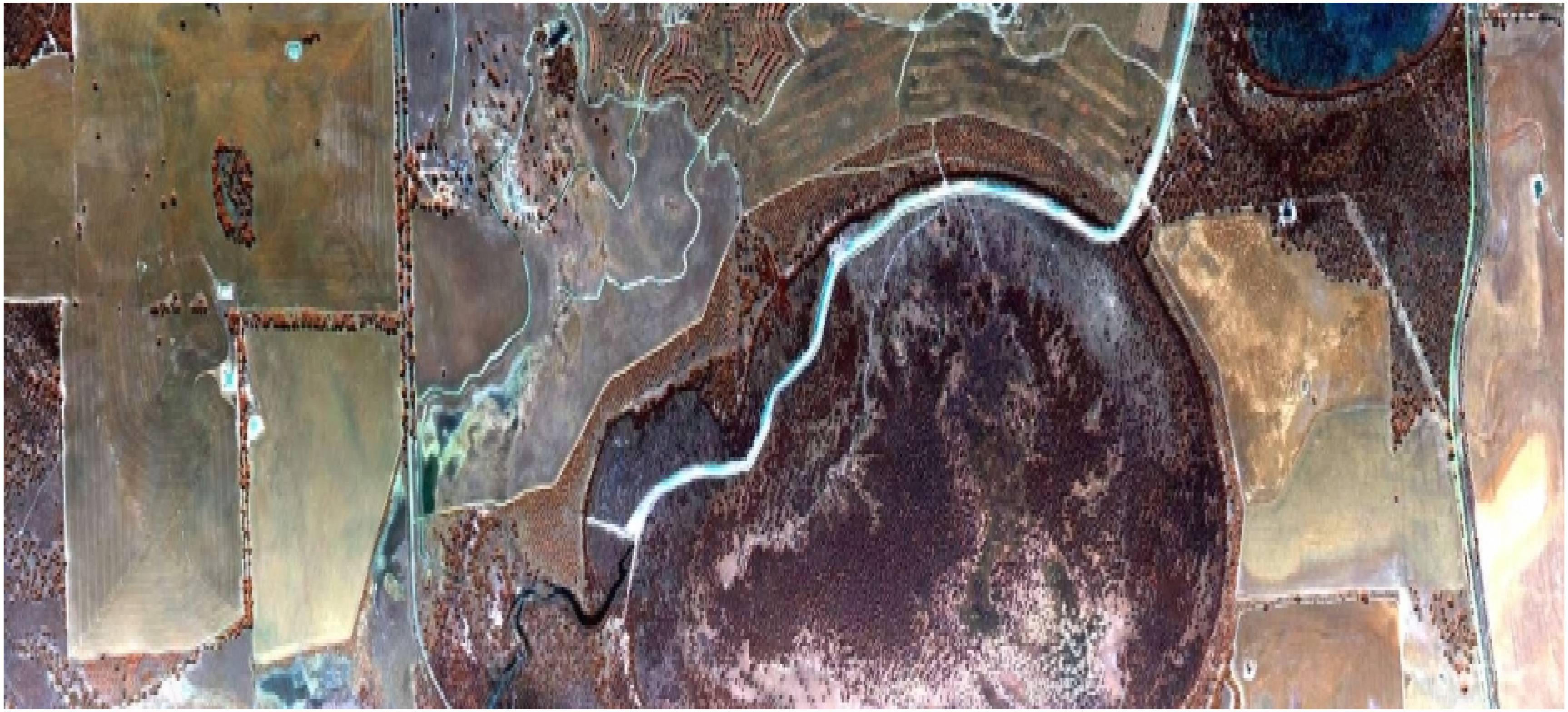
EOC Hyperspectral Science Meeting

May 4-5, 1999

OFFICE OF SPACE SCIENCE & APPLICATIONS
EARTH OBSERVATION CENTRE

Hyperspectral: PDF, Hymap Missions, Base Data & ARIES R&D



CEM, CLW, CWE, CFFP, CMIS, CMR

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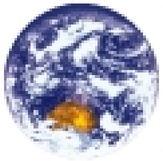
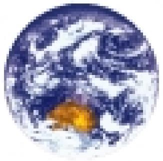


Outline of Discussion

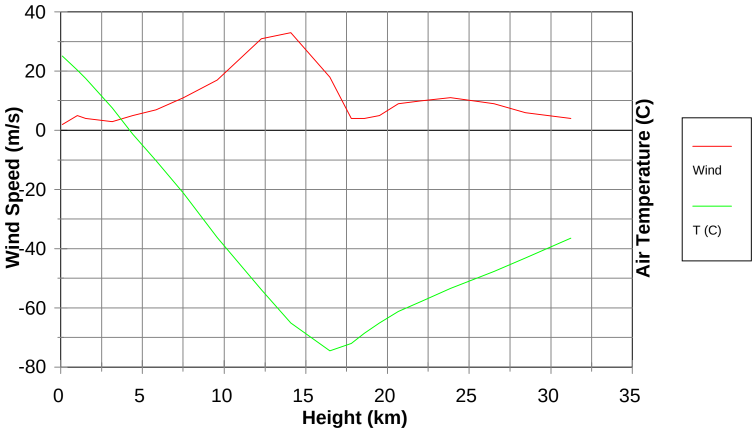
- Atmospheric Profiles (Sonde Data)
- Weather Station Data (Q,RH,Ta,V)
- Spectral Irradiance (Diffuse & Direct)
- Target Reflectance (PIFs and Panels)
- Atmospheric Modelling & Correction



Sonde or Atmospheric Profile Data

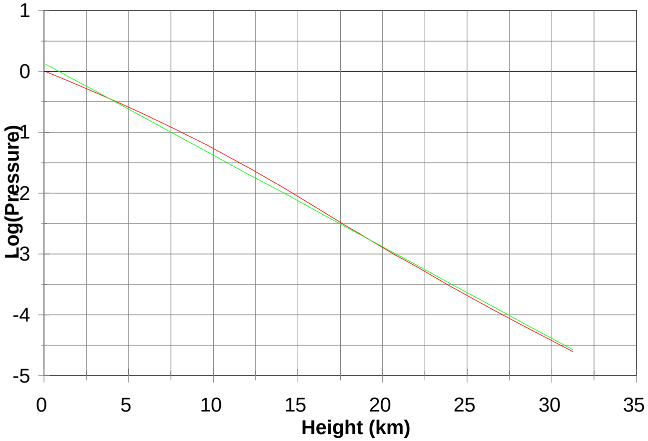
- Profile data are: [P, Ta, RH, [V]](z)
- Or Pressure, Air Temperature, Humidity, Wind Speed as a function of altitude (z)
- This is used in atmospheric correction and possibly surface energy balance
- Wind speed is not always available

Alice Springs Upper Air Statistics (UAS)



Alice Springs UAS November

Upper Air Winds



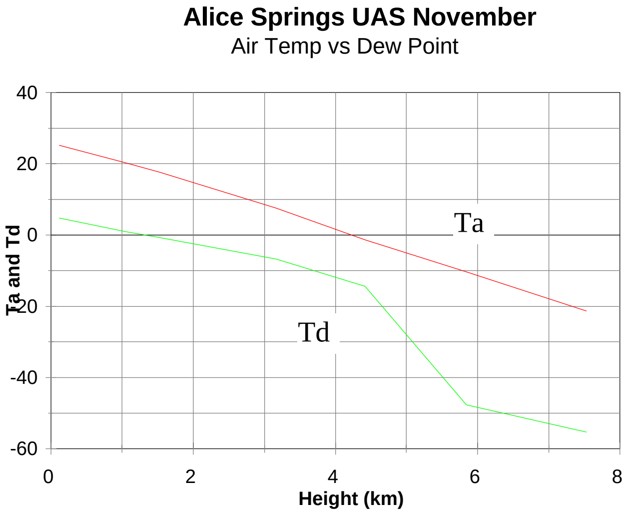
Alice Springs November

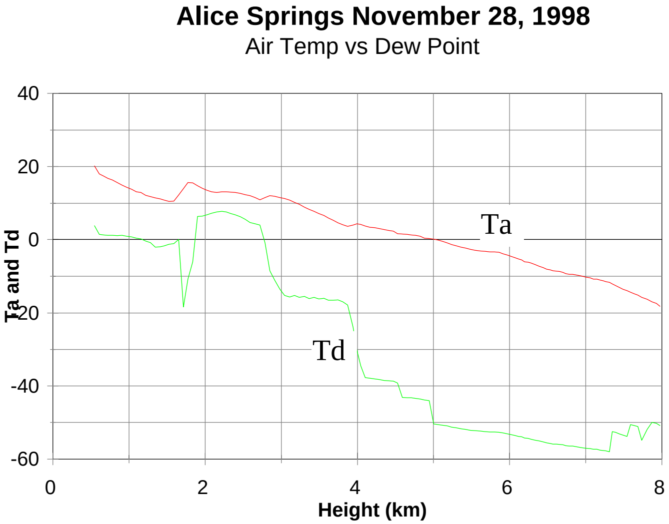
LogP vs Altitude

Sources of Data

- Upper Air Statistics (Maher & Lee, 1976)
- Nearby airport/met station
- EOC/CAR Sondes
- Aircraft measurements (esp at various heights)
- (Water Vapour can be RH%, MR, vapour pressure, dew point (Td) or vapour density)

Alice Springs Average UAS vs Local Radiosonde





Simplified Profile Models

$$\rho_a(z) = \rho_a(0)\, e^{-c_1 z}$$

$$\rho_w(z) = \rho_w(0)\, e^{-c_2 z}$$

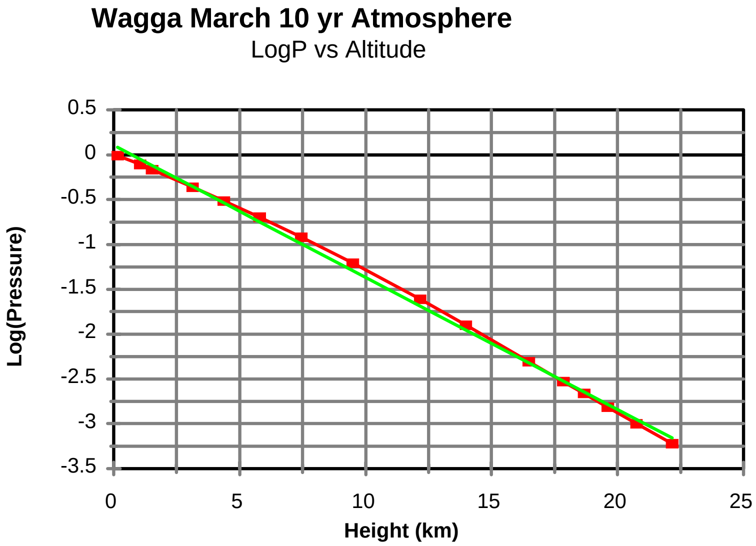
$$\frac{P(z)}{P(0)} \left[\frac{T(0)}{T(z)} \right]^{0.5} = e^{-c_3 z}$$

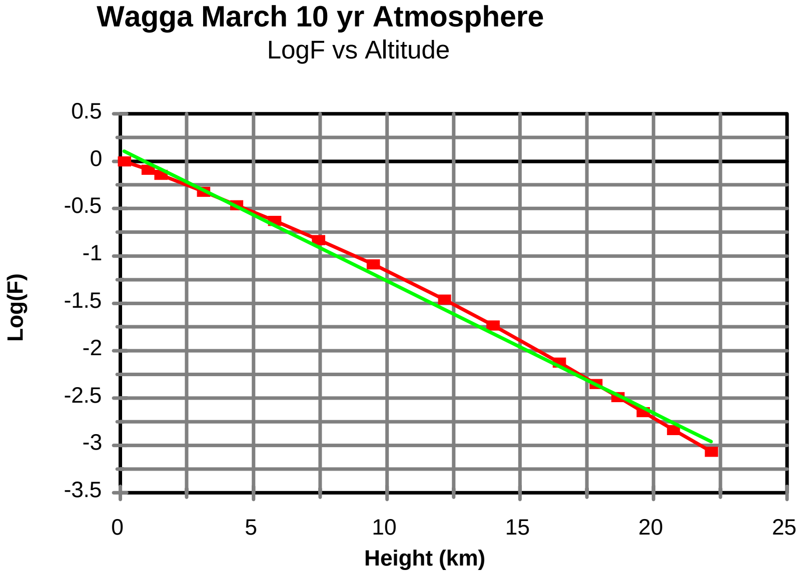
$$P(z) = P(0)\, e^{-c_1 z}$$

where:

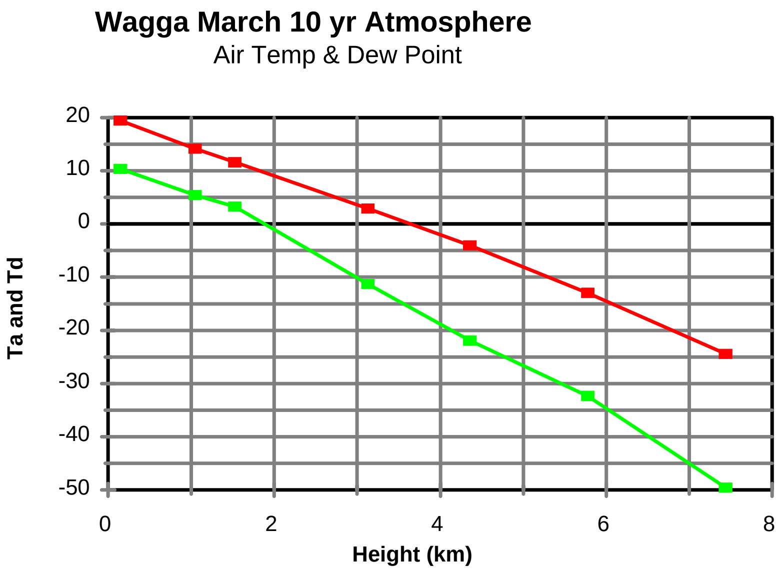
P is total pressure (Pa)
T is absolute temperature (K)
ρ_a is the density of air
ρ_w is water vapour density and
z is altitude above the surface.

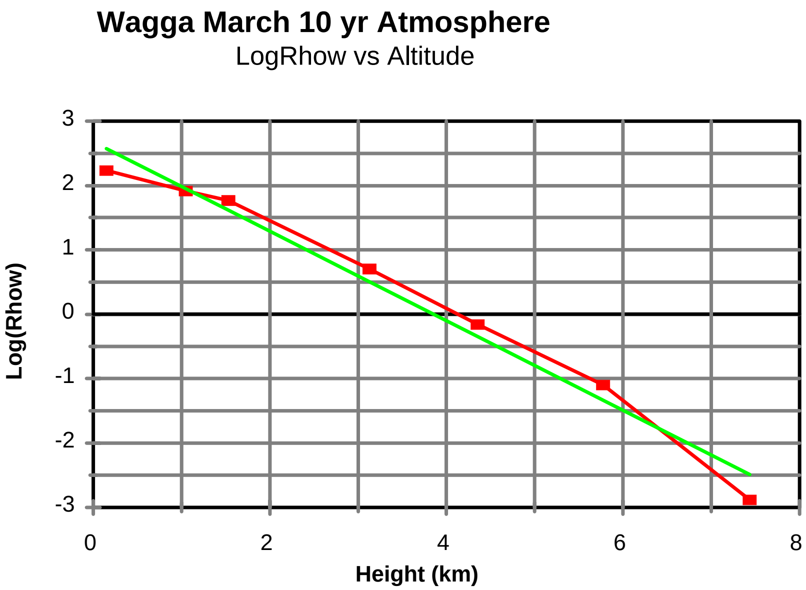
The constants c1 & c3 - Air Pressure and Temperature





Atmospheric Water Vapour - c2

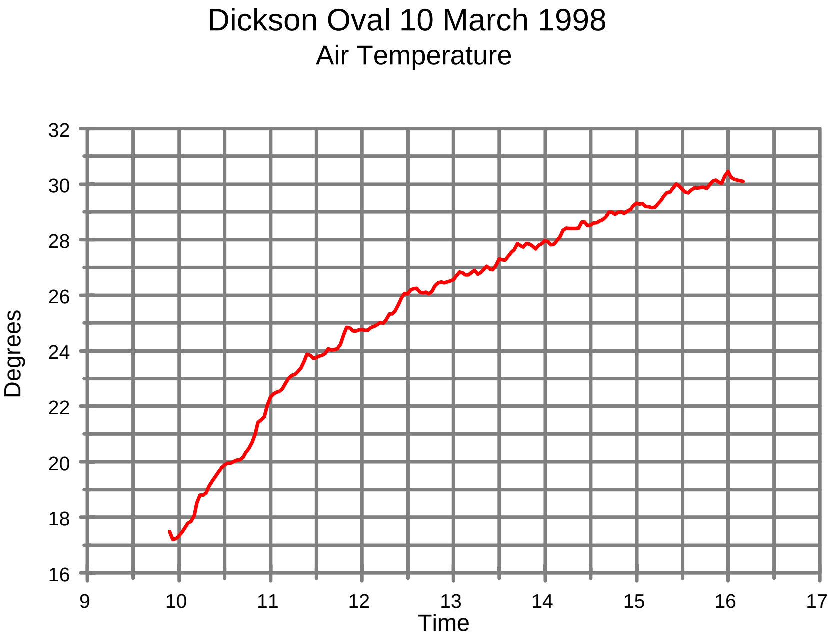


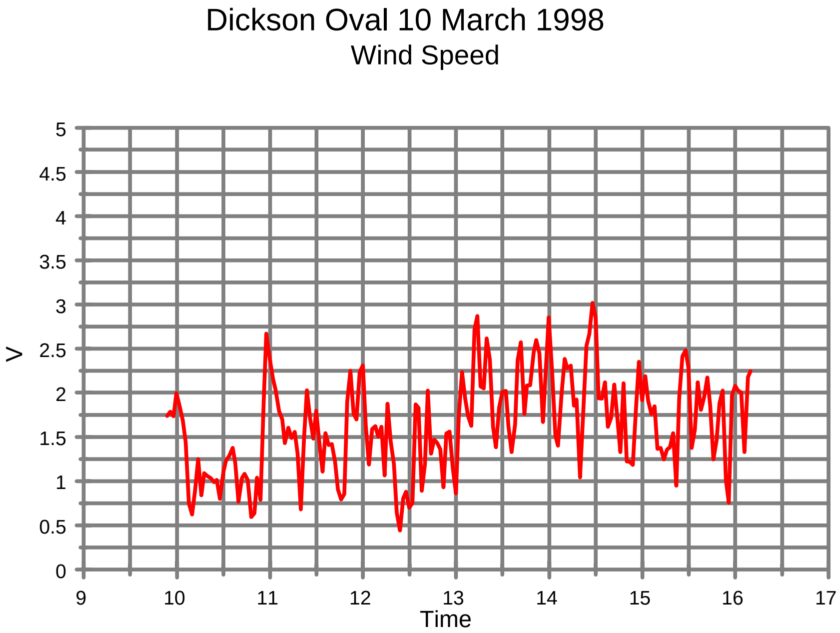


Data Use

- Combinations of UAS and local information are usually needed to construct a profile
- Simplified models allow the surface (Met Station) data to drive the atmospheric profile
- The detailed shape of the profile is not critical

Weather Station Data
Air Temperature & Wind Speed





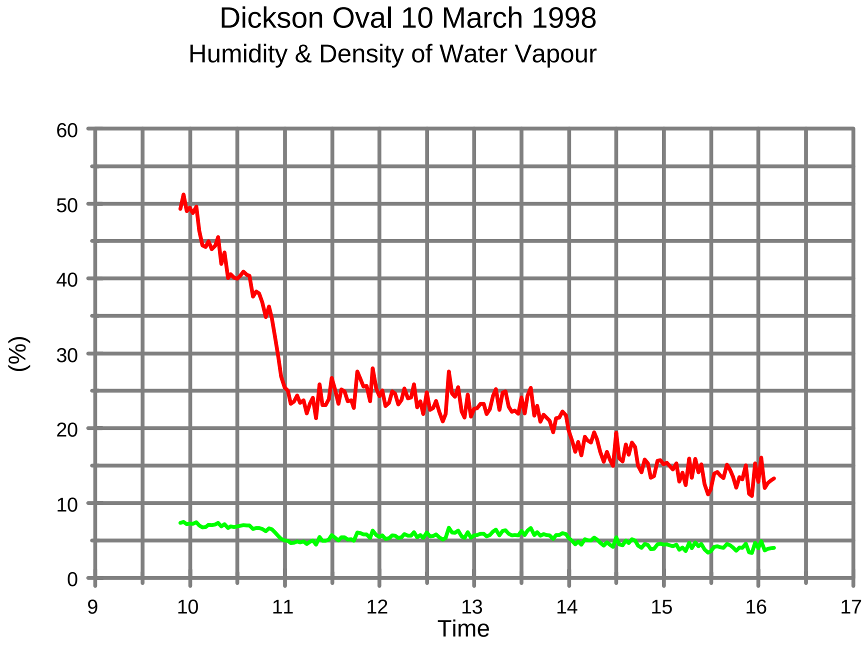
Atmospheric Water Vapour

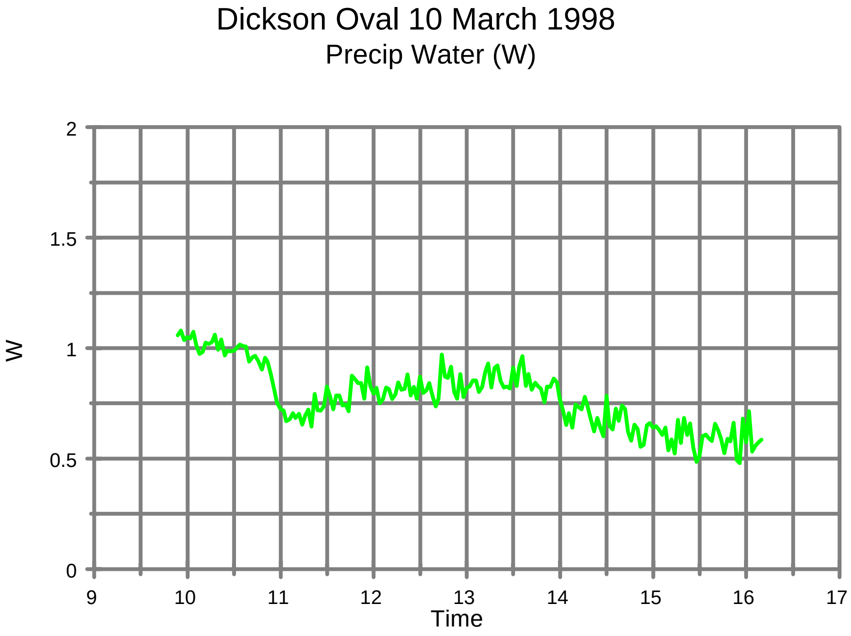
$$\begin{aligned} W(h) &= \int_0^h \rho_w(z)\, dz \\ &= \frac{\rho_w(0)}{c_2}(1-e^{-c_2 h}) \\ &= W\,(1-e^{-c_2 h}) \end{aligned}$$

$$RH = 100 \times \frac{\rho_w}{\rho_w^*(T)}$$

$$\rho_w^* = A\, e^{a_0 + a_1 A + a_2 A^2} \qquad (A = T_0 \,/\, T)$$

Weather Station Data
Humidity, ρ_w & W



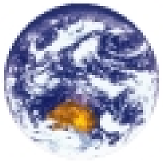


Solar Radiation Model

$$Q_s = Q_0' \cos\theta_s \, t^{m^{\alpha}/2}$$

where:

Q_0' is the exoatmospheric irradiance modified for sun-earth distance
θ_s is the solar zenith angle
m is the air mass (Kaasten’s formula)
t is atmospheric transmittance, and
α is a parameter modifying the air mass

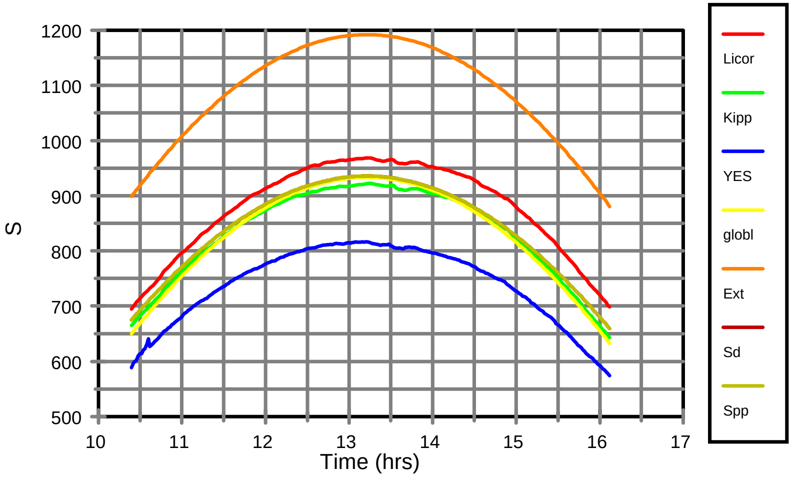


Clear Day Solar Radiation

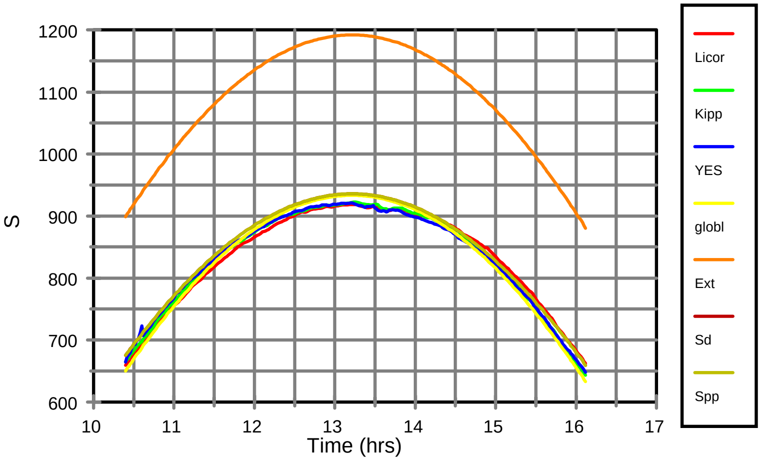
Case	t	α
Prata & Grant[1] (both)	0.6188	0.450
Prata & Grant (Darnell)[2]	0.6188	0.620
Paltridge & Platt[3] (both)	0.6422	0.5939
Paltridge & Platt (Darnell)	0.6469	0.6644
Dickson Oval[4] (both)	0.6288	0.5968
Dickson Oval (Darnell)	0.6318	0.6408

1. 248 apparently clear days at Uardry
2. $\alpha = 1.1 + 1.0\ Log t$
3. 5 years of clear days at Aspendale
4. One day March 3, 1998 at Dickson Oval

Cross-Calibrating Solar Radiation

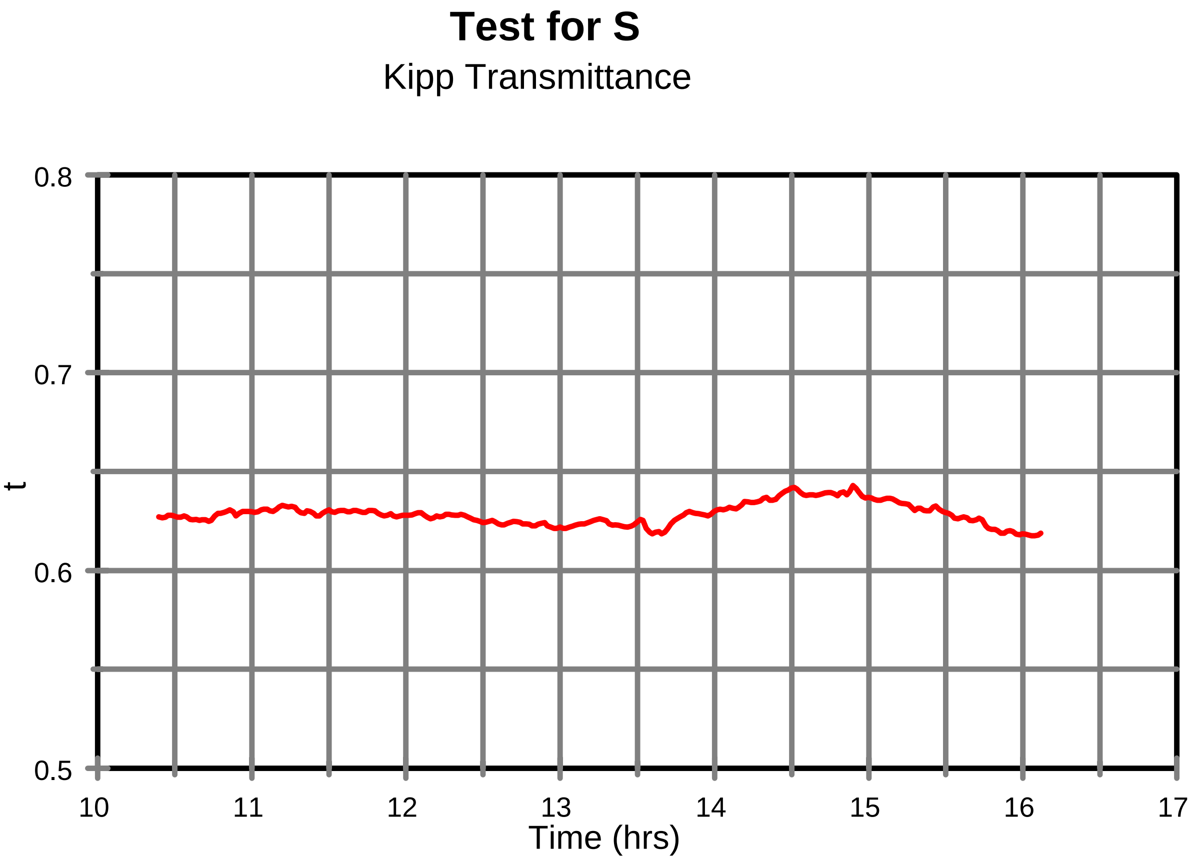


Test for Solar Radiation
Licor, Kipp & YES



Test for S
Licor, Kipp & YES

Dickson Oval Transmittance



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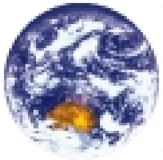


Solar Radiation Data

- These data provide data integrity and environmental conditions
- Learning to interpret Kipp transmittance will help “calibrate” atmospheric models
- Cross calibration with the Yankee MFR

Direct & Diffuse Spectral Irradiance

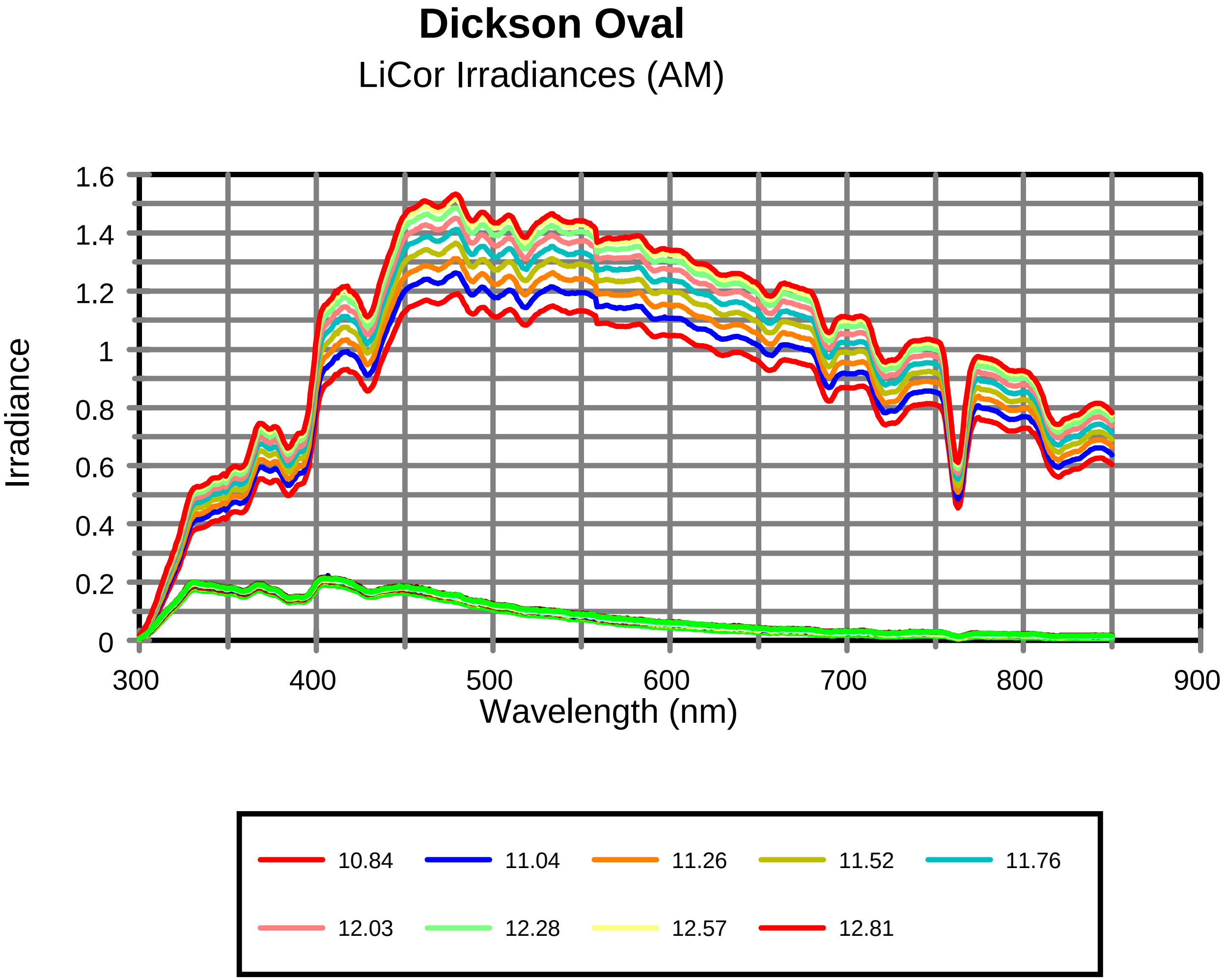
$$E_T(\mu_s, h, \lambda) = \frac{E_T(\mu_s, 0, \lambda)}{T(\mu_s, h, \lambda)}$$

$$E_{dir}(h, \lambda) = \frac{t(\mu_s, \infty, \lambda)}{t(\mu_s, h, \lambda)} \mu_s \, E_0^{'}(\lambda)$$

