III WISE (*WInd and Salinity Experiment*) 2000 and 2001 experiments

III.1 Introduction and scientific objectives

In May of 1999 the European Space Agency (ESA) selected SMOS (Soil Moisture and Ocean Salinity) as the second Earth Explorer Opportunity Mission, with a launch date in February of 2007. The main goals are the generation of soil moisture and sea surface salinity maps with a revisit time of three days. SMOS will carry the first space-borne two-dimensional synthetic aperture radiometer for Earth Observation. The SMOS's imaging configuration produces two-dimensional images of the scene with varying incidence and azimuth angles and pixel resolution and, as SMOS moves a pixel over Earth is seen in different positions of the alias-free field of view, and moves trough the alias-free field of view. Therefore it is necessary to know:

- the dependence of T_H and T_V with the incidence angle in the range 0° to 60° and its wind speed or in sea state dependence, including the effects of foam.
- the azimuth dependence of the first and second Stokes parameters (T_H,T_V) with wind direction, and
- the signature of the third and fourth Stokes parameters (*U*, *V*),

During the autumn of 2000 and 2001, two field experiments named WISE (WInd and Salinity Experiment) were sponsored by ESA, to collect experimental data under the widest range of wind conditions. In this experiments UPC was the prime contractor and responsible for the coordination of all the activities and studies

III.2 Experiment description

III.2.1 Instruments description

The required measurements were 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 (Figure 3.1a),
- a fully polarimetric Ka-band radiometer from the University of Massachussets (UMass), only in WISE 2000 (Figure 3.1b),
- a fully polarimetric L-band radiometer (UMass, only in WISE 2000) (Figure 3.1c),
- four oceanographic buoys from the Institut de Ciències del Mar (ICM) and the Laboratoire d'Oceanographie Dynamique et de Climatologie (LODYC), that measured the sea surface salinity (SSS) , the sea surface temperature (SST), the wind speed (WS), the wind direction (WD), the significant wave height (SWH), the wave period (WP), etc. (Figure 3.1d to Figure 3.1g),

- a salinometer (ICM) located 5 m below the sea level (Figure 3.1h),
- a portable meteorological station (UPC), that measured atmospheric pressure, temperature, relative humidity and rain rate (Figure 3.1i),

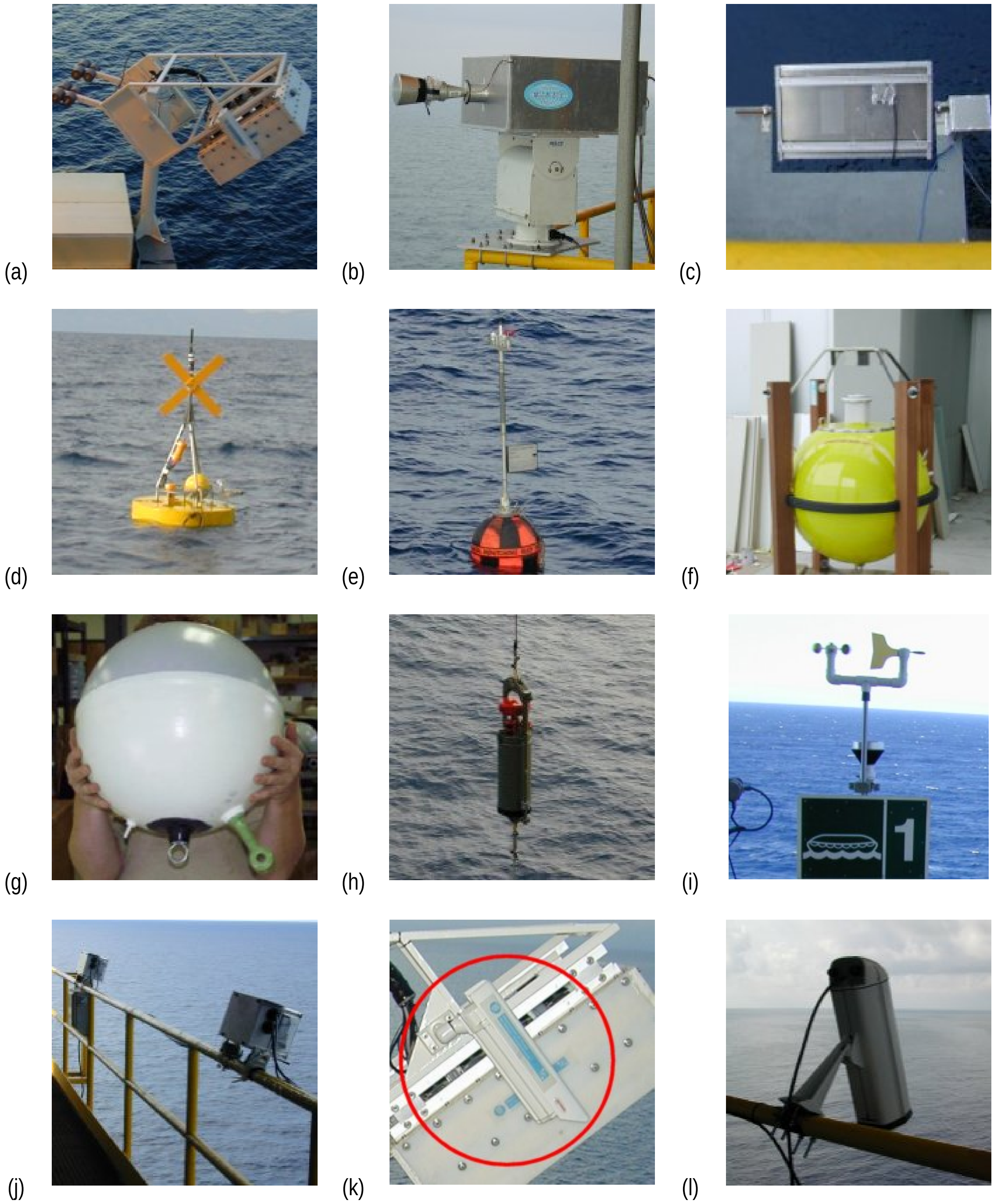


Figure 3.1. Instrumentation deployed during WISE 2000 and 2001: (a) L-band polarimetric radiometric (UPC), (b) Ka-band polarimetric radiometer (UMass, only in WISE 2000), (c) L-band polarimetric radiometer (UMass, only in WISE 2000), (d) EMS (buoy 1, ICM CMIMA/CSIC), (e) Aanderaa CMB3280 (buoy 2, ICM CMIMA/CSIC), (f) Datawell wave buoy (buoy 3, LODYC), (g) Clearwater SVP buoy (buoy 4, LODYC), (h) SBE37 Microcat, (i) meteorological station (UPC), (j) stereo-cameras (CETP), (k) video camera (UPC), and (l) IR radiometer (UV).

- a stereo-camera from the Centre d'Études Terrestres et Planétaires (CEPT) that provided 3D images of the sea surface, the foam coverage, and sea surface rms slopes, (Figure 3.1),

- a video camera to acquire video images of the antenna boresight (Figure 3.1k),
- an infrared radiometer from the Universitat de València (UV) that provided SST estimates (Figure 3.1l),
- additionally, satellite imagery and water samples were acquired for laboratory analysis.

III.2.1.1 Radiometric data

III.2.1.1.1 L-band AUtomatic RAdiometer (LAURA), UPC

During WISE 2000 field experiment LAURA radiometer was mounted on a Scientific Atlanta pedestal (Figure 3.2a), (originally by foreseen to support an Inmarsat receiver). Due to the wind stress suffered by LAURA's original pedestal during the first field experiment, a new pedestal designed to support higher wind loads was built (Figure 3.2b). This was a fortunate decision, since during the third week of the WISE 2001 field experiment, the two strongest storms during the past 25 years happened in the Casablanca oil rig, with winds reaching 140 km/h (Figure 3.2c).

