Annual Measurement of Solar UVB at a Reef Site Using a Polyphenylene Oxide Dosimeter

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Why study UVB?

- **UVB – environmental stressor and instigator of physiological change.**
- **Can influence phytoplankton, zooplankton, macroalgae, aquatic plants, crustaceans, fish and corals** (*Häder et al. 2011*)
- **Protection to UVB may be species specific having potential to change marine ecosystems by preferentially selecting the least sensitive populations. This has a secondary influence on total CO_2 absorption.** *(Banaszak & Lesser 2009)*
- **Although there is significant UVB (280-320 nm) attenuation in turbid seawater, acidification will lead to the faster degradation of DOM and greater penetration depth** *(Banaszak & Lesser 2009)*
- **Potential to change reef diversity by altering habitable depths of coral species favouring those with higher UVB tolerance.**
- **Low penetration of UVB ~ 3 m in turbid shallow water, suggests UVB will have the greatest influence in fringing tropical reef systems**

Aims

- Conduct a pilot study to investigate realistic underwater UVB exposure ranges by deploying a cost effective UVB dosimeter on a coral reef
- Determine the variation in UVB radiation over a period of a year at the reef site
- Consider the factors likely to influence the field UVB exposure
- Consider the implications for other fringing reef systems

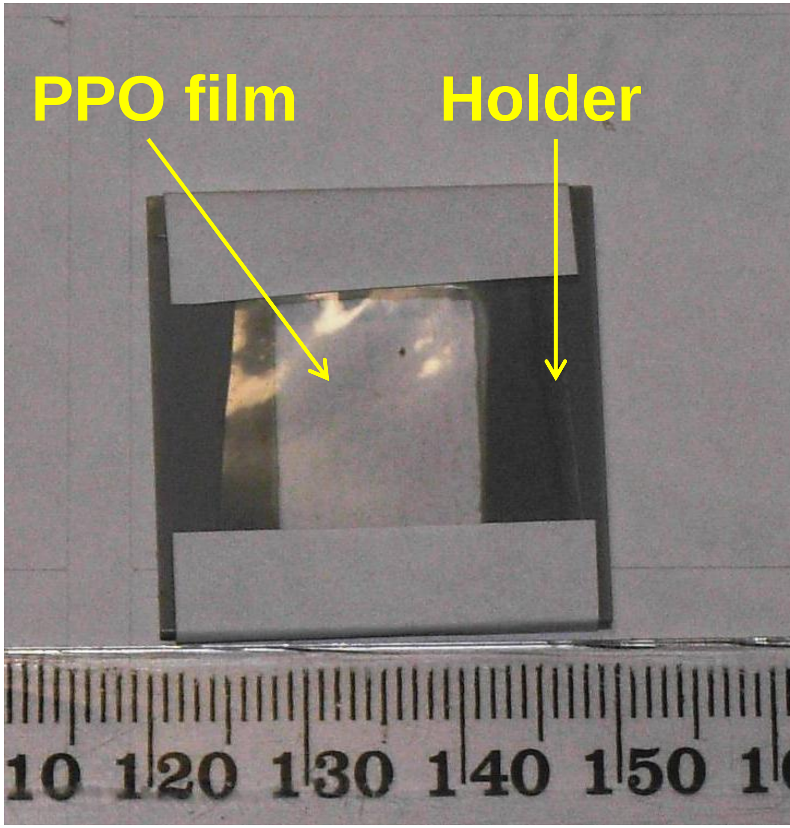

Intertidal juvenile colony
Established reef building colonies

Background – *Study Site*

- **Fringing coral reef in close proximity to urban environment**
- **Popular snorkelling site - Great Sandy Straits marine park, Hervey Bay (25ºS)**
- **Predominant corals: yellow scroll and Purple coral**
- **Rocky mudflats and established coral colonies**
- **High turbidity and susceptible to urban runoff**
- **Easy access for research**

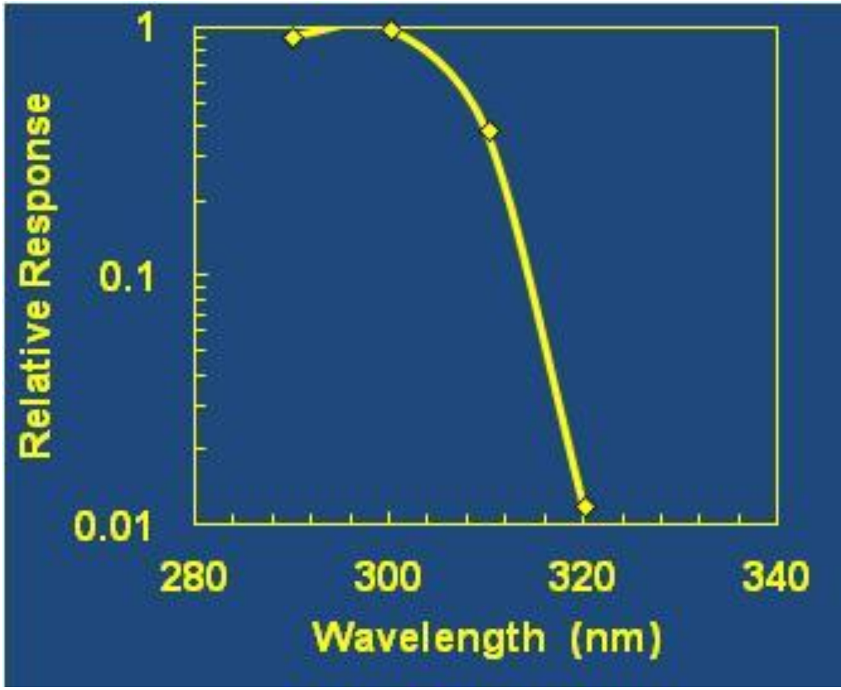
Methods

- UVB dosimeters fabricated by casting in thin films - polyphenylene oxide (PPO) dissolved in chloroform
- Dosimeters have an extended exposure range
- 40 µm thickness
- Taped to waterproof holder 3 cm x 3cm
- Attached to substrate with a piton and attached holder (horizontal orientation)
- Measurements made at one site in proximity to a juvenile coral colony for 9 months (2010-2011)



