GLEAM v3.3 Datasets

1. – GENERAL

The Global Land Evaporation Amsterdam Model[1,2] (GLEAM) is a set of algorithms that separately estimate the different components of terrestrial evaporation (i.e. '*evapotranspiration*') based on satellite observations: transpiration (*Et*), interception loss (*Ei*), bare-soil evaporation (*Eb*), snow sublimation (*Es*) and open-water evaporation (*Ew*). Intermediate outputs of the model include: potential evaporation (*Ep*), root-zone soil moisture (*SMroot*), surface soil moisture (*SMsurf*), and evaporative stress (*S*).

The rationale of the method is to maximize the recovery of information about evaporation contained in the available data stack of climatic and environmental observations from space. A Priestley and Taylor equation calculates *Ep* based on observations of surface net radiation and near-surface air temperature[3]. Potential evaporation estimates are converted into actual evaporation based on the multiplicative, evaporative stress factor *S*. The derivation of *S* is based on microwave observations of the vegetation optical depth – used as a proxy for the vegetation water content – and simulations of root-zone soil moisture. The latter is calculated using a multi-layer running water balance that describes the infiltration of observed precipitation through the vertical soil profile. To correct for random forcing errors, microwave observations of surface soil moisture are assimilated into the soil profile[4]. Interception loss is calculated separately based on the Gash analytical model of rainfall interception[5,6] driven by observations of precipitation and both vegetation and rainfall characteristics. Estimates of actual evaporation for regions covered by ice and/or snow are derived using a Priestley and Taylor equation adapted for ice and super-cooled waters. For a detailed description the reader is directed to Miralles *et al.* (2011)[1,2], Martens *et al.* (2016)[4], and Martens *et al.* (2017)[7].

The version 3 of the model (GLEAM v3) includes:

1. A new data assimilation scheme that has been validated for Australia[4] and further refined and evaluated in Martens *et al.* (2017)[7].
2. An updated water-balance module that describes the infiltration rates as a function of the vertical gradient in soil moisture[7].
3. Updated evaporative stress functions (based on experimental evidence) that combine the vegetation optical depth and the root-zone soil moisture estimates[7].

As of 8th of May 2019, two datasets produced using **GLEAM v3** are currently available at the www.gleam.eu server: **GLEAM v3.3a and GLEAM v3.3b**.

2. – DATA CHARACTERISTICS

Differences between the GLEAM v3.3 and the previous v3.2 datasets are:

1. The v3.3a dataset is now produced using surface radiation and near-surface air temperature from the latest reanalysis of ECMWF, ERA5 (as opposed to ERA-Interim in v3.2a).
2. Both GLEAM datasets are now produced using dynamic land cover information based on the MEaSUREs Vegetation Continuous Fields dataset (as opposed to a static map based on MODD44B v52 in the GLEAM v3.2 datasets).
3. All forcing datasets have been updated to their last versions and extended until the end of 2018. Due to the latency in CERES radiation data, GLEAM v3.3b only runs until September 2018.
4. Next to the traditional daily data, both monthly and yearly datasets are available now as well.

The two datasets available on this server differ only in their forcing and temporal coverage:

1. **GLEAM v3.3a**: a global dataset spanning the 39-year period 1980–2018. The dataset is based on reanalysis radiation and air temperature, a combination of gauge-based, reanalysis and satellite-based precipitation, and satellite-based vegetation optical depth (see Table 1).

2. **GLEAM v3.3b**: a global dataset spanning the approximately 16-year period 2003–2018 (September). The dataset is largely driven by satellite data (see Table 1).

Table 1 provides more information on the forcing variables used to produce these datasets. All GLEAM datasets are provided on a **0.25° x 0.25° latitude–longitude grid** and with a **daily temporal resolution**.

Table 1: Overview of the forcing datasets.

Forcing Variable	GLEAM v3.2a	GLEAM v3.2b
Radiation	ERA5[8]	CERES L3 SYN1deg Ed4A[18]
Air Temperature	ERA5[8]	AIRS L3 RetStd v6.0[19]
Precipitation	MSWEP v2.2[9]	MSWEP v2.2[9]
Snow Water Equivalent	GLOBSNOW L3Av2[10] & NSIDC v01[11]	GLOBSNOW L3Av2[10] & NSIDC v01[11]
Vegetation Optical Depth	LPRM[12,13,14*]	LPRM[12,13,14*]
Surface Soil Moisture**	ESA-CCIv4.5[15,16,17]	ESA-CCI4.5[15,16,17]
Vegetation fractions	MEaSUREs VCF5KYR_001[20]	MEaSUREs VCF5KYR_001[20]

*** This dataset is composed of LPRM-based VOD retrievals from different C and L-band passive microwave sensors.**
**** Note that the surface soil moisture is assimilated into GLEAM thus is not a forcing variable as such.**

