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Studies of Emissions and Atmospheric Composition, Clouds, and Climate Coupling by Regional Surveys (SEAC4RS) Field Campaign Report

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Studies of Emissions and Atmospheric Composition, Clouds, and Climate Coupling by Regional Surveys (SEAC4RS) Field Campaign Report

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Acronyms and Abbreviations

CPI	Cloud Particle Imager
DU	University of Denver
FCDP	Fast Cloud Droplet Probe
FFSSP	Fast Forwarding Scattering Spectrometer Probe
HVPS	High-Volume Precipitation Spectrometer
LWC	liquid water cloud
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NMASS	Nucleation Mode Aerosol Size Spectrometer
PCASP	Passive Cavity Aerosol Spectrometer Probe
PNNL	Pacific Northwest National Laboratory
SEAC4RS	Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys
TWC	total water cloud
2D-S	(Stereo) Optical Array Spectrometer

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1.0 Introduction

Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS), a National Aeronautics and Space Administration (NASA) field campaign, was based out of Ellington Field in Houston, Texas, during August and September 2013. The study focused on pollution emissions and the evolution of gases and aerosols in deep convective outflow, and the influences and feedbacks of aerosol particles from anthropogenic pollution and biomass burning on meteorology, clouds, and climate. The project required three aircraft to accomplish these goals. The NASA DC-8 provided observations from near the surface to 12 km, while the NASA ER-2 provided high-altitude observations reaching into the lower stratosphere as well as important remote-sensing observations connecting satellites with observations from lower-flying aircraft and surface sites. The SPEC, Inc. Learjet obtained aerosol and cloud microphysical measurement in convective clouds and convective outflow.

The three aircraft flew over 50 flight missions, mostly over the southeastern United States. The heavily instrumented aircraft measured cloud, aerosol, and trace gas properties, at times flying simultaneously through storms and above them to maximize data capture.

During the SEAC4RS field campaign SPEC, Inc. and the National Center for Atmospheric Research (NCAR) collaborated to deploy instruments on the NASA DC-8, NASA ER-2, and the SPEC Learjet. SPEC deployed cloud particle probes on all three aircraft. In addition, the University of Denver (DU) deployed aerosol instruments onboard the SPEC Learjet. SPEC, NCAR, and DU staff participated in the field project and provided support for operation of the instruments. This report describes the preparation and operation of these instruments during SEAC4RS.

2.0 Instrumentation deployed during SEAC4RS

Table 1 lists the SPEC instruments installed on the NASA ER-2 and DC-8. On the DC-8 the Fast Cloud Droplet Probe (FCDP), the (Stereo) Optical Array Spectrometer (2D-S), and High-Volume Precipitation Spectrometer (HVPS) were installed on the right wing tip (Figure 1) and the Cloud Particle Imager (CPI) on the left wing tip. The data from all probes on the DC-8 were displayed on a monitor at the SPEC scientist station (Figure 2). Data from each of the probes was saved on hard drives on individual data system computers. These data were retrieved after each flight, processed, and uploaded on the NASA SEAC4RS data server.

Table 1. Cloud instrumentation deployed on the NASA ER-2 and DC-8.

Aircraft	Instrument	Property Measured	Diameter Size Range
ER-2	Fast Cloud Droplet Probe (FCDP)	Cloud droplet/ice particle size	2 to 50 μm
DC-8	Fast Cloud Droplet Probe (FCDP)	Cloud droplet/ice particle size	2 to 50 μm
DC-8	2D-S (Stereo) Optical Array Spectrometer	Cloud hydrometeor size and image	10 μm to 3 mm
DC-8	High-Volume Precipitation Spectrometer (HVPS)	Cloud hydrometeor size and image	150 μm to 2 cm
DC-8	Cloud Particle Imager (CPI)	Cloud hydrometeor size and image	

Figure 1. SPEC, Inc. instruments installed on the NASA DC-8 during SEAC4RS.

