

# **The NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS) – a new partnership for supporting the UK academic community**

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## **Abstract**

This paper introduces the NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS) a new facility combining two existing services, one at the University of Dundee (the Dundee Satellite Receiving Station) and at the other at Plymouth Marine Laboratory (the Remote Sensing Data Analysis Service). Activities undertaken by the new service are described ranging from direct-broadcast data received at Dundee to higher level processing at Plymouth. Examples include processing of sea-surface temperature and ocean colour data in support of UK marine observation, model validation and research cruises support; terrestrial and atmospheric products making use of the extensive archive of MODIS and AVHRR data available at the service. A new service for atmospheric correction of NERC airborne remote sensing imagery is presented along with proposed future services and an opportunity to influence further developments by NEODAAS.

## **1 Introduction**

In September 2006 a new service called the NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS) will be launched bringing together the expertise at the Dundee Satellite Receiving Station (DSRS) and the Plymouth-based Remote Sensing Data Analysis Service (RSDAS). NEODAAS will continue the reception and archive of direct broadcast satellite data from polar orbiting and geostationary satellites started by DSRS in the 1970's. The Station currently receives around 25 passes per day from a range of satellites using several antennas and has a long-term archive of over 70,000 satellite overpasses. Historically, RSDAS has undertaken value-added near-real time data processing from the direct broadcast received at Dundee; in addition other data available globally within hours of reception from NASA and ESA are processed. By combining these two services it is aimed to provide a single portal for raw (level 0/1) to geophysical mapped or composite data sets (level 3) available in near-real time or from the archive, for the EO, marine, atmospheric, terrestrial and Earth science communities. This paper provides a brief description of the history of the two component services, details of the data available to the user, some examples of the high level services that NEODAAS is able to support and finally some indications of future developments in the new combined service.

## **2 History**

### *2.1. Dundee Satellite Receiving Station*

The University of Dundee has run the DSRS in support of NERC scientists and other users for almost 30 years providing a high quality data acquisition, archiving and dissemination service.

The first tracking antenna at DSRS was installed in 1975 and received 2-3 passes per day from the Very High Resolution Radiometer (VHRR). Digital transmissions from the Advanced Very High Resolution Radiometer (AVHRR) instrument lead to the upgrade of the antenna in 1978 and the installation of a second in 1981. Prior to the launch of the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) in 1997 a third system was installed along with additional receiver and processing computers. In 1998 an upgrade allowed for the reception from satellites transmitting in X-band, with the initial target missions being NASA's Terra and Aqua platforms carrying the Moderate-resolution Imaging Spectroradiometer (MODIS) instrument. The following year DSRS was the first UK facility to receive data from Terra-MODIS and has subsequently installed two further X-band antennas.

Until the late 1980's products comprised enhanced photographic prints and digital data on 10" computer tapes and were distributed by post and by courier/fax for near-real time requirements! A major landmark was the start of routine network delivery of data to researchers in Plymouth. This has become central to operations and is particularly critical in support of near-real time applications such as research cruises. It is an important factor in the NEODAAS partnership. In 1994 the DSRS Web site was launched and initially provided users with online access to browse images, a facility to search the archive catalogue and general information about the Station. The site has grown steadily in terms of facilities and user interest throughout the past 12 years and now has over 250,000 registered users and serves in excess of 24 million web pages per annum. The web site has also encouraged the shift towards internet distribution of products, such that almost all data have been provided over the internet in recent years.

## 2.2. *Remote Sensing Data Analysis Service (RSDAS)*

RSDAS at the Plymouth Marine Laboratory was established as a NERC funded service in 1995 to produce higher level, georeferenced physical or biological, near-real time and high spatial resolution products. The major user base for RSDAS has always been the marine community exploiting products including sea-surface temperature and ocean colour, such as chlorophyll (chl-a) and suspended particulates matter (SPM). However, RSDAS has also supported research on land cover (vegetation indices), volcanoes (brightness temperatures) and the atmosphere (cloud and aerosol optical properties). A key activity is the near-real time support of research cruises and observatories. Since the oceans are dynamic environments with transient features such as phytoplankton blooms or mesoscale eddies it is often necessary to modify sample locations subsequent to departure of a research vessel. By sending satellite data direct to the ship it is possible to modify or fine tune experiments "on the fly".

