"Atmospheric Characterization of Sites"

Prof. Sergio Ortolani
Dipartimento di fisica e astronomia Galileo Galilei
Università di Padova

The evolution of the astronomical sites selection and characterization

Walker (1984) introduced the main parameters and standard site evaluation criteria (for example for the seeing, the “Walker telescope”).

He fixed the criteria for clear/mixed nights

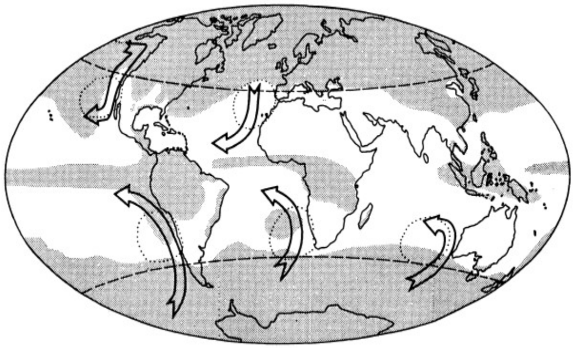


Figure 1. World map showing areas with more than two octas cloud cover at least 50% of the time annually (shaded), cold ocean currents (arrows), and approximate boundaries of the regions of maritime, tropical, stable air (dotted curves). Latitudes 40°N and S are indicated by dashed lines.

Recent evolution of the criteria and their relative weights: cloud coverage, atmospheric optical turbulence, **precipitable water vapour**, sky brightness, sky coverage, aerosols (dust), wind and humidity, ozone layer thickness, **contrails**...

Up to 20 parameters considered for the ELT site selection (2011-2013).

Very long investigations: the study for the LEST site (JOSO) took more than **one decade** .

Cerenkov light detectors (for example CTA) require “unusual” site conditions if compared to standard astronomical observatories.

Cerenkov light detection (CTA) site requirements

-Optical turbulence ? **Irrelevant**

-Sky background ? **Relatively high threshold**...

-Altitude ? **A complicate issue**...

-Clear sky (photometric ? Not really, non photometric conditions are acceptable)

-Contrails ? Irrelevant ?

-Temperature gradients ? Not very important (only for the structure)

-Sky coverage: yes

-Aerosols (dust): yes …

-Technical parameters: wind, earthquakes, (temperatures)

There is some overlap with standard astronomical sites, but there are also some relevant differences

Very tight schedule !

Site selection

Pre-selection of the sites: usually on the base of wide scale investigations (Sarazin, 2002), mainly based on satellite archives (TOMS, GOES, METEOSAT, MODIS...).

