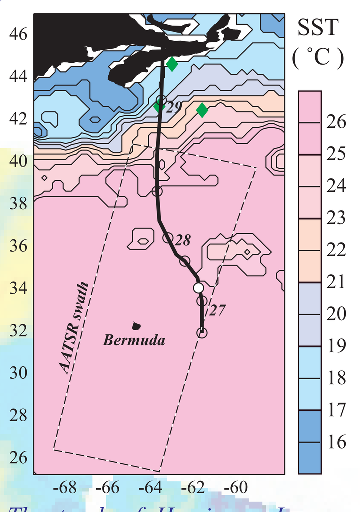
Hurricane Juan

A triple view from Envisat

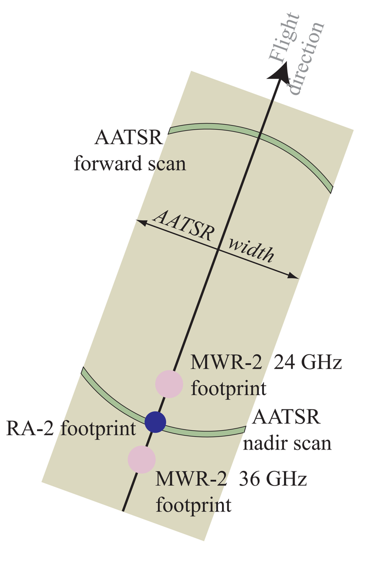
Graham Quartly & Trevor Guymer

Introduction



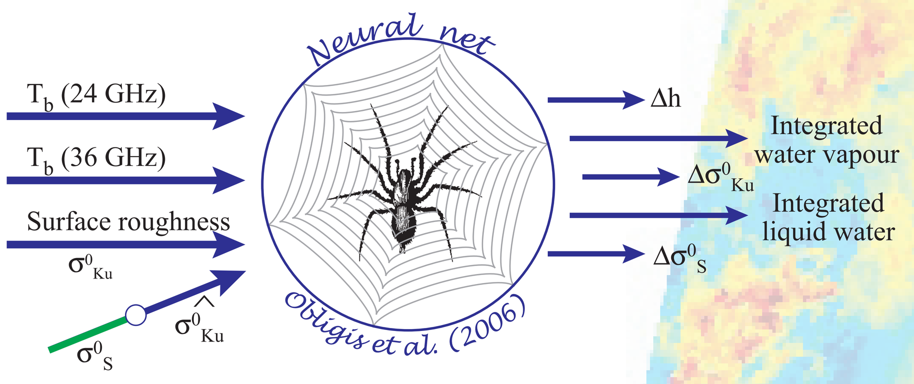
The track of Hurricane Juan over unseasonably hot waters helped to maintain its strength. Location at Envisat pass marked by white dot; green diamonds show wave buoys.

In late Sept. 2003 a tropical storm near Bermuda developed into a category-2 hurricane. Surprisingly, on moving north Hurricane Juan did not lose much of its strength, because of the unseasonably hot water present (Fogarty et al., 2006), and so became the most powerful hurricane to reach Nova Scotia since 1873. A few days earlier, Envisat overflew Juan whilst near Bermuda; this poster looks at the complementary information derived from three sensors — RA-2 (altimeter), MWR-2 (microwave radiometer) and AATSR (infra-red radiometer).



Schematic of interleaved footprints of the three rain/cloud sensors.

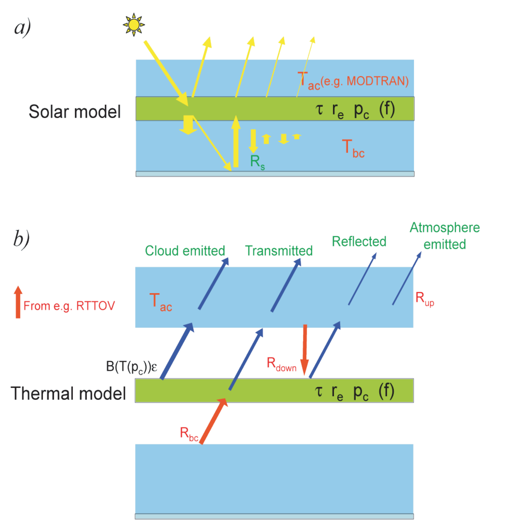
MWR-2: Water vapour & Liquid water



A radiative transfer model is used to determine how the MWR-2's brightness temperatures vary with atmospheric liquid water and water vapour. Obligis et al. (2006) invert this using a neural net, with σ^0_{Ku} being an extra input providing an estimate of sea surface roughness, and output terms including the height and attenuation corrections pertinent to altimetry. We find σ^0_{Ku} to be a poor measure of roughness when attenuation by rain is present; instead we use the unaffected σ^0_S records converted to K_u-band equivalents.

