

British Geological Survey

# Gateway to the Earth

#### Daily landslide hazard assessments The use of process models and weather regimes to enhance the capability to issue regionally specific forecast and provide longer outlooks

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### **Daily Landslide Hazard Assessment**

One particular activity of the NHP is the issuing of daily assessments on a range of natural hazards, including landslides.

The NHP Daily Landslide Hazard Assessment (DLHA) is regionally specific through the Met Office Hazard Manager as part of an all hazards summary to respond to, and be prepared for multi-hazard events.

At present, the DLHA covers the next 24 hours and efforts are progressing t 30-day forecasts in line with other hazard assessments (wind, flooding, sno

Colour State	5-day (unless of	herwise stated) U Assessment	K Hazard Impact		5-day (unles:	ctherwise stated) UK Hazard Forecast		
	Weather - Rain, wind, ice, snow, fog, lighining, hail	Flooding - River, tidal, coastel, surface water, groundwater (England, Wales & Scotland unly)	Volcanic Ash	Space weather (Earth impact forecast)	Landslide (24-hour forecast)	Wildfire	Extreme Temporatures iPublic Health England only)	Air Qu (48-h forec
Green	Disruptive weather not expected or low I kellhood of mincr disruption.	Disruptive flooding not expected or low likelhood of minor disruption.	Disruptive volcanic ash not expected or low likelihood of minor disruption.	No significant space weather event(s) expected.	Landslides are not like y and there are no reports of landslides.	Eevated wildfire conditions not precast (low risk of wilcfires).	Threshold conditions not forecast to be reached.	Low air p leve or Isolated a modera pollution foreca
Yellow <sup>1</sup>	Low Ikelihood of significantly disruptive woathor or minor disruption expected.	Low likelihood of sign ficandy disruptive flooding or minor disruption expected.	Low likelihood of significantly disruptive volganie gah or minor disruption expected.	Strong space weather event(s) expected.	Likelihood (or report) of isolated landslides	Eevated wildfire conditions (likelinood of monagcoble vildfires) forecast.	Moderate likelihood of threshold conditions being roached or exceeded.	Widesp modera pollution pr Isolatec a high air p levels for
Amber <sup>2</sup>	Likelihood of significantly disruptive weather.	Likelhood of signficantly disruptive flooding	Likelihood of significantly disruptive volcaric ash.	Severe space weather event(s) expected.	Increased likelihood (or reports) of multiple landslides.	Extreme wildfire conditions (likelinood of difficult to control vildfires) forecast.	High likelihood of threshold annditions heing reached or exceeded.	Widesp high air p leve or Isolatec a very hig pollution foreca
Red <sup>8</sup>	High I kelihood of severe y disruptive weather.	High likelihood of severely disruptive flooding.	Hich likelihood of severely disruptive volcanic ash.	High confidence of extreme space weather eventis).	High likelihood (or reports) of major lardslide events.	tigh confidence of everely disruptive wildfire(s).	Severe cr prolonged period of threshold conditions reached or exceeded.	Widesp very hig pollution foreca continu more th day:

Ongoing hazard assessment recorded under "Ongoing Issues" or updated as

Limited/localised hazard impact or low confidence in assessmen; of severity/location of hazard event

Significan: potential for hazard event impacting large numbers of peocle

Hazards impacling large numbers of people across multiple sectors and high confidence in assessment of severity/location cf hazard event

