collected during the campaign were used for satellite validation. The results of the campaign will be presented with an overview of the accuracy and precision achieved by each instrument. We show the benefits of the portable FTIR remote-sensing instruments by means of a few example cases.	
15:00 EDT	**Overview of the remaining ACT XCO2-related tasks, impacts and synthesis**	**Chris O'Dell, CSU**
	Overview of XCO2 research and results from ACT-America	
15:15 EDT	**XCO2 comparisons of MFLL, OCO-2, WRF-Chem; connections to atmospheric inversions**	**Emily Bell, CSU**
	The third mission goal of ACT-America is the evaluation of the regional variability of tropospheric XCO2 from OCO-2. To this end, we have built a system for intercomparison between OCO-2, lidar, in situ, and model data, and have presented results from a total of 8 OCO-2 underflights across four seasons of the ACT mission. Here we summarize our findings and discuss the lessons learned from this validation effort.	
15:30 EDT	**XCO2 curtains**	**Brad Weir, USRA/Goddard**
	We present a new collection of high-resolution, two-dimensional transects of CO_2 along ACT-America flight tracks, called curtains, which are built by ingesting in situ measurements into NASA's Goddard Earth Observing System (GEOS). These curtains have already been used in the evaluation of column-average CO_2 retrievals from the Orbiting Carbon Observatory 2 (OCO-2) satellite during coordinated overpasses and the Multi-functional Fiber Laser Lidar (MFLL) aboard the aircraft. An additional set of curtains are now being produced for frontal-crossing flights for the evaluation of an ensemble of transport models against the analyzed fields. This work helps us better understand the relative contributions of transport and surface flux in observed CO_2 frontal gradients with the eventual goal of understanding what transport model characteristics are necessary to accurately reproduce such gradients.	
15:45 EDT	Break / discussion	

16:00 EDT	**Exploring what ACT CO_2 data can tell us about the vertical information in OCO-2 retrievals**	**Susan Kulawik, JPL**
	Vertically resolved OCO-2 versus assimilated ACT-America, Susan Kulawik, Brad Weir, Emily Bell, Chris O'Dell. Previous work has compared OCO-2 XCO_2 to vertical profiles from Kalman filter assimilation of C-130 and B-200 into GMAO. We look at vertically resolved OCO-2 to further understand OCO-2 / ACT-America differences.	
16:15 EDT	**Frontal analyses with MFLL observations**	**Walley, Pal, Texas Tech**
	Understanding greenhouse gas (e.g. Carbon Dioxide) transport processes in the Earth's atmosphere is crucial during this current regime of dramatically changing climate. From previous research, it is known that mid-latitude cyclones aid in the transport of CO_2 and create spatial variability across frontal boundaries. This work is aimed at identifying the partial columnar content of CO_2 (XCO_2) in the lower troposphere across the frontal boundary during four seasons. The data used was collected during the Atmospheric Carbon and Transport-America (ACT-America) field campaigns. Two aircrafts were deployed during the 6-week period: B200 containing only in-situ instruments and C130 aircraft containing in-situ instruments, the Multi Functioning Fiber Laser Lidar (MFLL), and the Cloud Physics Lidar. The MFLL provided a columnar average of CO_2 which we used to identify XCO_2 structure modulated by the frontal passage in the lower troposphere and atmospheric boundary layer. The findings were compared with the in-situ measurements of CO_2 taken at different vertical levels. The in-situ data will also be used to examine CO_2 variability in the lower levels of the flight track, such as the boundary layer, where the MFLL is unable to collect measurements. Preliminary results suggest the presence of relatively higher XCO_2 in the warm sector than in the cold sector in summer and contrasting features in winter. During fall and spring, we obtained mixed signal in the XCO_2 field. In future, the vertical CO_2 structure observed by the in-situ and MFLL will be compared with WRF-Chem simulations. Finally, this research will help better understand the greenhouse gas transport in the lower troposphere during the passage of mid-latitude cyclones throughout all four seasons.	
16:30 EDT	**ACES XCO_2**	**A Corbett, LaRC**
	During the Atmospheric Carbon and Transport–America (ACT–America) suborbital mission (ACT-America) Mission Spring 2018 campaign, ASCENDS CarbonHawk Experiment Simulator (ACES), an intensity modulated continuous wave (IMCW) lidar system funded by NASA's Science Mission Directorate, measured differential optical depths leading to partial-column CO_2 lidar retrievals while flying aboard the C-130 aircraft across North America striving to advance technology critical to measuring column carbon dioxide mixing ratios (XCO_2) remotely. ACES was developed by NASA Langley Research Center in the aims to have an active remote sensing system able to accurately measure XCO_2 from space independent of the presence of sunlight, land surface type, and even through thin clouds. Differential absorption optical depth measurements made during the fourth campaign of ACT-America in Spring of 2018 were processed, analyzed and compared to on board in situ derived differential optical depth CO_2 measurements.	

16:45 EDT	**Discussion**	**C O'Dell, K Davis**

Day 2: Tuesday, April 28, 2020

Atmospheric Transport		
11:00 EDT	**Plan, gaps, opportunities**	**A Schuh**
11:15 EDT	**The CO2 Human Emissions (CHE) project: GHG nature runs**	**A Agusti-Panadera**
	The CHE global nature runs The CO2 Human Emissions (CHE) project has produced a set of high resolution 9km global nature runs for CO2, CH4 and CO to support Observation System Simulation Experiments (OSSEs) and other research applications. These global nature runs are part of a library of simulations that aim at providing realistic atmospheric CO2, CH4 and CO fields that can provide a reference to extract synthetic observations for OSSEs. The CHE global nature runs were performed in two tiers. The first tier used the same configuration as the Copernicus Atmosphere Monitoring Service (CAMS) high resolution CO2, CH4 and CO forecast. The tier 2 simulation builds on the tier 1 configuration with improved prior anthropogenic emissions, ocean fluxes, terrestrial biogenic fluxes, initial atmospheric concentrations, transport model and meteorological analyses. The impact of the improvements in all these prior and model components is assessed and their sensitivity compared to the uncertainty estimates provided by a perturbation-based ensemble.	
11:30 EDT	**TM5 and GEOS-Chem transport mechanisms: Meridional XCO2 Flux Decomp**	**Andrew Schuh, CSU**
	Mid-latitude storm systems are a critical mechanism for redistributing CO2 across the globe. Therefore, uncertainty in this transport component is of critical importance to CO2 flux inversion modelers who are responsible for using transport models to invert CO2 concentration data to recover upwind surface CO2 fluxes. In this work, we perform decompositions of atmospheric transport on several transport models, into mean and eddy terms, in order to identify transient storm system mixing statistics. We then discuss possible paths forward, potential rewards and challenges involved with using ACT-America data in this context.	
11:45 EDT	**OCO-2 v9 MIP model-data comparison**	**Andrew Jacobson, NOAA/CIRES**
	Andy Jacobson and OCO-2 modelers The OCO-2 program includes a model intercomparison project in which global CO2 inverse modelers have performed a set of uniform experiments. CO2 measurements from the ACT-America campaigns are simulated in each of these experiments, but since	

