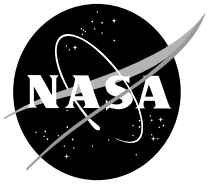
NASA/TM–2006–214142



EOS Aqua AMSR-E Arctic Sea-Ice Validation Program: Arctic2006 Aircraft Campaign Flight Report

Donald J. Cavalieri and Thorsten Markus

October 2006

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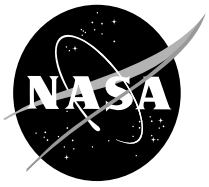

EOS Aqua AMSR-E Arctic Sea-Ice Validation Program: Arctic2006 Aircraft Campaign Flight Report

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October 2006

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Abstract

In March 2006, a coordinated Arctic sea-ice validation field campaign using the NASA Wallops P-3B aircraft was successfully completed. This campaign was the second Alaskan Arctic field campaign for validating the Earth Observing System (EOS) Aqua Advanced Microwave Scanning Radiometer (AMSR-E) sea-ice products. The first campaign was completed in March 2003. The AMSR-E, designed and built by the Japanese Space Agency for NASA, was launched May 4, 2002 on the EOS Aqua spacecraft. The AMSR-E sea-ice products to be validated include sea-ice concentration, sea-ice temperature, and snow depth on sea ice. The focus of this campaign was on the validation of snow depth on sea ice and sea-ice temperature. This flight report describes the suite of instruments flown on the P-3, the objectives of each of the six flights, the Arctic regions overflown, and the coordination among satellite, aircraft, and surface-based measurements.

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1. Introduction

The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) developed and built by the Japanese Aerospace and Exploration Agency (formerly the National Space Development Agency of Japan) for NASA was successfully launched on the EOS Aqua spacecraft in May 2002. This new state-of-the-art satellite radiometer provides a wider range of frequencies and twice the spatial resolution than is currently available with the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) series of radiometers. The standard AMSR-E sea-ice products include sea-ice concentrations at spatial resolutions of 12.5 km and 25.0 km (Comiso et al., 2003; Markus and Cavalieri, 2000), snow depth on sea ice at a spatial resolution of 12.5 km (Markus and Cavalieri, 1998), and sea-ice temperature at a spatial resolution of 25 km (Gloersen et al., 1992). The scientific usefulness of these products depends on their level of accuracy, which will be determined through the implementation of a sea-ice product validation program. The main objective of the sea-ice validation program is to establish statistical relationships between the sea ice parameters derived from the new AMSR-E sea-ice algorithms and those same parameters derived from validation data sets. These validation data sets have been obtained from satellite, aircraft, and surface-based measurements covering as many different sea-ice conditions as possible for the purpose of providing a comprehensive measure of accuracy for each product. Further objectives are to understand the limitations of each of the AMSR-E sea-ice algorithms, including the reasons for their particular level of performance under different conditions, and to suggest improvements to each of the algorithms based on the results of the validation studies.

The overall sea-ice validation program consists of three elements: satellite data comparisons, coordinated satellite/aircraft/surface comparisons, and a modeling and sensitivity analysis component (Cavalieri et al., 2006). The Arctic2003 campaign, the first of the two coordinated Arctic satellite/aircraft/surface campaigns, was completed in March 2003 and had as its focus the validation of the sea-ice concentration product. It also provided a preliminary validation data set for the snow depth and ice temperature products. The snow depth and ice temperature validation data collected during the 2003 campaign consisted of only surface measurements made at two study sites (Cavalieri et al., 2003). There were no direct AMSR-E comparisons. In contrast, the March 2006 campaign provided the first comprehensive data set for the validation of these two products. The validation will first involve a comparison of the airborne and surface measurements made near Barrow to assess and validate the airborne sensor retrievals. These sensors include an AMSR-E simulator, a laser altimeter, a radar altimeter, and a wide-band radar, which measures snow thickness directly. The second step involves a direct comparison of the airborne sensor measurements with AMSR-E retrievals covering large areas in the Chukchi and Beaufort seas under a variety of snow depth and sea-ice conditions.

This flight report describes the aircraft instrumentation, summarizes the validation objectives of each of the six flights, and provides illustrated examples of the coordination among satellite, aircraft, and surface-based measurements made in the vicinity of Barrow, Alaska. Participants in the Arctic2006 EOS Aqua AMSR-E sea ice validation field campaign are listed in Appendix A, including those associated with aircraft flights as well as those making surface measurements at the Barrow, Alaska study area. The aircraft flight logs for each flight are provided in Appendix B.

2. NASA Wallops P-3B Aircraft Instrumentation

A critical component of the validation effort is the acquisition of airborne sensor data over large areas, which can be used to validate the AMSR-E sea-ice products directly. This is particularly true of the snow depth and ice temperature products, because no other satellite sensors can measure these products. The platform for acquiring these data was the NASA Wallops Flight Facility (WFF) P-3B aircraft. The P-3 aircraft is a 4-engine turboprop capable of long duration flights (8–12 hours), large payloads up to 15,000 pounds, altitudes up to 30,000 ft, and true airspeeds up to 330 knots (Figure 1). More detailed information about the aircraft may be obtained from the Web site http://wacop.wff.nasa.gov/LAAPBDesc.cfm. A discussion of the instruments onboard the aircraft follow below.

Figure 1. *NASA P-3B aircraft at Wallops Flight Facility at Wallops Island, VA.*

The polarimetric scanning radiometers (PSR-A and PSR-CX) from the University of Colorado at Boulder, cover the AMSR-E range of frequencies (6.9–89.0 GHz) and polarizations (horizontal and vertical). Boresighted with each PSR scanhead was an infrared scanning radiometer operating at 9.6–11 μm providing surface temperature. At an altitude of 650 ft over the *in situ* data collection site, the PSR was operating in a fixed beam position looking forward at an incidence angle of 55°, which is identical to that of the AMSR-E instrument. The PSR spatial resolution was approximately 60 m at the 650 ft altitude.

The Airborne Topographic Mapper (ATM), a laser altimeter from NASA Wallops, was flown to obtain high resolution ice surface topography and surface height. In combination with the D2P described below, snow depth on sea ice can potentially be measured. At a 650 ft flight altitude, the ATM's swath width in scanning mode is 100 m with one shot per 2.4 square meters. In fixed beam mode the along-track spacing between shots is 2.4 cm.

