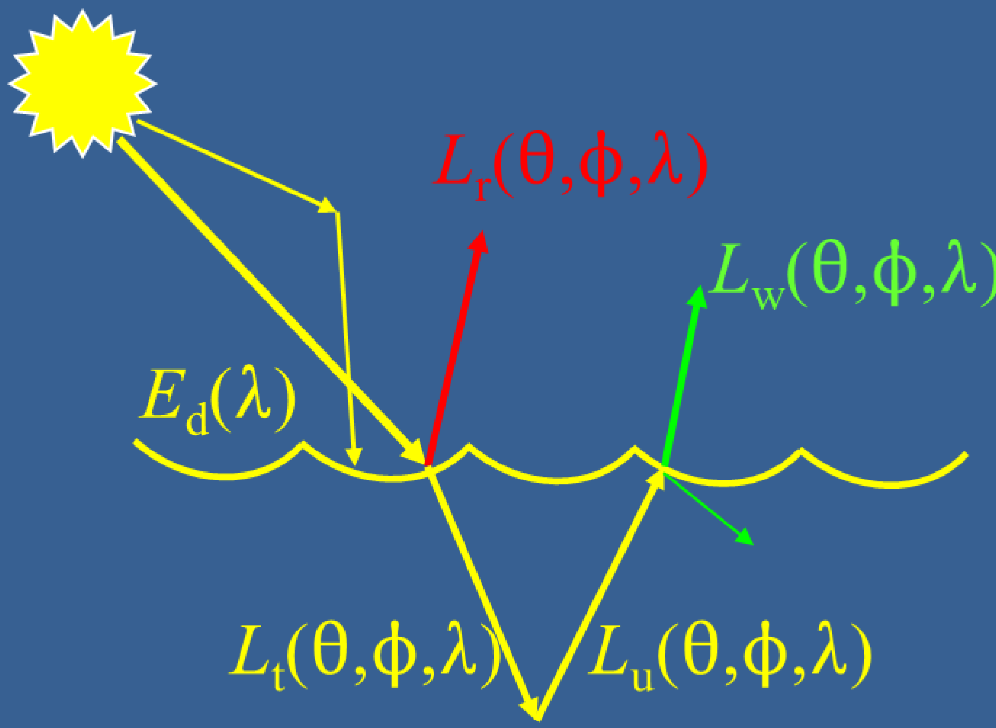
Multiple Choice Exam
on
Chlorophyll Fluorescence

(allowing you to show off all that you have learned this week)

with answers

The purpose of this exercise is to show why you work with R_{rs} and not L_w, and to get some experience analyzing R_{rs} spectra

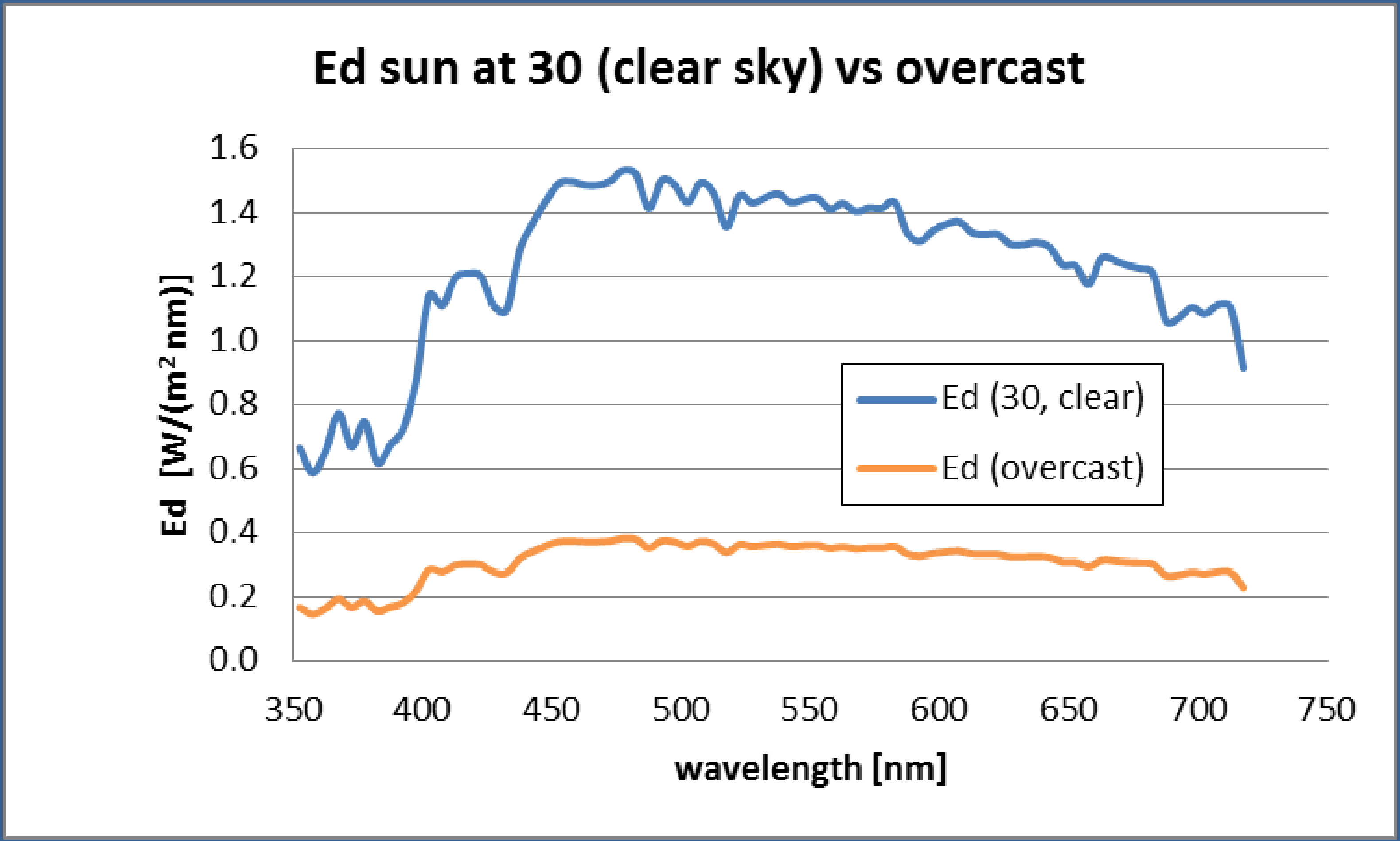
Quick review of R_{rs}: The apparent optical property (AOP) used for remote sensing



