

Exceptional rainfall in Scotland, 6 to 7 October 2023

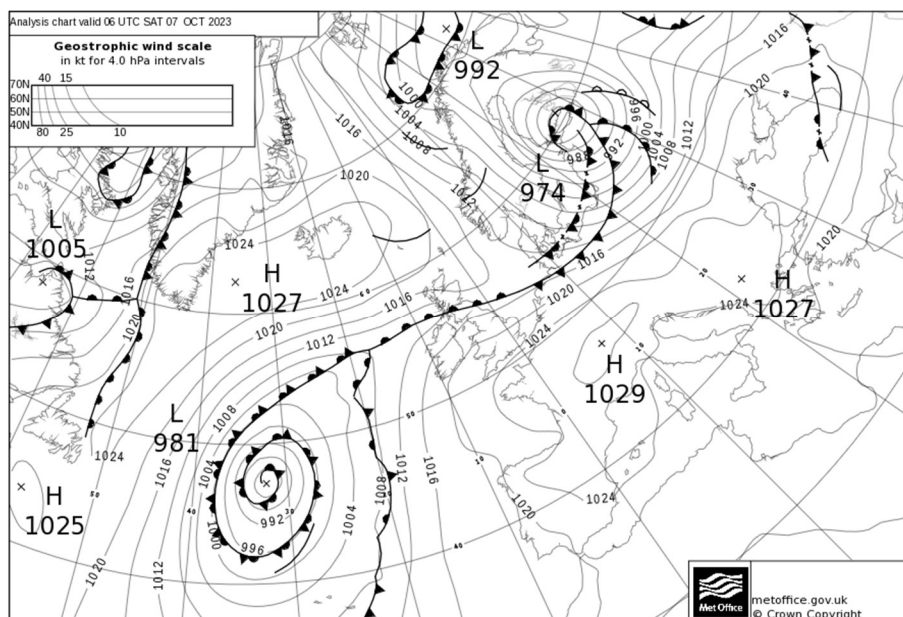
Much of Scotland experienced widespread and prolonged rainfall from 6 to 7 October 2023, with 100 to 150mm falling widely across a swathe of the Southern and Central Highlands and heavy rain also extending to the east coast. The heavy rain was due to an ‘atmospheric river’ – a narrow stream of moisture laden air capable of causing very high rainfall totals. This was the wettest 2-day period on record for Scotland in a series from 1891. The front causing the rainfall marked the contrast between cold air to the north and much warmer conditions further south. Temperatures in England and Wales reached the low 20s °C, with 25°C in parts of the south-east.

Impacts

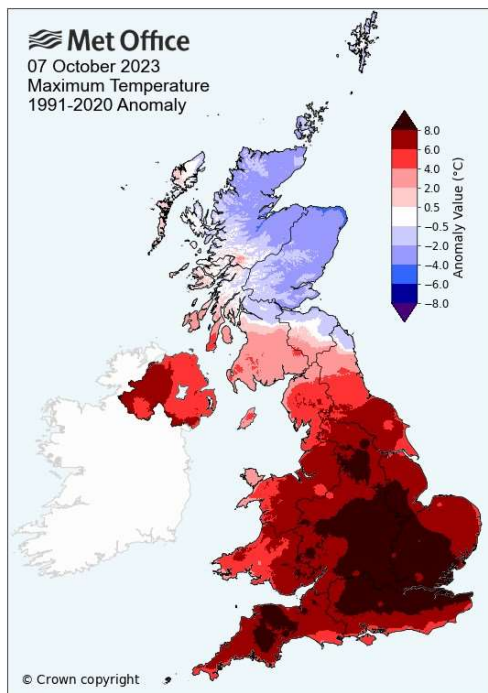
The heavy and persistent rain caused widespread flood impacts across Scotland. In Argyll, the A83 was closed due to a landslip with ten people airlifted from their vehicles and several other major trunk roads were also closed. Rail services across Scotland were severely affected with many trains cancelled. Flooding affected a number of properties, including in Dumbarton, while at Inverary, bales of silage were washed away by the River Aray. Scottish farmers reported the loss of several million pounds worth of unharvested vegetables damaged by floodwaters. Over 50 flood warnings were issued across Scotland, including severe flood warnings for parts of Aviemore and Perth. Many sports events were also cancelled.

