WInd and Salinity Experiment 2001 (WISE 2001)
EXPERIMENT PLAN

(ESTEC Contract 14188/00/NL/DC CR for CCN-2
Technical Assistance for the Implementation of the WISE 2000 Campaign).

Version 2.0, October 6, 2001

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1. Executive Summary

In May 1999 the European Space Agency (ESA) selected **SMOS** as the second **Earth Explorer Opportunity Mission**. Its goals are obtention of **S**oil **M**oisture and **O**cean **S**alinity maps with global coverage. SMOS will be the first two-dimensional synthetic aperture radiometer ever built for Earth observation. The scanning configuration of SMOS presents new challenges:

i) Two-dimensional imaging of the scene, with varying incidence angles and pixel resolution as the pixel travels trough the alias-free field of view.
ii) Polarization mixing between vertical and horizontal polarizations due to the relative orientation between the antenna reference frame and the pixel's local reference frame.
iii) Not yet well understood azimuthal dependence of the first two Stokes parameters (T_v and T_h) with wind direction.
iv) Unknown signature of the third and fourth (U and V) Stokes parameters and their azimuth/elevation dependence with wind speed.
v) Effect of sea foam at L-band.
vi) Feasibility of accurate retrieval of U, and eventually V, assuming that Faraday rotation effects (for a satellite borne sensor) have been corrected for by other means.

The **WISE 2000 campaign** was sponsored by ESA to collect experimental data under the widest possible range of wind conditions to better understand the polarimetric emission at L-band of the sea surface and its dependence with wind and salinity (points (i), (iii), (iv) and (v)). Point (ii) is a known geometrical problem that can be overcome during the SSS retrieval. Point (iii) is specifically addressed by the LOSAC campaign. Finally, point (vi) will depend on MIRAS antenna parameters and the amplitude of the azimuthal signature of the third (and fourth, if detectable) parameters.

Fully polarimetric L- and Ka-band radiometers, a video, an IR and a stereo-camera, and four oceanographic and meteorological buoys were installed in the Casablanca oil rig, located at 40° 43' 4" N 1° 21' 34" E, 40 km away from the Ebro river mouth at 40 Km from the coast of Tarragona (Spain). The sea conditions are representative of the open Mediterranean sea with periodic influence of the Ebro river fresh water plume. Systematic measurements were acquired from November 16th to December 18th, 2000 and continued during the January 9th to 15th, 2001.

Despite a number of technical, logistic, and RFI problems, the WIND AND SALINITY EXPERIMENT 2000 provided for the first time in the last 30 years, new data to better understand the effects of the wind in the emissivity of the sea at L-band. The experimental results confirm the existing experimental data [Hollinger, 1971] and have reduced their associated error bars.

The experimental results show a nadir sensitivity of 0.22 K/(m/s), increasing with incidence angle at horizontal polarization, and decreasing with incidence angle at vertical polarization. The magnitude of the azimuthal variation of the first two Stokes parameters is on the order of 0.1 – 0.2 K approximately, although these results have to be confirmed by the results of the LOSAC campaign.

Numerical simulations have been performed with different numerical techniques and models, and the range of validity has been determined. The comparison between measurements and numerical simulations indicate that the two-scale model using the Durden and Vesecky spectrum multiplied by two can be an appropriate description for the sea state. The analysis of the sea state reveals that often the wind stress and the sea state are correlated, and the wind intensity and direction can be used to describe its state. However, in some situations the correlation is quite low, meaning that the wave field was originated somewhere else. In this case a characterization and modeling of the swell would be required.

The SSS retrieval requires the estimation of the WS and the SST. Even though the WS measurements from the buoy anemometer, the meteo station and QUICKSCAT are in agreement ($\sigma_{buoy\text{-}met\ st}$ = 1.8 m/s, $\langle WS_{buoy\text{-}met\ st} \rangle$ = -0.9 m/s, $\sigma_{met\text{-}Quick}$ = 2.8 m/s, $\langle WS_{met\ st\text{-}Quick} \rangle$=0.4 m/s), it is found that if the WS measurement has a large error, the SSS retrieved performs better leaving the WS as a variable rather than a fixed parameter. The IR SST estimates have proven to be accurate enough for the SSS retrieval process, exhibiting a small bias (~ -0.2 K) that increases at high incidence wind speeds, probably because of a lack of accurate modeling of the sea foam emissivity at the IR. It has been demonstrated that SSS can be retrieved with enough accuracy from multi-angular measurements.

The stereo-camera and video imagery results have corroborated the sea foam coverage dependence with wind speed, although a large variability exists for the same wind conditions, and even different sides of the platform. In the North side of the platform the foam coverage was lower because of the stabilization of the incoming waves interfering with the reflected ones. This may be the reason for the discrepancy between the measured Ka-band horizontal brightness temperature and the predicted one [Camps and Reising, 2001].

The RFI coming from the Tarragona shore did not allow us to compare the evolution of the sea state and the brightness temperatures. This problem will be minimized in WISE-2001 by orienting the stereo-cameras to the West side.

Two fundamental points to be addressed in the near future are:

- **to get more data points and better WS measurements so as to reduce the sensitivity to WS uncertainty,**
- **to study the sea state stability by looking at a series of brightness temperatures, and**
- **to determine the emissivity of sea foam at L-band at different incidence angles.**

The first two will be addressed during the second WISE 2001 campaign (WISE 2000 project, CCN-2) during October-November 2001, while the third one would require a speciallized field experiment.

This document is organized as follows. Chapter 2 gives an overview of the WISE campaign, the measurements that will be performed and the products that will be delivered. Chapters 3, 4 and 5 give a detailed description of the ground-truth data that will be collected during WISE 2000: meteorological data and sea surface data required to relate geophysical variables with radiometric measurements, and the satellite data to be collected and processed for comparison. Chapter 6 describes the measurement strategy, while chapter 7 is focused on the experiment operations: management of the experiment, ground-truth and radiometer personnel for data acquisition and storage, as well as safety considerations for the platform environment. Chapter 8 describes the management and distribution of the data. Finally chapters 9, 10, 11 and 12 provide some additional information concerning the site, references, the list of participants and technical documentation.

2. Overview

The MIRAS radiometer aboard the SMOS mission is a two-dimensional L-band imager of the Earth's surface devoted to the measurement of the sea surface salinity and the soil moisture. MIRAS uses aperture synthesis techniques to achieve higher spatial resolution. However, since the antenna spacing is larger than the Nyquist rate ($1/\sqrt{3}$ wavelengths for hexagonal sampling), the two-dimensional image of the Earth suffers from aliasing (Fig. 1). This limits the range of incidence angles from nadir to approximately 60°, for pixels in the satellite's ground-track. In the case of the sea the brightness temperature at vertical and horizontal polarization ranges from about 50 K to 150 K and shows a small dependence with wind speed (Fig. 2).

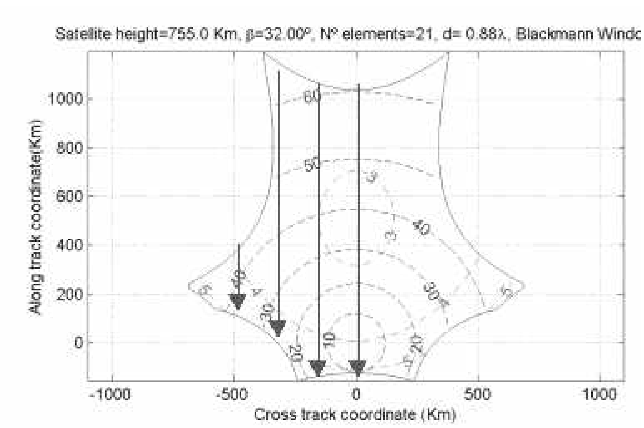


Figure 1. *SMOS Field of View over the Earth's surface [WISE Scientific Analysis Report, 2001].*

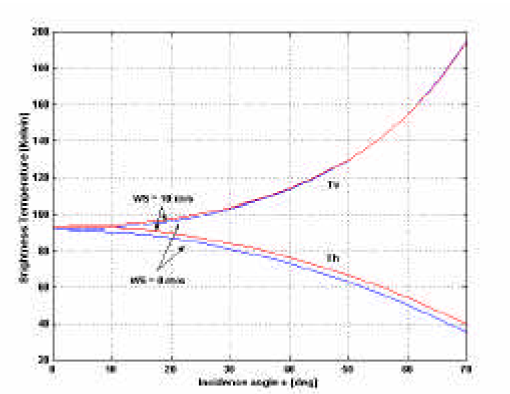


Figure 2. *Simulated vertical and horizontal brightness temperature for wind speed 0 and 10 m/s. Other variables: temperature 15°C, salinity 36 psu.*

2.1. Scientific Objectives

As discussed in the introduction, the scanning configuration of SMOS presents new challenges. The objective of the WISE 2001 experiment is:

- to get more data points and better WS measurements so as to reduce the sensitivity to WS uncertainty, and
- to study the sea state stability by looking to series of brightness temperatures,

so as to improve the determination of the sensitivity of the brightness temperatures to wind speed as a function of incidence angle.

2.2. Approach

The *Casablanca* oil platform owned and operated by the Repsol petrol company in the NW Mediterranean is an optimum location for this experiment. It is situated at 40° 43' 4" N 1° 21' 34" E, 40 km away from the Ebro river mouth, near the continental shelf break and shelf/slope front and over 165 m bottom depth. In this site wind intensities as high as 90 km/h (25 m/s) are not uncommon during the months of October and November (Fig. 3) when the campaign is foreseen to take place.

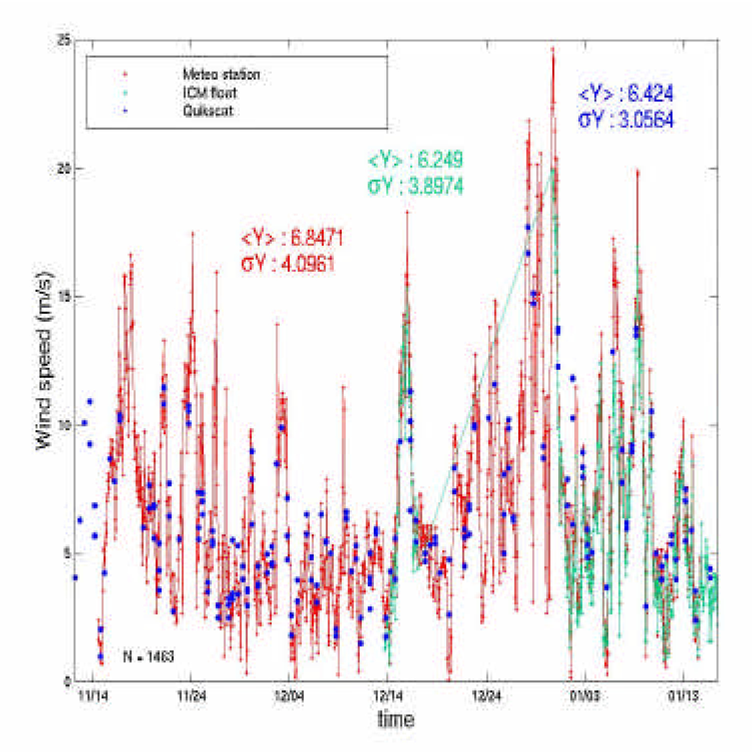


Figure 3. *Occurrence of strong NW and NE winds during the WISE 2000 campaign.*

The required measurements will be obtained from the following instrumentation:

- A fully polarimetric L-band radiometer (T_h, T_v, U and V) from the Universitat Politècnica de Catalunya (UPC), Spain,
- A fully polarimetric Ka-band radiometer (T_h, T_v, U and V) from the University of Massachusetts, Amherst, USA,
- Four oceanographic buoys from the Institut de Ciències del Mar (ICM) and the Laboratoire d'Oceanographie Dynamique et de Climatologie (LODYC) , that will measure sea surface salinity (SSS) , sea surface temperature (SST), wind speed (WS), wind direction (WD), wave height (WH), wave period (WP)...
- Portable meteorological station from UPC, that will measure atmospheric pressure, temperature, relative humidity and rain rate.
- Stereo-camera from CETP that will provide 3D images of the sea surface to determine the foam coverage and sea surface rms slopes
- Video images of the antenna boresight from a video camera mounted on UPC radiometer.
- Infrared radiometer from the Universitat de València that will provide SST estimates.

