EAGLE 2006 – Multi-purpose, multi-angle and multi-sensor in-situ and airborne campaigns over grassland and forest

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Abstract

EAGLE2006 - an intensive field campaign - was carried out in the Netherlands from the 8th until the 18th of June 2006. Several airborne sensors - an optical imaging sensor, an imaging microwave radiometer, and a flux airplane – were used and extensive ground measurements were conducted over one grassland (Cabauw) site and two forest sites (Loobos & Speulderbos) in the central part of the Netherlands, in addition to the acquisition of multi-angle and multi-sensor satellite data. The data set is both unique and urgently needed for the development and validation of models and inversion algorithms for quantitative surface parameter estimation and process studies. EAGLE2006 was led by the Department of Water Resources of the International Institute for Geo-Information Science and Earth Observation and originated from the combination of a number of initiatives coming under different funding. The objectives of the EAGLE2006 campaign were closely related to the objectives of other ESA Campaigns (SPARC2004, Sen2Flex2005 and especially AGRISAR2006). However, one important objective of the campaign is to build up a data base for the investigation and validation of the retrieval of bio-geophysical parameters, obtained at different radar frequencies (X-, C- and L-Band) and at hyperspectral optical and thermal bands acquired over vegetated fields (forest and grassland). As such, all activities were related to algorithm development for future satellite missions such as Sentinels and for satellite validations for MERIS, MODIS as well as AATSR and ASTER thermal data validation, with activities also related to the ASAR sensor on board ESA's Envisat platform and those on EPS/MetOp and SMOS. Most of the activities in the campaign are highly relevant for the EU GEMS EAGLE project, but also issues related to retrieval of biophysical parameters from MERIS and

MODIS as well as AATSR and ASTER data were of particular relevance to the NWO-SRON EcoRTM project, while scaling issues and complementary between these (covering only local sites) and global sensors such as MERIS/SEVIRI, EPS/MetOP and SMOS were also key elements for the SMOS cal/val project and the ESA-MOST DRAGON programme. This contribution describes the mission objectives and provides an overview of the airborne and field campaigns.

Introduction

Campaign overview

The understanding of bio-geophysical parameter retrieval from multi-parameter optical and SAR data as well as the direct modelling of the underlying physical processes in forests and grassland remain challenging due to lack of appropriate observation data. In EAGLE2006 an intensive filed campaign is carried out using different airborne sensors - an optical imaging sensor, an imaging microwave radiometer, and a flux airplane - for data acquisition and to collect extensive ground measurements simultaneously over one grassland (Cabauw) and two forest sites (Loobos & Speulderbos), in addition to acquisition of multi-angle and multi-sensor satellite data. As such the data set up is both unique and urgently needed for the development and validation of models and inversion algorithms for quantitative surface parameter estimation and process studies.

The understanding and quantification of bio-geophysical parameters of different vegetated surfaces is essential in the development of validated, global, interactive Earth system models for the prediction of global change accurately enough to assist policy makers in making sound decisions concerning the planning, sustainable use and management as well as conservation of water resources and environment. Multi-sensor remote sensing monitoring (using radar & optical data) are essential for the development and validation of models and retrieval algorithms for the above stated purposes.

The EAGLE2006 activities are performed over central parts of the Netherlands (the grassland site at Cabauw and two forest sites at Loobos & Speulderbos; with yearly precipitation around 750 mm and yearly average temperature about 10° Celsius) from the 8th until the 18th of June. EAGLE2006 originated from the combination of a number of initiatives coming under different funding. As such, the objectives of the EAGLE2006 campaign were closely related to the objectives of other ESA Campaigns (SPARC04, Sen2Flex2005 and especially AGRISAR2006).

One important objective of the campaign is to build up a data base for the investigation and validation of the retrieval of bio-geophysical parameters, obtained at different radar frequencies (X-, C- and L-Band) and at hyperspectral optical and thermal bands acquired over vegetated fields (forest and grassland). As such, all activities were related to algorithm development for future satellite missions such as Sentinels and for satellite validations for CHRIS, MODIS and MERIS data, with activities also related to AATSR and ASTER thermal data validation, as well as the ASAR sensor on board ESA's Envisat platform and those on EPS/MetOp and SMOS. Most of the activities in the campaign are highly relevant for EAGLE, but also issues related to retrieval of biophysical parameters from CHRIS and MERIS as well as AATSR and ASTER data were of particular relevance, while scaling issues and complementary between these (covering only local sites) and global sensors such as MERIS/SEVIRI, EPS/MetOP and SMOS are also key elements.