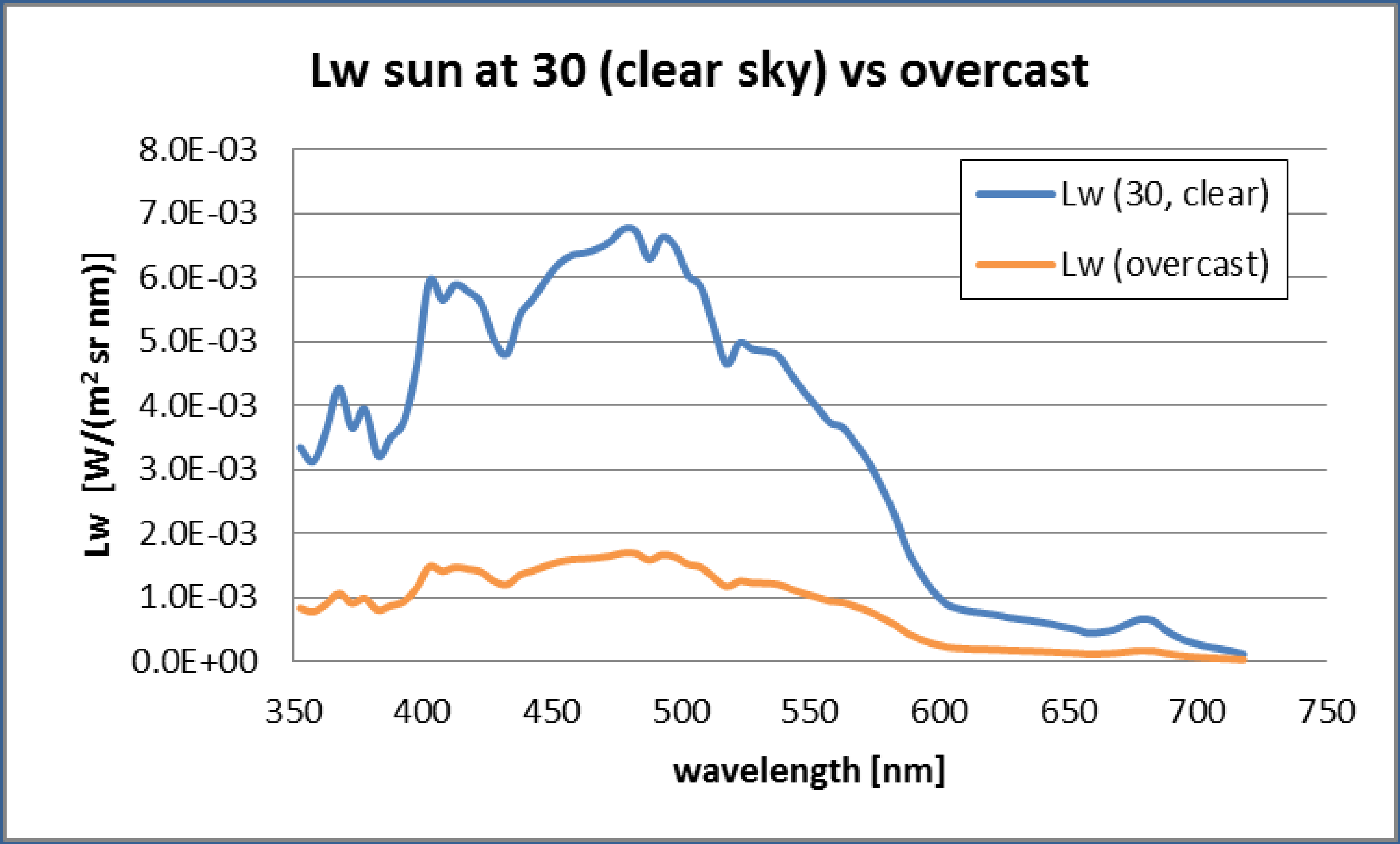
$$R_{rs}(\theta,\varphi,\lambda) = \frac{\text{upwelling water-leaving radiance}}{\text{downwelling plane irradiance}}$$

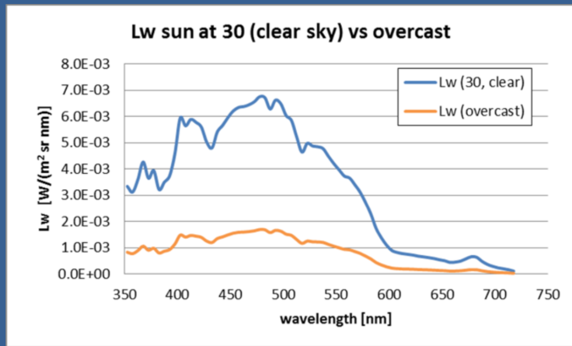
$$R_{rs}(\text{in air},\theta,\varphi,\lambda) \equiv \frac{L_w(\text{in air},\theta,\varphi,\lambda)}{E_d(\text{in air},\lambda)} \quad [\text{sr}^{-1}]$$

HydroLight run with sun at a 30 deg zenith angle in a clear sky vs an overcast sky (5 nm resolution, U = 5 m/s, RTE solved to 30 m, etc.)



HydroLight run with sun at a 30 deg zenith angle in a clear sky vs an overcast sky




Lw sun at 30 (clear sky) vs overcast
Lw [W/(m² sr nm)]
8.0E-03
7.0E-03
6.0E-03
5.0E-03
4.0E-03
3.0E-03
2.0E-03
1.0E-03
0.0E+00
350 400 450 500 550 600 650 700 750
wavelength [nm]
Lw (30, clear)
Lw (overcast)

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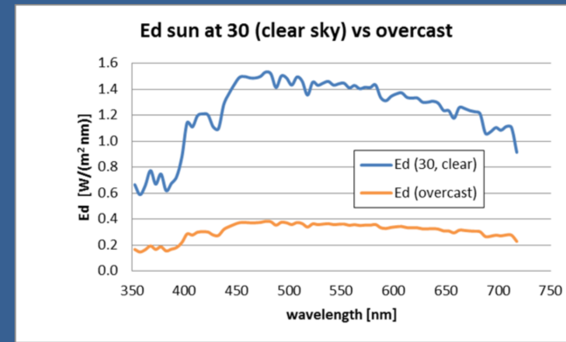
Ed sun at 30 (clear sky) vs overcast
Ed [W/(m² nm)]
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
350 400 450 500 550 600 650 700 750
wavelength [nm]
Ed (30, clear)
Ed (overcast)

