CLOUDMAP 2

Research Project Contract No. EVG1-CT- 2000-00033 co-funded by the
European Commission, Research Directorate-General
5th Framework Programme
Environment and Sustainable Development
Development of generic Earth observation technologies.

Data assimilation of remotely sensed water vapour into the HIRLAM NWP model

Objectives

Assimilation of satellite-based measurements of integrated water vapour above land (cloud-free) and water vapour above clouds into the High Resolution Limited Area Model (HIRLAM) assimilation scheme

Current status

Successful preparations for the assimilation of columnar water vapour above land derived from MODIS measurements (MOD05)

A first assimilation experiment showed a noticeable impact on assimilated specific humidity

This new data source can give additional information in areas of low radiosonde coverage

The additional information is not lost in the case of good radiosonde coverage

Action Plan

Increase area / time for MODIS observations

Better estimations of observation error

Bias correction for MODIS observations

Improve super-observations (spatial and time average)

Include water vapour above clouds

Partner list

FUB: Freie Universität Berlin

SMHI: Swedish Meteorological and Hydrological Institute

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UCL DLR FU Berlin KNMI CLRC ETH SMHI

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Data assimilation of remotely sensed water vapour into the HIRLAM NWP model

From satellite measurements to assimilation

FUB Water vapour above clouds

MOD05

FUB Water vapour above land

HDF

Observation errors

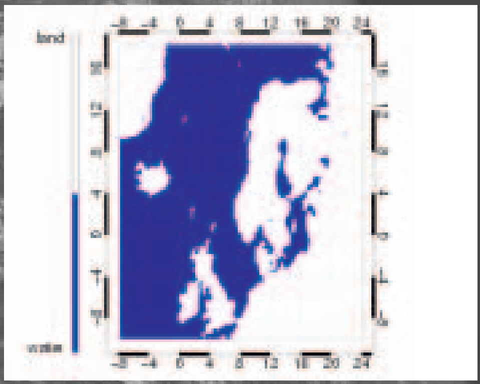
Spatial and time Average

ASCII

HIRLAM 3D-VAR

A first test

A first assimilation experiment was carried out for 01. 03. 2001:
MODIS MOD05 data was collected for this 1/6¡ HIRLAM area, the experiment was carried out for a larger area



Forecast 03 UTC + 3h

Observations between 04:30 and 07:30 UTC

Analysis 06 UTC

Forecast 06 UTC + 3h

Observations between 07:30 and 10:30 UTC

Analysis 09 UTC

Forecast 09 UTC + 3h

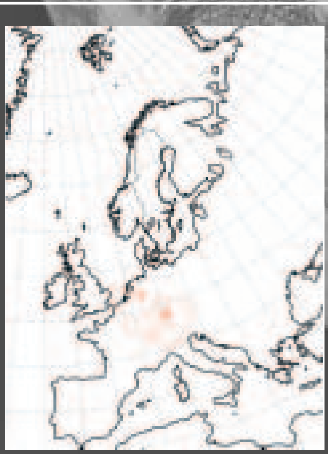
Observations between 10:30 and 13:30 UTC

Analysis 12 UTC

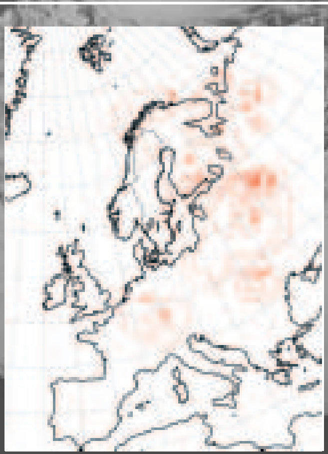
Current status

1.3.2001 09 UTC

Without MODIS data



With MODIS data



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Near Real-Time (NRT) Cloud Parameters from Satellite & Ground Based Sensors

Objectives

To develop fast, reliable and accurate algorithms to derive value-added cloud products within 30 minutes to 3 hours of data reception (NRT):

Level-2 cloud micro- and macro-physical products from direct broadcast MODIS data covering Europe and the North Atlantic region

Ground-based cloud data products available in NRT from the Chilbolton Radar Facility for comparative analysis

Value-added NRT Data products

Products from MODIS Data:
Cloud-detection, -cover, -type and physical properties in various map-projections

Products from ATSR-2 Data:
Cloud-detection and physical properties

Measurements from radar and lidar:
Vertical distribution and physical boundaries of clouds - complementary to ATSR and MODIS-overpasses

