Actinic UV film dosimetry: Indicators of occupational exposure risk for office workers and school teachers

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13/11/2013

- How do we make informed decisions?

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- The young people in Australia (ownership 83%).

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Answer: **It depends..**

- To be safe requires balancing optimal Vitamin D and over-exposure risk.
- Balancing an exposure requires detailed information on:
  - the *geographical location*
  - the *weather*
  - the *season*
  - the *atmospheric conditions*
  - the *individual*

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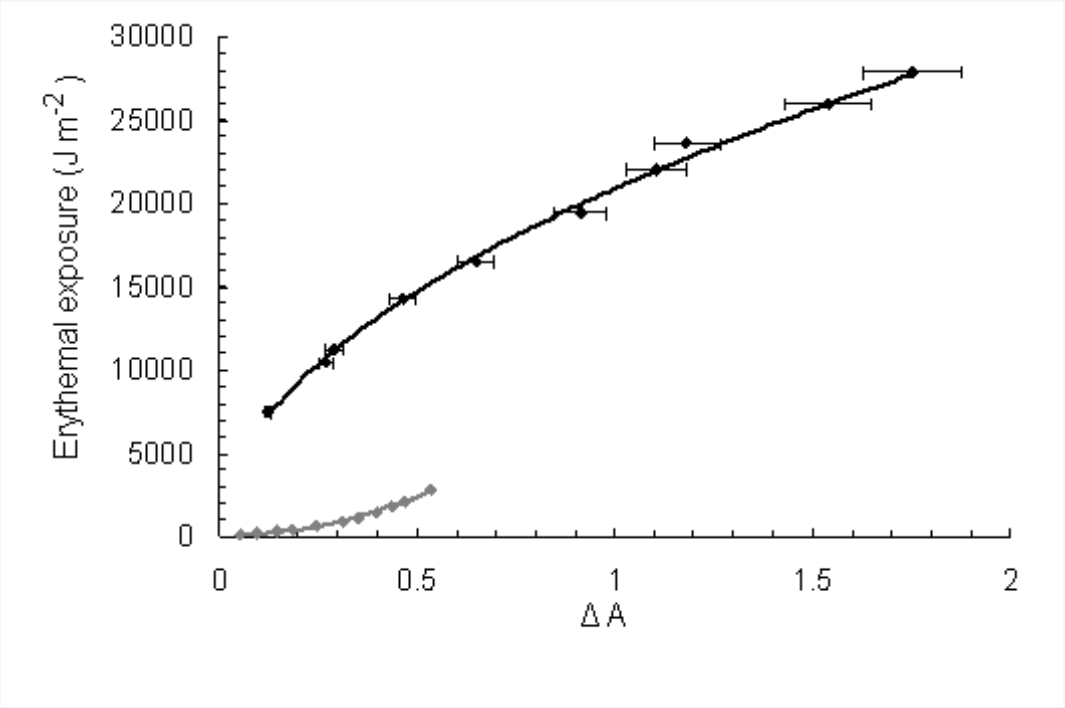
  This study:

  - Considers the risk to Australian workers.
  - Teachers - potential overexposure risk.
  - Office workers - potential Vitamin D risk.
  - Can the ICNIRP EL be used as an indicator of *both* a safe occupational exposure limit and optimal daily vitamin D?

Polysulphone and PPO film dosimetry:



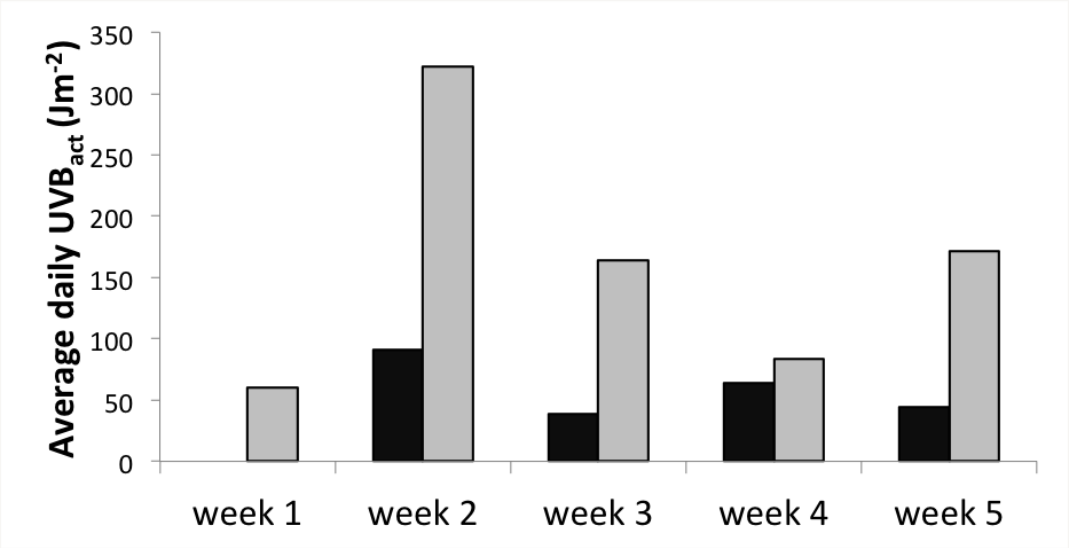
Turnbull, D. & Parisi, P. 2005, J Photochem. Photobio. B: Biol. (78), 61-67.

- Change in Absorbency, ΔA is calibrated against spectrally weighted UV
- Polysulphone: $\Delta A = 330$ nm
- PPO: $\Delta A = 320$ nm
- PPO range = $25\,000\,\mathrm{J m^{-2}}$
- PS range = $2\,500\,\mathrm{J m^{-2}}$

Measuring the ICNIRP exposure to teachers:

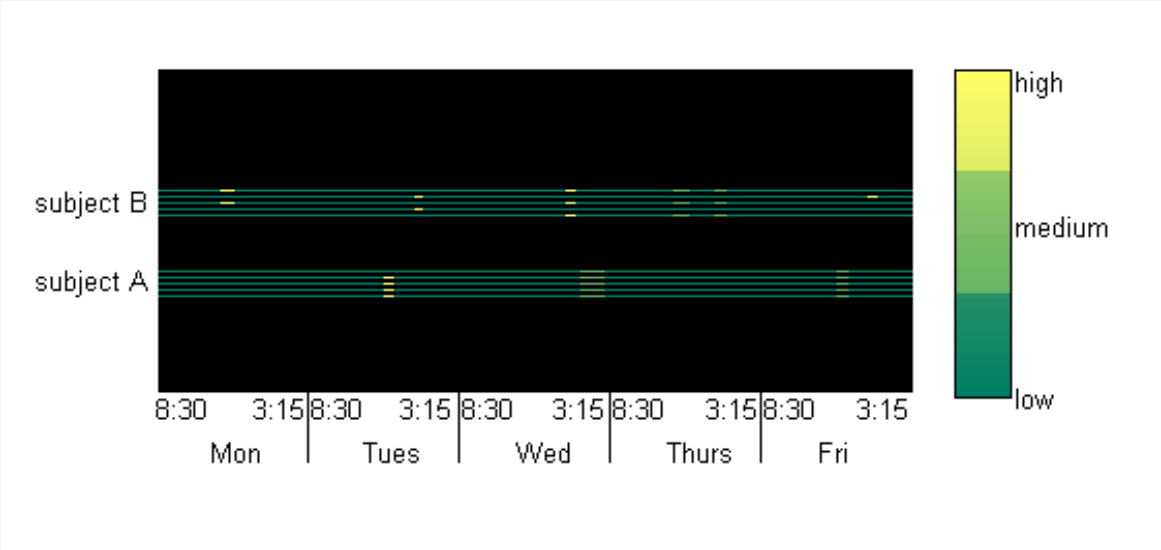
- Measured the ICNIRP weighted exposure to two teachers: 23.5° Emerald, Qld and 27.5° Toowoomba, Qld.
- Recorded weekly ICNIRP exposure to the rear shirt collar and on a horizontal plane over 5 weeks. ($10\% \pm 8\%(1\sigma)$ of ambient)

Week	*participant A* Days	Collar UV (Jm^{-2})	Ambient UV (Jm^{-2})	*participant B* Days	Collar UV (Jm^{-2})	Ambient UV (Jm^{-2})
29.10.12-02.11.12	Full	-	5053	W,Th,F	180	2726
05.11.12-09.11.12	Full	453	5513	M,Tu,W,Th	1287	5251
12.11.12-16.11.12	Tu,W,Th, F	153	3292	Full	821	4025
19.11.12-23.11.12	Tu,W,Th, F	256	4676	Full	420	3875
26.11.12-30.11.12	Full	224	6584	Tu,W,Th,F	686	4883



Measuring the ICNIRP exposure to teachers:

UV heat map - weighted exposure periods:



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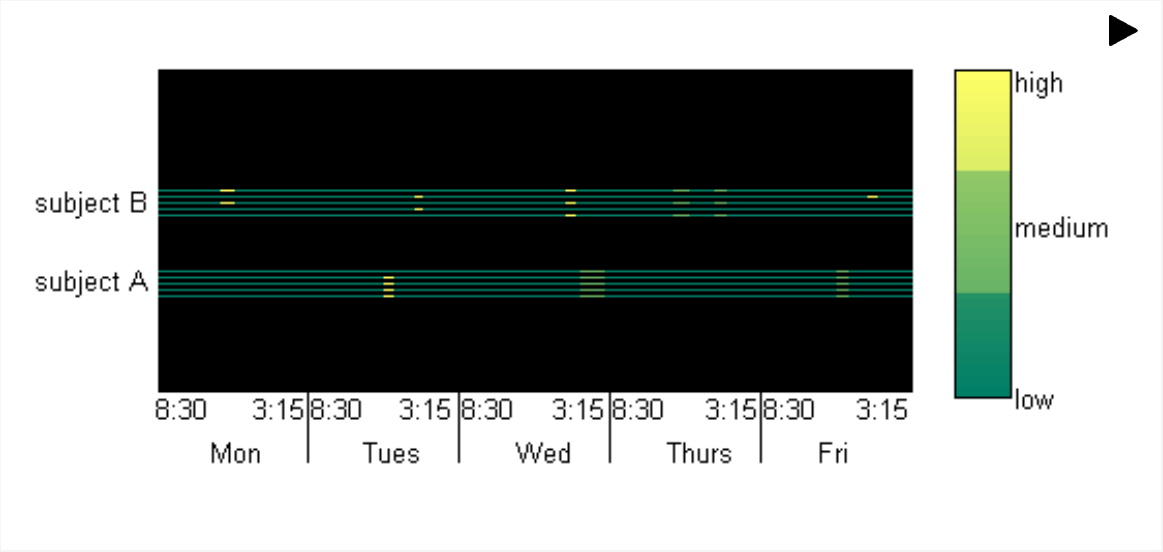

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  2. playground area.

