AMSR / AMSR-E
CALIBRATION AND VALIDATION PLAN

Ver. 4.0 / Mar. 31, 2004
Ver. 3.0 / Sep. 30, 2003
Ver. 2.0 / Feb. 18, 2003
Ver. 1.0 / May 7, 2002

Earth Observation Research and application Center

CONTENTS OVERVIEW

RANGE OF THE DOCUMENT

This document contains the calibration and validation plans for both the Advanced Microwave Scanning Radiometer (AMSR) that will be carried aboard the Advanced Earth Observing Satellite-II (ADEOS-II), launched in December 2002, and for Advanced Microwave Scanning Radiometer for EOS (AMSR-E) that is carried aboard NASA's Earth Observing Satellite PM1 (EOS-PM1 Aqua), launched in May 2002.

In order to carry out the necessary sensor calibration and standard (research) algorithm validation within a limited budget, it is necessary for a large number of different research organizations and different projects to collaborate.

In case of AMSR/AMSR-E calibration and validation, other science groups will obtain some truth data. However, this document contains all the AMSR/AMSR-E calibration and validation plans irrespective of financing.

This document will be revised whenever any of the plans is changed.

This version is equivalent to the version 5.0 of the Japanese document.

Appendix A Acronyms

ACMR	Airborne C-Band Microwave Radiometer
ADEOS-II	Advanced Earth Observation Satellite-II
AGC	Automatic Gain Control
AMeDAS	Automated Meteorological Data Acquisition System
AMR	Airborne Microwave Radiometer
AMSR	Advanced Microwave Scanning Radiometer
AMSR/DCS	AMSR/Data Collecting System
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
ARM	Atmospheric Radiation Measurement program
ASSH	Automatic Station of Soil Hydrology
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible Infrared Imaging Spectrometer
AWS	Automatic Weather Station
CAMP	CEOP Asia-Australia Monsoon Project
CEOP	Coordinated Enhanced Observing Period
CLIVAR	Climate Variability and predictability study
CREST-JST	Core Research for Evolutional Science and Technology - Japan Science and Technology Corporation
CRL	Communication Research Laboratory
CRYSTAL	the fire-Cirrus Regional Study of Tropical Anvils and Layers
CSM	Cold Sky Mirror
EOC	Earth Observation Center
EORC	Earth Observation Research Center
EOS	Earth Observing System
EOS-PM1	Earth Observing Satellite-PM1 (Aqua)
EOSD	Earth Observations Sensor Development laboratory
EPIC	Equatorial Pacific Information Collection
ESTAR	Electrically Scanned Thinned Array Radiometer
GAME	GEWEX Asian Monsoon Experiment
GAME-AAN	GAME-Asia AWS Network
GCIP	the GEWEX Continental-scale International Project
GEWEX	Global Energy and Water cycle Experiment
GHP	GEWEX Hydrometeorology Panel
GLI	Global Imager
GTS	Global Telecommunications System
IGBP	International Geosphere and Biosphere Program
IMH	(Mongolia) Institute of Meteorology and Hydrology
JAMSTEC	Japan Marine Science & Technology Center
JAXA	Japan Aerospace eXploration Agency
JPL	(NASA) Jet Propulsion Laboratory
MPM	Millimeter-wave Propagation Model
NASA	National Aeronautics and Space Administration

NASDA	National Space Development Agency of Japan
NDBC	National Data Buoy Center
NWP	Numerical Weather Prediction
PALS	Passive and Active L and S band system
PFM	Proto Flight Model
PI	Principal Investigators
POS	Position and Orientation System
PR	Precipitation Radar
PSR	Polar metric Scanning Radiometer
PSR/C & A	PSR/C-band & A
RASS	Radio Acoustic Sounding System
SD	Snow Depth
SGP	Southern Great Plains
SMMR	Scanning Multi-channel Microwave Radiometer
SMTMS	Soil Moisture-Temperature Measurement System
SOOH	Satellite Orbital Operation Handbook
SSM/I	Special Sensor Microwave / Imager
SST	Sea Surface Temperature
SWE	Snow Water Equivalent
T.B.D.	To Be Determined
TAO	the Tropical Atmosphere Ocean
TB	Brightness Temperature
TMI	TRMM Microwave Imager
TRMM	Tropical Rainfall Measuring Mission
USDA	(United States) Department of Agriculture
V & H	Vertical & Horizontal
WCRP	World Climate Research Programmed
WVP	Water Vapor Profiling radiometer

1. PURPOSE OF AMSR MISSION

1.1 Purpose of AMSR Science

One of ADEOS-II' s core sensors, Advanced Microwave Scanning Radiometer (AMSR), receives at multiple frequencies and polarizations the faint microwave radiation emitted from the surface of the earth and from the atmosphere.

Through various types of calibration, the intensity of the microwaves received is converted to brightness temperature, which is a basic product. Algorithms for estimating physical quantities are then used to determine eight kinds of physical quantity: water vapor, cloud liquid water, sea-surface wind speed, precipitation, sea-ice concentration, sea-surface temperature, snow water equivalent, and soil moisture. The main objective for AMSR is to acquire data to determine the status of global water and energy environments.

AMSR's largest antenna aperture is two meters, enabling 6.9 GHz observations with reasonable spatial resolution. Expectations are high for sea-surface temperature; soil moisture and similar parameters that have not been observed with conventional microwave radiometers. AMSR will observe water vapor, precipitation volume and cloud water as the conventional radiometers have done, but with a much higher spatial resolution that is expected to improve observation accuracy. AMSR will analyze frozen soil characteristics and ice and snow at higher latitudes using 89 GHz channel data with a spatial scale on the order of 5 km.

1.2 Purpose of AMSR Calibration

To assure reliable application, AMSR data must be carefully calibrated. Earth radiation observed by AMSR is externally calibrated by cosmic radiation (low) and hot load radiation (high). Its calibration is similar to one of the Special Sensor Microwave / Imager (SSM/I). AMSR data will be checked by comparison with SSM/I for higher frequencies (above 19 GHz). AMSR data for frequencies below 10 GHz will be checked by comparison with model calculated TB and with data from the Airborne Microwave Radiometer (AMR). Geolocation errors and scan bias errors will be checked in the initial phase. In the long term, AMSR data will be monitored in several areas (radiometric noise, gain, antenna rotation speed, and so on).