In order to properly calibrate the radiometers the antenna boresight must be pointed (as close as possible) to the zenith. Since the helipad must be free of obstacles, the radiometer will be placed at a lower floor (height = 32 m over the sea level) with zenith visibility. Another objective of the WISE 2001 experiment is the measurement of the azimuthal signature of the Stokes elements simultaneously with LOSAC overflights (November 19-22, 2001). Taking into account the limitations imposed by measuring from a fixed platform, the range of incidence angles is limited to $25° \leq \theta \leq 140°$ (0° = nadir, 90° = horizon, 180° = zenith), and $-80° \leq \varphi \leq +40°$ in azimuth (+: East, -: West). Figures 4 and 5 show the position of the radiometer's terrace. The UPC meteorological station will be located as close as possible to the radiometers, and closer than 25 m from the data acquisition system located in the platform control room. Its purpose is to get real time data mainly rain rate data, the only parameter not available from other meteorological stations.

Figure 6 shows a diagram of the terrace built at the platform so as to accommodate both radiometers. The mounting and the terrace were designed so that the UMass radiometer (present in WISE-2000, but not in WISE-2001) can perform an elevation scan from nadir to zenith, while the UPC radiometer pedestal allows both an azimuth scan free of obstacles larger than 120° and an elevation scan from about 25° incidence angle to an elevation of 140º (when pointing to the zenith the radiometer collects radiation from upper floors and the helipad).

In WISE-2001 the UMass Ka-band radiometer will be mounted at the North-West corner of 35.6 m platform level. This location is directly one floor above the radiometer platform at the 32 m level. This location allows scanning of the sea surface at incidence angles from 25 to 65 deg and the measurement of tipping curves at zenith angles from 30 to 70 deg.

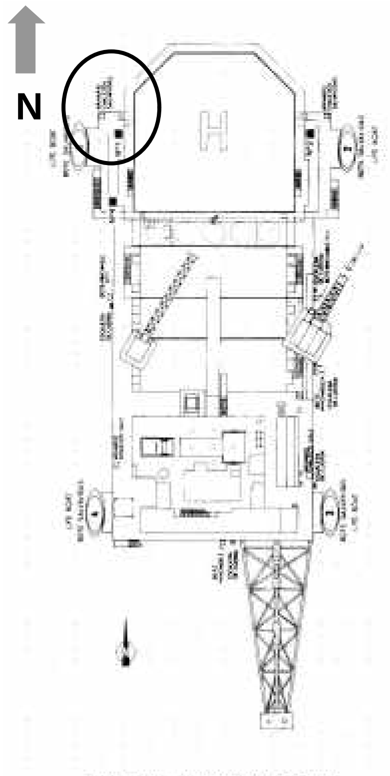


Figure 4. *Upper view of the Casablanca Platform*

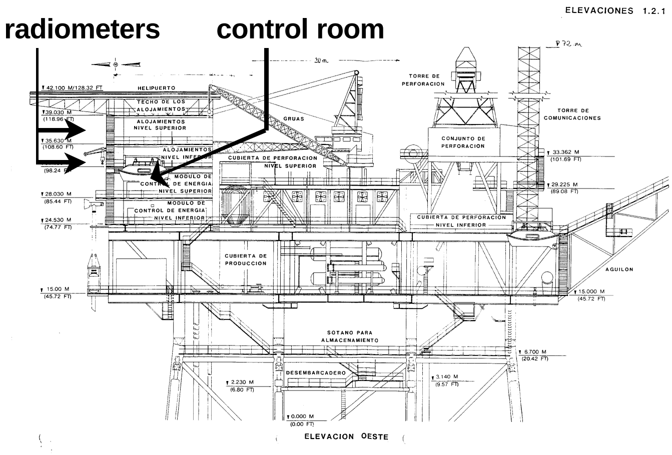


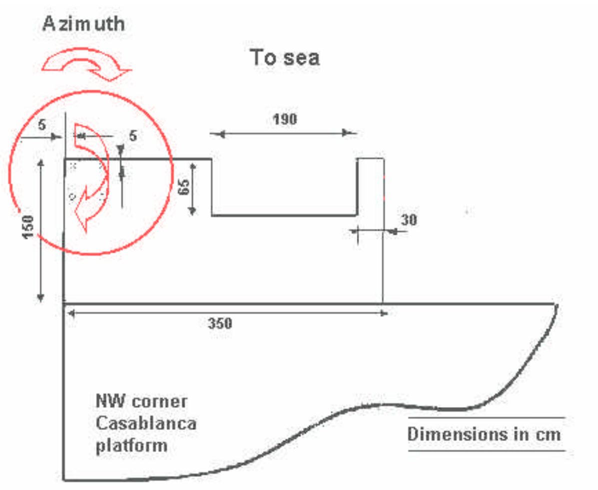
Figure 5. *Lateral view of the Casablanca Platform*

Four buoys are going to be moored by the ICM near the CASABLANCA oil platform in the North side (usually upwind in autumn) of the platform in a position so as not to interfere with the underwater petrol pipes.

- BUOY 1 will collect conductivity and temperature data (SeaBird MicroCAT system) near the sea surface (20 cm), as well as accurate wind speed (USONIC ultrasonic anemometer, 0.05 m/s resolution, 0.1-0.3 m/s accuracy) and send it to a data logging station installed on the platform, using a real time link.
- BUOY 2 is a meteorological and physical oceanographic data measuring system, with data storage and also a radio link to the same data logging station on the platform.
- BUOY 3 is a wave buoy of Spear-F type measuring the omnidirectional wave spectrum. The data are transmitted via the ARGOS system after onboard processing.
- BUOY 4 is a SVP drifter built by Clearwater, modified to be moored, which will measure the conductivity and the temperature of the surface water at about 20 cm depth. It will be tied to buoy 2. The data are transmitted via the ARGOS system.

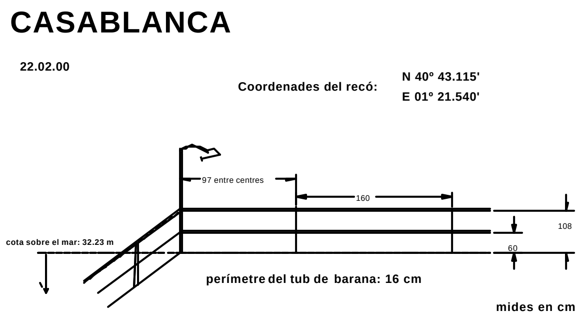
To check for any drift in the sensors in buoys 1 and 4, sea surface salinity will be measured with a Guildline AutoSal salinometer from water samples close to the buoys once a week[1]. A second SeaBird MicroCAT system will be hung from the platform at 5 m below the sea level to monitor the salinity vertical structure.

[1] In WISE 2000, water samples were taken twice a day nfrom the platform, but due to the recycled water dropout, the readings had no physical significance.

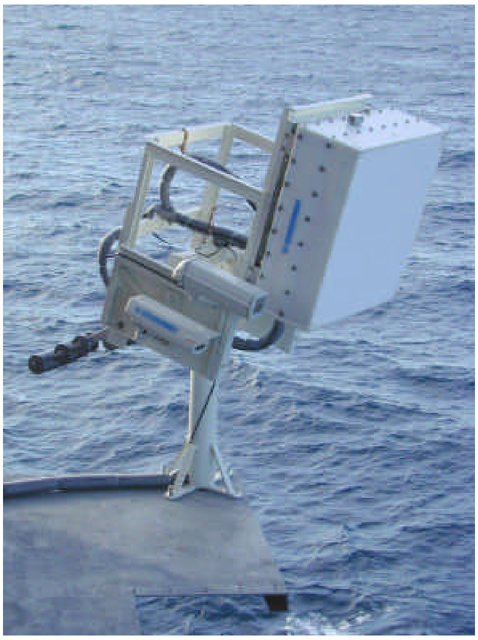


a)

b)



c)



d)

Figure 6. *a) Upper view of the terrace where the radiometer has to be placed.* b) View of the terrace at level 32 m from 15 m, *c) Location of the place where the terrace has been built. Access to the terrace will be made trough a door that will be opened on the rails. d) View of the radiometer mounted on the terrace at 33 m height (top) and the level at 15 m (bottom) where the stereo-camera will be placed. All the instruments will be able to look to the same area over the sea surface.*

2.3. Summary of key measurements and data products

Table 1. *Summary of key measurements and data products*

Instrument	Params.	Description	Units	Comments	Resolution
L-band polarimetric radiometer and meteorological station #1 (UPC), Infrared radiometer (UV)	Time	Absolute GPS time	H, m, s	Tag all measurements for easier comparison	1 s
	Pitch	Antenna orientation (±90°)	deg	Measured with a 1 axes digital inclinometer located in the back side of the radiometer antenna	< 0.01°
	Th	Horizontal brightness temp.	K	(2 min integration time)	0.02 K
	Tv	Vertical brightness temp.	K		0.02 K
	U	Third Stokes parameter	K		0.02 K
	V	Fourth Stokes parameter	K		0.02 K
	WS	Wind speed	m/s	V will not be delivered if it is not significant.	0.44 m/s
	WD	Wind direction	°	WS used only for safety purposes of the antenna in case of winds of very high intensity.	1°
	RH	Relative Humidity	%		1%
	RR	Rain Rate	mm/h		0.25 mm/h
	P	Atmospheric Pressure	mbar		1 mbar
	T	Atmospheric Temperature	°C		0.05°C
	Video images	Video camera on antenna		Used to determine fraction of foam sea coverage	
	IR images	IR camera on antenna (UV)	K	Estimate SST for cross-check with satellite and ground truth data (1 s integration time)	0.05 K (sensit) <±0.14 K (acc.)
Oceanografic buoys (ICM+LODYC)	WS	Wind Speed	m/s	Range: 0 – 60 m/s	0.05 m/s
	[1]WD	Wind Direction	°	Range: 0°-360° referred to magnetic North	0.4º
	AT	Air Temperature	°C	Range: -8°C ... 41°C	0.05°C
	RH	Relative Humidity	%	Range: 0 – 100%	0.1
	SR	Solar Radiation	W/m^2	Range: 0 - 2000 W/m^2	± 0.4 W/m^2
	WH	Wave Height	m	Range: 0 – 10 m	0.01 m
	WP	Wave Period	s	Range: 1- 30 s	0.03 s
	T	Water Temperature	°C	Range: -5°C ... 35°C	0.0001°C

	C H1/3 P WSPEC	Water conductivity Significant wave height Dominant period Wave spectrum	S/m m s m^2/s	Range: 0 – 7 S/m One averaged (8 times 200 s spectrum every 3 hours in 14 frequency bands)	0.0003 S/m
Stereo camera (CEPT)	[2]Primary data [3]Foam [4]Foam area [5]Topography	Digital pictures 2 x 1.4 Mbytes % pixels % surface Heights	Pixels % % cm	2 pictures every 10 seconds or 2 minutes Depending on light intensity and contrasts	832x624pixels one pixel minimum area 64 cm^2 depending on slanting angle / surface about <5 cm>

Remarks:

1) Absolute direction not available from buoy because of lack of compass. Absolute direction measurements will be taken from meteo station.

2) Corresponds to what will be made on real time and will be fast delivered to participants

3) and 4) three months after the campaign (if one obtains support for an operator to process the data)

5) 5 months after the campaign (if a support is obtained for an operator to process the data)

a) It has to be understood that pictures can be obtained from 1 hour after the sunrise to one hour before the sunset depending on the light and the contrast at the sea surface. An illumination of the surface can be achieved the night, but it has to be verified if the information remains convenient to analyze the surface properties.

b) 15 days at the platform is a maximum for the responsible. An operator from UPC will take care of the instrument for the second leg of 15 days.

6) KaPR data not available at the time of writting this document

2.4. Schedule

The WISE experiment is divided in three main tasks as presented in Figure 7. The original schedule of the project is presented in the bar graph of Figure 8.