	they are not used to optimize surface fluxes they are particularly useful for cross-validation exercises. In this talk, we consider biases and variability in model residuals from the OCO-2 MIP experiments to evaluate modeling systems and different types of assimilation constraints.	
12:00 EDT	Break / Discussion	
12**:30 EDT**	**Convective transport of GHGs in WRF-Chem**	**T. Lauvaux, LSCE**
	Despite the increase in the horizontal resolution of mesoscale modeling systems, deep and shallow convection schemes remain critical to represent the full magnitude of the vertical transport of GHG from the surface to the upper Troposphere. To address that problem, a coupled convection-chemistry option has been implemented in WRF-Chem using the 3D vertical mass fluxes to move tracers across the atmospheric column. We present here the first evaluation of the coupled scheme (here Kain-Fritsch) compared to the current option (offline coupling using the Grell convection scheme). The ACT-America data (2016 and 2017 campaigns) are used to illustrate the importance of sub-grid scale convective parameterization in simulated CO2 mole fractions over North America, resulting in a larger air mass flow of CO2 at high altitudes across the continent.	
12:45 EDT	**MPAS CO2 simulations for ACT**	**Tao Zheng, CMU**
	Tao Zheng1, Sha Feng2, and Kenneth J. Davis2 1Department of Geography, Central Michigan University, Mount Pleasant, MI. 48858 2Department of Meteorology and Atmospheric Science, The Pennsylvania State University, University Park, PA 16802 Chemistry transport model (CTM) plays a critical role in atmospheric inverse modeling for CO2. Regional scale CO2 inversions typically use limited area models which come with the lateral boundary problem. In this paper, we implement CO2 transport in the Atmosphere component of Model Prediction Across Scales(MPAS-A) for high resolution CO2 transport modeling on a variable resolution domain, and access the model's accuracy using high-resolution CO2 data collected through the ACT-America field campaigns. Treating CO2 as an inert tracer, we add in MPAS-A CO2 transport processes including advection, diffusion, turbulent mixing in the atmospheric boundary layer, and parameterized convective transport. We conduct simulations using the CO2 transport enabled MPAS-A model on a 60-15km variable grid covering the first four field campaign seasons of ACT-America project, with 15km grid over North America and 60km for the rest of the globe. MPAS-A simulated CO2 is first compared with the hourly CO2 data from more than 60 tower sites around the globe, then it is compared with the extensive high-resolution (500m) airborne CO2 measurement, and last it is compared with CO2 simulated from a regional model WRF-Chem. Simulation results analysis shows that the newly developed CO2 transport in MPAS-A achieves comparable accuracy as the WRF-Chem for simulating the observed CO2 structures observed in the ACT-America campaigns, including CO2 vertical profile, horizontal variation, warm-cold sector contrast, and frontal high CO2 bands in all four campaign seasons. Comparison against tower measurements indicates that the new model system reaches a comparable accuracy as other high resolution CO2 models reported in the literature.	

13:00 EDT	**How tracer transport in global models depends on their resolution**	**Sourish Basu, ESSIC/Goddard**
13:15 EDT	**Frontal Contrasts in Four Seasons over the Eastern US: A path toward the mechanistic understanding of GHG transport in the lower troposphere**	**Sandip Pal, Texas Tech**
	Diverse meteorological processes associated with mid-latitude cyclones (e.g. cold and warm fronts, dry line, meso-scale convective systems) play distinct roles in distributing atmospheric greenhouse gases (GHG, e.g., CO_2, CH_4) and other tracers (e.g. aerosols, water vapor, O_3). However, our understanding of the horizontal structures and vertical variability in GHGs across frontal boundaries remains limited, and their variation is largely unknown. Within the Atmospheric Carbon and Transport–America (ACT-America, a NASA Earth Venture Suborbital project), for the first time, we collected measurements of atmospheric GHGs and state variables within the atmospheric boundary layer (ABL) and free troposphere (FT) across many different fronts to capture repeated realizations of fluxes and weather conditions covering all four seasons (summer 2016, winter 2017, fall 2017, and spring 2018) in three regions of the United States (Mid-Atlantic, Mid-West, and South). In this work, we report on some key findings on the magnitude of GHG frontal structure in the ABL and FT using measurements obtained during a total of 39 research flights conducted across frontal environments in four seasons, and discuss the mechanisms governing the frontal contrasts (i.e., warm-sector mean GHG concentrations minus cold sector mean GHG concentrations) over the three regions. Results indicate that for all seasons except for summer, we mainly observed higher CO_2 in the cold sector than in the warm sector. Our results confirm that the ACT-America field campaigns successfully sampled a wide range of synoptic systems across the four seasons and that these observational findings are also broad and general. Finally, using WRF-Chem simulations of CO_2 field, we will provide a mechanistic understanding of CO_2 frontal contrasts over the three regions of the eastern US. These results will help us to improve the understanding of regional carbon fluxes and atmospheric transport processes during passage of mid-latitude cyclones across seasons.	
13:45 EDT	**Scalar budget calculations and high resolution transport simulations**	**Arkayan Samaddar, Penn State**
14:15 EDT	Break / Discussion	
14:30 EDT	**Model-data comparisons with ACT CO_2 and ABL depths**	**Lily Campbell, Penn State**
	This model-data comparison uses ACT Observational data and WRF model output from Sha's nudged reference run to look for qualitative relationships between ABL height biases and CO_2 mole fraction biases. Select days were used where the majority of CPL Lidar retrievals were deemed "good". Overall, the ABL depth is underestimated over all regions and seasons with winter being the worst performing season, and fall and the	

