COVID-19 Impacts on NEON Data Collection and Data Products, 2020

As described on the [Observatory Status](#) page, NEON operations were suspended from March 23, 2020, until May 18, 2020, or beyond, depending on safety conditions at each NEON field office and field site. Conditions continued to change at each site throughout 2020, impacting the amount of sampling and maintenance that could be safely performed at any given time, with impacts to operations continuing into 2021.

This page summarizes the impacts of the safety measures implemented in the face of major natural disasters to NEON data collection in 2020. The impacts described are primarily due to COVID-19. However, impacts from wildfires (Domain 17 California, Domain 16 Oregon, Domain 16 Washington, and Domain 13 Colorado), flooding (Domain 08 Alabama), and other causes are included to provide a complete picture of impacts to 2020 collections.

1   IMPACTS TO AQUATIC AND TERRESTRIAL OBSERVATION SYSTEM DATA PRODUCTS

Aquatic observations characterize channel and lake morphology, organism abundance and diversity, biogeochemistry, seasonal climatic and hydrologic changes, and riparian phenology. These data complement aquatic sensor data that capture hydrologic conditions and surface water and groundwater quantity and quality, as well as local atmospheric conditions and airborne remote sensing survey data. Overall, approximately 65% of the data were collected relative to the plan for Aquatic Observation System (AOS) data products in 2020 (Figure 1), with detailed impacts by aquatic data product listed in Table 1.

Terrestrial observations characterize plant phenology, diversity, biomass, and productivity, as well as the abundance, diversity, phenology, and (for some groups) pathogen status of organisms, including birds, small mammals, ticks, mosquitoes, ground beetles, and soil microbes. Biogeochemical measurements are made on plants and soils, with sampling designed to complement airborne remote sensing and soil sensor data sets. Overall, approximately 52% of the data were collected relative to the plan for Terrestrial Observation System (TOS) data products in 2020 (Figure 1), with detailed impacts by terrestrial data product listed in Table 2.

Some Observation System data products are only planned to be collected once every 5 years at each site, with only a subset of sites sampled for these products each year. The cross-site sampling schedule for the 5-year products has been revised to account for the sampling missed in 2020

to avoid 10-year gaps at any given site. Thus, the overall scientific impact of missed collections of these data products is lower than would be expected for annual products, given the rescheduling efforts (Figure 1).

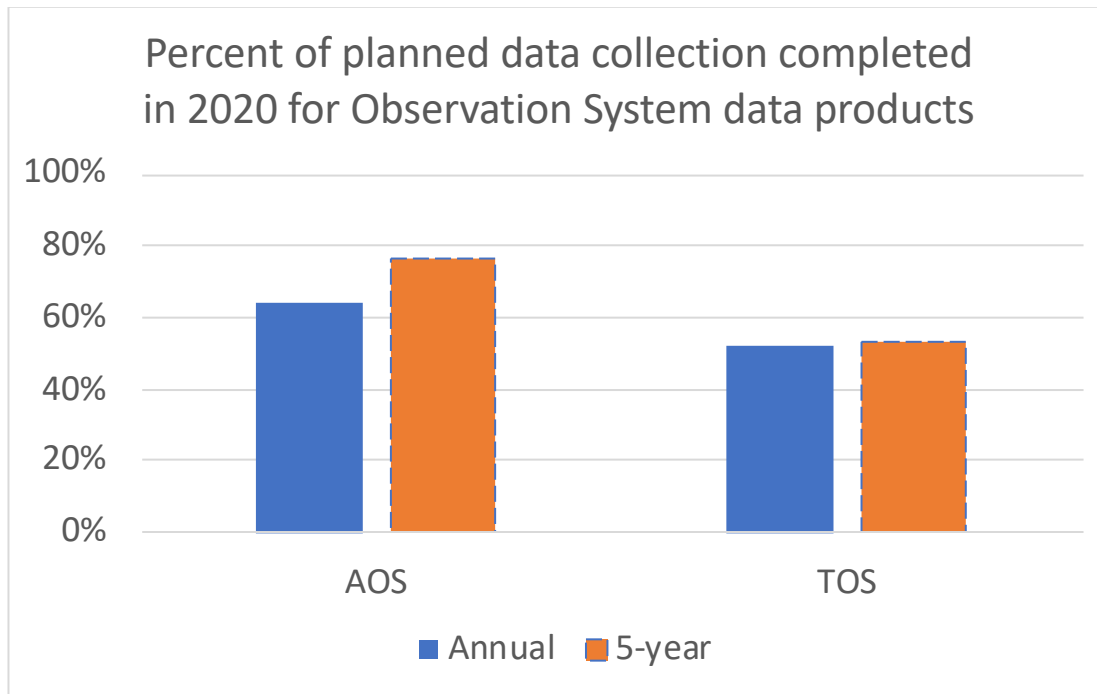Additional documentation on scientific design and methods for observational data products is available at https://www.neonscience.org/data-collection/protocols-standardized-methods.