CTA: candidates based on proposals from countries/institutions

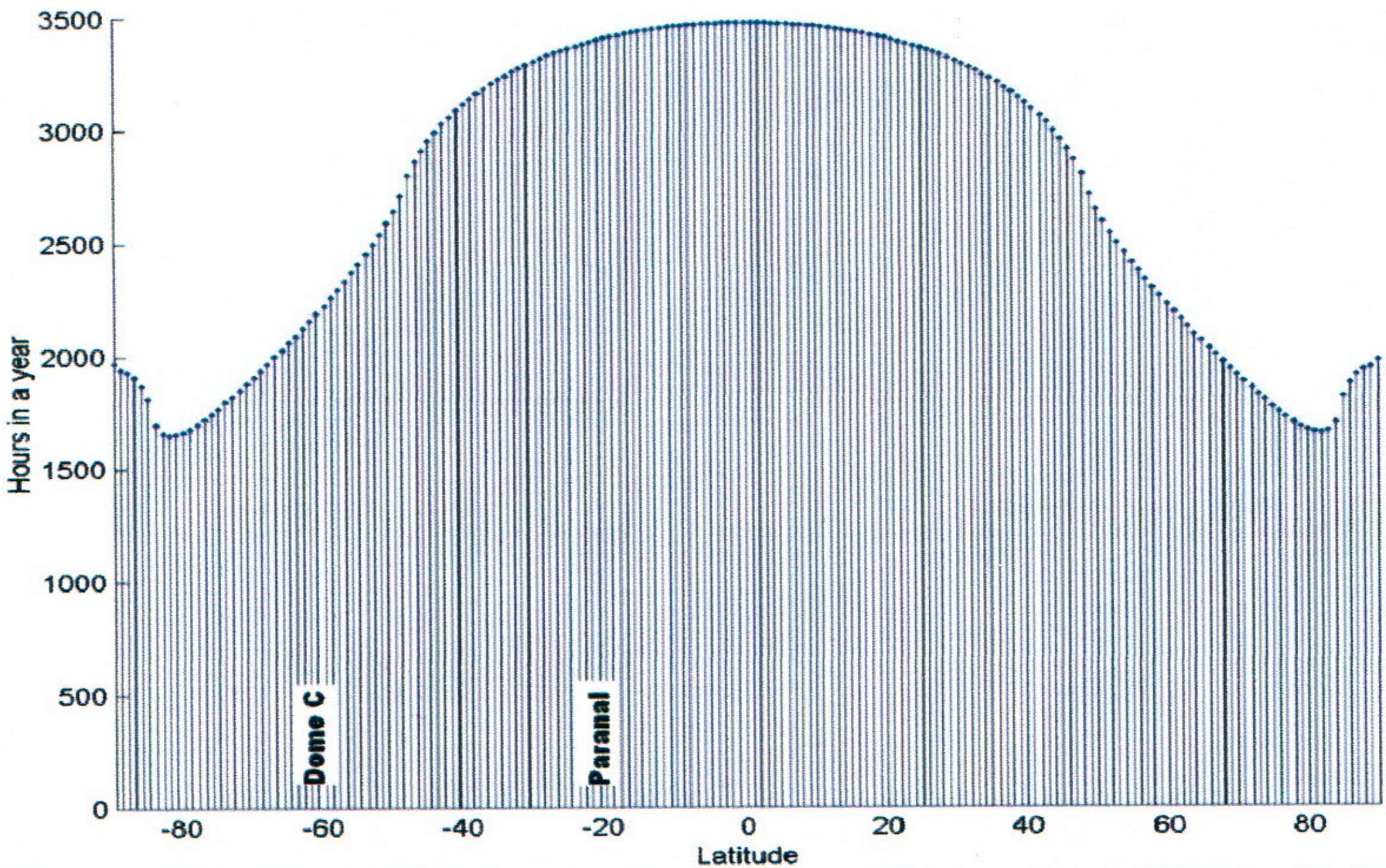
Analysis and detailed selection: standard meteorological instrumentation on site, **plus night sky coverage detectors, night sky brightness photometers, dust detectors.**

Current meteorological archives and models can support the analysis, but in principle they are not suitable for astronomy because they have different goals and targets

Number of potential dark hours (Sun at h=-18) per year as a function of the latitude (disregarding Moon light and clouds):

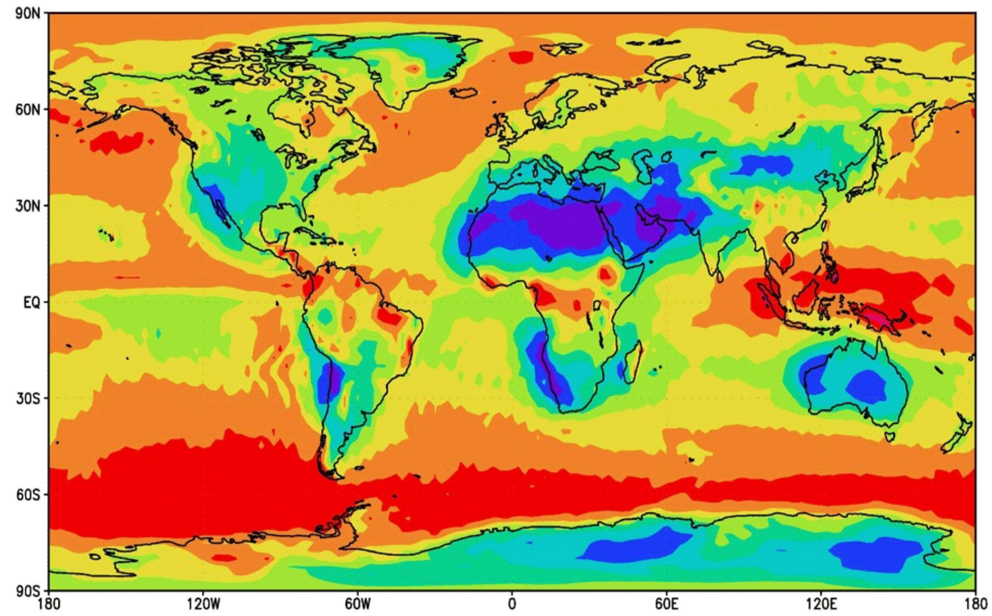
maximum 3400 (equator), minimum 1700 (l=84.5)