Methods

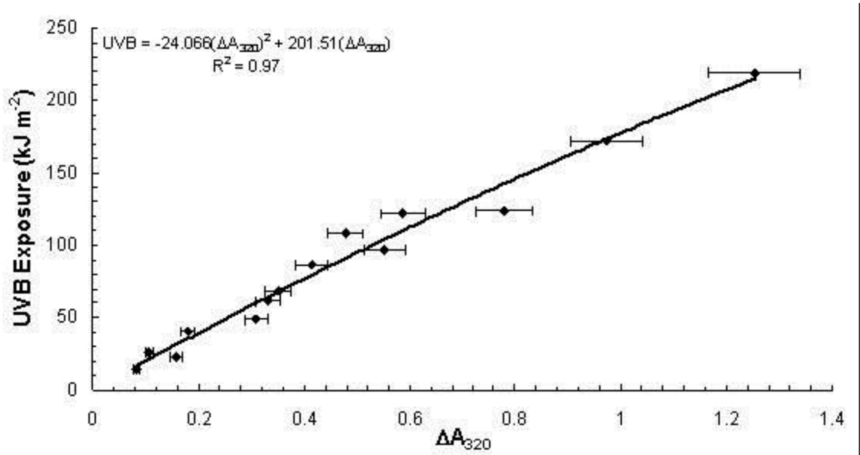
- **PPO dosimeters have a response to UVB wavelengths**
- **UVB causes photodegradation of the PPO**
- **Manifested as a change in optical absorbance (ΔA_{320})**
- **Measured at 320 nm in a spectrophotometer**

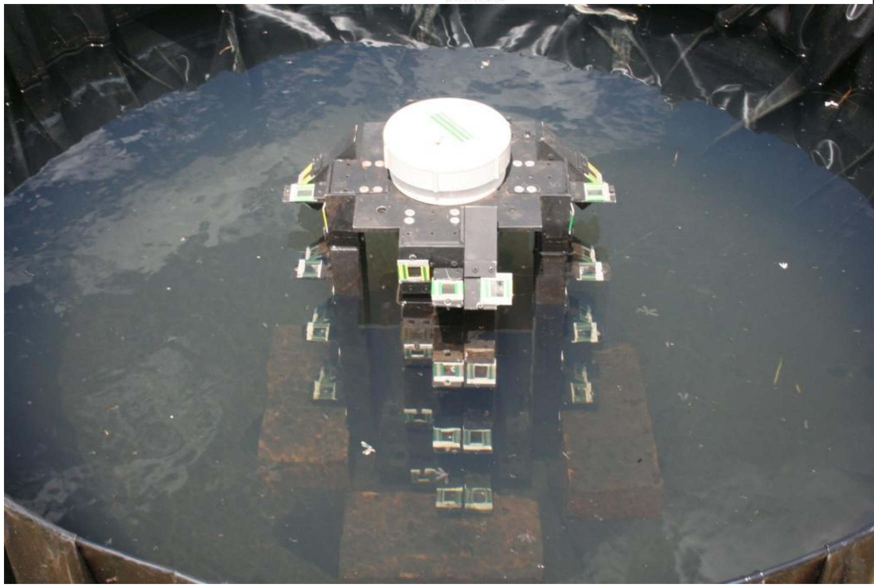


Methods

- **PPO dosimeters were calibrated underwater in seawater against a calibrated CCD spectrometer**
- **Provides an exposure response curve relating ΔA_{320} to UVB exposure**
- **Up to 250 kJ m^{-2} extended use**
- **Calibrated underwater accuracy of ±9%**

(Schouten et al. 2008)





Methods

- A single PPO dosimeter was deployed underwater near a small coral colony
- and replaced regularly during the study period
- The diurnal depth above the dosimeters varied from 0.05 to 3.69 m (1.6 m)
- Cloud cover, Rainfall, and global Solar exposure was also retrieved

Methods

- A total of 22 dosimeter deployments and retrievals were made in the period April 2012 to February 2011
- Dosimeters were cleaned with distilled water and allowed to dry once retrieved
- Exposed dosimeters were calibrated to seasonal seawater calibration curves
- Total exposure was converted to mean daily exposure in kJm^{-2} UVB

Results *A comparison of influencing factors*

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Underwater UVB exposure

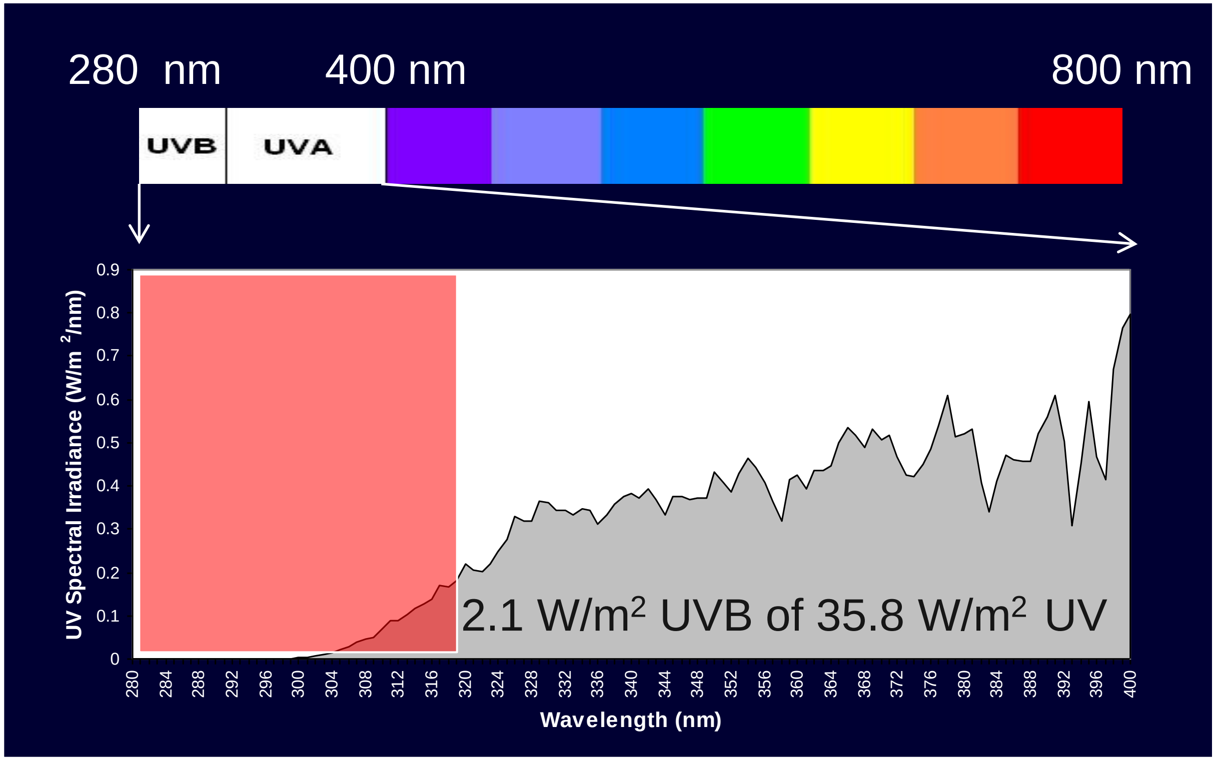
1. **Depth (tide)**
2. **Turbidity (rainfall)**
3. **Cloud cover and type**
4. **SZA**

