Contribution of POLDER to water vapour observation

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I Introduction

Observations of water vapour over land are mainly provided by the radiosonde network with a somewhat sparse distribution over continents of the southern hemisphere. Satellite sensors such as TOVS[1] and SSM/I[2] offer indirect measurements of atmospheric water vapour that may be used with a good accuracy over ocean, but retrivals lack sensitivity and precision over land due to high and variable emissivities. A 2-channel ratio method involving near-infrared measurements was initially developped by (Frouin), and was applied for POLDER-1 (Bouffiès et al., 1997, Vesperini et al., 1999), MODIS (Kaufman and Gao, 1992, Gao and Kaufman, 1998) and MERIS (Bennartz and Fischer, 2001) missions. These methods gave the first opportunity to observe atmospheric column water vapour with a satellite coverage over land, in clear sky conditions. This paper describes the updated algorithm for the POLDER-2 mission (ADEOS-2), starting in April 2003.

II Background of POLDER water vapour retrieval method

POLDER (POLarization and Directionality of Earth Reflectances, Deschamps et al. 1994) is a visible to near-infrared radiometer, providing up to 14 directional reflectance measurements of a given target together with its full polarization characteristics. Its nominal resolution is about 6 km and POLDER geophysical products are computed on an approximately 60km×60km grid. In addition to the innovative directional and polarization capabilities, two channels located beside and in an H_2O gaseous absorption band (respectively 865 and 910 nm) are used to estimate the atmospheric Total Column Water Vapour content (TCWV). Assuming that the surface reflectance does not vary between these two close bands, the 910 to 865 nm reflectance ratio is a function of the atmosphere transmission which is related to the TCWV content. This relation may be parameterized with a polynomial fit. This method is based on absorption so it applies only to situations where direct transmission (from sun to the surface and to the sensor) predominates over scattering by cloud or molecules. This restricts to clear sky over significantly reflecting surfaces such as land and ocean in glitter conditions.

For the first POLDER mission, the coefficients of the polynomial fit were determined from radiative transfer simulations based on HITRAN absorption database (Bouffiès et al, 1997). This needs the reflectances to be calibrated. In-flight calibration of the 865 nm band was performed by transferring the 656 nm band calibration over the spectrally flat sunglint over ocean. The 565 nm band was calibrated following method initially described by Vermote et al. (1992). To perform in-flight calibration of the 910 nm, it is necessary to have humidity observations to refer to over ocean glitter condition to guarantee a white and highly reflective surface. We thus need a data base containing reference humidity data in oceanic areas, together with coincident and colocated POLDER measurements in clear sky and glitter situations for a wide range of atmospheric conditions. In order to get such a data-set as soon as possible after the launch, the

[1] TIROS Operational Vertical Sounder
[2] Special Sensor Microwave Imager

calibration of 910 nm band for the POLDER-1 mission used meteorological analysis of humidity as reference (Hagolle et al., 1999).
Validation of the operational satellite water vapour product was performed by Vesperini et al. (1999) by comparisons with radiosondes and SSM/I TCWV (algorithm of Wentz 1994). These comparisons pointed out two biases in the POLDER water vapour retrievals. First, large POLDER TCWV were overestimated by roughly 10 kg.m^{-2} due to improper calibration of the 910 nm channel. Actually, meteorological analyses may be biased in areas where few observations are available (like ocean). Moreover, over land this bias is mixed with an underestimation of small humidity contents related to the spectral variation of the surface between 865 and 910 nm channels which was on a first attempt assumed to be negligible. The developpement of the new algorithm must settle the determination of the polynomial fit and calibration for the new 910 nm filter and must take into account the spectral variation of the surface reflectance.

III Calibration and Water Vapor parameterization

For the second POLDER mission, it was decided to perform directly the calibration of the TCWV content itself, through the determination of polynomial coefficients, instead of the calibration of the 910 nm reflectance.
A data base including reference humidity data in the form of TCWV, collocated with POLDER level-1 clear sky reflectances is required. Radiosonde/POLDER match ups were first used to develop a method to screen cloudy situations, independantly of level-2 processing, since water vapour calibration has to be performed before level-2 will processed. However, cloud screening does not leave enough matchups to perform calibration. SSMI TWCV observations were thus used as a main reference, the satellite coverage offering much more match-ups than the radiosonde network.