Delay-Doppler Phase-monopulse (D2P) radar altimeter data—from the Johns Hopkins University/Applied Physics Laboratory (JHU/APL)—were collected along with coincident ATM laser altimeter data to obtain elevation measurements of the snow-ice and snow-air interfaces, respectively. The difference (D2P-ATM) provides a rough measure of snow depth (e.g., Leuschen and Raney, 2005). These data along with the *in situ* snow depth measurements will be compared to the airborne snow radar. At an altitude of 650 ft, the footprint size is approximately 4 m along track and 30 m across track with a vertical precision of a few centimeters.

The snow radar from the University of Kansas is an ultra-wideband FM-CW radar with a sweep bandwidth from 2–8 GHz. This is the first time this radar has been mounted on a plane, but the radar was successfully tested on a sled on sea ice in Antarctica (Kanagaratnam et al., 2006). At an altitude of 650 ft, the footprint size is about 2.5 m with an anticipated vertical resolution of 3 cm.

Aerial digital cameras from NASA Wallops documented sea-ice conditions. A brief description of each sensor follows and a summary of their characteristics and purpose is given in Table 1. Sensor placement on the aircraft is illustrated in Figure 2.

Table 1. NASA Wallops P-3B Sensors for Arctic2006.

Sensor	Characteristics	Purpose	Sensor Scientist
Polarimetric Scanning Radiometer (PSR-A and PSR-CX)	Operating Frequencies (H&V-pol): 6, 10, 18, 22, 37, 89 GHz	Aircraft AMSR-E simulator	A. Gasiewski and M. Klein; Univ. Colorado
IR radiometers bore-sighted with the PSR	9.6–11 μm radiometer	Surface temperature	A. Gasiewski and M. Klein; Univ. Colorado
Snow Radar	FM-CW radar with a 2–8 GHz sweep bandwidth	Snow depth measurements	P. Gogineni and P. Kanagaratnam; Univ. Kansas
Delay-Doppler Radar	Radar altimeter	Sea-ice/snow inter-face elevation	C. Leuschen; JHU/APL (now Univ. Kansas)
Airborne Topographic Mapper (ATM-II)	Scanning lidar altimeter combined with a differential GPS system	Maps ice surface topography at high resolution	W. Krabill and J. Sonntag; NASA Wallops
Video and digital Cameras	2 Kodak digital cameras (3 megapixel)	Visible record of ice surface	W. Krabill and J. Sonntag; NASA Wallops

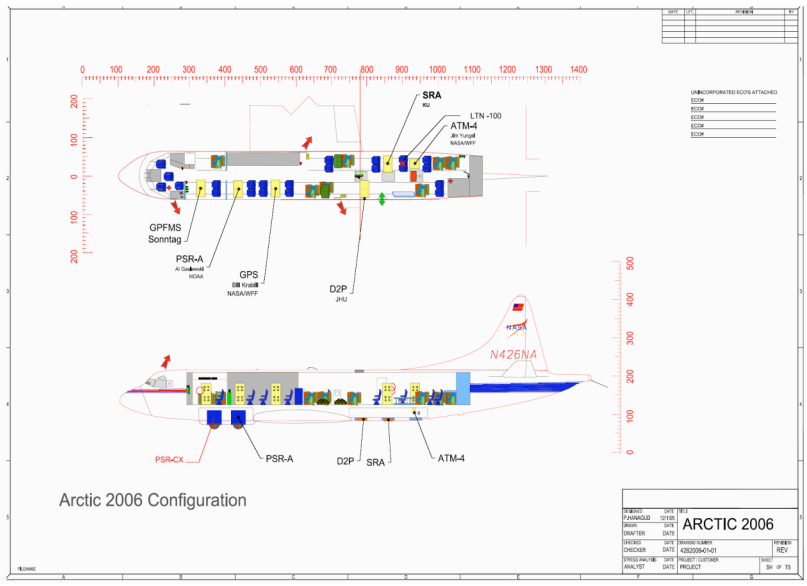

Figure 2. *Configuration of the NASA WFF P-3B aircraft for the Arctic2006 aircraft campaign.*

3. NASA Wallops P-3B Flight Summary

The P-3B made a total of six flights from Fairbanks International Airport, Alaska. The first two flights (March 18 and 20, 2006) were made over Elson Lagoon near Barrow, AK to coordinate with surface-based measurements of sea ice and its snow cover. Three other flights (March 21, 22, and 25, 2006) were made over areas of the Beaufort and Chukchi seas with patterns to cover as many AMSR-E footprints as possible. The sixth flight (March 24, 2006) was coordinated with an ICESat overpass in the high Arctic to support a study of the effects of snow cover variability on ice thickness retrievals from the ICESat laser altimeter. The location of all six flights is shown Figure 3. Each flight is summarized below including a brief description of the flight objective, sea-ice characteristics, and coordination with satellite and/or surface-based measurements.