	South performing the best. Bias structures show large spatial coherence on any given flight day, though CO2 biases are not similarly structured, especially on frontal flights. Future work includes expanding to all research days with available data as well as seeking collaboration to expand the analysis to other modeling systems.	
14:45 EDT	**Resolving Scales on Atmospheric Tracer Transport**	**Nick Geyer, CSU**
	The quantification and ability to model atmospheric tracer transport represents a strong source of uncertainty within carbon science. Poorly resolved transport by clouds and frontal circulations associated with synoptic weather systems has been recently highlighted as a critical transport process. Baroclinic waves are often associated with strong carbon dioxide (CO2) concentration gradients that lead to rapid meridional transport of CO2 anomalies. This implies a strong correlation between midlatitude carbon fluxes and Arctic concentrations that spans multiple,spatio-temporal scales. These processes are occluded from satellites due to cloud cover and their misrepresentation may lead to misattribution of carbon fluxes in transport inversions. Conventional global models are unable to resolve frontal transport and cloud-resolving regional models are too computationally expensive to run globally. We hypothesize that the frontal and convective CO2 transport can be characterized by introducing cloud-scale processes within a multi-scale global model. We investigated this by isolating the effects of parameterized versus resolved cloud-scale transport on CO2 within the Community Earth System Model 2 (CESM2). We ran 2 meteorologically identical super-parameterized CESM2 (SP-CESM2) simulations for 3 years at 0.9 by 1.25 degree spatial resolution during the ACT air campaign timeframe. SP-CESM2 replaces the standard parameterized convection and turbulence schemes with a 2-D “curtain” of cloud resolving models in each grid cell. This allows for global CO2 transport across multiple scales with a tractable computational expense. We allowed one simulation to transport CO2 through the conventional convective parameterization, while the other transported CO2 via the cloud resolving models. We compared the transport partitioning between the models and other global transport models. We found that both models produce a similar meridional transport contribution overall, but the transient component was different when CO2 was transported in the cloud resolving model. These results suggest that super-parameterized transport could be used in global models as a bridge between high-resolution case studies and traditional transport inversions.	
15:00 EDT	**Examine CO2 bands along cold fronts observed during ACT-America using WRF-VPRM, a weather-biosphere-online-coupled model**	**Xiao-Ming Hu, U Oklahoma**
	Xiao-Ming Hu1,2, Sean Crowell2, Qingyu Wang2, Sha Feng3, and Ken Davis3 1 Center for Analysis and Prediction of Storms 2 School of Meteorology, University of Oklahoma, Norman, Oklahoma, 73072, USA 3 Department of Meteorology and Atmospheric Science, The Pennsylvania State University, University Park, PA 16802, USA An enhanced CO2 concentration band was often observed immediately ahead of cold fronts during the Atmospheric Carbon and Transport (ACT)-America mission. Three such CO2 bands on Aug 4, 2016, Oct 18, 2017, and May 2, 2018 are investigated using WRF-VPRM, a weather-biosphere-online-coupled model, in which the biogenic fluxes	

	are handled by the Vegetation Photosynthesis and Respiration Model (VPRM) with calibrated parameters. WRF-VPRM simulations are conducted over the contiguous United States with a spatial resolution of 12 km. WRF-VPRM is able to capture some characteristics of the CO_2 bands, albeit with certain biases in magnitudes and/or locations. Terrestrial respiration leads to accumulation of near surface CO_2 through the night. As the cold fronts with low-CO_2 air mass penetrate southeastward, together with stronger photosynthesis further to the southeast of fronts, enhanced CO_2 concentration bands develop immediately ahead of the fronts.	
15:15 EDT	**Can we connect model-data metrics to transport bias?**	**Ken Davis, Penn State**
	A number of observational metrics have been developed using ACT observations and models in the hopes of diagnosing biases in atmospheric transport of CO_2. Directly connecting these metrics to transport bias, however, remains a challenge. I will present some simple hypotheses of how we might bridge this gap in understanding in an effort to initiate discussion and ongoing research.	
15:30 EDT	Break / Discussion	
15:45 EDT	**The predictability of CO_2 in a limited-area model and implications for data assimilation**	**J. Kim, Environment and Climate Change Canada**
	Jinwoong Kim, Saroja Polavarapu, Douglas Chan, and Michael Neish Climate Research Division, Environment and Climate Change Canada, Toronto, Canada Transport model error is an important source of uncertainty when estimating surface CO_2 fluxes by means of an atmospheric inversion. However, the relative importance of transport error to flux inversion estimates depends on the spatial scales of interest. At the large scale extreme, global flux estimates should be independent of transport error because constituent transport does not change the global mass of the constituent. However, we are entering a data rich era of CO_2 measurements so there is a desire to estimate CO_2 fluxes at increasingly higher spatial resolutions. There are two major components contributing to transport errors: (1) imperfect transport models due to the limitations of model dynamics, physical parameterization schemes and model parameters, and (2) errors in meteorological fields that drive atmospheric transport models. In this study, we investigate the latter. This source of transport error is often neglected in atmospheric inverse models. At Environment and Climate Change Canada, a limited area (covering most of North America) coupled weather and CO_2 transport model was recently developed (Kim et al. 2020). We investigate the extent to which errors in meteorological initial conditions (ICs) and lateral boundary conditions (LBCs) impact the quality of atmospheric CO_2 transport across spatial scales. Several experiments are conducted using different permutations of meteorological ICs and LBCs that possess varying levels of accuracy. We find that the predictability of CO_2 is more sensitive to errors in meteorology at smaller scales than at larger scales, and that surface CO_2 fluxes are important for the predictability of CO_2 at large scales. We also determine the limit of spatial scales resolvable in the context of imperfect meteorology. These findings have implications for the development of regional-scale inverse modelling systems. When assimilating CO_2 observations near the surface, using correct meteorological ICs is important for resolving fine-scale spatial variability of CO_2 because	

