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CONCURRENT USE OF RADARSAT AND ERS-2 SAR FOR INCREASED TEMPORAL MONITORING OF FLOODS AND SOIL MOISTURE

Principal Investigator: K Blyth

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Title of Project: Concurrent Use of RADARSAT and ERS-2 SAR for Increased Temporal Monitoring of Floods and Soil Moisture

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Sub-program for which the proposal is being submitted:

ADRO SUB-PROGRAM	SPONSOR	CHECK BELOW
International Research	NASA	
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Canadian Applications	CSA	
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28/3/95

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Date: 28/3/95

RADARSAT Proposal To ADRO
International Research Sub-Programme - CSA Sponsored

Concurrent Use of RADARSAT and ERS-2 SAR for Increased Temporal Monitoring of Floods and Soil Moisture

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1. INTRODUCTION

1.1 OVERVIEW

This proposal lies within the discipline of hydrology and the all-weather sensing capabilities of RADARSAT are particularly well suited to the collection of time-series data sets which can be used to study hydrological and hydrologically-related changes. Currently, many techniques used to extract useful hydrological information are empirical and rely on change detection to isolate the feature of interest and this is likely to remain the primary approach until multi-frequency sensors are available. Thus, for many hydrological applications, satellite data acquisition is required at weekly or more frequent intervals (Kuittinen, 1992; Schultz and Barrett, 1989). During key periods when rapid changes are occurring (e.g. during flooding or snow melt) daily or 12 hourly coverage is desirable. Such frequent coverage cannot be achieved with RADARSAT alone, so this proposal will study the feasibility of combining data from both the RADARSAT and ERS-2 SAR sensors.

1.2 OBJECTIVES

Three application areas will be covered within the hydrology discipline: 1) river and coastal flooding, 2) dryland soil moisture and 3) tundra soil moisture. All of these applications will use Radarsat data as a follow-on to studies already undertaken with ERS-1 and as complementary data to those of the ERS-2 SAR.

1.2.1 River and Coastal Flooding

The usefulness of satellite SAR to delineate floodwater has been widely demonstrated, but a number of difficulties, both physical and operational, still need to be addressed. This study will try to quantify the conditions under which wind-induced roughness of the floodwater surface makes delineation of the land/water boundary difficult or impossible and will evaluate the effects of different radar incidence angles on retrieval of flood boundaries. The effects of wind speed and other meteorological conditions, wind fetch, local topography and vegetation within the floodzone will be studied.

Satellite SAR is most useful for flood studies if it can be acquired at short notice, typically 2-7 days. This requires the development of a good communications network between user and distributor. Funds are being sought to improve this network within the European Union and Radarsat will be of integral importance in testing the network with the aim of developing an operational satellite flood monitoring system..

1.2.2 Dryland Soil Moisture

The main study area will be in the Save River catchment in Zimbabwe. Two sites will be used, one in the wetter savannah climate to the north and the other in the drier steppe climate to the south of the catchment. The main objective is to determine the seasonal change in extent of dambos. These are shallow grassy depressions at the headwaters of drainage systems where shallow groundwater reaches the surface and they represent the main source of water during the dry season. Time series Radarsat and ERS-2 SAR data will be used to determine changes in the extent of water seepage at the dambo/interfluve region following rain and under differing vegetation covers.

1.2.3 Tundra Soil Moisture

The study areas will be initially on the island of Svalbard in the Arctic Ocean and in Greenland and will move, probably towards the end of 1996 to a new site in northern Finland. In the short summer season, vegetation (mainly moss) is sparce and surface soil moisture can be quite variable as a result of snowmelt, local topography and depth to permafrost. The requirement is to study the changing surface soil moisture distribution during the snow-free season to help quantify the radiative, energy and water balance of arctic surfaces, to better understand the dynamics of permafrost and of hillslope runoff processes.

1.3 RELEVANCE TO ADRO SUB-PROGRAMME

The above objectives are highly relevant to the International Research, Science and Applications programme under CSA in that they have been specifically chosen to test the expected capabilities of the RADARSAT SAR. The objectives have been set as a result of work carried out over the past 3 years using similar ERS-1 SAR data and they seek to extend the knowledge gained during the ERS-1 programme.

The flood studies will improved understanding of the effects of wind and emerging vegetation on relatively shallow floodwater and the ability to delineate land/water boundaries during changing environmental conditions and radar incidence angles. Flood monitoring with satellite SAR is considered to be very close to operational application and a proposal entitled 'FLOODNET: A telenetwork for acquisition, processing and dissemination of Earth observation data for monitoring and emergency management of floods' has recently been submitted to the European Commission DG-XIII-C, Telematics Applications Programme. The proposal addresses the need within the European Union for improving and making more widely available, telematics systems designed specifically for disseminating Earth observation data for flood warning, monitoring and risk prevention. If this proposal is successful, RADARSAT data will be used alongside ERS-2 SAR data as the main satellite inputs to the information network which will distribute derived flood data in a number of formats suitable for operational use by water authorities, central and local government administrations and commercial operators such as insurance companies. Once the programme reaches the exploitation stage, it is anticipated that the majority of data would be acquired on a commercial basis.

