



# Hyperion Spectral Smile



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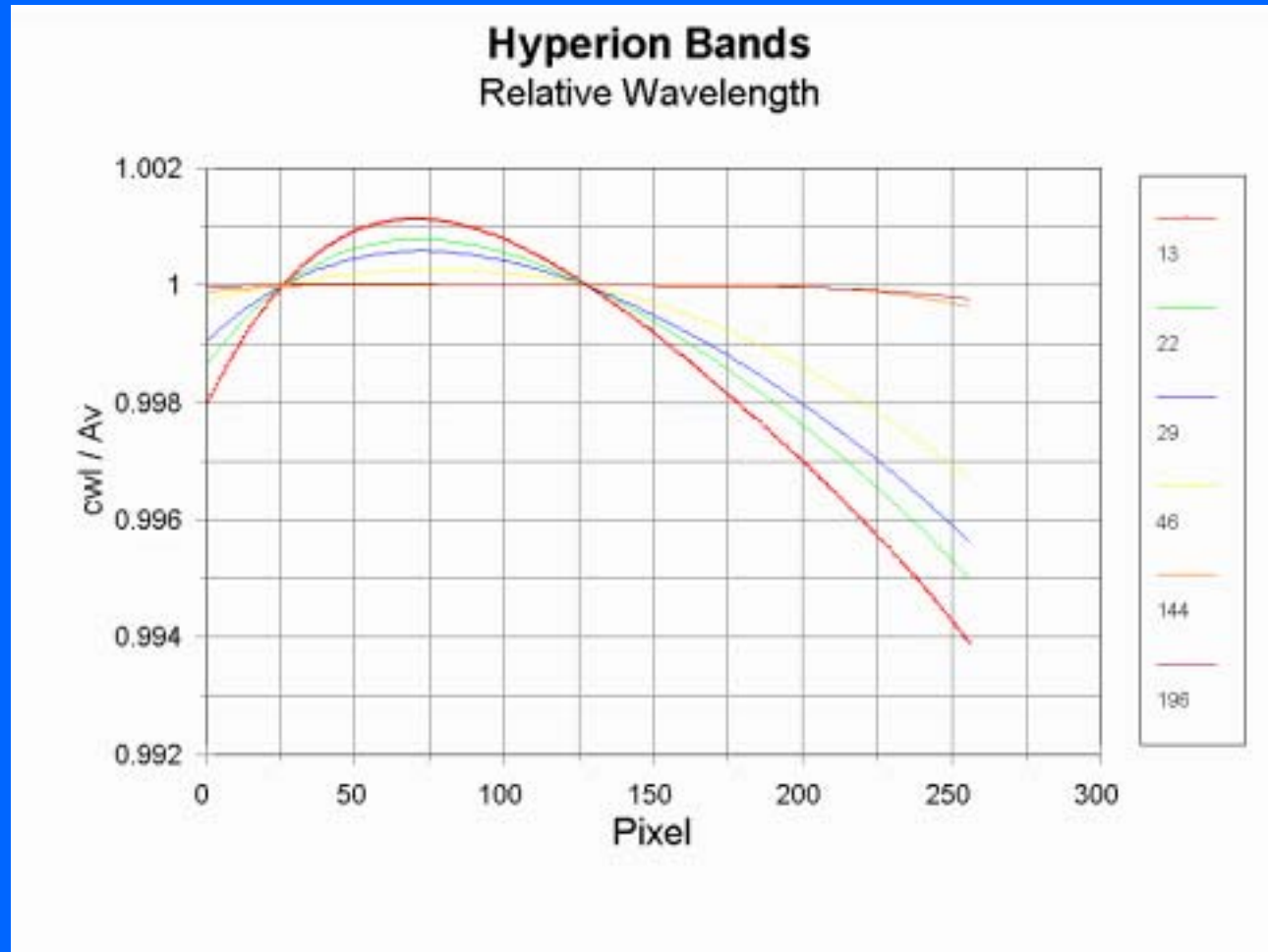
*(Based on notes provided by David Jupp)*



# Pre-launch smile model

- Pre-launch smile characterised by TRW using 25 points on the 242 by 256 detector array.
- this showed the effects to be most significant in the VNIR and effectively negligible in the SWIR.

