

Airglow UV background



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Basic notes

- Next slides contain results of AURIC calculations only for airglow emission in upward direction.
- There is no Albedo effect from - zodiac light, star light and airglow.
- All calculations was provided in altitude 400 km for nadir looking angle for night 20 – 21 of given month.
- Definition of night – zenith angle of sun is bigger than 110 degrees.
- Preliminary results – we need to compare our results with existing data.
- AURIC model provided by Computational Physics, Inc.
- AURIC reference: D. J. Strickland, J. E. Bishop, J. S. Evans, T. Majeed, P. M. Shen, R. J. Cox, R. Link, and R. E. Huffman, Atmospheric ultraviolet radiance integrated code (AURIC): theory, software architecture, inputs, and selected results, *J. Quant. Spectr. Rad. Transfer*, 62, 689, 1999.

AURIC - short introduction

- UV background in AURIC is produced by Herzberg I, II and Chamberlain emission inside range 300 - 400 nm.
- these emissions result from reactions involving downward diffusing atomic oxygen generated on the dayside by O_2 photodissociation.
- Recombination reaction:



- $M - O, O_2, N_2$
- Result of reaction is emission of photon

- Volume emission rate:

$$j_{\text{HzI}} = \frac{\varepsilon_{\text{HzI}} A_1 k_{43} [\text{O}]^2 [\text{M}]}{A_1 + k_{44}[\text{O}] + k_{45}[\text{O}_2] + k_{46}[\text{N}_2]},$$

$$j_{\text{Chm}} = \frac{\varepsilon_{\text{Chm}} A_2 k_{43} [\text{O}]^2 [\text{M}]}{A_2 + A_3 + k_{47}[\text{O}] + k_{48}[\text{O}_2]},$$

$$j_{\text{HzII}} = \frac{\varepsilon_{\text{HzII}} A_4 k_{43} [\text{O}]^2 [\text{M}]}{A_4 + k_{49}[\text{O}] + k_{50}[\text{O}_2]},$$

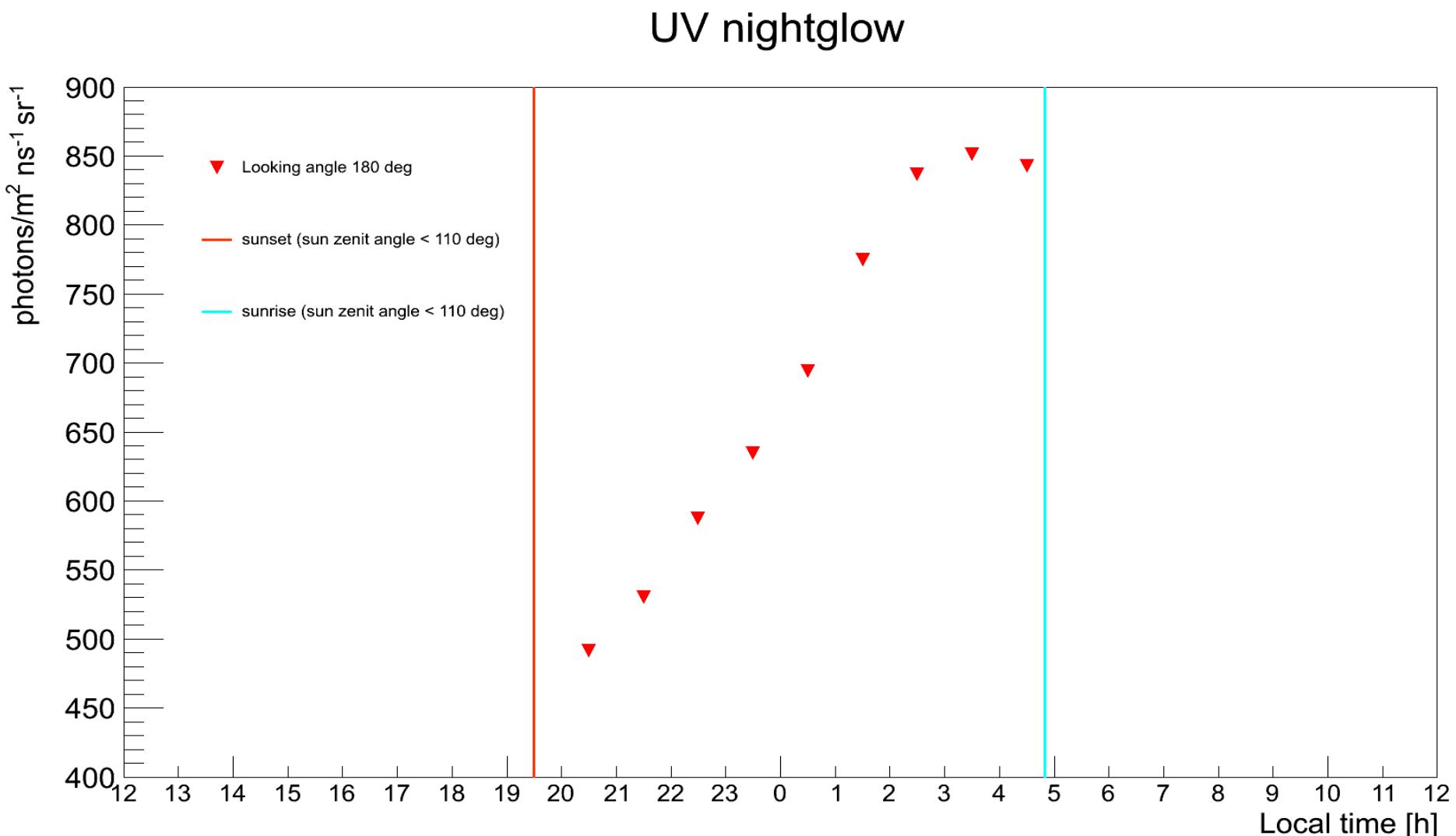
- $[\text{O}], [\text{M}], [\text{O}_2], [\text{N}_2]$ – densities of corresponding atoms and molecules

$$k_{43} = 2.1 \times 10^{-32} (200/T_n)^2$$

- T_n - temperature
- $A_1, A_2, A_4, k_{44}, k_{45}, k_{46}, k_{47}, k_{48}, k_{49}, k_{50}$ - rate coefficients
- $\varepsilon_{\text{HzI}}, \varepsilon_{\text{Chm}}, \varepsilon_{\text{HzII}}$ - production efficiencies

UV nightglow during one night

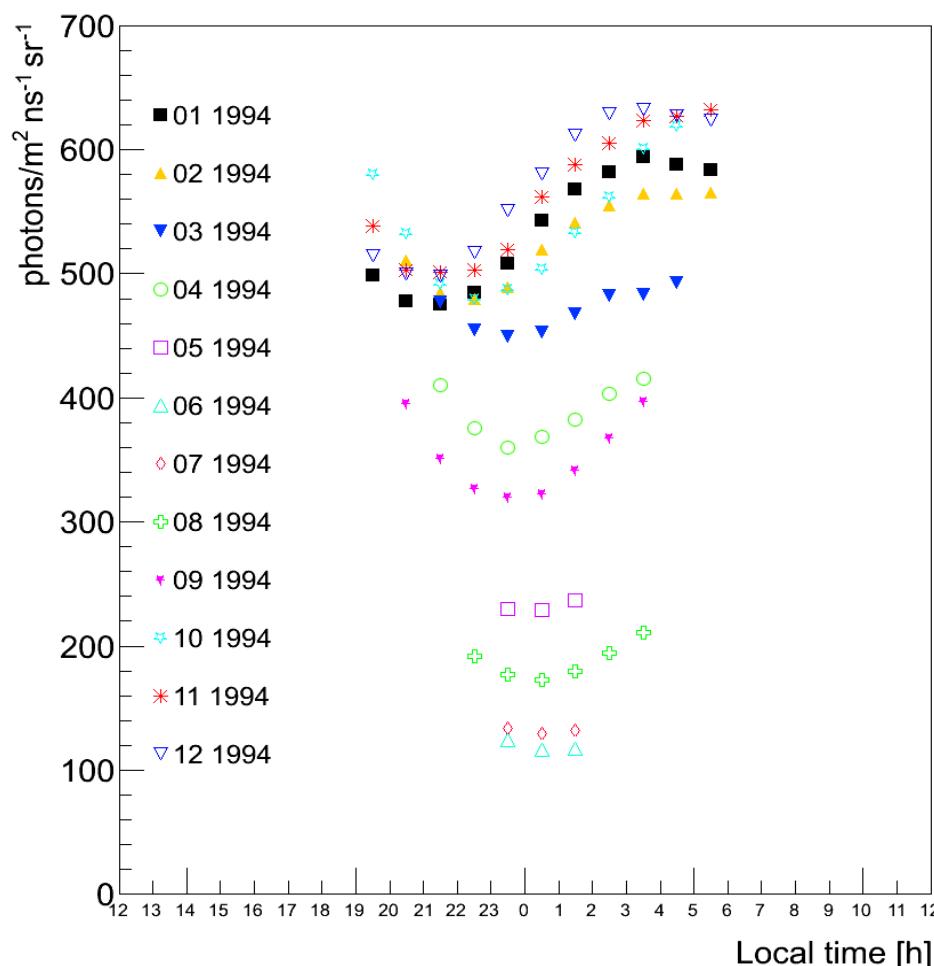
- Night 1994/03/20 – 21.
- Position: latitude – 0, longitude – 45.
- UV nightglow is not constant during night.



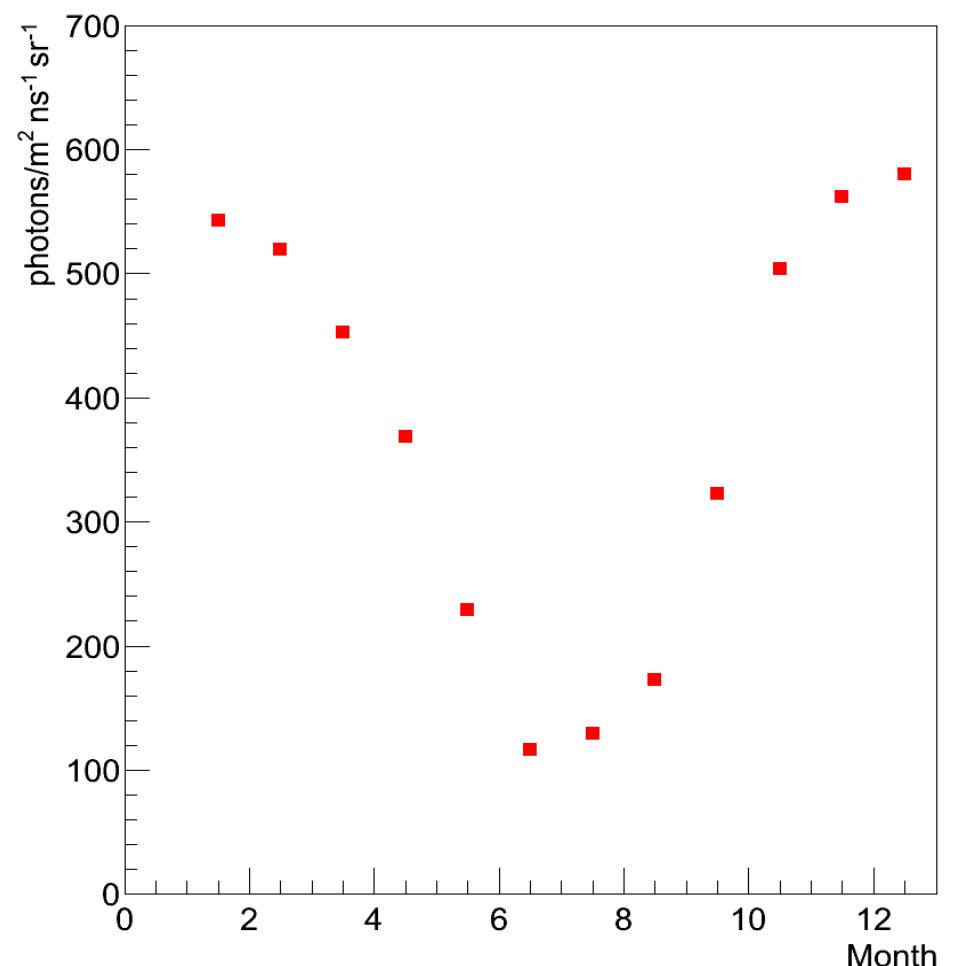
Seasonal dependence of UV nightglow

- Lat 45, long 45, 1994 – only one night (20-21) at each month.
- UV nightglow is not constant during night for most months.
- UV nightglow is seasonal dependent.

UV nightglow all night



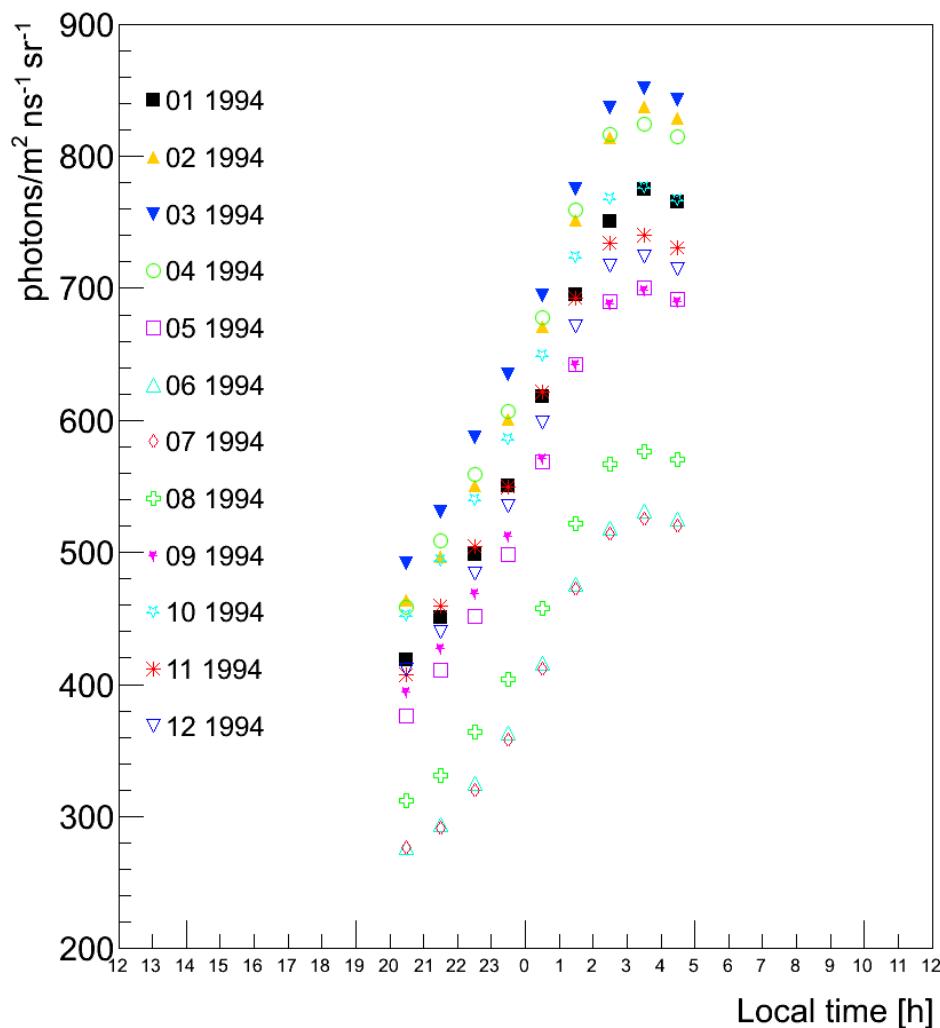
UV nightglow 00:00



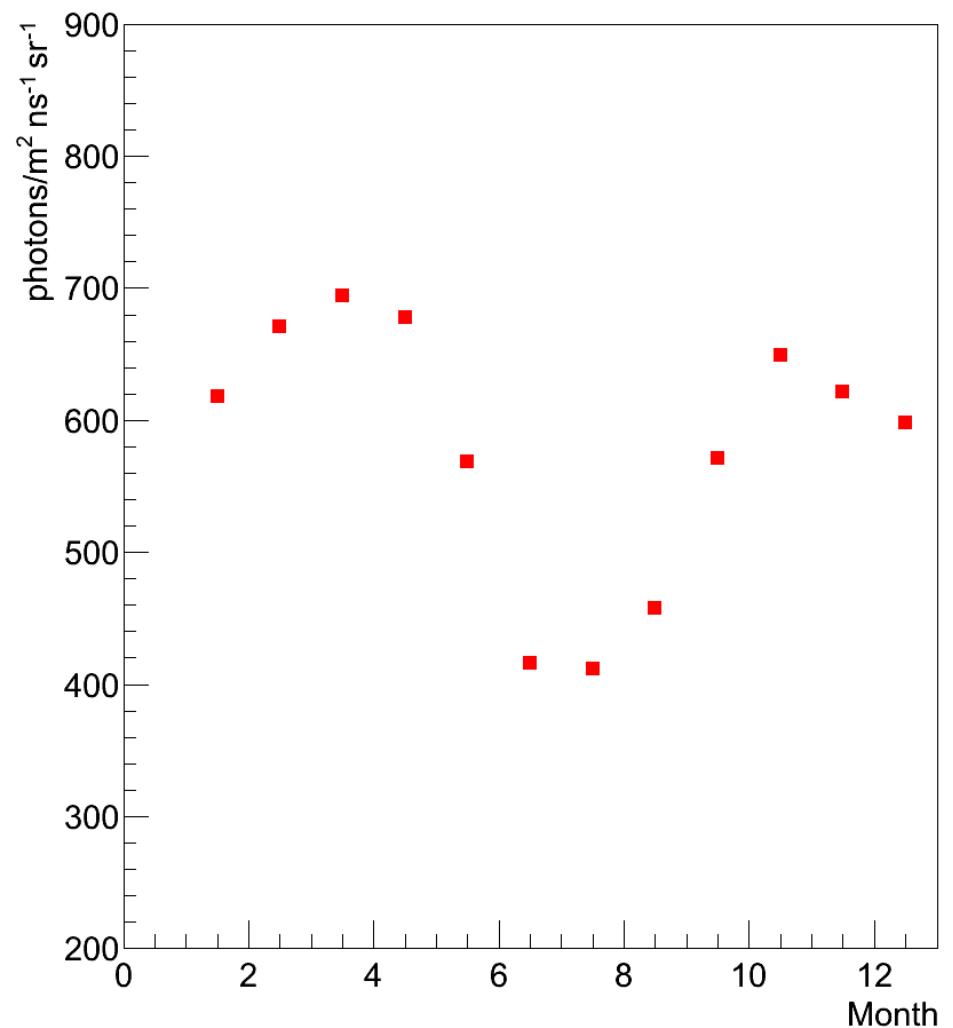
Seasonal dependence of UV nightglow

- Lat 0, long 45, 1994 – only one night (20-21) at each month.
- On equator – UV nightglow strongly increase.

UV nightglow all night

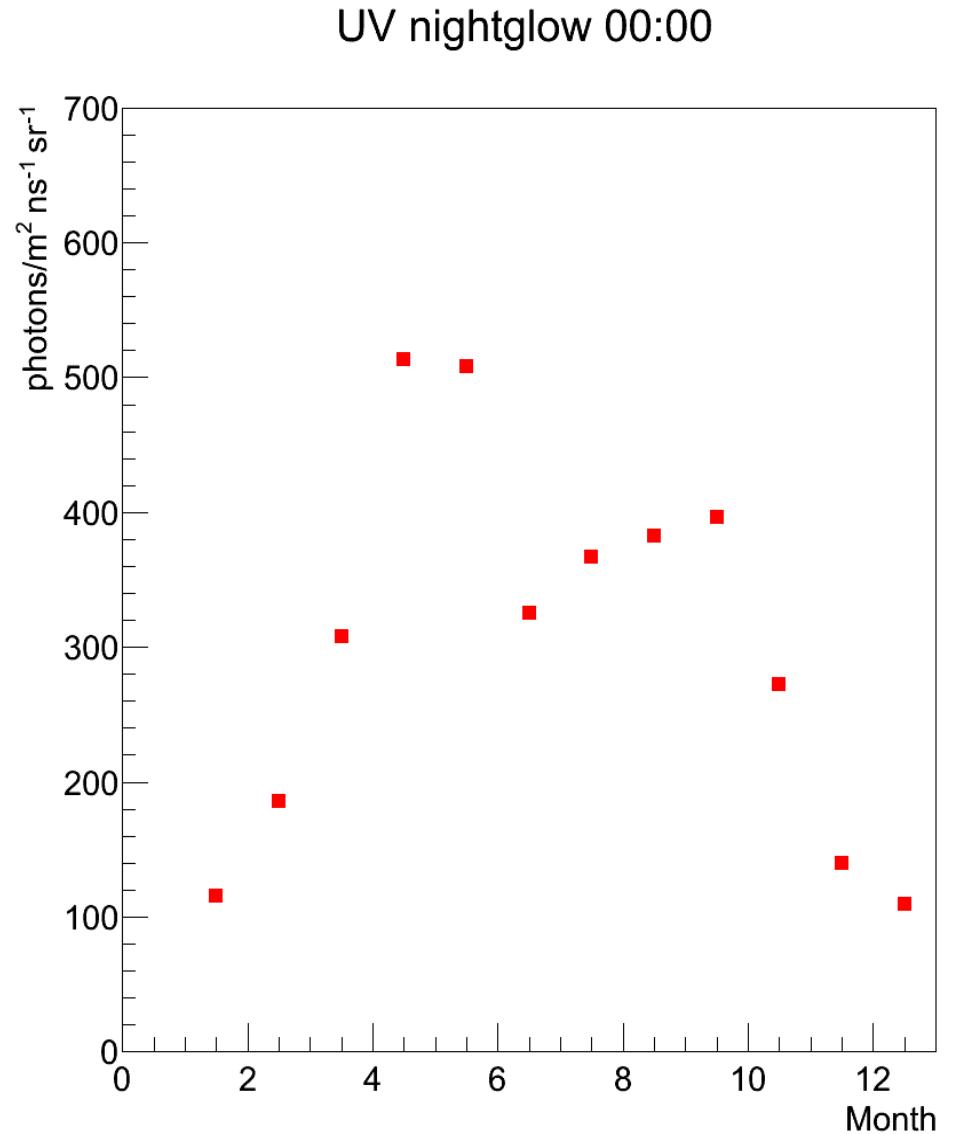
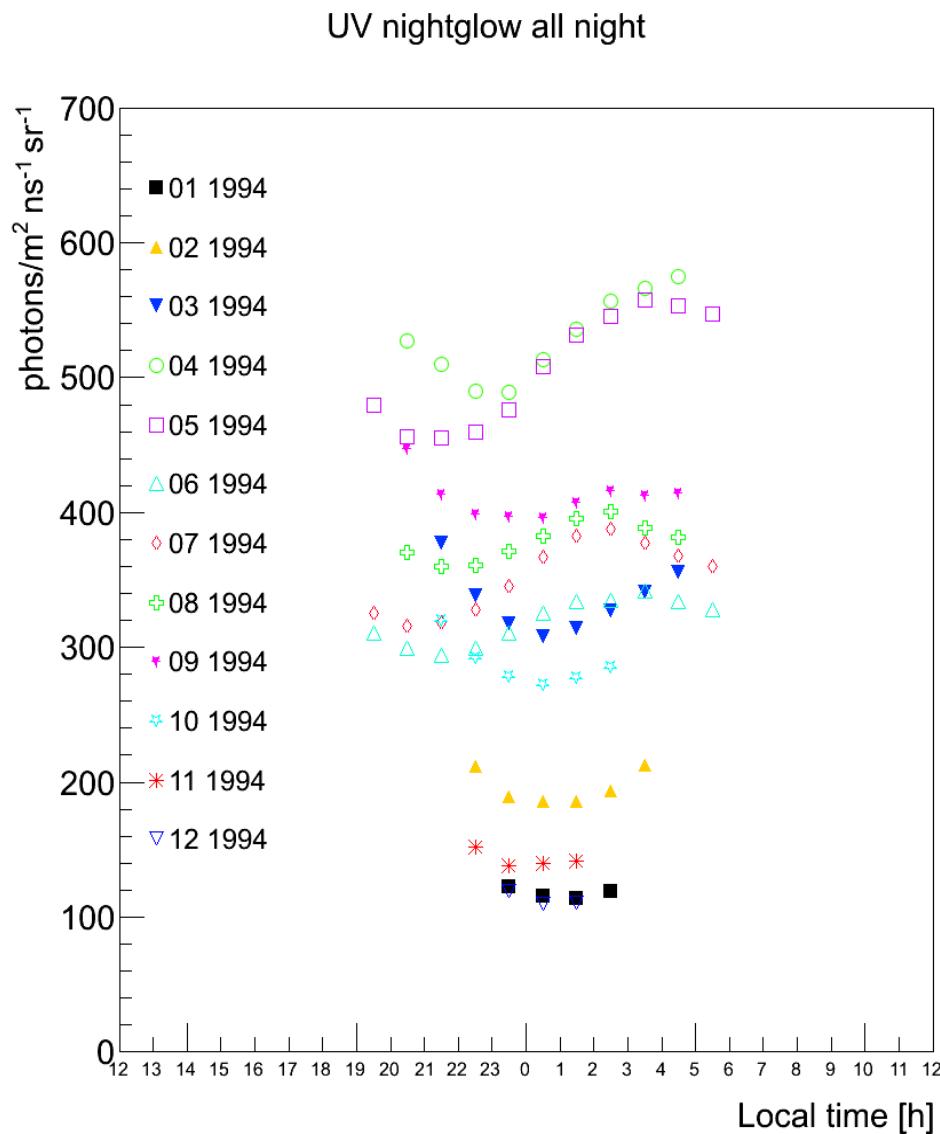


UV nightglow 00:00



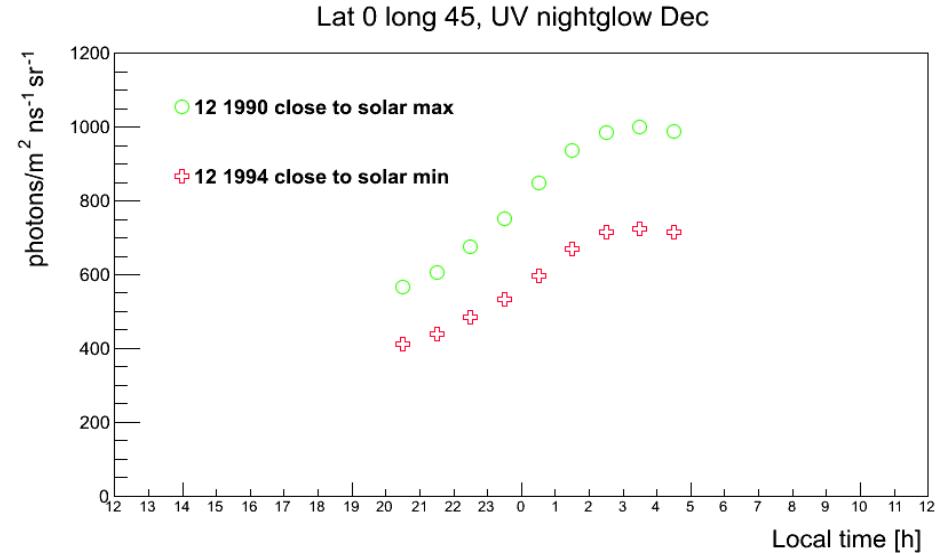
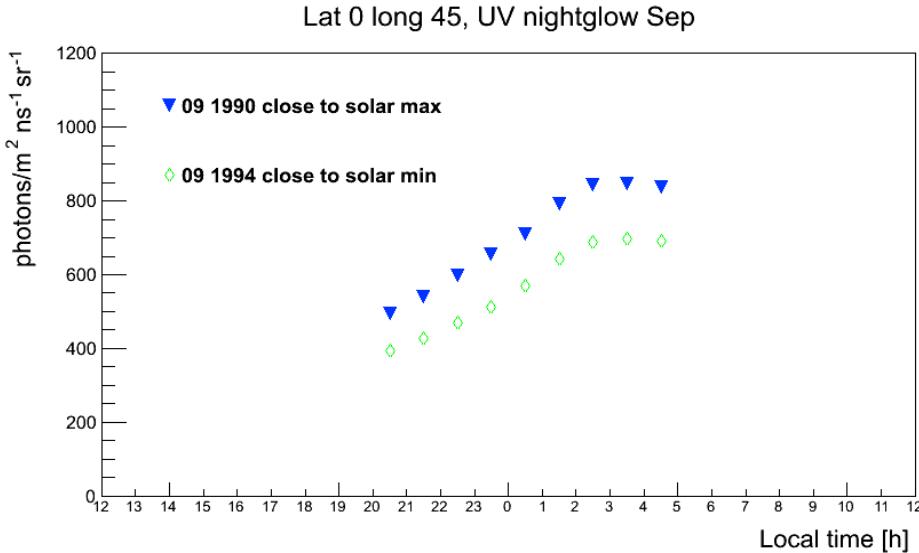
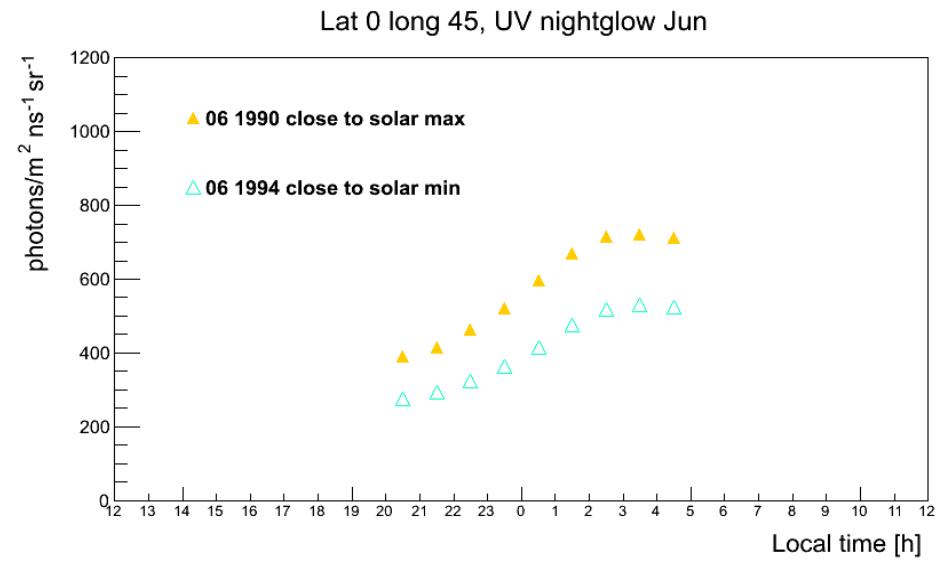
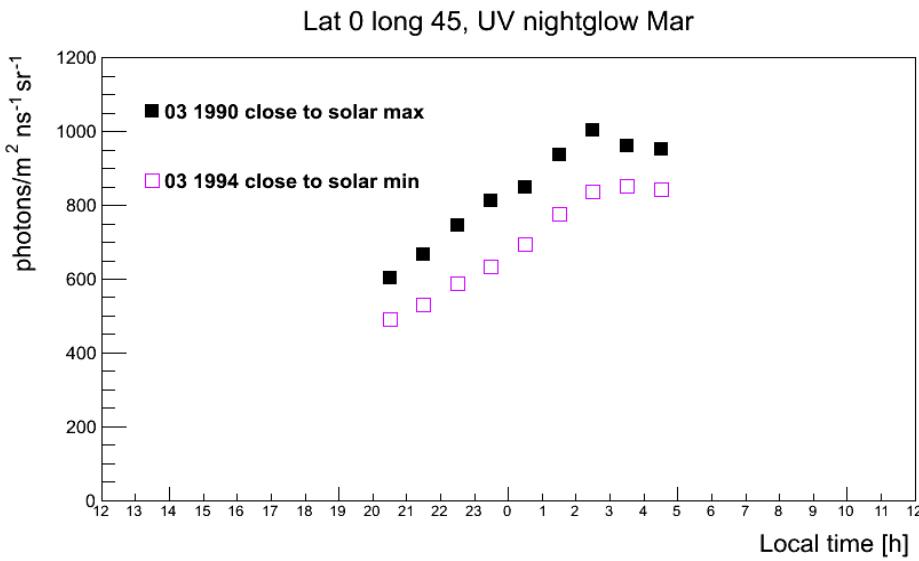
Seasonal dependence of UV background

- Lat -45, long 45, 1994— only one night (20-21) at each month.
- Opposite situation like on north hemisphere.



Comparison of nightglow – 1990 (close to solar max) vs 1994 (close to solar min)

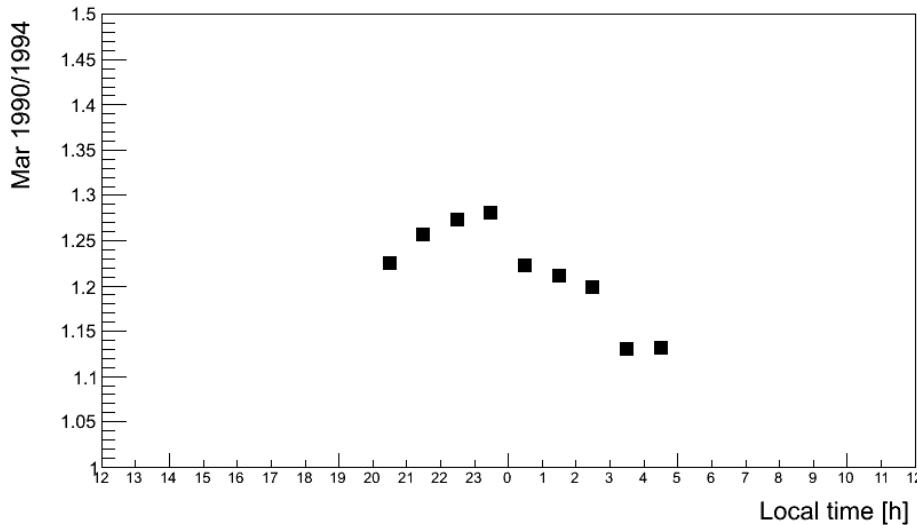
- 1990, 1994 – night from 20 -21 for March, June, September, December
- Dependence on solar activity.
- Bigger values close to solar maximum.



