Sentinel-3 - Uncertainty estimation

Following user requirements and in line with QA4EO principles the Sentinel-3 products will be given with the uncertainty per pixel.

The methods to retrieve the uncertainties are not yet harmonised (different algorithm, different approach)

Level 2 products

OLCI:

- Ocean colour products: Water leaving reflectance, Chl Case 1 – Uncertainty implemented and tested
- Ocean colour products: NN – Uncertainty implemented and tested
- Land Chlorophyll Index (OCTI) – Uncertainty being implemented
- Fapar : uncertainty algorithm under development

SLSTR:

- SST : generic approach
- LST : generic approach based

SYN:

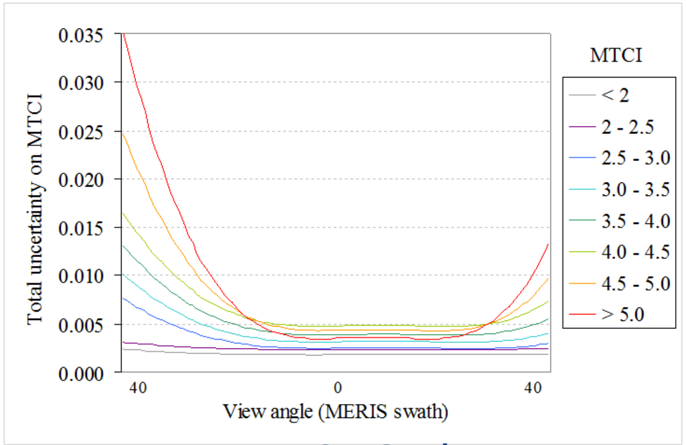
- Surface reflectance: – Uncertainty implemented and tested

OTCI Uncertainty Measurements

Quantification of uncertainties due to:

Soil background;
Varying view and sun angle configurations
Atmospheric influences
Sensor calibration noise;

- Based on law of propagation of uncertainty (Muira et al (2000) and QA4EO recommendations
- Estimates standard uncertainty of OTCI from standard uncertainties of input reflectances (first order Taylor series approximation)



Uncertainties on OTCI due to view angle

Error source	Min error	Max error
Acquisition noise	0.002	0.0124
Illumination and view geometry	0.0008	0.0745 (~ 7%)
Soil background	0.0003	0.0034

OLCI L2 water leaving radiance uncertainty

Uncertainty source: Currently Level 1 radiometric noise

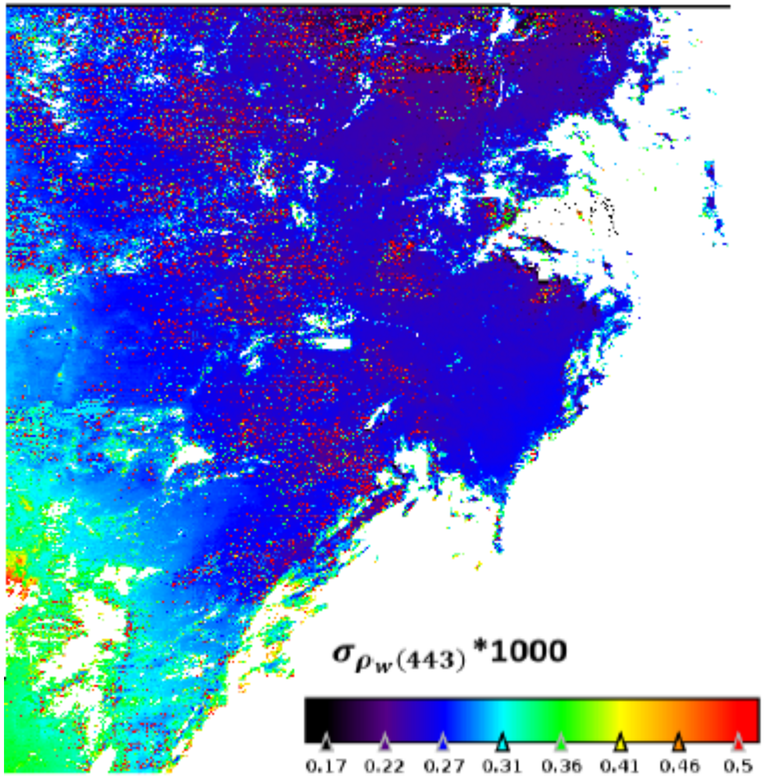
Uncertainty output: Pixel-by-pixel Rw uncertainty from atmospheric correction

Method: Propagate normal-law L1 uncertainty by 1st order Taylor series expansion (QA4EO framework)
Analytical propagation through OLCI clear water atmospheric correction (fast implementation)

Validation: Method successfully validated on MERIS RR

Requirements: Level1 uncertainty must be known through its full spectral variance-covariance matrix, and not only SNR (~ diagonal term)