$$E_T^*(\mu_s, h, \lambda) = \frac{E_T(\mu_s, h, \lambda)}{1 - s(h)\, \rho^*}$$

$$E_{dif}(h, \lambda) = E_T^*(h, \lambda) - E_{dir}(h, \lambda)$$

LiCor Measured Total & Diffuse Irradiance



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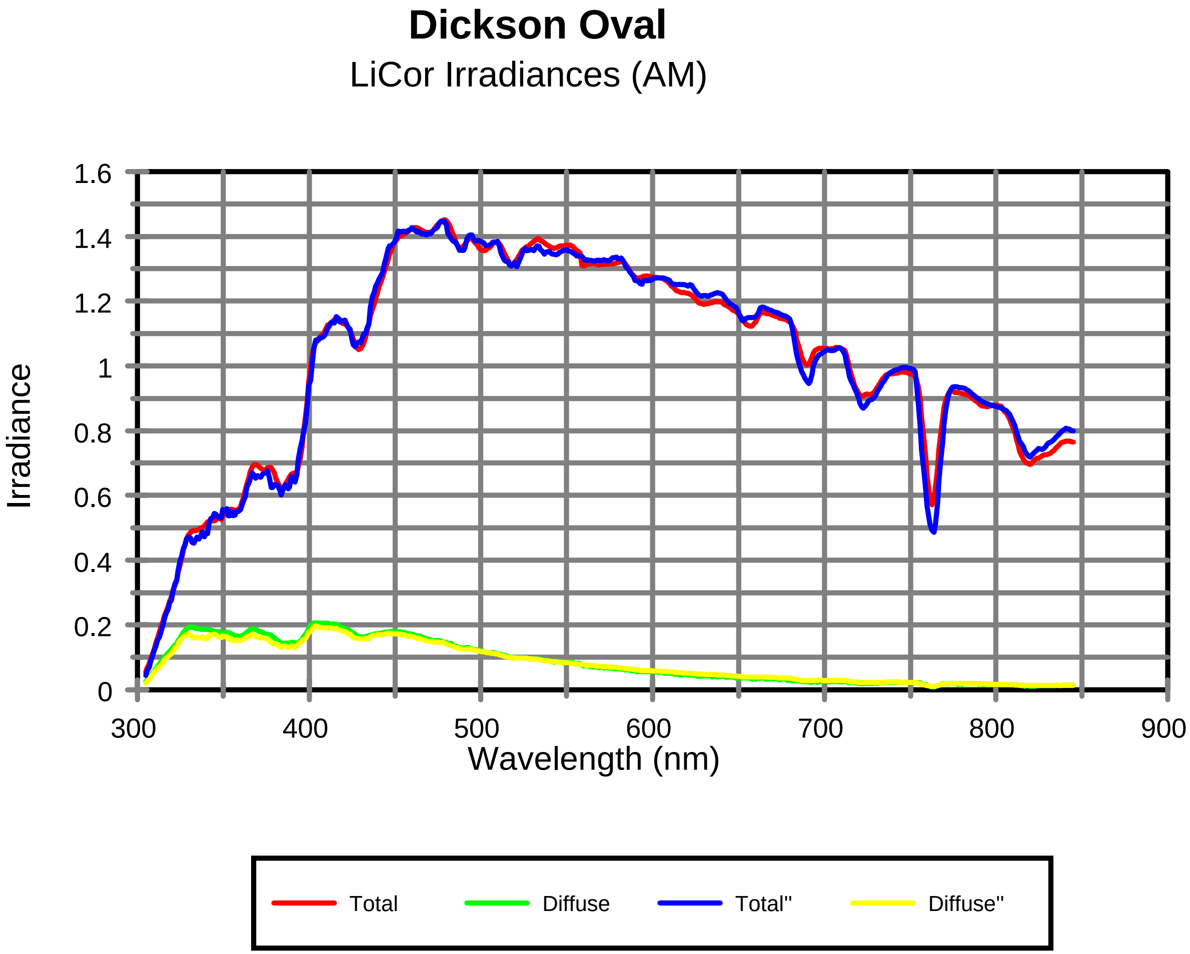
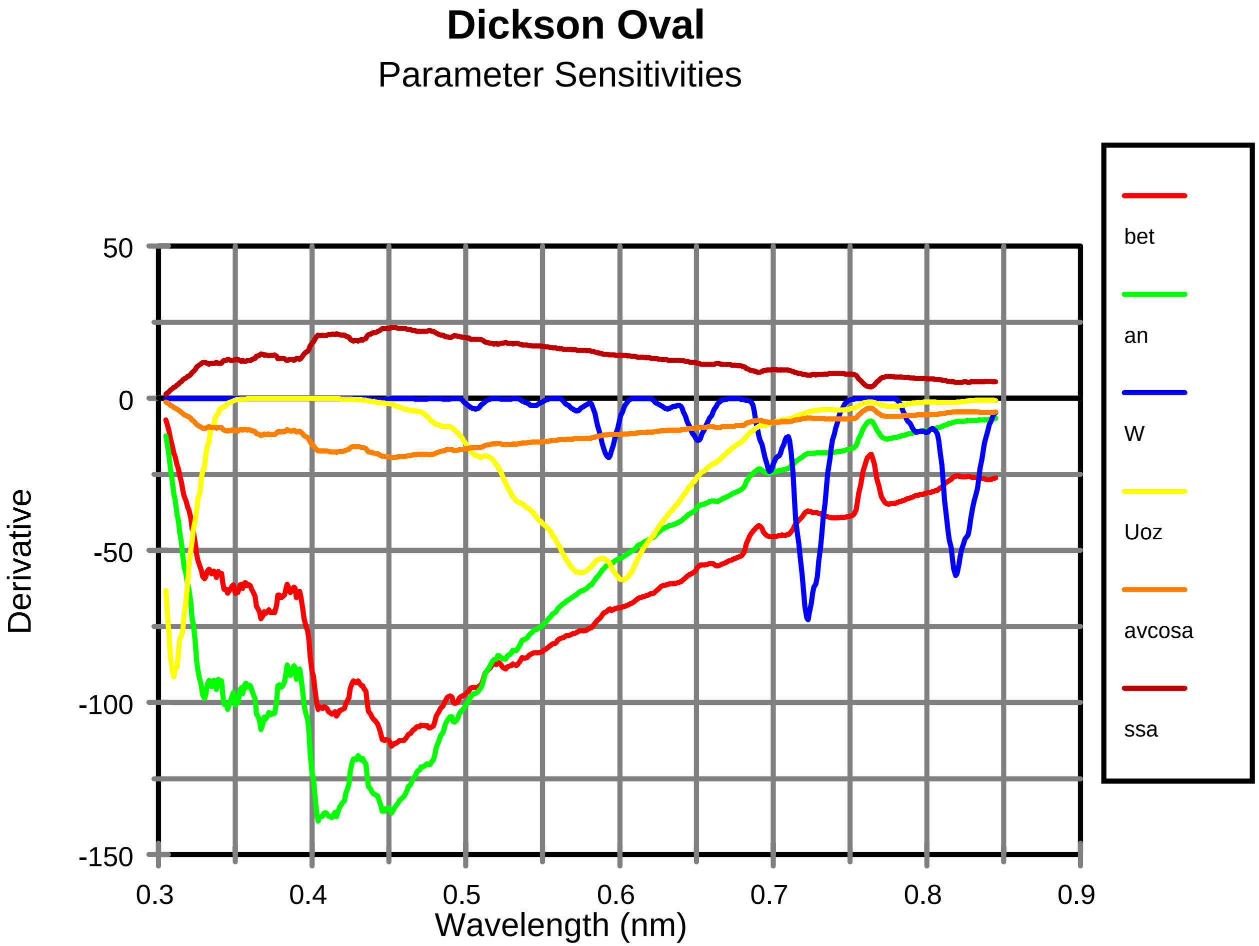
Inversion of Irradiance Model provides input to Atmospheric Model



Sensitivity Analysis of Irradiance Model



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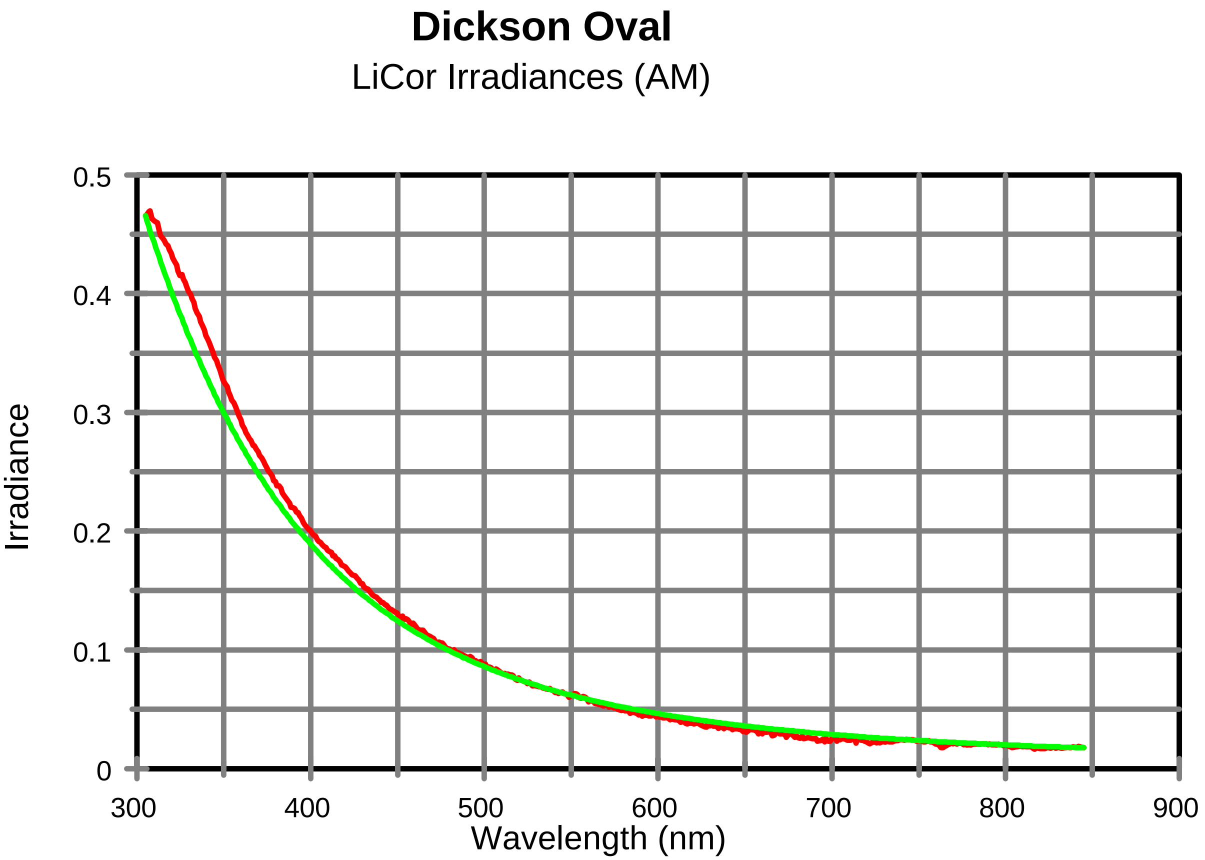
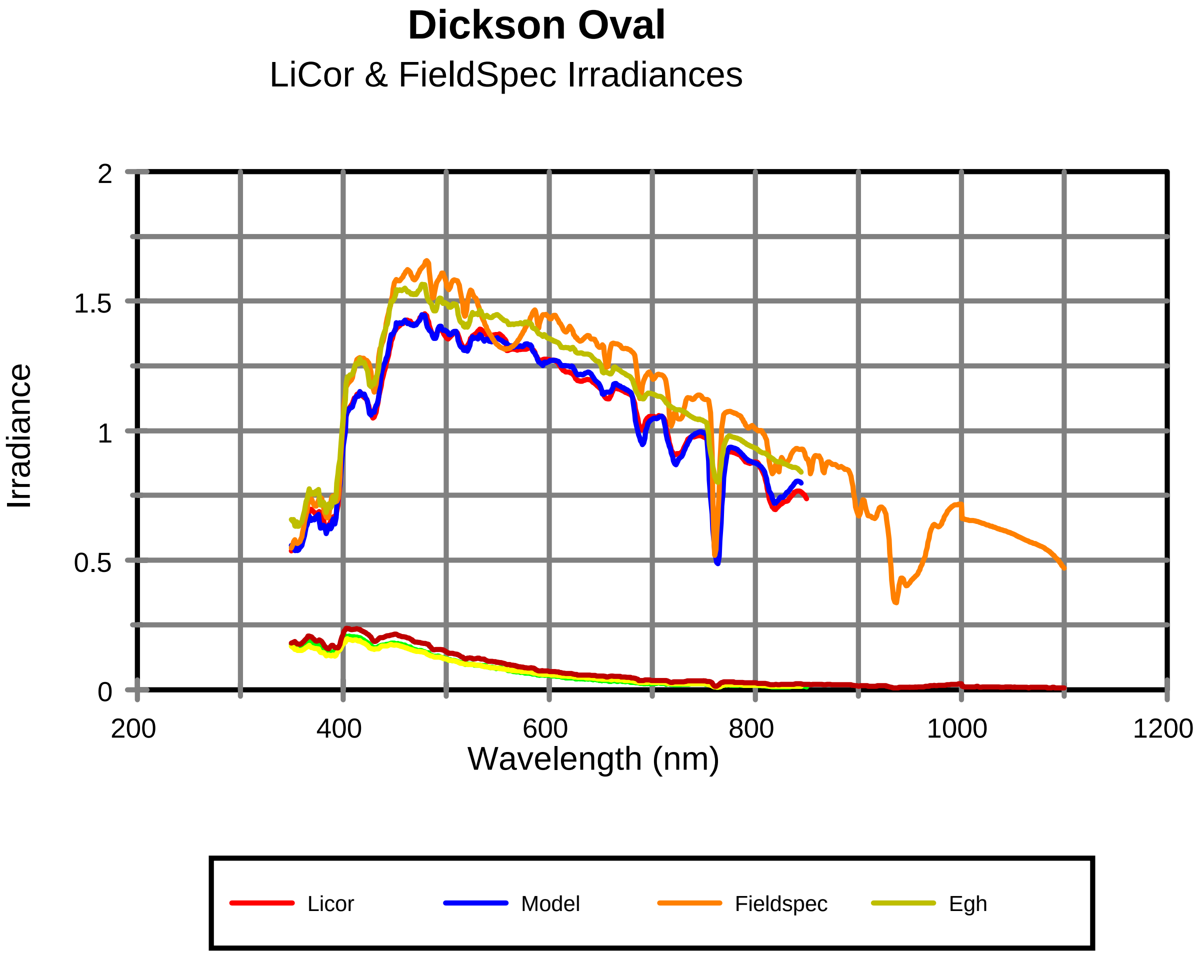
Diffuse to Total Ratio