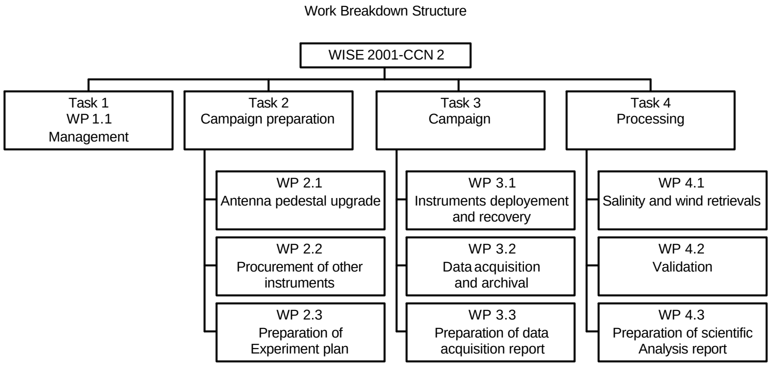


Figure 7. *WISE breakdown task structure*

WP number and title	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
WP 1.1 Management	■	■	■	■	■	■	■	■	■	■	■	■	■
WP 2.1 Antenna pedestal upgrade	■	■		■									
WP 2.2. Procurement of other instruments	■	■		■									
WP 2.3 Preparation of the Experiment Plan		■	■	■									
WP 3.1 Instruments Deployment and recovery					■	■							
WP 3.2 Data acquisition and archival					■	■							
WP 3.3. Preparation of Data acquisition report							■	■	■	■			
WP 4.1 SSS and WS retrieval from brightness	■	■		■	■	■	■	■	■	■	■		
WP 4.2 SST retrieval from IR radiometry imagery and SST, WS, WD pixel inhomogeneity									■	■	■		
WP 4.3 Validation									■	■	■		
WP 4.4. Preparation of scientific analysis report											■	■	■

Figure 8. *WISE 2001 schedule. Key milestones: June 26, 2001: joint WISE 2000 final presentation and WISE 2001 KO Kick-off meeting, October 11, 2001 PCM: Pre-Campaign Meeting, April 2002 PRM: Preliminary Results Meeting; June 2002 FPM: Final Presentation Meeting.*

This schedule foresees a kick-off meeting in June 26, 2001 at ESTEC coincident with WISE-2000 Final Presentation, a campaign from October 23 to November 25, 2001, and a final presentation in June 2001. Note that this schedule slightly differs from that in the proposal, since during the SMOS SAG meeting June 27-28, 2001 Dr. Wursteisen agreed to allow for extra time for the Data Processing (WP3.3) and the Preparation of the Scientific Analysis Report (WP 4.4). End of the project June 2002, instead of May 2000, as indicated in the proposal.

Repsol has confirmed that the platform will be available during October – November, and no drilling activities are foreseen at present.

3. Radiometric data

3.1. L-band AUtomatic RAdiometer "LAURA", UPC

3.1.1. Instrument description

The UPC fully polarimetric radiometer has been designed, implemented and tested completely in the facilities of the Electromagnetics and Photonics Engineering Group (EEF) of the Department of Signal Theory and Communications (TSC) of the Polytechnic University of Catalonia (UPC), Barcelona, Spain (http://www-tsc.upc.es/eef/).

The **antenna** is formed by a square array of 4 x 4 microstrip patches. The measured half power beamwidth is 20°, the side lobe level are –19 dB in the E-plane and –26 dB in the H-plane, the main beam efficiency (MBE) defined at side lobe level is 96.5% and the cross-polar level better than –35 dB in the whole pattern.

Due to the wind stress suffered by the Scientific Atlanta **pedestal**, a brand new pedestal has been designed to support higher wind loads. It has been built outside by a mechanical workshop. The gears and step-motors have not been changed and are controlled by a personal computer. In order to provide the greatest possible torque they are activated in half steps (800 half steps/360°). Additional reduction factors of 75 and 90 for the azimuth and elevation movements are achieved by gears. Consequently, the position can be controlled at least in steps of 0.006 degrees. A Seika 1 axis inclinometer[2] mounted on the back of the antenna will be used to measure the absolute position with a resolution < 0.01° in pitch, within a ±80º angular range. The absolute accurate calibration of this sensor has been performed when mounted on the radiometer antenna by cross-checking its readings with the absolute position of the positionner of the anechoic chamber[3] (http://www-tsc.upc.es/eef/research_lines/antennas/anechoic_chamber/ default.htm).

The **receiver architecture** is based on 2 L-band receivers with I/Q down-conversion. Receiver inputs can be switched between: i) the H and V antenna ports and ii) two matched loads, or iii) a common noise source.

The in-phase components of both channels are connected to two power detectors. The **Dicke radiometers** (T_h and T_v) are formed by switching receivers' inputs from

[2] In WISE 2000, the roll measurement was within the inclinometer noise level, and the yaw, which is measured by the Earth magnetic field, was corrupted by the metallic structure of the platform itself, therefore the absolute azimuthal position was obtained directly from the step motor control.

positions (i) and (ii), and performing a synchronous demodulation. The **third and fourth Stokes parameters** (U and V) will be measured with a complex digital correlator.

3.1.2. Polarimetric Radiometer Measurements and Data

Four types of **measurements** are foreseen:

- **Calibration**.

  It is planned to perform the calibration measurements at the beginning and at the end of each measurement cycle (< 100 min).

  Calibration of the Dicke radiometers will be performed by looking to the sky (cold source) and to a microwave absorber at known and controlled temperature (hot load). Although the terrace provides a clear view of the sky, if it is found that pointing to the zenith some radiation is picked up from the two higher floors through secondary lobes, other elevation angles will be used. The effect of galactic noise will be computed taking into account the geographic position of the platform, the date and time, the antenna orientation, the antenna pattern and the map of galactic noise at 1420 MHz [Reich, 1982; Reich and Reich. 1986].

  Atmospheric effects will be calibrated assuming a horizontally stratified atmosphere and measuring the down-welling radiation at two different incidence angles. Atmospheric models will also be used with input parameters: atmospheric pressure, atmospheric temperature and relative humidity, measured by the meteorological station.

  Calibration of correlator's offsets and local oscillator leakage etc. will be performed by injecting uncorrelated noise (switch in position (ii), section 2.1.1), while phase will be calibrated by injecting correlated noise (switch in position (iii), section 2.1.1).

- **Fixed (mode 1)**: at constant incidence and azimuth angles to determine the influence of sea state and its variability on the emissivity. The pointing angles will be computed so that the antenna spot overlaps with the stereo-camera field-of-view. The azimuth will be fixed in the direction of the minimum interference and undisturbed sea state (azimuth = -70°). This mode will be used 1 hour every day in the morning to avoid sun glint.

[3] At that time, the actual antenna pattern (mounted in the support) was measured.

- **Scan in elevation (mode 2)**: in order to determine the variation of the four Stokes parameters with the incidence angle: 25º, 35º, 45º, 55º and 65º. The radiometer will be 20 min at each position, thus the total sequence will last 5 x 20 min = 100 min. The azimuth will be fixed in the same direction as mode 1 in order to take advantage of the coincidence with the stereo-cameras field of view during part of the scan. During the afternoon-evening, to prevent sun glint, the azimuth will be set to +20° (largest angular distance free from terrace effects at 25° incidence angle). In this case the angular step will be 5° and the radiometer will be 5 min. at each position, thus a total of sequence will last 9 x 5 min = 45 min. The data acquired will be used mainly to study salinity retrieval algorithms.
  This will be the **normal mode of operation**.
- **Scan in azimuth (mode 3)**: this mode will not be used, except during the overflights of TUD radiometer (November 19-22, 2001).

The particular type of scans to be performed in conjunction with other instruments will be detailed in section 6 "Measurement Strategy".

Data structure

Data will be acquired using a personal computer satisfying industrial requirements (relative humidity 0-95%, vibrations, redundant power supply, etc.). The acquisition and control software was developed by UPC. The following data will be recorded:

- Output voltages of the detectors of the Dicke radiometers
- Number of counts of the digital complex correlator
- Output voltages of the temperature sensors in the radiometer
- Absolute time from a GPS receiver
- Readings from the digital inclinometer (14 bits)
- Rain rate, atmospheric pressure and temperature and relative humidity.
- Video and IR images will be saved in separated files with GPS time tags.

These data will be continuously saved in computer files using the naming and structure described in the following paragraphs. For each new date a directory named `yyyymmdd` will be created, and will contain all files generated in this date. At the end of every day during the campaign, all files included in this directory will be copied to a CD-Rom for processing. The schematic file structure is:

```
[rootdir]
    yyyymmdd                                (date directory)
        raw                                 (raw data directory)
            yymmdd[NN].rad                  (radiometer data files)
            yymmdd.ts                       (Cal temperature data file)
            yymmdd.met                      (Meteorological data file)
```

where [NN] stands for a two-digit sequential number starting at 00 each day. All names are compliant with MS-DOS operating system (8.3 convention)

All data files will be of binary type, and they will contain an indefinite number of lines, each one corresponding to a single measurement, and different fields in each line. A brief description of the fields for all the data files is given in the following paragraphs.

a) Radiometer data: `yymmdd[NN].rad`

This file contains the real time output of the radiometer, including the inclinometer. In order to avoid files too long, several ones will be created at each date, and their names will be automatically generated using the system clock and following the convention given above, where NN is a sequential number. The fields saved in this file are:

- Julian day (number of days within the year)
- GPS UTC time (hours, minutes and seconds) at 1 s interval
- Averaging value (number of samples averaged: 2)
- Switches status (1: Antenna, 2: Uncorrelated loads, 3: Correlated load)
- Vertical and horizontal receivers detector output voltages (V_v, V_h)
- Digital correlator counts (for 3rd and 4th Stokes parameters)
- Operation mode*
- Output voltages of internal temperature sensors
- Inclinometer pitch

*The operation mode is used for identifying the measurement that is being carried out at each time instance. The following values and corresponding status are defined:

1: Scene measurement at fixed azimuth and elevation angles
2: Scene measurement in azimuth scan
3: Scene measurement in elevation scan
4: Down-welling sky temperature measurement
5: Sky look for calibration.
6: Hot load look for calibration
7: Antenna moving. Not valid data

b) Calibration load temperature data: `yymmdd.ts`

A single file for the whole day will contain the physical temperature of the calibration target as a function of time. This temperature will be recorded only for the time instances when calibration will be performed, thus lowering significantly the data storage need. The following fields are considered:

- Julian day
- GPS UTC time (hours, minutes and seconds) at 10 s interval
- Output voltages of the temperature sensors

c) Meteorological data: `yymmdd.met`

Also a single file containing the data coming from the local meteorological station and with the following fields

- Julian day
- GPS UTC time (hours, minutes and seconds) at 10 s interval
- Rain rate
- Atmospheric pressure
- Temperature
- Relative humidity

Data Processing

Although data processing is foreseen to be done after the data acquisition so strictly speaking is not part of the experiment plan, it is important to have the main procedures well defined previously. This will ensure that the saved data is compatible with the processing, especially the control signals and flags. Thus, a global description of the data structure after processing is given.

Data processing will be performed by updating the data in several **levels**, getting at each one a higher degree of calibration/correction. The starting point is the raw data (level 0), collected by the instruments and saved in CD-Rom during campaign. Other levels (1.0 to 3.0) are obtained after processing.

The directory structure for processing follows the same convention as for raw data:

```
[rootdir]
    yyyymmdd                          (date directory)
        raw                           (raw data directory)
            (Raw data files. See previous section)
        cal                           (cal directory)
            ccyymmdd.mat              (calibration coefficients file)
        level[x.y]                    (x.y level directory)
            AzScan                    (scan mode directory)
                (Matlab files  L[xy][SN].mat)
            ElScan                    (scan mode directory)
                (Matlab files:  L[xy][SN].mat)
```

where `[x.y]` denotes the processing level and `[SN]` a four-digit serial number which is explained later. For example, for "level 1.2" the directory is named `level1.2` and the Matlab file containing the data at this level for serial number 1234 is named `L121234.mat`. The input data at each level is the output of the previous one. A first description of the different data levels and procedures is given below.

