Modelling frontal and convective rainfall distributions over North Wales

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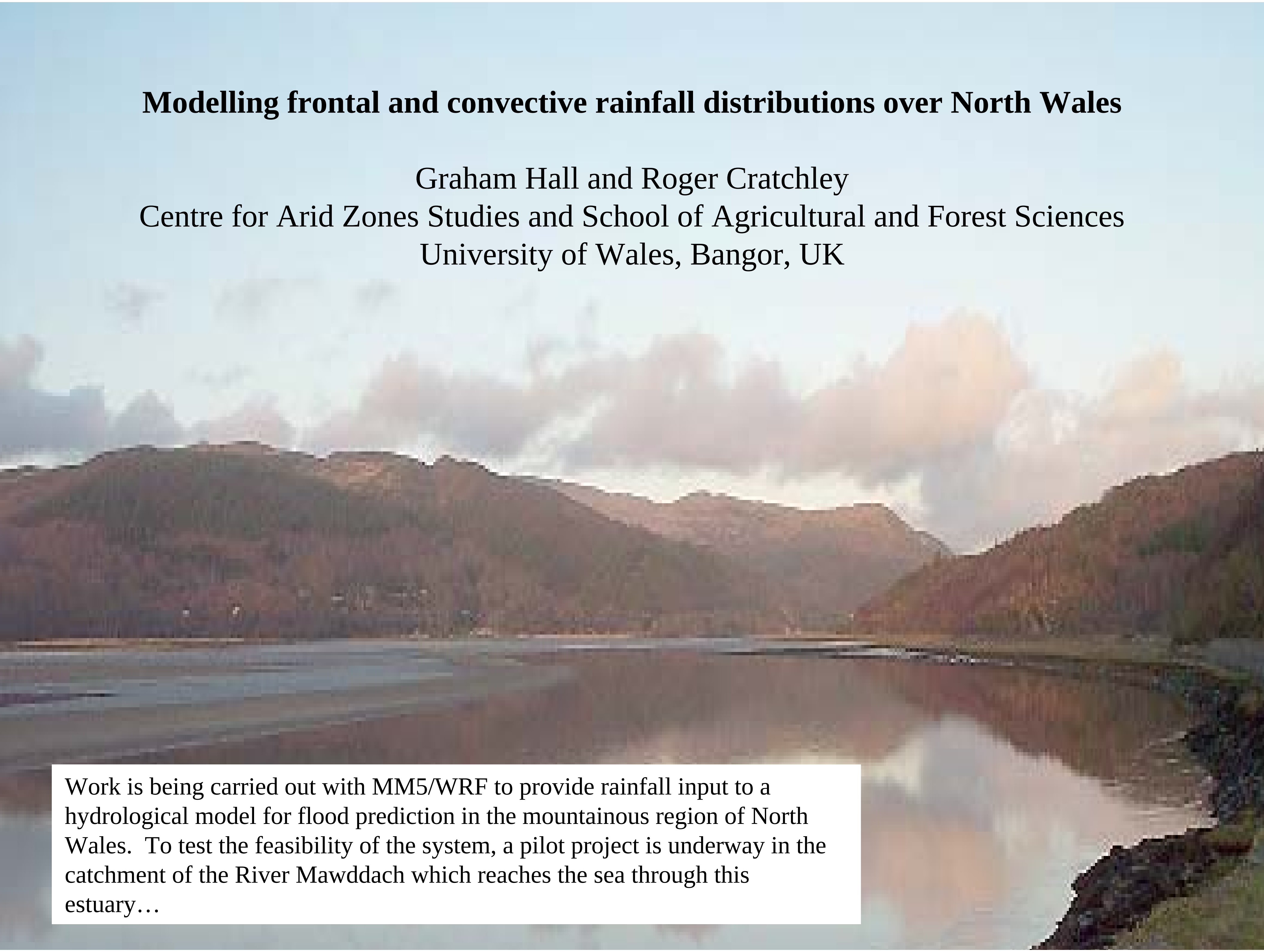
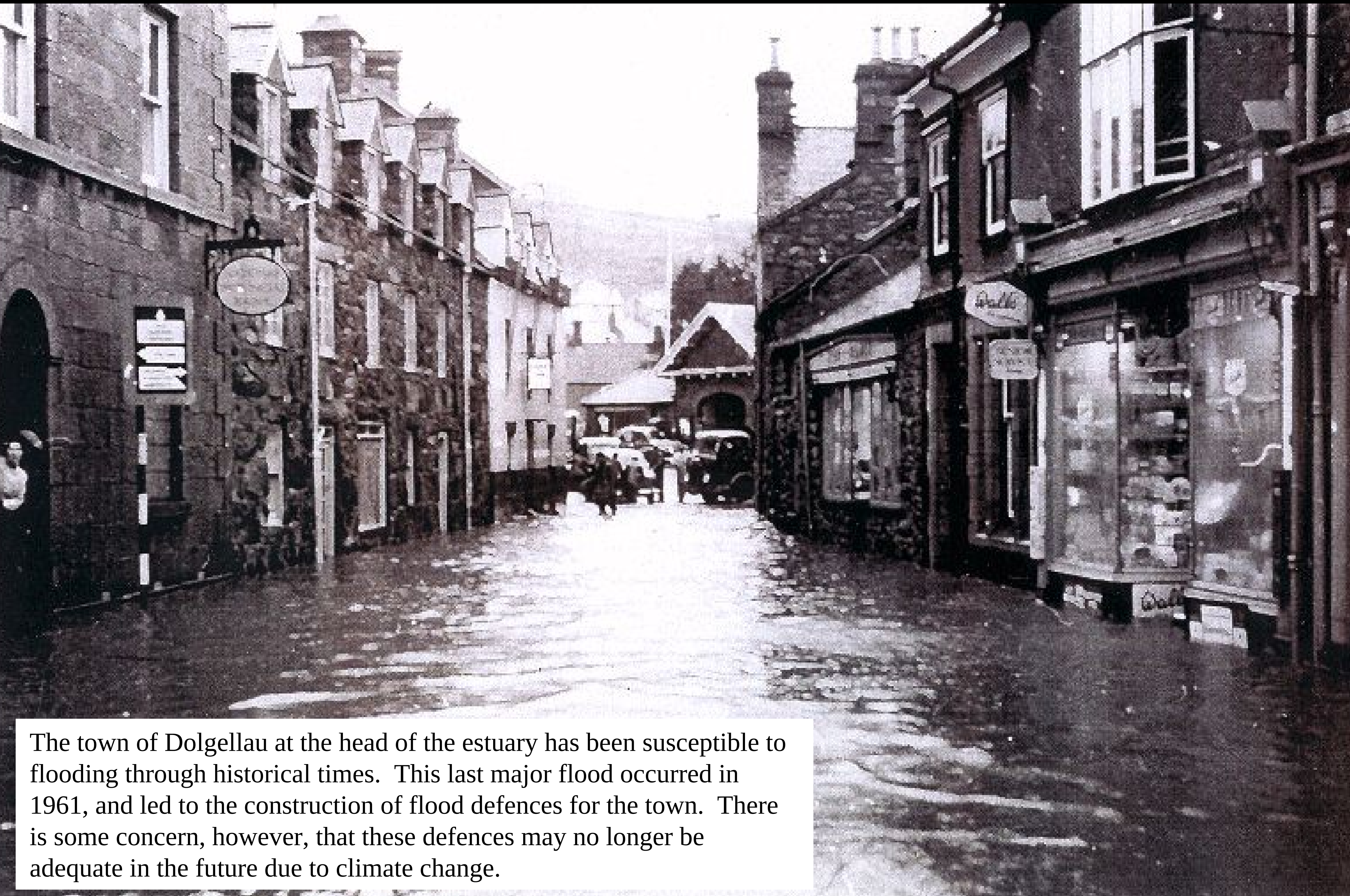