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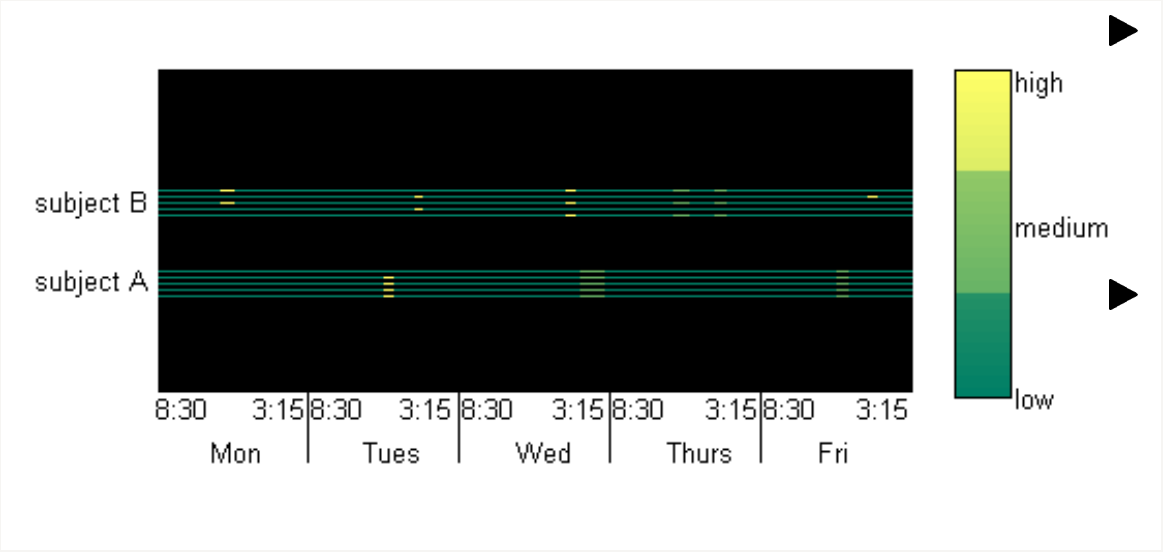

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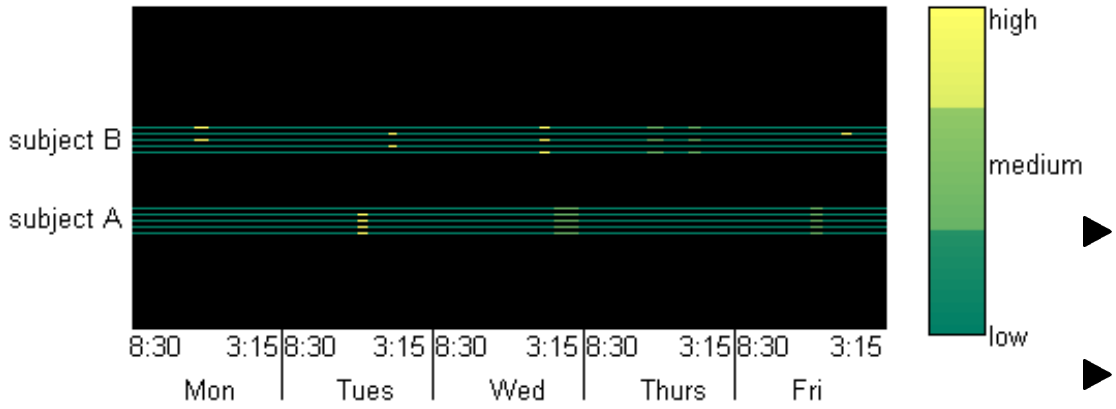

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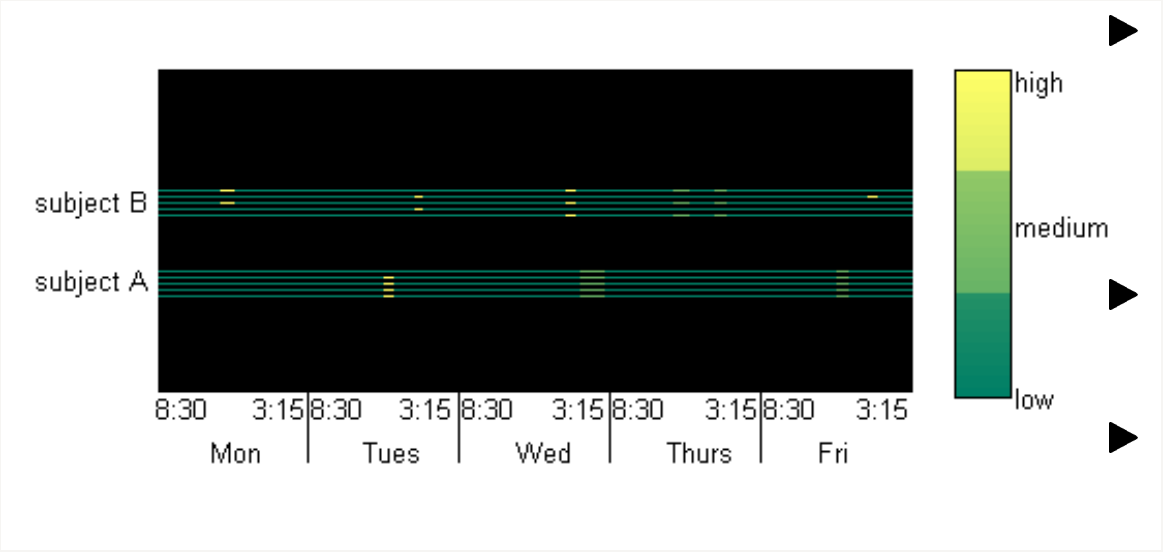

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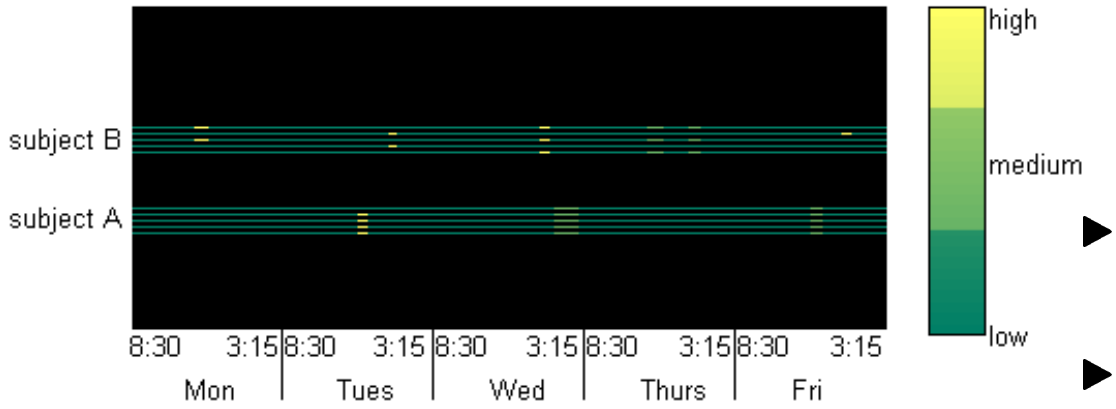

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Answer: Yes.

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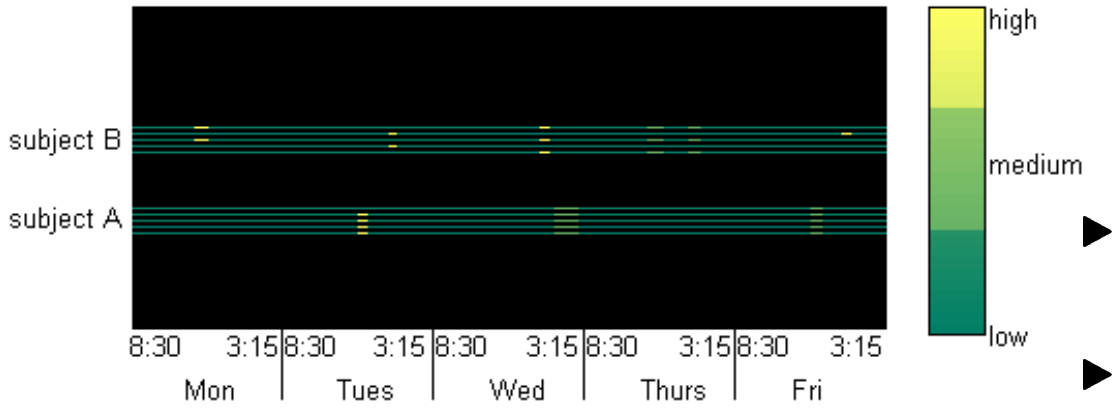