Weather data

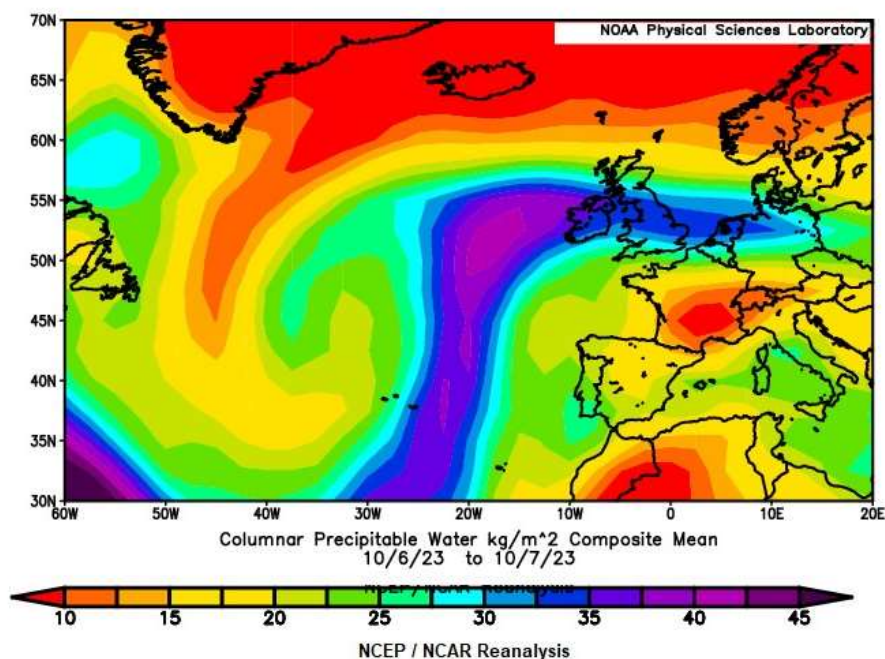
The analysis chart at 0600UTC 7 October 2023 shows a frontal system bringing sustained heavy rainfall across central Scotland in a westerly flow. This type of event is termed an ‘atmospheric river’, comprising a narrow band of moisture laden air capable of causing very large amounts of rain. The front marks the boundary between warm air to the south and much colder air to the north.



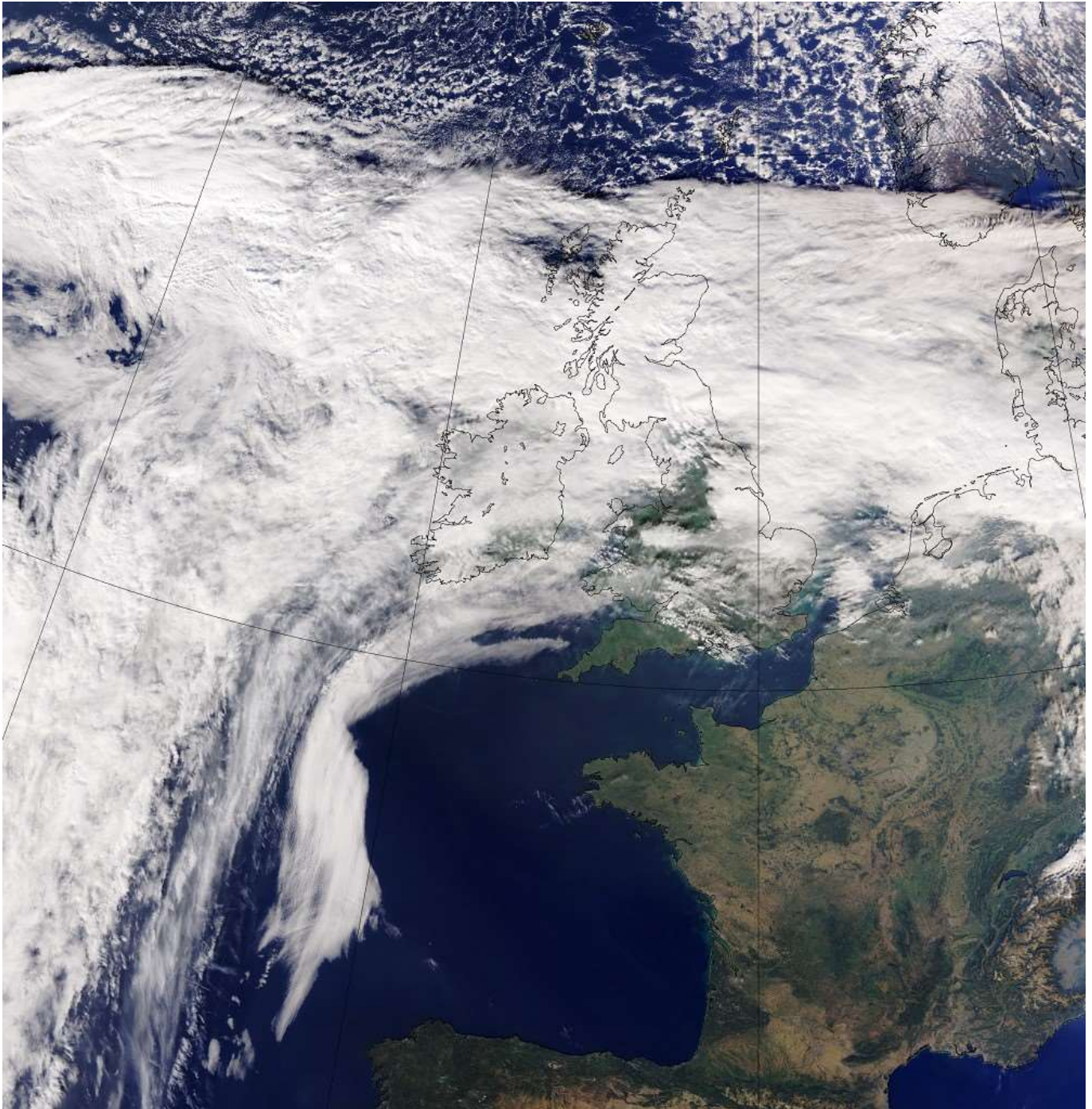
The map below shows daily maximum temperatures on 7 October 2023 relative to the 1991-2020 October long term average, emphasizing the temperature contrast to the north and south of this front. Daily maximum temperatures were widely in the low 20s °C across England and Wales, reaching 25.7°C at Faversham, Kent – around 10°C above average for the time of year. In contrast, daily maximum temperatures across Northern Scotland struggled to reach 10°C, with a maximum of only 7.7°C at Aviemore, Inverness-shire, around 4°C below average.