	CO2 transport at lower levels is more sensitive to meteorological ICs and surface CO2 fluxes than to meteorological LBCs. However, when assimilating aircraft CO2 measurements or XCO2 satellite retrievals which contain information at higher altitudes, using correct meteorological LBCs is also important.	
16:00 EDT	**Soil moisture in connection with atmospheric transport, chemistry, and photosynthesis**	**Min Huang, George Mason Univ**
	We will be showing results on WRF-Chem performance of weather and ozone and how it responds to SMAP soil moisture data assimilation during the summer 2016 ACT-America deployment. The WRF-Chem ozone sensitivities at various altitudes result from land influences on atmospheric transport as well as other processes (weather-dependent emissions, chemistry, deposition) related to ozone. These results are also compared with findings from modeling and data assimilation experiments for other field campaigns conducted in the central and southeastern US. Further, we will be discussing how WRF-Chem modeled carbon fluxes (e.g., gross primary productivity) respond to soil moisture changes, when the Noah-MP land surface model with dynamic vegetation is applied. Independent estimates of carbon fluxes, such as those from the SMAP Level 4 carbon product, are also being investigated	
16:15 EDT	**Discussion**	**A Schuh**

Day 3: Wednesday, April 29, 2020

	Inversions	
11:00 EDT	**Plan, gaps, opportunities**	**D Baker, A Jacobson**
11:15 EDT	**Splitting dynamical errors off of MDM errors - how can ACT help?**	**D Baker, CSU**
	Atmospheric CO2 inversions have often combined errors due to the transport model dynamics with errors in the measurements into a combined "model-data-mismatch error". This was appropriate for the old "Bayesian synthesis" inversion method, which used a Jacobian matrix that combined the effects of both the dynamics and the sampling of the model. However, the more advanced methods that have been used more recently (the Kalman filter, variational data assimilation) have the ability to characterize errors in the dynamics separately from measurement errors (and other transport model errors, such as representation errors). Generally, this capability is not actually used: in the ensemble Kalman filter, an inflation factor is used in place of the dynamical error covariance matrix; in variational data assimilation, a strong dynamical constraint is used in place of a weak one. Since a key goal of the ACT-America project is to improve both the transport models and how modeling errors are treated in the inversion methods, it seems appropriate here to highlight the benefits of accounting for transport model dynamical errors explicitly: i.e., separate from the measurement errors. We examine how ACT modeling products might be used to characterize these dynamical errors.	

11:30 EDT	**Progress toward new MDM errors in CarbonTracker using ACT observations**	**A Jacobson, T Gerken**
	Andy Jacobson, Tobias Gerken, and David Baker The ACT campaigns offer a unique opportunity to assess model performance as a function of weather conditions. In this talk, we will be discussing CarbonTracker performance against the ACT campaigns of 2016, 2017, and 2018. This analysis has two separate goals. First, we hope to develop a weather-dependent component of model-data mismatch (MDM) error to be applied at sites with continuous CO_2 monitoring. Current MDM schemes do not explicitly account for the effects of synoptic-scale CO_2 variations. Second, we intend to use ACT campaign data to evaluate whether a generalized scheme can be developed to represent the MDM of aircraft campaign measurements, permitting such data to be assimilated in models like CarbonTracker.	
11:45 EDT	**The CHE Project: Representation of Model CO_2 Uncertainty**	**Mcnorton, ECMWF**
	The CO_2 Human Emissions (CHE) project aims to develop a European capacity to monitor anthropogenic CO_2 emissions at policy-relevant scales. The global component of the inversion system will build on existing operational infrastructures (CAMS, C3S) at the European Centre for Medium-range Weather Forecast (ECMWF) to exploit ground-based measurements as well as space-based observations from current and future satellite missions (e.g., Sentinel 5p and CO2M). We will discuss several key components of the proposed system, specifically the representation of both prior emission and transport model uncertainty. Estimated errors in modeled CO_2 concentrations caused by uncertainties in wind fields and initial conditions are represented using an ensemble of the operational forward Integrated Forecasting System (IFS). These uncertainties, along with prior emission uncertainties, derived following IPCC guidelines, are used to calculate signal-to-noise ratios relevant for the proposed prototype inverse system. We will also provide an evaluation of the derived uncertainties using separate sensitivity experiments and TCCON observations.	
12:00 EDT	**Towards a hybrid satellite-based CO_2 flux inversion setup for CarbonTracker Europe**	**Florentie, Wageningen U.**
	Up until recently, global natural CO_2 flux estimates obtained with the CarbonTracker Europe (CTE) data assimilation system were constrained by surface observations only. The related sparse observational coverage, characterized by few observations over remote but important regions like the Amazon, posed a severe limitation to the system. As over the last years retrieval products of satellite-based XCO_2 have matured sufficiently to become suited for use in CO_2 flux inversion systems, the capability to assimilate satellite-based XCO_2 observations has now been added to CTE. We will present satellite-based CO_2 flux inversion results obtained with CTE based on two XCO_2 retrieval products (both using OCO-2 observations), and compare them to our default surface-only setup. In addition, we want to present our work towards building an alternative hybrid inversion setup. With this new setup we aim to exploit the full potential of satellite-based observations for constraining small-scale variations in biogenic CO_2 fluxes. It consists of a 2-step data assimilation approach. The first step accounts for the slow, large-scale	