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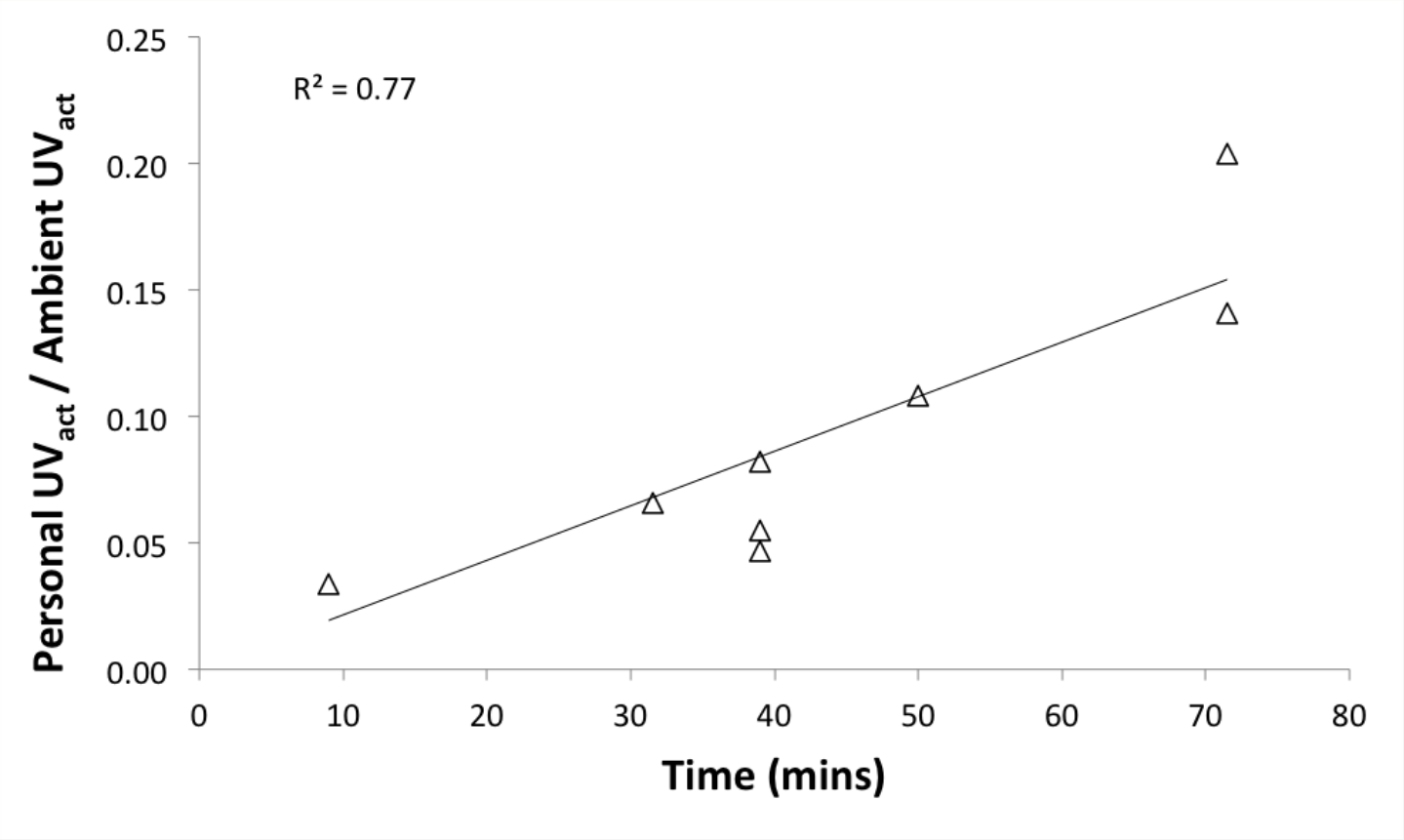
Answer: Yes. However the relationship depends on the outdoor environment..

Measuring the ICNIRP exposure to teachers:

If playground regions which offer some protection are considered... *assuming the exposure is reduced to 10% of that of an open environment*



Measuring the ICNIRP exposure to office workers:

- Measured the ICNIRP weighted exposure to two office workers in Toowoomba, Qld (2008).
- Recorded 12 exposures of 2.5 hours duration ($1\% \pm 1\%(1\sigma)$ of ambient)

Record	*participant A* Collar UV (Jm^{-2})	Ambient UV (Jm^{-2})	*participant B* Collar UV (Jm^{-2})	Ambient UV (Jm^{-2})
01.02.08	3.0	357.8	0	357.8
08.02.08	2.3	178.3	6.7	178.3
15.02.08	1.5	-	-	-
22.02.08	3.3	283.9	0.0	283.9
22.02.08	0.0	-	14.3	-
14.03.08	0.6	116.5	5.5	116.5
09.05.08	0.0	16.3	0	16.3
16.05.08	0.0	22.3	0	22.3
13.06.08	0.0	9.2	0	9.2
18.06.08	5.6	-	0	-
18.07.08	0.0	31.1	0	31.1
01.08.08	0.0	29.7	0	29.7

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16.05.08	0.0	22.3	0	22.3
13.06.08	0.0	9.2	0	9.2
18.06.08	5.6	-	0	-
18.07.08	0.0	31.1	0	31.1
01.08.08	0.0	29.7	0	29.7

- The office workers are well within the daily ICNIRP EL of 30 Jm^{-2}.

Balancing exposure risk and Vitamin D:

Over-exposure Risk:

- BoM (Australia) issues UV alert times when the UV index is *predicted* to exceed 3.
- Within these alert times sun protective strategies are advised:
  - Seek shade.
  - Wear a hat.
  - Wear protective clothing.
  - Apply sunscreen.
  - use sunglasses.
- The UV index is a unit-less quantity based on *erythemally effective* UVR.

Vitamin D deficiency:

- awareness of deficiency risk: dark skin, housebound elderly, medical pre-disposition.
- Incidental sunlight exposure is adequate.
- It is not necessary to deliberately seek UV exposure.
- Exposure of a few minutes either side of peak (UV alert) times to the face, hands and arms ($\frac{1}{4}$ of the available skin surface area.)
- For southern sates the advice is 2-3 hours exposure spread over a weekly period.

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Cancer Council Australia

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- Apps are now available for smartphone users - *increasing awareness*
- Individual advice however requires consideration of many factors..

Optimal Vitamin D:

- *All the possible health benefits of Vitamin D can be provided by the equivalent of a daily an oral dose of 1000 IU.* (Holick,2004)
- This can be produced by the full body exposure of pale skin to a UVI of 10 in under 1 min (McKenzie et al. 2009).
- It has also been stated that exposure of 6% of the body to 1 MED will produce the equivalent of 600 to 1000 IU.(Holick, 2002)

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Seckmeyer et al. 2013: *(erythemal UV to Vitamin D)*

$$\frac{\text{IU}}{\text{min}} = \frac{\text{IU}_{\text{LITERATURE}}}{\text{exposure time}} \cdot \frac{100\%}{\text{skin area (\%)}}$$

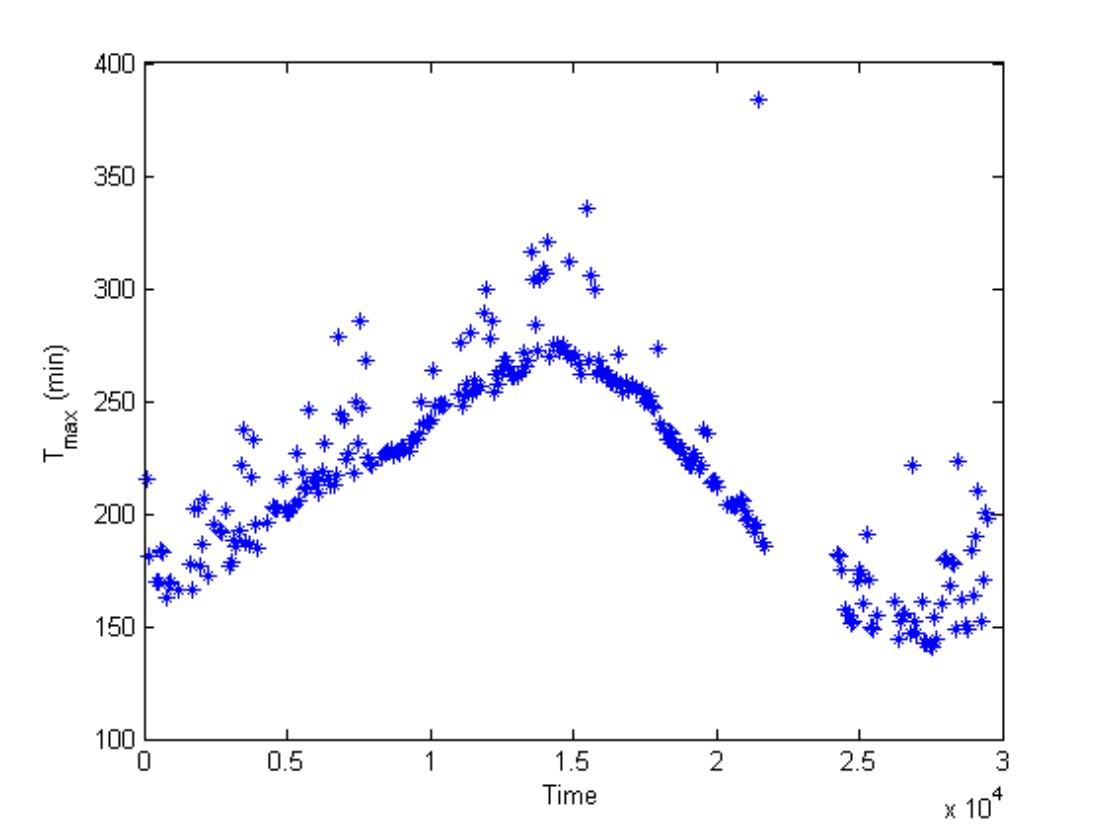
where exposure time is the time to receive 1 MED

Some points to consider:

- Care must be taken when using the erythemally weighted UV to predict a vitamin D effect (The two action spectra are different)
- The vitamin D effective UV is has a higher weighting than the erythemally effective UV above 300 nm but does not extend into the UVA.
- **Vitamin D is UVB sensitive** - solar elevation and ozone have a significant influence.