Work is being carried out with MM5/WRF to provide rainfall input to a hydrological model for flood prediction in the mountainous region of North Wales. To test the feasibility of the system, a pilot project is underway in the catchment of the River Mawddach which reaches the sea through this estuary…

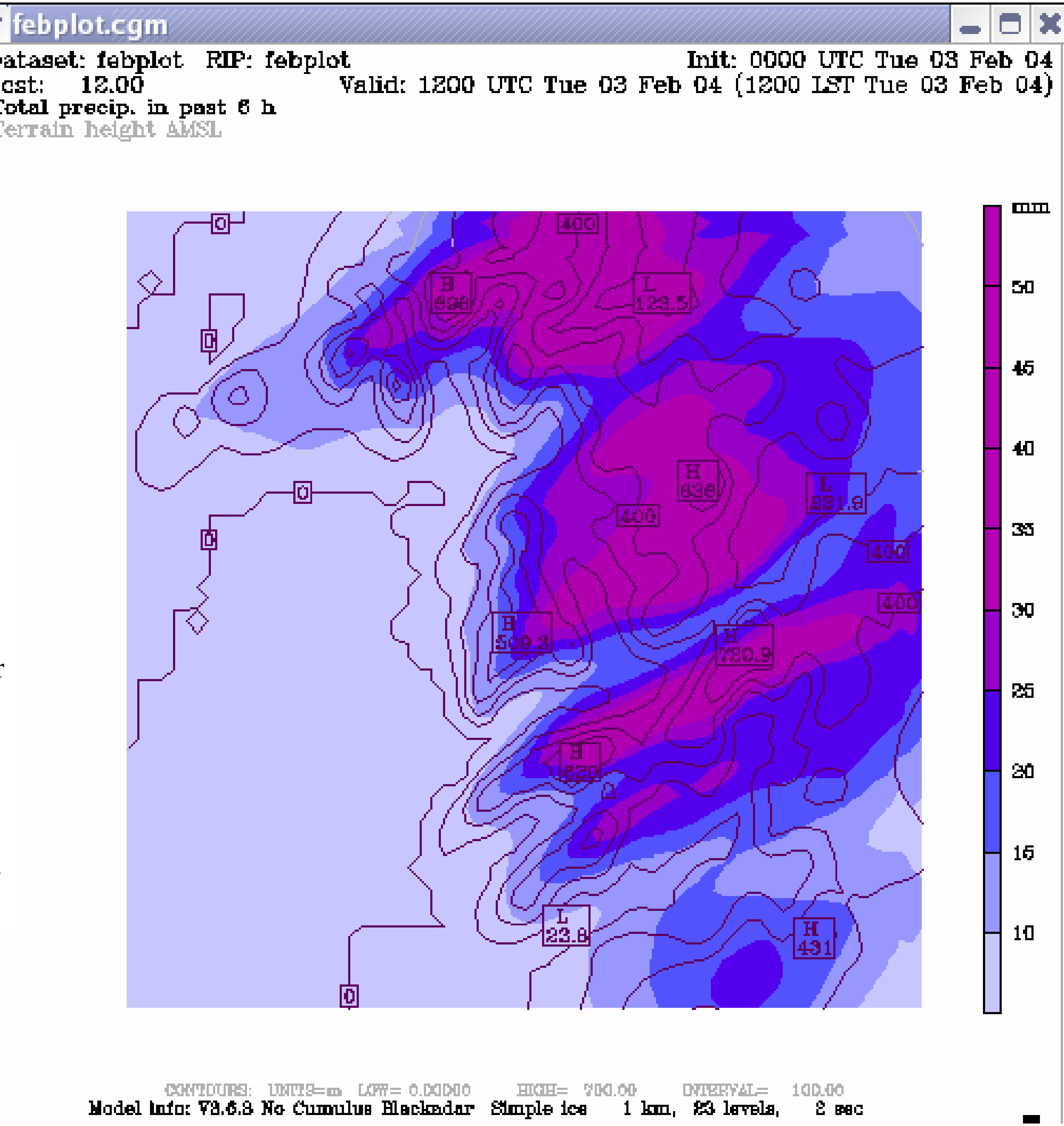


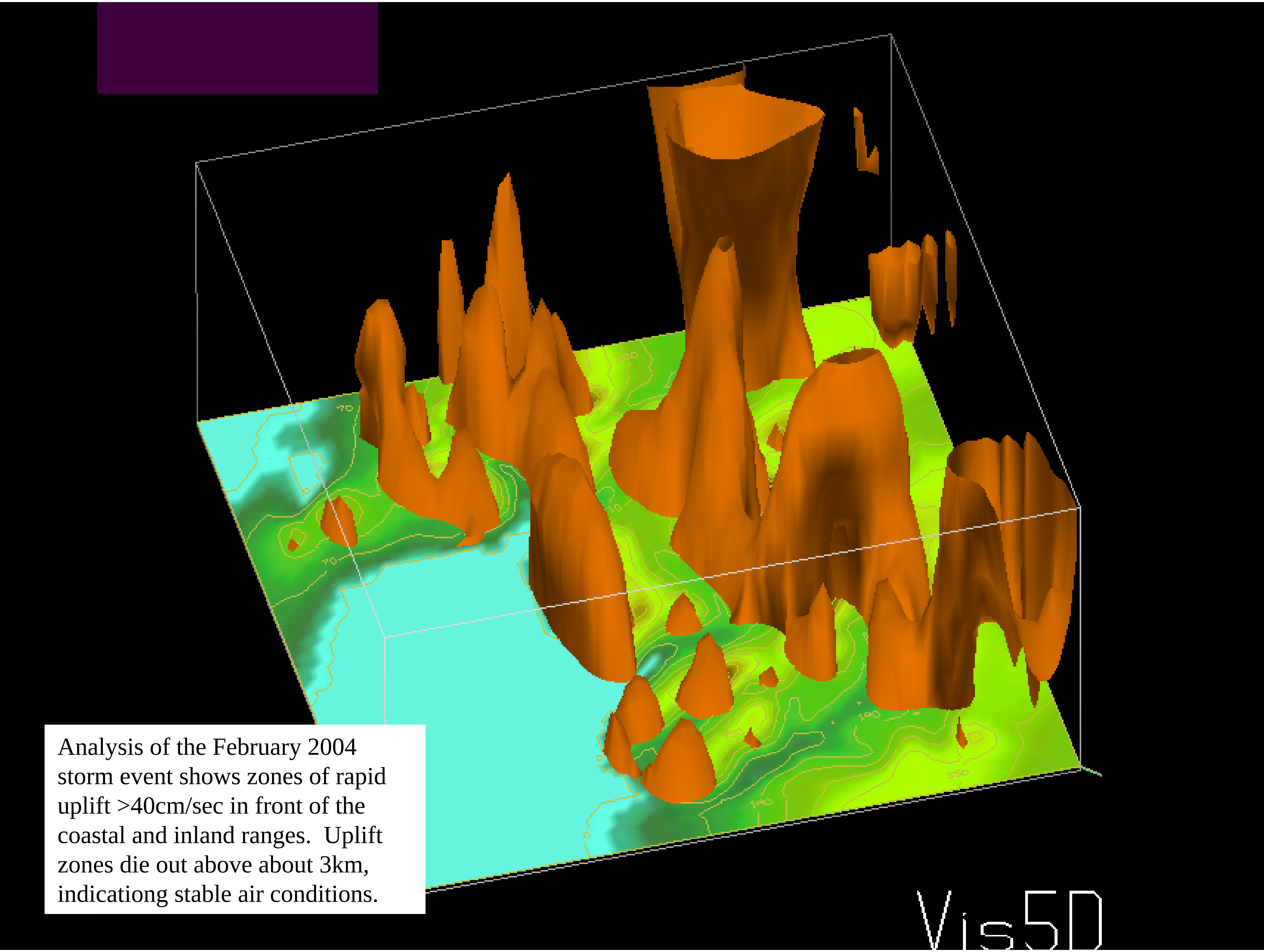
The town of Dolgellau at the head of the estuary has been susceptible to flooding through historical times. This last major flood occurred in 1961, and led to the construction of flood defences for the town. There is some concern, however, that these defences may no longer be adequate in the future due to climate change.

