Satellite-Based Estimates of River Runoff

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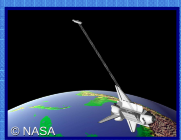
One promising technique for river runoff estimates from space is the retrieval of surface currents on the basis of along-track interferometric synthetic aperture radar (ATI). The German satellite TerraSAR-X, which was launched in June 2007, permits current measurements by ATI in an experimental mode of operation. Based on numerical simulations, we present first findings of the research project AnaNAF, in which the potential of satellite measurements for various parameters with different temporal and spatial sampling characteristics is evaluated. A dedicated data synthesis strategy for river discharge estimates is developed.

High-resolution 3-D current fields in the Elbe river (Germany) from a numerical flow model of the German Federal Waterways Engineering and Research Institute (BAW) are used as simulations input for a variety of possible measuring and data interpretation strategies. It appears to be feasible to obtain reasonable instantaneous flow rate estimates from satellite-derived surface velocities, river widths and stages, using different universal empirical relationships. However, we have to take into account the limited measuring accuracies and spatial resolutions, as well as the coarse spatial and temporal sampling patterns, particularly in estuaries.

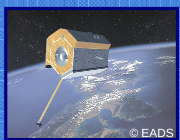
Along-Track Interferometry

Along-track InSAR (ATI) permits high-resolution surface current measurements. The technique uses two radar images of the same scene aquired with a short time lag on the order of milliseconds, whose phase differences are proportional to radial target velocities.

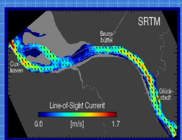
We have shown that the achievable accuracy and spatial resolution are sufficient for current measurements in rivers (*Romeiser et al.* 2007).

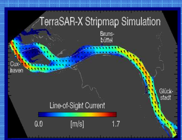


Artist's view of the Shuttle Radar Topography Mission (SRTM) instrument configuration (Feb. 2000)



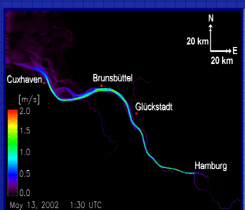
Artist's view of the German satelite TerraSAR-X, which was launched in June 2007





Actual SRTM-derived and simulated TerraSAR-X-derived line-of-sight surface current fields in the Elbe river (Germany). The SRTM-derived velocities are consistent with the BAW model (see "Runoff Estimates"). Our simulations indicate that TerraSAR-X will be even better suited for current measurements in river systems.

Test Site

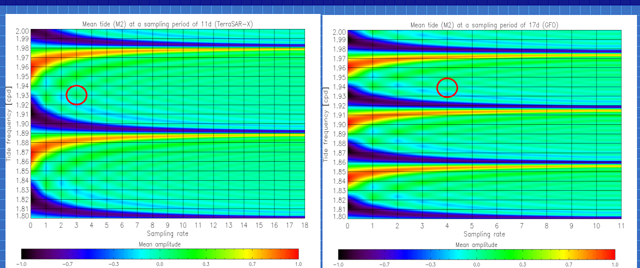


Surface velocity in the Elbe river test area according to the 3-D high-resolution numerical model data set from BAW.

Temporal coverage: Complete neap-spring tide cycle (17 days)
Temporal resolution: 10 min.
Spatial resolution: Horizontally gridded to 100 m; Vertical 1 m

Aliasing

Strong tide (M2, K1) induced aliasing effects at the test area can reduced by averaging different sampling periods for the various satellite sensors.



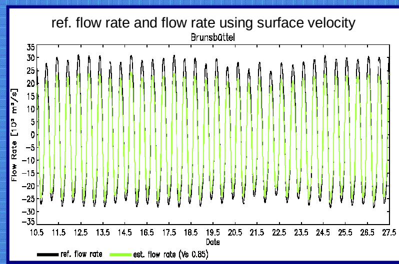
Example of minimum sample rate for the M2-tide for TerraSAR-X (left) and Geosat Follow-On (GFO) at the Elbe river test area. The advised mean sample period to reduce aliasing effects is marked with the red circle.

