**Resource Management**

# Reading between the lines: estimating rainfall for data-sparse catchments

***Richard Turner, Andrew Tait, Roddy Henderson,* and *Ross Woods* have found a way to fill in the gaps when data are few and far between.**

The quality of the water in New Zealand's lakes, rivers, and streams is a matter of great national importance. Increasingly, water-quality information derived from hydrological models is being used to help decide the fate of resource consent applications where degradation of waterways is an issue. Given the sensitive and important nature of such decisions, it is crucial that the hydrological models – and their key inputs – be as accurate as possible.

To meet this national need, we put a lot of effort at NIWA into studies of water and pollutant flow through soils, riparian buffer zones, and waterways. Our hydrological flow models and land-management software tools use rainfall and temperature as key climatic inputs. We apply these models over New Zealand catchments which vary in size from 25 to 10 000 km$^2$ Over larger or more inhabited catchments there are generally sufficient historic rainfall observations, so that entering the figures into the hydrological models is not a problem. However, there are large, mainly mountainous, areas and many river catchments where we have no long-term (or even short-term) rainfall observations. We call these data-sparse catchments.

## Filling in the blanks

To fill these gaps, meteorologists and hydrologists at NIWA have collaborated to make improved estimates of daily rainfalls and temperatures for these data-sparse catchments. Our aim was to create accurate daily maps of rainfall and temperatures for a period from 1960 to present day on a 0.05° latitude/longitude grid covering New Zealand. From these maps we would be able to extract rainfall and temperature data for any period for any of the grid points. As the scientific process often goes, we had to try a few methods before coming up with a reasonable technique that was better than the current practice of simply scaling the average annual rainfall map between the nearest observation points.

**How scaling works**

1. Assume Te Aroha has an average annual rainfall of 1500 mm.
2. On a particular day there is a rainfall event equaling 150 mm (or 10% of the annual average).
3. The estimated annual average for a certain hill in the Kaimai Range is 3000 mm.
4. Therefore a simple scaling estimate for that hill for the day of the rainfall event would be 300 mm.

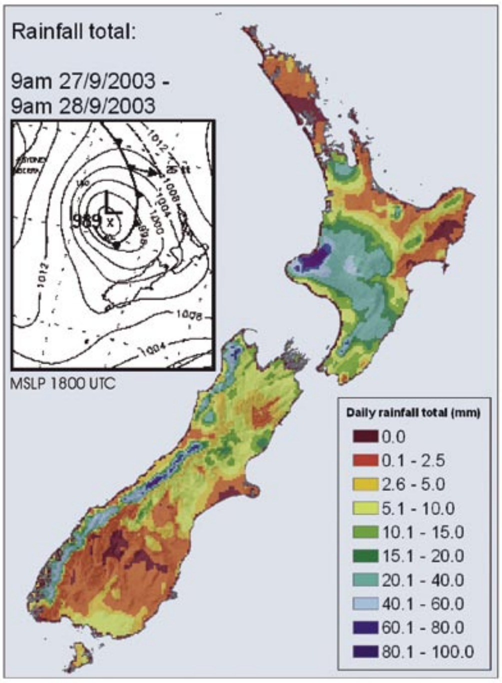
## Problems with scaling

A limitation of this scaling-type method is that sometimes a significant amount of rain falls over a remote catchment, while no rainfall is recorded at the nearest observing sites (which may be up to 40 km away). In that scenario the estimated rainfall from the scaling method would also be zero. By analysing past data, we found that for the mountainous Lewis Pass region, about 17 rainfall events a year could be missed at remote locations where the surrounding nearby stations are more than 30 km away. For other remote, but less mountainous, regions of New Zealand, there were between 2 and 10 missed rainfall events per year.

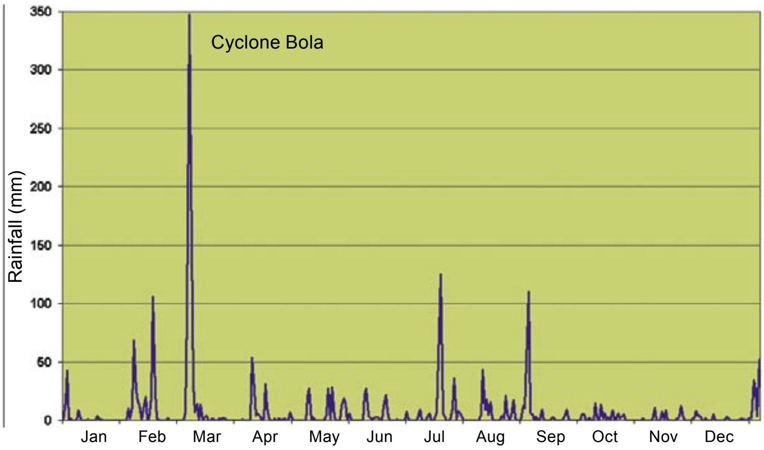
## Mesoscale modelling to the rescue

We determined that atmospheric mesoscale modelling offered the possibility (though no guarantee) that such elusive rainfall events would be captured. These models are increasingly used within the hydrological community in providing rainfall estimates for flood forecasting.