The RADARSAT soil moisture programme has been designed to maximise the chances of obtaining useful information in an area which is still at an early stage of development and which would benefit from multi-frequency and/or multi-polarisation SAR data. Consequently, the soil moisture proposal is not overly ambitious as the problems and limitations of soil moisture retrieval are recognised. Nevertheless, it is expected that the results obtained with ERS-1 can be improved upon by the selection of suitable validation areas combined with more frequent SAR acquisition using both RADARSAT and ERS-2 satellites. The effects of changing surface soil moisture, vegetation and roughness on radar backscatter will be studied under dryland conditions and in arctic environments the additional effects of snow and near surface permafrost will be evaluated. The use of both RADARSAT and ERS-2 SAR will enable the effects of different radar incidence angles, swath widths and polarisations to be compared.

2. TECHNICAL PROPOSAL

2.1 RIVER AND COASTAL FLOODING

2.1.1 U.K. Studies

Because of the unpredictable nature of flooding, detailed validation will be undertaken largely in the UK where quick response is possible and access to large scale maps and some DEM data are available together with the opportunity of acquiring aircraft underflights using a range of sensors. In contrast, major, life-threatening floods are currently being studied in The Philippines using ERS-1 SAR and the use of RADARSAT would increase the chances of capturing these major flood events. The results of ERS-1 flood studies indicate that floodwater extent is best delineated with a time series combination of two or more images. Ideally, a no-flood image should be acquired close in time to a flood image so that land use within the pair are as similar as possible. When the two images are added or ratioed using different display gun colours, the flooded areas will be depicted in an identifiable colour as a result of their lower backscatter (Blyth et al., 1994). If the flooded and non-flooded images are widely separated in time, land use and crop differences will produce colours which may be confused with those associated with inundation. The requirement to acquire such an image pair places greater demands on satellite acquisition and the high repeat capability of RADARSAT will be of great advantage. It is not yet clear how the different polarisations of RADARSAT and ERS-2 will affect temporal merging of images and this is one area which needs to be tested.

Work in the UK will concentrate on obtaining high quality support information to help determine the main factors affecting the delineation of land/water boundaries during flooding. The main validation area will be in southern or central England, preferably the River THames basin, but a flexible approach is necessary to take advantage of any major flood events which may occur during the experimental period. Wind speed has been already been identified as a major determinant (Blyth, 1994) but no quantified measure of its importance has yet been made. The UK has a well developed network of meteorological stations which will be used to determine mean wind speed at the time of SAR data acquisition. In addition to wind speed, local wind fetch effects will have to be quantified and include topography, vegetation type and height, the presence of buildings etc. This type of information can best be manipulated using a GIS and workstation based ARC/Info will be used for this assessment. Data input to the GIS will be from large scale maps and field measurements. Of particular interest are the effects of different types of crop which are partially submerged by floodwater and how their different structures and depth of flooding affect radar backscatter. The ability to compare the effects of VV polarisation on ERS-2 with the HH polarisation on RADARSAT will be particularly useful for modelling the plant/water interactions.

The Institute of Hydrology (IH) has, for many years, used a light aircraft modification to acquire vertical aerial photographs for the validation of floodwater extent (Blyth and Nash, 1980; Biggin and Blyth, 1995) and this will be used to determine the actual aerial extent of floodwater against which that recorded by RADARSAT can be assessed. It will also enable crop and land use types to be determined over relatively large areas within the floodplain. If the EC supported FLOODNET proposal is successful, other airborne sensors, such as microwave radiometers may be tested at the same time as RADARSAT overpasses.

The main users of flood information in the U.K. are the statutory authorities such as the National Rivers Authority who are responsible for fluvial flooding, The Ministry of Agriculture, Fisheries and Food who are largely responsible for the maintenance of coastal defences and the Water PLC's who are responsible for water supply and sewage disposal. IH has very good working relationships with these organisations and we will seek support from them for the supply of flood extent information if this application for RADARSAT data is successful. Currently, a pilot project is being set up to demonstrate to a major re-insurance company, the capability of ERS-1 SAR to provide flood extent information suitable for incorporation with a GIS holding topographic and property vectors. It is expected that this commercial market has great growth potential and the presence of new satellites like RADARSAT will encourage their continued interest as the chances of capturing flood events is increased. The electronically steerable antenna on RADARSAT is particularly well suited to monitoring flood events, as the effects of changing radar incidence angle are so critical as with some other applications