(a)  (b)  (c) 

Figure 3.2. (a) Scientific Atlanta pedestal (WISE 2000), (b) new LAURA radiometer pedestal used in WISE 2001, (c) due to the high winds the radiometer was out of control during the November 15th storm (wind speed > 100 km/h, peak wind speed > 140 km/h at 70 m height).

LAURA radiometer was the main instrument of the WISE field experiments, and it measured the four Stokes parameters (T_H, T_V, U, and V) of the sea surface, see chapter II for further details.

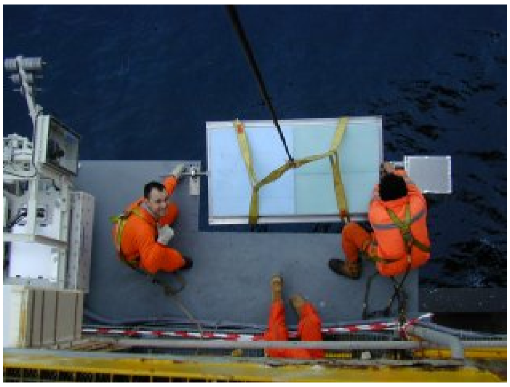
III.2.1.1.2 Dual-Polarized L-band Radiometer, UMass

The UMass L-band radiometer was designed at the facilities of the Microwave Remote Sensing Laboratory (MIRSL) of the Electrical and Computer engineering Department of the University of Massachusetts at Amherst, USA.

Most of the hardware had already been used in a previous L-band radiometer developed for the US Department of Agriculture. The antenna is formed by a 4 x 4 square array of microstrip patch elements. The measured half-power beamwidth is 19 degrees, the side lobe level is -24 dB, the cross-polarization level is -27 dB, and the main beam efficiency is 97 %.

Separate single-polarization antennas, were used to measure the horizontal and vertical components of the thermal emission.

The unit was enclosed in a rectangular box, whose dimensions were approximately 150 x 75 x 25 cm, and was mounted on a structure that performed scans in elevation at a fixed azimuth angle (Figure 3.3a and Figure 3.3b).

(a) 

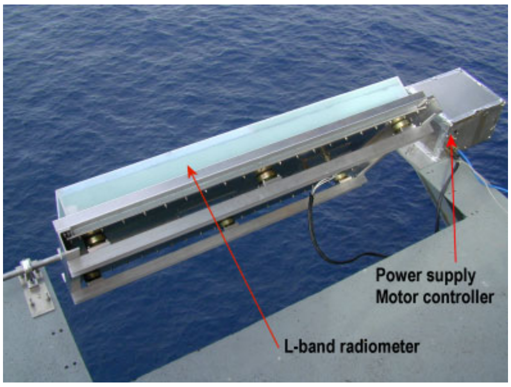
(b) 

Figure 3.3. Dual polarized L-band radiometer, (a) successfully installation, and (b) test measurements.

Computer-controlled motors were used to point the unit to view the ocean at angles from nadir to near 50°. The calibration sequence consisted of alternate views of the cold sky and an absorber. Operation in null feedback mode provided intermediate calibration during the data collection mode. Each data collection/calibration sequence did not exceed 100 minutes in order to have frequent calibrations. Inclinometers were installed in the unit in order to record the pointing angle as part of the data stream.

The receiver architecture uses one L-band receiver that switches between two microstrip antenna arrays. The radiometer utilizes a Dicke switch to eliminate errors resulting from variations in the receiver noise figure. A constant noise level is injected into the front end in a balanced mode to correct for gain variations.

III.2.1.1.3 Ka-band Polarimetric Radiometer "KaPR", UMass

The UMass Ka-band full-polarimetric radiometer was also designed and tested at the Microwave Remote Sensing Laboratory of the Electrical and Computer Engineering Department of the University of Massachussetts at Amherst, USA.

The Ka-band antenna is a horn antenna, manufactured by Millitech, LLC of Northhampton, Massachussetts. It has symmetry of revolution and the half-power beamwidth is 7° and, the 98 % power beamwidth is 18°. Figure 3.4a and Figure 3.4b present a picture of the KaPR radiometer and a detail of the system positioner, respectively.

KaPR measures the first two Stokes parameters, T_H and T_V, 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° 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 3th and 4th Stokes parameter (*U*, *V*).

(a)  (b) 

Figure 3.4. (a) Ka-band polarimetric radiometer, and (b) positioner internal view.

KaPR RF subsystem has five operating modes: 1) RF Mode 1 (Scene-Ref): (normal mode of operation) KaPR acquires Dicke measurements of the scene, 2) RF Mode 2 (Cal-Ref): KaPR acquires Dicke measurements of the internal hot calibration source, 3) RF Mode 3 (Ref-Ref): KaPR acquires offset measurements by measuring the Dicke reference load at 100 % duty cycle, 4) RF Mode 4 (Scene-Scene): KaPR acquires offset measurements by measuring the scene (antenna) at 100 % duty cycle, 5) RF Mode 5 (Cal-Cal): KaPR acquires offset measurements by measuring the internal hot calibration source (noise diode) at 100 % duty cycle.

The data acquisition process is carried out by an embedded computer (PC-104 Pentium 233 MHz), that enables all position control and data acquisition operations to be controlled from inside the instrument. A simple one-minute scan or a day-long measurements 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 finished or is manually aborted by the operator.

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 the data storage, that is divided in three modes: a) data is stored in the KaPR local hard drive, b) data is transferred over the network to a personal computer, and c) the combination of both solutions.

III.2.1.2 Ground-truth Data

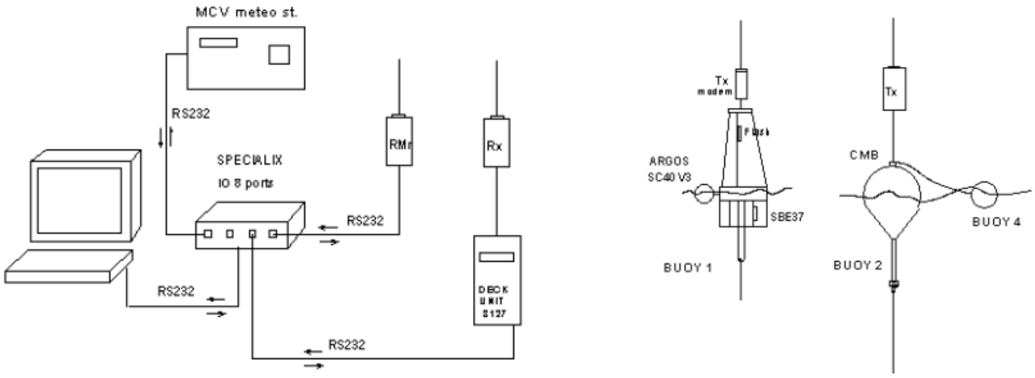
III.2.1.2.1 Meteorological Stations

Rain rate, atmospheric pressure, relative humidity and air temperature at 30 m height were measured by the meteorological station of UPC (Figure 3.1i), connected to the same computer than the radiometer (chapter II). These data were tagged with GPS time and saved in the same file structure as the raw Stokes emission vector and, they were used to estimate the down-welling atmospheric contribution.

On the other hand, on the Casablanca oil rig there is an automatic meteorological station installed on the top of a communications tower, ~70 meters above the sea level. It is operated in a real time acquisition configuration and uses an RS232C link to transmit the data to a personal computer. It has been manufactured by MCV S.A. and includes the following sensors: wind speed, wind direction, air temperature, air pressure, and relative humidity. These data were recorded every 15 minutes and they were used only as backup information.

III.2.1.2.2 Oceanographic buoys

Four buoys of the Institute of Marine Sciences (ICM CMIMA/CSIC) and the Laboratoire d'Oceanographie Dynamique et Climatologic (LODYC) were moored 200 m North of the Casablanca oil rig within the safety area forbidden to navigation. The distance was calculated to be close enough, but outside the radiometers field-of-view to avoid interferences. Figure 3.5 shows a schematic of the buoys and the data acquisition system on the oil rig.