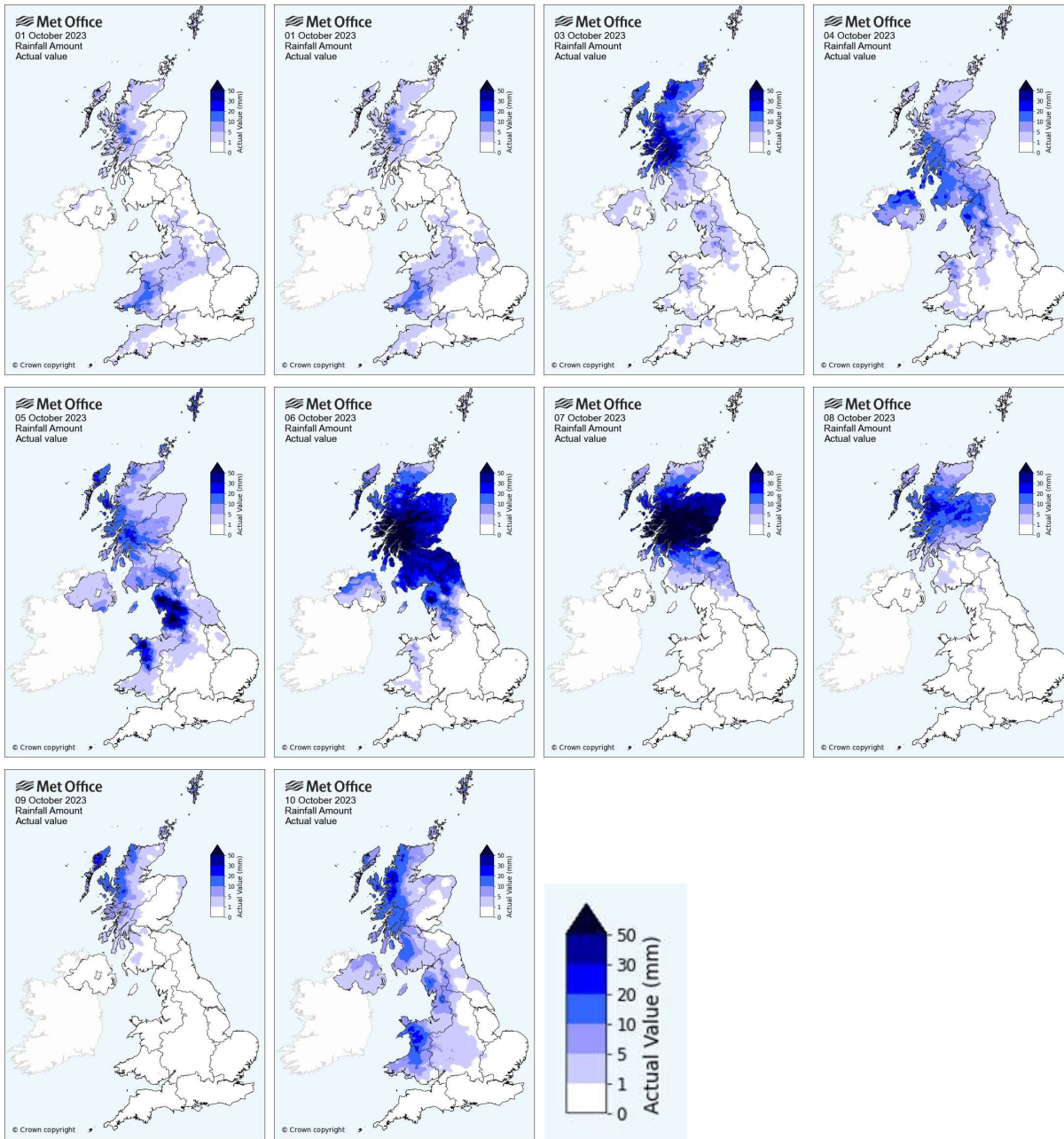
The chart below shows average precipitable water in the atmosphere in the North Atlantic for 6 to 7 October 2023 (1kg/m² is equivalent to 1mm depth). This illustrates the ‘atmospheric river’ of moisture laden air affecting the north of the UK. The chart is based on the NCEP / NCAR reanalysis (Kalnay et al, 1996). A reanalysis combines observations and a numerical weather forecast model to produce a 3 dimensional representation of the state of the atmosphere including temperature, pressure, wind speed and moisture content. Images provided by the NOAA-ESRL Physical Sciences Division, Boulder, Colorado from their web site at <https://psl.noaa.gov/>