ADS FieldSpec Irradiance



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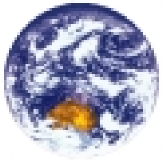
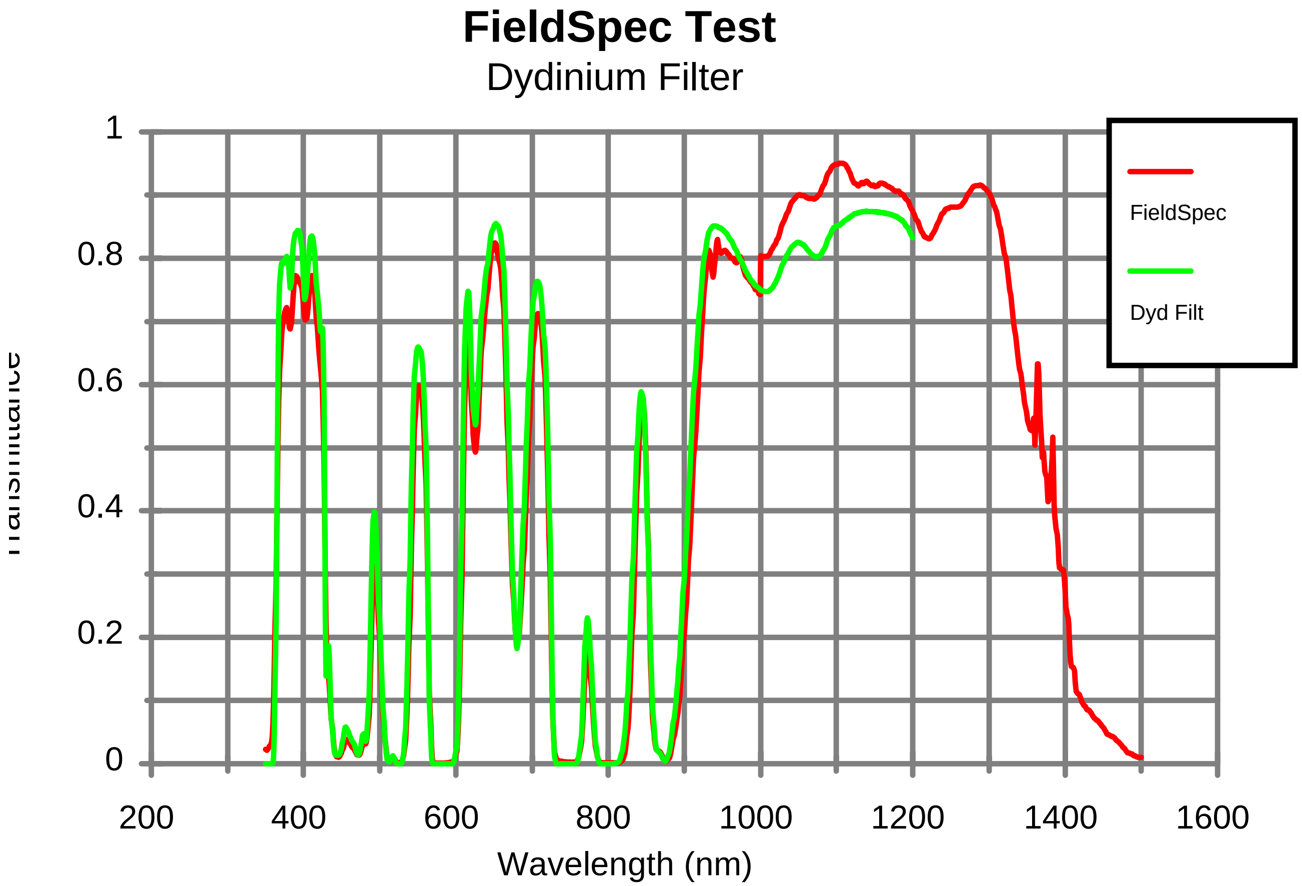


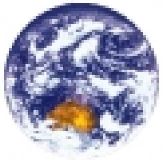
Wavelength Calibration

- Wavelength calibration is best done by instrument maker
- Tests for stability should always be done in the field
- Dydinium filter transmittance using irradiance or panel is a useful method

Testing FieldSpec Wavelength Cal



Measuring Field Spectra using a Reference Panel



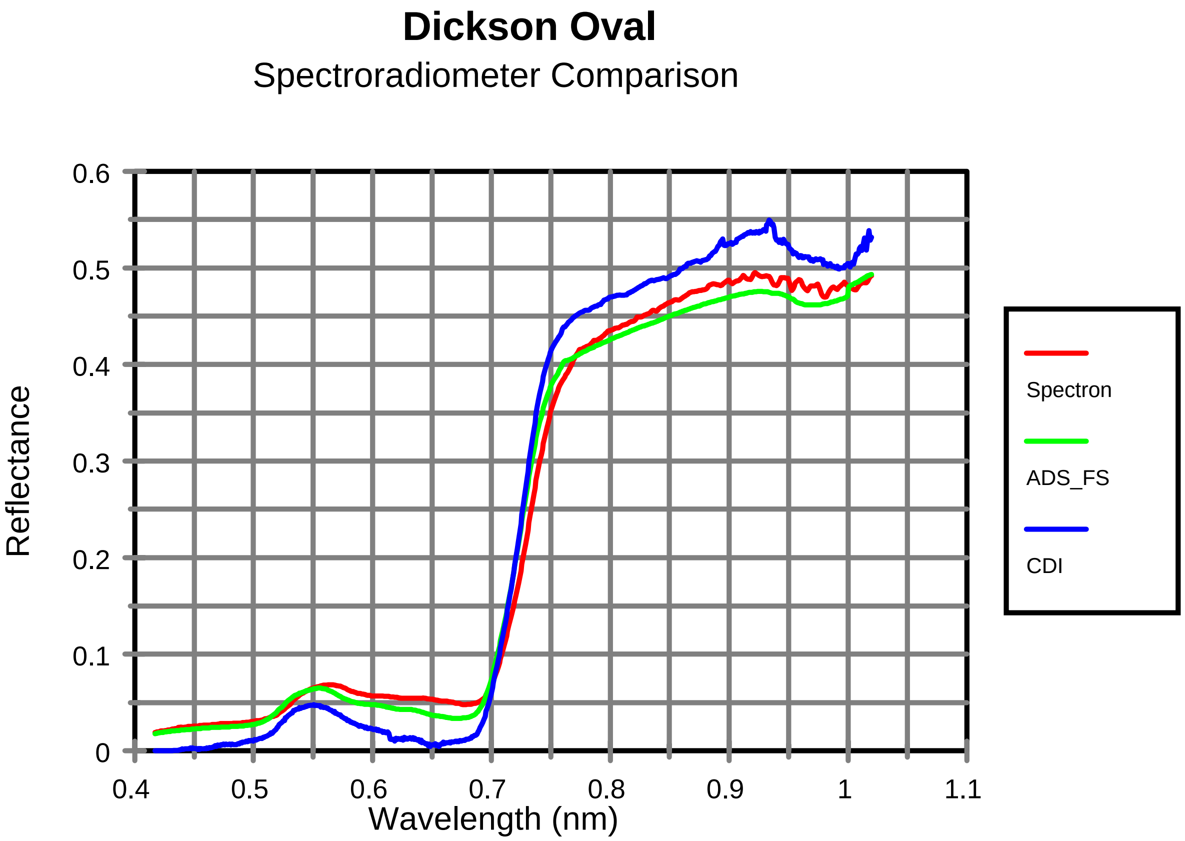
$$\rho_t(\mu_r, E_d) = \frac{\pi\, L_t(\mu_r)}{E_d}$$

$$\rho_s(\mu_r, E_d) = \frac{\pi\, L_s(\mu_r)}{E_d}$$

$$\rho_t(\mu_r, E_d) = \rho_s(\mu_r, E_d)\,\frac{L_t(\mu_r)}{L_s(\mu_r)}$$

$$= \rho_s(\mu_r, E_d)\,\frac{V_t}{V_s}$$

Grass Spectra at Dickson – The SAME Grass & Panel!



