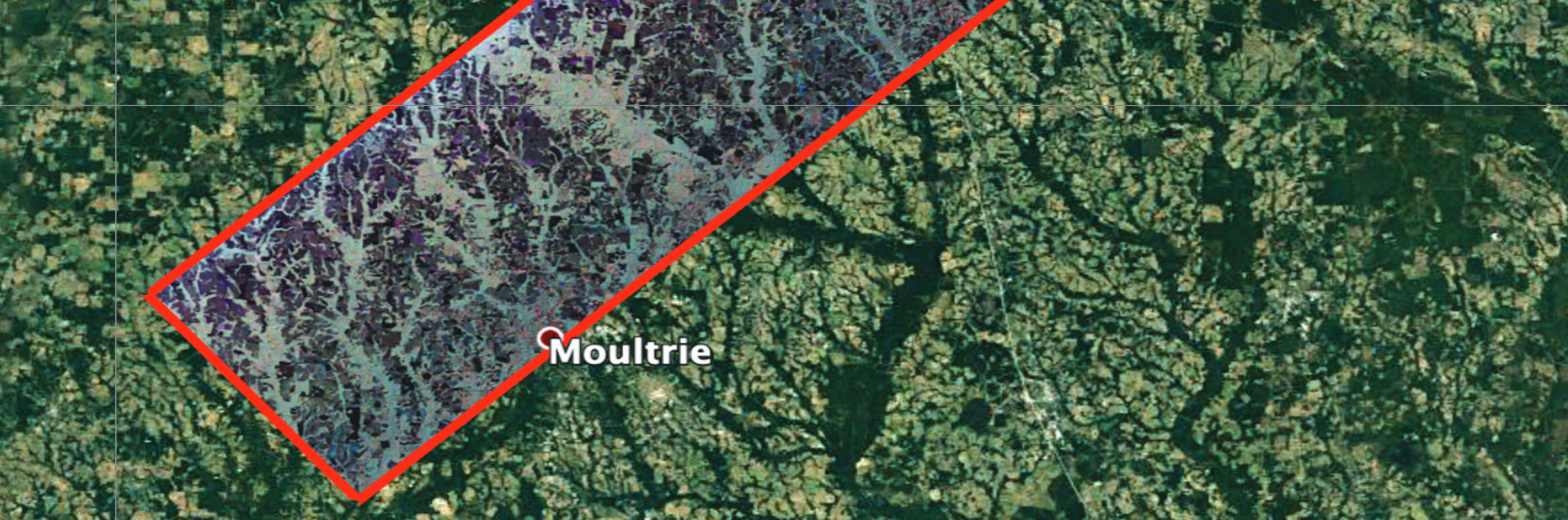

3. Science

Major Mission Highlights

Despite the unique safety and logistics challenges introduced by a global pandemic, in FY20 ASP conducted over 1600 flight operation hours in support of Earth science process studies, instrument flight-testing, and support for Earth Science space missions in all phases from definition to validation. Two of the five Earth Venture Suborbital-3 (EVS-3) missions, IMPACTS and ACTIVATE, were able to begin flight activities early in the calendar year. ACTIVATE was also able to return to flight in summer 2020. Operation IceBridge (OIB) completed activities in FY20, including GV deployment to Australia and a final Alaska mission. Table 5 shows flight hours for the largest campaigns.

Table 5. *FY20 Major Science Campaigns.*

Campaign	Flight Hours	Location	Aircraft
ACTIVATE	288.2	Atlantic coast	Falcon, UC12-B
OIB – Antarctica – Fall 2019 (FY20)	248.4	East Antarctica	GV
OIB – Alaska	48.0	Alaska	Twin Otter
NASA Methane Survey	239.1	California, Texas	B-200
UAVSAR Combined Missions	198.4	CONUS	G-III
SNOWEX	159.8	Colorado, Idaho, California	G-III, B-200, Twin Otter
OMG	134.8	Greenland	Airtec DC-3
IMPACTS	123.9	Atlantic coast	P-3, ER-2
NISAR SAR Campaigns	75.7	Alaska, South-East U.S.	G-III
CAMP2EX	48.2	Philippines	P-3, SPEC Lear
G-LiHT Post-hurricane Recovery	38.0	Florida	A90
Western Diversity Time Series	29.0	California	ER-2