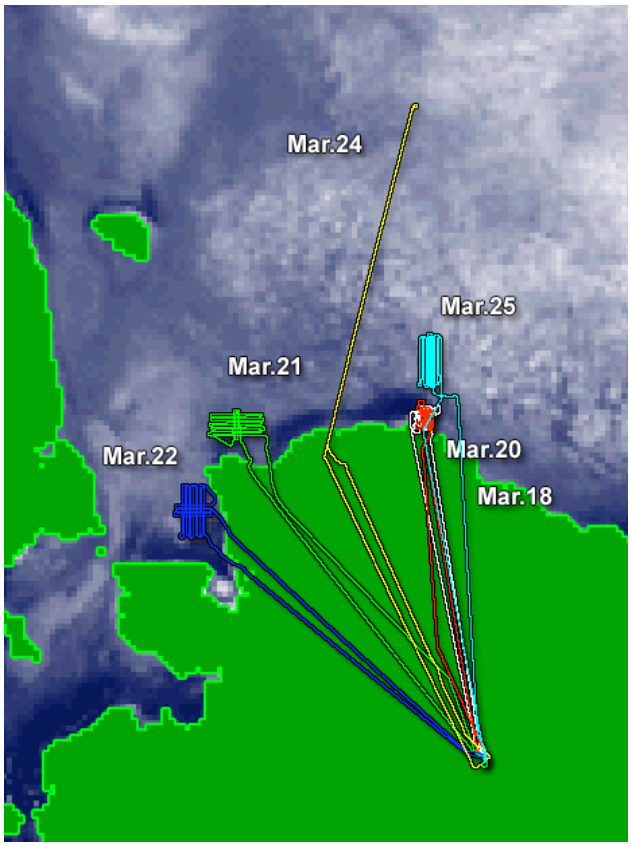

Figure 3. *Location of the six NASA P-3 flights in the vicinity of Alaska during the EOS Aqua AMSR-E Arctic sea-ice campaign during March 2006. The blue-gray shading over the sea-ice covered oceans indicates snow depth on sea ice. The lighter shades indicate deeper snow.*

Flight #1 (6.5 hr): March 18, 2006—Barrow. This flight was dedicated to obtaining aircraft measurements coincident with surface measurements of snow depth on sea ice and sea-ice temperature (Figure 4). Surface measurements were made along two transects each approximately 18 km long (Figure 5). Aerial photographic reconnaissance was undertaken with a Cessna 185 aircraft at an altitude of 4000 ft to provide a large-scale view of the study area before the NASA WFF P-3B arrived in Alaska. The P-3 made nine runs at altitudes of 600 ft and 1000 ft along each of the two transects to determine the optimum altitude for the new snow radar. The PSR operated in stare mode at these altitudes. In addition, the P-3 also made a survey flight at an altitude of 4300 ft to provide microwave and ATM coverage of the entire study region (Figure 6). Preliminary results show a wide range of snow depths promising an excellent validation data set.

Figure 4. *Surface-based measurements made over Elson Lagoon coordinated with the NASA P-3B overflights. The P-3 can be seen near the center of the photo (Courtesy of J. Maslanik taken during the 2003 campaign)*

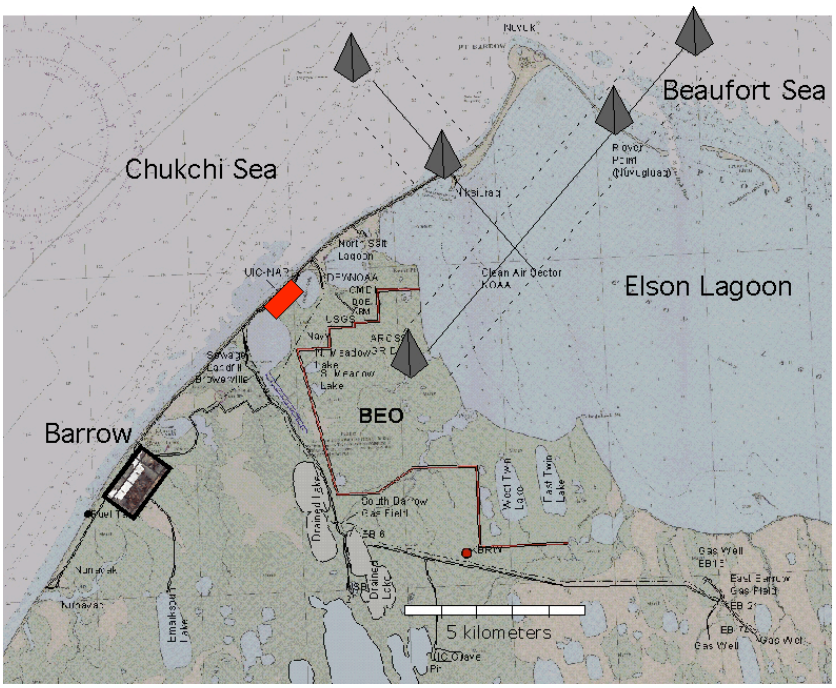

Figure 5. *Map showing the surface transects along which sea-ice and snow measurements were made at the Barrow study site. The "Chukchi" transect runs in a NW to SE direction whereas the "Elson" transect runs in a NE to SW direction. Both transects cut across Elson Lagoon.*

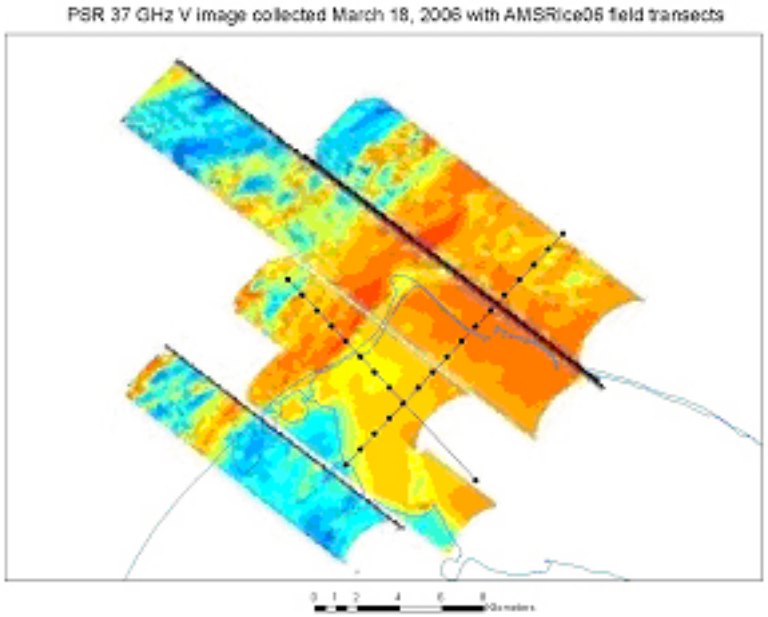

Figure 6. *University of Colorado PSR image at 37 GHz V-pol of the Elson Lagoon study area. Surface transects are indicated by dotted lines.*

Flight #2 (6.2 hrs): March 20, 2006—Barrow. This flight repeated the tracks made on March 18, but at the optimum altitude for the snow radar of 650 ft to increase the sample size of coordinated measurements and to cover an anomalous region in Elson Lagoon, which appeared in the PSR imagery acquired on March 18 (Figure 6). The PSR operated in stare mode at 650 ft altitude, whereas the PSR operated in scan mode at an altitude of 1100 ft and at 4300 ft.

