SMOS Campaigns Requirements
#03.2, October-2000

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1. Introduction

This document is a draft plan for the campaigns. Its goal is to give an overview of what should be done for the preparation of SMOS. It is in three parts: ocean, land (we include cryosphere here at the current level), and system validation. Also covered are the parts funded at national level for information. It is of course a skeleton of an actual campaign definition document! Currently, the critical part is to have access to radiometers suitable for the purposes of the studies, i.e., which cover the SMOS characteristics so that algorithms etc can be really tested and validated.

Globally we can consider several types of investigations under 3 headings:

A. Ocean

Medium to long term observations of the impact of sea surface state on the radiometric signal (Stokes parameters). The sea state means foam, roughness, temperature, but also background radiation, Faraday rotation, Sun and galactic glint must be considered. Tower and aircraft observations are needed.

B. Land

Medium term monitoring of land surfaces (physics of measurements, retrieval algorithms, influence of various vegetation canopies, surface roughness, Stokes parameters). Ground based observations required.

Analysis of more complex surfaces and perturbating factors such as forested areas, snow cover, influence of rugged terrain and the issues linked to mixed pixels. Aircraft observations.

Long term monitoring of land surfaces (specific effects (dew, frost), assimilation schemes). Ground based observations.

First analysis of the signal over snow and ice. Aircraft and "ground" based.

C. Interferometric demonstrators (ground based and aircraft)

System demonstration
Algorithms final tests/validation
Cal val activities at a later stage

The main actions are summarised in the table below:

Summary table

ID	Platform	Duration	Target	Science objective
1x	Tower	Medium	Sea	Impact of sea state on emissivity, modelling
1x	Aircraft	short	sea	Impact of sea state on emissivity (wind)
2x	Ground	medium	land	Various land use types, emissivity modelling
2x	Aircraft	Short	land	Mixed pixels, snow, forests, mountains
3x	Ground	Long	Land	Svat assimilation, dew, frost, diurnal cycle
4x	Aircraft?	Short	Land/sea	Layered snow, ice, sea ice: emissivity modelling
5x	Ground & Air	Medium	Land/sea	Technical assessments

The instrumentation necessary for all these campaigns includes various classical means and radiometers. At this level it should be noted that we need radiometers operating at L band, with good accuracy and sensitivity (for sea measurements with very good accuracy and sensitivity!), polarimetric capability, variable incidence angle. But the exact requirements are of course dependent on the application as discussed below.
Appendix A gives a summary of campaign needs. The ID numbers in the text refer to the reference number of the table in Appendix A. Appendix B gives an updated overview of existing or planned radiometers.

2. Oceans

2.1 Effect of Sea State on salinity retrievals (ID#11-14)

2.1.1 Scientific objectives

Scientific question: SSS retrievals present several major challenges directly linked to the instrument sensitivity required and to the related impact of perturbating factors. The first issue to be dealt with is the modelling of the emissivity as a function of sea state. The subsequent questions are linked to inferring the sea state to correct / improve measurements. (i.e. ancillary data necessary, averaging (space and time), ….)
The scientific objectives of the campaigns are thus to measure very accurately brightness temperatures and all relevant surface conditions over a large range of conditions as well as perturbating factors (in summary: SST, surface roughness, foam, sun glint, rain, ionospheric effects and galactic/cosmic background radiation). This will imply two sets of campaigns, some over a given point and for long periods of time, others with aircraft to sample over short periods varying sea states.

2.1.2 Requirements

The brightness temperature sensitivity to salinity is at best (warm ocean around 30°) ? T_B / ? S = 1K / psu dropping to 0.25 K / psu for arctic conditions (around 0°C). Hence, to find salinity in warm oceans to the 0.1 psu level requires radiometric measurements to better than 0.1 K and knowledge of the influence of other effects to the same level. Requirements are even stricter for cold oceans. This is the main specification driver for oceanographic campaigns.
The sensitivity to SST is small at high salinities, and for 34 psu water we find ΔT_B / ΔSST = -0.2 K / °C dropping to zero in arctic oceans around 0 °C.
The above considerations are based on well established models reflecting the fact that for a smooth ocean surface the brightness temperature is found from simple calculations if the dielectric constant is known. This is generally assumed to be the case, but some debate about the validity of the existing dielectric constant models is ongoing, and this should be checked out.
Concerning the sensitivity to wind speed, the situation is less favorable. Several models are around, but it must be borne in mind that they were often developed with focus at higher frequencies, and they often disagree at L-band. Very few measurements are available:
The only available V pol data seems to be "old" Hollinger measurements from the late 60's indicating 0.2 K / m/sec at 50° incidence, increasing to 0.3 K / m/sec at 20° incidence. One obvious weakness of the above quoted figures is that they do not at all reflect the possible significance of azimuth viewing angle, i.e. the polarimetric signature. So far, all polarimetric measurements have concentrated on much higher frequencies. Also model work has focussed on higher frequencies and L-band results must be regarded as indicative at best. The ESTEC – Pampaloni model shows a peak to peak brightness temperature variation of 0.3 K with azimuth angle (8 m/sec wind, 50° incidence, 10°C, and 35 psu). Simon Yueh's model finds a lower figure around 0.1 K.
Basic and accurate measurements of the L-band brightness temperature as a function of wind speed and direction must be carried out. The measurements should cover a wind speed range of 0 to 15 m/s and the

full 360° azimuthal range (due to symmetry only slightly more than 180° is strictly speaking required, which is important for practical reasons when doing tower based measurements). The incidence angle should ideally range from nadir to 60°, but bearing in mind the problems associated with nadir measurements, especially from a tower, the practical range is 10° to 60°. Knowledge of actual incidence angle is crucial. At 50° incidence angle the vertical brightness temperature of the sea depends on incidence angle by some 2.5 K / °. Hence to get uncertainties in the 0.1 K range we need to know the incidence angle to better than 1/20 of a degree. In the airborne case this is just possible with a high quality INU mounted directly on the antenna structure. In the tower case this require some care. Also the antenna beamwidth is an important issue. As we intend to measure brightness temperature as a function of incidence angle, a beamwidth of 20° is at best questionable due to the smearing effect. A 10° requirement has been mentioned, but as this results in a large aperture around 1.5 m there is a trade-off issue to be considered carefully. At least H & V polarisation are required, but the full set of Stokes parameters should ideally be measured. While measuring the brightness temperature, a range of other measurements must be carried out concurrently: wind speed and direction, sea surface temperature, salinity, foam coverage, wave spectrum (well into the capillary region), atmospheric conditions.

