Exploitation of the NAFE'05 campaign for cal/val activities of the SMOS mission

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Abstract The aim of this project is to use a combination of gridded airborne L-band brightness temperature, NDVI and surface temperature data and distributed in-situ soil moisture data acquired at the scale of several SMOS pixels during an intensive field experiment in SE Australia (NAFE) to test 1- the SMOS soil-moisture retrieval algorithms (inversion of local soil moisture from airborne brightness temperature data) 2- the SMOS disaggregation algorithms (inversion of local soil moisture from coarse brightness temperature and auxillary remote-sensing data) and 3- the assimilation of disaggregated soil moisture data in a distributed hydrological model. This work falls within the Cal/Val SMOS activities.

Objectives

Knowledge of the spatial and temporal variation in both near-surface and rootzone soil moisture is critical for achieving efficient and sustainable water use and for improvements in climate change prediction. Soil moisture information may be obtained in three different ways. First, there are direct ground-based measurements which need to be made at many individual points if regional data are required. Second, surface hydrology models may be used to predict the spatial and temporal variation of near-surface and rootzone soil moisture but those estimates suffer from inadequate model physics, parameter estimates and atmospheric forcing data. Third, remote sensing provides spatially distributed soil moisture data at a regional scale, but the data acquired (in the visible or the thermal infra-red wavelengths) are only indirectly related to soil moisture. In recent years there has been an increasing interest in using passive microwave remote sensing for large scale measurements of soil moisture in the top few centimetres, because the data acquired is directly related to surface soil moisture. Clearly, these different approaches are complementary and so one approach has been to utilise all three sources of data. In 2008, the Soil Moisture and Ocean Salinity (SMOS) sensor will be launched (Kerr et al., 2001). SMOS will offer a temporal resolution of the order of 3 days, compatible with the time-scale of the soil moisture evolution as driven by hydrological processes. Its spatial resolution will be on the order of a 50 by 50 km pixel, which is not well-matched with the observed scale of variability of soil moisture due to the average space-scale of hydrological processes (less than a km) and hence not particularly useful for small scale applications. Moreover, the depth of integration of the soil moisture measurements does not exceed a few centimetres, whereas for most hydrological applications an evaluation of the root-zone soil moisture is required. The future use of SMOS data for operational prediction of catchment scale soil moisture status will thus require three types of studies: (1) calibration and validation of SMOS surface soil moisture retrieval algorithms; (2) development of disaggregation techniques for downscaling the coarse scale SMOS surface soil moisture values to local-scale estimates and (3) development of data assimilation techniques for deriving estimates of root-zone soil moisture from surface soil moisture values. The project has two main objectives. Firstly, it aims at testing disaggregation and data assimilation techniques based on existing radiative transfer models and distributed hydrological modelling. Secondly, the project will provide calibrations and validations of the SMOS surface soil moisture retrieval algorithms using data obtained in intensive field campaigns involving high resolution airborne remote sensing as well as intensive ground-based soil moisture measurements. The proposed project is motivated by the existence of unique long-term data sets acquired in the Goulburn catchment in SE Australia (which is of the size of several SMOS pixels) and the National Airborne Field Experiments held in the Goulburn (NAFE'05, Walker et al., 2005) in November 2005. These two experiments provided high resolution maps of L band brightness temperature, Thermal Infra Red temperature and NDVI for both catchments as well as spatially distributed surface soil moisture data.

NAFE'05 and cosmos datasets

The NAFE'05 experiment was undertaken in the Goulburn River catchment during November 2005, with the objective to provide high resolution data for process level understanding of soil moisture retrieval, scaling and data assimilation. To meet this objective, the Polarimetric L-band Multibeam Radiometer (PLMR), a thermal imager and a tri-spectral scanner was flown onboard a small environmental research aircraft at four different altitudes from 625 ft to 10,000 ft AGL, resulting in L-band data at 62.5-m, 250-m, 500-m and 1-km resolution and thermal infrared data at approximately 1.25-m, 5-m, 10-m and 20-m resolution. Flights were targeted across a 50km x 50km area containing 18 soil moisture profile monitoring sites. On one day per week the entire area was flown while on the remaining four days two sub-areas containing four extensively instrumented and ground monitored farms each were flown on alternate days. Coincident ground data, the top (5 cm) soil moisture acquired with a capacitance probe, was collected at the farms on embedded spatial scales of 6.25m to 1km. Additionally, data was collected on rock coverage and temperature, surface roughness, skin and soil temperature, dew amount, and vegetation water content. A second L-band radiometer, the EMIRAD was flown on the same location for one month, with a 15-days overlap with NAFE'05 during the last 2 weeks of the campaign (Berger et al., 2006).

Methodology

1. Soil moisture retrieval algorithms (inversion)

The 1 km pixel airborne L-band data will be used to test the surface soil moisture retrieval capabilities of the L-Meb (Wigneron et al., 2007) radiative transfer model. This model is used in direct mode to simulate brightness temperatures from estimates of the surface soil moisture, and therefore an inversion procedure must be developed to obtain surface soil moisture from the remotely sensed brightness temperature. Comparison between measured in-situ and inversed soil moisture at the time of the aircraft overpass will be carried out for a range of contrasting land cover types for the Goulburn catchment.

2. Disagregation

First the high-resolution L-band brightness temperature maps acquired by the aircraft in the microwave domain during NAFE05 will be aggregated to produce a coarse-resolution brightness temperature corresponding to the size of one SMOS pixel. Next, higher-resolution (1km*1km) land surface data (texture maps, NDVI and surface temperature) and the coarse-scale SMOS brightness temperature will be combined into two different disaggregation approaches, one based on a deterministic approach (Merlin et al., 2006), the other on geostatistical techniques. The higher-resolution thermal infrared surface temperature data acquired by the aircraft will be used in a deterministic disaggregation approach together with the SMOS generated brightness temperature to produce high-resolution surface soil moisture maps. The surface soil moisture maps produced by both disaggregation techniques will be compared to soil moisture fields obtained by inversion of the L-band brightness temperature maps acquired by the aircraft as well as ground-based soil moisture measurements.

3. Data assimilation

The Inversion and Disaggregation procedures will be used to generate maps of surface soil moisture each time the aircraft flies. In order to produce continuous time-series of spatially distributed root-zone soil moisture, theses maps need to be assimilated into a distributed hydrological model. To achieve this, methods based on optimal estimation and optimal control will be developed to assimilate surface soil moisture fields and estimate distributed root-zone soil moisture. The coupled SVAT-hydrological model SEVE-V0 will first be calibrated against streamflow and in-situ soil moisture data obtained for the network of continuous sampling sites. Next the performance of the data assimilation methods will be assessed by comparing predictions and measurements of streamflow and soil moisture content during NAFE'05.

Current status of the project

The meta-database has been used to produce the input-layers (texture, LAI, land use maps, rainfall fields etc) for the hydrological model and the radiative transfer scheme; the model is calibrated for the 18 soil moisture monitoring stations with ancillary historical data acquired before the NAFE'05 campaign. Coupling between the model and the radiative transfer scheme L-MEB is underway and will be tested with selected homogeneous (one land cover type) 1*1 km pixels for the three main land cover types: openwoodland, native grass and crop (mainly wheat). Intercomparison of the EMIRAD and PLMR datasets and a new surface projection is being carried out (Saleh et al., 2007).

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