Flight #3 (7.5 hrs): March 21, 2006—Chukchi Sea. The objective of this flight was to validate the AMSR-E snow depth and ice temperature products directly by using the airborne sensors. The aircraft lines were oriented in a NE-SW direction (Figure 3). The area in the SW portion of the grid contained considerable gray and gray-white ice with numerous leads and finger rafting. In the NE portion of the grid, there was more thin (smooth) first-year and ridged first-year ice. This gradient of ice types should provide a gradient of both snow depth and ice temperature. All flight lines were flown at an altitude of 650 ft with the PSRs operating in stare mode.

Flight #4 (7.7 hrs): March 22, 2006—Kotzebue Sound. The objective on this day was again to validate the AMSR-E snow depth and ice temperature products directly by using the airborne sensors. The aircraft lines were oriented in a NW-SE direction (Figure 3). There were a variety of first-year ice types including new, young, thin first-year, and medium first-year. The thickest ice was found in the NW portion of the grid with considerable ridging. Snow cover, as identified from AMSR-E data, was deeper over portions of this grid than it was in the Chukchi Sea. All flight lines were flown at an altitude of 650 ft with the PSRs operating in stare mode.

Flight #5 (6.7 hrs): March 24, 2006—High Arctic. The objective of this flight was to underfly the ICESat spacecraft. Because clear weather is critical for ICESat, we waited with this flight until we could expect cloud-free conditions for the entire flight. The altitude was 650 ft with the PSRs operating in stare mode. The time of turning point of the aircraft coincided with the time of the ICESat orbit.

Flight #6 (7.9 hrs): March 25, 2006—North of Barrow. The objective of this flight was to acquire data in a region of mixed first-year and multiyear ice types. The grid on this day was oriented in a NW-SE direction. At the southern end of the grid, the ice cover was mixed young, first-year, and multiyear ice, whereas at the northern end of the grid the ice was mostly multiyear.

4. Concluding Remarks

The successful completion of the Arctic2006 aircraft campaign promises to provide the first comprehensive data set needed to validate the AMSR-E snow depth on sea-ice and ice temperature products. The new airborne snow radar (Gogineni et al., 2003) was flown for the first time during this campaign. Initial examination of some of the preliminary data collected suggests that the radar produced good discrimination between the snow-air and ice-snow interfaces and as such, should provide the requisite data needed to validate the AMSR-E snow depth product. This, in combination with the IR surface temperatures measured in combination with the altimeter data, the snow radar measurements, and the PSR radiances, should also provide the basis for obtaining an excellent validation data set with which to validate the sea-ice temperature product through the modeling of 1-D temperature profiles.

5. Acknowledgments

We thank all of the participants (Appendix A) whose dedication in both the planning and implementation phases of this campaign culminated in the acquisition of the first comprehensive data set with which to validate the AMSR-E snow depth and sea-ice temperature products. We also thank Michael King, EOS Senior Project Scientist; David Starr, EOS Validation Scientist; Claire Parkinson, Aqua Project Scientist; Elena Lobl, EOS Aqua AMSR-E Science Team Validation Scientist; and Waleed Abdalati, Cryospheric Sciences Branch Head, for their full support leading to the successful completion of this mission.

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7. Appendix A: List of Participants

Name	Organization	Function
Aircraft Personnel		
Sam Broyles	NASA WFF Code 830/Airtec	Safety Engineer
Willy Bugg	NASA WFF Code 830/Airtec	Flight Engineer
Donald Cavalieri	NASA/GSFC/Code 614	Arctic 2006 PI
Albin Gasiewski	Univ. of Colorado	PSR PI
Gary Givens	AeroUnion	Mechanic
Pannir Kanagaratnum	Univ. of Kansas	Snow Radar Lead / PI
Marian Klein	Univ. of Colorado	PSR PI/Operator
David Kraft	DOC/NOAA/ETL	PSR Operator
Carl Leuschen	JHU/APL	Lead D2P Engineer
Elena Lobl	Univ. of Alabama	AMSR-E Validation Coordinator
Thorsten Markus	NASA/GSFC/Code 614	Arctic 2006 Co-PI
John Paden	Univ. of Kansas	Snow Radar Operator
Peter Peyton	NASA WFF Code 830/Airtec	Avionics Tech.
George Postell	NASA WFF Code 830	Co-Pilot
Rich Rogers	NASA WFF Code 830	Co-Pilot
Johnny Scott	EG&G/WFF	ATM Ground Survey
Michael Singer	NASA WFF Code 830/AirTec	Pilot in Command
John Sonntag	EG&G/WFF	ATM Engineer
John Valliant	NASA WFF Code 840/CSC	Mission Manager
Bob Weber	DOC/NOAA/ETL	PSR Operator
Rick Willyard	Univ. of Kansas	Snow Radar Operator
Jim Yungel	EG&G/WFF	Lead ATM Engineer
Surface-Based Personnel		
Perry Anashugak	BASC	Guards/Ice Guides
Tom Douglas	CRREL, AK	Snow Water Equivalent Measurement
Charles Fowler	Univ. of Colorado	Airborne instrumentation
John Heinrichs	Fort Hayes State Univ., KS	GIS and Field Data Coordination
Jon Holmgren	CRREL, AK	Ground-based FM-CW (snow) radar
Carl Kippe	BASC	Guards/Ice Guides
Peter Marshall	CRREL, AK	Ground-based FM-CW (snow) radar
James Maslanik	Univ. of Colorado	Co-Field Leader
Don Perovich	CRREK, NH	Ice properties and ice thickness (EM-31)
Rick Rachow	CRREL, AK	Field work
Julienne Stroeve	Univ. of Colorado	Snow depth
Matthew Sturm	CRREL, AK	Co-Field Leader
K. Tape	CRREL, AK	Snow Pits and Grain size
Cessna 185		
Tom George	Terraterpret, Inc.	Pilot/Aerial reconnaissance