At the commencement of the project there were six rain gauges in and around the Mawddach catchment operated by government organisations. An additional 24 data-logging rain gauges have been added, particularly in the upland areas, so that accurate hourly rainfall maps of the catchment can now be produced for individual storm events.

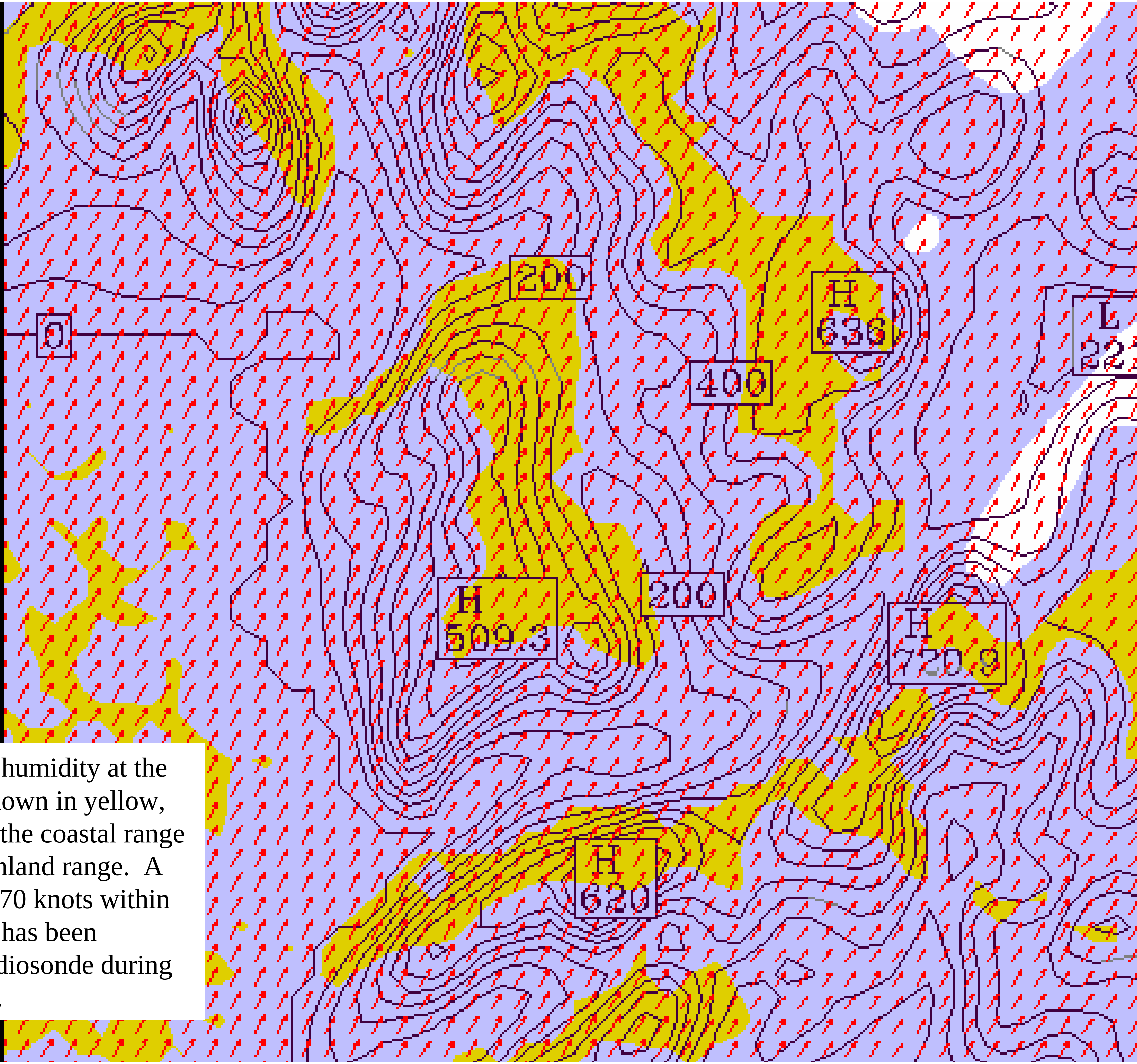
It has become clear from field data that large differences in rainfall occur across the catchment. This range of mountains, the Rhinogs, along the coast receives relatively little rainfall, whereas a second range of mountains some 20km further inland, the Arenigs, is the focus of maximum rainfall and the main source area for floods.

Modelling has been carried out with MM5 for five winter storm events of low CAPE associated with frontal systems from the Atlantic. In all cases the agreement with rain gauge data was within 10%, and often better than 5% error. The pattern of low rainfall over coastal mountains and rainfall increasing inland is correctly modelled, as in this example from a flood event of 3 February 2004

