MODIS NRT Global Flood Product

MODIS/Aqua+Terra Global Flood Product L3 NRT 250m

Provided by NASA LANCE

User Guide

Revision A

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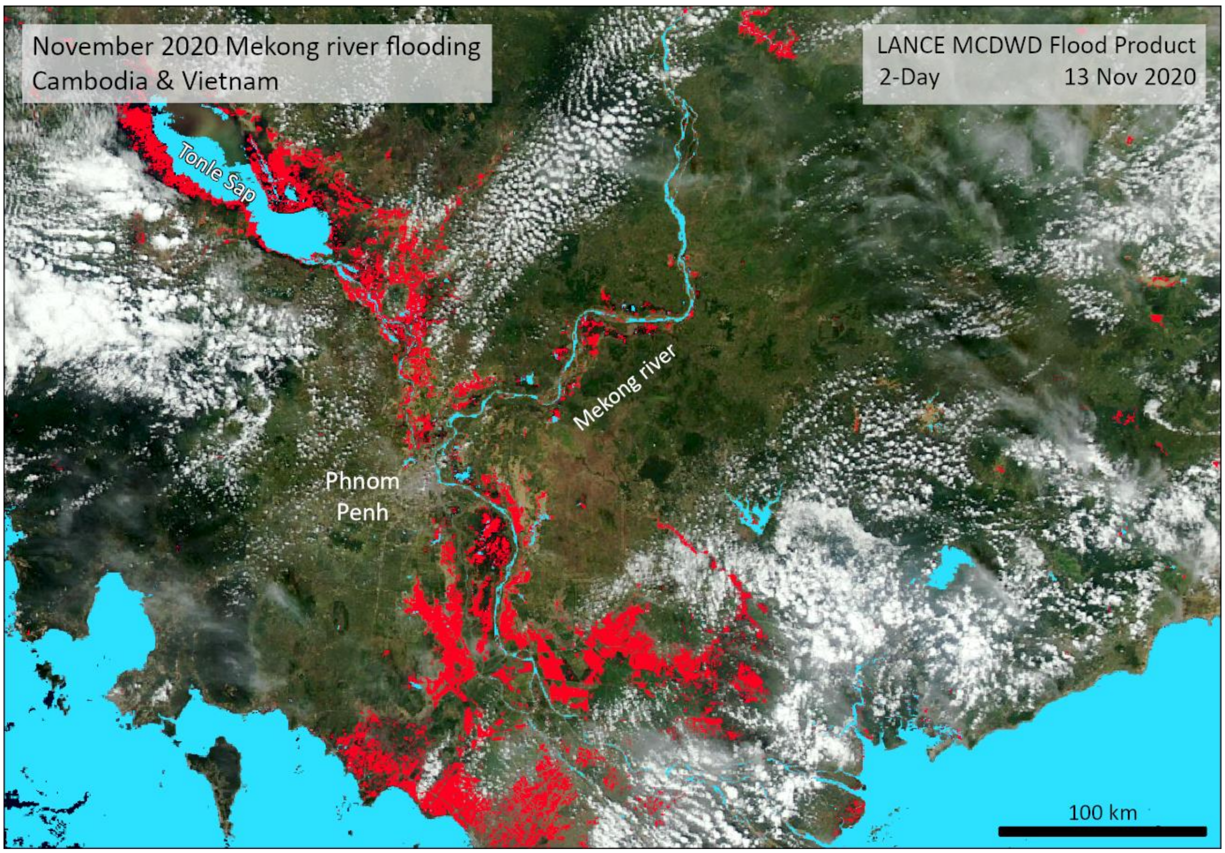
Website: https://earthdata.nasa.gov/earth-observation-data/near-real-time/mcdwd-nrt



The 2-Day flood product showing extensive flooding (in red) in the lower Mekong region of Cambodia and Vietnam, and normal water (in cyan), overlaid on MODIS-Aqua imagery. Although a dramatic example demonstrating the product capabilities, much of the displayed flooding here is typical seasonal flooding.

Document Change History

Revision	Date	Description
A	8 Mar 2021	Initial beta release

Contents

1 Quick Start Summary

The LANCE MODIS NRT global flood product (MCDWD) replaces the "legacy" flood product, (https://floodmap.modaps.eosdis.nasa.gov) which has been generated since 2012. The MCWD and the legacy product will run in parallel through 30 June 2021. The flood product was initially developed as an applications product, and so there is no associated science product.

Product Access

The product is identified with a longname: "MODIS/Aqua+Terra Global Flood Product L3 NRT 250m"; shortname: MCDWD_L3_NRT; and DOI: 10.5067/MODIS/MCDWD_L3_NRT.061. Its product page is: https://earthdata.nasa.gov/earth-observation-data/near-real-time/mcdwd-nrt

It can be downloaded directly from the LANCE nrt servers:

https://nrt3.modaps.eosdis.nasa.gov (planned from 1 April 2021), or
https://nrt4.modaps.eosdis.nasa.gov (from product launch)

by navigating to:

NRT Data → allData → 61 → MCDWD_L3_NRT

Or, directly in the URL address bar, for example:
https://nrt4.modaps.eosdis.nasa.gov/archive/allData/61/MCDWD_L3_NRT

Instructions for automating bulk downloads can be found here:
https://nrt3.modaps.eosdis.nasa.gov/help/downloads

At the initial release in March 2021, the nrt download sites are only populated with product files at the end of the day. In the near future (expected by end of April 2021), the download sites will be updated in near real-time, as each incoming swath granule is processed.

Users automating downloads by repeatedly polling the servers for new files would be advised to retain the file modification times for downloaded files and compare these to times observed on subsequent polls to determine if a file has been updated and thus should be re-downloaded.

The product will also available in Worldview: https://worldview.earthdata.nasa.gov

Product Format

The product is distributed in 10x10° tiles (Figure 4), in a lat/lon or geographic projection, in HDF files. Each file contains four flood composites (1-Day, 1-Day CS, 2-Day, and 3-Day; see below), and other ancillary layers (**Table 4**). An example product file name is MCDWD_L3_NRT.A2021046.h30v12.061.hdf, indicating date in YYYYDOY (year day-of-year) format, and tile h-v in MODIS lat/lon grid.

GeoTIFF files will be made available soon (est. by April 2021) for each of the four flood composites. An example GeoTIFF filename for a 2-day product is: MCDWD_F2_L3_NRT.A2021046.h30v12.061.tif

The data values in the flood product are provided in **Table 5**, on page 13. Note these differ from those in the legacy product.

Product Use and the 1, 2, and 3-Day Composites

Detecting flood water with MODIS 250m imagery is relatively straightforward. Unfortunately, cloud and terrain shadows will often also be detected as water because they are spectrally similar in the MODIS bands available at 250 m. By accumulating water observations from several observations, many false-positives can be removed because cloud shadows generally do not recur in the same locations between subsequent observations.

Because the location of flood water is not well known in advance, and because clouds are spatially variable, it is impossible to a-priori predict (and thus only generate) the best compositing period for a given date or potential flood event. Instead, several composites are pre-generated: 1-Day, 2-Day, and 3-Day. These require 1, 2, and 3 water detections, respectively, to mark a pixel as water. In the 1-Day case, this means that cloud-shadow false-positives will contaminate the product if clouds exist. But if no clouds are present, it will provide a more up-to-date view of current flood extent. It is incumbent on the user to make these decisions, which may vary over a region of interest. Furthermore, we have applied a useful-but-not-perfect cloud shadow mask on an additional version of the 1-Day product (1-Day CS) to remove many (but not all) cloud shadow issues, although at times it can also remove real water.

The product Use Notes and FAQs in section 9 on page 19 provide more detailed guidance and users are advised to review this material.

A low-volume distribution-only mailing list is maintained for flood product announcements. Users are invited to sign up here: https://lists.nasa.gov/mailman/listinfo/floodmap

2 Introduction

This User Guide provides the most current information about the Collection 61 Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) NRT Global Flood Product. It is intended to provide the end user with practical information regarding the use of the product as well as: a summary of the flood map algorithm; product evaluation; product format; product access; planned improvements; differences with the legacy product; use notes and FAQs; and future release plans.

2.1 Background

NASA's Near Real-Time (NRT) Global Flood Mapping Project was developed through a partnership between the Dartmouth Flood Observatory (since relocated to the University of Colorado, Boulder; https://floodobservatory.colorado.edu) and a team at NASA's Goddard Space Flight Center with funds provided by NASA's Applied Sciences program (Policelli et al. 2017). The production of daily global flood maps with that system started in late 2011, and is planned to continue for several months after LANCE product release; we anticipate it will continue to be available until mid-2021 at its current website: https://floodmap.modaps.eosdis.nasa.gov.

For the purposes of this document this original system is referred to as the "legacy" flood mapping system and product. Its core data product is the MWP (MODIS Water Product). The new LANCE product, the "MODIS/Aqua+Terra Global Flood Product L3 NRT 250m", has a "shortname" of MCDWD_L3_NRT, or MCDWD for short (WD for Water Detection; details on the naming convention follow in section 6.1). Thus the new product is referred to in this document as the LANCE or the MCDWD product.

Over its decade of existence, the legacy product has proven itself to be very useful for detecting many types of large-scale flooding, even though it is based on optical data, and thus cannot inherently observe water on the ground under cloud cover. Nevertheless, for many events cloud cover is not complete, or may shift over a period of a day or a few days, revealing flood water below. One of its major advantages is that the data used to generate the product – MODIS imagery – are available with near global coverage twice a day (the MODIS instrument being onboard two different satellites: Terra and Aqua). Thus, there is no need to rapidly program a specific acquisition to capture an event (e.g., as necessary for many commercial sensors), or wait for a defined and fixed revisit period (Landsat and similar sensors). The MODIS data are simply available, twice daily, well-calibrated, and without the user needing knowledge of precisely where the flood may be occurring and thus where to target imagery acquisition.

That said, clouds are an inescapable feature of the atmosphere, and so create obstacles for this product—by obscuring the ground, and also by casting shadows, which will often be detected as water (because they are spectrally very similar to water, in the wavelength bands available). Much of the complexity of this product, and of its use, derives from the need to address these issues from clouds.

Users of the legacy product have included the World Food Program, FEMA (Federal Emergency Management Agency), UN OCHA (Office for the Coordination of Humanitarian Affairs), MapAction, GeoSur, UNOSAT (UN Operational Satellite Applications Program), several large reinsurance companies, and a number of academic researchers. Section 9.2 shows some usage examples.

Unlike most LANCE products, this flood product was not derived from an existing MODIS science product; it was instead originally developed as an applications product by an early user of the MODIS Rapid Response imagery (Bob Brakenridge), who developed methods to map floods from rapid response images. Thus, there is no separately developed science product or supporting documentation.

2.2 LANCE product

In 2017, NASA Applied Sciences provided funds to transition of the MODIS (Aqua + Terra) Near Real-Time (NRT) global flood product to NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE) (http://earthdata.nasa.gov/lance) , with additional support provided by ESDIS (NASA Earth Science and Data Information System Project) and LANCE MODIS. LANCE is part of NASA's Earth Observing System Data and Information System (EOSDIS) and distributes NRT data and image products from 11 satellite-borne instruments, within three hours of data acquisition.

The primary goal of transitioning the legacy flood product to LANCE is to ensure reliable long-term production. The transition required a complete rewrite of the code to conform to the LANCE-MODIS environment. We took advantage of this recoding opportunity to optimize the algorithmic workflow.

The product is distributed through the LANCE webpages (section 6) and imagery are available via NASA's Global Imagery Browse Services (GIBS) (https://earthdata.nasa.gov/eosdis/science-system-description/eosdis-components/gibs) and Worldview (https://worldview.earthdata.nasa.gov).