In air UVB exposures

1. **Cloud cover and type**
2. **SZA**
3. **Altitude**
4. **Ozone**
5. **Other aerosols**

Results *Atmospheric Influences*

UVB makes up a small proportion of the global solar radiation incident at the water surface but has a significant biological influence

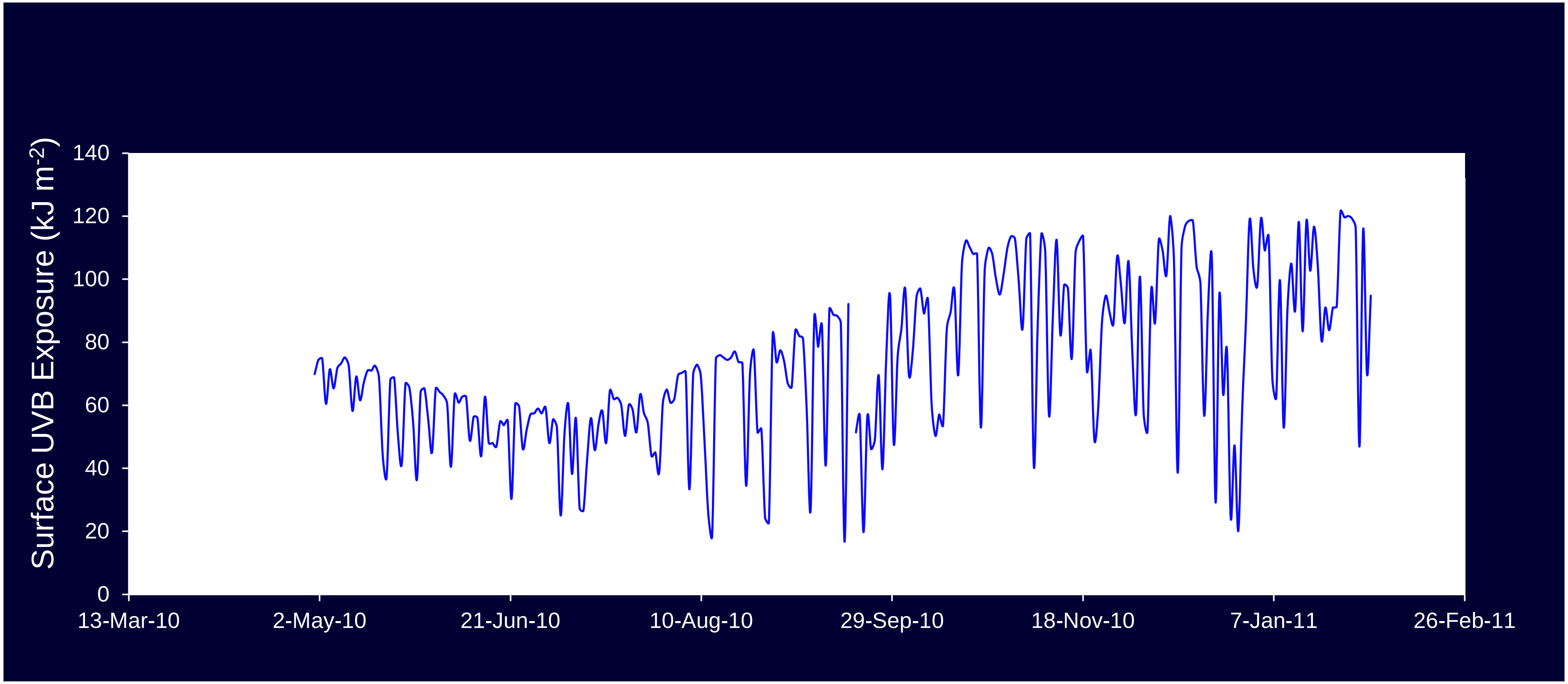


UVB is moderated by:

- Seasonal SZA
- Ozone concentration
- Aerosol concentration
- Cloud cover and type
- Aspect of reef
- Aspect of dosimeter