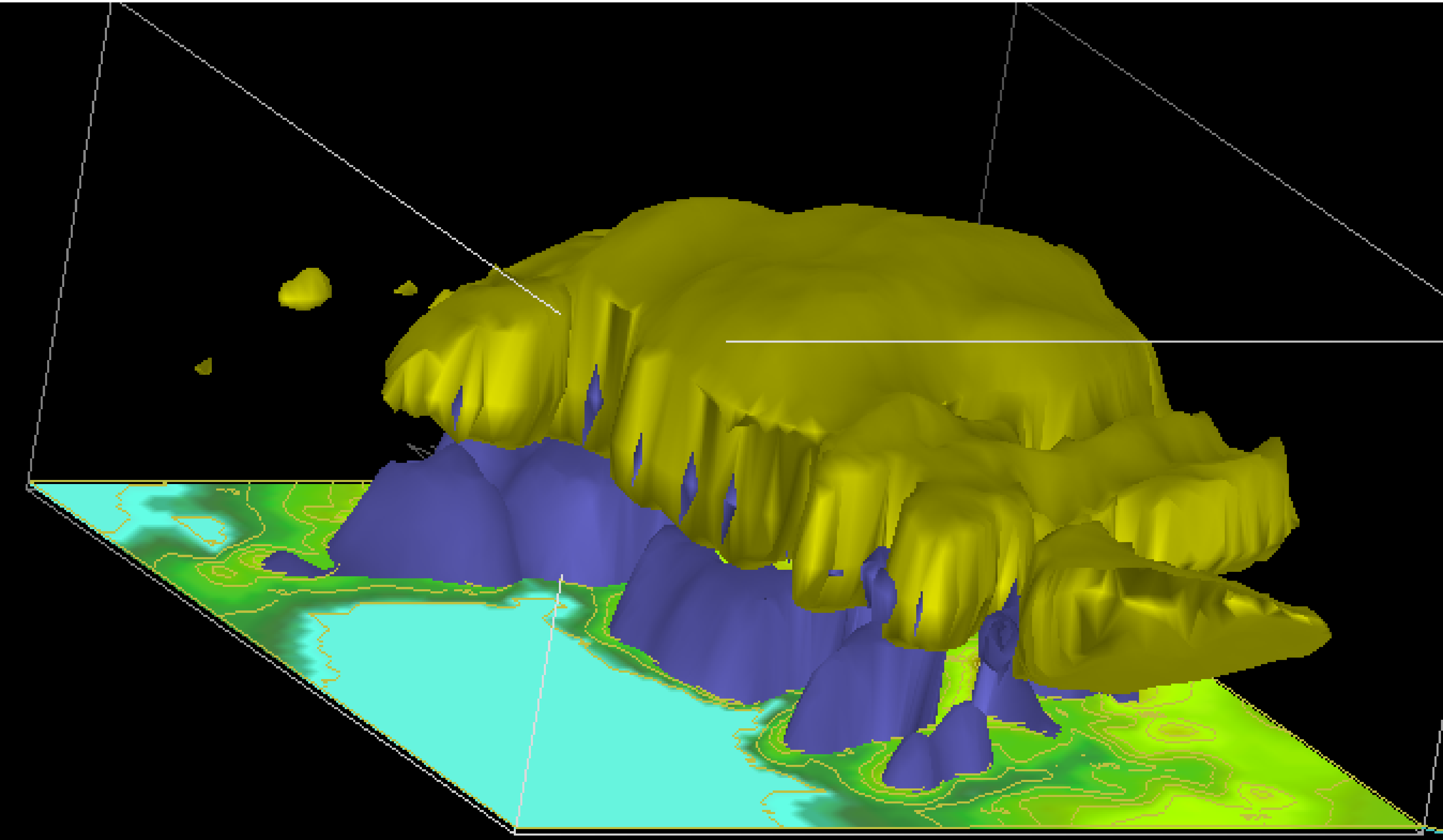




Analysis of the February 2004 storm event shows zones of rapid uplift >40cm/sec in front of the coastal and inland ranges. Uplift zones die out above about 3km, indicationg stable air conditions.



Zones of 100% humidity at the 900mb level, shown in yellow, occur inland of the coastal range and above the inland range. A low level jet of 70 knots within the SW airflow has been identified by radiosonde during the storm event.



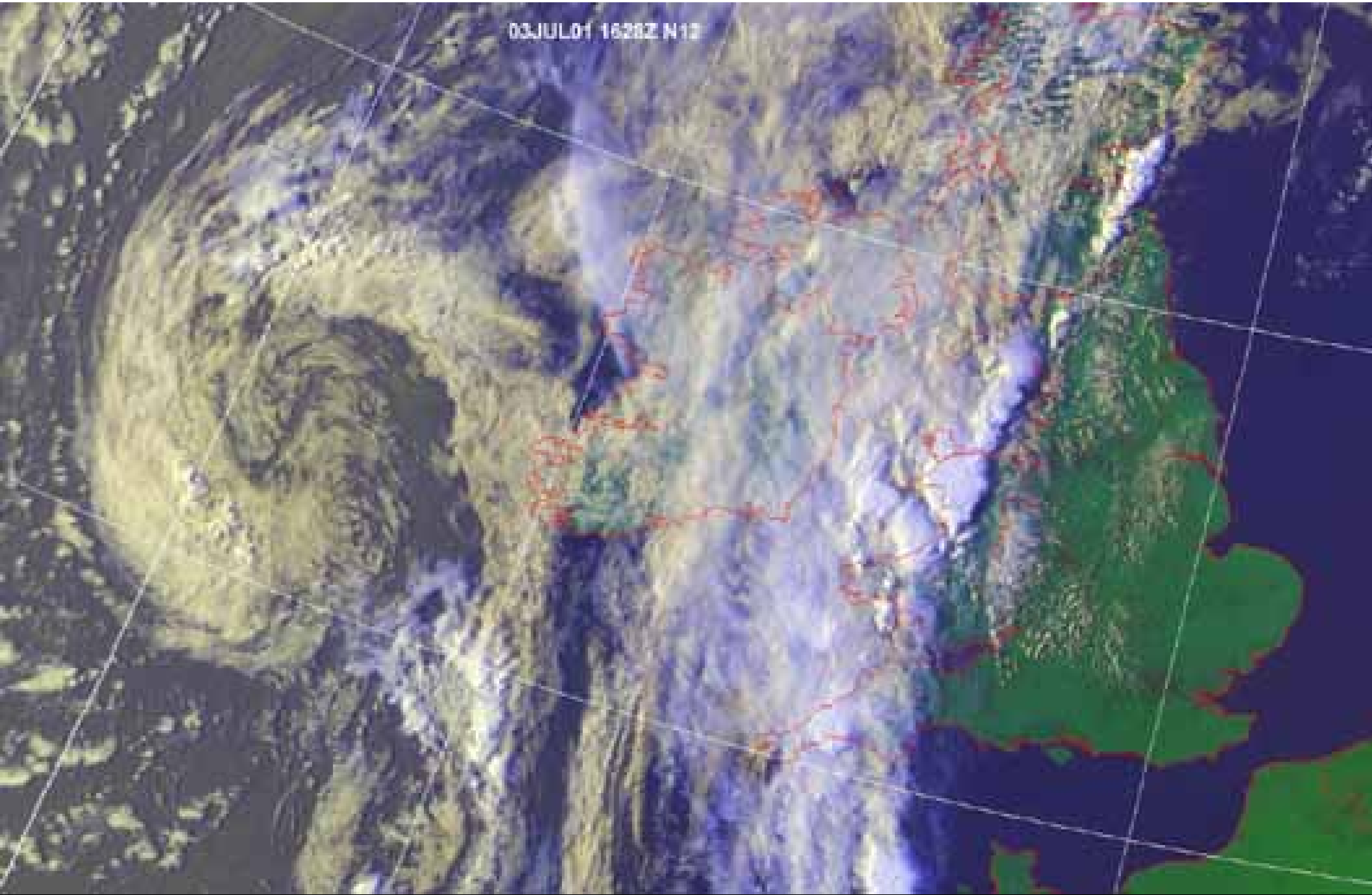
This diagram shows isosurfaces for cloud mixing ratio >0.4 (blue) and precipitation mixing ratio >0.4 (yellow). A seeder – feeder mechanism has been suggested to explain the rainfall enhancement inland. Droplets falling from higher level seeder clouds enter the saturated low level jet of stratiform cloud. The droplets grow within this feeder zone and are advected inland to fall as rain over the inland mountain range.

Flooding around the estuary caused by the Febraury 2004 storm. It has been possible to use the rainfall distribution generated by MM5 as an input to a MODFLOW groundwater model, and in turn to use river discharge from MODFLOW as an input to RIVER-2D software for modelling the depth and extent of flooding.