	processes. This part consists of a long-window inversion (LWI) in which we estimate model parameters for a statistical description for the long-term regional mean net ecosystem exchange (NEE), constrained by in situ observations only. As a second step small-scale NEE variations, both spatial and in time, are filled in by means of a short-window inversion (SWI), constrained by satellite-based XCO2 observations. This way we hope to make full use of the small-scale features included in satellite observations, while at the same time also constraining the large-scale patterns by observations.	
12:15 EDT	Break / Discussion	
12:45 EDT	**Applications of ACT results to CT-Lagrange / new progress in CT-Lagrange**	**Lei Hu, Arlyn Andrews, NOAA**
13:00 EDT	**OCO-2 error characterization using MFLL data and cloud-related metrics. Applications to inversions**	**D Baker, E Bell, C O'Dell, S Massie**
	The CO2 measurements taken by the OCO-2 satellite are quite dense along its narrow (~10 km) swath: 24 discrete retrievals are taken per second, or per ~7 km distance alongtrack. Such density is superfluous for assimilation into transport models with grid boxes with widths of 10s to 100s of km: the data are generally averaged to coarser scales. To properly characterize the uncertainty to place on these coarser-scale average values, the along-track correlation length scale is needed, though the ground-truth data required to characterize it has not been available previously. Data collected from the MFLL lidar instrument aboard ACT aircraft flying underneath OCO-2 overpasses now allows us to calculate these correlations directly. We use the MFLL-OCO2 column CO2 differences computed by Emily Bell, in a Fourier analysis approach, to calculate the spatial correlation length scale spectrum. We also attempt to account for the impact of OCO-2 XCO2 biases associated with cloud 3-D radiative transfer effects using a parameter computed by Steve Massie for the OCO-2 project.	
13:15 EDT	**NEE constrained by surface and space-based atmospheric CO2 measurements over 2010--2015 and satellite up-scaled GPP from FluxSat over 2001-2017**	**Brendan Byrne, JPL**
	Across North America, interannual variability (IAV) in gross primary production (GPP) and net ecosystem exchange (NEE), and their relationship with environmental drivers, are poorly understood. Here, we examine IAV in GPP and NEE and their relationship to environmental drivers using two state-of-the-science flux products: NEE constrained by surface and space-based atmospheric CO2 measurements over 2010-2015 and satellite up-scaled GPP from FluxSat over 2001-2017. We show that the arid western half of North America provides a larger contribution to IAV in GPP (104% of east) and NEE (127% of east) than the eastern half, in spite of smaller magnitude of annual mean GPP	

	and NEE. This occurs because anomalies in western North America are temporally coherent across the growing season leading to an amplification of GPP and NEE. In contrast, IAV in GPP and NEE over eastern North America are dominated by seasonal compensation effects, associated with opposite responses to temperature anomalies in spring and summer. Terrestrial biosphere models in the MsTMIP ensemble partially capture these differences between eastern and western North America, but generally underestimate the sensitivity of flux anomalies in western North America to variations in soil temperature and moisture by 0-31%. This suggests that ecosystems in western North America may be more sensitive to warming and increasing aridity than models predict, and that reductions in growing season productivity and carbon sequestration under climate change may be larger than predicted by models.	
13:30 EDT	**Discussion. Inversions using improved priors and prior errors, improved transport and transport errors, improved XCO2 errors.**	**D Baker, A Jacobson, K Davis**
	Methane	
14:00 EDT	**Quantification of nitrous oxide emissions in the U.S. Midwest – A top-down study**	**Max Eckl, DLR**
	Atmospheric nitrous oxide (N2O) is the third most import long-lived anthropogenic greenhouse gas in terms of radiative forcing. Mainly due to human-induced emissions, global concentrations are rising. Especially agricultural activity, i.e. the application of nitrogen fertilizer, contributes considerably to this trend. As the U.S. Midwest exhibits a high density of cultivated land, it is a regional hotspot of N2O emissions in the U.S. However, sparse observational data complicates the quantification of these regional fluxes. Only a few top-down studies in the Midwest exist, mainly based on Lagrangian models and ground-based measurements, proposing a significant underestimation of agricultural N2O emissions in established inventories like the Emission Database for Global Atmospheric Research (EDGAR). In this study we apply a top-down approach to quantify anthropogenic N2O emissions in the U.S. Midwest in fall 2017 and summer 2019. An extensive in-situ dataset was collected during the Atmospheric Carbon and Transport – America (ACT-America) campaign, spanning from summer 2016 to summer 2019, in the lower and middle troposphere onboard NASA's C-130 and B-200 aircraft. During fall 2017 and summer 2019 we conducted measurements onboard the NASA-C130 with a Quantum-Cascade-Laser-Spectrometer (QCLS) and over the whole campaign flask samples (NOAA) were collected on both aircraft. With the Eulerian Weather Research and Forecasting model with chemistry enabled (WRF-Chem) atmospheric enhancements and their spatial characteristics from various surface source emissions, i.e. included in the EDGAR inventory, are simulated. The numerical simulations enable the comparison of surface emission distributions with our airborne observations. By minimizing the differences between observations and simulations, source estimates can be optimized, thus quantifying N2O sources and evaluating the employed inventory. We found that agricultural EDGAR emissions in the Midwest in summer 2019 have to be multiplied by a factor of up to 30 to reproduce our observations with the simulations. To some extent this might be due to the extreme flooding event during our measurements in summer 2019. However, analyses of fall 2017 suggest that EDGAR also significantly underestimates agricultural emissions in the Midwest in the absence of flooding.	

14:15 EDT	**Plans, gaps, opportunities**	**Z Barkley**
14:30 EDT	**A catalogue of flight methane and ethane data. Characteristics, days, seasons, simulations**	**Zach Barkley, Penn State**
14:45 EDT	**A flight-by-flight analysis of continuous ethane data from the ACT-America aircraft campaign. Constraints on oil and gas methane emissions**	**Zach Barkley, Penn State**
	Methane (CH_4) is a potent greenhouse gas. Increasing atmospheric CH_4 concentrations in the past century are estimated to have contributed to a quarter of global temperature increases to date. A major source of anthropogenic methane emissions is oil and gas extraction. Top-down studies in the last decade have consistently found CH_4 emissions from USb gas basins to be larger than bottom-up inventory estimates. In this study, we use ethane (C_2H_6), a gas co-emitted with methane emissions from the oil and gas sector, to further constrain CH_4 emissions from oil and gas operations. Hundreds of hours of continuous C_2H_6 data in the boundary layer were collected across the eastern US as part of the ACT-America aircraft campaign. This data is used in a Bayesian inverse framework to identify C_2H_6 emissions from individual gas basins across the eastern and southcentral US. Using information about the gas content of each basin, these ethane emission estimates can be transformed into methane emission estimates and compared to bottom-up inventory estimates. Preliminary findings from this study show uniformly higher ethane emissions across all of the US compared to expectations, with both the Permian basin in western Texas and the Marcellus and Utica basins in West Virginia showing the largest anomalies.	
15:00 EDT	Break / Discussion	
15:15 EDT	**High-resolution constraints on methane emissions in the Upper Midwest based on GEM aircraft measurements and a multi-Inversion framework**	**Xueying Yu, U Minnesota**
15:30 EDT	**Long-Term Measurements Show Little Evidence for Large Increases in Total U.S. Methane Emissions Over the Past Decade**	**Xin Lan, NOAA/CIRES**
15:45 EDT	**Continental ethane inversion and potential connections to ACT-America**	**Scot Miller, Johns Hopkins**
16:00 EDT	**Peatland methane sensitivity to temperature mediated by seasonal water table dynamics**	**Julian Deventer**
16:15 EDT	**CH4 and CO2 fluxes from stream and river networks in agricultural watersheds of Southern Minnesota**	**Ashish Singh**