(a) (b)

Figure 3.5. (a) Data acquisition system from the MCV meteorological station and the buoys and, (b) three of the four oceanographic buoys (1,2,4) used in the WISE field experiments.

The data collecting side of the system for buoys 1 and 2 was set on the Casablanca's control room (Figure 3.5 a). It was build around one PC computer (220 V 50 Hz) through a UPS that also powered the receivers and interface components of the system, to ensure possible power line failures. RMr was the receiving part of the RS232 modem link, providing the data from buoy1. Rx was the receiver side of buoy 2. It was connected to the Computing Unit 3127 that gave power to it and converted 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 was needed. The SPECIALIX interface and the appropriate software did that and it was powered from the UPS. Data from buoys 3 and 4 were transmitted by satellite (ARGOS) to LODYC.

III.2.1.2.2.1 Buoy 1, ICM

Buoy 1 (Figure 3.1 d) 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 an
- ultrasonic anemometer (in WISE 2001, only).

Buoy 1 was located approximately 200 meters away from the Casablanca oil rig (NW, see Figure 3.18). The bottom depth in the chosen site was 165 m. and the mooring consisted of 375 kg train wheels on the bottom, attached to a 12 mm iron chain of 5 m in length (Figure 3.6), followed by 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. Buoy 1 was made of two 25 kg spherical floats, attached together. From the sub-surface buoy to buoy 1 a length of 30 meter nylon rope was used, protected with a 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.

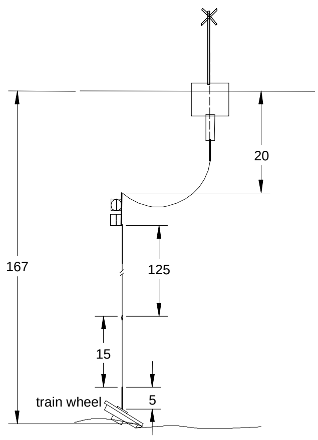


Figure 3.6. Detail of mooring of Buoy 1.

The conductivity and temperature of the water was measured using one SBE37 MicroCAT instrument from Sea-Bird Instruments. Data was stored in a local data unit, and also sent in real time to the oil rig via radio. Salinity was computed from a CardT using the Practical Salinity Equation [16].

The instrument was self-powered, having enough energy to keep it running during 2 months without battery change. The buoy included: one flashlight for night warning, one radar reflector and an ARGOS beacon, to ensure correct signaling and avoid damage from occasional fishing boats entering into the zone. Since the SBE37 and the ARGOS beacon were self-powered, it was necessary to power only the radio modem and the flashlight. Hence, it was decided to use one watertight cylinder containing 10 alkaline 1.5 V “D” size batteries. Another cylinder kept the modem inside, with the DC power input and the UHF coaxial output of the antenna. The antenna was a 1/4 λ vertical. It was small (at 433 MHz) and simple. Since the distance to the receiver was short (200 meters), the 10 mW output was enough to guarantee the link in spite of the probable buoy roll in bad sea state. The flashlight was also self-powered, but in order to ensure 1 month operation, it was necessary another tight cylinder with extra batteries. An

"X" shape iron reflector, having the legal size, provided the radar reflector. The ARGOS beacon used was a SC40 V3 spherical drifter attached to the main body of Buoy 1.

III.2.1.2.2.2 Buoy 2, ICM

Buoy 2 (Figure 3.1 b) is a CMB 3280 (Coastal Monitoring Buoy), from AANDERAA Instruments, and it was used to measure the following parameters:

- 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: significant wave height (SWH), and
- channel 8: wave period.

Buoy 2 was moored also on the restricted navigation zone, and very close to Buoy 1 during WISE 2000, and situated approximately 200 m away from the Casablanca oil rig (SW) during WISE 2001 (see Figure 3.18). The mooring system was similar to the one used for Buoy 1 (Figure 3.7). They were designed to operate on a theoretical depth of 165 meters. Individual differences were compensated by the upper part of the line. One train wheel was used as a bottom weight. Metallic elements had been avoided as far as possible in order to prevent corrosion, or by-passed by a security rope.

The CMB 3280 is a solar powered autonomous buoy that measures meteorological and oceanographic parameters storing the data and conveying it simultaneously to the oil rig by a real time radio link. The measuring rate was also 1 scan of 8 channels every 2 minutes. The data was sent to the oil rig 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 was 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, provided the security ARGOS localization. To save power, the current speed and direction (plus atmospheric pressure) sensors of the CMB3280 were disconnected. The meteorological sensors were fixed on a sensor arm at 2.6 m above the sea surface. The current meter and the water temperature sensors were placed at 1 m depth. The main floating body of the buoy had 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 had a 20 kg counterweight placed at 1.8 meters of the sea surface. The security elements were also one flashlight (switched on and off automatically by ambient light), one radar reflector provided by the wind direction fin and one ARGOS beacon.

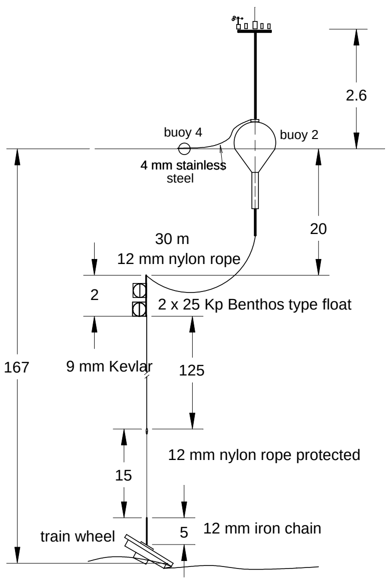


Figure 3.7. Detail of mooring of Buoy 2.

To record surface current (1 m below sea level), a second currentmeter of the same type (Aanderaa RCM9 Doppler Current Meter) was installed hanging from the oil rig (Figure 3.1h). It provided adequate data to compare air and sea velocity for flux calculations.

III.2.1.2.2.3 Buoy 3, LODYC

Buoy 3 is a SPEAR-F buoy used to measure:

- significant wave height (SWH), and
- wave period.

Buoy 3 is based on a Datawell accelerometer installed in a waverider 70 cm diameter sphere weighting 250 kg (Figure 3.1 f). The heart of the buoy is the data acquisition and handling onboard unit. The frequency modulated output of the waverider unit is transformed into an analogue signal which is then digitized on 12 bits with a 2 Hz sampling, and a Fourier transform is made on 200 seconds of measurement. This process was done 8 times during a three hour period and the spectral density of these eight data sets were averaged, resulting in 16 degree of freedom and a frequency resolution of 0.005 Hz. The information was compressed for transmission to satellite in 14 frequency bands containing a predefined fraction of the variance, the first band starting at 0.025 Hz.

A measurement cycle was made every three hours, and the results were transmitted via the ARGOS system. Buoy 3 was calibrated before going to the WISE field experiments.

III.2.1.2.2.4 Buoy 4, LODYC

Buoy 4 is an SVP drifter (16.63 kg buoyancy) built by Clearwater (USA) which measures:

- the conductivity, and

- the water temperature,

at about 20 cm depth (depending on the waves) using an FSI conductivity sensor placed on the lower part of the sphere. A barometer placed above the sphere measured the atmospheric pressure. The measurements were performed once per hour. The data were transmitted via the ARGOS system. It was attached to buoy 2 to minimize the number of moorings. The oceanographic vessel García del Cid performed the buoys' moorings and recovery, during October 1-2 and November 24-25, 2001.

III.2.1.2.3 Stereo camera, CETP

The system consisted of two digital video cameras Canon Powershot 600 (832x624 pixels), spaced 4 meters, and located at 28 m over the sea surface, just below the radiometers' terrace (Figure 3.1j). During WISE 2000 they were pointed to the North, where the radiometers were supposed to point most of the time (upwind direction of dominant winds). However, during WISE 2001 they were pointed to the West as the radiometer, to avoid the radio frequency interferences (RFI) coming from the North. Of course, to avoid Sun glints with this orientation, measurements with the stereo camera were restricted to the morning[1]. Systematic measurements coincident with the radiometer were performed every day from 9 AM to 10 AM.