2.1.2 Philippine Studies

The Philippines test area will enable floods of much greater magnitude and extent to be studied, but the degree of ground control is likely to be less comprehensive. As part of the EC-ASEAN ERS-1 Project, IH have been working with the Weather and Flood Forecasting Centre (WFFC) of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) on the Application of ERS-1 SAR data in Flood Hazard Assessments of Fluvial and Coastal Environments. The test area in southern Luzon is the 2700 km^2 Bicol River Basin which is prone to flooding following cyclonic storms or monsoonal rainfall and these often combine with wind-induced coastal surges to produce vast areas of inundation. Rainfall, river and lake levels within the basin are telemetered to WFFC in Manila where simple rainfall/runoff routing models are applied to help predict floodwater levels. RADARSAT and ERS-2 SAR data will be used to produce time series maps of floodwater growth and recession in this large basin which can be used to improve performance of the rainfall/runoff models.

2.2 DRYLAND SOIL MOISTURE

The determination of soil moisture will utilize the experience obtained in analysing C-band SAR images recorded by ERS-1 over temperate grassland test sites in the UK and semi-arid vegetation in Niger. It was found that, in both cases, good backscatter/soil moisture relationships were observed under certain conditions, but not under others. Combined RADARSAT and ERS-2 studies will focus on the partitioning of soil and vegetation contributions to radar backscatter at C-band to obtain a better understanding of the applications and limitations of its use. Partitioning will be easier by the synergetic use of the RADARSAT and ERS-2 sensors to provide more frequent coverage of test sites during periods of soil moisture change, especially in spring and autumn. The ERS-1 studies were carried out with a time separation of 35 days, during which vegetation changes occurred. Satellite repeat periods of 7 days or less are required to unequivocally separate soil moisture and vegetation effects and this should be possible using both RADARSAT and ERS-2 data.

2.2.1 Zimbabwe Test Sites

Results from our ERS-1 studies confirm that, at C-band VV, the effects of vegetation on the retrieval of surface soil moisture are greater in temperate climates than in semi-arid climates. Our follow-on work is therefore centred on a vegetation-sparce region where better soil moisture/backscatter relationships can be expected. Surface soil moisture will be measured with portable dielectric probes and profile soil moisture will be determined by neutron probe during seasonal wetting and dry-down periods. Vegetation and roughness effects will be quantified and simple backscatter models applied.

The study will be conducted in the Save catchment, Zimbabwe, an area covering approximately 3,000 sq km. It will be integrated with, and provide information for two multi-national, multi-disciplinary studies already being conducted in the area.

One study is being conducted in the wetter (annual rainfall approx. 1000 mm) northern part of the catchment. It is part of the Africa FRIEND (Flow Regimes from International Experimental and Network Data) initiative of UNESCO. This initiative, covering ten South African countries and over one thousand representative hydrological basins, has as its main objective the evaluation and understanding of the variability of hydrological regimes using regional data sets. The analysis of the remotely sensed images will utilize ground data being collected as part of the FRIEND initiative, whilst the results will contribute towards its objectives.

The second study is a collaborative research project involving the Institute of Hydrology, the British Geological Survey, and the University of Zimbabwe Lowveld Research Station into the feasibility of using shallow aquifers as a source of water for small-scale irrigation. It is being done in the drier (annual rainfall approx. 600 mm) southern part of the catchment. As in the FRIEND initiative, data being collected for this collaborative study will be used as an aid to image processing, while the results obtained may be useful to extrapolate observations from small plots to larger areas.

2.2.2 Dambo Studies in North Save Catchment

The main objective is to determine the seasonal change in extent of dambos. A dambo is defined as a "grassy depression, periodically inundated and at the headwater of a drainage system in a region of dry forest or bush vegetation". Dambos show considerable variation in physical attributes, but are widespread in central and southern Africa, occupying about 10% of the total land surface. Many dambos retain extensive wet regions during the dry season. It is the availability of water, in otherwise dry areas or during dry periods, that make dambos a valuable resource.

Three spatial zones can usually be identified within a natural dambo catchment:

1) The interfluve (upland), dominated by miombo forest of varying density.
2) The upper dambo, grassland seepage zone that is permanently wet.
3) The lower dambo, grassland that is wet during the rainy season (October to Aprol) but dries out by the end of the dry season (May to September).

Dambos can be considered as 'receiving sites' or interruptions to water flow, between the interfluve (upland) slopes and the stream channels below. Their form, function and maintenance are governed by the soil and the hydrological processes on the upland slopes, as well as processes within the wetland itself. Patterns of downstream flow emanating from dambos are regulated by the complex interaction of these influences. Consequently, it is necessary to gain an understanding of the important hydrological processes occuring in all regions of dambo catchments. These cannot be readily determined from ground observations alone and RADARSAT provides the opportunity of observing the temporal change of a surface soil moisture over a selection of different dambo types. Time series Radarsat and ERS-2 SAR data will be used to determine changes in the extent of water seepage at the dambo/interfluve region following rain and under differing vegetation covers.