Action Plan

Integration of cirrus- and contrail-detection in MODIS- and ATSR-chain

Inclusion of AATSR and MERIS data

Continuous validation of products

Partner list

UCL: University College London, UK
NRT MODIS and radar cloud products

FUB: Freie Universit t Berlin, D
NRT MODIS and MERIS cloud products

DLR: Deutsches Fernerkundungsdatenzentrum (DFD), D
NRT MODIS cloud products

RAL: Rutherford Appleton Laboratory, UK
NRT ATSR-2, AATSR and radar/lidar cloud products

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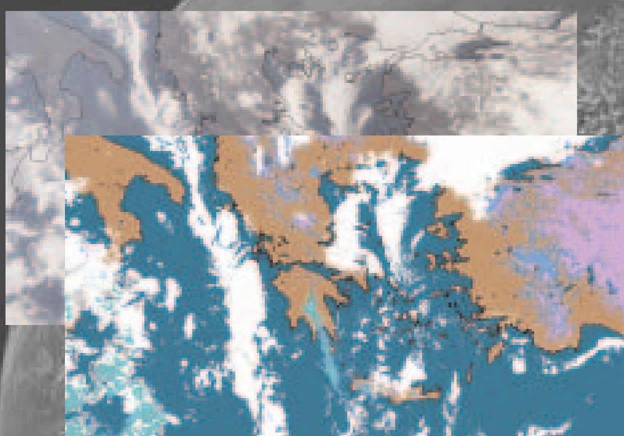
Examples of NRT Cloud Parameters for CLOUDMAP2

Cloud Products from MODIS - DLR
http://auc.dfd.dlr.de/modisnrt

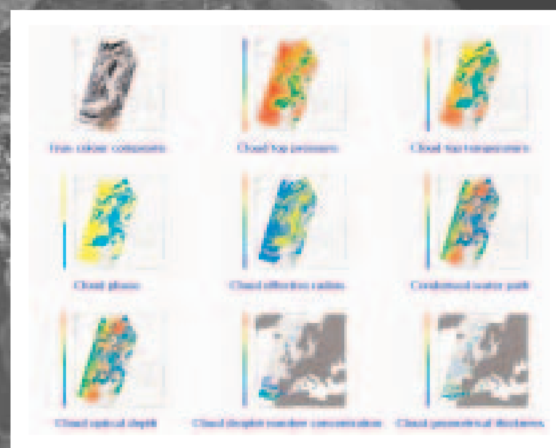
At DLR-DFD MODIS data is being received and processed up to level-2 and higher in NRT. Presently, the cloud analysis system includes cloud-detection, a separation between thick and thin clouds, water- and ice-phase and snow-detection.



False Colour Composite and corresponding cloud-mask

Cloud Products from MODIS - FUB
http://wew.met.fu-berlin.de/nrt

At FUB the following experimental cloud products are currently computed from MODIS NRT data received by the Dundee Satellite Receiving Station:
Top pressure - top temperature - phase - effective radius - condensed water path - optical depth - droplet concentration - geometrical thickness



ATSR and Active Sensing of Clouds at Chilbolton
http://www.atsr.rl.ac.uk/links/nrt/ and http://www.rcru.rl.ac.uk/weather

At RAL we produce NRT ATSR-2 data and shortly AATSR data, with greater spatial coverage, for many cloud parameters for Chilbolton and other areas. 94Ghz radar and lidar images made at the Chilbolton radar observatory map the vertical distribution and physical boundaries of clouds. Figures 1 and 2 show the cloud top pressure and optical depth derived from ATSR-2 data for the 13th of February 2002 at 11:27 UTC. X marks Chilbolton. The displayed images of radar reflectivity , Figure 3, and lidar backscatter, Figure 4, show cirrus cloud at the time of the ATSR-2 overpass (around 11:30 UT) ; they illustrate the complementary natureof the observations.

