MODIS NRT Global Flood Product

MODIS Aqua+Terra Global Flood Product L3 NRT 250m

Provided by NASA LANCE

User Guide

Revision C

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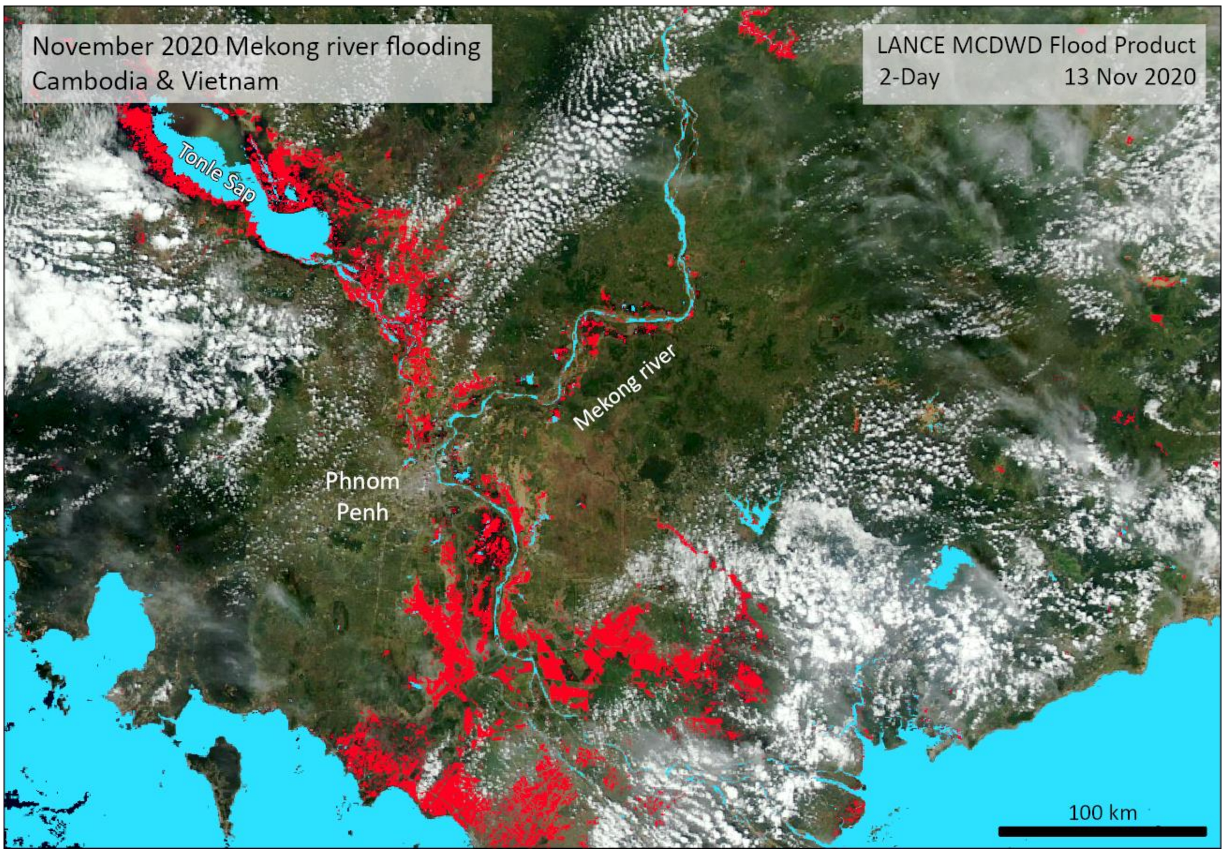

The 2-Day flood product showing extensive flooding (in red) in the lower Mekong region of Cambodia and Vietnam, and normal water (in cyan), overlaid on MODIS-Aqua imagery. Although a dramatic example demonstrating the product capabilities, much of the displayed flooding here is typical seasonal flooding.

Document Change History

Revision	Date	Description
A	8 Mar 2021	Initial beta release
B	25 June 2021	Final beta release: qualitative eval complete, updated access info.
C	12 Jan 2023	Beta 2 release: addition of HAND mask.

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1 Quick Start Summary

The LANCE MODIS NRT global flood product (MCDWD) replaces the "legacy" flood product (MWP), which was generated from 2012 through April 2022. The flood product was initially developed as an applications product, and so there is no associated science product (unlike most LANCE products).

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.

Homepage: https://www.earthdata.nasa.gov/global-flood-product

The product can be downloaded from the LANCE NRT servers:

https://nrt3.modaps.eosdis.nasa.gov (preferred/primary server), or
https://nrt4.modaps.eosdis.nasa.gov (backup server)

by navigating on those sites to:

NRT Data → allData → 61 → MCDWD_L3_NRT

Or, directly in a browser: https://nrt3.modaps.eosdis.nasa.gov/archive/allData/61/MCDWD_L3_NRT

Note you will need a (free) EARTHDATA account for access. Register at: https://urs.earthdata.nasa.gov.

GeoTIFF files of the four individual flood layers in each HDF file are also available. These have shortname MCDWD_L3_<FloodComposite>_NRT, where <FloodComposite> is one of: F1, F1C, F2, or F3 (for the 1-day, 1-day with cloud shadow screening, 2-day, and 3-day products). These are available in their own directories on the NRT servers: NRT Data → allData → 61 → MCDWD_L3_F1_NRT, etc.

The GeoTIFF product DOIs are:

1-day: 10.5067/MODIS/MCDWD_L3_F1_NRT.061
1-day with cloud-shadow screening: 10.5067/MODIS/MCDWD_L3_F1C_NRT.061
2-day: 10.5067/MODIS/MCDWD_L3_F2_NRT.061
3-day: 10.5067/MODIS/MCDWD_L3_F3_NRT.061

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

The nrt download sites are updated in near real-time as each incoming swath granule triggers product generation.

An API is available to query available files on the nrt systems. For example, the following URL will return a json-format listing of all files available for 2022-362 (day of year):

https://nrt3.modaps.eosdis.nasa.gov/api/v2/content/details?products=MCDWD_L3_NRT&archiveSets=61&temporalRanges=2022-362

The user can then interrogate this json listing for specific tiles of interest, and can review production time stamps to compare against previous queries, to determine (for example) if a file has been updated with new data.

The product is also viewable in Worldview: https://worldview.earthdata.nasa.gov by clicking on "Add Layer" and selecting the "Flood" item in the Floods category. The following link references Worldview with the flood layers already added: https://go.nasa.gov/3OiKtYB.

Product Format

The product is distributed in 10x10° tiles (Figure 1), in a lat/lon (geographic) projection, in HDF files. The tiles are 4800 x 4800 pixels, with pixel size of 0.0020833 degrees (~232 m at the equator). Each file contains four flood composites (1-Day, 1-Day CS, 2-Day, and 3-Day; see below), and other ancillary layers (Table 6). 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 tile grid (different from the MODIS sinusoidal tiling grid, which also uses h-v indexing).

Separate GeoTIFF files are also available 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 7, on page 22. Note these differ from those in the legacy product (see section 8 below for additional details).

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 detections from several satellite observations, many false-positives can be removed because cloud shadows generally do not recur in the same locations on subsequent observations.

Because the location of flood water is not well known in advance, and because clouds are spatially variable, it is impossible to predict (and thus only generate) the best composite product 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 cloud shadows are present. 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 30 provide more detailed guidance and users are advised to review this material.

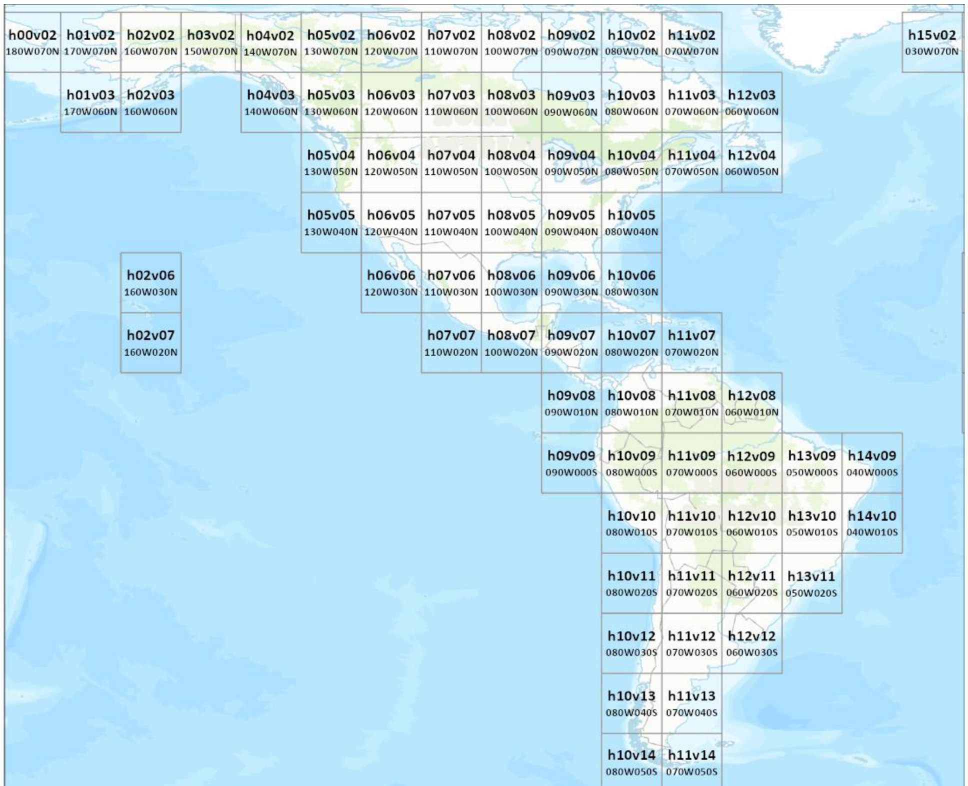
Support

Contact Earthdata Support for product support: https://www.earthdata.nasa.gov/contact

A low-volume distribution-only mailing list is also maintained for flood product announcements.