The main control measurements will be made within a 3.5km^2 experimental catchment near Marondera run by the Department of Research and Specialist Services, Horticultural Research Station. A member of IH will be undertaking PhD studies on this catchment and 20-30 soil access tubes will be installed to provide neutron and piezometric measurements within the soil profile across the main hydrological boundaries within the dambo. Within this catchment and other selected dambo catchments, vegetation and soil roughness parameters will be assessed and surface soil dielectric at 0-5cm and 0-10cm depth will be measured with an IH surface capacitance insertion probe (SCIP). This is a portable instrument which has been extensively tested for satellite validation of soil moisture and has proved to extremely stable and reliable. Soil dielectric can be determined by reference to calibration standards, whilst volumetric soil moisture is determined via a calibration curve determined for each soil type. Measurements can be taken very rapidly to determine local variability such as correlation length and mean values of soil moisture can be calculated with a high degree of confidence (Blyth et al., 1994). Surface soil moisture measurements will be concentrated on grassland areas which vary in length and density according to the degree of grazing. The controlled farmlands tend to have fairly long grass whilst communal lands tend to be overgrazed and have sparse vegetation cover. Such variations will enable the ability of RADARSAT to detect surface soil moisture to be tested for a range of vegetation covers. Intensive field programmes will be concentrated within the periods of soil moisture flux during wetting at the start of the rainy season and during dry-down at the end.

2.2.3 Lowveld Studies in South Save Catchment

The Lowveld test area lies only about 200km to the south of Marondera but is considerably drier and provides a useful contrast to the northern site. The two sites will used:

(i) To test the modelling of soil texture and permittivity effects by comparing data from different sites at one point in time.

(ii) To test the suitability of the radar system for long-term monitoring by studying data for each site over an annual cycle.

IH, in collaboration with the British Geological Survey and funded by the UK Overseas Development Agency are working with the Lowveld Research Station to instrument a catchment to study the feasibility of using an integrated catchment management approach as a means of halting land degradation in a typical semi-arid river catchmnet. Hydrological processes are being studied at a range of scales (plot,field, sub-catchment and catchment) in the Romwe Catchment. These data will be augmented by surface measurements similar to those described for the northern catchment for validation of the RADARSAT SAR. Various methods of irrigation are being tested in this area and these will provide a range of surface soil moisture levels at any one time which will aid calibration of the SAR data. It is hoped that the in-situ soil profile data from these sites can be used to test the surface/profile soil moisture modelling techniques developed by Ragab (1993 and 1995) using ERS-1 SAR data over UK grassland sites. Such models allow, under evaporating conditions, for profile soil moisture to be modelled using surface soil moisture input as derived from satellite data. The models have been tested on archived data sets derived from many climatic regions and are expected to be transportable to dry soil situations.

2.3 TUNDRA SOIL MOISTURE

2.3.1 The Requirement

The tundra biome occupies approximately 10% of the Earth's land area and contains perhaps 33% of the global terrestrial carbon. The ecosystems are expected to be very sensitive to changes in climate and GCM scenarios suggest that warming due to enhanced CO_2 will intensify towards the poles. Warming in these layers will deepen the active soil layer above the permafrost which forms in the summer months, providing the potential for enhanced CO_2 and CH_4 emissions. The permafrost has a central role in the hydrology and is crucial in determining the vegetation type, carbon balance and the surface/atmosphere exchanges. Thus, the response of the permafrost to global warming is a central component of the feedback between climate change and the tundra ecosystem. The depth of permafrost during the summer months determines the balance between melt water runoff and infiltration in that the permafrost horizon creates a general lower limit to soil water drainage, above which saturated and unsaturated soil horizons form. The measurement of permafrost depth can only be carried out at a limited number of sample points and it is expected that a measure of the spatial variation of surface soil moisture during the summer season can be help quantify the distribution and fluxes of the permafrost system, as well as providing key information for the calculation of the water and energy balances of the test areas.

2.3.2 Tundra Test Sites and Measurements

The processes briefly outlined above, do not occur homogeneously throughout the tundra biome and there are important differences between the southern and northern limits of this relatively narrow climate region. Three sites in Greenland, Svalbard and northern Finland will provide the extremes in oceanic and continental European Tundra. These sites have established and long-running research programmes which will provide the background data for long term comparison. For the validation of surface soil moisture, IH staff will carry out surface capacitance (SCIP) transect measurements at the Svalbard and northern Finland sites and the University of Copenhagen will carry out similar surface soil moisture measurements at the west Greenland site. The use of frequent RADARSAT data will enable change detection methods to be used to isolate the effects of changing soil moisture. Vegetation effects at the Svalbard site are known to be minimal, comprising mainly thin mosses and bare gravelly soil. Conditions at the West Greenland site are expected to be similar whilst a more substantial vegetation cover is likely for the north Finland site, but this has yet to be selected. Surface roughness will be sampled using standard linear measurement procedures and any seasonal changes in vegetation will be quantified, although these are expected to be small. Each site will have comprehensive automatically recording instrumentation for monitoring changes in profile soil conditions such as moisture and temperature and surface energy balance will be measured over different surfaces at each of the sites.