The product will be rolled out in stages: the beta release (see release details in section 10) replicates the legacy product (section 4 provides a comparison). This will allow users to transition to the new file format, download sites, and product browse sites without major changes in the data product itself. After a more detailed evaluation and comparison between the legacy and LANCE flood products, the beta release (with any needed adjustments) will be finalized. Then, a series of modifications will be made to improve the quality of the product and will be the basis of subsequent post-beta releases.

3 Algorithm

3.1 Overall approach

Flood product generation consists of three key steps:

1. Water detection algorithm applied to each MODIS observation (incoming swath granules).
2. Compositing of water detections, over time, to reduce errors and more rigorously identify water (including terrain and cloud shadow masking).
3. Differentiating flood from expected surface water.

The compositing step is necessary because false-positives (most usually from cloud or terrain shadows) can otherwise substantially contaminate the products. Terrain shadow masks are also applied to minimize errors. The flood products are generated with three compositing periods (1-day, 2-day, and 3-day) because the best product for a given flood event depends on four unpredictable factors: the specific area of interest; cloud cover over potential event; spatial extent of likely flood water; and likely duration of flooding. The best composite for a given event depends on the level of cloudiness, and the requirements of the user (latency, and tolerance for false-positives and/or false-negatives). This does unfortunately place a burden on the user to determine which product provides the best information for a particular event of interest. Having the product available in the Worldview web application helps users more easily compare and evaluate the different products.

3.2 Water detection algorithm

The water detection algorithm relies principally on a band ratio of MODIS bands 1 (red) and 2 (near infra-red), but also incorporates some single-band thresholding (including on band 7, a shortwave infra-red band) to eliminate outside cases of false water detection. Input data is from the MOD09 (Surface Reflectance) product (MOD09.NRT.061: http://doi.org/10.5067/MODIS/MOD09.NRT.061), in which bands 1 and 2 are provided at 250 m resolution, and band 7 at 500 m (it is pan sharpened to 250 m to match bands 1 and 2). The water detection algorithm is as follows:

$$\text{Mark pixel as water IF:} \quad \frac{(Band2 + A)}{(Band1 + B)} < C \quad \text{AND} \quad (Band1 < D) \quad \text{AND} \quad (Band7 < E)$$

The constants A, B, C, D, and E are those used in the legacy product, which were determined empirically by DFO. They are provided in **Table 1**. If bands 1 or 2 contain saturated or other bad data or NODATA values, the pixel is marked as NODATA. If only band 7 contains bad values or NODATA, the rest of the computation is completed (with the Band 7 threshold component ignored).

Table 1: Water detection algorithm constants. *Note A, B, D, and E assume input reflectance is scaled by 10000 (standard MOD09 product scaling).*

Constant	Value
A	13.5
B	1081.1
C	0.7
D	2027
E	675.7

3.3 Time compositing

Because cloud and terrain shadows are often detected as water by the water detection algorithm, multiple water observations are generally required to mark a pixel as water. The assumption is that cloud shadows move over time, so will usually not recur in the same place within days, and thus this requirement eliminates many cloud shadow false-positives. It has significantly less impact on terrain shadows. The disadvantage is that in order to acquire multiple observations, the compositing window needs to be expanded over time; a robust product typically cannot be created from a single observation, unless it happens to be cloud-free. The optimal composite for a given event and location thus depends on the cloudiness of the available MODIS imagery on the dates of interest.

Several different time composites are generated to provide different options to the user: 1-Day, 1-Day CS (with cloud shadow masking applied; see section 3.3.1.2), 2-Day, and 3-Day. Currently, the 1, 2, and 3 day products require a total of 1, 2, or 3 water observations, respectively, to mark a pixel as water (**Table 2**). Note these thresholds may change as the product is optimized in future releases (see section 7.2).

The composites are generated by summing valid water detections over the period of the composite from all available observations, and then comparing this sum to the threshold. For the 1-day, the composite period is the current day: all available Terra and Aqua swaths over a pixel on that day are included. For the 2-day, the composite period is the current day plus the previous day; for the 3-day product, the composite period is the current day plus the two preceding days. Note for the 1-day product, only requiring 1 water observation results in ***no*** removal of cloud-shadow false-positives, and thus this product can contain substantial false positives, unless the area of interest is cloud-free.

Table 2: Water observation thresholds for different products*. *Note that the number of observations will depend on latitude: at equatorial latitudes, swath gaps occur and either the Terra or the Aqua observation may not be available for a given location on a given day; thus the available observations may be lower by one. Conversely, at higher latitudes, where swaths increasingly overlap, multiple observations may be available per sensor, per day, potentially providing more opportunities to see under clouds as they move, but also more opportunities to pick up cloud-shadow false-positives.*

Product	Total Required Water Observations (Terra or Aqua)	Available Observations* (Terra and Aqua)
1-Day	1	2+
2-Day	2	4+
3-Day	3	6+

3.3.1 Terrain and Cloud Shadow Masking

To help reduce shadow false-positives, terrain and cloud-shadow masks are applied during the compositing step. Both masks are applied to the per-observation water detection results, before compositing: if water is detected in a pixel via the water detection algorithm, but this pixel is also marked in either the terrain or cloud shadow mask, that water detection is removed before compositing proceeds. At present, the cloud shadow masks is only applied to the 1-Day CS product.

3.3.1.1 Terrain shadow masks

For terrain shadows, a set of precomputed terrain shadow masks are applied to each tile. These were originally generated for the legacy product at a monthly time-step, on the 22nd of the month, using the

ASTER global digital elevation model (https://asterweb.jpl.nasa.gov/gdem.asp), version 2 (NASA/METI/AIST/Japan Spacesystems and U.S./Japan ASTER Science Team 2009), and computed at nominal times of 10:30 AM and 1:30 PM (to be applied to Terra and Aqua observations, respectively). For a given date, the most liberal monthly mask is applied: that closer in date to the winter solstice, and thus projecting more shadow. In the beta product release, these same masks from the legacy product are used. When originally generated, these were estimated to remove between 75-90% of terrain shadow false-positives in the 2-Day product. Improvements to these masks are planned after the initial beta release (see section 7.1 below).

3.3.1.2 Cloud shadow masks

To help identify and eliminate cloud-shadow false positives, water detections are masked using the "cloud shadow" flag from the MOD09 (Surface Reflectance) State QA layer (see table 13 in the MOD09 User Guide (https://lpdaac.usgs.gov/documents/925/MOD09_User_Guide_V61.pdf) in the 1-Day CS product. This cloud shadow mask is interpolated from 1 km to 250 m to match the resolution of the flood product. Unfortunately, detecting clouds, and especially their shadows, is difficult, and although this mask does a reasonable job much of the time, it can also miss areas of cloud shadow, and mask out real water, not under cloud shadow. Thus, this mask is only applied to the 1-day product, which suffers most from cloud shadow false-positives and a 1-day product without it is also provided (1-Day without this mask, 1-Day CS with).

3.3.2 Insufficient data

A flag value of 255 in the product indicates pixels with insufficient surface observations to be able to mark the pixel as water; in other words, the observation thresholds in **Table 2** cannot be met due to an excess of bad data, missing data (e.g., swath gaps), or cloudy data. Such pixels would not then be marked as water (or flood). "Insufficient data" is the term used to describe these pixels, instead of the more frequently used "No Data", because there may well be some valid data (including water observations), but there are *insufficient* such observations to meet the compositing threshold and thus for such a pixel to be marked as water. These "insufficient data" areas *might* be false-negatives, but may be true negatives: we cannot say with the data available.

To identify pixels with insufficient data due to cloud cover, we use the "cloud state" flag from the MOD09 State QA layer, which reports pixels as either: clear, cloudy, mixed, or "not set". Pixels are marked as cloud unless this flag is set to "clear". However, because this cloud information is not perfect, and the water detection algorithm will sometimes detect water in pixels that are reported as cloud (for example, if the cloud is thin, or along a cloud edge), any "insufficient data" values are **overwritten** by valid composited water detections. Thus, if water is detected in a pixel a sufficient number of times to exceed the compositing threshold, it **will** be reported as water in the product, even if the cloud layer suggests insufficient clear observations. In practical terms, insufficient data pixels are populated first, and then overwritten by the composited water detections. This can result, on occasion, in the product displaying, for example, detected water in rivers that are surrounded by Insufficient Data pixels.

3.4 Flood identification

In some ways, water detection is the easy part, even with the potential issues discussed above. Determining if detected water is actually *flood* water can be more difficult, as it depends on where water is expected to occur, and this may vary seasonally and over time. What then is a real flood, and when should the product report *expected* surface water (such as a lake, river, reservoir, or ocean), vs *unusual* water (= flood)? In this product, flood is identified by comparing detected water to a reference water map providing a snapshot of this information.

For the beta release, the same reference water map used for the legacy product is used: the MODIS/Terra Land Water Mask (MOD44W, Collection 5: Carroll et al. 2009), which was generated from MODIS Terra imagery and SRTM (Shuttle Radar Topography Mission) data. MOD44W was generated using a conservative water detection algorithm (different than the one used here), which required processing many years of data to identify areas that were consistently detected as water, and thus were classified as permanent surface water features. To identify flood in the MCDWD product, detected water pixels are compared against this static global surface water map: detected water falling within MOD44W's water mask is labelled as "surface water", while water falling outside is labelled as "flood".

An important limitation is that this original MOD44W (Collection 5 version, published 2009) layer has become increasingly out of date: new reservoirs have been built (which are then routinely reported as flood); tropical rivers have changed course (resulting in the new course being routinely reported as flood); lakes have dried up (resulting in no flooding being reported if they collect flood water for a short period); and coastlines of lakes and rivers have shifted, due to many factors (resulting in the product possibly reporting flood along such shores). Although the MOD44W algorithm and product has been improved since the original version we are using, updated versions have not been incorporated to this product. One of the important post-beta improvements will be an update of the surface water mask to correct such errors, and to allow us to introduce a "recurring flood" category (more details in section 7.4 below).

4 Product Evaluation

The initial release of the LANCE flood product will be evaluated in two phases: (1) a quantitative comparison to the legacy product (to understand differences between the two) (section 4.1); and (2) a qualitative evaluation, following the methods used for the legacy product evaluation (section 4.2). The legacy product was evaluated qualitatively (via visual interpretation), by examining its performance for a set of flood and non-flood 'events' and assigning a score. As new features and improvements are introduced over time (section 7), the LANCE product will increasingly diverge from the legacy product, and additional evaluation will be necessary to confirm the validity of the improvements.

For the initial beta release, only the quantitative comparison to the legacy product was deemed necessary. A more detailed Evaluation report will be published and available on the product page when the qualitative evaluation has been completed, and this User Guide updated with summary information.

4.1 Quantitative Evaluation

The performance of the MCDWD flood products has been statistically compared with the legacy MWP product. As an overall summary, Figure 1 shows the distribution of differences in reported flood area per tile, for the 3 products that exist in both systems (1-Day CS, 2-Day, 3-Day), over all tiles, for 98 days in late 2020 and early 2021. Figure 2 presents the same data as boxplots.

