CEOS CAL/VAL NEWSLETTER Issue 6

Committee on Earth Observation Satellites
Working Group on Cal/Val

Contents:

CEOS WORKING GROUP ON CALIBRATION AND VALIDATION WGCV - STATUS REPORT

Dr Lyn Arsenault (CCRS), WGCV Secretariat

The most recent meeting of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV), WGCV11, was held at Toulouse, France, on 21-23 February 1996. The meeting was hosted by the Centre National d'Etudes Spatiales (CNES). There were 21 members and two observers present. Also hosted by CNES immediately prior to WGCV11 were meetings of the subgroups on Terrain Mapping and Infrared and Visible Optical Sensors (IVOS).

Major items reviewed were the Dossier on Calibration and Validation which is now proceeding, Strategic Plan, and subgroup activities. A Special Session highlighted CNES activities and was followed by a tour of laboratories at CERT/DERO, CNES, and Matra Marconi Space. Two recommendations were formulated, concerning Interferometric SAR and Calibration and Test Sites; they will be presented at the next CEOS Plenary in October 1996.

The Chair of the WGCV for the past five years, Dr Susan Till (Canada Centre for Remote Sensing), announced at the meeting that she will step down from the position in November 1996.

Susan took on the Chair's position in late 1990, and the group was revitalised with a meeting in Ottawa in August 1991, which set new terms of reference and objectives. The SAR Calibration Subgroup was ongoing, and in 1992 three additional subgroups were formed: IVOS, Terrain Mapping, and Passive Microwave (the latter was renamed Microwave Sensors Subgroup in 1994).

Major outputs of the WGCV during Susan's term in office have been production of the Dossier and the Strategic Plan, periodic publication of the Newsletter, and organisation and documentation for test sites. The work has been accomplished through productive meetings with exchange of technical information, working sessions, and great support from the WGCV members.

Beginning in November, the WGCV will be chaired by Dr Alan Belward. Originally from the U.K., with a Ph.D. in remote sensing and global change, Alan is presently living with his family in Ispra, Italy. There he is employed on the Scientific and Technical staff of the European Commission, working with the Space Applications Institute of the Joint Research Centre.

The next Working Group meeting, WGCV12, is to be hosted by DLR and will be held at Oberpfaffenhoffen, Germany on November 27 to 29 1996. WGCV12 will be preceded by meetings of the subgroups of WGCV on Terrain Mapping and Infrared and Visible Optical Sensors.

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Information on the WGCV its strategic plan and the subgroups can be obtained from the CEOS Home Page on the World Wide Web at http://gds.esrin.esa.it/CEOSInfo.

The Cal/Val dossier web site URL is:

http://spso.gsfc.nasa.gov/calval/calval_hpage.html

TERRAIN MAPPING SUB GROUP

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1. Introduction

The fifth meeting of the Terrain Mapping sub group was held in Toulouse on 19th - 20th February 1996. The following is a report of the meeting and an indication of future activities of the subgroup.

2. Technical developments

A number of presentations were given which reported under three headings:

- New research and development
- Validation and testing of data and algorithms
- Instrument programmes - current and planned.

2.1 New research and development

The main new research was reported by Prati who described a 'quick and dirty' method of estimating coherence which reduced the time required from 40 minutes to 10 seconds. Prati also reported on a new method of determining the 3D characteristics of a target from multiple passes with varying base lines. This can help to give 3D without phase unwrapping and can overcome problems of poor coherence, layover and foreshortening.

Vadon reported on work at CNES on SAR Interferometry and highlighted problems due to atmospheric conditions which led to useful discussions on analysing and correcting errors. CNES are now working on processing long segments of data and to obtain better understanding of atmospheric effects. It was thought that large scale effects might be parameterised but that local effects could not. However local effects might be corrected if multi temporal data was available.

There was discussion on the use of ground control points: how many points to use; what kind of point and whether control points should be conformal or whether they should correct for other effects such as orbit and system errors. JPL reported that they had used only 30 co-ordinates, without features to orient an interferometric DEM. It was thought that it would be useful to state clearly the possible accuracy of DEMs from IfSAR and the limitations.