Figure 1. Percent of planned data collection completed in 2020 for Observation System data products by sampling frequency (at least once annually or every 5-years at a site) and by Subsystem (Aquatic Observation System [AOS] or Terrestrial Observation System [TOS]), demonstrating the successful collection of over 50% of the planned data in the face of COVID-19. AOS collections were more complete than TOS due to the reduced effort generally required for AOS collections relative to TOS; AOS data collection can be completed with smaller teams and shorter sampling windows.

Table 1. Percentage of planned data collection completed in 2020 for Aquatic Observation System data products; lower values are due to impacts of COVID-19, fires, and flooding. AOS data products collected approximately every 5 years at each site are indicated with an asterisk in the name. Fish sampling was the most impacted data product, as it typically requires large (4-6 person) teams to complete and therefore was not feasible in many locations during periods when COVID-19 safety precautions dictated teams of 2.

Data Product ID	Data Product Name	Data Product Description	Percent complete
DP1.20063.001	Aquatic plant bryophyte chemical properties	Carbon (C) and nitrogen (N) concentrations of aquatic plant and bryophytes from benthic collections in lakes, rivers, and wadeable streams	61%
DP1.20066.001	Aquatic plant bryophyte macroalgae clip harvest	Dry weight of aquatic plant, bryophyte, and macroalgae from benthic quadrats in lakes, rivers, and wadeable streams	61%
DP1.20072.001	Aquatic plant, bryophyte, lichen, and macroalgae point counts in wadeable streams	Point counts of aquatic plants, bryophytes, lichens, and macroalgae from transects in wadeable streams	61%
DP1.20086.001	Benthic microbe community composition	Counts and relative abundances of archaeal, bacterial, and fungal taxa observed in benthic microbial communities from wadeable streams	58%
DP1.20277.001	Benthic microbe group abundances	Counts and relative abundances of marker genes from total archaea, bacteria, and fungi observed by qPCR in benthic microbial communities	58%
DP1.20280.001	Benthic microbe marker gene sequences	DNA sequence data from ribosomal RNA marker genes from benthic samples	58%
DP1.20279.001	Benthic microbe metagenome sequences	Metagenomic sequence data from benthic samples	58%
DP1.20092.001	Chemical properties of groundwater	Grab samples of groundwater chemistry including general chemistry, anions, cations, and nutrients.	78%
DP1.20093.001	Chemical properties of surface water	Grab samples of surface water chemistry including general chemistry, anions, cations, and nutrients.	68%
DP1.20254.001	Depth profile at specific depths	Measurements of water column temperature and depth profile in non-wadeable streams and lakes	68%

