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How to model rare events?

J. Grieser and S. Jewson

Risk Management Solutions Ltd., Model Development, London, United Kingdom (juergen.grieser@rms.com, +44 207444 7601)

The risk of extreme meteorological events is often estimated using extreme value theory (EVT). However, EVT can't be expected to work well in all cases. Two examples are (a) very rare events which are not adequately captured in short observational records and (b) nonstationary situations where observations alone cannot provide risk estimates for the future.

For these reasons Risk Management Solutions (RMS) develops models of extreme weather risks that are based on a combination of both, physics and statistics, rather than just statistics. One example is the RMS TC-Rain model. In addition to wind and storm surge, tropical cyclones (TCs) can lead to torrential rain that may cause widespread flooding and landslides. The most prominent recent historical example is tropical storm Alison (2001) which inundated Houston and caused roughly US$ 5bn of damage. Since Alison was only tropical storm, rather than a hurricane, no damage due to wind and storm surge was expected and no serious warnings were issued.

RMS now has developed a TC-Rain Model which is based on a combination of observations, experience and physical parameterizations. It is an example on how the use of physical principles helps to estimate the risk of rare and devastating events. Based on an event set of TC tracks it allows the calculation of several hundred thousand TC rain footprints which can then be used for the estimation of flood levels and their return periods via a complex dynamical hydrological model.
The TC-Rain Model takes a number of physical mechanisms into account, including (a) the effect of surface roughness change at land fall, (b) orographic rain enhancement, (c) drift of rain due to strong horizontal winds, (d) asymmetry, (e) outer rain bands and (f) the dependence on sea surface temperature. It is calibrated using 35 US-landfalling tropical cyclones from 1998 to the 2008, and verified against all US-landfalling TCs since 1948.

The model is not designed as a forecasting tool, but rather a tool for risk assessment. Nevertheless using the model to make forecasts can provide a useful test, and this was tried during the 2008 US TC season.
Since the RMS TC-Rain Model is generic and physically based it can be applied to other regions of the world with only minor changes to meet local and regional conditions. Furthermore since it is based on physics it also allows for sensitivity analyses such as estimating the impact of climate change (via sea surface temperature rise) on tropical cyclone rain.