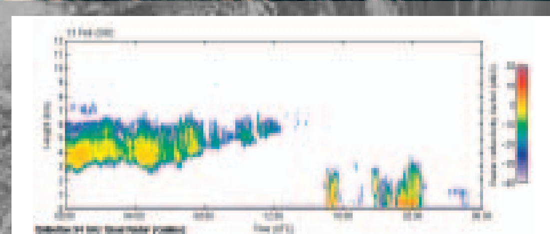


Figure 3

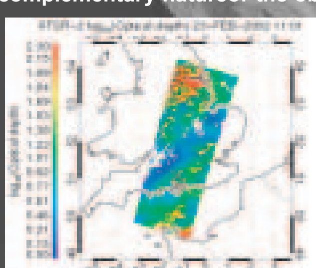


Figure 1

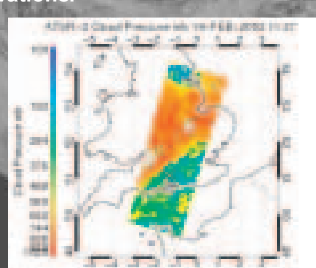


Figure 2

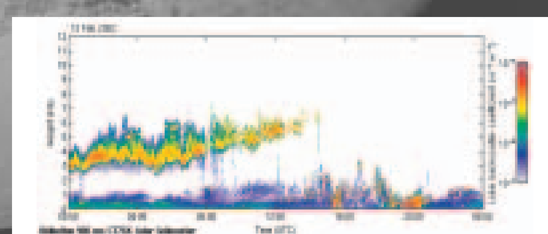


Figure 4

http://www.cloudmap.org

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CLOUDMAP2 Project Overview

Objectives

1) To develop semi-operational processing systems to provide validated cloud parameters for the operational NWP and research climate modelling community for Europe and the North Atlantic by combining satellite and ground-based remote sensing data
2) To create a database of at least 5 years of cloud products from the ERS ATSR2 sensor and Near Real-time (≤1.5 hours) products from Terra-MODIS, ENVISAT-AATSR & MERIS
3) To assess how these cloud products can be used in data assimilation schemes and subgridscale parameterisation schemes for mesoscale and Global Circulation Models

Value-added Data products

A) Satellite-derived macrophysical (e.g. cloud-top heights) and microphysical (e.g. cloud droplet effective radius) parameters
B) Ground-based radar/lidar, stereo visible, thermal IR wide-angle and in situ cloud boundary parameters for validation
C) 3D models of cloud-fields for radiative transfer simulations and subgrid parameterisation of NWP models

End User Plan

KNMI - market survey
SMHI - data assimilation of columnar WV above land and above clouds
SMI - data assimilation of cloud-fields

Partner list

UCL, UK - Co-ordination, stereo cloud-top heights and winds from ATSR2 and MISR, validation, NRT MODIS and radar cloud products
FUB, D - cloud and WV properties from MODIS and MERIS, validation, NRT MODIS cloud products
DLR, D - radiative transfer simulations, NRT MODIS cloud products, validation
ETH, CH - stereo cloud-base heights, validation
KNMI, NL - GOES/MSG cloud products, validation
RAL, UK - ATSR2 cloud database, NRT ATSR2 and AATSR and radar/lidar cloud products

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What CLOUDMAP2 results will deliver to Europe

Scientific Justification

Existing climate models parameterise clouds without taking into account their variability, including multiple layers and their broken nature. NWP models do not assimilate cloud data.

Technology

EO and ground-based data will be used in near real-time to provide new value-added products for the European weather forecasting community and climate modellers.

Socio-economics

Will provide inputs for improved short-range weather forecasting information for storm and flood predictions and improved aviation forecasting. Will stimulate new value-adding economic activities.

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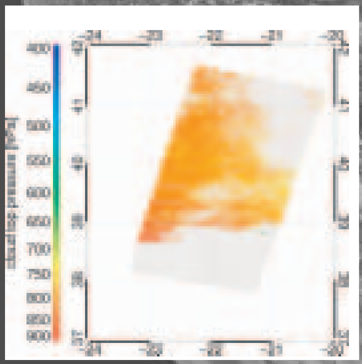
Satellite derived Cloud Parameters

Objectives

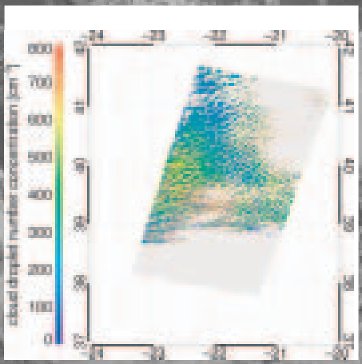
The creation of many new prototype processors for the routine automatic derivation of macroscopic and microscopic cloud properties from new (e.g AATSR, MERIS, SEVERI, MSG) and existing (e.g. ATSR-2, MISR, MODIS, and MOS) Earth Observing instruments.