## 3 **Methods**

### 3.1. *Data reception at Dundee*

Data have been received routinely from the following polar orbiting satellite instruments:

- AVHRR            1978 to present day
- MODIS           2000 to present day
- CZCS            1979 to 1986
- SeaWiFS        1997 to 2004 (and from Dec 2004 to present day but data encrypted)

The Geostationary archive from 0.0 degrees longitude consists of Meteosat data from 2001 – 2006 and Meteosat Second Generation data are also received every six-hours and images have been available on-line from 2005. A 30 day rolling archive of images is also available from the other geostationary satellites covering the Indian and Pacific Oceans and the American Continents.

The installation of 12 terabytes of storage capacity in 2003 has allowed for the entire AVHRR, SeaWiFS and CZCS archives to be made available on line providing the ability to run algorithms across the entire archive as demonstrated with the CONTRAILS project (see below).

### 3.2. Data processing at Plymouth

Immediately after reception at Dundee the direct-broadcast data are transferred over the internet to Plymouth where higher level processing is undertaken; AVHRR products are available less than hour after reception and processed into sea-surface temperature (SST) following Miller *et al.* (1997); MODIS data are processed into ocean colour and atmospheric products (Shutler *et al.*, 2005a) typically 1-2 hours after reception. Plymouth also receives satellite data via the internet providing global coverage including: MERIS level 2 data from the ESA rolling archive mapped in a similar manner to MODIS (Shutler, *et al.*, 2005b); SeaWiFS data at 4-km resolution (processed following Lavender and Groom, 1999). MODIS data from NASA and AVHRR data from the NOAA-CLASS archive are also processed using similar methods to those applied to data from Dundee. Finally, NEODAAS Plymouth have developed atmospheric correction software to process ocean coastal and inland water imagery from the NERC Airborne Research and Survey Facility (ARSF). A summary of the data available from NEODAAS either in near-real time or on request is shown in Table 1.

Table 1. Data available from NEODAAS in near-real time or on-demand.

Level	Sensor	Products
1	All	Top-of-atmosphere radiances and true-colour.
2	MERIS-reduced resolution	Ocean colour properties (case 1 & 2 chl-a, coloured dissolved organic matter, back scatter, radiances, true colour) Vegetation Indices Cloud Properties
	MODIS Aqua	Ocean colour properties (case 1 chl-a radiances); other products such as case 2 chl-a, coloured dissolved organic matter, backscatter available cloud and atmospheric properties are available on demand
	SeaWiFS	Ocean colour properties (case 1 chl-a radiances); other products such as case 2 chl-a, coloured dissolved organic matter, backscatter available on demand
	AVHRR	Sea-surface temperature; land brightness temperatures; vegetation indices
3	All	High spatial resolution (1 km) rolling 7-day and discrete weekly and monthly composites of most ocean colour and temperature properties.
	All	Medium spatial resolution (4 km or 9-km) composites (daily, 8-day, monthly, seasonal, annual, climatology) extracted from NASA & NOAA global time-series datasets.
	casi	Atmosphere-corrected water imagery for case 1 waters
4	Combined	Ocean primary production.
	All	Oceanic front map (based on temperature or ocean colour property)
	Ocean colour	Phytoplankton anomaly maps; HAB likelihood (development products)