To subscribe: Send an e-mail to floodmap-join@lists.nasa.gov (no subject or body text is required).

To unsubscribe: Send an e-mail to floodmap-leave@lists.nasa.gov (no subject or body text is required).



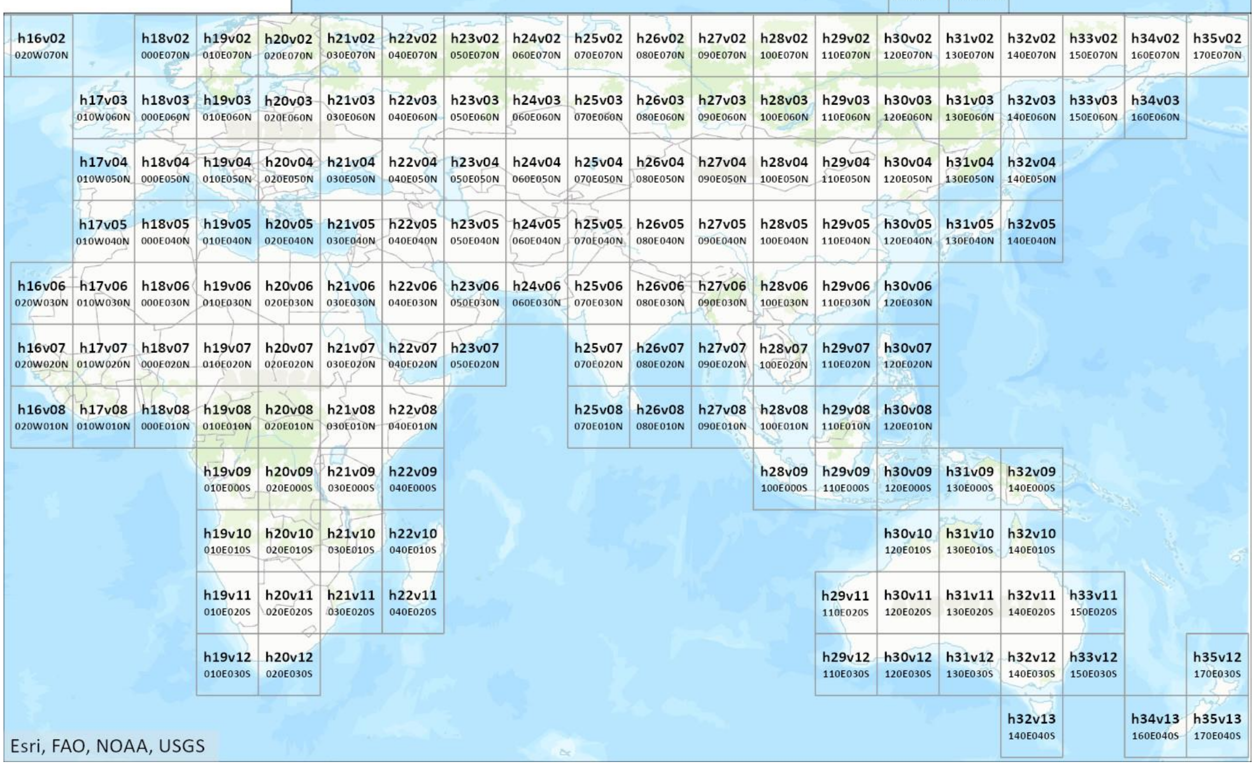


Figure 1: Flood product 10 x 10° tile scheme.

LANCE MCDWD product uses the MODIS lat/lon grid 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 currently in production.

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 concluded at the end of April 2022.

For the purposes of this document this original system is referred to as the "legacy" flood mapping system and product. Its core data product was the MWP (MODIS Water Product). Although it used custom inputs from LANCE (Land, Atmosphere Near real-time Capability for EOS: http://earthdata.nasa.gov/lance), the production system was otherwise separate and PI-maintained. The new LANCE **MCDWD** flood product is generated entirely within MODAPS (MODIS Adaptive Processing System: the production system within EOSDIS (Earth Observing System Data and Information System)), and thus production is substantially more robust. (MCDWD: "MCD" is the convention for products derived from both Terra and Aqua MODIS imagery; WD for Water Detection; see other details in section 6.1). 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 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 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 (morning overpass) and Aqua (afternoon)). 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 well calibrated and available twice daily, without the user needing knowledge of precisely where the flood may be occurring and thus where to target imagery acquisition.

That said, clouds are problematic in many areas, and create obstacles for this product—by obscuring the ground, and also by casting shadows, which may be detected as water (being 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 cloud-related issues.

Users of the legacy product have included the World Food Programme, 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, the 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 supported the transition of the legacy flood product to 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 was to ensure reliable long-term production. The transition required a complete rewrite of the code to conform to the EOSDIS MODAPS 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 has been rolling 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 improvements are planned 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 (from cloud or terrain shadows) can otherwise substantially contaminate the products. The flood products are generated with three compositing periods (1-day, 2-day, and 3-day), which indicates the number of days of data that are used for a given product: a 3-day product will incorporate data from the product date, as well as the two previous days. The requirements of the user (including latency requirements, and tolerance for false-positives and/or false-negatives), and the cloudiness during a given event will determine which product composites to use. This unfortunately does place a burden on the user to determine which product provides the best information for a particular event. With the product available in the Worldview web application, users can more easily compare and evaluate the different options.

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:

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

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 sum 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 **c**loud **s**hadow masking applied; see section 3.4.3), 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 7.1).

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 via compositing, and thus 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+

3.4 Terrain and Cloud Shadow Masking

To help reduce shadow false-positives, various masks are applied during the compositing step: terrain shadow, HAND (Height Above Nearest Drainage), and cloud-shadow. Terrain shadow and cloud shadow 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 of these masks, that water detection is removed before compositing proceeds. At present, the cloud shadow masks is only applied to the 1-Day CS product. The HAND mask is applied to the final composited result, removing any marked water or flood pixels.

3.4.1 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 (DEM) (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 legacy product, these masks were estimated to remove between 75-90% of terrain shadow false-positives in the 2-Day product: they are very helpful, but substantial false-positives may still remain. Thus an additional terrain mask, the HAND mask, is also applied to further minimize this issue.

3.4.2 HAND mask

The HAND (Height Above Nearest Drainage (Nobre et al. 2011)) model provides a terrain-based metric of local drainage potential that we use to help remove most remaining terrain shadow false positives, as well as many cloud shadow false-positives occurring in mountainous terrain. It serves to mask out water detections from areas that are physically unlikely to flood (at the scales visible with 250m optical imagery) because there is sufficient nearby drainage potential to carry away flood waters.

The HAND model assigns a height to each pixel indicating the vertical distance to that pixel's nearest drainage channel. These channels, and the heights, are generated from a DEM; the algorithm defines drainage channels using an *upstream area* parameter. Based on empirical experimentation, we chose an upstream area of approximately 48 km^2 (6000 pixels of the 90-m DEM). The resulting HAND layer is resampled to the flood product grid (0.002083 degrees), and then a 30 m threshold applied to create a binary mask. This 30 m threshold was also empirically determined. Next, we apply a series of morphological operators (dilation and erosion) to clean-up the raw mask (removing small islands, voids, and pixelated noisiness that occurs around the edges of the threshold). Finally, we modified the resulting mask by removing known water bodies from our reference water dataset (MOD44W), after dilating that layer by 1 pixel. This helped ensure water was reportable, if detected, in known water bodies, and that small-scale flooding would be detectible immediately adjacent to these water bodies. This was typically only important when the HAND mask contained inaccuracies due to errors or changes in the DEM, and for endorheic lakes and terminal basins elevated significantly above nearby drainages. When applied to the product flood layers, all pixels under the HAND mask are reassigned a value of 255 (NODATA), signaling to the user that a mask has been applied in such areas and water will not be reported.

We used the global Copernicus 90 m DEM ("GLO-90"; European Space Agency, Sinergise 2021) to generate HAND. GLO-90 is based on WorldDEM (itself from TanDEM-X data), filled with other datasets in problematic areas. We utilized the 3 arc second version distributed by OpenTopography in AWS. We chose GLO-90 over SRTM-based DEMs because it is based on more recent observations (2011-2015), and thus is more accurate where new reservoirs and other changes have modified topography, impacting HAND. PCRaster tools (version 4.3.3; Karssenberg et al. 2010) were used to generate HAND.

Figure 2 shows a global overview view of the HAND mask. Figure 3 shows the mask in detail in an area in Mississippi, and in comparison to FEMA flood hazard zones. Figure 4 shows an example of the impact of the mask on the products in a mountainous area. This demonstrates that although multi-day compositing is quite effective at reducing false-positives (vs the 1-day product), a substantial number still do get through, which are almost entirely eliminated by the HAND mask.

Caveats with HAND:

- Application of the mask dramatically reduces terrain and cloud-shadow false positives, but it will not entirely remove such false-positives; false positives falling outside the HAND mask are left in place. In mountainous areas, this can have the practical impact of making masked cloud-shadow false-positives look *more* realistic, even if greatly reduced in overall extent, by confining them to drainage channels where flooding could potentially occur.
- The HAND mask will be inaccurate when the source Copernicus GLO-90 DEM is in error, or does not reflect recent changes (for example, due to construction of dams and water control structures). New reservoirs may now exist in HAND-masked areas, and thus both detected surface water and adjacent potential flooding will be removed, if under the mask. We do plan to update our reference water, which will resolve many such issues (see section 7.3 below).
- Using a ~48 km^2 upstream area to define drainages can result in masking of small endorheic and ephemeral lakes, because their upstream drainage area may exist but be too small to define a drainage for HAND. Using smaller upstream areas results in too many drainages being defined in mountainous areas where the product will not be able to detect significant flooding due to its spatial resolution. The ~48 km^2 value (6000 DEM pixels) provide a good balance.