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Working together **Daily Hazard Assessment** Issued 14:00 on Wednesday, 23 October 2013 The Daily Hazard Assessment is intended to provide an 'at a glance' top level overview only. The links provided to the relevant Partner Organisations should then be used to obtain further and more detailed information as required. Hazards Five Day Summary – FLOOD: YELLOW, FLOOD: - There is a LOW risk of flooding affecting parts of southwestern Environment Agency Scotland, southwestern England and south Wales LANDSLIDE: - Isolated heavy showers falling on saturated ground. FLOODFORECASTINGCENTRE particularly in Wales and South-West England, will result in an increased potential for landslides. Hazards Five Day Summary Detail FLOOD: - The Met Office is forecasting further heavy rain moving northeast during the first part of Friday, with some areas having seen significant rainfall earlier in the week. There is consequently a Yellow rainfall warning in place for Friday for parts of southwestern Scotland, eastern Northern Ireland, southwestern England and south Wales (see Met Office link at the end of this National Oceanography Centre section for further details). For England and Wales, the Flood Guidance statement (FGS) from the Flood Forecasting Centre (FFC) states: "There is a LOW river flood risk along the River Ouse in York today [Wednesday] and on Thursday. There is also a LOW river and surface water flood risk in the southwest of England and South Ordnance Wales on Friday [See Figure 1]. "Rivers have responded to heavy rain across the north of England this morning, with the River Ouse expected to come out of bank this evening [Wednesday] around the York area. This leads to a high likelihood of minor disruption in this area tonight and into Thursday morning. "Further heavy rainfall from early Friday morning brings a LOW risk of surface water flooding across the southwest of England and south Wales and also a LOW risk of river flooding to Devon and Cornwall." For Scotland, the FGS issued by the Scottish Flood Forecasting Service (SFFS) states: "The overall flood risk is LOW for the areas coloured yellow on Friday [see Figure 2], mainly due to the river flood risk but isolated surface water impacts are also possible. This risk is specific to parts of Dumfries and Galloway and western parts of the Borders. Edinburgh and the Lothians are not currently thought to be at risk. Refer to [Figure 3] for more detail and other Working together in partnership on natural hazards

Natural Hazards Partnership

Daily Hazard Assessment

British Geological Survey

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Partnership

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### The Natural Hazard Partnership (NHP)

The Natural Hazards Partnership (NHP) was established in 2011 to provide information, research and analysis on natural hazards for the development of more effective policies, communications and services for civil contingencies, governments and the responder community across the UK.

The NHP is a consortium comprising mainly government departments and agencies, and public sector research establishments.



#### NHP Vision – 'The UK's trusted voice for coordinated natural hazards advice'





80 200.00 70 100.00 budget [mm] 0.00 50 GB precipitation cipitation 100.00 2006 baseline ----- England - Wales ۇ -200.00 Scotland 30 GB landslides ----- England -300.00 --- Wales 20 Scotland -400.00 10 -500.00 100

time [months]

landslides occurrence - accumulating monthly precipitation budget

### **DLHA**

300.00

Four warning levels (green, yellow, amber, red) are issued on the basis of significance of the reported events, the antecedent condition (slope wetness) and the magnitude of forecasted rainfall.

The variety of landslide types and the variability of landslide-triggering rainfall conditions can pose a significant challenge for the development of early warning/forecasting models, particularly when assessing events at a regional scale.



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October

# **DLHA**

The DLHA, operational since 2012, is at present largely an expert-driven exercise carried out by a team of specialists at the British Geological Survey (BGS).

Characterisation of the heterogeneities of antecedent and triggering conditions of slope systems requires ingestion of a wide range of information covering aspects of

- landslide susceptibility,
- engineering geology,
- geomorphology, .
- hydro-geology and •
- meteorology (delivered by the Met Office (MO)),
- supported by close monitoring of reported landslide events.











#### **DLHA**



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## **Model-support for DLHA**

Complexities in the interactions between landscape conditions and weather event sequences can obfuscate the timing and regional granularity of various warning levels.

Efforts are therefore underway to provide further modelling support to address these issues. Inspired by discussions with NVE

The main focus of these efforts is on precipitation-driven events affecting translational instabilities in the shallow sub-surface (that can potentially progress into debris flows).

Models are in development to characterise the antecedent hydrogeological/engineering geological 'slope condition'.

This provides a baseline against which we can evaluate the potential effect of forecasted precipitation and, in turn, the issuing of an appropriate landslide hazard assessment.



Soil moisture day x





precipitation day x+1 = landslide potential





## **Probabilistic precipitation forecasting**



Ensemble predication systems aim to take account of uncertainty in weather forecasts by providing a range of forecast scenarios, allowing the generation of probabilistic forecasts.