Gray reported on the combined use of aircraft IfSAR and ERS tandem data in differential mode to detect movement of glaciers.

2.2 Validation and testing of data and algorithms

Muller reported on comparisons between SPOT and IfSAR and on work designed to determine correlation between slope and accuracy and between land cover and accuracy. There was no evidence of the former but there is of the latter. Muller also showed fringes obtained over tropical vegetation over the Haut Sassandra test site.

Freeman reported on comparisons between SIR-C and TOPSAR over the Fort Irwin test site. Renouard reported on work done with MOMS-02 and with ERS 1 Interferometry.

Morgan reported on work done on three test sites in Australia and on the Aix Marseilles site. On the Australian sites good information was available on vegetation and these sites could be made more widely available.

2.3 Instrument programmes

The following systems were reported on:

- MOMS shuttle and Priroda missions
- Radarsat
- ASTER
- ALOR
- SRL-3

4. Evaluation guide

Peter Muller introduced the latest version of the evaluation guide and after some discussion it was agreed that all present would give comments and a final revision would then be done prior to distribution.

5. DEM Formats

There had been an exchange between the chair of the subgroup on Terrain Mapping and the chair of the WGISS subgroup on formats. There was no need for any immediate action but the forthcoming meeting of the CEOS Global Mapping Task Team would address this issue and Muller and Kosmann, who would be attending, were asked to report back to the group.

Muller presented information on GeoTIFF which was being proposed as a format for the exchange of raster data.

6. Reports from other groups

Reports were received from:

GLOBE (Muller)
SWAMP at launch DEMs (Muller)
ASTER Science Team (Miyazaki)
SIR-C Science Team (Freeman)

7. Resolutions

After some discussion resolutions were agreed by the subgroup on:

- ERS Tandem Mission extension;
- ASAR frequency shift to match that used for the ERS SAR; and
- in support of NASA's Spaceborne Radar Terrain Mapper.

The following resolution was accepted by the WGCV for presentation to the CEOS Plenary and for immediate transmission to ESA and to NASA:

Recognising the importance of long sequences of data for validation and for understanding of interferometric SAR data and
Recognising the need for a global digital elevation model for effective validation and use of other earth observation data and the current lack of complete global coverage and

Noting a number of opportunities for collection of interferometric SAR data, such as:

- an extension of the ERS-1/ERS-2 tandem mission

- co-ordination of central frequencies of SAR sensors to make tandem missions possible

- the NASA Spaceborne Radar Terrain Mapper mission

The WGCV recommends that agencies take any available opportunity to collect SAR data for interferometric processing with high coherence, and to plan such missions when possible.

8. Future activities

The work of members in developing techniques of deriving DEMs would continue as would comparison of techniques over the test sites.

Work would continue to obtain data over test sites for wide use and ERS Tandem data, Radarsat, MOMS and IRS-1C Pan data were of particular interest.
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INFRARED AND VISIBLE OPTICAL SENSORS SUBGROUP (IVOS)

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The IVOS subgroup met for two days in Toulouse immediately prior to WGCV#11. During the first day the subgroup dealt with standard business related to the cal/val of satellite sensors. The second day of the meeting was then devoted to a special session on the application of radiative transfer techniques in the vicarious calibration of satellite sensors.

Most agency and country representatives provided a brief report on their progress over the last year. These included a report by NASDA on the upcoming launch of the ADEOS-1 satellite. Jim Butler from NASA gave details of the status of the CEOS Dossier. This data base would now contain three components connected with IVOS activities. These are a list of test-sites, details of