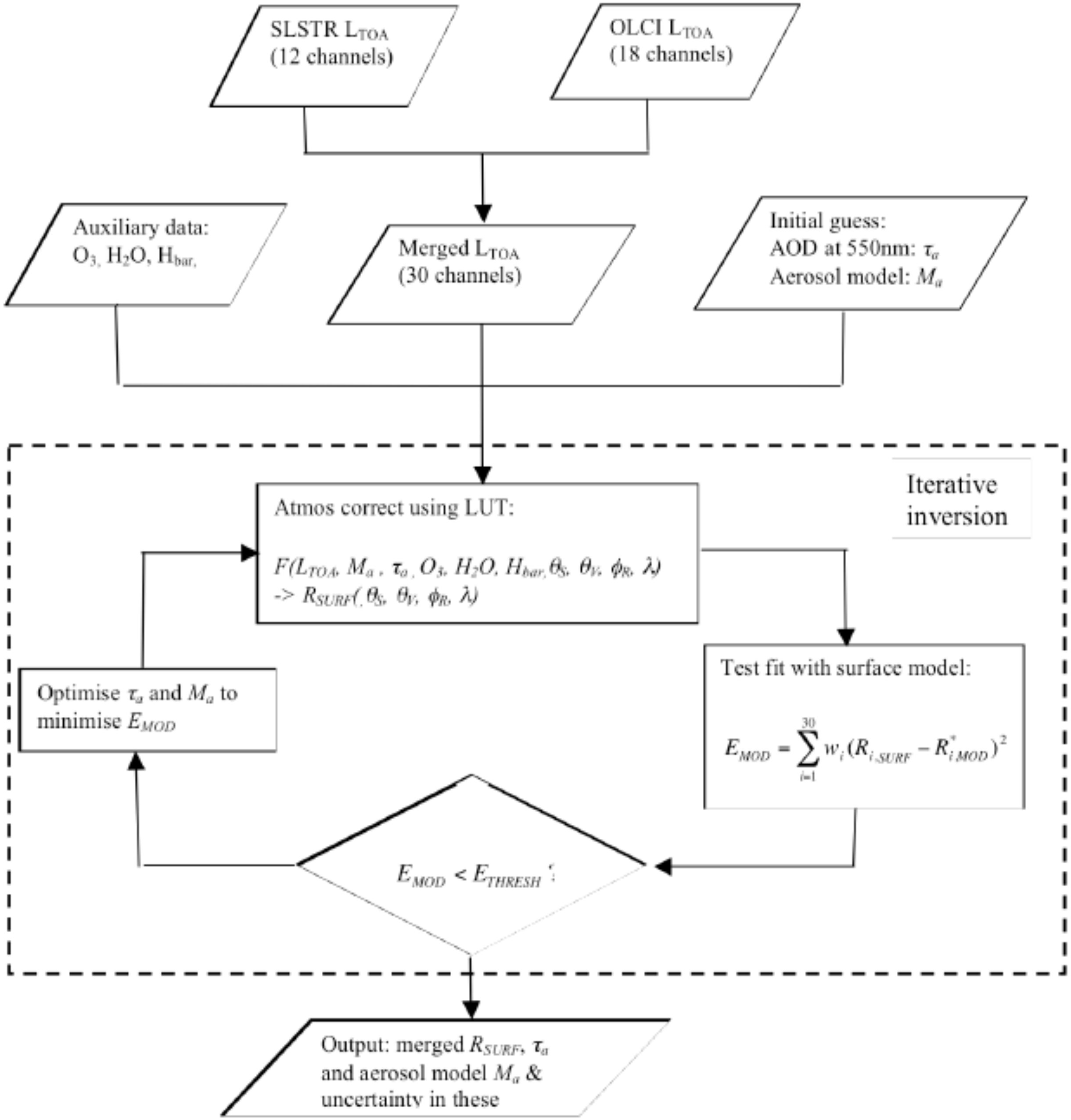
$$C = \begin{pmatrix} \sigma_\lambda^2 & \sigma_{\lambda,779} & \sigma_{\lambda,865} \\ \sigma_{\lambda,779} & \sigma_{779}^2 & \sigma_{779,865} \\ \sigma_{\lambda,865} & \sigma_{779,865} & \sigma_{865}^2 \end{pmatrix}$$



$\sigma_{\rho_w(443)} \approx 2.5\ 10^{-4}$ for most of the scene
(1% relative uncertainty)
Higher values on specifics pixels and regions

Limitations: If OLCI radiometric performance is as good as MERIS RR, the main driver will be physics: there is a need to add modelling uncertainty (aerosol, radiative-transfer, etc.), to be assessed by other means