The stereo-camera provided:

- the sea foam coverage estimates, and
- the sea surface topography, by observing the sea surface from an incidence angle under two different views.

The system used a 220 V power line (used to charge the CdNi batteries) and for the computer. Two synchronized pictures were stored on a PC disk (1.4 Mbytes each picture). The computer processed the acquisition of the two cameras. Two sampling periods were possible with one slide every 10 s or 2 minutes. Every one or two hours, it was necessary to verify the acquisition of the cameras and put the 2 x 30 or 2 x 60 pictures on the hard disk. This sequence lasted around fifteen minutes. As a time base, the computer was synchronized with the GPS time. As it is difficult to make simultaneous observations with the other instruments; the precision requirements on the time were not so drastic for these "statistic observations".

III.2.1.2.4 Video camera, UPC

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) was mounted in the antenna pedestal (Figure 3.1k) to provide an instantaneous view of the sea surface being measured by the radiometer. Images were acquired at a frequency of 1 frame per

[1] The L-band radiometer cannot make measurements in this direction in the afternoon/evening either

second. The analysis of the images restricted to a 20° field of view (coincident with the antenna beamwidth) was used to:

- evaluate the sea foam coverage as a function of wind speed (by analysis of the image histograms),
- estimate (as much as possible) the sea foam emissivity by comparing the instantaneous sea foam coverage and the instantaneous brightness temperatures (T_H and T_V),

and also to disregard erroneous measurements when the security vessel that makes circles around the platform or even whales passed through the antenna beamwidth.

III.2.1.2.5 Infrared radiometer, UV

The CIMEL thermal-infrared radiometer (Figure 3.1l), CE 312, from the UV is a multi-band radiometer with a Field of View of 10º. It has been used to provide:

- the sea surface temperature estimates, simultaneous with LAURA's measurements.

Since in the SMOS SSS retrieval algorithms, the SST information should be provided by other sensors (e.g. AVHRR), the inter-comparison of in-situ measurements (bulk temperature) and the IR-derived SST (skin temperature) allows to estimate the SST error under different atmospheric conditions.

During WISE 2000 the CE 312 was mounted on the LAURA pedestal (Figure 3.2 a) to observe the sea surface with identical conditions (zenith and azimuth angles). However, since the CE 312 read-outs are brightness temperatures, these data had to be corrected from the atmospheric and sea emissivity effects, before being compared with the SST estimates from the AVHRR and the oceanographic buoys. This means that the IR radiometer needed to point to elevation angles > 90° more often than the LAURA radiometer in order to measure the downwelling sky radiance. To overcome this conflict a second hand-held IR radiometer was used to point to the sky, but the different technical specifications of this instrument could introduce larger errors in the final SST.

In addition, the best SST estimates were found for the lowest observation angles. Therefore, in WISE 2001 the IR radiometer was mounted alone on a handrail pointing to the sea (West direction) with an observation angle of 25º, and the downwelling sky radiance was simulated using the MODTRAN 4 radiative transfer code.

The CE 312 is composed of two major components: the optical head containing the detector (thermopile) and optics, and 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 step-motor allows the filter selection. This design includes a 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.

III.2.1.3 Satellite imagery and other data

III.2.1.3.1 QUICKSCAT Wind Speed data, LODYC

Measurements of the NASA satellite borne QUIKSCAT scatterometer (nudge algorithm) at 25 km resolution co-located with the oil rig using a radius of 0.27° latitude and 0.37° longitude have been collected. During WISE 2000 and 2001, 196 and 74 measurements were found, respectively. Since the scatterometer cannot approach closer than 50 km from the coast no measurements were coincident with the oil rig: all of them were East and South. These wind speed data were averaged for each satellite pass and the resulting average was compared with one-hour average of the in-situ measurements. The accuracy at global scale is about 1 m/s.

III.2.1.3.2 AVHRR SST data, LODYC

LAC images of the AVHRR instrument at 2 km resolution were recorded and processed by the SATMOS data center (Service d'Archivage et de Traitement Meteorologique des Observations Spatiales, Meteo-France/CNRS). Many images were cloudy. During WISE 2000 the Ebro plume was observed, but it was not during WISE 2001.

III.2.1.3.3 ARPEGE Wind Speed data

Surface wind speed from the analyzed surface fields of ARPEGE (the meteorological model of MéteoFrance) have been co-located with the Casablanca oil rig. The resolution of the model is 25 km, 6 h. The co-location radius is the same as for QUIKSCAT, that is 0.27° latitude and 0.37° longitude, resulting in nine grid points co-located for each field. The data are from October 1st to November 30th, 2001 and the format is the same as QUIKSCAT.

III.2.1.3.4 Water samples, ICM

To check for possible drifts in the conductivity sensors, water samples were taken when deploying and recovering the buoys for later salinity determination with a Guildline Autosal salinometer. These instruments, when used under strictly controlled room conditions, can provide the best salinity values by comparing the relative conductivity of the sample to a reference standard water of 35.0000 psu. The absolute accuracy is 0.002 psu with a resolution 0.0002 of psu.

III.2.2 Summary of key measurements and data products

Table 3.1. Summary of key measurements and data products.

Instrument	Parameters	Description	Units	Comments	Resolution
GPS (Garmin)	Time	Absolute GPS time	[h, m, s]	Tag all measurements for easier comparison.	1 s
L-band polarimetric radiometer	Yaw	Antenna orientation (±180°)	[deg]	Measured with a 3 axes digital clinometer 3DM located in the back side of the radiometer antenna. (WISE 2000). Problems due to the metallic structure	< 0.1°
	Pitch	Antenna orientation (±180°)	[deg]		< 0.1°
	Roll	Antenna orientation (±70°)	[deg]	Measured with a SEIKA analog clinometer, (WISE 2001), to solve the metallic structure problems.	< 0.1°
	Pitch (analog)	Antenna orientation (±70°)	[deg]		< 0.01°
	T_H	Horizontal brightness temp.	[K]		< 0.3 K @ 1s
	T_V	Vertical brightness temp.	[K]		< 0.3 K @ 1s
	U	Third Stokes parameter	[K]		< 0.424 K @ 1s
	V	Fourth Stokes parameter	[K]		< 0.424K @ 1s
Motors		Antenna's elevation movement		Gear reduction included (750)	0.0006 °
		Antenna's azimuth movement		Gear reduction included (75)	0.006 °
Meteorological station (UPC)	WS	Wind speed	[m/s]	V not to be delivered.	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 camera (UPC)	Video images	Video camera on antenna		Used to determine fraction of foam sea coverage	512x582 pixels
Infrared radiometer (UV)	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
	WD	Wind Direction	[°]	Range: 0°-360° referred to magnetic North	0.4°
	T	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	±0.4W/m^2
	WH	Wave Height	[m]	Range: 0 – 10 m	0.01 m
	WP	Wave Period	[s]	Range: 1- 30 s	0.03 s
	CS	Current Speed	[m/s]	Range: 0 – 500 cm/s	±2 cm/s
	CD	Current Direction	[°]	Range: 0°-360° referred to magnetic North	± 5°
	WT	Water Temperature	[°C]	Range: -5°C ... 35°C	0.0001° C
	C(S)	Conductivity	[S/m]	Range: 0 – 7 S/m	0.0003 S/m
	H1/3	Significant wave height	[m]	Range: 0 to 10 m for wave periods of 3 to 8 seconds	1/3 of the Max. peak wave
	P	Dominant period	[s]	One averaged (8 times 200 s spectrum every 3 hours in 14 frequency bands)	
	WSPEC	Wave spectrum	[m^2/s]		
Stereo camera (CEPT)	Primary data	Digital pictures 2 x 1.4 Mbytes	[Pixels]	2 pictures every 10 seconds or 2 minutes	832x624 pixels
	Foam	% pixels	[%]	Range 0-100 %	one pixel
	Foam area	% surface	[%]	Range 0-100 %	minimum area 64 cm^2 depending on slanting angle / surface
	Topography	Heights	[cm]	Depending on light intensity and contrasts	about <5 cm>

III.2.3 Organization and logistics

III.2.3.1 Introduction

The WISE 2000 and 2001 field experiments were divided in the following tasks as presented in Figure 3.8 and Figure 3.10. The original schedule of the project is presented in the bar graph of Figure 3.9 and Figure 3.11.