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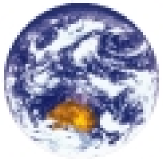
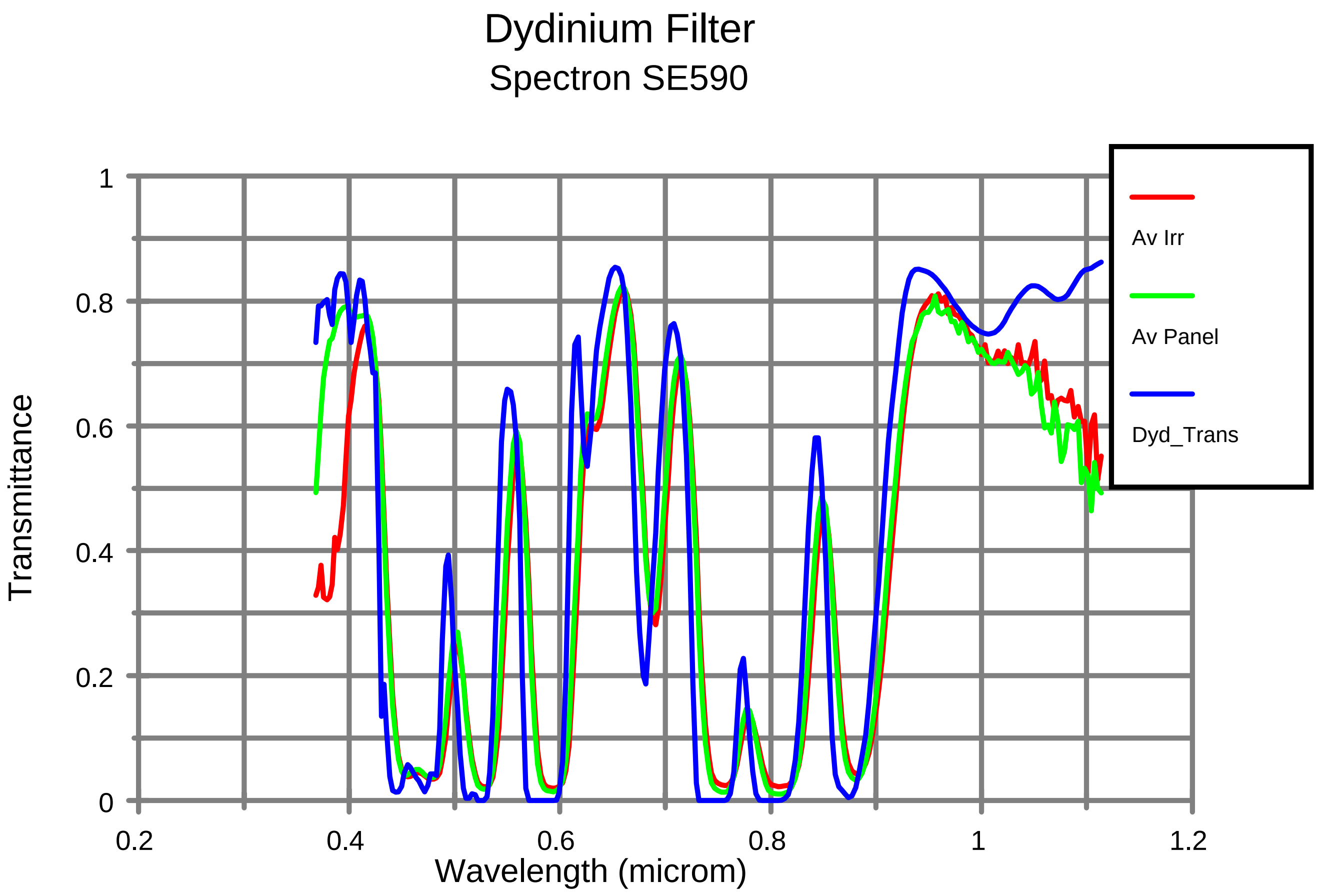
Varying Results for the same target?



- The spectron had lost wavelength calibration
- The CDI detector radiometric calibrations seem to be variable
- The ASD has unacceptable “jumps” even after division by panel radiance

Testing Spectron Wavelength Cal



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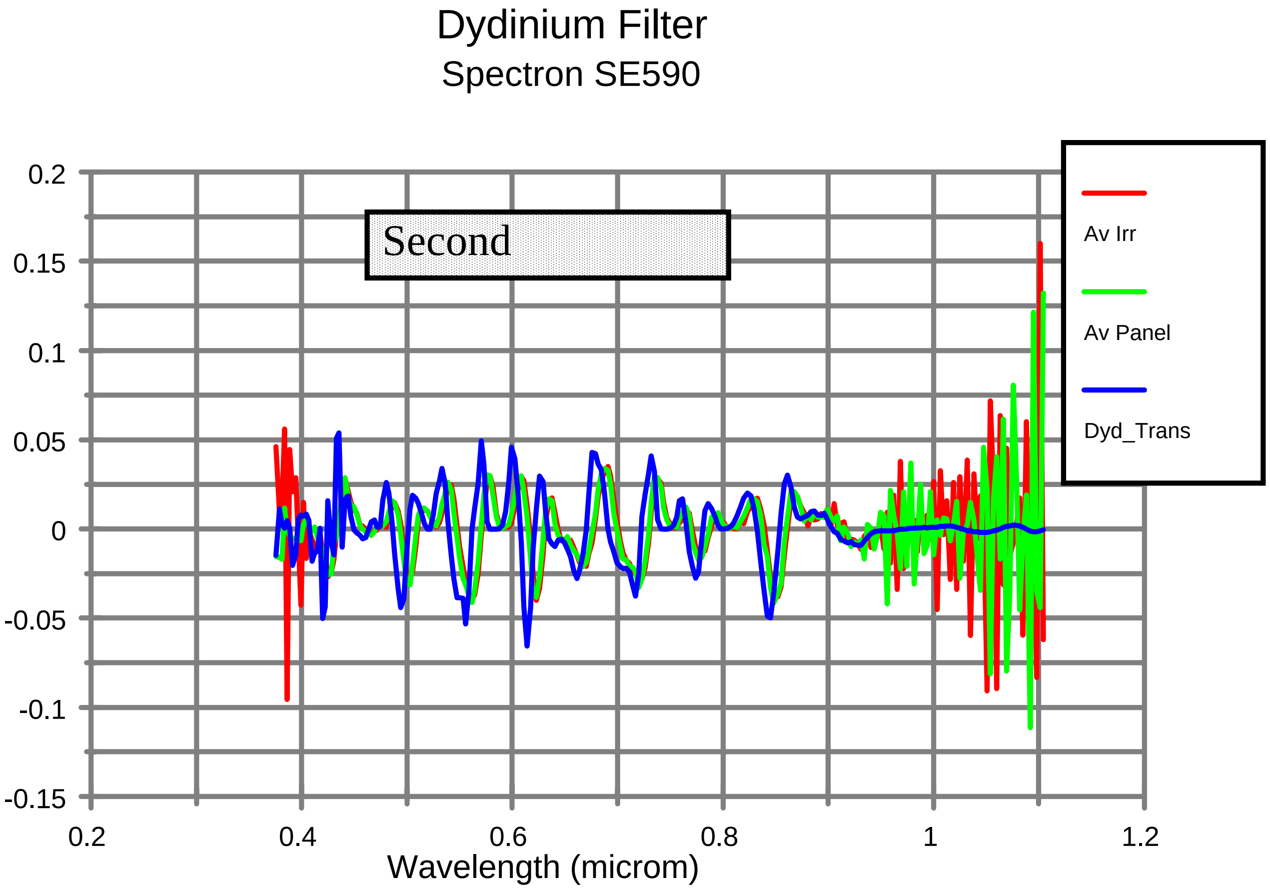
Second Derivatives of Spectra



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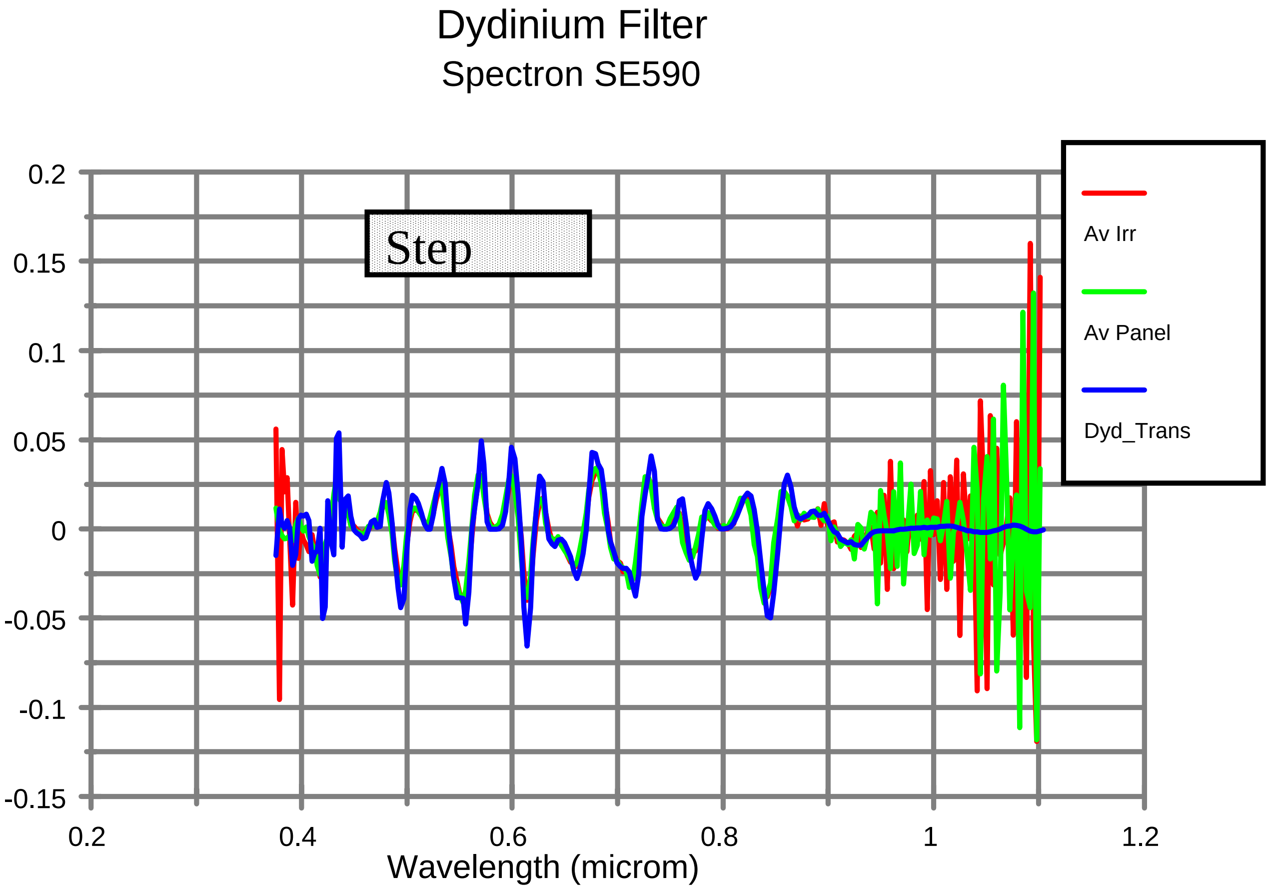
Shifted 3 Detectors



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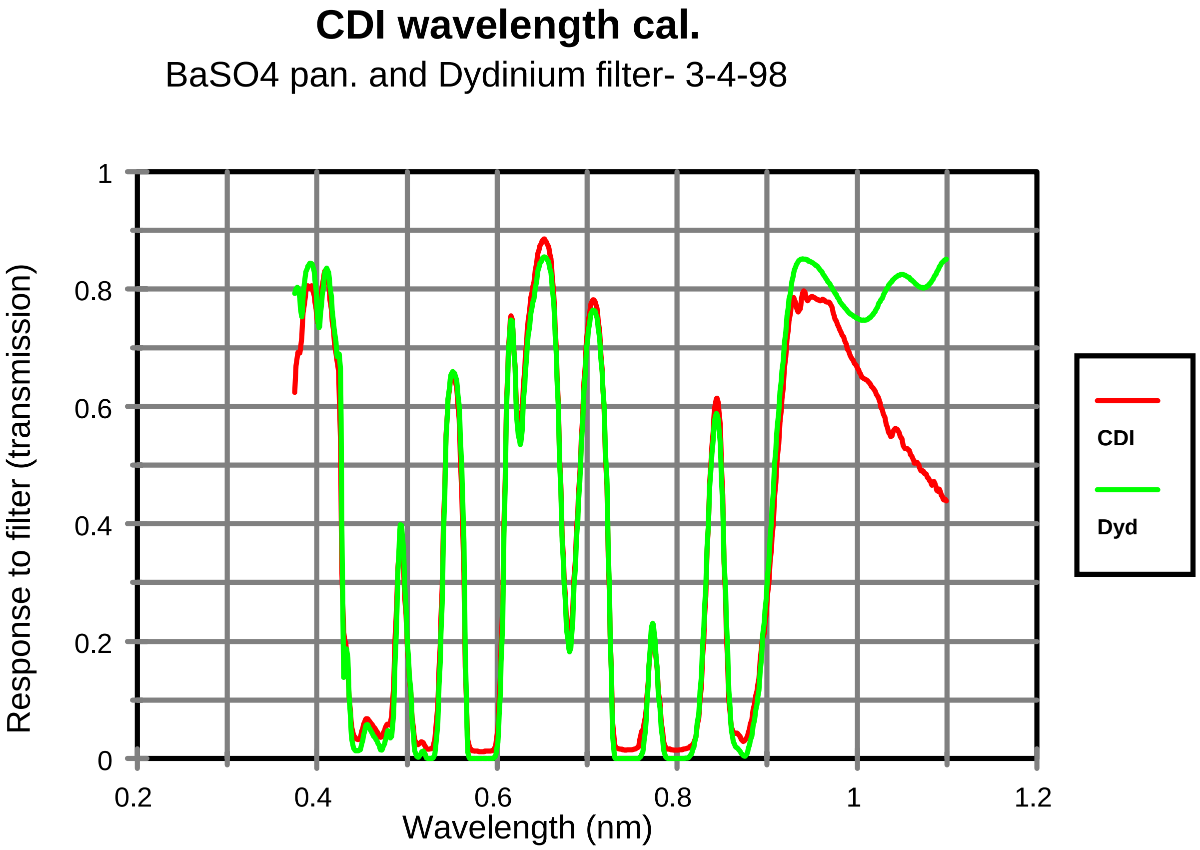
Testing CDI Wavelength Cal