The next phase of the project has been to examine summer storms over the region. The largest storm event ever recorded was on 3 July 2001, when an intense line of thunderstorms developed ahead of a cold front. Photo: John Mason

At the height of the storm, roads became impassable and golf-ball sized hail was experienced.
Lightening strikes occurred at a rate of one per second. 35mm of rainfall was recorded in one hour.
Photo: Bob Chilton

Bridges were severely damaged or washed away by flood waters…



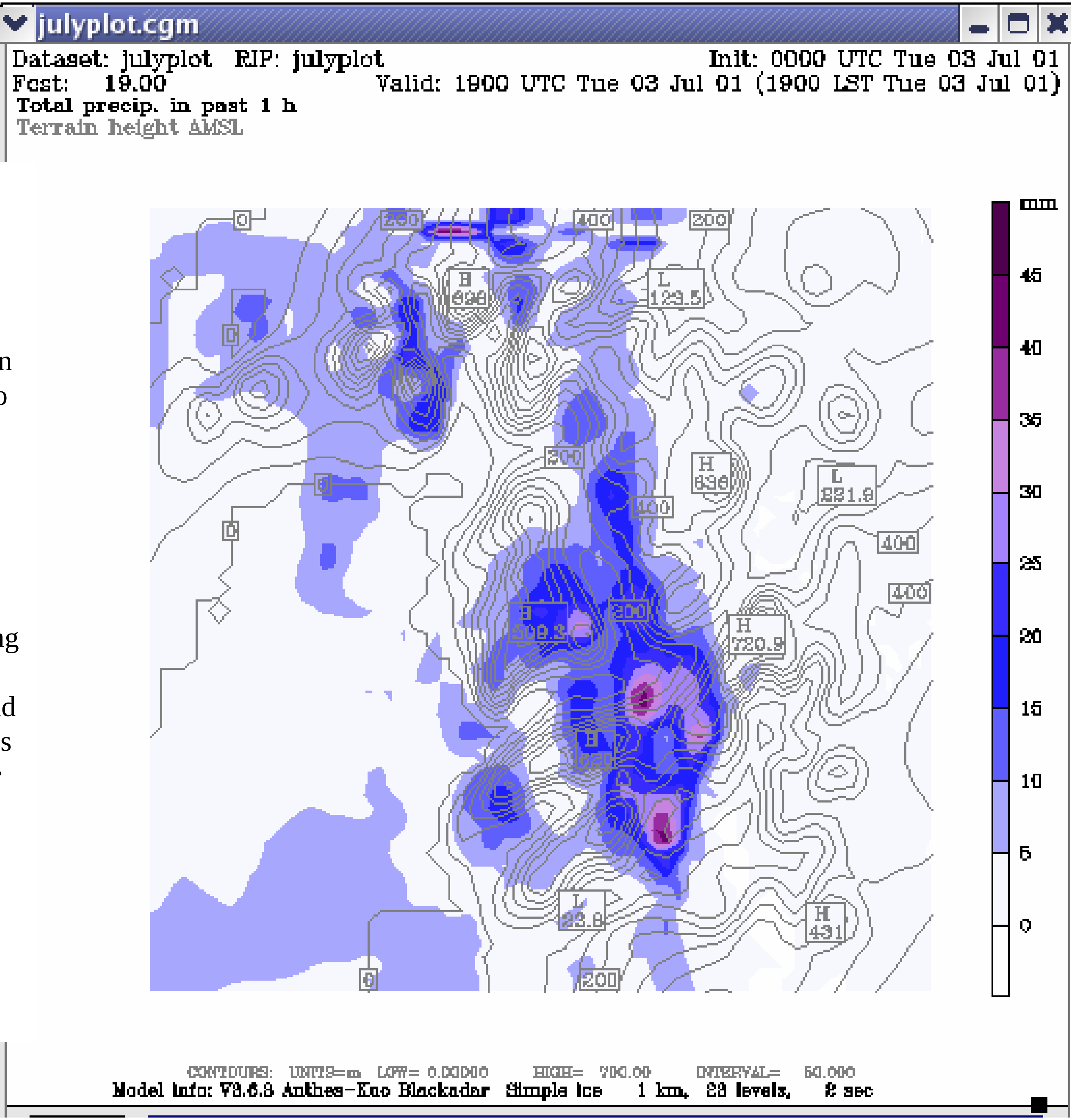
Satellite image of the July 2001 storm, with a depression over the Atlantic and cold front along the coast of Wales. Squall line storms occurred ahead of the cold front at the mixing zone with warm moist air over Britain.

Modelling of the July 2001 storm was carried out with MM5:

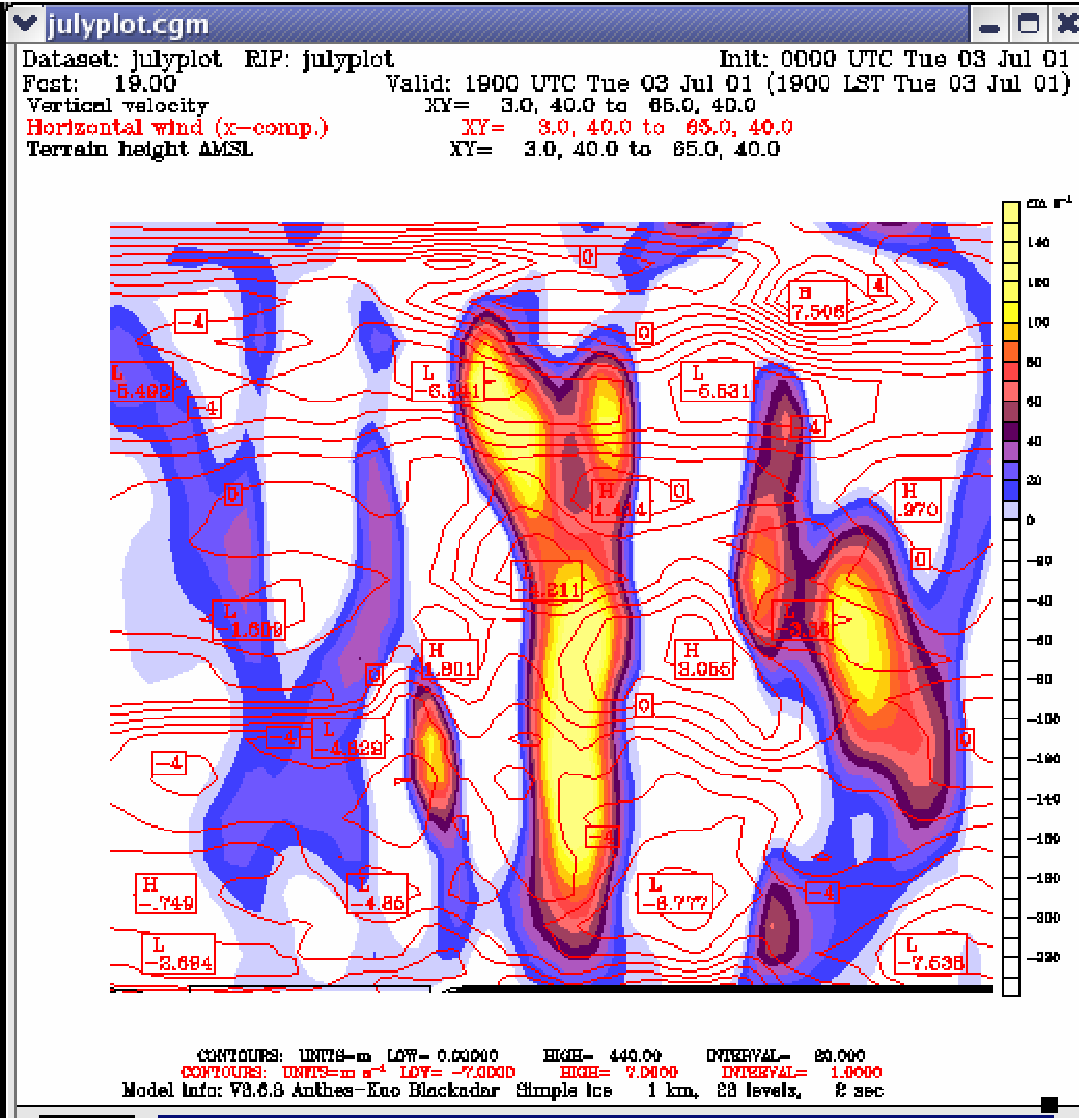
•An initial model with no convective parameterisation on the inner 1km domain failed to generate the storm rainfall at all.