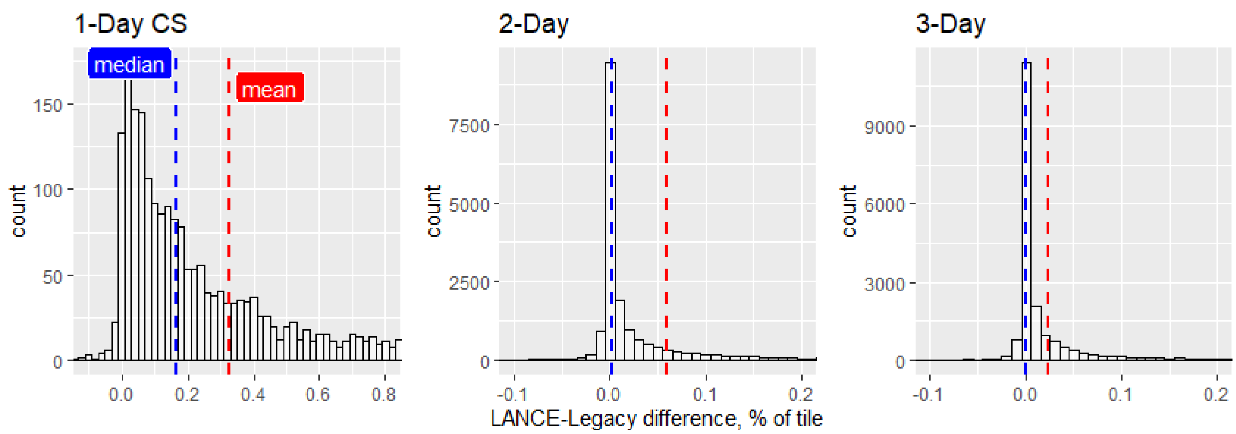


Figure 1: Histograms of differences in area of reported flood, per tile (as percent of tile reported as flood), between LANCE MCDWD and legacy MWP products, with mean (red) and median (blue) marked. Computed over dates: 23-Sep-2020 – 07-Dec-2020 and 11-Jan-2021 – 01-Feb-2021 (non-contiguous because the NRT product was not archived between 8 Dec and 10 Jan). Note that because the 1-Day CS product was only run over the USA in the legacy system, there are substantially fewer observations.

The positive bias shown in both figures, for all products, indicates that the MCDWD product is reporting more flood than the legacy product, but this effect decreases with increasing compositing window. A detailed look at individual products reveals that most of these differences are due to increased contamination of the product by cloud-shadow false-positives at higher latitudes. In the LANCE implementation of the product, all swaths are processed, and where swath overlap becomes significant (at higher latitudes), this results in several more observations. Whereas in the legacy product, overlapping swaths are composited into a single Terra and Aqua image per day before the water

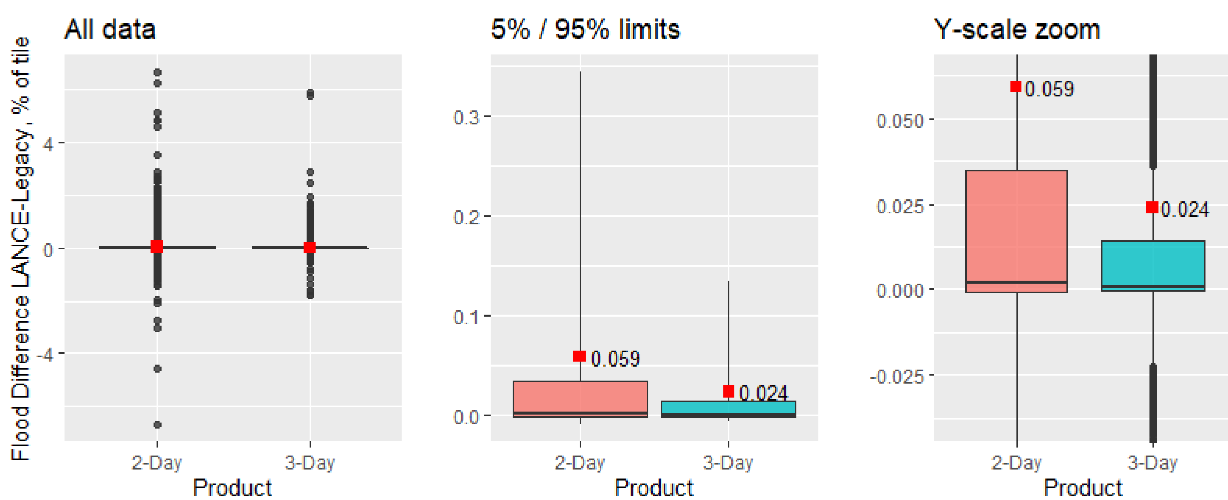


Figure 2: Boxplots of differences in area of reported flood per tile (as percent of tile reported as flood), between LANCE MCDWD and legacy MWP products, for all tiles. Mean is marked with red dots and labelled. Same data as in Figure 1. Note mean values fall outside the boxplot boxes (which indicate the interquartile range) because the distributions are significantly biased, and deviate from a normal gaussian. Center panel has data trimmed to 5/95% limits to see more detail. Right panel zooms in further on the y-scale so the medians (horizontal bars in boxes) are visible, very close to zero.

detection algorithm is applied. Although the additional observations in the LANCE implementation can result in additional opportunities to see the surface as clouds move, it also presents additional opportunities for cloud shadow false-positives to recur in the same location, and thus contaminate the product. See additional discussion in sections 8.1 and 9.1.

Figure 3 shows the differences grouped by latitude band, confirming that differences are restricted to higher northern latitudes, and thus are explained by the higher number of available observations propagating cloud-shadow false-positives into the product. At worst, in the 60N band (over these dates in the winter when lower sun angles lead to more cloud shadow), the median difference is about 0.15% of a tile. With the tile dimensions of 4800x4800 pixels, 0.15% of a tile is 34560 extra flood pixels (with a tile containing ~23 million pixels). Of course, these 'extra' flood pixels (which, where examined in detail, are due to cloud-shadow false-positive) are not randomly distributed, but will be lumped around dates and tiles with more frequent broken clouds. It is expected – and has been observed with the limited data available at this writing – that these differences further reduce as the date moves away from the winter solstice, sun position rises, and shadows recede.

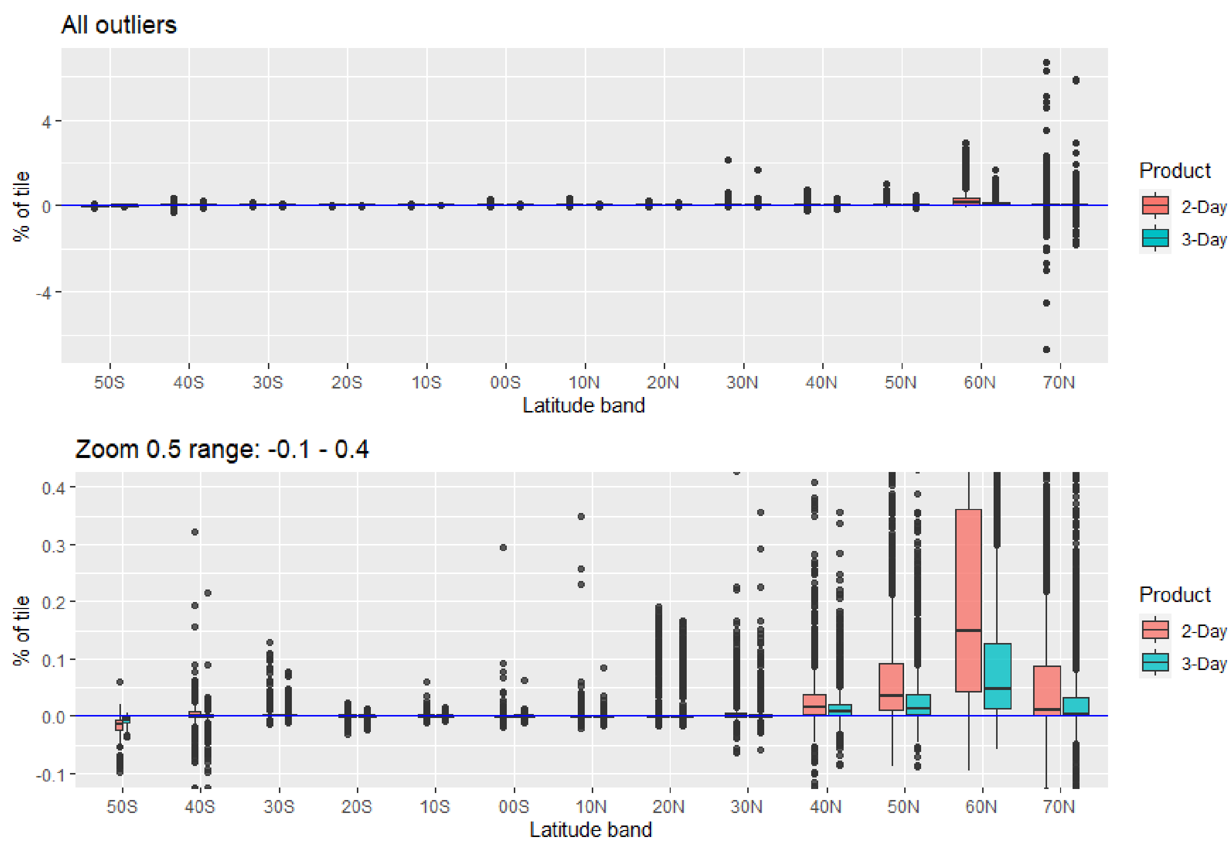


Figure 3: Boxplots of differences in area of reported flood per tile (as percent of tile reported as flood), between LANCE MCDWD and legacy MWP products, grouped by latitude bands (refer to Figure 4 for map of tiles). Top plot includes all outliers; bottom zooms to -0.1 – 0.4 range on y-axis (% tile). Box width is proportional to number of observations (thus, number of tiles): 50S has only two tiles (tip of S America) while 50N has 24 (see Figure 4).

4.2 Qualitative Evaluation

The legacy product was evaluated by qualitatively examining its performance for 100 'events' – roughly 50 flood events, and another 50 locations without flood, but containing surface water. These evaluations were performed by visually comparing the product to available imagery sources, including Landsat, and the MODIS reflectance imagery itself (in which one can generally visually identify flood).

For the MCDWD qualitative evaluation, the product will be evaluated using the same events and locations from the legacy evaluation and reported in an updated version of this document.

5 Product Format and Content

5.1 File format

The MCDWD flood product and associated layers are delivered in a single HDF file per 10x10° tile, per day. The HDF file conforms to HDF-EOS2 standard (version 2.19, based on HDF version 4; see https://wiki.earthdata.nasa.gov/display/DAS/Toolkit+Downloads and https://hdfeos.org). For user convenience, a set of GeoTIFF files will be provided for each HDF file: one GeoTIFF for each flood product within each HDF file (1-Day, 1-Day CS, 2-Day, 3-Day); these are simply extracted from the HDF file (see section 9.3 below (FAQs) for examples). **Table 3** provides details on the product grid and projection. Note that this is a fixed grid, with fixed pixel boundaries for all dates.

Projection	Geographic
Pixel size	0.002083333333333 (=~ 232 m at equator)
Grid dimension	4800 x 4800
Tiling	MODIS HV geographic, with 10° x 10° tiles

Table 3: Grid and projection details for MCDWD product. *Note because this is a geographic "projection", the product's ground pixel size will vary with latitude, from ~232 m at the equator, to about 116 m at 60° latitude. This increase in product resolution does* ***not*** *reflect a real increase in the ability of the product to discriminate smaller bodies of water, but is simply an artifact of using a geographic projection.*

The LANCE product uses the standard LANCE/MODAPS h-v tiling scheme for geographic (lat/lon) projection (https://modis-land.gsfc.nasa.gov/MODLAND_grid.html), shown in Figure 4. Tiles are the same size and position as those used in the legacy product, but are differently labelled. The flood product is generated for a total of 223 tiles.