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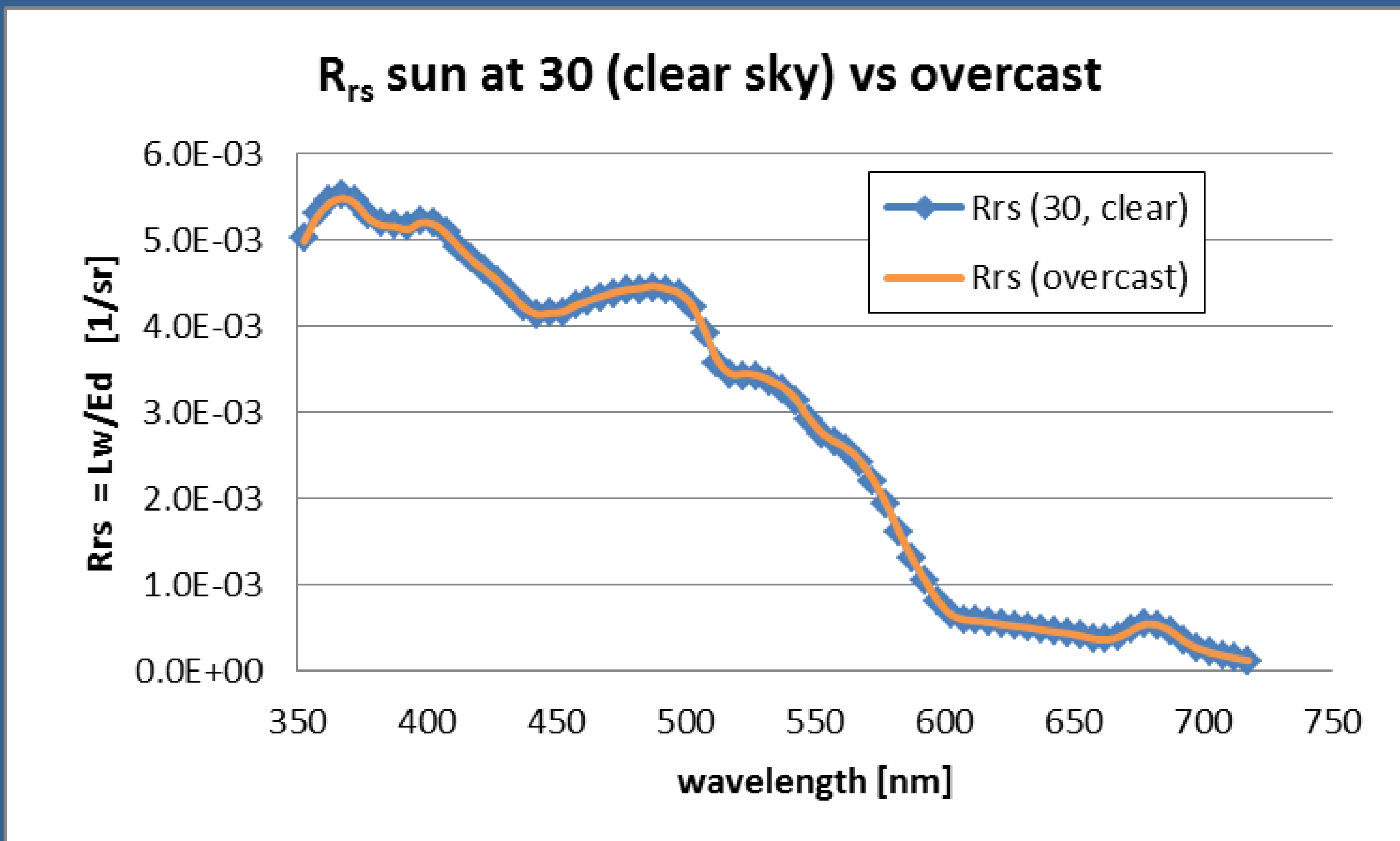
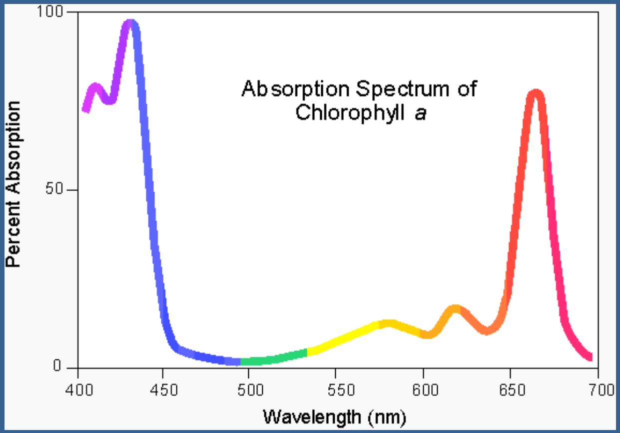

Rrs sun at 30 (clear sky) vs overcast
Rrs = Lw/Ed [1/sr]
6.0E-03
5.0E-03
4.0E-03
3.0E-03
2.0E-03
1.0E-03
0.0E+00
350 400 450 500 550 600 650 700 750
wavelength [nm]
Rrs (30, clear)
Rrs (overcast)

Remember that Chl fluorescence is proportional to

- How much chlorophyll there is to absorb light
- How much light is available to be absorbed
- How efficiently the chlorophyll re-emits photons (the quantum efficiency)