If these constraints are undesirable, a non-masked product can be reconstructed using the layers in the product HDF file, by recomputing the composites (see section 5.2.1 below).

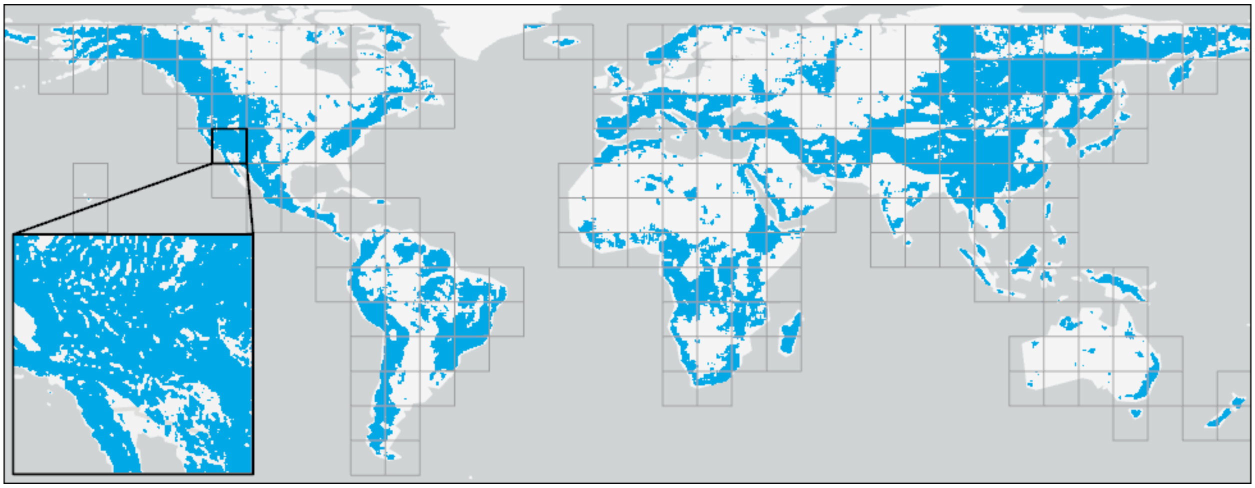


Figure 2: Global overview of HAND mask (with product tile grid). For display at this scale, mask pixels are aggregated and appear to cover areas more completely than they do; inset provides higher detail for one tile.

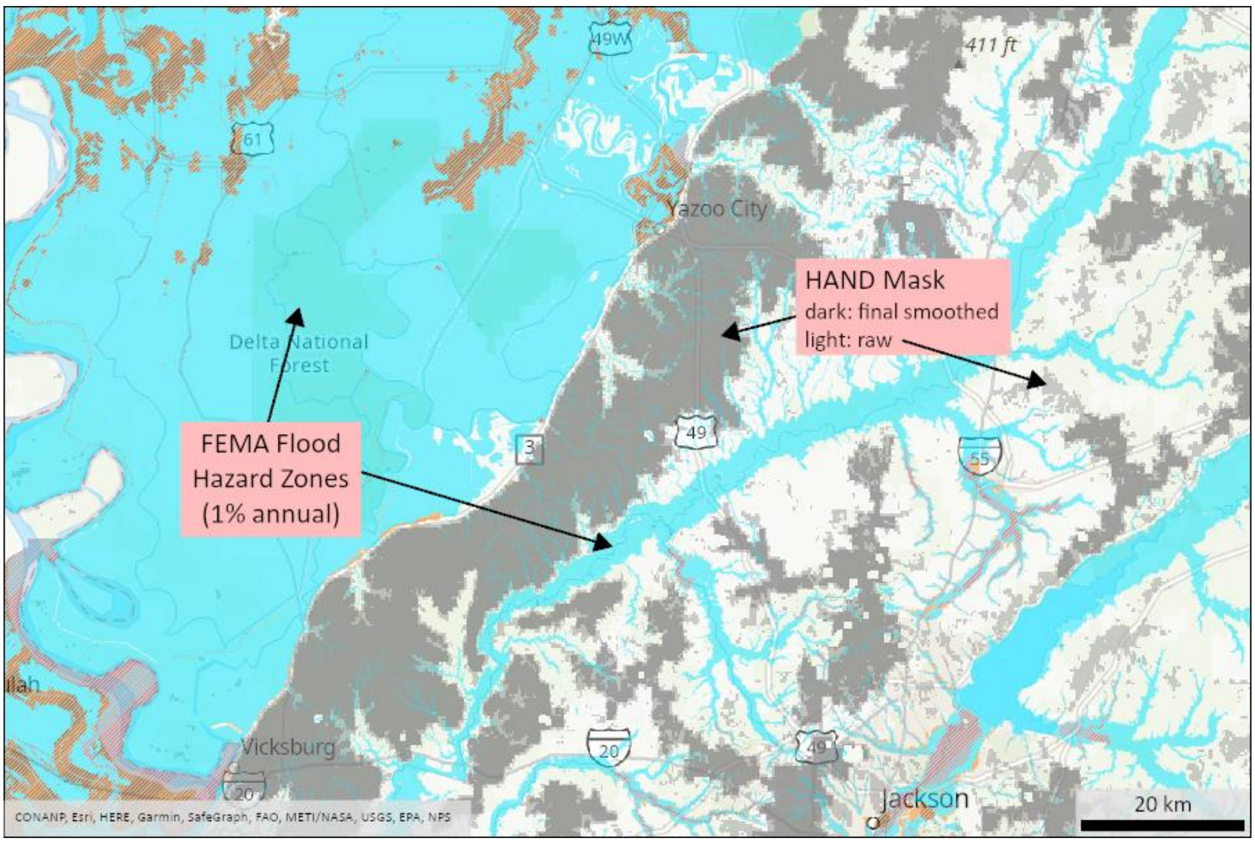


Figure 3: HAND mask in detail, Yazoo City / Jackson Mississippi area, with FEMA flood zones in cyan for comparison. Original unsmoothed HAND mask shown in lighter gray. Note small flood zone streams are masked by HAND (center of figure), but flooding in such small scale streams would not be detectible with 250 m MODIS imagery.

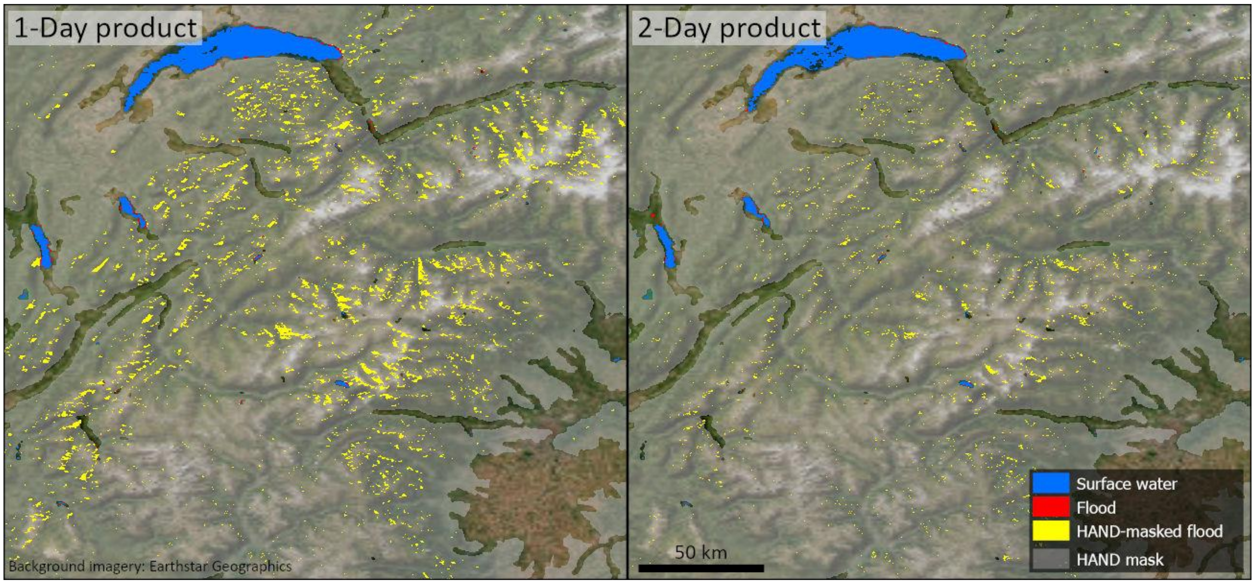


Figure 4: Example of impact of HAND on 1 and 2-day products, in the Alps south of Lake Geneva (tile h18v04; date 11 Nov 2022). Yellow indicates false-positives removed by the HAND mask. Note small areas of likely false-positives are retained (red pixels), but far less than without the HAND mask.

3.4.3 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, or 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, resulting in two 1-day products: "1-Day" (no cloud shadow mask); and "1-Day CS"(with **C**loud **S**hadow mask). A user who is concerned about potential cloud-shadow false-positives in a 1-day product should review both, and do so in conjunction with viewing the reflectance imagery at the site of interest (as can easily be done in in the Worldview web application), to determine the best product for their needs.

3.4.4 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. All pixels falling under the HAND mask will also be assigned 255. These pixels will then not be marked as water (or flood). "Insufficient data" is used to describe these pixels instead of "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, or they 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 considered 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 derived from clouds are **overwritten** by valid composited water detections. Thus, if water is detected in a pixel the number of times required to exceed the compositing threshold, it **will** be reported as water in the product, even if the cloud layer suggests insufficient clear observations, unless it is then masked by HAND. Operationally, the output layer is first populated by insufficient data pixels, then it is overwritten by composited water detections, and finally overwritten by HAND. On occasion, this can result in the product displaying, for example, detected water in rivers that are entirely surrounded by Insufficient Data pixels, because the clouds were marked in the cloud state flag, but were thin enough for the algorithm to detect water through those clouds.

