DUE GLOBVAPOUR

Algorithm Theoretical Baseline Document
L2 AATSR

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Table of Contents

1 Introduction

1.1 Purpose

This document provides the Algorithm Theoretical Baseline for the GlobVapour Level 2 AATSR product.

1.2 Definitions, acronyms and abbreviations

AATSR	Advanced Along-Track Scanning Radiometer
RTTOV	Radiative Transfer for TIROS Operational Vertical Sounder
GFS	Global Forecast System
SST	Sea Surface Temperature
TCWV	Total Columnar Water Vapour

1.3 Applicable Documents

[AD-1] DUE GLOBVAPOUR Requirements Baseline Document (RBD), issue 1, revision 0, dated 16 April 2010.

[AD-2] DUE GLOBVAPOUR Technical Specification Document (TSD), issue 1, revision 0, dated 16 April 2010.

[AD-3] DUE GLOBVAPOUR Software Development Plan (SDP), issue 1, revision 0, dated 16 April 2010.

[AD-4] DUE GLOBVAPOUR Summary Report on Existing Algorithm Comparison and Validation Reports (SVR), issue 1, revision 0, dated 29 July 2010.

[AD-5] ESRIN Statement of Work, EOEP-DUEP-EOPS-SW-09-0003, issue 1 rev. 1, 13.05. 2009

[AD-6] DUE GLOBVAPOUR Proposal, issue 1 revision 3, dated 9 July 2009

1.4 Reference Documents

[RD-1] Rodgers, C., 2000, Inverse Methods for Atmospheric Sounding: Theory and Practice *World Scientific, London*

[RD-2] Saha, Suranjana, and Coauthors, 2010: The NCEP Climate Forecast System Reanalysis.

Bull. Amer. Meteor. Soc., 91, 1015.1057. doi: 10.1175/2010 BAMS3001.1

[RD-3] Mutlow, C.T., Zavody, A.M., Barton, I.J. and Llewellyn-Jones, D.T.; *Sea-surface temperature-measurements by the Along Track Scanning Radiometer on the ERS-1 Satellite - early results*. J. of Geophysical Research-Oceans, **99**, No.C11, 22575-22588, 1994

[RD-4] Saunders R.W., M. Matricardi and P. Brunel 1999: An Improved Fast Radiative Transfer Model for Assimilation of Satellite Radiance Observations. Q.J.Royal Meteorol. .Soc. , 125, 1407-1425.

[RD-5] ESA, The AATSR Product Handbook, http://envisat.esa.int/dataproducts/aatsr/, 2002

1.5 Structure of the document

Section 2 gives an overview of the AATSR instrument and the retrieval algorithm scheme developed within the GlobVapour project. The used methods, models and preparatory works are introduced. In section 3 both the theoretical basis of the algorithm as well as the practical application are detailed. Necessary assumptions and limitations are described in section 4. Section 5 gives a conclusion.

2 Algorithm overview

The algorithm for the retrieval of TCWV from measurements of AATSR is based on the exploitation of the weak but articulated water vapour absorption and emission around 3.7 µm and 11 µm using inverse modelling. The retrieval is limited to night time observations above cloud-free ocean.
The (Advanced) Along Track Scanning Radiometer ((A)ATSR) are multi-channel imaging radiometer with three bands in the thermal infrared TIR (3.7 µm, 11 µm and 12 µm) and up to four other bands in the visible and near infrared spectral range. Their conical scan principle gives a dual-view (‘forward’ and ‘Nadir’) of the Earth's surface with a 500 km wide swath. The spatial resolution is approximately 1 km for Nadir and 1.5 km for the forward view. (A)ATSRs principal objective were to provide the global Sea Surface Temperature (SST) with the highest level of accuracy and stability. The ATSR instruments fly on board the ERS- satellites, AATSR is mounted on ENVISAT, all sun synchronous polar orbiter.
The retrieval scheme for AATSR is using these bands at forward and Nadir view in a 1D variational approach. In practice: the input is two times three bands plus two observation geometries, the output are the best fitting surface temperature and the total column water vapor. To reduce ambiguities due to unknown surface emissivities, the retrieval is limited to ocean scenes and to reduce ambiguities at 3.7 µm due to sun glint the retrieval is further limited to the night scenes. The high optical thickness of clouds in the TIR allow only cloud free pixel to be used. The variational approach requires a forward radiative transfer model, for which the necessary profiles of temperature and humidity are taken from a 6 year GFS model climatology [RD-2]. Thus no numerical weather model assimilation is done and no other auxiliary data is needed.