DP1.20048.001	Discharge field collection	Discharge measurements from field-based surveys (provides inputs to DP4.00133 Stage-discharge rating curves and DP4.00130 Continuous discharge)	61%
DP1.20097.001	Dissolved gases in surface water	Grab samples of surface water dissolved gases including carbon dioxide, methane, and nitrous oxide	68%
DP1.20107.001	Fish electrofishing, gill netting, and fyke netting counts	Counts of fish from electrofishing surveys in wadeable streams, or electrofishing, gill netting, and/or fyke netting surveys in lakes. Includes fish standard length and individual mass	31%
DP1.20105.001	Fish sequences DNA barcode	CO1 DNA sequences from select fish in lakes and wadeable streams	47%
DP1.20120.001	Macroinvertebrate collection	Collection of benthic macroinvertebrates using multiple sampling methods in lakes, rivers, and wadeable streams	73%
DP1.20126.001	Macroinvertebrate metabarcoding	CO1 DNA sequences of the aquatic macroinvertebrate community	73%
DP1.20163.001	Periphyton, seston, and phytoplankton chemical properties	Carbon (C), nitrogen (N), phosphorus (P), isotopes, chlorophyll a, and pheophytin of periphyton and phytoplankton from benthic and water column samples in lakes, rivers, and wadeable streams	68%
DP1.20166.001	Periphyton, seston, and phytoplankton collection	Collection and biomass of periphyton and phytoplankton using multiple benthic and water column sampling methods in lakes, rivers, and wadeable streams	68%
DP1.20190.001	Reaeration field and lab collection	Field and external laboratory data from the salt-tracer and gas injection field reaeration measurements, including stream widths, inert gas concentrations, conservative tracer concentrations, and conductivity times series.	57%
DP1.20275.001	Riparian composition and structure	Assessment of riparian vegetation composition and physical structure in lakes, non-wadeable streams, and wadeable streams	50%
DP1.20191.001	Riparian vegetation % cover	Assessment of riparian vegetation percent cover in wadeable streams	52%
DP1.20193.001	Salt-based stream discharge	Discharge measured using a constant-rate addition salt tracer during reaeration measurements	57%

DP1.20252.001	Secchi depth	Measurement of water column Secchi depth in non-wadeable streams and lakes	68%
DP1.20194.001	Sediment chemical properties	Field collection and analysis of nutrients, carbon, inorganic and organic contaminants in sediments of wadeable streams, rivers, and lakes	64%
DP1.20197.001	Sediment physical properties	Field collection and analysis of size and texture of sediments in wadeable streams, rivers, and lakes	64%
DP1.20276.001	Stable isotopes in groundwater	Grab samples for stable isotopes of water in groundwater	78%
DP1.20206.001	Stable isotopes in surface water	Grab samples for stable isotope chemistry including water and particulate organic matter, in lakes, rivers, and wadeable streams	68%
DP1.20138.001	Surface water microbe cell count	Cell counts from surface water microbial collection in lakes, wadeable streams, and non-wadeable streams	63%
DP1.20141.001	Surface water microbe community composition	Counts and relative abundances of archaeal, bacterial, and fungal taxa observed in surface water microbial communities in lakes, rivers and streams	63%
DP1.20278.001	Surface water microbe group abundances	Counts and relative abundances of marker genes from total archaea, bacteria, and fungi observed by qPCR in surface water microbial communities	63%
DP1.20282.001	Surface water microbe marker gene sequences	DNA sequence data from ribosomal RNA marker genes from surface water samples	63%
DP1.20281.001	Surface water microbe metagenome sequences	Metagenomic sequence data from surface water samples	63%
DP1.20219.001	Zooplankton collection	Collection of zooplankton from water column samples in lakes	100%
DP1.20221.001	Zooplankton metabarcoding	CO1 DNA sequences of the zooplankton community	100%
DP4.00132.001	Bathymetric and morphological maps*	Bathymetry of lake bottoms and non-wadeable streams for detecting environmental change as well as for determining lake morphology, estimating primary productivity, habitat features, and water quality.	86%
DP4.00131.001	Stream morphology map*	Map showing the morphology of streams. These maps denote topography of the stream basin as well as location of the thalweg, coarse woody debris, gravel/sand bars, and other features of interest.	67%

Table 2. Percentage of planned data collection completed in 2020 for Terrestrial Observation System data products; lower values are primarily due to impacts of COVID-19, fires, and flooding. Data products collected approximately every 5 years at each site are indicated with an asterisk in the name. Small mammal sampling was one of the most impacted data products, as it typically requires large (4-6 person) teams to complete and therefore was not feasible in many locations during periods when COVID-19 safety precautions dictated teams of 2. Tick and mosquito sampling were also significantly impacted, as these sampling efforts were not prioritized at sites with historically low capture rates. A minimum number of plots were prioritized for herbaceous clip harvest; thus, some data were collected at many sites, but the percent complete is low as it represents percentage of total plots expected.