Max exposure times before exceeding ICNIPR EL:

- Considering a full range of ICNIRP and vitamin D spectrally weighted values for Toowomba, 2009 ($n = 14\,310$, 265 full days)



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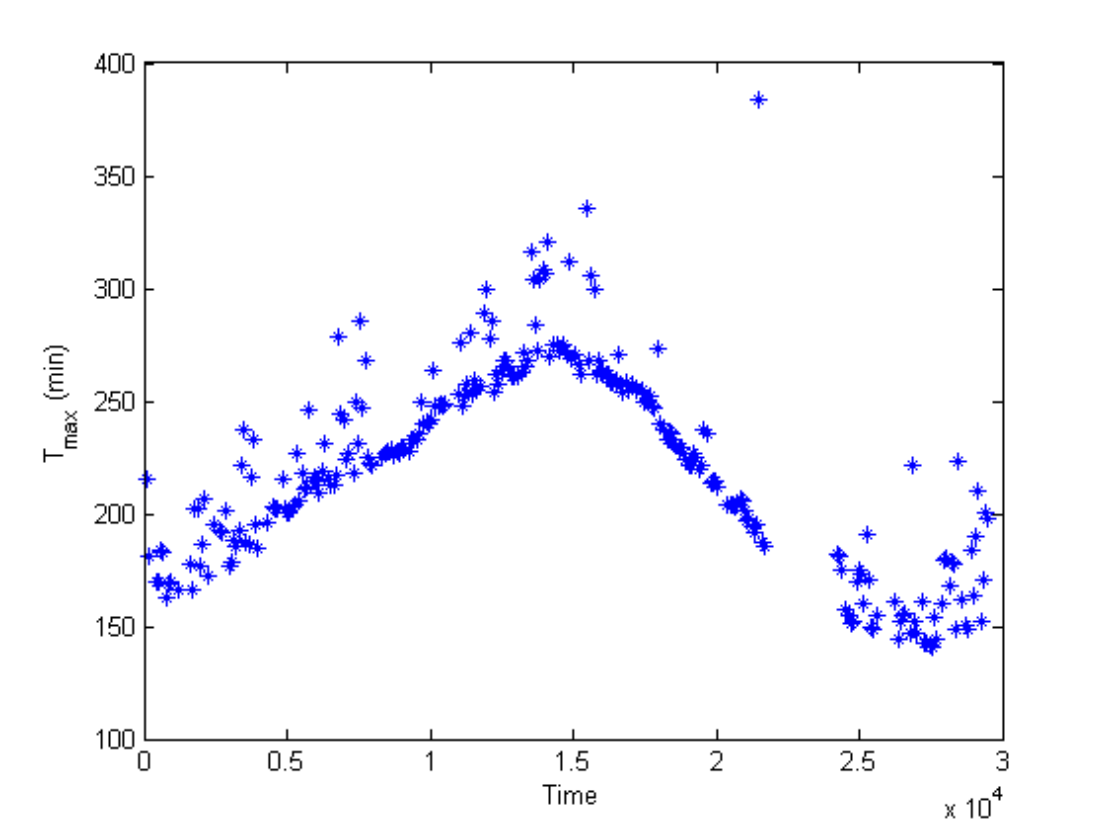
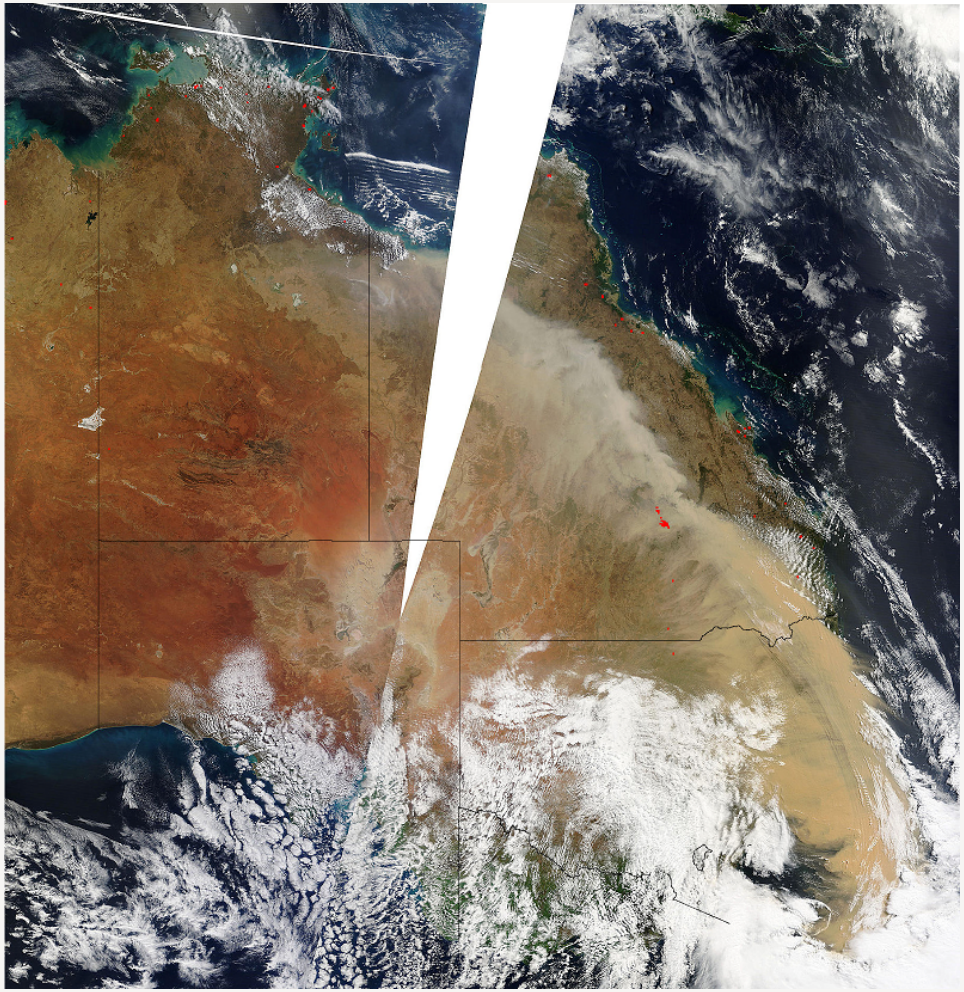


Provided an individual can rise at 5 am..

23 September 2009:



MODIS TERRA image, 23 September, 2009.

23 September 2009:

Red Haze Envelopes Sydney Harbour Bridge, ABC 2009.

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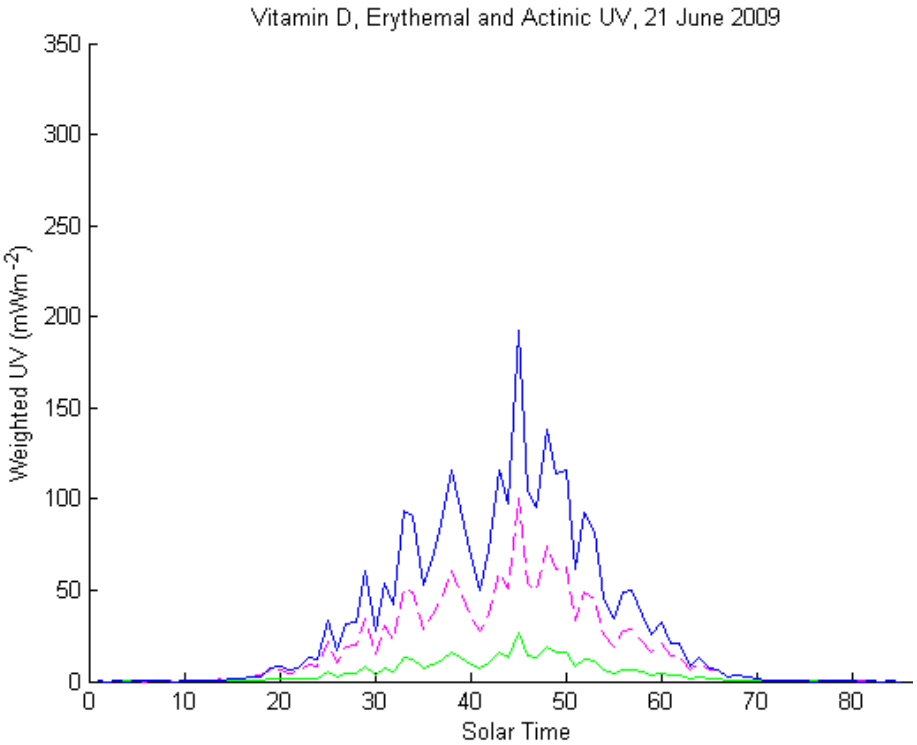
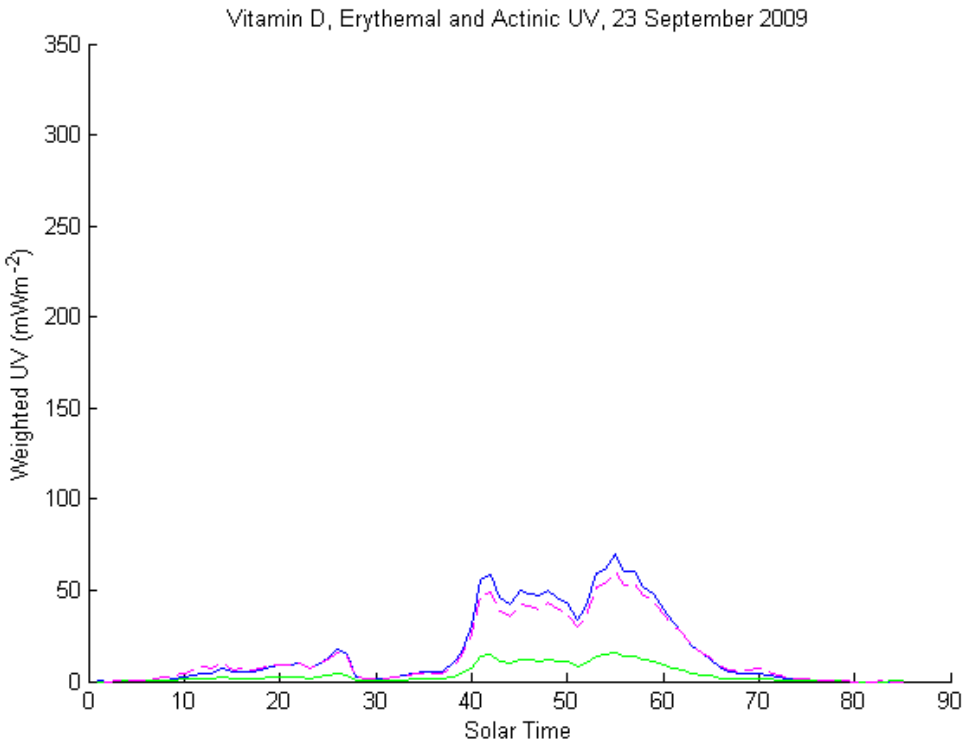
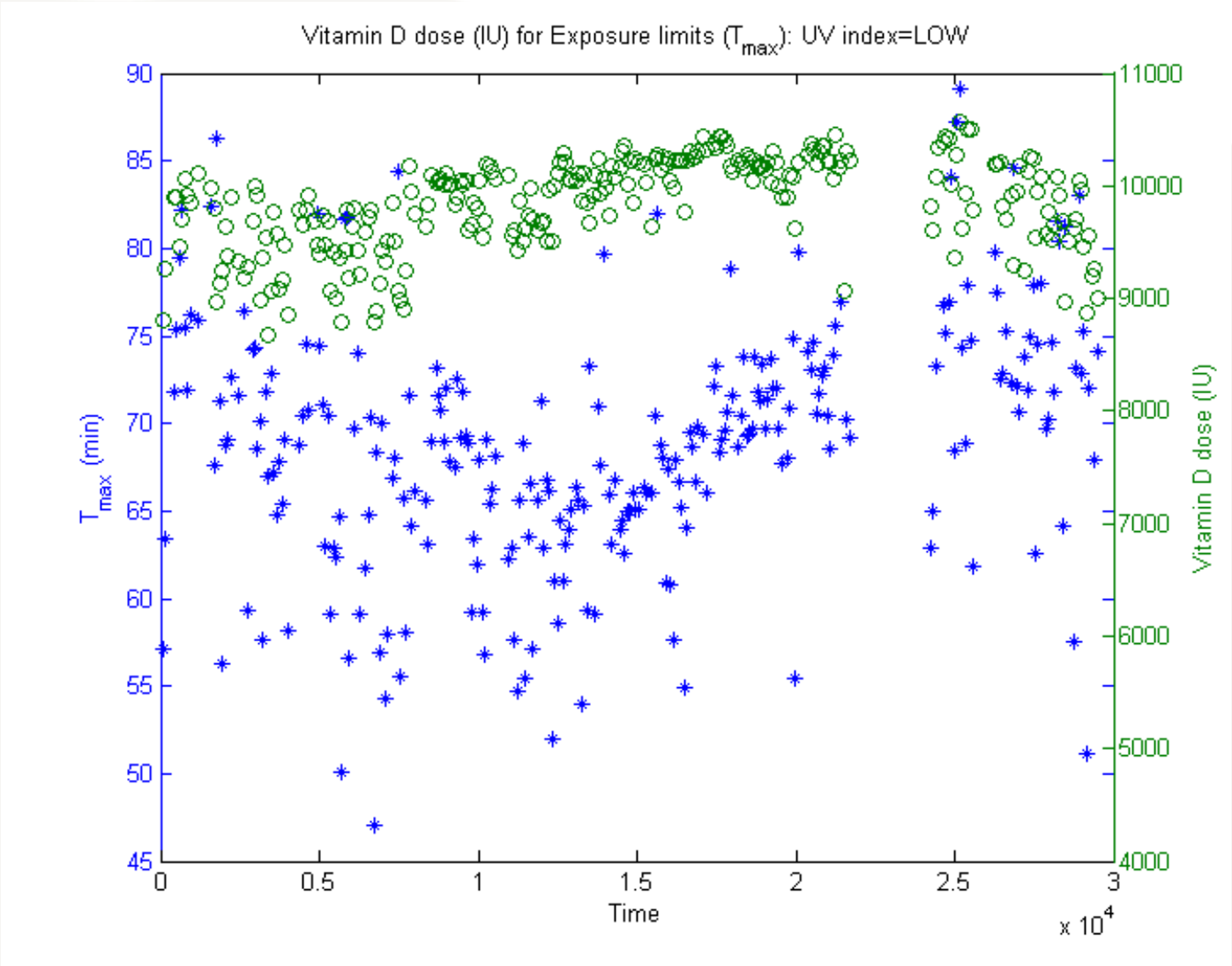