(Sadibekova, 2005, PHD thesis)

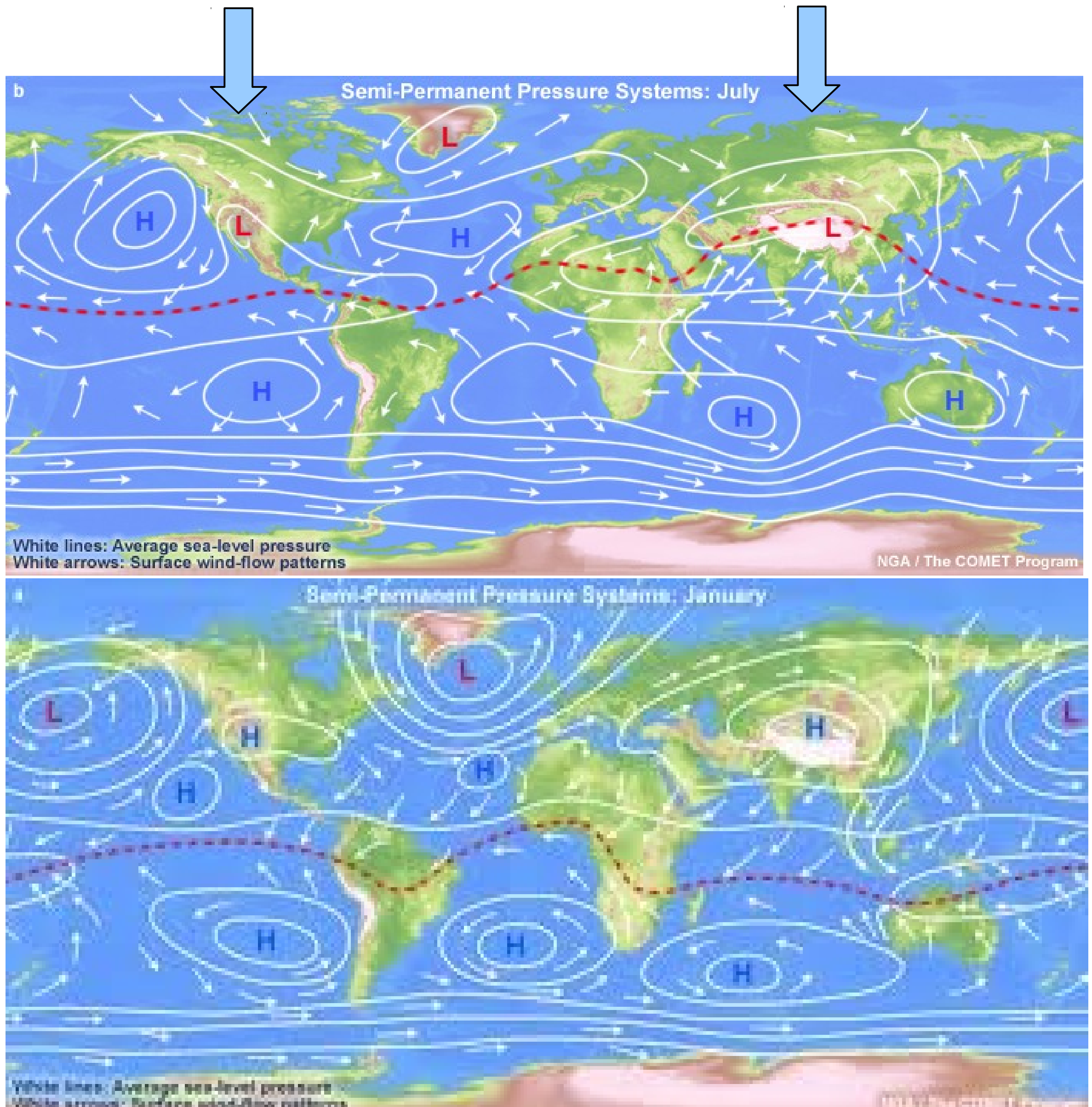


ELT early investigation