Campaign objectives

The general purposes of the campaign are:

1. Acquisition of simultaneous multi-angular and multi-sensor (from visible to microwave domain) data over a grassland and a forest.
2. Advancement of process understanding in description of radiative and turbulent processes in land-atmosphere interactions.
3. Validation of primary bio-geophysical parameters derived from satellite data using in-situ and airborne data.
4. Improvement of soil moisture retrieval accuracy by synergy of multi-angular (L-band) SMOS and multi-angular C-band SAR/Optical-thermal observations.
5. Development of operational algorithms to extract land surface parameters and heat fluxes from the future EPS/MetOp mission.
6. Development of physically based drought monitoring and prediction method (Hydro-climatologic modeling) on the basis of EPS/MetOp observations.

In particular, the EAGLE2006 campaign addressed important specific programmatic needs of Sentinel-1 and -2:

1. To assess the impact of Sentinel-1 and Sentinel-2 sensor and mission characteristics for land applications (land use mapping, parameter retrieval) over forest and grassland.
2. To provide a basis for the quantitative assessment of sensor or mission trade-off studies, e.g. spatial and radiometric resolution.
3. Simulate Sentinel-1 and Sentinel-2 image products over the land (forest and grassland).

In the context of Sentinel-1, EAGLE2006 aimed primarily at the investigation of radar signatures over forest and grassland simultaneously which is currently not addressed. An important dataset of coordinated in-situ and airborne SAR measurements is collected which provides support both to studies of the Sentinel-1 technical concept, as well as contributing to studies of future mission concepts involving parameter retrieval at L-band.

As part of the refinement and verification of the Sentinel-1 technical concept, EAGLE2006 data will be used for the assessment of land use classification using the proposed nominal operating configuration (i.e. IW mode, VV + HH polarisation plus co-polarisation). Simulation of Sentinel-1 image products is planned.

By including an optical data acquisition component, the campaign also provides feedback on key issues relating to definition of the ESA Sentinel-2 multi-spectral mission requirements. Attention focuses on the investigation of the optimum position and width of spectral bands for land cover/change classification and retrieval of bio-geophysical parameters (e.g. improved surface classification, quantitative assessment of vegetation status – forest and grassland). The imaging spectrometer data acquired as part of EAGLE2006 will be used to simulate Sentinel-2 L1b products using the proposed different configurations, and to investigate compatibility with the envisaged L2/L3 products.

Campaign participating institutions

EAGLE2006 involved 16 different institutions coming from 6 different countries. During the intensive ground campaign in total 67 people from 16 different countries were involved.

Experimental Sites

Simultaneous measurements took place at three sites:

- Cabauw, grassland, 51°58’00” N, 04°54’00” E, -0.7 m. a.m.s.l.
- Loobos, forest, 52°10’02.8” N, 05°44’38” E, 23 m. a.m.s.l.
- Speulderbos, forest, 52°15’08.1” N, 05°41’25.8” E, 52 m. a.m.s.l.

Figure 1. Overview of the EAGLE2006 experimental sites in the Netherlands – Cabauw, Loobos and Spelderbos towers.

Cabauw

The Cabauw site is located approximately at the central western part of the Netherlands near the village of Cabauw. In 1972 at Cabauw a 213 m high mast was built by the Koninklijk Nederlands Meteorologisch Instituut (KNMI). This tower was built to establish relations between the state of the atmospheric boundary layer (ABL), land surface conditions and the general weather situation for all seasons. The Cabauw mast is located in a polder 0.7 m below average sea level.

Figure 2. The 213 meter high Cabauw tower as seen during different weather conditions (Source: KNMI).

The instruments are mounted on a 213 m tower placed in an extensive grassland area. In the immediate surroundings of the tower (corresponding to an area of 1 ha) the grass is kept at a height of 8 cm by frequent mowing. Apart from scattered villages, roads and trees the landscape within a radius of at least

20 km consist of flat grassland. Approximately 1.5 km south of the tower runs the river Lek, which is one of the main branches of Rhine. The river is a few hundred meters broad. The water holding capacity of the soil at the site is high, the soil being fine grained with a high content of organic matter. The ground water level in the whole catchment area, within which the field tower is located, is artificially managed through narrow, parallel ditches spaced 40 m apart from each other. The water level in the ditches is always kept at 40 cm below the surface level maintaining the level of the ground water table near the surface. Due to the rich supply of water and the fine grained soil, the evaporative fraction rarely falls below 0.6.