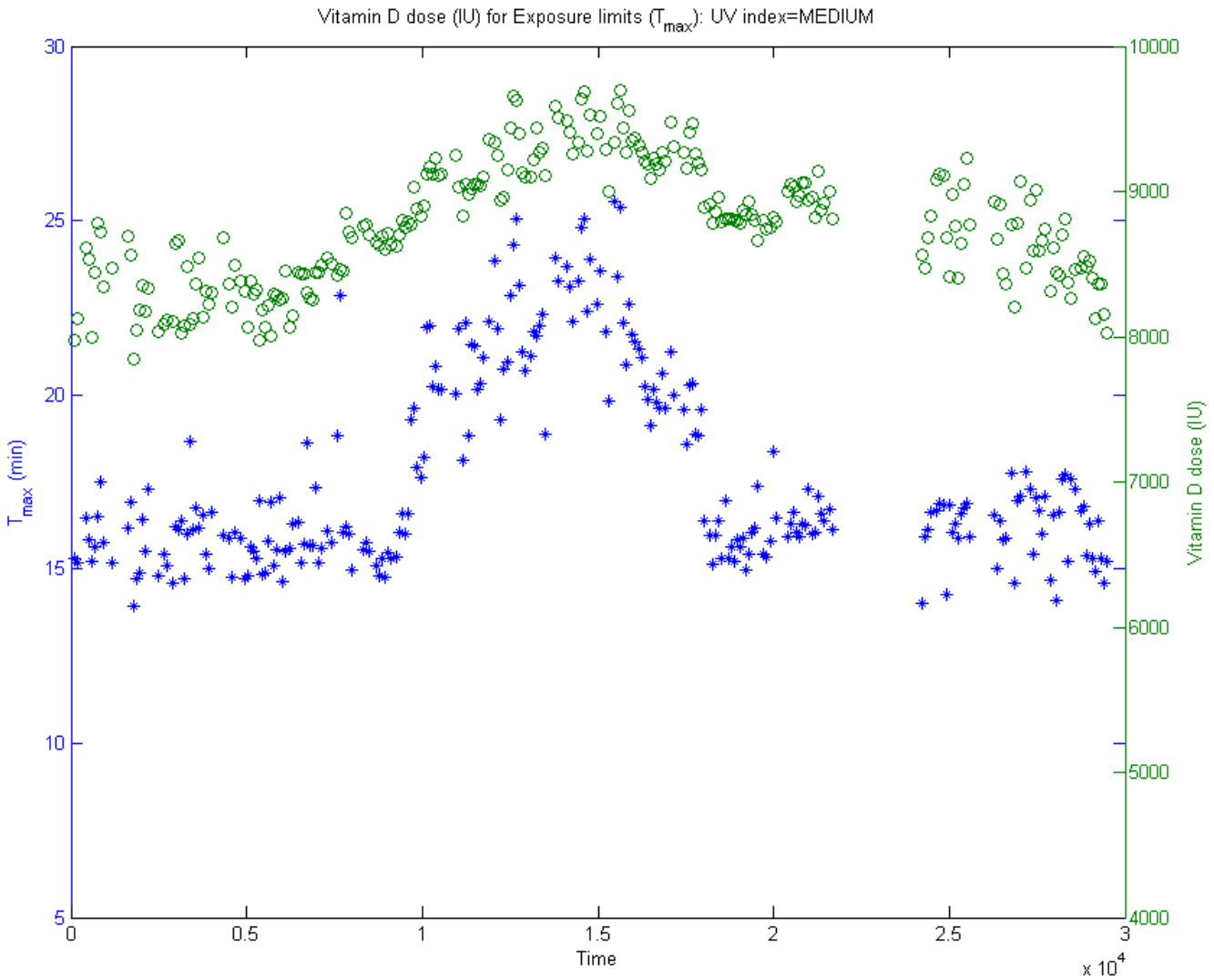


- Mean UVI on 23 September = 0.60
- Max UVI = 2.4

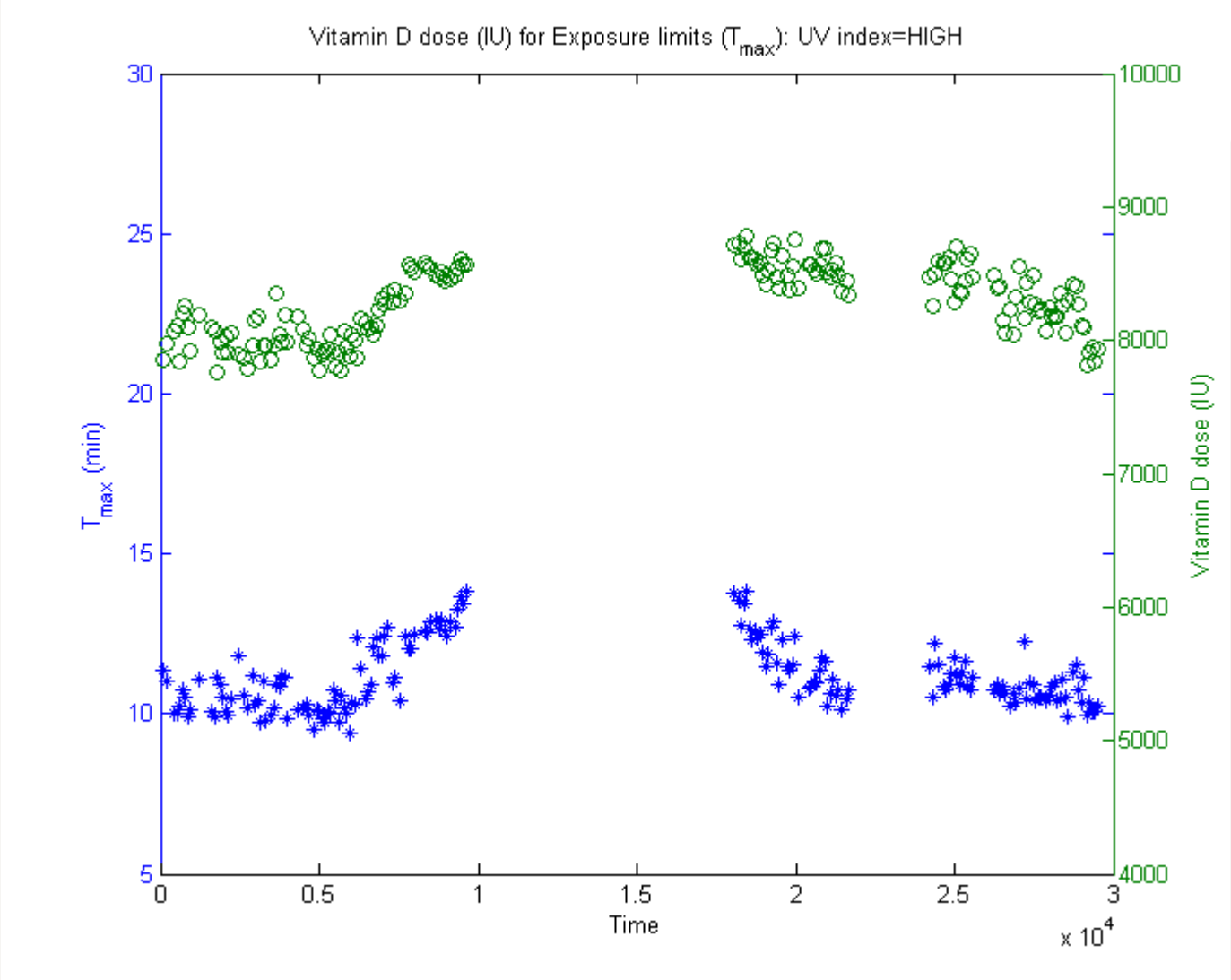
Max exposure time and IU dose, UVI (low):