16:30 EDT	**Discussion**	**Barkley, Davis**

Day 4: Thursday, April 30, 2020

	Bio CO2	
11:00 EDT	**Plan, gaps, opportunities**	**Ian Baker, Parazoo, Baier, Feng**
11:15 EDT	**Constraint of terrestrial model parameters from ensemble forward simulations**	**Sha Feng, Penn State**
	Recent estimates of the North American carbon budget have shown a moderate convergence at annual and longer time scales between terrestrial biogeochemical models (BGCMs) and atmospheric inversions. However, multi-BGCM comparisons revealed large discrepancies both spatially and temporally among net ecosystem exchange estimates, illustrating our limited understanding of the underlying mechanisms. To bridge the gap between processes and atmospheric inversions, we propagated process-based errors in a BGCM, here an ensemble of CASA model simulations, into a mesoscale atmospheric system to identify and possibly optimize parameters instead of surface fluxes. Our offline atmospheric-ecosystem coupled model also represent uncertainties from the atmospheric transport in an ensemble-based framework. The unique collection of continental Planetary Boundary Layer measurements of CO2 mixing ratios and meteorological variables from the NASA Atmospheric Carbon and Transport-America (ACT-America) mission provides new perspectives on our understanding of transport and fluxes of greenhouse gases across three regions of the U.S., four seasons, and a variety of synoptic weather conditions. We have assembled a calibrated, continental-scale, 27-km resolution atmospheric model ensemble including biospheric and fossil fuel contributions, prescribing the large-scale inflow of CO2 from several global models. The ensemble system can separate and quantify the uncertainties in modeled CO2 mixing ratios from atmospheric transport, biospheric fluxes, fossil fuel emissions, and boundary inflows. Key parameters of CASA, driving ecosystem respiration and photosynthetic uptake, are constrained using both atmospheric mixing ratio measurements. We identified discrepancies between bottom-up and top-down approaches spatially using aircraft footprints from a backward Lagrangian particle model, to define optimal parameter values for dominant ecosystems across the US.	
11:30 EDT	**Constraining seasonal biogenic and fossil fuel CO2: observations of critical tracers and model evaluation**	**Bianca Baier, NOAA/CIRES**
	Bianca Baier1,2, Colm Sweeney2, John Miller2, Scott Lehman3, Chad Wolak3, Kenneth Davis4, Sha Feng4, Thomas Lauvaux4, Josh DiGangi5, John Nowak5, Yonghoon Choi5	

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Carbon dioxide (CO2) is the most important greenhouse gas given its atmospheric growth rate and impact on earth's radiative balance. Fluxes of CO2, especially its biogenic sink which acts to partially offset atmospheric CO2 accumulation resulting from fossil fuel combustion, are not well-characterized by atmospheric inversion models on regional to sub-continental scales which complicates future climate predictions. Minimizing biases in CO2 inverse flux estimates from fossil fuel combustion or the terrestrial biosphere requires decreasing uncertainties in model transport, underlying emissions fields, and background assumptions. The airborne Atmospheric Carbon and Transport (ACT)–America campaigns gathered seasonal observations during 2016-2019 for testing transport and flux models. Whole-air flask samples were collected during ACT and analyzed for radiocarbon isotopes, among other trace gas species. Here, we analyze four seasons of flask sample measurements of the radiocarbon content of CO2 (Δ14CO2) in the Mid-Atlantic U.S. to determine the fossil fuel (CO2FF) and biogenic (CO2BIO) components of observed CO2 enhancements. Using flask radiocarbon for the Mid-Atlantic U.S., we propose a method to derive "continuous" CO2FF and CO2BIO for the entire ACT observational domain and use these observationally-derived CO2 components for the eastern United States to interrogate model partitioning of biogenic and fossil fuel CO2. We further demonstrate how radiocarbon observations can help to distinguish between modeled CO2 flux and transport errors. Our results will highlight the value of using radiocarbon to estimate source-specific components of CO2 fluxes, and for guiding regional inverse modeling frameworks.

11:45 EDT	**CASA suite and uncertainty**	**Yu Zhou, Christopher Williams, Clark U**

Yu Zhou and Christopher Williams, Clark University

Accurate, high-resolution estimates of surface biogenic carbon fluxes are critical for measuring and monitoring the biosphere's responses to climate, land use, and disturbances, and its feedbacks on the climate system. They are also a key component of large-scale monitoring systems that utilize atmospheric data (e.g. atmospheric inversions). Currently-available data products from site-level flux measurements and model-intercomparison projects (e.g., MsTMIP) struggle to represent the explicitly spatio-temporal dynamics of surface biogenic carbon fluxes, and to quantify their uncertainties.