<u>Calibration</u>: At the beginning and at the end of each measurement sequence (30 minutes in mode 3, 60 minutes in mode 1 and 100 minutes in mode 2) a complete calibration (sky and hot load, correlated and uncorrelated noise sources) will be performed each day during the campaign. This allows to compute the gain and offset for the vertical and horizontal channels. Since the radiometers use the Dicke switch principle and are temperature compensated, it is assumed that the drifts are very slow, and a linear interpolation of gain and offset can be safely used between calibrations. Also these calibration looks will give information about the losses and noise temperature of the antenna and other subsystems located before the noise injection switch, which is useful to calibrate the third and fourth stokes parameters.

The calibration coefficients will be computed from the radiometric data (.rad) and also from the physical temperature of the hot load (.ts file) and the cold load (sky looked at a given date and time with a given antenna pointing + atmospheric model for the down-welling temperature). The output file (in Matlab format and named `ccyymmdd.mat`) will thus contain the computed calibration coefficients, along with the time stamp from the GPS time. That is, it will contain data ready to be used later in the calibration processing.

Nevertheless, a quick calibration procedure will be performed on-line during the campaign, in order to have a first-hand information of the parameters being measured. Video images will be processed to estimate sea surface foam coverage.

Level 0: It is the raw data saved directly during operation, and already described. In the processing procedure it will be simply copied from the CD-Rom.

Level 1.0: Data parsing according to different scanning modes. Three scanning mechanisms are envisaged: Fixed, azimuth and elevation scans. So, the first procedure to carry out from the raw data consists of separating the segments that correspond to each one of the two modes. The input information for identifying the

scanning mode will come from the variable "operation mode" saved in the radiometric data. From this information, a catalog text file, named `WISEcat.txt`, will be automatically generated. It will contain the following fields in each line:

- A unique four-digit serial number
- Date
- Starting Time
- End Time
- Scan mode (Elevation or azimuth)
- Average meteorological values: wind speed/direction, rain rate, temperature

There will be a single catalog file for the whole campaign, having as many lines (and so, serial numbers) as different single scans. This is very useful for getting quick access to a given data, particularly interesting from the scientific point of view.

The files on level 1.0 contain exactly the same information as level 0 (raw) but:

a) Converted to Matlab format (.mat).
b) Split into as many files as different serial numbers
c) Saved in subdirectories according to the two scanning modes.

As explained before, the naming convention for each Matlab file contains information about the level and the serial number: `L10[SN].mat`.

Level 1.1: *Calibrated Stokes Parameters*. At this level, the four Stokes parameters will be computed from the data available in the files at the previous level. Use will be made also of the calibration coefficients computed before, the down-welling measurements and the internal noise diode measurements. The output Matlab files will include only the data for valid time instances, which means discarding the time segments for which the antenna is moving, or measuring the down-welling temperature or the calibration targets, and also the times for which the switch is connected to the internal noise sources.

The Matlab files at this level will include

- The GPS time
- The four Stokes parameters and
- The inclinometer data (yaw, pitch, roll).

Level 2.0: At this level, the stokes parameters of the previous level will be *corrected* for cross-polarization of antenna, platform motion (the platform may roll by up to 4° in case of high winds) and deconvolution by the antenna pattern. The Matlab data files will only contain GPS time, Stokes parameters, azimuth and elevation angles. This level is already usable by an external user since it contains all relevant information regarding the radiometric measurement. The Matlab files contain the corrected Stokes parameters and the true elevation and azimuth angles:

- The GPS time
- The four stokes parameters
- True Incidence and azimuth angles

Level 2.1: At this level, information from *other sensors* is included, appended to the radiometric data (without modification) and interpolated in the same time grid. This other information is: foam coverage, rain rate, atmospheric pressure and temperature and wind speed and direction. This is the final product of the WISE campaign.

3.2. Ka-band Polarimetric Radiometer "KaPR", UMass

3.2.1 Instrument Description

The UMass Ka-band fully polarimetric radiometer was designed and tested at the Microwave Remote Sensing Laboratory of the Electrical and Computer Engineering Department of the University of Massachusetts at Amherst, U.S.A.

RF/IF Subsystem:

The Ka-band antenna is a scalar horn antenna, manufactured by Millitech, LLC of Northampton, Massachusetts. It is symmetric both physically and electromagnetically, with a ½ power (-3dB) beamwidth of 7deg. The 98% power beamwidth is 18 deg.

KaPR measures the first two Stokes parameters, T_v and T_h, using a Dicke radiometer configuration employing two single sideband super heterodyne receivers. KaPR operates alternately in both polarization-combining and correlating modes to obtain the 3rd Stokes parameter (U). In its polarization-combining mode KaPR uses a ferrite polarization rotation device to measure the brightness temperature at +/- 45 deg. linear polarization. The 3rd Stokes parameter can be derived from these measurements. In the correlating mode, KaPR uses an analog correlator to measure both the 3rd and 4th Stokes parameters (U, V).

KaPR RF subsystem has five operating modes.

a) RF Mode 1 (Scene-Ref): (normal mode of operation) KaPR acquires Dicke measurements of the scene.
b) RF Mode 2 (Cal-Ref): KaPR acquires Dicke measurements of the internal hot calibration source.
c) RF Mode 3 (Ref-Ref): KaPR acquires offset measurements by measuring the Dicke reference load at 100% duty cycle.
d) RF Mode 4 (Scene-Scene): KaPR acquires offset measurements by measuring the scene (antenna) at 100% duty cycle.
e) RF Mode 5 (Cal-Cal): KaPR acquires offset measurements by measuring the internal hot calibration source (noise diode) at 100% duty cycle.

Modes 1, 2, and 3 will be the primary modes used in WISE-2001.

Data Acquisition Subsystem:

KaPR contains an embedded computer (PC-104 Pentium 233MHz) enabling all position control and data acquisition operations to be controlled from inside the instrument. A simple one-minute scan or a day-long measurement series, as described by a control script, can be requested via the network link. Once the instrument receives the control script, all subsequent control is internal until the script has finished or is manually interrupted or terminated by the operator.

KaPR Control Software

The KaPR control software consists of two programs: a server and a client. The server, running on the embedded PC-104 computer inside KaPR, controls all radiometer positioning and data acquisition. The client, running on a personal computer, sends the control script to the server and provides monitoring of the scene. The software requires a TCP/IP network link between the server and client.

In WISE-2001 the network link will be a simple point-to-point Ethernet link between the radiometer terrace and the control room.

Position control of KaPR is achieved using a QuickSET QPT-500 pan & tilt and a QuickSET QuickComm position controller. The QuickComm can manually control the instrument position or it can be controlled via software. Normally, the server will issue all position commands.

The server can designate data storage in three modes.

a) Storage Mode 1 (the normal mode of operation): Data is stored locally on a hard drive inside KaPR. Once a day, all data is transferred to the client computer for auxiliary storage and backup to CD-RW. This mode allows KaPR to operate independently of the client once the control script has been loaded onto the server. The operator is free to disconnect the client computer for tasks such as data processing and data backup.

b) Storage Mode 2: Data is transferred over the network to the personal computer for immediate storage on the client. The network link must remain active at all times.

c) Storage Mode 3: Data is stored both locally on the embedded hard drive and transferred over the network to the personal computer.

3.2.2 Polarimetric Radiometer Calibration

Internal Calibration:

Every 30 seconds KaPR will perform a two-second internal calibration, consisting of a one-second offset measurement, and a one-second hot calibration source measurement.

In Dicke radiometers the output of each receiver is the scene temperature minus an internal reference temperature (Scene-Ref). When switching of a Dicke receiver is suspended, the receiver will observe either Scene-Scene or Ref-Ref. This signal is theoretically zero. Any measured signal is due to the offset of the video circuits used to generate the difference output signal. Previous experiments have shown (FAIRS-2000, WISE-2000) that constant monitoring of this offset is necessary.

To characterize and track internal gain variations, KaPR's RF subsystem includes a calibrated noise diode to serve as a hot calibration source. This source will be observed for one second after each offset measurement.

Calibration of the analog correlator will be performed by injecting uncorrelated noise into both receivers and using a digital phase shifter to vary the phase of one channel from 0 to 360 deg. In this manner the correlator's offset, in-phase, amplitude, and quadrature errors are characterized and therefore can be corrected in post-processing.

External Calibration:

The primary calibration of the instrument will be performed using external calibration, through the measurement of 'hot' and 'cold' targets.

The 'hot' target is a temperature-monitored microwave absorber load, sheltered in an environmentally–sealed chamber. This calibration target contains circuitry to condition the output from temperature probes inside the target. The conditioned temperature output is input to an RS-232 data acquisition module, which digitizes and outputs the data via a standard serial port interface. This data is sent to and stored on the KaPR embedded computer.

The 'cold' target is the derived brightness temperature of the sky (T_{sky}). This 'cold' target is synthesized by performing tip-curves, during which the brightness temperature of the sky is measured at a series of zenith angles.

The effects of reflected atmospheric downwelling will be characterized by performing measurements of the sky at angles complementary to the observed ocean-incidence angles.

3.2.3 Polarimetric Radiometer Measurements and Data

KaPR has three operating modes:

a) Mode 1: Scene/Internal Calibration Data.
b) Mode 2: Cold load (tip-curve) data
c) Mode 3: Hot load (ambient load) data

Experiment plan:

All measurement sets taken by KaPR on WISE-2001 will be preceded and followed by an external calibration. External calibration consists of a tip-curve, consisting of eight one-minute sky measurements, and a 90-second ambient-load calibration. The tip-curve zenith incidence angles include the subset of angles complementary to the scene incidence angles. Inclusion of this subset of measurements also enables us to characterize the effects of reflected downwelling, as described in section 3.2.2. The time required for each external calibration is 10 minutes.

KaPR will normally perform azimuthal scans of the sea surface. The scans will consist of taking two-minute measurements at incidence angles of 35, 45, 55, and 65 deg. At each incidence angle, measurements will be performed at seven azimuth angles spanning the allowable field of view. This results in 28 measurements per scan set, requiring approximately 70 minutes per azimuthal scan set. The time required for a complete azimuthal scan set, including two external calibrations, is 90 minutes.

KaPR will also perform elevation scans at a fixed azimuth twice per day to characterize the influence of the sea-state variability throughout the day. All elevation scans will be performed at zero deg. azimuth with respect to the oil platform, approximately 10 deg magnetic. Each elevation scan set will consist of 15-minute measurements at 35, 45, 55, and 65 deg incidence, requiring 60 minutes per elevation scan set. The time required for a complete elevation scan set, including two external calibrations, is 80 minutes.

Data Structure

Data files recorded during WISE-2001 will have the following file structure:

yymmddss.dat	*(radiometer data files scene/internal data)*
yymmddss.cal	*(calibration 'hot' load temperature data)*

Note, that a separate file will be created for each radiometer position; therefore, an azimuthal scan will consist of 20-30 files, in contrast to some instruments which record one large file for an scan.

<u>KaPR Radiometer Data Files</u>:

KaPR radiometer data files are ASCII text files. Each file contains a file header and an indefinite number of data buffers, each with its own buffer header.

Each file header contains:

- Text "Ka-band Polarimetric Radiometer (KaPR) Data File - University of Massachusetts, Amherst"
- Radiometer Mode (1,2,3)
- GPS Date/Time
- Position (recorded from control script)

Each buffer header contains:

- RF Mode (1,2,3,4,5)
- GPS Date/Time
- Measured Position (measured using electronic clinometers)

Each buffer contains the output of the 16 A/D channels: four channels of radiometric data, four position channels, four channels recording 16 multiplexed temperature sensors placed throughout the instrument, and four channels recording timing signals (for debugging purposes).

Calibration Load Temperature Data Files:

Calibration load temperature files are ASCII text files. Each file contains a file header and an indefinite number of lines containing the output voltages of the calibration load.

Each file header contains:

- Text "Ka-band Calibration Load Temperature - University of Massachusetts, Amherst"

Each line contains the GPS Date/Time and output of all calibration load temperature sensors, comma separated.