3.5 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 a more difficult assessment, 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 an ocean, lake, river, reservoir, or seasonally flooded plain), vs *unusual* water (= flood)? In this product, flood is identified by simply comparing detected water to a reference water map showing normally expected water (lakes, rivers, seas).

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. A very conservative water detection algorithm (different than the one used in this product) was used to generated MOD44W. The algorithm identified areas that were consistently detected as water over many years of observations, 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 layer (Collection 5 version, published 2009) has become increasingly out of date: new reservoirs have been built (which are then reported as flood in the product); 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 into the flood product. An important future improvement will be an update of the surface water mask to correct such errors, and to allow us to introduce a “recurring flood” category (see section 7.3 below).

4 Product Evaluation

The initial release of the LANCE flood product was 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 had originally been evaluated qualitatively (via visual interpretation), by examining its performance for a set of flood and non-flood events, and manually assigning performance scores.

4.1 Quantitative evaluation

> *NOTE for User Guide revision C: the evaluation in section 4.1 has not been redone after the HAND mask was introduced to the product (January 2023), which may well impact these results. We plan to update this analysis after some additional improvements are made to the product.*

The performance of the MCDWD flood products has been statistically compared with the legacy MWP product. As an overall summary, Figure 5 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 6 presents the same data as boxplots.

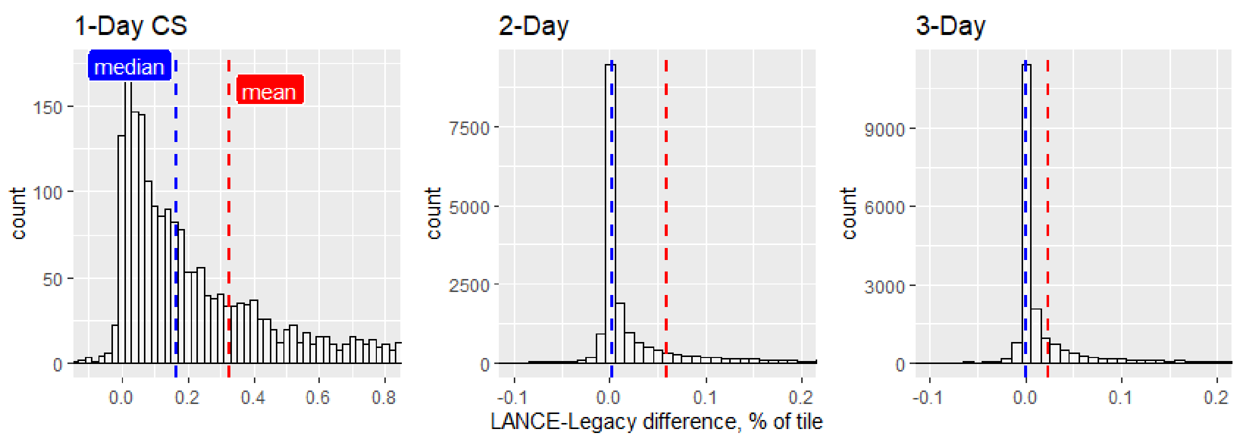


Figure 5: Histograms of differences in area of reported flood, per tile (as percent of tile reported as flood), between LANCE MCDWD and legacy MWP products, with mean (red) and median (blue) marked. Computed over dates: 23-Sep-2020 – 07-Dec-2020 and 11-Jan-2021 – 01-Feb-2021 (non-contiguous because the 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 additional observations being available. Whereas in the legacy product, overlapping swaths are composited into a single Terra and Aqua image per day before the water 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.

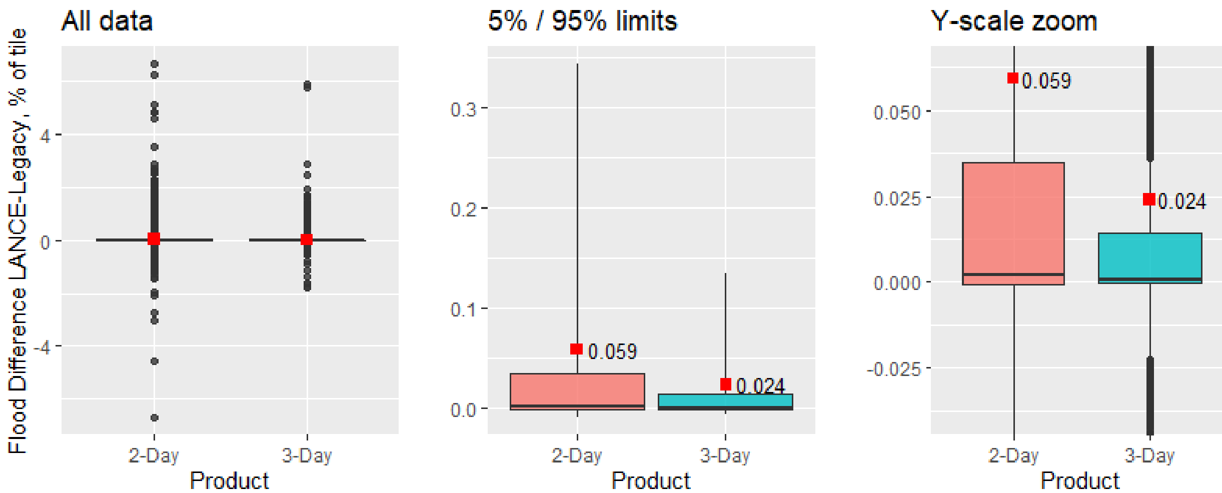


Figure 6: Boxplots of differences in area of reported flood per tile (as percent of tile reported as flood), between LANCE MCDWD and legacy MWP products, for all tiles. Mean is marked with red dots and labelled. Same data as in Figure 5. Note mean values fall outside the boxplot boxes (which indicate 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.

Figure 7 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 4800 x 4800 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 randomly distributed, but will be lumped around dates and tiles with more frequent broken clouds. It has been observed that these differences further reduce as the date moves away from the winter solstice, sun position rises, and shadows recede.

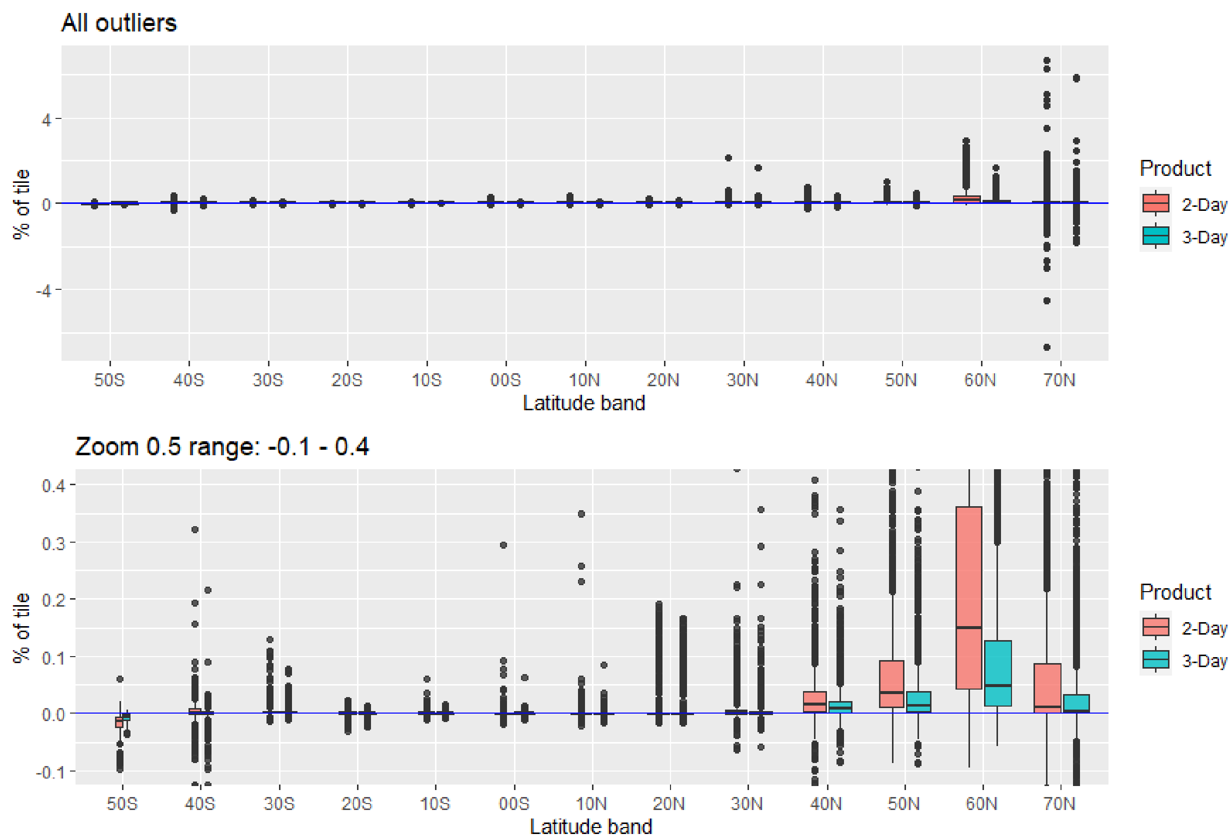


Figure 7: Boxplots of differences in area of reported flood per tile (as percent of tile reported as flood), between LANCE MCDWD and legacy MWP products, grouped by latitude bands (refer to Figure 1 for map of tiles). Top plot includes all outliers; bottom zooms to -0.1 – 0.4 range on y-axis (% tile). 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 1).