5.2 The MCDWD product layers

Each product HDF file contains 12 raster layers. These include four flood layers (1-Day, 1-Day CS, 2-Day, and 3-Day), along with ancillary layers that would allow a user to construct alternative composites; most users will likely only be interested in the actual flood product layers (layers 5, 6, 9, and 12). The separate GeoTIFF products are generated for only the flood layers. **Table 4** provides details of all layers in the MCDWD HDF file, and **Table 5** provides pixel coding for the flood layers.

Two versions of the 1-day product are available: "1-Day" and "1-Day CS". In the latter, "CS" refers to **c**loud-**s**hadow masked: that is the only product in which the cloud shadow masks are applied. Due to potential inaccuracies which can lead to masking of real water, and the general effectiveness of the time-compositing approach to deal with false-positives over longer composites, this masking is not applied to the 2 and 3-Day product, but only to this version of the 1-Day product. In future releases this may change.

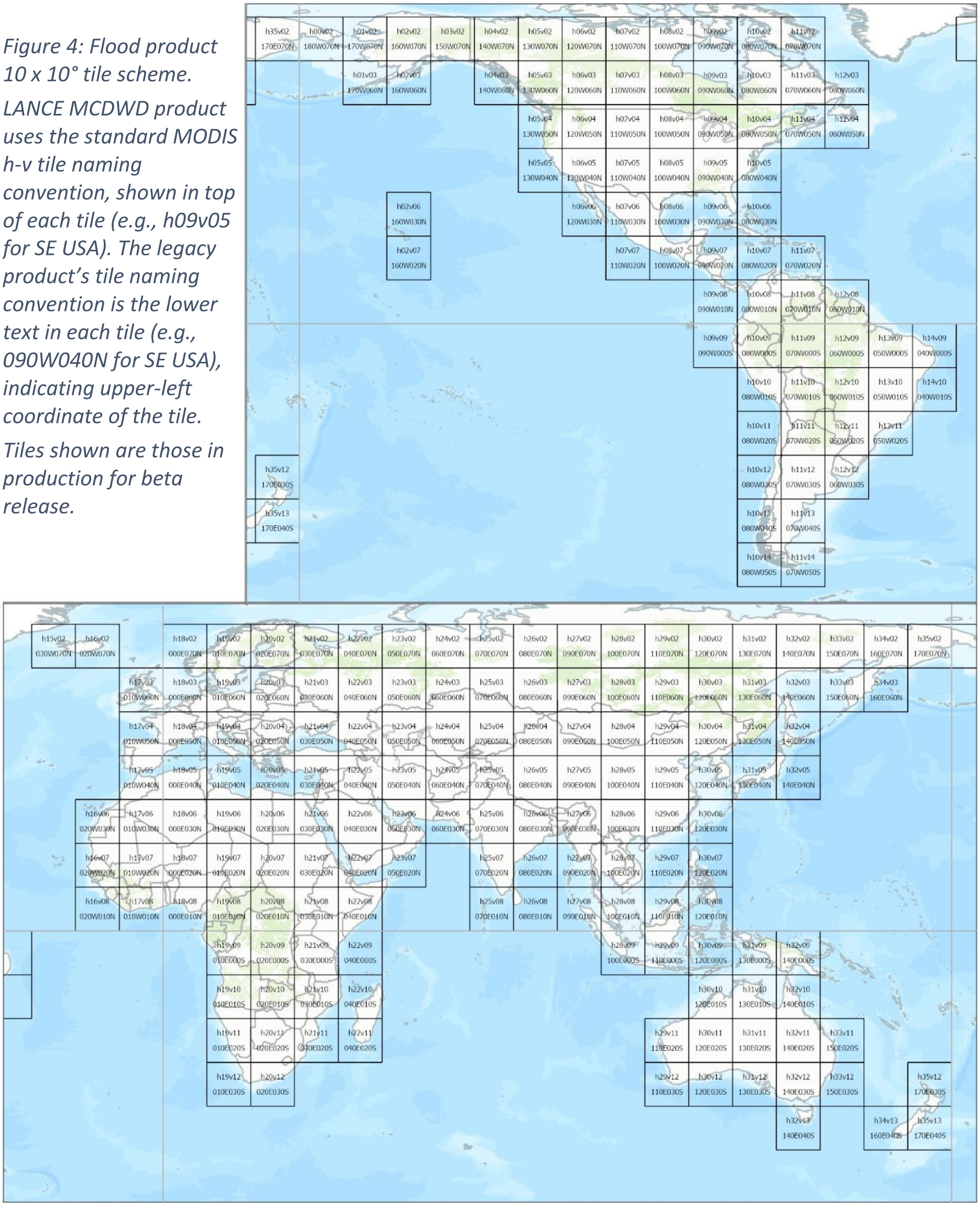


Figure 4: Flood product 10 x 10° tile scheme.

LANCE MCDWD product uses the standard MODIS h-v tile naming convention, shown in top of each tile (e.g., h09v05 for SE USA). The legacy product's tile naming convention is the lower text in each tile (e.g., 090W040N for SE USA), indicating upper-left coordinate of the tile.

Tiles shown are those in production for beta release.

Table 4: MCDWD product layers. *Key outputs are the flood products in layers 5, 6, 9, and 12 (in bold). Flood products are derived from the Water Counts and Valid Counts layers (along with the MOD44W reference water layer). Users can use these layers to compute different composites, if desired.*

Layer	Composite	Name	Description (per pixel)
1	1-day	Water Counts 1-Day 250m	Total water detections from current day, from all available Terra and Aqua images, after applying terrain shadow mask.
2		Water Counts CS 1-Day 250m	Total water detections from current day, from all available Terra and Aqua images, after applying terrain and cloud shadow masks.
3		Valid Counts 1-Day 250m	Total valid observations from current day, from all Terra and Aqua: no bad data values; not in swath gap; not cloud; not terrain shadow.
4		Valid Counts CS 1-Day 250m	Total valid observations from current day, from all Terra and Aqua: no bad data values; not in swath gap; not cloud; not terrain shadow; not cloud shadow.
5		**Flood 1-Day 250m**	**Flood product, 1-Day: from current day's data. (no cloud-shadow masks applied to water detections).**
6		**Flood 1-Day CS 250m**	**Flood product, 1-Day: from current day's data. (cloud-shadow masks applied to water detections).**
7	2-day	Water Counts 2-Day 250m	Total water detections from current AND previous day, from all available Terra and Aqua images, after applying terrain shadow mask.
8		Valid Counts 2-Day 250m	Total valid observations from current AND previous day, from all Terra and Aqua: no bad data values; not in swath gap; not cloud; not terrain shadow.
9		**Flood 2-Day 250m**	**Flood product, 2-Day: from current and previous day's data.**
10	3-day	Water Counts 3-Day 250m	Total water detections from current AND previous two days, from all available Terra and Aqua images, after applying terrain shadow mask.
11		Valid Counts 3-Day 250m	Total valid observations from current AND previous two days, from all Terra and Aqua: no bad data values; not in swath gap; not cloud; not terrain shadow.
12		**Flood 3-Day 250m**	**Flood product, 3-Day: from current and previous two day's data.**

Table 5: Flood product layer pixel values. **Value 2 (Recurring flood) is not populated in the beta release.*

Value	Description
0	No water
1	Surface water (matching expected water)
2	Recurring flood*
3	Flood (unusual)
255	Insufficient data

6 Product Access

The flood product will be available in HDF, GeoTIFF and as imagery in GIBS and Worldview.

At the initial release, only the HDF files are available. This document will be updated as this changes.

6.1 Product filenames

The LANCE flood product has a longname of "MODIS/Aqua+Terra Global Flood Product L3 NRT 250m" and a shortname of MCDWD_L3_NRT. The HDF product filename is constructed as follows:

<SHORTNAME>.A<DATE>.<TILE>.<COLLECTION>.<FILEFORMAT>

Example: MCDWD_L3_NRT.A2021046.h30v12.061.hdf

<SHORTNAME> = MCDWD_L3_NRT: See details below.
<DATE> = 20201046: In YYYYDOY format (DOY = day of year = Julian day).
<TILE> = h30v12: product tile in MODIS HV grid (see Figure 4).
<COLLECTION> = 061: processing collection number 6.1. This is the latest and current MODIS processing collection.
<FILEFORMAT> = hdf

The elements of the shortname MCDWD_L3_NRT are:

MCD: standard shorthand for products generated from a combination of Terra and Aqua imagery.
WD: Water Detection.
L3: level-3 product.
NRT: near real-time (implying generation by LANCE system).

The core product file is an HDF file containing all flood products (1-Day, 1-Day CS, 2-Day, and 3-Day), plus ancillary layers (**Table 4**), for each product date and tile.

From each HDF file, a separate GeoTIFF file is extracted for each of the flood composites. The shortnames for these products have an additional component identifying the flood product:

MCDWD_F1_L3_NRT	(for 1-Day product)
MCDWD_F1CS_L3_NRT	(1-Day CS)
MCDWD_F2_L3_NRT	(2-Day)
MCDWD_F3_L3_NRT	(3-Day)

6.2 Download access

The product DOI for MCDWD_L3_NRT is: DOI:10.5067/MODIS/MCDWD_L3_NRT.061, with a landing page found here:
https://earthdata.nasa.gov/earth-observation-data/near-real-time/mcdwd-nrt

The LANCE near real-time distribution sites are:
https://nrt3.modaps.eosdis.nasa.gov (**from 1 April 2021**)
https://nrt4.modaps.eosdis.nasa.gov (from product launch)

nrt3 is the primary server, and nrt4 is the secondary; the products are generated independently on each system. If one is down, please try the other.

Downloading products requires free registration with the Earthdata Login registration system:
https://urs.earthdata.nasa.gov

On the nrt download sites, the product can be found by navigating:

NRT Data → allData → 61 → MCDWD_L3_NRT

Or, directly in the URL address bar with, for example for nrt4:
https://nrt4.modaps.eosdis.nasa.gov/archive/allData/61/MCDWD_L3_NRT

See the following for instructions on automating downloads:
https://nrt3.modaps.eosdis.nasa.gov/help/downloads

6.3 Worldview & GIBS

The product will be available for viewing in the Worldview web application:
https://worldview.earthdata.nasa.gov/.

The product imagery displayed in Worldview can also be directly accessed via GIBS (Global Imagery Browse Services):

https://earthdata.nasa.gov/eosdis/science-system-description/eosdis-components/gibs

As of the initial beta release, the product is not yet available in Worldview or GIBS, but is expected by the end of April 2021 or earlier.

6.4 Timing and latency

Initial release note: At the initial release in March 2021, the nrt download sites are only being populated with flood product files at the end of the day. In the near future (late April 2021 or sooner), the nrt download sites will be updated in near real-time, as each product is generated, which is expected to be within the standard LANCE latency window of 3 hours or less from observation.

As swath data are received, the flood product is processed in 10x10° tiles and immediately published to the nrt download sites. If subsequent incoming swath data is received that overlaps a previously published 10x10° tile product, that product will be updated (and the original product replaced, and no longer available).

In practice, this may result in a user seeing an initial product with just a portion of the 10x10° tile populated, covering where a particular swath (or available swaths, at the time of processing) intersected the tile. The rest of the tile will then be blank (filled with Insufficient Data values). Then, within a few hours (or less), that product may be updated if additional incoming swath granules intersect the tile.

Note the product filename itself will not indicate if a tile is potentially "incomplete", or, equivalently, potentially may be updated with additional swath data later. Thus, users who may be automatically polling the nrt servers for new files would be advised to retain the file modification times for downloaded files and compare these to times observed on subsequent polls to determine if a file has been updated and thus should be re-downloaded. If users who are downloading files manually find gaps in the product, they may want to wait a few hours and redownload.