Data Product ID	Data Product Name	Data Product Description	Percent complete
DP1.10003.001	Breeding landbird point counts	Count, distance from observer, and taxonomic identification of breeding landbirds observed during point counts	83%
DP1.10014.001	Coarse downed wood bulk density sampling*	Raw bulk density measurements of coarse downed wood >= 2 cm diameter	56%
DP1.10010.001	Coarse downed wood log survey*	Tally and raw measurement of coarse downed wood >= 2 cm diameter	39%
DP1.10017.001	Digital hemispheric photos of plot vegetation - Distributed plots*	Upward and/or downward facing digital 180-degree images of vegetation in plots used to calculate leaf area index	52%
DP1.10017.001	Digital hemispheric photos of plot vegetation - Tower plots	Upward and/or downward facing digital 180-degree images of vegetation in plots used to calculate leaf area index	41%
DP1.10020.001	Ground beetle sequences DNA barcode	CO1 DNA sequences from select ground beetles	TBD (not yet processed)
DP1.10022.001	Ground beetles sampled from pitfall traps	Taxonomically identified ground beetles and the plots and times from which they were collected.	40%

DP1.10023.001	Herbaceous clip harvest	Dry weight of herbaceous vegetation harvested from individual clip strips, by functional type	31%
DP1.10033.001	Litterfall and fine woody debris production and chemistry*	Dry weight of litterfall and fine woody debris collected from elevated and ground traps, sorted to functional group, as well as periodic measurements of litter chemistry and stable isotopes	Annual production 60%; 5-year chemistry 57%
DP1.10038.001	Mosquito sequences DNA barcode	CO1 DNA sequences from select mosquitoes	100%
DP1.10041.001	Mosquito-borne pathogen status	Presence/absence of a pathogen in a single mosquito sample (pool)	36%
DP1.10043.001	Mosquitoes sampled from CO2 traps	Taxonomically identified mosquitoes and the plots and times from which they were collected	47%
DP1.10045.001	Non-herbaceous perennial vegetation structure	Field measurements of individual non-herbaceous perennial plants (e.g. cacti, ferns)	38%
DP1.10026.001	Plant foliar traits	Traits of sun-lit canopy plants reported at the level of the individual (woody plants) or community (herbaceous plants).	65%
DP1.10055.001	Plant phenology observations	Phenophase status and intensity of tagged plants	38%
DP1.10058.001	Plant presence and percent cover	Plant species cover-abundance and presence observed in multi-scale plots. Plant species and associated percent cover in 1m2 subplots and plant species presence in 10m2 and 100m2 subplots are reported from 400m2 plots. Archived plant vouchers and foliar tissue support the data and additional analyses.	57%
DP1.10064.001	Rodent-borne pathogen status	Presence/absence of a pathogen (or antibodies to a pathogen) in each single	NA (planned

		rodent sample. From 2014-2019 samples were tested for hantaviruses and, starting in 2020, they will be tested for tick-borne pathogens.	pilot year for tick pathogens only)
DP1.10067.001	Root biomass and chemistry, periodic*	Fine root biomass to 30cm depth via soil core sampling. Includes root carbon (C) and nitrogen (N) concentrations and stable isotopes.	62%
DP1.10072.001	Small mammal box trapping	Individual- and trap-level data collected using box traps designed to capture small mammals	37%
DP1.10076.001	Small mammal sequences DNA barcode	CO1 DNA sequences from select small mammals	50%
DP1.10080.001	Soil inorganic nitrogen pools and transformations*	Soil inorganic nitrogen concentrations from the top 30 cm of the profile. Data are reported by horizon (organic vs. mineral) within a soil core. Data from incubated samples can be used to estimate rates of net nitrogen mineralization and net nitrification	47%
DP1.10104.001	Soil microbe biomass	Quantitative abundance of microbes in soil samples	58%
DP1.10081.001	Soil microbe community composition	Counts and relative abundances of archaeal, bacterial, and fungal taxa observed in soil microbial communities	58%
DP1.10109.001	Soil microbe group abundances	Counts and relative abundances of marker genes from total archaea, bacteria, and fungi observed by qPCR in soil microbial communities	58%
DP1.10108.001	Soil microbe marker gene sequences	DNA sequence data from ribosomal RNA marker genes from soil samples	58%