\* NWP - numerical weather prediction



Individual ensemble member forecasts feed into a water balance model to produce probabilistic landslide hazard assessment



time (days)

#### Weather regimes



Regime 5 of 30

A weather regime can be described as one of many circulation types over a defined region, which differs in its characteristics from other weather patterns over the same region and varies on a daily basis.

Regime 1 of 30

 Objectively derived by clustering 154 years of daily mean sea level (MSLP) data Regime 7 of 30 Regime 8 of 3 Regime 9 of 3 Defined in terms of their MSLP anomalies (red and blue shading) Definitions remain static throughout the Regime 13 of Regime 15 Lower numbered regimes have weaker MSLP anomalies and occur more in summer Regime 16 of 3 Regime 17 of Regime 20 1 they Higher numbered regimes have stronger MSLP anomalies and occur more in winter Regimes are ordered according to their mean annual occurrence (most common  $\rightarrow$  Forecast ensemble members are assigned to the closest matching regime definition 10 15 20 -20 -15 -10-5 5 Mean Sea Level Pressure (MSLP) anomalies (hPa)

Regime 2 of 30

Regime 3 of 30

Regime 4 of 30

year



least common)

## Identifying 'high risk' weather regimes



High risk regimes are identified from the set of 30 mapped regime definitions, based on a comparative analysis of historic weather regime occurrence and landslide events.

By calculating the relative contribution (as a percentage) of each weather regime to the total rainfall accumulated prior to the landslide event and comparing it against the weather regime frequency within the same period, it was possible to identify which regimes contributed most significantly to the rainfall which led to the observed landslide.





December (ERA-Interim)



## Medium-to-long range forecasting tool

The medium-to-long range tool gives the forecast probability of weather regimes which have the potential to heighten a regions susceptibility to rainfall-induced landsliding.

These forecasts are considered to be most useful in providing medium-to-long term forecast trends, highlighting periods with a heightened susceptibility for landslide occurrence.

#### Ensemble forecasting systems

Ensemble for	ecasting system	Centre	Lead time	Number of members	Decider update times	
OGRES	MOGREPS-G Time-lagged	Met Office	7 days	24 members <sup>1</sup>	00Z run ⇒ 0615 GMT 06Z run ⇒ 1215 GMT	
	MOGREPS-G Latest run only			12 members	12Z run ⇒ 1815 GMT 18Z run ⇒ 0015 GMT	
0	ECMWF Medium-range	ECMWF	15 days	51 members	00Z run ⇒ 0930 GMT 12Z run ⇒ 2130 GMT	
ECMWF	ECMWF Monthly		32 days		00Z run $\Rightarrow$ 2230 GMT <sup>2</sup>	
NCEP	GEFS	NCEP	16 days	21 members	00Z run ⇒ 0630 GMT 06Z run ⇒ 1230 GMT 12Z run ⇒ 1830 GMT 18Z run ⇒ 0030 GMT	
Glo Sea	<u>GloSea5</u>	Met Office	51 days	4 members <sup>3</sup>	00Z run $\Rightarrow$ 0840 GMT <sup>4</sup>	







We will be evaluating the performance of the winter trial for both the short and medium-to-long range probabilistic forecasting tools. Depending on how this winter proceeds, the trial may need to be extended.

Review methods, thresholds and 'high-risk' regimes used in the trial and make appropriate tweaks based on the output from the evaluation of the winter trial.

Continue to maintain landslide database to improve and update existing thresholds and 'high-risk' regimes.

#### Questions for future research?

Determine how the two systems will be used to communicate to stakeholders - what should warnings look like?

How long should warnings remain in force after rainfall has moved away?

What do we want stakeholders/users to do in response to such warnings and can this be communicated effectively within their existing decision-making frameworks?

How can the medium-to-long range forecasting tool be improved and used effectively?

Currently the medium-to-long range forecasting tool does not provide warnings – should it and if so what would such warnings look like/contain? Who should receive them?



#### References



Neal R, Fereday D, Crocker R, Cromer R. 2016. A flexible approach to defining weather patterns and their application in weather forecasting over Europe: Weather patterns and their forecasting application. *Meteorological Applications*, 23, 3: 389-400.