8. Appendix B: Flight Logs

Arctic06 Experiment Log—PSR on NASA Wallops P-3 N426NA

Date(s):	March 18, 2006
PSR Flight Code:	DF006
NAVFLIR Number:	
T/O Location:	Fairbanks, Alaska
T/O Time (UTC):	171338
Recovery Location:	Fairbanks, Alaska
Landing Time (UTC):	000200
Mission Scientist:	Al Gasiewski
PSR Operator(s):	Marian Klein, David Kraft
Scanhead(s):	PSR/A, PSR/CX
Purpose of Sortie:	First of our science flight, low altitude mapping over the Barrow area.
Synoptic Conditions:	
Local Site Conditions:	
Instrument Status:	
Operating Instruments on P3:	
Notes/Flight Synopsis:	

Time (UTC)	**Event**
173338	Take off
	Acquisition processes started
	On transit scanning mode: conical –o –p3 –n20 –c2 –e5
	`a lot of problems
2030	PSR start operating
204035	Start of Chukchi line at 935 feet (second set)
204426	End of Chukchi line feet (second set)
205331	Start Elson line at 750 feet
205531	End Elson line
210230	Start of Chukchi line at 2500 feet due to weather
2105	End of Chukchi line
211008	Start of line 2 of Mapping Grid @4300 feet
211433	End of line 2 of mapping grid
211921	Start of line 3 of mapping grid at 4300 feet
212204	End of line 3 of mapping grid
212835	Start of line 4 of mapping grid at 4300 feet
213231	End of line 4 of mapping grid
213847	Start of line 5 of mapping grid at 4300 feet
214146	End of line 5 of mapping grid
215036	Start of crossing line of mapping grid at 4300 feet
215312	End of crossing line of mapping grid

220038	Start of line 1 of mapping grid at 4300 feet
220324	End of line 1 of mapping grid
220604	GSR Clock stopped
221039	GSR Clock Reset
221800	Peak of calibration roll 1
222029	Peak of calibration roll 2
222305	Peak of calibration roll 3
2235	Acquisition processes stopped.
000200	Landing time in Fairbanks

Arctic06 Experiment Log—PSR on NASA Wallops P-3 N426NA

Date(s):	March 20, 2006
PSR Flight Code:	DF008
NAVFLIR Number:	
T/O Location:	Fairbanks, Alaska
T/O Time (UTC):	195336
Recovery Location:	Fairbanks, Alaska
Landing Time (UTC):	021052
Mission Scientist:	Marian Klein
PSR Operator(s):	Marian Klein, David Kraft
Scanhead(s):	PSR/A, PSR/CX
Purpose of Sortie:	Second data flight, Sea Ice observation near Barrow, Chukchi Sea and Elson Lagoon
Synoptic Conditions:	
Local Site Conditions:	Temperature ~ -7°C, overcast sky. At Barrow: 9000 feet overcast, 10 miles visibility
Instrument Status:	Both PSR/A and PSR/CXI system function as expected.
Operating Instruments on P3:	Airborne Topographic Mapper (ATM) – NASA Wallops, Snow Radar – University of Kansas, Delayed Doppler Phase Monopulse radar -D2P – John Hopkins University, PSR/CXI and PSR/A Center for Environmental Technologies at University of Colorado.
Notes/Flight Synopsis:	

Time (UTC)	**Event**
195336	Take Off
2007xx	Start Acquiring Data

	Scanning mode: Conical –o –e55 –p3 –c2 –n100
	Both PSR systems are in hcs scanning mode, staring forward at 55° incident angle. Hcs –a0 –e55 –c2 –t999 Hardware trigger value is 7- along track.
	3 figure "8" at Barrow, 6 lines total at 650 feet:
212131	Line 1 starts
212340	Line 1 stops
212829	Line 2 starts
213046	Line 2 stops
213620	Line 3 starts
213826	Line 3 stops
214633	Line 4 starts
214835	Line 4 stops
2155	IRIGB clock on P-1 (node 1) hangs up. By operator error (MK) the archival computer on P-1 (node 2) was shutdown. The system needed to be rebooted, acquisition processes restarted. PSR/CXI acquisition radci_acq was not restarted properly. NO PSR/CXI data were recorded for the rest of the mission.
2200	P-1 is back online, operational. Motion software was successfully uploaded on second try.
21	Line 5 starts
215655	Line 5 Set 1 Stop
220333	Line 6 Set 1 Start
220533	Line 6 Set 1 Stop
	Because PSR/A did not get any data on 650 feet in conical mode we are repeating one more figure "8" at 650 feet altitude. Both scanheads in conical scan.
221155	Line 7 starts
221348	Line 7 stops
222045	Line 8 starts
222247	Line 8 stops
	Three figures "8" at Barrow, 6 lines total at 1100 feet:
	Both PSR systems are in hcs scanning mode, staring forward at 55° incident angle. Hcs –a0 –e55 –c2 –t999 Hardware trigger value is 7- along track.
222920	Line 1 starts
223114	Line 1 stops
223744	Line 2 starts
223951	Line 2 stops
224428	Line 3 starts

224615	Line 3 stops
225014	IRIGB clock hanging again, Nav2 (node1) restarted.
225234	Line 4 starts
225440	Line 4 stops
	Both PSR systems are in conical scanning mode, at 55° incident angle. Conical –o –e55 –p3 –c2 –n300
225949	Line 5 starts
230142	Line 5 stops
230834	Line 6 starts
231041	Line 6 stops
231915	IceSat line South to North at 1100 feet altitude starts.
232315	IceSat line stops.
	PSR mapping lines:
233406	Line 1 starts
233730	Line 1 stops
234430	Line 3 starts
234806	Line 3 stops
235315	Line 5 starts
235637	Line 5 stops
000051	Line 2 starts
000431	Line 2 ends
001007	Line 4 starts
001329	Line 4 stops
001816	IceSat line North to South at 4300 feet altitude starts. Both PSR systems in scanning mode.
002132	IceSat line stops.
	PSR calibration rolls – aircraft heading for the rolls is 340 true.
002838	Roll 1
003052	Roll 2
003253	Roll 3
0120	PSR/CXI radiometric data acquisition (radci_acq) restarted.
0132	Acquisition processes stopped.
0134	Test reboot for a system. All the computers were powered down and upload of the at6400 software was tested. The arch2 (node#2) motion controller software was uploaded successfully on a third try. Of six tries, two were successful uploads. Others ended up hanging during a motion controller program (*.prg). The arch3 (node#6) motion controller software successfully uploads the operating system and setup program (psrset.up),

	but is freezing at random lines during upload of some motion control programs (*.prg). The motion controller software upload does not perform reliably. The reason for this behavior is unknown. Nav2 computer seems to have more reliable upload - ~ 30% success rate. Nav3 computer did not successfully uploaded the at6400 programs even after 10–15 tries.
020416	IRIGB clock on Nav2 (node#1) freezes.
021052	Landing