calibration facilities and laboratories, and information on field instruments used in cal/val activities. A new questionnaire would soon be distributed and members are urged to respond to this request to ensure that maximum use is made of these instruments and facilities. The subgroup also discussed the possibility of a low-key activity involving the establishment of a data set based on one or more calibration test sites. One possibility is to collect data from as many sensors as possible for a set time period. The members of the subgroup will discuss this further with their agencies and countries and the matter would be raised again at the next subgroup meeting.
The special session on radiative transfer started with a presentation from Nagaraja Rao of NOAA who described the techniques used to monitor the calibration coefficients of the short wave channels of the operational NOAA satellites. The coefficients are determined using a ground based site in Northern Africa. Beatrice Berthelot (CESBIO, CNES) then described the procedures to be adopted for analysing data from the VEGETATION instrument. For atmospheric correction this uses a simplified parametrisation of the 5S and 6S methods developed at the University of Lille. The method requires a good measure of aerosol optical depth to obtain the required accuracy. Marc Leroy (also from CESBIO, CNES) described the POLDER instrument that is soon to be launched on the ADEOS-I satellite. This instrument has channels at eight wavelengths in the VIS/NIR, four of which have dual polarisation. Details of the data processing steps were given including cloud clearing and allowances for stratospheric and tropospheric aerosols. Atmospheric absorption and scattering would be based on the 5S radiative transfer code. Robert Santer (University of Arizona) described the reflectance and radiance based methods employed at White Sands and other calibration sites. The former method requires the characterisation of a bright surface and the use of "exact" radiation codes. In contrast he radiance method relies on aircraft measurements of the upwelling radiance at altitudes above the surface aerosol layer and then a simple correction for the remaining atmosphere above the aircraft.

Stephen Tjemkes (EUMETSAT) presented details of a program to merge data from different meteorological sensors to form a unified data set. This would require a correction for view angle and atmospheric effects, and then validation of the final product. Helene Cerbelaud (CNES) reported on the status of data analysis for the SCARAB instrument. Several problems had been encountered with the on-board calibration lamps, but the data were giving new details on the earth's radiation budget.

Catherine Ottle (CETP, France) gave the first of two presentations on radiative transfer in the thermal infrared. She described new differential absorption techniques for the correction of water vapour absorption in the atmosphere. Standard surface temperature algorithms use a linear relationship between brightness temperatures but a quadratic relation appears to give an improved atmospheric correction. The last contribution was from Ian Barton (CSIRO) who showed a large discrepancy between satellite measured brightness temperatures and those calculated using radiative transfer models with the accepted water vapour continuum absorption coefficients. The results appeared to indicate that these coefficients were too low by 30 per cent.

The discussion following the presentations focused on two issues. First, the main problem with the application of radiative transfer codes in the vicarious calibration of satellite sensors is not the performance of the codes, but rather the specification of the true state of the atmosphere. In particular this was related to the identification of aerosol type, size and amount. The second issue was the continuing need for ground-based vicarious calibration sites. Even if all future sensors had perfect on-board calibration systems there would still be a requirement to confirm the on-board calibration with ground measurements. These matters were taken to the WGCV meeting and a recommendation relating to the importance of test sites and ground based measurements would be presented to the next CEOS Plenary meeting.

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STATUS OF NASDA'S CAL/VAL ACTIVITIES

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1. JERS-1 program

1.1 JERS-1 satellite status

Over four years have past since the launch of JERS-1 on 11 February 1992. Although the designed mission life of two years expired in

February 1994, the JERS-1 satellite and most of the sensors are functioning well. Following-on from the completion of the one time global coverage by SAR and the JERS-1 verification program (December 1994) a new data acquisition strategy was established. This is composed of two major themes:

1) Global rain forest mapping program

The aim of this program is to generate L-band SAR image maps for three major rain forest regions, Amazon, South East Asia, and central Africa. Each region will be observed twice in different seasons, dry season and rainy season for further investigation, such as the classification of rivers, re-growth, flooded regions, etc. Data acquisition commenced on 27 September 1995 and will finish in late 1996. Each region is to be composed of 2,500 to 3,500 SAR images, and each SAR image is 75 Km x 75 Km in size. The data will be processed and analysed so as to generate publishable CD-ROMS containing mosaic images, classifications, and textures. This program will be conducted as a collaboration between NASDA, MITI, NASA and JRC.

2) SAR interferometry

SAR interferometry is the powerful remote sensing technology to detect the surface deformation caused by earthquakes and active volcanoes with the accuracy of 2 - 3 cm. Since the successful detection of the Awaji-Kobe surface deformation pattern caused by the Hanshin earthquake, the global coverage of SAR data is urged so that the closest SAR data take after the earthquake can provide the SAR image pair for the monitoring of the surface deformation. Currently, data for more than 90% of the global surface has been acquired. L band SAR is less sensitive to the scene decorrelation than C band and X band data. The difficulty for the JERS-1 SAR interferometry is its relatively large baseline distance, however, the combination of the small scene decorrelation and large number of data takes will solve the problem.