Cloud macro- and microphysical products

FUB has developed algorithms for the remote sensing of cloud top heights / pressure using oxygen (MOS, MERIS) or CO2-absorption (MODIS) and cloud microphysical parameters (MERIS, ATSR, MODIS) such as cloud droplet number concentration as shown below.



Cloud-top Pressure from MOS



Cloud droplet number concentration (MOS)

Cloud Parameters

- Cloud top height/pressure
- Cloud amount
- Cloud type
- Cloud top motion
- Cloud top temperature
- Cloud Optical Depth
- Cloud albedo
- Cloud droplet effective radius
- Cloud droplet/crystal size distribution

Partners

FUB, RAL, DLR, ETH, UCL

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Satellite derived Cloud Parameters

Geocoded Imagery

ETH has developed algorithms for georeferencing images acquired with linear array sensors with along-track stereo viewing (figure 1). Images consist of lines independently acquired with a different sensor external orientation (position, attitude). According to the available data on the sensor orientation, a direct or an indirect approach (figure 2) can be used to georeference points on clouds.

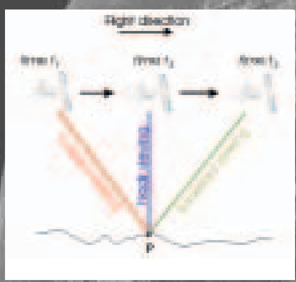
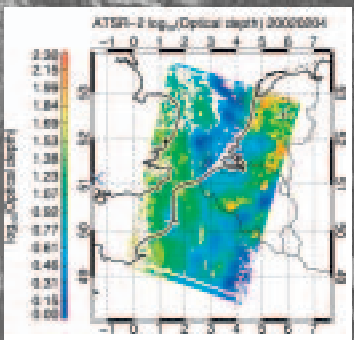


Figure 1

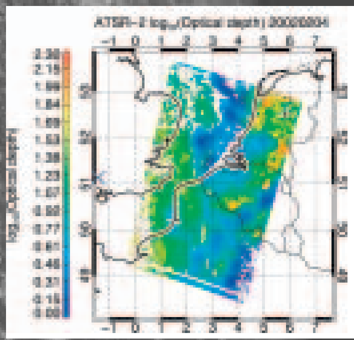
Figure 2

Optimal Estimation

RAL model has developed an 'Optimal Estimation' (OE) method for parameter retrieval enabling the extraction of information from all channels simultaneously. OE allows us to characterise the error for each parameter in each individual observation under the assumption that the cloud observed is consistent with the modelled cloud. Quality control and a priori information is applied which enables us to resolve most cloud parameters in most situations. At RAL we are compiling a data set of cloud parameters from ATSR-2 and AATSR data from 1995 to the present day. The figures below show examples of retrieved parameters from ATSR2.



Retrieved optical depth (ATSR2)



Particle size (ATSR2)

Stereo Products

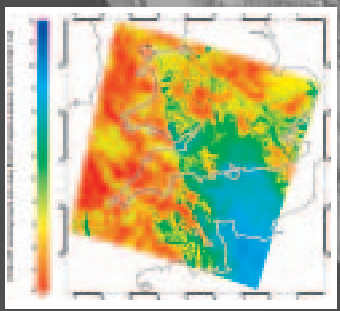


Figure 1

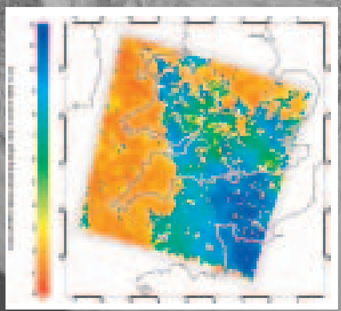


Figure 2

UCL has developed an automated processing system in IDL for extracting Cloud Top Heights (CTHs) and a Cloud Mask from ATSR-2 stereo images. This is being applied to the production of a six-year dataset of all ATSR-2 data over Europe and North Atlantic region. Figure 1 shows Cloud -top heights derived using the 11 um brightness temperatures from the ATSR-2. Temperatures have been converted into geopotential height using the closest in time ECMWF objective analysis values. Note the lack of very high clouds in the SE quadrant. Figure 2 shows the Stereo-derived cloud-top heights using the 11 um Forward/Nadir channel from the ATSR-2. Note the very high clouds observed in the stereo product but not seen at 11 um in the brightness temperature derived CTH.

