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## Cumbrian floods, 5-6 December 2015

A very mild and moist warm sector associated with an almost stationary frontal system brought continuous rainfall to many parts of southern Scotland and northern England in early December 2015. Orographic enhancement of the existing persistent frontal rainfall was particularly pronounced in the strong, steady south-westerly airflow, particularly over the Cumbrian mountains, where new 24 hour and 48 hour rainfall records for the British Isles were established.

The main rainfall event occurred in the 38 hours between 1800 UTC Friday 4 December and 0800 UTC Sunday 6 December. During this period, rainfall amounts varied from less than 25 mm on the Cumbrian coast to 100 to 150 mm over much of the high ground of north-west England and south-west Scotland, while 200 to 300 mm fell quite widely across the central Cumbrian fells (Figure 1). The highest known total to date for the two rainfall days 4 and 5 December combined (i.e. the 48 hours commencing 0900 UTC on 4 December) was 405.0 mm at Thirlmere (129 m above MSL), closely followed by 382.0 mm at Honister Pass (358 m AMSL), both in Cumbria. The Thirlmere value is a new British Isles rainfall record for 48 hours duration, surpassing the 395.6 mm recorded at nearby Seathwaite as recently as 18-19 November 2009 (Eden and Burt, 2010; Sibley, 2010, Stewart et al, 2012, Miller et al, 2013). At Honister Pass, 341.4 mm of rainfall fell in the 24 hours commencing 1800 UTC on 4 December, itself a new British Isles rainfall record for 24 hours duration, surpassing the 316.4 mm recorded at Seathwaite on 19 November 2009 (Burt and Eden, *op cit*). Thirlmere also exceeded the previous British Isles 24 hour record, with 322.6 mm. For the standard 'rainfall day' 5 December (the 24 hours commencing 0900 UTC), three sites recorded in excess of 200 mm, notably 264.4 mm at Thirlmere and 244.6 mm at Brothers Water, both just under the existing British Isles 'rainfall day' rainfall record of 279 mm at Martinstown, Dorset on 18 July 1955<sup>1</sup>. The synoptic circumstances during the December 2015 episode were very similar to those of the November 2009 event, when the highest 'rainfall day' fall was 253.0 mm at Seathwaite on 19 November, its highest daily fall on a record extending back to 1844. This time, the highest 3 day total (450.2 mm at Thirlmere) was slightly lower than the 456.4 mm recorded at Seathwaite over 17 to 19 November 2009.

Extensive and severe flooding resulted, with two fatalities, thousands of homes and businesses inundated, schools and hospitals closed, and road and rail links cut. Flooding was exacerbated by already saturated ground – November 2015 was an extremely wet month in the north-west of England, Honister Pass recording 1039 mm during the month, more than twice normal even for this extremely wet location (average annual rainfall > 3500 mm). Evidence of the unprecedented volume of water is afforded by the loss of several bridges to floodwater, including the Pooley Bridge in Ullswater which was built in 1764. Several rivers established new peak flow records, including the Eden downstream of Carlisle which, if the provisional figure is confirmed, represents a new maximum peak flow on *any* river in England and Wales. Power was lost to over 60,000 properties in Cumbria and Lancashire, for several days in some places.

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<sup>1</sup> The majority of the Met Office digital rainfall archive consists of daily accumulations for the standard rainfall day spanning the 24 hour period 0900 to 0900 GMT. Comparisons for other 24 hour periods are therefore more reliant on the less extensive archive of sub daily data. However it is noteworthy that the 341.4 mm recorded at Honister between 1800 UTC 4 December to 1800 UTC 5 December 2015 exceeds any previous two day rainfall accumulation recorded in the Met Office digital archive, with the exception of 18 to 19 November 2009.

Advance warning of the event was provided by the Met Office, who issued an Amber warning on 4 December for 'More than 150 mm rainfall expected over Cumbria' and a rare Red warning early on 5 December. These timely and geographically accurate advance warnings enabled emergency services and river management/flood defence authorities to enact major flood contingency plans in good time, without which loss of life and damage to property could have been much greater.

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FIGURE CAPTION

Figure 1. Total rainfall (mm) for the 48 hours commencing 0900 UTC on Friday 4 December (i.e. the raindays of 4 and 5 December). This is a preliminary map, assembled from telemetered tipping-bucket raingauges operated by the Environment Agency and Met Office, subject to revision once quality control procedures have been completed. Source: Met Office, National Climate Information Centre. Crown Copyright.