For Worldview, there is an additional latency of about 2 hours: 5 hours total (at maximum) from observation to the product appearing in Worldview. Worldview product imagery will also be updated as additional swath data are received and processed.

6.5 Archive availability

LANCE products are generally archived for 7-14 days and users wishing to access older products would generally obtain the standard (science quality) products from the appropriate NASA Distributed Active Archive Center, which maintains data indefinitely. However, the MODIS NRT Global Flood product is an applications product, and does not have a corresponding standard product, so currently no long-term archive is available. This is different from the legacy product, where users could (and still can) browse the ~10 year archive.

Please note the MODIS NRT Global Flood imagery accessible in Worldview through GIBS will remain available. The rolling archive does not apply to GIBS imagery.

It is expected that a long-term archive will be established to address the needs of application users. When this is available, the User Guide will be updated with additional details.

For more information on Near Real-Time versus Standard Products see:

https://earthdata.nasa.gov/earth-observation-data/near-real-time/near-real-time-versus-standard-products

6.6 Legacy Product

The legacy MWP product will continue to be generated and available until 30 June 2021 at its current website: https://floodmap.modaps.eosdis.nasa.gov

The legacy product archive (currently about 10 years of the product for most areas of the world) will remain available at the product's current website, until historical data have been reprocessed with the new algorithms.

6.7 Mailing list

Product questions should be submitted to: support@earthdata.nasa.gov (include "lance flood" in subject line to help direct your email).

A low-volume distribution-only mailing list is maintained for product announcements. Users are invited to sign up here: https://lists.nasa.gov/mailman/listinfo/floodmap

For alerts about LANCE production, which may for example suggest users use nrt4 instead of nrt3 or provide other notices about production issues, please sign up for the LANCE-MODIS mailing list: https://lists.nasa.gov/mailman/listinfo/lance-modis

7 Planned Improvements

A number of planned improvements to the beta version of the NRT global flood product are anticipated.

7.1 Updated Terrain Shadow Masks

Terrain shadows are particularly problematic in mountains, or in any area with topography when sun elevation angle is low (higher latitudes, and winter). Generally, this product will not perform well for mountainous floods due to resolution issues (see section 9.1 for more discussion), and because terrain shadow false-positives will propagate into the products, where they will be visually distracting and confusing for novice users.

Current terrain shadow masks were generated for the original legacy product from the average solar geometry on a monthly basis for each tile at the nominal MODIS overpass times. They work reasonably well, eliminating 75-90% of terrain shadows, but this can still leave significant false-positive pixels in the product. To improve the terrain shadow masks, they will be regenerated at higher time-steps, with improved DEMs (where available), and possibly at swath-relevant geometries. An additional mask – the HAND mask (Height Above Nearest Drainage: (Nobre et al. 2011)) – may also be added to further minimize such errors. The HAND mask is a static mask that identifies pixels that, based on local topography and drainage networks, should not be able to retain substantial flood water.

7.2 Algorithm Improvements

The current implementation of the algorithm follows the legacy product, which had at most two observations per day (one from Terra, one from Aqua). And thus the fixed rules of 2 water observations required for the 2-day product (where potentially 4 observations may be available), and 3 for the 3-day product, made sense and were effective. In the LANCE implementation, however, several additional observations are available at latitudes above 30°, when swaths begin to overlap. (Note that although swath overlaps begin at approximately 30°, they do not become significant until around 50° and higher.) Although this provides additional opportunities to observe water, if clouds move, it also provides additional opportunities for cloud-shadow false positives to accumulate and propagate into the product. To address this, the thresholds may be adjusted by making them dependent on the number of looks available. This should reduce the increased number of false positives that are appearing in the beta release, particularly at tiles above 50° north (see section 4.1 for more details).

The algorithm does not reliably detect water over sunglint areas (specular reflectance off the water surface), due to the secondary screening using bands 1 and 7 (section 3.2). Adjustments to the water detection algorithm will be explored to minimize this issue.

7.3 Production Grid

There are plans to expand the grid of tiles in production to cover small pieces of land that are excluded in the initial production grid (Figure 4), (note these are also excluded in the legacy MWP product). Examples include h18v09 (000E000S, western tip of Gabon) and h21v12 (030E030S, small piece of southeastern South Africa).

7.4 Reference Water & Recurring Flood

The reference water layer tells us where “normal” water is expected to be observed: rivers, lakes, reservoirs, oceans. The current reference water layer is the initial version of the MOD44W product (Collection 5, c2009 : Carroll et al. 2009) and is increasingly out of date (see section 9.1), leading to errors in the product. To address this, a new reference water layer will be developed by analyzing reprocessed product data.

A "recurring flood" layer will also be developed from the same reprocessing, identifying areas that have regularly flooded. This will allow us to populate the product's "Recurring flood" pixel value (value=2; see **Table 5**), marking pixels where flooding has been identified, but has been observed in previous years with some frequency.

In any case, users with their own customized or in-house "reference water" layers that indicate where they believe water should be, are advised to use such resources to update flood identification from these products.

8 Differences between LANCE MCDWD and legacy MWP product

Differences between the products are discussed below in terms of: (1) data production; (2) product features; and (3) data product format.

8.1 Data production:

The primary *production* difference between the legacy MWP product and the LANCE MCDWD product is that the legacy product uses as its main input data a set of pre-composited 10x10° daily Terra and Aqua images, whereas the MCDWD product processes each swath granule separately. For the legacy product, for each day, all Terra (and separately, Aqua) imagery intersecting each 10x10 degree tile was composited (by closest to nadir rule) into a single daily Terra and single daily Aqua dataset. This was done for surface reflectance (MOD09) as well as for Cloud Mask (MOD35) and Cloud (MOD06). One disadvantage was that this resulted in possibly clear observations being overwritten by cloudy pixels, in the mosaicking process when multiple observations were available. Another was the possibility of discontinuities in the product at the mosaicking line, especially if cloud or cloud shadows were present in such areas.

In the LANCE implementation, the water detection algorithm is applied on the swath granules first, which are then mapped to the 10x10° grids, and those grids are time-composited to create the products. In higher latitude areas where swaths begin to overlap substantially, this results in more actual looks at the surface, and more chances to see the ground as clouds move. Thus, one expected change is due to these additional looks at higher latitudes. See discussion in section 4.1 for impacts.

Furthermore, in the legacy implementation, the MOD35 cloud mask product was used to determine cloudy pixels, and thus where there is insufficient data to see the ground to make a water determination. In the LANCE implementation, the Cloud flag that is included in the MOD09 QA State layer is used. This is slightly different than the MOD35 cloud mask, but appeared of roughly equal quality. This will likely result in slight differences between the products, but note this only impacts the product's Insufficient Data values, and does not impact if water is detected; in both products, if water is detected where the cloud mask reports cloud, these pixels will still be labeled as water. In such cases, usually the cloud is high, thin, and fairly transparent, or this occurs around cloud edges. Note both of these cloud masks (MOD35 and MOD09 QA State layer) are provided at 1 km resolution, and thus are interpolated to the product's 250 m resolution (and likely suffer edge errors from this).

Finally, in the legacy implementation, the clouds (from MOD35) are projected to ground using cloud height information derived from the MOD06 cloud product (cloud top temperature interpolated to a standard atmosphere), and solar position information. Largely due to limitations of the heights derived in this method, the limitations of the accuracy of the cloud mask, and the spatial resolution of both (5 km and 1 km, respectively) the cloud shadow projections were helpful but often not sufficiently accurate. In the LANCE implementation, the cloud shadow flag included in the MOD09 QA State layer is used instead; this appears to be a reasonable mask in many cases. Nevertheless, due to limitations in its accuracy, it is only applied to one version of the 1-day product – the "1-Day CS" (CS for Cloud Shadow). A 1-Day product without this applied is also available ("1-Day"). And thus, some differences between the legacy and LANCE 1-day products are expected due to differences in the cloud shadow masking applied.

8.2 Product features

The LANCE MCDWD product has several new or improved product features, although some will not be implemented until later releases. As discussed in section 7.4, the MCDWD product will provide a "recurring flood" data value in the flood product, which will be a significant advance as it will greatly reduce the area of reported flood when such flood is entirely ordinary and expected.

The legacy product also included a 14-day product, which is not provided in the LANCE product. This was essentially a second-order composite: it summed up the previous 14 3-day composites, and presented the result as a fraction (out of 14). This provided a picture of short-term flooding history. And could be useful to consult when, for example, one might be checking the product for reported flooding but not see anything because it had recently been cloudy. The 14-day product would then show the user if flood had recently been detected, without having to check all recent available products. With the LANCE product being made available in the Worldview interface, it is now much easier for a user to rapidly browse through recent products.

8.3 Data format

In terms of data format, the two products have substantial differences. The core legacy product is provided in a set of MWP raster GeoTIFF files, generated for each product composite (1-Day, 2-Day, 3-Day). Earlier in its history, derivative files (MFW=MODIS Flood Water, and MSW=MODIS Surface Water) were generated from the MWP, in both raster and vector (shapefile and KML) formats, but these were discontinued due to processing difficulties and will not be included in the LANCE product. The core LANCE MCDWD product is a single HDF file containing all products (1-Day, 1-Day CS, 2-Day, 3-Day) along with ancillary layers (see section 5 above for details). The LANCE flood product's data values also differ from those of the legacy product, as described in **Table 6**.

Table 6: Comparison of flood product data values, between legacy MWP and LANCE MCDWD. ** Note the legacy product did not have the "recurring flood" label, and although this is planned for the LANCE product, it will not be implemented immediately.*

Description	Legacy flood product (MWP) data values	LANCE flood product (MCDWD) data values
No Water	1	0
Surface Water	2	1
Recurring Flood*	NA	2
Flood	3	3
Insufficient Data	0	255

The product grid is fixed in the LANCE MCDWD product (**Table 3** provides details), resulting in each product raster being exactly 4800 x 4800 pixels, with fixed cell boundaries (they do not vary by date). In the MWP product, the product grid was slightly smaller (4552x4552), could vary slightly in pixel dimension (by one or two pixels, such as 4551x4552), and cell boundaries would shift from one product or date to another. For the MCDWD 4800x4800 grid, the pixel size is smaller: 0.0020833 degrees square, vs 0.0021968 in the legacy MWP. At the equator, this results in a pixel size of ~232 m for MCDWD vs ~245 m for MWP.

The tile naming scheme has also changed. In the legacy MWP product, tiles were identified by their upper-left latitude-longitude coordinate, such as 100E020N. In the LANCE MCDWD product, a standard geographic (lat/lon) product tiling scheme in use for other MODIS products has been adopted, the HV tiling scheme (https://modis-land.gsfc.nasa.gov/MODLAND_grid.html). In this scheme, for example, 100E020N becomes h28v07. Figure 4 shows a map with both schemes labelled, for the current tile production grid.

9 Use Notes and FAQs

9.1 Usage Notes

This product detects water in 250 m pixels, when that water is observable by the satellite. Obstructions, whether they be clouds, treetops, or building roofs, will limit the capability of the system to detect water. Some important considerations are outlined below.

Cloud obscuration

This product relies on MODIS bands (red and near infra-red, primarily), which cannot penetrate clouds. Thus, if an area is cloudy, as is often the case, there may not be sufficient clear imagery to observe flood (or other) water on the ground. However, the MODIS sensor is on board two different satellites (Terra and Aqua), typically providing two looks per day (at roughly 10:30 am and 1:30 pm local time). Thus if cloud cover is patchy, or is moving out of an area, there may be clear imagery from one overpass. The various composites (see below section on composites) are an approach to deal with the complications of cloud cover by accumulating water detections over 1, 2, or 3 days.