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Intercomparison of radiative transfer simulations and measurements

Objectives

A) Combine satellite and ground-based information to determine three-dimensional cloud structure and microphysics
B) Study the remote sensing of inhomogeneous clouds and their influence on the radiation budget
C) Visualise three-dimensional cloud structures

Value-added Results

A) 3D cloud characterisation
B) Simulation of satellite observations
C) Improved knowledge about the remote sensing of inhomogeneous clouds and their influence on the radiation budget

Action Plan

A) Determine 3D cloud structure
B) Simulate radiation field
C) Compare with remote sensing
D) Calculate radiation budget

Partner list

A) DLR
B) ETH
C) UCL

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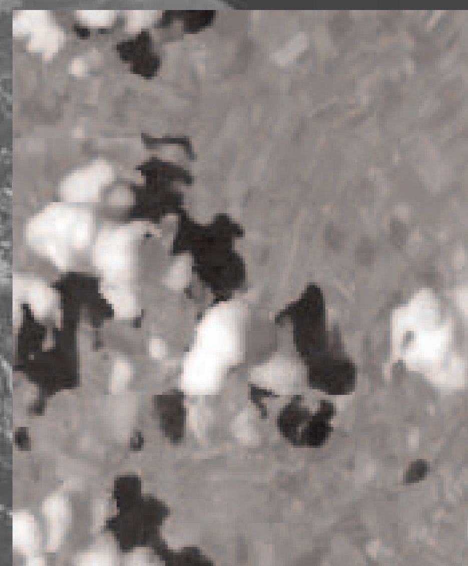
Examples of CLOUDMAP2 results

Cloud observation and simulation

3D radiative transfer simulation



What do these images show?

A rigorous 3D radiative transfer model (MYSTIC) is being used to study the remote sensing of inhomogeneous clouds and their influence on the radiation budget.

Left: Photograph of a broken cloud layer (top) in comparison with a simulated image; cloud data were extracted from stereo camera observations and used as input to MYSTIC (bottom).

Right: MYSTIC calculation of the nadir radiance over a simulated cumulus cloud system.

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End-user requirements for CLOUDMAP2 products

Objectives

Collect user requirements for application of CLOUDMAP2 data to meteorology and climate research in general and for Numerical Weather Prediction (NWP) and Global Climate Modelling (GCM) data assimilation in particular.

Anticipated end-use

A) Numerical Weather Prediction (NWP) modelling: The use of satellite data by NWP models has three applications each having their own requirements concerning the cloud data:

- Use for initialisation of NWP models (data assimilation).
- Use for improvement of physical para meterisation of NWP models (model validation).
- Use for monitoring of NWP analysis/forecast fields.

B) Climate research in general and Global Climate modelling (GCM) in particular:

- Research on the role of clouds in climate change is largely dependent on cloud observations.
- Use in GCM: same as for NWP models.

C) Weather Nowcasting / Very short term forecasting by operational meteorologists

New generation operational weather satellites (MSG and Metop) will encourage a more quantitative use of satellite data by forecasters. Direct use of CLOUDMAP2 products helps forecasters to prepare for MSG and Metop.

Action Plan

User requirements are collected through the following mechanisms:
A) Organising user workshops
B) Interviews with individual user experts
C) Literature study

Partner list

A) KNMI
B) SMHI
C) DLR

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Preliminary end-user requirements

Use in NWP models

User requirements of NWP models to satellite cloud data are not yet defined due to the fact that not much experience is available yet (except for the input of cloud motion vectors). Within the CLOUDMAP2 project further research and experiments on the assimilation of CLOUDMAP products in NWP is being carried out. This work will hopefully result in a refinement of the following **baseline** NWP requirements to cloud data:

Frequency of product: 1x per hour
Timeliness of product: 1 hour
Horizontal resolution: 5 - 10 km
Vertical resolution: 50 - 100 hPa

Use in Climate Research

The first CLOUDMAP2 user workshop resulted in the following preliminary requirements:

- Climatologists need **global coverage** of the earth.
- **Cirrus information** is relevant for researching the impact on temperature and radiance balance.
- The climate research community has a large interest in **independently** observed **CTH** data.
- Climate researchers showed a high interest in **microphysical cloud parameters.**

Baseline requirements:
Frequency of product: 1x per hour
Horizontal resolution: 5 - 10 km
Vertical resolution: 50 - 100 hPa

Nowcasting / Forecasting

Operational forecasting of clouds relies heavily on the frequent and timely distribution of cloud information.