In a first step, the AATSR L1B data is screened for clouds and land surfaces, using the standard flags delivered with the L1B file. ([RD-5])

3 Algorithm description

3.1 Theoretical description

Measurements around 3.7 µm, 11 µm and 12 µm provide a high sensitivity to the surface temperature and additionally a marginal sensitivity to the atmospheric water vapour. If the spectral emissivity is known in the respective channels and if the vertical profile of water vapour is primarily determined by the surface temperature, the total column water vapour can be roughly estimated in a joint retrieval together with the surface temperature. For night time ocean pixel, these requirements are fulfilled.

The retrieval is based on a simplified variational approach, that minimizes a weighted difference between a measurement *Y* and a modelled measurement *F(X)*:

$$J(X)=\frac{1}{2}(Y-F(X))^T S_E^{-1}(Y-F(X)) \quad (1)$$

where the state vector *X*, that minimizes the *cost function J(X)*, is the most probable estimate (if *least squares* a supposed to be the *maximum likelihood estimator*). Here the state vector is composed of the surface temperature and the TCWV. The measurement vector *Y* is composed of the 2x3 top of atmosphere brightness temperatures from AATSR. S_E is the error covariance matrix

$$S_E = S_M + K_B^T S_B K_B \quad (2)$$

which is composed of the measurement error co-variance S_M and model parameter error co-variance S_B. K_B is the *Jacobian* of the forward model *F* with respect to its parameterisations *B*.

This approach is not using any weather or climate model outputs, to be "climatologically independent" and to be not incestuous. On the other hand the negligence of *a priori* information, will cause a miss of a *best estimate* in a Bayesian sense. Nevertheless, the uncertainty of the retrieved state vector S_R is estimated using:

$$S_R^{-1} = K^T S_E^{-1} K \quad (3)$$

K is the *Jacobian* of the forward model with respect to the state variables.

The minimisation of equation (1) is done by an iterative gradient descent:

$$\begin{aligned} X_{i+1} &= X_i + S_i \left(K_i^T\ S_E^{-1}\left(Y-F(X_i)\right)\right) \\ S_i^{-1} &= \left(K_i^T\ S_E^{-1} K_i\right) \end{aligned} \quad (4)$$

until either the residual $\left(Y - F(X_i)\right)$ is smaller than 0.1 K or the number of iterations is larger than 5 (these numbers can be subject of changes in future). In the later case, the algorithm is regarded as non-converging. The diagonal elements of the last S_i are the uncertainties of TCWV and SST.

Currently the forward operator is a Look Up Table (LUT) filled with radiative transfer calculations from RTTOV [RD-4] for a fixed set of temperature and humidity profiles (see next paragraph). The top of atmosphere brightness temperatures are calculated by means of a 5-dimensional linear interpolation with respect to the LUT dimensions: (Viewing angle, TCWV, SST, CO2, T-RH profile).

Six representative temperature and humidity profiles as well as their variance have been extracted from 5 years (2006-2011) of global cloud free ocean GFS datasets [RD-2]. The variance has been used to estimated forward model uncertainty. The sea surface temperature is used as the determining quantity. This approach is very simple but applicable, since most water vapour is in the lowest part of the atmosphere and in particular above the ocean the amount of humidity is mainly determined by the sea surface and air temperature due the Clausius-Clapeyron relation.

3.2 Practical application

The processor is written in IDL with inline C code. It needs AATSR L1B data as input and produces NetCDF output files, containing the SST and TCWV as well as the corresponding uncertainties. No further ancillary data is needed.

4 Assumptions and limitations

The retrieval algorithm is applicable over ocean only during night time for cloud free pixel.

There are two main sources of uncertainty:

1. The unknown profile of humidity and temperature, but this uncertainty is pixelwise quantified.

2. Undetected thin clouds, which lead to dry biased TCWV. A later verification of the retrieved SST could help to filter out these cases

5 Conclusions

The GlobVapour AATSR L2 is based on the exploitation of the relatively weak absorption and emission of water vapor in the thermal infrared, as measured by AATSR bands 3.7 µm, 11 µm and 12 µm forward and Nadir. The output is used for the generation of gridded L3 products, namely daily nightime composites and monthly means. The algorithm is totally complementary to MERIS (daytime/land vs. nighttime/ocean) and partly supplemental to SSM/I due to its much higher spatial resolution.