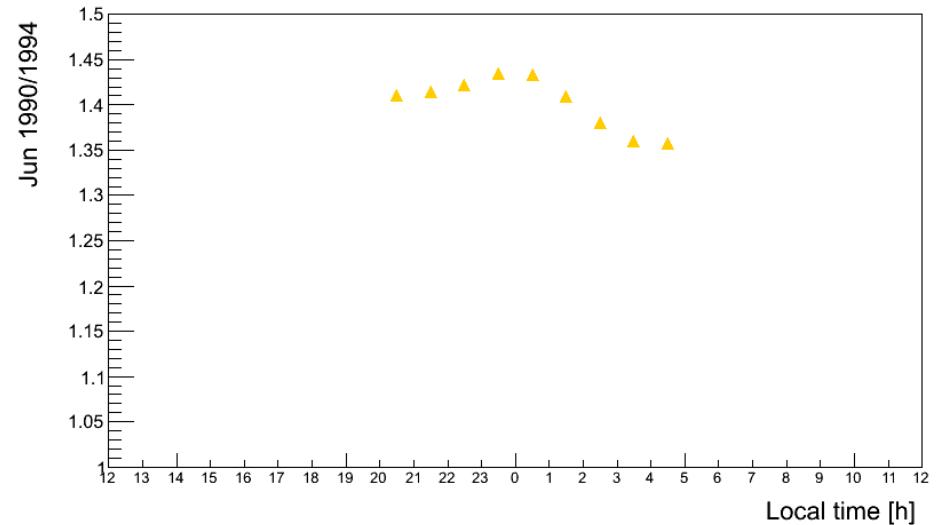
Ratio - 1990 vs 1994

- For March and September ~ 20-25%
- For June and December ~ 40-45 %

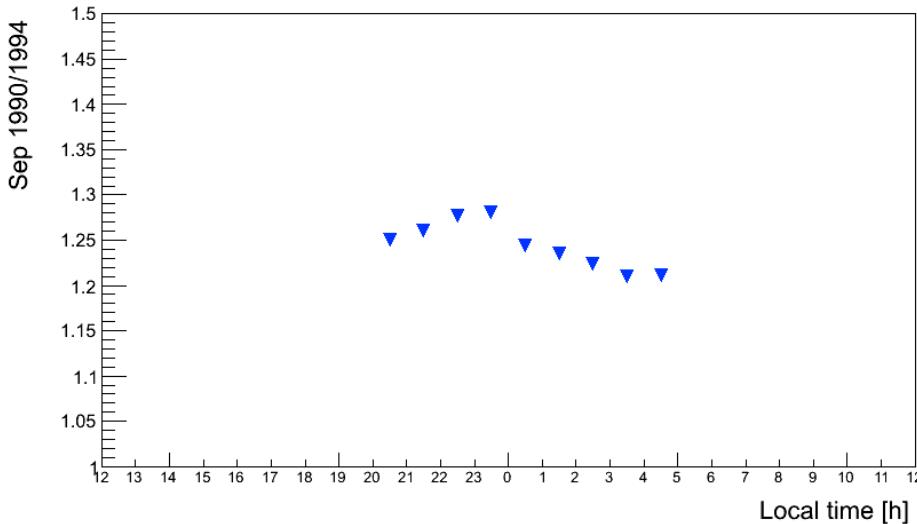
Lat 0 long 45, UV nightglow Mar, Ratio 1990/1994



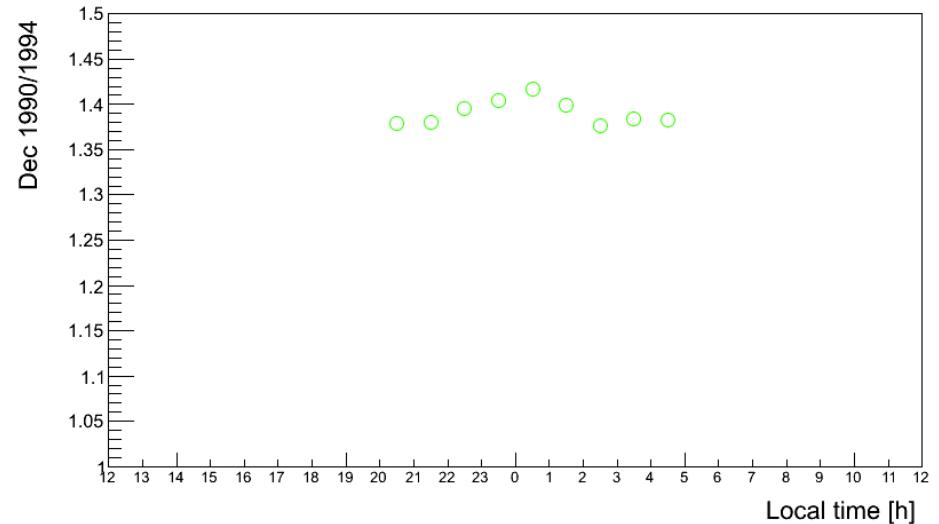
Lat 0 long 45, UV nightglow Jun Ratio 1990/1994



Lat 0 long 45, UV nightglow Sep Ratio 1990/1994

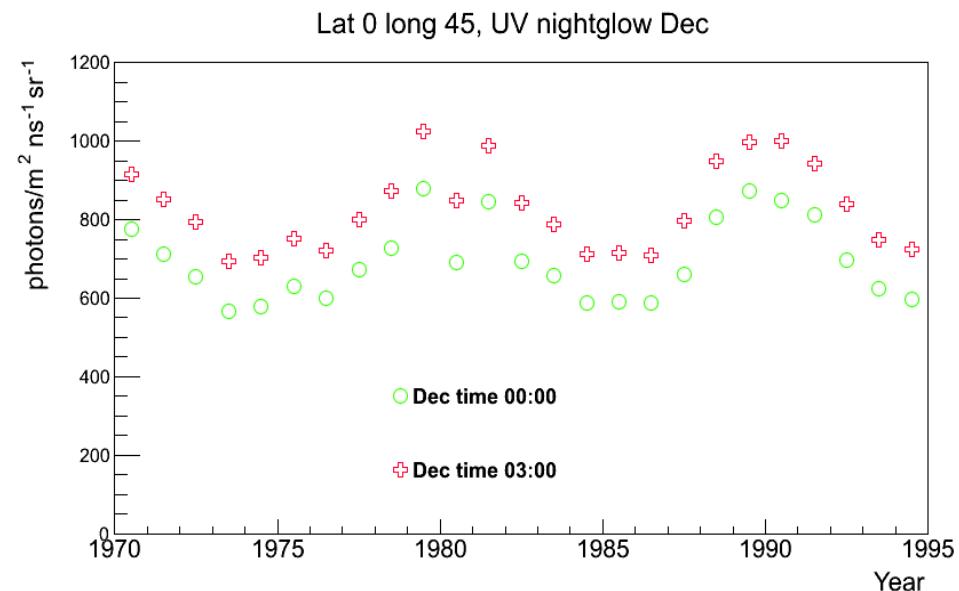
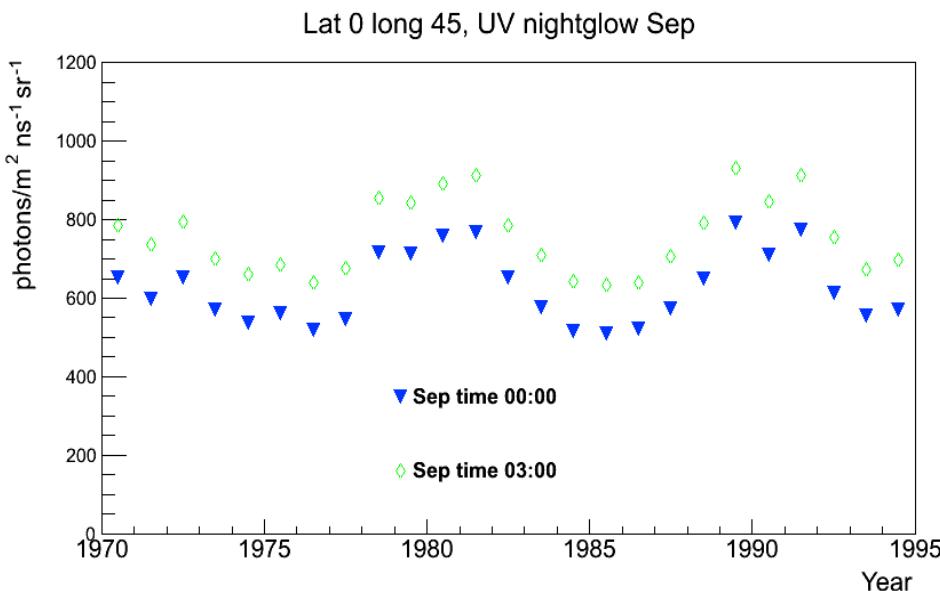
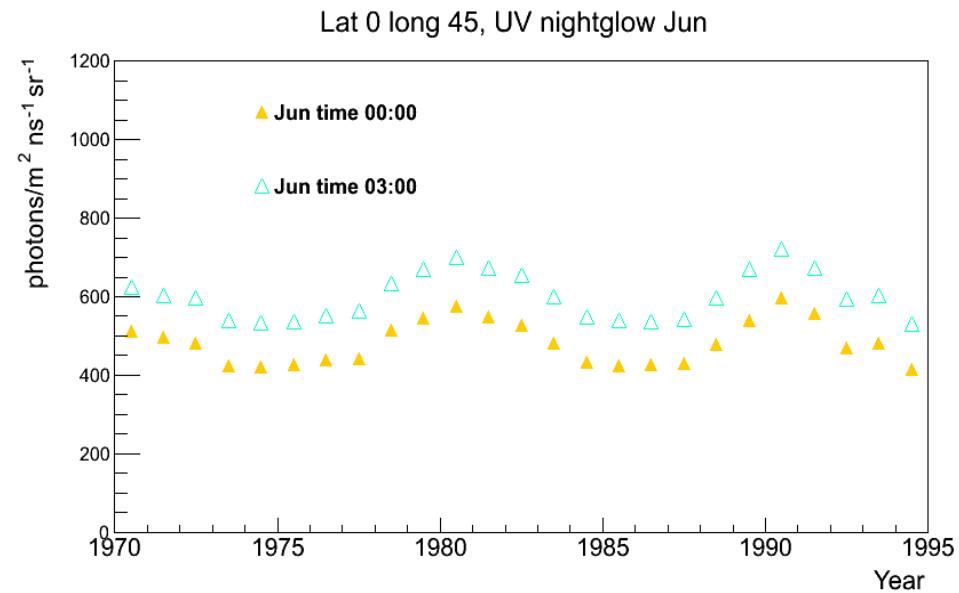
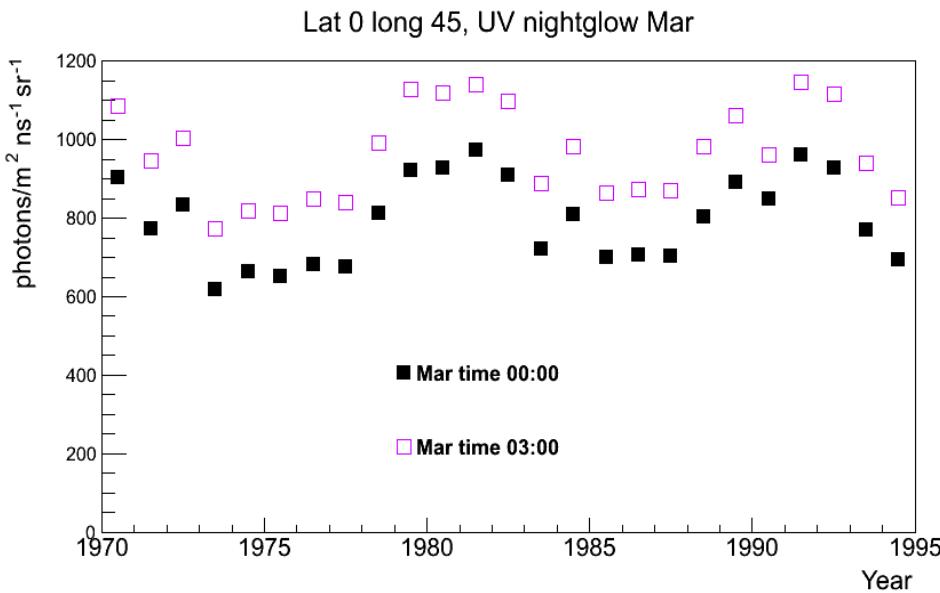


Lat 0 long 45, UV nightglow Dec Ratio 1990/1994



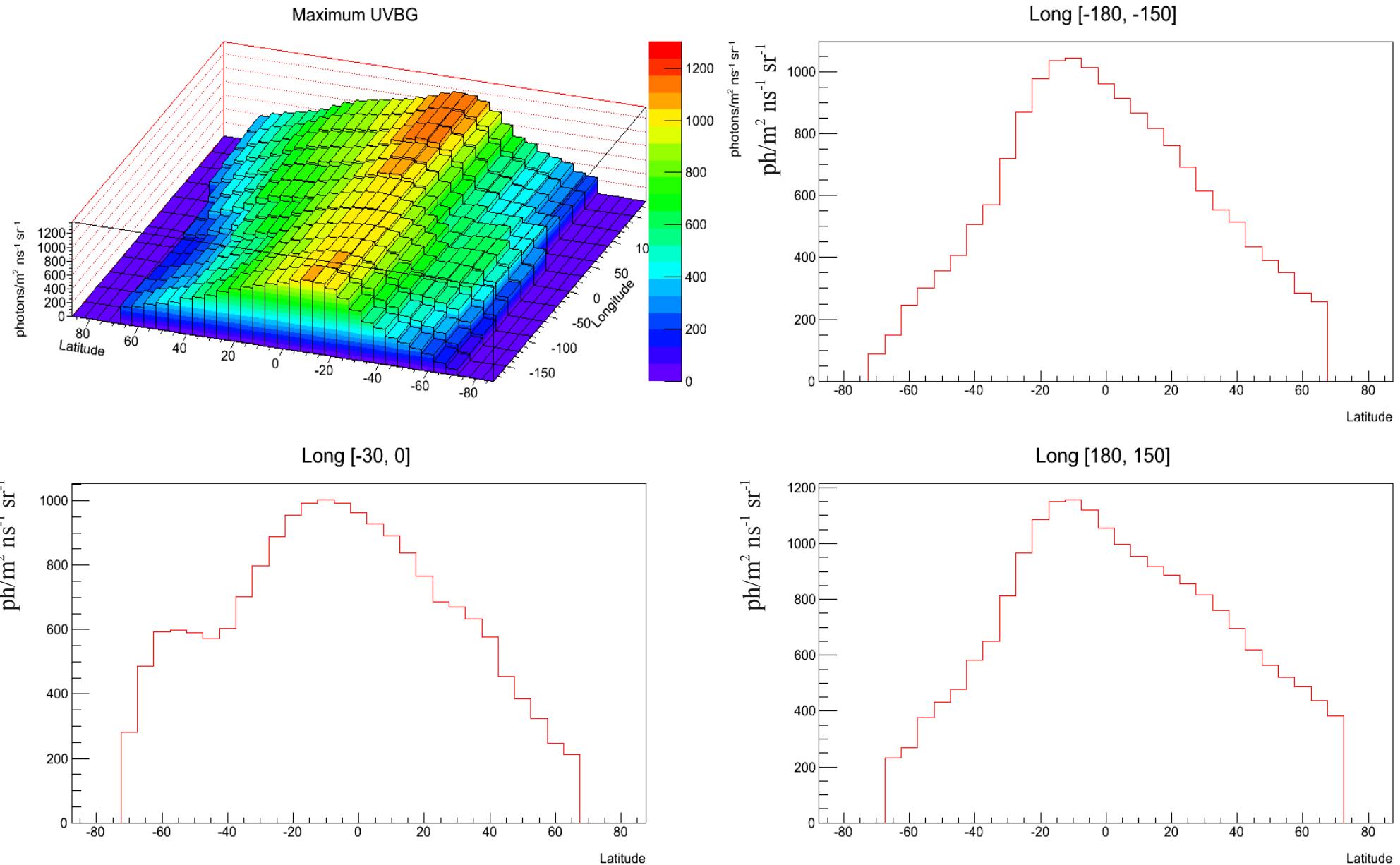
1970 – 1994 of solar activity

- Nightglow is correlated with solar activity.



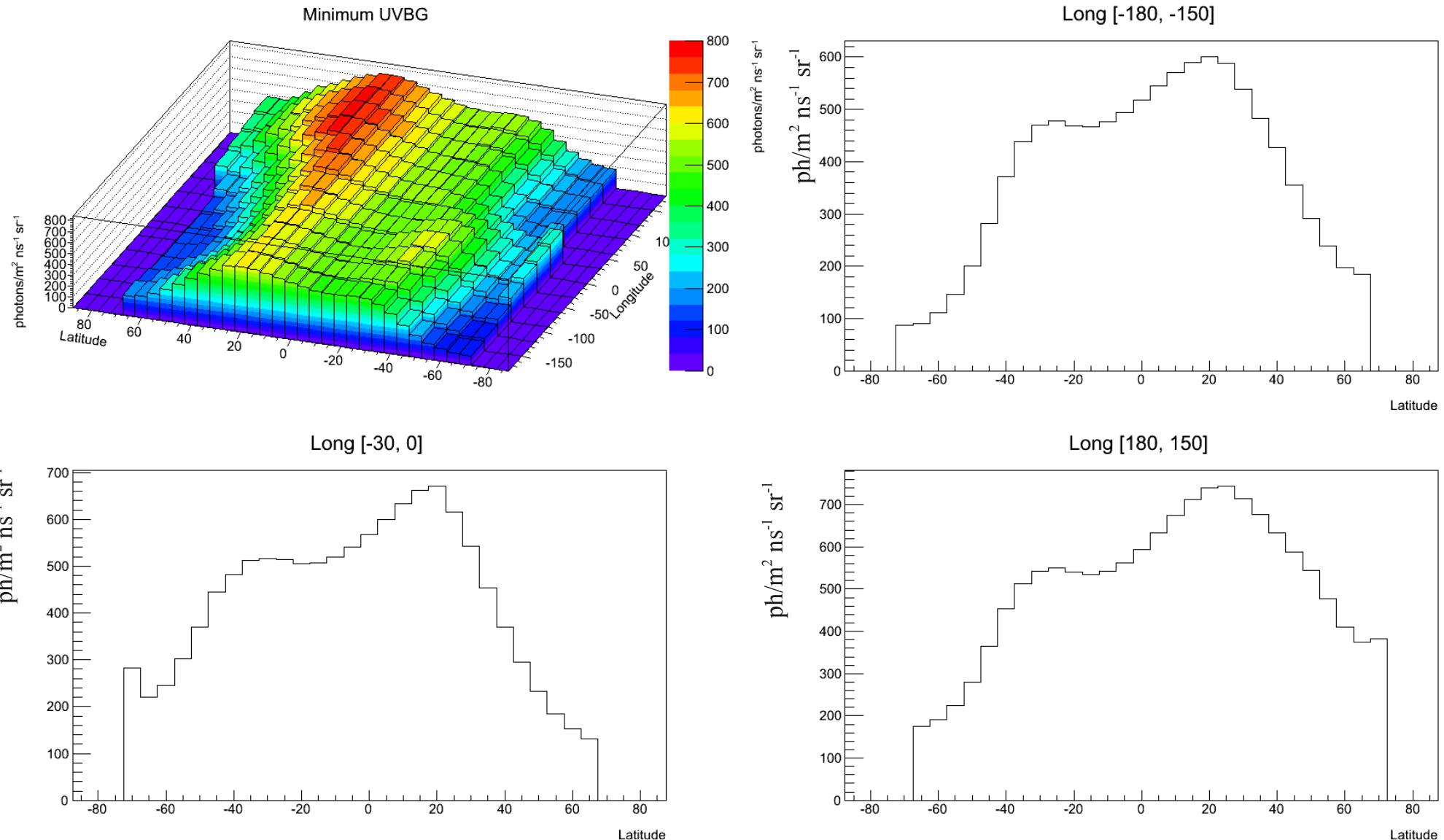
Map of maximal values of nightglow, 1990 (close to solar max), March 20-21

- Range of values $\sim (100 - 1200) \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$



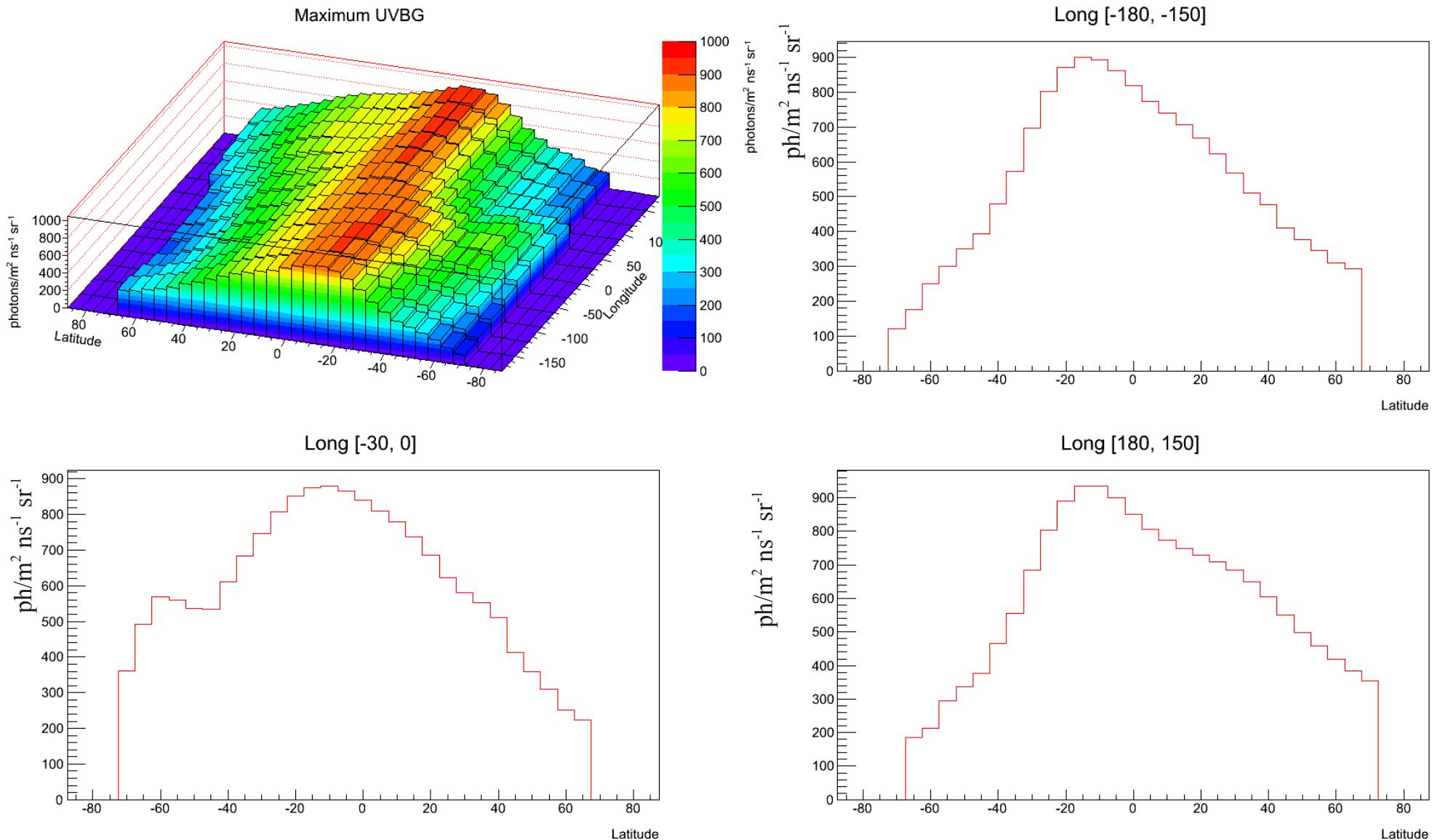
Map of minimal values of nightglow, 1990 (close to solar max), March 20-21

- Range of values $\sim (100 - 700)$ ph/m² ns⁻¹ sr⁻¹



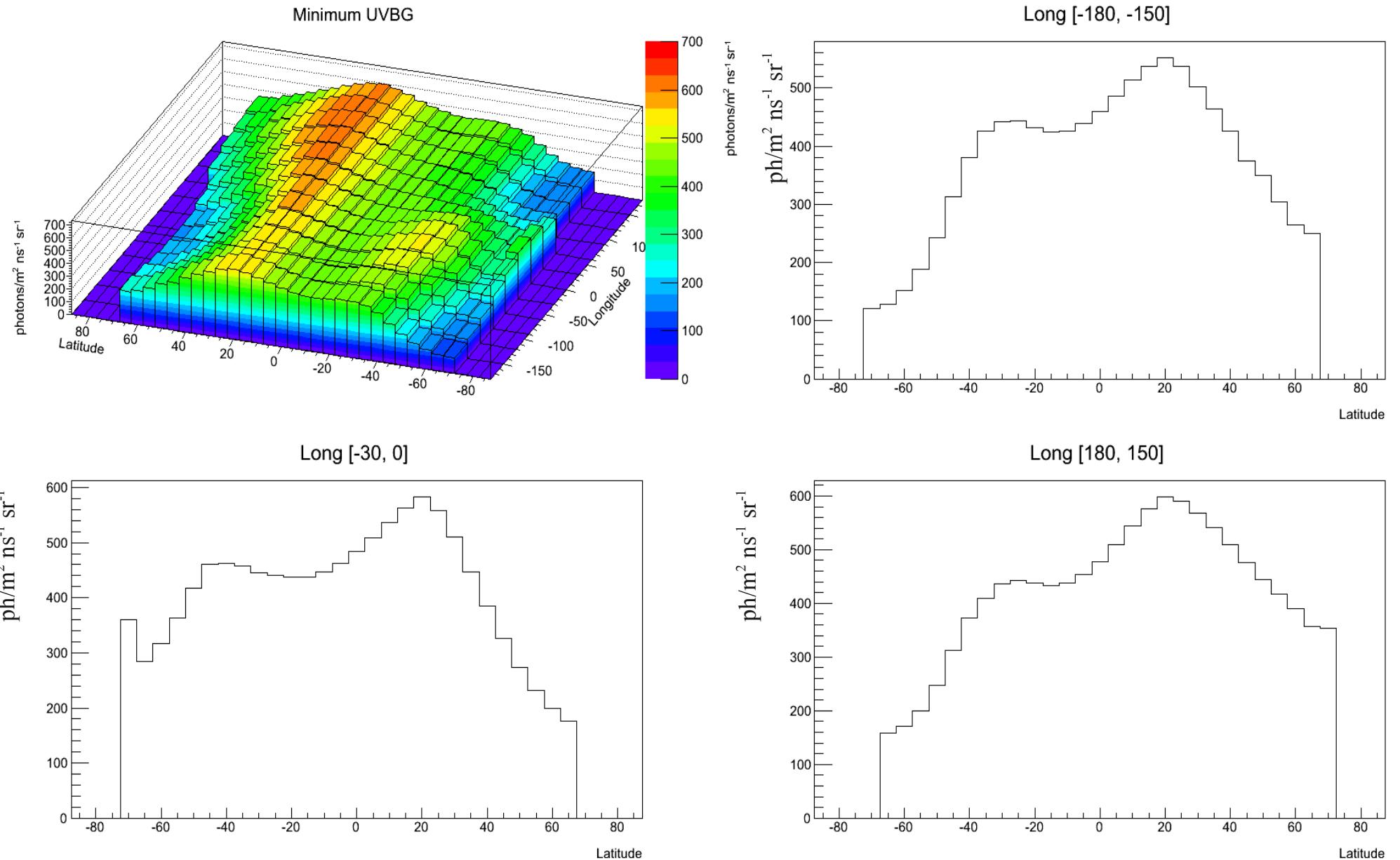
Map of maximal values of nightglow, 1994 (close to solar min), March 20-21

- Range of values $\sim (100 - 900) \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$



Map of minimal values of nightglow, 1994 (close to solar min), March 20-21

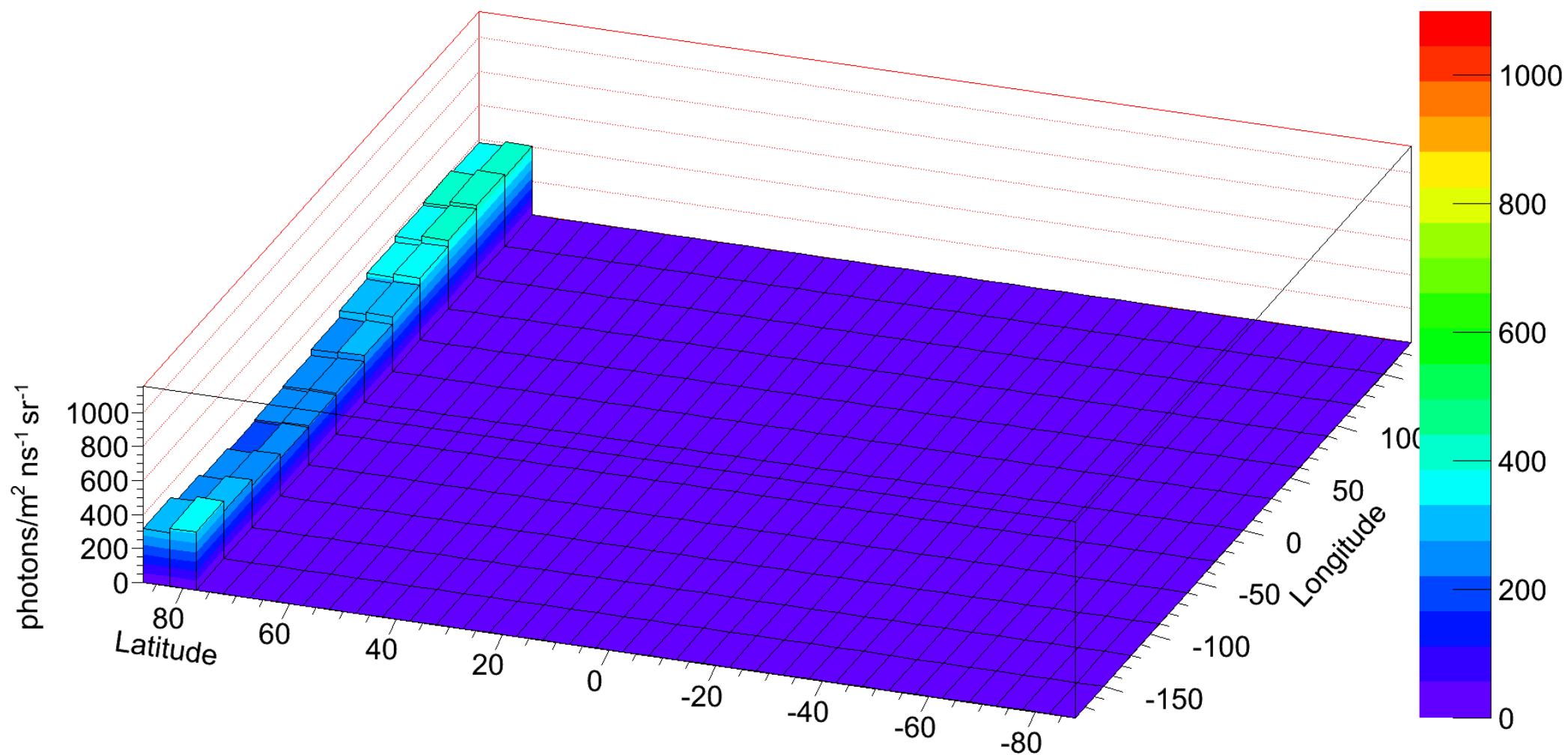
- Range of values $\sim (100 - 600) \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$



Slides 17 – 31 shows how UV nightglow is changing with local time on the whole Earth (one night 1994, Dec. 20 - 21).