Tower: Accurate L-band radiometer with full polarimetry. The stability should be better than 0.1 K over 3 days. The instrument should be able to withstand seawater (brine). Calibration 1K.

Aircraft: Fully polarimetric radiometer. A good stability is required here as well (0.05 K over 15 minutes). Careful attitude measurements required.
It is planned to near simultaneously operate the EMIRAD Ku- and Ka-band system, which is fully polarimetric. It will help in emissivity modelling and frequency behaviour validation.

2.1.3 Framework

A first Campaign (WISE) is planned for November 2000 on the “Casablanca” platform. (ESA funding) but this campaign will not address all the questions, so subsequent campaigns will have to be planned. A proposal was submitted to EU (MIMOSA), but failed. An updated proposal is being considered.
A first airborne campaign, LOSAC, funded by ESA is taking place in November 2000 through 2001. It makes use of the Danish L-band system (TUD funded by Danish programme).

2.1.4 Status

A first tower campaign in the NW Mediterranean (WISE 2000: one month, November 2000) has been organised and funded by ESA. It will use the polarimetric radiometer now under construction at UPC. ICM and LODYC/CETP will make the measurements of the environmental parameters.
Measurements to be made during WISE: Horizontal and vertical brightness temperature, and third/fourth Stokes parameters (Th, Tv, U and V) from the L-band polarimetric radiometer at different incidence and azimuth angles. Foam coverage from video recording of the radiometer field-of-view. Whitecapping surface, sea surface elevation, directional slope variance and some properties of the small-scale spectrum derived from a 3D camera. Sea surface temperature from an infrared radiometer. Salinity from near-surface moored sensors and water samples at different depths. Sea surface and air temperature, wave period and height, surface current intensity and direction, atmospheric pressure, relative humidity, wind speed and wind direction from a moored buoy. Buoys deployment and recovery, and initial 3D survey of the temperature and salinity fields, will be made from an oceanographic vessel.
Additional radiometers are expected to be incorporated into WISE measurements by US colleagues: L/S band H/V radiometer (UMass) and C to W band polarimetric radiometer (NOAA-ETL).

A longer (4 months) campaign in “Casablanca”, to catch more different conditions in winter-spring 2001, and a series of airborne measurements (TUD radiometer, Danish Air Force C-130, over “Casablanca” and North Sea) was submitted for funding (MIMOSA proposal) to the EU 5th Framework Program. The

proposal failed, but the work is still required to be carried out. An update and reissue of the proposal is being considered.
At least another tower campaign in a colder (and probably rougher) environment should be organised, after analysing the WISE results. The North Sea could be an adequate choice. This campaign requires specific funding to be identified. Now that MIMOSA was not approved, a “Casablanca” WISE extension is considered in 2001, requiring funding by ESA. Funding for 2 C-130 flights is available (ESA and Danish funding).
The TUD instrument is scheduled to be ready by late fall 2000.

In the airborne campaigns it is planned to acquire also some in situ data. In the Mediterranean the flights are proposed over the platform and a ship performing surface conditions monitoring. In the North Sea ground data would be provided by nearby oil drilling platforms.

2.1.5 Calendar

The contract for WISE 2000 had the Kick off meeting at the end of February 2000. Ship time for buoys mooring near the tower has been obtained for mid September. The campaign should be completed by the end of November 2000.
By June 2000 the decision on MIMOSA funding was known.
A first test flight with the TUD radiometer is scheduled for the 16'th of November 2000. The rest of flights are carried out in spring 2001 (the North Sea) and late fall 2001 ("Casablanca").
The HUT 36 GHz polarimetric radiometer on the Skyvan has successfully passed flight tests, and will collect preliminary data over the Gulf of Finland in the fall of 2000.

2.1.6 Campaign skeleton

a) Tower campaigns: the instrument should be operated in a place where the environment variables change (wind, salinity, and tremperature) and over a period of time sufficient to have a fair chance to observe various conditions. Ideally the campaign should be repeated in several places (cold waters, tropical waters etc…). Ground data collection should be exhaustive with equipped buoys, and other instrument (met, wind at different levels, and possibly a scatterometer?). The instrument should take angular measurements (10-60°) and have fine specifications. Perturbating factors (background radiation etc..) should also be measured.
b) Aircraft campaigns. The basic concept is here the same as in (a) but should allow a better sampling of varying sea surface states and conditions. Also airborne experiments are well suited for measuring the azimuthal signature of the sea using circle flights and a range of incidence angles. It is planned to include polarimetric measurements at higher frequencies (Ku and Ka-bands), but this has some impact on the programme (cost and time schedules) as the higher frequencies and L-band cannot be operated simultaneously on the C-130 (one is backwards looking, the other side looking so they do not both cover the target area at the same time). Also, combinations of the HUT-2D / HUT 36 GHz polrad / HUT L-band polrad are available from some time in 2001.

2.2 Cal val campaigns (ID#19)

This is still TBD. It will be based upon results from the first campaigns, but will obviously be based on aircraft campaigns with adequate ground measurements, and this over a number of areas to sample the main conditions. Calibration/validation campaigns have to be carried out after SMOS launch. Besides using large external data sets for validation (and control for possible instrument drifts) specific campaigns have to be organised. One of the suggested areas was the upwelling region off NW Africa, near the Canary islands, where a permanent station is operated, ships are easily available, and important salinity variations exist on a warm ocean. Another region in a cold ocean should be identified.
Details TBD. Low priority now, but everything has to be ready by the end of 2004.