Baseline requirements:
Frequency of product: 4x per hour
Timeliness of product: 5 minutes

Forecasters are satisfied with the present resolution of the NOAA-AVHRR (1 km). Higher resolutions are of course appreciated but do not have a high priority. Higher vertical resolutions certainly have a high priority. A high vertical resolution for low clouds and fog is very important for aviation meteorology and has therefore a direct economical impact (50 to 100 m is needed). An accuracy of at least 10% is required for an acceptance of quantitative cloud products by forecasters.

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Validation and inter-comparison of EO and GB derived cloud parameters

Objectives

A) Comparison of multiple cloud products from the same EO sensor
B) Comparison between different EO sensors (cross-calibration)
C) Validation with ground-based and airborne data
D) Comparison with NWP models (model validation)

Value-added Data products

A) Validated MISR stereo heights and winds
B) Validated MERIS cloud products
C) Validated ATSR2 and AATSR cloud products
D) Validated MODIS cloud products
E) Validated radiosonde derived cloud boundaries

Action Plan

A) Validation of MISR stereo heights and winds (UCL+ PSU+ETH)
B) Validation of MERIS and MODIS new cloud products and intercom-parison (FUB)
C) Validation of ATSR2 and AATSR cloud products and comparison with MODIS and MISR (RAL+FUB+UCL+ETH)
D) Comparison between GOES CTH and radar over SGP (KNMI)
E) Comparison of radar and radiosonde derived cloud bound-aries (UCL+PSU)

Partner list

A) University College London
B) Freie Universität Berlin
C) Rutherford Appleton Laboratory
D) Royal Netherlands Meteorological Institute (KNMI)
E) Swiss Federal Institute of Technology Zürich (ETH)

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CLOUDMAP2 Cloud Top Heights and Wind validation

Example cloud top height validation

GOES CO2 slicing

MODIS CO2 slicing

MISR stereo

ATSR2 stereo

MERIS O_2 A-band

Radar Chilbolton (UK) and ARM sites (USA)

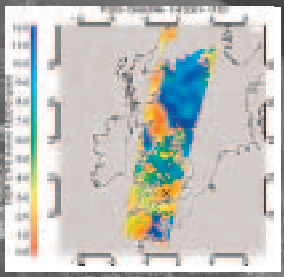
Radiosondes ARM sites and stations globally

- Intercomparison
- Comparison with Ground Based instruments

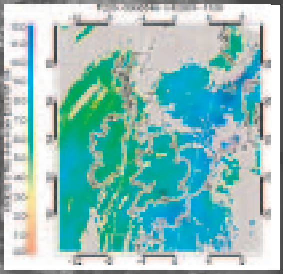
Validation results

MISR – MODIS CTH

Example for 01-04-01 over British Isles



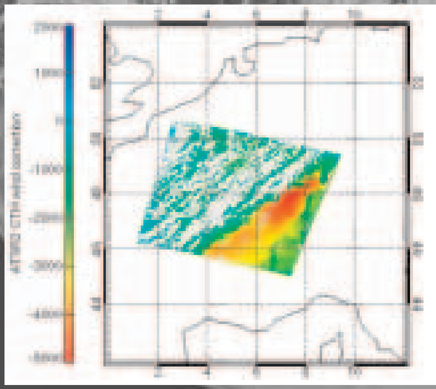
MISR CTH



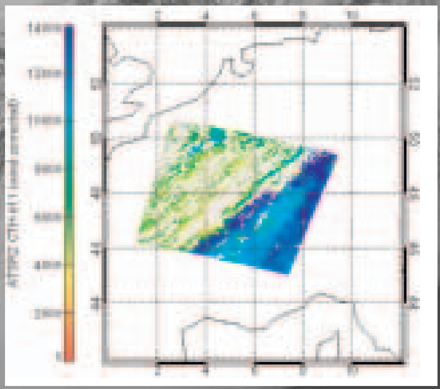
MODIS CTH

Example of CTH and CTW

ATSR2 Stereo CTH, corrected with Meteosat-6 tracked cloud motion winds. With the multi-view capability of MISR, Stereo CTH and CTW can now be estimated simultaneously.



Meteosat-6 CTW, converted into ATSR2 CTH correction [m]



ATSR2 Stereo CTH motion-corrected [m]

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