4.2 Qualitative evaluation

The legacy product was evaluated by qualitatively examining its performance for 109 events – 53 flood events from the DFO flood archive, and another 56 locations without flood, but containing surface water (generally in the same product tile as the flood event) (Nigro et al. 2014). These evaluations were performed by visually comparing the product to available imagery sources, including Landsat (when available), and the MODIS reflectance imagery itself (in which one can often visually identify flood), and assigning a qualitative score. As event selection was not based on clear imagery necessarily being available, a number of events (approximately 1/3) were unable to be evaluated.

For the LANCE product evaluation, the MCDWD product was generated using historical MODIS data (from 2012-2014) for the same 109 events, and qualitatively evaluated in comparison to the legacy product. There were expected pixel-level differences due to geolocation improvements and differences in output grid, but overall, the MCDWD performed very well, and in some aspects notably better than the legacy product. Note that unlike the archived legacy products, the MCDWD product was run from archived science products, and not the near real-time data stream (which may account for some geolocation improvements).

There were two notable types of differences between the products: (1) increased cloud-shadow false-positive issues in MCDWD in winter and higher latitudes; and (2) improved surface water detection with

MCDWD. These differences stem from the same source: the additional available swath observations in the LANCE product, as discussed above (section 4.1). On the one hand, these are useful for allowing additional chances at cloud-free observations, which clearly impacts the ability of the product to more accurately delineate surface water extent. On the other hand, this allows more chances for cloud-shadow false-positives to propagate into the product, as was observed in several cases. We do plan to adjust the compositing rules in a future release to limit these cloud-shadow false-positives (see section 7.1 below). Table 3 summarizes the differences between the products, including how often increased cloud-shadow false-positives were observed. Overall, the LANCE product provided a better product in 26% of cases (14% of flood cases, 37% of non-flood surface water detection).

Table 3: Summary of qualitative differences *between legacy product and MCDWD. Numbers given as raw numbers and as percent of all events in the class (flood, surface water, or both). Cloudy indicates the number of events where clouds completely obscured water observations; the number of "Clear" events is thus simply the total number of events minus cloudy events. (Flood events were chosen for legacy product evaluation without regard to availability of clear imagery). "Better" indicates qualitative improvement in performance of MCDWD product in delineating water extent; percentages are of "Clear" events. CSFP indicates events where an increase in cloud-shadow false-positives in the MCDWD product was noticeable (which generally does not impact the detection of actual flood or surface water that may be present, but it can be distracting and confusing by littering the product with false positives).*

	Flood	Surface Water	Total
# Events	53	56	109
# Cloudy / %	16 / 30%	15 / 27%	31 / 28%
# Clear events	37	41	78
# Better / %	5 / 14%	15 / 37%	20 / 26%
# CSFP / %	5 / 14%	5 / 12%	10 / 13%

Events were also rated using the legacy evaluations five-point scale (1=poor; 2=fair; 3=good; 4=excellent; 5=almost perfect). Table 4 shows the comparison of these ratings, aggregated into just two classes, between the legacy and LANCE products. Again, the LANCE product shows a mild improvement in flood detection (from 69% to 72% rated Good or better), but a more significant improvement in surface water detection (84% to 95% rated good+).

Table 4: Summary of Qualitative Evaluation of LANCE flood product*, compared to legacy product. Ratings have been consolidated into two groups. Legacy ratings are from tables 6 and 10 in Nigro et. al. (2014), with a few legacy ratings being modified during the current evaluation exercise.*

Type	Dataset	Poor-Fair (1-2)	Good+ (3-5)
Flood	Legacy	11 / 31%	24 / 69%
	LANCE	10 / 28%	26 / 72%
Surface Water	Legacy	6 / 16%	32 / 84%
	LANCE	2 / 5%	38 / 95%

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 is also 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 5 provides details on the product tiling 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)
Tile dimension	4800 x 4800
Tiling scheme	MODIS HV geographic, with 10° x 10° tiles

Table 5: Tile 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 1. 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 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 6 provides details of all layers in the MCDWD HDF file, and Table 7 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 MOD09 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.

5.2.1 Customized composites

The additional layers in the product file (water counts, valid counts) allow the interested user to create custom composites, for example requiring a different number of water observations than in the standard product. Users could also re-create the standard composites without the HAND mask, if desired. For example, to compute a 2-day product without HAND masking:

If Layer8 < 2 then output = 255 [InsufficientData]	Populates insufficient data
If Layer7 >= 2 then output = 1 [Water]	Populates water detections

The user could then determine if the detected water is flood by comparing to MOD44W, or any other reference water map they may prefer, to convert 1 values (surface water) to 3 (flood).

***Table 6: 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 7: 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 LANCE flood product has a longname of "MODIS Aqua+Terra Global Flood Product L3 NRT 250m" and a shortname of MCDWD_L3_NRT. MCD is the standard shorthand for products generated from a combination of Terra and Aqua imagery, and WD is derived from "Water Detection".

The standard product is a single HDF file per tile, per day. Additionally, separate geotiff products are available for each of the flood layers in the HDF file.

Product homepage: https://www.earthdata.nasa.gov/global-flood-product

Standard HDF product DOI: DOI:10.5067/MODIS/MCDWD_L3_NRT.061

GeoTIFF products DOIs:
1-day: 10.5067/MODIS/MCDWD_L3_F1_NRT.061
1-day with cloud-shadow screening: 10.5067/MODIS/MCDWD_L3_F1C_NRT.061
2-day: 10.5067/MODIS/MCDWD_L3_F2_NRT.061
3-day: 10.5067/MODIS/MCDWD_L3_F3_NRT.061

6.1 LANCE download servers

The LANCE near real-time distribution sites for HDF and geotiff files:
https://nrt3.modaps.eosdis.nasa.gov : preferred/primary server
https://nrt4.modaps.eosdis.nasa.gov : backup server

The products are generated independently on each system. If nrt3 is down, please try nrt4.

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

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

NRT Data → allData → 61 → MCDWD_L3_NRT

For GeoTIFF products (2-day example):

NRT Data → allData → 61 → MCDWD_L3_F2_NRT

Or, directly in the URL address bar with:
https://nrt3.modaps.eosdis.nasa.gov/archive/allData/61/MCDWD_L3_NRT

And for 2-day (F2) GeoTIFFS:
https://nrt3.modaps.eosdis.nasa.gov/archive/allData/61/MCDWD_L3_F2_NRT

Info on automating downloads: https://nrt3.modaps.eosdis.nasa.gov/help/downloads

6.1.1 API access

An API allows users to query available files on the nrt systems. For example, the following URL will return a json-format listing of all files available for 2022-362 (day of year):

https://nrt3.modaps.eosdis.nasa.gov/api/v2/content/details?products=MCDWD_L3_NRT&archiveSets=61&temporalRanges=2022-362

The user can then interrogate this json listing for specific tiles of interest, and can review production time stamps to compare against previous polls, to determine (for example) if a file has been updated with new data.

6.2 Product filenames

The HDF product filename is constructed as follows:

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

Example: MCDWD_L3_NRT.A2022361.h19v06.061.2022362024142.hdf

<SHORTNAME> = MCDWD_L3_NRT: MCDWD = flood product; L3=level-3; NRT=near real-time (LANCE).
<DATE> = 2022361: In YYYYDOY format (DOY = day of year = Julian day).
<TILE> = h19v06: product tile in MODIS geographic HV tile grid (see Figure 1).
<COLLECTION> = 061: MODIS processing collection number 6.1. This is the latest and current MODIS processing collection.
<PRODTIMESTAMP> = 2022362024142: production timestamp, YYYYDOYHHMMSS: year, day-of-year, hour (24-hour), minute, second: 2022, day 362, 02:41:42. Note although this timestamp is in the actual filenames, it is missing from the listings on nrt download sites.
<FILEFORMAT> = hdf

The core product file is an HDF file containing all flood products (1-Day, 1-Day CS, 2-Day, and 3-Day) along with ancillary layers (Table 6), 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	(1-Day product)
MCDWD_F1CS_L3_NRT	(1-Day CS)
MCDWD_F2_L3_NRT	(2-Day)
MCDWD_F3_L3_NRT	(3-Day)

6.3 Worldview & GIBS

The product as imagery (colorized) is available for viewing in the Worldview web application (https://worldview.earthdata.nasa.gov), by clicking on “Add Layer”, and selecting the “Flood” item in the Floods category. The following link directly references Worldview with the flood layers added: https://go.nasa.gov/3OiKtYB.

Worldview also allows the user to view the MODIS reflectance imagery used to generate the product. By default, Worldview displays Corrected Reflectance (True Color) for Terra/MODIS, and Aqua/MODIS is also available in the Base Layers section of Worldview's table of contents. The 7-2-1 band combination can sometimes be more helpful for visually evaluating water extent; this can be added by clicking on the red "Add Layers" button, and then the "Corrected Reflectance" item in the "Floods" tile.

Users can use the Comparison feature to compare the flood products for different dates, or to compare different composites, or to compare a flood product to the source imagery used to generate it (e.g., the current plus two previous days imagery for a given 3-day product). Clicking on the "Start Comparison" button adds two tabs (A and B), and allows the user to set any products on each, and page through the dates on each independently. Users can then swipe between the displayed products.

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

Note at present, Worldview and GIBS only contain flood product imagery beginning on 23 March 2021.

6.4 Timing, latency, and partial products

The NRT download sites are updated in near real-time, as data is received and products are generated. This should be within the standard LANCE latency window of 3 hours or less from observation. With Aqua overpass occurring at approximately 1:30pm local time, the flood product containing both Aqua and Terra observations should be available no later than approximately 4:30pm local time.