3. Land

3.1 Medium term monitoring of land surfaces (ID# 21-24)

3.1.1 Scientific objectives

Scientific question: what is the exact emission (Stokes parameters) over land, how do retrieval algorithms behave with varying canopy structures and surface characteristics?
The goal here is to monitor several controlled targets during whole vegetation cycles and varying surface conditions. The radiometer is installed on a rail mounted crane (in Avignon) over several targets with various vegetation types (e.g. wheat, alfalfa, and corn representing different geometries, and being widely spread), and various surface roughnesses. Irrigation will enable varying surface soil moisture, vegetation interception etc… A possible experiment layout is to prepare 3 fields (corresponding to the 3 crop types) each subdivided into 2 parcels. One parcel per crop should be left evolving in accordance with its natural cycle, while the other parcel could be subjected to artificial irrigation, or stress. The data collected will be used to test retrieval algorithms under all possible conditions and for vegetation evolving from seeds (bare soil) to senescence, analyse the Stokes parameters and allow finalising the viewing conditions necessary to efficient retrievals and with potential limitations. A boom mounted instrument would be used in the Paris area (or Reading) to assess a number of related issues (frost-dew ID#24).
The highest priority would be on "well behaved" targets (smooth terrain, crops, grassland/fallow). Other targets such as forests would be addressed in a second step, once aircraft radiometers/demonstrators are available.
There is also a funded Spanish contribution through a Special Action (already granted to TSC/UPC) to analyse experimentally emissivity modelling issues. This campaign will be performed during two or three years (depending on the budget finally allocated) and four weeks per year in the controlled fields that the Agricultural Engineers of the Universitat de Lleida and the IRTA (Institut de Recerca en Tècniques Agropecuàries). The objective is to analyse the active (radar) and passive (radiometer, four Stokes parameters) response of land at different stages of vegetation growth: from bare land to senescence. This activity may be fitted in action ref # 21.

3.1.2 Requirements

Forcing variables (sensible and latent heat fluxes, net radiation, ground heat flux, rainfall), ground measurements of temperature and humidity profiles, vegetation characterisation, plus a polarimetric radiometer, possibly operating continuously. The surfaces will have different levels of roughness and vegetation cover will evolve with time. It is expected to have also different types of crops (wheat, alphalpha, corn,…).
Angular scanning (-50°/ +50° step 7° TBD), beamwidth less than 15°, stability better than 1K over a month, calibration at least once a month, sensitivity 0.5 K. Here again measurements with the EMIRAD Ku & Ka band radiometers, or the HUT 36 GHz radiometer could be very beneficial especially for the polarimetric issues.

3.1.3 Framework

Specific work is funded at french level (ground experiments) and Danish level (radiometer) under an INRA/TUD collaboration.
In addition, at UK level a request for funding has been submitted to NERC. Funding for using the Reading radiometer in Paris is yet to be found.

3.1.4 Status

The radiometer is currently under construction at TUD while the site is being prepared in Avignon. A first campaign will be carried out this fall to test thoroughly the procedure and equipment.

The first full campaign will start during spring 2001.
For the Reading instrument, we are waiting for the results of the answer to the NERC AO.

3.1.5 Calendar

Tests and fine tuning of the radiometer Avignon Fall 2000
First campaign spring 2001 Avignon
A campaign is currently underway at Reading Univ.

3.1.6 Campaign type

In Avignon measure T_B at various angles over different types of vegetation and surface roughness, with the possibility to influence artificially moisture with irrigation. Measurements performed throughout the vegetation cycle with possibly stresses imposed. The scheme would follow the usual procedure used in Avignon

The Reading campaign is not yet fully finalised (pending funding) but the INRA and IPSL groups are in close contact for collaborative studies.

3.2 Analysis of perturbation factors (ID# 25 and 26)

There are here several objectives linked to the science questions of interest, such as snow cover, influence of rugged terrain, forests, and mixed pixels. To be carried out primarily by aircraft, but Reading is planning a small experiment over a scale model scene (they will also start the investigation of the variable pixels). There are several potential sites for these studies.

3.2.1 Scientific objectives

There are several objectives to be fulfilled:
<u>Science questions</u>: The main scientific question is the mixed pixel issue. How to relate retrievals to actual soil moisture over a pixel of mixed vegetation cover and impact of the presence of free water, snow, forests on the ground. The pixel size variations should also be analysed.
The second is the quantification of the signal perturbation linked with mountains / hilly terrain.
Finally, it will be necessary to address with real data the impact of snow and the actual penetration through forest canopies.

3.2.2 Requirements

An instrument mounted on an aircraft and preferably having all the characteristics of SMOS: polarimetric, frequency (of course), but also muti incidence angle and imaging capability. The calibration stability should be of 1 K for a whole flight.
There is also the related question of ground measurements. In some cases the task might be daunting.

3.2.3 Framework

It is expected to have ESA funding for these campaigns.

3.2.4 Status

We are thinking of using in a first step the instrument made currently by TUD (Danish funding) which could fly on the Danish Air Force C-130 (TBC- funding to be found). The instrument is planned to be ready by fall 2000. Also the HUT L-band polarimetric radiometer on the Skyvan can be used.
Obviously, a SMOS demonstrator is absolutely necessary and should be used once validated. Currently, the most promising system is the HUT-2D instrument on the Skyvan. It is scheduled to be available for data missions by spring 2001

3.2.5 Calendar

Depending upon funding:
L-band instruments ready by fall 2000, test and flights before the end of the year 2000 (sea and land?)
In 2001 several campaigns should be planned over land, in winter in northern areas (forest & snow), over mountains where ground campaigns are taking place (Ardeche?), and over equipped sites (Toulouse, Valencia, Avignon, Reading…possibly co-ordinated with flights over oceans. Two test sites in Finland offer a possibility for airborne data collection on mixed pixels, boreal forest, topography, frost,and snow: one near Helsinki (ground truth on soil moisture, precipitation, weather) and one near Oulu (EMAC'95 test site in northern Finland).