3. – FILE ORGANISATION

Datasets are organised in netcdf files. There is one netcdf file per variable and per year, and they are stored as a **3D array with dimensions 720 x 1440 x *ndays*** (*ndays* is the number of days in the corresponding year). Therefore, the first cell corresponds to the 1st of January of the corresponding year, and it is centred at latitude 89.875 and longitude -179.875. The following 10 variables are available:

1. ***E*** – Actual evaporation [mm/day]
2. ***Ep*** – Potential evaporation [mm/day]
3. ***Ei*** – Interception loss [mm/day]
4. ***Eb*** – Bare-soil evaporation [mm/day]
5. ***Es*** – Snow sublimation [mm/day]
6. ***Et*** – Transpiration [mm/day]
7. ***Ew*** – Open-water evaporation [mm/day]
8. ***S*** – Evaporative stress factor [–]
9. ***SMroot*** – Root-zone soil moisture [m³/m³]
10. ***SMsurf*** – Surface soil moisture; 0–10 cm [m³/m³]

Note that by definition: ***E = Et + Eb + Ew + Ei + Es*** and ***S = (E – Ei)/Ep***. Missing values in the files are masked with –999.

Next to the daily data, temporally aggregated files (monthly and yearly) are also available. There is one netcdf file per variable with the entire record at either monthly (dimensions **720 x 1440 x *nmonths***), or yearly (dimensions **720 x 1440 x *nyears***) temporal resolution.

4. – DATA POLICY

Datasets are freely available and can be downloaded from this server. Use of the data is however subject to the following terms and conditions:

1. **Acknowledgements**. Whenever GLEAM datasets are used in a scientific publication, the following references should be cited:

- Martens, B., Miralles, D.G., Lievens, H., van der Schalie, R., de Jeu, R.A.M., Fernández-Prieto, D., Beck, H.E., Dorigo, W.A. and Verhoest, N.E.C.: GLEAM v3: satellite-based land evaporation and root-zone soil moisture, *Geoscientific Model Development*, 10, 1903–1925, doi: 10.5194/gmd-10-1903-2017, 2017.
- Miralles, D.G., Holmes, T.R.H., De Jeu, R.A.M., Gash, J.H., Meesters, A.G.C.A., Dolman, A.J.: Global land-surface evaporation estimated from satellite-based observations, *Hydrology and Earth System Sciences*, 15, 453–469, doi: 10.5194/hess-15-453-2011, 2011.

2. **Scientific use only**. GLEAM datasets will not be used for commercial purposes.

5. – FINAL REMARKS

1. The datasets at this server will be regularly updated when new forcing data becomes available.
2. The reader is referred to the **references below for more detailed information** about the model.
3. Please consider having a look at our list of frequently asked questions and answers at www.gleam.eu.
4. Any feedback about the datasets and/or website is highly appreciated and can be sent through email to Brecht.Martens@ugent.be.

6. – REFERENCES

1. Miralles, D.G., Holmes, T.R.H., de Jeu, R.A.M., Gash, J.H., Meesters, A.G.C.A. and Dolman, A.J.: Global land-surface evaporation estimated from satellite-based observations, *Hydrology and Earth System Sciences*, 15, 453–469, doi: 10.5194/hess-15-453-2011, 2011a.
2. Miralles, D.G., de Jeu, R.A.M., Gash, J.H., Holmes, T.R.H. and Dolman, A.J.: Magnitude and variability of land evaporation and its components at the global scale, *Hydrology and Earth System Sciences*, 15, 967–981, doi: 10.5194/hess-15-967-2011, 2011b.
3. Priestley, J. H. C. and Taylor, J.: On the Assessment of Surface Heat Flux and Evaporation Using Large-Scale Parameters, *Monthly Weather Review*, 100, 81–92, 1972.
4. Martens, B., Miralles, D.G., Lievens, H., Fernández-Prieto, D. and Verhoest, N.E.C.: Improving terrestrial evaporation estimates over continental Australia through assimilation of SMOS soil moisture, *International Journal of Applied Earth Observation and Geoinformation*, 48, 146–162, doi: 10.1016/j.jag.2015.09.012, 2016.
5. Gash, J.H.C.: An analytical model of rainfall interception by forests, *Quarterly Journal of the Royal Meteorological Society*, 105, 43–55, doi: 10.1002/qj.49710544304, 1979.
6. Valente, F., David, J. S., and Gash, J. H. C.: Modelling interception loss for two sparse eucalypt and pine forests in central Portugal using reformulated Rutter and Gash analytical models, *Journal of Hydrology*, 190, 141–162, doi: 10.1016/S0022-1694(96)03066-1, 1997.
7. Martens, B., Miralles, D.G., Lievens, H., van der Schalie, R., de Jeu, R.A.M., Fernández-Prieto, D., Beck, H.E., Dorigo, W.A. and Verhoest, N.E.C.: GLEAM v3: satellite-based land evaporation and root-zone soil moisture, *Geoscientific Model Development*, 10, 1903–1925, 2017, doi: 10.5194/gmd-10-1903-2017.
8. ECMWF, https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5, last access: 30th April, 2019.
9. Beck, H.E., van Dijk, A.I.J.M., Levizzani, V., Schellekens, J., Miralles, D.G., Martens, B. and de Roo, A.: MSWEP: 3-hourly 0.25° global gridded precipitation (1979–2015) by merging gauge, satellite and reanalysis data, *Hydrology and Earth System Sciences*, 21, 589–615, doi: 10.5194/hess-21-589-2017, 2017.
10. Luojus, K., Pulliainen, J., Takala, M., Lemmetyinen, J., Kangwa, M., Smolander, T., and Derksen, C.: Global snow monitoring for climate research: Algorithm theoretical basis document (ATBD) - SWE-algorithm, Tech. Rep. Version/Revision 1.0/02, 2013.
11. Armstrong, R., Brodzik, M., Knowles, K., and Savoie, M.: Global Monthly EASE-Grid Snow Water Equivalent Climatology, Version 1, doi: http://dx.doi.org/10.5067/KJVERY3MIBPS, 2005.
12. Liu, Y.Y., de Jeu, R.A.M., McCabe, M.F., Evans, J.P., and van Dijk, A.I.J.M.: Global long-term passive microwave satellite-based retrievals of vegetation optical depth, *Geophysical Research Letters*, 38, L18 402, doi: 10.1029/2011GL048684, 2011.