Max exposure time and IU dose, UVI (mod):



Max exposure time and IU dose, UVI (high):



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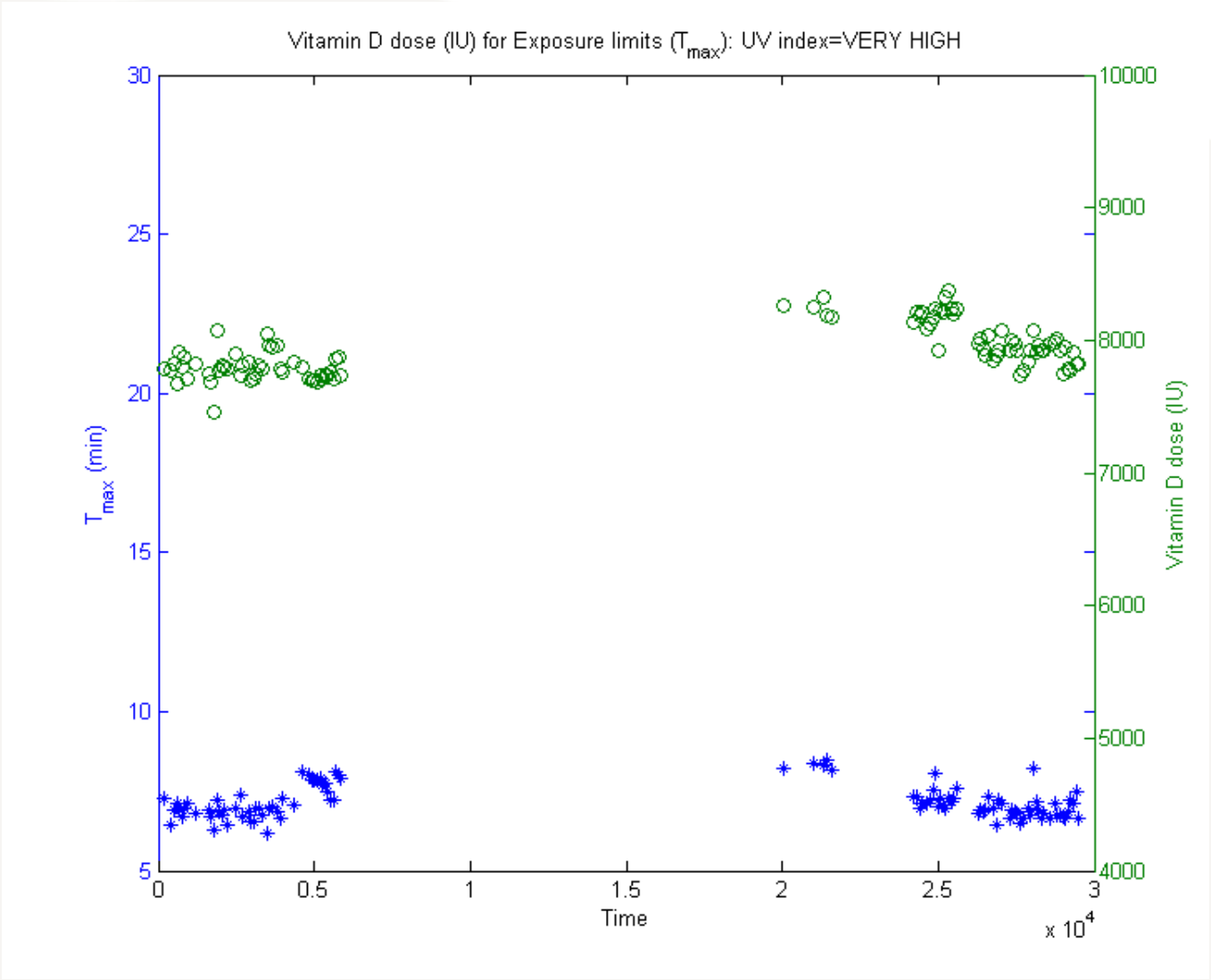
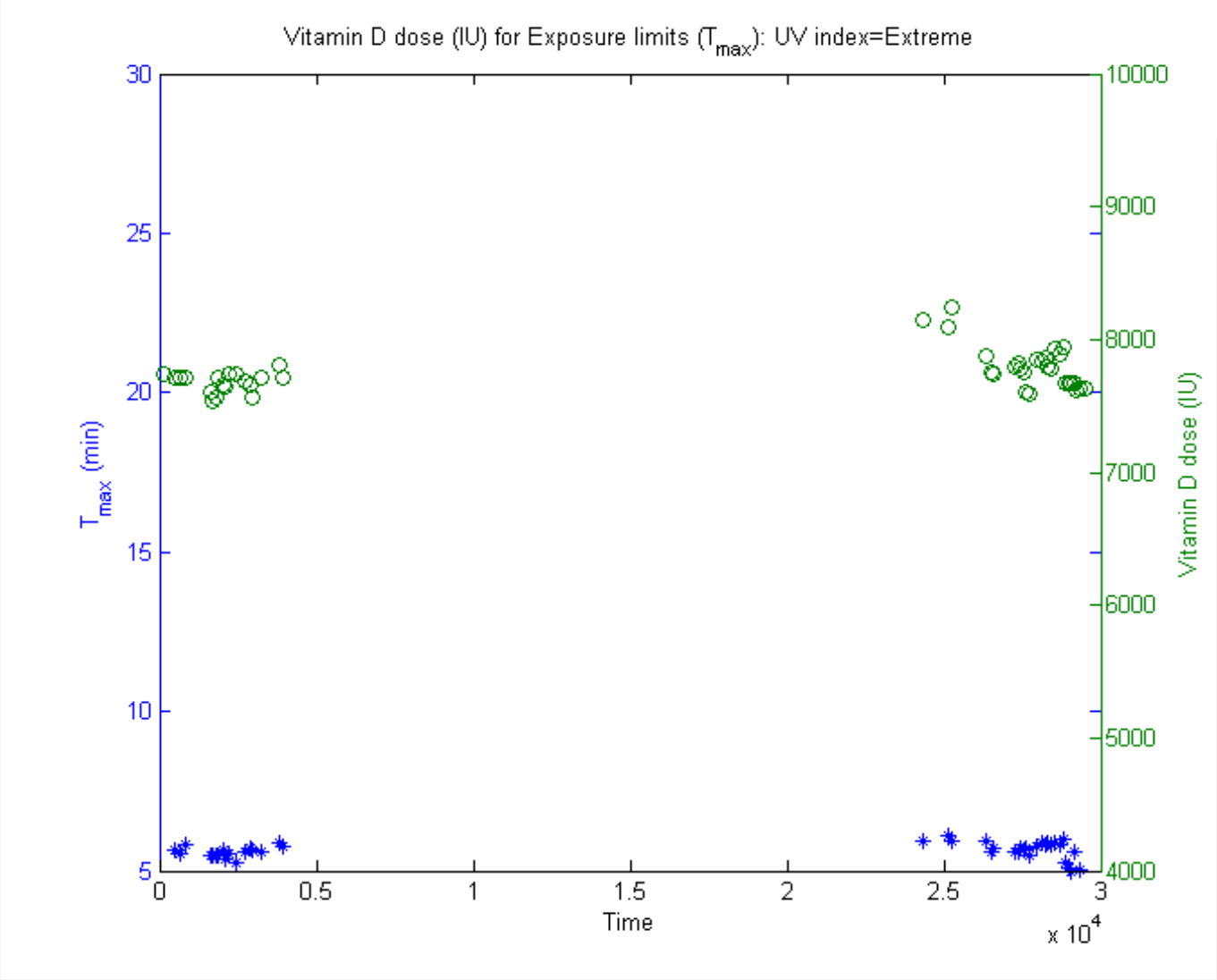


Max exposure time and IU dose, UVI (extreme):