Initial tests in Svalbard using ERS-1 SAR indicate the difficulties of geo-location in tundra regions and the consequent need for corner reflectors within the areas of interest. A number of reflectors suitable for geo-location only will be installed at each of the three sites.

The quantification of snow distribution using RADARSAT data are not planned as part of this proposal because of the difficulties of identifying the complex returns from the many different types of snow experienced during transition periods. However, at IH sites, images from an automatic camera placed 15m a.g.l. will provide a record of snow distribution within the immediate environs of instrumented sites and these will be used to assess the effects of snow on the radar images. The key periods for soil moisture measurement should correspond to essentially snow-free conditions, but this of course cannot be guaranteed.

3. ANTICIPATED RESULTS AND DELIVERABLES

3.1 FLOODING

A better understanding of the physical factors affecting land/floodwater differentiation will be achieved in both temperate and tropical climates and this will allow more efficient planning of satellite data acquisition and distribution. For example, a threshold surface wind speed may be derived, beyond which data acquisition is not recommended. This would save much effort and expense by only acquiring and processing data which has a good likelyhood of providing the required information. For such a system to work, good communication is required between end user (or other agency) and satellite operator, and it is hoped that the FLOODNET proposal to the EC will be successful in its bid to improve these communication links. If FLOODNET proceeds, the RADARSAT and ERS-2 SAR's will be the key satellite sensors around which the system will be designed and their profile within the EU will be maximised amongst potential users of flood data.

Deliverables will in the form of (at least annual) reports to sponsoring agencies and publication of results in refereed journals and proceedings of relevant symposia, including those specified within the ADRO agreement for this project. The FLOODNET proposal will generate a number of important deliverables which are relevant to the efficient distribution of RADARSAT data within the hydrological community and within administrative bodies associated with the planning for and consequences of flooding.

3.2 SOIL MOISTURE

Within each Radarsat image, it will be possible to study the dynamics of a large number of dambos, some of which will have ground validation information. This will provide, for the first time, a method of relating dambo extent to local geological, topographic, soil and vegetation effects and will help define the main factors controlling water availability. Such information will allow more realistic management of this key water resource.

The arctic ecosystem is a fragile environment and is extremely sensitive to disturbance by man and little is known about its climate, hydrology, permafrost and ecology. Surface soil moisture exerts an important control on all of the above and measurement of its spatial and temporal dynamics using Radarsat data will provide new insight into its vulnerability and ability to recover from man's influences.

Effective monitoring of soil moisture is particularly important in marginal lands where the effects of drought or inappropriate land management can have disastrous consequences. Deliverables from the dryland research will be directed towards the South African countries participating in the FRIEND initiative, through UNESCO. Data from the Tundra soil moisture studies will be used to improve the parameterisation of Soil-Vegetation-Atmospher Transfer (SVAT) models and the RADARSAT data will be particularly important for scaling up from local models through mesoscale and ultimately for the development of appropriate SVAT schemes for inclusion into GCM's. Deliverables will be in the form of publications etc. relating the application of satellite radar to the above global modelling requirements.

4. DATA REQUIREMENTS

4.1 RIVER FLOODING

4.1.1 Timing of Data Acquisition

In Europe, flooding is most common after soils have reached field capacity and the primary period for field activities and SAR data collection will be January - March of each year, with secondary likelyhood in December and April.

In the Philippines, the climate can vary from one region to another and consequently, flooding can occur almost at any time of the year. The main Bicol test area in southern Luzon has no dry season, but has a pronounced rainy season from November to January. The climate is determined by topographical features, open towards the northeast, and monsoons and cyclones. Northeast monsoons between November and February have a great influence on the basin, while trade winds are obstructed by mountain ranges. There are low mountain ranges to the southwest, therefore the basin is only slightly affected by southwestern monsoons. Tropical cyclones average two per year, with October - December being the key period.

4.1.2 Frequency of Observation

Ideally, for flood mapping, it is necessary to combine images of flooding with a recent non-flood image to allow non-ambiguous separation of floodwater from surrounding land. Depending on location and river catchment characteristics, the flood may have a duration ranging from a few days to several weeks. Several observations would be desirable to follow the development of the flood. Thus, for each flood event, a minimum of two images would be required and for major, long duration events, four or five images may be needed.

4.1.3 Product Type

Two distinct requirements prevail for flood data. The first is to acquire some test data under pseudo-operational conditions to determine its capabilities for providing flood information for emergency response planning. The main requirement is speed of production and dissemination, coupled with a ground resolution as fine as possible for the fast delivery product. The most appropriate product would therefore appear to be the SFG operating on Fine Beam with a ground range resolution of 11m x 9m.