3.3. Radio Frequency Interference

Radio frequency interference (RFI) was a problem during WISE 2000. The main source of RFI was coming at horizontal polarization from the North side and at high incidence angles (Tarragona city) (see Figure 4.2 of WISE 2000 Scientific Analysis Report). RFI in this direction was almost constant and it may be due to harmonics of UHF transmitters.

A second source of strong RFI were some of the walkie-talkies used during the campaign, which, even though were out of band, led to saturation the radiometer receivers. As soon as this problem was detected the walkie-talkies were no longer used.

A third source of RFI detected was the 9th harmonic of the 156 MHz (9x156 MHz = 1404 MHz) frequency channel used by the fisher ships. This is a weak source, but may account for a few Kelvin.

Finally, sporadically a weak sawtooth-like RFI was detected, with a period of ~ 5 min. This source was not identified as any known beacon in the area.

Other potential sources of RFI could have been the transmitter links from the buoys: at 433 MHz (10 mW), ARGOS emissions around 402 MHz (>1 W), and emissions from the AANDERAA meteorological buoy at 142.025 MHz, that emits during 40 s every minute. This problem was avoided by inserting a 200 MHz low-pass filter between the transmitter and the antenna, with an attenuation larger than 75 dB at 1.4 GHz (approximately the whole dynamic range of the network analyzer).

4. Ground-truth Data

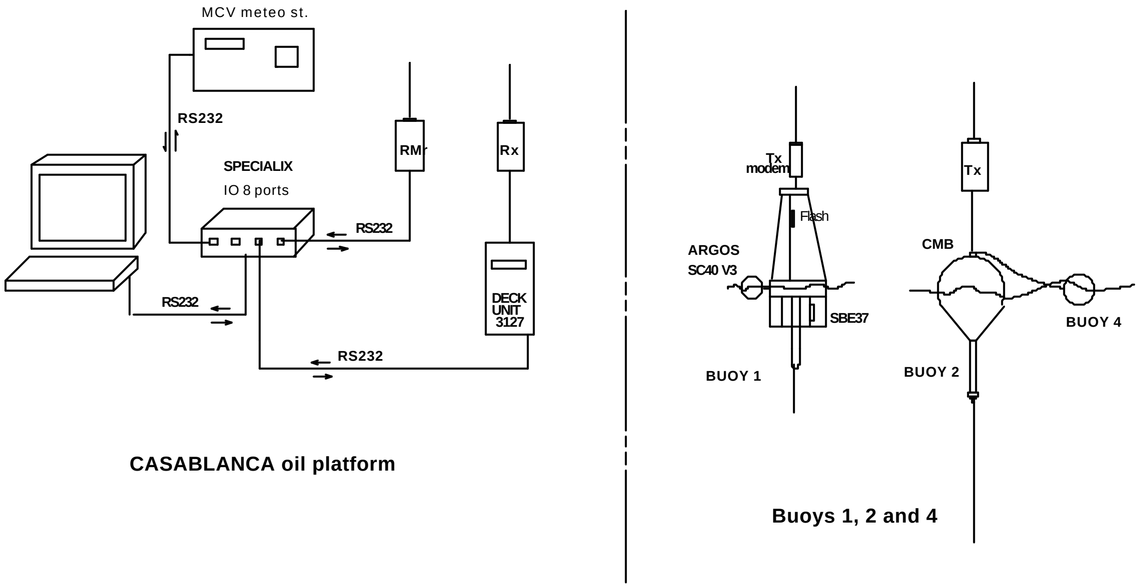
4.1. Meteorological Stations

Rain rate, atmospheric pressure, relative humidity and air temperature at 30 m height will be measured by the meteorological station of UPC connected to the same computer than the radiometer. These data will be tagged with GPS time and saved in the same files structure as the Stokes emission vector (section 3.2). These data will be used to estimate the down-welling atmospheric contribution.

On the Casablanca Platform there is an automatic meteorological station installed on the top of a communications tower, 69 meters above the sea level. It is operated in a real time acquisition configuration and uses an RS232C output to feed the data to a personal computer. It has been manufactured by MCV S.A. Wind speed and wind direction will be recorded. The meteorological station was calibrated the day WISE 2000 started and no re-calibration is required fro WISE-2001 (< 1 year).

4.2. Oceanographic buoys

Four buoys are going to be moored 200 – 500 m north of the Casablanca oil platform within the safety area forbidden to navigation. The distance has been calculated to be close but outside the radiometers field-of-view to avoid interferences. Fig. 9 shows a schematic of the buoys and the data acquisition system on the platform.



a) b)

Figure 9. *a) Data acquisition system from the MCV meteorological station and the buoys. b) Oceanographic buoys.*

The data collecting side of the system for buoys 1 and 2 is set on the oil platform (Fig. 9a). It is build around one PC computer powered from the 220 volt 50 Hz supply through a UPS that should also power the receivers and interface components of the system, to ensure possible power line failures. RMr is the receiving part of the RS232 modem link, providing the data from buoy1. Rx is the receiver side of buoy 2. It is connected to the Computing Unit 3015 that gives power to it and converts the PDC-4 data format to the standard RS232C output. In order to handle both serial data flow, one interface to feed the PC through a serial port is needed. The SPECIALIX interface and the appropriate software do that. It is powered from the UPS. Data from buoys 3 and 4 will be transmitted by satellite (ARGOS) to LODYC.

4.2.1. Buoy 1

The BUOY 1 is a floating system that holds a Conductivity and Temperature measuring system placed at 20 cm below the sea surface and programmed for a sampling rate of one sample every 2 minutes, and a ultrasonic anemometer programmed for a sampling rate of one sample every 10 seconds.

The data is stored in a local data storage unit and also sent at fixed time intervals (20 min) to the oil platform data logger. The conductivity and temperature of the water is measured and stored using one SBE37 MicroCAT instrument from Sea-Bird Instruments and sent to a radio modem link via an RS232C port. The instrument is self-powered, having enough energy to keep it running during 2 months without battery change. Salinity will be computed from a CardT using the Practical Salinity Equation [UNESCO, 1978].

The buoy includes one flashlight for night warning, one radar reflector and buoy 4 also acts as ARGOS beacon, to ensure correct signaling and avoid damage from occasional fishing boats entering into the zone. Since the SBE37 and the buoy 4 are self-powered, we need to power only the radio modem and the flashlight. The anemometer needs extra power supplied by 3 lead batteries with a total power of 180 Ah.

Another cylinder will keep the modem inside, with the DC power input and the UHF coaxial output of the antenna. The proposed antenna is a 1/4 λ vertical. It is small (at 433 MHz) and simple. Since the distance to the receiver is short (200 meters), the 10 mW output will be enough to guarantee the link in spite of the probable buoy roll in bad sea state. The flashlight is also self powered, but in order to ensure 1 month operation, we will need also another tight cylinder with extra batteries. An “X” shape iron reflector, having the legal size, provides the radar reflector. The technical specifications of the SBE37 are presented in Section 12. The data are collected from the two sensors (anemometer and SBE37) and sent to the modem using a microprocessor unit FM-200 (Cambridge Microprocesssor Systems Limited, UK). It reads two RS232 serial ports, each at a different rate, and feeds the modem at another rate.

The bottom depth in the chosen site is 165 meter. The mooring will consist of two 375 kg train wheels on the bottom, attached to a 12 mm iron chain of 5 m in length (Fig. 10). It follows a piece of 15 meters of nylon rope of 12 mm protected by a external PVC tube, attached to a Kevlar 9 mm rope of 125 meter, fixed to a sub-surface buoy placed at a depth of 20 meters. This buoy is made of two 25 kg spherical floats, attached together. From the sub-surface buoy to buoy 1 we plan to use a length of 30 meter nylon rope, protected with flexible tube and a piece of 2 meters of 12 mm iron chain attached to the lower part of buoy 1, by-passed with a security nylon rope.The final buoyancy will be 300 kg approximately..

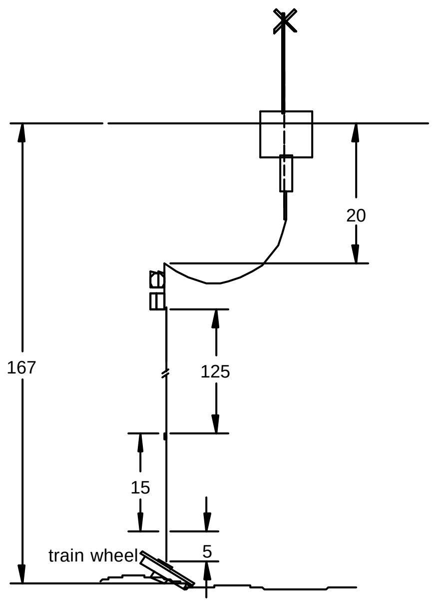


Figure 10. *Detail of mooring of BUOY 1*

4.2.2. Buoy 2

This buoy is a CMB 3280 (Coastal Monitoring Buoy), from AANDERAA Instruments, moored also on the restricted navigation zone, close to the oil platform and the BUOY 1. The CMB 3280 is a solar powered autonomous buoy that measures meteorological and oceanographic parameters storing the data and conveying it simultaneously to the platform via a real time radio link.

The measuring rate is also 1 scan of 8 channels every 2 minutes. The sensors installed on the buoy are (see Appendix 2 for sensor characteristics):
Channel 1: Identification of the buoy (fixed number for that buoy)
Channel 2: Wind Speed
Channel 3: Wind Direction
Channel 4: Air Temperature
Channel 5: Solar Radiation
Channel 6 Relative Humidity
Channel 7: Wave Height
Channel 8: Wave Period

To safe power the Current Speed and Direction (plus Atmospheric Pressure) sensors of the CMB3280 will be disconnected.

The meteorological sensors are fixed on a Sensor arm that is kept at 2.6 m above the sea surface. The current sensor and the water temperature are placed at 1 meter depth.

The main floating body of the buoy has a “wet” diameter of 90 cm and a total buoyancy of 345 kg. In order to keep a good vertical performance, the lower part of the buoy has a 20 kg counterweight placed at 1.8 meters of the sea surface.

The mooring system is similar to the one used for buoy 1. They are designed to operate on a theoretical depth of 165 meters. Individual differences are compensated by the upper part of the line (Fig. 11). We plan to use one train wheel as a bottom weight (Fig. 10). Metallic elements have been avoided as far as possible in order to prevent corrosion, or by-passed by a security robe.

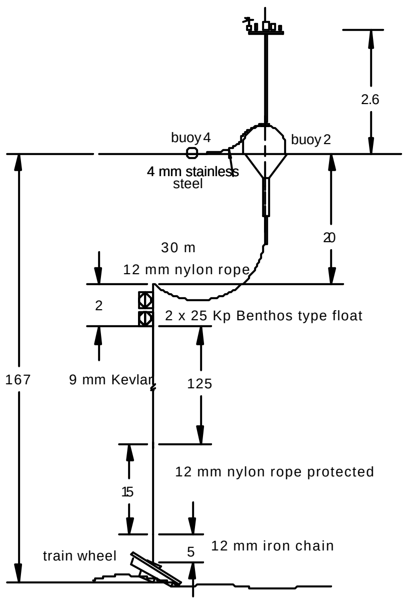


Figure 11. *Detail of the Mooring of Buoy 2*

The security elements are also one flashlight (switched on and off automatically by ambient light), one radar reflector provided by the wind direction fin and one ARGOS beacon.

The data is sent to the platform via a radio transmitter placed on the sensor arm and also stored on a RAM Data Storage Unit housed inside the wind direction fin. The data is transmitted to the receive unit in a 10 bit word format, standard PDC-4 AANDERAA format and stored also on the memory DSU 2990 E in the same format. Buoy 4, attached to buoy 2, will provide the security ARGOS localization.

The data from Buoys 1 and 2 will be tagged with GPS time. The calibration process for the oceanic buoys is the following: The sensors of the buoys 1 and 2 will be send to calibrate before and after the experiment, and it will allow detecting if there has been any bias in the measurements.