Arctic06 Experiment Log—PSR on NASA Wallops P-3 N426NA

Date(s):	March 21, 2006
PSR Flight Code:	DF009
NAVFLIR Number:	
T/O Location:	Fairbanks, Alaska
T/O Time (UTC):	181900
Recovery Location:	Fairbanks, Alaska
Landing Time (UTC):	015006
Mission Scientist:	Marian Klein
PSR Operator(s):	Marian Klein, David Kraft
Scanhead(s):	PSR/A, PSR/CX
Purpose of Sortie:	Third data flight, this one to Chukchi Sea, high resolution observations of sea ice. The PSR scanheads are in stare mode for the duration of box observation. Expected local site conditions – first year ice and some snow, not very much. Don Cavalieri after observing site from the airplane window was describing the condition as first year ice with thickness from 30cm to 1 m.
Synoptic Conditions:	
Local Site Conditions:	Fairbanks: Overcast skies, Temperature ~ -6°C, it was snowing during last night. Weather at grid location: clear sky, not a cloud in view, some haze, visibility ~ 6 miles, -28°C outside air temperature at 650 feet.
Instrument Status:	Both PSR system operations are normal. The motion controller software was uploaded into the motion controllers on both systems on the first try.
Operating Instruments on P3:	Airborne Topographic Mapper (ATM) – NASA Wallops, Snow Radar – University of Kansas,

Center for Environmental Technologies at
University of Colorado.

Notes/Flight Synopsis:

Time (UTC)	Event
181900	Take off
1849	Acquisition processes started.
	Both scanheads in conical mode: conical –o –p3 –c2 –e55 –n5
1900	Both scanheads in conical mode: conical –o –p3 –c2 –e55 –n200
1917	After several stalls, the PSR/A scanhead was restarted with a 3.5 s scanning period.
1945	Nav2 IRIGB clock is frozen. Nav2 computer powered down and rebooted.
	Box A mapping grid: 11 parallel lines and four perpendicular lines, all at the altitude of 650 feet. Both PSR/A and PSR/CXI are in staring mode: hcs –a0 –e55 –c2
200305	Line 11 begins, M11N to M11S
201634	Line 11 ends
	NOTE: all vertically polarized channels in PSR/CXI are showing certain level of interference, most likely from snow radar. Horizontally polarized channels are clean of interference.
202149	Line 9 begins, M09S to M09N
203537	Line 9 ends
204026	Line 7 begins M07N to M07S
205330	Line 7 ends
205804	Line 5 begins M05S to M05N
2104	PSR video recorder switched to PSR/A scanhead camera. Tape 3 started.
211203	Line 5 ends.
211318	Line 3 begins M03N to M03S
2118	Nav2 IRIGB clock is frozen. Nav2 computer powered down and rebooted.
212941	Line 3 ends
213345	Line 1 begins M01S to M01N
214733	Line 1 ends
215056	Line 2 begins M02N to M02S
2203	Tape 4 started in video recorder, PSR/A scanhead camera is being recorded.
220425	Line 2 ends
220757	Line 4 begins M04S to M04N
222147	Line 4 ends
222514	Line 6 begins M06N to M06S
223852	Line 6 ends
2239	Nav2 IRIGB clock is frozen. Nav2 computer powered down and rebooted.
224218	Line 8 begins M08S to M08N
225558	Line 8 ends

225543	Nav2 IRIGB clock is frozen. Nav2 computer powered down and rebooted.
225855	Line 10 begins M10N to M10S
2303	Tape 5 started in video recorder, PSR/A scanhead camera is being recorded.
231247	Line 10 ends
231530	Conical scanning mode on both scanheads.
231730	Conical scanning is over.
	Crossing lines next:
2318	Nav2 IRIGB clock is frozen. Nav2 computer powered down and rebooted.
232334	Line 4 begins X04S to X04N
233211	Line 4 ends
	Nav2 IRIGB clock is frozen and rebooted itself. It was out of synchronization for ~30 seconds.
233415	Line 3 begins X03N to X03S
234226	Line 3 ends
234448	Line 2 begins X02S to X02N
235327	Line 2 ends
235555	Line 1 begins X01N to X01S
0001	Tape 6 started in video recorder, PSR/A scanhead camera is being recorded.
000323	Line 1 end
	PSR calibration rolls (altitude 15000~). We are doing right banks today, left wing goes up. (command: sky –a90 –e55)
001035	Roll 1
001325	Roll 2
001451	Roll 3
0118	Acquisition processes stopped.
	Start_motion was tested on both computers. Neither of the at6400 system was able to upload the motion control software. It was tried approximately 10 times on both machines. After power off the Arch2 (node#2) motion control software was uploaded successfully on first try.
015006	Landing

Arctic06 Experiment Log—PSR on NASA Wallops P-3 N426NA

Date(s):	March 22, 2006
PSR Flight Code:	DF010
NAVFLIR Number:	
T/O Location:	Fairbanks, Alaska
T/O Time (UTC):	175838
Recovery Location:	Fairbanks, Alaska

