Coincident cloud observations by altimetry and radiometry

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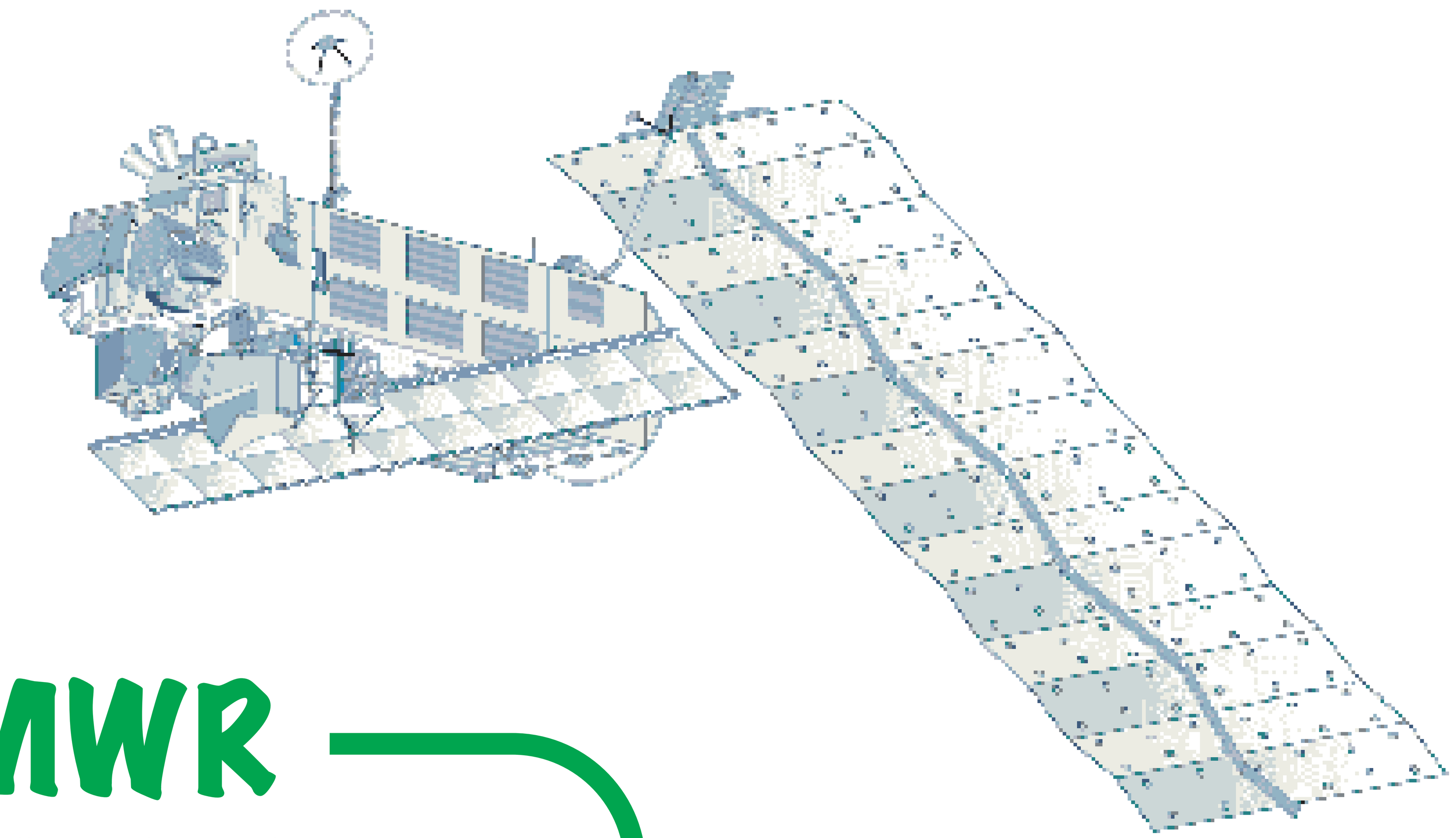
Clouds & Rain