The MODIS instruments collect data in orbital swaths, as the satellite travels from pole to pole in sun-synchronous orbits. The Terra satellite overpass occurs at roughly 10:30 AM local time (moving earlier as the satellite reaches end-of-life), and Aqua at 1:30 PM local time. The swath data is processed (upstream from this product) in 5-minute chunks, termed granules: one granule contains the data collected as the satellite travels 5 minutes (approximately 2000 km over the ground). Due to the orbital characteristics of these satellites, the granules are not fixed in space, but vary from day to day, as does the position of the swaths. Thus, there is no fixed alignment between granule extents and the product's 10x10° tiling scheme; their intersections and the resulting production times vary from day to day.

As soon as new swath granules are available, all 10x10° flood product tiles that intersect the newly acquired granules are generated, or updated if they already existed from an earlier received granule. Thus, if the product is downloaded shortly after the initial granule is received, the product may only have a portion of the full 10x10° tile populated with data from the current date. Figure 8 shows an illustrative example. For a 1-day composite product, the impact will be easier to see: missing swath granules will appear as chunks of Insufficient Data values, as in the figure. But for the 2-day and 3-day composites, it may be less obvious that more data may be coming, because those composites incorporate data from previous days, which may result in a more complete looking product (without large sections of Insufficient Data) even with only initial fragmentary coverage from the current date.

The product naming convention provides no explicit indication that a product is "complete" (contains all data for the day). As subsequent incoming swath data is processed, previously published products are updated (and the original product file replaced). The product filenames are also updated with a new production timestamp, although this is only visible on downloaded files, or by using the API interface, because the web interface drops the timestamps from its listing of available product files.

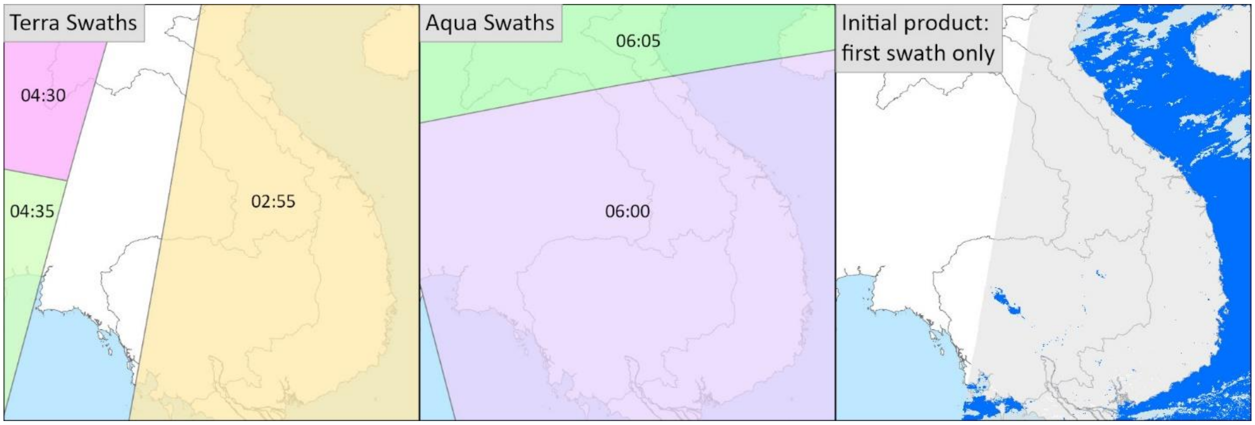


Figure 8: Swath granule intersections within a product tile. The colored sections of the left two panels show the intersection of individual swath granules from Terra and Aqua, respectively, with granule times (UTC) noted, for the 10° tile (h28v07) covering SE Asia (Thailand/Laos/Cambodia/Vietnam), for 2021173. On the right, the very first 1-day product is shown, which incorporates only the 02:55 Terra granule, with all water detections shown in dark blue. The clear area to the left contains Insufficient Data values. The shaded gray area on the right is where data exists, but no water is detected (value 0 in the data product). Thus, although this initial product does capture water (and flooding if present) in central Cambodia, it would not show flooding in central Thailand. Even waiting for the two additional Terra swath granules (04:30 and 04:35) would not provide complete coverage, due to the swath gap. Only when Aqua imagery becomes available (granules 06:00 and 06:05) a few hours later would the product potentially be able to show flooding in all areas of the tile.

Users manually viewing and downloading data products can do a few checks to help determine if they have the final product for the day (with all expected data), or if they should check back later for updates. First, if both the Terra and Aqua Corrected Reflectance imagery is available in Worldview for a given area (these are the default layers displayed in Worldview), the available flood product has very likely incorporated the same data. Second, if there are large areas of Insufficient Data values in the 1-day composite product, this will suggest more data is likely coming.

For scripted or automated downloads, users who may be polling the NRT servers for new files would be advised to compare the production timestamps (in the filenames) between any downloaded files and subsequent queries (see 6.1.1 above) to determine if a file has been updated and thus should be re-downloaded.

For display of the product in Worldview, there is an additional latency of about 2 hours for ingest into GIBS/Worldview, resulting in potentially a 5 hour total latency (maximum) from observation to the product appearing in Worldview. The product imagery in Worldview is also updated as additional swath data are received and processed. Thus, although Worldview is very convenient for quickly viewing the product, users requiring the most recent and up-to-date information would be advised to download the product files from the nrt site directly, as these may potentially be available up to 2 hours before the product appears in Worldview.

6.5 Archive availability

LANCE products are typically available in a rolling archive for about one week after generation. For standard products, users wishing to access older products would then generally obtain the standard (science quality) products from the appropriate NASA Distributed Active Archive Center, which maintain data indefinitely. However, the MODIS NRT Global Flood product is at present only an applications product, without a corresponding standard product, and so currently no long-term DAAC archive is available. This is different from the legacy product, where a user accessible archive was maintained.

Please note the LANCE Flood product 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 details, and a notice sent to the mailing list.

For more information on Near Real-Time versus Standard Products see: https://www.earthdata.nasa.gov/learn/find-data/near-real-time/near-real-time-versus-standard-products

6.6 Legacy product

The legacy MWP product was discontinued as of April 30, 2022, after being generated for 10 years. Its website and archive are no longer online. For more information, please contact support (support@earthdata.nasa.gov).

6.7 Support & Mailing list

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

A low-volume distribution-only mailing list is maintained for flood product announcements.

To subscribe: E-mail floodmap-join@lists.nasa.gov (no subject or body text is required).

To unsubscribe: E-mail floodmap-leave@lists.nasa.gov (no text required).

For mailing list issues: floodmap-owner@lists.nasa.gov.

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:

To subscribe: E-mail lance-modis-join@lists.nasa.gov (no subject or body text is required).

To unsubscribe: E-mail lance-modis-leave@lists.nasa.gov (no text required).

For mailing list issues: lance-modis-owner@lists.nasa.gov.

7 Planned Improvements

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

7.1 Algorithm improvements

Several algorithm improvements are being implemented or considered:

1. The mapping procedure used in the beta product is contributing to excess false-positives in higher latitudes. We are actively updating the mapping procedure to address this, which we hope to release in early 2023.
2. 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 very 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. Along with item #1 above, this should also 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).
3. The water detection 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.

7.2 Production tile 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 1). Note: these were also excluded in the legacy MWP product. Examples include h18v09 (000E000S, western tip of Gabon) and h21v12 (030E030S, small piece of southeastern South Africa).

7.3 Reference water & recurring flood

The reference water layer delineates 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 7), 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 reference water layers that indicate where they believe water should be, are advised to use such resources to update flood identification (potentially convert "surface water" to "flood", or vice versa).

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 the LANCE implementation, the water detection algorithm is applied on the swath granules first, which are then mapped to the 10x10° tiles, and those tiles 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 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 cloud masks (MOD35 and Cloud flag in 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 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 7.3, 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 routine 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 to provide a picture of short-term flooding history. It could be useful to consult when, for example, flooding is present but is blocked by clouds in the current day's product; 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 directly.

8.3 Data format

The two products have substantial differences in data format. 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 have been discontinued for some time, and are not 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 (see Table 8).

Table 8: 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's pixel grid is fixed in the LANCE MCDWD product (Table 5 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 tiles were slightly smaller (4552x4552), could vary slightly in pixel dimension (by one or two pixels), and cell boundaries would shift from one product 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 1 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 Terra and/or Aqua satellites. Obstructions, whether they be clouds, treetops, or building roofs, will limit the capability of the system to detect water, and shadows (cloud or terrain) may introduce false-positive errors. These 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, there may not be sufficient clear imagery to observe flood (or other) water on the ground. However, MODIS sensors are onboard 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 through an area, there may still be clear imagery from one satellite. 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, and 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, and also usually flowing more rapidly, 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) periods, 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 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 and detect water. But it may take days, or longer, for clouds to move 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 false-positive “water” detections, because cloud shadows generally move over time. Even so, 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. The source surface reflectance data does contain a useful cloud shadow flag. But as it is not perfect, and thus can remove real water detections, we only apply this to the 1-Day CS composite (see section 3.4.3).

Thus, although four different composites are provided to help address varying conditions, it is recommended that the user review the MODIS imagery to determine the level of cloud cover and thus better understand the different composites for a given flood event. This is greatly facilitated by the ability to view both the product and source reflectance imagery in Worldview (see below). A user with some experience with the product will also more readily be able to detect reasonable flooding patterns, vs the typically 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.

We apply two masks to deal with this: First, terrain shadow masks (computed on a monthly basis from average solar positions) attempt to directly mask out areas where shadows will fall; these remove 75-90% of terrain shadow artifacts. And second, the HAND mask provides a general topographic mask to remove flood pixels from areas where we are unlikely to be able to detect it (section 3.4.2)HAND mask.

Volcanic areas
Exposed areas of substantial dark volcanic rock will often trip the 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, the Craters of the Moon area in south-central Idaho is one such site. There are many other sites worldwide. In a future upgrade, masks could be used to remove these false-positives, and mark such areas in our products accordingly.