The data structure of the Buoys 1 and 2 will be the following: The outputs of the different sensors as well as the absolute time from GPS will be continuous saved in computer files named b1_yymmdd.prn and b2_yymmdd.prn, for buoy 1 and 2 respectively. At the end of the day, during the campaign, all files will be saved in a CD-ROM in compressed form (.Zip). All data files will be of ASCII type and they will contain indefinite numbers of lines, each one corresponding to a single measurement. Each file will contain approximately 1441 lines.

4.2.3 Buoy 3

This buoy is a SPEAR-F buoy which is based on a Datawell accelerometer installed in a waverider 70cm diameter sphere weighting 250 kg. The heart of the buoy is the data acquisition and handling onboard unit. The frequency modulated output of the waverider unit is transformed in an analog signal which is then digitized. The acquisition phase lasts 200 s. A Fast Fourier Transform is then performed, the spectrum is corrected for the instrument transfer function and compressed in 14 frequency bands. This is repeated 8 times during three hours and the eight spectra are averaged to produce a spectrum every three hours. The results are transmitted via the ARGOS system, the two last three hours spectra being transmitted. Considering ARGOS satellite coverage, we should have constant monitoring of the wave spectrum. The wave buoy was seriously damaged during WISE 2000 campaign and factory calibrated buoy 3 will be send by the manufacturer to ICM for mooring.

4.2.4 Buoy 4

This buoy is an SVP drifter (16.63 kg buoyancy) built by Clearwater (USA) which measures the conductivity and temperature of the water at about 20 cm depth (depending on the waves) using an FSI conductivity sensor placed on the lower part of the sphere. The measurements are performed once per hour. The data are transmitted via the ARGOS system. It will be attached to buoy 2 to minimize the number of moorings.

Buoy moorings and recovery will be performed by the oceanographic vessel García del Cid during October 3-4 and November 24-25, respectively.

4.3. Stereo Camera

A system of two numerical video camera Canon Powershot 600 (832x624 pixels) will be used. The separation between both cameras is 4 meters of distance. They will be located at 28 m over the sea surface, just below the radiometers terrace (see Fig. 5b) **pointing to the West-North West,** since it is better that the L-band radiometer does not point to the North because of the RFI problem. Of course, to avoid Sun glitter with this orientation measurements with the stereo-camera will be restricted to the morning[4].

The stereo-camera will observe the sea surface from an angle to be determined to have the "best resolution" taking into account the different systems on the site and the height of the measurement [*Tessier*, 93; *Renaudon*, 94; *Mellul* et al., 99]. It is necessary to choose the place of the system to prevent from sun reflections which can occur at some hours.

The system uses a power of 220 V (which is utilized for the CdNi accumulators) and for the PC system. Two synchronized pictures are stored on a PC disk (each picture corresponds to 1.4 Mbytes). The PC system is used to process the acquisition of the two cameras. Two sampling periods are possible with one slide every 10 s or two minutes.

Every hour or two hours, it is necessary to verify the acquisition of the cameras and to put the 2 x 30 or 2 x 60 pictures on the hard disk (case of the 2 min sampling which is probably an optimum for the experiment): this sequence last around fifteen minutes.

As a time base, we shall take the time from the GPS system (synchronization of the PC hour); however as it is difficult to make simultaneous observations with the other instruments; the precision requirements on the time are no so drastic for these "statistic observations".

After agreement between participants and according to the meteorological forecast at the platform the sea state evolution will be documented (cases of increasing or decreasing wind intensity). This configuration will involve to take 10 seconds interval stereo pictures (wind speeds of 5 m/s, 10 m/s, 15 m/s and 20 m/s will have to be documented with this sampling period). The 10 seconds sampling

[4] The L-band radiometer cannot make measurements in this direction in the afternoon either. During the afternoon, the elevation scans will be performed pointing to 40º East, to try to maximize the data acquired, even though there may be some RFI –not as important as at North-.

interval will not be the systematic mode because of: 1) the huge amount of information that will have to be stored, and 2) the long processing time of each pair of stereo images.

4.4. LAURA Video Camera

A video camera (8.5 mm lens, auto-iris, resolution 512 x 582 pixels, field of view: 35.6º in horizontal and 25.2 º in vertical) will be mounted in the antenna support of LAURA radiometer to provide a view of the sea surface being measured by the radiometer. The images will be used to:

- evaluate the sea foam coverage by analyzing the image histograms and
- disregard erroneous measurements when the security vessel that makes circles around the platform or even whales pass through the antenna beamwidth.

  Images will be recorded at a rate of one frame per second.

4.5. KaPR Video Camera

Description

A video camera will be mounted on the same pan/tilt positioner as KaPR. The video capture system was designed and tested by Dr. William Asher of the Applied Physics Laboratory (APL) of the University of Washington at Seattle, U.S.A.

Analog images output from this video camera are captured and stored using a high-bit depth video frame grabber. The stored images are 640 x 480 pixels. The video feed is normally sampled at 2 Hz, although during interesting sea-surface conditions, such as high winds, the frame rate can be increased, up to 5 Hz.

Data Storage and Processing

APL software will use well-tested algorithms to measure the fractional coverage of foam in the radiometer's field of view. This video data will be made available once it is processed.

4.6. Infrared radiometer

The CIMEL thermal-infrared radiometer, CE 312, from the University of Valencia (UV) is a multi-band radiometer with a Field of View of 10 º. It will provide sea surface temperature read-outs simultaneous to the LAURA's scans.

For these periods of sequences of measurements, the CE 312 has to observe the sea surface with the appropriate zenith and azimuth angles. This condition will be ensured by placing the CE 312 at the hand-rail, looking at a preset and fixed zenith angle and performing azimuth scans.

Since the CE 312 read-outs are brightness temperatures, these data have to be corrected from the atmospheric and emissivity effects, before being compared with the SST estimates from the AVHRR and the oceanographic buoys. The spectral condition of the CIMEL data will be used to get the spectral behaviour of the sea foam emissivity in the TIR spectral region.

4.6.3. Description of the instrument

The CE 312 is composed of two major components: (1) The optical head containing the detector (thermopile) and optics, and (2) the electronic unit, which performs the data collection configuration, display and storage. A filter wheel with four interference filters is located between the objective lens and a stepper motor allows the filter selection. This design includes one broad filter, 8-13 μm, and three narrow filters: 11.5-12.5 μm, 10.5-11.5 μm, and 8.2-9.2 μm. The radiometer is provided with a concealable, gold coated mirror, which enables comparisons between target radiation and a reference radiation from inside the optical head. A platinum probe attached to the detector's surface monitors the head's internal temperature and is used to give the reference temperature from which the reference signal is calculated. The radiometric sensitivities at 20°C are 0.008 K for the first channel, and 0.05 K for the other three. The radiometric accuracy of each channel is ±0.10 K, ±0.12 K, ±0.09 K and ±0.14 K respectively. More details can be found at the Cimel Electronique web site (http://www.cimel.fr).

The data are stored in the memory of the local data storage unit and sent in real time to a PC through a serial port. Other characteristics of the acquisition system are: (1) self-contained (one-day time range with batteries or unlimited time range with solar panels), and (2) automatic with a motorized support.

4.6.4. Measurements and data

Different modes of acquisition or scenarios can be selected. The idea is to select a mode which starting with filter 1, makes 1 measurement of the detector temperature, and 2 measurements for each filter alternating with and without mirror, starting with mirror.

Duration about 20 s stored in an unique line of a file. In a posterior step, these data will be tagged with GPS time and saved in the same files structure as the meteorological station data (section 3.2)

Infrared radiometer data files will be named yymmdd.r2m. The temperature readings will be continuously saved in computer files. All data files are of ASCII type, and they will contain an indefinite number of lines, each one corresponding to one selectable scenario measurement. The general format of the ASCII files is a series of lines with the following fields:

	internal	DC for the measurements	
Date	time	T	mirror field

“dd/mm/yy”,”hh:mm:ss”, n, Tt.t, M1 , F1 , M2 , F2 , M3 , F3 , M4 , F4

n has no meaning. M1, F1, M2, … are the DC for the measurements made with mirror and filter for filter 1, filter 2, filter 3 and filter 4.

5. Satellite Data Acquisition

5.1. QUIKSCAT Wind data

QUIKSCAT level 2 wind velocity data at 25 km resolution in the vicinity of the platform will be provided during the duration of the campaign in order to assess the regional context of the campaign.

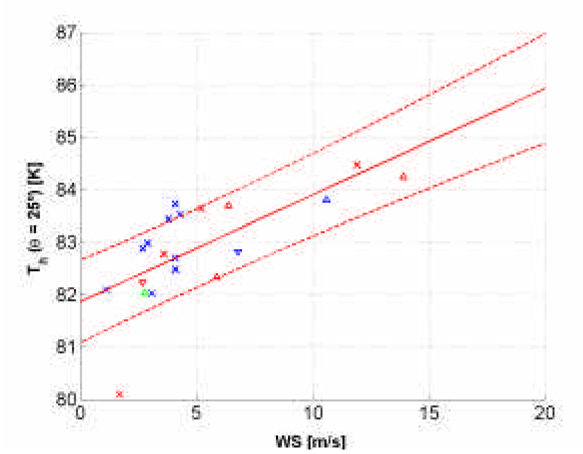
5.2. AVHRR SST and SEAWIFS ocean color images

AVHRR-derived sea surface temperature (2 km resolution) in the vicinity of the platform will be provided during the campaign for comparison with in-situ ground-truth data from oceanographic buoys and the one estimated by the IR camera. In case of very low wind speed the EBRO river plume, which is colder than the surface sea, will be seen and monitored.

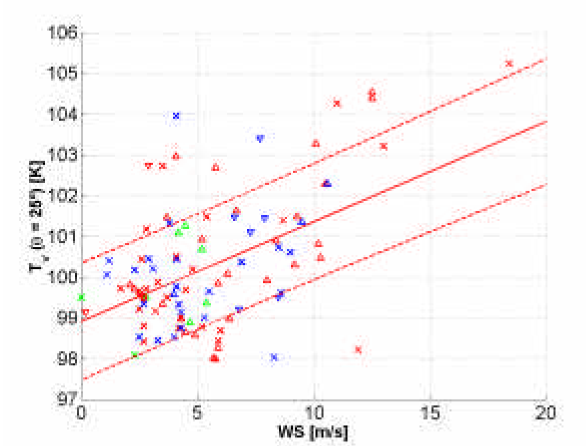
SEAWIFS LAC data (2 km resolution) will be used to monitor the Ebro river plume.