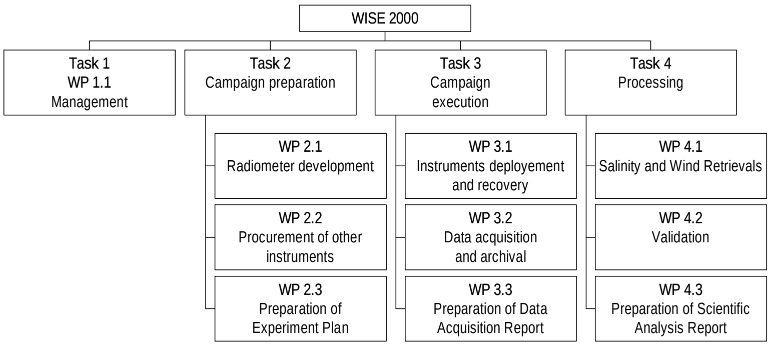


Figure 3.8. Work Breakdown Structure (WISE 2000).

Work package name	1999	2000												2001				
	12	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04	05
Management	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
Radiometer development	■	■	■	■	■	■	■	■										
Proc. of other instruments	■	■	■	■	■	■	■											
Prep. Experiment Plan	■	■	■	■	■	■	■											
Inst. deploy. and recovery								■		■	■	■	■	■				
Data acq. and archival												■	■	■				
Prep. of Data Acq. Rep.														■	■	■		
Salinity and Wind Retriv.														■	■	■		
Validation														■	■	■		
Prep.Scient. Analys. Rep.																■	■	■
	KO			PM			PCM							PRM				DRM

Figure 3.9. WISE 2000 Schedule. KO (kick-off meeting), PM (progress meeting), PCM (pre-campaign meeting), PRM (preliminary results meeting), and DRM (data review meeting).

This schedule foresaw a kick-off (KO) meeting in mid-December 1999, a progress meeting (PM) in March, and a Pre-Campaign meeting (PCM) at the end of June 2000. Although the field experiment should have started during October 2000, on summer 2000 Repsol confirmed that the oil rig will not be available during this month due to their drilling activities. Therefore, they suggested re-scheduling the campaign for November 2000. In February 2001 the First Preliminary Results Meeting were presented (PRM) and in

May 2001, a Data Review Meeting (DRM) of the WISE 2000 field experiment took place at the UPC facilities. In June 2001, WISE 2000 Final Presentation took placed at ESTEC

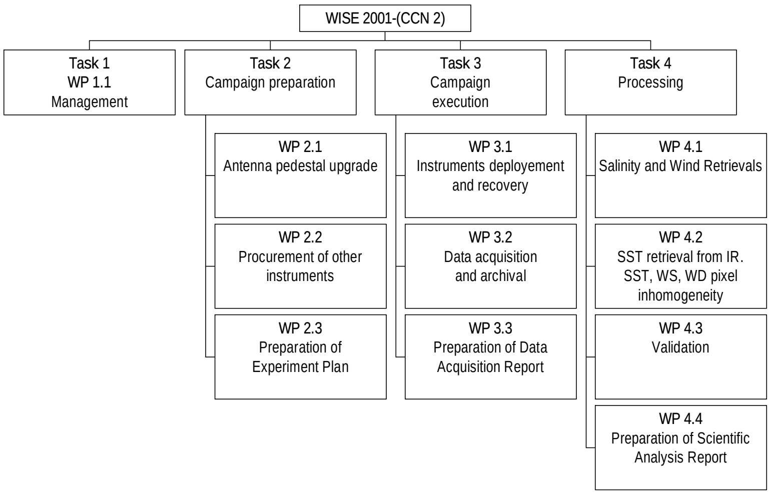


Figure 3.10. Work Breakdown Structure (WISE 2001).

WP number	2001							2002					
	06	07	08	09	10	11	12	01	02	03	04	05	06
WP 1.1	■	■	■	■	■	■	■	■	■	■	■	■	■
WP 2.1	■	■		■									
WP 2.2	■	■		■									
WP 2.3		■	■	■									
WP 3.1					■	■							
WP 3.2					■	■							
WP 3.3							■	■	■	■			
WP 4.1	■	■		■	■	■	■	■	■	■	■		
WP 4.2									■	■	■		
WP 4.3									■	■	■		
WP 4.4											■	■	■

Figure 3.11. WISE 2001 Schedule.

This schedule foresaw a kick-off meeting at the end of June, 2001 at ESTEC coincident with WISE-2000 Final Presentation, a campaign from October 23rd to November 25th, 2001, and a final presentation in June 2002. Note that this schedule slightly differed 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). Finally, it happened that the final presentation took place in November 2002 in Toulouse France, in an open joint workshop, to present the results from two other ESA-sponsored field experiments: EuroSTARRS and LOSAC.

III.2.3.2 Material preparation, transportation, and instruments deployment and recovery

The Casablanca oil rig (Figure 3.12a and Figure 3.12b) is owned by the petrol company Repsol, and it is located in the North Mediterranean Sea at 40° 43’ 4” N 1° 21’ 34” E, 40 km offshore the Ebro River Delta, near the continental shelf break and shelf/slope front, and at 165 m bottom depth (Figure 3.12 c). Although the strongest winds blow from the East, the dominant wind direction is the North West. In this site, wind intensities as high as 90 km/h (25 m/s) are not uncommon during the autumn due to the atmospheric instability. This fact can be observed in Figure 3.12d, which shows the occurrence of high wind speeds during the period of October-December 1992 is presented. For this reason the WISE 2000 field experiment spanned from November 25th, 2000 to December 18th, 2000 and from January 8th, 2001 to January 15th, 2001 and WISE 2001 from October 23rd, 2001 to November 22nd, 2001. In Figure 3.13a and Figure 3.13b the occurrences wind speed during WISE 2000 and 2001 respectively are presented.

(a)

(b)

(c)

(d)

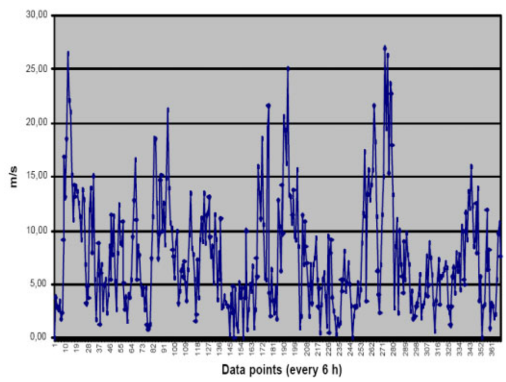
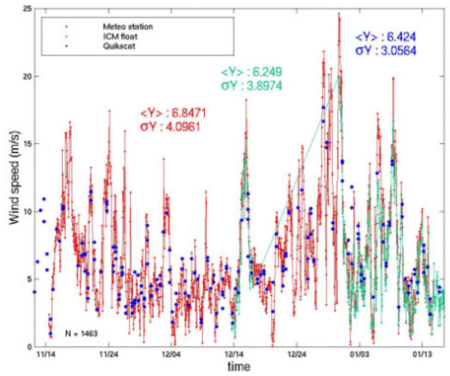


Figure 3.12. Casablanca oil rig views, (a) East, and (b) NW, (c) its location, (d) occurrence of strong NW and NE winds in autumn: wind speed recorded during the period of October-December 1992.