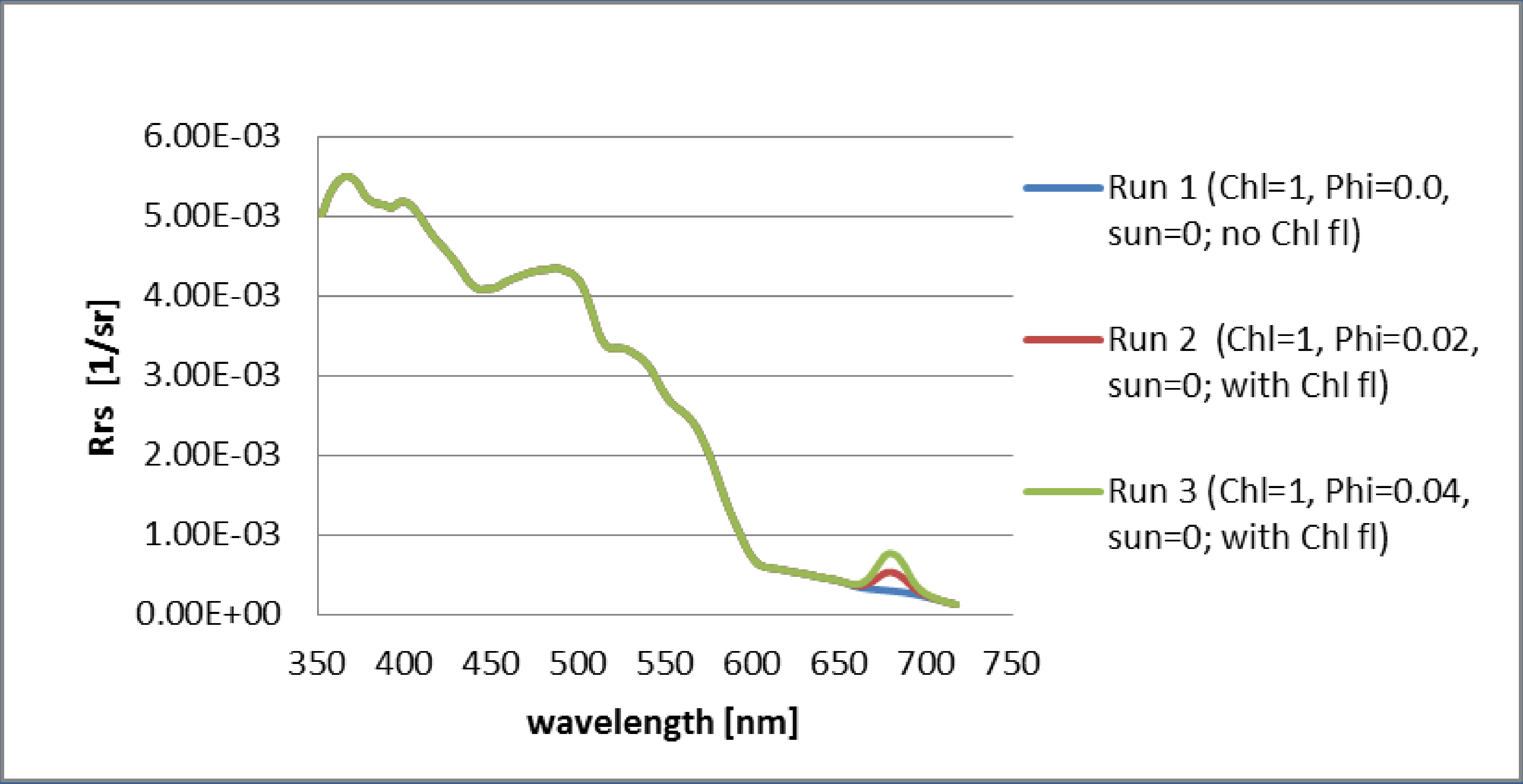


From MJP

Now you explain the following R_{rs} spectra. Your choices are

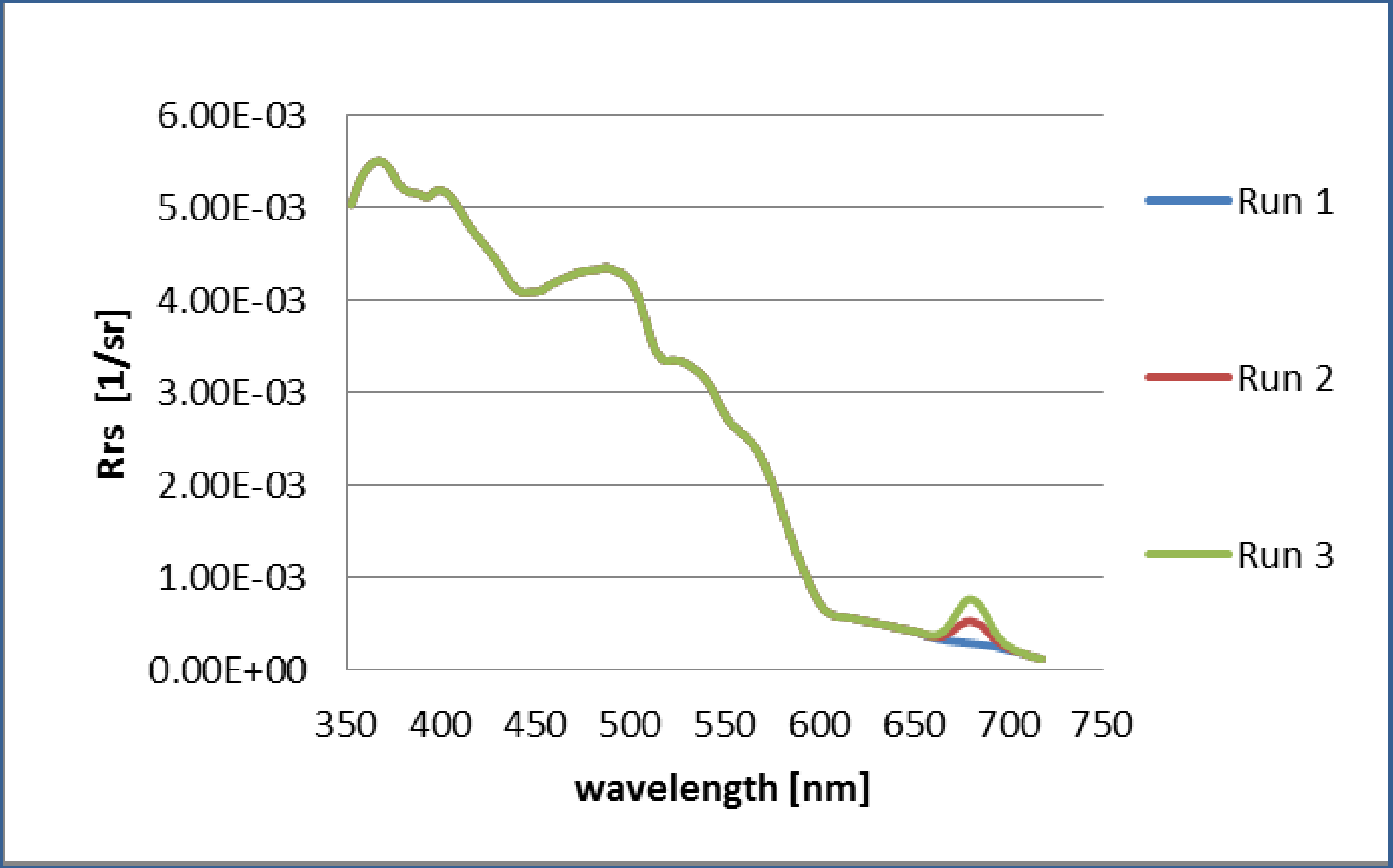
- Chl = 1 mg m^{-3} vs 5 mg m^{-3}
- Quantum Efficiency Φ_{Chl} = 0 (no chl fl) vs 0.02 vs 0.04
- Sun zenith angle = 0 vs 60 deg

What is the Chl value : 1 or 5?