3.2.6 Campaign skeleton

Fly over areas having the above-specified characteristics. The main issues will be related to the availability of some sort of ground truth and of an airborne L-band instrument without scanning capability until the SMOS demonstrators are available. One should keep in mind the idea of using helicopters for some cases.
We believe it would be profitable to extend an EMIRAD flight over the sea to some acquisitions over land (known and monitored area) to make a first analysis of polarimetry.

3.3 Cal / Val (ID#29)

This is yet TBD from first results. Several sites (TBD) will have to be selected and monitored. This is not an easy question. We are currently considering a site over Antarctica (instrument performances), a site over the rain forest (but still many open questions). Sites over a large rather homogeneous and well known area (as the Southern Great Plains also used for AMSR) and or GEWEX sites. There is also a potential site near Valencia where basis information and ground measurements are available. The area is of medium complexity (vegetation and topography) with semi arid conditions.

3.4 Snow and Ice (ID#41)

3.4.1 Scientific objectives:

Apart from the question mentioned above, there are several science issues to be addressed at this level (as well as for sea ice). The maturity of the analysis is not yet sufficient to draft a campaign plan. It is intended to progress on this part when the ocean and land part are more advanced.

3.4.2 Framework

The idea would be to use existing instruments and piggyback planned experiments with the addition of specific campaigns in the northern countries with HUT and/or TUD instruments. In the longer term, it will be necessary to plan a campaign over Dome C (Antartica) to address the SMOS Cal/Val point.

3.4.3 Status

Not mature

3.4.5 Calendar

Start of planning at the end of 2000 for campaigns in 2001-2003.

3.5 Long term monitoring: (ID# 31 and 32)

3.5.1 Scientific objectives

Scientific question: Validate with actual data the possibility to retrieve root zone soil moisture from regular measurements of surface soil moisture in an assimilation scheme. The tests have already been done but with classical measurements of soil moisture (gravimetric for example), and it is necessary to test it in "real life" i.e. with all the perturbating factors (frost, dew…) over at least an annual cycle and over at least two different sites with adequate accompanying measurements. The second goal is to assess the impact of the acquisition time (local time of the day), and temporal sampling in terms of perturbations and possible biases.
To achieve this goal it is necessary to have a radiometer working continuously for a long period of time over two "simple" targets (short grass and bare soil) in a first step and then move to agricultural areas.

3.5.2 Requirements.

Forcing variables (incoming and reflected long wave and shortwave radiation, latent sensible heat fluxes, ground fluxes, near surface humidity, rain, winds, air temperature and pressure), ground measurements of temperature and humidity profiles plus a radiometer working continuously (rain or hail!).
Angular scanning (-50°/ +50° step 7° TBD), beamwidth less than 15°, stability better than 1K over a month, calibration at least once a month, sensitivity 0.5 K.

3.5.3 Framework:

It is intended to have a first experiment in the Toulouse area (March 2000, fall 2001) and the Paris area (2002-2003). The Paris experiment will constitute different climatic and surface conditions, and will be used to test several assimilation schemes for GCMs.

3.5.4 Status.

At the French level we have funding for the construction of a radiometer (to be ready by fall 2000) and field experiment (Meteo France, CESBIO, INRA, IPSL,…). The site will be installed in March 2000 with start of the monitoring right after. There is also a potential site in Spain (UV).

3.5.5 Calendar

May 2000: site is installed and running.
End 2000: tests and installation of a radiometer and then start of continuous operations.
Spring 2002: installation of Paris site.
Fall 2002: end of operations in Toulouse and transfer of the radiometer to Paris.
Early 2003: continuous operations in Paris, to mid 2004?

4. Interferometric demonstrators (ID #51, 52)

4.1.1 Scientific objectives

The objectives are quite obvious: It is necessary to have an instrument a) demonstrating the concept, b) helping in improving reconstruction algorithms, and testing approaches/ solutions to eventual problems, c) allowing data acquisition to validate retrieval algorithms etc…especially over sites where 2D is absolutely necessary. This will be only a second priority after the demonstration activities.

4.1.2 Framework

There is an instrument currently under construction at HUT (HUT-2D), and the ESA MIRAS Demonstrator (some failure analysis has been carried out, and considerable refurbishment is to be done if this instrument should be used). It is worth noting that the experience shows that such an instrument should be first tested on the ground (crane/ boom mounted) before being implemented on an aircraft.

4.1.3 Calendar

The HUT-2D demonstrator is scheduled to be ready for data collection by spring 2001.
MIRAS Demo TBD, but will probably not happen

5. Conclusion

To summarise the text above, we have included the appendix A. But to make things (hopefully) clearer here is a brief summary.
Considering that currently aircraft campaigns do not seem very feasible over land in the short term (lack of an instrument with adequate characteristics i.e. 2D images with various angles), the overall priorities for 2000-2001 could be as shown below, including campaigns already funded and realistic time schedules (these schedules susceptible to change if more radiometers are made available)[1]:

1. demonstrator (tower and then aircraft) (#51-52)
2. *land based long term measurements (funded in France) (#31)*
3. *land based physics of measurements (funded France and Denmark, Spain) (#21)*
4. *Sea based short experiment: lead by UPC and funded by ESA (WISE) (#11)*
5. airborne over sea : *TUD instrument (L, Ku, and Ka), Danish funding, flights funded by ESA and Danish sources*. *HUT instruments (L, Ka), Finnish funding*, funding required for flight hours *(#13)*
6. airborne over land : *TUD instruments and HUT instruments available.* Funding required for flight hours and ground measurements (#22, 25)
7. ground based short term: *parts funded*, *some funding requested at national level* some totally to be funded (#24).