Earth Venture Suborbital

The Earth System Science Pathfinder (ESSP) Earth Venture Suborbital (EVS) projects are flagship equivalent $15-30M, 5-yr efforts that focus on the most compelling science questions where aircraft measurements are absolutely critical to resolving uncertainties. The single remaining EVS-2 mission, OMG, continued flight activities in 2020, while two of the new EVS-3 missions were able to begin flight operations. As detailed below, ACTIVATE successfully carried out a winter and summer series and IMPACTS completed a winter 2020 mission. Three other EVS-3 missions, DCOTSS, S-MODE, and Delta-X, will begin flight operations in 2021.

Aerosol Cloud Meteorology Interactions Over the western ATlantic Experiment (ACTIVATE)

PI – Armin Sorooshian, University of Arizona
Program – EVS-3
Aircraft – HU-25A, UC12-B
Payload Instruments: CVI, AC3, RSP, HSRL-2

Complex interactions between aerosols and clouds represent one of the largest sources of uncertainty when simulating climate processes. ACTIVATE is focused on studying these interactions over the Western North Atlantic Ocean (WNAO). Without aerosol particles, there cannot be cloud droplets, and the number and type of particles can have critical impacts on how clouds form and evolve. Clouds in turn have important impacts on aerosol particles, such as modifying their properties, redistributing them vertically, and removing them via precipitation scavenging. Advancing knowledge of aerosol-cloud interactions requires immense amounts of data collected under a variety of conditions to be able to disentangle the impacts of meteorology and aerosol particles on cloud behavior. To respond to this need, the ACTIVATE team made strategic design choices related to aircraft flight operations. Deploying the aircraft from NASA LaRC minimizes logistical and travel costs, increasing the number of flight hours. It also provides easy access to the wide range of meteorological and aerosol conditions (and thus cloud types) over the WNAO region, which is helpful for building statistics relevant to aerosol-cloud interactions.

ACTIVATE is acquiring for the first time detailed, simultaneous, and systematic measurements of aerosols and clouds from in situ and remote sensing instruments deployed on two coordinated aircraft over multiple years. The HU-25A Falcon flies underneath the UC-12B King Air to conduct in situ sampling of boundary layer clouds, such that ACTIVATE can measure clouds that range from stratiform to thicker cumulus clouds. The Falcon payload consists of instruments characterizing gases, aerosols, clouds, and meteorological state parameters and winds. Key measurement aspects are the duo of a counterflow virtual impactor (CVI) inlet that enables characterization of droplet residual particle properties when flying in cloud, and the Axial Cyclone Cloud water Collector (AC3) that collects cloud water samples for post-flight chemical analysis.

Flying well above the HU-25A at 8-10 km, the UC-12B instruments include the Research Scanning Polarimeter (RSP) and High Spectral Resolution Lidar (HSRL-2) to characterize aerosol and cloud properties from above. Dropsondes are also deployed from the UC-12B to measure profiles of atmospheric state parameters. ACTIVATE uses these advanced remote sensors to assess and advance aerosol and cloud retrieval capabilities to study aerosol-cloud interactions. The joint deployment of these remote sensors additionally helps assess current (e.g., CALIPSO) satellite measurements and can help the NASA Aerosol, Clouds, Convection, and Precipitation (ACCP)

Figure 5.** ACTIVATE scientists Ewan Crosbie (facing camera) talking to Michael Shook and Simon Kirschler after an ACTIVATE flight. Note the sampling probes on the top of the aircraft.* ***Photo credit: *Armin Sorooshian*

Study assess how such satellite and suborbital measurements can be used to address the National Academy of Science 2017 Decadal Survey recommendations.