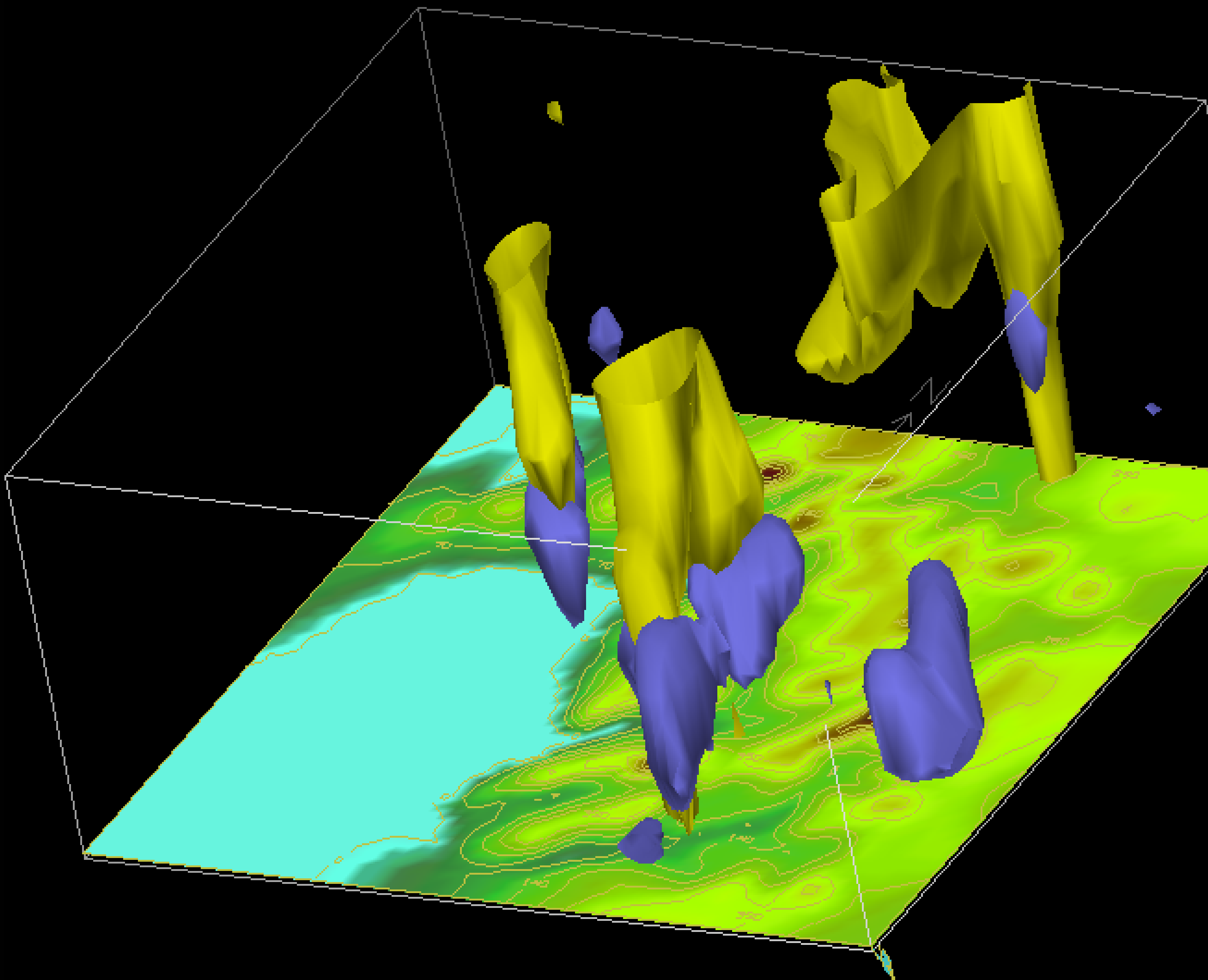
•A model using the Anthes-Kuo scheme generated a good representation of the storm as shown here… Location, timing and rainfall intensity all have good correspondence with field data. The squall line illustrates a bow echo structure with rear inflow notch and central supercell.

•Models using the Grell and Kain-Fritsch schemes again failed to generate any storm rainfall in the required area.