[1] Underlined → to be funded; *italics* → *funded*; normal → in between

Short notations: ID=reference number; P= priority (1 highest, 3 lowest); E=emissivity; R. = radiometer; GD= ground data

ID	P	objective	needed	set-up	duration	possible participants	status
11	1	sea state E modelling	R. : accurate L band, scan, polarimeter; GD	platform	1 month	UPC, LODYC, CETP,ICM	WISE 2000
12	2	sea state E modelling	R. : accurate L band, scan, polarimeter; GD	platform	4 months	TBD	
13	1	sea state E modelling	R. : accurate L band, polarimeter ; GD	aircraft	5 flights	TUD+?	LOSAC
14	2	sea state E modelling	R. : accurate K band, polarimeter ; GD	aircraft	5 flights	TUD+ HUT?	(LOSAC)
19	3	Cal/Val over sea	TBD				
21	1	assess full E over land	R: accurate L band, scan, polarimeter; GD	crane	3 month	TUD + INRA	Scheduled
22	1	assess full E over land	R: accurate L band, polarimeter; GD	aircraft	2 flights	TUD? + HUT?	
23	2	assess full E over land	R: accurate K band, polarimeter ; GD	aircraft	2 flights	TUD? + HUT?	
24	1	dew, frost over land	R. : accurate L band, scan, polarimeter ; GD	mast or crane	2 x 2 months	CETP + NERC + HUT	
25	1	Mixed pixel response	R: L band, scan?	aircraft		INRA + HUT	
26	2	Forests, mountains, snow	R: 2D scan?	aircraft		CETP + HUT	
29	3	Cal/Val over land	TBD				
31	1	SVAT assimilation over land	R. : L band, scan, polarimeter ; GD	mast or crane	15 month	CNRM	
32	2	SVAT assimilation over land	R. : L band, scan, polarimeter ; GD		15 month	CETP	
41	2	Response over ice	TBD			HUT	
51	0[2]	Technical assessment	R. : 2D demonstrator ; GD	mast or crane	2 weeks	HUT	
52	0	Technical assessment	R. : 2D demonstrator ; GD	aircraft	6 flights	HUT	

ID	P	objective	Comments
11		sea state E modelling	Will have to be performed over a longer duration (4 months min) → MIMOSA? With SOC
12		sea state E modelling	repeat 11 for other climatic conditions (cold and rough seas)
13		sea state E modelling	Optimal accuracy, various conditions, comparison with other remote sensors
14		sea state E modelling	K band necessary for theory checking
19		Cal/Val over sea	???
21		assess full E over land	Stokes 3 and 4 for a cultivated area
22		assess full E over land	Stokes 3 and 4, general case
23		assess full E over land	K band necessary for checking theory
24		dew, frost over land	
25		Mixed pixel response	2D scan wished for
26		Forests, mountains, snow	2D scan necessary. Perhaps only possible with demonstrator
29		Cal/Val over land	???
31		SVAT assimilation over land	high priority because long duration and to be followed by 32…
32		SVAT assimilation over land	Repeat 31 for other site conditions
41		Response over ice	???
51		Technical assessment	
52		Technical assessment	

[2] urgent and necessary, and not only for the science depicted in this document

European Airborne L-Band Radiometers

Status July 2000

Parameter/System	AMRS	HUT-2D	HUT-POL	IROE-CNR	MIRAS-DEM	TUD-EMIRAD
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Operational	1991	May 2001	June 2001	Yes	Presently not operational: needs major changes	Autumn 2000
Centre frequency Bandwidth	1413 MHz	1413 MHz 8 MHz	1413 MHz 8 MHz	1420 MHz 30 MHz	1413.5 MHz	1413 MHz 20 MHz
Radiometer type	Noise injection radiometer	Interferometric (2-D) radiometer by aperture synthesis Receivers: total power and heterodyne	Polarimetric radiometer Receivers: total power and heterodyne	Total power with frequent calibration	Y11 2-D Interferometric	L-band polarimetric total power radiometer with direct sampling
Polarisations	H	H and V (switching)	Stokes parameters	H or V (changed by rotation)	H and V	4 Stokes parameters simultaneously
Platform	Pilatus Turbo Porter	Short SC7 Skyvan	Short SC7 Skyvan	Ultralight aircraft	C-130	C-130
Aircraft owner	Private	Helsinki University of Technology	Helsinki University of Technology	Scuola di Volo		Danish Air Force
Availability of aircraft for campaigns	Yes	Yes	Yes	Yes Within limited distance from Italy		Generally good Only limited periods Planning: long time in advance
Imaging/non-imaging	Non-imaging	Imaging	Non-imaging	Non-imaging	Imaging	Non-imaging
Incidence angle Field of view	5 deg	0 or 30 deg depending on sensor location. Field of view ± 30 deg	TBD (possibly adjustable)	0 to 50 deg	0 to 35 deg	22 to 62 deg
Antenna type	Microstrip patch antenna	Aperture coupled microstrip patch antenna	Under investigation	Flat panel array – printed circuit	Cup dipole	Horn
Antenna dimensions	0.67 m x 0.67 m	7.9 x 7.9 cm for each of 36 antennas in U-shape (total 1.8 x 1.95 m)	Aperture <1.5 m	0.31 m x 0. 62 m x 0.2 m	1.5 m x 1.5 m x 0.5 m	Aperture 90 x 90 cm, length 2 m
Antenna beam efficiency						
Antenna 3 dB beamwidth	19 deg	5 - 7 deg depending on weighting	10 to 15 deg	18 deg (E plane) 35 deg (H plane)	10 - 17 deg depending on weighting	15 deg
Antenna radome	Yes	No	No	Yes (fixed to aperture)	Yes	No