1.3 Purpose of AMSR Validation

There are the eight AMSR standard products: water vapor, cloud liquid water, sea-surface wind speed, precipitation, sea-ice concentration, sea-surface temperature, snow water equivalent, and soil moisture. One of the major objectives of the AMSR validation plan is to generate the products with required accuracy and to improve the algorithms if necessary. Two strategic approaches are adopted in the AMSR validation, an operational path and an experimental one. The former is based on the existing operational real-time data collection systems, the Global Telecommunications System (GTS) for upper air sounding, precipitation, snow depth, and sea-surface temperature and wind velocity observed by buoys. The routinely observed data, soil moisture and snow, will be also introduced. The JAXA EORC will undertake to archive the in-situ data, make match-data sets with the AMSR data and deliver them to the AMSR Principal Investigators (PIs). The experimental path for the AMSR validation consists of two types of field activities: one is automatic-system-based field measurement such as water vapor and cloud water measurement by using microwave radiometers, and the other is field campaign type validation by deploying more sophisticated sensor systems including the AMR. Pre-launch validation will mainly focus on validation and improvement of selected algorithms for the AMSR standard products by adopting operational path using SSM/I and TMI besides several AMR flights and pre-phase observations. As post launch validation, the operational path approach will be done based on the heritage of the pre-launch validation only by the efforts of EORC and the PIs of the standard and research algorithms. The experimental one will be mainly implemented in cooperation among JAXA, the AMSR PIs, and some of the international scientific field activities. The both, pre- and post-launch validation should be carried out under mutual cooperation with the EOS-PM1 / AMSR-E team.

International scientific communities have plans for addressing their own scientific objectives. Some of them such as World Climate Research Programmed (WCRP) and International Geosphere and Biosphere Program (IGBP), are closely related to the ADEOS-II sciences and will be done the success of the ADEOS-II program in the premise. Those international scientific communities endorsed the ADEOS-II program to contribute to their own scientific goals. To coordinate the field campaign type validation of AMSR and field activities of international science projects will contribute considerably to the both goals of ADEOS-II program and the scientific ones.

For example, the World Climate Research Programmed (WCRP) proposed a Coordinated Enhanced Observing Period (CEOP) which could take advantage of the new suite of satellites and instruments expected to be operating in orbit in the 2002- 2004 time frame. The WCRP design a CEOP as an international experiment to carry out a case study of the influence of continental hydro climatic processes on the predictability of global atmospheric circulation and changes in water resources on time scales up to seasonal. It further recommended that the CEOP take place over the two-year period October 2001 to September 2003 (it changes with satellite launch adjournment in October 2002 to December 2004). The CEOP reference sites under the world climate variability will contribute to the ADEOS-II / AMSR project as test bets for validation and, in turn, the AMSR validation activities will play an important role on the CEOP.

The AMSR validation plan should be made based on the possible cooperation and coordination with international scientific activities.

2. SCHEDULE

Schedules of each work of calibration and validation are shown in Appendix B.

2.1 Procedure of Calibration

- Pre-launch calibration
- AMR modification
- AMR test flight
- Post launch calibration
- AMR data acquisition
- Evaluation

2.2 Procedure of Validation

- Truth data acquisition
- Creating match-up data
- Evaluation (algorithm, accuracy and data quality)
- Revision of algorithm

3. GENERAL CONCEPTS OF CALIBRATION AND VALIDATION

3.1 Calibration

3.1.1 Pre-launch Calibration

Signifies all AMSR pre-launch testing, including AMSR's initial checkout, as officially described in the Satellite Orbital Operation Handbook (SOOH).

3.1.2 Post launch Calibration

3.1.2.1 Brightness Temperature Calibration

Accuracy of brightness product radiation will be evaluated.

3.1.2.2 Geometric Calibration

Evaluation will include rough beam patterns, inter-channel co-registration and absolute position accuracy. Antenna rotation speed, attitude notation and the like will be monitored regularly.

3.1.2.3 Data Quality Evaluation (EOSD and EOS)

Includes evaluations of the quality of initial data, the soundness of all engineering values and deductive algorithms.

3.2 Validation

3.2.1 Pre-launch Validation

Algorithms created by principle investigators (PIs) will be checked using SSM/I, TMI and other data.

3.2.2 Post launch Validation

3.2.2.1 Evaluation of Accuracy of Physical Quantities (EORC)

Accuracy of physical quantities will be evaluated. Although the method will differ with each quantity, comparing the physical quantities will generally do evaluation estimated from AMSR data with independently measured quantities (survey data, aircraft observation data and other similar satellite data).

3.2.2.2 Evaluation of Data Quality

Initial quality will be evaluated, the same as for Level 1. Data insufficiencies resulting from algorithm malfunction and the like and image quality when viewed as images will be evaluated.

4. BASIC PLANS FOR AMSR CALIBRATION

4.1 Prelaunch Calibration

4.1.1 Level 1B brightness temperature

Level 1B brightness temperature is derived from a linear combination of the measured antenna temperature (V & H) and cosmic radiation. These coefficients are determined by the least square method relating brightness temperature and calculated antenna temperature. In the model for calculating antenna temperature, a uniform ocean surface is assumed, and appropriate geophysical conditions are changed (profile of air temperature and humidity, cloud liquid water, surface wind speed, and SST). AMSR PFM antenna pattern measurements are used in antenna temperature calculation. The number of scans used in averaging the hot load and cold count will be determined after launch, considering AMSR radiometric noise and stability.

4.1.2 Measurements of PFM characteristics

Information on radiometric noise, accuracy of antenna direction, antenna pattern of main reflector & CSM, and linearity of receiver gain will be useful in estimating the accuracy of retrieved geophysical parameters. The hot load temperature must be corrected in Level 1B processing since there is a temperature difference between the surface and the inside of the hot load (temperature where the sensor is located). Likewise, eight points of measured hot load and cold count values (sixteen points for 89GHz) must be corrected since there is an error depending on the relative position between the horn and hot load.

4.1.3 AMR

AMR will fly over the ocean under ADEOS-Ⅱand Aqua to make sure of AMSR/AMSR-E measurements, particularly for 6 and 10 GHz. Now, AMR has been reconstructed to become a sensor calibrated by two points of around 300 and 400 K. Experimental 3 flights will be conducted from March to April 2000 around Aoga-shima island. Purposes of the flights are to check the stability of AMR during each flight of 3 hours, to check the repeatability of AMR after reconstruction (one time), and to get offsets from antenna to brightness temperature for each frequencies and polarizations.

4.2 Post launch Calibration

Initial check must be carried out until six months after launch. Monitoring must be carried out until the end of the sensor observation. In order to carry out monitoring, EORC will produce necessary items from level 1B every one day.

4.2.1 Brightness Temperature Calibration

4.2.1.1 Initial check

4.2.1.1.1 Absolute calibration

a) Evaluation of CSM count and hot load

Evaluating the data acquired from eight points of measured values of CSM count and hot load at each frequency. In the first place, relative differences among eight points and time changing are carefully evaluated. The relations between hot load and count values and also the relation between hot load and heater on and off are investigated. In the second place, the number of the data points used, weight function, the number of scan for averaging, and etc. are determined. The available term on data is for a week.

b) Scan bias error

The TB bias between scanning positions is sought at each frequency and polarization. For each scanning position, the available term on data is for one to three months after launch.

c) Correction of 89 GHz difference

AMSR-E has two horn antennas for 89 GHz (A and B). Differences in the incident angles of horns A and B differ (55.0 degrees and 54.5 degrees) and receiver characteristics may also cause the brightness temperature to differ. This difference is investigated, and a correction coefficient is determined as necessary. The available term on data is for two to three days.

d) Cosmic observation

The cosmic observation with only one revolution around the earth is carried out on the 40 days after launch.