In addition to these major programs, the generation of a DEM of the north west Amazon region is planned by using OPS stereo, SAR stereo, and SAR interferometry. Acquisition of OPS stereo data is unlikely due to the high cloud cover in this region. However, SAR stereo (15 Km width long strips per path) data will be available. SAR interferometry may cover the region, if the baseline condition is satisfied. The generation of the dataset will be conducted as a collaboration between NASDA and NASA.

Calibration of the JERS-1 SAR is underway by using active radar calibrators every four months. Data analysis shows that SAR transmission power has not changed and the conversion factor from SAR product's DN to the normalised radar cross section is updated accordingly.

1.2. Airborne SAR program

To investigate radar signature dependency on the target, an airborne (L band, multi-polarisation, high resolution of ~3 meter) SAR is under development to be operated on-board a Gulf Stream II jet. The development will be completed by the end of August 1996. Several experiments will be conducted for calibration, vegetation, and interferometry research purposes.

2. ADEOS science program

2.1 Sensor/Facility Status

ADEOS system protoflight testing at the Tsukuba Space Center was completed in February 1996. After which the ADEOS satellite was shipped to the Tanegashima Space Center for its final tests until its launch. ADEOS was successfully launched on 17 August 1996. ADEOS Ground System was completed in March 1996.

2.2 CAL/VAL Status

In order to attain the OCTS goal, to generate accurate chlorophyll-a products within 30% error, we will conduct the calibration and validation on a large scale. Three types of calibration methods will be adopted:

1) on-board calibration,
2) airborne sensor calibration, and
3) vicarious calibration.

As for airborne sensor calibration, NASA/NASDA will underfly AVIRIS over western US area in California and Nevada every 6 months for three years from February 1997. OCTS validation will be conducted using sea truth data of chlorophyll-a and normalised water leaving radiance, which will be acquired by buoys and ship measurements. A collaboration between NASDA and Japan Fishery Agency will conduct the sea truth data acquisition especially for the ocean around Japan. The match up of OCTS data of sea truth data will be made and injected into the validation routine. As for the data distribution, OCTS products validated for around Japan and those for the world will be started 8 months, and 12 months after launch, respectively. A CAL/VAL subsystem has been developed, by which the image quality, match-up dataset generation, and CAL/VAL coefficient calculation, etc. will be done.

3. ADEOS II science program

3.1 ADEOS II research announcement

First research announcement for ADEOS II was released at the end of October 1995 to solicit the algorithms for NASDA's core sensors, GLI and AMSR. 102 proposals were received. The announcement of the selected PIs following a peer review process occured in June 1996.

CHINESE CALIBRATION ACTIVITIES

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1. Chinese CEOS

Chinese CEOS (CCEOS) was established in late 1994 for responding to the CEOS. The Centre of Satellite Metreologic of Metreological Bureau of China is responsible for the Working Group on Information Systems and Services and the Shanghai Institute of Technical Physics is responsible for the Working Group on Cal/Val.

2. Pre-flight calibration

The method of the pre-flight calibration for satellite remote sensors such as the multispectral scanner (similar to the AVHRR) is that under stable atmosphere conditions, using the sun as a standard source, measurements are made of the transmittance of the atmosphere and scattering radiance. With different standard reflectance irradiated by the sun, the outputs of the remote sensor are measured. The integrating sphere is the approach used for calibrating the visible, near infra-red and short wave infrared channels of the imaging spectrometer.

3. On-board calibration

The method of a standard lamp in an integrating sphere is used for calibrating the imaging spectrometer in-flight, and the approach of the solar energy led by optical fibre will be adopted. For calibrating the airborne imaging spectrometer, a portable calibration source was developed, which consists of a monochromator with a high pressure, mercury vapour lamp for spectrum calibration and an integration sphere with a standard lamp which is transmitted from the Chinese Institute of Measurement Science for radiance calibration.