# Hyperion Spectral Smile





# Stability of the smile



- The success of interpolations and column dependent atmospheric correction to overcome smile effects depends on a good knowledge of the extent and scope of the smile.
- Recent discussions have suggested that the smile effect may currently be different from the TRW characterisation and may have changed over time. Suggestions of 2-4 nm shift have been made



# Stability of the smile

- These notes are around the subject of the **stability of the smile** and the **possible causes for the differences** found by different people.
- It uses data provided by NASA to test the smile in a consistent way between investigators plus some very different sites to provide examples from different parts of the world, different land covers and different times.
- It is based only on the Oxygen-A band area.

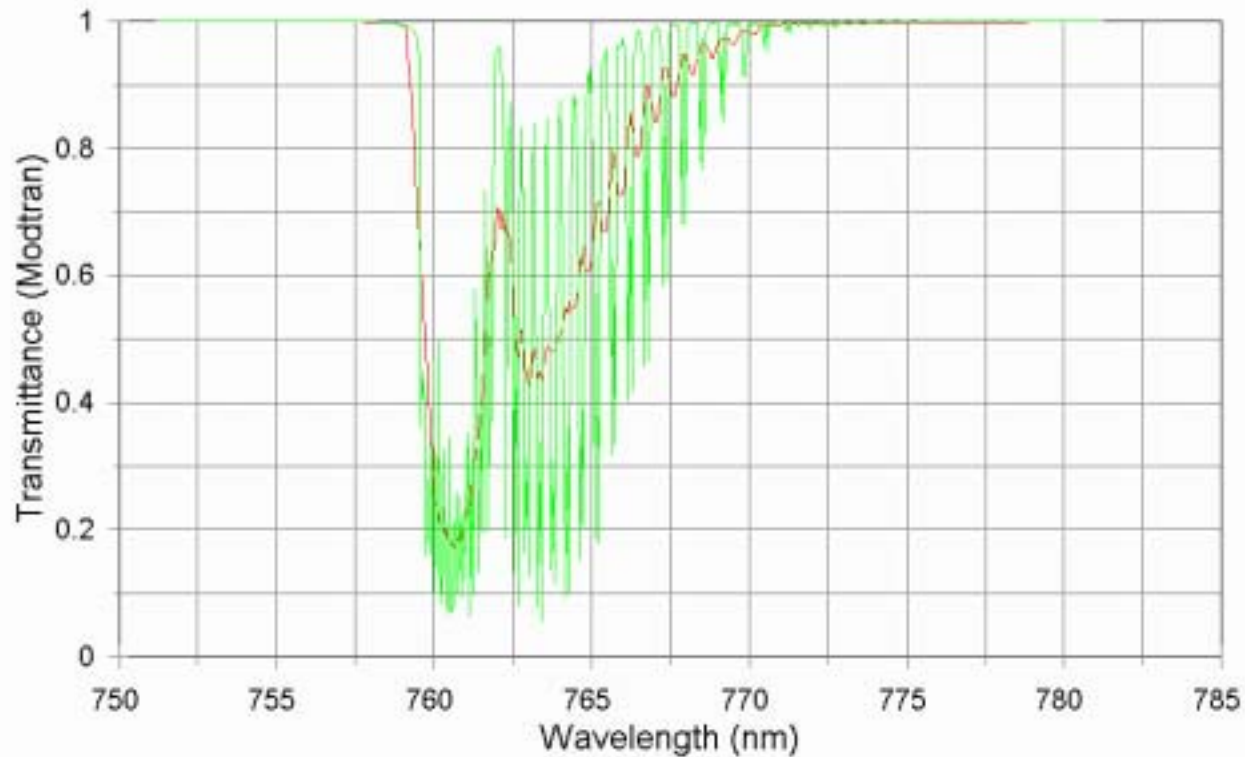


# The Oxygen-A Band at 762 nm



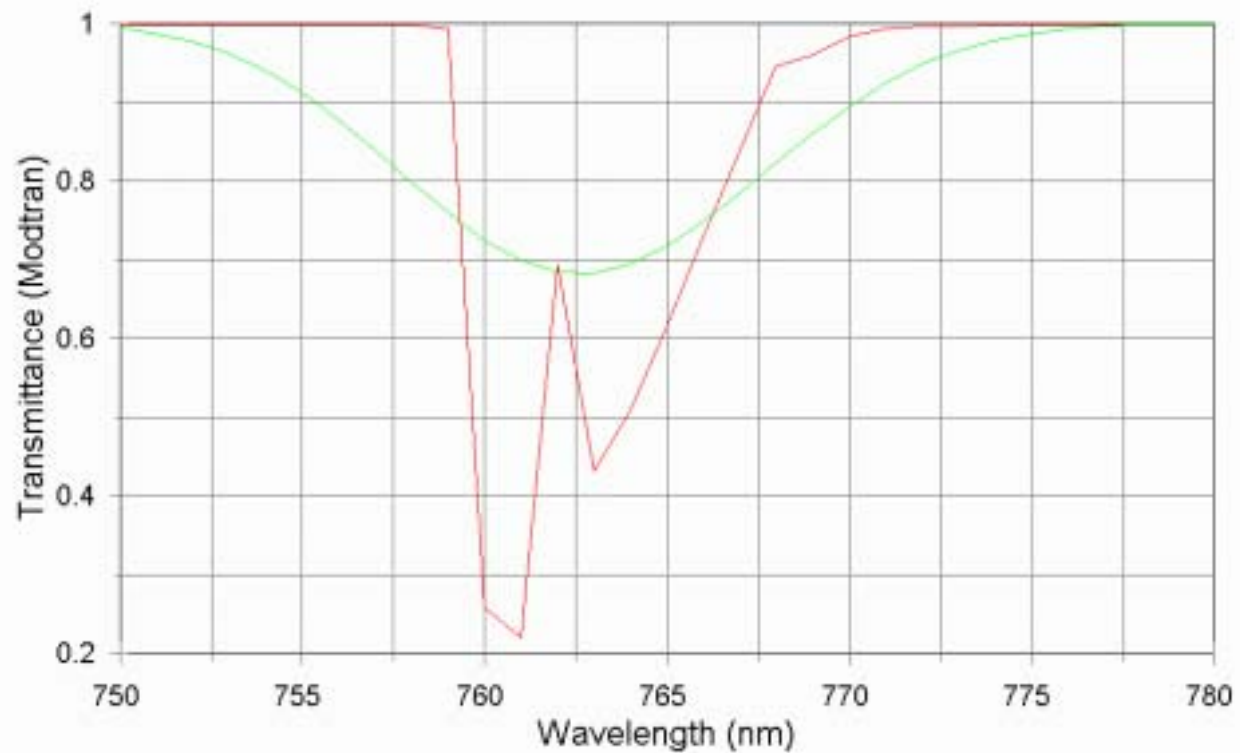
- Hyperion Band 41 is very close to the centre of absorption and Bands 40 and 42 are affected by it as well.
- The Oxygen-A area is not a single absorption band but a set of lines that even show a lot of detailed structure in MODTRAN.
- The plot of the absorption for a standard atmosphere at full MODTRAN scale ( $1 \text{ cm}^{-1}$  step) and with smoothing to equivalent of 1 nm step is as follows:

## Hyperion Smile Issue Modtran O2-A "Band"

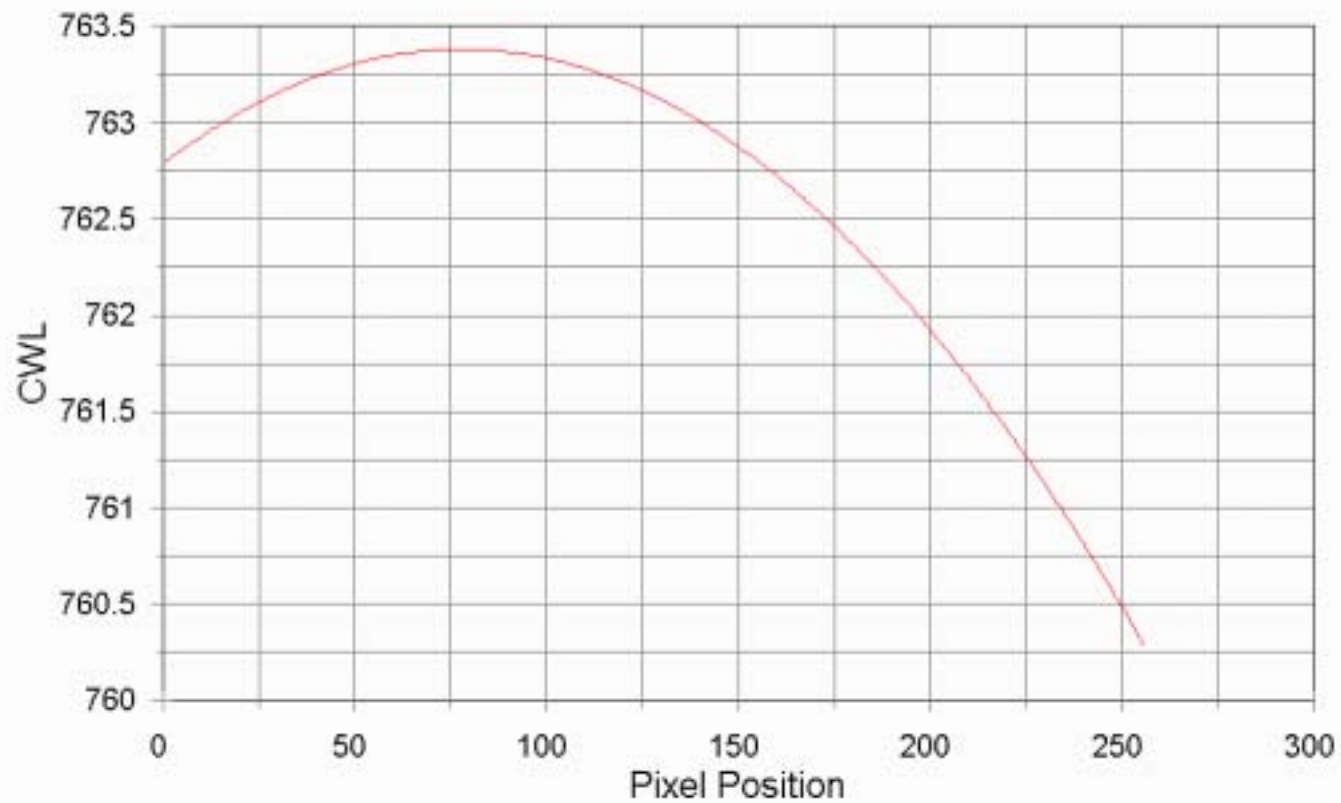


- At best the band is a “doublet” with two general absorption peaks at 761 nm and 763 nm.
- However, at the Hyperion resolution of 10 nm FWHM the band effectively reduces to a single band with centre 762.5 nm and 11 or 12 nm FWHM:

## Hyperion Smile Issue Modtran O2-A "Band"



### Summary for O2A Diff TRW Smile Model for Band 41





# Measuring the smile across the Oxygen-A band area

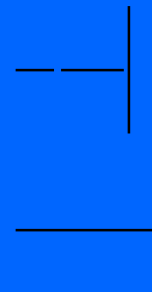


- A convenient way to track the smile effect across the area is suggested by examining the loadings of the MNF band that seems to show the smile. This is discussed in Jupp et al. (2002). Basically, we form the index:

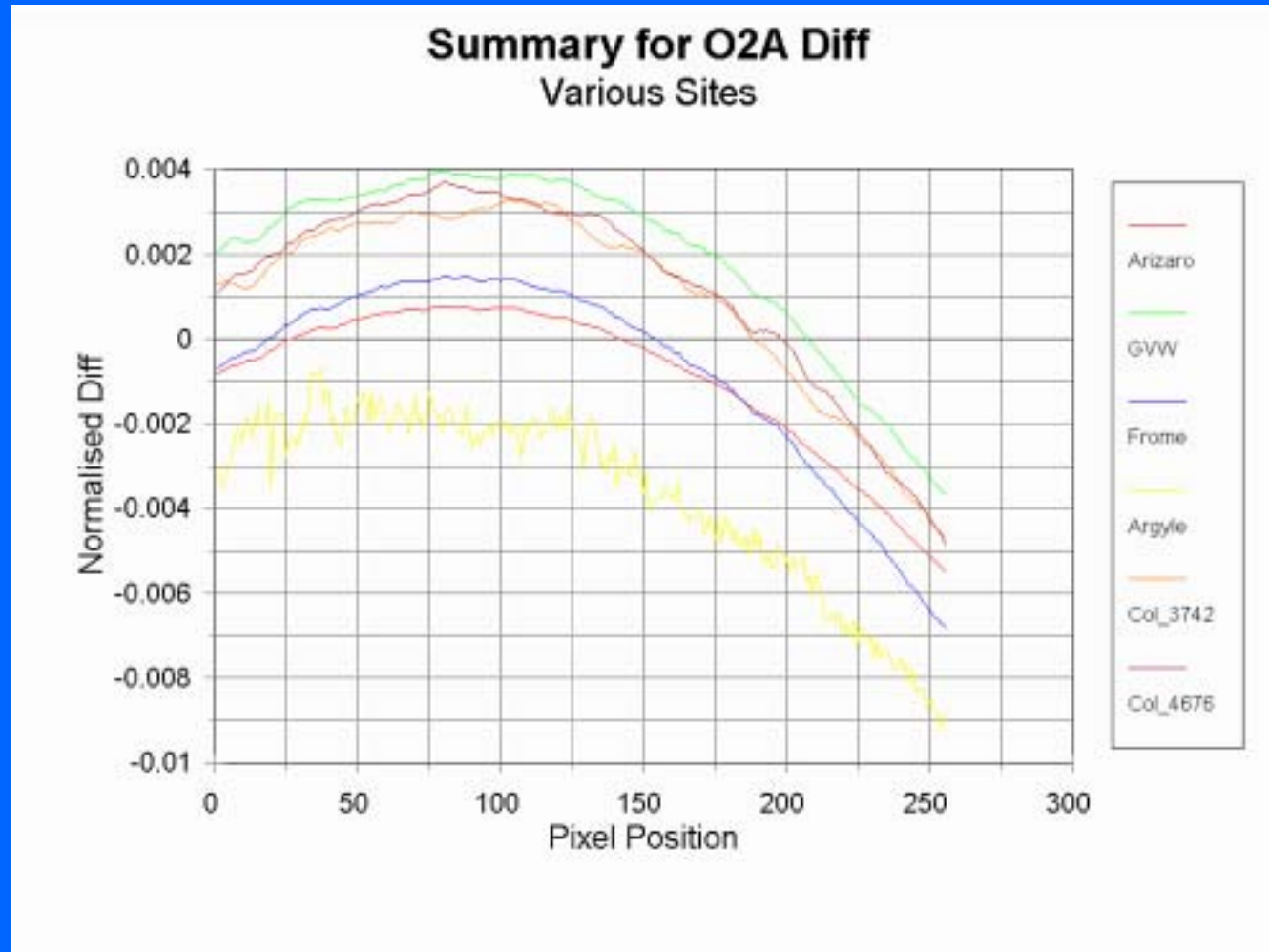
$$\frac{I_{\lambda} - I_{\lambda+h}}{h}$$

