Table 6.3
NSF/NCAR C-130Q Hercules (N130AR)
Aircraft Instrumentation Specifications
Cloud Physics Sensors

<table>
<tr><th>Variable Measured</th><th>Instrument Type</th><th>Manufacturer & Model No.</th><th>Range</th><th>Accuracy</th><th>Resolution</th></tr>
<tr><td>Cloud Liquid Water Content (PLWC, PLWC1)</td><td>Heated wire</td><td>PMS KLWC-5</td><td>0 to 5 g/M3</td><td>0.02 g/M3</td><td>0.001 g/M3</td></tr>
<tr><td colspan="6">OPS Characteristics: This unit is commonly known as the "King" probe and uses the direct measurement of the power changes in a heated wire assembly needed to evaporate impacted water droplets to measure total liquid water content. The raw output of the system (PLWC) is power (Watts). It is more useful to examine the corrected output (PLWCC) when reviewing system performance. This derived parameter is closely dependent upon airspeed (TASX) and to a lesser degree temperature (ATX) ,static pressure (PSXC) and wire temperature (TWIRE). A certain amount of zero drift in clear air can be expected, particularly at airspeed extremes and over large altitude variations. The instrument response is relatively fast and the output should closely track similar measurements derived from PMS 1-D optical probes (PLWCF/PLWC6). However, the King probe cannot measure water in solid form and tends to under sample water droplets with diameters less than 10 um or greater than 30 um. An examination of particle habit from the PMS 2-D optical probes will help in this analysis.</td></tr>
<tr><td>Cloud Liquid Water Content (XGLWC)</td><td>Laser scattering</td><td>Gerber PVM-100</td><td>0 to 5 g/M3</td><td>0.02 g/M3</td><td>0.001 g/M3</td></tr>
<tr><td colspan="6">OPS Characteristics: Particle Volume Monitor (Gerber Scientific) measures scattering intensity of a laser beam at a number of angles (Fraunhofer diffraction). For spherical particles, the intensity is a well defined function of the size and angle, and the integrated volume (LWC) and surface area can be derived. In ice clouds, the scattering relationship is not simple.</td></tr>
<tr><td>Icing Rate Detector (RICE)</td><td>Accretion of Water Droplets</td><td>Rosemount 871FA</td><td>0 to 0.5 mM</td><td>----</td><td>0.0005 mM</td></tr>
<tr><td colspan="6">OPS Characteristics: The icing rate indicator is actually a device for measuring super-cooled liquid water - that is water which exists in liquid form at temperatures below zero (ATX < -5.0 oC due to dynamic heating of all aircraft sensors). Such water is typically found in large scale orographically or synoptically induced stratiform clouds or large convective cells. In non-icing conditions the system output will remain fairly constant with only small amounts of aerodynamically induced drift about a value near 1.0 vdc. In the presence of super-cooled liquid water, the unit's output will increase at a rate proportional to the rate of ice accumulation until a value of around 5.0 vdc is reached. At that time the sensor is flash heated to remove the ice buildup. This "cycling" of the system results in a large spike in the output signal and produces a 10-60 sec gap in data collection while the sensor head returns to a near ambient temperature. The accumulation of ice is not always sufficient to initiate the recycle process. In this instance the output signal will increase gradually until icing has ceased and then slowly decrease as the ice is sublimated off the sensor by the air stream.</td></tr>
<tr><td>Aerosol Spectrum (PCASP)</td><td>Laser Spectrometer</td><td>PMS SPP-200</td><td>0.12 to 3.12 uM</td><td>----</td><td>0.025 to 0.375 uM</td></tr>
<tr><td colspan="6">OPS Characteristics: The PCASP probe counts individual particles that are pulled into the laser cavity by a pump and scatter light as they pass through the laser beam. The dynamic heating caused by accelerating the particles to flight speeds probably evaporates most of any liquid layer on the particles, thereby shifting the size distributions to smaller values. Noise in the first two channels is quite common and may dominate the output for total concentration (CONCP). This is often a sign of an alignment problem or a flow problem at the mounting location on the aircraft. The most common failures in this unit have been laser or pump malfunctions. A lack of particle counts usually indicates a laser failure. Laser function is monitored (PREF_XXX) and should remain stable at roughly -8.0 Vdc. Erratic concentration spikes appearing on a reduced mean concentration usually indicates a loss of sample flow. Sample flow is monitored (PFLW_XXX) and will vary with altitude, but should remain between 0.5 - 1.0 cm3/s. In-cloud sampling will show erratic concentration spikes due to cloud drops and should not be considered valid.</td></tr>
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Table 6.3 Cloud Physics Sensors (cont.)