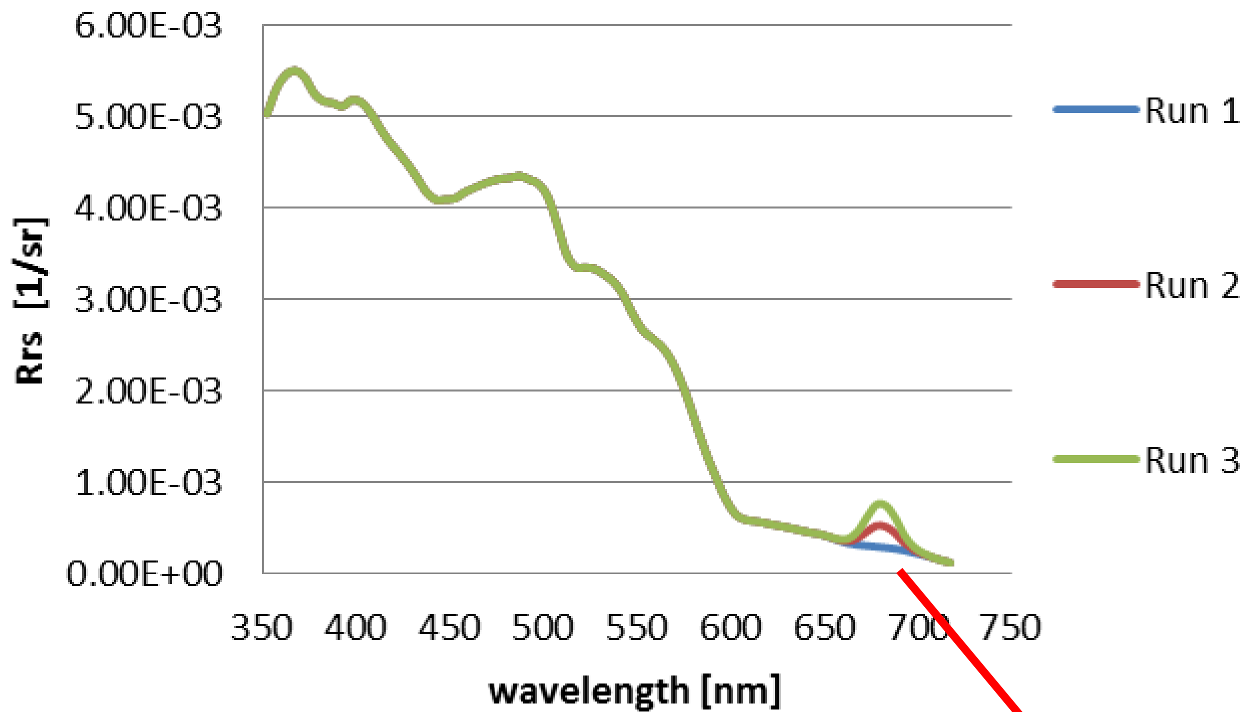


This is a very blue spectrum, so low Chl. Chl = 1 rather than 5, which would be green water

What is the sun zenith angle: 0 or 60 deg?

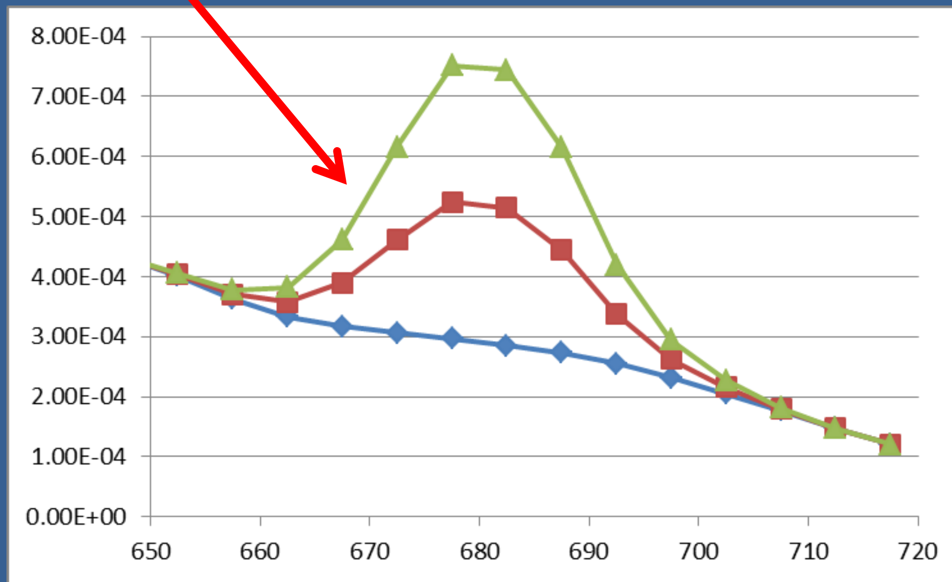


You can't say anything about the sun angle from Rrs; that's the whole reason for using an AOP like Rrs, which normalizes out the sky effects

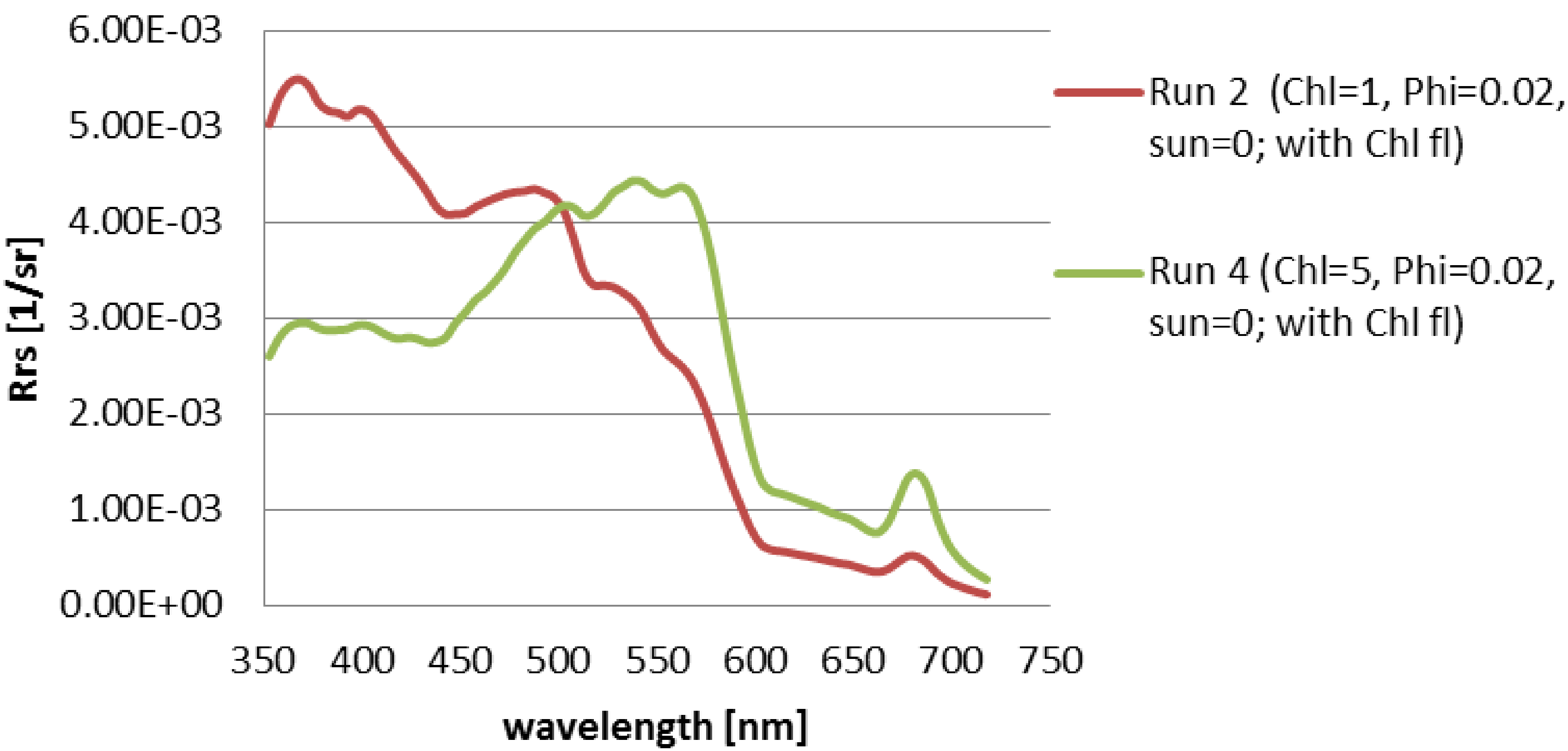


What causes these differences?