Spatial resolution

Flood pixels have a spatial resolution approximately 250 m. Flood water that does not cover a significant portion of a 250 m pixel may not be classified as water. This can result in events that are locally significant, such as local flooding swamping roadways, not being reliably detected. It will depend on the extent of flood water: a submerged four-lane highway should be picked up, but a two-lane road may not be, especially if the road margins are not extensively flooded, or if the water is obscured by vegetation or tree cover (next section). Similarly, detecting flooding in mountainous regions without significant flat land is difficult, as such flooding is usually more spatially constrained. It is also usually more rapid, due to the topographic constraints on water flow. Thus 'flash floods' are usually not detected, both because they are often too small in spatial extent, and because the water may be present only for short (if dangerous) period, and quite possibly not at the particular times of satellite observation (let alone to be captured by multiple observations).

Canopy cover & buildings

As with clouds, tree cover and buildings can obscure water detection; extensive flooding may be occurring on the ground, but if the area is heavily wooded, there may not be sufficient water signal reaching the satellite to be detected. Buildings can present the same problem in urban areas: the streets may be flooded, but generally the rooftops are providing a 'dry' signal to the satellite (unless flat roofs are pooling water) at the scale of these observations (250 m).

Composite products – 1-day, 2-day, 3-day

The composites work by setting a threshold for the number of water observations required to mark an output pixel as water, over a given number of days. These thresholds are 1, 2, and 3, for the 1-day, 2-day, and 3-day products respectively. Each composite generally has twice as many observations available, due to the twice-daily MODIS observations. The goal is that with additional looks (over additional days) clouds may move, allowing the satellite to observe water, and for this to be detected. But it may take a day or two or three for clouds to get out of the way. If there were no clouds (or we could see through them perfectly), the product could be simpler – just the 1-day. And thus if the user can verify that no clouds are present over their site and dates of interest, the 1-day product will provide the most up-to-date information on water extent. If clouds are present, then the 2-day or 3-day may better capture flood extent, but this is at the expense of potentially being less timely: the 2-day product could be showing water that was only present (and observable) on the previous day, or that was only present (and observable) on the current day, or that was present (and observable) on both days.

A complicating factor is cloud shadows, which will generally be detected as water by the algorithm (this is a common problem across optical satellite imagery: the reflectance of shadows is very similar to that of water). The requirement that water is observed multiple times in the 2 and 3-day products is an attempt to filter out these spurious one-off false-positive "water" detections, because cloud shadows generally move over time. That said, they can recur in the same location from one observation to the next (albeit somewhat uncommon). The 3-day product, requiring 3 "water" observations, almost entirely eliminates such persistent cloud-shadow false-positives. However, this comes again at the expense of timeliness.

Thus, although three different products are provided to help address varying conditions, it is strongly recommended that the user look at the MODIS imagery themselves, to determine the level of cloud cover and thus better understand the results in the product. And a user with some experience will also more readily be able to detect reasonable flooding patterns, vs more random patterns from false-positives.

Terrain shadow

Like cloud shadow, terrain shadows may be detected as water. Unlike cloud shadows, they do not move significantly between days, although they will shift from morning observations (Terra satellite) to afternoon (Aqua) due to sun angle. Nevertheless, during local winter, especially at higher latitudes, terrain shadow can significantly contaminate the flood products. Terrain shadow masks remove 75-90% of these artifacts, but this can still leave considerable false-positives in winter and mountainous areas. The terrain shadow masks will be updated in a future release. In the meantime, the user is advised to be particularly wary of flood detections in mountainous regions, especially in winter.

Volcanic areas

Exposed areas of substantial dark volcanic rock will often trip our water detection algorithm, and be flagged as water. Because they do not change over time, they will then usually get marked as flood. In the United States, such areas include the central volcanic areas of Hawaii and Maui islands, and the Craters of the Moon area in south-central Idaho. There are many other sites worldwide. In a future upgrade, masks could be used to remove these false-positives , and mark such areas on in our products accordingly (likely with the Insufficient Data flag to emphasize that it is not possible to be certain if water is present on such pixels, even if clear).

Viewing product in Worldview web application: https://worldview.earthdata.nasa.gov (coming soon)

The flood product will be available in NASA EOSDIS Worldview by April 2021. This is a very useful tool for both browsing the flood products, and for determining if clear imagery exists over an event of interest – and thus the reliability of reported flood in the different composites. See section 6.3 for more details. Please note: only 2 and 3 day products will be initially available in Worldview.

9.2 Product examples

This section provides examples of the product to demonstrate product utility, limitations, and best practices for use. Most of the figures are screenshots from the NASA Worldview interface, and show surface water in cyan and flood water in red. Insufficient data is typically shown in gray, but has been turned off in most examples for clarity.

Effective flood mapping of Cyclone Eloise in Mozambique, January 2021. Figure 5 demonstrates the utility of the product for the recent flooding near Beira, Mozambique, following the passage of Cyclone Eloise on 23 Jan. The area remained cloudy until 27 Jan, and substantial flooding was then detected in the riverine flood plains on the 27th and 28th.

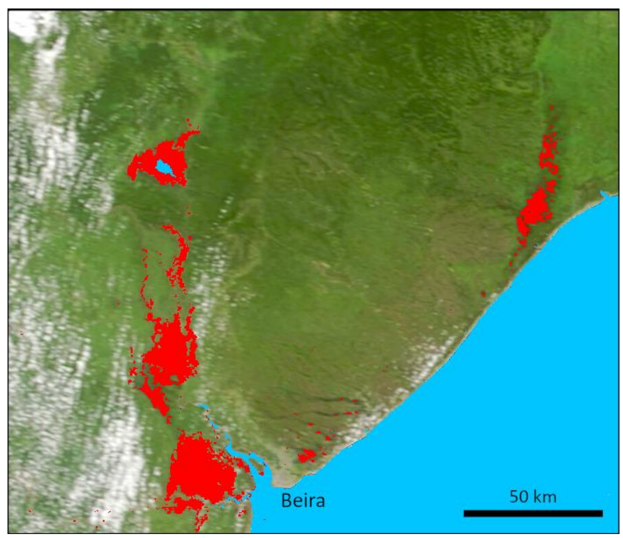


Figure 5: Flood detected 28 Jan 2021 in Beira area, Mozambique. 2-Day product shows extensive flooding, along the Pungwe and Buzi rivers. Background image is MODIS-Aqua from 28 Jan.

Effective flood mapping of annual Mekong river flooding, SE Asia. Figure 6 (same as title page figure) shows extensive, but likely largely routine, flooding along the Mekong river and Tonle Sap lake in Cambodia and Vietnam, on 13 Nov 2020. Although the image is clearly cloudy (and this is a cloudy region of the world), substantial flooding is still detectable with the product.

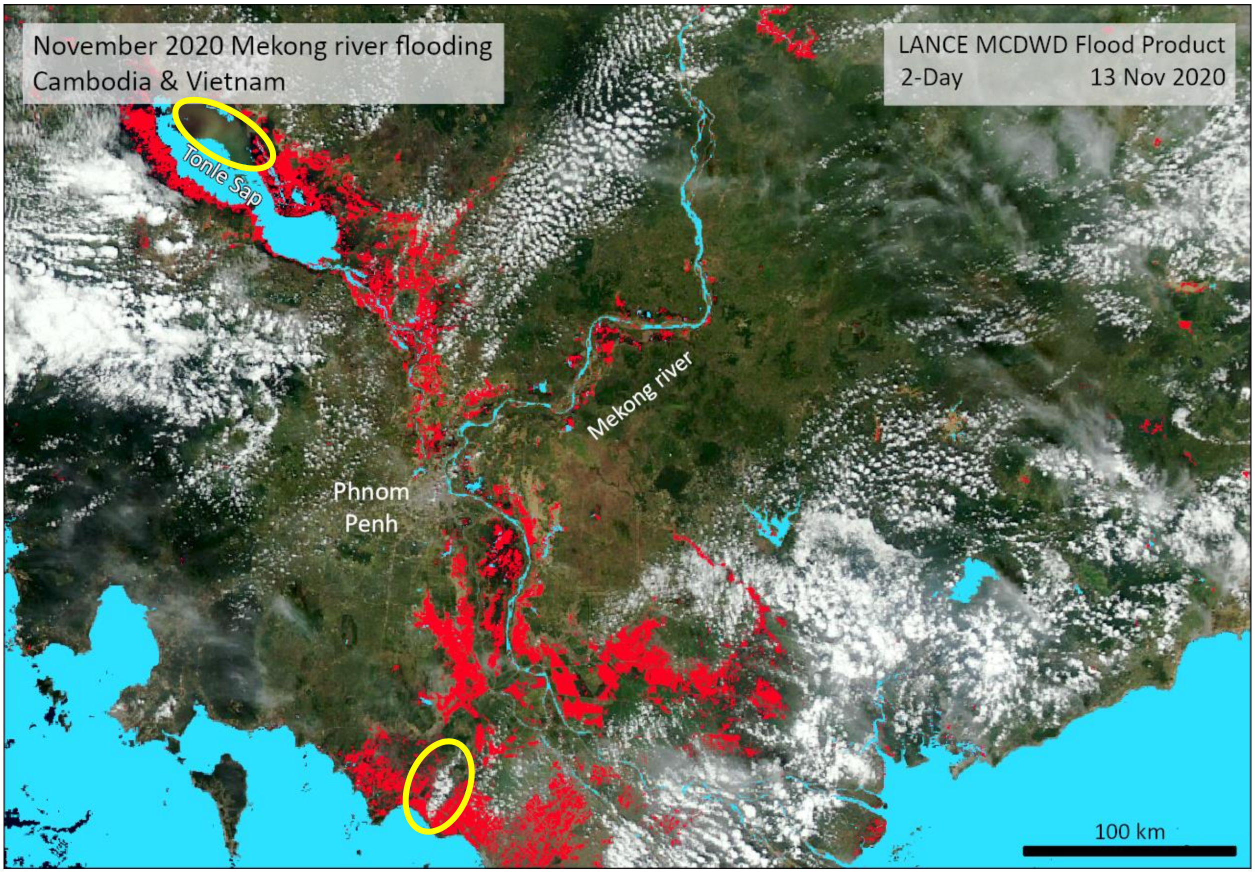


Figure 6: The 2-Day flood product showing extensive flooding in the lower Mekong region of Cambodia and Vietnam, overlaid on MODIS-Aqua imagery from 13 Nov 2020. Upper yellow polygon shows portion of Tonle Sap lake not being detected in this composite, even though this particular Aqua image appears relatively clear; that area reappears in the 1-Day composite due to water detections from this Aqua image. Lower polygon shows an area where cloud in this Aqua image is obscuring likely flood detection.

Incorrect reference water resulting in flooding false positives. Figure 7 shows a reservoir in Cambodia formed after the completion of the Lower Sesan II dam in 2017 (https://earthobservatory.nasa.gov/images/91761/a-new-reservoir-in-cambodia). The reservoir is routinely reported as flood in the product, and yet this "flooding" is not of concern. With the planned reference water update, this will instead be reported as "Surface Water". At that point, if reservoir levels vary seasonally or yearly, some edge areas may be reported as flood if the new reference water layer has not captured is maximal extent.

Figure 7: New reservoir behind recently constructed Lower Sesan II dam in Cambodia misidentified as flood. 2-Day product, 24 Nov 2020, Worldview display.