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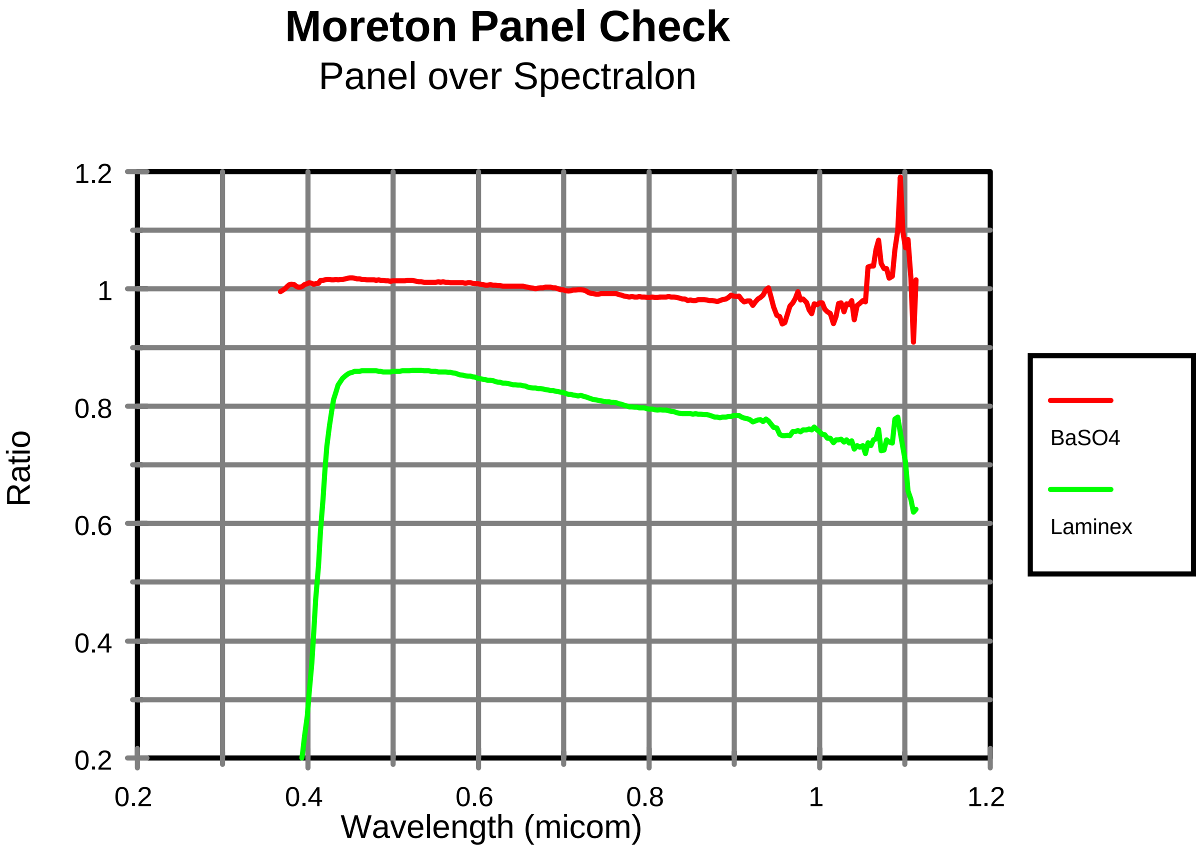
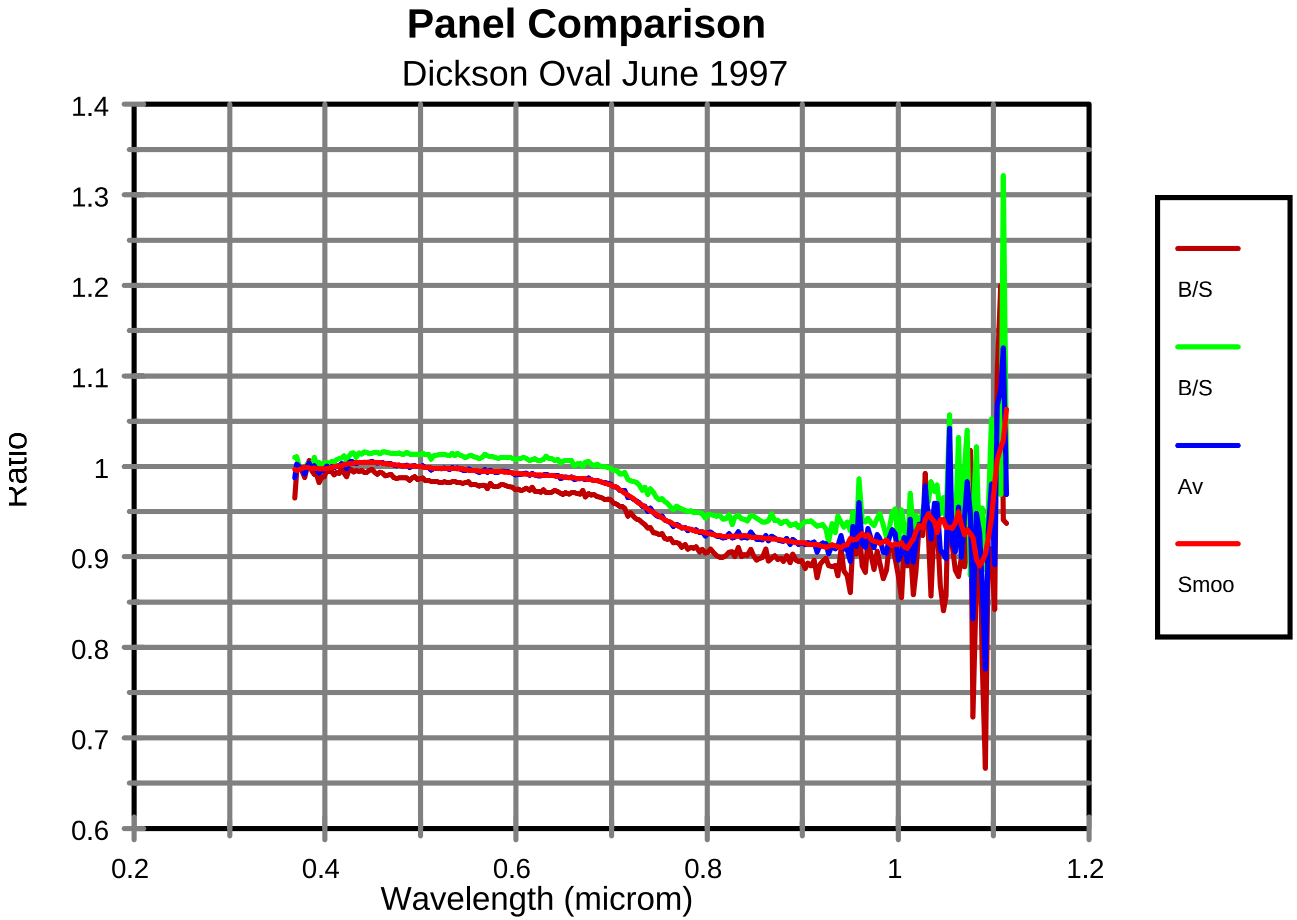
Panel “Calibration”

- Panels must also be calibrated and tested
- Laboratory reference panel must be carefully maintained
- Field standards need testing after each mission
- Panel K factors – including BRDF must be known

Comparing Panels



Panel Variations



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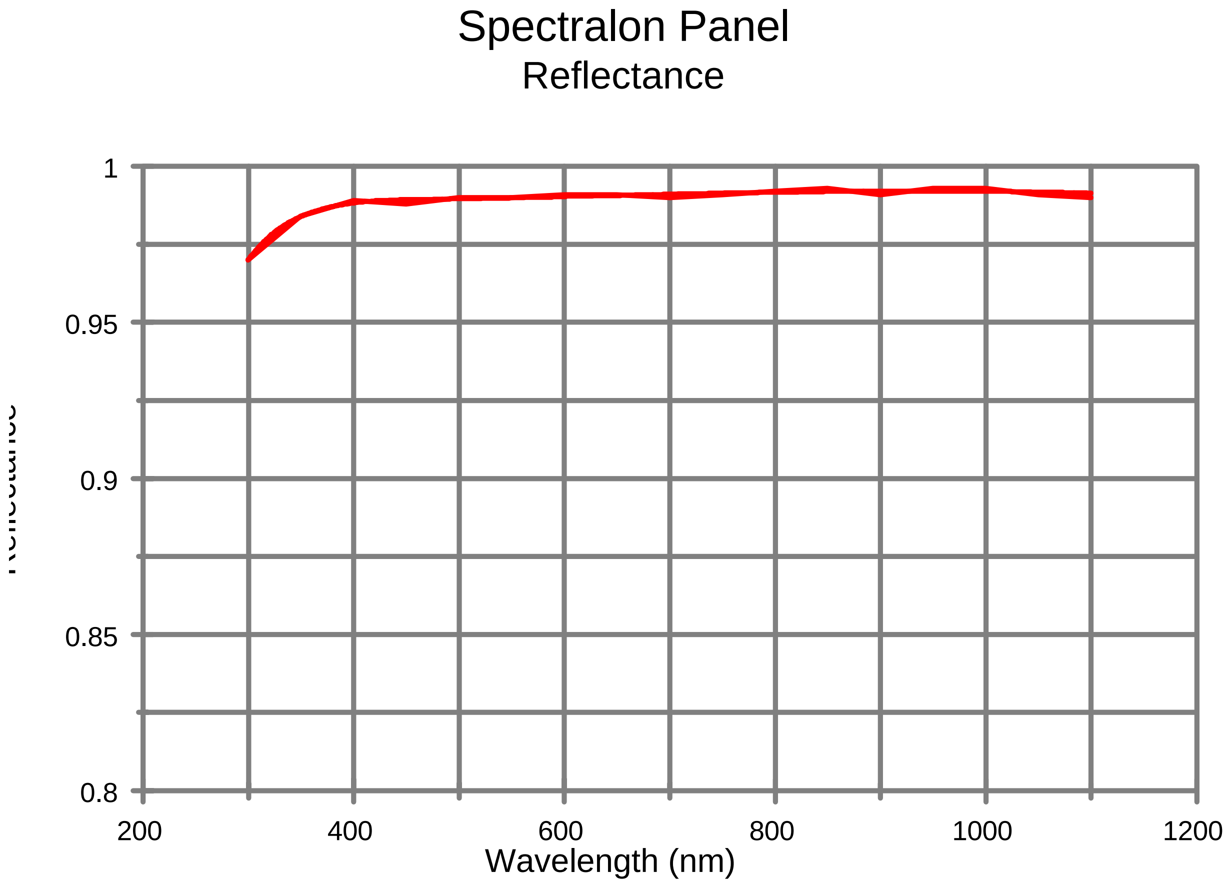
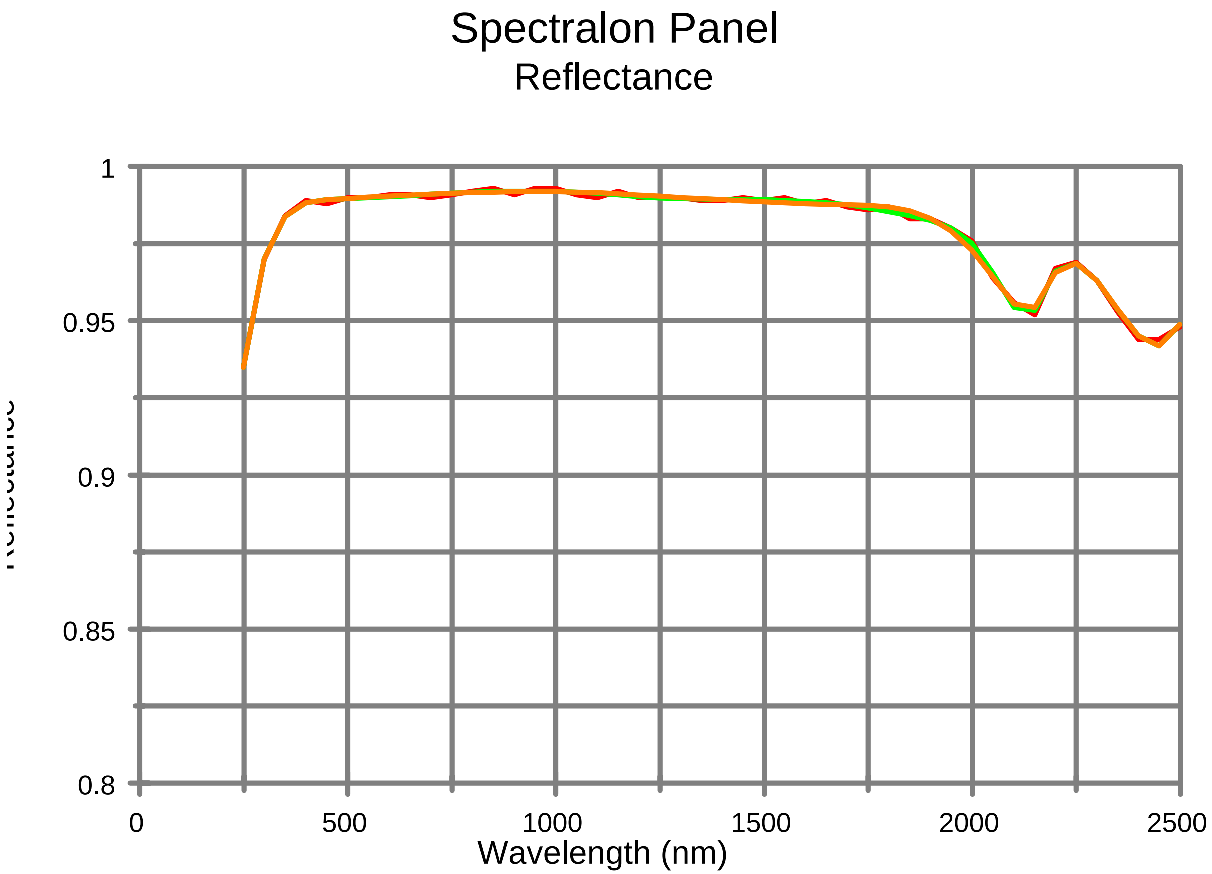
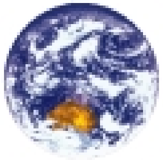
Spectralon Published Reflectance