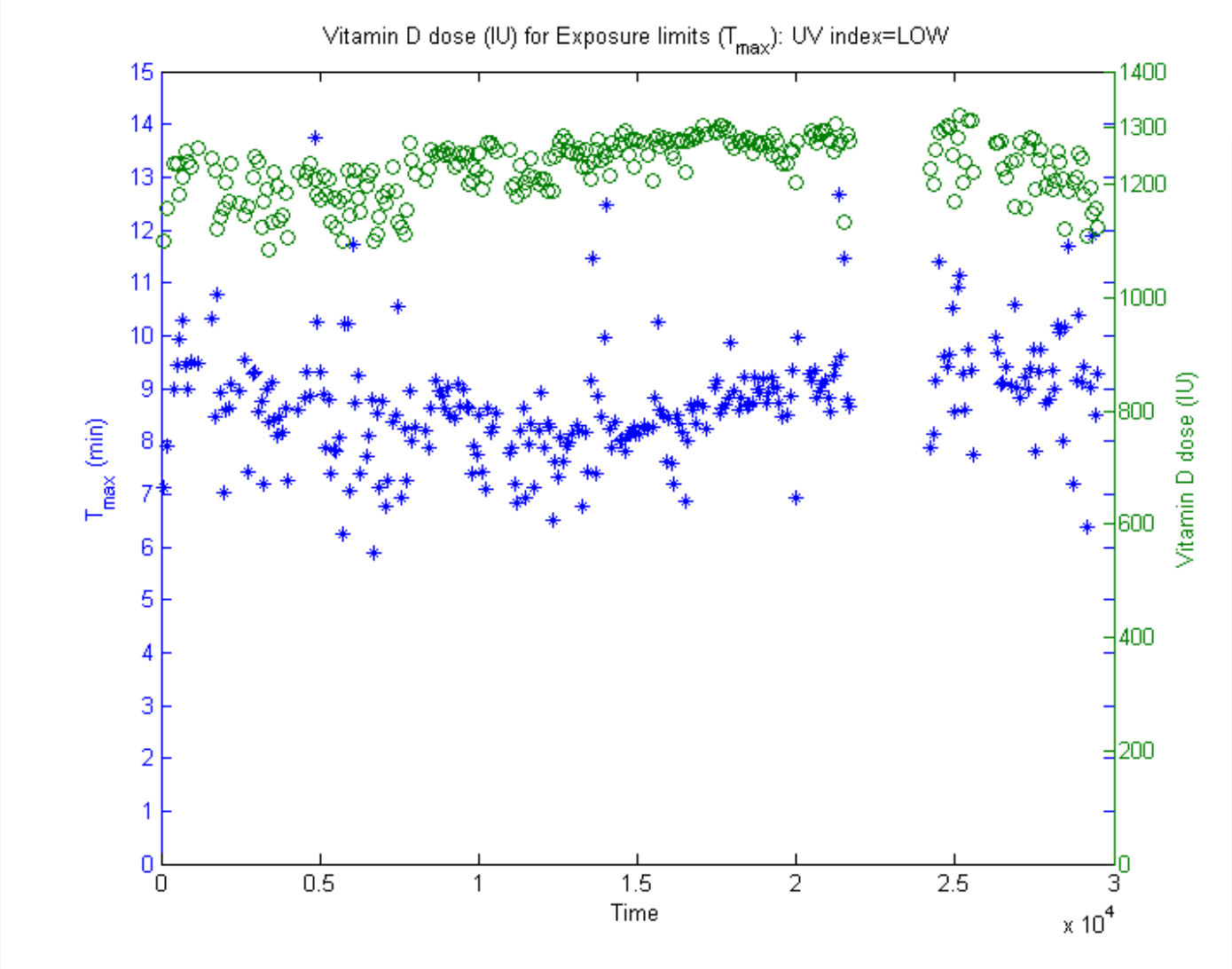


Summary of findings:

For pale type I skin exposed up to the ICNIRP EL:

UV index	$T_{max} \pm 1\sigma$ (min)	Vit D dose (IU)
LOW	69.71 ± 8.65	9848 ± 411
MODERATE	17.66 ± 2.78	8775 ± 424
HIGH	11.10 ± 1.02	8272 ± 271
VHIGH	7.14 ± 0.51	7916 ± 186
EXTREME	5.58 ± 0.32	7752 ± 149

Max exposure time/8 & IU dose, UVI (low):



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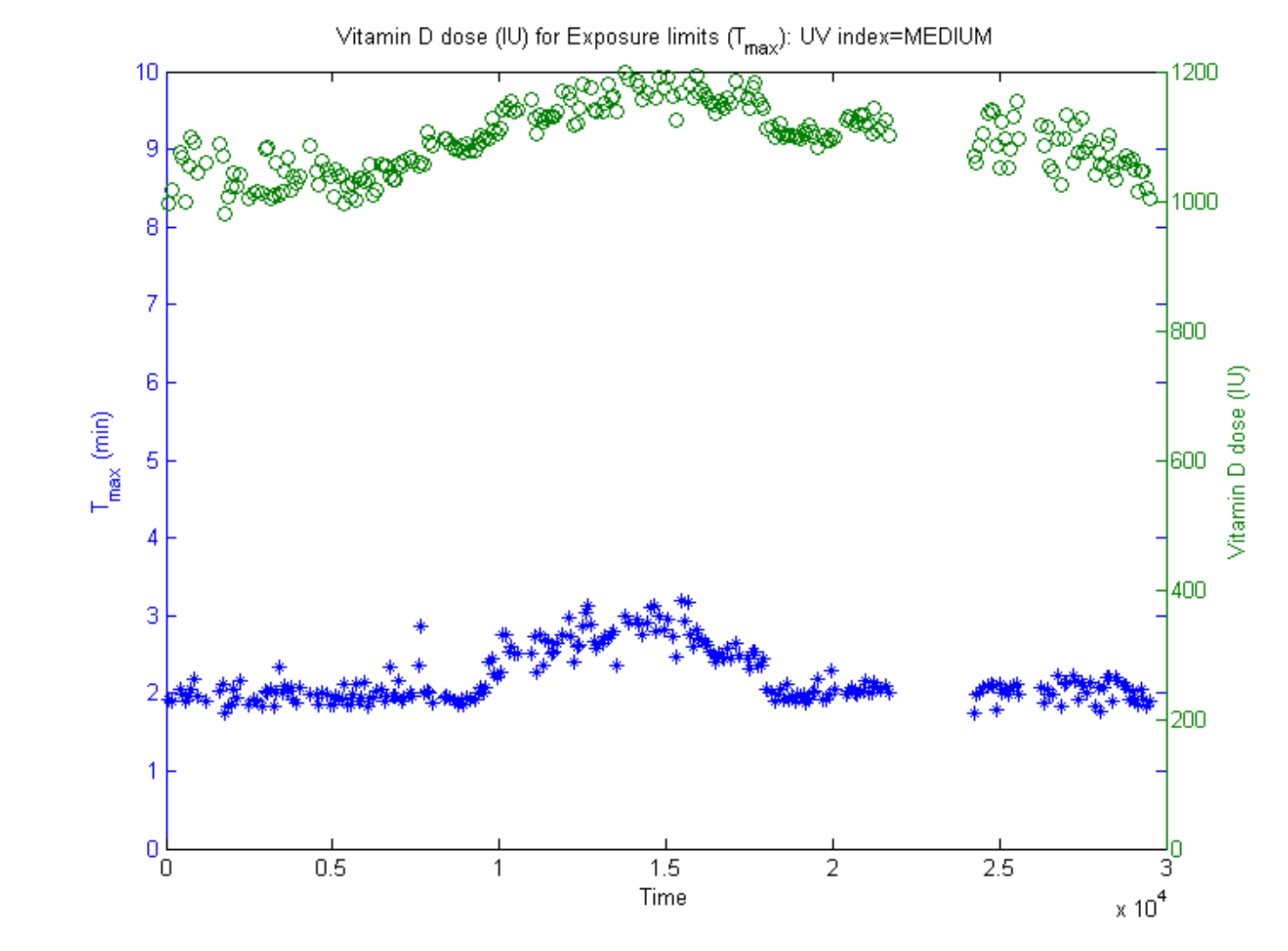

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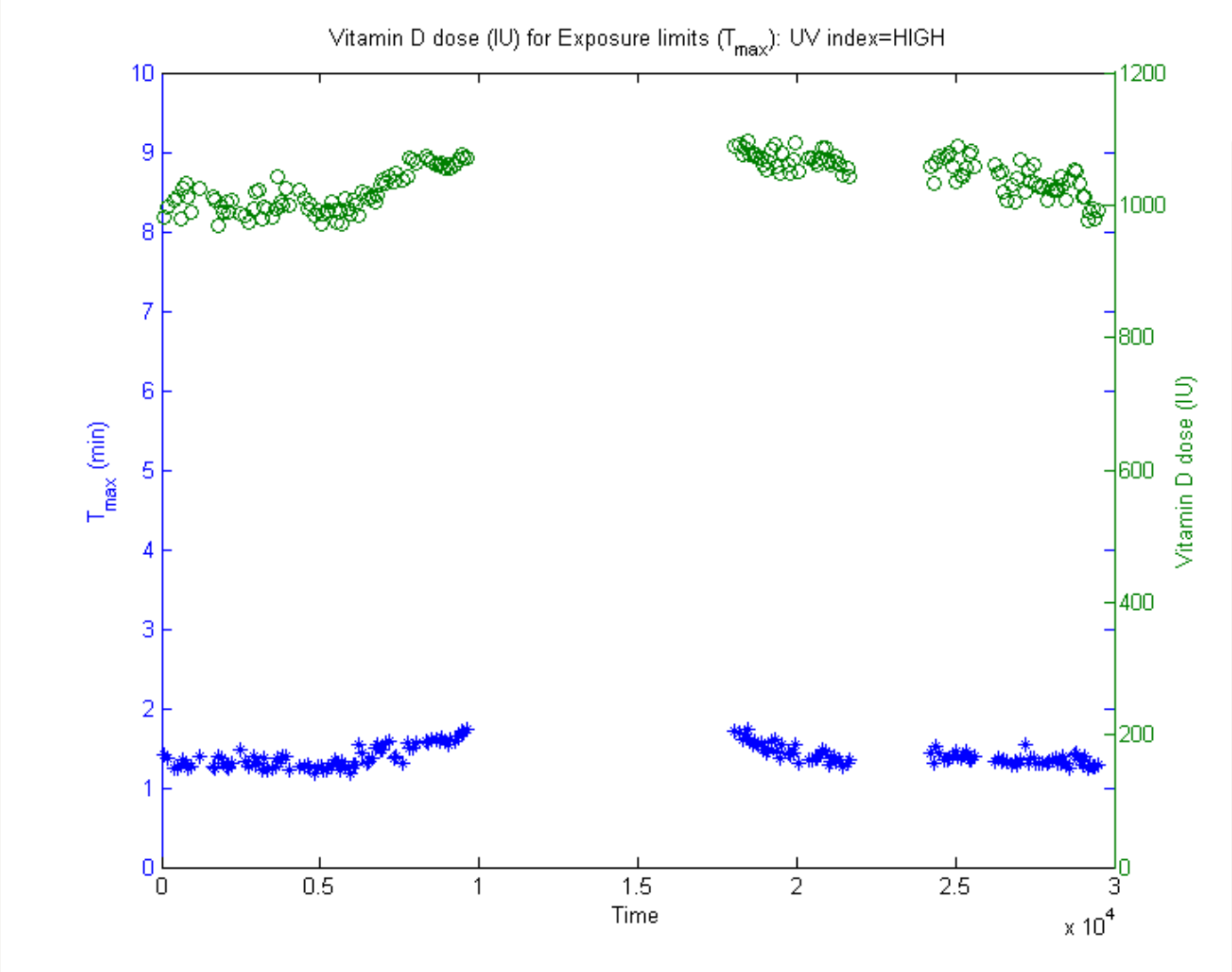