### 3.3. Data access

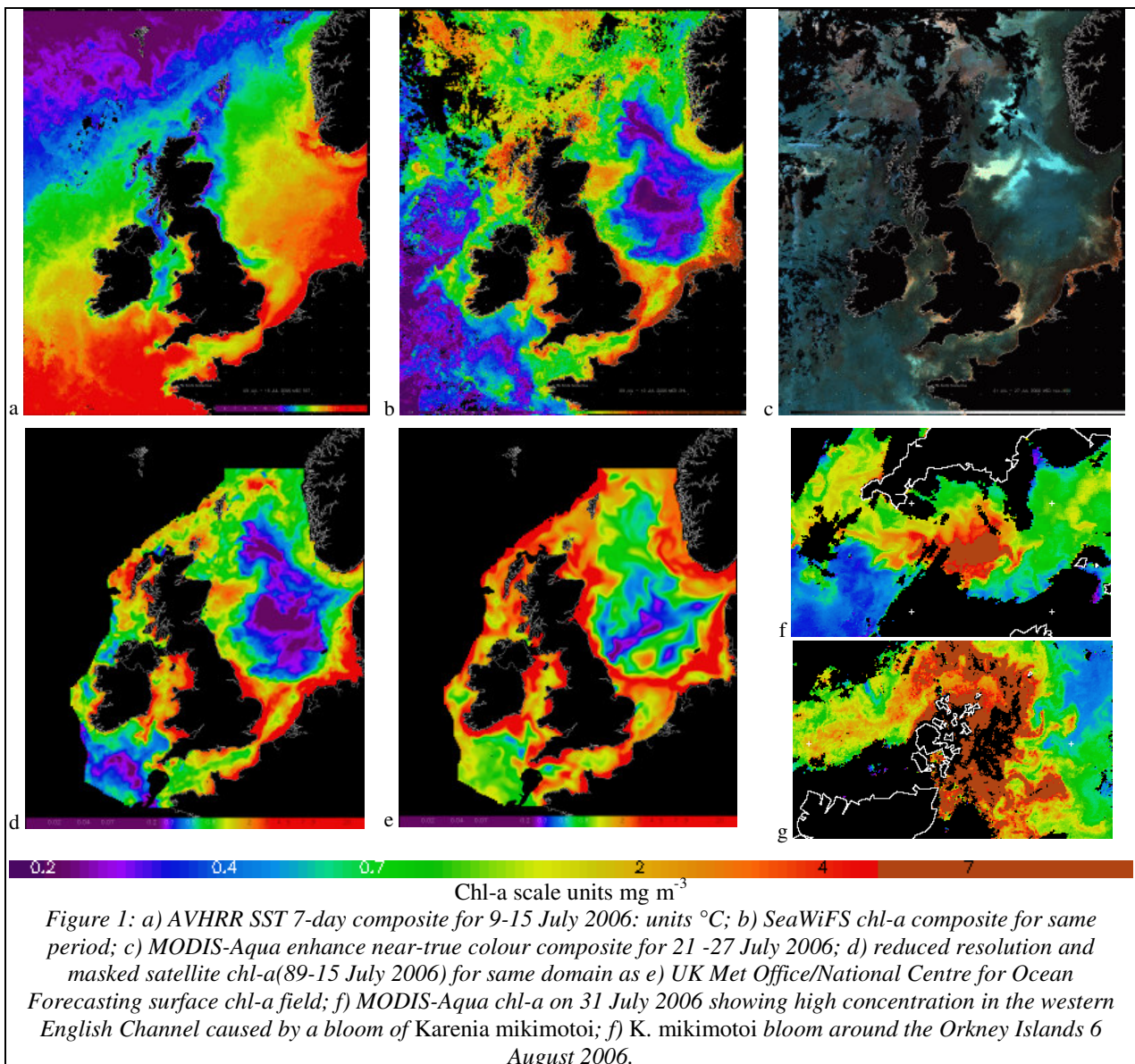
Data can be obtained from the NEODAAS web site (currently [www.npm.ac.uk/neodaas](http://www.npm.ac.uk/neodaas)) in a variety of forms. Quicklooks can be obtained following a simple and quick automatic on-line registration, whereas full resolution, processed or long-term datasets require a simple application to meet the requirements of NERC for supported work to be peer-reviewed. NEODAAS holds all AVHRR, SeaWiFS (1997-2004) and Coastal Zone Colour Scanner (CZCS) data at level 0/1 on-line together with a large collection of level 2 and mapped biological and physical properties.

