Supplementary Materials

S1. The estimation of fine resolution surface water map based on the MRF

X can be formulated by applying the maximum a posteriori rule in Bayesian framework by solving the maximization problem:

$$\left\{\mathrm{P}^{\mathrm{posterior}}\left(X\middle|Y\right)\right\}=\mathrm{argmax}\left\{\frac{1}{Z}\exp\left[-\mathrm{U}^{\mathrm{posterior}}\left(X\middle|Y\right)\right]\right\} \tag{S1}$$

where $\mathrm{U}^{\mathrm{posterior}}(X|Y)$ is the posterior energy function of X given Y, and Z is a normalization constant. The optical X can be estimated by minimizing the energy function $\mathrm{U}^{\mathrm{posterior}}(X|Y)$:

$$\mathrm{U}^{\mathrm{posterior}}\left(X\middle|Y\right)=\lambda\cdot\mathrm{U}^{\mathrm{spatial}}\left(X\right)+\mathrm{U}^{\mathrm{fraction}}\left(Y\middle|X\right) \tag{S2}$$

where $\mathrm{U}^{\mathrm{spatial}}(X)$ is the spatial constraint function and $\mathrm{U}^{\mathrm{fraction}}(Y|X)$ is the surface water fraction constraint function that represents the inconsistency between Y and X. λ is a balance parameter.

The spatial constraint function is used to maximize the spatial dependence for the water class and land class. For each 2 m resolution pixel, the spatial dependence for the water (or land) pixel is calculated by a weighted sum of all water (or land) pixels within a local window using the target pixel as the window center. The spatial constraint function is calculated according to the spatial dependences of all the 2 m pixels as:

$$U^{spatial}\left(X\right)=\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{s^2}\left(-1\times\sum_{l\in N\left(a_{ijk}\right)}\delta\left(c\left(a_{ijk}\right),c\left(a_{l}\right)\right)\Big/d\left(a_{ijk},a_{l}\right)\right) \tag{S3}$$

where I and J are the number of Sentinel-2 pixels, a_{ijk} is a target 2 m resolution pixel, $N(a_{ijk})$ is a $w \times w$ sized window with which a_{ijk} is its center, a_l is its neighborhood pixel $N(a_{ijk})$, $d(a_{ijk}, a_l)$ is the geometric distance between a_{ijk} and a_l, $c(a_{ijk})$ and $c(a_l)$ are the class labels of the pixels a_{ijk} and a_l, and $\delta(c(a_{ijk}),c(a_l))$ is the Kronecker delta function that equals 1 if $c(a_{ijk})$ and $c(a_l)$ are the same or 0 otherwise.

The water fraction constraint function is used to minimize the surface water fractions between the unmixed Sentinel-2 pixels and the predicted 2 m surface water map as:

$$U^{fraction}\left(Y\middle|X\right)=\sum_{i=1}^{I}\sum_{j=1}^{J}\left(F_{ij}^{unmix}-F_{ij}^{predict}\right)^2 \tag{S4}$$

where F_{ij}^{unmix} and $F_{ij}^{predict}$ are the surface water fractions within the 10 m Sentinel-2 pixel (i,j). $F_{ij}^{predict}$ is calculated by dividing the total number of 2 m resolution water pixels within the Sentinel-2 pixel (i,j) by s^2. , and the value of $F_{ij}^{predict}$ is iteratively updated.