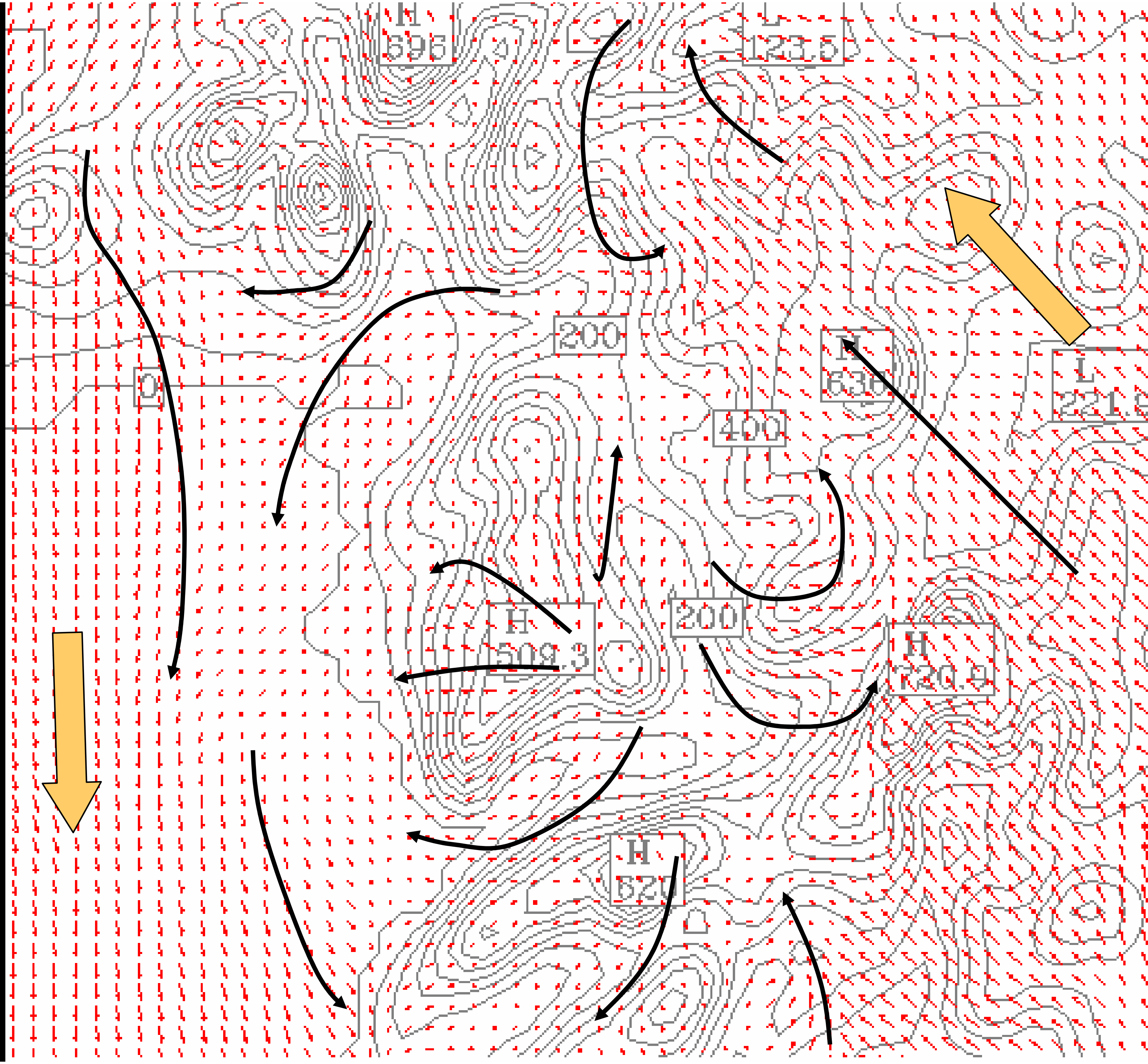
W-E Cross section of the Anthes-Kuo model showing the convective supercell. Colour fill indicates vertical velocities, and red contours indicate horizontal velocities. There is evidence of mid altitude coupling of regional wind shear to generate cyclonic motion…



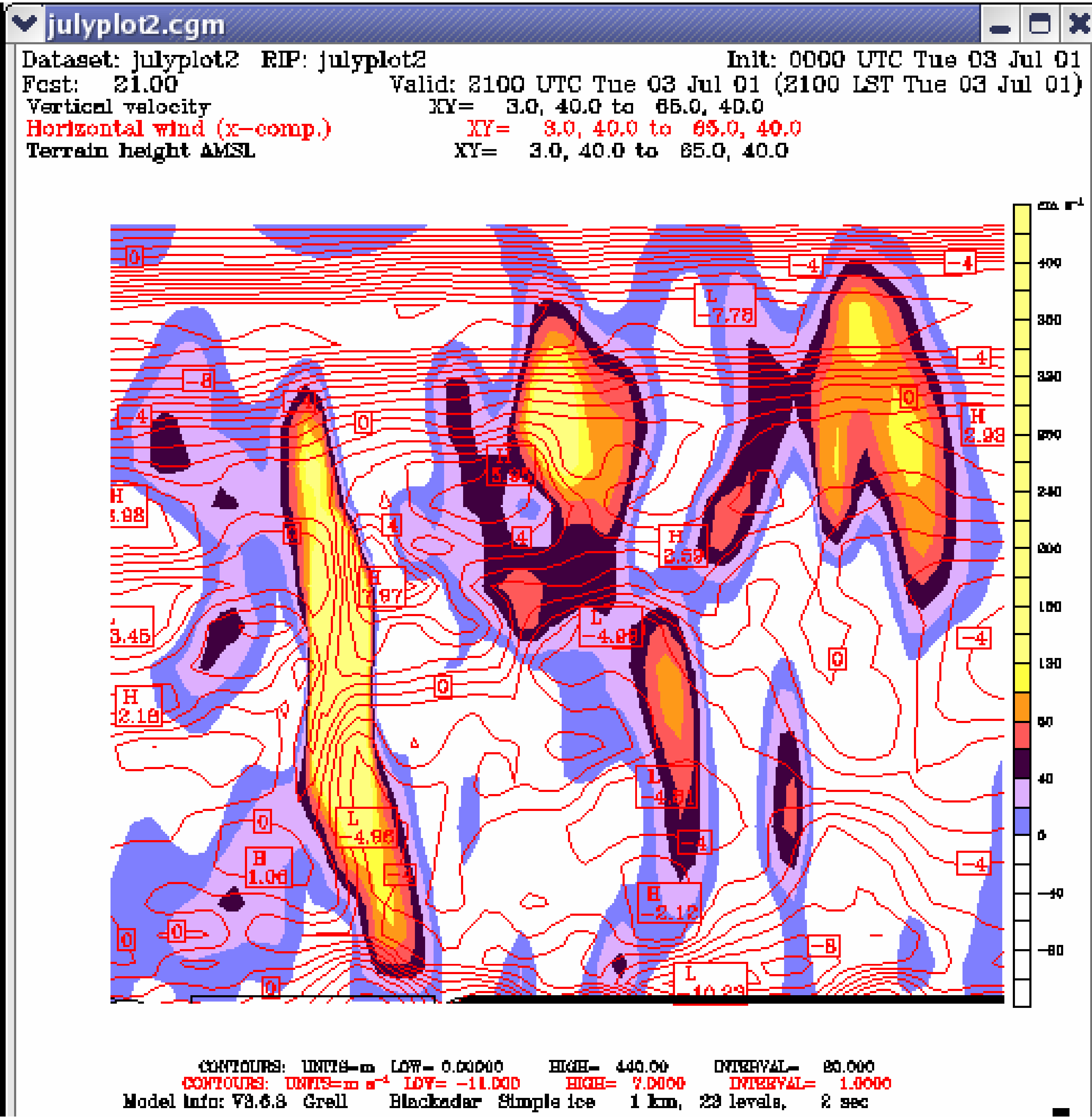


Isosurface (yellow) for precipitation mixing ratio>0.4 indicates localisation of rainfall within the squall line