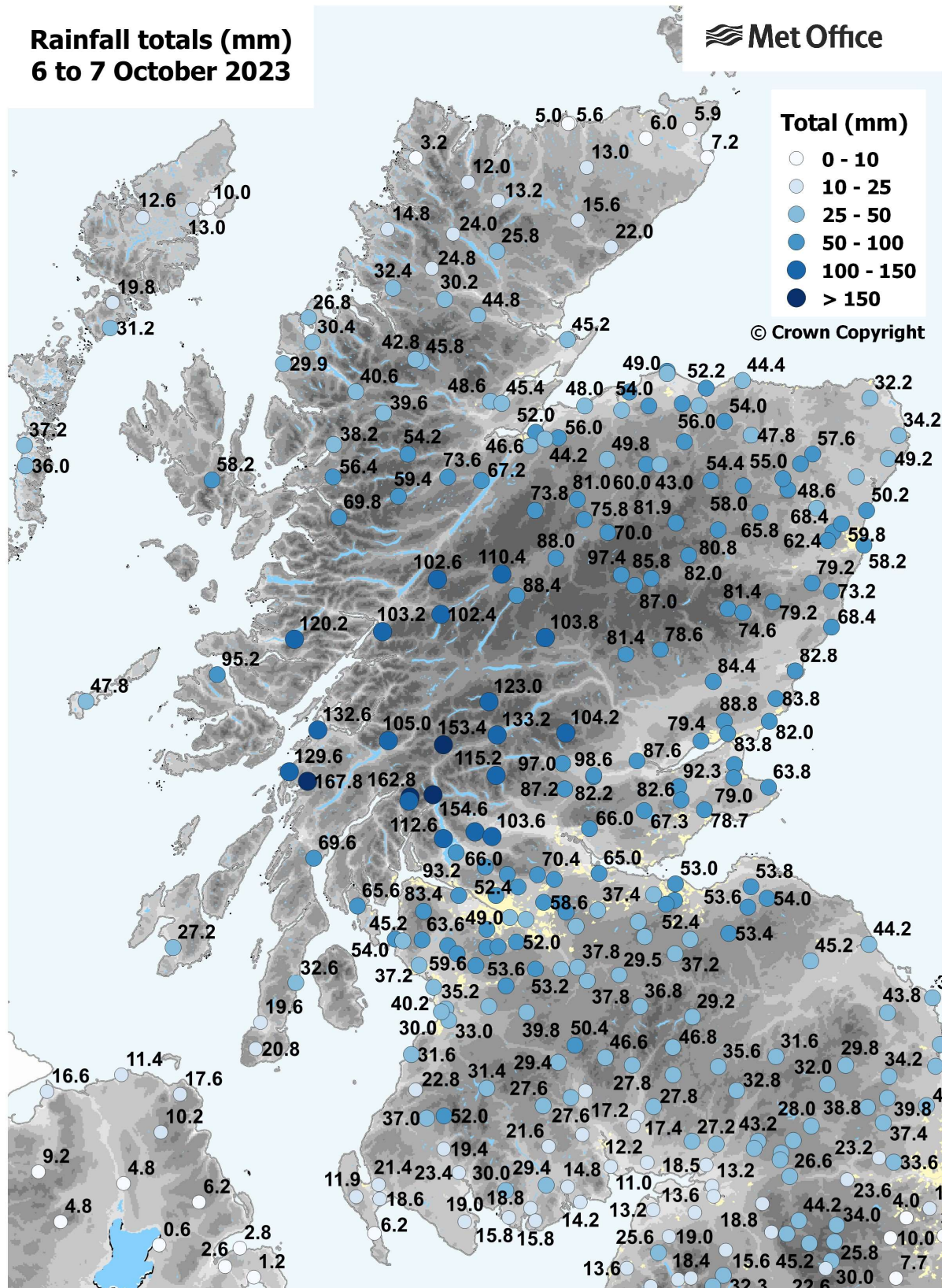
The satellite image at 1306UTC 7 October 2023 shows the swathe of cloud marking the stream of moisture-laden air in a westerly clockwise flow affecting northern parts of the UK, with high pressure across the near continent and France entirely cloud-free. Image copyright Met Office / NOAA / NASA.