4.2.1.1.2 Multiple calibration

Evaluating the calibration of brightness temperature involves a method-based ambiguity, so a fixed method cannot be achieved. Multiple methods for evaluating calibration are prepared, and the agreements of results from each method are viewed.

a) Inter-satellite calibration

Mutual calibration of former AMSR-E and SSM/I or AMSR-E and TMI is performed. The accurate mutual calibration of AMSR and AMSR-E might be difficult since both AMSR and AMSR-E are the Sun synchronous satellites that bring about a time lag of five hours on the observation. The accurate mutual calibration of later AMSR-E and TMI also might be difficult since there are 3K errors with TMI calibration although TMI is the no Sun synchronous satellite that brings a time lag within only some ten minutes. Inter-satellite calibration, thus, is comprehensively evaluated after the results are obtained. The central frequency and incident angle have already been calculated by using an ocean radioactive transfer model. The term of calibration is six months.

Using a 0.25 scale grid of the entire sphere compares AMSR-E and SSM/I. The data of SSM/I is acquired from MSFC. The average values, the numbers, and the scattering of the data are put in as grid data.

Using a 0.1 scale grid match up data, which are obtained within ten minutes observed, compares AMSR-E and TMI.

AMSR and AMSR-E data will also be compared with SSM/I data of the past 14 years (1987 to 2000) and so with its climate values every month.

b) Evaluation by model calculation

Absolute values are evaluated by comparing the satellite-observed brightness temperature computed with a radiation transmission model using Truth Data with observed values. By using upper air observed data over the observational vassal and the small islands, brightness temperature compared with a radiation model and AMSR observed value are compared. The condition for comparison must be when it is sunny day with faint wind. The available term is for three to six months; however, producing match up data will be carried out all the time during the satellite operation.

Radiative transfer model

・Seawater dielectric constant: Klein and Swift (1977)

・Atmospheric attenuation: Liebe et al. (1993); Millimeter-Wave Propagation Model (MPM)

c) Comparison with AMR

After satellite launch, the flight of AMR and the satellite in the same period will be performed. AMR’s flight altitude is supposed to be 4 to 5 km. POS data, which is simultaneously acquired position and attitude data of the airplane, is used to correct the angle of incidence. The difference between the brightness temperature and the antenna temperature, that are resulted from the antenna patterns, is supposed to be sought in advance by using data from test flight over and around Aoga-shima Island. This depends on the AMR’s flight altitude. AMR cannot validate channels of the 50 GHz band.

4.2.1.2 Monitoring

The following items will be constantly monitored and sensor performance observed.

4.2.1.2.1 Radiometric noise

Radiometric noise is computed from CSM and hot load calibration source data. Monitoring is done for each revolution, seasonal change, short- and long-term trends, and other time scales.

4.2.1.2.2 Calibration counts

Counts of CSM and hot load are monitored.

4.2.1.2.3 Physical temperature

Physical temperatures of the main reflector, calibration sources, receivers, etc. are monitored.

4.2.1.2.4 Receiver gain variations

Receiver gain variations and AGC telemetry are monitored.

4.2.1.2.5 Scan bias error

Scan bias error, as described in Para. 4.2.1.1.1 b) are monitored regularly.

4.2.2 Geometric Calibration

4.2.2.1 Initial calibration

4.2.2.1.1 Rough evaluation of beam patterns

Beam width is roughly confirmed using coastlines and other domains with major contrast in brightness temperature and clearly defined boundaries. (However, this is only possible for low- frequency bands with a large overlap.)

4.2.2.1.2 Inter-channel co-registration

The accuracy of the positional agreement between all frequencies is evaluated using data of coastlines and regions with clearly defined boundaries. t 89GHz, the accuracy of the positional agreement between A horn and B horn is evaluated. Based on this, sensor alignment might be corrected if necessary. The available term is for few days to one week.

4.2.2.2 Monitoring

4.2.2.2.1 Antenna rotation speed

Antenna rotation speed is monitored.

4.2.2.2.2 Attitude fluctuations

Attitude data is monitored.

5. BASIC PLANS FOR AMSR VALIDATION

5.1 Prelaunch validation

5.1.1 Creating match-up data

5.1.1.1 Water Vapor

- SSM/I vs. GTS/sonde
- SSM/I vs. microwave radiometer
- TMI vs. microwave radiometer

5.1.1.2 Cloud Liquid Water

- SSM/I vs. microwave radiometer
- TMI vs. microwave radiometer

5.1.1.3 Sea-surface Wind Speed

- SSM/I vs. Internet/buoy

5.1.1.4 Precipitation

- SSM/I vs. truth data
- TMI vs. truth data

  Truth data: radar AMeDAS, rainfall gauge, field campaign data, etc.

5.1.1.5 Sea-ice Concentration

- SSM/I vs. AVHRR

5.1.1.6 Snow Water Equivalent

- SSM/I vs. GTS/snow
- SSM/I vs. snow depth gauge

5.1.1.7 Soil Moisture

- SSM/I vs. USSR data
- SMMR vs. USSR data
- TMI vs. truth data (US Oklahoma/SGP data, Nagaoka data, GCIP data, Thai and Tibet AWS data, China routine data)

5.1.2 Ground-based observation and aircraft observation

5.1.2.1 Water Vapor / Cloud Liquid Water

5.1.2.1.1 Hegura-jima Island (Oct. 2000 to Apr. 2002)

a) Ground-based microwave radiometer (WVP-1500) observation
b) Tipping-bucket rain recorder observation
c) Ceilometer observation (only Nov. 2001 to Apr. 2002)
See 7.2.1.3 for more details.

5.1.2.1.2 Minamidaito-jima Island (Nov. 2000 to Apr. 2002)

Ground-based microwave radiometer (WVP-1500) observation

5.1.2.2 Precipitation

5.1.2.2.1 Wakasa Bay (Feb. 2000, Jan. to Feb. 2001)

a) Ground-based observation
b) Ministry of Land, Infrastructure and Transport radar and NASDA radar (only 2001)
Collaborate with TRMM Team and CREST-JST.

5.1.2.2.2 Tibet (Aug. 2000 to Apr. 2002)

a) Automatic weather instrument (AWS) observation
b) Transportation of Ground-based microwave radiometer (WVP-1500), Wind profiler, RASS, etc. (Aug. 2001)

5.1.2.3 Snow Water Equivalent

5.1.2.3.1 Siberia (Nov. 2000 to Apr. 2002)

Automatic snow depth gauge observation
Collaborate with CAMP.