We introduce a new method and dataset to address these gaps. We use a perturbed-parameter model ensemble with the CASA biogeochemical model to estimate surface biogenic carbon fluxes at monthly and 3-hourly scales from 2003 to 2019 for North America at two spatial resolutions (463 m and 5 km). Our approach uses the Extended Fourier Amplitude Sensitivity Testing (EFAST) to determine the sensitivity of

	carbon fluxes (NPP: net primary productivity; Rh: heterotrophic respiration; NEP: net ecosystem productivity) to model parameters. We then choose the three most sensitive parameters to be perturbed in our data product, the maximum light use efficiency (Emax), the optimal temperature of photosynthesis (Topt), and the temperature response of respiration (Q10). The initial range for each parameter is broadly sampled but then pruned with an initial evaluation using carbon flux measurements from AmeriFlux, FLUXNET, and LaThuile datasets. The resulting carbon flux dataset is evaluated with flux tower measurements and a diverse range of data products that are derived from MsTMIP, SiB3, and CarbonTracker (CT2017). We find that the ensemble spread encompasses the pooled AmeriFlux observations, and is well correlated with these observations at monthly and 3-hourly scales. The new data product also outperforms most members in the MsTMIP suite of models. We also identify the dominant sources of uncertainty and spread in the model ensemble and demonstrate a range of uses including applications for NASA's ACT-America project. This data product is available through the Oak Ridge National Laboratory Distributed Active Archive Center at https://doi.org/10.3334/ORNLDAAC/1675.	
12:00 EDT	Break / Discussion	
12:30 EDT	**BioCO2 fluxes and process understanding across seasons**	**Ian Baker, CSU**
	Ian Baker (CSU), Tobias Gerken (PSU), Sharon Gourdji (NIST), Chris Williams(ClarkU), Yu Zhou (ClarkU) Large-scale aspects of the North American carbon cycle are generally accepted, such as the wintertime being a source of CO2 over the continent, and summer being a sink. However, some aspects of this behavior, in particular with regard to the transition from summer sink to winter source, are not fully understood. ACT-America airborne CO2 data suggest that the southeastern USA is a source of CO2 in mid- to late-summer, at a time when many models represent the region as a sink (e.g. Huntzinger et al., 2012). We are investigating the seasonal carbon dynamics of the eastern USA using both an enzyme-kinetic model (or process model: SiB4) and light response models (VPRM, CASA), with particular focus on the transition from summertime sink to autumn source of CO2. We will evaluate model-specific behavior, and compare/contrast our understanding of CO2 transition dynamics, as expressed in models, against airborne and surface observations. Ultimately, we expect to identify particular model behaviors that are unsupported by observations, and formulate hypotheses with which to improve performance.	
12:45 EDT	**Influence functions and their applications to evaluating BioCO2 fluxes**	**Yuyan Cui, Penn State**
	Yuyan Cui[1], Sha Feng[1], Andrew R. Jacobson[2], David Baker[3], Daniel Wesloh[1], Zachary R. Barkley[1], Tobias Gerken[1], Joshua P. Digangi[4], Lily Campbell[1], Bianca Baier[2], Thomas Lauvaux[1,5], Kenneth J. Davis[1]	

	1. PSU, 2. CIRES/GML/NOAA, 3.CIRA/CSU, 4. Langley/NASA, 5. LSCE, France. Atmospheric CO_2 hotspots and their pronounced seasonal variability were seen in the multi-seasonal ACT-America aircraft campaign. To top-down estimate CO_2 fluxes, we established a source-receptor relationship to link the atmospheric CO_2 with the source fluxes using a Lagrangian dispersion model (FLEXPAR-WRF). A suite of Influence functions was calculated for 171 aircraft profiles during the four ACT sub-campaigns (Summer 2016- Spring 2018). We use the influence functions (hourly and 10-day backward simulations) to evaluate the different CO_2 flux inversion products as part of The Orbiting Carbon Observatory-2 model inter-comparison project (OCO-2 v9 MIP). In particular, we built a hybrid framework to focus on evaluating the biogenic component of CO_2 fluxes, combining both Eularian forward and Lagrangian backward simulations. We use the analysis of the root-mean-square-error and mean biases to rank the different inversion products and examine their overall performances. The evaluation results will be presented and discussed. In addition, the biogenic source sectors are explored to explain the discrepancies between the model and measurements.	
13:00 EDT	**GPP from OCS and GIM inversion. ACT-America as a testbed to demonstrate consistency between SIF and OCS as constraints on GPP (Exploring North American carbon fluxes at the component level using the dual constraints of atmospheric COS and CO2)**	**Yoichi Shiga, Ames**
	The response of the terrestrial carbon cycle to future climatic changes, while critical for determining the future state of the climate, remains a major source of uncertainty. Evaluating terrestrial biosphere models (TBMs) using continental-scale networks of atmospheric observations allows for the investigation of model performance over broad integrated regional-to-continental scales. Previous work has shown that atmospheric CO2 observations can be used to examine model estimates of net ecosystem exchange (NEE) while atmospheric carbonyl sulfide (COS) observations can be used to examine model estimates of gross primary productivity (GPP). Here we examine a variety of TBM estimates of summertime GPP and NEE using the North American atmospheric observation networks of both CO2 and COS to investigate model performance at the component-level. We find that models fall along a spectrum between models that either overpredict both GPP and NEE (derived via their ability to match atmospheric COS and CO2 concentration data) to those that underpredict both GPP and NEE. Using the dual constraints of atmospheric CO2 and COS data, we can attribute the reasons for these biases to either biases in modeled GPP or modeled ecosystem respiration or both. This work offers key insights into TBM performance by providing a critical component-level constraint at regional scales.	
13:15 EDT	**Tracer-tracer analysis of biological co2**	**Nick Parazoo, JPL**
	The terrestrial biosphere is a dominant driver of observed CO2 variability across northern temperate latitudes, but attribution of biosphere carbon exchange is confounded by	