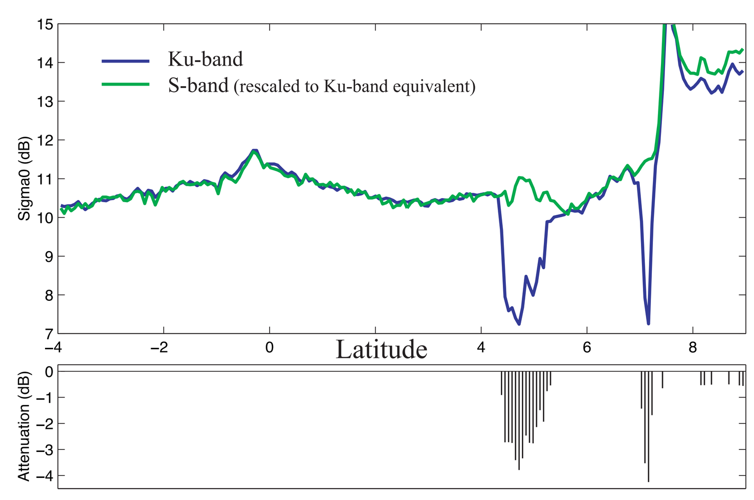
Clouds and rain are an integral part of the cycle of freshwater between atmosphere and ocean, and they also affect the radiative heat flux between the Earth and space. Many different sensors show sensitivity to various properties of clouds; due to its payload of multiple high-precision instruments, Envisat is the first satellite to provide simultaneous observations of these parameters on a nearly global basis. Such simultaneity of diverse measurements is critical to the understanding of rapidly-evolving rain systems.

This poster highlights the complementary information available from the altimeter (RA-2), the microwave radiometer (MWR) and the infra-red radiometer (AATSR). The examples are taken from 3 separate Envisat passes across the ITCZ (Inter-Tropical Convergence Zone) to the west of Africa. Large convective cells can develop over land, typically peaking in the afternoon before dying away. However, when coupled with atmospheric waves from the east, these systems can grow with a new storm being generated every 4-7 days. As the storms move away from the Equator, they gain rotation, with winds intensifying as they head further north over warm seas. The region of West Africa thus acts as the spawning ground for many of the hurricanes that reach the United States.



RA-2

Dual-frequency altimeters have been around for more than 10 years, with Quartly et al. (1996) demonstrating that the difference in normalized backscatter at the two frequencies was a good indicator of rain. This was later developed in to an algorithm giving quantitative rain rates (Quartly et al., 1999). Although using a different secondary frequency, the technique is readily extended to RA-2, with similar patterns of rainfall being achieved (Tournadre, 2004). The rain rates correspond to an altimetric footprint approximately 8 km in diameter, with observations every 7 km along track.



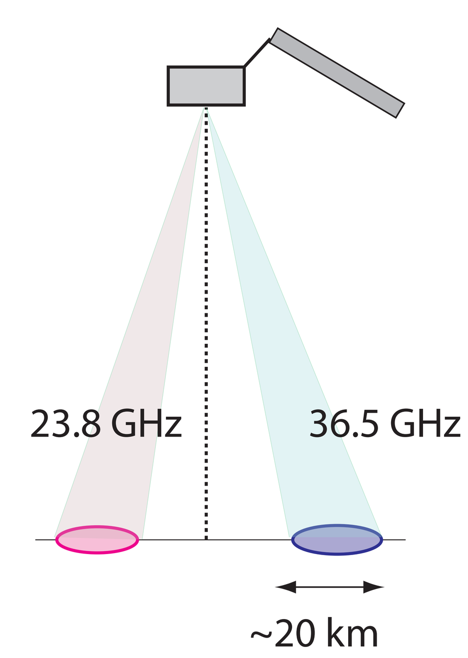
In the above example, sigma0 at both frequencies respond to the large-scale changes in the wind field; however the Ku-band also shows large drops in value, ascribed to attenuation by rain.