III-a Use of radiosondes

We have selected the level-1 POLDER data for the 3x3 full resolution pixels surrounding each radiosounding from TEMP (fixed stations) and TEMPSHIP (shipstations) messages, available over the globe during the eight-month POLDER-1 mission (between November 1996 and June 1997). 3278 colocations were found over sea, of which 1142 for small islands and 2136 for ships. POLDER data include between 1 and 14 directions for each of the 3x3 pixels. From this initial data set, only the sea and glitter cases were kept. A cloud screening was then performed on this sea-only-and-glitter data set. The cloud detection is based on the fact that unlike liquid-water cloud, glitter targets are highly polarized. A 0.05 threshold on the glitter amplitude was choosen to perform a first cloud screening, which left 219 island and 482 ship cases. Since the glitter amplitude test did not screen out all the cloudy cases, we added a test on the apparent pressure. The apparent pressure of cloud is used for cloud detection in the "Radiation Budget and Cloud" processing line (Vanbauce et al., 1998). The apparent pressure of the target is computed from the oxygen transmission estimated from the 763 to 765 nm reflectance ratio. The cloud detection threshold is calculated as function of geometry and surface pressure. Only the directions within 15^o of the specular reflexion were kept in the final test (Figure 1). The final test leaves only 19 island and 37 ship cases giving a total of 1339 pixel-directions.

III-b Use of SSMI data

To complement the scarse POLDER-radiosonde collocations, further comparisons were made with SSM/I TCWV. The SSM/I instrument (Hollinger et al., 1990) on board the DMSP[3] F10 spacecraft provides TCWV estimates with about 15mn time lag with ADEOS-1. F10 has a shorter lag, revoir figure avec F10. The Wentz algorithm (Wentz, 1997) minimizes iteratively the distance between observed and simulated 19-, 22-, and 37-GHz brightness temperatures in order to find the most probable values of TCWV and other environmental parameters. This algorithm showed very good agreement with in-

[3]Defense Meteorological Satellite Program

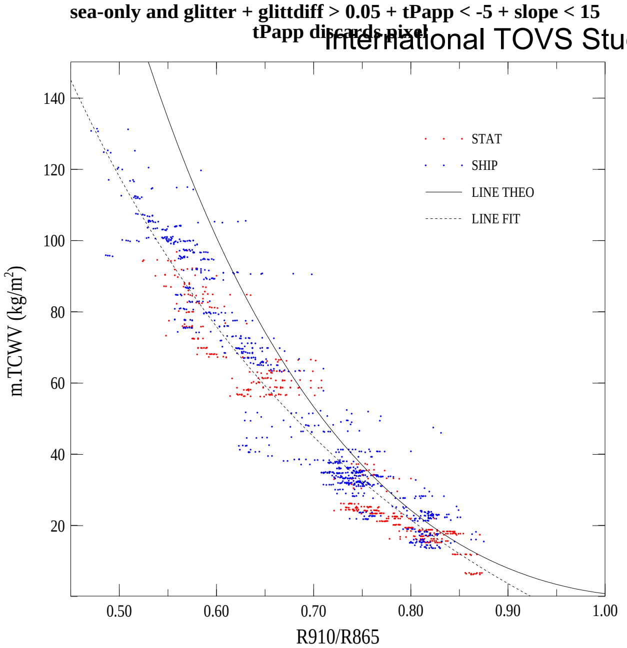

figure 1: Radiosonde TCWV multiplied by airmass m versus POLDER reflectance ratio X=R_{910}/R_{865} for all sea-only-and-glitter cases and after complete cloud screening: glitter amplitude, apparent pressure, reflexion angle

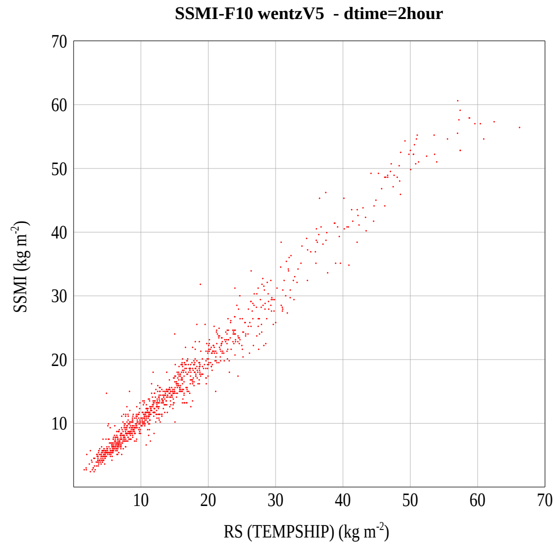

figure 2: SSMI TCWV as function as colocated ship radiosounding (2 hour time lag) between November and June 1997 (kg/m^2)