Published Spectralon Reflectance



Using the Data



- Atmospheric Irradiance Model can be used to set parameters for the atmosphere
- Field spectra can be used to modify the atmospheric correction of the airborne data
- Changes in atmospheric conditions can be monitored by Weather Station
- BRDF effects can be established in the field

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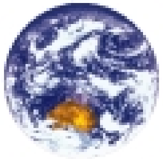
Atmospheric Model



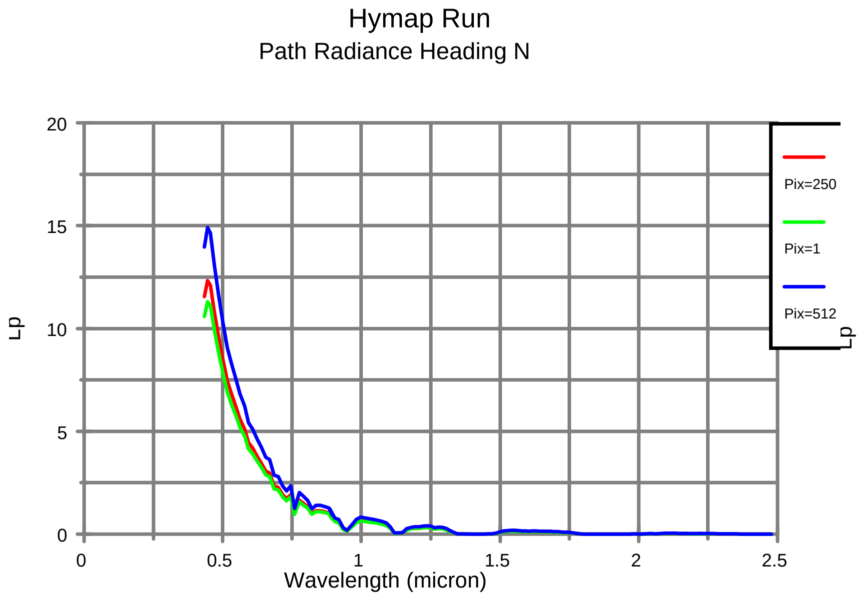
$$L_t(\mu_o,\mu_s,h,\lambda)=\frac{1}{\pi}E_T\; t(\mu_o,h,\lambda)\,\frac{\rho_t+\rho_{env}}{1-s\rho^*}+L_p(\mu_o,\mu_s,h,\lambda)$$

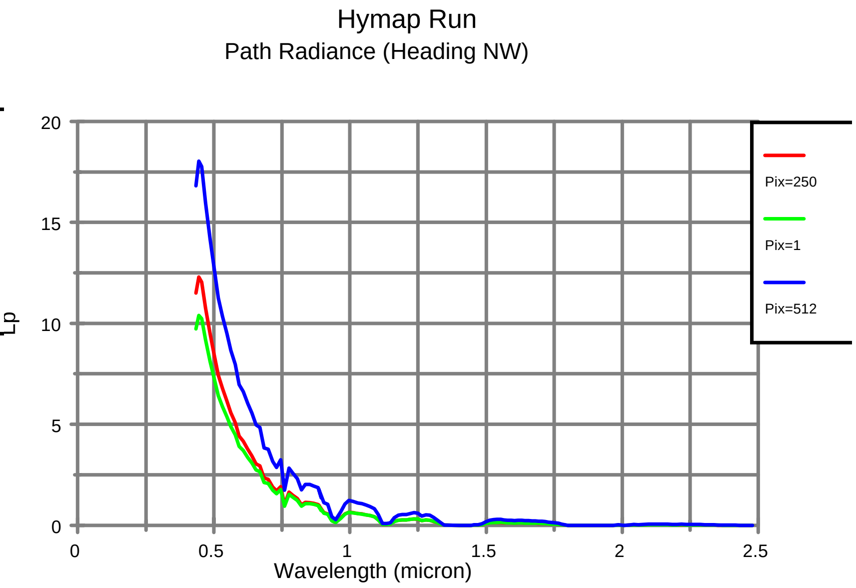
$$\rho_{env}=\rho^*\left[\frac{T(\mu_o,h,\lambda)}{t(\mu_o,h,\lambda)}-1\right]$$

$$\Big[E_T,t(\mu_o),T(\mu_o),T(\mu_s),s,s(h),L_p(\mu_o)\big[,L_g(\mu_o)\big]\Big]$$

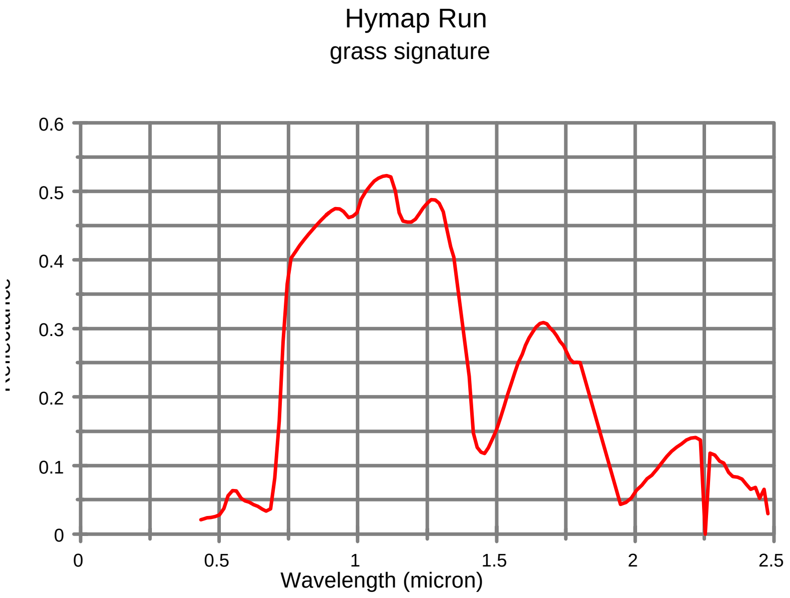
Hymap Simulated Transmittance (aircraft at 10,000 feet)

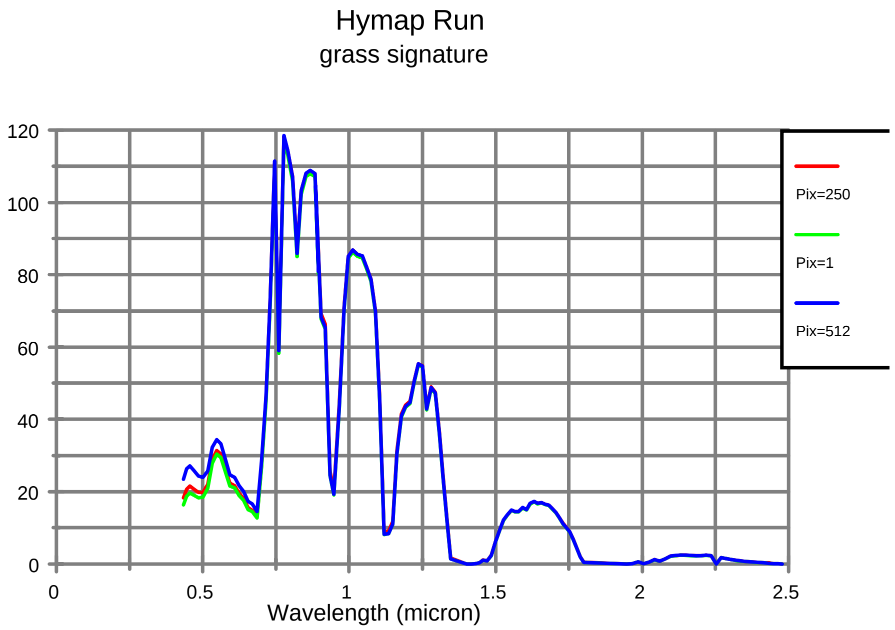
Path Radiance MVA Effects

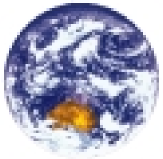




HyMap Simulated Grass Signature







Atmospheric Correction

$$L^{*}(\mu_o) = \frac{1}{\pi} E_T \; T(\mu_o) \frac{\rho^{*}}{1 - s\rho^{*}} + L_p(\mu_o)$$

$$L_{\min}(\mu_o) = \frac{1}{\pi} E_T (\; T(\mu_o) - t(\mu_o)) \frac{\rho^{*}}{1 - s\rho^{*}} + L_p(\mu_o)$$

$$\rho_t = \frac{\pi(1 - s\rho^{*})(L_t - \dfrac{L_p(\mu_o)}{(1 - s(h)\rho^{*})} \left[-L_g(\mu_o) \right])}{E_T \; t(\mu_o)} - \rho_{env}$$