The second requirement is for non time-critical mapping of floods. This calls for the highest ground resolution together with the best available geocoding for the precise placement of flood boundaries onto map bases. The SPG product would appear to be the most appropriate for this requirement.

4.1.4 Summary of Data Requirements for Flooding

The following are generalisations for guidance only and each flood event will require individual treatment.

EUROPE

The main test area will be the upper River Thames basin, U.K., scene centre: West 1deg. 35min., North 51deg. 41min. Coverage of some major floods will also be required within central Europe.

* Key observation periods:	December - April each year
* Observation frequency:	Daily at flood peak, otherwise every 3 days
* Duration of observation period:	Typically 1 week
* Duration of total activity:	December 1995 - March 1999 (then revised)
* Preferred incidence angles:	Willing to initially test all available angles.
* Ascending or descending:	Either; timing of acquisition is more important.
* Estimated no. of products:	SFG: 6 over 3 year period SPG: 9 over 3 year period

PHILIPPINES

The main test area will be the River Bicol basin in southern Luzon, scene centre: East 123deg. 15min, North 13deg. 30min. At 50km swath, more than one scene will be required to cover the basin - exact details not yet known.

* Key observation period	October - February each year.
* Observation frequency	Every 3 days.
* Duration of observation period	Typically 2-3 weeks.
* Duration of total activity	October 1995 - March 1995 (then revised)
* Preferred incidence angles	Willing to initially test all available angles.
* Ascending or descending	Either, timing of acquisition is more important
* Estimated no. of products	SFG: 4 over 3 year period SPG: 12 over 3 year period

4.2 DRYLAND SOIL MOISTURE

4.2.1 Timing of Data Acquisition

The key periods of interest for the Zimbabwe work will be during seasonal transition from April - May and November - December each year, together with some dry season images in July - August

4.2.2. Frequency of Observation

Comparison of the wetter northern site and drier southern site will require pairs of images each month during the 6 month wetting and drying period to augment the data already approved for ERS-2. In the following year (November 1996 - May 1997) weekly data may be required at the beginning and end of the wet season, but the financing of this programme is not yet certain. To follow the dynamics of surface soil moisture in the dambo region, intensive field campaigns will be conducted over 2 week periods. The first could be in November 1995, depending on availability of RADARSAT data following launch. The second is likely to be in March/April 1996. Coverage will be required every 3 days during this period.

4.2.3 Product Type

The key requirement for soil moisture measurement is for steep incidence angle data to reduce the effects of surface roughness on radar backscatter. The preferred option would appear to be the SAR Mode 7, low incidence beam centred around 15deg. off nadir. If this is not available for extended periods, the standard beam would be an alternative. Speed of data acquisition is not an issue, so the precision geocoded product would be preferred.

4.2.4 Summary of Dryland Soil Moisture Data Requirements

Two test areas are to be used in Zimbabwe, the first being the most important for dambo studies:

Marondera Dambo Site, scene centre: East 31deg. 40min., South 18deg. 12min.
Chiredsi Lowveld Site, scene centre: East 31deg. 35min., South 21deg. 0min.

* Key observation period	November - May each year
* Observation frequency	a) Monthly in 95/96, weekly in 96/97
	b) Every 3 days over 2 week period
* Duration of total activity	November 1995 - May 1997
* Preferred incidence angles	1)Mode 7, Low incidence, 2) Standard @ 20deg.
* Ascending or descending	Dawn mode preferred
* Estimated no. of products	Nov. 1995 - May 1996: 18 scenes
	May 1996 - May 1997: 18 scenes

4.3 TUNDRA SOIL MOISTURE

4.3.1 Timing of Data Requirements

For the arctic studies, soil moisture validation is confined to the summer months, from early June to mid-September.

4.3.2 Frequency of Observation

Ideally, weekly data is required at the Svalbard and Greenland sites during the 1996 summer season and at the northern Finland and Greenland sites during the 1997 summer season. However, this would require more images than could be readily handled so the period of observation will be reduced to six or seven weeks sometime within the summer period. The exact period will be selected nearer to the observation time when prevailing conditions are known.

4.3.3 Product Type

The key requirement for soil moisture measurement is for steep incidence angle data to reduce the effects of surface roughness on radar backscatter. The preferred option would appear to be the SAR Mode 7, low incidence beam centred around 15deg. off nadir. If this is not available for extended periods, the standard beam would be an alternative. Speed of data acquisition is not an issue, so the precision geocoded product would be preferred.

