Deutsches Geodätisches Forschungsinsitut (DGFI-TUM) Technische Universität München



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Reede

DAHITI - Deriving hydrological products for inland waters using remote sensing and future integration of SWOT data

Christian Schwatke, Daniel Scherer, Denise Dettmering

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SWOT-Project

- Project: SWOT for Monitoring Terrestrial Water Storage Changes: Quality Assessment and Combination with other Remote Sensing Data
- Objective 1: Combination of water levels from satellite altimetry and surface areas from optical imagery in order to derive volume variations for lakes and reservoirs
- Objective 2: Integration of SWOT data into existing approaches
- Objective 3: A quality assessment on how SWOT data will affect water levels, surface areas and volume variations using in-situ data will be performed



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SWOT-Project

- SWOT nadir altimeter data will be added to the water level processor (L2_NALT_GDR)
- SWOT surface datasets (raster, pixel cloud) will be included into the three processors (L2_HR_PIXC, L2_HR_Raster)
- The spatial resolution of gridded SWOT surface datasets (100 m or 250 m) will be lower than from the existing surface area processor (10 m-30 m)
- Switching to SWOT pixel cloud dataset depending on inland water size will be investigated
- The benefit of simultaneous SWOT water levels and surface areas for processing volume changes of inland waters will be investigated
- The approaches for estimating water levels, surface areas and volume changes are also used for the estimation of river discharge which is not part of this SWOT project (but also highlighted in this presentation)



Hydrological Products in DAHITI

ПШ

Overview of hydrological DAHITI products

- Water level time series from satellite altimetry
- **Surface area** time series from optical imagery
- Water occurrence masks
- Land-water masks
- Time series of volume variations
- Hypsometry
- Water level time series from Hypsometry
- Time series of river discharge

Water Level - Processor (Schwatke et al.,2015)

Surface Area - Processor (Schwatke et al.,2019)

Volume - Processor (Schwatke et al.,2020)

River Discharge - Processor (Scherer et al.,2020)

-0.25 • Limitations: Water body has to be crossed by at 200

- least one satellite track
- Temporal resolution: 10 35 days
- Methodology: Extended outlier detection and Kalman filter approach (Schwatke et al., 2015)

Water Level Time Series from Satellite Altimetry

- Satellite altimetry has been designed for operational monitoring of the ocean (since 1992) 35° 35 Accurate water level time series for smaller 356
- lakes/reservoirs can be derived since 2002
- Accuracy: Few centimeters (larger lakes) / few decimeters (smaller lakes)



RMSE: 14.8 cm, R²: 0.997

35/ 352 ΠΠ

Water Level Time Series from Satellite Altimetry

- Ongoing work on improving the existing DAHITI approach (Schwatke et al., 2015)
- The new approach will be fully automated
- The following auxiliary data are currently used:
 - SWOT River Database (SWORD) (Altenau et al., 2021)
 - Global Surface Water Explorer (Pekel et al., 2016)
 - ECMWF surface temperature
- The following aspects will be considered:
 - Off-nadir effects
 - Multi-peak waveform analysis
 - Range biases / Inter-mission biases
 - Ice-coverage in winter
 - River slopes
- New Missions: ICESat-2 (ATL13), Sentinel-6A
- SWOT nadir altimeter data (L2_NALT_GDR) and SWOT surface water datasets (L2_HR_PIXC,L2_HR_Raster) will be integrated



Selected preliminary results







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	current	new	Perf.
Points	36	35	-2.8%
RMSE	0.075	0.038	-47.4%
R2	0.878	0.939	+6.9%
NRMSE	11.0%	9.1%	-17.1%



	current	new	Perf.
Points	26	26	±0.0%
RMSE	0.155	0.038	-75.3%
R2	0.178	0.883	+395.5%
NRMSE	26.7%	12.3%	-52.5%



Surface Area Time Series from Optical Imagery

- Since 1972, the Landsat program is the longest-running for the acquisition of optical satellite images
- The combination of Landsat-4/-5/-7/-8 and Sentinel-2A/-2B provides optical images since 1984
- An advantage compared to satellite altimetry is that every inland water body on Earth is captured
- Temporal resolution: 16 days in the 1980s to about 2-3 days since 2017.
- Spatial resolution: 10 m-30 m
- Methodology: Combination of five water indexes and iterative gap filling approach (Schwatke et al., 2019)
- This approach runs in the Google Earth Engine
- It provides additional products such as water occurrence mask and land-water masks
- SWOT surface water datasets (L2_HR_PIXC, L2_HR_Raster) will be integrated in future



Time Series of Volume Variations



- Hydrological models mainly use storage changes of lakes or reservoirs or river discharge
- Volume variations are computed by combining water level time series from satellite altimetry and surface areas from optical imagery
- The methodology is based on a hypsometry model assigning water levels and surface areas in which a modified Strahler approach is applied (Schwatke et al, 2020)
- The time series of volume variations are derived from the computed bathymetry
- This approach provides additional products such as bathymetry, hypsometry model and water level time series derived from surface areas using the hypsometry model



• For 32 study cases, the abs. volume accuracy varies between 1.5% and 6.4% (Schwatke et al, 2020)

Hypsometry

- The relationship between water level and surface area of lakes and reservoirs are described by a hypsometric curve
- For this purpose, the function of a modified Strahler approach is fitted.
- This function describes the relationship better than often used linear or polynomial functions
- It is expected that the SWOT surface area datasets (L2_HR_Raster, L2_HR_PIXC) will improve the hypsometry since water level and surface area are measured simultaneously.