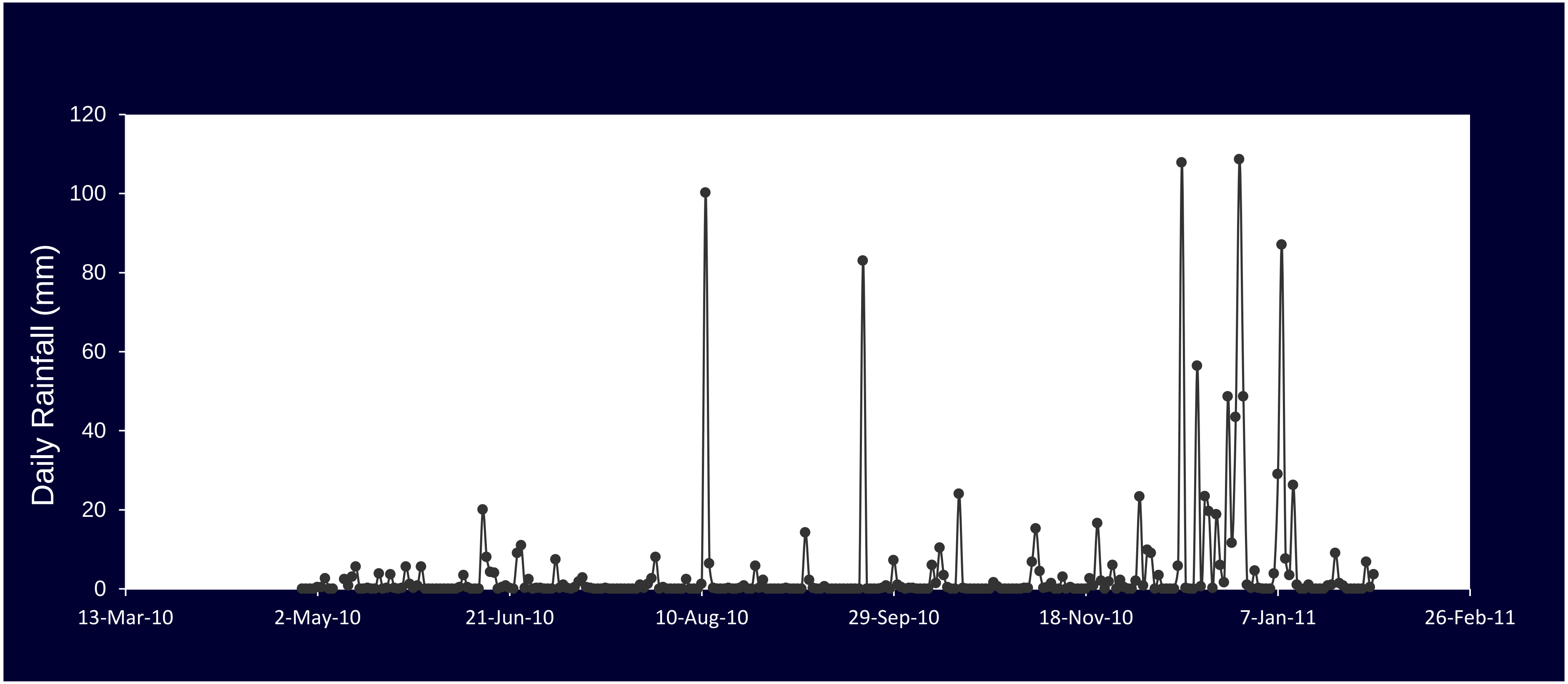
Results *Atmospheric Influences*

— Modelled surface UVB Radiation in the period April 2010 to February 2011
— Measured Global Solar Radiation (Hervey Bay Airport, BOM)



Results *Atmospheric Influences*

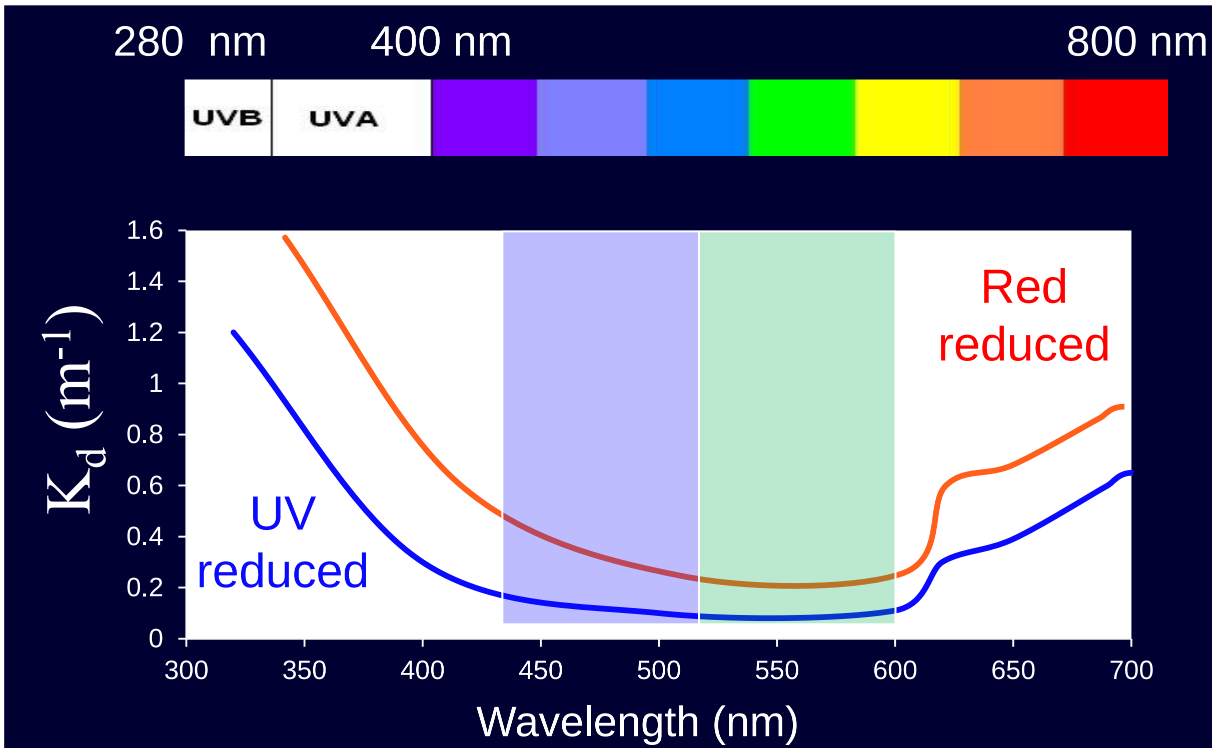
Rainfall was a significant factor during the study period and included flooding of the Mary river in January 2011 (Hervey Bay Airport, BOM)



Results *Underwater Influences*

The attenuation of solar radiation in seawater changes with wavelength and water type.