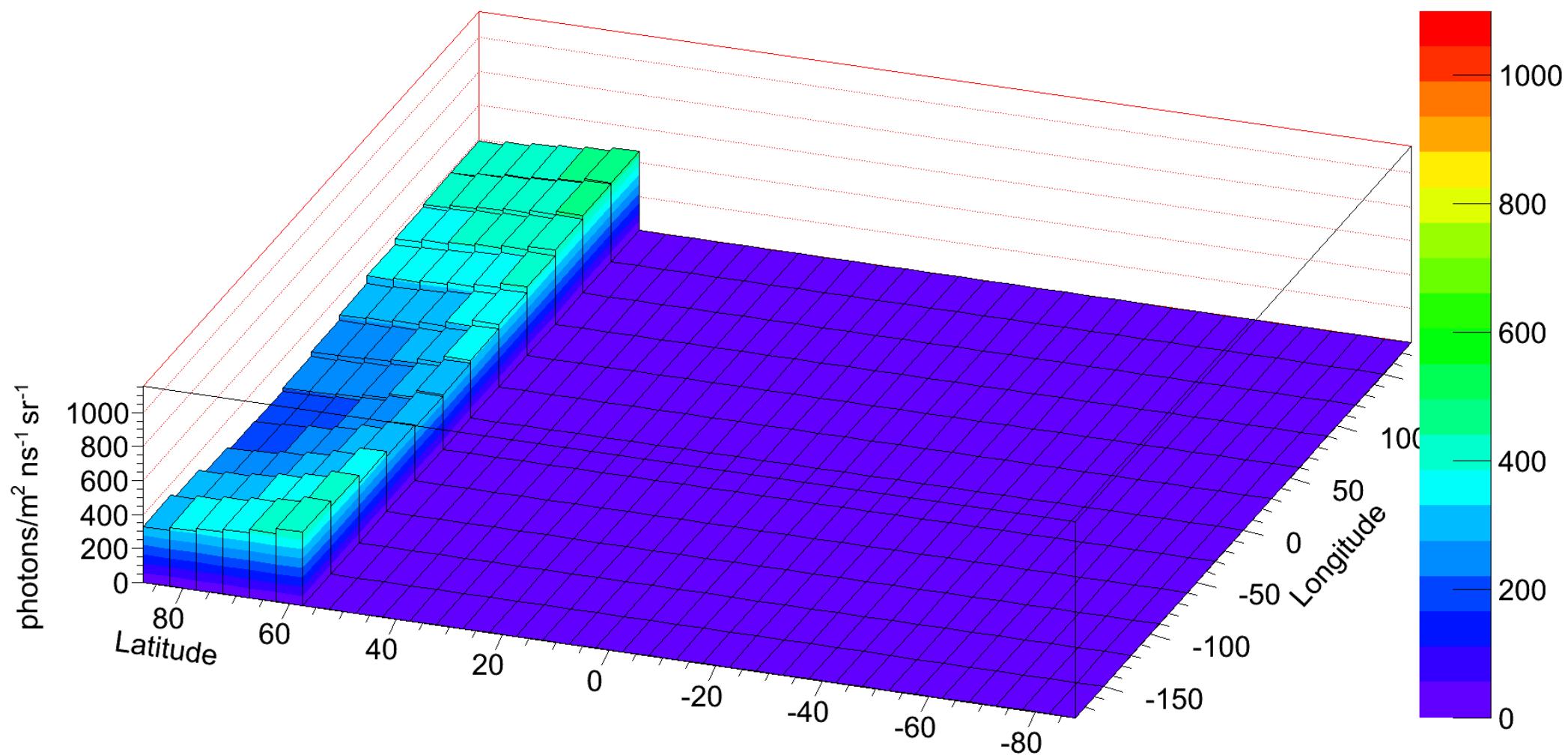
1994, 20 - 21 Dec, Local time

17 hour UVBG



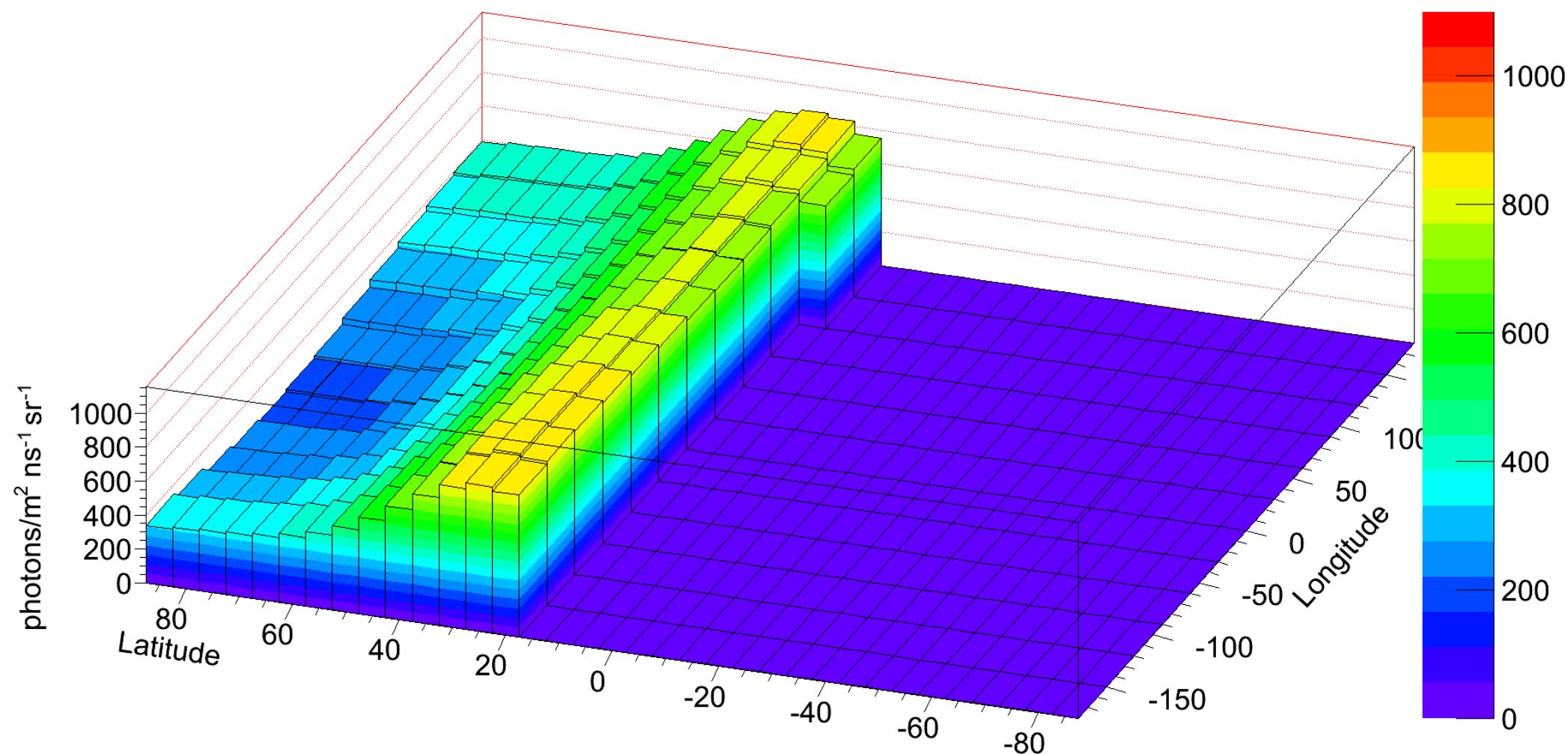
1994, 20 - 21 Dec, Local time

18 hour UVBG



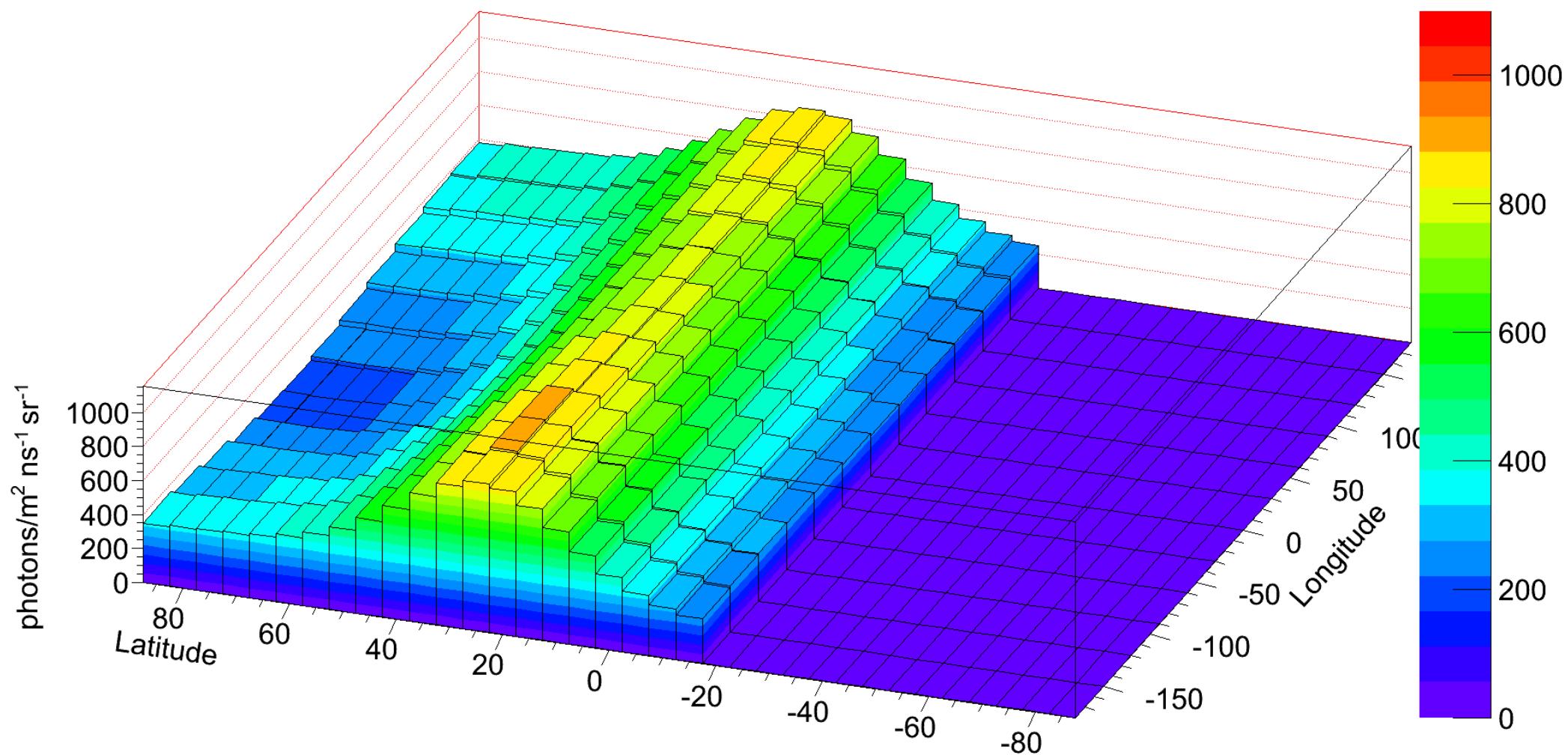
1994, 20 - 21 Dec, Local time

19 hour UVBG



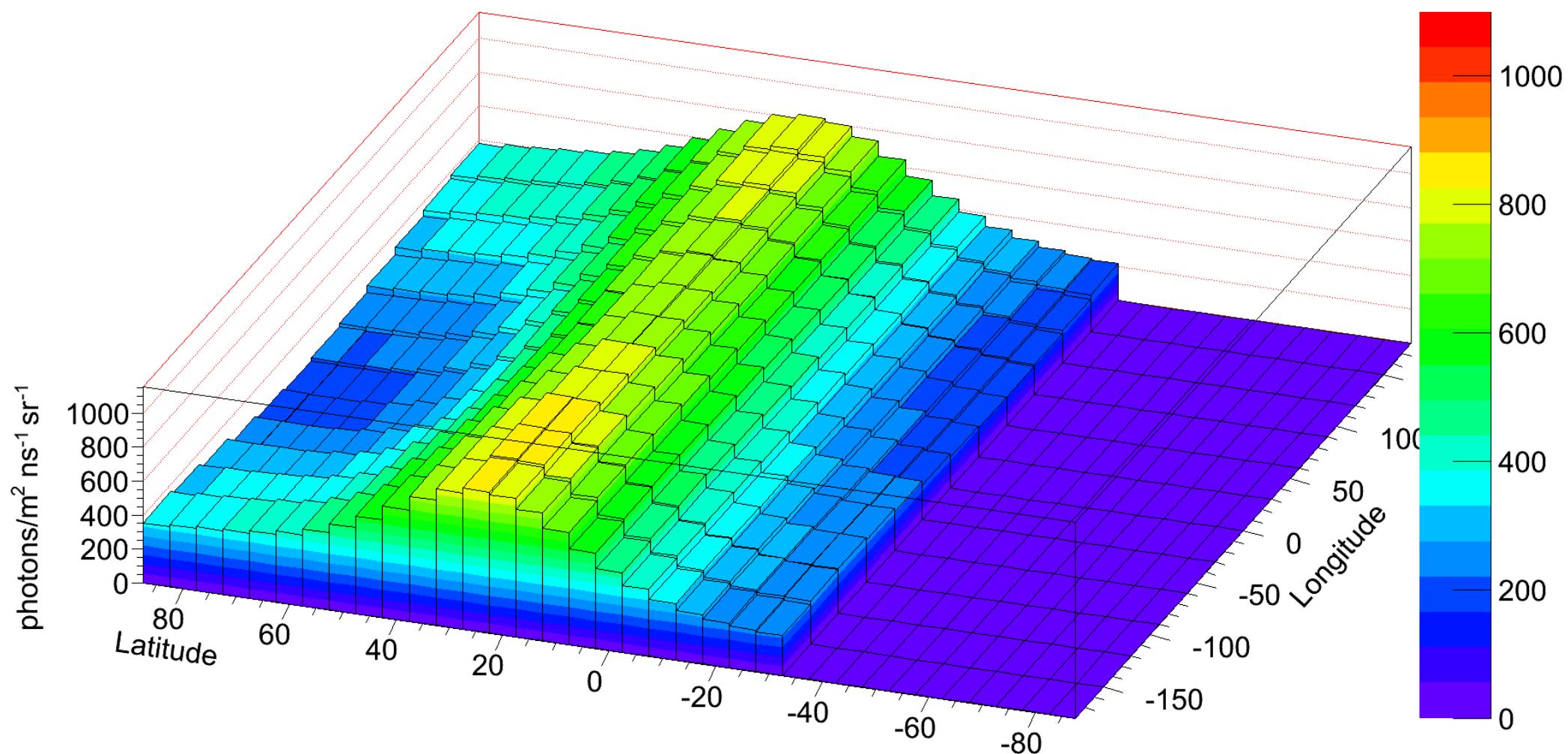
1994, 20 - 21 Dec, Local time

20 hour UVBG



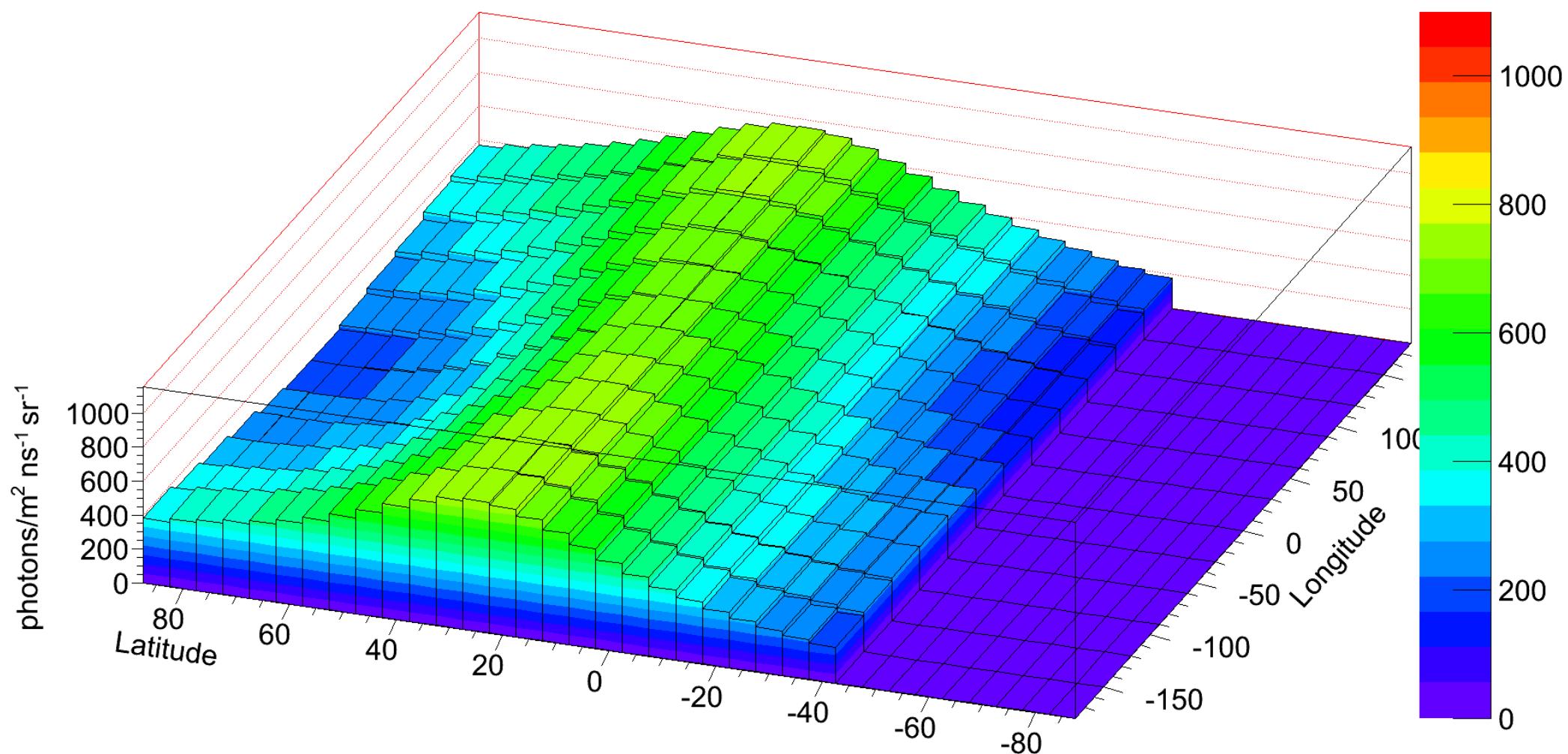
1994, 20 - 21 Dec, Local time

21 hour UVBG



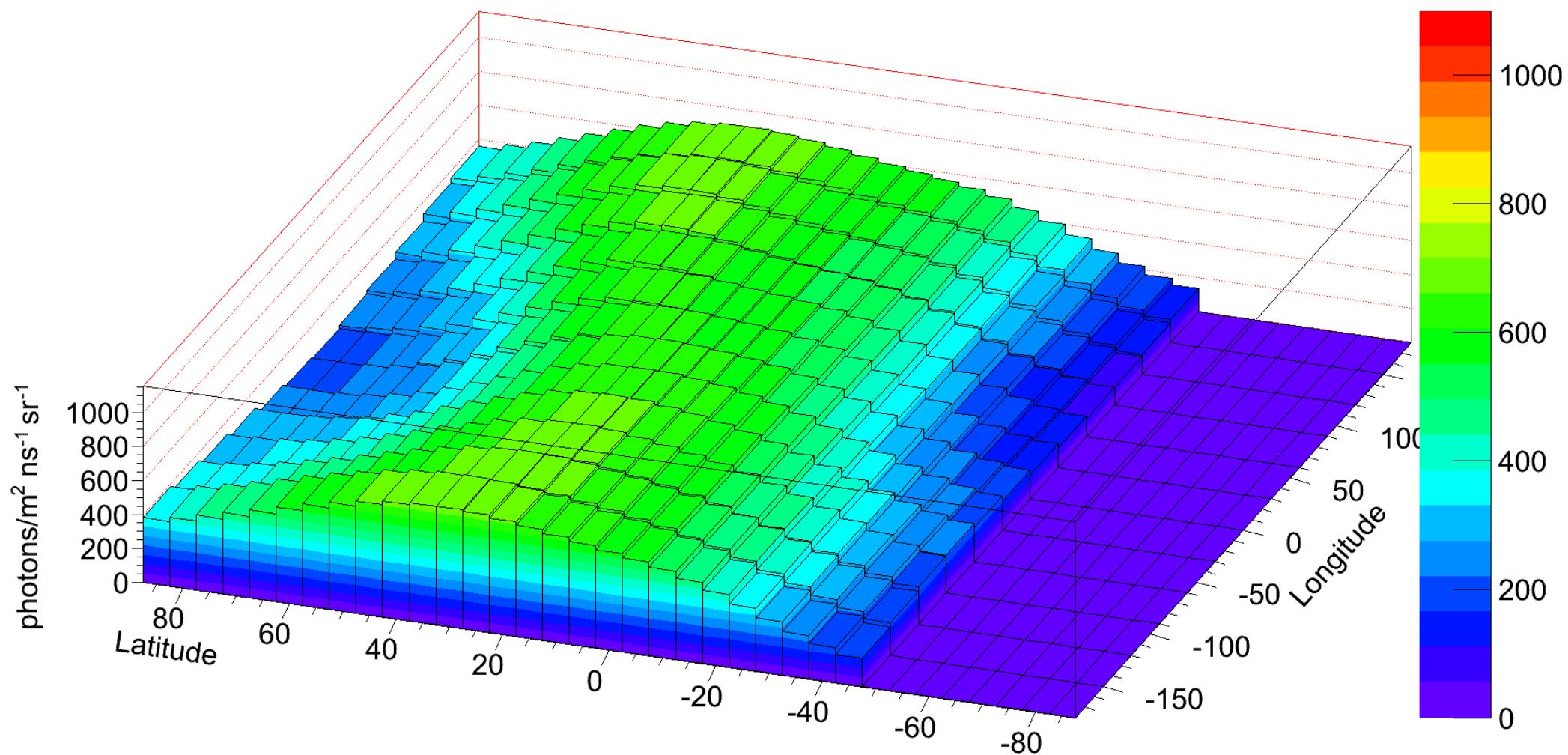
1994, 20 - 21 Dec, Local time

22 hour UVBG



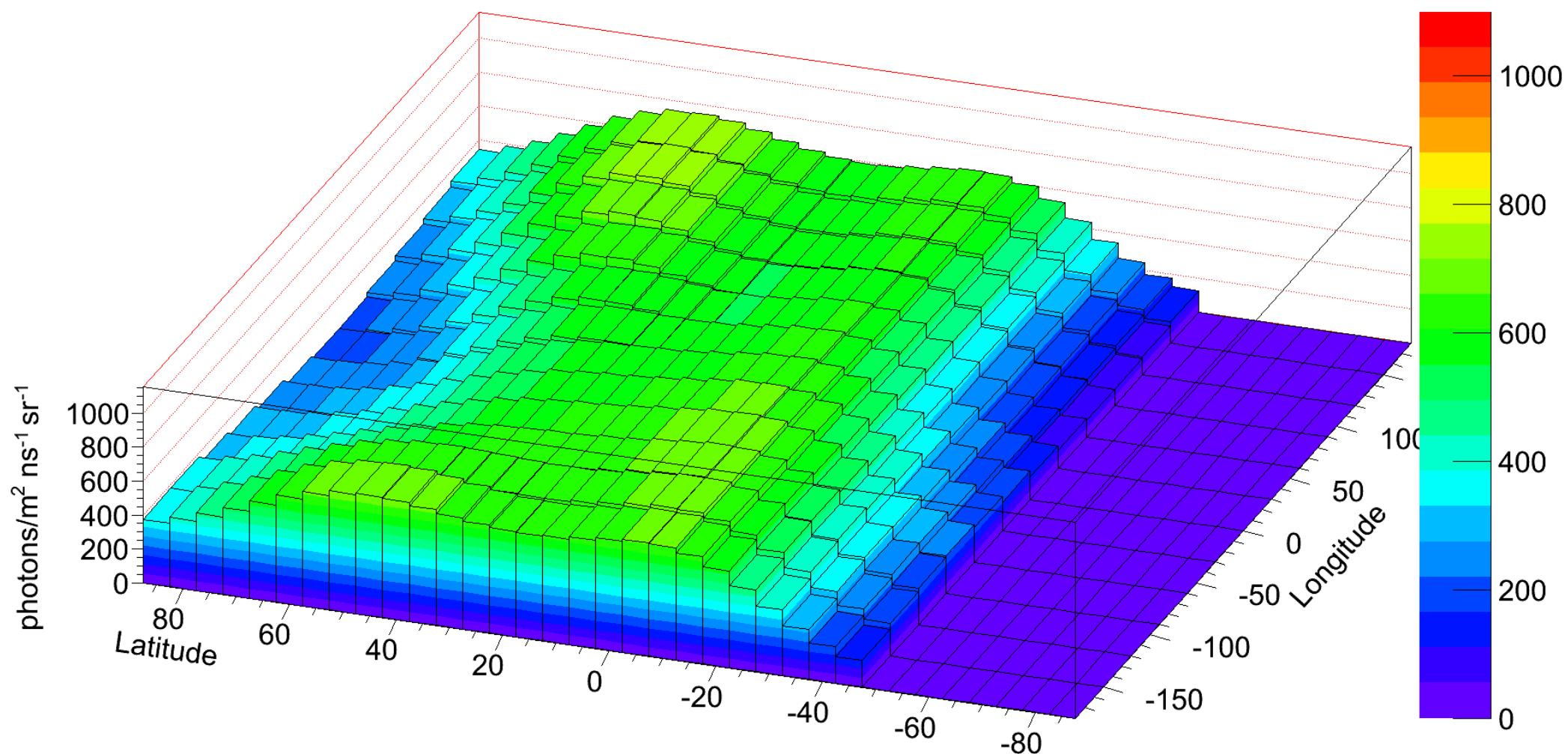
1994, 20 - 21 Dec, Local time

23 hour UVBG



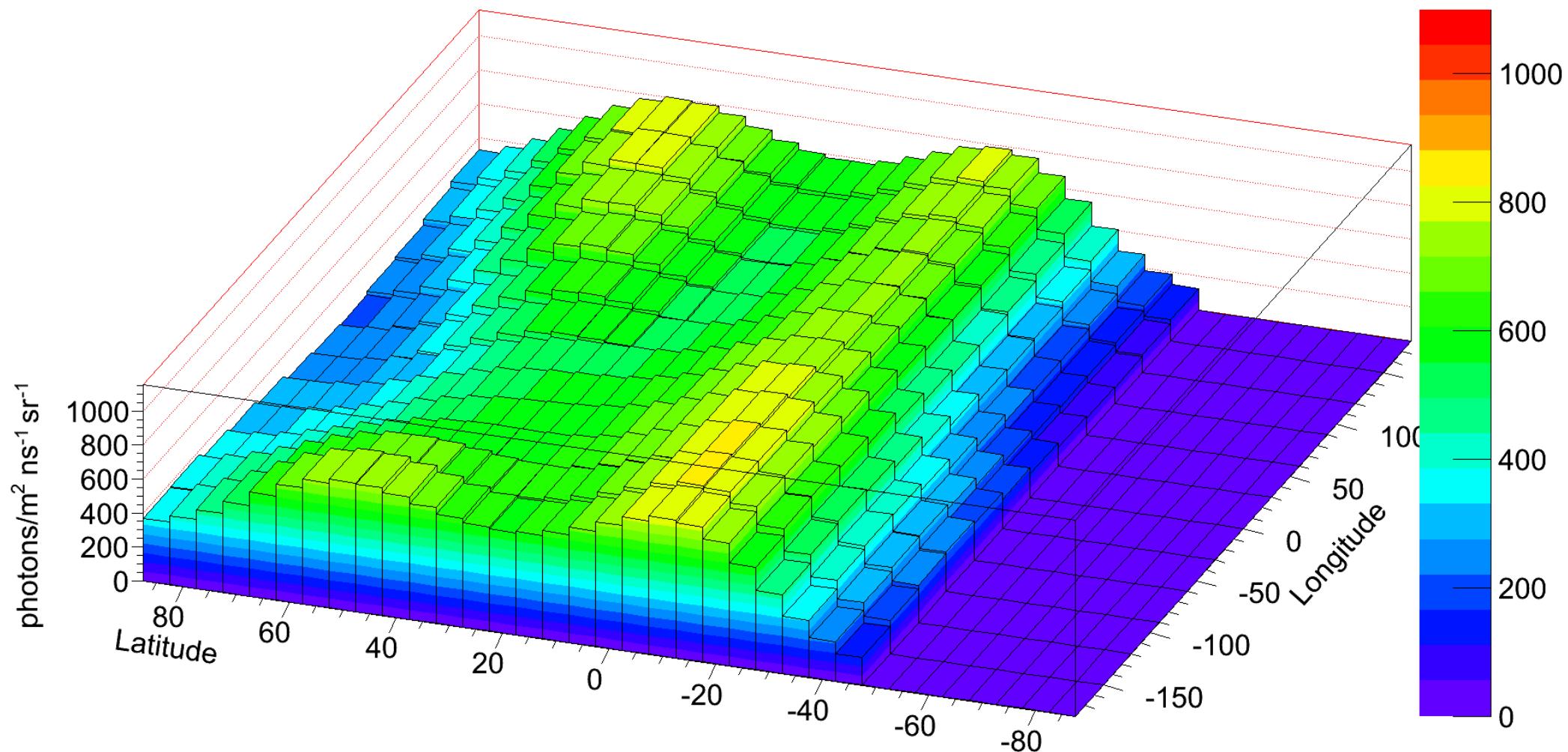
1994, 20 - 21 Dec, Local time

0 hour UVBG



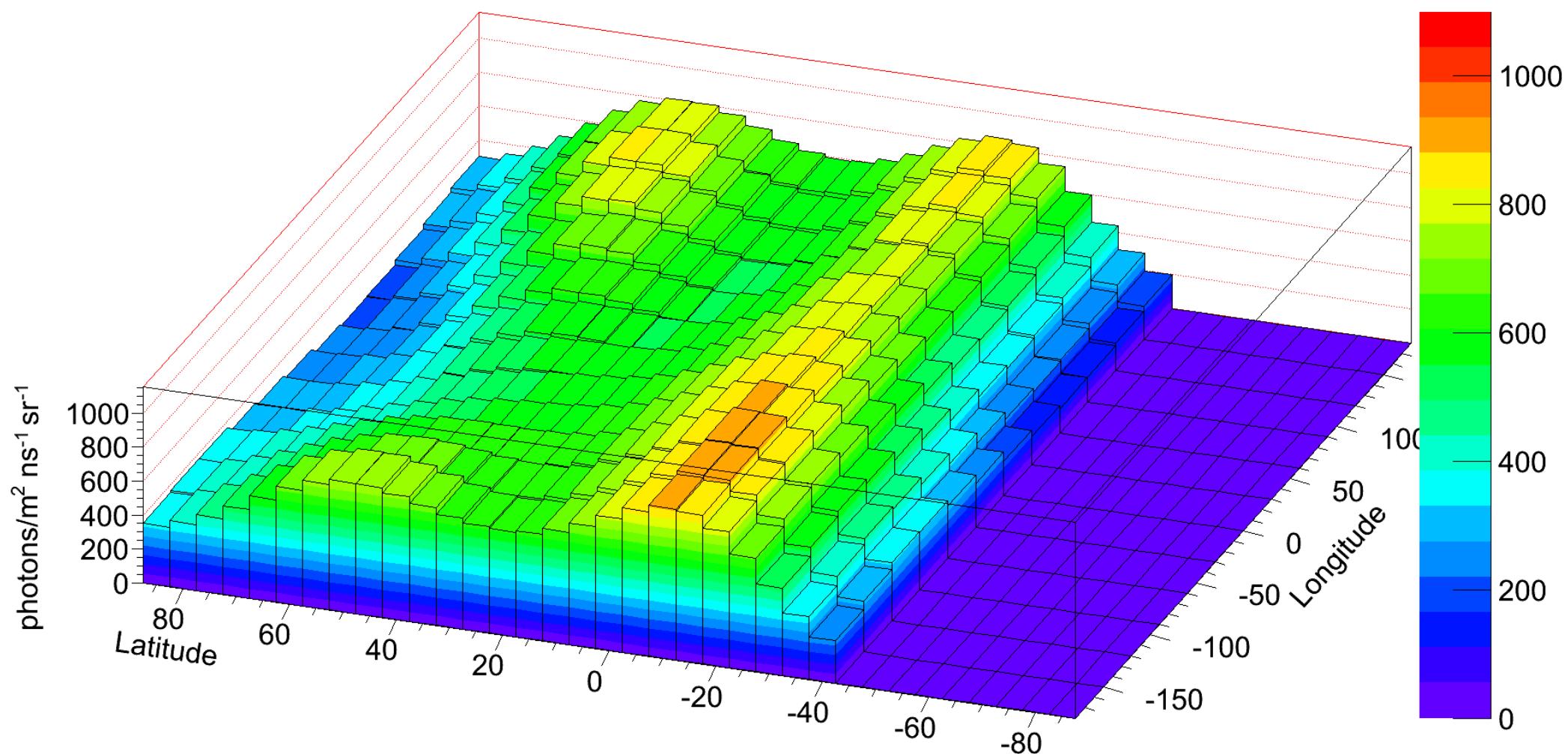
1994, 20 - 21 Dec, Local time

1 hour UVBG



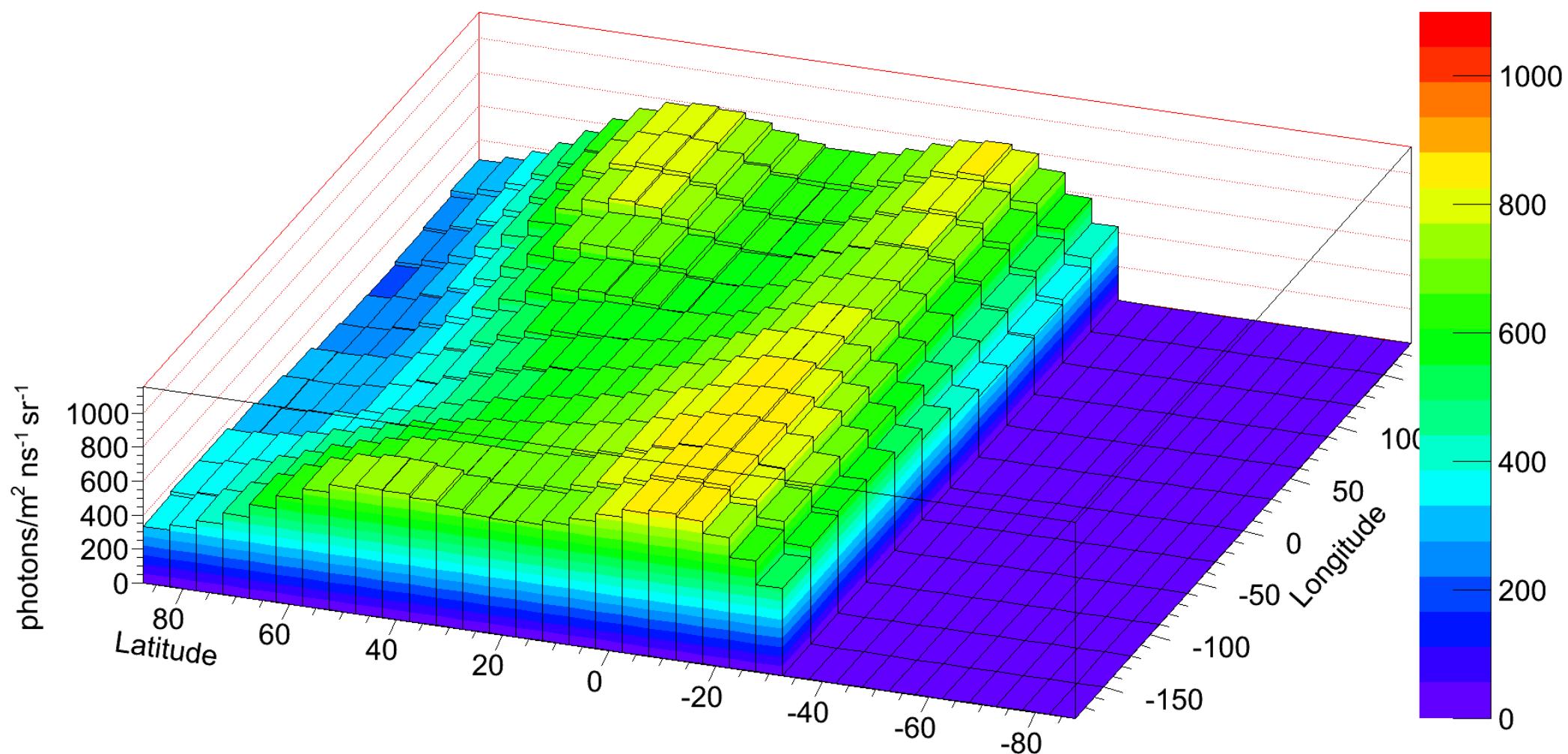
1994, 20 - 21 Dec, Local time

2 hour UVBG



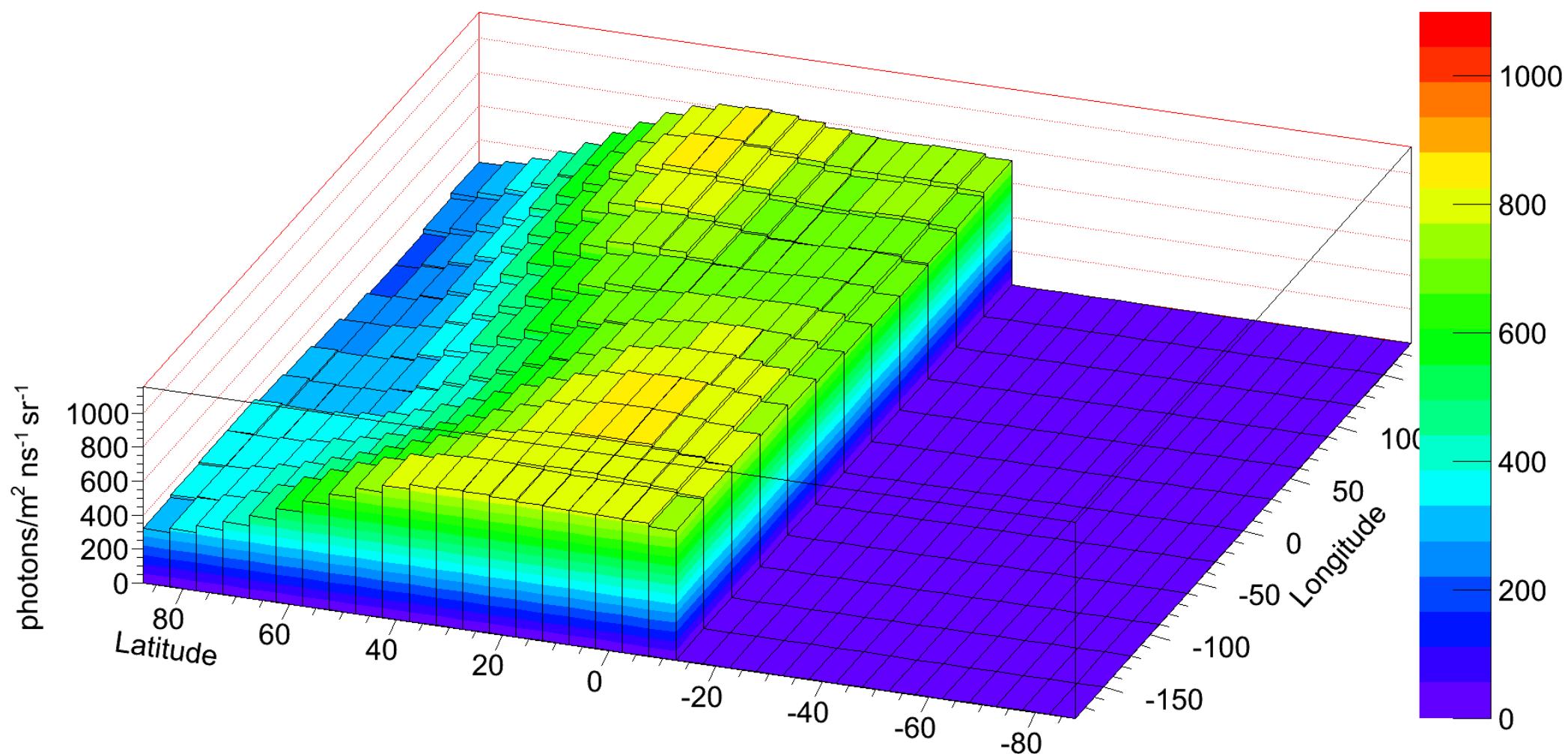
1994, 20 - 21 Dec, Local time

3 hour UVBG



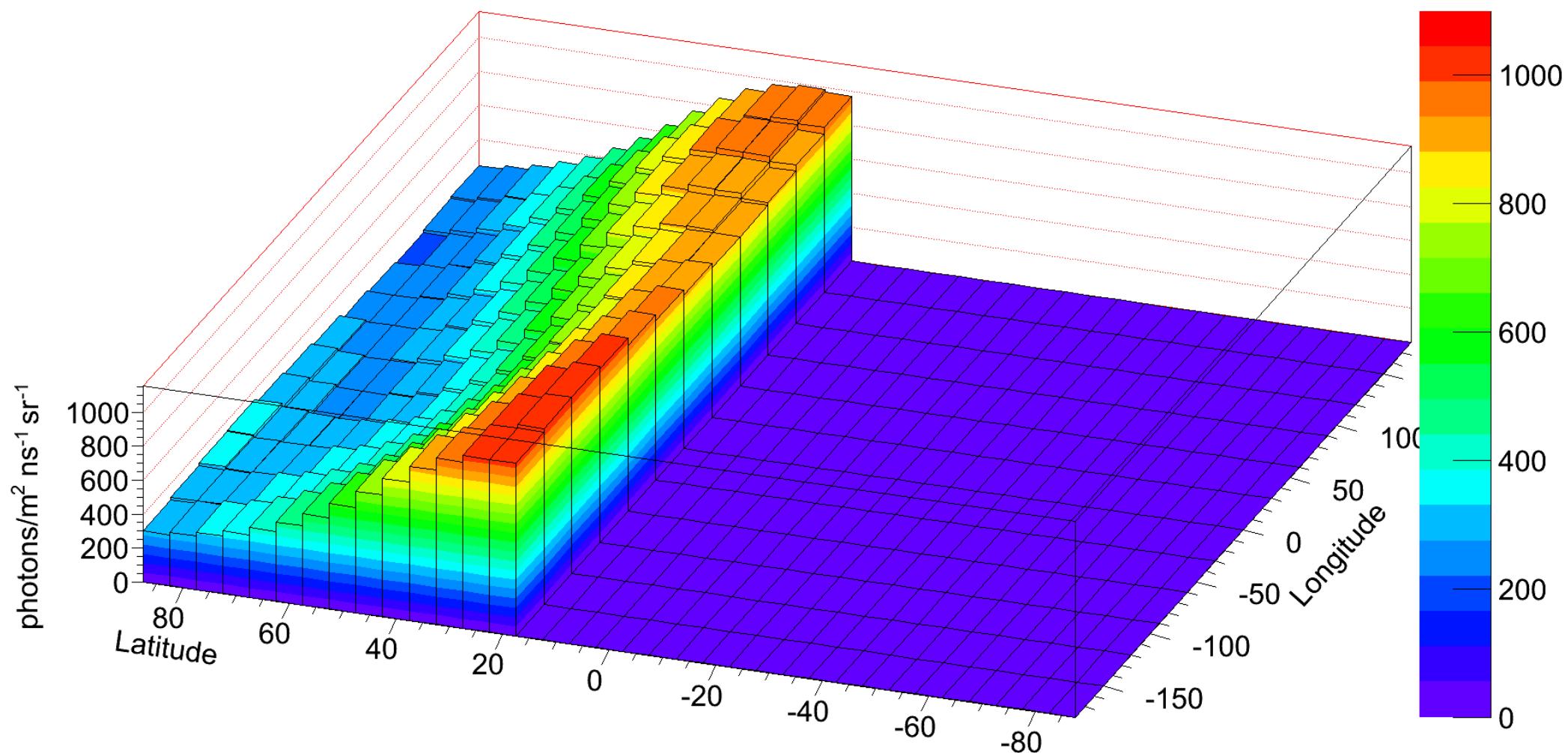