Sarazin, 2008,

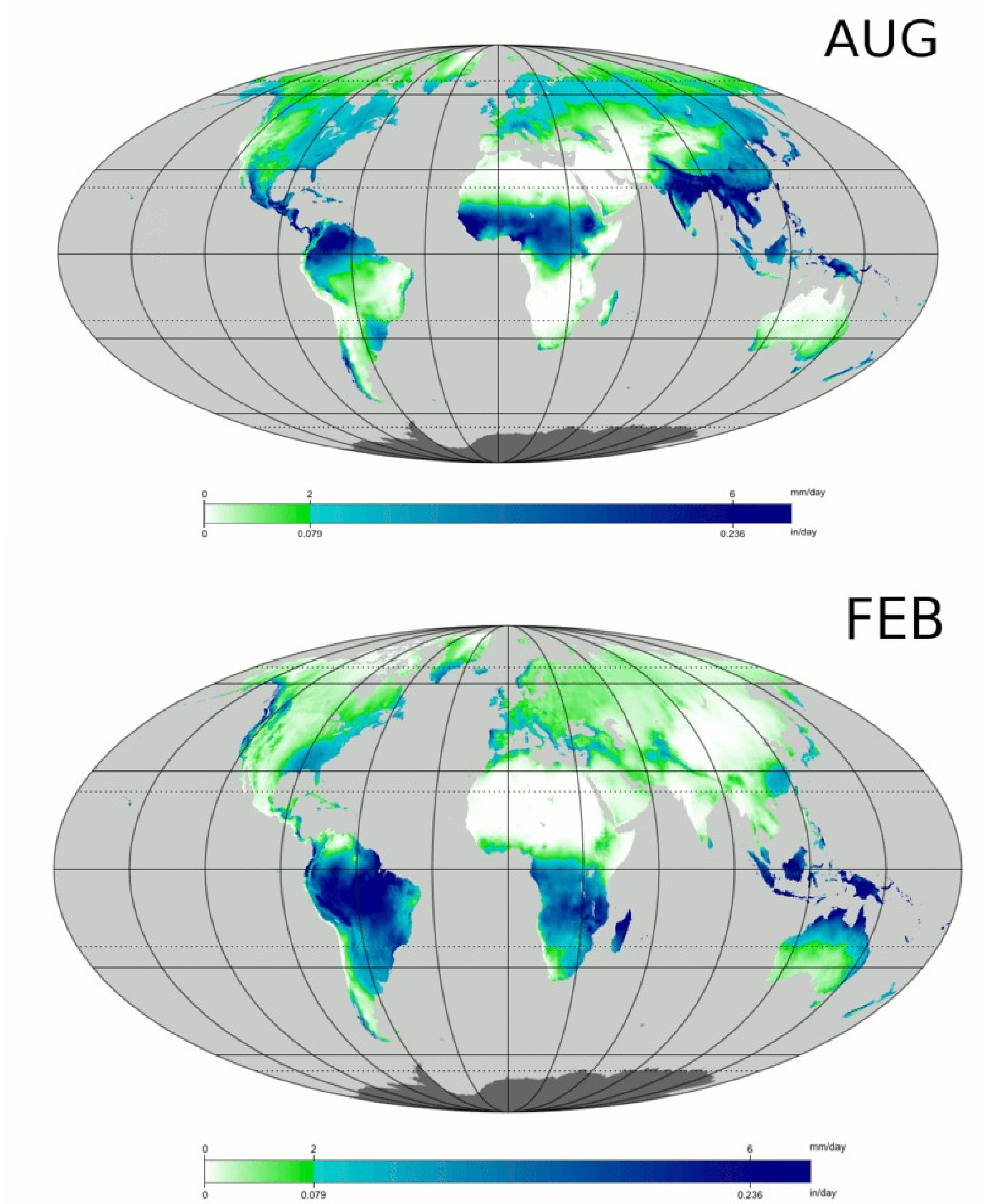
Cloud coverage