— ocean — Inshore turbid water



$$\ln\left(\frac{E(z)}{E(0)}\right) = -K_d z$$

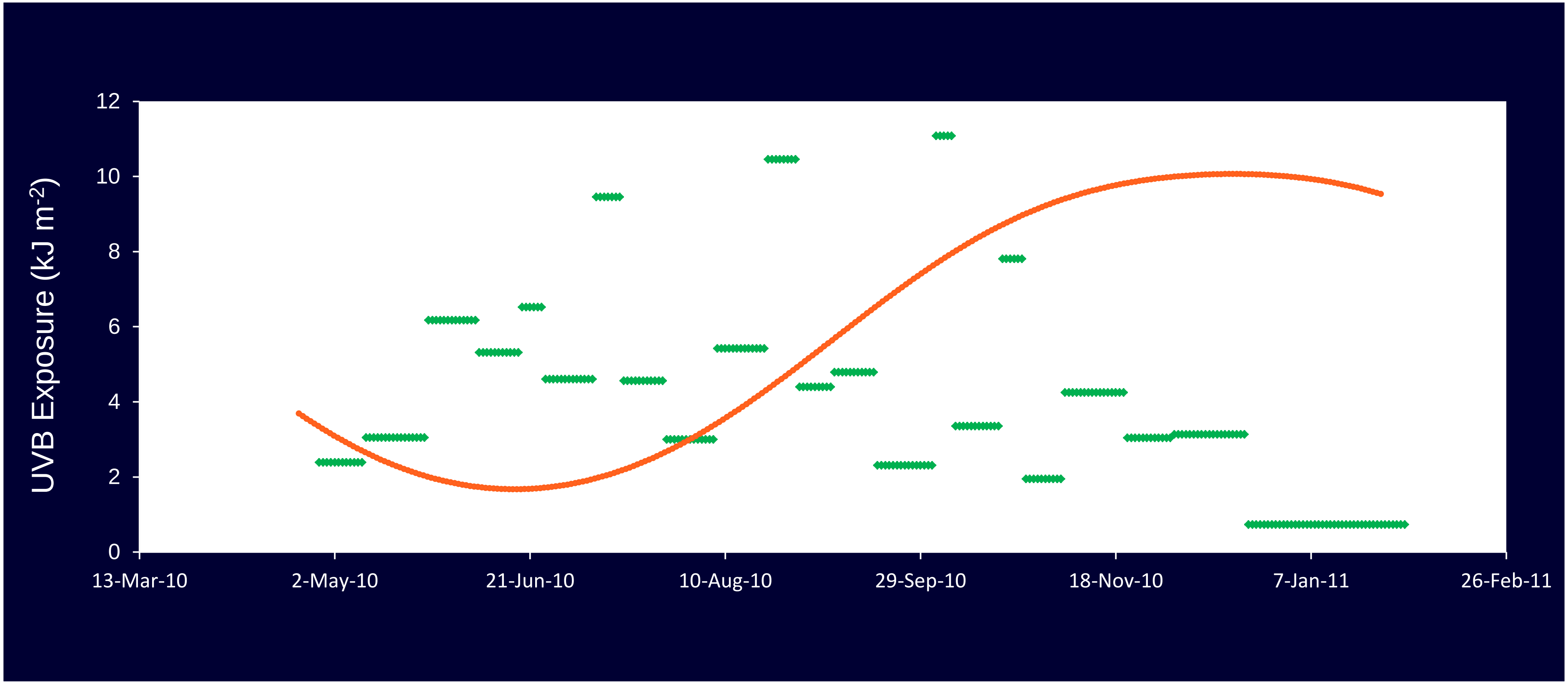
1. Irradiance at depth z
2. Irradiance just below surface
3. Depth
4. Attenuation coefficient

UVB is moderated by:

- Surface waves
- Tidal level
- Turbidity of the water
- Overall sediment loading - river floods
- Beers law for water penetration with wavelength