DP1.10107.001	Soil microbe metagenome sequences	Metagenomic sequence data from soil samples	58%
DP1.10086.001	Soil physical and chemical properties, periodic*	Soil physical and chemical properties from the top 30 cm of the profile from periodic soil core collections. Data are reported by horizon (mineral vs. organic). See initial characterization and megapit products for additional soil data.	60%
DP1.10092.001	Tick-borne pathogen status	Presence/absence of a pathogen in each single tick sample	37%
DP1.10093.001	Ticks sampled using drag cloths	Abundance and density of ticks collected by drag and/or flag sampling (by species and/or lifestage)	37%
DP1.10098.001	Woody plant vegetation structure	Structure measurements, including height, crown diameter, and stem diameter, as well as mapped position of individual woody plants	60%

2   IMPACTS TO AIRBORNE OBSERVATION PLATFORM DATA PRODUCTS

The Airborne Observation Platform (AOP) conducts remote sensing surveys over areas where NEON's observational and instrumented sampling is occurring and allows relationships to be drawn between NEON's detailed *in situ* observations to the broader environmental and ecological conditions.

Following the restart of operations in May 2020 after suspension of planned flights on March 23, 2020, flights were replanned to conduct campaigns that could be efficiently reached without requiring commercial air travel for the sensor operators. Collections over 6 Domains originally planned to be sampled were cancelled, while 3 Domains were *added* to the 2020 flight plan (Figure 2). A total of 7 domains were flown successfully in 2020, representing approximately 58% of the pre-COVID-19 plan (i.e., 12 domains). All 28 AOP data products derived from the aircraft were equally impacted by COVID-19 and were successfully completed for all flown domains, with minor impacts of non-COVID related issues. The field spectra data product, the AOP data product not generated from aircraft observations, was rescheduled from YELL to RMNP in 2020 to limit travel for AOP scientists.