Different Phi values, since only the chl fluoresence band is different

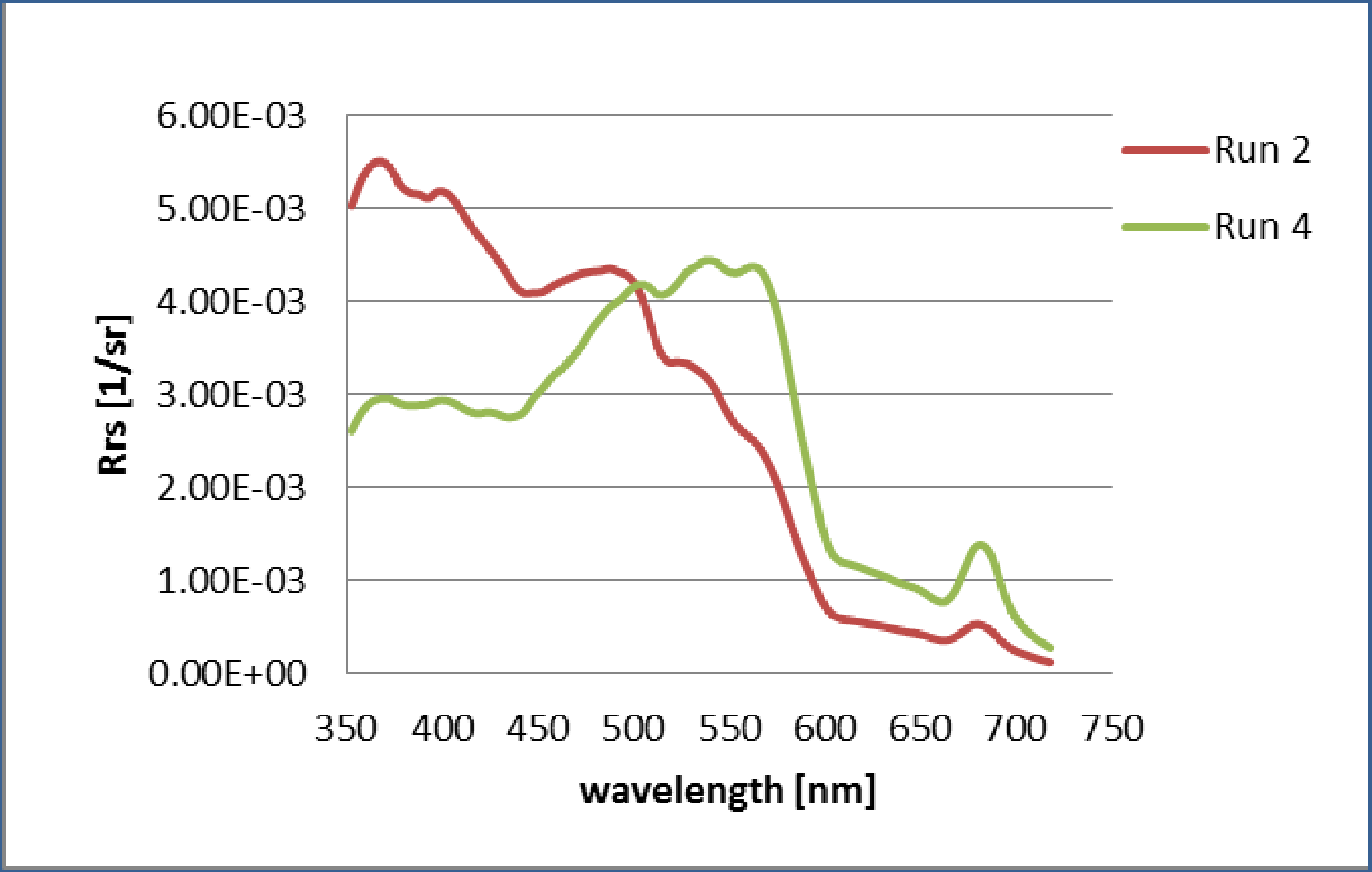


What causes these differences?



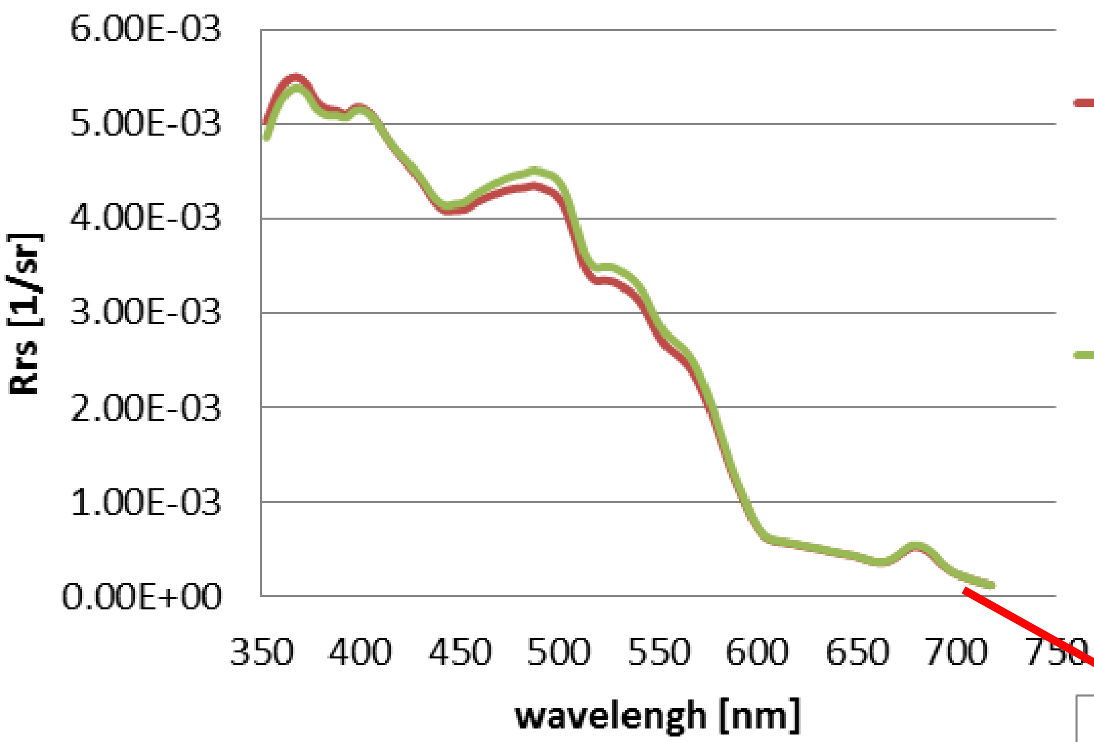
These are low (blue water) vs high (green water) Chl values