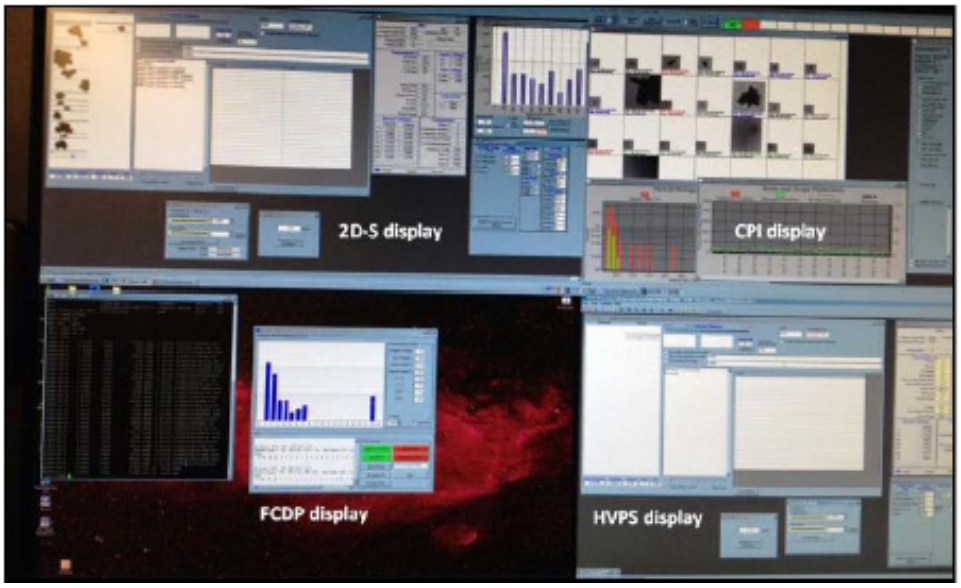

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Figure 2. The SPEC, Inc. computer monitor in the DC-8 during SEAC4RS, with four screens, each dedicated to a specific cloud probe instrument.

The SPEC Learjet deployed during SEAC4RS was equipped with a complete suite of cloud microphysical instruments (e.g., FCDP, Fast Forwarding Scattering Spectrometer Probe (FFSSP), 2D-S, CPI, HVPS, Nevzorov Liquid Water Cloud/Total Water Cloud (LWC/TWC) and state (e.g., temperature, pressure) and aircraft parameters (e.g., altitude, position, heading, airspeed) measurements. In addition to SPEC's cloud spectrometer probes, the Learjet was also equipped with the DU Nucleation Mode Aerosol Size Spectrometer (NMASS) and a Passive Cavity Aerosol Spectrometer Probe (PCASP) that was modified to reduce the decrease in volume flow rate with increasing altitude above the boundary layer. With all these instruments onboard, the Learjet was able to carefully document regions of warm rain, supercooled water drops, and mixed-phase and glaciated regions of cloud, including images of ice particles (ranging from a few micrometers to several millimeters) that are automatically classified into ice particle habits. The aerosol instrumentation also permitted the identification of the formation and growth of new aerosol particles in regions affected by deep convective outflow.

Table 2. Instrumentation deployed on the SPEC Learjet.

Equipment List	Manufacturer	Range	Accuracy
Temperature	Rosemount Model 102 & 510BH Amplifier	−50 to +50 °C	0.5 °C
Altitude	Royal Air FAA RVSM Certification	0 to 45,000 ft (0 to 13.7 km)	60 ft (18.3 m)
Airspeed	Royal Air FAA RVSM Certification	0 to 220 m s^{-1}	1 m s^{-1}
Cloud Liquid Water (2)	Sky Tech Nevorov LWC Probe	0 to 4 g m^{-3}	N/A
Cloud Total Water (2)	Sky Tech Nevzorov TWC Probe	0 to 4 g m^{-3}	N/A
Aircraft Position	Aventech AIMMS-20 Differential GPS	N/A	10 m
Aircraft Heading	Learjet Sperry Directional Gyro	0 to 360°	1°
Horizontal Wind	Aventech AIMMS-20	0 to 360° 1 to 100 m s^{-1}	1° 1 m s^{-1}
Vertical Wind	Aventech AIMMS-20	0 to 50 m s^{-1}	0.5 m s^{-1}
2D-S (Stereo) Optical Array Spectrometer	SPEC Model OAP 2D-S	10 µm to 3 mm	10 µm
Fast Cloud Droplet Probe	SPEC Model FCDP-100	2 to 50 µm	2 µm
Fast Forward Scattering Spectrometer Probe (FFSSP)	SPEC Model FFSSP-100	2 to 50 µm	2 µm
High-Volume Precipitation Spectrometer (HVPS)	SPEC Version-3 HVPS	150 µm to 2 cm	150 µm
Combination FCDP, 10 and 50 µm 2D-S, V 2.5 CPI	SPEC Hawkeye	1 µm to 6.4 mm	FCDP: 1 µm 2D-S: 10 to 50 µm CPI: 2.3 µm
Nucleation Mode Aerosol Size Spectrometer (NMASS)	University of Denver	4 nm to 0.1 µm	5 size bins
Passive Cavity Aerosol Spectrometer Probe (PCASP)	Particle Measuring Systems modified by University of Denver	0.1 to 3 µm	0.05 µm