5.1.2.3.2 Tibet (Nov. 2000 to Apr. 2002)

Automatic snow depth gauge observation
Collaborate with CAMP.

5.1.2.3.3 Colorado (Oct. 2001 to Mar. 2002)

Ground-based microwave radiometer observation

5.1.2.4 Soil Moisture

5.1.2.4.1 Oklahoma / SGP'99 (Jul. 7 to 22, 1999)

a) Ground-based microwave radiometer observation
b) Aircraft observation (PSR/C & A, ACMR, Step-C, PALS, ESTAR);
Conduct jointly with AMSR-E; also collaborate with CREST-JST and CEOP.

5.1.2.4.2 Nagaoka (May to Jun. 2000)

a) Ground-based microwave radiometer observation

b) Ground-based soil moisture observation

Soil type, ground-surface roughness, ground-surface temperature, and vegetation coverage will be measured under various conditions.

c) Aircraft observation (AMR)

5.1.2.4.3 Tibet (Aug. 2000 to Apr. 2002)

a) Soil moisture-temperature measurement system (SMTMS) observation

b) Automatic weather instrument (AWS) observation

c) Ground-based soil moisture observation (only Aug. 2001)

Collaborate with CAMP.

5.1.2.4.4 Mongolia (Aug. 2000 to Apr. 2002)

a) Soil moisture-temperature measurement system (SMTMS) observation

b) Automatic weather instrument (AWS) observation

c) Automatic Station of Soil Hydrology (ASSH) observation (since Jun. 2001)

d) Ground-based soil moisture observation (only Aug. 2001)

Collaborate with CAMP.

5.1.2.4.5 Thailand (Jun. 2000 to Apr. 2002)

a) Soil moisture-temperature measurement system (SMTMS) observation

b) Automatic weather instrument (AWS) observation

Collaborate with CAMP.

5.2 Post launch validation

5.2.1 Water Vapor

5.2.1.1 Outline

The main activity with regard to total water vapor quantity will be validation using the worldwide radio sonde network.

5.2.1.2 Product accuracy

Total water vapor will be calculated for all of the world's oceans and sea areas (excluding areas of sea-ice). The required accuracy is 3.5 kg/m^2 for values in the range 0 to 70 kg/m^2.

5.2.1.3 Ground-based observation and vessel observation

5.2.1.3.1 Hegura-jima Island and Minamidaito-jima Island (May 2002 to Sep. 2004)

<Ground-based microwave radiometry observation>

Total water vapor will be estimated through use of a ground-based microwave radiometer that has an observation frequency band around the 20 to 30 GHz region; results will be compared with AMSR/AMSR-E estimated values. By collecting data while scanning through different azimuth angles and elevation angles, it will be possible to calculate spatial averages to some extent. In addition, it will be possible to collect data continuously over periods of time. Since AMSR/AMSR-E estimated values are only valid over sea areas, the microwave radiometers will be set up on Hegura-jima Island and Minamidaito-jima Island, which are both small in area and are situated more than 50km from other larger islands. Total water vapor will then be observed continuously (Oct. 2000 to Sep. 2004). The equipment will basically operate automatically, although a supervisor will visit each observation site as the need arises. The supervisor will recover the collected data and inspect the equipment (from the outside only).

The WVP-1500 Water Vapor Profiling Radiometer (which incorporates an azimuth turntable, a fan (T.B.D.) and a computer for data collection) made by the US company Radiometrics Corp. will be used.

5.2.1.3.2 The Oceanographic Research Vessel MIRAI (Aug. 2002 to Mar. 2004)

<Vessel-based microwave radiometer and radio sonde observations>

Truth data for validation of water vapor estimated from AMSR/AMSR-E data will be acquired using the Oceanographic Research Vessel MIRAI provided by JAMSTEC as the observation platform. MIRAI will voyage and observe the region from the Arctic Ocean to equatorial ocean for 280 days per year. MIRAI will be the best use for observing various geophysical parameters about water over the ocean where influenced of land does not affect. Since AMSR/AMSR-E will estimate water vapor only over the seas, in-situ vessel observation will be effective to validate AMSR/AMSR-E data.

A microwave radiometer (Water Vapor Radiometer WVR-1100 made by Radiometrics Corp.) will be carried on MIRAI. Microwave radiometer will measure two wavelength (23GHz and 31GHz) microwaves. Water vapor will be estimated using the microwave radiometer data and compared with the AMSR/AMSR-E data. Moreover, radio sonde observation will be carried out from MIRAI. Water vapor estimated from radio sonde data will be also used for comparison with AMSR/AMSR-E data. Radio sonde observation will be carried out simultaneously with the satellites as much as possible.

5.2.1.4 Creating match-up data

a) Match-up with global radio sonde data

Once a day (from May 2002 to Mar. 2005), total water vapor calculated from air temperature, air pressure and relative humidity profiles collected by radio sonde will be compared with the AMSR and AMSR-E estimated values. With regard to the worldwide radio sonde data, standard isobaric surface data that is distributed over GTS lines and data that include singular points will be used.

Since AMSR estimated values exist only for sea areas, radio sondes will be installed in places such as small islands. Radio sondes that are not influenced by radiation coming from land areas will be selected. Datasets that match the radio sonde data with the AMSR and AMSR-E footprints in both space and time will be created regularly, and validation will be carried out. It has been agreed that the Meteorological Agency will provide the radio sonde data. The sort data will include both standard isobaric surfaces and singular points.

・AMSR vs. GTS/sonde (Dec. 2002 to Mar. 2006)
・AMSR-E vs. GTS/sonde (May 2002 to Mar. 2006)

b) Match-up with microwave radiometer data

Total water vapor will be calculated from the microwave radiometer data collected at Hegura-jima Island and Minamidaito-jima Island. The values will be compared with AMSR and AMSR-E estimated values.

・AMSR vs. microwave radiometer (Dec. 2002 to Sep. 2004)
・AMSR-E vs. microwave radiometer (May 2002 to Sep. 2004)

c) Match-up with vessel observation data

Match-up data between AMSR/AMSR-E and water vapor data calculated from the vessel-based (MIRAI) observations will be created.