				Fixed antenna/radome distance regardless of incidence angle		
Integration time	0.01 to 10 sec	0.3 to 2 sec	0.3 to 2 sec	0.01 to 1 sec	0.3/ 0.6/ 0.9/1.2 sec	From 0.008 sec
Sensitivity for τ = 1sec	<0.3 K	TBD	Less than 0.3 K	0.3 K	2 K	0.1 K
Stability		TBD	TBD	1 K/h		0.2 K/h
Receiver linearity verified	Verified			Yes		
On-ground calibration method	Black body		Under investigation	Absorber stabilised target, sky (tipping curve) and noise source; calm water	Yes	Hot (ambient)/cold (LN2) target
In-flight calibration method	Water surface with thermal infrared data	Noise injection	Internal calibration	No		Ambient load and noise diode
Accuracy of calibration				± 2 K	2 K	
Data storage medium		Hard disk on network server	Hard disk on network server	Hard disk on notebook		Hard disk on industrial PC
Aircraft positioning method and its accuracy	GPS/video	DGPS, accuracy ±5 m. Pixel positioning accuracy 10 m	DGPS, accuracy ±5 m. Footprint positioning accuracy 10 m	GPS		GPS and INU
Aircraft attitude information availability		Multiple antenna GPS and inertial measurement unit (IMU), accuracy ±0.1°	Multiple antenna GPS and inertial measurement unit (IMU), accuracy ±0.1°	No (TV camera used for footprint location)		INU, accuracy ±0.05 deg
Data collection flight altitude		Typically 300 to 2000 m	Typically 300 to 2000 m			Max 2500 m
Aircraft range for data collection		1000 km - 5 h	1000 km - 5 h	150 km - 1 h		Over 8 hours
Suitability for ground-based use			Yes	Yes (far-field: 2 m)		Yes (needs environmental protection)
Primary use	Soil Moisture	Technology verification and calibration studies Various applications	Various applications	Soil moisture Vegetation biomass Forest monitoring		Airborne sensing of the sea
Availability for international campaigns	Updating of sensor necessary	Yes	Yes	Yes		Yes
Additional information		Data: 13x12 complex matrix of 32-bit integers, data timing synchronised to UTC with millisecond precision	Data timing: synchronised to UTC with millisecond precision	Dual-polarisation antenna under study. The system can be accommodated on any aircraft with a suitable hole		

Non-European Airborne L-Band Radiometers

Status July 2000

Parameter/System	ASLFMR	ESTAR	ESTAR-2D	MSC-LBD	PALS	SLFMR	STARRS
	Jorg Hacker Airborne Research Australia, GPO Box 2100, Adelaide 5001, Australia Tel: +61 8 81824000 mojmh@es.flinders.edu.au	David M. Le Vine Code 975 Goddard Space Flight Center, Greenbelt, Maryland 20771 USA Tel: +1 301 614 5640 Fax: +1 301 614 5558 dmlevine@priam.gsfc.nasa.gov	David M. Le Vine Code 975 Goddard Space Flight Center, Greenbelt, Maryland 20771 USA Tel: +1 301 614 5558 Fax: +1 301 614 5558 dmlevine@priam.gsfc.nasa.gov	Anne Walker Climate Research Branch, Meteorological Service of Canada (MSC), 4905 Dufferin Street Downsview Ontario Canada M3H 5T4 Tel.: +1 416 739 4357 Fax: +1 416 739 5700 anne.walker@cc.gc.ca	William Wilson Jet Propulsion Laboratory M/S 168-321 4800 Oak Grove Drive Pasadena, CA 91109 USA Tel: +1 818 354-5699 wjwilson@pop.jpl.nasa.gov	Albin Gasiewski NOAA Environmental Technology Laboratory 325 Broadway R/E/ETL Boulder CO 80303 USA Tel: +1 303 497 7275 agasiewski@etl.noaa.gov	Jerry Miller, Naval Research laboratory, Stennis Space Center, MS 39529, USA Tel: +1 228 688 4169 jmiller@cbmngm.nrlssc.navy.mil
Operational	January 2000	Yes	Mid-2002	October 2000 (aircraft installation in progress)	Yes	1994	June 2001
Centre frequency Bandwidth	1413 MHz 24 or 100 MHz	1413 MHz 20 MHz	1413 MHz 20 MHz	1415 MHz 5 MHz (adjustable within a 60 MHz band)	1413 and 2690 MHz 20 MHz	1413 MHz 24 MHz	1413 MHz 24 MHz
Radiometer type	Dicke null feedback	Interferometric (1-D)	Interferometric (2-D)	Dicke-type	Dicke switched with noise diode calibration	Dicke null feedback	Total power with frequent calibration
Polarisations	V	H	H and V	H	V and H at both frequencies	V	V
Platform	Small aircraft	P3 Orion C-130	P3 Orion C-130	Twin Otter	C-130	Small aircraft or various P3 aircraft	Small aircraft
Aircraft owner	Airborne Research Australia			National Research Council Canada	National Center Atmospheric Research (NCAR)	NOAA, NASA, U.S. Navy	
Availability of aircraft for campaigns	Yes	Yes	Yes	Within North America, scheduled 1 year in advance via submitted proposal	Yes	Yes At least 6 months advanced request	
Imaging/non-imaging	Imaging	Imaging (cross-track ±50 deg)	Imaging	Non-imaging	Non-imaging, plans for scanning 4 pixels	Imaging	Imaging
Incidence angle (deg)	Cross-track stepped ±7, ±22, ±39 deg	0 to >50 deg		10 deg (planned)	35 to 55 deg	Cross-track stepped ±7, ±22, ±37, ±50 deg	Cross-track simultaneous ±7, ±22, ±37 deg
Antenna type	8x8 dipole array, Butler matrix beamforming	Dipoles		Flat slot array	Conical horn	8x8 dipole array, Butler matrix beamforming	8x8 dipole array, Butler matrix beamforming
Antenna dimensions	Aperture ~ 1 m	Ground plane 0.95 m x 0.95 m		0.50 m x 0.50 m	Aperture: 1 m at L-band, 0.5 m at S-band Length: 3 m at L-band	Aperture ~ 1 m	Aperture ~ 1 m
Antenna beam efficiency				>90 %	>92 %		
Antenna 3 dB beamwidth	16 deg (nearest nadir)	8 deg (synthesised beam)	4 deg (synthesised beam)	30 deg	13 deg at L & S	16 deg (nearest nadir)	16 deg (nearest nadir)
Antenna radome	Fiberglass	Fixed			None	Fiberglass	Fiberglass