(a)


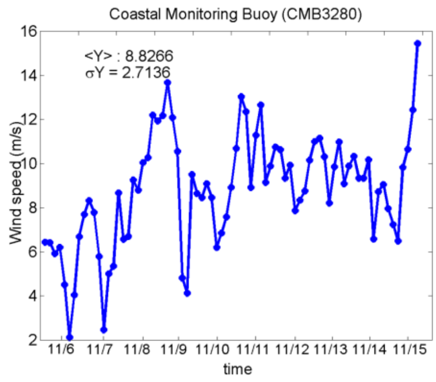
(b)


Figure 3.13. (a) Occurrence of strong NW and NE winds during the WISE 2000 campaign measured by: the oil rig meteorological station (red), the Coastal Monitoring buoy from ICM (green), and from Quickscat (blue), and (b) occurrence winds during WISE 2001 from November 6th, 2001 to November 15th, 2001 when a severe storm destroy the buoy. Data points are averaged every three hours.

The weeks previous to the WISE 2000 and WISE 2001 field experiments were devoted to the campaigns preparation. The LAURA instrument except for the receiver and the hard disks, the oceanographic buoys, the stereo camera, and their corresponding instrumentation were loaded at the UPC facilities (Figure 3.14a), and transported by truck to the Sant Carles de la Ràpita harbor (Figure 3.14b). Transportation of the radiometers and the rest of instrumentation from land to the Casablanca oil rig was performed by the Repsol cargo ship, that links Sant Carles de la Ràpita with the oil rig once a week. The oceanographic research vessel of ICM "Garcia del Cid" (Figure 3.14 c) was available on October 3-4 and November 24-25, 2001 for mooring and retrieval of the buoys. Unfortunately in the first field experiment, the "García del Cid" vessel was not available on October-November, 2000. A fishing boat was rented to recover the oceanographic buoys, which were transported to Barcelona harbor with the UMass radiometers.

(a)

(b)

(c)


Figure 3.14. Instruments load and recovery (a) UPC facilities, (b) Sant Carles de la Ràpita harbour, (c) Buoy 3 recovery by the research vessel of ICM "García del Cid" (WISE 2001).

The personnel traveled by helicopter. Repsol's helicopter made around trip to the oil rig on Tuesdays and Wednesdays departing and returning to Els Garidells (Tarragona), close to the Repsol refinery facilities.

In order to properly calibrate the radiometers, the antenna boresight had to be pointed (as close as possible) to the zenith (cold load calibration). Since the helipad must be free of obstacles, the radiometer was placed at a lower floor (height ~ 32 m over the sea level) with restricted zenith visibility (Figure 3.15 a). Taking into account the limitations imposed by measuring from a fixed oil rig (Figure 3.15 b), the range of incidence angles was limited to approximately 25° ≤ $\theta \leq$ 140° (0° = nadir, 90° = horizon, 180° = zenith), and to -110° ≤ $\varphi \leq$ +20° in azimuth (0° = North, -: West, +: East). Figure 3.15c and Figure 3.15d show the position of the radiometer's terrace. The UPC meteorological station was located as close as possible to the radiometers, and also closer than 25 m from the data acquisition system located in the oil rig control room. Its purpose was to get real time data, mainly rain rate data, the only parameter not available from the other meteorological stations.

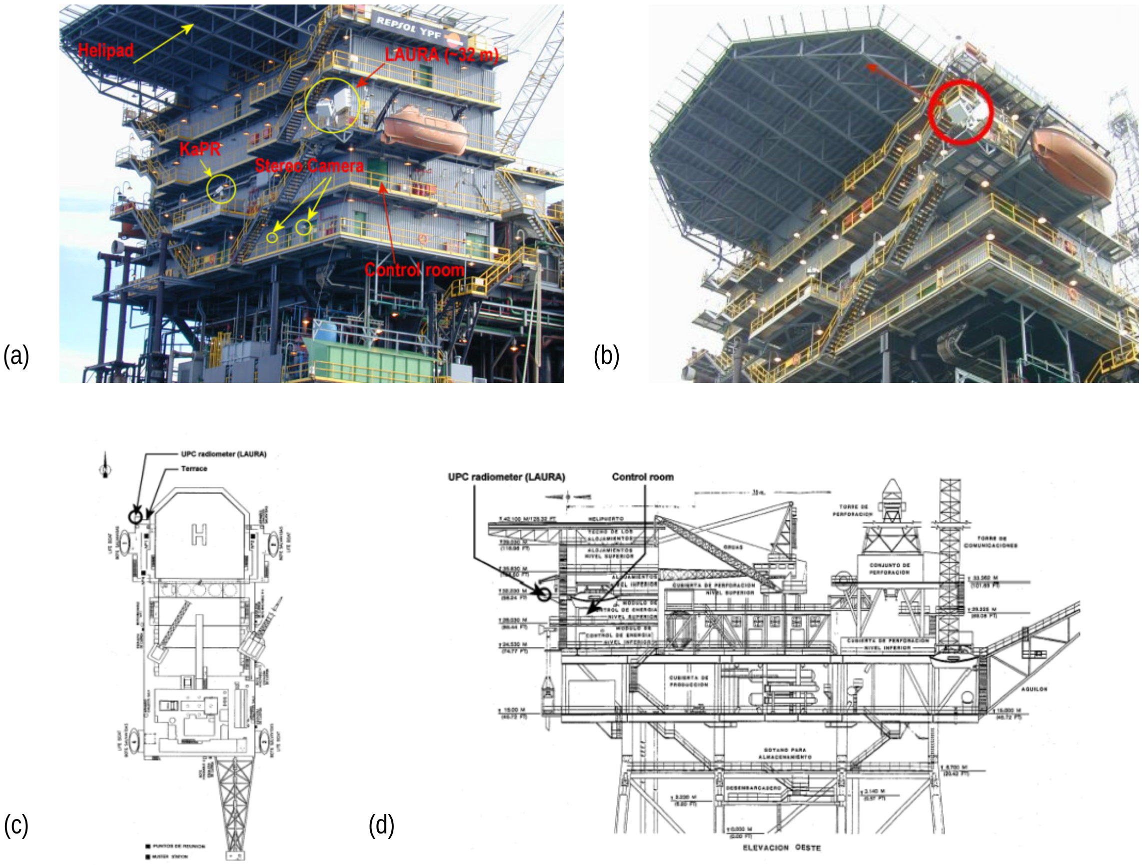
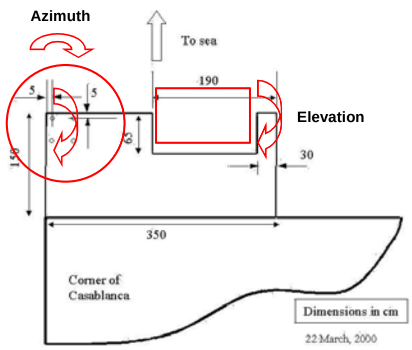


Figure 3.15. Casablanca oil rig, (a) North view, radiometers and stereo camera location, (b) Casablanca's helipad limitation for the radiometers cold load calibration (pointing to the sky), (c) upper view, and (d) West lateral view.

Figure 3.16a shows a diagram of the terrace built at the oil rig to accommodate the two L-band radiometers. The mounting and the terrace were designed so that the UMass radiometer (present in WISE-2000, but not in WISE-2001) could perform an elevation scan from nadir to zenith, while the UPC radiometer pedestal allowed both an azimuth scan free of obstacles larger than 120° and an elevation scan from a 25° incidence angle to an elevation of 50º over the horizon (Figure 3.16b) when pointing to the zenith the radiometer collected radiation from upper floors and the helipad.

The deployment of the instrumentation was made during the first three days of WISE 2000 and 2001 field experiments. After unloading the instruments from the ship, the radiometer was fixed to the pedestal (Figure 3.17a), counterweighted and placed at the terrace using a complex pulley (Figure 3.17b).