Landing Time (UTC): 014235
Mission Scientist: Marian Klein
PSR Operator(s): Marian Klein, David Kraft
Scanhead(s): PSR/A, PSR/CX
Purpose of Sortie: Fourth data flight. Observation at Kotzebue Sound, North on Nome. Low altitude grid, both scanheads in staring mode. Expected conditions within the area of observation are first year ice and thick snow. Don Cavalieri's estimate from airplane window is that ice thickness is approximately 1 m and the snow cover is thicker here than it was on yesterday's grid.
Synoptic Conditions:
Local Site Conditions: Overcast skies at Fairbanks, temperature ~–10°C. Weather at Kotzebue Sounds: -24°C at 650 feet altitude, visibility 10 miles, a little bit of haze, clear skies, no clouds in view.
Instrument Status: Both PSR/A and PSR/CXI systems are operating within established parameters. Motion control software was uploaded into both at 6400 cards on the first try.
Operating Instruments on P3: Airborne Topographic Mapper (ATM) – NASA Wallops, Snow Radar – University of Kansas, Delayed Doppler Phase Monopulse radar -D2P – John Hopkins University, PSR/CXI and PSR/A - Center for Environmental Technologies at University of Colorado.
Notes/Flight Synopsis:

Time (UTC)	Event
175838	Take off
1836	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
1840	Acquisition processes started.
	Xtrack scanning mode: xtrack –n5 –p4 –c2
1847	Conical on PSR/CXI was with 66° incident angle, it was corrected later.
1850	Conical scanning mode both scanheads: conical –o –e55 –p3 –c2 –n200
1905	PSR/A stalled, it was restarted in the same scanning mode.
1912	PSR/A stalled, it was restarted in the same scanning mode.
	Both scanheads are in staring mode: hcs –a0 –e55 –c2 –t999
	Low altitude grid ~ 650 feet
193549	Line 11 starts M11S to M11N

195040	Line 11 ends
195433	Line 9 starts M09N to M09S
1955	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
200726	Line 9 ends
201128	Line 7 starts M07S to M07N
202557	Line 7 ends
202942	Line 5 starts M05N to M05S
204238	Line 5 ends
204638	Line 3 starts M03S to M03N
210109	Line 3 ends
210156	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
210453	Line 1 starts M01N to M01S
211803	Line 1 ends
212336	Line 2 starts M02S to M02N
213321	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
213804	Line 2 ends
214140	Line 4 starts M04N to M04S
215437	Line 4 ends
215934	Line 6 starts M06S to M06N
2209	Video recorder switched to PSR/CXI video camera. It seems to have a little clearer image that PSR/A.
221411	Line 6 ends
221738	Line 8 starts M08N to M08S
221920	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
222334	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
223033	Line 8 ends
223449	Line 10 starts M10S to M10N
224924	Line 10 ends
	Scanheads in conical mode.
	Crossing lines next, same altitude (~650 feet, same scanning mode for the PSR scanheads).
225948	Line 6 starts X06N to X06S
230139	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
230752	Line 6 ends
231206	Line 4 starts X04S to X04N
232028	Line 4 ends
232438	Line 2 starts X02N to X02S
233247	Line 2 ends

233815	Line 1 starts X01S to X01N
234633	Line 1 ends
235028	Line 3 starts X03N to X03S
235832	Line 3 ends
000223	Line 5 starts X05S to X05N
001050	Line 5 ends
	PSR calibration rolls, left wing up again – right turn, heading 090 true, command: sky –a90 –e65
001620	Roll 1
001800	Roll 2
001948	Roll 3
0121	Acquisition processes stopped.
014235	Landing

Arctic06 Experiment Log—PSR on NASA Wallops P-3 N426NA

Date(s):	March 24, 2006
PSR Flight Code:	DF011
NAVFLIR Number:	
T/O Location:	Fairbanks, Alaska
T/O Time (UTC):	201112
Recovery Location:	Fairbanks, Alaska
Landing Time (UTC):	025342
Mission Scientist:	Al Gasiewski
PSR Operator(s):	Marian Klein, Al Gasiewski
Scanhead(s):	PSR/A, PSR/CX
Purpose of Sortie:	Fifth data flight, IceSat line underflight, starting at Purdue Bay and going North.
Synoptic Conditions:	
Local Site Conditions:	Fairbanks: overcast skies, with snow flurries, temperature ~-5°C. IceSat line: temperature -27°C (at 1100 feet altitude), clear skies, some haze, visibility 15 miles.
Instrument Status:	PSR/A and PSR/CXI operate within established parameters.
Operating Instruments on P3:	Airborne Topographic Mapper (ATM) – NASA Wallops, Snow Radar – University of Kansas, Delayed Doppler Phase Monopulse radar -D2P – John Hopkins University, PSR/CXI and PSR/A - Center for Environmental Technologies at University of Colorado.

Notes/Flight Synopsis:

Time (UTC)	**Event**
201112	Take Off
2033	Acquisition processes started.
2034	Xtrack scanning mode on both scanheads, xtrack –n5 –p4 –c2
2038	Conical scanning: conical –o –e55 –p3 –c2 –n200, for the PSR/A scanning period is 3.3 s.
213814	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
213901	IceSat line starts, both scanheads in a staring mode: hcs –a0 –e55 –c2 –t600 – calibration every ~10 minutes. Flight altitude ~650 feet.
230606	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
233130	North end of the IceSat line reached.
233717	IceSat line heading South starts.
	Both scanheads in conical scan mode: conical –o –e55 –c2 –p3 –n200, flight altitude ~ 1100 feet.
2338	PSR/A scanhead stalled. It was restarted with scanning period of 3.3 s.
2346	PSR/A scanhead stalled. It was restarted with scanning period of 3.3 s.
000028	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
002800	PSR/A scanhead stalled. It was restarted with scanning period of 3.3 s.
003100	PSR/A scanhead stalled. It was restarted with scanning period of 3.3 s.
0044	PSR/A scanhead stalled. It was restarted with scanning period of 3.5 s.
010636	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
011730	Wings over land.
012123	IceSat line heading South ends.
012135	Snow radar shut down
	PSR calibration rolls, left wing up again – right turn, heading 070 true, command: sky –a90 –e65
012555	Roll 1
012756	Roll 2
013015	Roll 3
	Return to base
0136	Both scanheads in a scanning mode, PSR/CXI 3 seconds period, PSR/A 3.5 s period, both calibrating ~ every 10 minutes. Altitude ~24000 feet.
	Tape 3 has some recording from the multiplexer output at the end.
020723	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
0230	Acquisition processes stopped.
025342	Landing