Viewing the product in the Worldview web application: https://worldview.earthdata.nasa.gov
The flood product is also available in the NASA EOSDIS Worldview application, which provides a 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. It also allows users to compare flood products for different dates. See section 6.3 for more details. Note only 2- and 3-day composites are currently available in Worldview. A Worldview story has also been published which demonstrates use of the product: https://worldview.earthdata.nasa.gov/?tr=flood-product

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.

> *NOTE for User Guide revision C:* *the examples in this section have not been updated after the HAND mask was introduced to the product (January 2023), which would likely visibly impact the product. We will update these examples in a future User Guide release.*

Effective flood mapping of annual Mekong river flooding, SE Asia. Figure 9 (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.

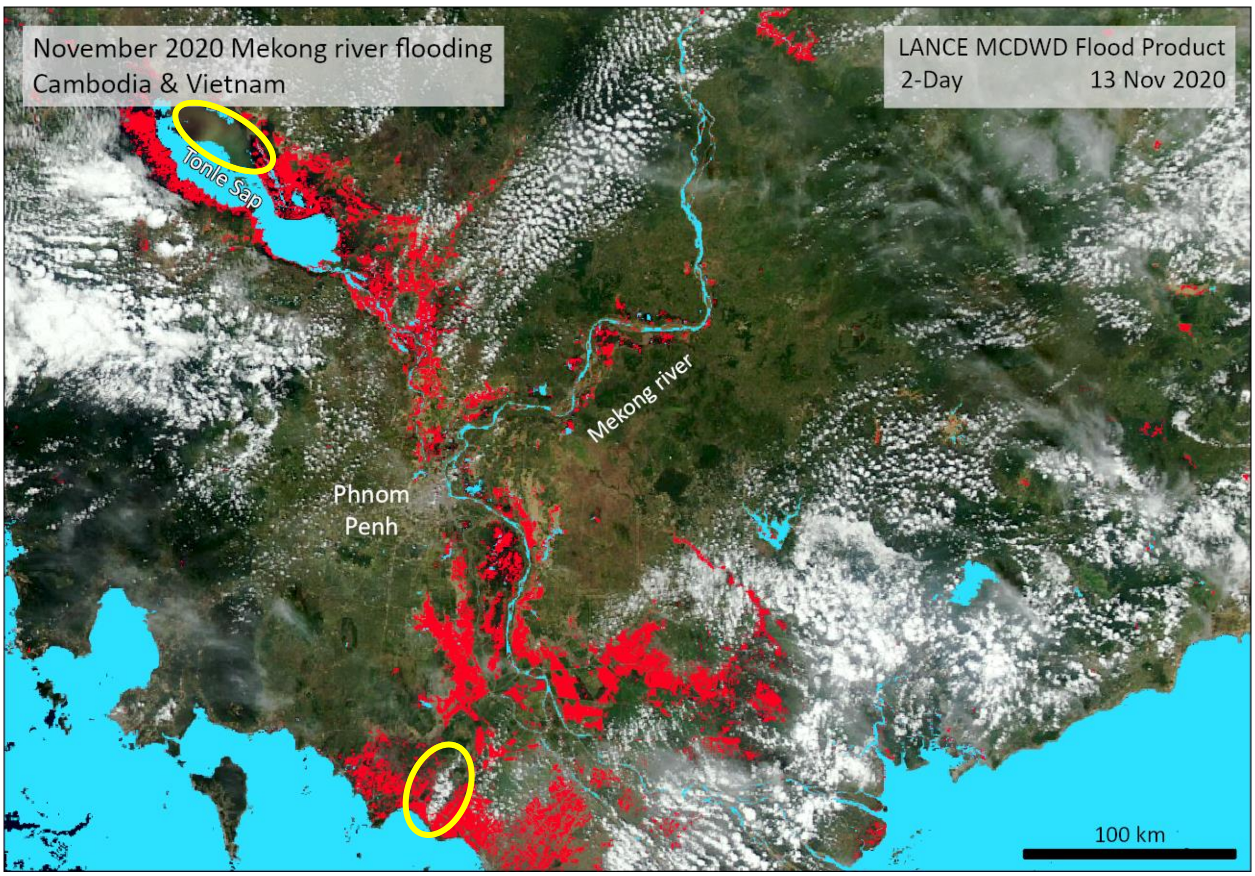


Figure 9: Example: The 2-Day flood product showing extensive flooding in the lower Mekong region of Cambodia and Vietnam, overlaid on MODIS-Aqua imagery from 13 Nov 2020. Upper yellow polygon shows portion of Tonle Sap lake not being detected in this composite, even though this particular Aqua image 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.

Effective flood mapping of Cyclone Eloise in Mozambique, January 2021. Figure 10 demonstrates the utility of the product for the flooding near Beira, Mozambique, following the passage of Cyclone Eloise on 23 Jan 2021. The area remained cloudy until 27 Jan, and substantial flooding was then detected in the riverine flood plains on the 27th and 28th.

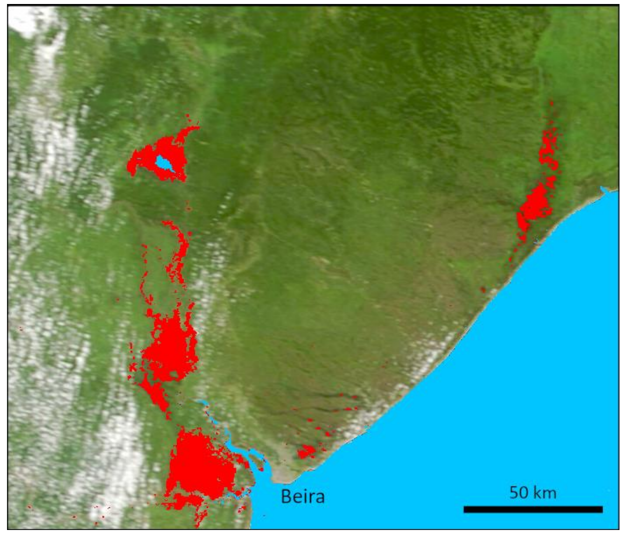


Figure 10: Example: Flood detected 28 Jan 2021 in Beira area, Mozambique. 2-Day product shows extensive flooding, along the Pungwe and Buzi rivers. Background image is MODIS-Aqua from 28 Jan.

Incorrect reference water resulting in flooding false positives. Figure 11 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 11: Example: 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 12 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.

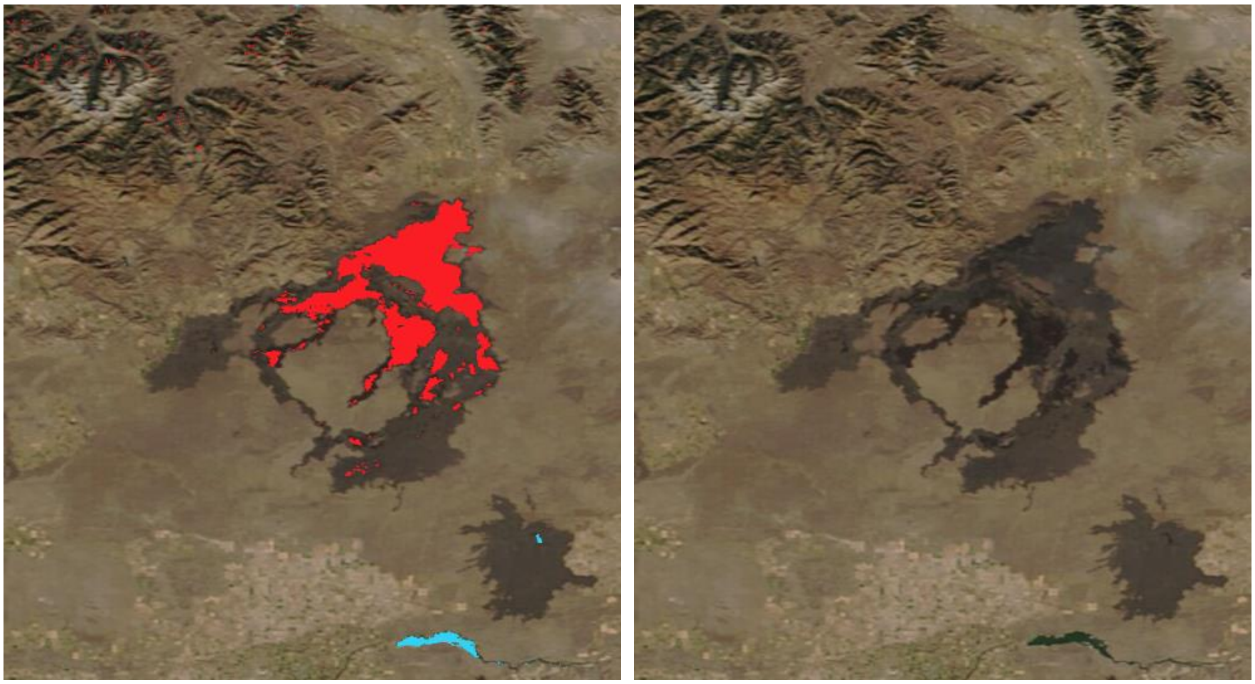


Figure 12: Example: Flood false-positives due to dark lava fields at Craters of the Moon National Monument, Idaho USA. Left shows flood product with false-positives; right the underlying MODIS-Terra reflectance imagery, demonstrating that only the darkest lava flows are misidentified. Note also scattered terrain-shadow false positives in the mountains in the northwest. 4-Nov-2020, south-central Idaho, 3-Day flood product.

Snow-melt "flood". In springtime, it is not uncommon for the product to report flooding over agricultural fields that were recently snow covered. For example, we have observed this in the northern great plains of the US (North Dakota), and in Kazakhstan. Although the product appears to be accurately reporting unusual water on the ground, it is typically not flooding of much concern, probably because it is very shallow water ponding on field (unless accompanied by news reports suggesting otherwise). Examining the reflectance imagery for the preceding days will usually show snow cover recently present, that has turned dark (e.g., has melted into water). Figure 13 shows an example of this over Kazakhstan in April 2021.