1994, 20 - 21 Dec, Local time

4 hour UVBG



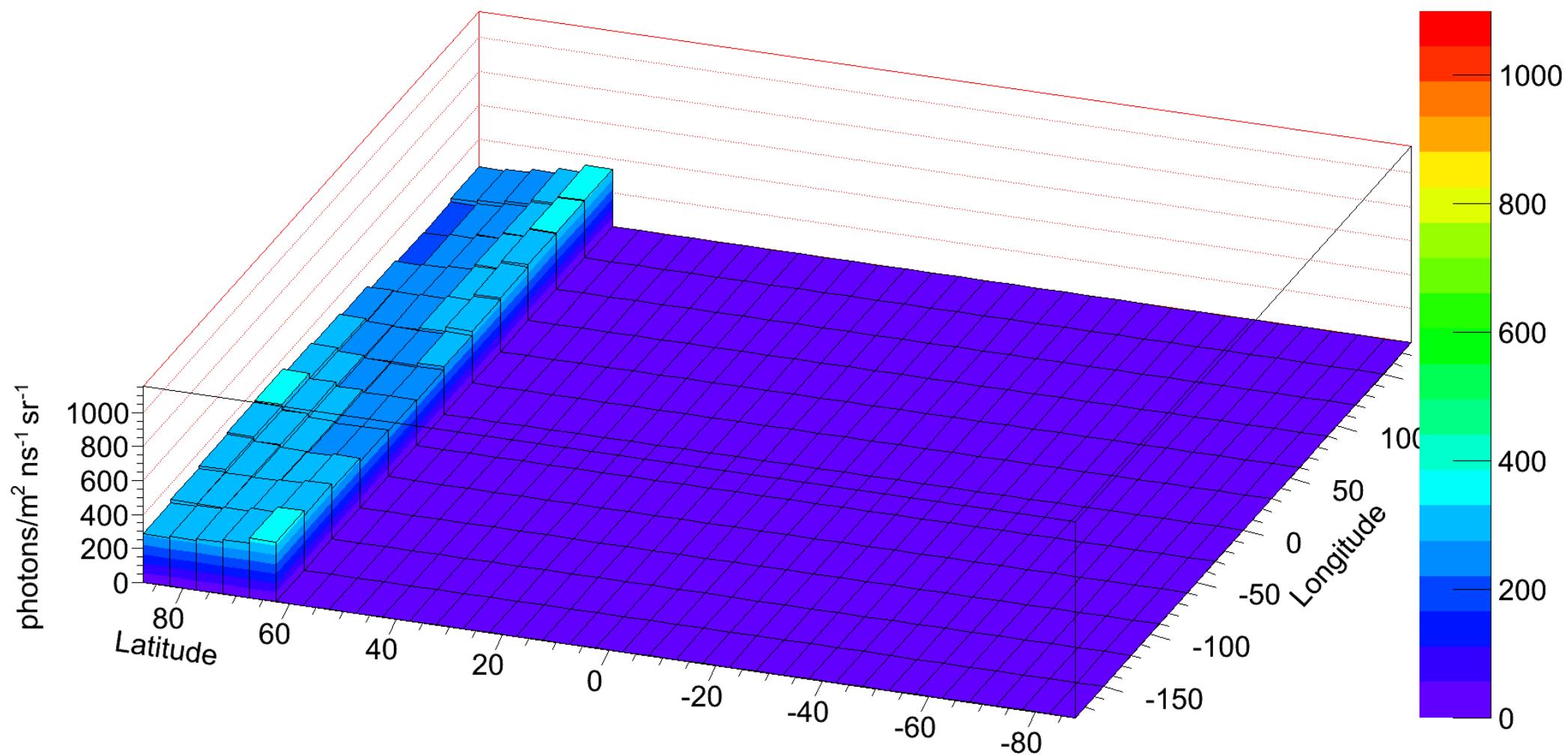
1994, 20 - 21 Dec, Local time

5 hour UVBG



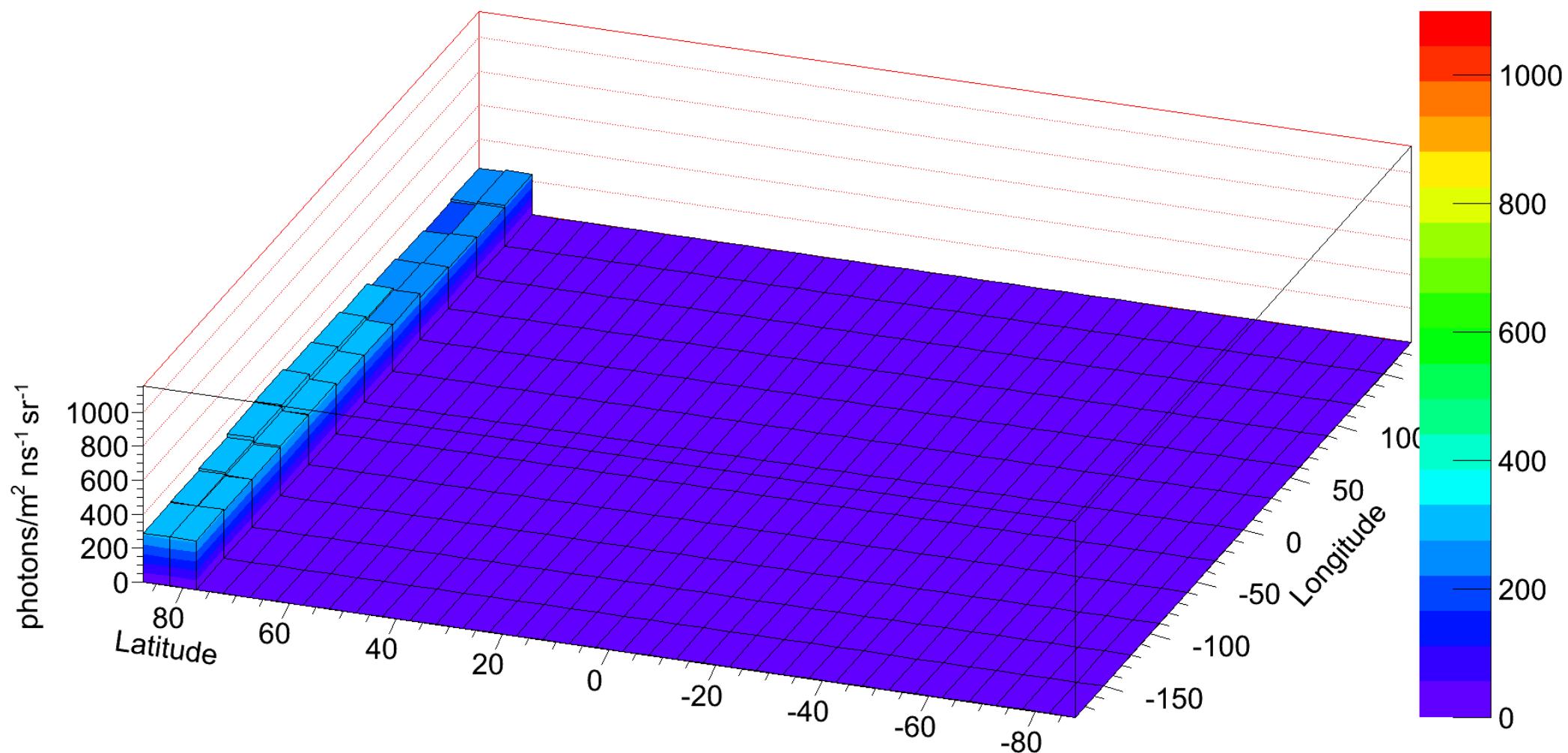
1994, 20 - 21 Dec, Local time

6 hour UVBG

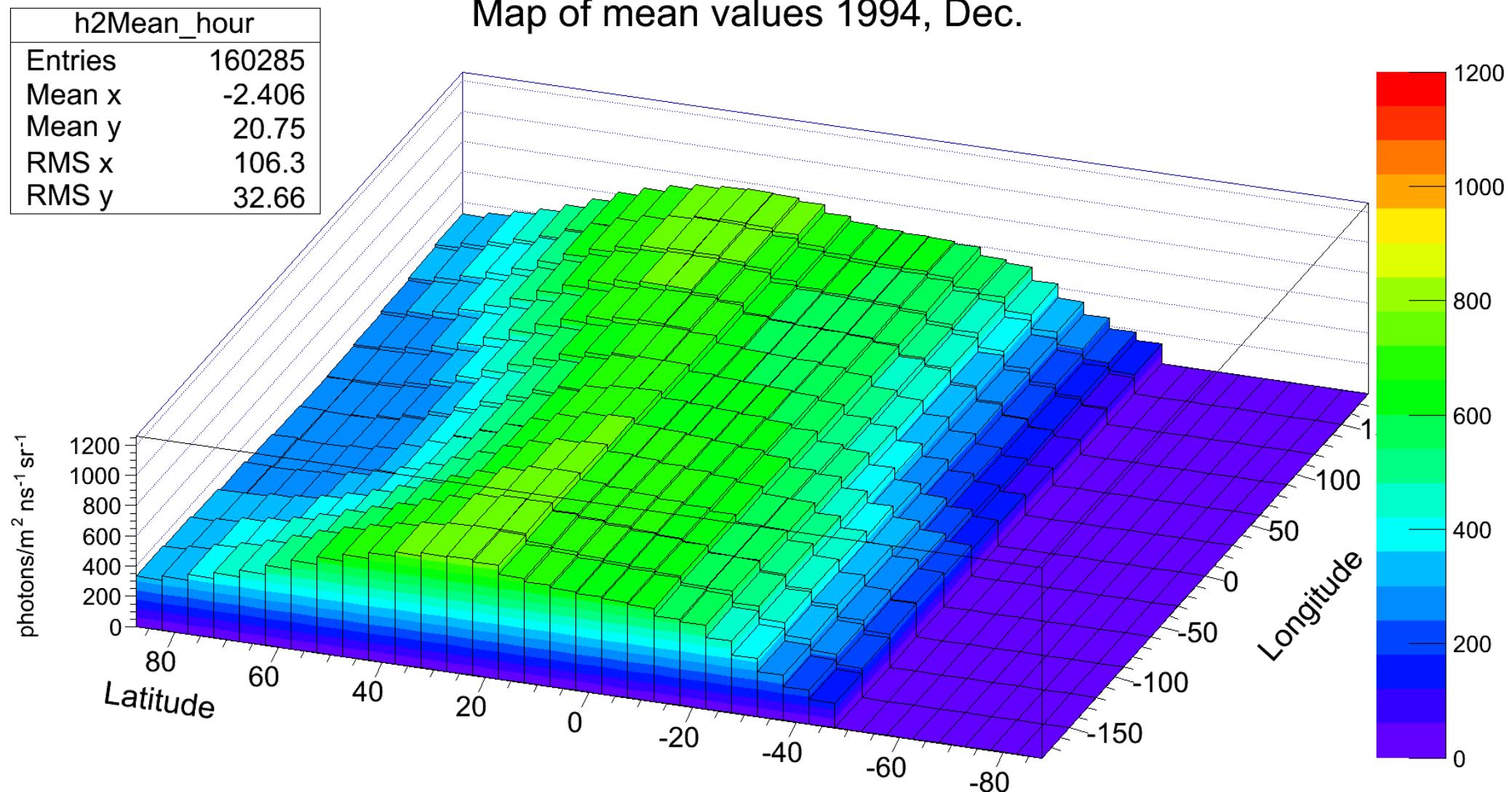


1994, 20 - 21 Dec, Local time

7 hour UVBG

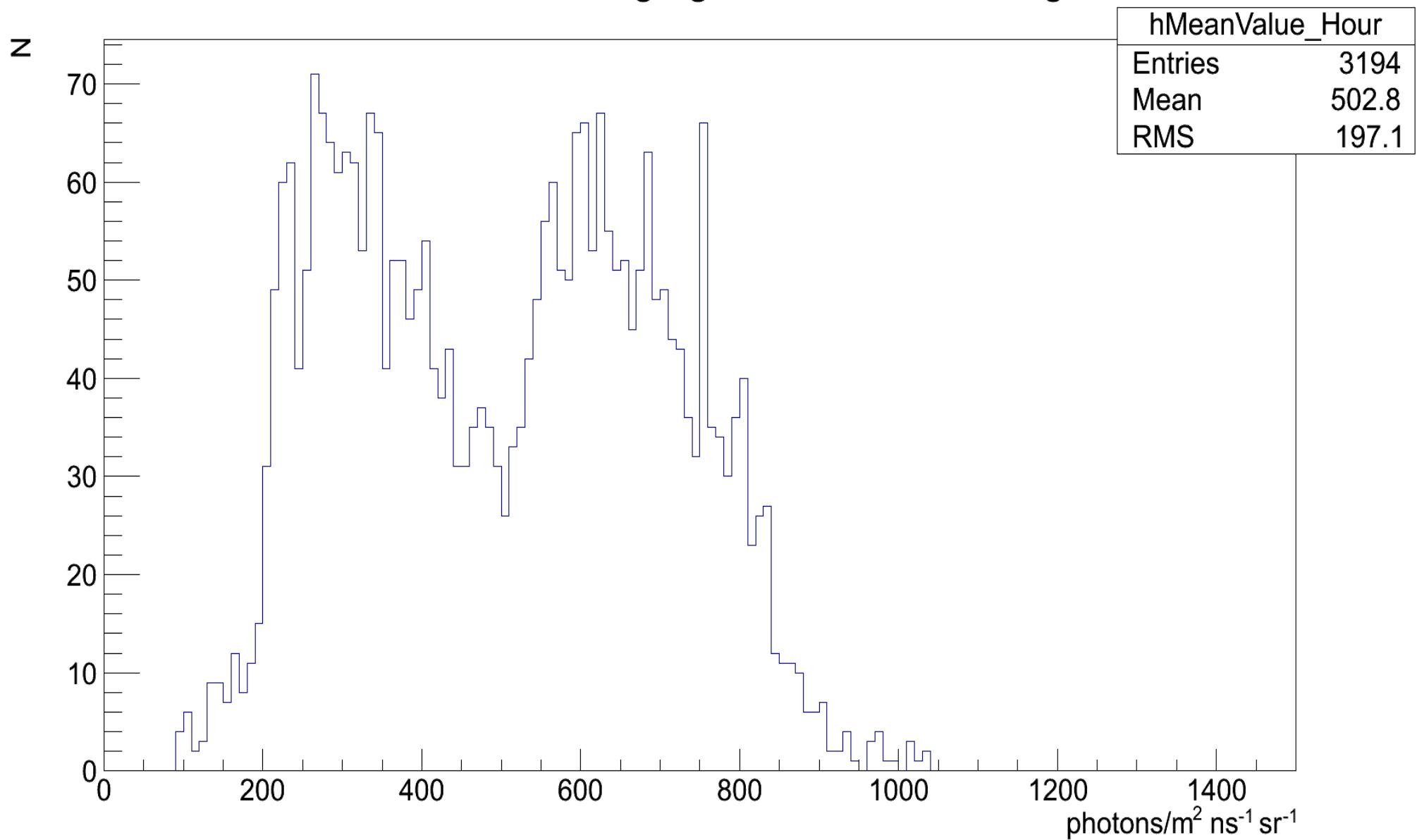


Map of mean values 1994, 20 - 21 Dec.



Histogram of nightglow 1994, 20 - 21 Dec

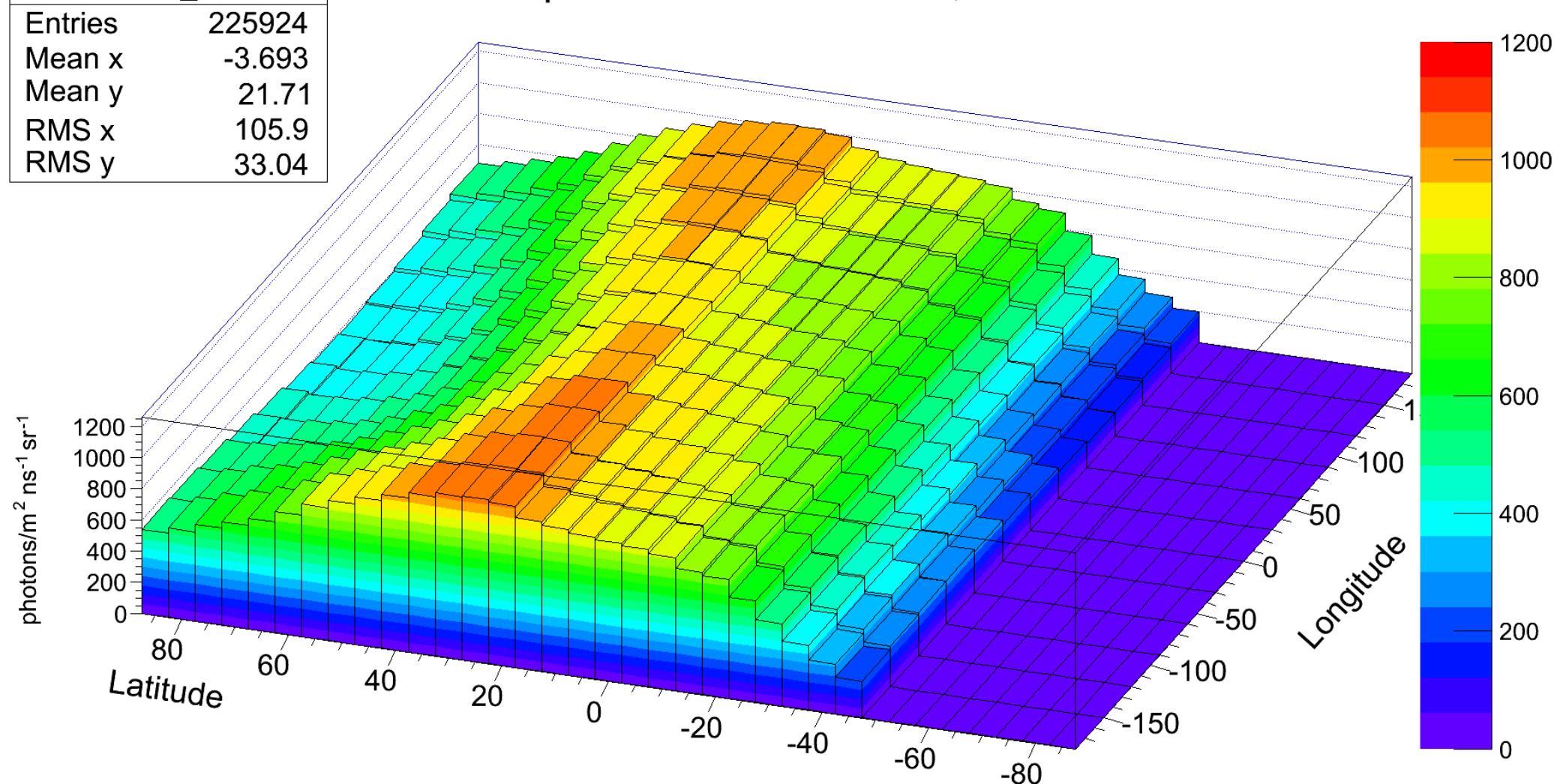
Distribution of UV nightglow values for all night



Map of mean values 1990, 20 - 21 Dec

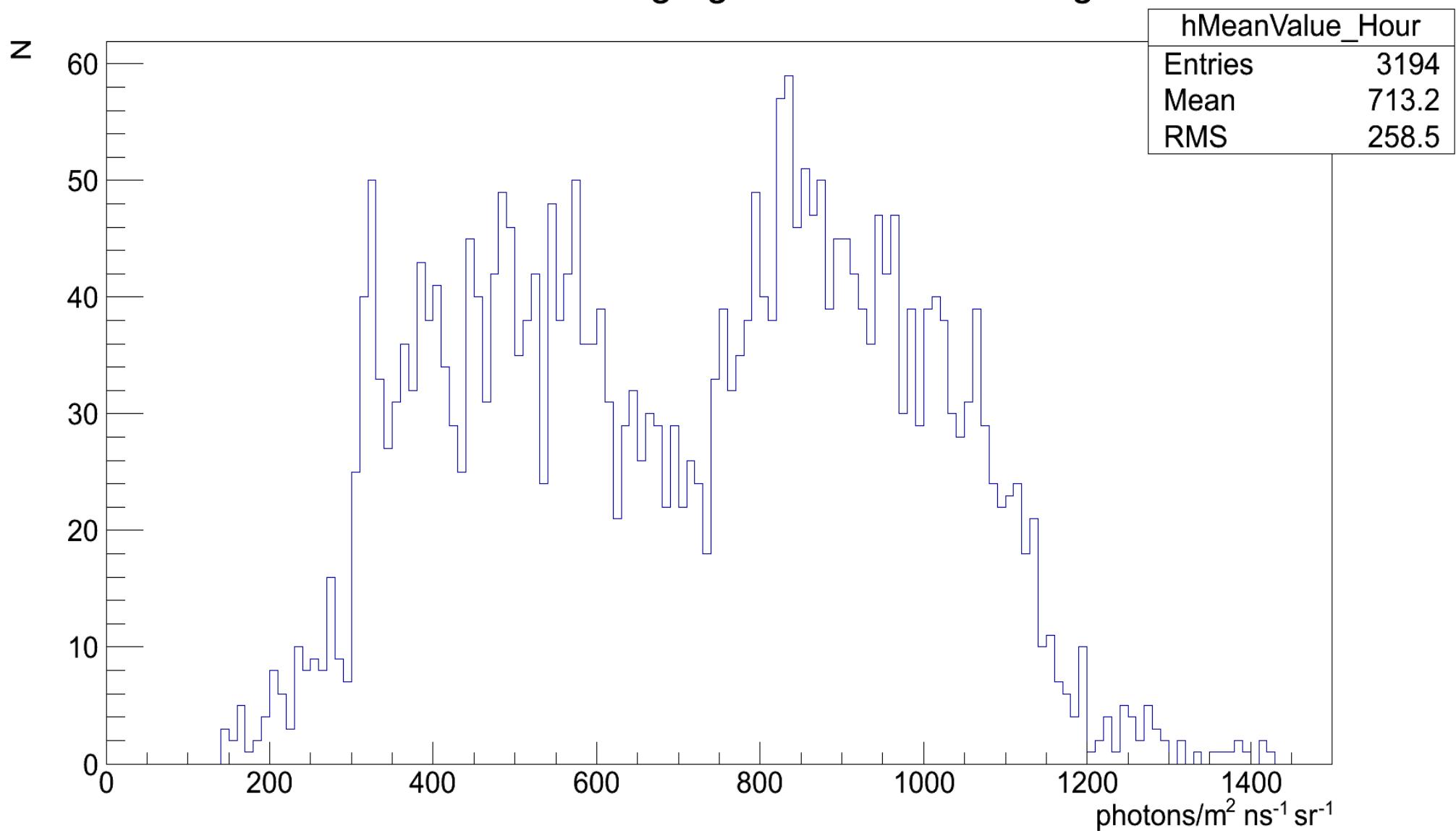
h2Mean_hour	
Entries	225924
Mean x	-3.693
Mean y	21.71
RMS x	105.9
RMS y	33.04

Map of mean values 1990, Dec.



Histogram of nightglow 1990, 20 - 21 Dec

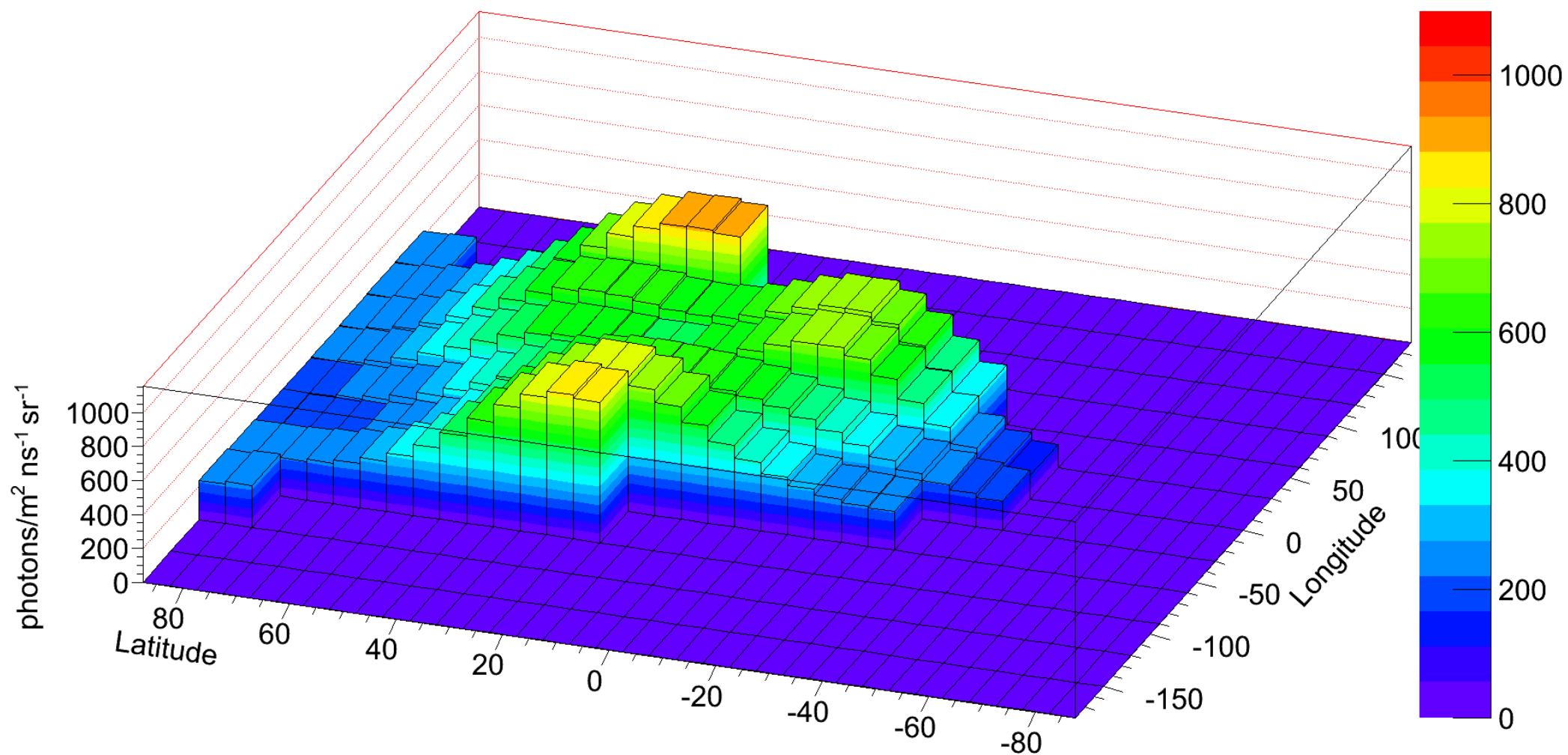
Distribution of UV nightglow values for all night



Slides 37 – 60 shows how UV nightglow is changing with UTC time on the whole Earth (one night 1994, Dec. 20 - 21).

