MERLIN PERFORMANCE

MERLIN aims to provide global measurements of the spatial and temporal gradients of atmospheric methane (CH4) with a precision and accuracy sufficient to significantly constrain Methane surface fluxes. The very low level of systematic error is designed to avoid geographical biases in the XCH4 fields that could lead to uncertainties in fluxes.

1 PERFORMANCE REQUIREMENTS

The MERLIN system is designed to the following performance requirements:

Parameter	Requirement
XCH4 random error	< 22 ppb
XCH4 systematic error	< 3 ppb
Spatial coverage	Global
Horizontal resolution	50 km
Vertical resolution	Total column
Objectives	▪ Seasonal and annual budgets on a country scale ▪ Resolves country scale gradients

2 BASIC SIGNAL PROCESSING ALGORITHM

The backscattered signal in the "off" wavelength and the "on" signal gives a direct measurement of the differential absorption optical depth (DAOD) of methane:

$$DAOD = \frac{1}{2}\ln(\frac{P_{off}}{P_{on}}) \qquad \text{Equation 1}$$

The DAOD is then converted into a vertically-integrated dry mixing ratio of methane, XCH_4, which is the measurement used for assimilation in atmospheric transport models:

$$XCH_4 = \frac{DAOD}{\int_0^{p_{surf}} WF(p)dp} \qquad \text{Equation 2}$$

Where the weighting function (WF) is integrated vertically from surface pressure P_{surf} to the top-of-atmosphere.
It can be demonstrated that the weighting function, WF, is:

$$WF = \frac{(\sigma_{on} - \sigma_{off})}{g(m_{dry} + m_{H2O}x_{H2O})} \qquad \text{Equation 3}$$

where σ is the methane absorption cross-section for the "on" or "off" wavelength, m denotes the molecular mass of dry air or water vapour, g is gravitational acceleration and x_{H2O} the water vapour mixing ratio.
The cross-sections are computed with a radiative transfer code using spectroscopic parameters. This process requires good knowledge of the laser's spectral shape and central frequency. There is a dependency on meteorological profiles (pressure, temperature and humidity) which are provided by a numerical weather prediction centre (NWP).
Surface pressure P_{surf} is calculated using the LIDAR-measured Scattering Surface Elevation (SSE) and auxiliary data from NWP models (pressure and temperature) according to the figure below.

$$SSE - Z_{NWP} = -\frac{R}{g}\int_{P_{NWP}}^{P_{surf}} T_{NWP}(p)\partial \ln p \qquad \text{Equation 4}$$

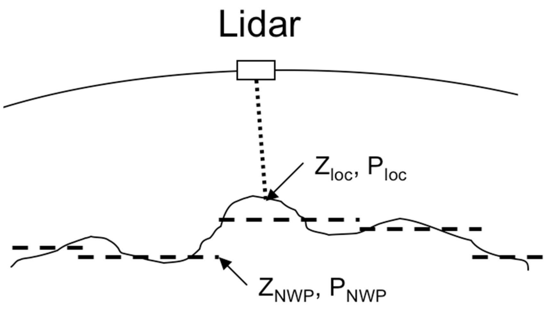

Figure 1.- Link between grid box elevations provided by NWP models, range and target altitude

3 ESTIMATED PERFORMANCE BUDGET

Contributors to the error budget are analytically evaluated from the above equations according to the tree below:

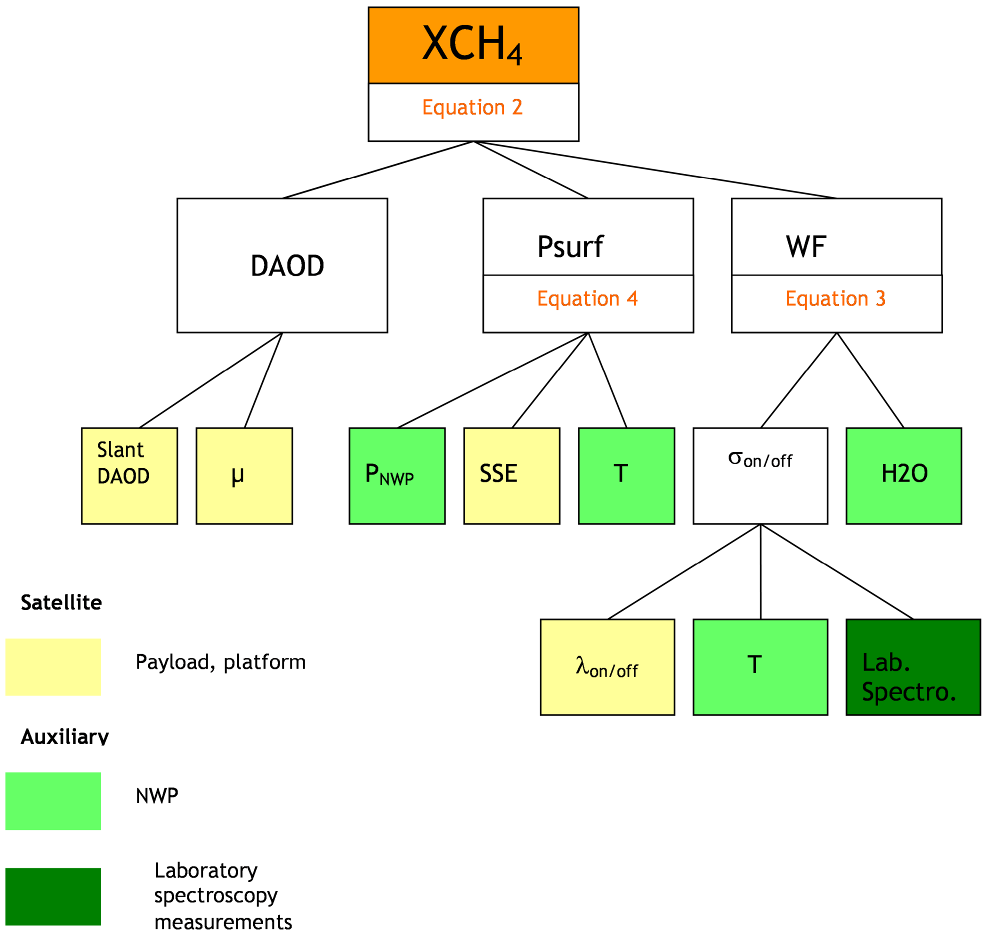

Figure 2.- Contributors to level 2 XCH4 performance

The values shown here are based on the system requirement specifications for MERLIN mission phase B.

	Random error	Impact on XCH4 (in ppb)
DAOD	1.3%	23.1 ppb
PNWP	2 hPa	
SSE	10 m	
T	2 K	
Psurf	2.4 hPa	5.0 ppb
H2O	10%	
Cross-section	0.1%	
WF	0.1%	1.8 ppb
XCH4 (random error)		**23.8 ppb**
Equivalent XCH4 error (with scaling factor from weighting function)		**19.4 ppb**

	Systematic error	Impact on XCH4 (in ppb)
DAOD	0.13%	2.31 ppb
PNWP	0.2 hPa	
SSE	7 m	
T	-	
Psurf	0.87 hPa	1.85 ppb
H2O	10%	
Cross-section	0.1%	
WF	0.1%	1.84 ppb
XCH4 (systematic error)		**3.51 ppb**
Equivalent XCH4 error (with scaling factor from weighting function)		**2.86 ppb**

A scaling factor is defined by the weighting function’s actual sensitivity in the boundary layer compared to a constant weighting function. At MERLIN wavelengths, measurement is more sensitive in the lower atmosphere — a favourable configuration for retrieving sources and sinks — so the scaling factor has been defined as 1.23.