## 4 Results and discussion: case studies of NEODAAS data and services

A number of case studies are included below to show how data supplied by NEODAAS may be used in support of scientific research.

### 4.1. Marine applications: the UK observatory

One of the main activities at Plymouth is the processing of marine data for standard user regions of interest (ROI): all data received covering the ROI are automatically processed and made available via the website. The most utilised ROI is the northwest continental shelf region that includes the UK, Ireland and coastal regions of the North Sea and English Channel. Individual satellite overpasses together with daily and rolling 7-day composites are produced and these are used for a variety of activities.



#### 4.1.1. Observation of physical and biological characteristics

The AVHRR-SST weekly composite for 9 -15 July 2006 (Fig 1a) shows the general north-south temperature gradient, and also mesoscale features such as eddies in the North Atlantic and tidal fronts in the western English channel, Irish Sea and North Sea. The corresponding SeaWiFS chl-a composite is presented in Fig 1b; the phytoplankton spatial structure in many locations is

related to physical processes, essentially through vertical mixing, stratification and availability of nutrients in surface waters. The Aqua-MODIS enhanced near-true colour composite for 21- 27 July 2006, a combination of the 443, 490 and 555 nm MODIS bands, in Fig. 1d shows the variability in reflectance: in the northern North Sea and western English Channel enhanced scattering is caused by blooms of the coccolithophore *Emiliana huxleyi* whereas in the Thames Estuary, Bristol Channel and Irish Sea scattering by inorganic particulates enhances the water reflectance.

#### 4.1.2. Numerical model validation

The SST and chl-a images are also used in a prototype validation of outputs from a physical-ecosystem model run by the UK Meteorological Office for the National Centre for Ocean Forecasting (NCOF). The satellite data (Fig 1d: chl-a from 9-15 July) are reduced in resolution and masked to cover the model domain (Fig. 1e), the model output is also masked to remove any cloud covered areas in the satellite image. Various analyses are undertaken including Receiver Operator Characteristics and Skill Score (see <http://www.npm.ac.uk/rsg/projects/mceis/zx>). The satellite and model SST comparisons (data not shown) have good agreement but the chl-a less so: broad scale variability is similar but problems in case 2 waters limit the accuracy of the satellite data while improvements are also required in the modelled phytoplankton. These comparisons are preliminary but it is likely that the use of satellite data to validate numerical models (coupled with data assimilation to initialise or update models) is to be an increasingly important activity for NEODAAS.

