Release Notes for the CSH V6 Level 2 pixel product (2HCSH) and Level 3 gridded (3GCSH) and monthly (3HCSH) products

25 October 2019

1. Tropical / warm season algorithm and changes for V6

For V6, the Goddard CSH algorithm (Tao et al. 2010) Level 2 pixel product is now the primary CSH product with the V6 Level 3 gridded product now merely an aggregation of the V6 Level 2 pixel product. For the 2HCSH pixel product, mean heating profiles from the Goddard Cumulus Ensemble (GCE) model (a cloud-resolving model) are computed over 4-km GCE sub-domains (roughly consistent with the DPR surface pixel size) and then binned according to the mean surface rain rate and whether the sub-domain is convective or stratiform. In addition to the 36 surface rain intensity bins (every 20 mm/day) and convective and stratiform bins, the CSH look-up-tables (LUTs) are further binned according to mean echo top height (5 bins, 0-2, 2-4, 4-6, 6-8, and 8+ km) and low-level (0-2 km AGL) vertical reflectivity gradient (downward increasing or decreasing), which were introduced in V5 (Lang and Tao 2018) to improve heating depth and intensity of low-level evaporative cooling in stratiform regions, respectively. For V6, the CSH LUTs are still composited into land and ocean regions; however, the "near rain" and "far from rain" LUTs for latent heating (LH) are no longer used (i.e., LH is only retrieved for rainy pixels). The CSH land and ocean LUTs are still composited from 6 multi-week ocean cases and 4 multi-week land cases (see Table 1).

LUT cases	Type	Location	Period	Duration
ARM 1997	Land	Southern Great Plains	June-July, 1997	29 days
ARM 2002	Land	Southern Great Plains	May-June, 2002	20 days
MC3E	Land	Southern Great Plains	April-May, 2011	33 days
GoAMAZON	Land	Amazon Basin	Feb-March, 2014	40 days
GATE	Ocean	Tropical Atlantic	Aug-Sept, 1974	20 days
KWAJEX	Ocean	Marshall Islands	July-Sept, 1999	52 days
SCSMEX	Ocean	South China Sea	May-June, 1998	45 days
TOGA COARE	Ocean	Equatorial West Pacific	November, 1992 - February, 1993	120 days
TWPICE	Ocean	Darwin, Australia	Jan-Feb, 2006	24 days
DYNAMO	Ocean	Equatorial Indian Ocean	Nov-Dec, 2011	31 days

Table 1 Cases simulated with the GCE model to build the CSH land and ocean LUTS

The GCE is still run in 2D using the improved 1-moment Goddard 4ICE (cloud ice, snow, graupel and hail) cloud microphysics scheme (Lang et al. 2014; Tao et al. 2016), which includes a bin microphysics-based rain evaporation correction. But, for V6, the GCE CSH LUT database is generated using a horizontal resolution of 200 m (versus 1 km for V5) and a horizontal domain of 1024 km (versus 512 km for V5) to improve the simulation of shallow clouds and large mesoscale convective systems, respectively.

A major change for V6 is the use of a convective-stratiform separation scheme that is more consistent with that applied to the GPM satellite data. The V6 separation method is now based on a Steiner-type method (Steiner *et al.* 1995) similar to the 2A23 method as opposed to the GCE model method used previously (including in V5), which incorporated cloud and vertical velocity data not available from the satellite. Table 2 shows the similarities and differences between V5 and V6.

	V5	V6
Cases	6 Ocean + 4 Land	Same
Microphysics	4ICE	Same
GCE grid size	1000 m	200 m*
GCE domain size	512 km	1024 km
Look-Up Tables	36 intensity bins 2 conv-strat bins** Land and Ocean Rainy, near rain, and far from rain	Same except no “near rain and far from rain” for LH
Echo Top Height Bins	0-2, 2-4, 4-6, 6-8, > 8km	Same
Low-level (0-2 km) Vertical dBZ Gradient	Downward increasing or decreasing	Same
Vertical Levels	80	80
Horizontal Resolution	pixel	pixel
Convective-Stratiform Separation	GCE method at model resolution (1 km)	2A23-like method at 4-km resolution

* The 200 m grid is averaged to 4-km for the LUTs and convective-stratiform separation

** The V5 gridded product had 20 stratiform fraction bins (every 5%) that are not needed for V6

Table 2 Similarities and differences between the V5 and V6 CSH warm season algorithms

2. Extratropical / cold season algorithm and changes for V6

For the extra-tropics and cold season, LH profiles obtained from 6 NU-WRF (NASA-Unified Weather Research and Forecasting Model) simulations using the same improved 4ICE scheme for 3 eastern US synoptic snow storms and 3 West Coast atmospheric river events are mapped to the satellite using a similar but differing set of metrics than those used for the tropical / warm season algorithm (Tao et al. 2019).