Volcanic false-positives. Volcanic lava fields will often trigger the water detection algorithm because like water, they are optically very dark, and thus can often be reported as "flood" in the product. Figure 8 shows an example from the Craters of the Moon area of south-central Idaho. Note not all the visible lava flows are identified as water, but the darkest portions are. Some problematic lava flows on the islands of Hawaii and Maui have been masked out and others, such as this area in Idaho along with many others globally, could be masked in the future.

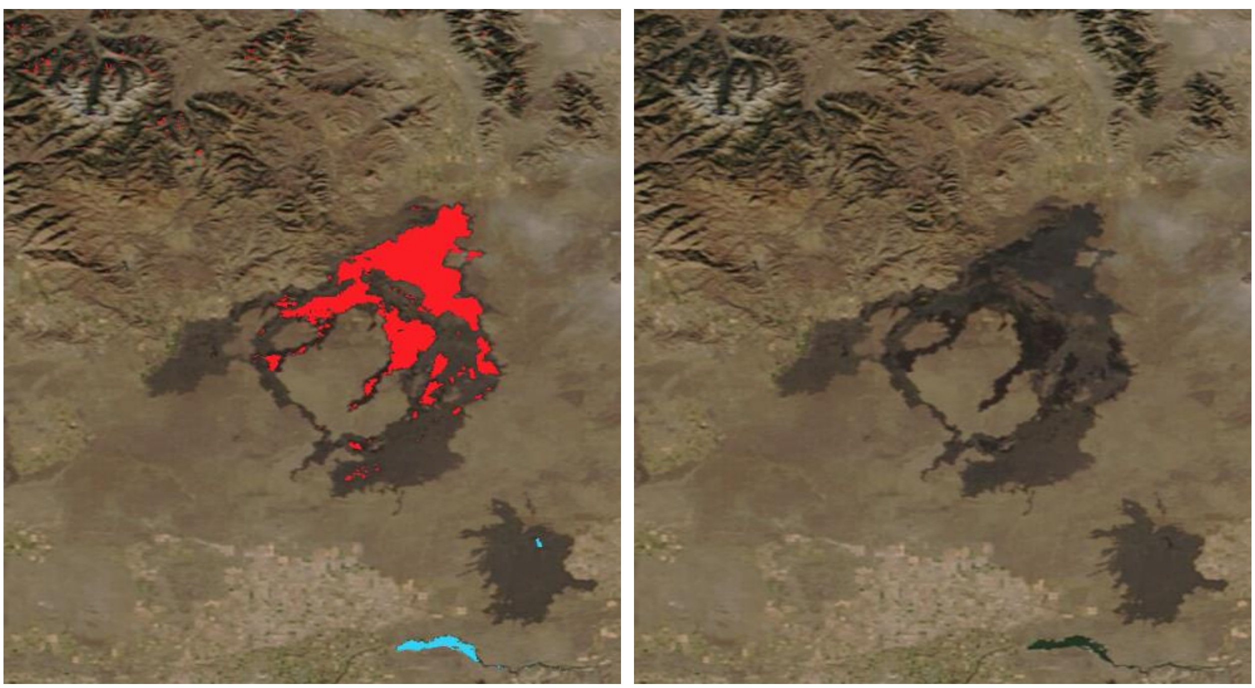


Figure 8: Flood false-positives due to dark lava fields at Craters of the Moon National Monument, Idaho USA. Left shows flood product with false-positives; right the underlying MODIS-Terra reflectance imagery, demonstrating that only the darkest lava flows are misidentified. Note also scattered terrain-shadow false positives in the mountains in the northwest. 4-Nov-2020, south-central Idaho, 3-Day flood product.

Persistent cloud and terrain shadow false-positives. Figure 9 shows a typical example demonstrating both cloud and terrain shadow false positives, in this case in a 2-Day product. Note that simply switching between the Terra and Aqua imagery for the day of the product (04 Nov 2020), the user would see many of the cloud-shadow false-positives falling directly next to visible clouds, and generally following the pattern of clouds. In this case, these clouds did not move substantially between the 10:30 AM Terra overpass and the 1:30 PM Aqua, resulting in substantial false-positives even in the 2-day product. Interestingly, even on the previous day (03 Nov 2020), clouds are similarly positioned, resulting in substantial false-positives in the 3-Day product (but less than the 2-Day shown here). The 1-Day product is even more contaminated.

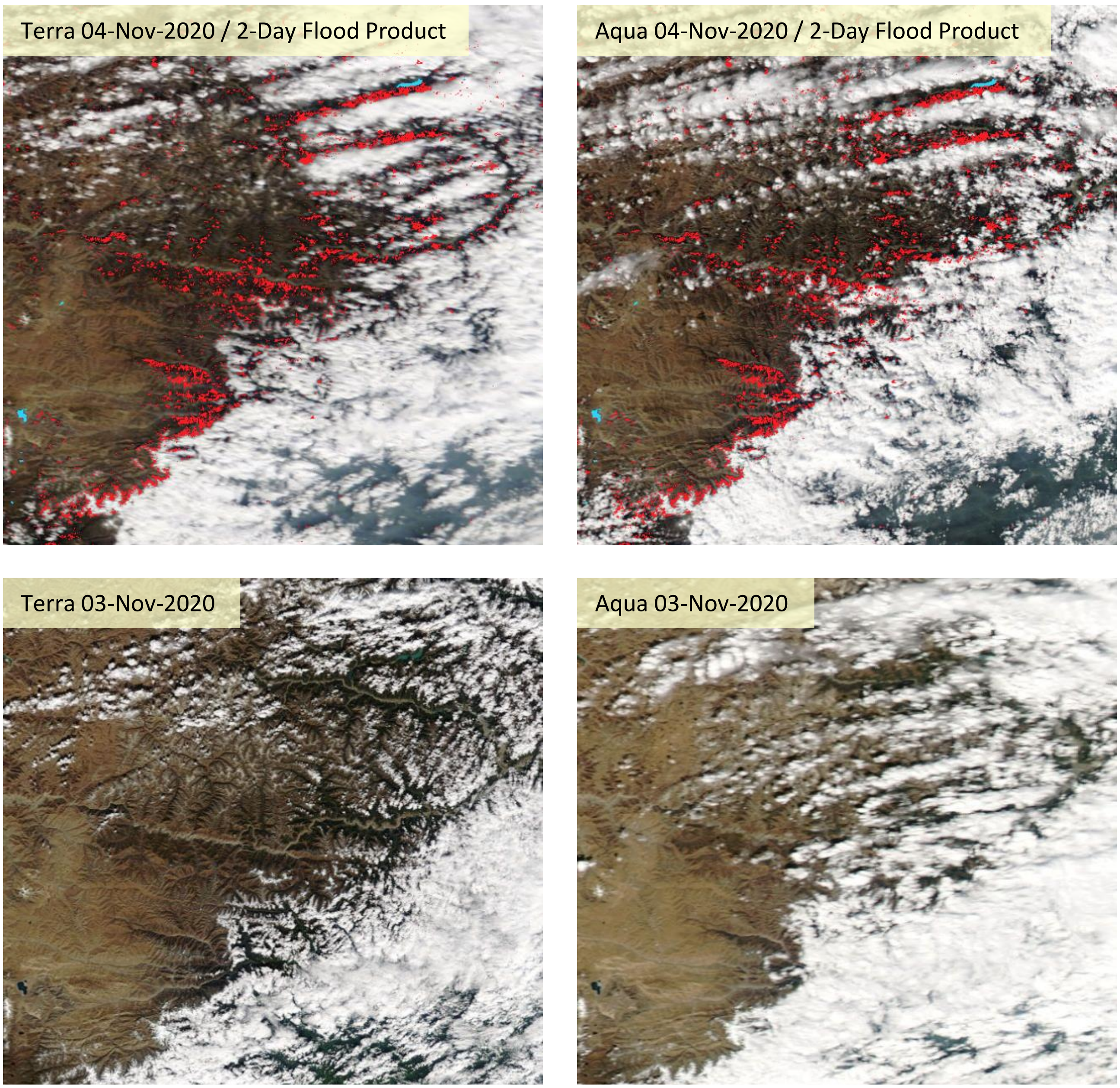


Figure 9: Example of persistent cloud-shadow and terrain-shadow false-positives in 2-Day product. Area shown is at the intersection of SW China, Bhutan, and India (Arunachal Pradesh).

The example also shows terrain shadow false-positives, which do not move much between Terra and Aqua overpasses, and will be very similar from one day to another (unless cloud obscured), and thus accumulating in the product. Although terrain shadow masks are currently applied, these are imperfect and will be updated in a future release. Terrain shadow can usually be readily identified by eye, due to its characteristic scattered appearance clinging to one aspect of a mountainous area. These are also areas where significant flooding is generally less likely to occur, or to remain on the ground long enough to be detected.

Difference between 1-Day, 1-Day CS, 2-Day, and 3-Day products. Figure 10 shows all four products for a site in northeastern China (west of Harbin) with substantial river flooding in late October 2020. In this case, substantial (but not wall to wall) cloud was present on the current product date (26 Oct), which limited the ability to detect water on that date, and also introduced cloud-shadow false-positives – an arc of this is apparent in the west, going against the topography (another hint it is not real). The 1-Day CS product (with cloud shadow screening) substantially but not entirely removes those false-positives, another clue they are not reliable. The 2-Day product then shows an area of flood largely omitted by the 1-Day and 3-Day (southeast of Qiqihar). If that area were of concern to a user, the 2-Day product looks best, but they would be advised to check the reflectance imagery to confirm.