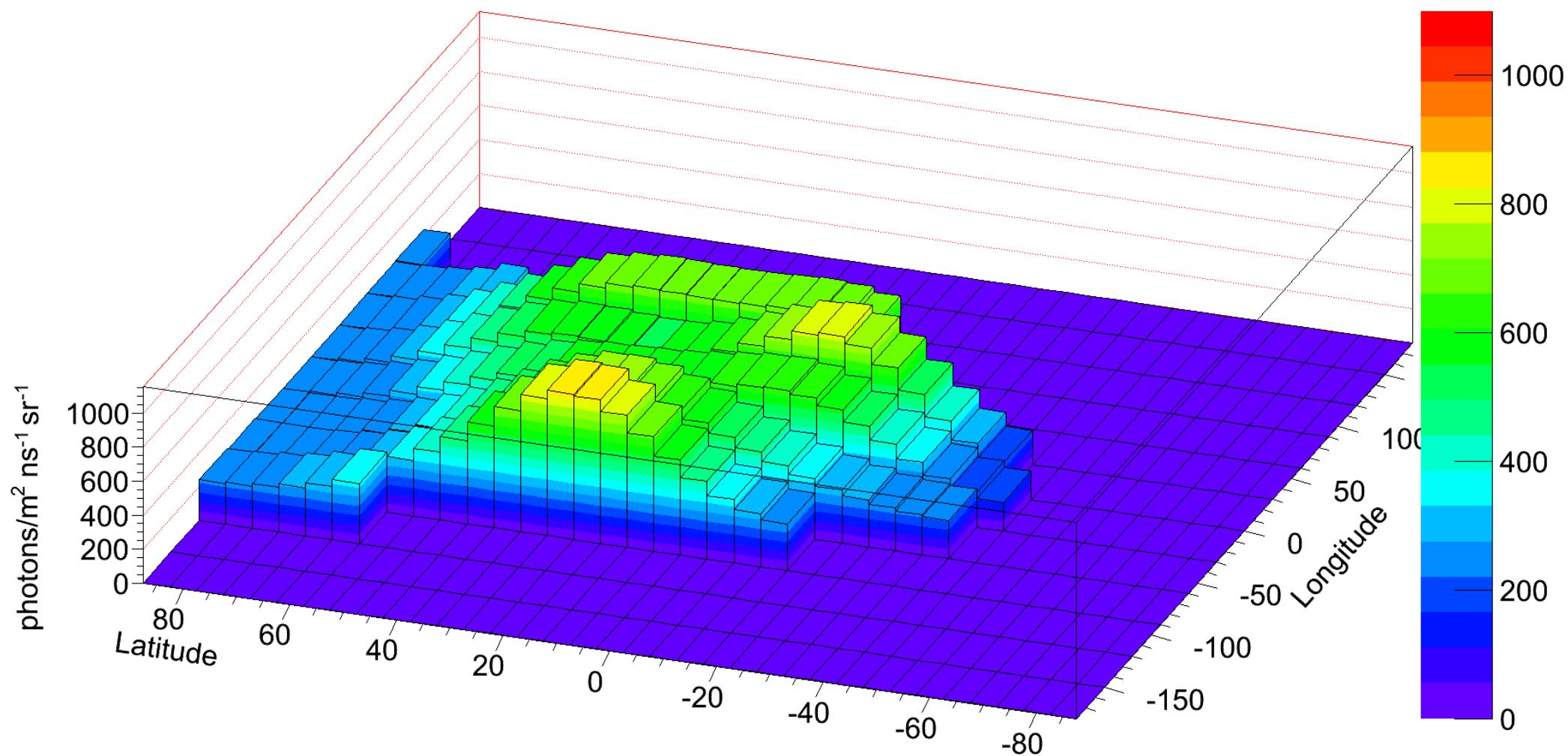
1994, Dec, UTC time

0 UTC UVBG



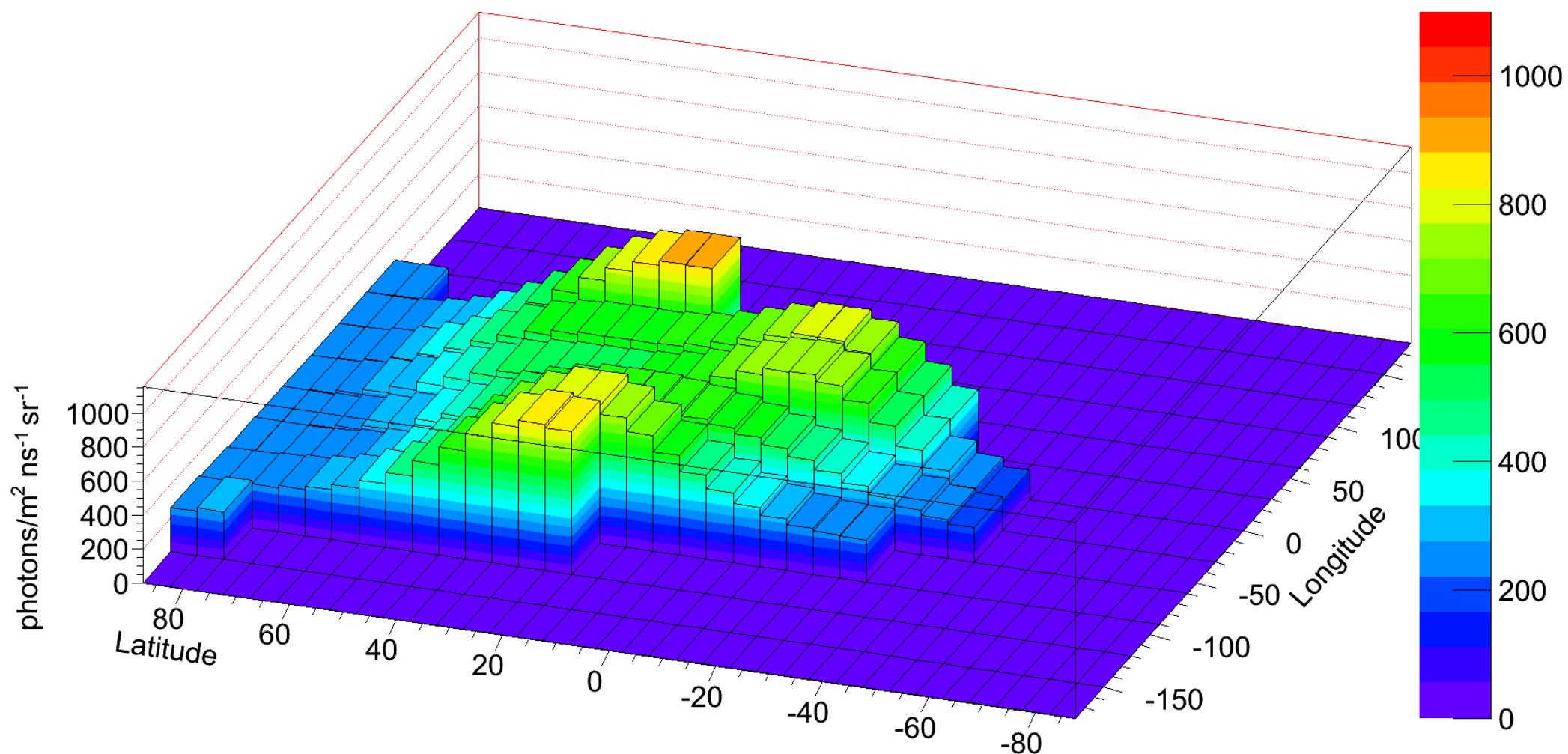
1994, Dec, UTC time

1 UTC UVBG



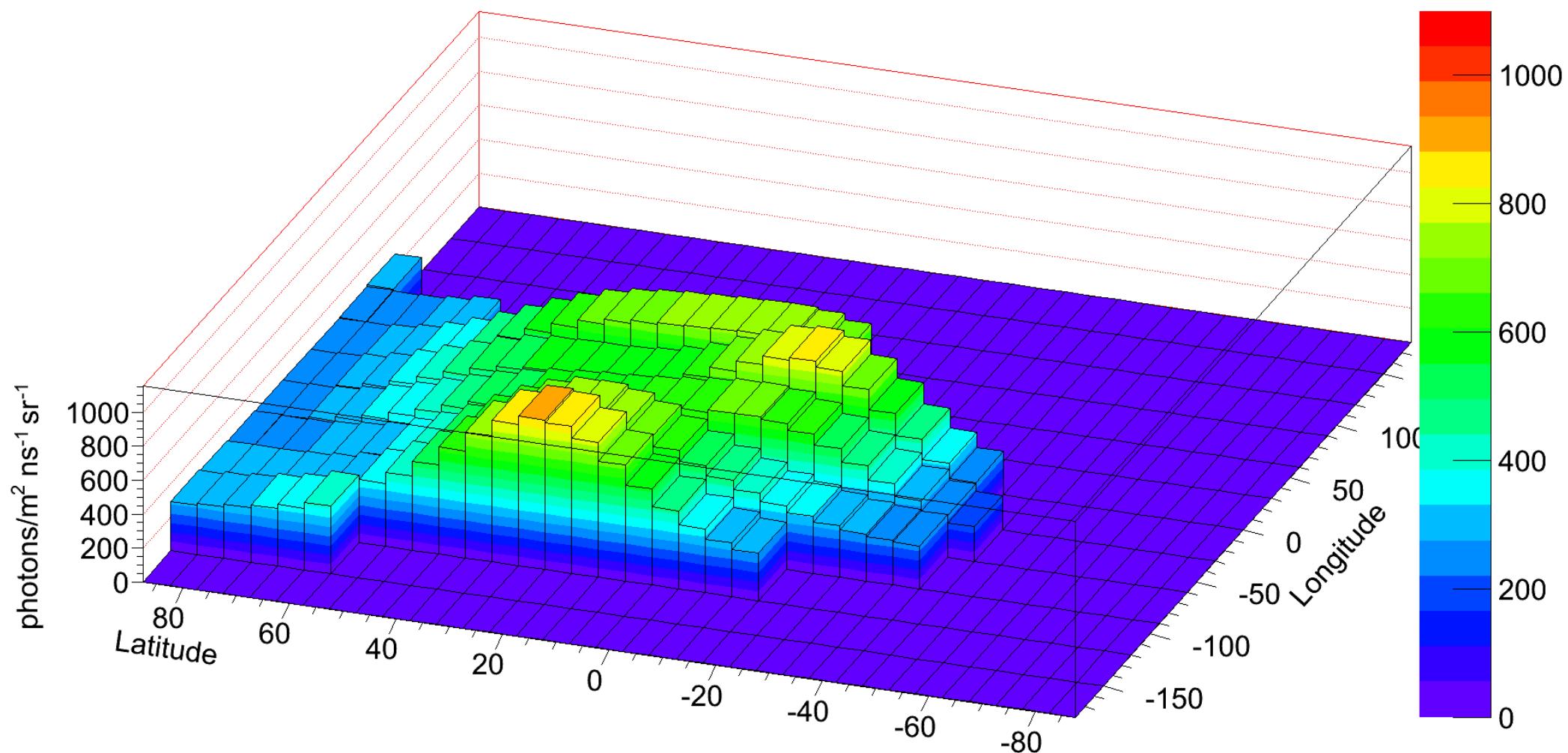
1994, Dec, UTC time

2 UTC UVBG



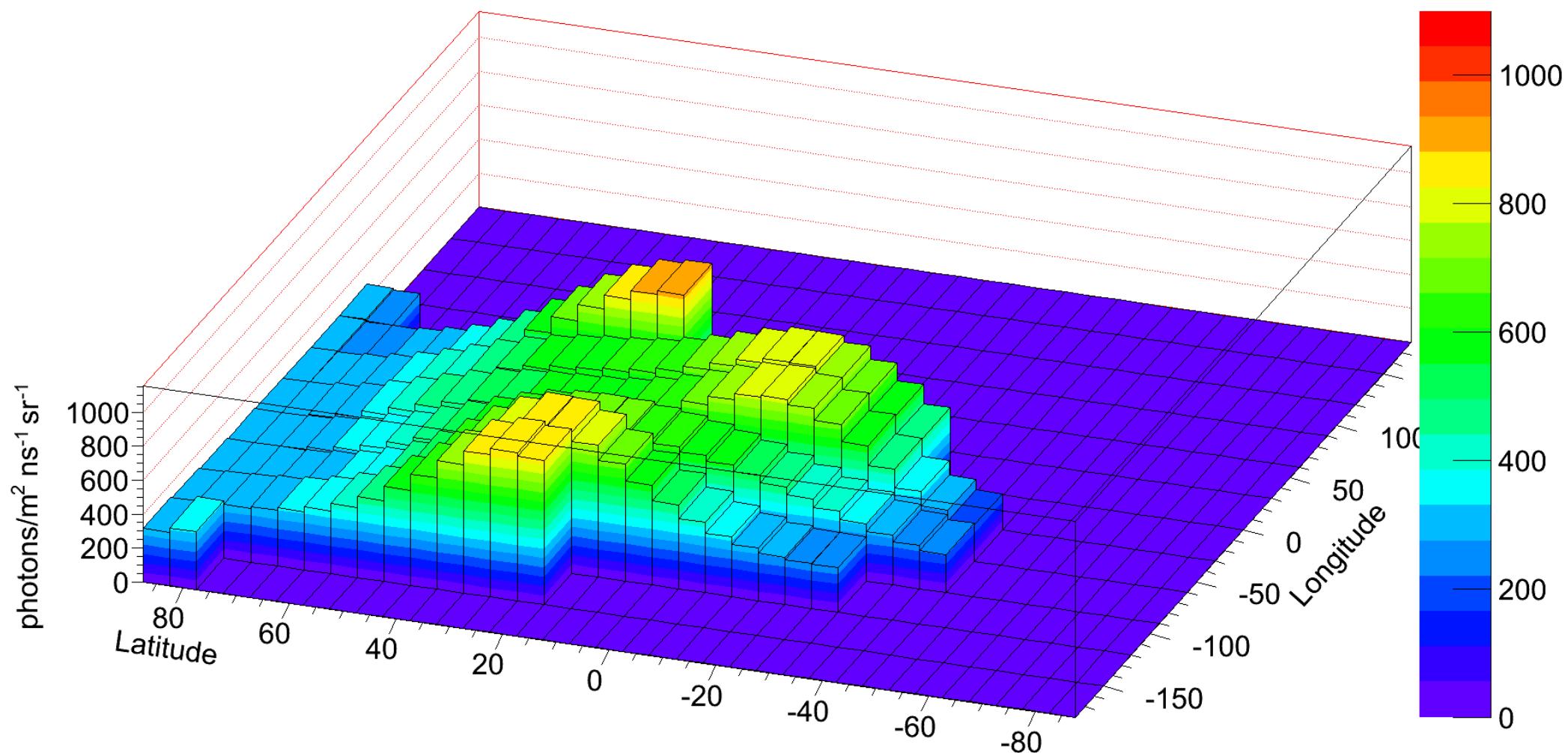
1994, Dec, UTC time

3 UTC UVBG



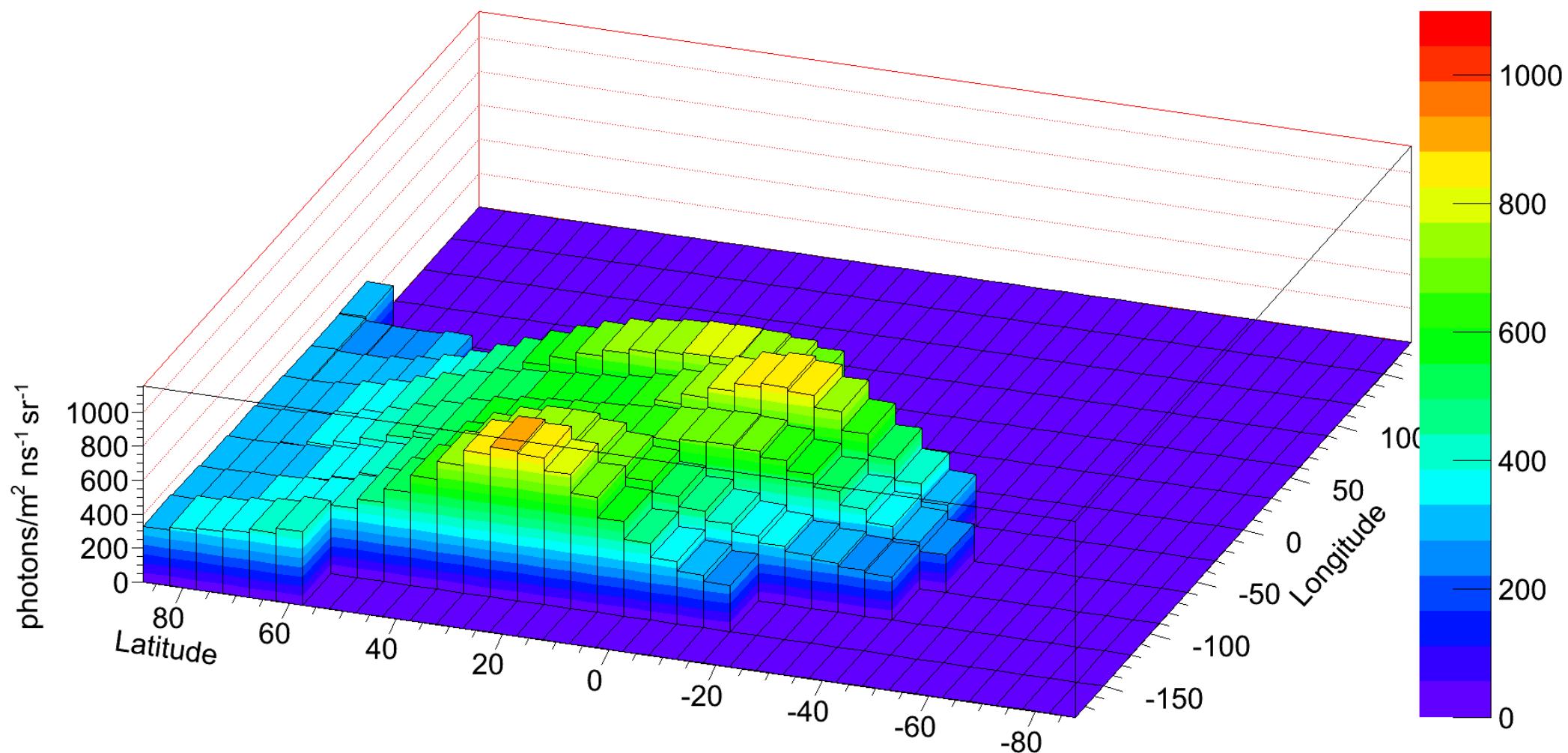
1994, Dec, UTC time

4 UTC UVBG



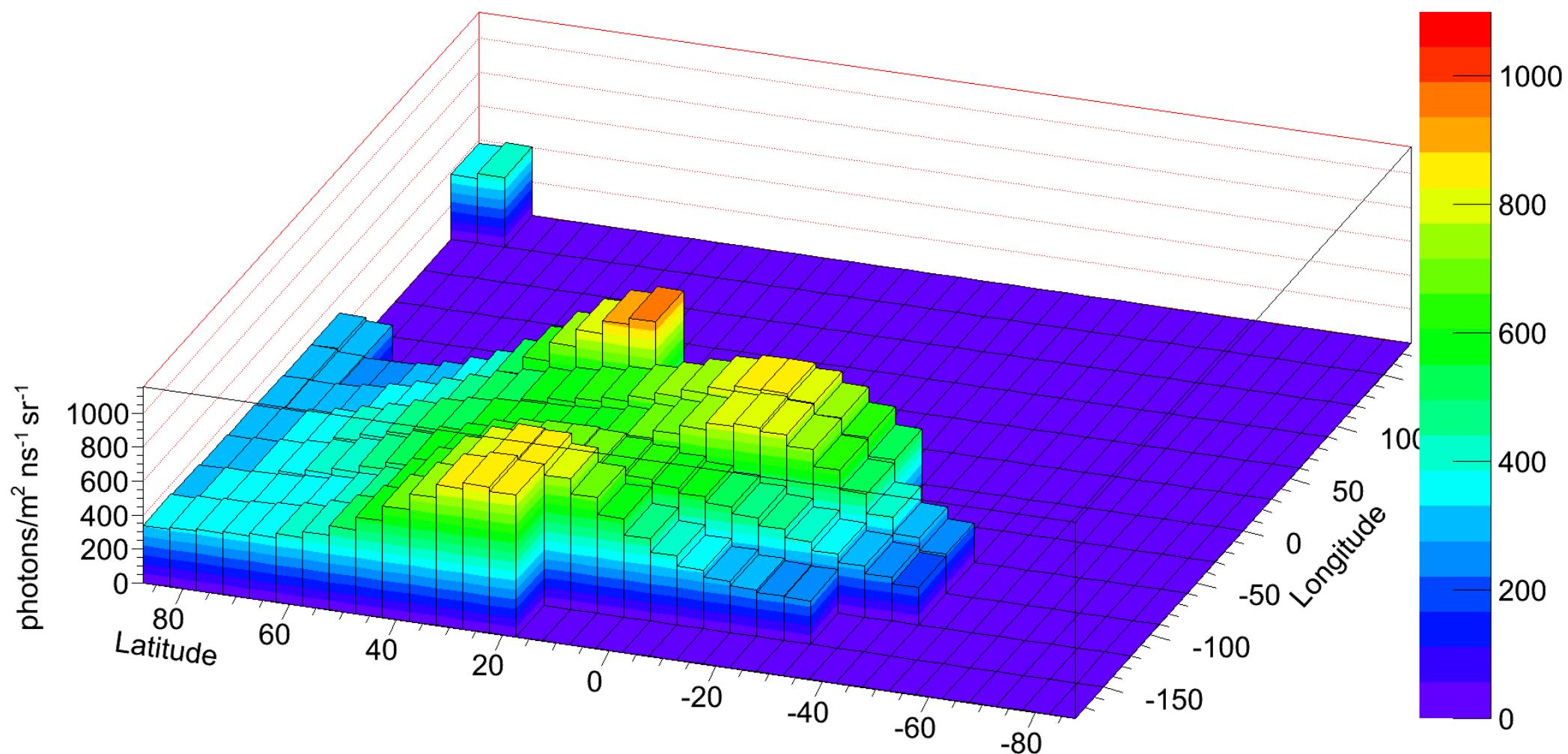
1994, Dec, UTC time

5 UTC UVBG



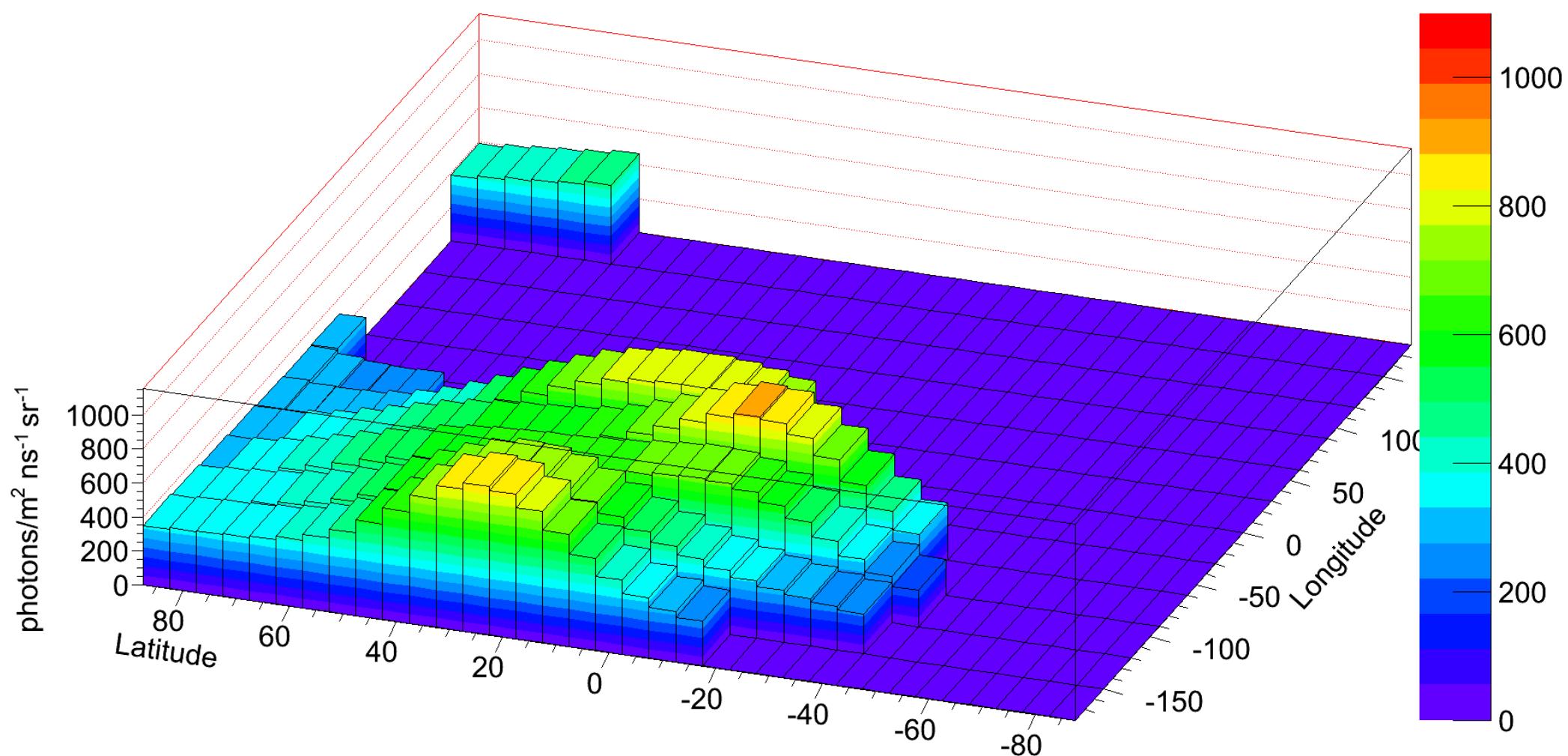
1994, Dec, UTC time

6 UTC UVBG



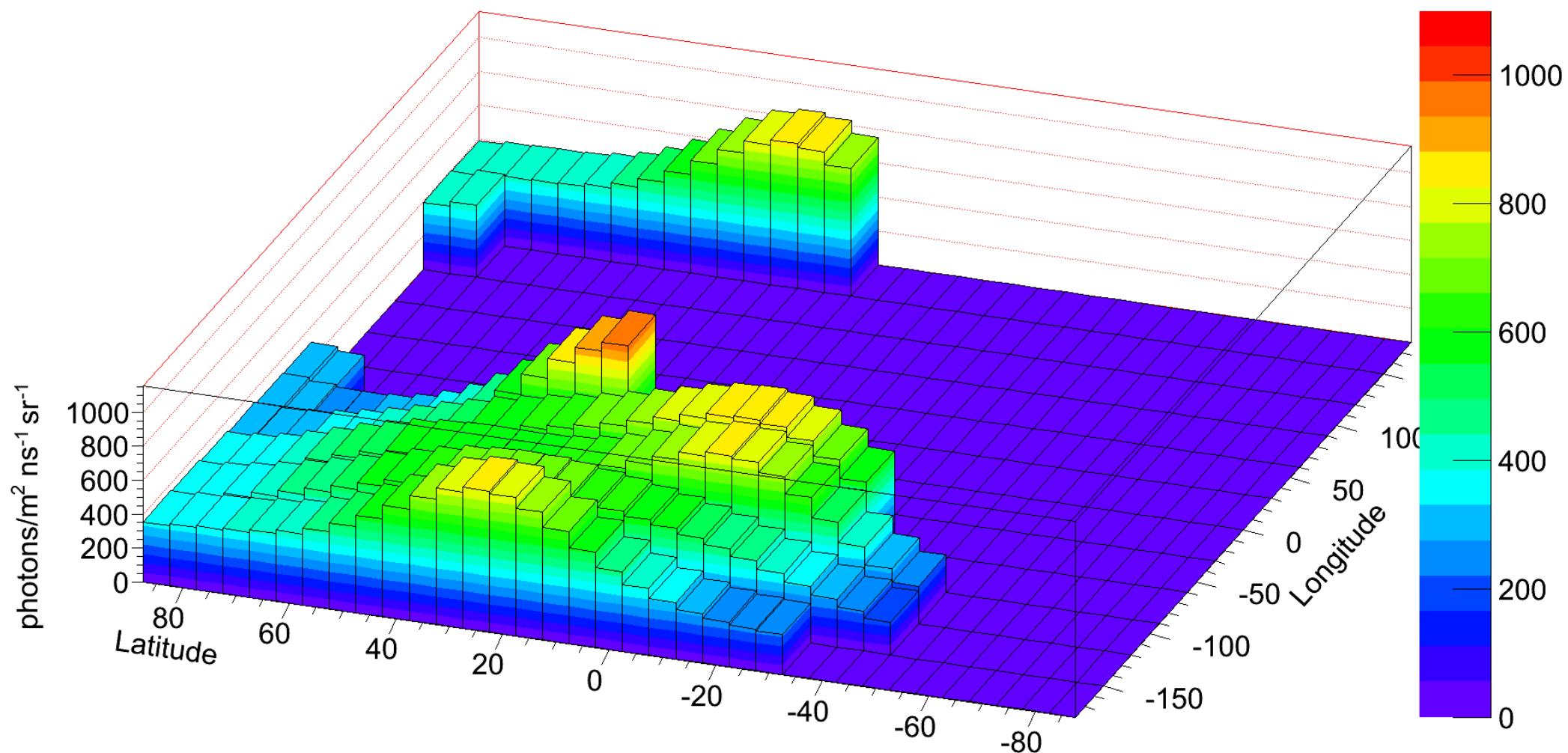
1994, Dec, UTC time

7 UTC UVBG



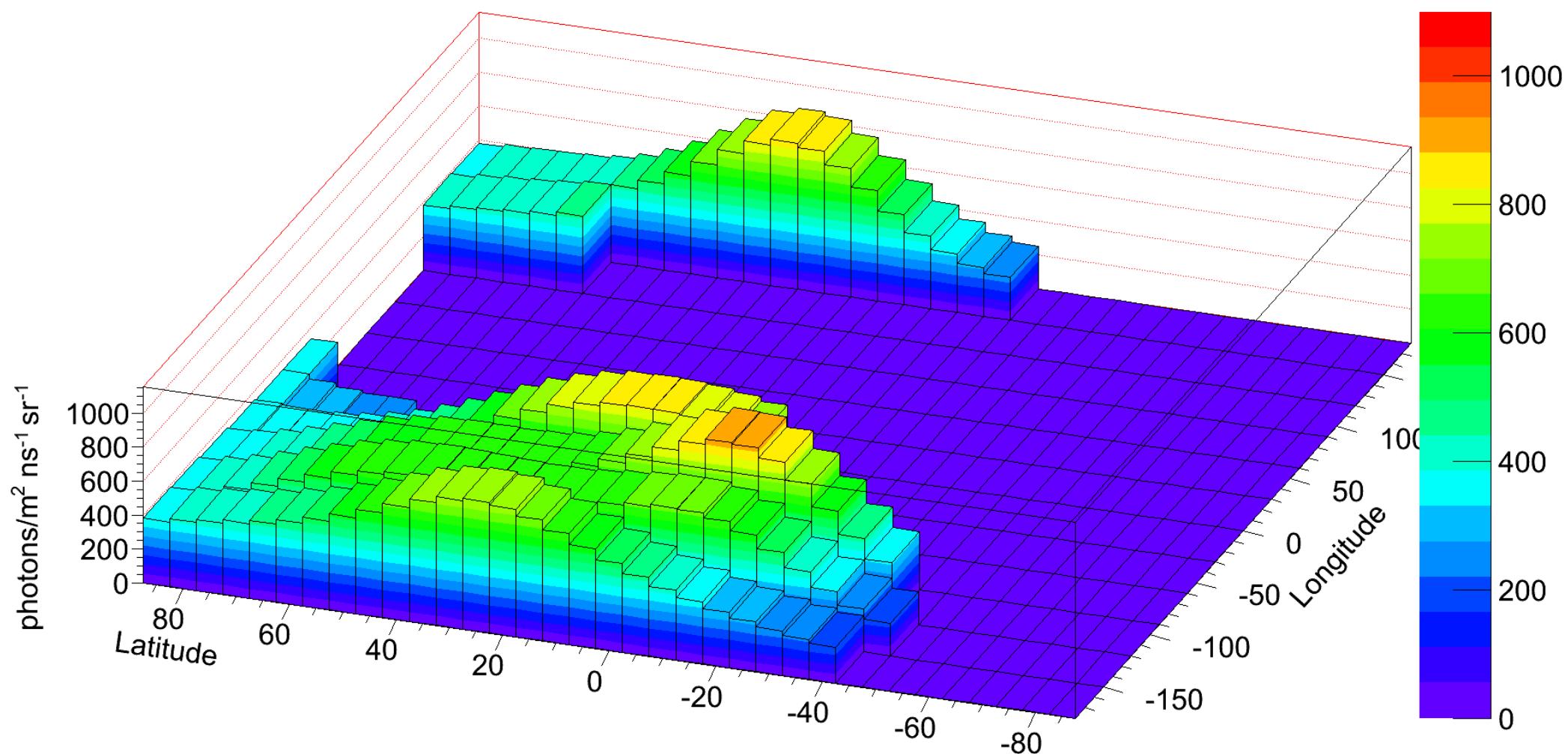
1994, Dec, UTC time

8 UTC UVBG



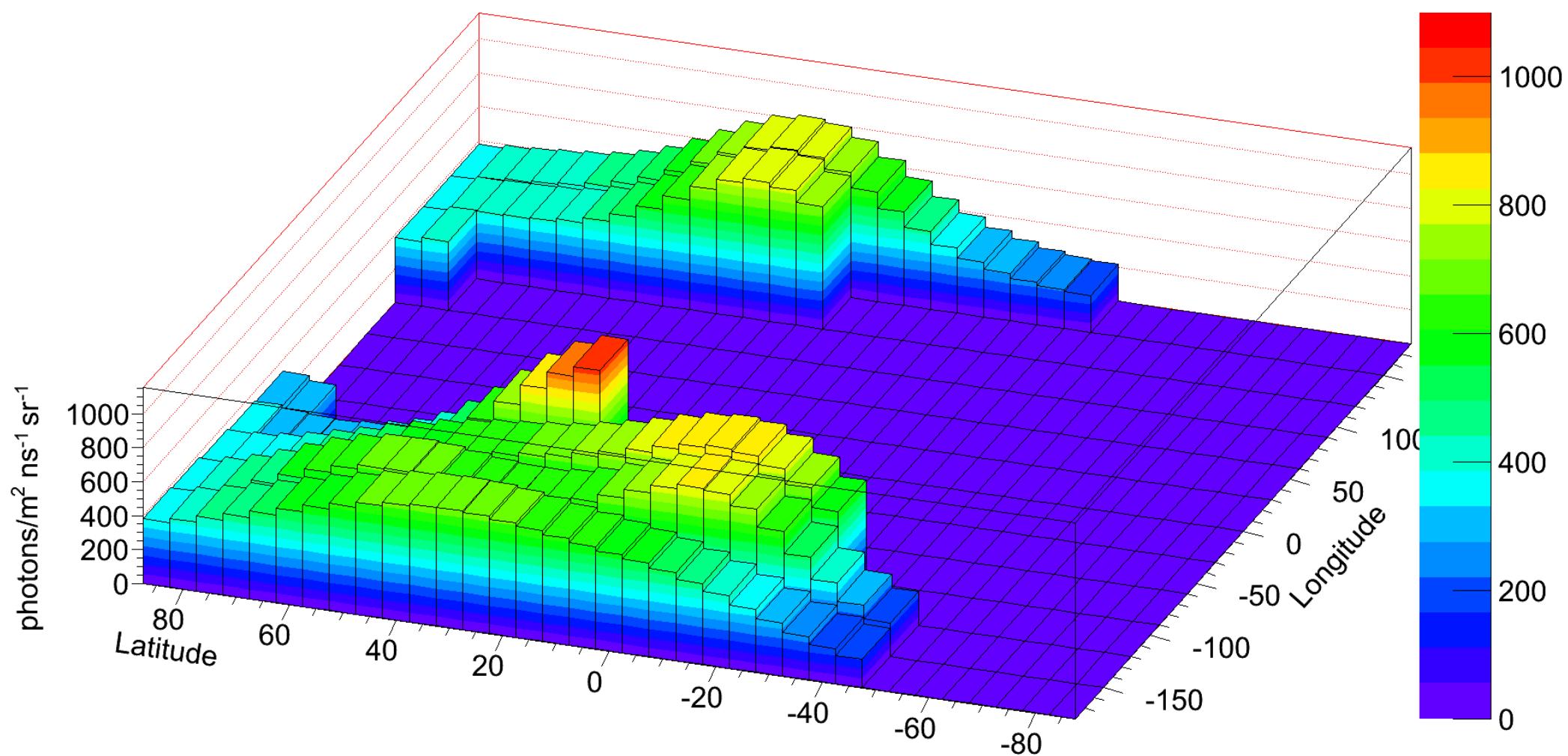
1994, Dec, UTC time

9 UTC UVBG



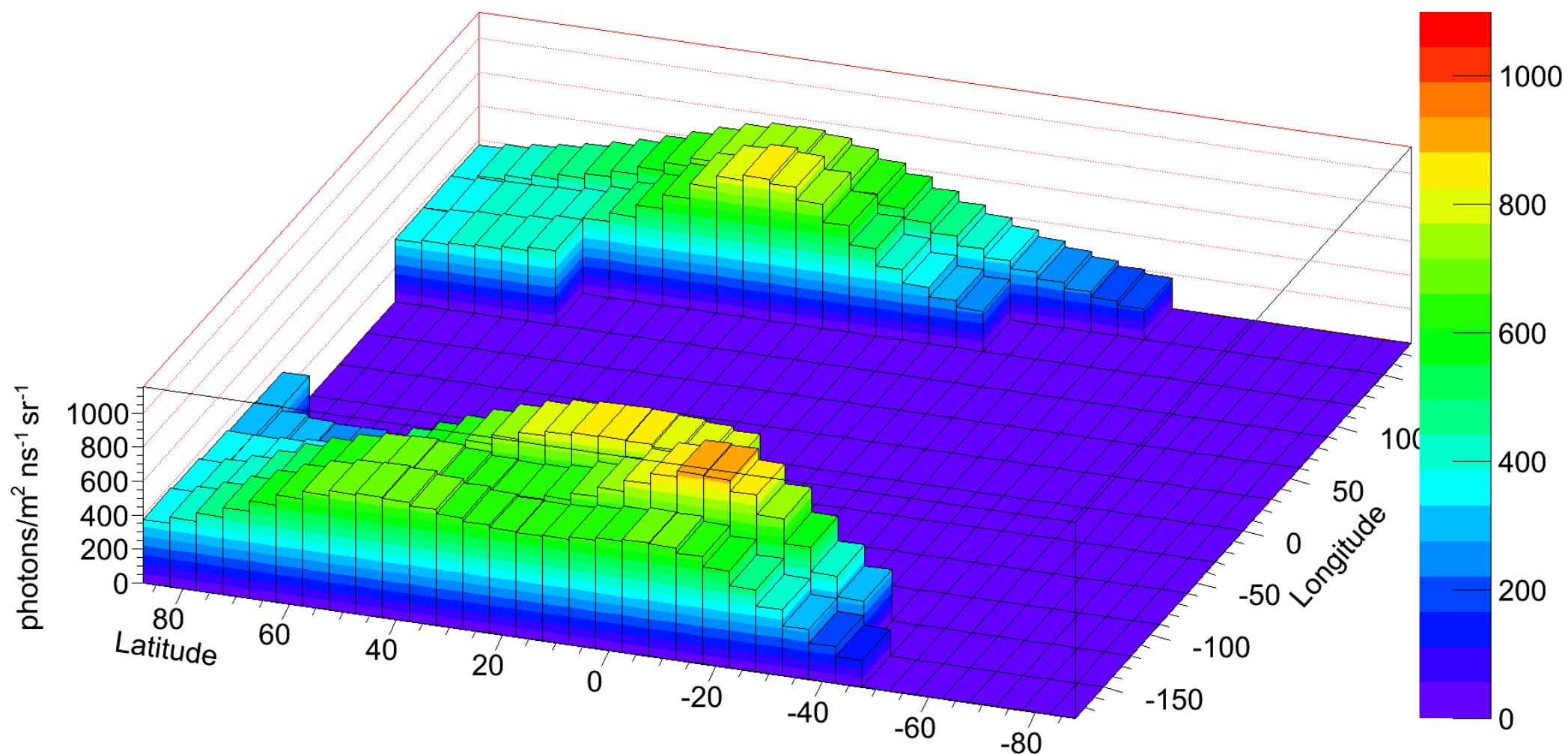
1994, Dec, UTC time

10 UTC UVBG



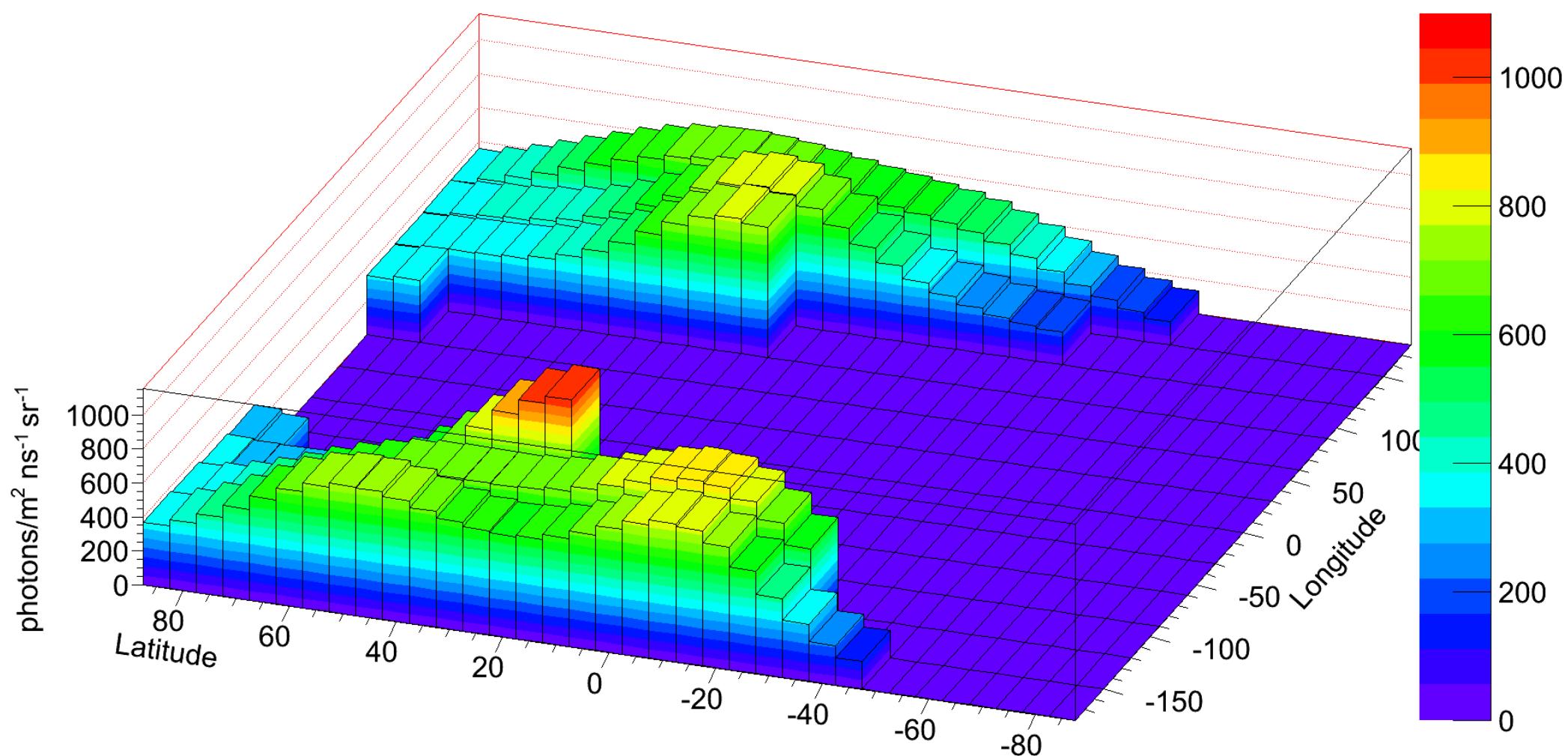
1994, Dec, UTC time

11 UTC UVBG



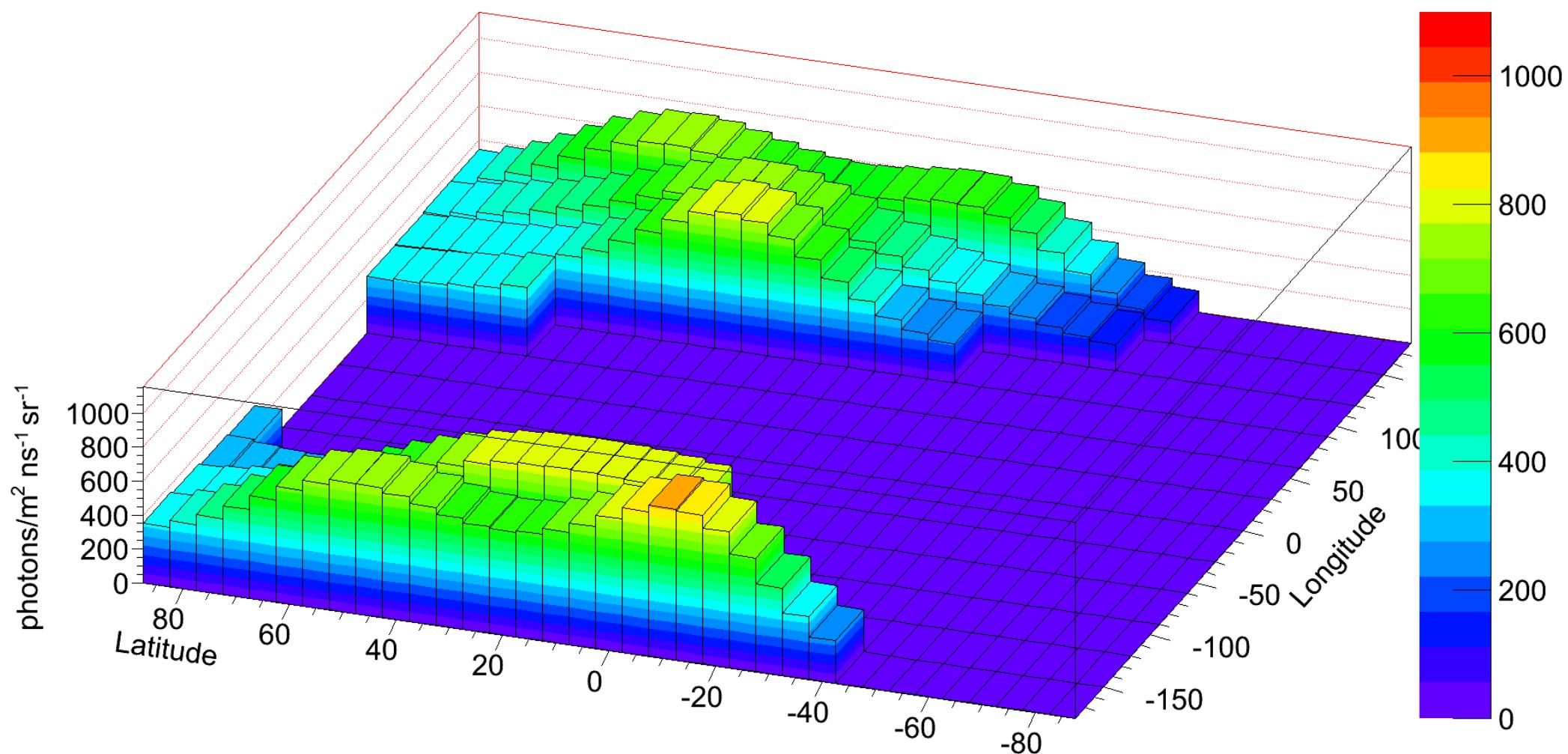
1994, Dec, UTC time

12 UTC UVBG



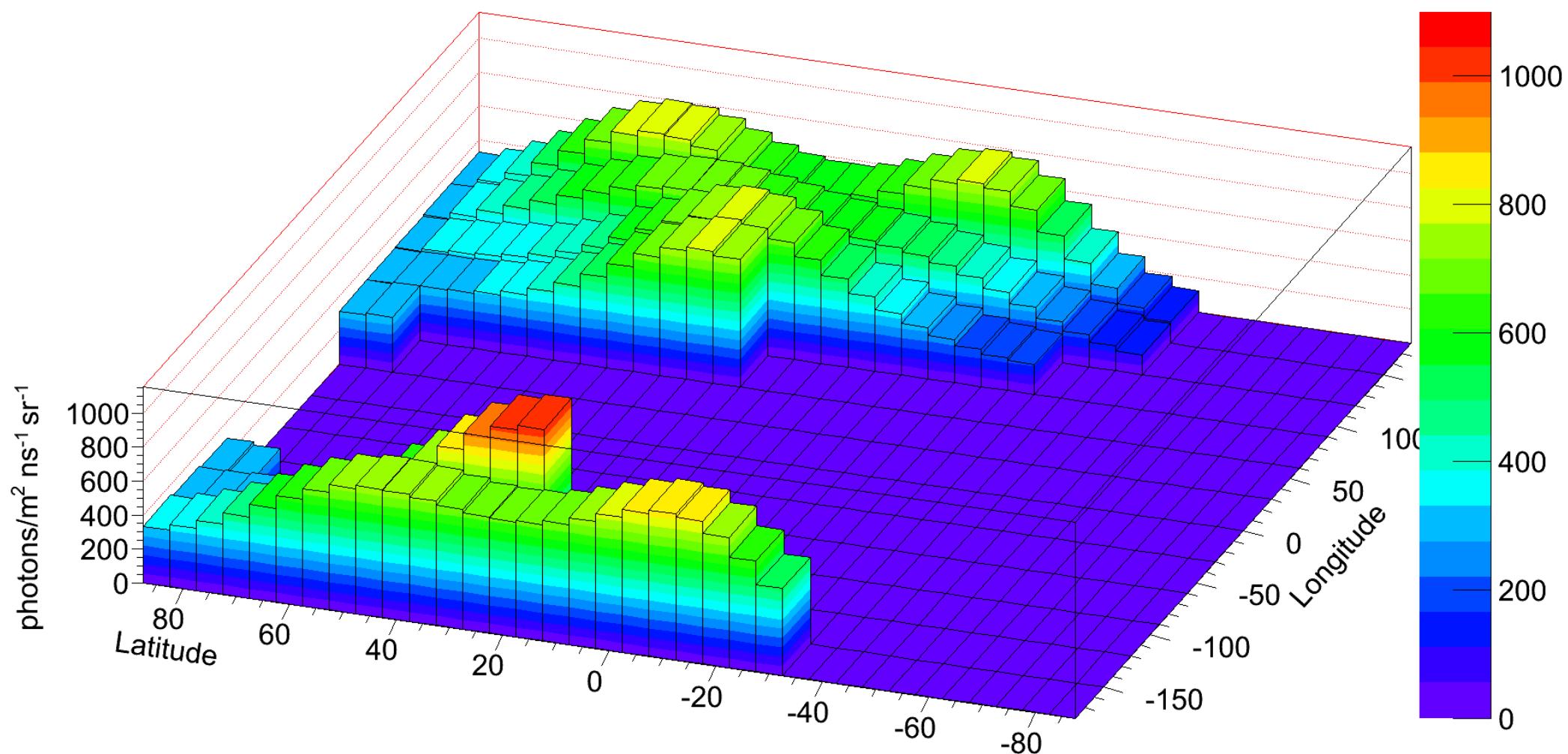
1994, Dec, UTC time

13 UTC UVBG



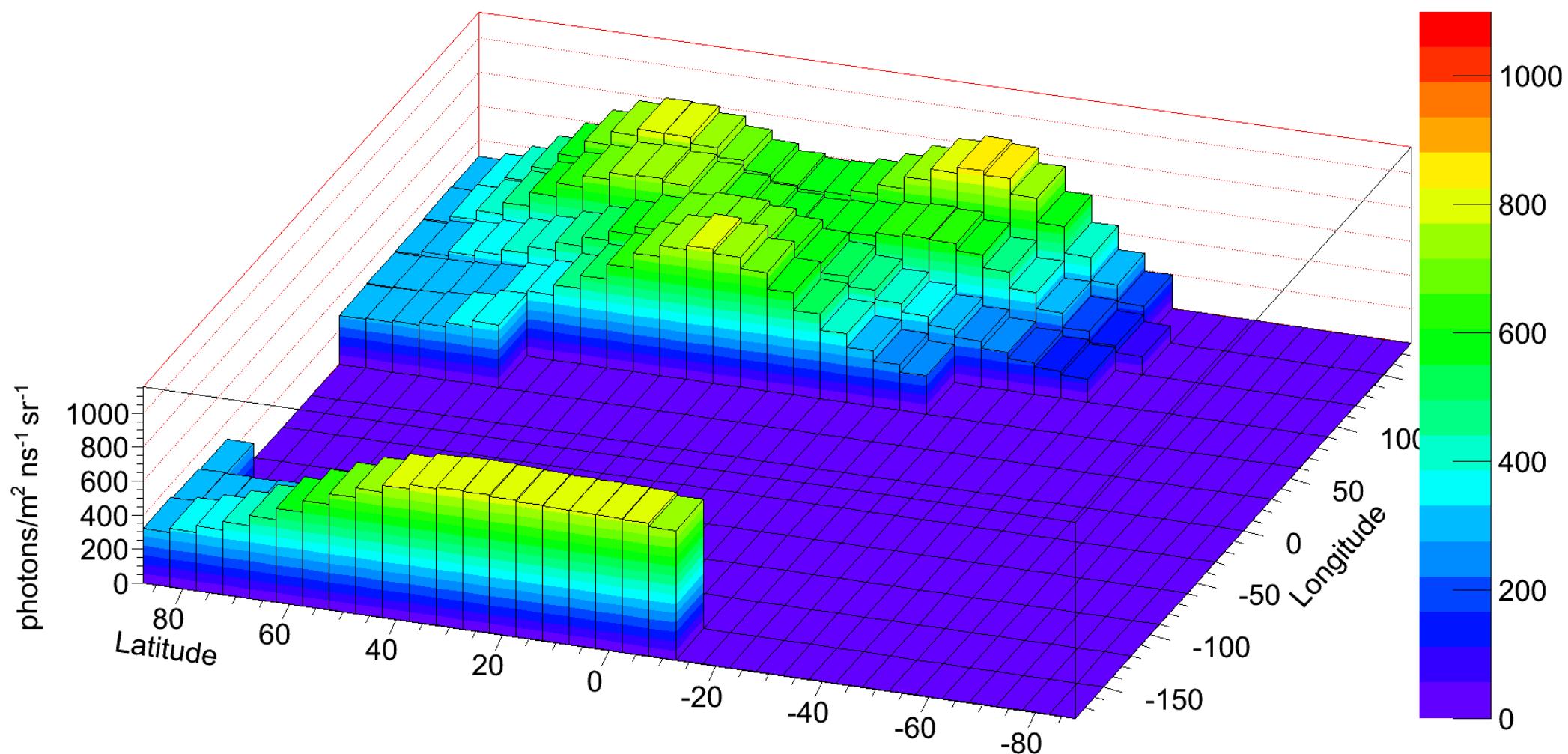
1994, Dec, UTC time

14 UTC UVBG



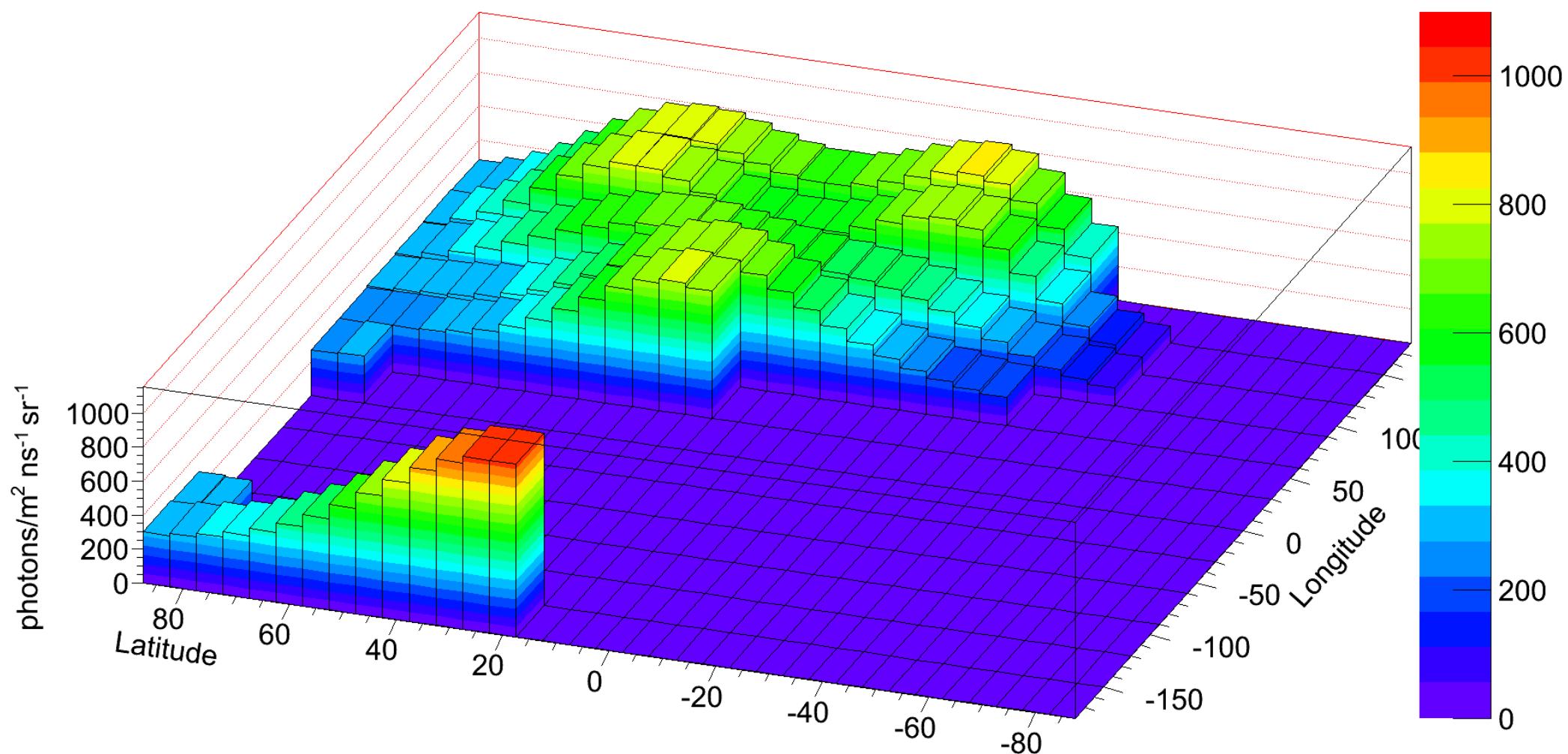
1994, Dec, UTC time

15 UTC UVBG



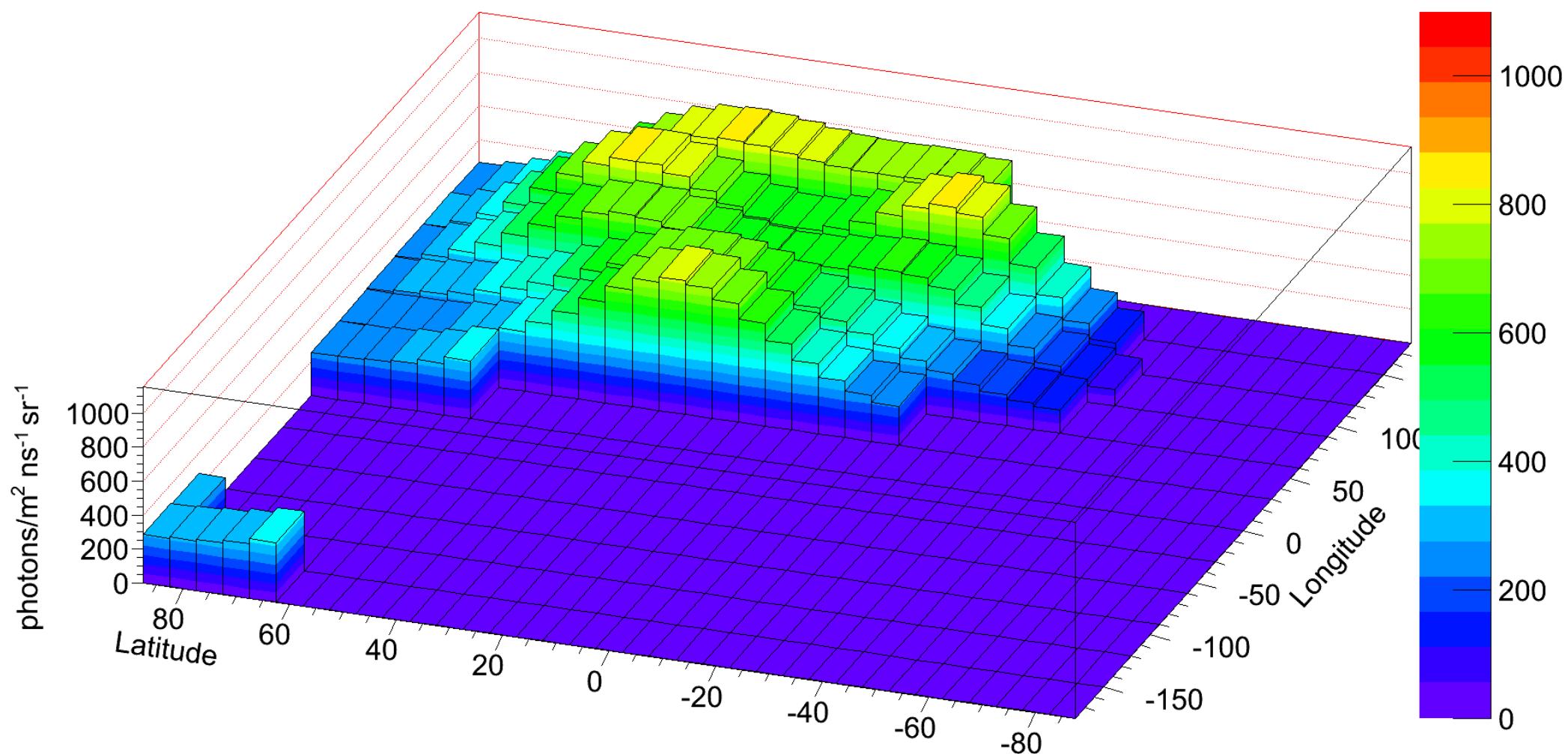
1994, Dec, UTC time

16 UTC UVBG



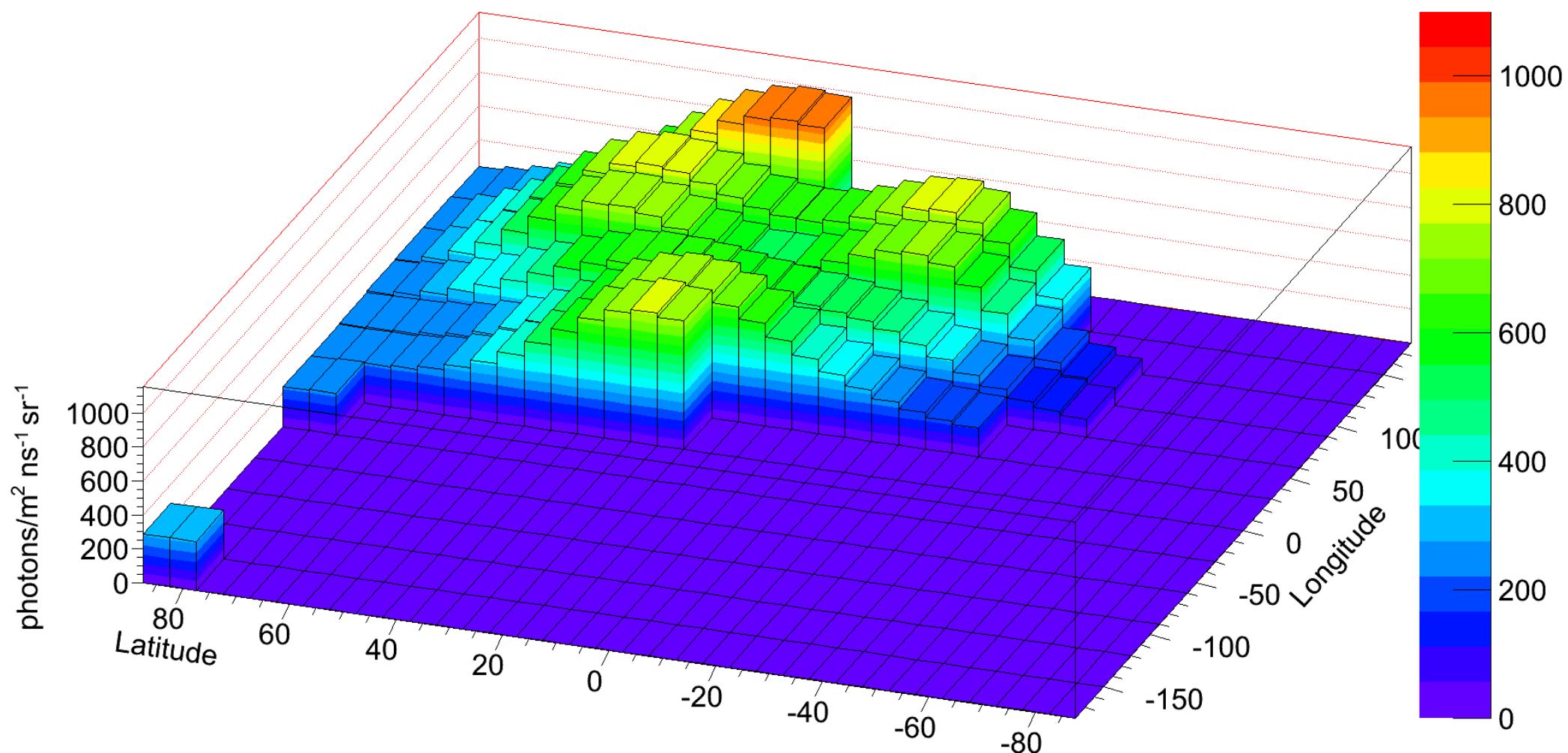
1994, Dec, UTC time

17 UTC UVBG



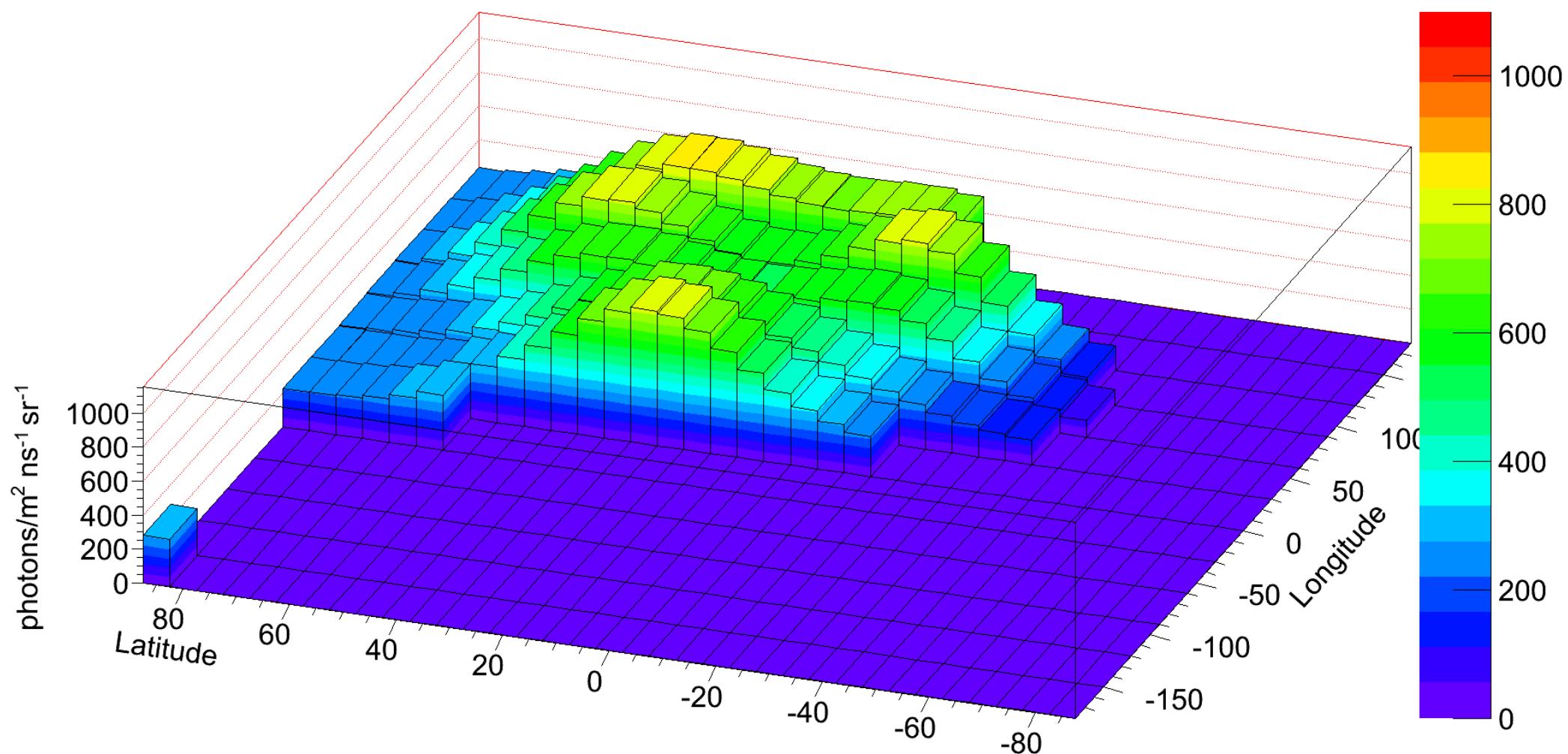
1994, Dec, UTC time

18 UTC UVBG



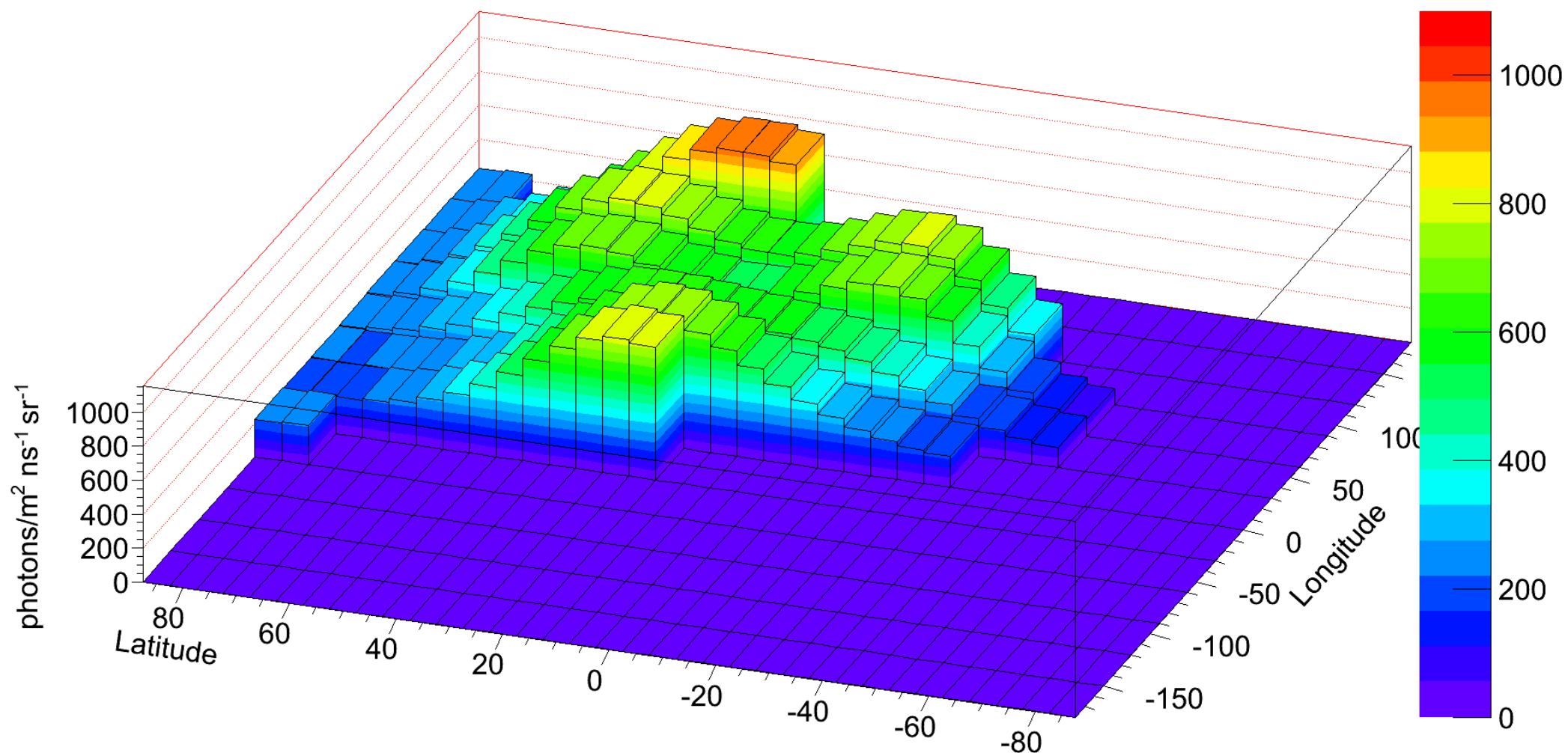
1994, Dec, UTC time

19 UTC UVBG



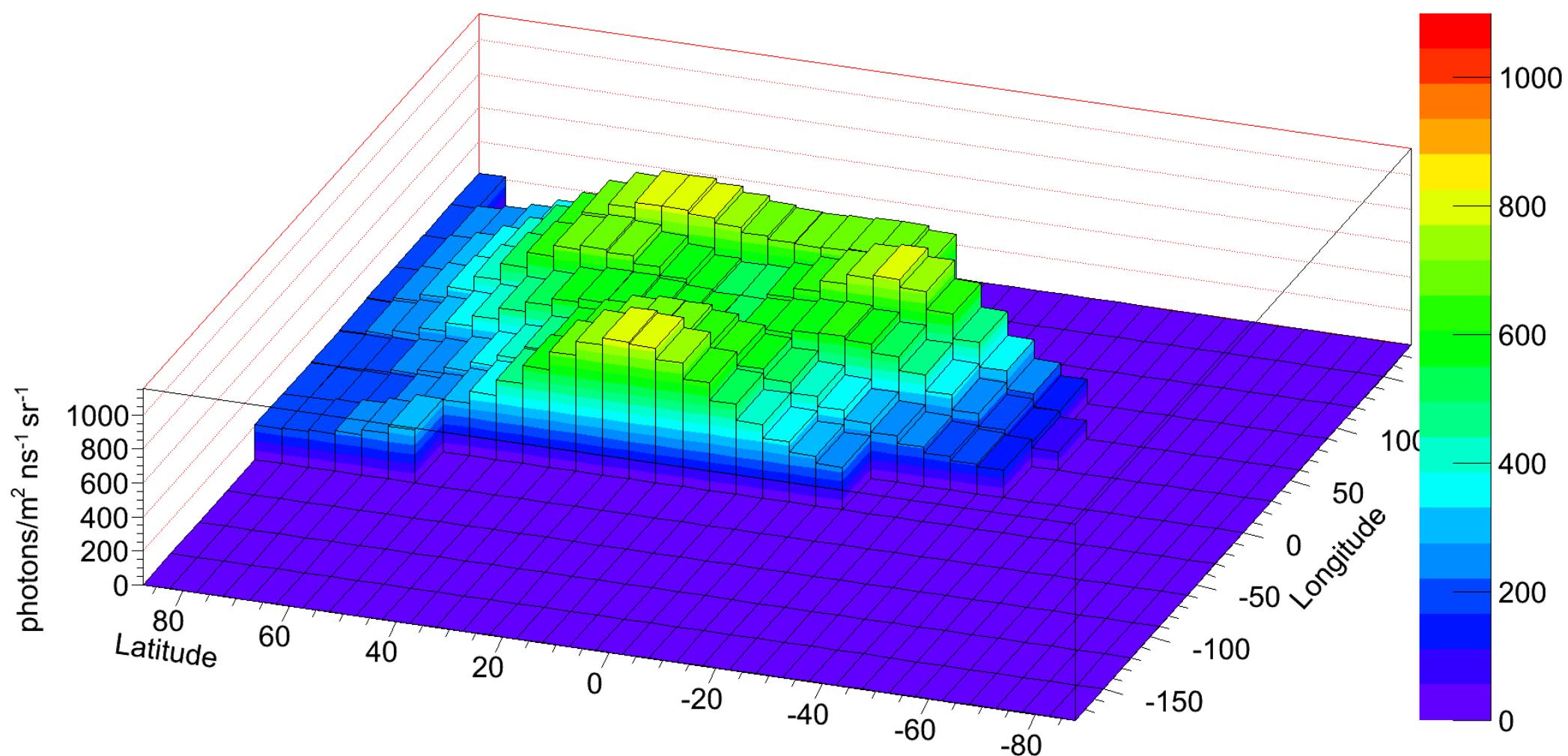
1994, Dec, UTC time

20 UTC UVBG



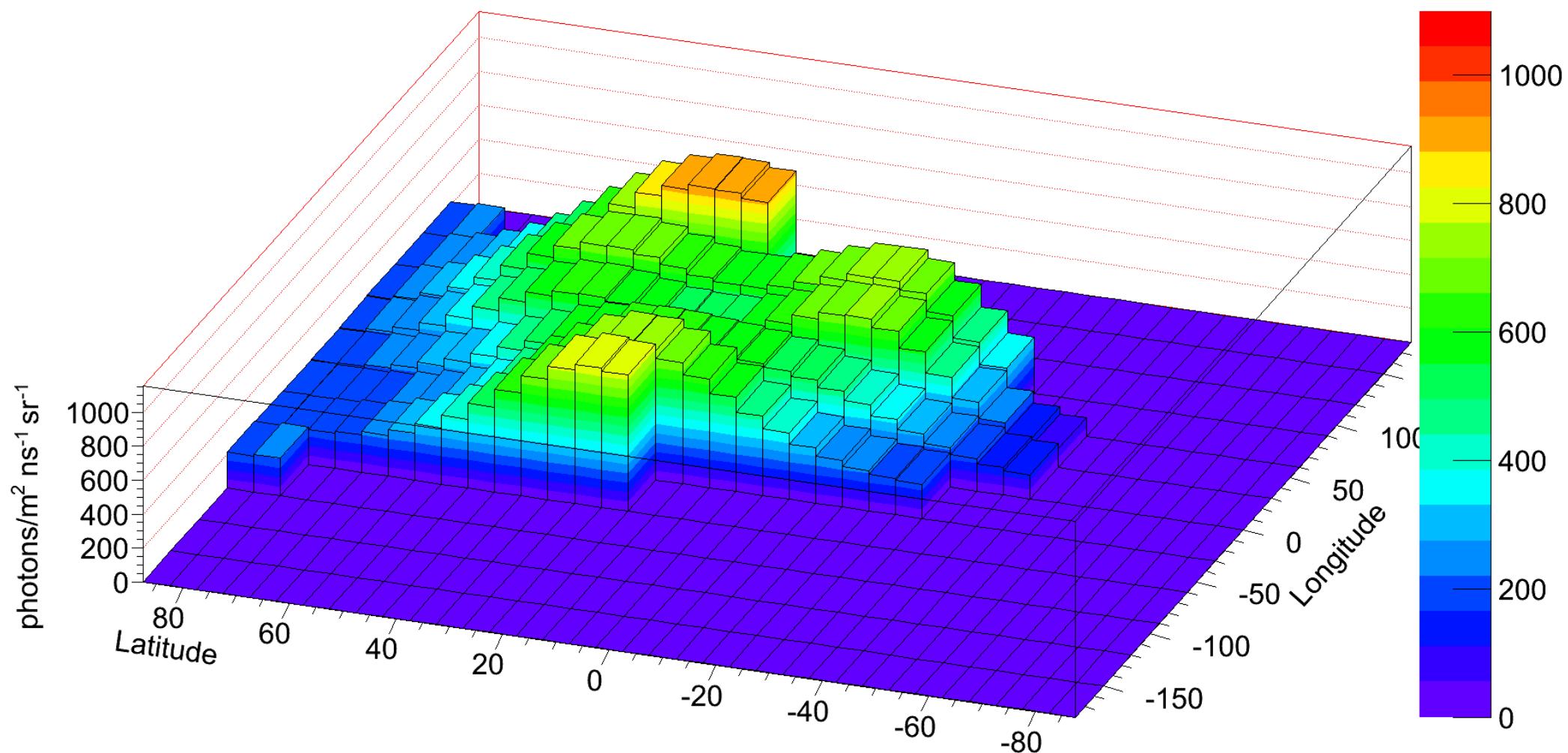
1994, Dec, UTC time

21 UTC UVBG



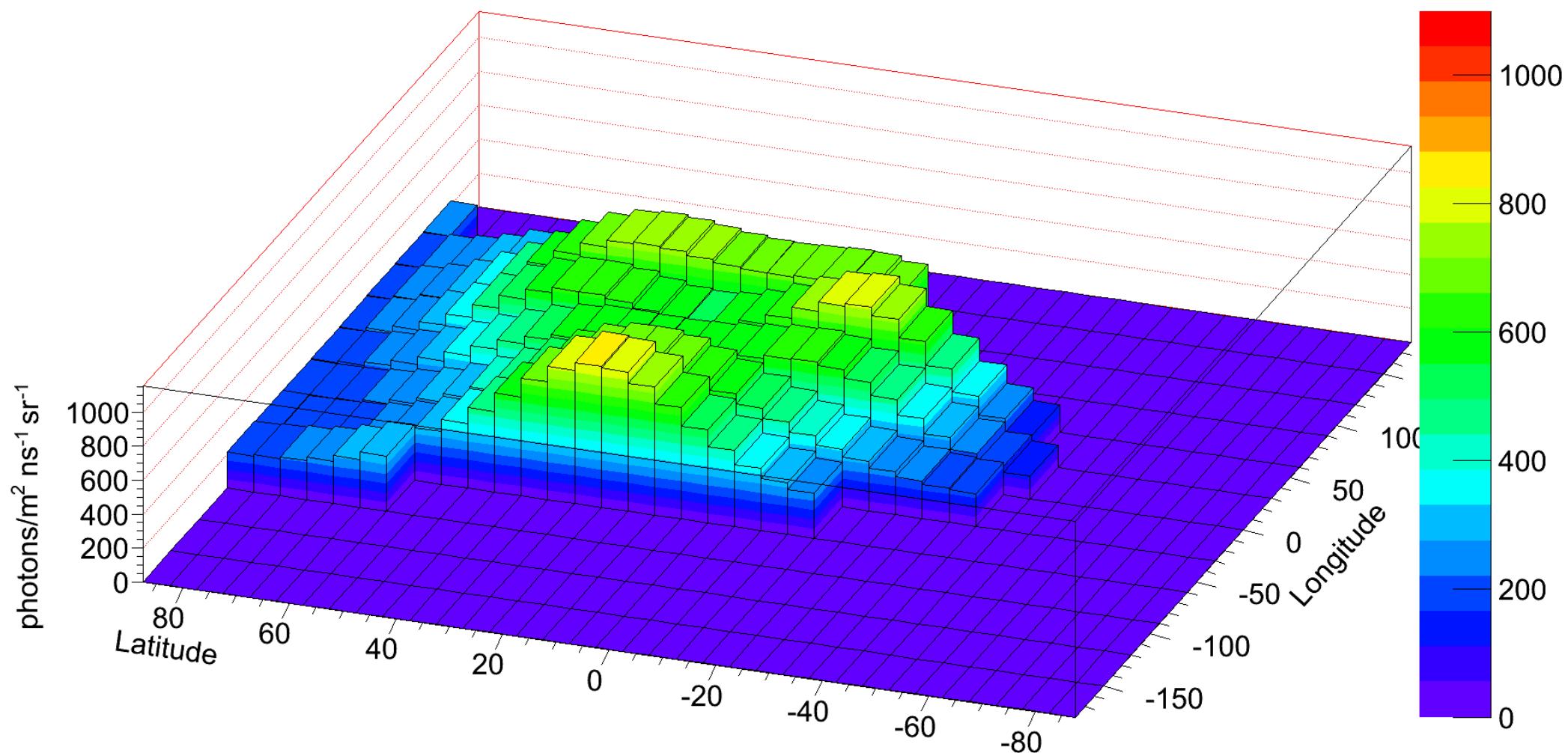
1994, Dec, UTC time

22 UTC UVBG