	sources from wildfires, power plants, and cropping systems, and large offsetting exchanges from plant uptake and soil emissions. ACT-America airborne flask samples enable high precision analysis of key biogenic GHG species and their seasonal and spatial variability across diverse North American ecoregions. Covariance of CO_2, CO, and OCS measurements in the atmospheric boundary layer can help disentangle biospheric processes from other sources, partition biospheric exchange into plant and soil components, and provide a benchmark for model representations of these processes. We analyze model simulations of CO_2, CO and OCS using the JPL GHG-Flux land-atmosphere modeling system against ACT flask samples to better understand variations in these diverse carbon sources across South, Midwest, and Northeast US regions.	
13:30 EDT	Break / Discussion	
14:00 EDT	**Summer 2019 evaluation of GEOS system**	**Nikolay Balashov, Goddard**
	During the NASA's Atmospheric Carbon and Transport - America (ACT-America) summer 2019 campaign, we used new experimental CO_2 forecasts from NASA's Goddard Earth Observing System (GEOS) as well as CO and C_2H_6 forecasts from NASA's GEOS – Composition Forecast (CF) as an additional guidance for flight planning meetings. The GEOS forecasts are initialized using fields produced by the GEOS meteorological data assimilation system, coupled to the GEOS-Chem chemistry module and are run at 25-km resolution, globally. Fluxes of CO_2 are estimated in near real time (NRT) based on a suite of remote sensing data including greenness, night lights, and fire radiative power. In this preliminary version, the NRT biospheric fluxes are determined by extrapolating the retrospective CASA-GFED fluxes forward in time. The ACT-America team used these forecasts to identify interesting transport patterns across different types of weather systems and then investigated several of these cases using research aircraft. The results provide several examples that illustrate the ability of high-resolution global models to predict CO_2 gradients at 2-3 days lead times and identify the distribution of CO_2 across different layers of the atmosphere. Summary performance of GEOS model over the whole summer is also presented.	
14:15 EDT	**Spatiotemporal structure of model-data residuals**	**Daniel Wesloh, Penn State**
	Spatiotemporal structure of model-data residuals CASA ensemble mean minus AmeriFlux biogenic carbon dioxide surface flux residual correlation model fitting.	
14:30 EDT	**Eastern U.S. bio flux evaluation in support of urban inversions**	**Sharon Gourdji, NIST**
	I will show a comparison of VPRM, SiB4 and CASA ensemble mean fluxes in eastern US/ Canada, and also compare convolved fluxes with observed enhancements at ~25	

	regional towers using 2 different transport models. The goal will be to identify biospheric model features that are working well at sub-annual (diurnal, seasonal) timescales, and also identify needed improvements for separately identifying biospheric and anthropogenic signals in urban and regional CO_2 atmospheric inversions.	
14:45 EDT	**Net ecosystem exchange anomalies contribute to growing season warm-sector CO_2 enhancement**	**Nina Randazzo, Stanford**
	Our work has focused on the response of biosphere-atmosphere carbon dioxide exchange to synoptic and mesoscale meteorological systems. This investigation is designed to determine average biospheric net carbon exchange anomalies during various meteorological events and thereby allow the relative contribution of transport error to be more accurately diagnosed. Specifically, our work has identified spatially coherent carbon exchange anomalies across the continental United States in response to mesoscale meteorological systems. We have classified the mesoscale atmospheric circulation of ACT-America flight days based on a clustering analysis of gridded reanalysis precipitation over North America. Using eddy flux covariance FLUXNET2015 data from across the country, we found consistent regional responses of CO_2 exchange to atmospheric circulation types exemplified by the days of the ACT-America flights. Furthermore, we found that these regional net ecosystem exchange anomalies are consistent with the boundary layer CO_2 anomalies observed in the ACT-America flights, indicating that both flux and transport anomalies are contributing to observed gradients in CO_2 concentrations. This analysis thereby sheds light on phenomena such as the consistent warm-sector CO_2 enhancement seen during the ACT growing season campaigns.	
15:00 EDT	**SIF**	**Yi Yin, CalTech**
	While large-scale floods directly impact human lives and infrastructures, they also profoundly impact agricultural productivity. New satellite observations of vegetation activity and atmospheric CO_2 offer the opportunity to quantify the effects of such extreme events on cropland carbon sequestration, which are important for mitigation strategies. Widespread flooding during spring and early summer 2019 delayed crop planting across the U.S. Midwest. As a result, satellite observations of solar-induced chlorophyll fluorescence (SIF) from TROPOspheric Monitoring Instrument (TROPOMI) and Orbiting Carbon Observatory (OCO-2) reveal a shift of 16 days in the seasonal cycle of photosynthetic activity relative to 2018, along with a 15% lower peak photosynthesis. We estimate the 2019 anomaly to have led to a reduction of -0.21 PgC in gross primary production (GPP) in June and July, partially compensated in August and September (+0.14 PgC). The extension of the 2019 growing season into late September is likely to have benefited from increased water availability and late-season temperature. Ultimately, this change is predicted to reduce the crop yield over most of the midwest Corn/Soy belt by ~15%. Using an atmospheric transport model, we show that a decline of ~0.1 PgC in the net carbon uptake during June and July is consistent with observed CO_2 enhancements from Atmospheric Carbon and Transport - America (ACT-America) aircraft and OCO-2. This study quantifies the impact of floods on cropland productivity	

	and demonstrates the potential of combining SIF with atmospheric CO2 observations to monitor regional carbon flux anomalies.	
15:15 EDT	**Variation in growing season CO_2 fluxes in the Mississippi Delta Region**	**Ben Runkle, U. Arkansas**
	In this study we present and report field measurements from more than 10 eddy covariance towers in the Lower Mississippi River Basin taken during the summer months of 2016. Many towers, some recently deployed, are being aggregated into a regional network known as Delta-Flux, which will ultimately include 15-20 towers. Set in and around the Mississippi Delta Region within Louisiana, Arkansas, and Mississippi, the network collects flux, micrometeorological, and crop yield data in order to help construct estimates of regional CO_2 exchange. These time-series data are gap-filled using statistical and process-based models to generate estimates of summer CO_2 flux. The tower network is comprised of sites representing widespread agriculture production, including rice, cotton, corn, soybean, and sugarcane; intensively managed pine forest; and bottomland hardwood forest. Unique experimental production practices are represented in the network and include restricted water use, bioenergy, and by-product utilization. Several towers compose multi-field sites testing innovative irrigation or management practices. Current mapping of agricultural carbon exchange – based on land cover layers and fixed crop emission factors – suggests an unconstrained carbon flux estimate in this region. The observations from the Delta-Flux network will significantly constrain the multi-state C budget and provide guidance for regional conservation efforts.	
15:30 EDT	**Break / Discussion**	**Ian Baker, Parazoo, Baier, Feng**
16:00 EDT	**Closing Remarks**	**Ken Davis, Penn State**