・AMSR vs. microwave radiometer (Dec. 2002 to Mar. 2004)
・AMSR-E vs. microwave radiometer (Aug. 2002 to Mar. 2004)
・AMSR vs. radio sonde (Dec. 2002 to Mar. 2004)
・AMSR-E vs. radio sonde (Aug. 2002 to Mar. 2004)

5.2.1.5 Relationship to organizational setup and other research projects

The match-up datasets will be created at EORC; the Algorithm Development PI will conduct both within EORC and assessment and validation using these datasets. The two ground-based microwave radiometers will be the property of EORC, and EORC will perform the observations at Hegura-jima Island and Minamidaito-jima Island. In the case of Minamidaito-jima Island, suitable cooperative tie-ups will be entered into, for example a tieup involving joint research with the Meteorological Agency. In addition, other organizations within Japan, such as the Meteorological Research Institute, possess similar equipment. It will thus be desirable to seek the cooperation of such organizations in order to form a multipoint observation network. In particular, in order to obtain data for a number of different latitudes, observations at high latitudes are required.

The collected data will be analyzed by both the Algorithm Development and Validation PI and by EORC. JAXA hopes to form multipoint observation network through collaboration with the AMSR-E Team, ARM, CLIVAR (EPIC), CRYSTAL and the GLI Atmosphere Team.

5.2.2 Cloud Liquid Water

5.2.2.1 Outline

Cloud liquid water will be validated primarily through comparison with observation values obtained using ground-based (vessel) radiometers.

Cloud liquid water is a physical quantity that is difficult to validate by quantitative. There are a number of ways of measuring cloud liquid water. One involves use of video sondes; another, radar measurement from aircraft. However, even though clouds are scattered widely through space and cloud formations change rapidly over time, a video sonde takes observations at one point only. Observations by aircraft are also limited both in the area in which they cover and the frequency with which they can be taken. Moreover, such observations do not constitute perfectly quantitative measurements. Estimating cloud liquid water quantity by ground-based microwave radiometer observation is an indirect remote sensing technique. However, the observation background is background radiation from space where is uniform and remains at a stable level. This means that the accuracy is higher than estimates from satellite orbits.

Cloud bottom height will be observed by ceilometers. The presumed accuracy of cloud liquid water will be improved by estimating cloud temperature from cloud bottom height data.

5.2.2.2 Product accuracy

Total cloud water will be calculated for all of the world's oceans and sea areas (excluding areas of sea-ice). The required accuracy is 0.05 kg/m^2 for values in the range 0 to 1.0 kg/m^2.

5.2.2.3 Ground-based observation and vessel observation

5.2.2.3.1 Hegura-jima Island and Minamidaito-jima Island (May 2002 to Sep. 2004)

<Ground-based microwave radiometer and ceilometer observation>

As in 5.2.1.3.1. At Hegura-jima Island, the ceilometer is installed and the cloud bottom height is observed too. At Minamidaito-jima Island, the data of the ceilometer which is installed at the airport can be used.

5.2.2.3.2 The Oceanographic Research Vessel MIRAI (Aug. 2002 to Mar. 2004)

<Vessel-based microwave radiometer and ceilometer observation>

As in 5.2.1.3.2. The ceilometer installed on MIRAI is used too.

5.2.2.4 Creating match-up data

a) Match-up with microwave radiometer data

Total cloud water will be calculated from the microwave radiometer data collected at Hegura-jima Island and Minamidaito-jima Island. Match-up data between these and AMSR / AMSR-E will then be created.

- AMSR vs. microwave radiometer (Dec. 2002 to Sep. 2004)
- AMSR-E vs. microwave radiometer (May 2002 to Sep. 2004)

b) Match-up with vessel observation data

Match-up data between AMSR/AMSR-E and cloud liquid water data calculated from the vessel-based (MIRAI) observations will be created.

- AMSR vs. microwave radiometer (Dec. 2002 to Mar. 2004)
- AMSR-E vs. microwave radiometer (Aug. 2002 to Mar. 2004)

5.2.2.5 Relationship to organizational setup and other research projects

As in 5.2.1.5

5.2.3 Sea-surface Wind Speed

5.2.3.1 Outline

Sea-wind velocity will be validated primarily through comparison with observation values obtained using buoys.

5.2.3.2 Product accuracy

Sea-wind velocity will be calculated for all of the world s oceans and sea areas (excluding areas of sea-ice). The required accuracy is 1.5 m/s for values in the range of 0 to 30 m/s.

5.2.3.3 Creation of match-up data

Sea-wind velocities obtained using ocean buoys and AMSR / AMSR-E estimated values will be compared. At present, the buoy data that can be used is from sources such as the National Data Buoy Center (NDBC), the TAO array, and JAMSTEC. Datasets that match the buoy measurements (which include information other than sea-wind velocity such as wind direction and sea-surface temperature) with the AMSR footprints in both space and time will be created and validated regularly. The height at which wind velocity observations are made will vary according to the type of measuring instrument used on the buoy, so the comparison will be made after adjusting for this factor.

The latest TAO buoy data is always distributed over the Internet, so this will be used. For NDBC buoys, it will be necessary to use the Internet.

- AMSR vs. GTS/buoy (Dec. 2002 to Mar. 2006)
- AMSR-E vs. GTS/buoy (May 2002 to Mar. 2006)
- AMSR vs. Internet/buoy (Dec. 2002 to Mar. 2006)
- AMSR-E vs. Internet/buoy (May 2002 to Mar. 2006)

5.2.3.4 Relationship to organizational setup and other research projects

JAXA hopes to collaborate with the Japan Meteorological Agency, the Frontier observational research program for global change, and CLIVAR.

5.2.4 Precipitation

5.2.4.1 Outline

Observations from ground-based radar and rain gauges, etc. will be compared. Since AMSR-estimated values for precipitation volume exist only for sea areas, it will be necessary to select observation values for rain gauges that are installed on islands that are as small as possible.

The AMSR precipitation intensity retrieval will have to satisfy the following requirements.

a) A high-accuracy data set that covers all of the world's oceans and sea areas.
   In particular, the presumed accuracy for high latitudes can still be improved, and there is a lack of reliable measurement data.

b) Capable of contributing to the meteorological and water budget research of GEWEX, CLIVAR, etc.
   WCRP has decided to draw up plans for a Cooperative Enhanced Observation Period (CEOP) which will focus mainly on the period 2002 to 2004. Collaboration with CEOP will be necessary for precipitation validation.

c) Data assimilation with the NWP model must be considered.
   In order to fulfill these goals it will be necessary to prepare cases that are complete with as wide a variety of different data as possible.

Sufficient accuracy of land precipitation measurements by the microwave radiometers has not been confirmed since information on atmosphere above land is relatively limited due to strong and space-timely variable emission from the surface. Since AMSR/AMSR-E will estimate geophysical parameter of soil moisture and vegetation water content that affects emissivity, accurate land precipitation measurement will be possible, comprehensive data about three-dimensional distribution of precipitation, rain grain size distribution, water vapor, cloud water, air temperature, surface emissivity, and ground temperature must be observed in order to estimate and validate precipitation with relatively less information.