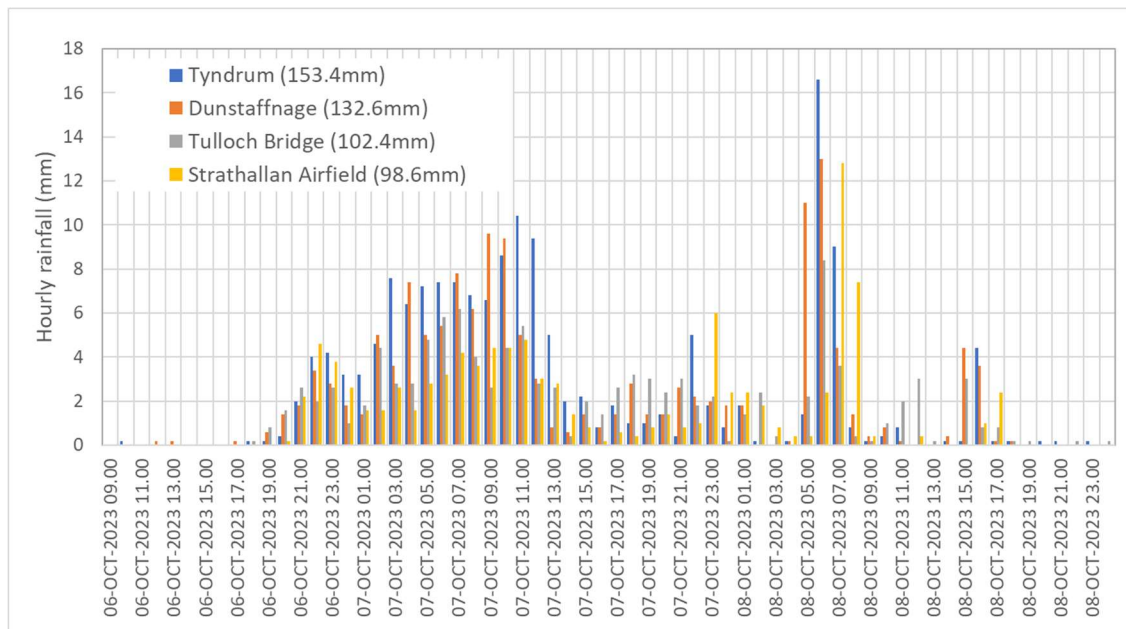
The maps below illustrate the sustained period of wet weather across western Scotland during the first ten days of October 2023, with low pressure systems bringing a succession of fronts in a westerly Atlantic flow.



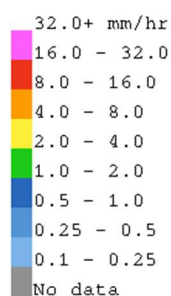
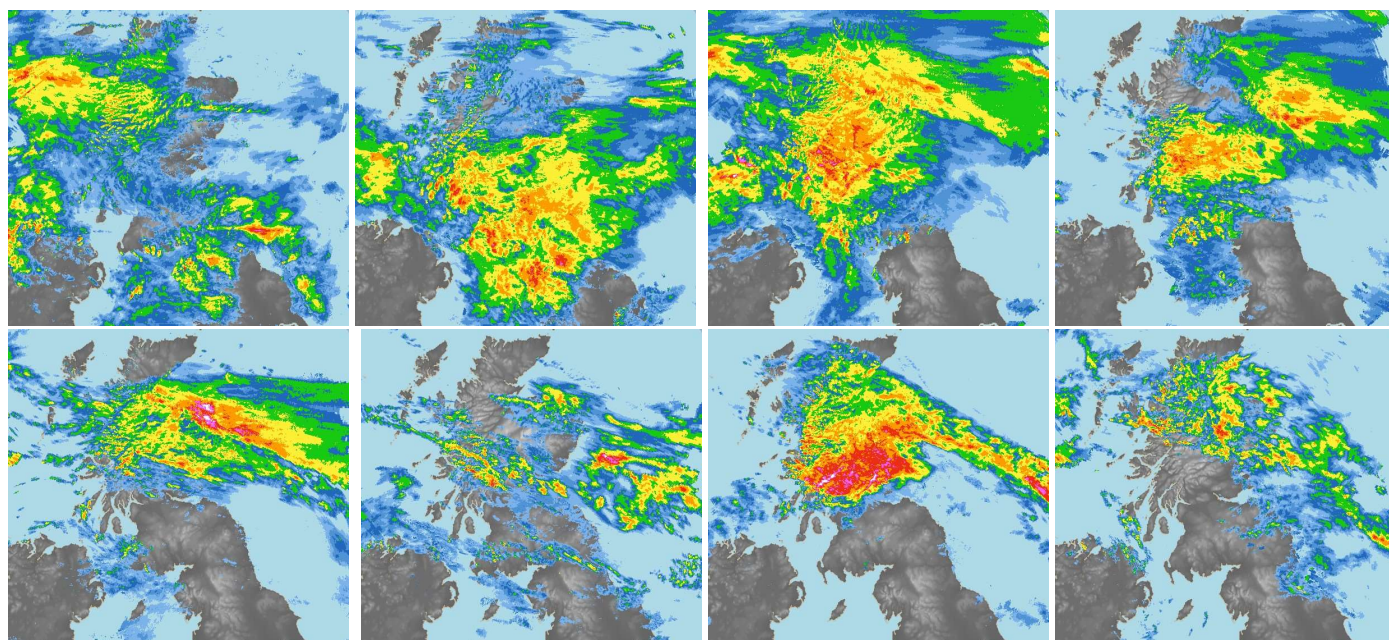
The map below shows rainfall accumulations at stations across Scotland for 6 and 7 October 2023 (0900 UTC on 6th to 0900 UTC on 8th). 75 to 100mm of rain fell widely across a swathe of the Southern and Central Highlands, with 150mm in the wettest areas. Several raingauges approached or exceeded 150mm including 167.8mm at Kilmelford, 162.8mm at Loch Restil and 148.4mm at Rest and be Thankful (all Argyll), 154.6mm at Inveruglas (Dunbartonshire) and 153.4mm at Tyndrum (Perthshire).