3.0 Instrument performance and data quality

Overall, the SPEC instrumentation payload on the ER-2, DC-8, and Learjet worked well. The scientists and instrument technicians were able to maintain the instruments as operational and collecting good data throughout the campaign. Routine instrument checks and maintenance were the standard procedure. The

SPEC instruments on the DC-8 aircraft were exposed to the natural elements and the instruments had to be routinely removed for maintenance, especially after episodes of heavy rainfall. Also, the DC-8 flew routinely at low altitude for extended periods, which exposed the probes to overheating. When an instrument issue arose, the necessary parts were quickly replaced and in most cases the issue was resolved.

Table 3 summarizes the instrument status for each NASA DC-8 and ER-2 flight during SEAC4RS. Assessment of the data quality was done immediately after each flight by scientists on the SPEC team. "Green" means that the data are available and appear good based on bounds checking and cursory comparisons with similar data streams. "Yellow" indicates that the data has been inspected and there are problems with data quality. These data could be corrected, but this cannot be confirmed for each case. "Red" and "Blue" indicate that the data are unusable or erroneous, or that no data was collected.

Table 3. DC-8 and ER-2 SEAC4RS data quality.

DC-8 Aircraft						ER-2 Aircraft		
Flight #	Date	FCDP	2D-S	CPI	HVPS	Flight #	Date	FCDP
R1	2-Aug-13	✓	✓	✓	✓	R1	1-Aug-13	✓
R2	5-Aug-13	✓	✓	✓	✓	R2	2-Aug-13	✓
S1	6-Aug-13	✓	✓	✓	✓	S1	6-Aug-13	✓
S2	8-Aug-13	✓	✓	✓	✓	S2	8-Aug-13	✓
S3	12-Aug-13	✓	✓	✓	✓	S3	12-Aug-13	✓
S4	14-Aug-63	✓	✓	✓	✓	S4	14-Aug-13	✓
S5	16-Aug-13	✓	✓	✓	✓	S5	16-Aug-13	✓
S6	19-Aug-13	✓	✓	✓	✓	S6	19-Aug-13	✓
S7	21-Aug-13	✓	✓	✓	✗	S7	21-Aug-13	✓
S8	23-Aug-13	✓	✓	✓	✓	S8	23-Aug-13	✓
S9	26-Aug-13	✓	✓	✓	✓	S9	27-Aug-13	✓
S10	27-Aug-13	✓	✓	✓	✓	S10	30-Aug-13	✓
S11	30-Aug-13	✓	✓	✓	✓	S11	2-Sep-13	✓
S12	2-Sep-13	✓	✓	✓	✓	S12	4-Sep-13	✓
S13	4-Sep-13	✓	✓	✓	✓	S13	6-Sep-13	✓
S14	6-Sep-13	✓	✓	✓	✓	S14	9-Sep-13	✓
S15	9-Sep-13	✓	✓	✓	✓	S15	11-Sep-13	✓
S16	11-Sep-13	✓	✓	✓	✓	S16	13-Sep-13	✓
S17	13-Sep-13	✓	✓	✓	✓	S17	16-Sep-13	✓
S18	16-Sep-13	✓	✓	✓	✓	S18	18-Sep-13	✓
S19	18-Sep-13	✓	✓	✓	✓	S19	22-Sep-13	✓
S20	21-Sep-13	✓	✓	✓	✓	S20	23-Sep-13	✓
S21	23-Sep-13	✓	✓	✓	✓			

✓ Good data
⚠ Data issues that require care

DC-8 Aircraft						ER-2 Aircraft		
Flight #	Date	FCDP	2D-S	CPI	HVPS	Flight #	Date	FCDP
✗ No data or data not useful								

4.0 Performance of the FCDP Onboard the DC-8 during September 4, 2013 Sampling of Convective Clouds over the Gulf of Mexico

For this example, the SPEC Learjet and the NASA DC-8 flew coordinated research flights through convective cloud systems over the Gulf of Mexico. A complementary set of measurements were obtained from both aircraft. For this report, we focus on the FCDP observations onboard the DC-8 in the context of the other cloud microphysical observations on the DC-8.