MWR

The microwave radiometer is a passive microwave instrument operating at 23.8 GHz and 36.5 GHz, both with a footprint ~20km across. The lower frequency lies near a peak of the water vapour absorption spectrum, whilst the higher frequency is at a local minimum. Using the radiative transfer equation, Eymard et al. (1994) derived estimates of water vapour (WV) and liquid water content (LWC) via:-

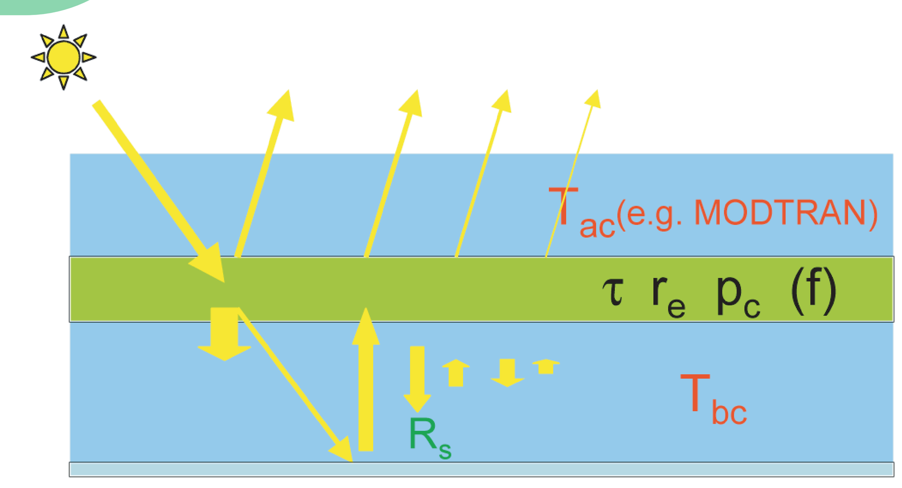
$$WV = a_1 \log(280 - T_{23.8}) + a_2 \log(280 - T_{36.5}) + a_3 + a_4 U_{10}$$
$$LWC = b_1 \log(280 - T_{23.8}) + b_2 \log(280 - T_{36.5}) + b_3 + b_4 U_{10}$$