Arctic06 Experiment Log—PSR on NASA Wallops P-3 N426NA

Date(s):	March 25, 2006
PSR Flight Code:	DF012
NAVFLIR Number:	
T/O Location:	Fairbanks, Alaska
T/O Time (UTC):	191145
Recovery Location:	Fairbanks, Alaska
Landing Time (UTC):	030441
Mission Scientist:	Al Gasiewski
PSR Operator(s):	Marian Klein, David Kraft, Al Gasiewski,
Scanhead(s):	PSR/A, PSR/CX
Purpose of Sortie:	Sixth data flight, observation box north of Barrow in Beaufort Sea.
Synoptic Conditions:	Fairbanks: Overcast skies with some snow precipitation, temperature: On the grid: Haze, visibility 5 -6 miles, 10 miles at some places, clear skies, temperature -26° C at 650 feet altitude.
Local Site Conditions:	Sea ice conditions based on Don Cavalieri's estimate: Mostly multi-year ice connected by areas of first year ice. Some frozen meltponds.
Instrument Status:	Both PSR systems operate within established paramaters.
Operating Instruments on P3:	Airborne Topographic Mapper (ATM) – NASA Wallops, Snow Radar – University of Kansas, Delayed Doppler Phase Monopulse radar -D2P – John Hopkins University, PSR/CXI and PSR/A - Center for Environmental Technologies at University of Colorado.
Notes/Flight Synopsis:	

Time (UTC)	**Event**
191145	Take off
1927	Acquisition processes started
	Both scanheads in conical scanning mode: conical –o –e55 –p3 –c2 –n200
1937	PSR/A stalled, it was restarted in conical scanning mode with period of 3.3 s.
2015	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
	Box observations are at 650 feet altitude. Both PSR systems are in stare mode, hcs –a0 –e55 –c2 –t999
204725	Line 11 starts M11S to M11N
210142	Line 11 ends

210425	Line 9 starts M09N to M09S
211741	Line 9 ends
212104	Line 7 starts M07S to M07N
213521	Line 7 ends
213740	Line 5 starts M05N to M05S
215150	Line 5 ends
215515	Line 3 starts M03S to M03N
220937	Line 3 ends
221252	Line 1 starts M01N to M01S
222610	Line 1 ends
220701	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
223030	Line 2 starts M02S to M02N
223246	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted. At this time IRIGB clock would again fail in short periods three times. Most of the time it was out of sync and it would reset itself and start counting from zero. The GPS preamplified power divider bias supply was changed by MK from the positioner P1 (Nav2 computer card GPS) to the positioner P3 (Nav3 computer).
	PSR/CXI acquisition processes were restarted. For unknown reason the radci_acq and radci_log stopped between the 2209 and 2219.
224447	Line 2 ends
224747	Line 4 starts M04N to M04S
230101	Line 4 ends
230421	Line 6 starts M06S to M06N
230838	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
231839	Line 6 ends
232140	Line 8 starts M08N to M08S
233203	
233458	Line 8 ends
233816	Line 10 starts M10S to M10N
234251	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
235239	Line 10 ends
	Higher altitude observations – 4300 feet. Both PSR scanheads in conical scanning mode. PSR/A scanhead scanning period is 3.5 s and PSR/CXI 3 s.
235618	Line 5 starts H05N to H05S
000843	Line 5 ends
001400	Line 3 starts H03S to H03N
002713	Line 3 ends
003207	Line 1 starts H01N to H01S
004425	Line 1 ends

004933	Line 2 starts H02S to H02N
010248	Line 2 ends
010817	Line 4 starts H04N to N04S
011337	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
	Radci_acq restarted
012049	Line 4 ends
	PSR calibration rolls: right wing goes up (left turn), 090 true heading, command: sky –d or sky –a270 –e65
012625	Roll 1
012816	Roll 2
012948	Roll3
0135-0205	After completing rolls flew straight into a long transit line at 24,000 ft over sea ice back to land, including passage over a large frozen coastal plain lake (Teshekpuk Lake). Also passed over many small frozen coastal plain lakes. Terrain flat and snow covered until Brooks Range overflown starting at ~0205
0230	Nav2 IRIGB clock is frozen. Nav2 computer was powered down and rebooted.
0246	Acquisition processes stopped.
030441	Landing

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
25-10-2006	Technical Memorandum	

4. TITLE AND SUBTITLE

EOS Aqua AMSR-E Arctic Sea-Ice Validation Program: Arctic2006 Aircraft Campaign Flight Report

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

D.J. Cavalieri and T. Markus

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NASA GSFC
Code 614.1
Greenbelt, MD 20771

8. PERFORMING ORGANIZATION REPORT NUMBER

2006-02057-0

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING REPORT NUMBER

TM-2006-214142

12. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified-Unlimited, Subject Category: 42
Report available from the NASA Center for Aerospace Information,7121 Standard Drive, Hanover, MD 21076. (301)621-0390

13. SUPPLEMENTARY NOTES

14. ABSTRACT

In March 2006, a coordinated Arctic sea-ice validation field campaign using the NASA Wallops P-3B aircraft was successfully completed. This campaign was the second Alaskan Arctic field campaign for validating the Earth Observing System (EOS) Aqua Advanced Microwave Scanning Radiometer (AMSR-E) sea-ice products. The first campaign was completed in March 2003. The AMSR-E, designed and built by the Japanese Space Agency for NASA, was launched May 4, 2002 on the EOS Aqua spacecraft. The AMSR-E sea-ice products to be validated include sea-ice concentration, sea-ice temperature, and snow depth on sea ice. The focus of this campaign was on the validation of snow depth on sea ice and sea-ice temperature. This flight report describes the suite of instruments flown on the P-3, the objectives of each of the six flights, the Arctic regions overflown, and the coordination among satellite, aircraft, and surface-based measurements.

15. SUBJECT TERMS

AMSR-E, sea ice, Arctic, validation

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19b. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Donald J. Cavalieri
Unclassified	Unclassified	Unclassified	Unclassified	27	19b. TELEPHONE NUMBER *(Include area code)* (301) 286-5901