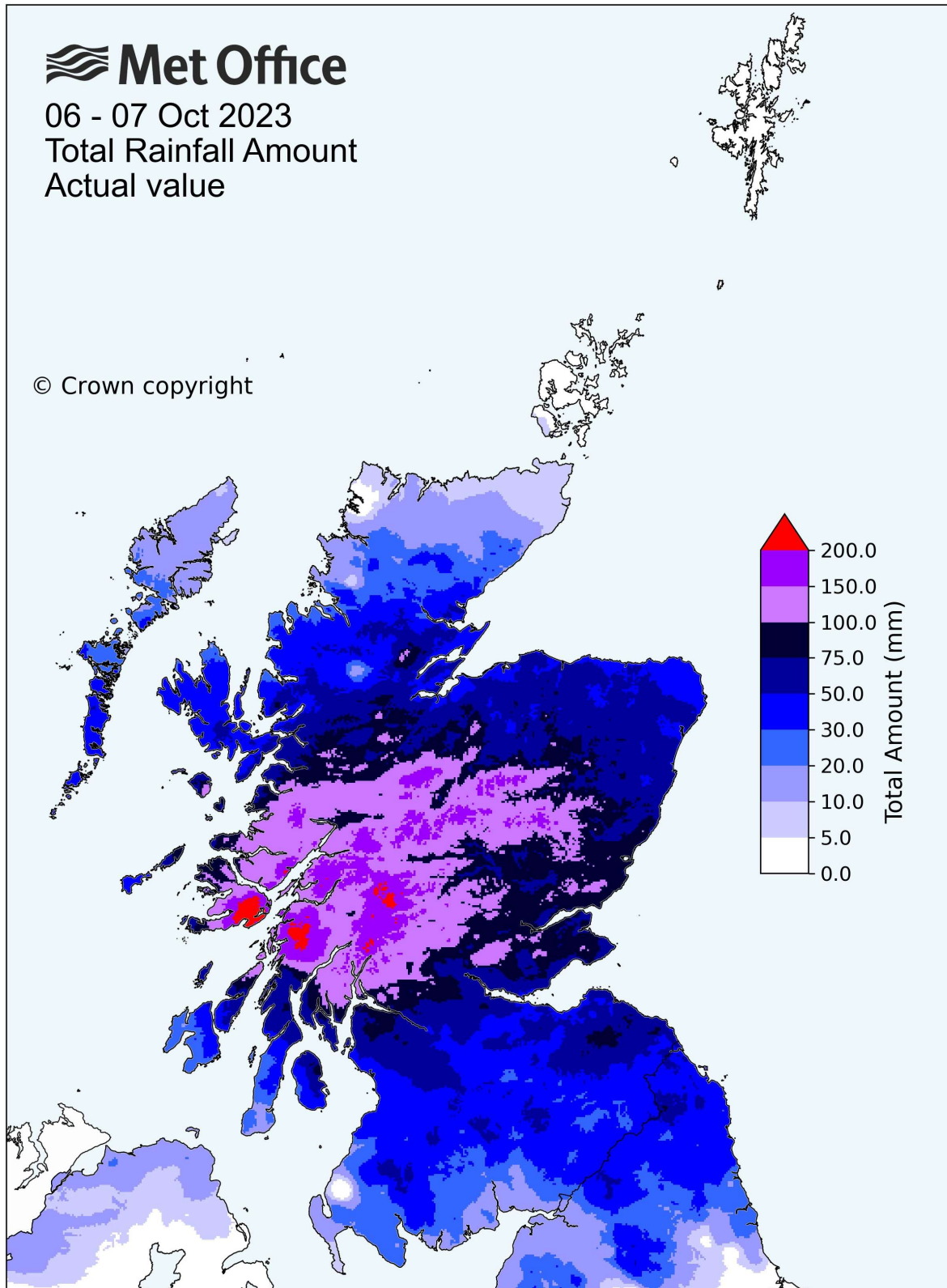
The chart below shows hourly rainfall totals for four stations at Tyndrum (north of Loch Lomond), Dunstaffnage (Argyll, north of Oban), Tulloch Bridge (Highland, east of Fort William) and Strathallan Airfield (Perthshire, west of Perth). The legend shows totals from 0900 on 6th to 0900 on 8th at each station (see also on map). Rainfall rates through this event were typically between 2 and 10mm per hour with a brief burst of heavier rainfall early on the morning of the 8th. The flood impacts from this event were due to the sustained and very widespread nature of the rainfall over this 48-hour period.



The sequence of rain-radar images at 6-hour intervals from 1800UTC 6 October 2023 to 1200UTC 8 October 2023 show the sustained and widespread nature of the rainfall across Scotland during this period with the heavier burst toward the end of the event shown on the penultimate map.