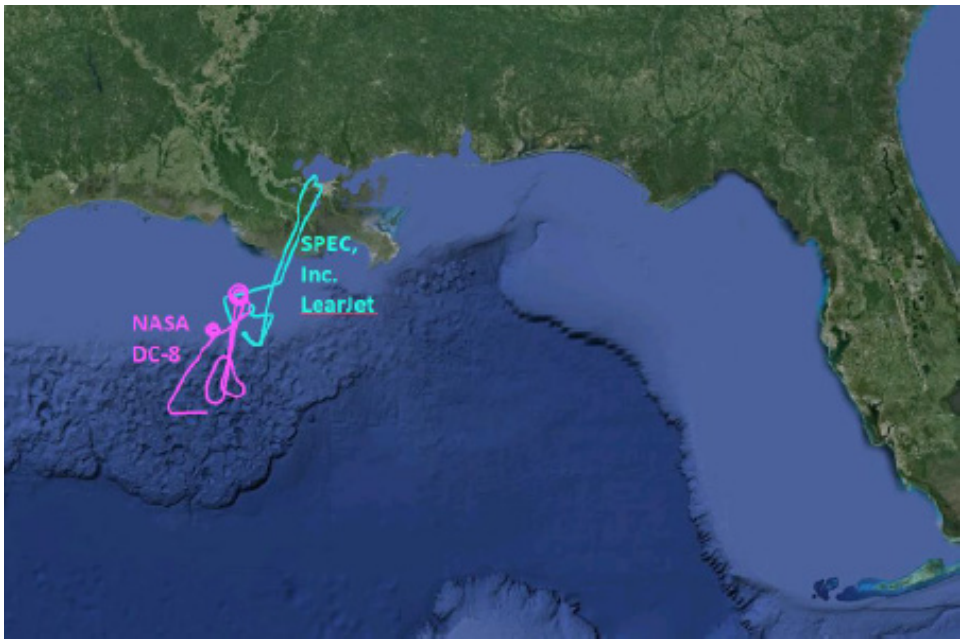

Figure 3. Flight tracks over the Gulf of Mexico for the NASA DC-8 and SPEC Learjet on 4 September 2013.

Simultaneous observations from the HVPS, 2D-S, and FCDP onboard the DC-8 are shown in Figure 5 below at ~20–28 kft altitude for a short duration during the flight when several cloud penetrations were obtained in rapid succession. The ambient temperature during these cloud penetrations was typically ~−10°C, but as low as −25°C during the early part of this time series. The cloud particle observations shown are particle size distributions, with vertical axis representing the particle size in microns, horizontal axis representing the time of the measurement, and color scale representing the concentration of particles at that size (diameter) and at that time. There are periods when the 2D-S and HVPS both detected relatively large particles (e.g., ~200–1000 μm), while the FCDP (which has a nominal size range of 2–50 μm) reported very low concentrations (e.g., at ~13:47 UTC), indicating that shattering of precipitation particles did not significantly contaminate the FCDP measurements.

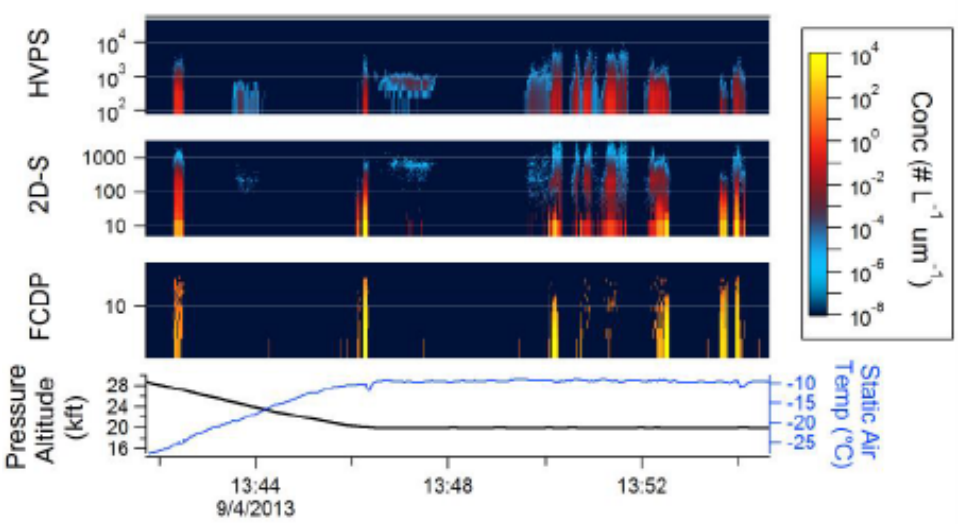

Figure 4. Cloud probe measurements onboard the NASA DC-8 for a sample of the 4 September 2013 flight.