Variable Measured	Instrument Type	Manufacturer & Model No.	Range	Accuracy	Resolution
Cloud Drolet Spectrum (FSSP)	**Laser Spectrometer**	**PMS SPP-100**	**3 to 45 uM**	**----**	**1.55 uM**
OPS Characteristics: The FSSP-100 counts individual particles that pass through the laser beam and scatter light. It cannot distinguish between water droplets, aerosol particles, or ice. Measurements in mixed phase clouds must therefore be viewed with caution because of the unknown response characteristics to ice particles. The size distribution in these conditions will typically show a relatively well-defined peak in the smaller size channels, and then a long tail running to the larger sizes. The OPS sampling size range can be varied between droplet sizes from 1 - 50 um to large aerosol particles ranging from 0.5 - 8.25 um in size. Abnormally high counts in the first channel usually signal a problem with probe misalignment, dirty optics, or other type of malfunction that need to be rectified. Clear air conditions should yield concentrations of essentially zero. If the instrument fails to respond during cloud penetrations, check the reference voltage on the laser (FREF_XXX) which should be stable and near -8.0 Vdc. CONCF and PLWCF both require TASX, so any problems with TASX will be reflected in the values of those parameters.					
Cloud Droplet Spetrum (260X)	**Laser Spectrometer**	**PMS 260X**	**50 to 640 uM**	**----**	**10 uM**
OPS Characteristics: The 260X probe counts and sizes cloud and precipitation particles as they pass through the laser beam. The particles obscure the beam and produce shadows that pass over a 64 element array of 10 um diameter photo diodes. Sampling times can be set to either 1 or 10 Hz and statistical corrections are made to the data to account for particles that are only partially in the field of view of the laser. While the range of this probe is nominally specified to be 10 - 640 um in 10 um increments, it has some problems sampling the smaller sizes when mounted on an aircraft. NCAR data processing uses the Baumgardner correction alogrithms (Baumgardner, Korolev,1997; *Airspeed Corrections for Optical Array Probe Sample Volumes,* JTECH, 14, 1224-1229) to correct the 260X data for these problems. Effectively this changes the range of the unit to 50 - 640 mm when it is mounted on the C-130.					
Cloud Particle Spectrum (2DC)	**Laser OAP**	**PMS 2D-C**	**25 to 800 uM**	**----**	**25 uM**
OPS Characteristics: The 2D-C probe produces 2-dimensional shadow images of particles as they pass through a laser beam. The particles obscure the beam and produce shadows that pass over a 32 element array of 25 um photo diodes. The particles are monitored, in time, as they pass over the diode array thus producing the image. Particle sizing and number concentrations are determined in post processing. Size distributions will be affected by the analysis criteria applied during this process. The structure of the probe can lead to particle splashing if large droplets are present. Contrary to the 1-D probes, groupings of droplet artifacts are more likely to be sized as larger particles as opposed to increased numbers of smaller particles. Stuck diodes and water streaks can cause misinterpretation of the sizes of particle shadows. This probe has no set sampling rate. Particles are images at a variable rate dictated by the presence of particles above the sampling threshold. Recent upgrades have improved the response time.					
Hydrometer Spectrum (2DP)	**Laser OAP**	**PMS 2D-P**	**200 to 6400 uM**	**----**	**200 uM**
OPS Characteristics: The 2D-P probe produces 2-dimensional shadow images of particles as they pass through a laser beam. The particles obscure the beam and produce shadows that pass over a 32 element array of 200 um photo diodes. The particles are monitored, in time, as they pass over the diode array thus producing the image. Particle sizing and number concentrations are determined in post processing. Size distributions will be affected by the analysis criteria applied during this process. The structure of the probe can lead to particle splashing if large droplets are present. Contrary to the 1-D probes, groupings of droplet artifacts are more likely to be sized as larger particles as opposed to increased numbers of smaller particles. Stuck diodes and water streaks can cause misinterpretation of the sizes of particle shadows. This probe has not set sampling rate. Particles are images at a variable rate dictated by the presence of particles above the sampling threshold.					

Table 6.3 Cloud Physics Sensors (cont.)