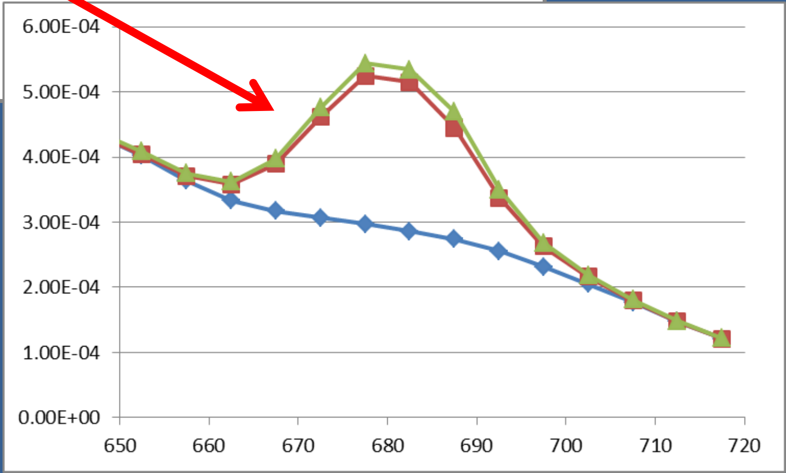
What is the value of Φ_{Chl}?



You can't really say much about the Phi value without additional information

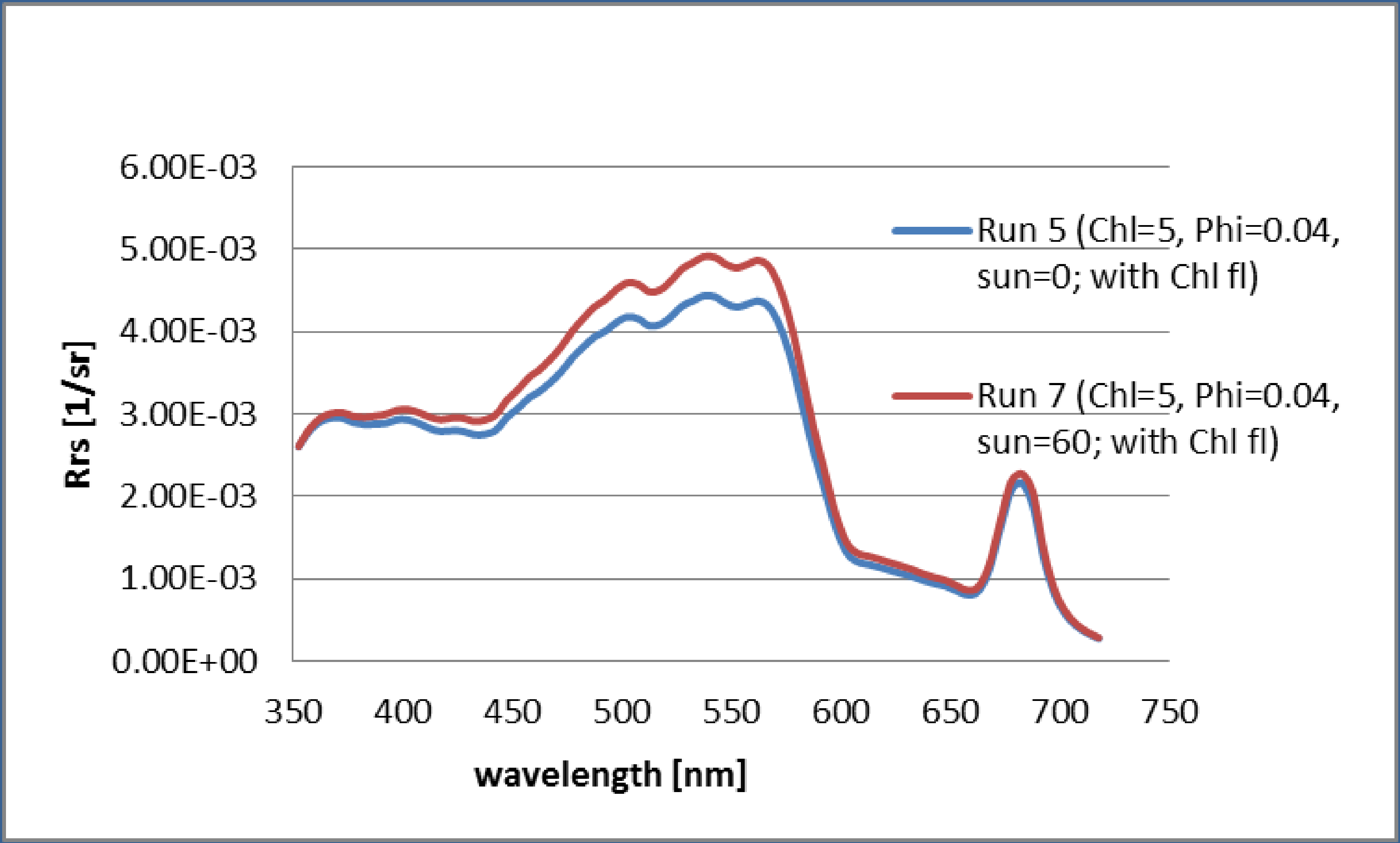
What causes these differences?