6. Measurement strategy

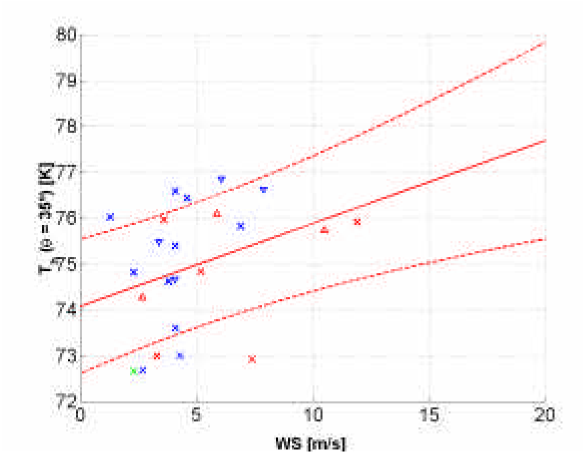
Figure 12 shows the clouds of points of T_v and T_h vs. wind speed, and the linear fits derived from the WISE 2000 measurements. The slopes of the regression lines correspond to the sensitivity of the brightness temperatures at different elevation angles (figure 13).



a)



f)



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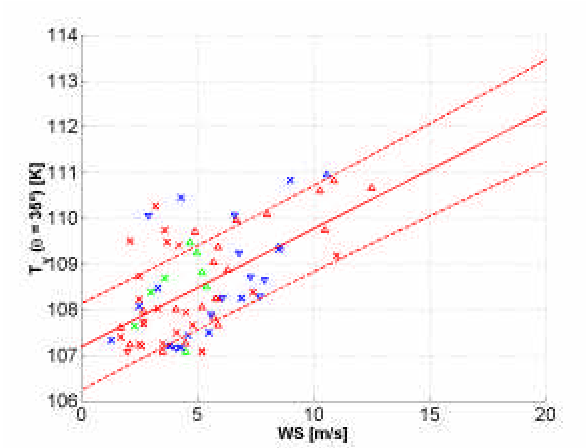
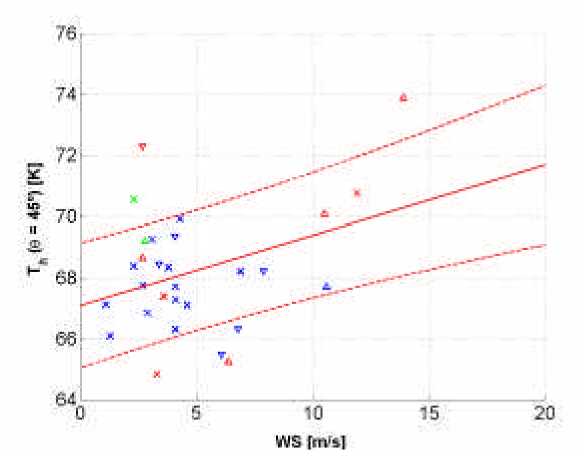
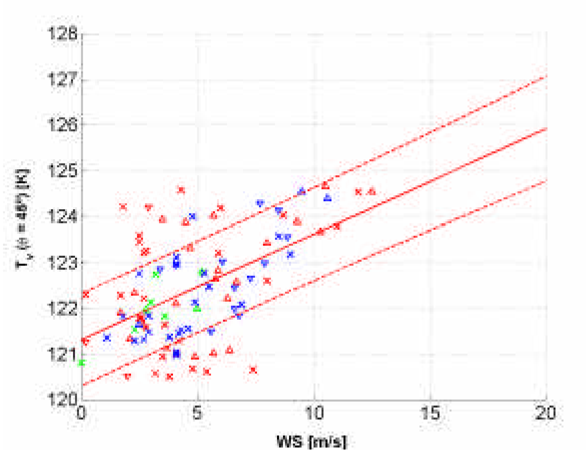


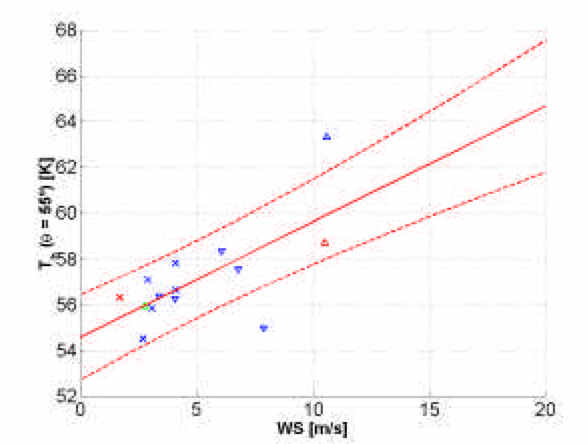
g)

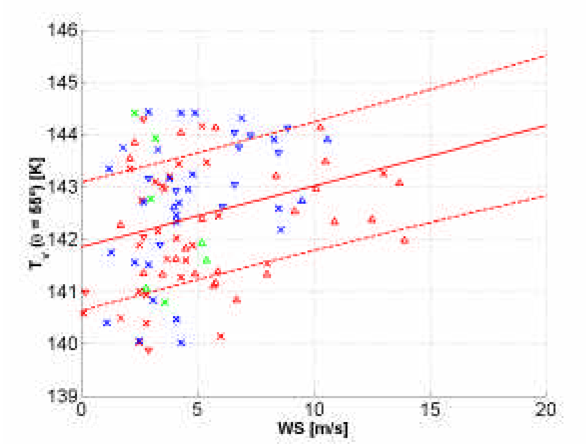


c)



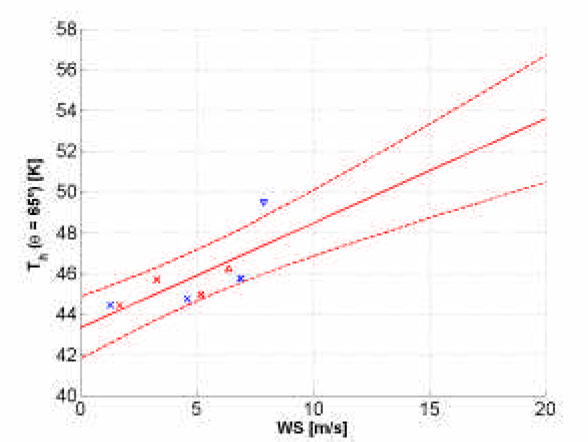
h)

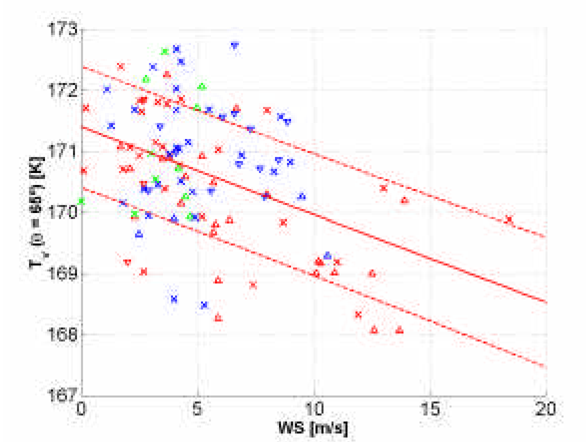




d)

i)





e)

j)

Figure 12. Sensitivity to wind speed of the L-band brightness temperature at horizontal (left) and vertical (right) polarizations at different incidence angles: (a-f) θ=25º, (b-g) θ=35º, (c-h) θ=45º, (d-i) θ=55º and (e-j)θ=65º.

Legend: SST: Blue: < 14.5 °C, Green: 14.5 °C, 15.5 °C, Red: >15.5 °C
Wind direction relative to radiometer: ▲: up-wind, ▼: down-wind, **x** : cross-wind

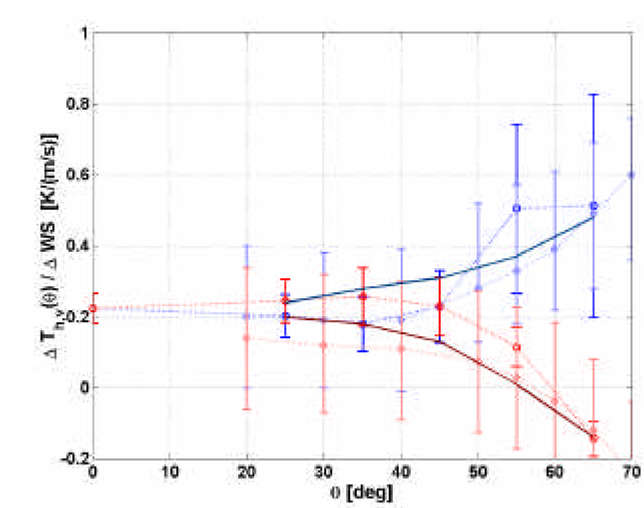


Figure 13. WISE 2000-derived brightness temperature sensitivities to wind speed vs. incidence angle at vertical (red circles) and horizontal polarizations (blue circles) and comparison with Hollinger's measurements (diamonds) and Yueh-LODYC 2-scale model (Durden-Vesecky spectrum x 2, solid line).

From figures 12 and 13 it is clear that the variation of the brightness temperatures with wind is very weak and to detect signal variations on the order of 1 K, a large post-integration time is required[5] (~ 1 min) so as to improve the radiometric sensitivity much below this value. On the other hand, the post-integration time cannot be made arbitrarily long, since the stationarity of the sea state conditions cannot be guaranteed. These issues are discussed below in order to define an optimum measurement strategy.

Sea state variability

This is an important point and the only thing on which we can rely at the present time is that the sea state at the scales we are interested in should be stationary for about 5 minutes. It might be more, but nothing is sure. This implies that:

1. We should have a mode to study the time scale of stability of the sea state and its consequences on L band emissivity. We should keep in mind that T_B depends on a wide range of wavelengths, a dependence which we do not know in detail at present. The time to put the sea state in equilibrium with the wind depends on the wavelength, on the time history of the wind (increasing and decreasing winds should not have the same effect for instance), etc. For this reason we will have a mode at fixed direction (incidence and azimuth, the azimuth will anyway vary with the wind direction but we should not in addition change it ourselves) and to keep this mode for about 1 hour, in conjunction with the stereo-camera (mode 1). As compared to WISE-2000, the duration of the elevation scans (mode 2) has also been increased from 4 min to 20 min, to be able to analyze this effect.

2. We should make sets of coherent measurements usable alone on durations as short as possible, on the order of 5 min. To do so, the 20 min data acquired during the elevation scans will be sliced and averaged in 5 min intervals. If the sea state is stable for the whole scan we can use the complete scan and get measurements at all angles. If not, we can use the scan by parts as short as necessary, down to a pair of successive measurements, and still have a large angular coverage, with less angles sampled: it is not as good but we still have information on the whole angular range.

[5] The elementary integration time (hardware-limited) is 0.5 s.

Galactic noise

During relatively long periods of time the contribution from the galactic noise is approximately constant and in any case, it can be modeled using the measured antenna pattern and the brightness temperature maps measured by Reich and Peich [1986]. If we are not obliged to couple systematically a measurement of the galactic noise with each measurement of the sea, we will half the measurement time which is very important for the stationarity of the sea state. During the azimuthal scans the galatic noise reflected in the instrument should vary by less than 0.1 K.

Angular scan

From the WISE-2000 experience, a 10° step in incidence angle is acceptable. The range of angles to be swept must be as large as possible (within the limitations of not seeing the platform nor the sky). This way we end with 25°, 35°, 45°, 55°, 65° which we propose to scan in the following order: 25°, 55°, 35°, 65°, 45°. Since we have only 5 incidence angles we can use all of them for the studies at fixed direction (mode 1) and for the SSS retrieval problem. As commented, to maximize the acquisition time while on the platform, measurements during the afternoon-evening will be performed pointing to azimuth +20° and using a 5° angular step.

For the azimuth, the amplitude of the modulation of T_B is much smaller, at most 0.2 K at 5 m/s wind speed for 90° variation in azimuth. Thus it is proposed to scan a 120° angular range in a 30° steps: 260°, 290°, 320°, 350°, 20° (North=0°, positive angles to the East), in the following order: 290°, 350°, 320°, 260°, 320°, 20°, 250°. (**mode 3**). Thus we have 6 azimuth angles scanned, and we keep the time duration of 4 min. The duration is 7 x 4 min = 28 min + movement time.

Duty cycle

With these new angular scans in elevation the duty cycle is longer: 100 min, which seems reasonable, according to radiometer's stability.

For practical reasons, especially data handling, it is convenient to have a fixed duty cycle and to know that we will find a calibration at known intervals between which the mode will not change. However, this is not crucial, since each measurement will be tagged with a flag indicating the type of measurement (calibration, hot/cold loads, correlated/uncorrelated noise sources etc).

Summary

We stand now with 3 modes:

- **mode 1**: fixed direction for one hour every day with coincident measurements of the stereo-camera.
- **mode 2** : scan 5 elevation angles (25°-65°, $\Delta\theta=10°$), 20 min each (normal mode of operation), during the morning pointing to the West (azimuth = 260°). Scan 9 elevation angles (25°-65°, $\Delta\theta=5°$), 5 min each, during the afternoon-evening pointing to the North-East (azimuth = +20°) to avoid Sun glitter.
- **mode 3** : scan 6 azimuth angles, 4 min each, at constant incidence angle during LOSAC overflights (November 19-22, 2001).

The measurement modes also apply in case of rain.