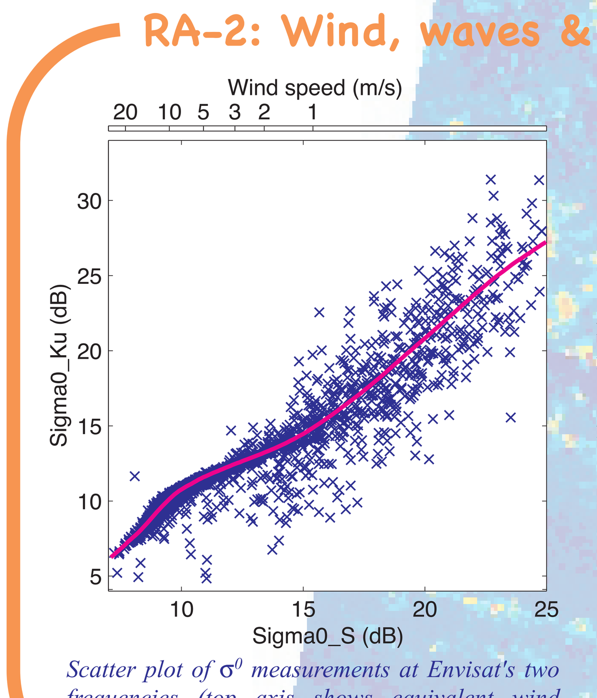
AATSR: Cloud properties

Cloud properties are derived from 5 nadir-viewing channels of the AATSR. A model involving solar input and thermal equilibrium in atmospheric layers is used to link the cloud properties to the multi-channel radiances. Matrix inversion using simulated scenarios is used to populate look-up tables for ease of operational processing. For studies such as this, the most useful observed properties are cloud top height and optical depth.



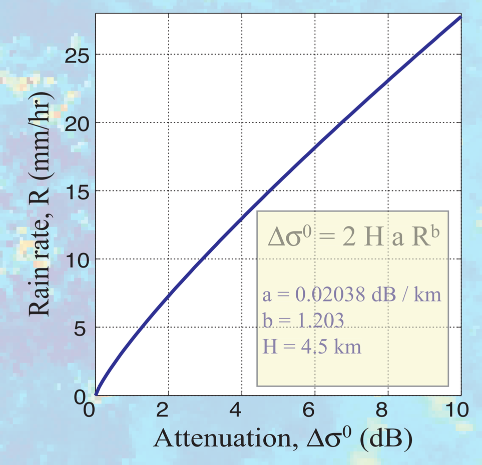
Schematic of model used in inversion (see Watts et al., 1998 for details).

RA-2: Wind, waves & rain



Scatter plot of σ^0 measurements at Envisat's two frequencies (top axis shows equivalent wind speeds); pink line shows mean relationship.

Since the launch of TOPEX it has been demonstrated that dual-frequency radar altimeters can be used to infer attenuation of radio signals by raindrops. Quartly & Srokosz (2003) derived the mean relationship between the σ^0 (backscatter) measured at the RA-2's two frequencies (there being a very tight relationship at moderate to high wind speeds), with departures from this probably indicating attenuation, $\Delta\sigma^0$. Rainfall rate is then calculated from this using the coefficients of Goldhirsh & Walsh (1982)



Relation between attenuation and rain rate (for height of rain column, H = 4.5 km).