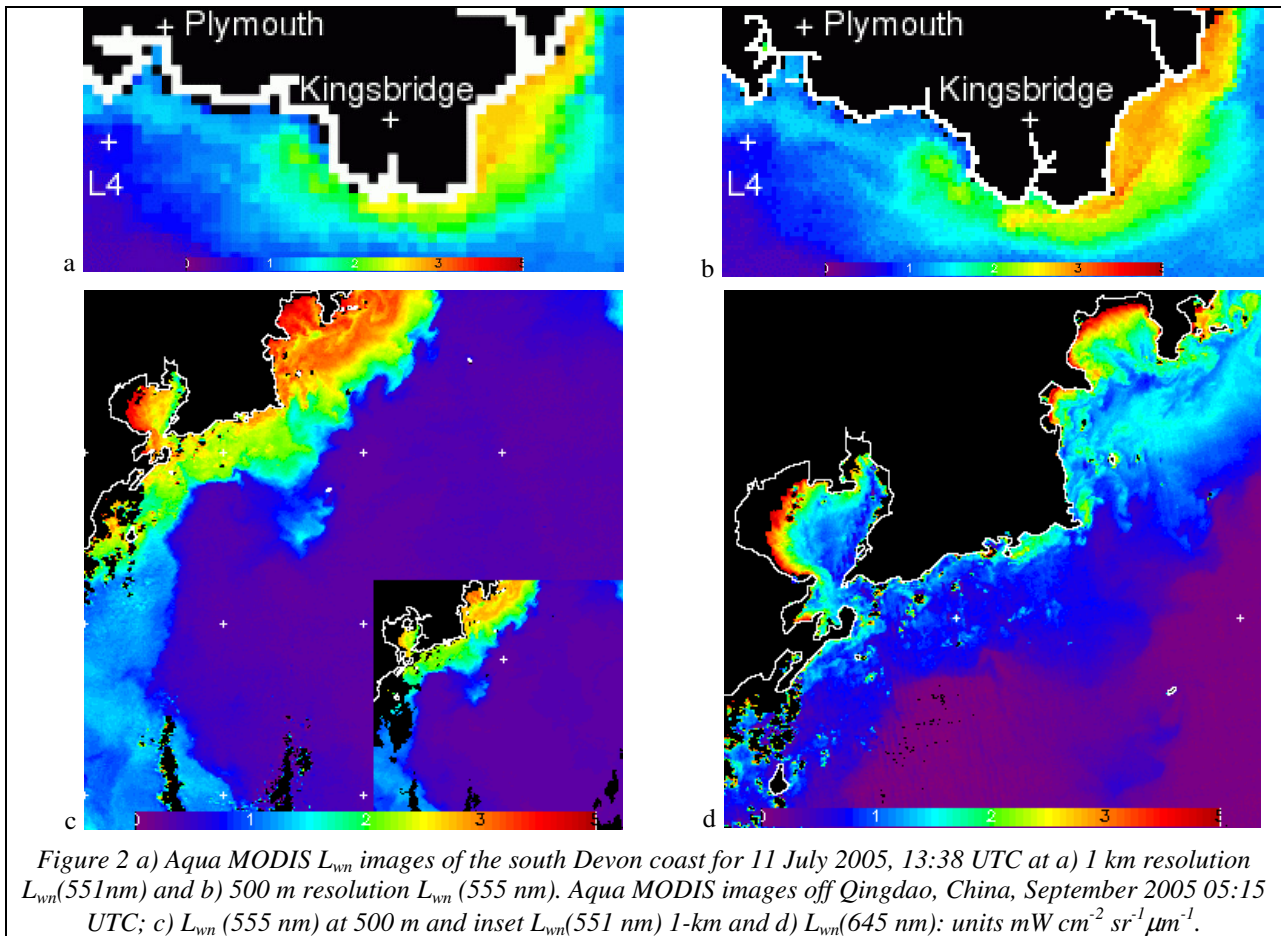
#### 4.1.3. Cruise guidance and *in situ* monitoring

Fig 1 f & g show enlargements from Aqua-MODIS chl-a images of the Orkney Islands on 31 July 2006 and the western English Channel on 6 August 2006. Both images show very high chl-a concentrations caused by blooms of the dinoflagellate *Karenia mikimotoi* (confirmed by *in situ* sampling). In the case of the western English Channel images like this were used to guide research sampling on 26 July southwest of Plymouth to measure biological properties of both *K. mikimotoi* and the coccolithophores visible on Fig. 1d. *K. mikimotoi* is known to be toxic to fish and harmful algal blooms are of major concern to the aquaculture industry – the remote sensing data processed in near-real time were able to show the extent and development of the bloom around the Orkneys (Fig. 1f). The satellite data on both blooms were provided to the regulatory authorities and the aquaculture industry and such EO data will be a crucial data source for of coastal zone monitoring in the European Global Monitoring for Environment and Security (GMES) projects.

## 4.2. Coastal monitoring and the 2008 Olympics

The ocean colour data presented above are at 1-km spatial resolution but for coastal and estuarine applications higher spatial resolution is required. NASA's MODIS on Terra and Aqua can capture data at both 250 m and 500 m spatial resolutions and the existence of two sensors provide the possibility for multiple daily passes over a scene. NEODAAS Plymouth have developed algorithms to allow these higher resolution channels to be used in ocean colour studies (Shutler *et al.*, 2006). Figure 1 a & b shows a comparison of 1 km and 500 m  $L_{wn}$  estimates along the south Devon coastline on 11 July 2005, 13:38 UTC.

