NASA GSFC global mascon solution HDF5 format description: RL06v2.0 (No changes from RL06v1.0)

When using this data please cite: Loomis, B.D., Luthcke, S.B. & Sabaka, T.J. (2019) Regularization and error characterization of GRACE mascons. *J Geod* **93,** 1381–1398. https://doi.org/10.1007/s00190-019-01252-y

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Group: /size

This group contains variables that describe the dimensions of the variables in subsequent groups.

Dataset	**Description**	**Value**
N_arcs	Number of one-day arcs of L1B data used in the full set of mascon solutions	5487 (sample)
N_mascon_times	Number of solution times in data product	189 (sample)
N_mascons	Number of global mascons	41168

Group: /time

This group contains the full list of GRACE L1B dates used in the solution and the beginning, middle, and end of each mascon solution time window.

Dataset	**Description**	**Size**	**Sample value**
list_ref_days_solution	The full list of days of GRACE L1B data used in the full set of mascon solutions (days since Jan 0, 2002)	N_arcs x 1	4504
n_ref_days_solution	The number of days of GRACE L1B data used in the mascon solution for this time window	N_mascon_times x 1	30
n_ref_days_window	The number of days in the mascon solution time window (greater or equal to n_ref_days_solution)	N_mascon_times x 1	31
ref_days_first	The first day in the mascon solution time window (days since Jan 0, 2002)	N_mascon_times x 1	4504
ref_days_last	The last day in the mascon solution time window (days since Jan 0, 2002)	N_mascon_times x 1	4534
ref_days_middle	The middle day of the mascon solution time (days since Jan 0, 2002)	N_mascon_times x 1	4519
yyyy_doy_yrplot_middle	Four-digit year, day of year, and year plus fractional year for the middle of the mascon solution time window	N_mascon_times x 3	2014 136 2014.369863

Group: /mascon

This group contains the parameters that fully describe the spatial characteristics of the global masons.

Dataset	**Description**	**Size**	**Description / Sample value**
area_deg	Area of each global mascon in square degrees at the equator	N_mascons x 1	1.011449
area_km2	Area of each global mascon in km^2	N_mascons x 1	12453.61
lat_center	Center latitude of mascon (degrees)	N_mascons x 1	78
lat_span	Size of mascon in latitude (degrees)	N_mascons x 1	1
lon_center	Center longitude of mascon (degrees)	N_mascons x 1	289.4594595
lon_span	Size of mascon in longitude (degrees)	N_mascons x 1	4.8648649
location	Numerical identifier for each region	N_mascons x 1	1, 3, 4, 5, 80, 90 (see table below)
basin	Numerical identifier for basin within the region	N_mascons x 1	(see table below)
elev_flag	Low/high elevation identifier for Greenland only	N_mascons x 1	1 = elevation < 2000 m 2 = elevation > 2000 m

Regional information contained in **/mascon** datasets:

Region	Indices	/location	/basin
Greenland Ice Sheet	00001:00198	1	1.1, 1.2, 1.3, 1.4, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.0, 6.1, 6.2, 7.1, 7.2, 8.1, 8.2
Antarctic Ice Sheet	00199:01251	3	1–27 East AIS = Basins 2–17 West AIS = Basins 1 & 18–23 AIS Peninsula = Basins 24–27
Gulf of Alaska	01252:01293	5	N/A
Ice Shelves	01294:01425	4	0 = Small ice shelves, 1 = Ross Ice Shelf, 2 = Ronne Ice Shelf
Land	01426:13028	80	1nnn = North America 2nnn = Mexico & Central America 3nnn = South America 4nnn = Europe 5nnn = Asia 6nnn = Middle East 7nnn = Africa 8nnn = Oceania
Water	13029:41168	90	0 = Ocean 1 = Mediterranean Sea 2 = Black Sea 3 = Red Sea 4 = Caspian Sea 5 = Hudson Bay

Constraint regions are: 1.) GIS elevation below 2000 m; 2.) GIS elevation above 2000 m; 3.) Antarctic ice sheet and Ronne and Ross ice shelves; 4.) Gulf of Alaska; 5.) Land including glaciers; 6.) Ocean including other ice shelves; 7-11.) Large seas.

Basin definitions for Greenland Ice Sheet and Antarctic Ice Sheet are from:
Zwally, H. et al., 2012, <http://icesat4.gsfc.nasa.gov/cryo_data/ant_grn_drainage_systems.php>

Group: /solution

This group contains the time-variable gravity time series for each mascon in terms of cm equivalent water height. The mean over the span 2004.0–2010.0 has been removed.