Additional documentation on scientific design and methods for airborne remote sensing data products is available at
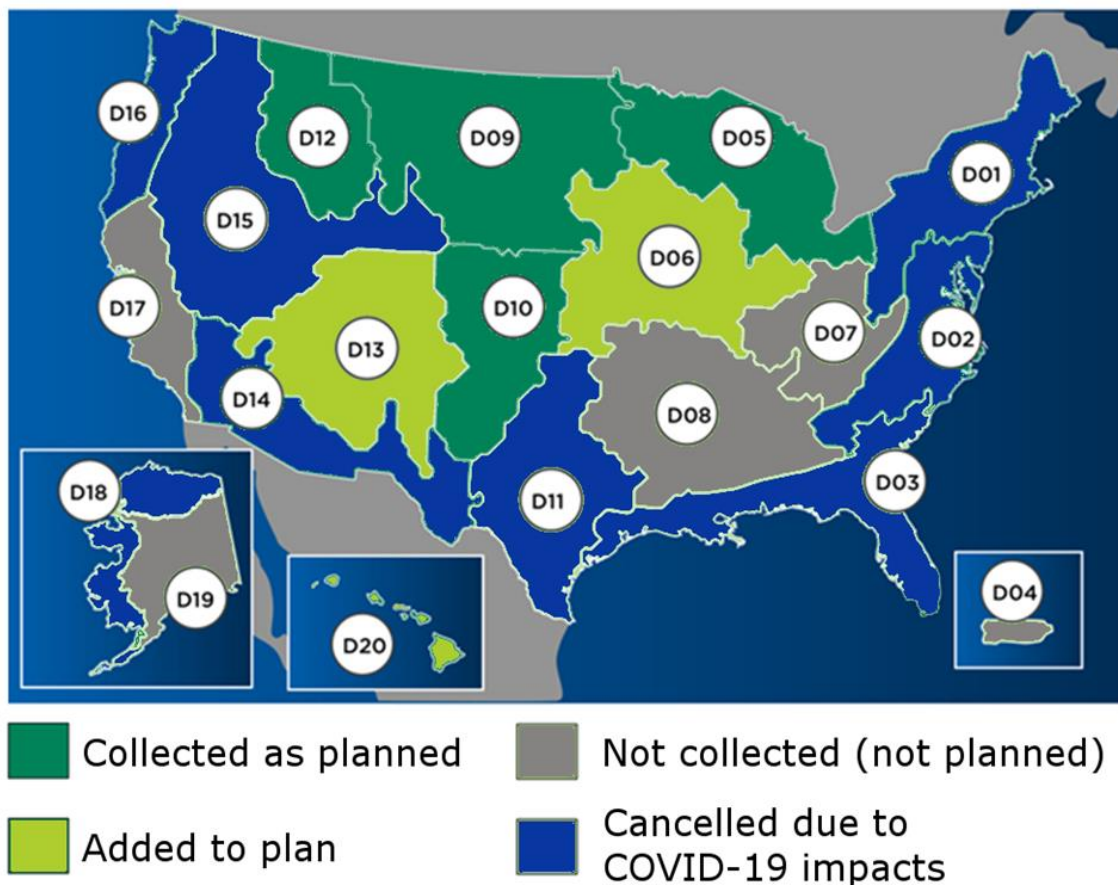https://www.neonscience.org/data-collection/airborne-remote-sensing.

Figure 2. Map of the AOP 2020 flight campaign indicating the domains with data successfully collected relative to the pre-COVID-19 plan; domains close to NEON Headquarters in D10 were prioritized to reduce travel for airborne sensor operators. Approximately 58% of the planned data was collected in 2020, due to the shortened flight season and safety precautions taken in the face of COVID-19.

3   IMPACTS TO AQUATIC AND TERRESTRIAL INSTRUMENT SYSTEM DATA PRODUCTS

At aquatic field sites, NEON deploys *in situ* sensor stations to collect surface water quality, temperature, and depth measurements, groundwater wells, a riparian meteorological station, precipitation gauges, and phenocams. At terrestrial field sites, NEON deploys a micrometeorological tower, a soil sensor array, precipitation gauges, and phenocams. Additional documentation on scientific design and methods for instrument system data products is available at https://www.neonscience.org/data-collection/automated-instruments.

Routine maintenance and field calibration were interrupted starting in March 2020, with Observatory staff responding only to issues prioritized based on the potential for damage to infrastructure. Multiple NEON field offices restarted operations on May 18, 2020 and were able to resume calibration of aquatic sensors to restore data streams to expected accuracy. We expanded our response strategy in mid-June for sites that remained closed to allow staff to respond to site outages to restore power and communications and conduct corrective maintenance on high priority sensors. The expanded strategy did not include routine (monthly) field calibrations of sonde or SUNA sensors in Domains that remained closed due to COVID-19 conditions. Wildfires in Colorado, California, Oregon and Washington also impacted site access and our ability to maintain sensor systems in fall 2020.