An interesting use of the high resolution data, that also demonstrates the global capability of the NEODAAS data processing, is the 250 m 500 m and 1-km data around Qingdao, China, on the 6 September 2005 05:15 UTC (Fig. 2 c & d). Qingdao is the 2008 Olympic sailing venue and NEODAAS is processing data for this area during Summer 2006 coincident with sampling and sailing by the Royal Yachting Association. A tidal model has been set up at Proudman Oceanographic Laboratory and this will be compared to the satellite data. This joint modelling and near-real time EO processing approach was successfully during the Sydney Olympics to provide information on water conditions, current regimes and their variability (Proctor *et al.* 2001).



#### 4.3. Terrestrial land use and agricultural applications

NEODAAS can supply AVHRR derived Normalised Differential Vegetation Index (NDVI) values derived for terrestrial and land use research; for example, 1,600 AVHRR scenes of the Iberian Peninsula over six years were processed and integrated into monthly composite maps. These were compared with sampled distributions of three bird species and analyses of seasonal and interannual variability in their habitats (Suarez *et al.*, 2002). NEODAAS can also supply MERIS vegetation index values. Alternatively, level 0/1 data can be provided to users to undertake their own processing as follows.

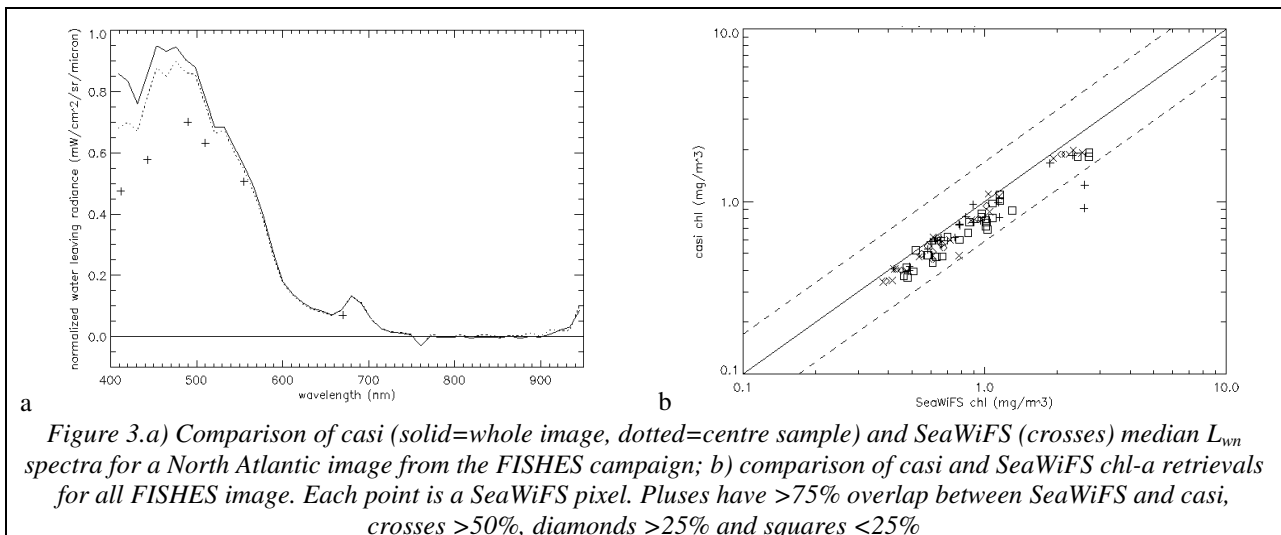
NEODAAS is providing MODIS data to the NERC Centre for Ecology and Hydrology (CEH) to support their UK Phenology Observatory project to monitor seasonal vegetation cycle indicators. Using a long time-series of data, CEH hope to detect and monitor change and distinguish cyclic variations from long-term trends that may indicate climate change. Near-real time delivery to CEH of MODIS data over the UK began in March 2006 and a CEH prototype processing chain is used to derive cloud cleared NDVI composites. More standard MODIS processing modules will be implemented to generate higher level products from the data. Once the full processing chain is complete, all archived MODIS data for the UK since 2000 will be supplied to fully validate any underlying seasonal variations and long-term trends. In the longer-term CEH hope to derive a wider range of terrestrial and atmospheric products and validate these against *in situ* ground-based measurements.

