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Why rainfall may reduce when the ocean warms

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Conventional wisdom is that higher sea surface temperatures (SSTs) favour higher rainfall rates, because warmer air reaches saturation with a higher specific humidity. However, relative humidity (RH) near the surface has been shown to be more closely correlated with rainfall than specific humidity in regions, such as western Europe, that lie immediately downwind of oceans, suggesting that other aspects of the SST pattern are potentially of greater importance. Using a combination of observational data, idealised numerical model runs (using the Met Office unified model) and operational model reruns with a different underlying SST (using the ECMWF model), this has been investigated. The hypothesis under test is that the SST anomaly gradient along the incoming airmass trajectory is of particular importance. This was motivated by physical reasoning coupled with ad-hoc observation over many years. The conceptual model is that when SSTs remote from western Europe are above average, and SSTs closer to western Europe are below average (the 'cold east Atlantic pattern'), incoming airmasses will be cooled more from below, and therefore their boundary layer RH will increase. Conversely, with the reverse (the 'warm east Atlantic pattern'), the boundary layer RH would in relative terms reduce. The moister the boundary layer (in RH terms), the lower the cloud base, and as cloud base height shows a remarkably strong correlation with rainfall intensity, we therefore expect higher rainfall for the 'cold east Atlantic pattern'.

Evidence to support the hypothesis will be presented from the 3 components of this study. Each component has also been useful in highlighting other aspects, which will also be discussed. For example the idealised model study shows different partitioning of convective and dynamic precipitation in two different SST scenarios, which has implications for coastal and inland sites in western Europe. These idealised runs also highlight, for the 'warm east Atlantic pattern', a period of enhanced total precipitation followed by a marked reduction. Meanwhile the observational study reveals marked differences, between scenarios, in the frequency distribution of mean boundary layer humidity values in 3 seasons out of 4, and also shows that surprisingly small SST anomalies, of order tenths of a degree Celsius, can have a statistically significant impact. The operational model reruns highlight the benefits of running in atmosphere-ocean coupled mode from day 0, provided the ocean model has sufficiently thin layers.

Dynamically, one might expect that for the 'cold east Atlantic pattern' the lower level and greater release of latent heat during cyclone/front passage would have lead to synoptic patterns that were more cyclonic. Although we are not discounting this as a possibility we nevertheless uncovered no such connections, and so it seems that the mechanisms for modulating rainfall proposed here are independent of any modulation of the synoptic pattern.