For this reason, validation measurement for soil moisture will be performed in Tibet Plateau, and vertical profile of rain grain size distribution, cloud water and water vapor, cloud bottom and top height, vertical distribution of water vapor and temperature, and air temperature and wind distribution will be acquired by using micro-rain radar, microwave radiometer, lidar, sonde, wind profiler and RASS instrument. Combination of these acquired data will enable to describe radiative transfer process when a satellite detects microwave emitted by land surface. It will also enable to validate algorithms dealing with radiative transfer process. Combined data will be very valuable as observation data of assimilated precipitation and contribute to estimate precipitation by AMSR/AMSR-E. There are two types of algorithms that has been developed, one to calculate soil moisture supposing no precipitation, and another to calculate soil moisture supposing either case of precipitation and no precipitation. Comprehensive observation data will enable to validate later algorithm.

5.2.4.2 Product accuracy

Precipitation volume will be calculated for all of the world's oceans and sea areas (excluding areas of sea-ice). The required accuracy is 10 % for precipitation volumes of up to 20 mm per hour. Accuracy on land will be defined one year after the satellite launch.

5.2.4.3 Ground-based, vessel and aircraft observation

Data will be acquired also in land region or snowfall region because precipitation volume will be calculated also in land region after one year since the satellites launch.

5.2.4.3.1 Wakasa Bay (Jan. to Feb. 2003)

a) Ground-based radar observations
   Collect Ministry of Land, Infrastructure and Transport radar and private company multi-parameter radar data, and direct by compare this data with that of TMI and PR.
   Wakasa Bay is the site where solid precipitation can be observed by TRMM.

b) Rain gauge and Disdrometer observations
   Observe precipitation on the ground and precipitation grain size.

c) Aircraft observation
   NASA will observe by aircraft.

5.2.4.3.2 Tibet (May 2002 to Mar. 2005)

a) Automatic weather instrument (AWS) observation
b) Wind profiler and rain gauge observations (Jul. to Oct. 2002, Apr., Jul. to Aug. 2004)

5.2.4.3.3 Miyako and Yaeyama Islands (May to Sep. 2003)

a) Ground-based precipitation intensity observation
b) Japan Meteorological Agency radar observations
   Precipitation Intensity Observation Systems will be installed and acquired truth data in small islands of Miyako and Yaeyama for estimation of precipitation on the ocean.

5.2.4.3.4 The Oceanographic Research Vessel MIRAI (Aug. 2002 to Mar. 2004)

a) Vessel-based radar observations
b) Rain gauge and disdrometer observations

5.2.4.4 Creating match-up data

Match-up data between AMSR/AMSR-E and data from the above-mentioned ground-based observations will be created.

・AMSR	vs.	Radar AMeDAS (Dec. 2002 to Mar. 2006)
・AMSR-E	vs.	Radar AMeDAS (May 2002 to Mar. 2006)
・AMSR	vs.	Truth Data (Dec. 2002 to Mar. 2006)
・AMSR-E	vs.	Truth Data (May 2002 to Mar. 2006)

5.2.4.5 Relationship to organizational setup and other research projects

JAXA hopes to collaborate with the Japan Meteorological Agency, the NASA/AMSR-E Team, the GAME-Siberia Team, CEOP, the TRMM Team, and the AMSR Snowfall and Soil Moisture Team.

5.2.5 Sea-ice Concentration

5.2.5.1 Outline

Sea-ice concentration will be validated primarily through comparison with observation values obtained using other satellites or airplanes.

5.2.5.2 Product accuracy

Sea-ice concentration will be estimated for places like Polar Regions and the Sea of Okhotsk. The required accuracy is within 10 %.

5.2.5.3 Ground-based, vessel and aircraft observation

5.2.5.3.1 Okhotsk (Jan. to Feb. 2003, Jan. to Feb. 2004, Jan. to Feb. 2005, Jan. to Feb. 2006)

a) Aircraft observation (PSR) will be carried out (Jan. to Feb. 2003).
b) Aircraft observation (SAR) will be carried out (Jan. to Feb. 2004, Jan. to Feb. 2005, Jan. to Feb. 2006).
c) Photographs will be taken and video observation conducted from ships.

5.2.5.3.2 Antarctic (Jul. to Sep. 2002, Dec. 2002 to Feb. 2003, Sep. to Nov. 2003, Aug. to Oct. 2004, Aug. to Oct. 2005)

a) Aircraft observation (PSR and AVIRIS) will be carried out (Aug. 2002, Sep. to Nov. 2003, Aug. to Oct. 2004, Aug. to Oct. 2005).
b) Ground-based observation

5.2.5.4 Creating match-up data

Match-up data between AMSR/AMSR-E and data from the above-mentioned ground-based observations or other satellites will be created.

- AMSR vs. GLI (Dec. 2002 to Mar. 2006)
- AMSR-E vs. GLI (Dec. 2002 to Mar. 2006)
- AMSR vs. AVHRR (Dec. 2002 to Mar. 2006)
- AMSR-E vs. AVHRR (May 2002 to Mar. 2006)
- AMSR vs. RADARSAT (Dec. 2002 to Mar. 2006)
- AMSR-E vs. RADARSAT (May 2002 to Mar. 2006)
- AMSR vs. Truth Data (T.B.D.)
- AMSR-E vs. Truth Data (T.B.D.)

5.2.5.5 Relationship to organizational setup and other research projects

JAXA hopes to carry out joint observations with the AMSR-E Team and to collaborate with the GLI Cryosphere Group; CRL; and the Japanese, USA and European Antarctic Survey Teams.

5.2.6 Sea-surface Temperature

5.2.6.1 Outline

Sea-surface temperature will be validated, predominantly through comparison with buoy observation values.

5.2.6.2 Product accuracy

Sea-surface temperature will be estimated for all of the world's oceans and sea areas; the desired accuracy is 0.5 deg. C for temperatures from -2 to 35 deg. C.

5.2.6.3 Creating match-up data

Sea-surface temperatures collected using ocean buoys and AMSR/AMSR-E estimated values would be compared. The buoys that can be used are the same as for sea-wind velocity (sea above). Datasets that match the buoy (fixed and drifting) measurements (which include information on sea winds as well as on sea-surface temperature) with the AMSR footprints in space and time will be created and validated regularly.

- AMSR vs. GTS/buoy (Dec. 2002 to Mar. 2006)
- AMSR-E vs. GTS/buoy (May 2002 to Mar. 2006)

5.2.6.4 Relationship to organizational setup and other research projects

JAXA hopes to collaborate with the Japan Meteorological Agency, the Frontier observational research program for global change, and the GLI Ocean Team.

5.2.7 Snow Water Equivalent

5.2.7.1 Outline

Profiles of snow water equivalent, snow depth and grain size of snow and snow temperature will be targeted and they will be validated by acquired truth data. It will also be necessary to observe the changes in these items over time (in a time series). In addition, it will be necessary to confirm the influence of forest canopy on snow parameter estimation.

