SUMMARY:
EUMETSAT will produce a Cloud Top Pressure (CTP) product from the Oxygen A-band solar reflectance measurements made by the METImage instrument on the EPS-SG platform to provide services in the 2020-2040 time frame. A baseline algorithm has been designed and successfully tested on simulated METImage and real MERIS data by Mathieu Compeigne et al. This algorithm is a 1DVar retrieval of CTP and cloud optical thickness (COT) using METImage measurements at 0.67 μm (0.865 μm) and the ratio of the A-Band channels. Whilst the algorithm performs as expected it is clear that diagnoses have no sensitivity to multi-layer cloud situations and that CTP retrievals in such cases will be highly erroneous. As a first step to provide at least for the detection of multi-layer cloud it is suggested that a further METImage reflectance channel measurement be added to the system and that to detect the presence of separated cloud layers this channel must be at a wavelength where there is absorption from a gas other than oxygen. The candidate channel is therefore the water vapour channel at 0.914 μm.

The EUMETSAT Optimal Cloud Analysis (OCA) product developed for the MSG SEVIRI instrument is an analogous 1DVar retrieval based on the (non-A) reflectance and infra-red channels and is intended also for application to METImage. It has proven ability to detect multi-layer cloud and the detection arises also through the inclusion of water vapour sensitive channels (in this case at infra-red wavelengths). OCA is also able to retrieve two-layer properties - a task aided by the relative simplicity of cloud radiative transfer outside of the A-Band region. Because multi-layer detection with OCA arises from the infra-red measurements, detection capability disappears when upper layer clouds are optically thinner than ~5. The sensitivity of the O2-A band CTP to multi-layer remains very significant until very high upper layer optical depths. These diverse characteristics suggest that a synergy between the measurements might be very useful.

O2-CTP is a 1DVar estimation of a cloud state parameter vector, \( x \), with a measurement vector, \( y \), consisting of 3 of the METImage channels. Outputs are the estimate of \( x \), the measurement fit or ‘cost’, \( \lambda_m \), and parameter error estimates, \( \lambda_e \).

OCA is a 1DVar estimation of a cloud state parameter vector, \( x \), with a measurement vector, \( y \), consisting of 11-16 of the 20 METImage channels. Outputs are the estimate of \( x \), the measurement fit or ‘cost’, \( \lambda_m \), and parameter error estimates, \( \lambda_e \).

O2-CTP fast forward model is based on LUTs which cover all radiative interactions over the entire vertical column. This includes interactions between vertically inhomogeneous cloud and the absorbing scattering atmosphere above and below the cloud and the bi-directionally reflecting surface.

The OCA forward model is based on LUTs which cover only radiative interactions within the cloud column which is modelled as vertically homogeneous and geometrically infinitely thin. Interactions between the cloud and the absorbing atmosphere above and below the cloud and the Lambertian surface are modelled in terms of simple reflecting streams.

2. Synergy with OCA

The plot from Persuiker and Lindstrodt [2009] shows (black line) the CTP retrieved in multi-layer scenes as a function of the upper layer COT. The CTP responds only when this reaches a value of 2 or so and reaches the upper cloud CTP at a value of COT=50. We have added a figurative response (blue) obtained from an IR driven algorithm like OCA - the response to the upper cloud is already present at an upper COT of 0.35 the lowest sensitivity is at around COT=0.1 and beyond upper COT -5 the lower cloud no longer has an effect. Thus the two measurement systems have very different response and some synergy is clearly suggested.

2.1 Simple Synergies

- **OCA** (or more generally, techniques based on IR channels) can reliably detect multi-layer conditions within a range of upper layer COTs of 0.1 to 5. OCA appears to be able to retrieve two-layer CTPs but with the lower layer CTP error rapidly increasing with the upper layer COT. However, within this range the oxygen A-band CTP is an accurate estimate of the lower layer COT. The simplest synergy is therefore the use of the A-band CTP as a prior estimate for the OCA lower CTP.
- The second clear observation from the figure is that CTPs which OCA and A-band CTPs differ significantly within a range of upper layer COT from at least 2 to 20. This might suggest that the simple synergy of comparison can extend the OCA multi-layer detection to a range of upper layer COTs of 0.1 to 20 rather than 0.1 to 5.
- As the OCA upper layer CTP is quite reliable for upper layer COTs > 5, it could be used as strong prior input to an A-band algorithm that is able to handle two layers.

2.2 Full Synergy

Ideally the two algorithms would be combined into a single 1DVar to simultaneously extract the complementary information has been done by two different ways to this is to recast the A-band RTM method in the OCA LUT form or vice versa. Since the A-band RT is so much more (critically) sensitive to the cloud structure, it would seem clear that OCA RT in A-band form is the most likely route. However, there are open questions:

- **Is it possible to achieve LUT-based A-band RT for two-layers?** (Alternatively disable these channels for multi-layer when upper layer COT > 3?)
- Should the ‘non-A’ bands channels (VIS and potentially also IR) for consistency use the A-band LUT cloud definitions (GT and extinction) that depend on COT and CTP?
- OCA LUTs have no explicit CTP dependency - is there a need to add a?