A significant amount of AVHRR archive data are being supplied to the Flemish Institute for Technological Research (VITO) to create daily reflectance, radiance and brightness temperature composites and derive vegetation and crop yield indicators. This is in support of an EC Joint Research Centre project Monitoring Agriculture with Remote Sensing (MARS) that uses remote

sensing data in combination with models to derive crop yield estimates and forecasts in support of the EC's Agriculture Directorate and EU agricultural policy.

#### 4.4. NERC Aircraft Atmospheric Correction

Algorithms have been developed at NEODAAS for atmospheric correction of NERC airborne compact airborne spectrographic imager (casi) data over water. The method corrects for sunglint and aerosols and applies a correction for nonzero near infrared (NIR) water leaving radiance. For case 1 waters, where the optical properties are determined by the plant plankton and co-varying detrital material, the default is to use the algorithm from NASA's processing package SeaDAS. This may also be applicable in "mildly" case 2 waters where some influences on the optical properties are independent of the plant plankton. For case 2 waters affected by SPM and coloured dissolved organic matter (CDOM), two methods are being developed of which one is operational and region-specific, suitable for use in physically limited systems such as estuaries where the specific inherent optical properties (SIOPs) have been measured. The motivation for this is that ARSF data have been obtained for at least two such systems, the Tamar in Devon and the Conwy in north Wales. The method has been extended to correct airborne thematic mapper (ATM) data using the atmospheric correction parameters retrieved from casi. This extension is working but not thoroughly validated.



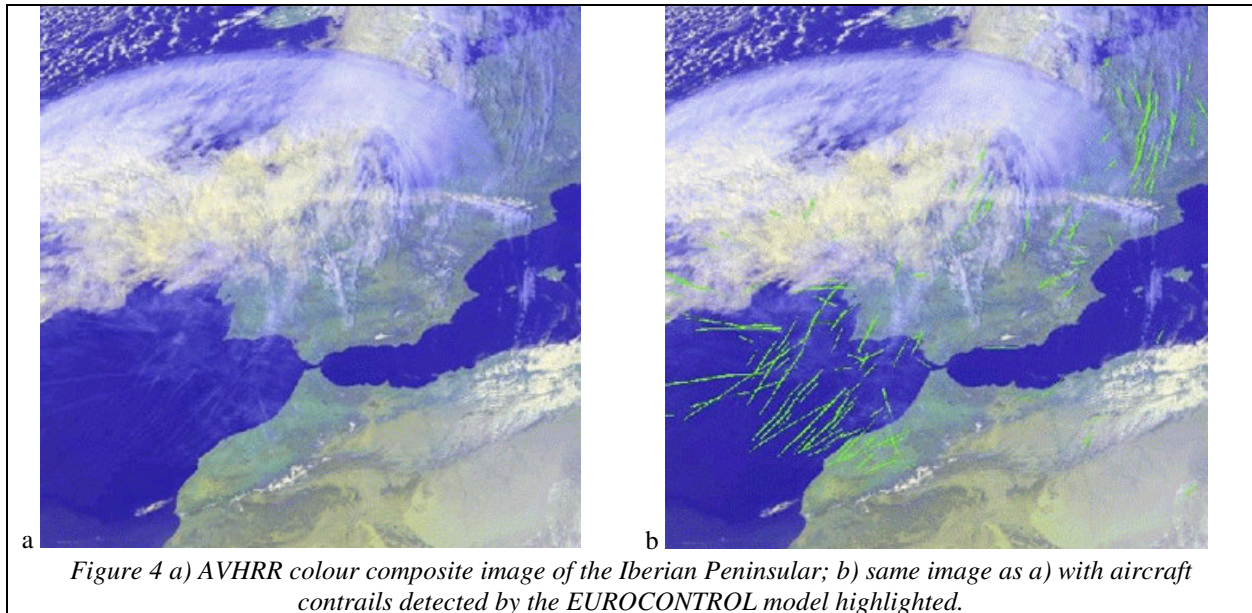
Some example results are shown in Figure 3a & b for casi data obtained by the NERC aircraft on 13 June 2001 in the North Atlantic coincident with a research cruise: The normalised water-leaving radiances ( $L_{wn}$ ) agree well with equivalent SeaWiFS data in the case 1 waters though with some overestimation in the blue and green part of the spectrum. Chl-a estimates are very similar to those from SeaWiFS (Fig. 3b) with an underestimation due to the residual  $L_{wn}$  errors. The atmospheric correction has also been applied to case 2 waters in a selection of inland waters and is being offered as an optional service for applicants to the ARSF.