Snowfall will be estimated by microwave radiometer using the characteristic of naturally-occurred radiation that is emitted by the ground beneath a snow cover and scattered in a snow pack. The microwave radiometer will measure change in amount of emission. Although change in amount of emission depends on the diameter of snow particle, if fundamentally depends on the total ice quantity (snow depth x snow cover density) of a snow cover. The quantity directly obtained with microwave radiometer is snow water equivalent. Snow depth mainly measured by ground-based observations is usually used to validate snow water equivalent because there are few measurement points of snow cover density. In addition to snow water equivalent, snow depth will be also provided as sub product. From a viewpoint of water resources, snow water equivalent products are generally applied to investigation. From a viewpoint of snow coverage calamity, snow depth products are generally applied to investigation.

Although two algorithms have been currently proposed for snow water equivalent estimated by AMSR/AMSR-E, results from algorithm comparison test using SSM/I points out following three problems.

(1) Footprint size data for validation of sensors on satellite has not been acquired.
(2) Effects of vegetation, especially taiga have not been sufficiently evaluated.
(3) Snow metamorphosis leads to deterioration of estimation

Consequently, special observation plan considering these problems will be necessary for validation of snow cover.

To deal with the problem (1), (a) it will be necessary to perform simultaneous satellite observation considering footprint scale data in uniformed observational areas as much as possible, and (b) the system configuration of ground observation that produce variety of footprint will be necessary. The observations that will be performed in Tibet Plateau and Yakutsk, Siberia are planned to deal with the problems (a) and (b). To deal with the problem (2), validation data will be acquired. The five flat and extensive areas of Tibet Plateau will be chosen for the observations, and the snow depth sensor and the automatic weather station will be set up in the middle of these four areas. An area of Yakutsk, Siberia will be chosen for footprint scale observation, and seven automatic snow depth sensors will be set up in this area. The six of these seven sensors will be set up in taiga, and the rest one will be set up out of taiga. In all these areas, snow density and snow grain size will be estimated during the winter for the problem (3). To deal with (3), it will be necessary to perform in-situ measurement and observe state variable of snow (change in grain size) and microwave brightness temperature during a winter; however, it will be very difficult to perform in-situ measurement simultaneously with footprint scale satellite observations. For this reason, we work out our strategy for validation with long-term observation using the microwave radiometer on the ground and will acquire fundamental data. The results will be reflected on algorithms and products will be validated by footprint size data. Long-term ground observations will be performed in Rocky Mts. Colorado with the cooperation of the AMSR-E team from University of Colorado.

WCRP has decided to draw up plans for a Cooperative Enhanced Observation Period (CEOP) which will focus mainly on the period 2002 to 2004. Collaboration with CEOP will be necessary for snowfall validation.

5.2.7.2 Product accuracy

a) SWE : 20 % or 10 mm
b) SD : 20 % or 5 cm

5.2.7.3 Ground-based and aircraft observation

Ground-based observations using both ultrasonic wave snow depth gauges and manual observation will be conducted in areas of GAME concentrated observation in Tibet and Siberia. Ground data, such as data on snow depth, snow density, snow temperature, grain size, and vegetation moisture content, will be collected.

5.2.7.3.1 Siberia

a) Ground-based snow observation (Nov. 2002 to Mar. 2003, Nov. 2003 to Mar. 2004, Nov. 2004 to Mar. 2005)
b) Snow depth measurement using automatic gauges (May 2002, Nov. 2002 to May 2003, Nov. 2003 to May 2004, Nov. 2004 to May 2005)

5.2.7.3.2 Tibet

a) Snow observation on the ground (Jan. 2003, Jan. 2004, Jan. 2005)
b) Snow depth measurement using automatic gauges (May to Jun. 2002, Nov. 2002 to Jun. 2003, Nov. 2003 to Jun. 2004, Nov. 2004 to Jun. 2005)

5.2.7.3.3 Colorado

a) Aircraft observation (Feb. to Mar. 2003).
b) Ground-based microwave radiometer observation (Sep. 2002 to Mar. 2003)

5.2.7.4 Creating match-up data

Match-up data between AMSR/AMSR-E and the above-mentioned ground-based observation data (GTS/snow and snow depth gauge) will be created.

- AMSR vs. GTS/snow (Dec. 2002 to Mar. 2006)
- AMSR-E vs. GTS/snow (May 2002 to Mar. 2006)
- AMSR vs. truth data (Dec. 2002 to Mar. 2006)
- AMSR-E vs. truth data (May 2002 to Mar. 2006)

5.2.7.5 Relationship to organizational setup and other research projects

JAXA hopes to conduct the joint observation with GEWEX / CEOP and the AMSR-E Team and to collaborate with the AMSR Precipitation Group, the GLI Cryosphere Group, the Frontier observational research program for global change, and CREST-JST.

5.2.8 Soil Moisture

5.2.8.1 Outline

Algorithms that estimate soil moisture using the 6.9 GHz channel will be compared internally. Ground-based observations of soil moisture and related parameters will be conducted under various conditions of vegetation, soil, and climate.

These data will be compared with AMSR, AMSR-E and aircraft AMR data. AMR observation is necessary to detect influences of land surface heterogeneity on the satellite observation.

Although four algorithms have been currently proposed for soil moisture estimated by AMSR/AMSR-E, the algorithm comparison test shows the large gap between the results produced from each algorithm. For this reason, soil moisture has not been established as standard products. The two major causes are described as follows.

(1) Foot size truth data for validation of sensors on satellite has not been acquired.

(2) For various land cover condition, data for validation of the sensor on the satellite has not been acquired.

Consequently, special observation plan considering these problems will be necessary for validation of soil moisture.

To deal with the problem (1), (a) it is necessary to perform simultaneous satellite observation providing footprint scale data in uniformed observational areas as much as possible, and (b) it is necessary to perform simultaneous satellite, airborne, and ground observations considering variety of footprint. The observation that will be performed in Mongolia is planned to deal with the problems (a). The observation covering an area of 60 km x 60 km and estimate dense soil moisture, vegetation water content, ground temperate and the moving observation on 100km will be performed. To deal with the problem (b), the airborne observation that measures large extensive soil moisture distribution will be performed in Iowa.

In order to deal with the problem (2), it is necessary to consider that effects of vegetation are particularly important. Therefore, the observations will cover Tibet Plateau as bare land, grassland in Mongolia, cassava fields (Manihot utilissima) as crops in Thai, teak grove (Tectona grandis) as deciduous forest in Thai. Also the observations will cover soybean fields and cornfields in Iowa and grasslands and wheat fields in Oklahoma. In Tibet Plateau, validation data for soil moisture considering the interaction with freezing and melting of permafrost will be acquired. Acquisition of validation data under such various land cover and hydrological conditions will improve algorithm certainty and produce choices of algorithms that can be matched off against all conditions.