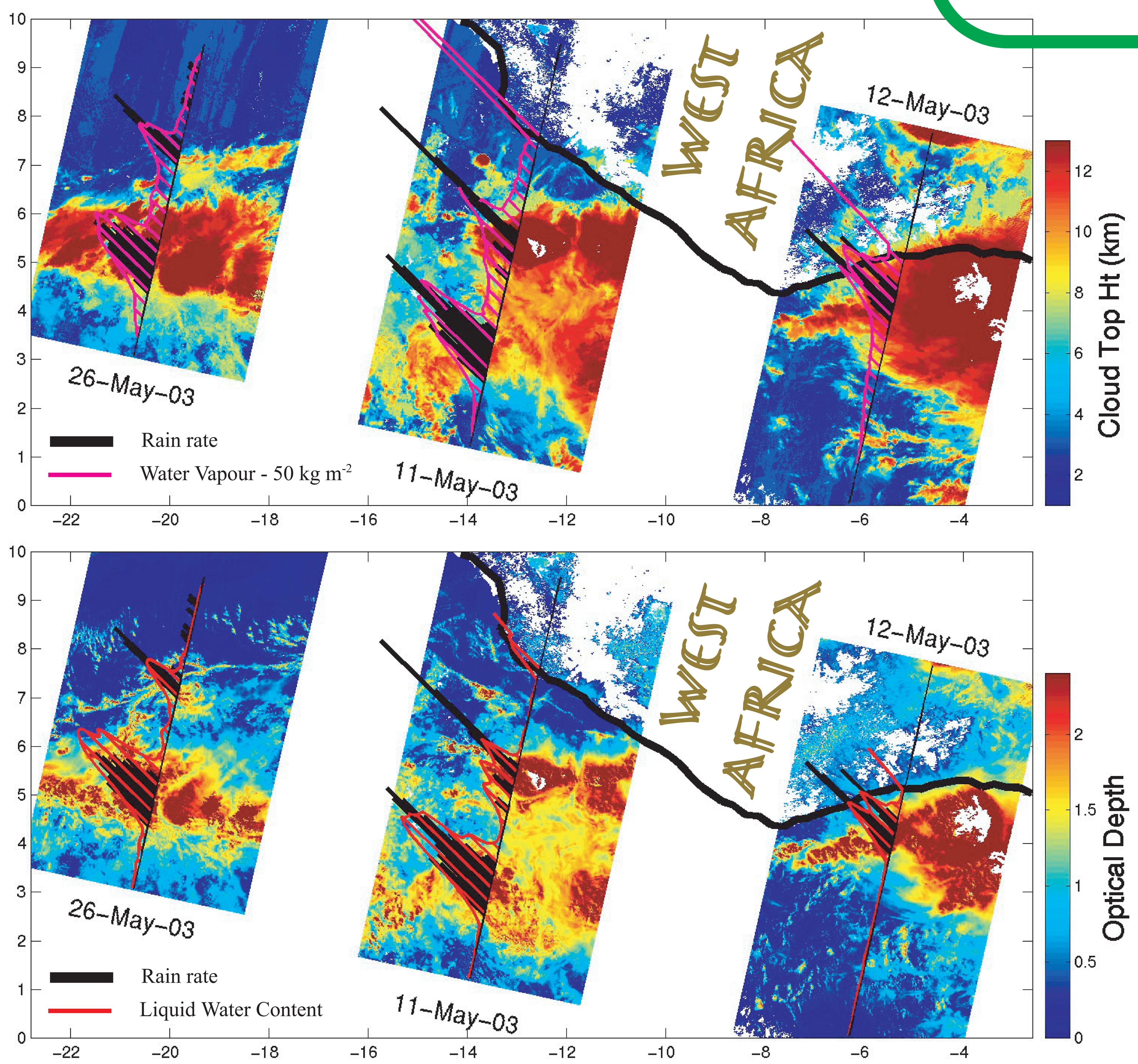
(The wind speed, U_{10}, makes a contribution due to its effect on sea surface roughness and thus emissivity.)



AATSR

The Advanced Along-Track Scanning Radiometer is the third of a series of high-precision dual-viewing infra-red radiometers. Although originally designed with precise measurements of sea surface temperature in mind, AATSR data can be used for a number of other studies. A layered cloud model has been developed at RAL, utilizing parameterizations of the solar input and thermal interactions (emission, transmission and reflection); this has been used to calculate top-of-atmosphere (TOA) radiances for a wide range of cloud parameters, with the results stored in look-up tables. Such parameters can then be derived using observations from all AATSR channels simultaneously via 'Optimal Estimation' (Watts et al., 1997), which also calculates the errors in each retrieval.





AATSR provides full swath coverage of Cloud Top Height and optical Depth, whereas rain rate (from RA-2) and WV & LWC (from MWR) are solely along central track.

Interpretation

The three scenes show intense storms developing at ~5°N off the coast of West Africa. Each has a cloud top exceeding 13 km above sea level, and extending over 300-400 km along track. However, the active regions are more confined. For example, on the swath of 11th May, the rain and LWC are concentrated at 3.5° and 5.5°N, where the cloud is optically thickest, whereas between these two peaks there is a high cirrus shield of remnant cloud from previously active convection.

For the 6 scenes studied (3 shown), it is noted that rain only occurs for *Optical Depth* > 1.4 AND *LWC* > 0.5 kg m^{-2}. Such simultaneous records could be used to infer rain rates across an infra-red swath. However, they also show that the suite of sensors on Envisat provides us with complementary information on the large-scale structure of clouds and the active rain cells within them.

Acknowledgements & References

Picture of Envisat acquired from http://www.Envisat.esa.int. Thanks also to Trevor Guymer for meteorological interpretation, and to Val Byfield, who helped in the painful process of requesting data from ESA.

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