More detailed info is provided in (Ulden & Wieringa, 1996). An overview of recorded data is provided on the web at:

http://www.knmi.nl/kodac/ground_based_observations_climate/cabauw.html

Loobos

The Loobos site is located two kilometers south-west of the village Kootwijk. Continuous micrometeorological measurements are carried out since 1997 at a height of 23 m above the surface. In a radius of 500 m 89% of the vegetation consists of pine trees, with an average height of about 16 meter, 3.5% is open vegetation e.g. heather and the remainder is a mixture of coniferous and deciduous trees.

Figure 3. The Loobos forest (left panel) and the ALTERRA flux tower (right panel) (Source: Alterra)

Some more detailed information is available from the ALTERRA research web-site at: http://www.loobos.alterra.nl

Speulderbos

The Speulderbos site, operated by the National Institute for Public Health and the Environment (RIVM), is located approximately 60 km northeast from Cabauw within a large forested area in the Netherlands. The tower is placed within a dense 2.5 ha Douglas fir stand planted in 1962. The tree density is 785 trees per hectare and the tree height in 1995 was approximately 22 m, which has grown till 32 meter in 2006! The tower, which is currently not used for operational measurements, is 46 meter high and has power until a height of 34 m. The single-sided leaf area index varies between 8 and 11 throughout the year. The surrounding forest stands have typical dimensions of a few hectares and varying tree heights. Dominant species in the neighbourhood of the Douglas fir stand are Japanese Lark, Beech, Scotch Pine and Hemlock. At a distance of 1.5 km east from the tower the forest is bordered by a large heather area. In all other directions the vegetation consists of forest at distances of several kilometers. The topography is slightly undulating with height variations of 10 to 20 m within distances of 1 km.

Figure 4. Speulderbos RIVM (left panel) and a view from the top (46 m) of the tower in the direction of the forester tower (Source: RIVM/ECN/ITC).

Another tower, currently used by foresters of SBB, in the area is located in Drie at about 2 km distance at 52°15'54.8" N latitude and 5°40'39.4" E longitude. A Large Aperture Scintillometer (LAS) is installed between this and the previous tower to obtain spatial average sensible heat fluxes.

Base data for the experimental sites include topographic data, a Digital Elevation Model data (AHN), and National data.

Topographical data for the entire study area is digitally available, originating from scale 1:50,000 and scale 1:10,000 topographical maps.

Digital elevation data from the Actual Height model of the Netherlands (AHN) is available for the areas of interest. The AHN is a detailed elevation model of the entire country obtained form Airborne Laser Altimetry. The Actual Elevation Model is an initiative of three layers of authorities in the Netherlands, i.e. "Rijkswaterstaat" (Ministry of Transport, Public Works and Water Management), the water boards, and the provinces. As such, it consists of a uniform, country-covering dataset that is commercially available to third parties.

Basically two data formats are available; the so-called "base database", which contains filtered elevation points, with X, Y and Z coordinates of the RD (triangulation of national grid) and NAP (Amsterdam Ordnance Datum, the Dutch National leveling reference system), and the grid database of the 5x5 m resolution raster data for the EAGLE2006 campaign.

Satellite data acquisitions

Successful satellite data acquisitions include: MERIS, MODIS, AATSR, ASAR, ASTER, MSG/SEVIRI for the entire campaign period. Figure 5 shows an example of a MERS image and figure 6 a SEVIRI image.

Figure 5. Part of MERIS scene as acquired on 11th of June 2006 over the study area (RGB: 3-2-1).

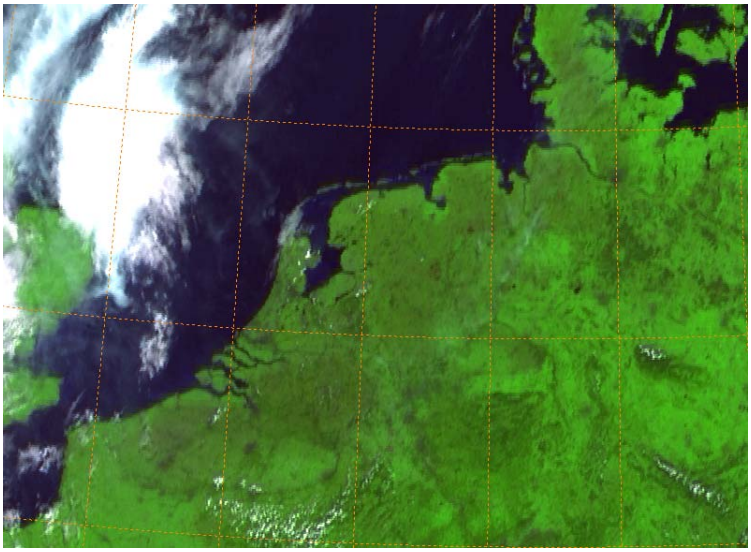

Figure 6. SEVIRI observation over the Netherlands of 13 June 2006, 1200 GMT.