13. van der Schalie, R., Parinussa, R., Renzullo, L.J., van Dijk, A.I.J.M., Su, C.-H., and de Jeu, R.A.M.: SMOS soil moisture retrievals using the land parameter retrieval model: Evaluation over the Murrumbidgee catchment, southeast Australia, *Remote Sensing of Environment*, 163, 70–79, doi: http://dx.doi.org/10.1016/j.rse.2015.03.006, 2015.
14. van der Schalie, R., Kerr, Y.H.,Wigneron, J.-P., Rodríguez-Fernández, N.J., Al-Yaari, A., and de Jeu, R.A.M.: Global SMOS soil moisture retrievals from The Land Parameter Retrieval Model, *International Journal of Applied Earth Observation and Geoinformation*, 45 (B), 125–134, doi: http://dx.doi.org/10.1016/j.jag.2015.08.005, 2016.
15. Liu, Y.Y., Dorigo, W.A., Parinussa, R.M., de Jeu, R.A.M., Wagner, W., McCabe, M.F., Evans, J.P., and van Dijk, A.I.J.M.: Trend-preserving blending of passive and active microwave soil moisture retrievals, *Remote Sensing of Environment*, 123, 280–297, doi: http://dx.doi.org/10.1016/j.rse.2012.03.014, 2012.
16. Gruber, A., Dorigo, W. A., Crow, W., Wagner W. Triple Collocation-Based Merging of Satellite Soil Moisture Retrievals, *IEEE Transactions on Geoscience and Remote Sensing*, 1–13, doi: 10.1109/TGRS.2017.2734070, 2017.
17. Dorigo, W.A., Wagner, W., Albergel, C., Albrecht, F., Balsamo, G., Brocca, L., Chung, D., Ertl, M., Forkel, M., Gruber, A., Haas, E., Hamer, D. P. Hirschi, M., Ikonen, J., De Jeu, R. Kidd, R. Lahoz, W., Liu, Y.Y., Miralles, D., Lecomte, P. ESA CCI Soil Moisture for improved Earth system understanding: State-of-the art and future directions, *Remote Sensing of Environment*, 185–215, doi: https://doi.org/10.1016/j.rse.2017.07.001, 2017.
18. Wielicki, B.A.: Clouds and the Earth's Radiant Energy System (CERES): An earth observing system experiment, *Bulletin of the American Meteorological Society*, 77, 853–868, 1996.
19. Aumann, H.H., Chahine, M.T., Gautier, C., Goldberg, M.D., Kalnay, E., McMillin, L.M., Revercomb, H., Rosenkranz, P.W., Smith,W.L., Staelin, D.H., Strow, L.L., and Susskind, J.: AIRS/AMSU/HSB on the Aqua mission: design, science objectives, data products, and processing systems, *IEEE Transactions on Geoscience and Remote Sensing*, 41, 253–264, doi: 10.1109/TGRS.2002.808356, 2003.
20. Hansen, M., Song, X.P.: Vegetation Continuous Fields (VCF) yearly global 0.05 deg, NASA EOSDIS Land Processes DAAC, doi: 10.5067/MEaSUREs/VCF/VCF5KYR.001 , 2018.