The extratropical / cold season LUTs are constructed from the inner-most, 3-km domain and mapped using the following quantities: storm top height (11 bins), freezing level (13 bins), max dBZ level (8 bins), and vertical dBZ gradient (2 bins). For V6, the number of bins for the first 3 metrics was increased, and a new metric (surface precipitation rate) was added with 17 bins. Heating intensity is based on the composite dBZ intensity. For V5, there were 90 bins every 1 dBZ, but for V6, the bin size was increased to every 2 dBZ over the same range. Table 3 shows the parameters and the corresponding bins used for the CSH V6 extratropical / cold season LH LUT. The bin ranges are based on close examination of the results from the NU-WRF simulations.

Metrics	Bin ranges
Surface precipitation rate (mm h^{-1})	0., 0.178, 1., 1.78, 3.16, 5.62, 7.5, 10., 13.3, 17.8, 22.4, 27.0, 31.6, 44.0, 56.2, 70.0, 100., 999.
Max dBZ height (m)	0., 500., 1000., 1500., 2000., 3000., 4000., 5000., 99999.
Freezing level height (m)	Negative, 0., 500., 1000., 1500., 2000., 2500., 3000., 3500., 4000., 4500., 5000., 5500, 99999.
Echo top height (m)	0., 1000., 2000., 3000., 4000., 5000., 6000.,7000., 8000., 9000., 10000., 99999.
Downward Echo Trend	"Decreasing" or "Non-decreasing"
Max dBZ intensity	-10, -8, …78, 80 (from-10 to 80 with a 2 dBZ interval)

Table 3 Parameters and associated bins used in the CSH cold season LH LUT

As with V5, the CSH V6 cold and warm season heating retrievals are selected according to the height of the freezing level. When the freezing level is above 4 km, the warm season retrievals are used; when it is below 3 km, the cold season values are used. Between 3 and 4 km the cold and warm season values are averaged with a linear temperature weighting. For the satellite orbits, the freezing level height is obtained from the corresponding re-analysis data.

3. PMM (TRMM and GPM) products and changes to 3GCSH for V6

There are 3 standard CSH products: 2HCSH (pixel), 3GCSH (instantaneous, gridded), and 3HCSH (monthly, gridded). A major change for V6 is that the 3GCSH gridded product is now produced by averaging the 2HCSH pixel product rather than being retrieved separately using LUTs built by sampling the GCE model database at resolution of the grid. The 3HCSH monthly product is computed by averaging all of the 3GCSH gridded products in each month. Table 4 lists the input data, spatial and temporal scales, and retrieved fields for each of the 3 Goddard CSH algorithm products. Note that poleward of the TRMM domain (i.e., 37N to 3&S), only LH is retrieved.

Product	Spatial Scale	Temporal Scale	Input	Fields
2HCSH	Pixel (5 km) 80 vertical levels	Instantaneous	Combined	LH, EHT, Q_R, Q_2
3GCSH	0.25 x 0.25 degrees 80 vertical levels	Instantaneous	Combined	LH, EHT, Q_R, Q_2
3HCSH	0.25 x 0.25 degrees 80 vertical levels	Monthly	Combined	LH, EHT, Q_R, Q_2

Table 4 Standard CSH products and their attributes where EHT is the eddy heat transport, Q_R radiative heating/cooling, and Q_2 apparent moistening. Q_2 is retrieved as 2 separate components: microphysical moistening and eddy moisture transport.

Caveats:

CSH retrievals are derived from the Combined Radar-Radiometer Algorithm (CMB). Users are encouraged to check related CMB documentation.

Tropical / warm season CSH retrievals are based upon GCE model simulations that do not include terrain. At higher latitudes, the CSH cold season LUTs are based upon NU-WRF simulations that do include terrain. However, areas with domain heights above 500 m were screened out in the construction of the LUTs. Therefore, CSH retrievals both in the Tropics and at higher latitudes in areas with higher terrain should not be relied upon.

References:

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