dependent radiosonde data from both small islands and ships (-0.2 kg/m^2 bias and 3.7 kg/m^2 rms difference) (Deblonde and Wagneur, 1997). The updated version of Wentz processing (full intercomparisons between the DMSP spaceraft series) gives slightly lower values (by 1 to 2 kg/m^2) for TCWV larger than 55 kg/m^2. Figure 2 shows Wentz version 5 estimates, as function of colocated radiosoundings on ship for the POLDER-1 period. It shows a very good correlation (0.99) with 1.00 slope, 0.33 intercept, and 1.55 kg/m^2 RMS error. Level 1 POLDER measurements colocated with SSM/I 0.25 squared gridded TCWV over ocean have been selected for June 1997. Each SSM/I-POLDER-L1 colocation consists in the SSM/I TCWV content and POLDER measurements (all channels) for the 3×3 full resolution pixels closest to the center of the SSM/I pixel. The time lag between POLDER and SSM/I F10 is kept to 15 mn. These colocated data are also filtered to keep cloud-free sunglint directions, with similar test as used for radiosondes match-ups but with more stringent thresholds (refpol>0.2, Tpapp<-100 and, GlitdifP> 0.15).

Figure 3 shows the colocated POLDER / SSMI data after cloud screening together with obtained polynomial $m.U_{WV} = a_2 ln(X^2) + a_1 ln(X)$ fit (a_2=204.55 and a_1=-49.75).

In order to check the algorithm for high and small water vapour contents for which few satellite colocations are available, the polynomial fit is represented with simulated data. Reflectances in the 910 and 865 nm POLDER bands were computed using line-by-line radiative transfert (HITRAN 2000 spectroscopic data base) from atmospheric profiles. Figure 4 shows atmospheric $m.U_{WV}$ as function of computed reflectance ratio together with the polynomial fit obtained with POLDER/SSMI colocations. The agreement is very good even for higher and smaller $m.U_{WV}$ values.

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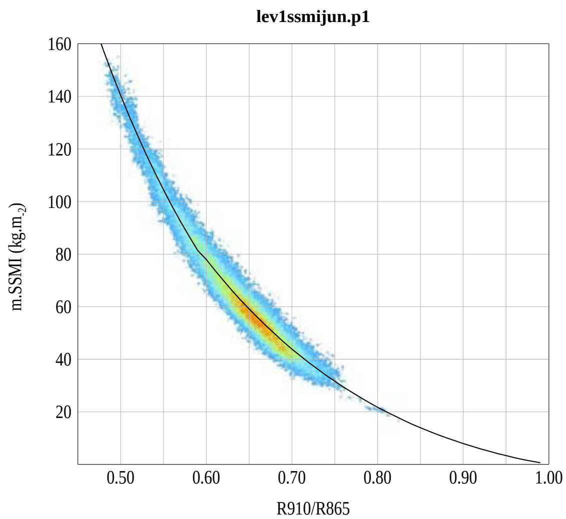

figure 3: SSMI TCWV multiplied by airmass m versus POLDER reflectance ratio $X=R_{910}/R_{865}$ after cloud screening

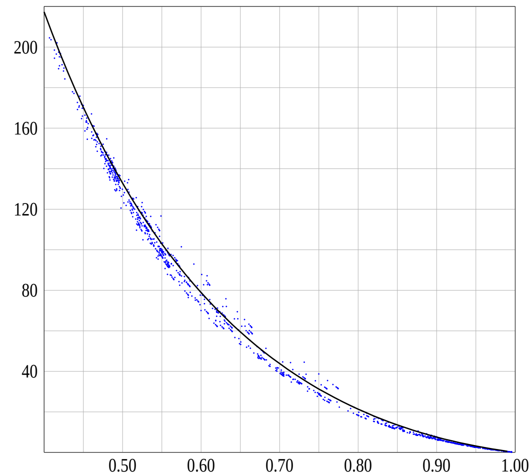

figure 4: profile data base TCWV multiplied by airmass m versus 5A similated HITRAN reflectance ratio $X=R_{910}/R_{865}$ (POLDER channels)

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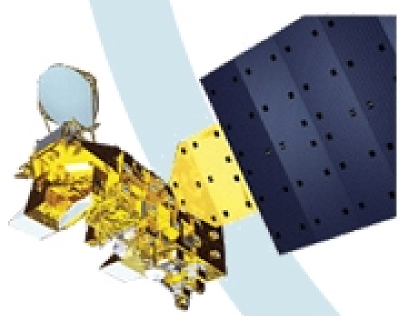

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