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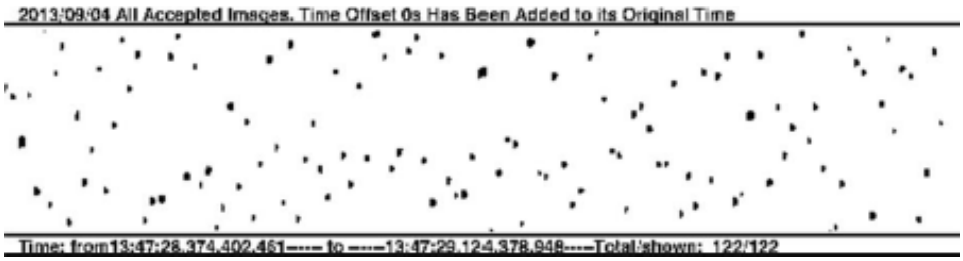

Figure 5. Particle images obtained by the HVPS during a precipitation event intercepted at 13:47 UTC during the 4 September 2013 NASA DC-8 flight.

Cloud microphysical observations from onboard the NASA DC-8 for a cloud penetration later during the 4 September 2013 flight are shown below in Figure 6. The HVPS and 2D-S measurements both show that large particles (> 1mm) were intercepted throughout the cloud pass, but the FCDP responds only to the portion of the cloud pass when the 2D-S observations also showed many particles < 50 um (i.e., just prior to 15:45).

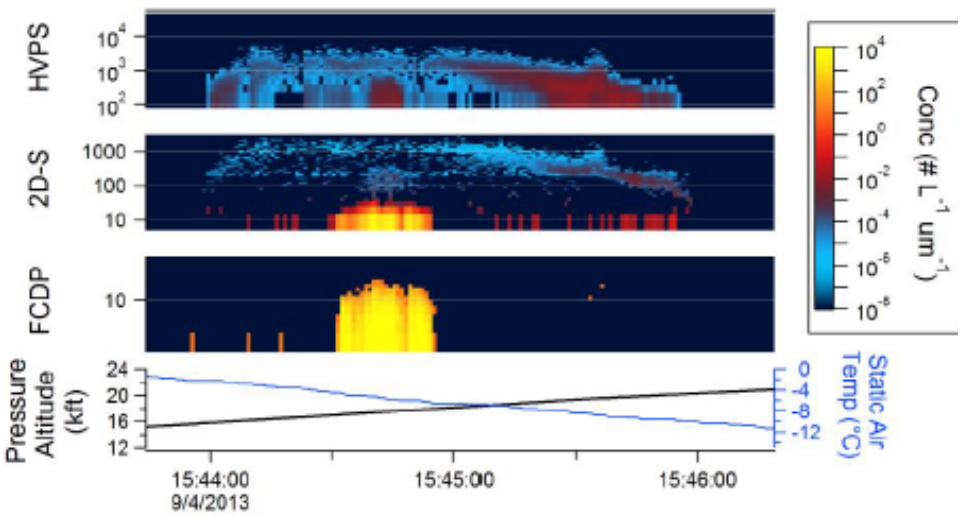

Figure 6. Same as Figure 4 but for a later portion of the 4 September 2013 flight.

The particle size distributions from each of the cloud probe measurements are averaged over this time period and displayed in Figure 7, exhibiting excellent agreement in the measurements over a large range of particle sizes.

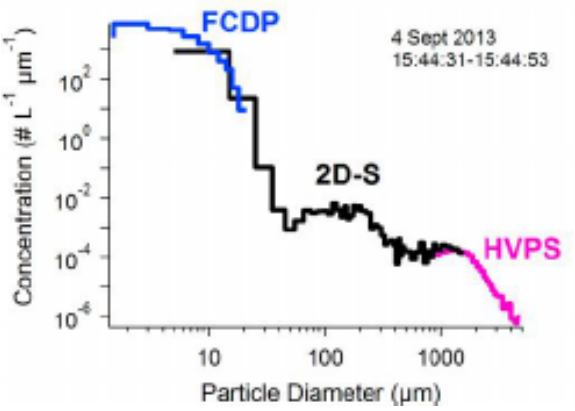

Figure 7. Particle size distributions for a cloud pass on the 4 September 2013 NASA DC-8 flight.

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