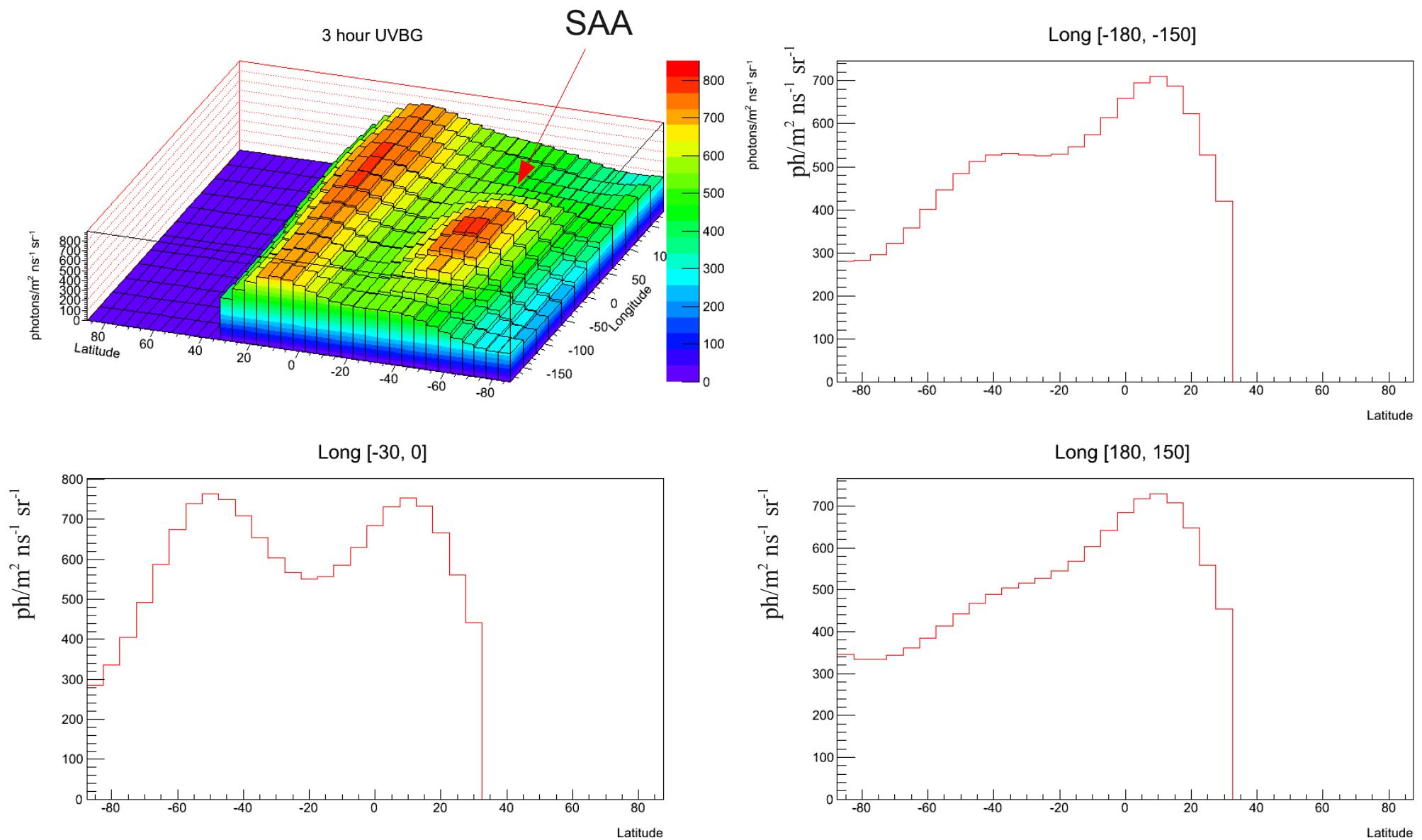


1994, Dec, UTC time

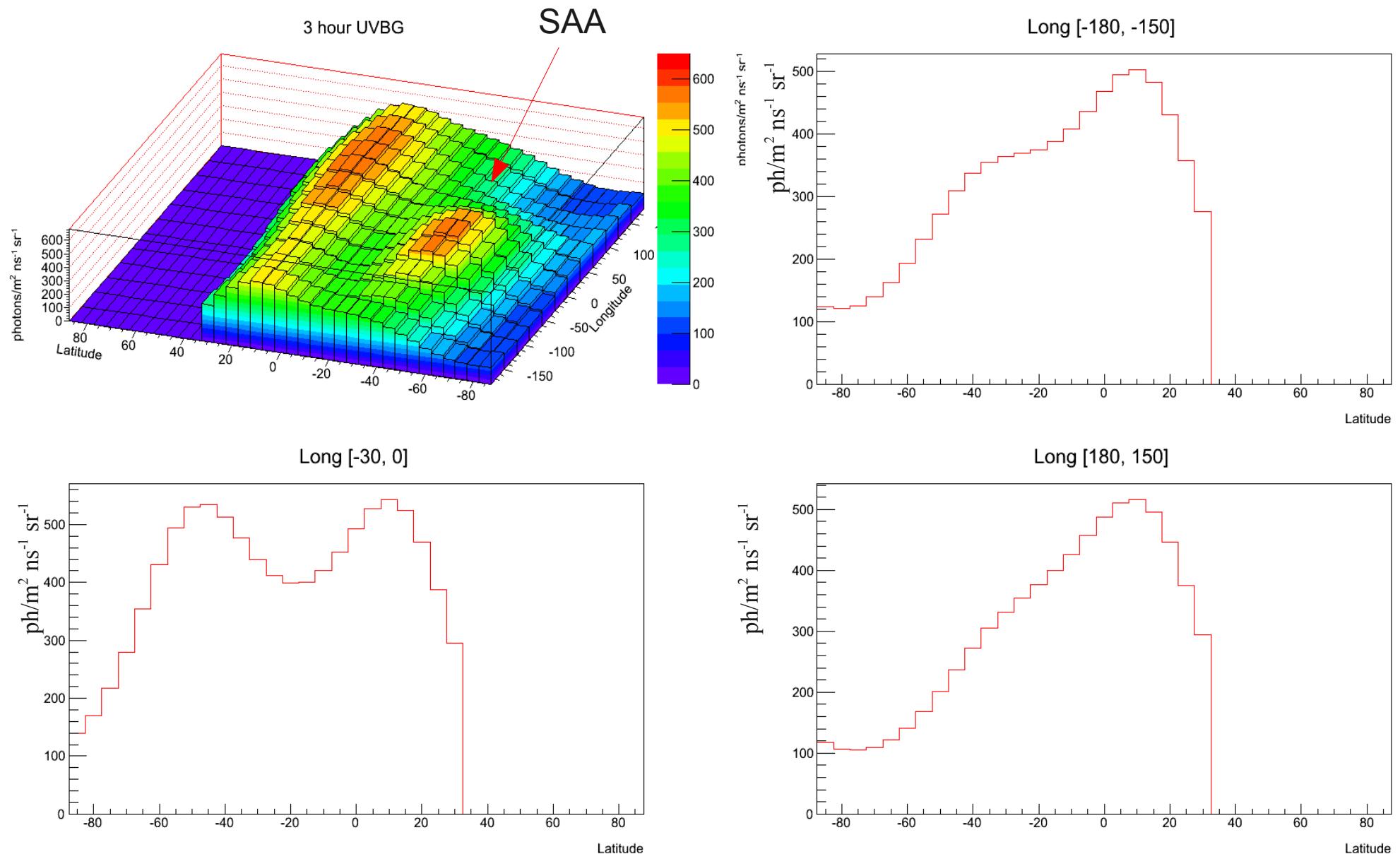
23 UTC UVBG



South Atlantic Anomaly, Map of UV nightglow, 1990, 20 -21. June, Local time 03:00

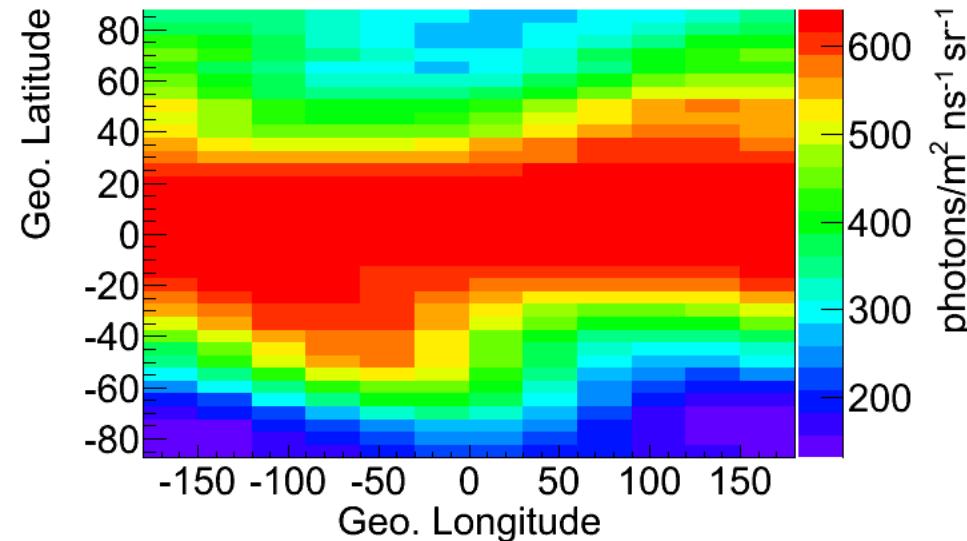


South Atlantic Anomaly, Map of UV nightglow, 1994, 20 -21. June, Local time 03:00

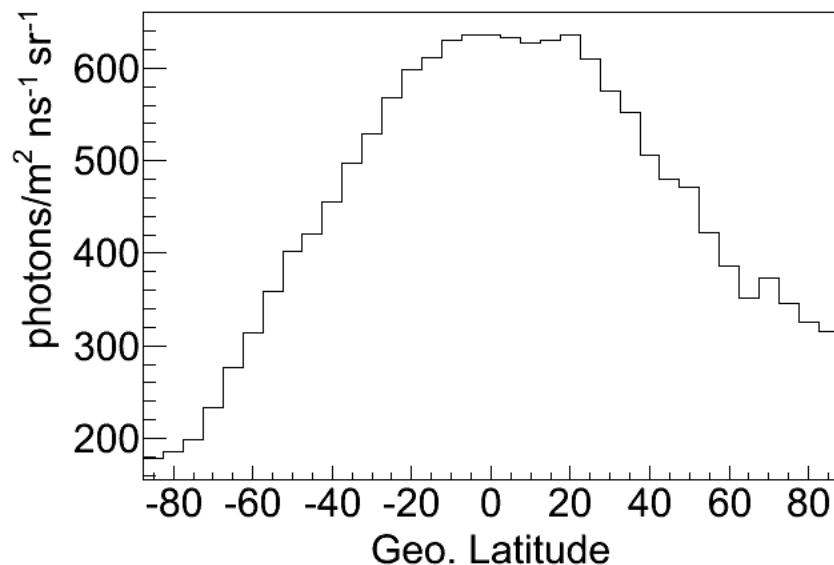


Map of mean values of UV nightglow radiation in March, June, September and December for period 1970 - 1994

Map of mean values of UV nightglow radiation for period 1970 - 1994



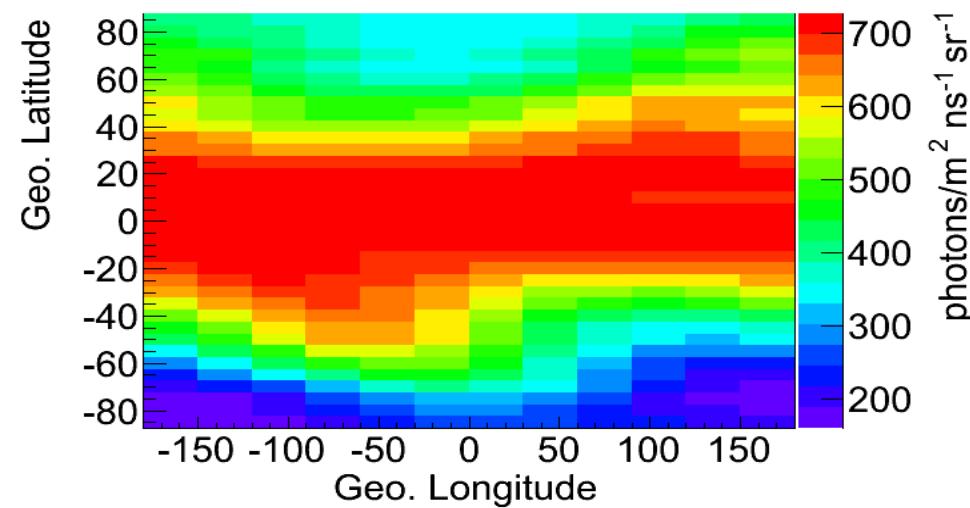
Latitudinal average projection



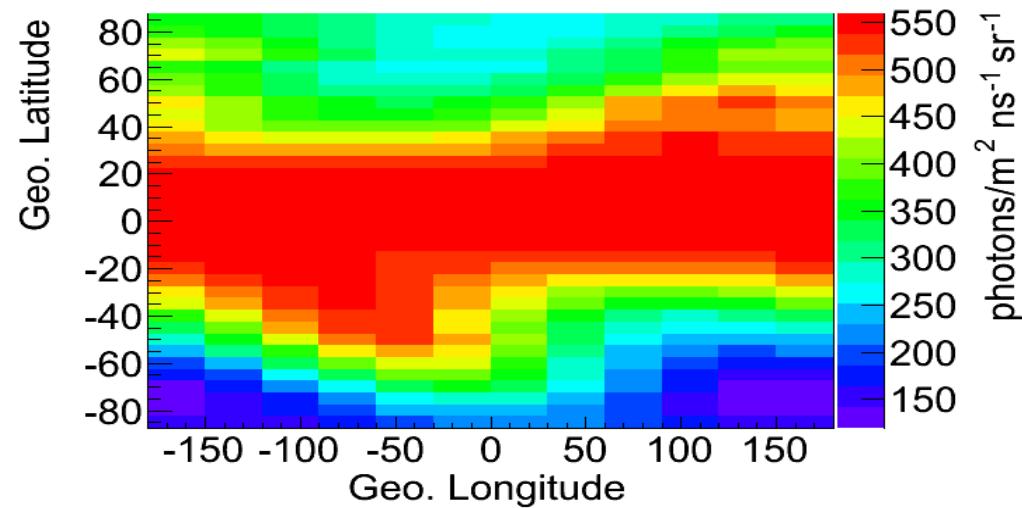
- UV radiation for 4 months (March, June, September, December) in years from 1970 to 1994 (1994 is limited year for AURIC parameters database).
- Area with increased values of radiation from -20 to -50 deg. geographic latitude and from -90 to 0 deg. geographic longitude.
- This increase is not visible for example on east hemisphere in same latitudes.
- However this radiation is not bigger than other areas around equator.
- Maximal values $\sim 630 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
- Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ in range ~ -40 to 40 deg. of geo. latitude.⁶³

Maps of mean values of UV nightglow radiation in March, June, Sep., Dec. for years 1971, 1981, 1991 (solar max., left) and years 1976, 1986, 1994 (solar min., right)

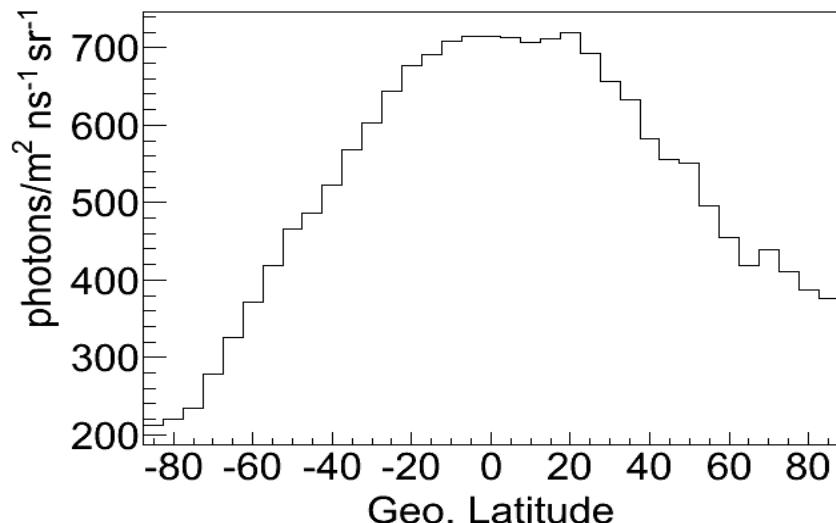
Map of mean values of UV nightglow radiation for 1971, 1981, 1991



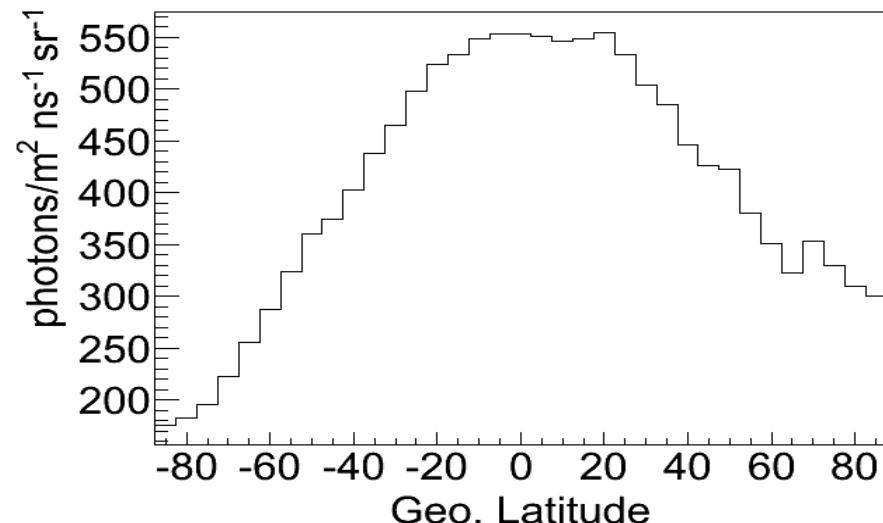
Map of mean values of UV nightglow radiation for 1976, 1986, 1994



Latitudinal average projection



Latitudinal average projection



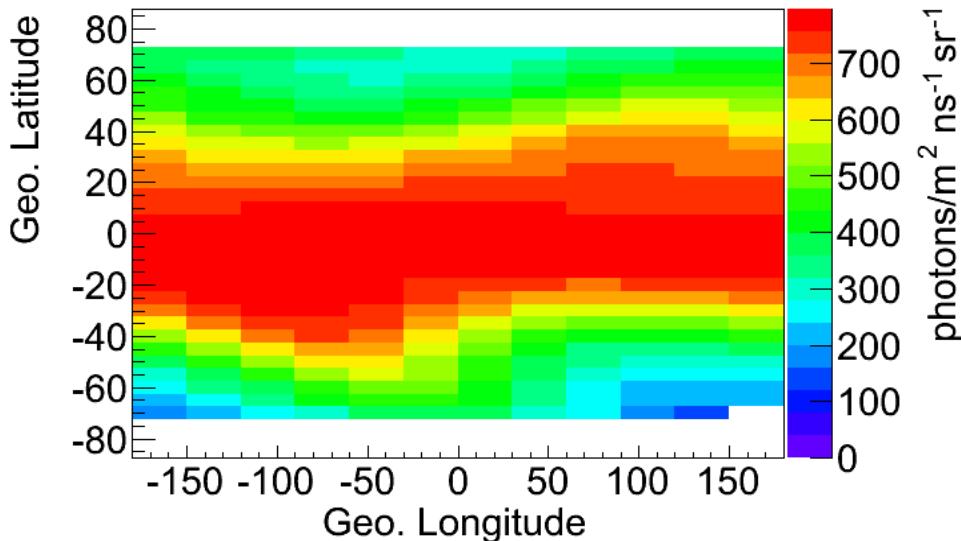