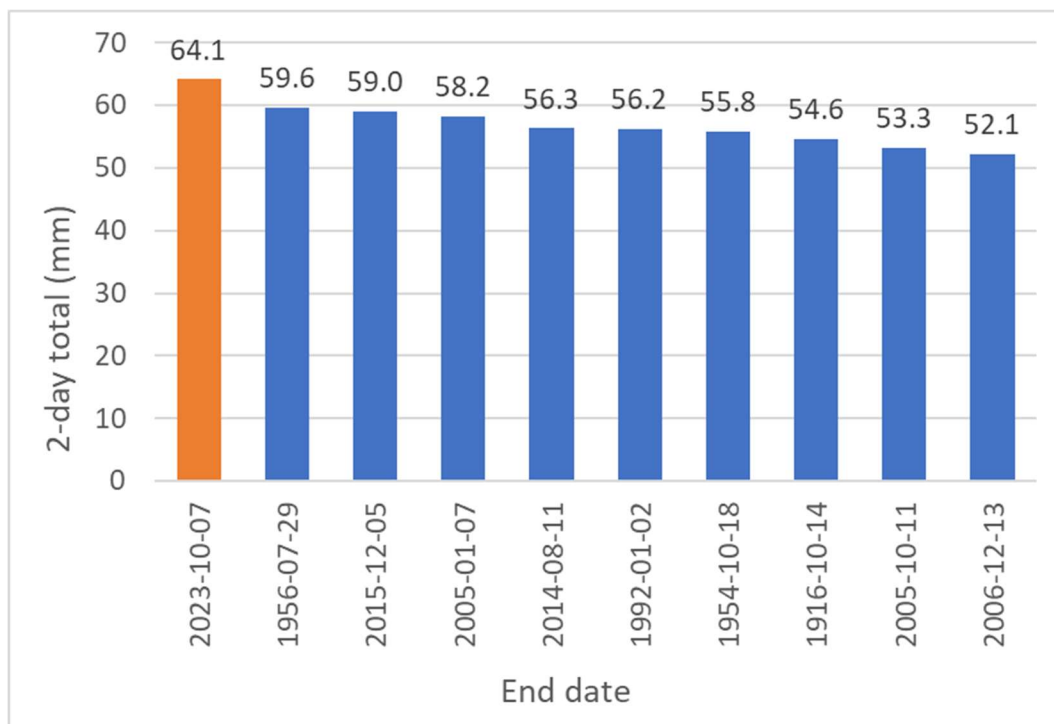


The map below shows the 2-day total across Scotland for 6 and 7 October 2023, emphasizing the widespread nature of this rainfall event. While the wettest areas were over central and western Scotland, particularly Argyll, the area of heavy rainfall extended much further east, including across Perth and Kinross, Stirling and Falkirk, Angus and Fife, with 80mm falling at some stations near the East Coast. A few of the wettest areas are estimated to have totals exceeding 200mm (shown in red). This is due to the interpolation process used to generate the map, which attempts to take topographical influences into account.