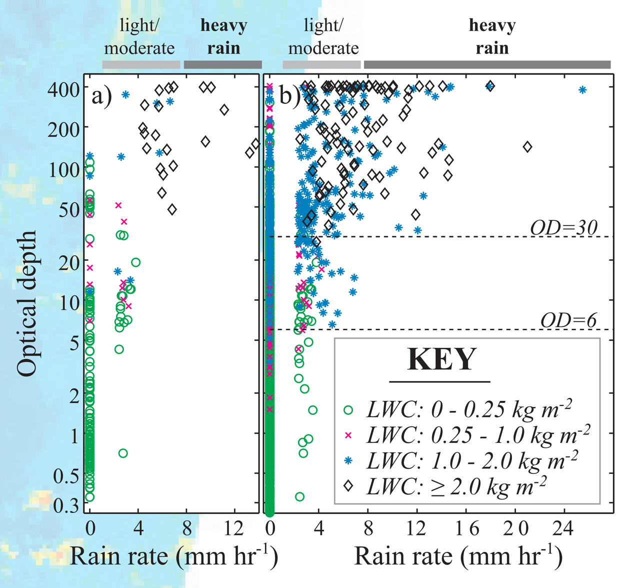
Synergy

Profiles across Juan

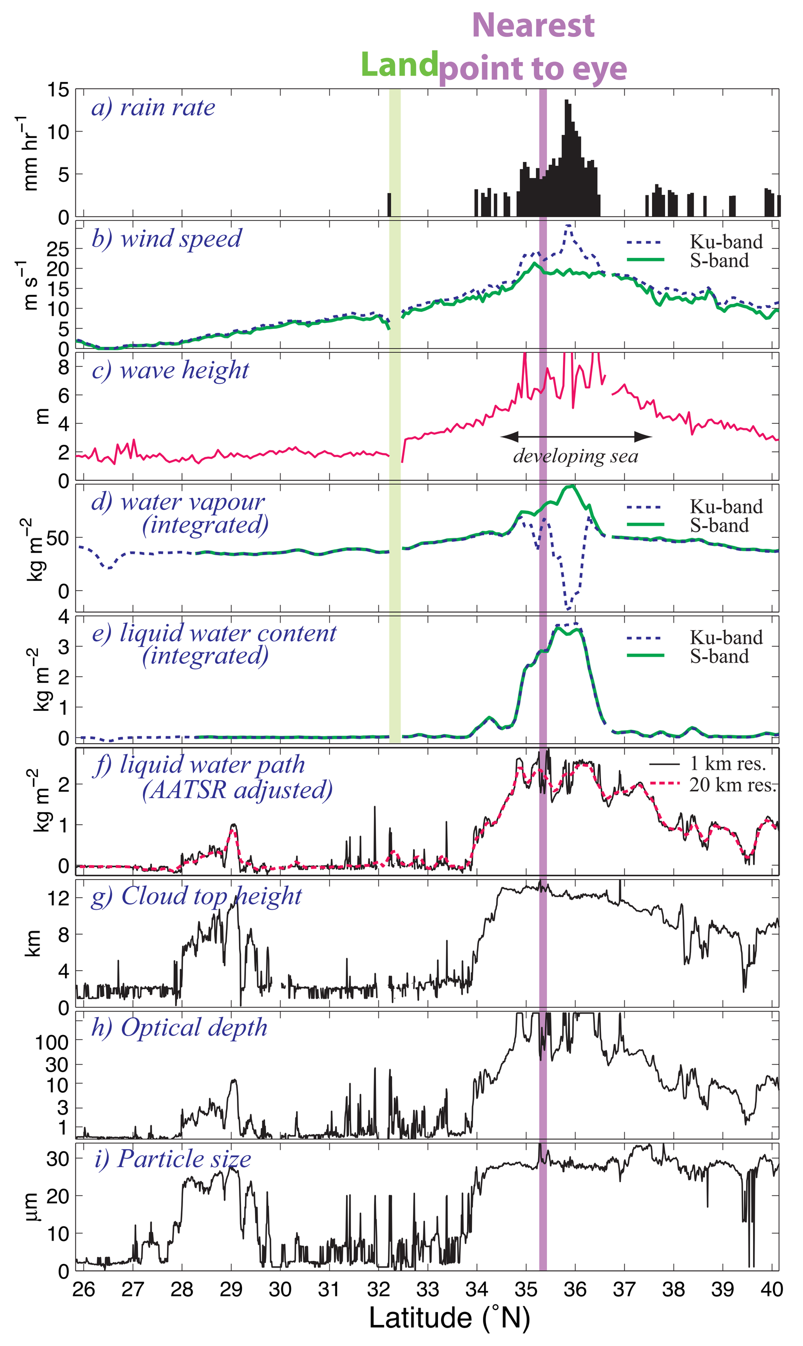
The three instruments provide profiles of rain and cloud parameters along the nadir track. The altimeter profile shows the wind and wave fields centred slightly to the north of the eye, with the waves in the central 300 km being still developing. The rain roughly coincides with this centre, but with occasional bands of rain extending further north.

The integrated measures of water vapour (d) and liquid water content (e) only show a pronounced change for a 200 km section, with no response at 29˚S where there is remnant cloud from earlier events. Note the more realistic profiles obtained by using σ^0_S rather than σ^0_{Ku}, which is affected by rain.

The infra-red data give a significantly different picture, with a strong signal at 29˚S and then a very asymmetric profile for Hurricane Juan — a sharp increase in Optical Depth, Cloud Top Height and Liquid Water Path on the southern edge of the hurricane, with a gradual tail off in parameters to the north. Note the very different estimates of liquid water by the MWR-2 and AATSR; this is due to their differing sensitivity to small droplets.



Scatter plot of optical against rain rate for different values of LWC a) Hurricane Juan only, b) Collation of ten N. Atlantic storms.



Profiles across Juan. The vertical green bar marks where Bermuda lies within the RA-2 footprint; the purple one shows the point on section nearest to the hurricane's eye. Added red line in panel f) shows that smoothing AATSR data to MWR-2 footprint does not explain the difference in profiles in e) and f)

Conclusions

So what does it tell us about the association of rain with clouds? Looking at the collation of simultaneous altimeter, infra-red and passive microwave data over ten N. Atlantic storms we find:

♦ There is only light rain unless there is both optical depth (OD) is greater than 6 and the integrated liquid water content (LWC, from MWR-2) exceeds 1.Kg m^{-2}. Heavy rain only occurs for OD>30. (Similar values were noted in the equatorial Atlantic by Quartly & Poulsen, 2005).

♦ A given set of OD and LWP conditions encompass a wide range of rain rates. Thus it is difficult to combine broad footprint passive microwave data with infra-red data to give high-resolution profiles of rain.

Acknowledgements & references

Data were acquired from ESA under AO-267 'Accurate Rain Information from Envisat Sensors (ARIES)', and the AATSR data were processed by Caroline Poulsen (Rutherford Appleton Laboratory). Our thanks to her and to Estelle Obligis for providing the neural net code for MWR-2 geophysical processing.

Paper: *Realizing Envisat's potential for rain cloud studies*, submitted to GRL

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