4. Test site activities

The Metreological Bureau of China is responsible for the development of the Chinese calibration test site located in the Xinghai province. It will be completed in 1997.

5. Test site flight experiments

For the purpose of developing validation algorithms for SeaWiFs remote sensing, the National Ocean Bureau is responsible for the flight experiments at test sites. In September 1995, flight experiments for ocean colour were performed over the Yellow Sea east sea of China. An imaging spectrometer (the Modular Airborne Imaging Spectrometer (MAIS)) with 71 channels and portable instantaneous spectrometer (PIS-II) were used, developed by the Shanghai Institute of Technical Physics (SITP).

In the flight experiment, the on-board calibration was performed for spectrum and radiance, and the reflectance radiance of oceanic targets was measured from the surface and aircraft by MAIS and PIS-II. At that time, the atmospheric transmittance was also measured. These instruments were calibrated in pre-flight and post-flight with integrating sphere and monochromator at SITP to get uniform parameters.

6. Calibration of the MAIS

6.1 Spectral calibration

The purpose of the MAISs spectral calibration is to determine the spectral pass band and the central wavelength. The spectral calibration involves 3 steps:

1. to calibrate the model monospek-100 monochromator with a high pressure mercury vapour lamp

2. to measure the MAIS channel's spectral response curves

3. to determine the pass band and central wavelength

6.2 Radiometric calibration

The standard lamp calibration system and the integrate sphere calibration system are used in radiometric calibration. The reference of the calibration is supplied from the Chinese Institute of Measurement Science.

The radiometric calibration of MAIS involves 5 steps:

1. measurement of the MAIS's response to the standard lamp calibration system

2. measurement of the MAIS's response to dark target

3. measurement of the MAIS's response to different integrate sphere output

4. computation of the MAIS's linear degree

5. computation of the MAIS's radiance response function.

6.3 In flight calibration

A tungsten lamp integrating sphere with a constant current power supply is adopted for the in-flight calibrator. The in-flight calibration factor is obtained by comparing the MAIS's response in-flight and its response in the laboratory calibration.

6.4 Reflect factor inversion

To gain the reflect factor of the target from the remote sensing data. By the 'Ground Test Method', to achieve the inversion the parameters required are the atmospheric path radiance, MAIS response rate, the in-flight calibrate factor and the image data.

SCIENTIFIC INVESTIGATION OF SAR INTERFEROMETRY

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BACKGROUND

SAR interferometry has demonstrated its capability to produce large scale digital elevation models or to detect small moves of various origins, such as surface deformation produced by large earthquakes, landslide, subsidence, smaller earthquakes or fault slip as small as 2 cm. More studies detected glaciers movements or phase surface changes.

CNES engaged itself in an effort to give interferometry a scientific and operational status which requires a lot of activity along two axes:
• The precise understanding and quantification of the phenomena involved in the interferometric measurement
• The assessment of the extent and the gravity of coherence losses, which is critical for interferometric applications assessment and scene selection.

We decided to promote the first point by organising a large distribution (through SPOT Image) of selected interferometric products, and by specific actions, such as interferometric DEM feasibility study conducted by ISTAR under CNES contract. This has been made possible by an in-depth analysis of a large amount of data, that in turn, demands the availability of an almost fully operational interferometric processing chain. Such a tool has been developed at CNES and processed more than one million square kilometres of interferograms with time separation ranging from one day (tandem mission) to 3 years and orbital separations ranging from two meters to eleven hundred meters, and spotted interesting phenomena, such as landslide, earthquake, volcano or atmospheric propagation errors.
The second point is now better understood as well. We observed a clear case of coherence rebuilding with time, indicating that coherence may be lost temporarily. A tentative explanation of such a phenomena could be found in moisture changes. This situation could be corrected by being more demanding in orbit selection in such areas, at the cost of DEM accuracy.

The success of this initial phase urged us to go beyond the conventional uses of interferometry and differential interferometry. Conventional DEM computation deal with typical scene size of less than 100 km. Conventional moves detection amounts to 10 cm to several meters and develop on at least one square kilometre. We tried to go further with the study of the Landers earthquake, were the large extension of the site (300 km) required very accurate orbit modelling. However, the amount of moves to be measured was still very large. New applications may be much more demanding in terms of scene length and calibration accuracy.