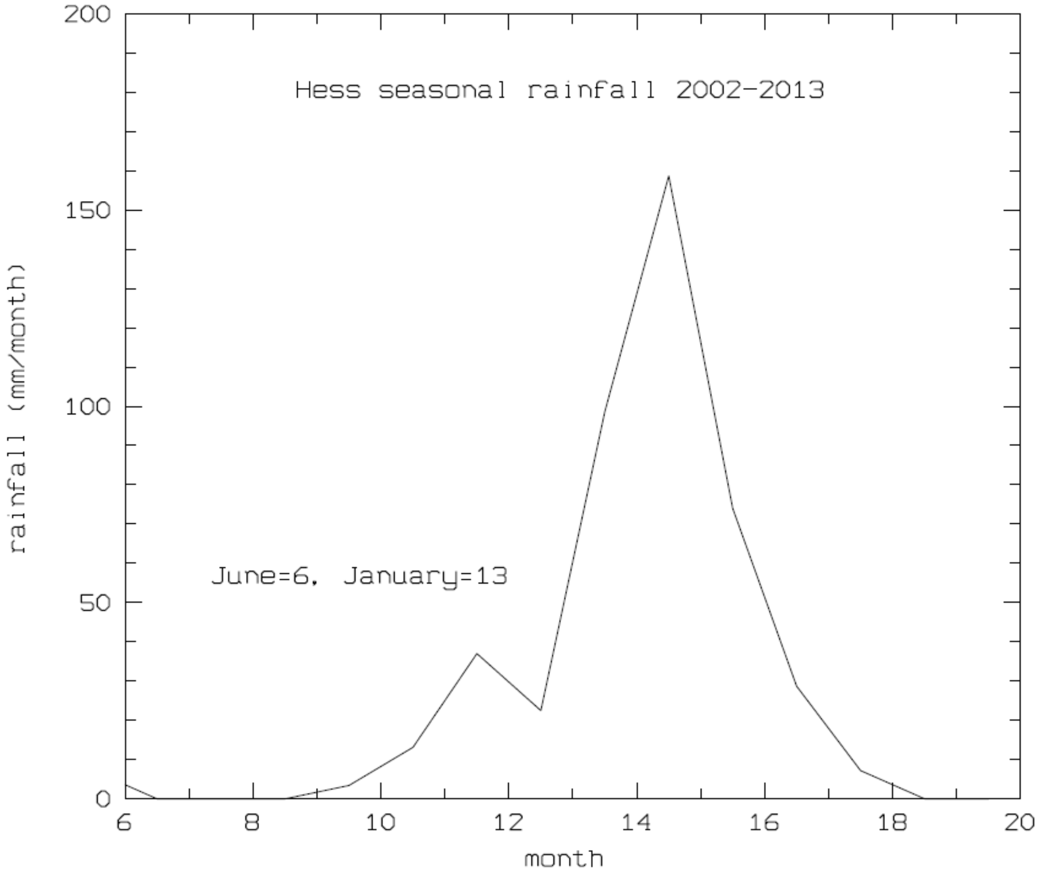
Sea level seasonal pressure: subtropical sites
The monsoon rainfall