Dataset	Description	Size
cmwe	Solutions for each mascon location and time (cm equivalent water height)	N_mascon_times x N_mascons

Group: /uncertainty

This group contains the necessary information to build the mascon uncertainties for individual mascons, as well as any collection of mascons used to define a basin, region, ice sheet, etc. The details will be presented in a forthcoming manuscript. The noise component is determined from numerical estimates of the covariance, and the leakage component applies monthly resolution operators, following the procedure presented in [Loomis et al., 2019].

To summarize, the user should build the mascon uncertainties as follows (**see sample MATLAB code below**):

95% confidence uncertainty for individual mascon	$= \lvert \ell_{trend} \rvert + 2\sigma_{\ell} + 2\sigma_{noise}$
95% confidence uncertainty for mascon regions	$= \lvert \overline{\ell_{trend}} \rvert + (\overline{2\sigma_{\ell}} + \overline{2\sigma_{noise}})/\sqrt{N/Z}$

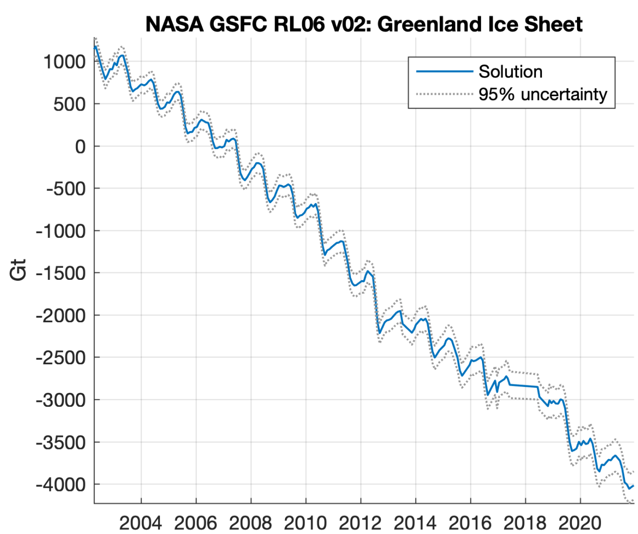
Where,

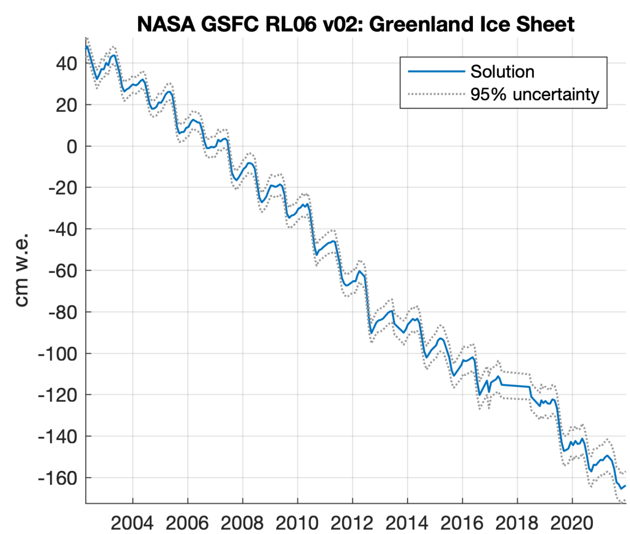
- ℓ_{trend}, $2\sigma_{\ell}$, and $2\sigma_{noise}$ are the datasets contained in the uncertainty group (see below)
- $\overline{\ell_{trend}}$, $\overline{2\sigma_{\ell}}$, and $\overline{2\sigma_{noise}}$ are the spatial averages at each time step for the selected mascon region
- $\sqrt{N/Z}$ accounts for the fact that stochastic uncertainties are uncorrelated at a certain distance
- N is the number of mascons in the region
- Z is the number of mascons that defines the approximate spatial resolution:
  $Z = 22$ mascons (~300 km)
  If $N \leq Z$, then set $Z = N$, as all the uncertainties are correlated

Dataset	Description	Size
leakage_trend	Leakage trend uncertainty (cm equivalent water height/year)	1 x N_mascons
leakage_2sigma	2-σ stochastic leakage uncertainty (cm equivalent water height)	1 x N_mascons
noise_2sigma	2-σ stochastic noise uncertainty (cm equivalent water height)	N_mascon_times x N_mascons