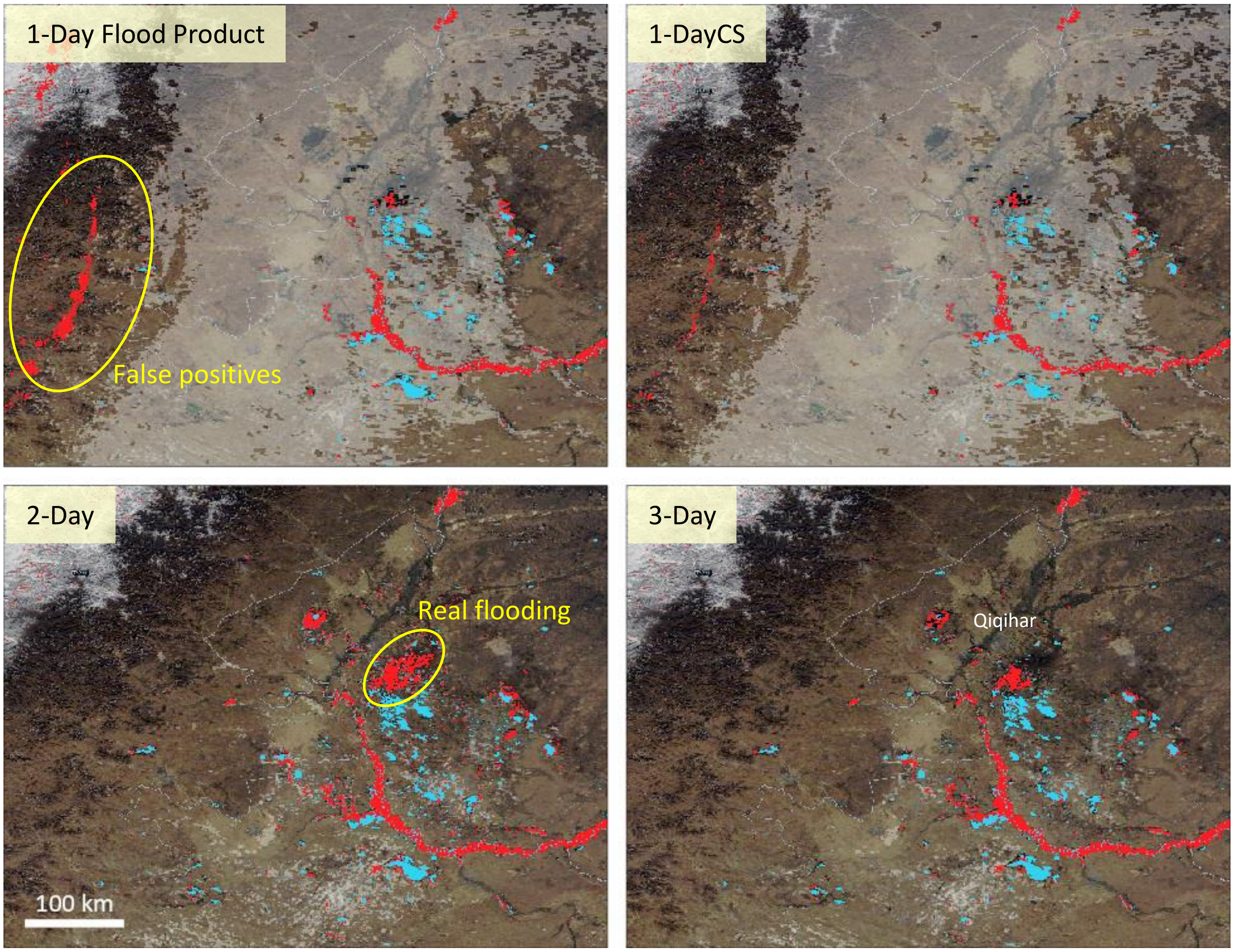


Figure 10: Demonstration of the difference between the four products: 1-Day, 1-Day CS (with Cloud Shadow screening), 2-Day, and 3-Day, during flooding of Songhua river, NE China, 26 Oct 2020. Yellow outline in 1-Day panel shows area of cloud-shadow false-positive, which is substantially ameliorated in the 1-Day CS product (but not entirely), and is completely removed from the 2 and 3-Day products. Yellow outline in 2-Day panel shows an area of flooding that is only here captured in the 2-Day product; the 1-Day products had some cloud over this in both Terra and Aqua, and the 3-Day suggests there were not sufficient water observations (3) in the two previous days, for this to be captured. It is possible the water was not fully present on the two previous days if this is a rapidly evolving event, or that there was cloud obscuration; a review of the contributing MODIS imagery would be needed to make a clear determination.

For reference Harbin is just east of the image. In this figure, semi-transparent white is displayed for the "Insufficient data" data value in the product (value 255). Similar appearing whitish area in NW corner of the image is snow. Displayed background image is Terra from 23 Oct 2020, which had fewer clouds so was chosen for clearer background display. In the reflectance images relevant to this product (but not shown here) there is substantial cloud on 26 Oct, but much less on 24 or 25 Oct.

9.3 FAQs

Which product will show me the water extent for this particular flood event?

Please read through section 9.1, and then examine the MODIS reflectance imagery in the Worldview application (https://worldview.earthdata.nasa.gov), to determine the level of cloudiness on the dates of interest.

Why are there two 1-day products in the HDF file? Which should I use?

The 1-Day CS product has cloud shadow masks applied to the water detections, to help remove cloud-shadow false positives. However, these masks can be inaccurate, and thus can remove real water. If you are able to review the MODIS reflectance imagery and confirm there are no clouds over your specific area of interest, then either product is fine, as they should be identical. If you see clouds, then it is recommended you use the "1-Day CS" product, keeping aware some cloud shadow false-positives may still exist; examine reported flood pixels carefully. In general, it is recommended that you only use the 1-day product if either: (1) you need the most timely information, or (2) you know there are no potential cloud shadow concerns, or you have been able to review the MODIS Terra and Aqua corrected reflectance (or land surface reflectance) imagery in the Worldview to confirm. If there **are** clouds **and** you need the most timely information, it is recommended to examine both 1-day products to see if either is showing flood water in areas of concern. If either does, then be sure to confirm from the reflectance imagery (most easily done via Worldview) that the reported flood pixels are not falling on cloud shadows for either Terra or Aqua observations.

If reviewing products in Worldview, please note that Worldview shows a composited view of overlapping swath granules. So for a given day, the Corrected (or Land Surface) Reflectance layers will show just one of potentially a few overlapping MODIS images (for a given sensor: Terra or Aqua), when swaths overlap, towards the poles. It is possible that water detections for a true flood (or for a false positive) are coming from imagery that is **not** actually viewable in Worldview. E.g., those water detections could be from a swath that was superseded in the mosaicking process to generate the Corrected (or Land Surface) Reflectance imagery for Worldview; when swath data overlaps, the data with view angle closest to nadir is selected for the imagery mosaic. These individual granules for clouds or shadows at: https://lance3.modaps.eosdis.nasa.gov/imagery-apps/swaths (be sure to select MODIS Aqua or Terra, as VIIRS imagery is the default setting). Note the granules on that site are not mapped to a projection, so can appear quite distorted near the edges, and towards the poles. Swath imagery may be available in a future release of Worldview, which will provide an easier browsing experience, and allow direct comparison to the flood product.

How can I pull out a specific layer (such as the 2-Day flood product) from the HDF file?

Standard gdal command-line utilities are one method to extract layers from the HDF files to geotiff or other formats. To do so, ensure you have gdal utilities installed – check https://gdal.org/ for more information. Both linux and windows installations are possible. Alternatively, if you use python, python package managers, such as conda, can also be used to install gdal, including command-line utilities.

With gdal utilities available, retrieve a listing of the layers in the HDF file, as interpreted by gdal. The gdalinfo command will provide this:

```
gdalinfo MCDWD_L3_NRT.A2020104.h08v04.061.hdf
```

Below, only the Subdatasets section returned by gdalinfo for this example is reproduced:

```
Subdatasets:
 SUBDATASET_1_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Water Counts 1-Day 250m"
  SUBDATASET_1_DESC=[4800x4800] Water Counts 1-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_2_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Water Counts CS 1-Day 250m"
  SUBDATASET_2_DESC=[4800x4800] Water Counts CS 1-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_3_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Valid Counts 1-Day 250m"
  SUBDATASET_3_DESC=[4800x4800] Valid Counts 1-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_4_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Valid Counts CS 1-Day 250m"
  SUBDATASET_4_DESC=[4800x4800] Valid Counts CS 1-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_5_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Flood 1-Day 250m"
  SUBDATASET_5_DESC=[4800x4800] Flood 1-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_6_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Flood 1-Day CS 250m"
  SUBDATASET_6_DESC=[4800x4800] Flood 1-Day CS 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_7_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Water Counts 2-Day 250m"
  SUBDATASET_7_DESC=[4800x4800] Water Counts 2-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_8_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Valid Counts 2-Day 250m"
  SUBDATASET_8_DESC=[4800x4800] Valid Counts 2-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_9_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Flood 2-Day 250m"
  SUBDATASET_9_DESC=[4800x4800] Flood 2-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_10_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Water Counts 3-Day 250m"
  SUBDATASET_10_DESC=[4800x4800] Water Counts 3-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_11_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Valid Counts 3-Day 250m"
  SUBDATASET_11_DESC=[4800x4800] Valid Counts 3-Day 250m Grid_Water_Composite (8-bit unsigned integer)
  SUBDATASET_12_NAME=HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Flood 3-Day 250m"
  SUBDATASET_12_DESC=[4800x4800] Flood 3-Day 250m Grid_Water_Composite (8-bit unsigned integer)
```

Note there are 12 subdatasets, one for each of the layers in the product (**Table 4**), and each has a NAME and DESC field. For a given layer of interest, the NAME field is what is required here. Thus, for the 2-day flood product, the name of the relevant subdataset (here, the 9th layer), as output by gdal, is:

```
HDF4_EOS:EOS_GRID:"MCDWD_L3_NRT.A2020328.h04v02.061.hdf":Grid_Water_Composite:"Flood 2-Day 250m"
```

The gdal_translate command can then be used to extract that subdataset to another file, such as GeoTIFF. The general syntax for gdal_translate is:

```
gdal_translate <LAYERNAME> <OUTPUTFILE> <OPTIONS>
```

Thus, for the above example, to extract the 2-Day flood layer to a GeoTIFF file named "FloodProduct2Day.tif", the gdal_translate command would be:

```
gdal_translate HDF4_EOS:EOS_GRID:MCDWD_L3_NRT.A2020328.h04v02.061.hdf:Grid_Water_Composite:"Flood 2-Day 250m" FloodProduct2Day.tif
```

Note quotes can be removed from the layer name that are not required to maintain spaces, but must be retained to maintain space characters, if any are present, as they are here in the last component.

You can also convert to other formats, or include compression or other formatting requirements via various command-line options – see https://gdal.org for more information. For example, to make the output GeoTIFF file substantially smaller by applying DEFLATE compression, add a `-co` option as follows:

```
gdal_translate HDF4_EOS:EOS_GRID:MCDWD_L3_NRT.A2020328.h04v02.061.hdf:Grid_Water_Composite:"Flood 2-Day 250m" FloodProduct2Day.tif -co "COMPRESS=DEFLATE"
```

How should I cite this product?

Please use the following:

MODIS/Aqua+Terra Global Flood Product MCDWD_L3_NRT distributed from NASA LANCE. Available on-line [https://earthdata.nasa.gov/earth-observation-data/near-real-time/mcdwd-nrt].
DOI: 10.5067/MODIS/MCDWD_L3_NRT.061

10 Product Releases

Table 7 provides an estimated product release schedule. Note future releases may be combined, or come in different order; this table will be updated with each release according to current plans.

Table 7: Planned product release schedule.

Release	Product maturity[1]	Description	User Guide revision	Date [est] / actual
Beta	Beta	Initial beta release	A	5 Mar 2021
Beta[2]	Beta	Evaluation Report completed: product is deemed comparable to legacy MWP, with any substantive differences documented.	[B]	[30 Apr 2021]
Release 1	Provisional	Update compositing rules		[Q2 2021]
R2	Provisional	Update water detection algorithm		[Q3 2021]
R3	Provisional	Update terrain shadow		[Q3 2021]
R4	Provisional	Update reference water		[Q4 2021]
R5	Provisional	Update to add "recurring flood", completing all initially planned improvements.		[Q1 2022]

[1] : Please see the following for a description of MODIS product maturity status levels:
https://landweb.modaps.eosdis.nasa.gov/cgi-bin/QS/new/pages.cgi?name=help&sensor=MODIS&fileName=maturity

[2] : It is anticipated that the completion of the Evaluation Report (including the pending qualitative evaluation) will not motivate any changes in the product algorithm or production workflow, and thus the data product at this second Beta "release" will remain the same as that in the initial Beta release, with only the User Guide updated with the additional evaluation information. If changes are necessitated, a new beta product release number will be introduced.

10.1 Beta release

The initial beta release is designed to most closely mimic the legacy product, by focusing on getting the core production operational within the new data workflow in LANCE, while holding back the planned product improvements. This also allows a more meaningful comparison between the legacy and the LANCE product (section 4). Nevertheless, there are still differences, mostly due to the additional looks available due to the change in the processing workflow (now processing all granules when overlapping, not just a daily per-sensor mosaic).

Under the beta release, there are a few additional release points. These do not impact the product contents, only its availability:

- GeoTIFF file availability for flood layers: est by 31 Mar 2021
- Worldview availability (excluding 1-Day products): est by 31 Mar 2021

- NRT product file availability (at release, product files are only appearing on nrt download sites at the end of each day): est by 30 Apr 2021 or sooner
- Finalized Evaluation Report (and updated User Guide): est by 30 Apr 2021

These will be announced via the product mailing list: https://lists.nasa.gov/mailman/listinfo/floodmap

11 References

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