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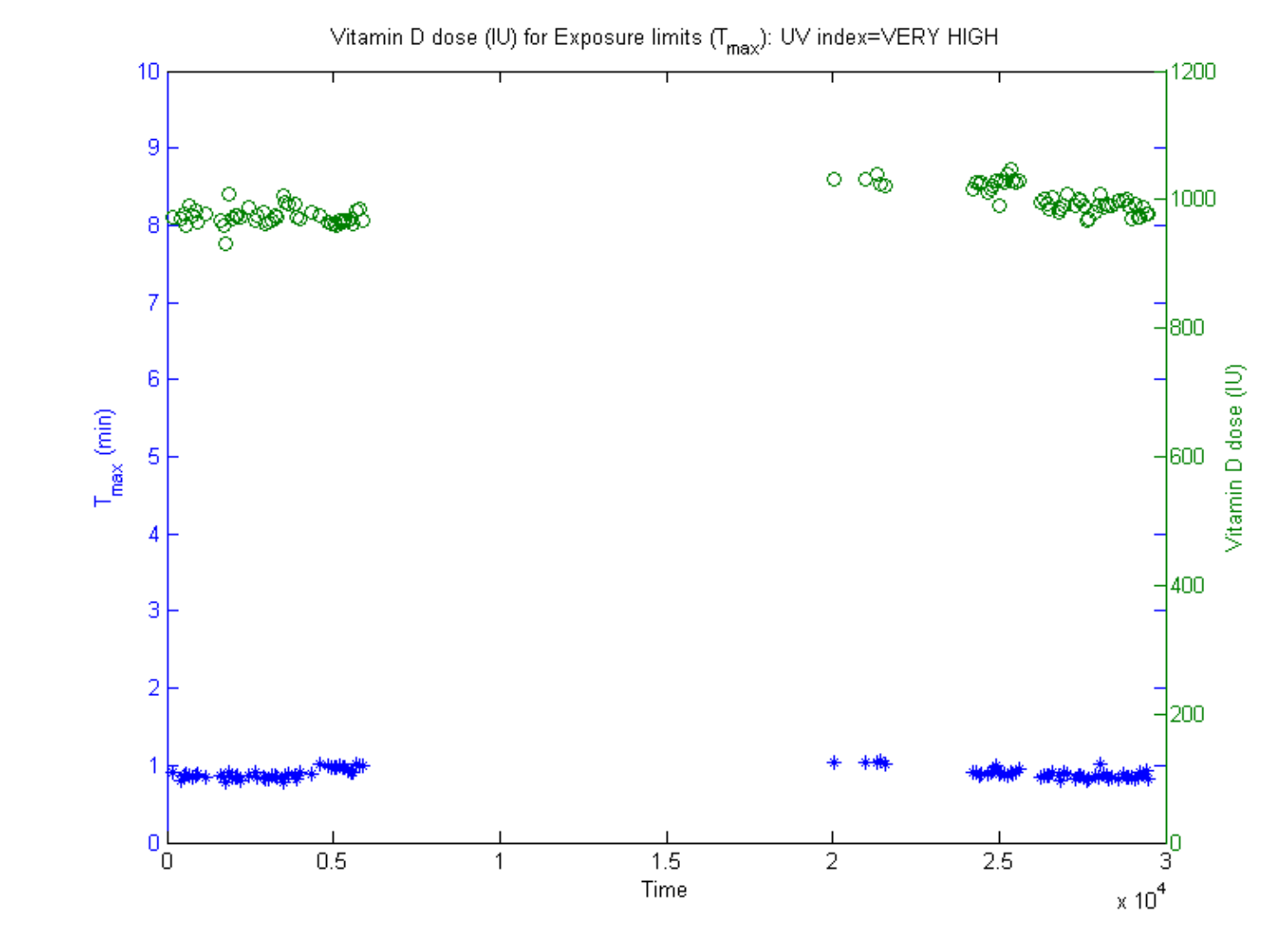

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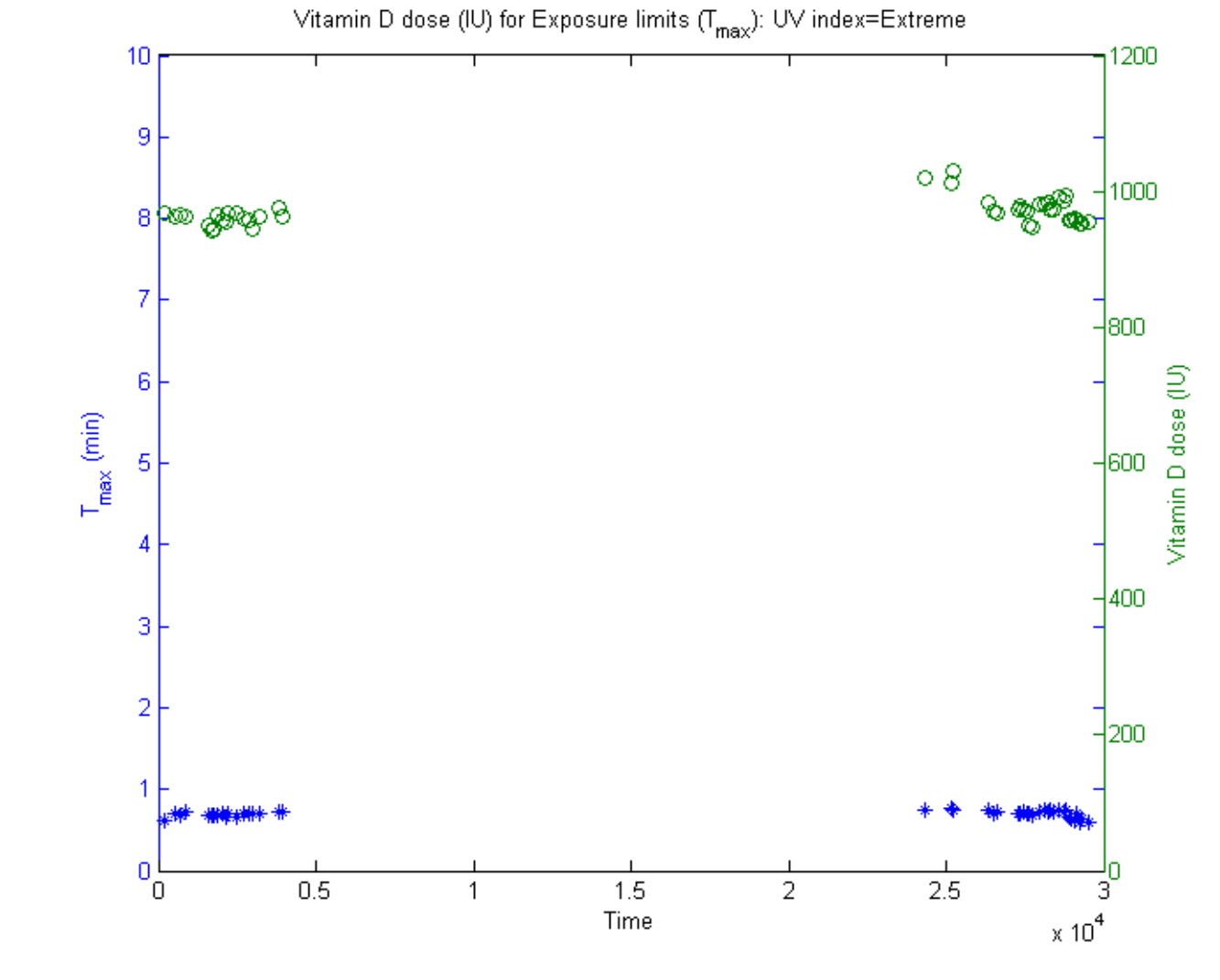

Vitamin D dose summary:

For pale type I skin exposed for $\frac{1}{8}$ of the time to reach ICNIRP EL:

UV index	$T_{max} \pm 1\sigma$ (min)	Vit D dose (IU)
LOW	8.71 ± 1.08	1231 ± 51
MODERATE	2.21 ± 0.35	1097 ± 53
HIGH	1.39 ± 0.13	1034 ± 34
VHIGH	0.89 ± 0.06	989 ± 23
EXTREME	0.70 ± 0.04	969 ± 19

Summary of Vitamin D dose at ICNIRP EL (30 Jm^{-2}):

Considering the 6 skin types, Fitzpatrick (1988):

UV index	Tmax (min)	Vit D type I (IU)	VitD type II (IU)	VitD type III (IU)	VitD type IV (IU)	VitD type V (IU)	VitD type VI (IU)
LOW	69.71	9848	7879	6565	4377	3283	1970
MODERATE	17.66	8775	7020	5850	3900	2925	1755
HIGH	11.10	8272	6618	5515	3677	2757	1655
VHIGH	7.14	7916	6333	5277	3518	2639	1583
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- The time required for a daily 1000 IU vitamin D dose can be estimated for each of the six skin types.
- This information can be useful for individualising sun exposure times..

Summary:

- Current advice on sunlight exposure for healthy Vitamin D is in agreement with the time limits predicted here, provided a person has type I skin.
- There is room for the individualisation of these limits and integration of these with new technologies.
- An awareness of the exposure time limits for occupational groups will contribute to better health outcomes for the Australian public.

Reference List:

1. Fioletov, V.E., McArthur, L.J.B., Mathews, T.W. & Marrett, L. (2009), On the relationship between erythemal and vitamin D action spectrum weighted ultraviolet radiation., J. Photochem. Photobiol. B:Biol., 95, 9-16.
2. Fitzpatrick, T.B. (1988), The validity and practicality of sun-reactive skin types I through VI, Arch. Dermatol., 124(6), 869-871.
3. Holick, M.F. (2002), Vitamin D: the underappreciated D-lightful hormone that is important for skeletal and cellular health. Curr. Opin. Endocrinol. Diab. 9, 87-98.
4. Holick, M.F. (2004), Vitamin D: Importance in the prevention of cancers, type 1 diabetes, heart disease and osteoporosis, Am. J. Clin. Nutr. 79, 362-371.
5. McKenzie, R.L., Liley, J.B. & Björn, L. O (2009), UV radiation: Balancing risk and benefits, Photochem. Photobiol., 85, 88-98.
6. Seckmeyer, G. *et. al.* (2013) A novel method to calculate solar UV exposure relevant to vitamin D production in humans, Photochem. Photobiol. 89, 974-983.
7. Turnbull, D. & Parisi, A. (2005), Increasing the ultraviolet protection provided by public shade structures, J Photochem. Photobio. B: Biol. (78), 61-67.