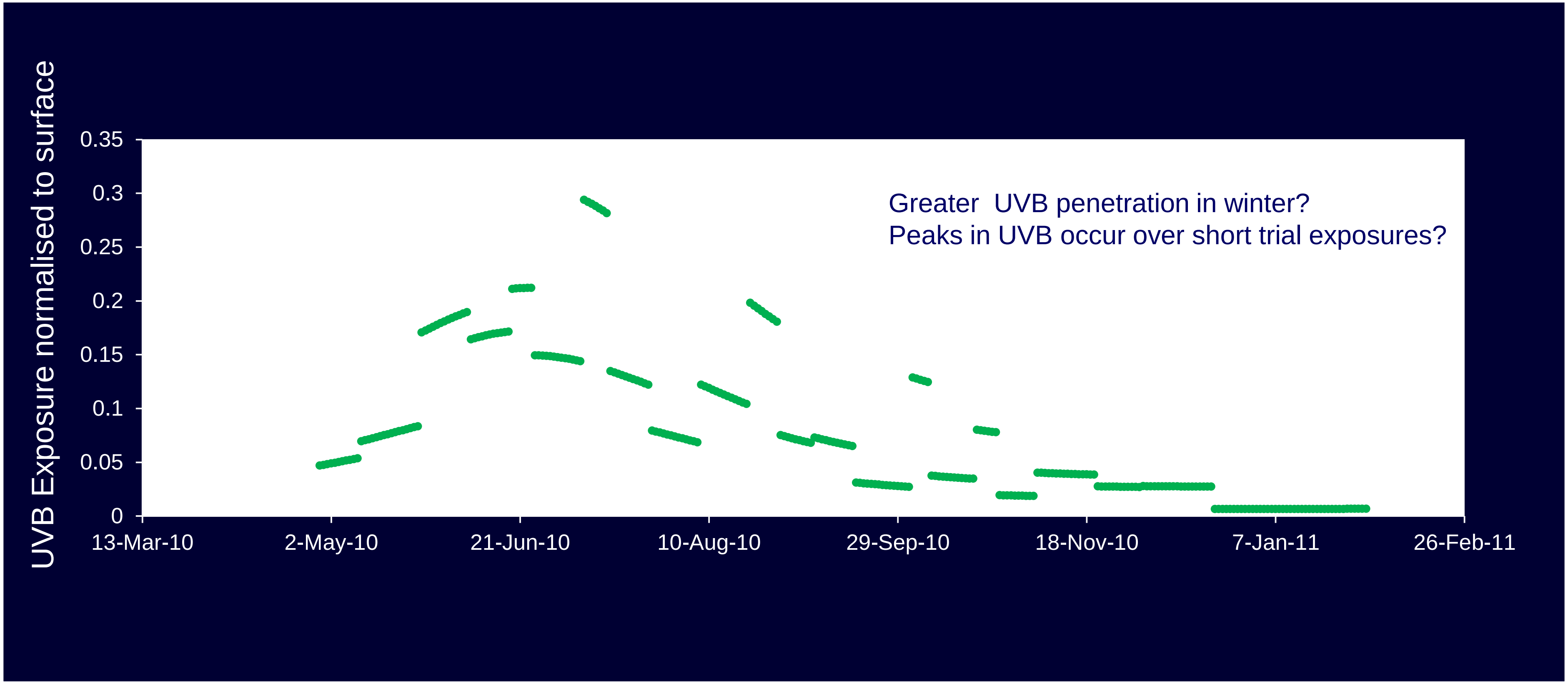
Results *UVB data*

— Measured underwater UVB expressed as a daily average
— Model Surface UVB (Clear conditions, 272 DU)



Results *UVB data*

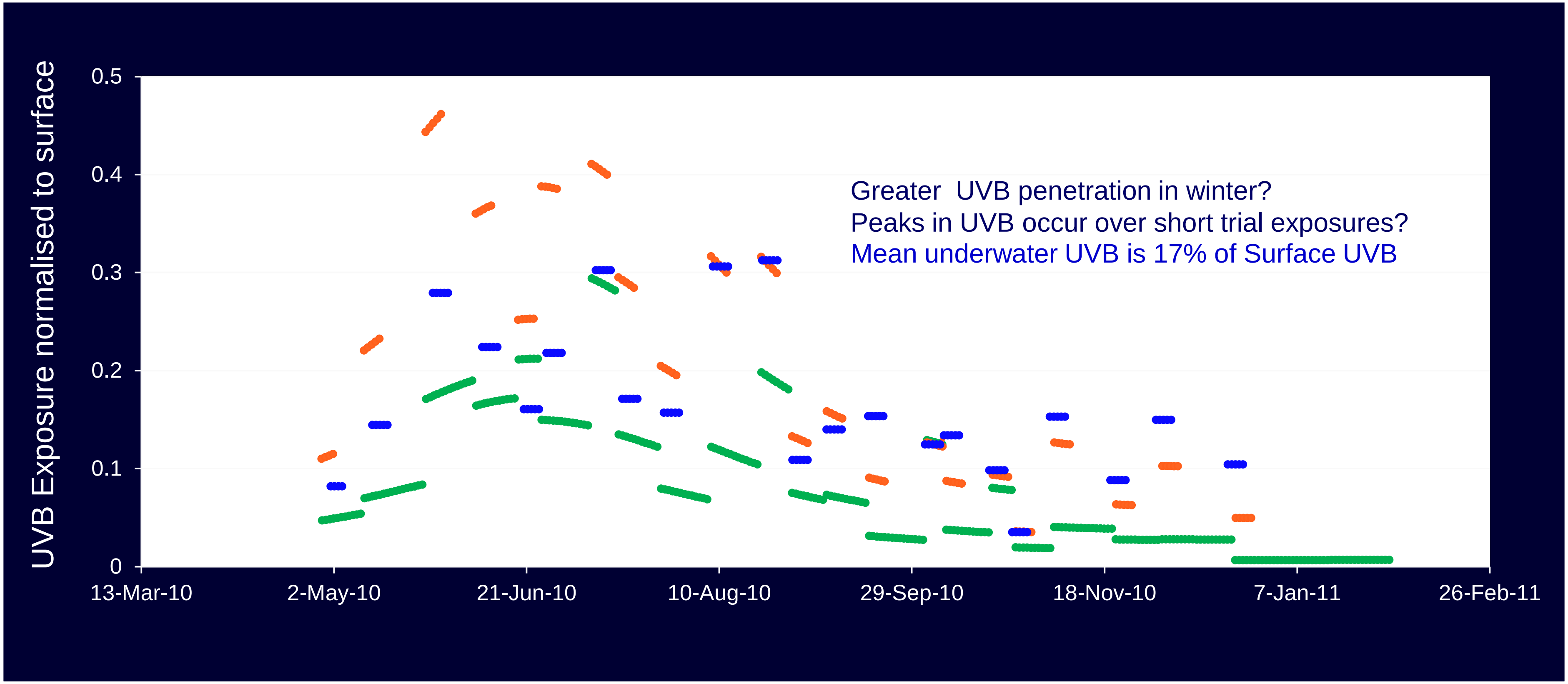
— Underwater UVB normalised to the Surface model UVB (Clear sky model)
- Tendency for higher relative exposure in winter
- Normalisation does not take cloud cover into account



Results *UVB data*

— Underwater UVB normalised to the Surface model UVB (Clear sky model) and given a maximum exposure range of 5 days