During 2020, the two ACTIVATE aircraft flew together successfully for 35 total joint flights and demonstrated the effectiveness of the joint flight approach. In the winter deployment (ACTIVATE 1), 17 joint flights took place from February 14 – March 12, 2020, with five additional flights using only the HU-25A. The winter flights sampled cold air outbreak conditions, which are of special importance, as climate models struggle to simulate the postfrontal clouds associated with these conditions. The winter flights ended early due to operational restrictions imposed as a result of the COVID-19 pandemic. After extensive consultation with LaRC personnel, the ACTIVATE team developed a plan to safely proceed under a high level of caution to conduct summertime flights in August and September.

The summer deployment (ACTIVATE 2) consisted of 18 joint flights from August 13 – September 30, 2020. A major reason the second deployment was successful is because team members live near the base of operations at NASA LaRC. In addition, only a few team members are needed to operate the numerous instruments on these aircraft. While the pace of operations was reduced due to safety restrictions, the summer flights were successful in addressing the aerosol-cloud studies described earlier. The summer flights were marked by different cloud scenes, as compared to the winter campaign, which was part of the rationale to fly in different seasons. Biomass burning plumes from the extensive wildfires in the western U.S. were a common feature sampled during the summer flights. Some of these flights were coordinated with the ASTER and CALIPSO satellites, including some where smoke aerosols resided in the vertical column below the UC-12B King Air and CALIPSO. Early ACTIVATE results point

Figure 6. *ACTIVATE team photo in front of the HU-25A Falcon in the NASA Langley hangar during the first science team meeting.* ***Photo Credit:*** *Evan Horowitz*

to the broad range of cloud droplet number concentrations, spanning several orders of magnitude, which makes the dataset important to understanding the key fundamental drivers of this cloud microphysical variable, as well as other cloud characteristics, such as reflectivity and precipitation formation.

ACTIVATE team members include: University of Arizona, NASA LaRC, NASA GISS, Columbia University, Pacific Northwest National Laboratory (PNNL), College of William and Mary, German Aerospace Center (DLR), Rochester Institute of Technology, SciSpace LLC, NASA WFF, Yulista Holding LLC, and Bay Area Environmental Research Institute (BAERI).

Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS)

PI – Lynn McMurdie, University of Washington
Program – EVS-3
Aircraft – P-3, ER-2
Payload Instruments: CRS, HIWRAP, EXRAD, CoSMIR, AMPR, CPL, CDP, CAPS, HVPS, Nevzorov, Hawkeye, TAMMS, AVAPS, RICE

In winter 2020, IMPACTS flew two aircraft in a coordinated fashion to characterize snow band structure, understand the dynamical and microphysical mechanisms that produce the observed structures, and apply this understanding to improving remote sensing and modeling of snowfall. The ER-2 aircraft operated out of Hunter Airfield near Savannah, Georgia. It flew at a high altitude (~65k ft) above the storm systems and was equipped with passive and active remote sensing instruments similar to those flown on satellites. The ER-2 flew nine missions for a total of 62.6 hours. The P-3 operated out of its home base at Wallops Flight Facility (WFF) and was equipped with in situ microphysical and environmental instrumentation and dropsonde capability. The P-3 flew at a variety of altitudes (4-25k ft) within the storm systems depending on the depth of the cloud, height restrictions, and temperature structure as determined by the mission scientists. The P-3 flew ten missions for a total of 61.3 hours. Of these missions, five were coordinated flights where the two aircraft were no more than 10 minutes apart during straight flight legs.

IMPACTS sampled storms that occurred over Illinois, Indiana, North Carolina and offshore waters, New York, and New England (see Figure 7). The storms exhibited a wide-range of characteristic structures that contribute to snow bands, such as strong frontogenesis, elevated convection, weak and strong synoptic forcing, generating