4.3.4 Summary of Tundra Soil Moisture Data Requirements
Three test sites will be employed; Svalbard and Greenland will be used in summer 1996 and then northern Finland and Greenland in summer 1997.
Svalbard, scene centre: East 11deg. 55min., North 78deg. 56min.
Zackenberg, Wollaston Forland, northeast Greenland, scene centre: West 20deg. 10min., North 74deg. 28min.
Northern Finland site not yet selected. Approximate likely position: East 23deg., North 66deg.

* Key observation periods	June - mid-September 1996 and 1997
* Observation frequency	Weekly within 7 week window
* Duration of total activity	June 1996 - September 1997
* Preferred incidence angles	1) Mode 7, Low Incidence, 2) Standard@20deg.
* Ascending or descending	Dusk mode preferred
* Estimated no. of products	June - September 1996: 14
	June - September 1997: 14

4.4 SUMMARY OF DATA REQUIREMENTS

The following SAR scenes are requested as Exabyte tapes:

Flooding, Europe:	15
Flooding, Philippines:	16
Zimbabwe soil moisture:	36
Tundra soil moisture:	28
Total	**95**

5. PROJECT ORGANISATION

K. Blyth will act as overall project leader and will be reponsible for the organisation of all flooding investigations and the dryland soil moisture studies, whilst Dr. R. J. Harding will be responsible for the organisation of the tundra soil moisture studies.

K.Blyth works in the Remote Sensing Section of the Hydrological Processes Division of the Institute of Hydrology specialising in the application of microwave remote sensing in hydrology. He is currently an ERS-1 Principal Investigator studying the use of ERS-1 SAR for monitoring soil moisture, lowland snow and river flooding and has been accepted as joint Principal Investigator on the IH ERS-2 proposal. He has also acted as Principal Investigator for a number of aircraft microwave experiments studying the effects of soil moisture on grassland test sites in the UK (European SAR-580, AGRISAR, AGRISCATT, MAESTRO-1) and has carried out soil moisture investigations for the SIR-B and SIR-C programmes. In 1987 and 1989 he was a participant in the First International Satellite Land Surface Climatology Project Field Experiment (FIFE) in Kansas, USA studying surface heat exchange and in 1992 he undertook field validation measurements of heat budget and surface soil moisture as part of the international HAPEX-Sahel remote sensing experiment in Niger, West Africa. He has been involved in the remote sensing of river floods since 1980 and is currently acting as joint European advisor on the EC-ASEAN ERS-1 Project (PHIL-2) studying the use of ERS-1 SAR for monitoring fluvial and coastal floods in the Philippines. Recent publications relevant to this proposal are listed in Section 9, References.

R. J. Harding works in the Global Processes Section of the Hydrological Processes Division of the Institute of Hydrology and is currently leader of a group researching soil/vegetation, atmospheric transfer schemes for global circulation models. He was previously Section Leader of Sub-catchment processes where his research included:

* Simple methods of estimating changes in soil moisture in the UK and overseas
* Effects of land-use changes on evaporation and river flow
* Snow hydrology
* Water-use of forest in tropical areas

He gained M.Sc. and Ph.D degrees in Meteorology and worked as a research associate at the Department of Agricultural Sciences, University of Oxford, researching upland climatology. Dr. Harding has extensive experience in setting up and operating mainly energy budget field experiments which he has done in Norway (1983), Greenland (1985), Canada (1993/94) where he was Principal Investigator in the BOREAS Project, and in Svalbard (1994). Recent publications relevant to this proposal are listed in Section 9, References.

6. EQUIPMENT AND FACILITIES

6.1 COMPUTING AND IMAGE ANALYSIS

The Institute of Hydrology has computing facilities which are organised and supported centrally by its parent organisation, the Natural Environment Research Council. Communication to other institutions and universities are via the JANET network and Internet and World Wide Webb links are widely used.

The Remote Sensing section has 3 Sun workstations for image analysis, GIS and general computing use. Image analysis is done using ERDAS Imagine and GIS uses ARC/Info. The section also has 8 PC's and most of these are connected to the Institute's distributed computing system via a LAN. ERGOVISTA is the main SAR processing package currently in use.

6.2 OTHER IN HOUSE SUPPORT

IH has expertees in soil physics and has an instrument development section and precision workshop which have produced custom-made instruments such as the Surface Capacitance Insertion Probe (SCIP) which is used for validation of surface soil moisture. Automatic recording field instrument packages are individually tailored to the needs of each field site and support in their installation and operation is available if required. IH have great experience in successfully installing and operating such instrument packages in all parts of the world from tropical to arctic environments.

6.3 FIELD VALIDATION FACILITIES

In addition to the automatic instrumentation above, IH routinely carry out measurements of soil moisture using neutron probes, capacitance probes, tensiometers and volumetric sampling devices and standard meteorological measurements. Such instruments will be deployed where necessary.

The dambo field site in Zimbabwe is supported by the Horticultural Research Station as described in 2.2.2 and meteorological and stream runoff data is available for this small catchment. Similarly the southern site, as described in 2.2.3 is supported by the University of Zimbabwe/Lowveld Research Station facilities for streamflow measurement, rainfall measurement, weather station, etc.