Runoff Estimates

Results of a 3-D numerical flow model are used as input for simulations of varying runoff estimate methods. Comparing the approach of *Bjerklie et al.* [2005], using the empirical relationship between river width and surface velocity retrieving by TerraSAR-X and the Manning-equation, using surface velocitiy, river width, stage deriving by TerraSAR-X and Altimetry to estimate volume transports.

The resulting accuracies and net discharges still show some differences, but owing to its simplicity, we presently favorate TerraSAR-X for runoff estimates, because of retrieving river width and surface velocity only by one satellite.

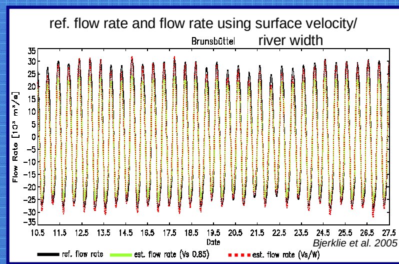
The evaluation of temporal and spatial sampling characteristics for different satellite sensors is ongoing work.



$$Q_{ref} = A \cdot V_m$$

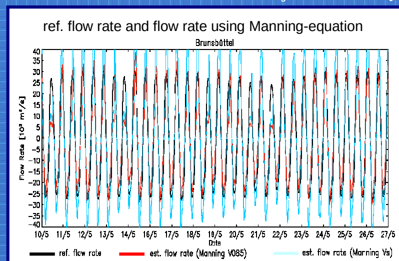
$$Q_{est} = A \cdot (V_s \cdot 0.85)$$

A = cross-sectional area
V_m = average velocity
A = cross-sectional area
V_s = surface velocity



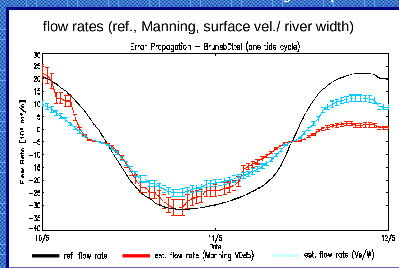
$$Q_{est} = k_2 \cdot W^{1.67} \cdot V^{1.67}$$

k_3 = 0.05
W = surface width
V_s = surface velocity



$$Q_{est\_Man} = A \cdot R_h^{2/3} \cdot \frac{S^{1/2}}{n}$$

A = cross-sectional area
R_h = *hydraulic radius*
$S^{1/2}$ = *slope*
n = *roughness parameter*



Net discharges

	Net runoff [m³/s]	ΔQ
Ref. runoff	758	
Est. runoff (*Vs*)	1886	
Est. runoff (*Vs/W*)	1180	95
Est. runoff (*Man V085*)	606	64

$$\Delta Q_{est\_(Vs/W)} = \left[\left(k2 \cdot V \cdot 1.67 \cdot W^{0.67} \cdot \Delta W\right)^2 + \left(k2 \cdot W \cdot 1.67 \cdot V^{0.67} \cdot \Delta V\right)^2\right]^{1/2}$$

$$\Delta Q_{est\_Man(V085)} = \left[\left(c \cdot \frac{5/2 \cdot v^{3/2} \cdot W}{S^{3/4}} \cdot \Delta V\right)^2 + \left(c \cdot \frac{v^{5/2} \cdot 1 \cdot B^0}{S^{3/4}} \cdot \Delta W\right)^2 + \left(c \cdot v^{5/2} \cdot W \cdot (-3/4) \cdot s^{-7/4} \cdot \Delta s\right)^2\right]^{1/2}$$

V = velocity
W = width
S = slope
Δ*V* = accuracy velocity = 0.1 [m/s]
Δ*W* = minimum river width (using ATI) = ≥ 300 m
Δ*S* = standard deviation slope = 3.52429E-05
Δ*Q* = discahrge error

References:
Bjerklie, D. M., D. Moller, L.C. Smith, and S.L. Dingman, Estimating discharge in rivers using remotely sensed hydraulic information, *Journal of Hydrology*, *309*, 191-209, 2005.
Romeiser, R., H. Runge, S. Suchandt, J. Sprenger, H. Weilbeer, A. Sohrmann, and D. Stammer, Current measurements in rivers by spaceborne along-track InSAR, *IEEE Trans. on Geosci. and Remote Sensing*, *45*, 4019-4030, 2007.