Difference of max. values with respect to the total average (all years 1970 - 1994): 64

for solar max. ~11%

for solar min. ~13%

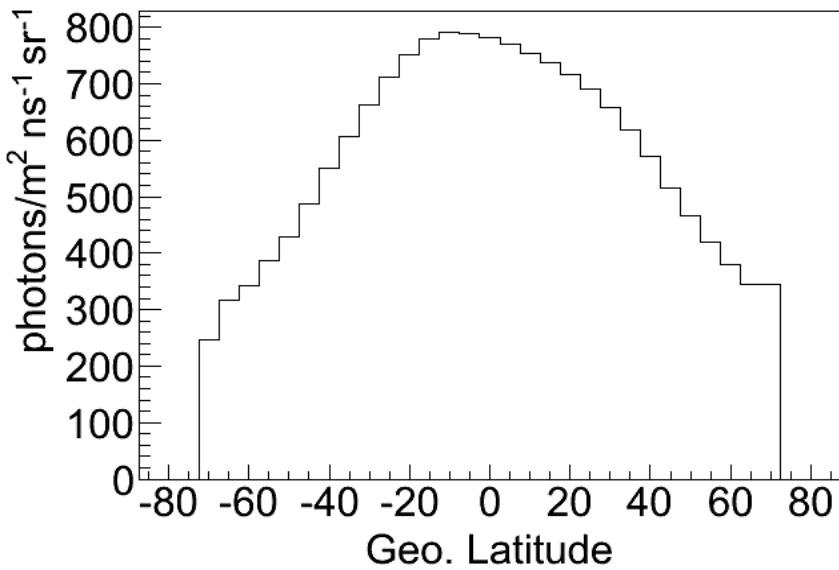
Map of mean values of UV nightglow radiation in March for period 1970 - 1994

Map of mean values of UV nightglow radiation in March for period 1970 - 1994



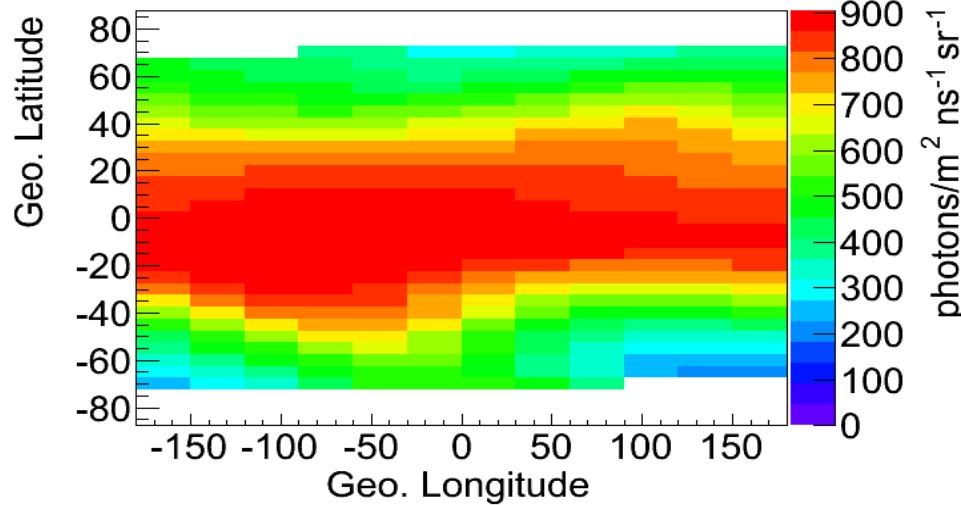
- Maximal values $\sim 800 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
- Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ in range in range ~ -50 to 50 deg. of geo. latitude.

Latitudinal average projection

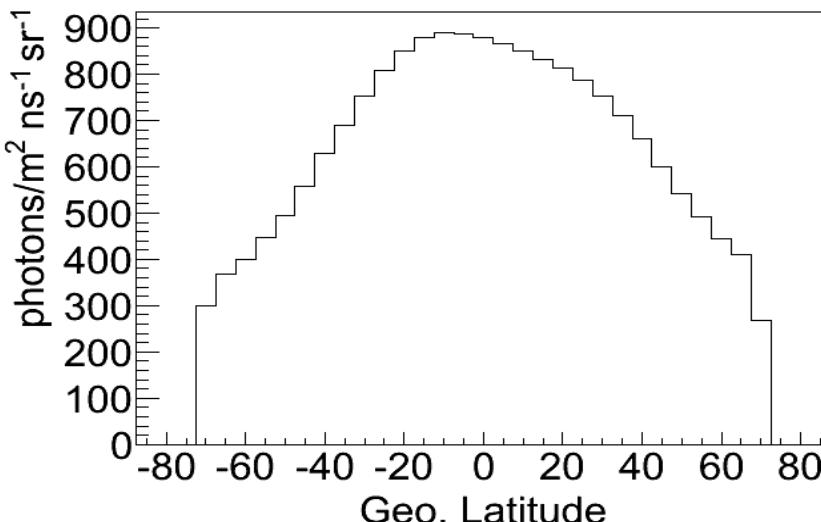


Maps of mean values of UV nightglow radiation in March for years 1971, 1981, 1991 (solar max., left) and years 1976, 1986, 1994 (solar min., right)

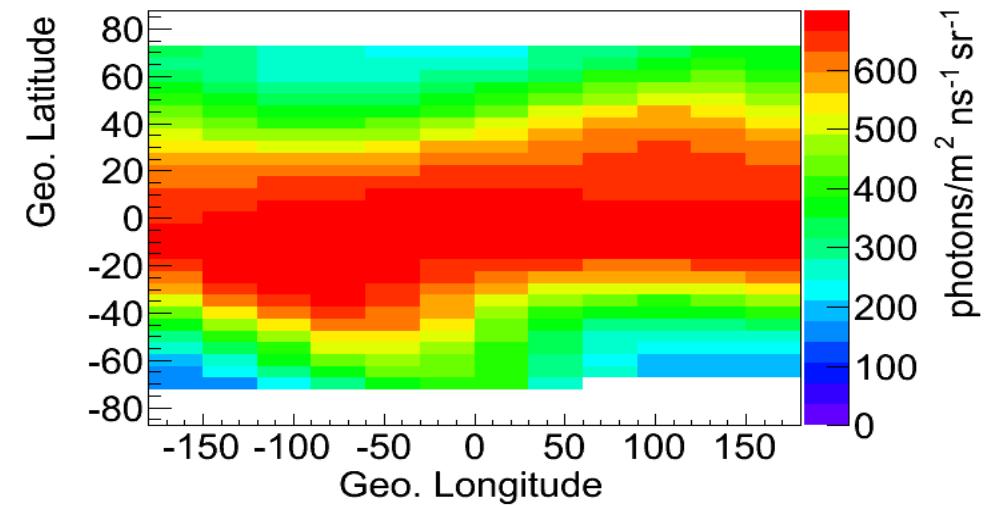
Map of mean values of UV nightglow radiation in March for 1971, 1981, 1991



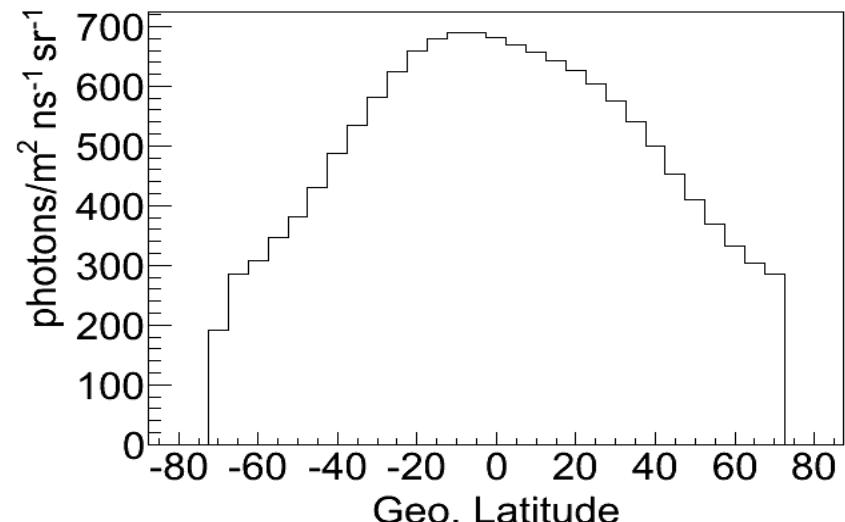
Latitudinal average projection



Map of mean values of UV nightglow radiation in March for 1976, 1986, 1994



Latitudinal average projection



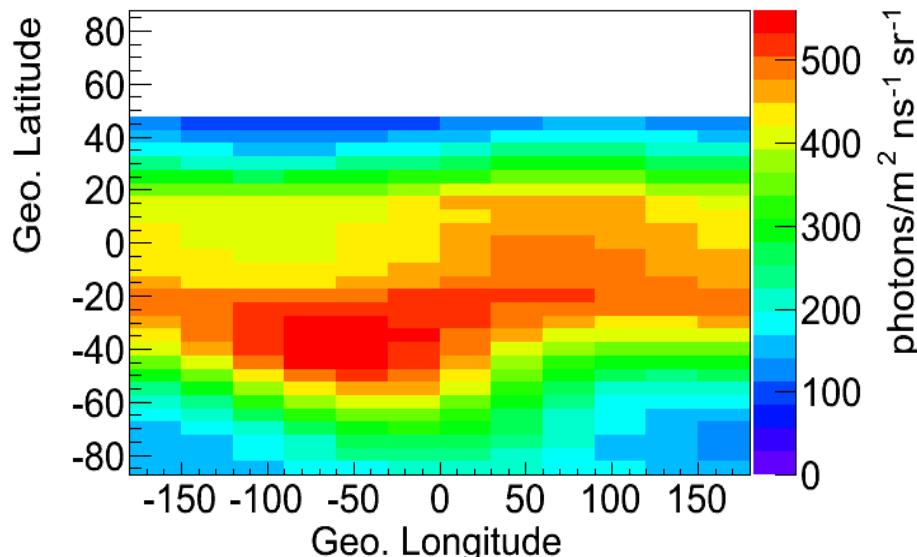
Difference of max. values with respect to the total average (all years 1970 - 1994): 66

for solar max. ~12%

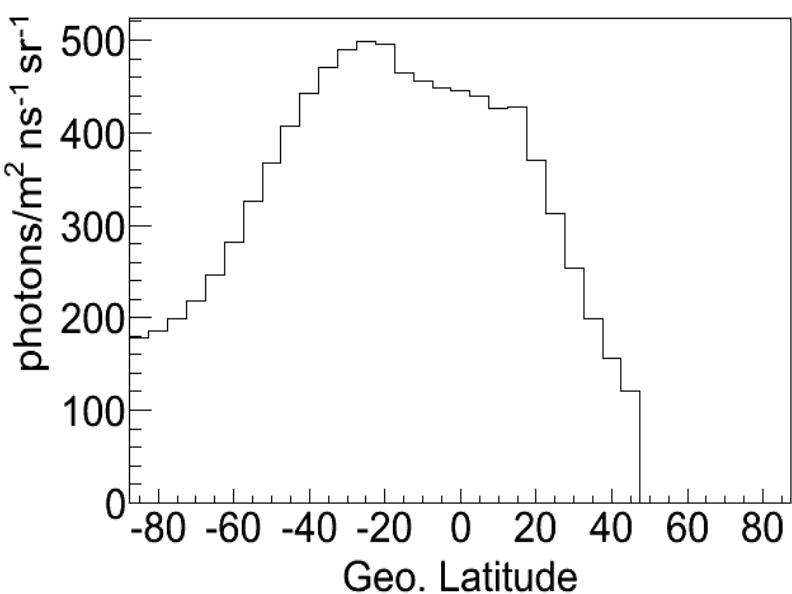
for solar min. ~12%

Map of mean values of UV nightglow radiation in June for period 1970 - 1994

Map of mean values of UV nightglow radiation in June for period 1970 - 1994

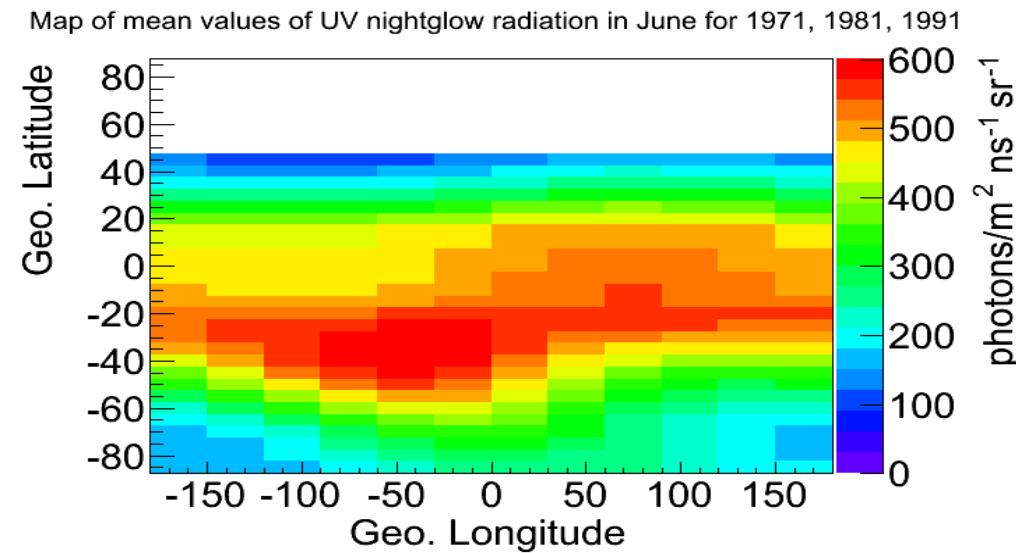


Latitudinal average projection

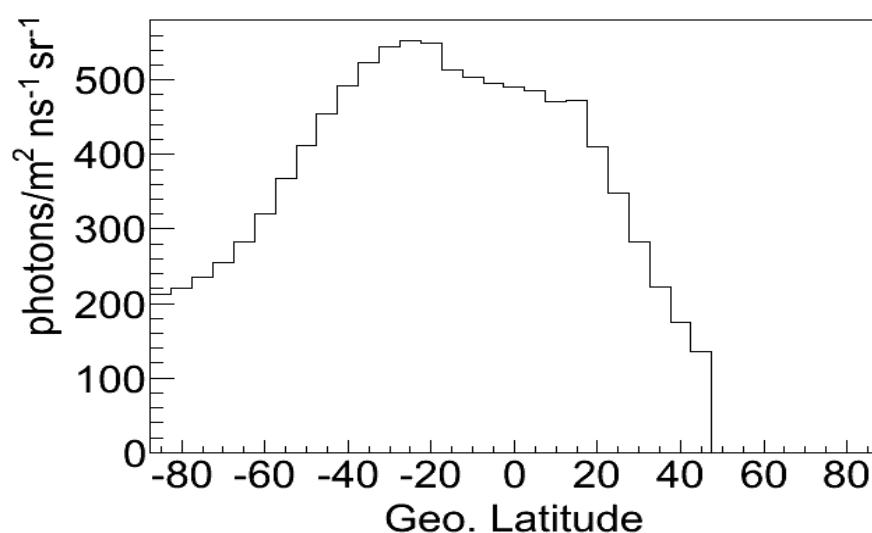


- Area of SAA is most dominant ($\sim 550 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$) but still it doesn't reach bigger average values than average values of places with different positions on previous figures.