An example where interferometry would be pushed forward in terms of performance is the measurement of local tidal loads on Earth's crust, caused by ocean tides. We plan to study the effect of such a loading on the Cotentin (Normandy, France) in cooperation with GRGS. For this purpose we should be able to study a 600 km long scene for the detection of centimetre sized phenomena.

This urges us to place a high priority on the study of the specific artefacts which could make such applications difficult.

AUTOMATIC PROCESSING METHOD

It is clear that a proper development of radar interferometry depends on the existence of a software package capable of dealing with the data automatically. This requirement is already obvious at the scientific investigation level, due to the large number of potential applications and also to the large number of unknown factors, such as the list of artefacts or the success rate in terms of quality. It becomes even more obvious when talking of offering an industrial service.

We developed such a software package based on the method we proposed for dealing with differential interferometry: the digital elevation model elimination method (DEME). This package has been successfully used with ERS1 as well as J-ERS1 data.

This method consists in simulating and subtracting the topographic fringes from the interferogram in order to extract any motion experienced by the ground between the data takes or to extract any topographic error from the DEM injected in the process.

The method contrasts with the one used by JPL, the double difference method (DD), in differential interferometry. The reason of our choice results of the respective advantages and disadvantages of the two methods.

A clear disadvantage of the DEME is the need for a DEM, which does not exist everywhere. However, this disadvantage is attenuated by the fact that the heavy geometric distortion of a radar image will require a DEM anyway, for proper geometric correction and data analysis. Furthermore, a DEM can be obtained by a variety of methods: map digitisation, optical stereoscopy, and, of course, radar interferometry, but using a pair which has not to be related with the pair of interest (ascending pair versus a descending pair, ...). At worse, if a triplet is available, one could build a DEM from one pair, provided it is motionless, and use the method with the other pair. On this regard, the DD method is the worst case of the DEME method.

We find several advantages to the DEME method:

• the quality of the interferogram is improved, since the data fusion process is improved by slope dependant finite impulse response filters
• most of the unwrapping is eliminated since the only remaining fringes come from the moves or the errors in the DEM. Even the roughest DEM, (obtained from 1/1000000 scale map digitisation) will leave only a few remaining fringes.
• the probability of finding two adequate scenes on a given site, complying to the orbital and surface preservation conditions, is much higher than the probability of finding three such scenes
• however rough, a DEM is generally unbiased regarding the long spatial periods. It allows an easy detection of artefacts such as propagation problems or unsuspected moves. These artefacts, if on the "DEM pair" of the DD method, would be modified by equations which apply only to topographic features, which could make the final result very difficult to interpret
• finally, the DEM method proved to be very easy to automate, even a very rough DEM helps the prediction of the deformation between the images of the pair. The co-registration is obtained not only between the images of the pair, but also between the images and the DEM, which acts as a very large collection of poor ground control points, with an excellent final result. This allows to better the orbits and the near-range knowledge, then to process the second image being slaved to the first one in terms of geometry, using the deformation prediction which is now very precise.

Once the data have been produced on the high resolution complex format with the same geometry, they are merged, using the above mentioned filters, and produce the three components of the interferometric product : phase, coherence and combined amplitude, with the choice of a slant range or a map geometry.

MAJOR HURDLES AND VALIDATION

The procedure we used to validate SAR interferometry is clearly explained by the following table, which list all the sites we used for interferometric investigation (past, present, or future). The number of scenes involved and the surface of each site is given (in 1000 sq. km). The cooperations we built are also indicated with the expected application. This program is itself a way to ease the access to interferometry for a large number of people. But the availability of large quantities of high quality interferograms is of little help if we cannot define precisely what is measured.

We documented clock instabilities using a very long interferometric strip, acquired during orbits 1014 and 1100 (91/09/25 and 91/10/01), when ERS1 was in commissioning phase. We modelled the clock instabilities and internal studies were conducted in CNES in order to define new clock specifications. The modifications are feasible and not very costly.