Sample MATLAB code: Read HDF5 file and plot Greenland Ice Sheet mass change & uncertainties

```
clear;

% Read information from HDF5 file
h5filename = 'GSFC.glb.200204_202112_RL06v2.0_OBP-ICE6GD.h5';
size_group.N_mascon_times = h5read(h5filename,'/size/N_mascon_times');
time_group.yyyy_doy_yrplot_middle = h5read(h5filename,'/time/yyyy_doy_yrplot_middle');
mascon_group.area_km2 = h5read(h5filename,'/mascon/area_km2');
mascon_group.location = h5read(h5filename,'/mascon/location');
mascon_group.basin    = h5read(h5filename,'/mascon/basin');
solution_group.cmwe   = h5read(h5filename,'/solution/cmwe');
uncertainty_group.leakage_trend  = h5read(h5filename,'/uncertainty/leakage_trend');
uncertainty_group.leakage_2sigma = h5read(h5filename,'/uncertainty/leakage_2sigma');
uncertainty_group.noise_2sigma   = h5read(h5filename,'/uncertainty/noise_2sigma');

% Get Greenland Ice Sheet time series in Gt
ind_region = find(mascon_group.location==1);
cmwe2GT = repmat(mascon_group.area_km2(ind_region)'*1e-5,size_group.N_mascon_times,1);
GT2cmwe = 1/(sum(mascon_group.area_km2(ind_region))*1e-5);
Gt = sum(solution_group.cmwe(:,ind_region).*cmwe2GT,2);

% Get uncertainty
N = length(ind_region);  Z = 22;
t0 = 2003.0;
dt = time_group.yyyy_doy_yrplot_middle(:,3) - t0;
leakage_trend  = abs(sum(uncertainty_group.leakage_trend(ind_region).*cmwe2GT(1,:)));
leakage_2sigma = sum(uncertainty_group.leakage_2sigma(ind_region).*cmwe2GT(1,:))/sqrt(N/Z);
noise_2sigma   = sum(uncertainty_group.noise_2sigma(:,ind_region).*cmwe2GT,2)/sqrt(N/Z);
total_uncertainty_Gt = abs(leakage_trend*dt) + leakage_2sigma + noise_2sigma;

% Make figure
figure('position',[560   651   839   297]);
subplot(121); hold on;
plot(time_group.yyyy_doy_yrplot_middle(:,3), Gt);
plot(time_group.yyyy_doy_yrplot_middle(:,3), Gt + total_uncertainty_Gt,':','color',[1 1 1]*0.6);
plot(time_group.yyyy_doy_yrplot_middle(:,3), Gt - total_uncertainty_Gt,':','color',[1 1 1]*0.6);
ylabel('Gt'); grid on; axis tight;
legend('Solution','95% uncertainty')
title('NASA GSFC RL06 v01: Greenland Ice Sheet');
subplot(122); hold on;
plot(time_group.yyyy_doy_yrplot_middle(:,3), Gt*GT2cmwe);
plot(time_group.yyyy_doy_yrplot_middle(:,3), (Gt + total_uncertainty_Gt)*GT2cmwe,':','color',[1 1 1]*0.6);
plot(time_group.yyyy_doy_yrplot_middle(:,3), (Gt - total_uncertainty_Gt)*GT2cmwe,':','color',[1 1 1]*0.6);
ylabel('cm w.e.'); grid on; axis tight;
legend('Solution','95% uncertainty')
title('NASA GSFC RL06 v02: Greenland Ice Sheet');
```





Sample MATLAB code: Read HDF5 file and plot map of Amazon basin for a selected month

```
clear;

% Read information from HDF5 file
h5filename = 'GSFC.glb.200204_202112_RL06v2.0_OBP-ICE6GD.h5';
mascon_group.location   = h5read(h5filename,'/mascon/location');
mascon_group.basin      = h5read(h5filename,'/mascon/basin');
mascon_group.lon_center = h5read(h5filename,'/mascon/lon_center');
mascon_group.lat_center = h5read(h5filename,'/mascon/lat_center');
mascon_group.lon_span   = h5read(h5filename,'/mascon/lon_span');
mascon_group.lat_span   = h5read(h5filename,'/mascon/lat_span');
time_group.yyyy_doy_yrplot_middle = h5read(h5filename,'/time/yyyy_doy_yrplot_middle');
solution_group.cmwe = h5read(h5filename,'/solution/cmwe');

% Amazon basin mascons for May 2009
ind_region = find(mascon_group.location==80 & mascon_group.basin==3005);
gsfc_month = 83;

% Make figure
figure; hold on;
for i=1:length(ind_region)
    mcn = ind_region(i);
    x = [-1 1 1 -1]*mascon_group.lon_span(mcn)/2 + mascon_group.lon_center(mcn);
    y = [-1 -1 1 1]*mascon_group.lat_span(mcn)/2 + mascon_group.lat_center(mcn);
    fill(x, y, solution_group.cmwe(gsfc_month,mcn))
end
cc=colorbar; ylabel(cc,'cm w.e.');
title('NASA GSFC RL06 v02: Amazon basin (May 2009)')
grid on; axis tight; box on;
```