Map of mean values of UV nightglow radiation in June for years 1971, 1981, 1991 (solar max., left) and years 1976, 1986, 1994 (solar min., right)

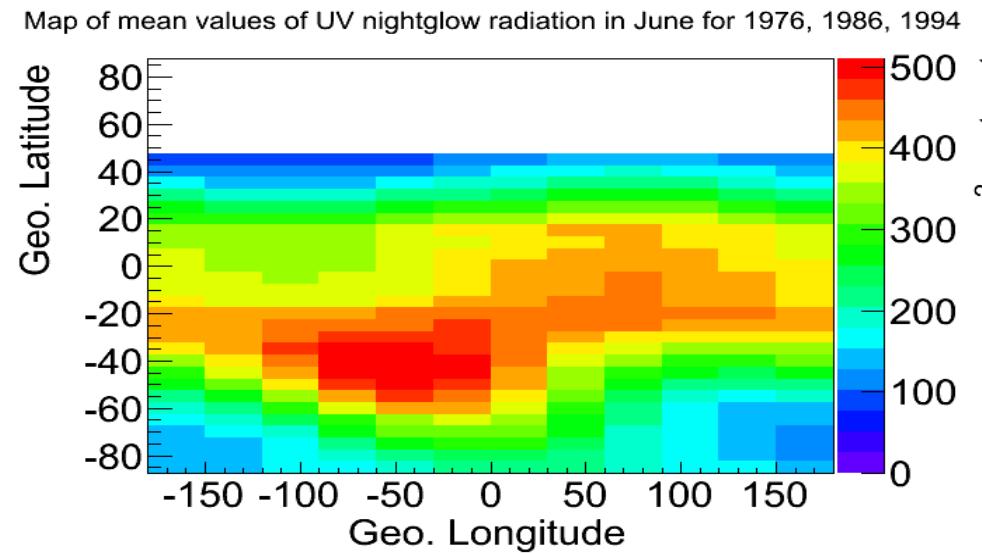


Latitudinal average projection

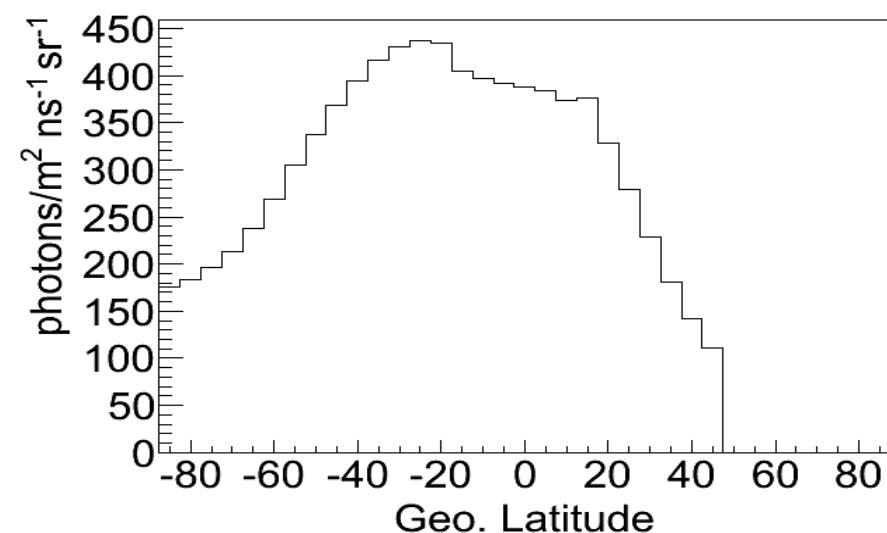


Difference of max. values with respect to the total average (all years 1970 - 1994): 68

for solar max. ~9%



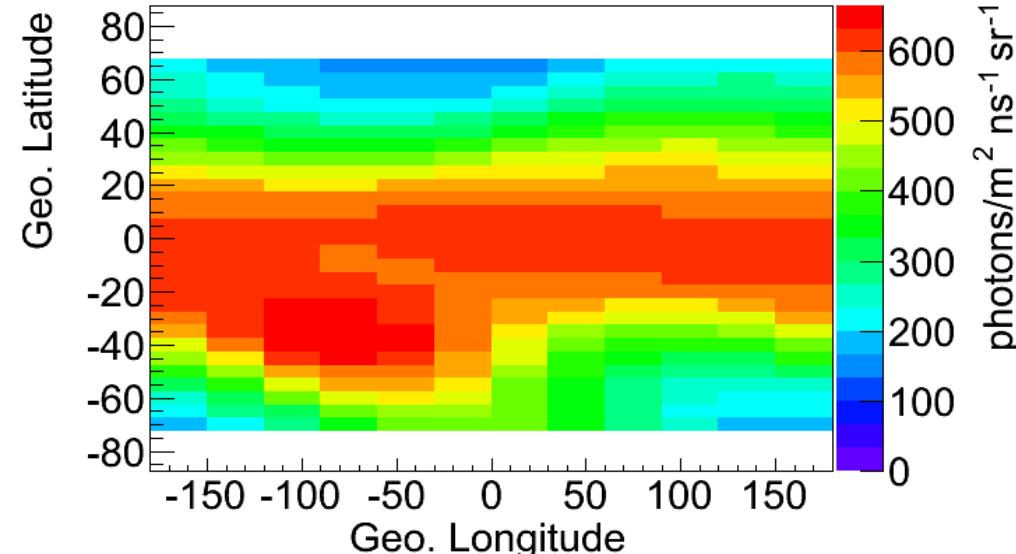
Latitudinal average projection



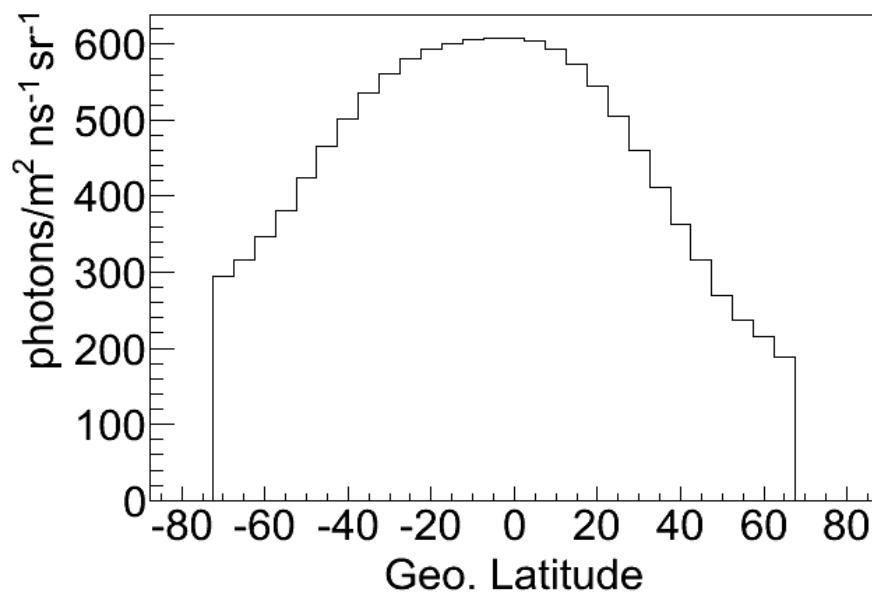
for solar min. ~10%

Map of mean values of UV nightglow radiation in September for period 1970 - 1994

Map of mean values of UV nightglow radiation in Sept. for periode 1970 - 1994



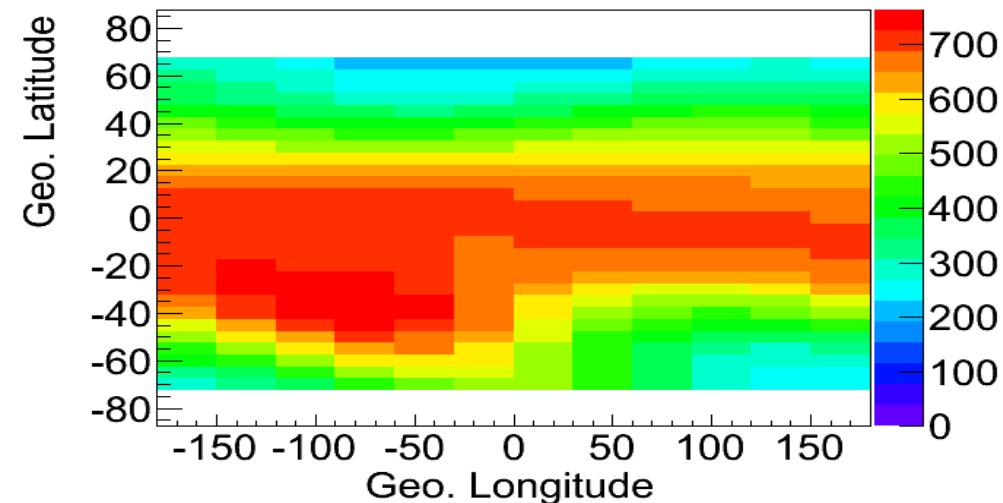
Latitudinal average projection



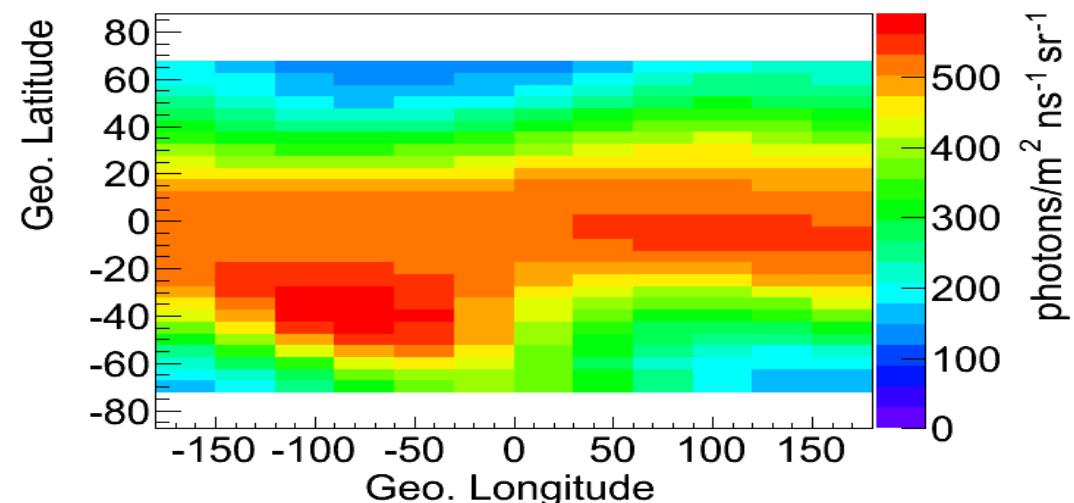
- Maximal values $\sim 650 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
- Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ in range ~ -30 to 30 deg. of geo. latitude + area with increased values of radiation from -20 to -50 deg. geographic latitude and from -90 to 0 deg. geographic longitude.

Maps of mean values of UV nightglow radiation in Sep. for years 1971, 1981, 1991 (solar max., left) and years 1976, 1986, 1994 (solar min., right)

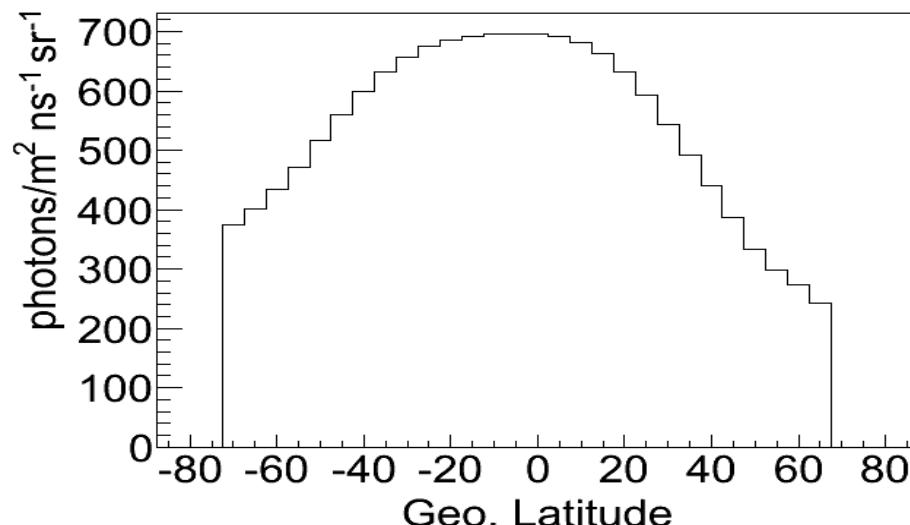
Map of mean values of UV nightglow radiation in Sep. for 1971, 1981, 1991



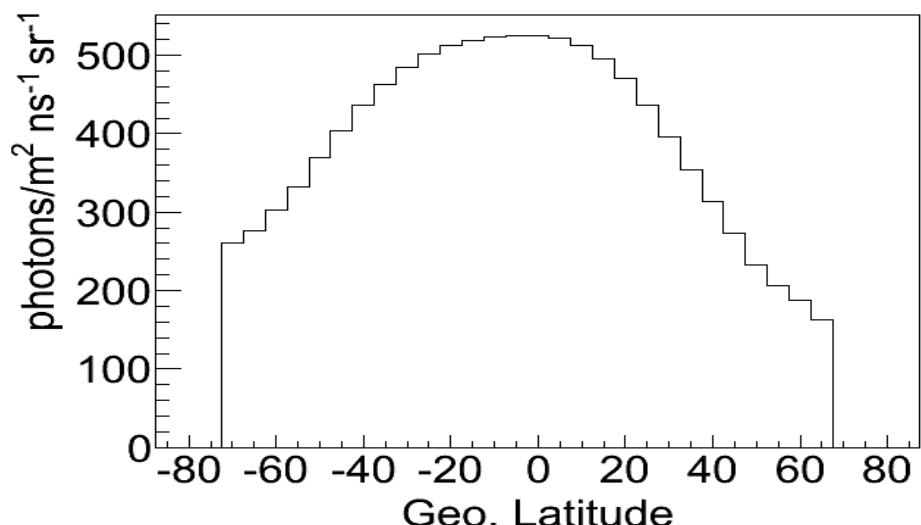
Map of mean values of UV nightglow radiation in Sep. for 1976, 1986, 1994



Latitudinal average projection



Latitudinal average projection



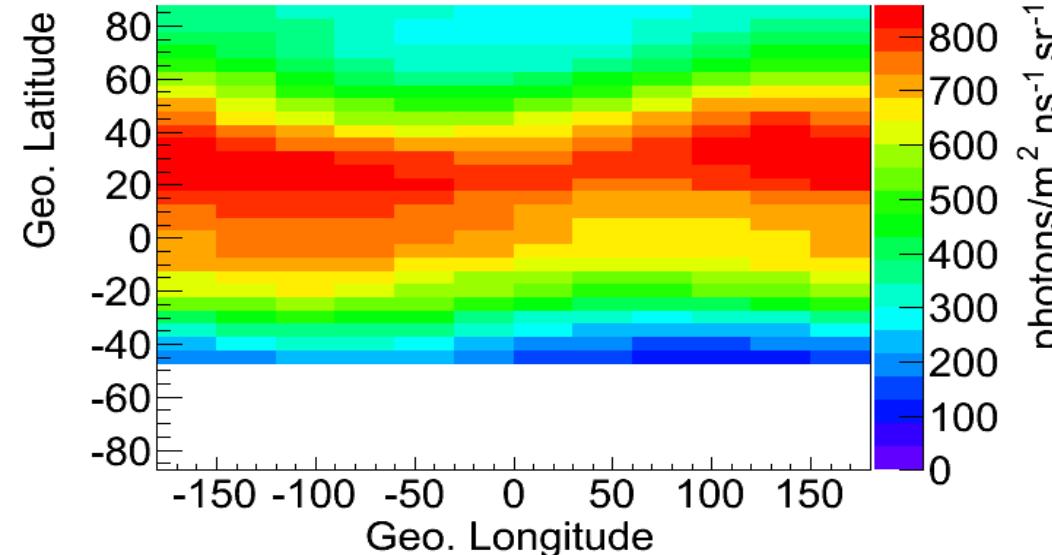
Difference of max. values with respect to the total average (all years 1970 - 1994): 70

for solar max. ~15%

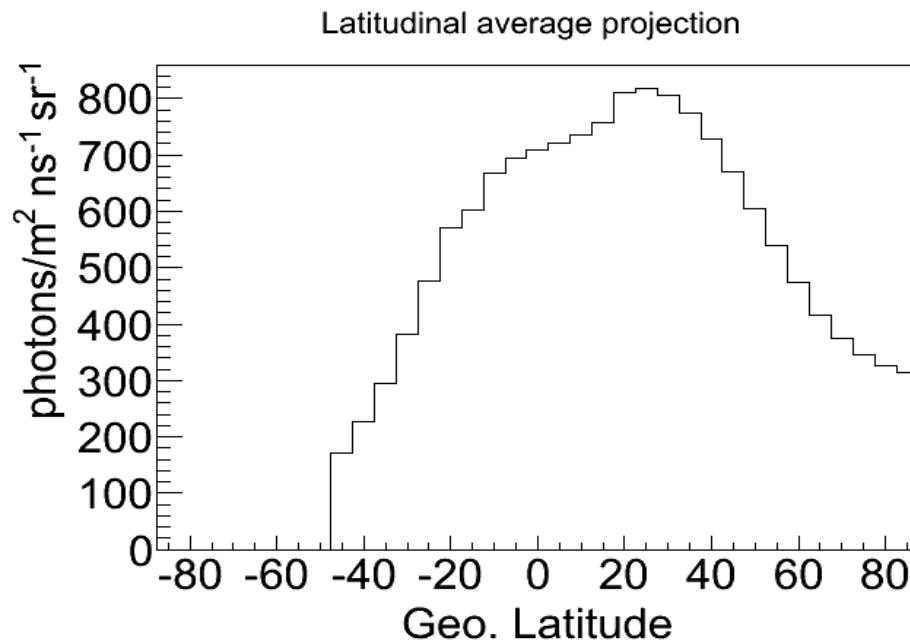
for solar min. ~11%

Map of mean values of UV nightglow radiation in December for period 1970 - 1994

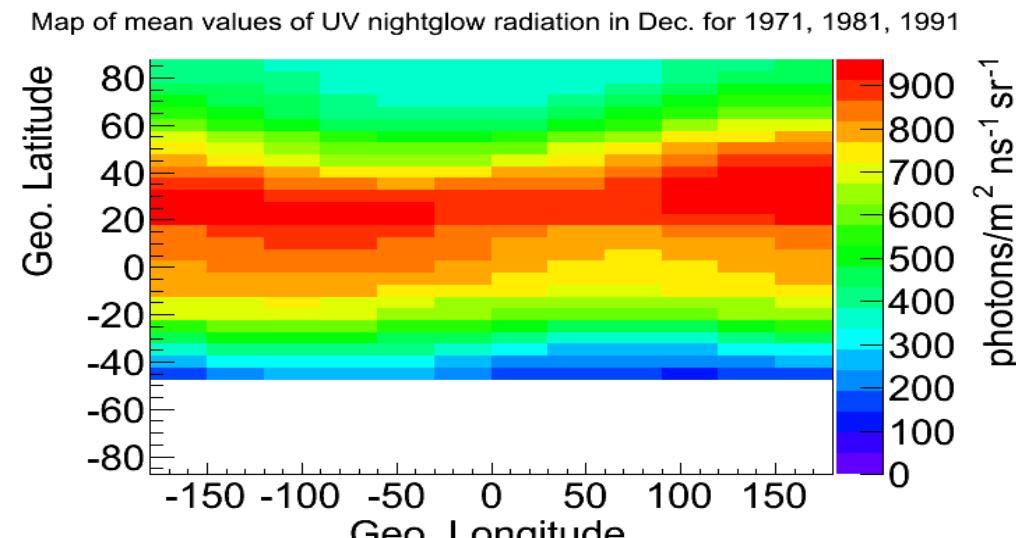
Map of mean values of UV nightglow radiation in Dec. for period 1970 - 1994



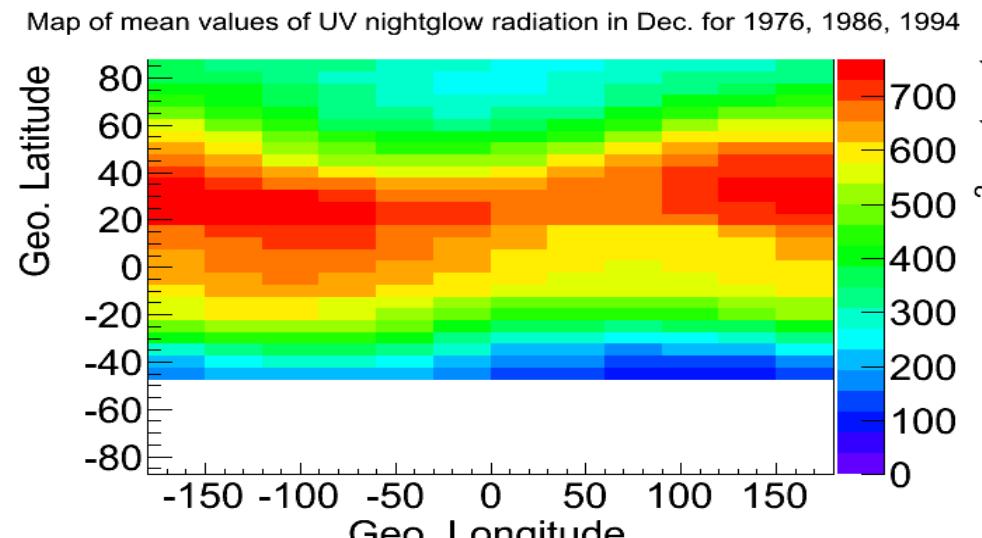
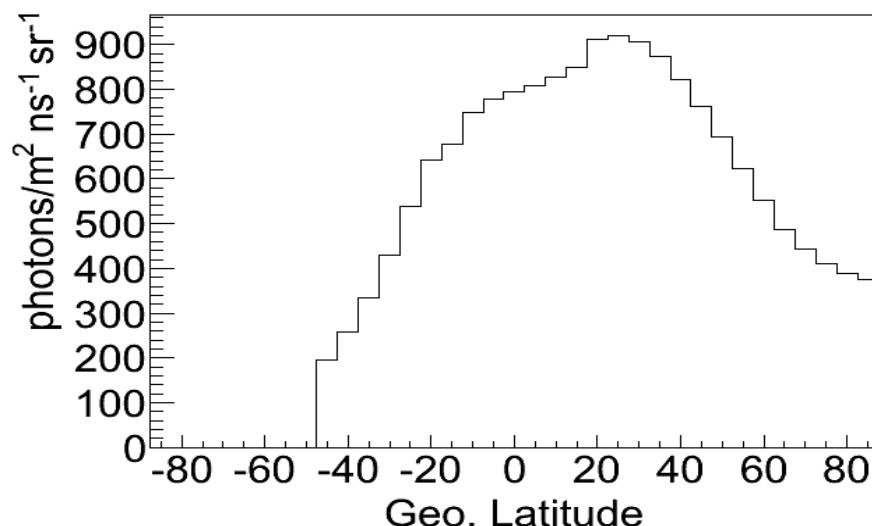
- Maximal values $\sim 850 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
- Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ in range ~ -30 to 60 deg. of geo. latitude.



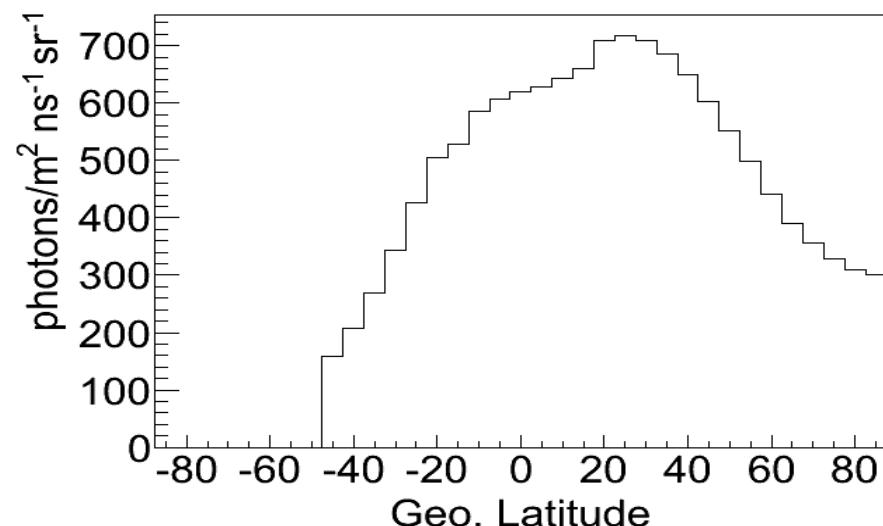
Maps of mean values of UV nightglow radiation in Dec. for years 1971, 1981, 1991 (solar max., left) and years 1976, 1986, 1994 (solar min., right)



Latitudinal average projection



Latitudinal average projection

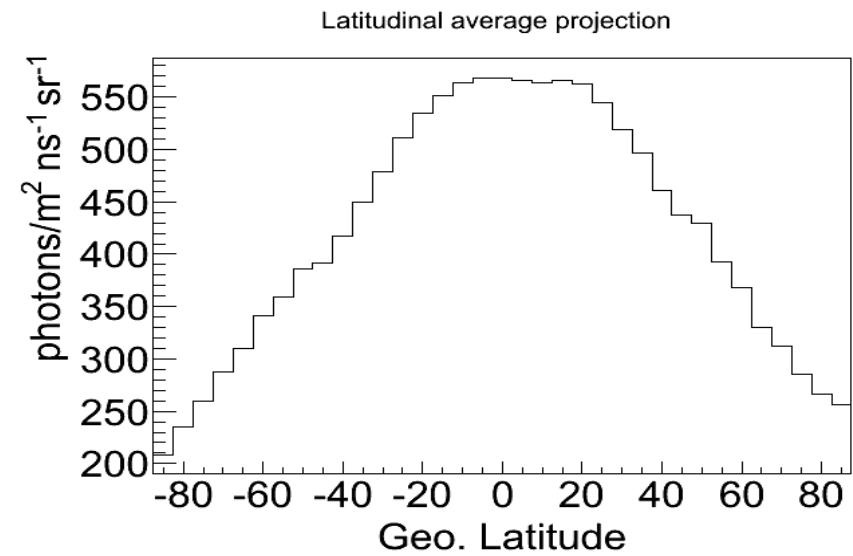
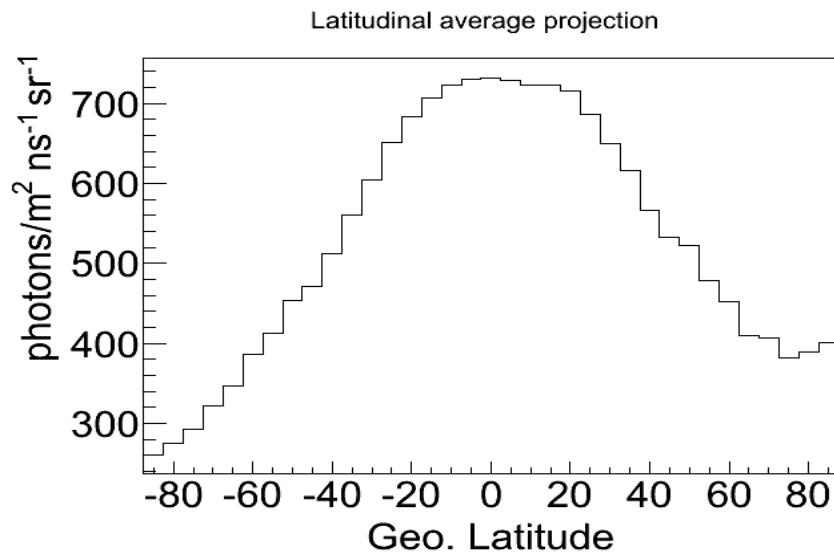
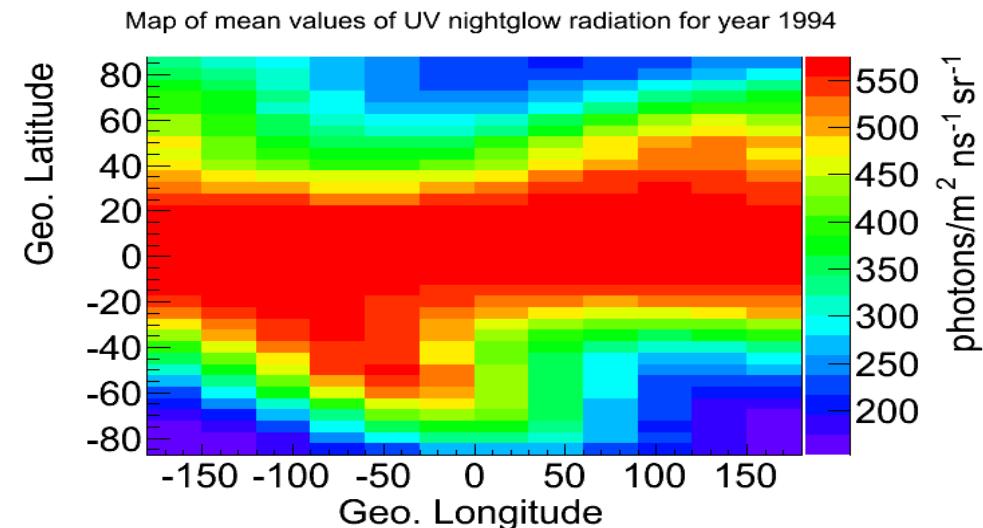
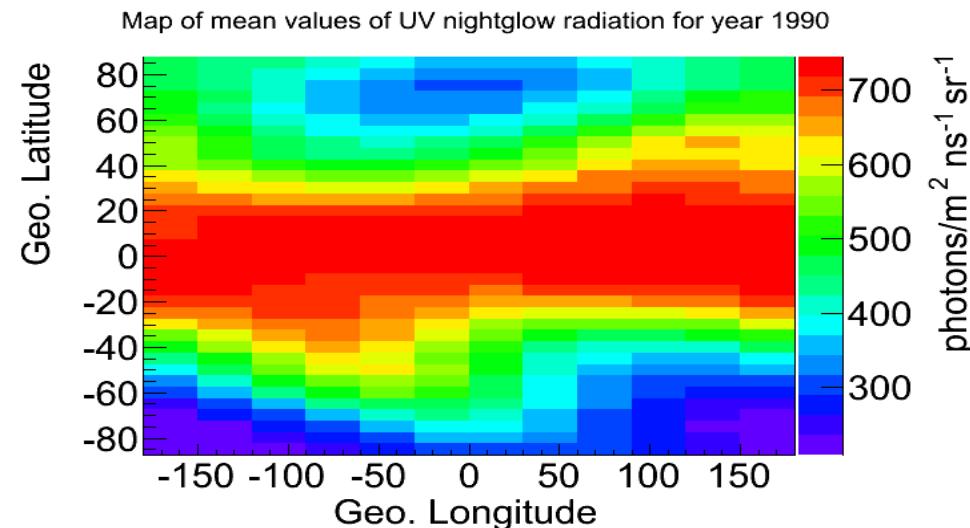


Difference of max. values with respect to the total average (all years 1970 - 1994): 72

for solar max. ~11%

for solar min. ~12%

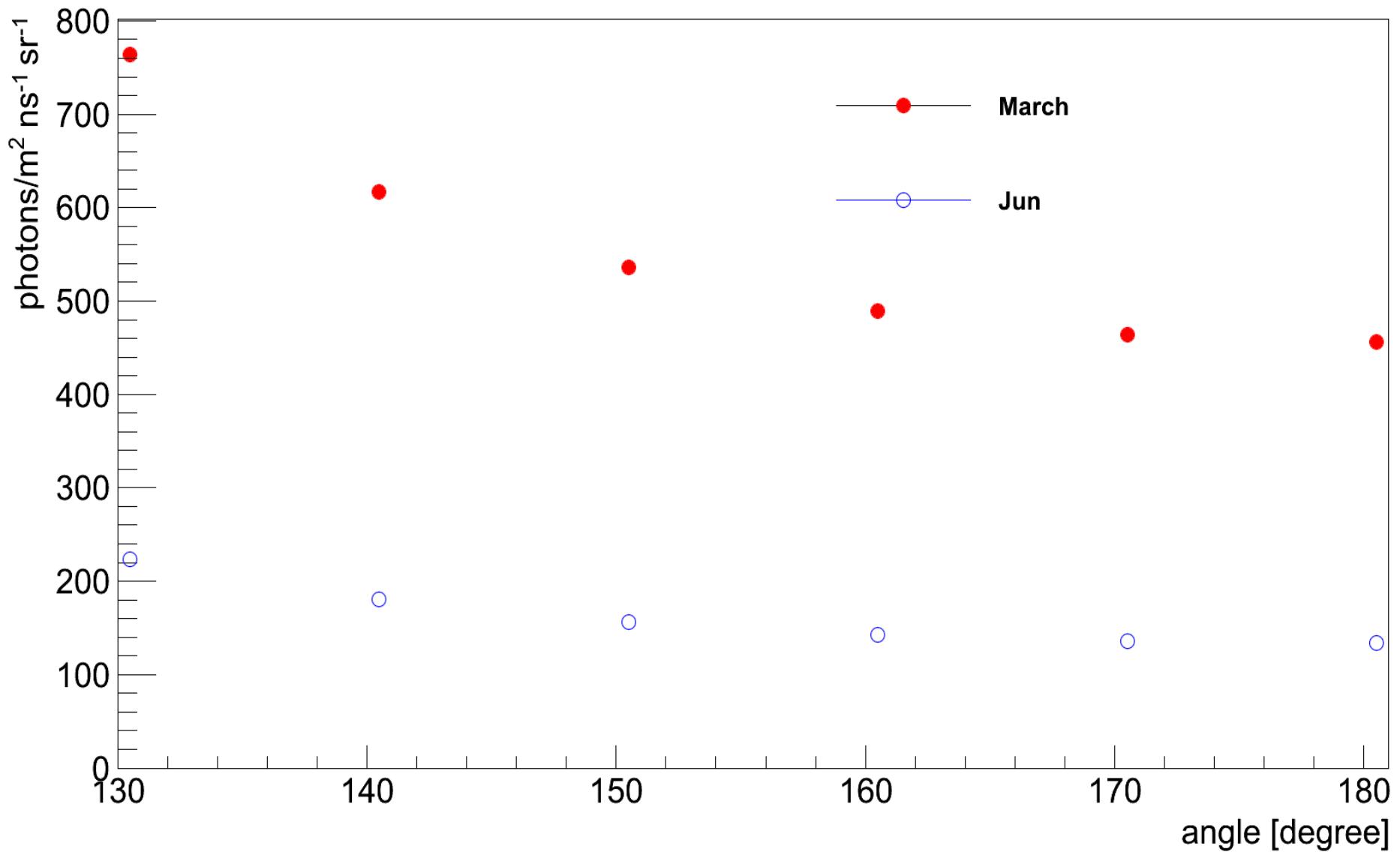
Maps of mean values of UV nightglow radiation for all months in 1990 (close to solar max.) and 1994 (close to solar min.)



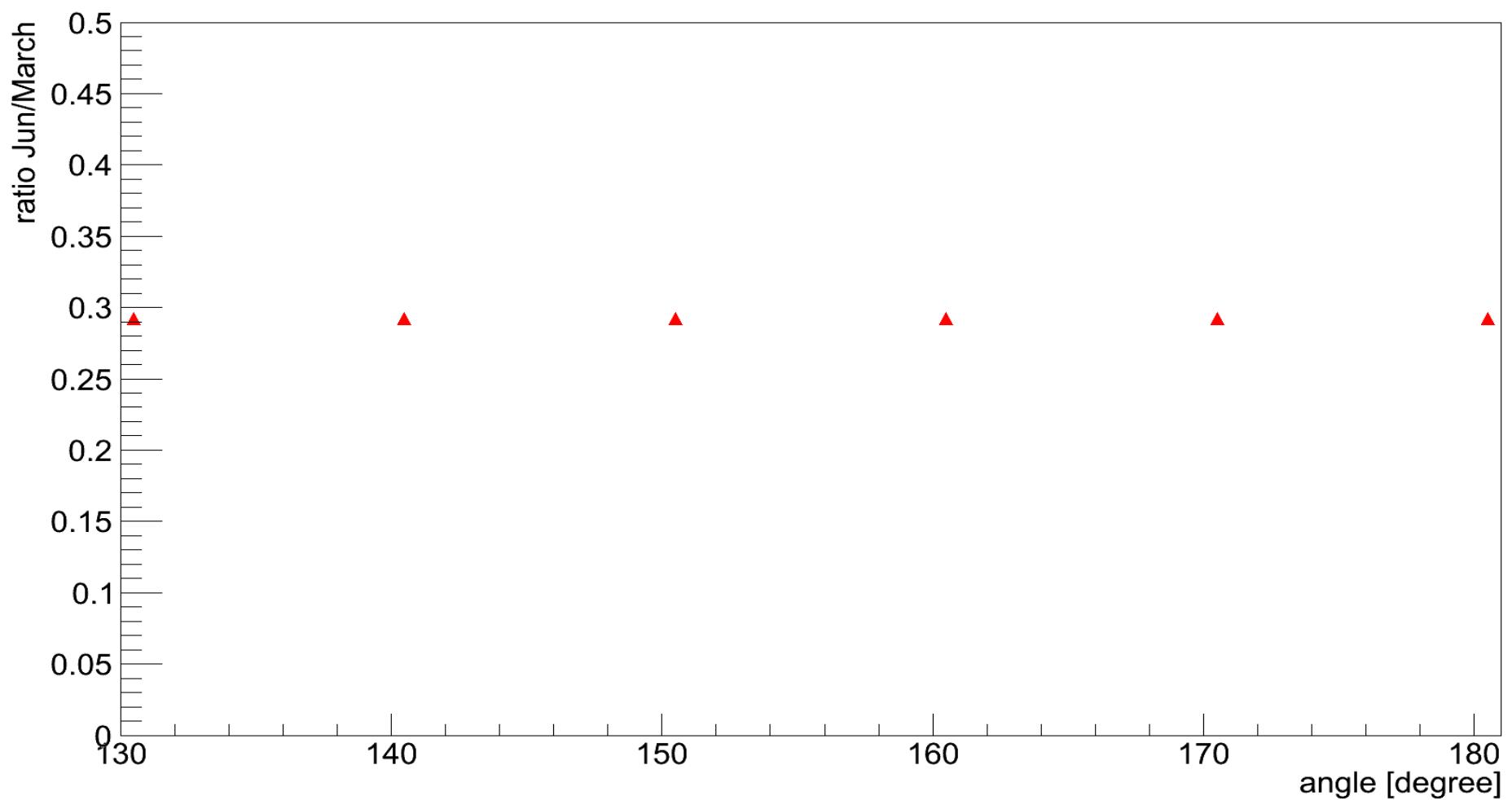
- There is no significant increase of radiation in SAA area for these two years with respect to other geopositions.

Looking angle dependence

UVBG for different looking angles, Year: 1994, time: 00:00, position: Lat 40, Long 20



- Ratio June/March – constant
- Some “simple function” scaling radiation from nadir looking angle.



Conclusion

- UV nightglow in AURIC is produced by Herzberg I, II and Chamberlain emission inside range 300 - 400 nm.
- UV nightglow depend on O, O₂, N₂ densities and on temperature.
- UV nightglow depend on:
 - local time – consequence of density and temperature change during the night,
 - season of year,
 - solar activity,
 - position on Earth.
- Values are in interval $\sim 100 - 1400 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$

- SAA - in some periods we can observe maximum of produced UV light in South Atlantic anomaly, generally this maximum not exceed usual maximal on the Earth surface.
- Maximal average values (March, June, Sep. Dec.) $\sim 630 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
 - Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ in range ~ -40 to 40 deg. of geo. latitude.
- March: max. $\sim 800 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
 - Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ in range -50 to 50 deg. of geo. latitude.
- June: max. $\sim 550 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
 - Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ SAA area.
- September: max. $\sim 650 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
 - Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ in range -30 to 30 deg. of geo. latitude and SAA area.
- December: max $\sim 850 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$
 - Radiation $> 500 \text{ ph/m}^2 \text{ ns}^{-1} \text{ sr}^{-1}$ in range -30 to 60 deg. of geo. Latitude.
- Difference of max. average values for solar max. and min. is $\sim 10\%$ with respect to the total average.
- Dependence on looking angle in AURIC: Some “simple function” scaling radiation from nadir looking angle. There is no special simulation procedure for this.