STEREO-CAMERA

There is no way in which the radiometer which scans in angle can have always the same field of view as the camera which does not move. If the camera is at 28 m height it looks between 30 m and the horizon, the proper resolution in wavelengths (of sea waves) being achieved only between 30 and 47 m. The axis of the radiometer will look between $\approx$24 m (incidence 25°) and $\approx$112 m (incidence 65°), looking in the proper part of the cameras field of view for incidence between $\approx$20° and 35°. In addition the radiometer integrates over 2 min (0.5 s measurements averaged to get the required sensitivity) while the picture is «instantaneous». In any case the instruments will never see the same thing and the comparison can only be statistical. The measurements of the cameras are valid only statistically whatever the problem dealt with is. The priority is to measure the sea state in the relevant wavelength range, that means to increase the space resolution : for that we should be as close as possible to the sea.

Shadow and sun glitter

It appears that shadows of the platform are not a problem. Sun glitter cannot be avoided during the afternoon because of the orientation to the West-NortH West (Fig. 14). Therefore, measurements will be acquired only during the morning.

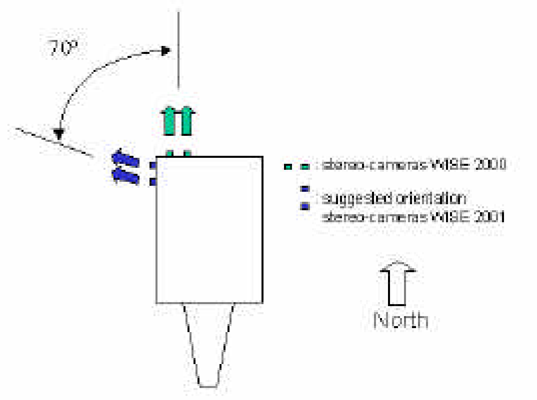


Figure 14. Stereo-cameras orientation during WISE-2001

VIDEO AND INFRARED CAMERAS

Video camera will be mounted on the UPC antenna pedestal so it will point to the antenna boresight. Since their field of view is different the central pixels of the pictures corresponding to the antenna beam will be selected. IR radiometer will be mounted on a tripod and pointed manually to the optimum incidence angles for SST retrieval.

7. Operations

7.1. Transportation

The Oceanographic research vessel of ICM "García del Cid" will be available on October 3-4 and November 24-25, 2001 for mooring and retrieval of the buoys. Transportation of the radiometers and the rest of the instrumentation from land to the Casablanca platform will be performed by a Repsol cargo ship that links Sant Carles de la Ràpita with the platform once a week –it may vary-.

Personnel will be transported by helicopter. Repsol's helicopter makes a round trip to the platform on Tuesdays and Wednesdays departing at 8:15 AM from Els Garidells and returning around 12:00 PM. Els Garidells is a small town at the North of Tarragona city, close to the Repsol refinery facilities.

7.2. Experiment Management

Three people are required to be at the platform permanently during the experiment to control the instrumentation and save the acquired data: one from UV to control the IR radiometer, one from CETP (first 15 days) and UPC (second 15 days) to control the stereo-cameras and take water samples, and one from UPC to control the L-band radiometer.

7.2.1. WISE-2001 headquarters

During the WISE-2001 campaign, the headquarters will be located at a room in the new facilities of ICM, from where Dr. Wursteisen will coordinate the LOSAC/WISE campaigns during the week November 19-22, 2001. Telephone, fax and internet access will be available.

LOSAC flights will take off and land from “El Prat” Barcelona Int’l Airport.

7.2.2. Radiometric Data and Sampling

Although the operation of the UPC radiometer is controlled by a computer, it requires an operator to define the measurement cycles, put the antenna in safe position in case the automatic mode fails, perform a daily back-up of the data recorded, clean the radiometer antenna with fresh water etc.

7.2.3. Ground Truth Data and Sampling

The oceanographic buoys do not require any special operator since data is transmitted through a radio (buoys 1 and 2) or satellite link (buoys 3 and 4) Just periodic checking of correct reception and daily backup of recorded data. Surface water sampling for precise salinity determination requires one operator once a week, and two during the special vertical profiling (one hour 4 or 5 times during the experiment). The stereo camera requires one operator at a time.

Experiment has been designed to endow the IR data acquisition system with the maximum autonomy, even so, one operator of the University of Valencia is required for performing a daily backup of the data to the PC and purge the local memory of the electronic unit.

7.2.4. Weather forecast.

Weather and sea state forecasts (every 6 h) are available through the Internet web servers of the Met Office and the Servei Català de Meteorologia:

http://svt.es/meteosort/mapes_aero.htm
http://www.inm.es/wwc/indpuer1.html
http://www.gencat.es/servmet/mar/ixmar.htm

Internet access is being installed on Casablanca, but we don't know yet if it will be fully operative during the campaign. If not, we will proceed as during WISE 2000, sending the weather forecasts by fax.

7.3. Power Supply

Recommended power supply is the European standard for low power consumption: 220 V, 50 Hz, single phase. However, 380 V, 50 Hz, three phase is also available. Power supply is generated at the same platform and it is not well regulated. The use of an UPS (uninterrupted power supply) is strongly recommended. During WISE 2000 a general power failure longer than 10 min happened in the platform –not even the second generators-. All the "autonomous" systems had to be re-started by the personnel aboard.

7.4. Safety Considerations

When living in the platform for more than one day (not just a 3 h visit), the following safety considerations have to be considered at the platform:

- Use of protective boots or shoes with steel sole and steel protection for the toes.
- Use of protective glasses
- Use of protective helmet (color white)
- Use of protective dressing (brilliant orange or brilliant red collars)
- It is forbidden to smoke in the so-called operations area.
- The use of electronic equipment (cellular phones, photographic cameras etc) is forbidden in the operations area, except if a preliminary test of risk of explosion is performed by the platform personnel.

  Notes: The area where the instruments will be deployed and controlled is not in the operations area. <u>The protective boots (or shoes), glasses, helmet and orange or red labor dress must be purchased in advance by the people that will be working on the platform.</u>

8. Data Management and Availability

Data calibration and formatting is responsability of each research team. All data will be put together in a common format (task WP3.2, Fig. 6) and will be available to the consortium members through FTP and/or CD-ROM as soon as possible so as to proceed with task 4.

Preliminary data will be released to ESA during the Data Review Meeting, and the final Data Set at the end of the contract.

9. Communications with land

Personal communications with land can be performed by means of the dedicated telephone line of the platform (platform supervisor: +34+977.260.484, helicopter base at Garidells: +34+977.610.068) and a fax (helicopter base at Garidells: +34+977+625+366). Data lines are not reliable, which make email and Internet access almost impossible. The Repsol radio link could also be eventually used in case of necessity. The use of a VHF-marine link is available for occasional links to the Garcia del Cid or other vessels.

Internet access may be operative during the campaign if the installation of the new phone lines is finished.

10. Local Information

Els Garidells is right at the North of Tarragona city, at one-hour drive from Barcelona. To go to Els Garidells you may take the National road 240 that goes from Tarragona to Lleida. The exit is at the km 10.5 and is called Els Garidells. The Repsol office is on the left of the road after the village. To get to Tarragona from Barcelona, you should take the highway A7 and leave it on the exit to Valls.

The Institut de Ciències del Mar (ICM) is near to the port of Barcelona, address is given afterwards.

The Casablanca platform is located 40 km away of the Ebro river mouth. The helicopter trip from Els Garidells is about 20 minutes long. There is not much tourism to do at the platform, but offers excellent views to the sea at a modest price: about 50 USD per person and day, which includes meals and a gymnasium. Whale watching is also probable at no extra cost. If the WISE operators will work in basis of one week of work, one week free, tourism to the city of Barcelona (http://www.bcn.es) and the city of Tarragona and the Costa Daurada or Golden Coast (http://www.costadaurada.org/costadaurada-oa/pagines/uk/general.html) are highly recommended. The amusement park Universal Studios - Port Aventura is also a nice place to spend one or two days (http://www.portaventura.es/).

Acknowledgements

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12. Appendices: List of participants and Technical documentation

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TECHNICAL DOCUMENTATION
Appendix 1
Sea-Bird 37-SM (MicroCAT) characteristics
(Data provided by Sea-Bird Electronics)

The SBE 37-SM is a conductivity and temperature recorder, with internal power supply and memory for data recording. It has a RS232C serial interface and it can be programmed to give sampling rates between 10 seconds and 9.1 hours.
The system uses a 24-bit A/D converter to digitize the temperature sensor voltage. The sensor is an ultra-stable aged thermistor and is referred to a VISHAY reference resistor.

PARAMETER CHARACTERISTICS

	Temperature ºC	Conductivity (S/m) *
Range	-5 to +35	0 to 7
Accuracy (1)	0.002	0.0003
Stability (2)	0.0002	0.0003
Resolution	0.0001	0.0001
Calibration (3)	+1 to 32	0 to 6

Notes:
***** 1 S/m = 10 mS/cm
(1) Initial accuracy. When factory delivered.
(2) Stability per month
(3) Range of calibration reference data.

The RMS deviation on the salinity calculation from conductivity and temperature is 0.003 psu.

The time base is a TCXO of ± 5 ppm vs. temperature (in the range of –5 to +30 ºC), with a ±2 ppm per year ageing, equivalent to ±2.6 minutes per year. The memory capacity, expressed as number of samples, of the SBE 37-SM MicroCAT, is 410.000 samples (C and T only). For C, T and time, the capacity is 225.000 samples. At a rate of 0.5 sample per minute 410.000 samples mean 569.4 days of operation (19 months). At the same sampling rate 225.000 samples mean 312.5 days of operation. (10.4 months). Each full power pack is capable of endure 175.000 samples (4 months).

The battery power pack is made of six 9 volt lithium batteries, having a total of 6 Ah charge.

Salinometer Guildline Autosal characteristics

The salinometer that will be used is the Model 8400B. This instrument measures the conductivity and the temperature of a sample comparing from a reference water. This reference water has a salinity of 35.0000 psu. The technical characteristics of the instrument are the following:

Accuracy	0.002 psu
Resolution	0.0002 psu
Stability on temperature	0.001ºC/day

USONIC Ultrasonic Anemometer

Wind speed:	Range:	0-60 m/s
	Resolution:	0.05 m/s
	Accuracy:	±0.1 m/s (0-5 m/s)
		< 1.5% (5-60 m/s)
Wind direction:	Range:	0º-360º
	Resolution:	1º
	Accuracy:	< ±3º
Temperature:	Range:	-30º... +60º
	Resolution:	0.1 ºC
	Accuracy:	± 1ºC

AANDERAA CMB 3280 Coastal Monitoring Buoy characteristics
Reference reading: 413

Sensors:
Wind Speed
Type: three-cup rotor.
Method of measurement: Average over the past measured interval
Range: 0.4 to 76 m/s
Resolution: 0.0746 m/s
Accuracy: ± 2 %

Wind Direction (Buoy orientation sensor)
Type: Direct Earth magnetic field measured by a Hall effect compass.
Method of measurement: Average over the past measured interval.
Range: 0 to 360º refereed to magnetic North
Resolution: 0.352º
Accuracy: ± 5º

Air Temperature
Type: Platinum PTC resistor in a radiation screened housing.
Method of measurement: Resistor bridge
Time constant (63 %): 6 minutes
Range: -8 to 41º C
Resolution: 0.048º C
Accuracy: ± 0.1º C

Solar Radiation
Type: Pyranometer
Range: 0 - 2000 W/m^2
Resolution: 0.4 W/m^2
Accuracy: ± 20 W/m^2

Relative Humidity Sensor
Type: Capacitive film sensor, in a radiation screened housing.
Method of measurement: Frequency of an oscillator capacitively tuned. Digital output.
Time constant: 1.5 minutes
Range: 0 to 100 %
Resolution: 0.1 %
Accuracy: ± 3 %

Wave Height

The significant wave height measured as the mean of the highest third of all the waves during the sampling interval.
Type: silicon accelerometer, mounted on a pendulum. Microprocessor controlled, measured each 200 ms and averaged.
Range: 0 to 10 meters (for wave periods of 3 to 8 seconds).
Resolution: 0.01 m
Accuracy: ± 10 % or ± 0.2 meters (whichever is greater).

Wave Period

Type: Calculated in the same sensor with wave height.
Range: 1 to 30 seconds
Resolution: 0.03 s
Accuracy: ± 10 %