In a year without natural disasters, sensor uptime is expected to be around 90% due to impacts of local utility power outages, scheduled maintenance, and routine equipment failure. In 2020, the reduced maintenance and field calibrations described above, combined with COVID-19 impacts on the suppliers for sensors and associated parts that reduced availability and delayed shipments, further negatively impacted the uptime of a number of sensors. Aquatic Instrument System (AIS) data products were more significantly impacted than Terrestrial Instrument System (TIS) data products (70% vs. 89%; Figure 3), due to a subset of sites that were not able to be restored following vandalism, flooding damage, or fuel cell power failures that occurred in 2020. Uptimes by instrument system data product are detailed in Tables 3 and 4 below.
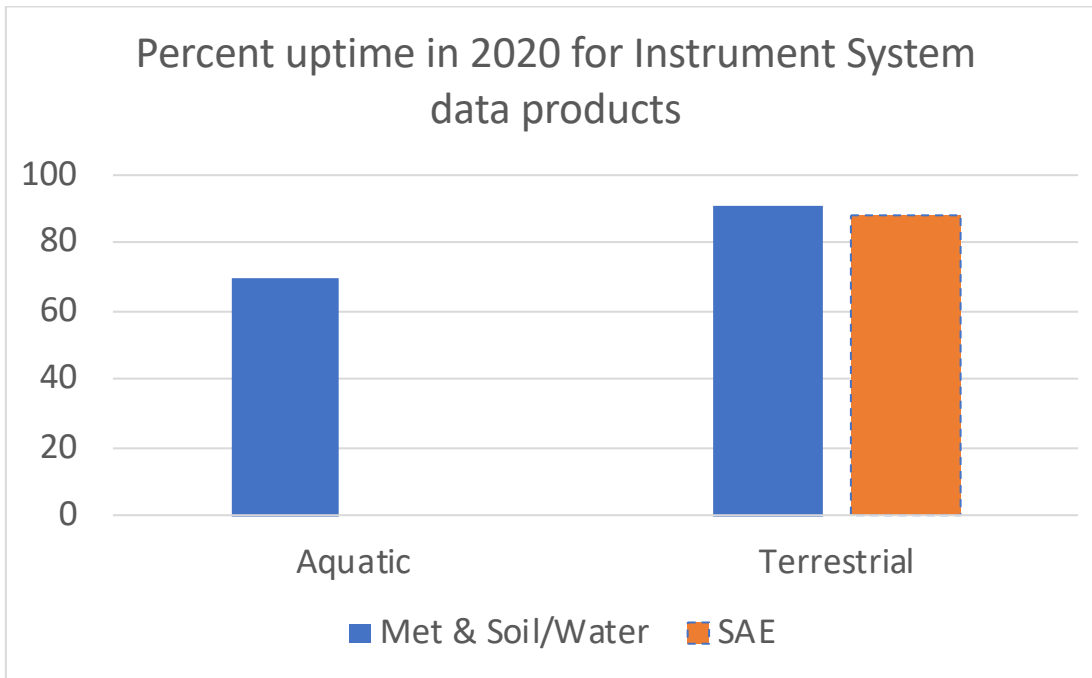
Figure 3. Percent uptime in 2020 for Instrument System data products by Site Type (Aquatic vs. Terrestrial) and by sensor set (meteorological (met) and in-water/in-soil sensors) vs. Surface-Atmosphere Exchange sensors [SAE]), demonstrating the continued collection of a majority of IS data in the face of COVID-19. Aquatic instruments were more significantly impacted than terrestrial instruments due to a subset of sites that were not able to be restored following vandalism, flooding damage, or fuel cell power failures that occurred in 2020.

Table 3. Percent uptime of sensors in 2020 for Aquatic Instrument System data products, with relatively low availability primarily due to impacts of COVID-19, as well as fires, power, and flooding at a subset of sites. Specifically, the on-buoy and other buoy-deployed data products (e.g., DP1.20264.001 Temperature at specific depth in surface water) were the most impacted, given the delays in restoring the damaged buoys at D03 FLNT, D08 TOMB and D08 BLWA due to COVID-19.