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Bathymetry

- The computation of the bathymetry is based on the surface area time series and the corresponding water levels derived from the hypsometric curve
- All stacked land-water masks with corresponding water level exhibit the final bathymetry with respect to the smallest available surface area
- The bathymetry below is unknown because of missing data (highlighted in gray)
- The spatial resolution of the high-resolution bathymetry is 10 m 30 m
- Water levels and surface areas derived from the SWOT surface water datasets (L2_HR_Raster, L2_HR_PIXC) can be compared directly with the observed bathymetry



River Discharge

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- River discharge time series is the latest product in DAHITI
- This approach uses water level time series from satellite altimetry and surface areas from optical imagery which are combined by a modified hypsometric curve used for the estimation of volume variations
- However, surface areas for rivers are computed for each SWORD reach
- River discharge is computed at single cross sections defined by SWORD nodes within a SWORD reach using geometrical information from remote sensing and physical flow equations
- The accuracy shows NRMSE between 10.95% and 28.43% for the Mississippi River (Scherer et al., 2020)
- SWOT will provide information such as water levels, river width and river slope directly derived from the SWOT surface water datasets (L2_HR_Raster,L2_HR_PIXC) used for an improved estimation of river discharge



SWORD river reach at Mississippi

River Discharge



Longitude [°]

Deutsc

- Cross-sectional area A_i and wetted perimeter P_i of the Manning's equation can be derived quite accurate from "bathymetry" with assumptions
- *I* can derived from water levels between two virtual stations or ICESat-2 $\bar{v_i}$ (Scherer et al., in review) in combination with

the SWORD centerline

Cross Section at Node 74210000280581

200

400

600

Width [m]

Roughness coefficient k_{st}
is the challenging unknown

 $Q(t) = \sum_{i=1}^{n} \bar{v}_i(t) \cdot A_i(t)$

$$\bar{v}_i(t) = k_{st} \cdot R_i(t)^{\frac{2}{3}} \cdot I^{\frac{1}{2}} \quad R_i(t) = \frac{A_i(t)}{P_i(t)}$$



RMSE: 2354 m³/s / R²: 0.946 / NRMSE: 7.5%

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1000

1200

800

Conclusion / Outlook

- Satellite altimetry and optical imagery are valuable remote sensing techniques to derived hydrological products for monitoring inland waters
- The "Database for Hydrological Time Series of Inland Waters" (DAHITI) provide currently 9 different products which are derived from four different approaches
 - Water level time series from satellite altimetry
 - Surface area time series from optical imagery (incl. water occurrence masks, land-water masks)
 - Time series of volume variations (incl. hypsometry, bathymetry, water levels from hypsometry)
 - River discharge time series
- SWOT will help to improve approaches where water levels and surface areas are ideally available at the same time (e.g. volume variations, river discharge)
- The SWOT surface area datasets has the potential to capture new inland waters which where not crossed by any other altimeter satellite before.
- Currently, the data holding of DAHITI contains more than **7000 inland water targets** which will be further extended in future
- All products are freely available on the DAHITI web portal (https://dahiti.dgfi.tum.de) after a short registration process

Database for Hydrological Time Series of Inland Waters (DAHITI) Deutsches Geodätisches Forschungsinstitut Technische Universität München

Free data access on https://dahiti.dgfi.tum.de



Database for Hydrological Time Series of Inland Waters (DAHITI) DAHITI Contact Products -Christian Schwatke 🖸 christian.schwatke@tum.de Virtual Stations + Мар 80333 München Arcisstr.21 Lake/River not found? Tel. +49 89 23031-1109 Fax +49 89 23031-1240 Publications DAHITI-API (Beta) DAHITI-Targets Tools Africa : 1427 Projects Observing Long-Term, Short-Term and Seasonal Events 951 Asia 32 Australia 420 Europe North America 809 Q Search ... South America 3498 WELCOME TO DAHITI ... Extended Search

The **Database for Hydrological Time Series of Inland Waters** (DAHITI) was developed by the <u>Deutsches Geodätisches</u> <u>Forschungsinstitut der Technischen Universität München</u> (DGFI-TUM) in 2013 to provide water level time series of inland waters. Today, DAHITI provides a variety of hydrologial information on lakes, reservoirs, rivers, and wetlands derived from satellite data, i.e. from multi-mission satellite altimetry and optical remote sensing imagery. All products are available free of charge for the user community after a short registration process.



DAHITI-Flyer

Related Project(s):

Global :

7277

DAHITI - Products



Water Level Time Series from Satellite Altimetry

This product "Water Levels (Altimetry)" provides water level time series for lakes, reservoirs, rivers and wetlands derived from multi-mission satellite altimetry. [More]

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