The total weight of the system was about 250 kg. The control unit was located into the oil rig control room (Figure 3.17c), and connected to radiometer by a cable. Control unit was 15 m away from LAURA's pedestal. The video camera and the meteorological station were mounted at this time too, and the hot load was fixed to the terrace with special caution due to the common hard environmental conditions. Finally, the system was tested and properly adjusted before starting the acquisition of the radiometric data. During this phase, the participation of three people was required and the collaboration of the oil rig personal was essential, specially when the radiometers were located over the terrace.

(a) 

(b) 

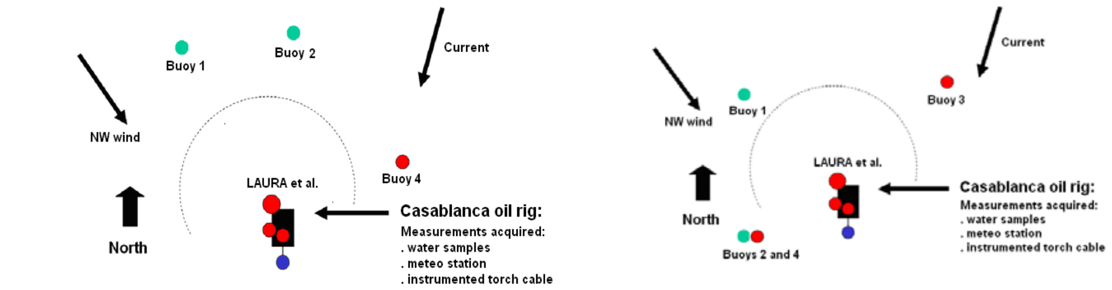
Figure 3.16. Upper view of terrace of the radiometers have to be placed, (a) diagram, and (b) picture.

(a)  (b)  (c) 

Figure 3.17. (a) Mounting LAURA in the pedestal (WISE 2000), (b) Radiometer is situated in the right point (WISE 2001), and (c) control unit is mounted into the control room.

Simultaneously, the instrumentation required by the oceanographic buoys installed, by two persons from ICM and, another two persons from CEPT and LODYC worked mounting the stereo cameras cables and components. The buoys location was not the same in WISE 2000 and 2001, as it can be observed in Figure 3.18a and Figure 3.18b. Buoy 2 was moored from the NW in WISE 2000 (very close to Buoy 1), to the SW, to avoid the RF interferences produced during its transmission to the oil rig.

During WISE 2000 field experiment, after the installation of the LAURA radiometer, and to avoid the collision in the terrace, the two UMass radiometers were mounted. Two persons from UMass were required to mount the L-band radiometer, and KaPR during one day each one.



(a) (b)

Figure 3.18. Instrumentation and buoy location during (a) WISE 2000, and (b) WISE 2001.

The power supply was generated at the same oil rig by two diesel generators and a gas generator, and it was not well regulated. An UPS (Uninterruptible Power Supply) was then needed for the instrumentation. During WISE 2000, a general power failure happened in the oil rig at least for more than 10 minutes. All the "autonomous" systems were shut down and had to be re-started by the personnel aboard the oil rig.

The power consumption of the LAURA instrument was divided into the following two parts:

- electronic equipments: power radiometer, synthesizer, power computers, motor controllers, UPS, video cameras (~ 2 kW) , (220 V, 50 Hz single phase),
- peltier cells and fans (~0.8 kW), (220 V, 50 Hz single phase).

III.2.3.3 Organization scheduling. Problems encountered.

During the WISE 2000 field experiment a total of six groups participated in the deployment of the instruments. At the beginning of this campaign some difficulties were encountered such as: the drilling activities of the company, scheduling for that spring-summer that were carried out of time, and the coordination of an important number of investigators aboard the oil rig, (3 persons from UPC, 2 from ICM, 1 from LODYC, 1 from CEPT, 1 from UV and 2 from UMass), during the deployment phase. Since the instruments deployment overlapped with the end of the drilling activities, the total number of people overcame the maximum capacity of the oil rig (78 persons), and consequently some of them were forced to sleep in the floor, or in the ship. The WISE 2000 field experiment was originally 1 month, although it was extended 15 days thanks to a contract extension (CNN-1: Contract Change Notice) issued by ESA.

In the normal situation, and during the rest of the campaign the required personnel were reduced, since most of the instruments were operated in automatic manner. The total personnel from UPC was 2 people to supervise the LAURA radiometer and the ICM data acquisition, and to download the pictures from the stereo cameras during the last week of the field experiment, one person from CEPT during the first three weeks, one from UV, and one from UMass.

The instruments recovery was made by three persons from UPC, one from ICM, and one from UV, with the help of the oil rig personnel. UMass instruments and ICM oceanographic buoys were sent directly to Barcelona's harbor. The rest of the instrumentation was sent to the UPC facilities.

During WISE 2001, five groups participated in this new experiment. The instrument deployment phase was not so complicated as in WISE 2000, first of all because there were not drilling activities (the total personnel in the oil rig was about 30), and also because of the experience acquired in the WISE 2000 campaign. The duration of this campaign was approximately one month. The instrument deployment phase was similar than in WISE 2000. During the data acquisition phase, one person from UPC, one from UV and one from LODYC (only the first two weeks) were required to control the different instrumentation. The recovery phase was performed by three persons from UPC and two from ICM.

Furthermore, the following safety considerations had to be considered at the oil rig, when living in the oil rig for more than one day:

- 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 (bright orange or red collars) and, 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 oil rig personnel.

During the first days of the WISE 2000 field experiment a failure in the Dicke switch of the H channel was detected. Once a spare part was brought from UPC, the RF board was repaired in situ and the radiometer performed correctly during the rest of the campaign.

Radio frequency interference (RFI) was a great problem during WISE 2000. The main source of RFI was found at horizontal polarization from the North side (Figure 3.19) and at high incidence angles (Tarragona city, and probably the Barcelona airport). A second source of strong RFI were some of the walkie-talkies used during the campaign by the companies working in the drilling operations (Figure 3.20a). A third source of RFI detected was the 9th harmonic of the 156 MHz (9x156 MHz = 1404 MHz) channel used by the fisher ships. This is a weak source, but may account for a few Kelvin. Finally, sporadically a weak saw-tooth like RFI was detected (Figure 3.20b), with a period of ~ 5 min. This source was not identified as any known beacon in the area. Other potential sources of RFI were the transmitter links from the buoys: at 433 MHz (10 mW), ARGOS emissions around 402 MHz (>1 W), and emissions from Buoy 2 at 142.025 MHz, that emits during 40 s every minute. This problem was detected before the campaign and avoided by inserting a 200 MHz low-pass filter between the transmitter and the antenna, with an attenuation >75 dB at 1.4 GHz.

In WISE 2000, Buoy 3 was damaged during the mooring, and was recovered as soon as this situation was detected. During WISE 2001 a new buoy was moored since the previous one could not be repaired. During November 15th, 2001, a very strong storm, (winds U_{70} > 100 km/h, $U_{70_{peak}} \cong$ 140 km/h) hit the Catalan coasts, the step-motors were not longer able to control the radiometer position, and it was left to move freely with the wind direction during one day. Buoy 4 link to Buoy 2 broke (Figure 3.7) and started drifting to the South. This buoy was recovered by a Spanish Coast Guard vessel on November 29th. Buoys 1 and 2 suffered serious damages (Figure 3.21b and c) and some data was lost after this date. In WISE 2001, the correlator block had to be disconnected. Therefore, *U* and *V* measurements are only available for WISE 2000 data.