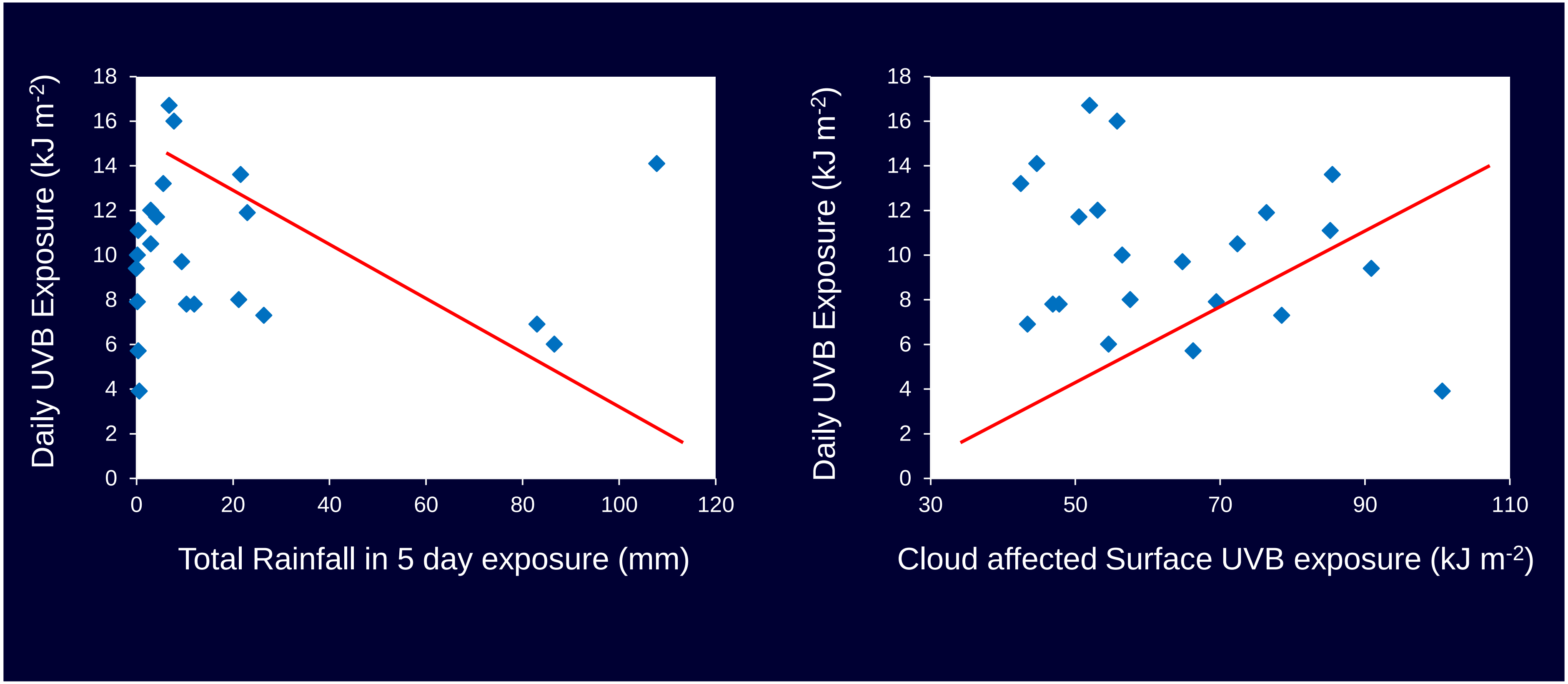
— Underwater UVB normalised to weighted surface UVB (mean cloud sky model BOM)



Results *Rainfall and surface UVB*

Large variation in Underwater UVB for exposure period that experienced limited Rainfall

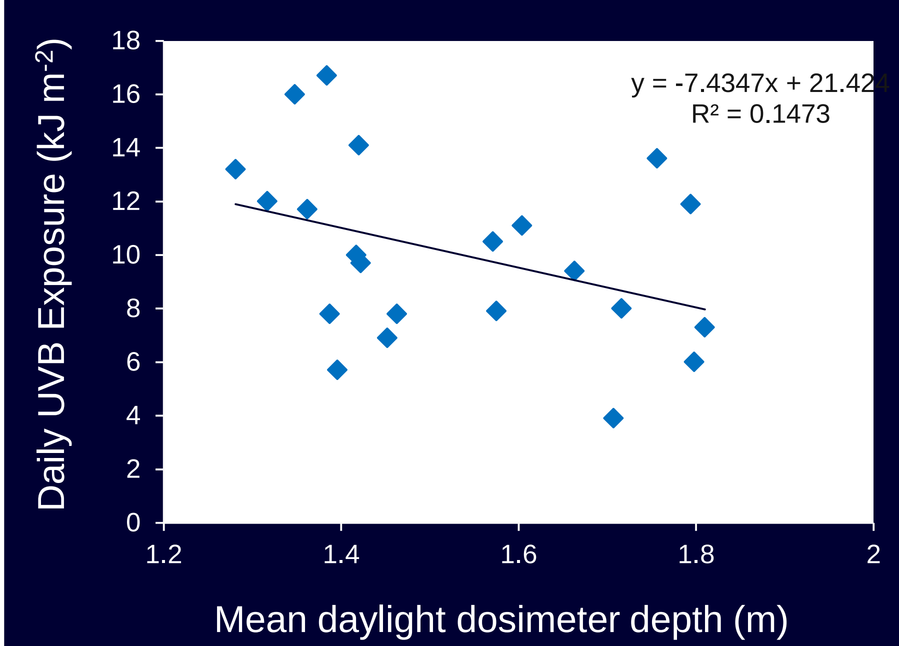
No obvious correlation between underwater and surface UVB exposure

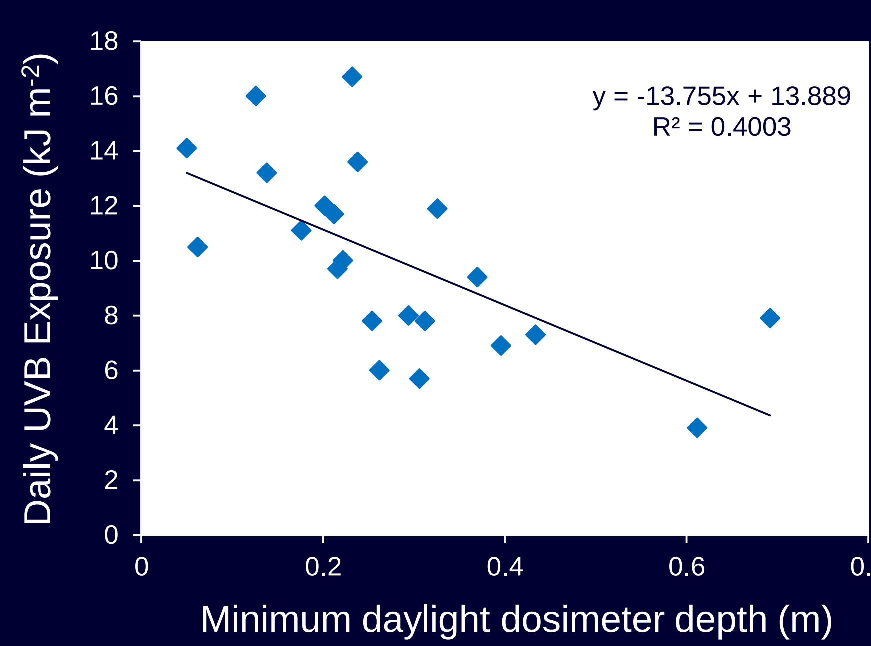


Results *Influence of Tide*

Better correlation between underwater UVB exposure and mean daylight dosimeter depth