- Here,  $h$  is the spacing between bands that is nominally 10 or 11 nm. This can be seen to be a discrete approximation to:

$$\frac{dI}{d\lambda}$$



# Normalised Difference O2A Index



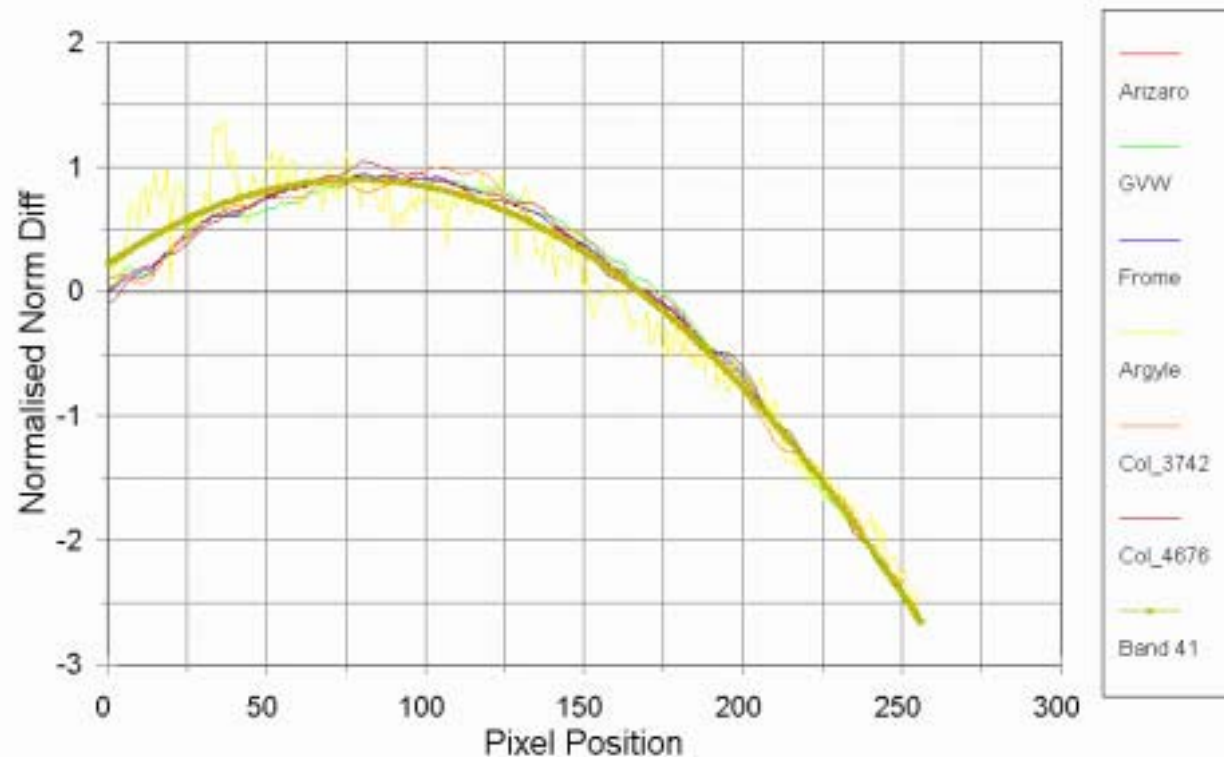


# Normalised Difference O2A Index



- There is quite a lot of difference in the vertical offsets but the shapes are similar.
- The Lake Argyle data are noisy since the signal is lowest.
- All of the areas with vegetation cover have a similar result as do the two bright targets and the water is shifted most down of them all.
- Hence, there is vertical offset stratification by land cover. There is little vertical change between the Coleambally images which are both taken during the crop maturity period – albeit in different seasons.
- If these curves and the TRW model smile are all normalised to mean zero and standard deviation 1.0 and plotted together we obtain the following plot:

### Summary for O2A Diff Various Sites Normalised to $m=0, sd=1$



- Clearly, except for the left hand side all of the curves follow a very similar shape and, provided the index is following the smile linearly, it seems that there has been little change in the smile *shape* over time and between covers and places in the world since launch with some possible difference to the TRW modelled smile. However, since the TRW model is based on 25 points it is not surprising that there are some differences.



# The Index as a measure for smile



- The mechanism for the results can be explained by letting  $R_c$  be the radiance that would be measured if there were no Oxygen-A absorption lines/bands present. Since the oxygen absorption is localised this is effectively the same in most areas.
- We can write as a model:

$$I = R_c \left( \frac{1}{2} + \frac{1}{2} \cos \theta \right)$$

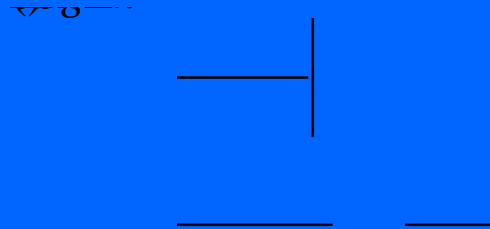
- However, in the terms for  $R_c$  there is no effect added for the Oxygen-A absorption. The absorption applies equally to diffuse and direct terms.
- In addition, Let us assume that the Oxygen-A transmittance, after convolution with the Hyperion 10 nm FWHM bandpass has the form:

$$T = \exp(-\tau)$$

# The Index as a measure for smile



It follows that:

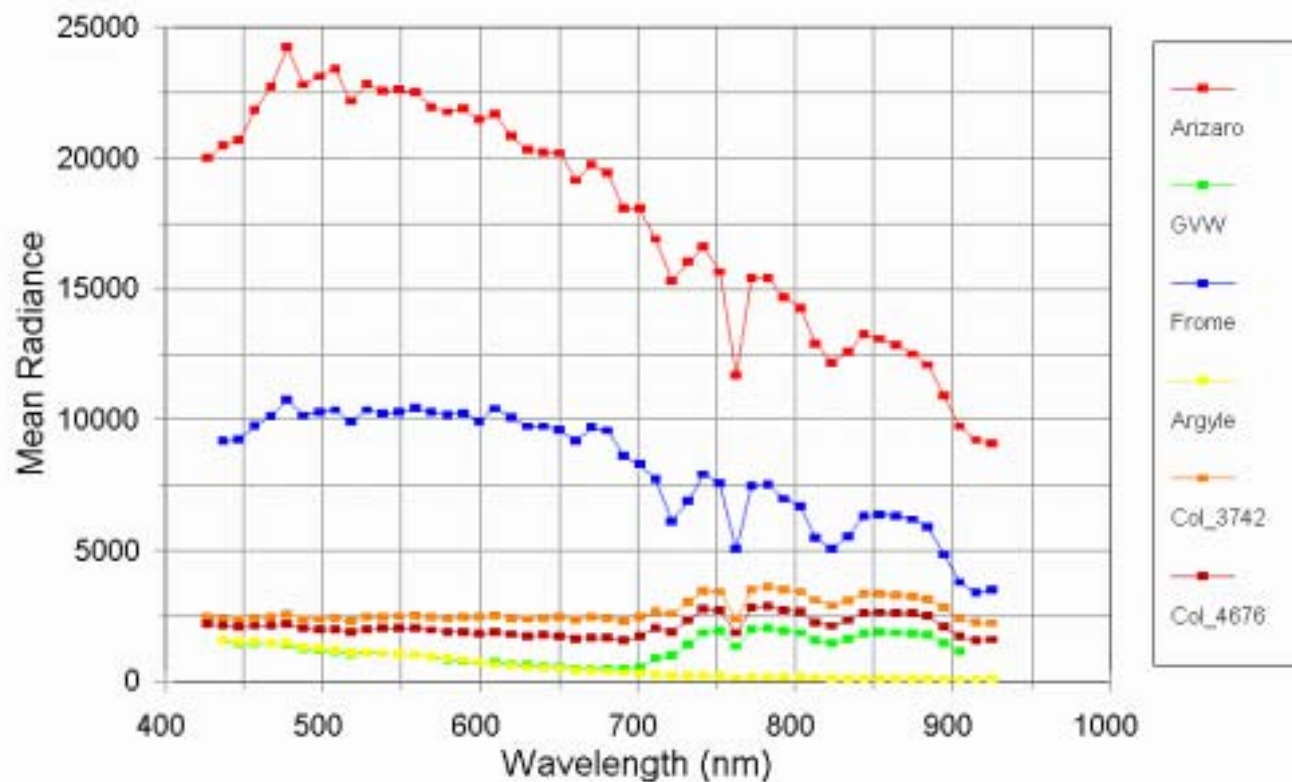


- The first term can be looked at as the slope of the “continuum” near the absorption area which produces a vertical offset in the data and the second term will be near linear positive near to the absorption maximum and crossing zero at the absorption maximum.
- It is the second term that creates a shape matching the smile.
- The following graph shows the means for the VNIR data in the images used:

# Mean VNIR Radiance



Summary for O2A Study  
Various Sites



# Continuum effect

- The oxygen-A area is clearly visible in all but the water data.
- It can also be seen that the local “continuum” has a weak negative slope for the two bright targets, positive for vegetation and very negative for water.
- This is what creates the vertical offsets in the previous plots.



# Discussion



- The simple index is sufficient to show that the shape of the smile is very stable and uniform between covers, between dates and in different parts of the world.
- However, it also shows that in order to estimate the absolute shifts in the smile it is necessary to know the underlying reflectance and the atmospheric model very well.
  - If these are uncertain the “continuum” variation can offset the smile effect and create apparent shifts that are not real shifts.
  - They will also be consistent for all the images if the land cover does not change very much. However, they will change a lot between land covers.
- The Lake Frome target is a very well known signature and can be used in such a study. However, it may not be needed if the groups investigating the smile establish that not only the shape but also the offset at this time is consistent with the TRW model.



# Discussion...

- It needs to be checked carefully if the 3 to 4 nm shifts previously suggested are artefacts due to the continuum effect or some offset based on the convention for the band centres in the ENVI header.
  - If not, and it is established that there is an offset then it must have occurred at launch since these studies and Rob Green have shown a high degree of consistency in the same area (same land cover) over time since launch and high consistency everywhere with the *shape* of the TRW model.
- The consistency of shape with the pre-launch model further suggests the smile was not altered during launch as mis-alignment would most likely create new shapes as well as magnitudes. However, all returns must be in to come to a final conclusion.
- This discussion is simply contributed to add information and suggest a pitfall that may create false offsets. Whatever the conclusion, the effects above are real and lead to some valuable conclusions and methods for smile reduction as described in Jupp et al. (2002).



# References

- Jupp, DLB, Jenny Lovell & Edward King, (2001). *The effects of spectral “smile” on Hyperion data analysis and options for their reduction*. Unpublished CSIRO Earth Observation Centre Report, June 2001.
- Jupp, D.L.B., Datt, B., McVicar, T.R., Van Niel, T.G., Pearlman, J.S., Lovell, J. and King, E.G. (2002). *Improving the Analysis of Hyperion Red Edge Index from an Agricultural area. Proceedings of the SPIE, Hangzhou, China, October 2002.*