Integration time	Variable	0.25 sec		1sec	2 sec per pixel/2	Variable – typically 0.5 s	Variable
Sensitivity for τ = 1sec	0.4 K	0.5 K		0.6 K	0.3 K for τ = 2 sec	0.4 K	0.13 K
Stability	<1 (K/h)			0.33 (K/h)	0.1 to 0.2 (K/h)	<1 (K/h)	<1 (K/h)
Receiver linearity verified					No	Yes	Yes
On-ground calibration method	Absorber, sky and thermal cycling experiments	Warm target (absorber) before flights		Absorber, clear sky	Hot/cold loads, noise diode	Absorber, sky and thermal cycling experiments	Absorber, sky and thermal cycling experiments
In-flight calibration method	Calibration tied to physical temperatures inside sensor	Internal calibration		Clear sky, water target (calibration check)	Switch to ambient and cold load	Calibration tied to physical temperatures inside sensor	Calibration tied to physical temperatures inside sensor
Accuracy of calibration				TBD	<1.0 K	±2 K	
Data storage medium	Laptop PC	Hard disk	Hard disk	Exabyte tape	Hard disk and CD	Hard disk	PC
Aircraft positioning method and its accuracy	GPS	GPS	GPS	GPS 20 m	GPS <100 m	GPS/INU 20 m	GPS
Aircraft attitude information availability	Yes, Trimble TANS Vector	Yes	Yes	Yes, Litton 90 inertial reference system	A/C instrument data into data files every 1 sec	INU, angular accelometer and/or gyroscope	Yes
Data collection flight altitude	Depends on flight speed for contiguous mapping, <5 km	0.3 to 8 km	0.3 to 8 km	Flexible (up to 3 km)	1 to 2 km	Function of desired resolution, < 5 km	
Aircraft range for data collection		8 hrs	8 hrs	500 km – 2.5 hours	2000 km	Typically 8 hrs	
Suitability for ground-based use	Yes	Yes			Yes	Yes	Yes
Primary use	Sea Surface Salinity	Soil Moisture Sea Surface Salinity	Soil Moisture	Soil Moisture, Cryospheric research and validation of satellite retrievals	Sea Surface Salinity Soil Moisture	Sea Surface Salinity Soil Moisture	Sea Surface Salinity
Availability for international campaigns	Yes	Yes			Yes	Yes	Yes
Additional information	Improved version of NOAA SLFMR. Includes multibeam infrared SST sensor				Includes L & S band, 10 W polarimetric scatterometers	Can be flown with NOAA PSR series of conically-scanned imaging radiometers. Includes IR sensors for SST.	Dedicated receiver for each of the 6 beams. Infrared SST sensor. C-band radiometer ocean roughness sensor. Galactic background characterisation software

European Ground-Based L-Band Radiometers

Status May 2000

Parameter/System	LICEF-1/2	Univ. Reading	RON (ONERA)	UPC	UPV
Contact	European Space Agency Manuel Martin-Neira ESA/ESTEC/TOS-ETP Postbus 299 Keplerlaan 1 2200-AG Noordwijk The Netherlands Tel: +31 71 565 4052 Fax: +31 71 565 4596 E-mail: mneira@estec.esa.nl	Robert Gurney University of Reading Environmental Systems Science Centre (ESSC) The University of Reading Harry Pitt Building 3 Earley Gate Whiteknights PO Box 238 Reading RG6 6Al, UK Tel: 0118 931 741/2/3 Fax: 0118 931 6413 Rjg@mail.nerc-essc.ac.uk	Yann Kerr CESBIO 18 avenue Edouard Belin 31401 Toulouse Cedex 4 France Tel: +33 5615 58522 Fax: +33 5615 58500 Yann.Kerr@cesbio.cnes.fr	Adriano Camps Polytechnic University of Catalonia Dept. of Signal Theory and Communications (UPC) Campus Nord, D4-016 08034 Barcelona Spain Tel: +34 3 401 6085 Fax: +34 3 401 7232 Camps@tsc.upc.cs	Luis Sempere Polytechnical University of Valencia Dto. De Comunicaciones (U.P.V.) C/ Camino de Vera s/n 46022 Valencia, Spain Tel: +34 96 387 7756 Fax: +34 96 387 7309 E-mail: lsempere@dcom.upv.es
Operational	LICEF-1 (2 identical units): June 2000. LICEF-2 (4 identical units): December 2000	September 1999	By 2001	Fall 2000	By 2003
Centre frequency Bandwidth	1413.5 MHz 19 MHz	1413.5 MHz 27 MHz	1413 MHz 26 MHz	1413 MHz 20 MHz	1400 MHz 25 MHz
Radiometer type	Total power output and digital I and Q outputs	Total power, direct detection	Conventional	Dicke radiometer	Pulsed noise injection Dicke superheterodyne, IF = 881.5 MHz
Polarisations	Receives H and V sequentially	H and V	H and V	H and V simultaneously	Rotation of platform
Platform	Stand-alone units with fixation points for mechanical interface	Boom	Tower	Mounted on a pedestal (azimuth and elevation)	Boom on vehicle
Imaging/non-imaging	Non-imaging. FOV (3 dB) appr. 70 deg. Intended as an element of an interferometer. Proper arrangement can make it an imaging radiometer.	Non-imaging	Non -imaging	Non-imaging	Non-imaging
Incidence angle	Depends on antenna pointing, will integrate all incidences within field of view	0 to 60 deg	0 to 60 deg plus sky	From nadir to zenith Azimuth >270 deg	Nadir observation
Antenna type	Circular slot antenna	1.3 m centre fed parabolic reflector with crossed dipole design	Potter horn	4 x 4 microstrip patch array	16-element patch array
Antenna dimensions	Aperture 19 cm Length 6 cm	Aperture 130 cm	Aperture 110 cm Length 250 cm		70 cm x 70 cm
Antenna beam efficiency		97 %	>90 %	>90 % (TBC)	80 % (present design)
Antenna 3 dB beamwidth	70 deg	12.5 deg	13 deg	18 deg (TBC)	19 deg
Antenna radome	No	No	No	Yes	Yes, dielectric