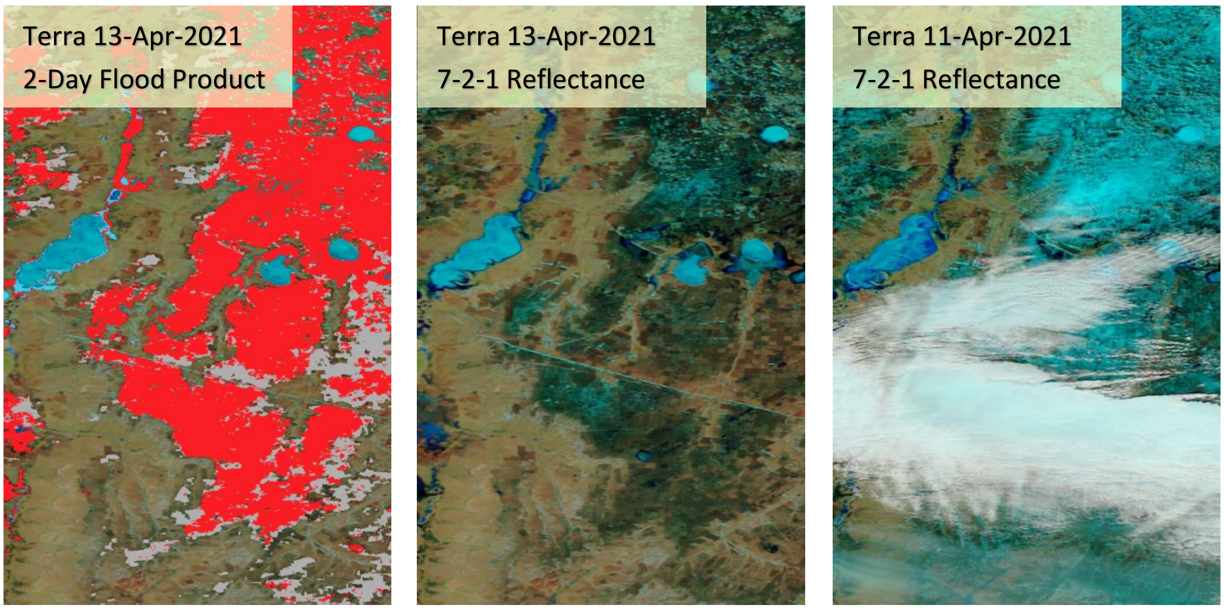


Figure 13: Example: snow melt detected as "flood". Left shows 2-day flood product in an agricultural region of northern Kazakhstan (52.6° N, 65.6° E) from 15 Apr 2021. Middle shows MODIS/Terra (7-2-1) imagery for the same day. Right shows MODIS/Terra for 13 Apr 2021. These images clearly show significant snow cover (in bluish tones in the 7-2-1 imagery, vs cloud in white) on April 13th, but which had largely melted by the 15th. Although not shown here, the flood product for 13 April also shows flood in the darker portions of that image; much melting was already underway by this date. Imagery from 11 April is more solidly snow covered, and shows few flood pixels.

Difference between 1-Day, 1-Day CS, 2-Day, and 3-Day products. Figure 14 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.

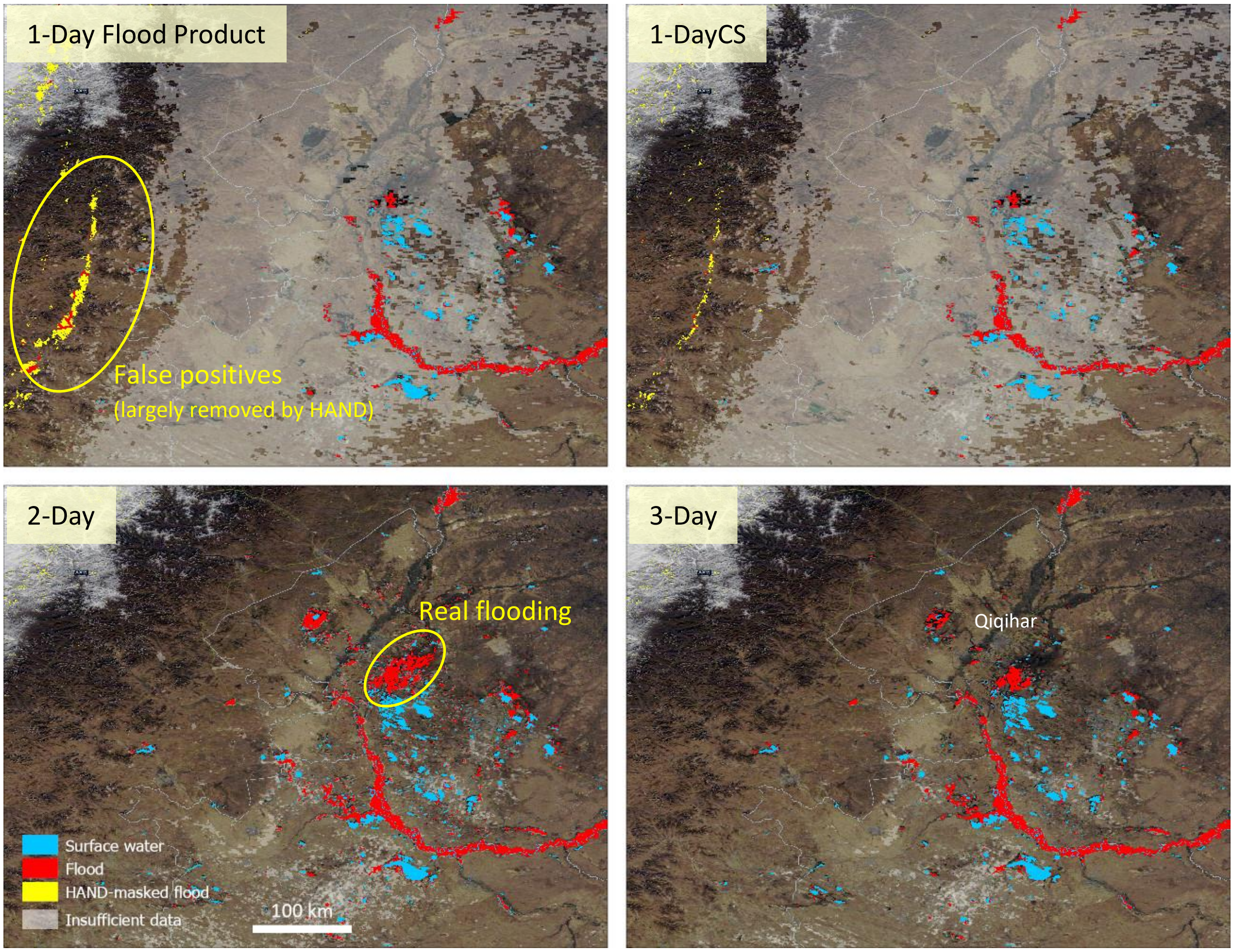


Figure 14: Demonstration of the difference between the four products: 1-Day, 1-Day CS (with Cloud Shadow screening), 2-Day, and 3-Day, during flooding of Songhua river, NE China, 26 Oct 2020. Oval in 1-Day panel highlights an area of cloud-shadow false-positives (in yellow and red). Most of these are eliminated by the HAND mask, leaving some (those in red). 1-DayCS panel shows the cloud-shadow mask is also quite helpful. These false-positives are completely removed by compositing in 2 and 3-Day products, even without HAND mask applied. However, the HAND mask does remove some persistent terrain shadow false-positives in the upper-left corner. Note that the remaining cloud-shadow false-positives in the 1-Day product, after HAND masking (in red), fill areas more realistically capable of flooding – along drainages – vs the original arc of false-positives cutting across drainages.

Yellow outline in 2-Day panel shows an area of flooding that is best 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 clarify.

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 (thus large areas of insufficient data on the 1-day panels), 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 product in light of the MODIS reflectance imagery in the Worldview application (https://worldview.earthdata.nasa.gov), to determine if the product has likely captured your event 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: 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 visible 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 in Worldview; when swath data overlaps, the data with view angle closest to nadir is selected for the imagery mosaic. If of interest, the individual granules are viewable 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. 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 6), 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:

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10 Product Releases

Table 9 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 9: 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	Beta	No change to product, only documentation: Updates to User Guide re Worldview, GeoTIFF. Qualitative evaluation completed: product is deemed comparable to legacy MWP, with substantive differences documented.	B	25 June 2021
Beta 2	Beta	Add HAND mask.	C	12 Jan 2023
R1	Provisional	Update pixel selection rules.		[Q1 2023]
R2	Provisional	Update reference water		[Q2 2023]
R4	Provisional	Update to add "recurring flood", completing all initially planned improvements.		[Q3 2023]

[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

10.1 Beta release (5 Mar 2021)

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). The initial beta product used the same compositing logic as in the legacy product: 1 or more water detections in a 1-day product required to mark a pixel as water; 2 or more in the 2-day product; and 3 or more in the 3-day product. The Beta 2 update will revise these rules to be 50% of available observations.

10.2 Beta 2 release (12 Jan 2023)

The second beta release adds the HAND mask to remove flood detections in mountainous areas unlikely to be able to retain floodwaters long enough for observation at the resolution of this product. See section 3.4.2 above for details.

10.3 Upcoming - Release 1 (2023, 1st quarter)

Release 1 is planned to have updates to the algorithm mapping issues that are negatively impacting the product with excessive false-positives in higher latitudes. Expected release in first quarter of 2023.

All releases will be announced via the product mailing list (see section 6.7 above).

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