Airborne data acquisitions

Four airborne sensors were operated during the EAGLE 2006 campaign to acquire valuable data for bio-/geo-physical parameter estimation over the grassland and forest sites. The AHS from INTA and the CASI sensor of ITRES were both mounted on the CASA 212-200 N/S 270 “Paternina” airplane of INTA. Because the objective of the campaign was primarily aiming at AHS acquisitions the configuration was designed such that if conflicting criteria between AHS and CASI occurred preference was given to AHS. Furthermore, DLR-HR flew a Do228 aircraft that carried their multi-frequency and multi-polarisation Synthetic Aperture Radar system, and ISAFoM operated a Sky-Arrow airplane for flux measurements.

Successful AHS and CASI acquisitions were made on 13 June 2006. Some quicklooks are shown in figures 7 and 8.

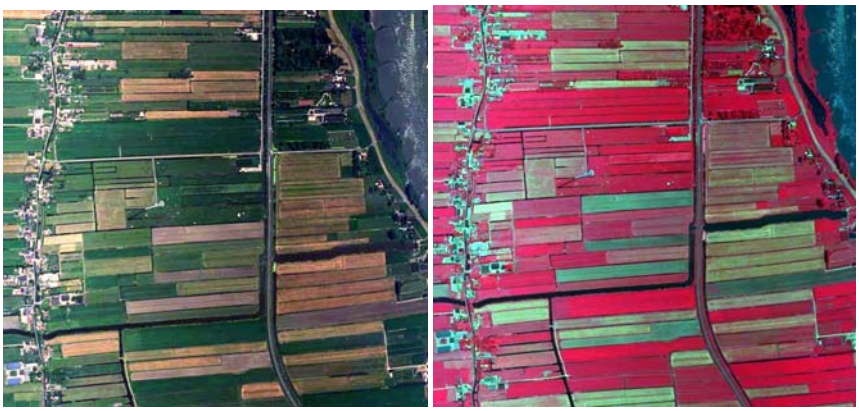

Figure 7. Quicklooks of AHS images (Left: AHS Channel 01, 04, 08 as RGB combination, right: AHS Channel 04, 08, 15) for the Cabauw site, the Netherlands of 13 June 2006 (The Cabauw tower with its shadow is visible).

Figure 8. A quicklook of CASI image (CASI channel 29, 17, 05 as RGB combination) for the Cabauw site, the Netherlands of 13 June 2006 (The Cabauw tower with its shadow is visible)

Eleven ESAR flight tracks were carried on the 15 June 2006 to cover three sites of interest flying X-, C-, and L-band configurations, as well as to obtain an X-band DEM. Figure 9 shows a C band polarimetric image of yhe Cabauw site.

Figure 9. C-band ESAR image of the Cabauw tower site, acquired on 15 June 2006 (The Cabauw tower is visible as a white dotted line in the middle)

The Sky Arrow flux flights were performed over the three tower sites to compare the airborne fluxes measurements with the towers fluxes measurements, and also to quantify the exchange of carbon dioxide, sensible and latent heat, momentum fluxes between the biosphere and different vegetated surfaces. Table 1 shows the flight configurations. The flight on 13 June 2006 was performed at the same time as the INTA CASA aircraft mission, to collect fluxes information and hyperspectral data

simultaneously. First results of the profiles flown in the first mission over the different areas are shown in Figure 10.

Table 1. Sky ERA flight overview.