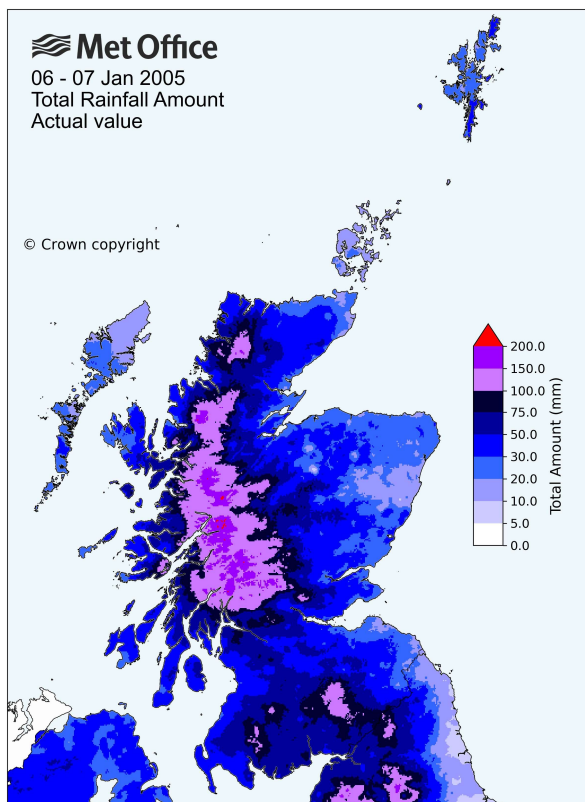
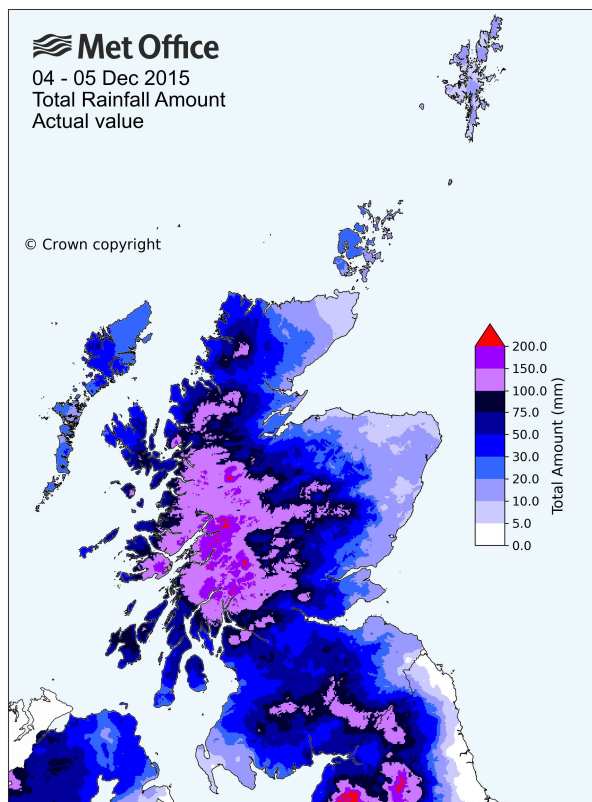
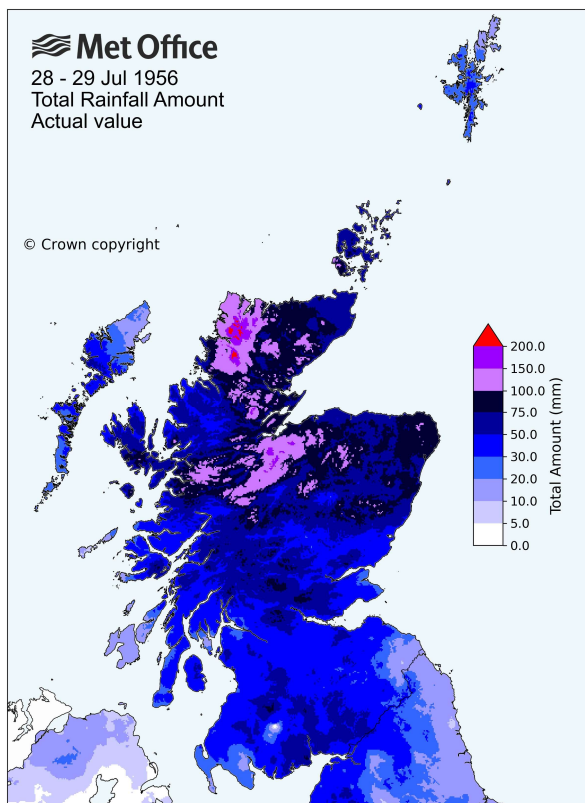
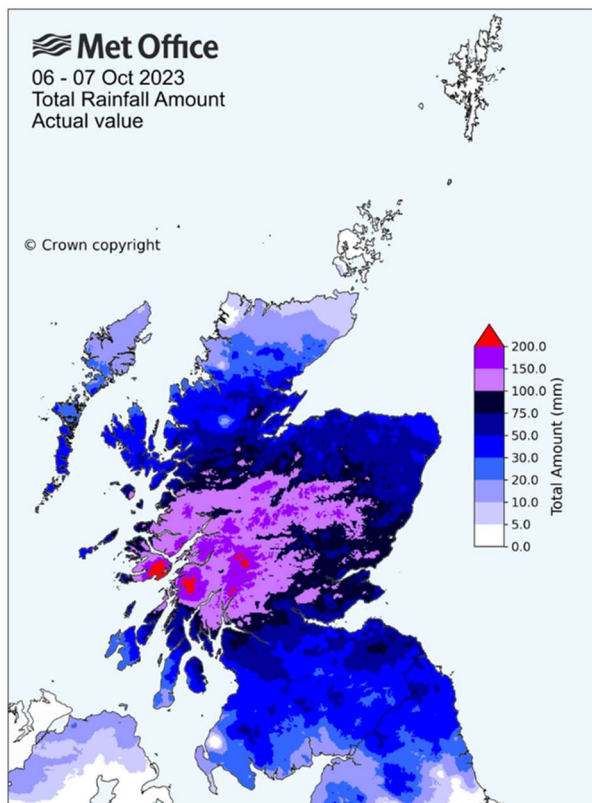


The two-day rainfall total averaged across the whole of Scotland for 6 and 7 October 2023 was 64.1mm, 38% of the 1991-2020 October whole-month average. This was provisionally the wettest two-day period on record for Scotland in a series from 1891, ahead of 28-29 July 1956 and 4 to 5 December 2015 (storm Desmond). This statistic emphasizes the exceptional nature of this rainfall. (Note that data prior to 1961 are based on a smaller number of stations due to more limited data availability). The Scotland rainfall totals for these two consecutive days were 32.6mm and 31.6mm respectively – each within Scotland’s top-30 wettest days in this series and each, independently (discounting the other) – Scotland’s wettest day since 3 October 2020.

The chart below shows Scotland’s ten wettest independent 2-day periods on record. Six of the wettest 10, including four of the wettest five, have occurred in the 21st Century; consistent with increases in rainfall extremes seen in the observational records as the UK’s climate continues to warm.



The maps below compare and contrast the spatial pattern of rainfall for Scotland’s four wettest 2-day spells on record. While the spatial patterns of rainfall across Scotland on 4 to 5 December 2015 and 6 to 7 January 2005 were broadly similar, these events saw much higher rainfall totals further south across southern Scotland and northern England, each event causing severe flooding – for example in Carlisle. The event of 28 to 29 July 1956, in contrast, saw the heaviest rain across northern Scotland, causing severe flooding in the Moray area.



References:

Kalnay, E., Kanamitsu, M., Kistler, R., et al., 1996. The NCEP/NCAR 40-Year Reanalysis Project. Bull. Amer. Meteor. Soc., 77, 437–471

Author: Mike Kendon, Met Office National Climate Information Centre

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