SYN surface reflectance Uncertainty Measurements



SYN surface reflectance Uncertainty Measurements

The error in surface reflectance at each waveband is calculated as the sum of errors due to the error in AOD estimation Δτ , sensor noise Δ*sens*, and estimated error in the radiative transfer model Δ*RT*. For each channel, the uncertainty is given by:

$$\Delta R_{surf} = \left(\Delta_{\tau}^{2} + \Delta_{sens}^{2} + \Delta_{RT}^{2}\right)^{0.5}$$

- Aerosol uncertainty given :

$$\Delta_{\tau} = \frac{\delta R_{surf}}{\delta \tau} \Delta\tau$$

Where

$$\Delta\tau = k\sqrt{\frac{E_{\min}}{a}}$$

- Emin is the value where the AOT minimise the error metric *Emod following optimisation procedure*
- *a is the curvature term of a a parabolic fit to Emod.*
- *The term k is estimated to be 1.58, but should be tuned by post-launch calibration.*

- Sensor noise

Error in surface reflectance Δ*sens* due to instrument noise in the TOA measurement Δ '*sens* :

$$\Delta_{sens} = \frac{\delta R_{surf}}{\delta R_{TOA}} \Delta'_{sens} \approx \frac{\Delta'_{sens}}{T_{O_3} T(\theta_s) T(\theta_v)}$$

Estimate of the channel-dependent instrument noise Δ '*sens* should include the combined effects of quantisation and calibration error.

- Error in RT model:

the error in the radiative transfer model Δ*RT* includes the net effect of numerical approximation of atmospheric radiative transfer variation and composition (column ozone, water vapour and aerosol model) from reality. A value of 0.005 should be used as default.

AATSR LST pixel uncertainties

$$LST = a_{f,i,pw} + b_{f,i}(T_{11} - T_{12})^n + (b_{f,i} + c_{f,i})T_{12}$$

Pixel uncertainty budget is a combination of all the uncertainty components of the LST retrieval algorithm:

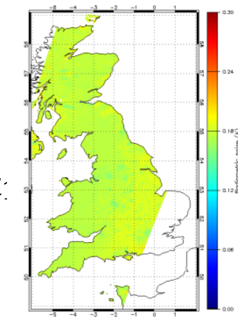
- Systematic uncertainty of forward model
- Radiometric noise
- Surface state
- Atmospheric state
- Geolocation uncertainty
- Model fitting uncertainty
- Uncertainty due to cloud contamination (under development)

Radiometric noise

$e_{T_{11}}$ = $NE\Delta T_{11}$ = 0.05 K

$e_{T_{12}}$ = $NE\Delta T_{12}$ = 0.05 K

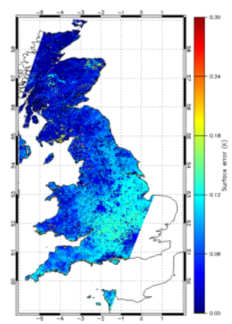
$$S_{noise}^2 = (\partial F/\partial T_{11})^2 e_{T_{11}}^2 + (\partial F/\partial T_{\ldots}$$



Surface state

e_f = uncertainty due to fractional vegetation cover

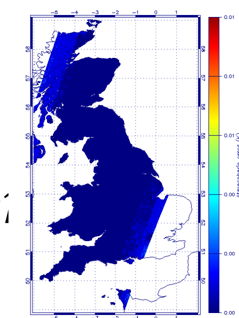
$$S_{sfc}^2 = (\partial F/\partial f)^2 e_f^2$$



Atmospheric state

e_{pw} = uncertainty due

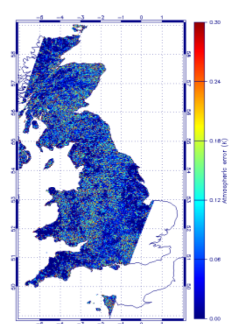
$$S_{atm}^2 = (\partial F/\partial pw)^2 e_{pw}\ldots$$



Geolocation

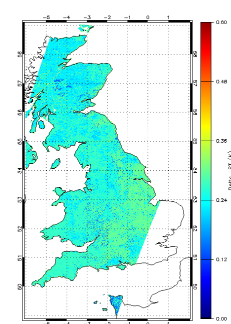
The geolocation of the image data may be up to 0.5 km away from the 'true' instrument pixel coordinates

Estimate the probability that the underlying biome is correctly assigned



Model fitting

For each biome-diurnal condition the set of retrieval coefficients is derived by minimizing the model fitting error (*ΔLST)*



Uncertainties per Pixel - Conclusion

- Sentinel-3 Level 2 products will be given with the uncertainties per pixel
- The algorithm are not at the same level of maturity
- The approaches are different according to algorithm
- Currently there is no uncertainties at Level 1 (constant value)
  - On progress (see work on Sentinel-2 by NPL/ESA)
- Validation of the uncertainties !
- Good start but we need to improve