Mission ID	Date	Target	(UTC)	Site
1	13/06/2006	Fluxes	11:41	Speulderbos, Loobos, Cabauw
2	13/06/2006	Fluxes and divergence	16:00	Speulderbos, Loobos
3	14/06/2006	Fluxes	11:56	Speulderbos, Loobos

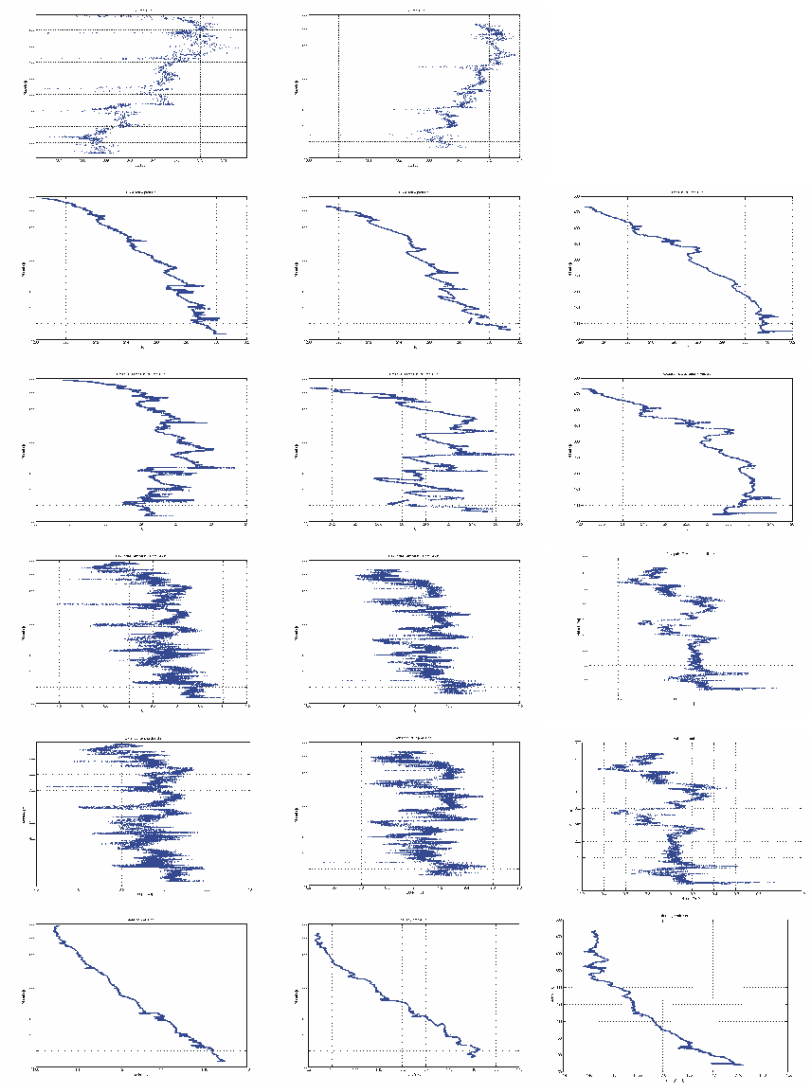

Figure 10. Atmospheric profiles as measured by over the three sites on 13 June 2006. The left column shows the profiles over the start at the Speulderbos (North), the middle column shows profiles over the Southern part of the Speulderbos, approaching the Loobos area, whereas the right column shows profile measurements over the Cabauw site. From the top to the bottom, the 6 panels in each column show Carbon dioxide, air temperature, potential temperature, dewpoint temperature, water content and air density, respectively (Carbon dioxide is missing of the Cabauw site).

Atmospheric measurements

Knowledge of the atmospheric conditions its vertical profile and the water content is required to perform accurate atmospheric corrections of space and airborne observations. Two types of measurements were performed. In-situ atmospheric soundings were carried out during airborne overpasses at the Cabauw site (Figure 11). Furthermore routine measurements carried out at De Bilt, KNMI and at the Cabauw tower site are available as well.

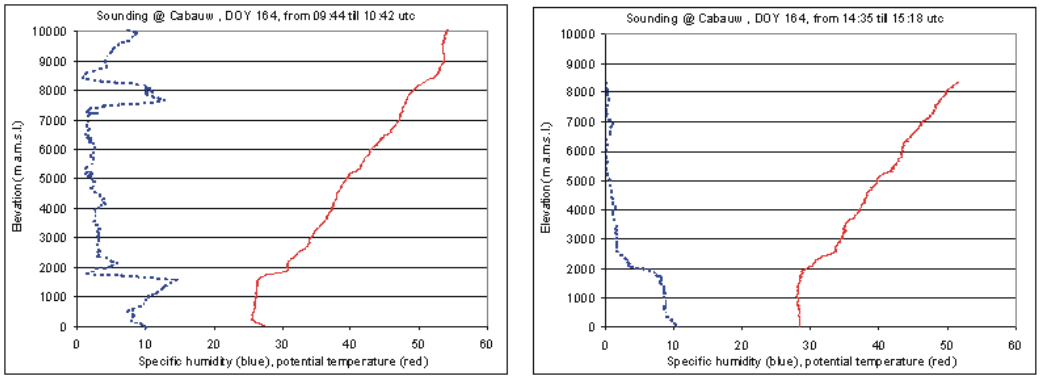

Figure 11. The processed soundings output from 13th of June 2006, Cabauw.