The Svalbard station is a multinational scientific base and NERC have permanent laboratory facilities there from which our measurements will be conducted, whilst similar logistics and support facilities are available to the University of Copenhagen team who will operate from the Zackenberg base in Greenland.

6.4 SUPPORTING SATELLITE DATA

The RADARSAT data will be used in parallel with ERS-2 SAR data to improve the temporal availability when necessary and to take advantage of the different polarisations and incidence angles available. Flood studies in the Philippines are supported by Landsat and SPOT data, primarily for the identification of land use to help understand the interrelationships between vegetation and floodwater and their combined effect on radar backscatter. In Europe, more detailed information on land use will be acquired via aerial photography and ground survey. The Zimbabwe study, in addition to using ERS-2 SAR also runs in parallel to an evaporation project which utilises the ERS-2 ATSR sensor to measure surface temperature. This data will be extremely valuable when used with SAR data to help explain local variations in surface soil moisture. Landsat will also be employed in Zimbabwe to produce land cover classifications over the area of interest and to help extend the knowledge gained at the test site scale to wider areas. The tundra work is at an early stage of development and will concentrate on understanding the processes at work at the local scale so no supporting satellite data is currently planned to be used.

7. PROJECT FUNDING

7.1 FLOODING

The European work is supported internally within IH science budget which will also support some management and data analysis time for the Philippine work. A proposal for 1.9 million ECU has been submitted to the EC Framework-IV Programme for flood related remote sensing and, if this is successful, much of the above programme would be supported within the project.

7.2 DRYLAND SOIL MOISTURE

The project leaders time is supported internally within the IH science budget, and the IH member carrying out PhD research will be supported mainly by IH, with some backup support from the University of Zimbabwe. Support in the Lowveld test site will be provided by IH personnel already working on the shallow acquifer irrigation project. Data being collected from this collaborative study will be used as an aid to image processing and interpretation, while the results of the remote sensing may be useful to extrapolate observations from the small instrumented plots to larger areas.

7.3 TUNDRA SOIL MOISTURE

This will be funded at 50% by the EC and 50% by IH science budget.

8. PROJECT SCHEDULE

8.1 FLOODING

EUROPE

Dec. 1995 - April 1996	First winter season. Carry out aerial photography of major flooding within the Thames Basin, or other U.K flood events. for validation of RADARSAT. Produce land use maps of inundated areas and measure vegetation parameters within these areas. Collect meteorological data for satellite overpass periods, particularly wind speed.
April 1996 -Dec 1996	Analysis of combined RADARSAT / ERS-2 data sets and ground data Presentation of results in journal/conferences
Dec. 1996 - April 1997	Second winter season. Carry out ground validation as above together with use of advance aircraft sensors through FLOODNET project Test area may move to central Europe if appropriate.
April 1997 - Dec. 1997	Data analysis. Presentation of results at ADRO Mid-term symposium.
Dec. 1997 - April 1998	Third winter season. Carry out work to requirements of 'end-user' e.g. rivers authority, insurance company.
April 1998 - Dec. 1998	Analysis of results, production of Final Report including recommendations for 'operational use'. Presentation of results at ADRO Final Symposium.

PHILIPPINES

The project schedule will closely follow that for the European flooding with the exception of the aircraft support. The main period for flooding is likely to be from October to February each year, but major floods can still occur outside this period. Ground validation will be carried out by PAGASA Weather and Flood Forecasting Branch personnel.

8.2 DRYLAND SOIL MOISTURE

June 1995 - Aug 1995	Initial site visits and equipment installation
Oct. 1995 - May 1996	Setting up and testing ground measurement equipment. Collection of some data towards end of wet season for validation of RADARSAT and ERS-2.
May 1996 - Nov. 1997	Analysis of data. Delivery of one or two dry season RADARSAT images for reference purposes.
Nov. 1997 - May. 1998	Main experiment period.
May 1998 - Nov. 1998	Analysis of results. Presentation of results to ADRO Mid-term symposium

Schedule not known beyond this date.

8.3 TUNDRA SOIL MOISTURE

June 1995 - Sept. 1995	Instrument installation and site logistics at Svalbard and Zackenberg. Collection of ground data for ERS-1/ERS-2.
June 1996 - Sept. 1996	Main test period at Svalbard. Collection of ground data for RADARSAT and ERS-2. Instruments removed at end of season for transport and installation at north Finland site.
Sept. 1996 - June 1997	Analysis of satellite and ground data. Presentation of results at ADRO Mid-term Symposium
June 1997 - Sept. 1997	Main test period at North Finland site.
Sept. 1997 - Mid 1998	Analysis of results. Preparation of Final Report. Presentation of results at ADRO Final Symposium

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