Raw Data Stream ID	Raw Data Stream Name	Published Data Product ID(s)	Published Data Product Name (if different)	Percent uptime 2020
DP0.00001	2D Wind Speed and Direction	DP1.00001.001		85%
DP0.00002	Single Aspirated Air Temperature	DP1.00002.001		84%
DP0.00004	Barometric Pressure	DP1.00004.001		87%
DP0.00006	Precipitation	DP1.00006.001		48%
DP0.00023	Shortwave and longwave radiation (net radiometer)	DP1.00023.001		88%
DP0.00024	Photosynthetically active radiation (PAR)	DP1.00024.001		88%
DP0.00098	Relative humidity	DP1.00098.001		85%
DP0.20004	Barometric pressure above water on-buoy	DP1.20004.001		54%
DP0.20005	Water Quality	DP1.20288.001		73%
DP0.20015	Specific conductivity, temperature, and elevation of groundwater	DP1.20015.001; DP1.20217.001; DP1.20100.001	Specific conductivity in groundwater; Temperature of groundwater; Elevation of groundwater	75%
DP0.20016	Elevation of surface water	DP1.20016.001		81%
DP0.20032	Shortwave and longwave radiation above water on-buoy (net radiometer)	DP1.20032.001		47%
DP0.20033	Nitrate in surface water	DP1.20033.001		64%
DP0.20042	Photosynthetically active radiation at water surface	DP1.20042.001		79%
DP0.20053	Temperature (PRT) in surface water	DP1.20053.001		82%
DP0.20059	Windspeed and direction above water on-buoy	DP1.20059.001		49%
DP0.20261	Photosynthetically active radiation below water surface	DP1.20261.001		61%

	Temperature at specific depth			
DP0.20264	in surface water	DP1.20264.001		41%
DP0.20271	Relative humidity and temperature above water on-buoy	DP1.20271.001; DP1.20046.001	Relative humidity above water on-buoy; Air temperature above water on-buoy	50%

Table 4. Percent uptime of sensors in 2020 for Terrestrial Instrument System (TIS) data products, demonstrating relatively limited impacts of COVID-19. Precipitation was the most impacted TIS data product, as primary precipitation sensors (weighing gauge housed within a small double fence intercomparison reference; DP1.00006) that use hazardous chemicals were covered and shut down during the temporary suspension of operations at sites with risk of overflow to avoid environmental contamination.

Raw Data Stream ID	Raw Data Stream Name	Published Data Product ID(s)	Published Data Product Name (if different)	Percent uptime 2020
DP0.00001	2D Wind Speed and Direction	DP1.00001.001		92%
DP0.00002	Single Aspirated Air Temperature	DP1.00002.001		93%
DP0.00003	Triple Aspirated Air Temperature	DP1.00003.001		93%
DP0.00004	Barometric Pressure	DP1.00004.001		94%
DP0.00005	IR Biological Temperature	DP1.00005.001		94%
DP0.00006	Precipitation	DP1.00006.001		75%
DP0.00014	Shortwave radiation (direct and diffuse pyranometer)	DP1.00014.001		96%
DP0.00017	Dust and particulate size distribution	DP1.00017.001		82%
DP0.00022	Shortwave radiation (primary pyranometer)	DP1.00022.001		94%
DP0.00023	Shortwave and longwave radiation (net radiometer)	DP1.00023.001		94%
DP0.00024	Photosynthetically active radiation (PAR)	DP1.00024.001		95%

DP0.00040	Soil heat flux plate	DP1.00040.001		94%
DP0.00041	Soil temperature	DP1.00041.001		83%
DP0.00066	Photosynthetically active radiation (quantum line)	DP1.00066.001		94%
DP0.00094	Soil water content and water salinity	DP1.00094.001		80%
DP0.00095	Soil CO2 concentration	DP1.00095.001		91%
DP0.00098	Relative humidity	DP1.00098.001		91%
DP0.00007	3D wind speed, direction and sonic temperature	DP4.00200.001	Bundled data products - eddy covariance	89%
DP0.00016	ECTE Infrared Gas Analzer (Turbulent CO2 & H2O)	DP4.00200.001	Bundled data products - eddy covariance	89%
DP0.00102	Atmospheric CO2 Isotope	DP4.00200.001	Bundled data products - eddy covariance	85%
DP0.00103	Atmospheric H2O isotopes	DP4.00200.001	Bundled data products - eddy covariance	87%
DP0.00105	ECSE profile CO2 & H2O concentration (storage)	DP4.00200.001	Bundled data products - eddy covariance	70%
DP0.00106	ECSE profile mass flow controller (sampling)	DP4.00200.001	Bundled data products - eddy covariance	95%
DP0.00108	ECSE profile mass flow meter	DP4.00200.001	Bundled data products - eddy covariance	93%