The KNMI Cabauw tower site is also part of the CESAR (Cabauw Experimental Site for Atmospheric Research) Consortium. This is a consortium of seven national institutes in the Netherlands working together on land-atmosphere and atmospheric research. For the duration of the EAGLE2006 Campaign we have direct access to the data recorded and they are included in the EAGLE2006 database.

Other essential measurements include ground based data, including ground-based data (radiometric data in both solar range and thermal range data, surface surface energy budget data, micro-meteorological data, and gniometric data); ground bio-physical data (biomass data, PAR data, soil moisture data, wter data, LAI data, rughness data, eissivity data, laser scan data, and DGPS data), reference meteorological data (Cabauw-KNMI data and Loobos-ALTERRA data).

The data analysis included simulation of Sentinels (Sentine-1/2) and biophysical products. Advanced products include the following:

- Net ecosystem exchange and footprint analysis above forest and grassland
- Temperature and emissivity form AHS data
- Modeling fluxes of energy, water and carbon dioxide above the Speulderbos
- MBRDF's acquired by directional radiative measurements
- Soil moisture field observations over the Cabauw grassland
- Technique for validating remote sensing products of water quality

Full details of these data can be found in the EAGLE 2006 final report (Timmermans, et al., 2007) and the description of advanced products are given in other contributions to this proceedings by other team members.

Conclusions and recommendations

This contribution describes the mission objectives and provides an overview of the airborne and field campaigns. A unique dataset has been acquired, including (quasi)simultaneous SAR and optical (hyperspectral, visible and thermal) and atmospheric turbulence airborne datasets as well ground measurements. Atmospheric data from different ground based sensors has been gathered in combination with in-situ atmospheric soundings to characterize the atmospheric conditions during airborne and satellite acquisitions. The SAR data are of high quality at different frequencies (with relevance to Sentinel-1 simulation) and the optical data are of high quality as well (for Sentinel-2 simulation). In addition, the turbulence acquisitions and ground data are of also good quality.

Analysis showed a high potential of the data for use in further studies as well as a high potential for new product development. With respect to SAR, a combination of L- and C-band is preferred for

classification purposes and the optical CASI and AHS system specifications are all together optimal for bio-physical parameter retrieval. With respect to the atmosphere, validation and sensitivity of water and heat (energy) balance has been performed, where thermal data has been found an essential input to the models.

With respect to potential products for the Sentinel-1 and Sentinel-2 missions, land cover classification maps currently can be considered as in a pre-operational phase. For soil moisture maps, surface roughness, biomass, fractional vegetation cover and LAI products, the algorithm are in an experimental stage, whereas maps of actual evapotranspiration can be considered as a potential level 3 experimental product as well (providing the thermal input).

Furthermore, we have observed the need for a continuous agricultural data acquisition to cover a bigger variability. With respect to that, a higher crop diversity and variability in surface conditions is needed for future field campaigns. In addition, multi-temporal, as well as simultaneous observations with both SAR and optical sensors are desirable. With respect to ground observations, a higher data acquisition frequency might be needed, in combination with the need for investigation of the separation between bio-physiological (vegetation growth) and natural (wind, rain) effects.

Preliminary results on retrieval of biophysical parameters are available and the entire EAGLE2006 dataset allows the development of new processing and retrieval algorithms, and the validation of such algorithms by in-situ, airborne and space-borne data. More details on several processing aspects of the data acquired within the campaigns are presented in the successive papers in the proceedings. All in all, the strongly multi-disciplinary character of the EAGLE2006 field campaign is considered a very strong aspect. Hence, an intensive analysis by the (very) different teams, and external users, with the collected data should be supported.

All data as acquired in and during the EAGLE2006 Field Campaign are available via the Field Campaign ftp site (ftp.itc.nl/pub/eagle06/EAGLE2006_Database/). Access is possible via the ESA Principle Investigator portal.

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