Far-field limit	0.33 m		10 m		5 m
Integration time	Output is 1-bit 55.84 MHz I and Q signals. PMA signal is detected voltage in LICEF-1 and filtered detected voltage in LICEF-2. Integration time to be arranged through a user-supplied control unit.	Software adjustable, typically 0.8 s	Software controlled	N x 0.5 s (N≥1)	Controlled by software
Sensitivity (τ)	Receiver noise figure better than 2.5 dB	05 K (0.8s)	0.5 K (1s)		< 1 K
Stability			1K/ month		
Receiver linearity verified					
Calibration method	Correlated external input to inject correlated noise or a known temperature signal for calibration. Also internal uncorrelated noise input for calibration purposes. Antenna falls outside the point of injection of calibration signals. Correlated external input can also be used as external antenna connection.	Hot/cold noise sources Sky and reference targets	Two sources at different temperatures, sky view, reference target	Th and Tv channels: Sky + absorber U & V channels: Correlated and uncorrelated noise injection	Absorber filling (a) entire beam, (b) main lobe
Accuracy of calibration	External calibration signals to be provided by user	TBD	TBD	TBD	
Data storage medium	No data storage supplied with the unit	PC	PC	PC	PC
Primary use	Demonstration of spaceborne MIRAS elements	Physics of measurements/SVATs	Long-term monitoring of ground surface. Analysis of optimal acquisition time, minimum temporal sampling, effects of special events (dew, frost)	Sea Surface Salinity (WISE Campaign) Soil Moisture	Soil Moisture
Availability for international campaigns	LICEF-1: January 2001 LICEF-2: January 2002	Yes	Yes	Yes	Yes
Special requirements for international campaigns	Loan agreement signed with ESTEC	Boom/platform	Tower		Platform
Additional information	Operational temperature range 0 to 50 C. No thermal stabilisation incorporated. No correlator supplied with the units. LICEF-1 needs external regulated power supply. Need protection for outdoor operation		Operational temperature range: -5 to +40 C. Sophisticated thermal regulation. Needs external power. Continuous operations. Secondary lobes < 40dB	Thermal stabilization Hermetically scaled	

Non-European Ground-Based L-Band Radiometers

Status May 2000

Parameter/System	UMICH/TMRS3	UMICH/TMRS3-A	USDA-1/2	CRESTech
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Operational	January 2000	January 2001	Operational. Replacements are being developed in cooperation with Calvin Swift University of Massachusetts	1996
Centre frequency Bandwidth	1413,5 MHz (L-band)	1413,5 MHz (L-band)	1413 MHz	1400 MHz
Radiometer type	Total power DSDR (direct RF sampling digital radiometer)	Two-element correlation DSDR (direct RF sampling digital radiometer)	Conventional	
Polarisations	H or V	H and V	H and V	
Platform	Truck	Truck	Truck	
Imaging/non-imaging	Non-imaging	Non-imaging	Non-imaging	
Incidence angle	0 to 90 deg	0 to 90 deg	Positioning done by truck	
Antenna type	Septum horn	2 septum horns	16-element patch array	
Antenna dimensions	Aperture 79.44 cm Length 74.3 cm	Aperture 79,4 cm Length 74,3 cm (each)	60 cm x 60 cm	
Antenna beam efficiency	95,9 %	95,9 %	97 %	
Antenna 3 dB beamwidth	21 deg	21deg	18 deg	
Antenna radome	None	None	Dielectric	
Far-field limit	5.9 m	5.9 m	3.4 m	
Integration time	Controlled by software	Controlled by software	Hardware adjustable	
Sensitivity (τ)	0.126 K	0.126 K	<1 K	
Stability	Under investigation	Under investigation		
Receiver linearity verified	Yes	Yes		
Calibration method	Beam-filling absorber + zenith sky	Beam-filling absorber + zenith sky, uncorrelated (internal) + correlated (transmitted) noise sources	Absorber filling entire beam, sky	
Accuracy of calibration	Untested	Untested	Depends on stability and accuracy of absorber, RFI	
Data storage medium	Laptop PC/harddrive	Laptop PC/harddrive	PC	
Primary use	Soil Moisture Vegetation Snow	Soil Moisture Vegetation Snow	Soil Moisture	

Availability for international campaigns	Yes	Yes	August 2000	
Special requirements for international campaigns	Beyond our own research, we will operate it as a service	Beyond our own research, we will operate it as a service		

List of Abbreviations

AMSR	Advanced Microwave Scanning Radiometer
AO	Announcement of Opportunity
Cal/Val	Calibration/Validation
CESBIO	Le Centre d'Etudes Spatiales de la BIOsphere
EMIRAD	Polarimetric Radiometer System of the Electromagnetics Institute (TUD)
ESA	European Space Agency
EU	European Union
GCM	General Circulation Model
GEWEX	Global Energy and Water Cycle Experiment
HUT	Helsinki University of Technology
ICM	Institut de Ciencies del Mar
INRA	Institut National de la Recherche Agronomique
IPSL	Institut Pierre Simon Laplace
IRTA	Institut de Recerca en Tecniques Agropecuaries
LICEF	Light Weight Cost Effective Antenna Front-end Assembly
LODYC	Laboratoire d'Oceanographie DYnamique et de Climatologie
LOSAC	L-band Ocean Salinity Airborne Campaign
CETP	Centre d'études des Environnements Terrestre et Planétaires
MIMOSA	Microwave Measurements of Ocean SAlinity
MIRAS	Microwave Imaging Radiometer with Aperture Synthesis
NERC	National Environmental Research Council
NERSC	Nansen Environment and Remote Sensing Center
NOAA-ETL	National Oceanic and Atmospheric Administration -Environmental Technology Laboratory
Pixel	Picture Element
psu	Practical Salinity Unit
S	Salinity
SMOS	Soil Moisture and Ocean Salinity
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
T	Temperature
T_B	Brightness temperature
TBC	To Be Confirmed
TBD	To Be Defined
TSC/UPC	Signal Theory and Communications / UPC
TUD	Technical University of Denmark
UPC	Universidad Polytechnica Catalonya
UV	University of Valencia
WISE	Wind and Salinity experiment