WCRP has decided to draw up plans for a Cooperative Enhanced Observation Period (CEOP) which will focus mainly on the period 2002 to 2004. The cooperation of CEOP and AMSR-E team is necessary for validation.

5.2.8.2 Product accuracy

T.B.D.

5.2.8.3 Ground-based and aircraft observation

Ground-based soil moisture observations will be conducted in Thailand, Tibet, and

Mongolia, where ground data such as soil moisture, vegetation moisture content, ground-surface temperature, ground-surface roughness, and soil texture will be collected. In addition, Aircraft observation will be conducted as well.

5.2.8.3.1 Thailand

a) Ground-based soil moisture observation (May, Sep., Nov. 2002, Aug, Sep. 2003, Feb., May, Sep. 2004)
b) Ground-based automated observation (Meteorological data, soil moisture) (May 2002 to Mar. 2005)

5.2.8.3.2 Tibet

a) Ground-based soil moisture observation (Jun. to Oct. 2002, Sep. 2003, Apr., Jul. to Aug. 2004)
b) Ground-based automated observation (Meteorological data, soil moisture) (May 2002 to Mar. 2005)

5.2.8.3.3 Mongolia

a) Ground-based soil moisture observation (Jun., Aug. 2002, Jun., Aug. 2003, Jun., Aug. 2004)
b) Ground-based automated observation (Meteorological data, soil moisture) (May 2002 to Mar. 2005)

5.2.8.3.4 Iowa

a) Ground-based microwave radiometer observation (Jun. to Jul. 2002)
b) Aircraft observation (PSR/C & A, ACMR, Step-C, PALS, ESTAR) (Jun. to Jul. 2002)

5.2.8.3.5 Oklahoma

a) Ground-based soil moisture observation (Jun. to Jul. 2003)
b) Aircraft observation (PSR/C & A, ACMR, Step-C, PALS, ESTAR) (Jun. to Jul. 2003)

5.2.8.4 Creating match-up data

Match-up data between AMSR/AMSR-E and the above-mentioned ground-based observation data will be created.

Including matching up with Mongolia routine data and USA (Oklahoma) soil moisture data.

- AMSR vs. truth data (Dec. 2002 to Mar. 2006)
- AMSR-E vs. truth data (May 2002 to Mar. 2006)

5.2.8.5 Relationship to organizational setup and other research projects

JAXA hopes to conduct the joint observation with the WCRP / CEOP and NASA / AMSR-E teams and to collaborate with the AMSR Precipitation Team, the GLI Land Team, the Frontier observational research program for global change, and CREST-JST.

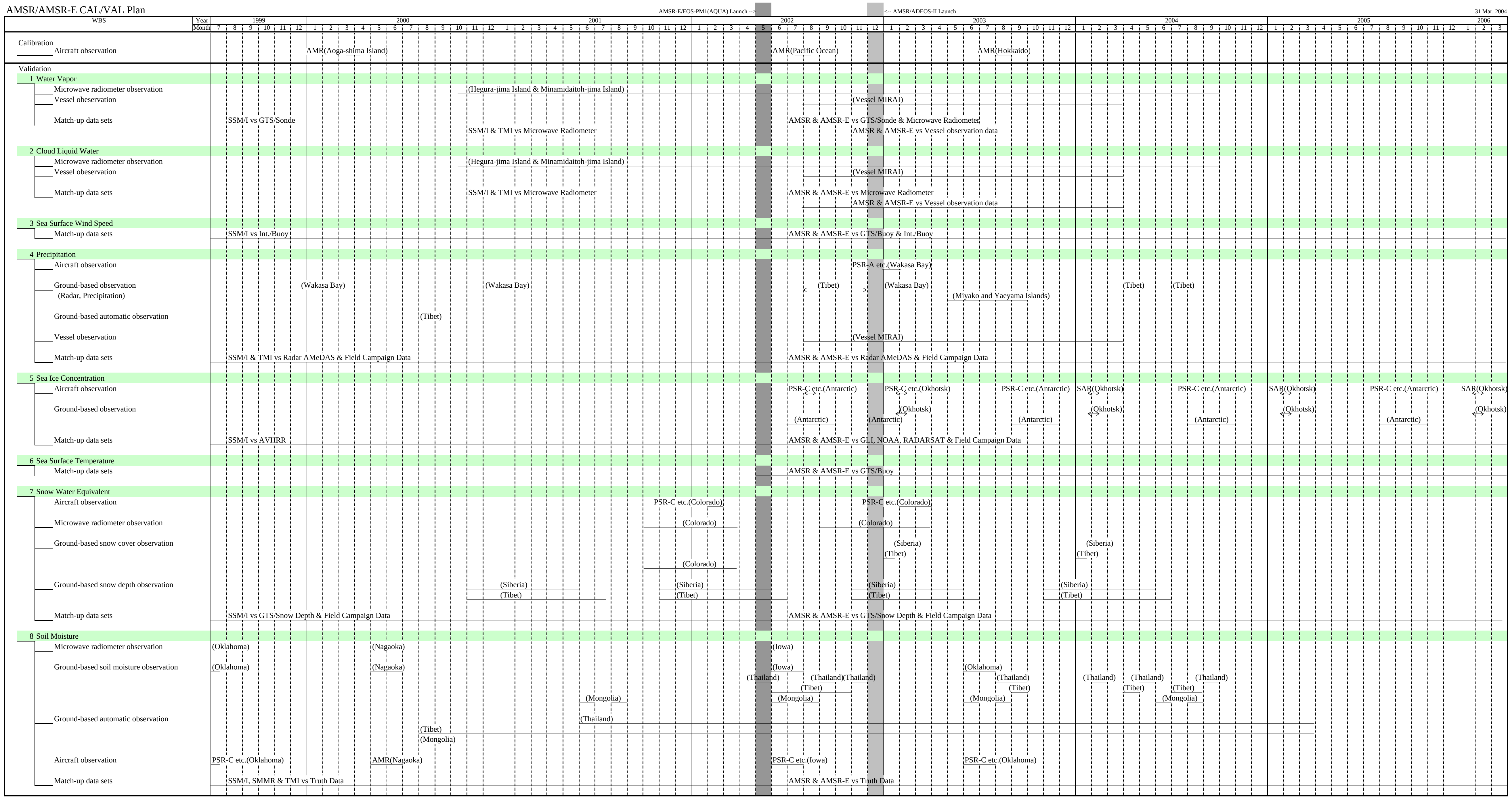
6. OPERATION TEAMS

Organization of Cal/Val Planning Team is shown in Appendix C

Appendix B AMSR CAL/VAL Plan

AMSR/AMSR-E CAL/VAL Plan

31 Mar. 2004



Appendix C Organization of Cal/Val Planning Team

Organization of Cal/Val Planning Team