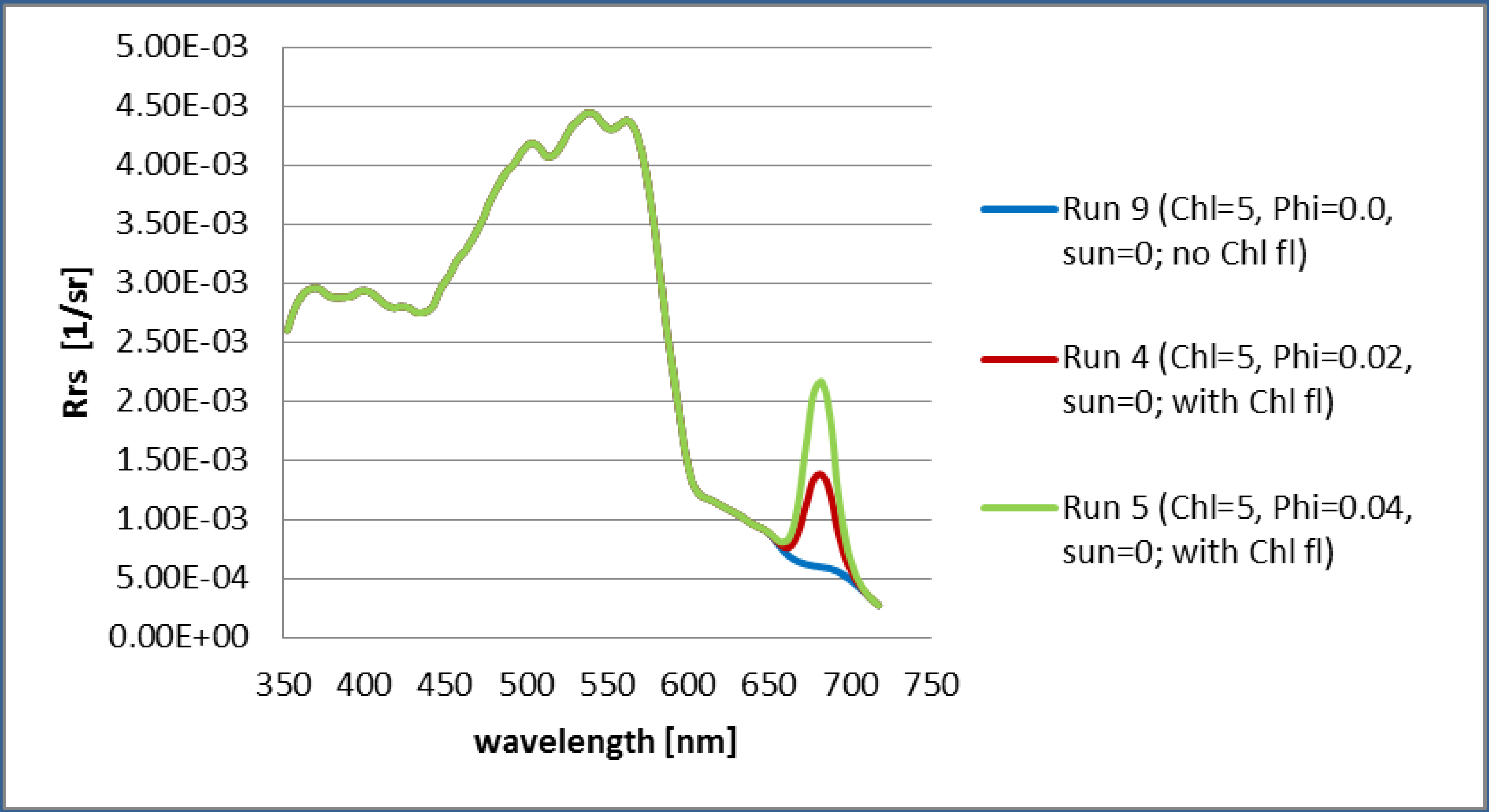
These are sun angle differences, because the differences cover the whole spectrum, not just the Chl fl band. The two sun angles are sampling different parts of the VSF, with complicated interactions of absorption and scattering.

What causes these differences?



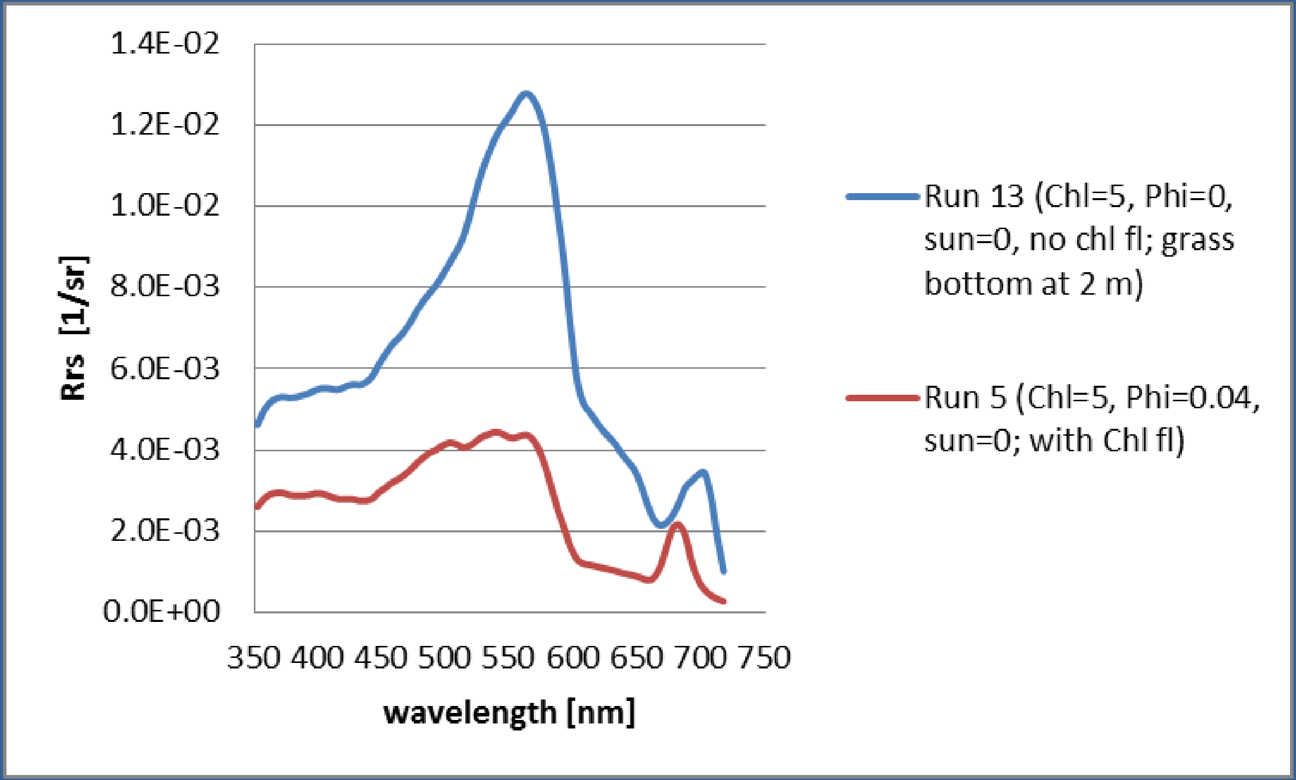
The sun angle effect is more noticeable for the high Chl case because there is more scattering and the phase function is different from the low Chl case

What causes these differences?



Differences in Phi affect only the Chl fluorescence band

Extra credit question: Explain the blue curve (red is Chl = 5, Φ_{Chl} = 0.04; sun at 0)



The overall magnitude increase could be caused by increased scattering by non-absorbing particles, but that would not shift the peak of the Chl fl band. The max near 700 instead of 685 flags this as being something else. In this case, a grass bottom at 2 m depth

The rising "red edge" reflectance of the sea grass bottom at 2 m starts the rise in R_{rs}, which is then suppressed by the increasing water absorption