More important are the artefacts due to changes in the propagation conditions in the atmosphere. They present a very different signature than topographic or instrumental artefacts. The scene where the problem occurred is identified because all the interferometric pair to which it participated are affected by the artefact with a constant level, unlike the inaccuracies in the DEM which are weighted by the baseline of each pair. In this, it is similar to the instrumental clock artefact, but unlike the latter, it is not linked to the pulse lines and its amplitude is unlikely to reach more than a few fringes. Once the faulty image has been identified, one can check, knowing the very minute of the data take, the meteorological conditions at that time.

An image over Southern California, taken on August 27 1993, 18:28 UT, shows several 5 to 10 km wide irregular, circular patterns, amounting to up to three fringes, which are clearly identified as propagation problems using the above logic. The meteorological image of 19:31 shows a chain of small circular clouds which are not yet formed in the 17:01 image. This indicates that the fringes are due to tropospheric turbulence, possibly linked to the formation of thunderstorm clouds.

Another problem can occur with high relief: the atmospheric variations from the bottom to the top of mountains, even in steady weather conditions, are not linear and can vary from the first acquisition to the second. This produces a relief dependant artefact, much more difficult to detect than punctual effect. However, the variations can be modelled and the effect can be removed, if well known and measured.

Nevertheless, the Landers earthquake, and the Etna deflation interferograms have been fully validated by geophysical measurements. The two studies have been published in "Nature" magazine (vol 364, jul. 8, 93 - vol 375, jun. 15, 95), on cover page. In this two cases, a centimetric accuracy has been achieved, all over the 100 x 100 km scenes. The theoretical limit, without atmospheric artefacts, is 2 mm accuracy for ground movement.

The SAR wavelength is well known and stable, and does not need to be calibrated. The 2 mm corresponds to the standard phase noise of ERS1 (360° = 28 mm --> 25° = 2mm).

For DEM reconstruction, an elevation accuracy down to one meter can be achieved locally, or less than 5 meters RMS error on a full scene. This is possible on moderate relief regions, with a small time interval and large intertrack. In the other cases, elevation accuracy is comparable to that one from optic stereo (SPOT for example) : about 10 meters RMS errors.

Name of site	**Cooperation**	Coverage	scenes	**Application**	**Result**
Ukraine	ISTAR	14	2	DEM	good
Ukraine	internal CNES	315	50	System stability	good
Ukraine	SCOT	14	2	Phasimetry	promising
Ukraine	internal CNES	10	4	sub metric DEM	good
Flevoland	ESA - MCS	2,5	2	Processor validation	good
Sardinia	ESA - ISTAR	5	2	DEM ERS1 vs SPOT	good
--------	--------	14	2	undergr. nuclear tests	average
Landers I	GRGS	35	18	earthquakes	good
Landers II	internal CNES	25	4	earthquakes	poor
Joshua tree	internal CNES	14	4	earthquakes	average
Northridge	GRGS	20	5	earthquakes	good
St Etienne Tinée	ESA - IPGP or BRGM	5	6	Landslide	good
Papua N. Guinea	SPOTIMAGE	40	8	DEM	poor
Nice	ISTAR	14	6	DEM	average
Berne	ISTAR	14	2	DEM	average
Utah drum Mt	ISTAR	14	4	DEM	good
Utah Irish Cany.	ISTAR	14	4	DEM	good
Pic St Loup	ISTAR	14	4	DEM	average
Spitsberg	ISTAR	14	3	DEM	average
Khystim	SICORP for US Defence	14	2	submetric DEM	poor
Mount Etna	ESA - IPGP	5	21	volcanic crisis, atmos	good
Awaji shima	NASDA	5	3	J-ERS1 investigation	good
Northern Hokaï.	NASDA	2	4	J-ERS1 investigation	average
Sevilla	SCOT	14	3	Phasimetry	
Iceland	Univ Paris-Nordic Ins.	14	2	Rift expansion	
Turkey	ESA - IPG	25	6	Fault slip	