#### 4.5. Atmospheric remote sensing: the "CONTRAILS" project

The University of Dundee is partnering DLR of Germany and KNMI of the Netherlands in the ESA CONTRAILS project that aims to develop and demonstrate a service to monitor aircraft condensation trails and resulting cirrus clouds, assess environmental effects of these and validate a contrail prediction model of the EUROCONTROL (European organization for the safety of air navigation) agency. A DLR algorithm was implemented at Dundee to produce contrail maps (figures 4a & b) and an automated processing chain set up to make use of the entire online AVHRR archive at NEODAAS. The local archive was supplemented by data from the NOAA archive to provide US East coast coverage. The first phase delivered prototype contrail maps

from a subset of the archive. The second phase involves processing the substantial volume of archive data to produce historical contrails maps extending back over a 20-year period.

This project demonstrates the importance of long-term strategic data acquisition and archiving and the shows how on-line data access and automation of processing can be used to produce decadal time scale analyses. It is also a good illustration of how users might provide algorithms to NEODAAS for implementation eliminating the need for processing by the user.



## 5 Conclusions and the future

NEODAAS brings together expertise in satellite data reception, archiving, processing and analysis into a single service. It is planned that this “one stop shop” will seamlessly provide access to level 0/1 data to level 3 high level products and enable the UK academic community to better exploit EO data. The “tie-up” will have a number of advantages that will be (hopefully) transparent to users such as greater robustness of systems including mirroring of data and processing capability at the two sites, and will lead to increases in speed of processing and data availability.

NEODAAS aims to develop new products and implement new services and is interested in hearing from potential users about their areas of interest. The service also aims to receive data from new satellite systems include the National Polar Orbiting Environmental Satellite System (NPOESS), the NPOESS Pilot Project and MetOp. NEODAAS are also seeking to receive data from other international space projects. Regarding products in development current plans include, *inter alia*:

- MODIS: new products will be made operational including ocean colour inherent optical properties (Smyth *et al.*, in press) and phytoplankton primary production (Smyth *et al.*, 2005).
- MERIS: it is hoped hope to introduce a full-resolution (300m) service when ESA make these data available in near-real time.
- Combined ocean colour products: we will investigate production of a full resolution (1-km) ocean colour product based on combined MODIS, MERIS and SeaWiFS data.
- Envisat: it is aimed to start a service for global ASAR products available from ESA.
- NCOF: following discussions we aim to make available NCOF ocean model forecasts for research cruise support
- Observatories and calibration/validation: during the year tools will be available to automatically extract data from satellite imagery in both un-gridded (satellite geometry) or

mapped imagery to enable construction of time series data, automated calibration/validation or input to observatories.

Users are encouraged to contact NEODAAS to apply for existing services or to suggest future developments: please see our website currently at [www.npm.ac.uk/neodaas](http://www.npm.ac.uk/neodaas).

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