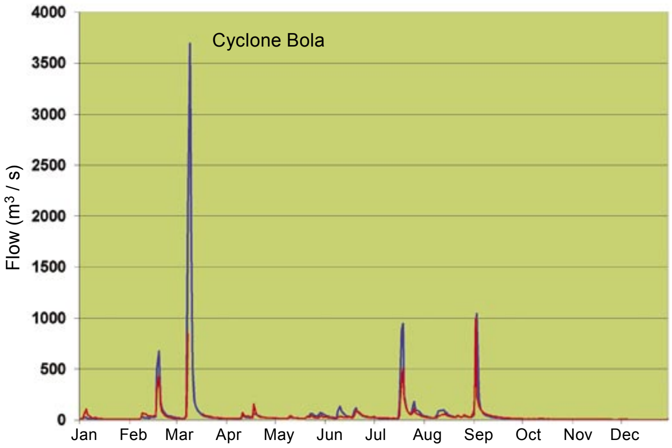
The first two methods we tested relied heavily on simulations of rainfall by mesoscale weather models. For the first method, we generated characteristic rainfall maps for 12 synoptic weather patterns that affect New Zealand. However, the rainfall was much too low and occurred on too many days, so this method was discarded.




Modelled daily rainfall for 27 September 2003 on the 0.05° grid. Floods, slips, and road closures were reported in Taranaki on this day.




Using the 'hybrid method': estimated daily rainfall for 1988 at a grid point over the Waipaoa catchment, upstream from Kanakanaia.




Daily flow of Waipaoa River for 1988 as measured by a flow recorder (red line) and modelled using the rainfall estimates from the first graph (blue line). Cyclone Bola damaged the flow recorder, so the record of flow data (red line) is broken at that point.

For the second method, we developed statistical relationships between modelled rainfall and observations from the closest stations for each of the synoptic weather patterns for a two-year period. However, this technique could not explain enough of the day-to-day variations in rainfall, and there were too many large discrepancies between estimates of rainfall at station locations and the observed station data. This method was also discarded.

Our third attempt was based on interpolation using a so-called trivariate thin-plate smoothing spline (see box below). It produced more realistic maps, but still under-predicted rain amounts at high elevations.

## Success with a hybrid method

We came closer to our goal by using a fourth hybrid method, where the spline estimates at each remote (generally elevated) grid point were merged with detailed rainfall maps produced by a high-resolution mesocale model. To come up with the rules for merging the spline estimates with the detailed model rainfall patterns, we used data and rainfall maps from the SALPEX 96 field experiment, when we knew the mesocale model agreed well with our ground observations over the high terrain of the Southern Alps. Although additional calibration was necessary for the hydrological models in some locations, we decided this fourth method produced reasonable and useful estimates when applied to water-flow models.

The graphs above show modelled daily rainfall for 1988 for a grid point in the Waipaoa catchment (near Gisborne) and river flow – modelled and observed – for the Waipaoa River for the same period. They include the extreme rain caused by Cyclone Bola.

The map (facing page) shows the spatial pattern of daily rainfall that can be generated using the hybrid method. On the particular day shown, flooding, slips, and road closures affected Taranaki. Using the data from this project we can produce such maps for each day from 1960 to the present. W&A

*Dr Richard Turner is a meteorologist with special interest in mesoscale modelling. Dr Andrew Tait studies climate variability and produces NIWA's climate maps. They are based at NIWA in Wellington. Roddy Henderson and Dr Ross Woods work with hydrology and water resources; they are with NIWA in Christchurch.*

**Interpolation with trivariate thin-plate smoothing spline**

This is a method of estimating the value of a variable (such as rainfall) at locations where no data exist. A surface (such as a map) is associated with the observed data with some error allowed at each data point, so the surface can be smoother than if the data were fitted exactly. The 'thin-plate smoothing spline' is a numeric formula that accounts for geographic information in fitting the surface, while still minimising the error.

In this case, we performed a thin-plate smoothing spline interpolation on rainfall data from raingauges throughout the country for every day between January 1960 and December 2003. The computation included a trio of variables – latitude, longitude, and elevation – hence the name 'trivariate'.

**Further reading**

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