Washington	NPOM	2	2	interf. with ALMAZ	poor
Siberia	NPOM	2	2	interf. with ALMAZ	poor
Le Boulc	BRGM - ESA	25	10	Landslide	poor
Pottstown	GRGS	14	3	earthquake	poor
Eureca	GRGS	14	2	earthquake	good
Gardanne	BRGM	25	6	subsid. from mining	good
Spitsberg	Norsk polar institut	14	12	contin. glacier flows	average
Caucasus	CNRS montpellier	14	2	DEM	
Thassos	LTIS	14	3	DEM unwrapping	average
Bretagne	LGST	14	6	Phasimetry	good
Merapi	IPGP	25	4	Volcanic crisis	
Atacama	IPGP	25	4	earthquake	
Latur	ESA	25	14	earthquake	poor
Cotentin	GRGS	80	12	Tidal loads	
Larzac	LTIS	14	3	DEM unwrapping	average
Colmar	UPMC	14	6	Subsidence	poor
Guyana	UPMC	25	6	Equatorial forest	poor
------	ISTAR for French Def.	80	100	DEM	average
Western US	ESA investigation	560	409	propag, clock, geoph.	
Angoulème	CNES - ISTAR	14	3	DEM	good
Caucase		14	2	DEM	
Vesuve		14	3	volcano	average
Long Valley		14	2	volcano	good
La Palma		14	4		good
Chili		30	7	earthquake	good
Taal-Philippines		14	2	volcano	poor
Southern Calif.		10	7	geothermal activ.	good
Pinatubo		14	3	volcano	
Iceland		35	5	tectonics, volcano	good
Landers IV	Internal CNES	5	5	super resolution	good
Erzincan (Turk.)		14	2	earthquake	average
Aqaba		20	2	earthquake	good

We have no clue as to what could cause a reversible surface state, but soil moisture appears to be a very likely candidate, as it can be restored in its initial value.

A critical knowledge for the future of SAR interferometry is the behaviour of the coherence, which measures the quality of phase preservation, with time and surface types. Generally accepted models assume a linear loss of coherence with time with a slope depending on surface type. Although it is clear that the general trend of coherence versus time could only be a decrease, we observed clear examples of coherence rebuilding with time.

The coherence of a pair could also be spoiled by bad conditions (for instance high winds) applied to one of the images of the pair.

Another important point in coherence assessment is the major impact of volume scattering. In Southern California, we observed more severe coherence losses on forested areas, as compared to areas where the terrain slopes were similar. However, the situation is not hopeless, as data acquired much later, but with a better orbital configuration, showed an almost complete recovery of the coherence losses. This suggests that targets showing volume scattering are more demanding in terms of orbital repetition than surface targets. As a consequence, the filters we use for interferometric scene matching, which were empirically optimised for surface targets using only the local terrain slope as input, could be optimised with a target dependence. Early results are promising. However, one could question the ability of SAR interferometry to remain operational status and automated if target dependent filtering is required.

CONCLUSION

CNES engaged itself in an effort to validate SAR interferometry from the processing of a large amount of data, and very promising results have already been achieved.

These activities allows us to have a much clearer view of the potential and limits of interferometry and of the technical features of a future SAR mission which would allow even better performances.

FUTURE MEETING DATES
WGCV12: 4-6 December 1996, DLR, Germany.
WGCV13: Date and venue TBD
Terrain Mapping Subgroup:
19-20 September 1996, Sioux Falls, South Dakota, USA
2-3 December 1996, DLR, Germany.

IVOS Subgroup:
2-3 December 1996, DLR, Germany.

Other cal/val meetings:

Nagaraja Rao (nrao@orbit.nesdis.noaa.gov) is arranging a Special Session on 'Calibration and Characterisation of Meteorological Satellite Sensors' at the Fall Meeting of the American Geophysical Union, San Francisco, December 15-19, 1996. Details of the meeting are found in the May 21 issue of EOS, Transactions, American Geophysical Union; the session description in the July 30 issue.

REMINDER

Issue 7 of the WGCV Newsletter is intended to be completed in December 1996. Contributions for inclusion in the next issue should be submitted to the Newsletter editor Mark Hutchins preferably by email to M_S_Hutchins@scs.dra.hmg.gb or by fax. to +44 1252 396310 by 15 November 1996.

The CEOS cal/val newsletter is prepared and distributed on behalf of the CEOS WGCV by the DRA, UK, acting for the British National Space Centre.