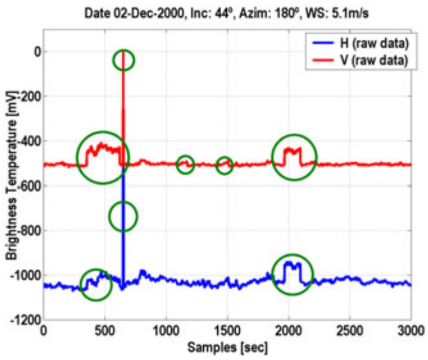
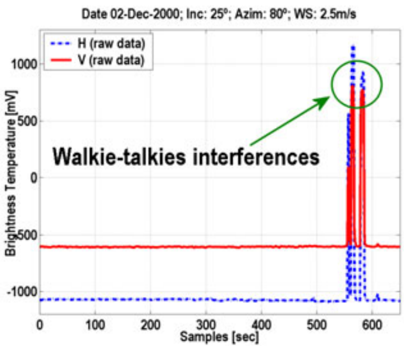
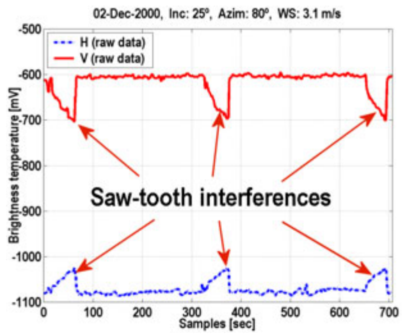


Figure 3.19. RFI during WISE 2000. Radiometer was pointing to the North (ϕ = 180° referred to the South) and θ = 44°).



(a)

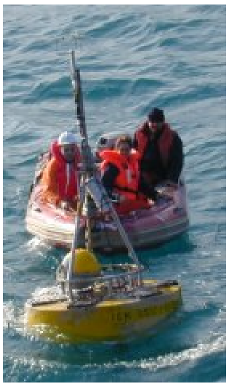


(b)

Figure 3.20. Types of interferences collected during WISE 2000, interferences originated by (a) the walkie-talkies, and (b) saw-tooth interference.

(a)

(b)



(c)

Figure 3.21. Detail of the repair of (a) the video camera cable to acquire data foam, (b) Buoy 1 and, (c) detail of the damage Buoy 2, and ultrasonic anemometer of Buoy 1 (WISE 2001).

III.3 Radiometric measurements strategy

During the WISE field experiments the following types of measurements were performed

- Calibration: at the beginning and at the end of each measurement cycles limited to less than 100 min.

  - Calibration of the Dicke radiometers was performed pointing to a cold and hot loads. The *cold load calibration* consisted of looking to the sky (cold source) during 4 minutes, (Figure 3.22a). The antenna was oriented to θ = 145° (35° from zenith) and ϕ = 320° azimuth angle referred to the North (40° West). T_A was computed by integrating the resulting brightness temperature contributions (atmospheric, cosmic and galactic noise), weighted by the antenna pattern (Figure 3.22b). The cosmic noise is constant and its value is 2.7 K. The galactic noise was computed taking into account the geographic position of the rig, the date and time, the antenna orientation, the antenna pattern and the 1,420 MHz galactic noise map [18]. Atmospheric noise was accounted for using models that take into account the atmospheric pressure, temperature and relative humidity as input parameters. Sun glint was also accounted for, but it is such an important term that had to be avoided.

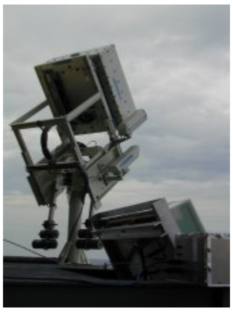
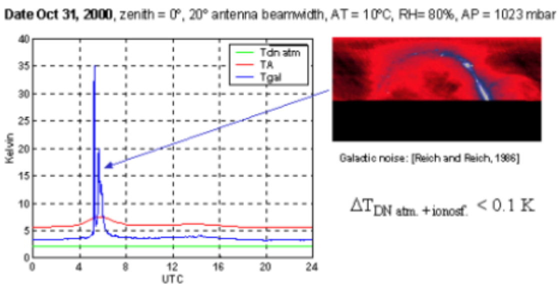
(a)  (b) 

Figure 3.22. (a) Radiometer cold load calibration, and (b) simulated antenna temperature with contributions from the atmosphere, cosmic and galactic noises.

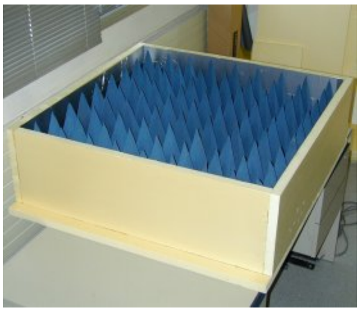
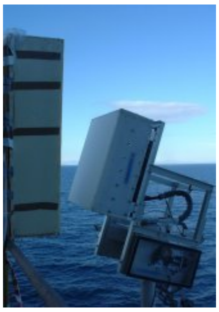
(a)  (b)  (c) 

Figure 3.23. (a) The 90x90 cm microwave absorber in a sealed poly-styrene box with the two temperature sensors, hot load calibration, (b) WISE 2000, θ = 105°, and (c) WISE 2001, θ = 0°.

The hot load calibration consisted of pointing the radiometer to a 90 x 90 cm microwave absorber put into an hermetically closed poly-styrene box at known temperature, measured by two temperature sensors (Figure 3.23a). At L-band the reflectivity of the absorber is less than –30 dB. During WISE 2000 hot load was installed on the handrail and the hot load calibration was made elevating the radiometer to θ = 105° (Figure 3.23b). During WISE 2001 the hot load was fixed to the terrace, and hence the radiometer could be pointed to nadir to make the hot load calibration.

- ♦ Calibration of correlator's offsets is performed by injecting uncorrelated noise (independent matched loads), while phase is calibrated by injecting known and common correlated noise. In both cases the radiometer's antenna is internally switched and the RF front-end connected to the matched load or to the correlated noise source. This process is performed automatically

- 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 were computed so that the antenna spot overlaps with the stereo-camera field-of-view (FOV). This mode was used one hour every day. During WISE 2000 radiometer was pointing to the North, but due to the RFI encountered, to minimize its effect, in WISE 2001 it was decided to point LAURA to ϕ = 250° referred to the North.
- Incidence angle measurements (mode 2): to determine the variation of T_H, T_V, U and V with the incidence angle a total of five incidence angle positions were measured: θ = 25º, 35º, 45º, 55° and 65º. The radiometer was 20 minutes at each position, thus the total sequence was 100 minutes. The azimuth position was fixed in the same direction as in mode 1, in order to take advantage of the coincidence with the stereo cameras FOV during part of the scan. During the afternoon and to prevent Sun glint, radiometer was pointed to ϕ = 20°. In this case the angular step was 5°, and the radiometer acquired samples during 5 minutes at each position. The total sequence was 45 minutes. These scans were particularly used to study salinity retrieval algorithms. Mode 2 was the normal mode of operation as in WISE 2000 as in WISE 2001.
- Azimuth angle measurements (mode 3): radiometer was pointed to a constant incidence angle and to a 6 different azimuth positions: ϕ = 20°, 250°, 260°, 290°, 320°, and 350°, to determine the azimuth dependence of the Stokes parameters. The measurement process was identical to the elevation scans. First of all a full calibration was made. After this measurement process began. The instrument was placed in the different azimuth positions and samples were taken for 4 minutes in each position. Finally a calibration process was performed again to check the thermal stability. The duration of the process was 1,800 s approximately. From November 19-22, 2001 this mode was used simultaneously with the EuroSTARSS overflights.

III.4 Conclusions

The WISE field experiments that took place in the Casablanca oil rig during 2000 and 2001 contributed to a better knowledge of the influence of the wind speed and the sea state in the brightness temperature measurements. The purpose of these campaigns was to acquire enough data to improve the theoretical models related to the salinity retrieval. Both campaigns were sponsored by ESA and five groups of four different countries participated. Along the chapter, a detailed description of the experiments has been presented. Radiometric measurements made by the radiometer need to be contrasted with the ground-truth data from a set of instruments, which are also described. In the second part of this Chapter, a work package description related to the campaign preparation, which its principal goal was the construction of the radiometer, and its execution are made. Furthermore, an explanation of the problems encountered was made. Finally, the different types of radiometric measurement that were programmed according to the previous specifications of both experiments are described.