<table>
<tr><th>Variable Measured</th><th>Instrument Type</th><th>Manufacturer & Model No.</th><th>Range</th><th>Accuracy</th><th>Resolution</th></tr>
<tr><td>Aerosol Concentrations (CONCN)</td><td>Butanol Cond. Nuclei</td><td>TSI 3760</td><td>0.01 to 3 uM</td><td>+- 6% (reading)</td><td>1 per cM3</td></tr>
<tr><td colspan="6">OPS Characteristics: CN concentrations (CONCN - in n/cm3) are calculated from raw counts and corrected sample flow rates. Particle concentrations vary significantly with environment, and the true signal may appear rather noisy. Normal values range from less than a few hundred per cm3 in clean air (high altitude free troposphere or marine environments) up to 100,000 per cm3 in heavily polluted environments. Well-defined particle layers are seen where the air is stable and mixing is inhibited, such as the top of the PBL and the tropopause. Narrow "spikes" in concentration may be caused by industrial emissions at low altitudes or aircraft emissions at high altitudes. The counting efficiency of the instrument decreases at lower operating pressures (high altitudes) due to reduced flow rqates. This effect only becomes significant at sampling pressures approaching 200mb. The CN inlet is small and unheated, thus limiting its use under icing conditions. The presence of liquid water results in a multiplication of “sensed” particles due to droplet splashing. Data from this instrument should not be used in-cloud.</td></tr>
<tr><td>Aerosol Concentrations (XUFCT)</td><td>Butanol Cond. Nuclei</td><td>TSI 3025</td><td>0.003 to 3 uM</td><td>----</td><td>1 per cM3</td></tr>
<tr><td colspan="6">OPS Characteristics: This unit is basically the same technology as the TSI 3760 and the same basic discussion applies. In the Model 3025, sample flows and sample chamber pressures are controlled and are not output as separate measurements. CN concentrations are calculated directly as a system output. Comparisons of XUFCT and CONCN are useful for QA purposes. The OPS range of the 3025 is roughly 0.003 – 3.0 um. Since this size range includes the entire Model 3760 operating range plus much smaller particles, XUFCT should always exceed CONCN, and usually by 100’s - 1000's of particles per cm3. As with CONCN, vertical profiles of XUFCT tend to be very complex. In terms of concentration trends the two systems should be well matched. There is size discrimination by this instrument.</td></tr>
<tr><td>Cloud water concentration, Liquid and Ice</td><td>Hot wire</td><td>Skytech Research, Nevzorov probe</td><td>0 to 3 g/m3</td><td>----</td><td>----</td></tr>
<tr><td colspan="6">OPS Characteristics: Works on the same principle as the King probe. The Nevzorov has three heated elements. One is shadowed from cloud particles and gives the “dry” heat loss. The other two hot elements compare ratio to it. The second element is a narrow (2 mm) blade that senses liquid cloud. The third element is a forward-facing cone (~8mm) that captures liquid water and ice particles.</td></tr>
<tr><td>Aerosol Light Scattering Extinction Coefficient (+P,T,RH)</td><td>Wet/Dry Nephelometers</td><td>Radiance Research M903</td><td>1 to 1000 (Mm)^-1</td><td>----</td><td>----</td></tr>
<tr><td colspan="6">OPS Characteristics: The nephelometer measures the extinction coefficient of light at 530nm wavelength due to scattering by particles . Response time is typically a few seconds and depends on the rate that air is pumped through the sample volume and the number of light pulses that are averaged. Scattering is a strong function of size (~r^6 to r^2), hence the measurement is very sensitive to humidity if the aerosol is hygroscopic. RAF typically deploys two nephelometers, with one sampling at ambient humidity and the other at a controlled humidity, such as 85%.</td></tr>
<tr><td>Aerosol Spectrum (FSSP-300)</td><td>Laser Spectrometer</td><td>PMS SPP-300</td><td>0.3 to 20 uM</td><td>----</td><td>0.05 to 1.0 uM</td></tr>
<tr><td colspan="6">OPS Characteristics: The FSSP-300 counts individual particles that pass through the laser beam and scatter light. In a sense, this is a hybrid probe because it covers moderate to large aerosols as well as small cloud droplets. However, it is primarily deployed to sample aerosols. Functionally, the probe is almost the same as the FSSP-100. Abnormally high counts in the first channel usually signal a problem with probe misalignment, dirty optics, or other type of malfunction that need to be rectified. Often the first 1-2 bins are removed from the total concentration calculations when this occurs. Due to its OPS range, concentrations (CONC3) are typically much lower than either CONCP or CONCN. Comparing trends between these measurements is more difficult, but the basic patterns discussed in the PCASP section still apply. The widths of the 30 size bins for this probe are not uniform as they are in the other probes. Special care must be taken when analyzing size distributions from this probe.</td></tr>
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