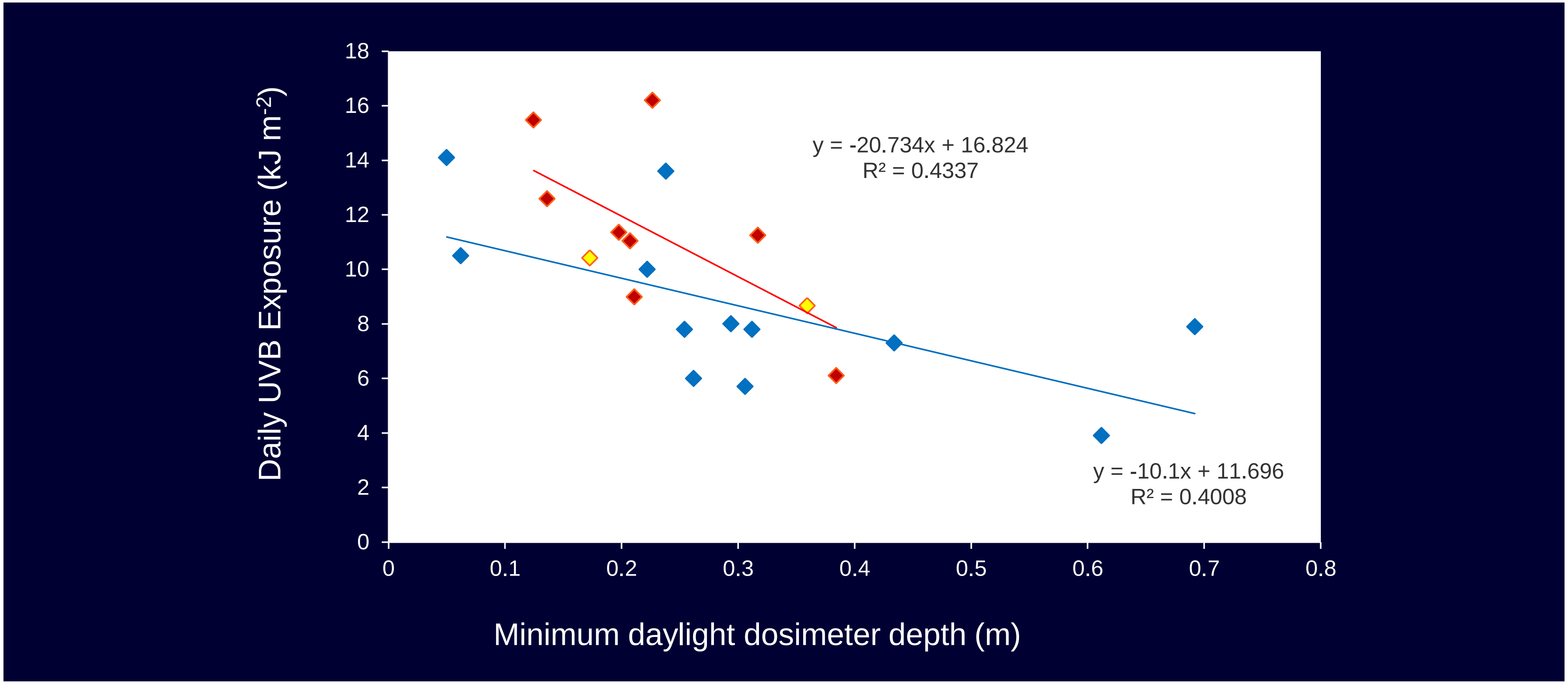
Correlation becomes apparent for minimum depth above dosimeter level





Results *minimum depth & solar noon*

- Minimum depth above dosimeter occurring outside solar noon
- Minimum depth above dosimeter occurring near solar noon (10:00 → 14:00)
- Exposure periods with less than 1 mm rain



Results *UVB data*

- **Seasonal trends as a percentage of Surface UVB are evident, however these are not dependent upon the SZA**
- **Variation in the underwater UVB exposures were not dependent upon Rainfall and possibly turbidity**
- **Underwater UVB exposures on the fringing reef study site were best correlated with tide level**
- **Correlation was greatest when minimal tide conditions occurred near solar noon**

Some more points:

- **Mean daylight depth above dosimeters was 1.6 m (0.05 m to 3.69 m)**
- **Typical UVB Attenuation coefficient for turbid inshore water ~ 1.51 m^{-1}**
- **UVB exposures in turbid conditions were likely to occur only at depths below the mean, however turbidity was variable.**
- **Dosimeter blackout due to sedimentation results in an effective daily exposure measurement range**

Conclusions

- **Advantages:**

  Cost effective, deployable on mass; medium deployment range of several days optimum

- **Disadvantages:**

  Sediment loading of film, Algae growth

  Blackout time - (reduces the extended 250 kJ m^{-2} exposure range of PPO on a turbid inshore reef, maximum of 80 kJ m^{-2} measured in winter)

Conclusions Further study

- Influence of UV on marine ecosystem including phytoplankton modelling
- Influence of UV on reef building corals and possible surface exposures to corals and their associated microalgae
- Potential use on different reef types
- Wide area measurement campaign
- Phenothiazine and UVA filter marine dosimeter

Conclusions

- **Most significant factors for a shallow fringing reef:**
  1. Tide
  2. SZA (at solar noon)
  3. ? Turbidity
  4. ? Cloud cover
- **High UVB in winter (up to 30% of Surface UVB)**
- **Low UVB in summer (< 5% of Surface UVB)**
- **Highest exposures were recorded in the winter and spring**
- **Results have implications for UVB modelling over larger areas particularly surface exposure to corals**
- **Measurements of UVB in reef areas are important as modelling is will likely prove difficult to predict all factors**