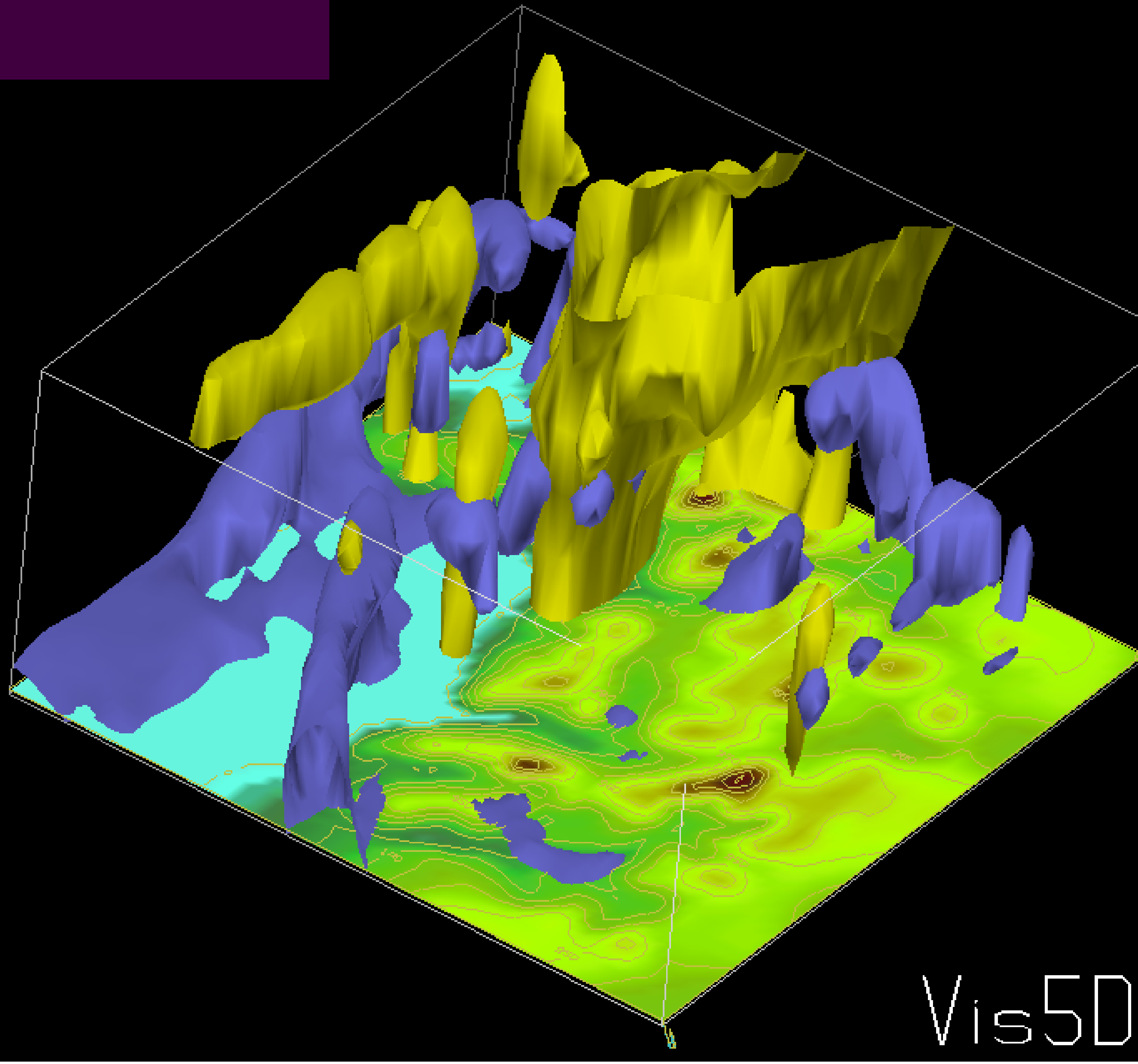
Air flows at the 900mb level indicate cyclonic outflows of descending air around the convection centre



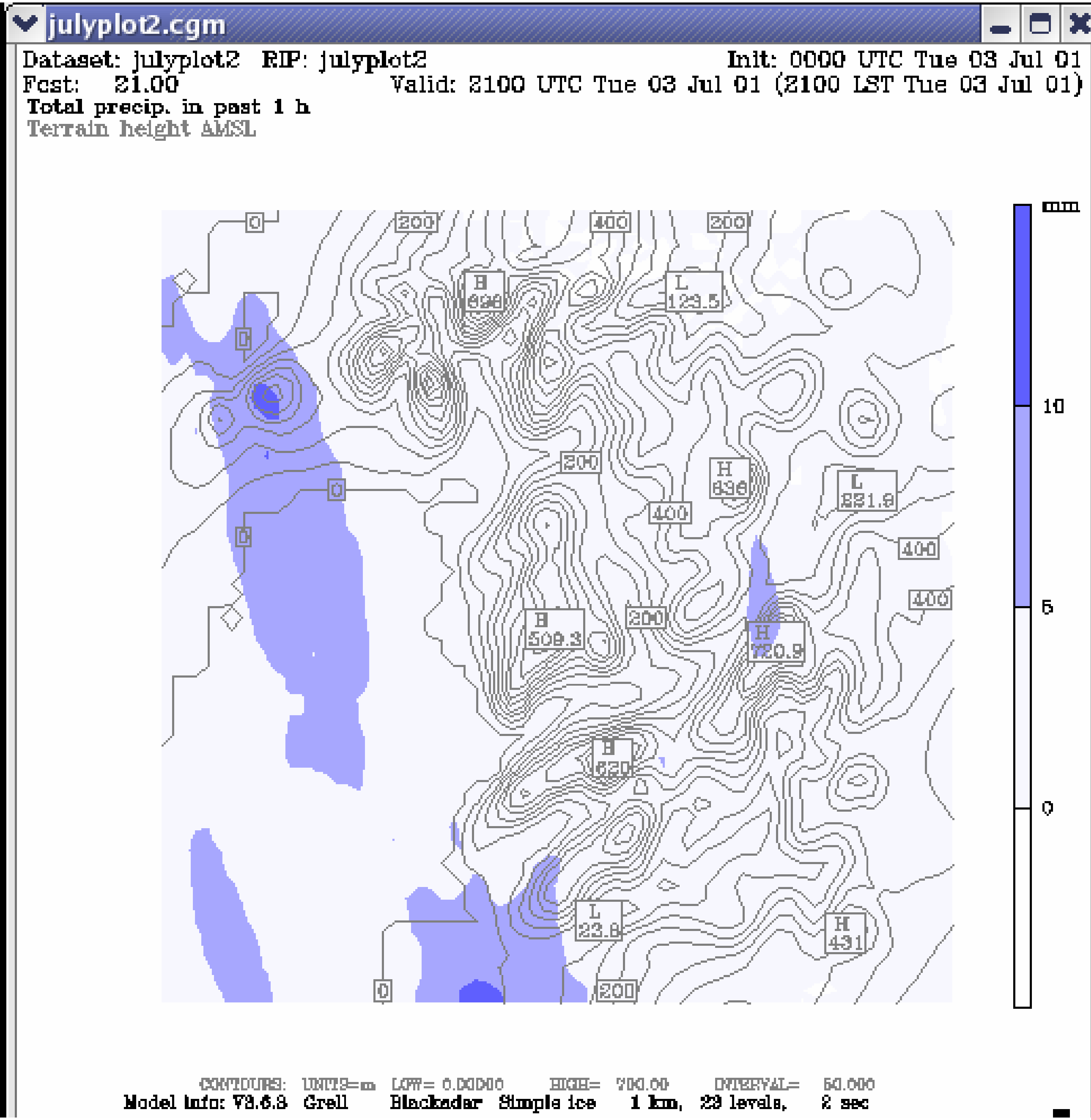
Results using the Grell cumulus scheme generate a number of small convective cells over the region…



Cloud formation under the Grell scheme is evident, but rainfall is restricted to the cold front along the coast…



No rainfall is generated along the inland axis of the squall line…



High CAPE storm events are becoming increasingly violent in Britain – this example is the disastrous flooding of Boscastle in Cornwall in August 2004. It is clearly important to have a convective scheme available in WRF which can reliable predict such events.

Preliminary results of the Mawddach project suggest that a simple bulk convective scheme such as the Anthes-Kuo scheme may be the most effective in generating rainfall patterns on a high resolution 1km grid. It is necessary to model the convergence of air masses, condensation and release of latent heat to realistically drive convective cells.