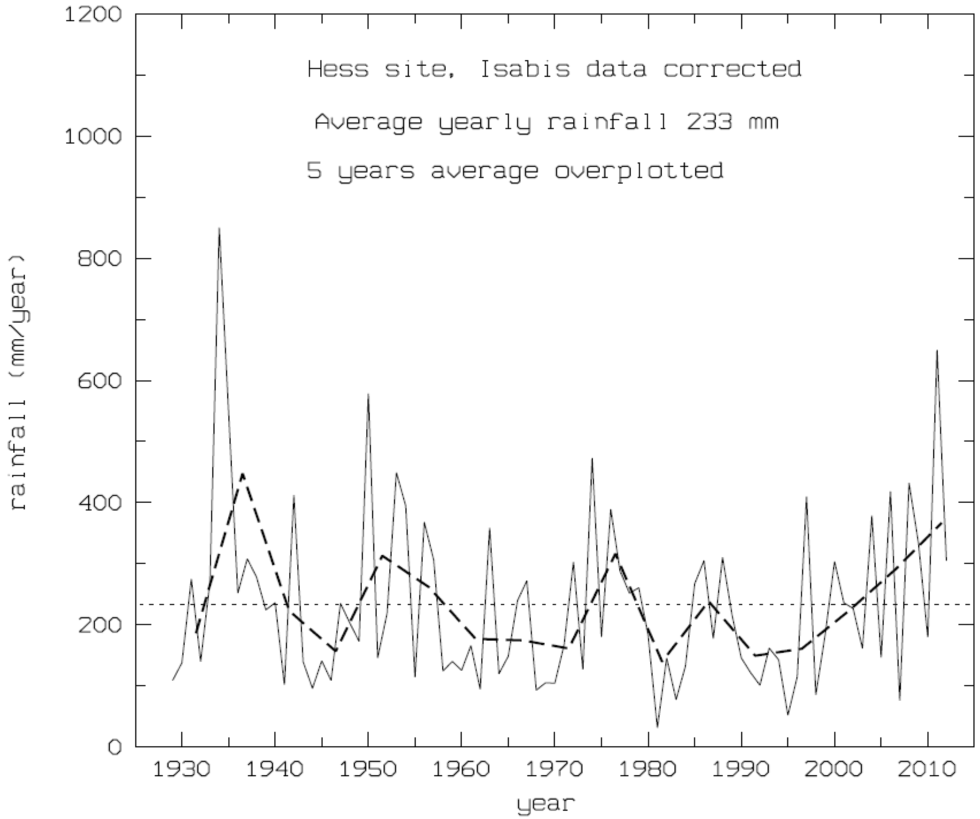


Seasonal (summer) rainfall: the shift of the equatorial rain



Rainfall as a cloud proxy: Namibia, Hess-Isabis site: seasonal effects, local variations

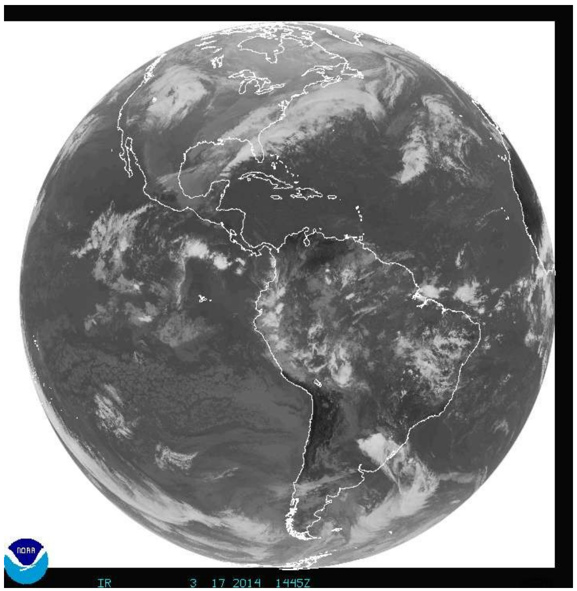




The use of satellites: polar or geostationary

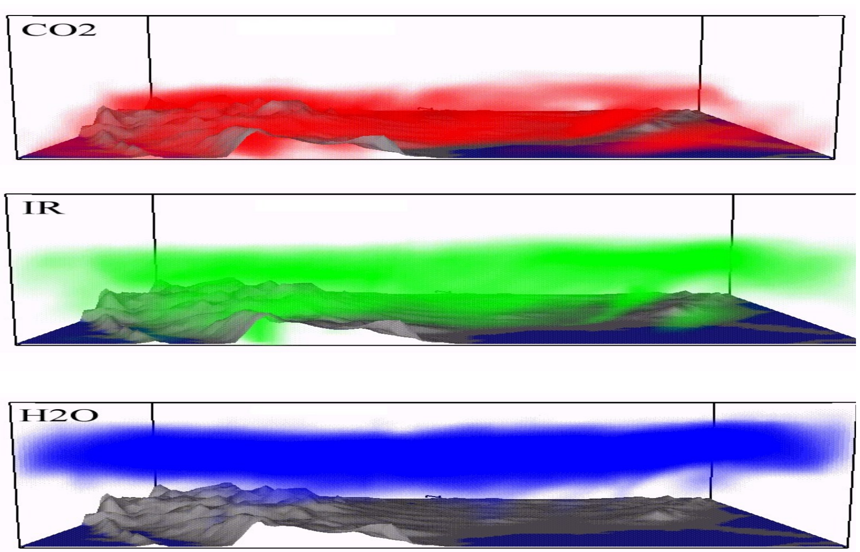
Example GOES (Cavazzani, 2014, PHD thesis)

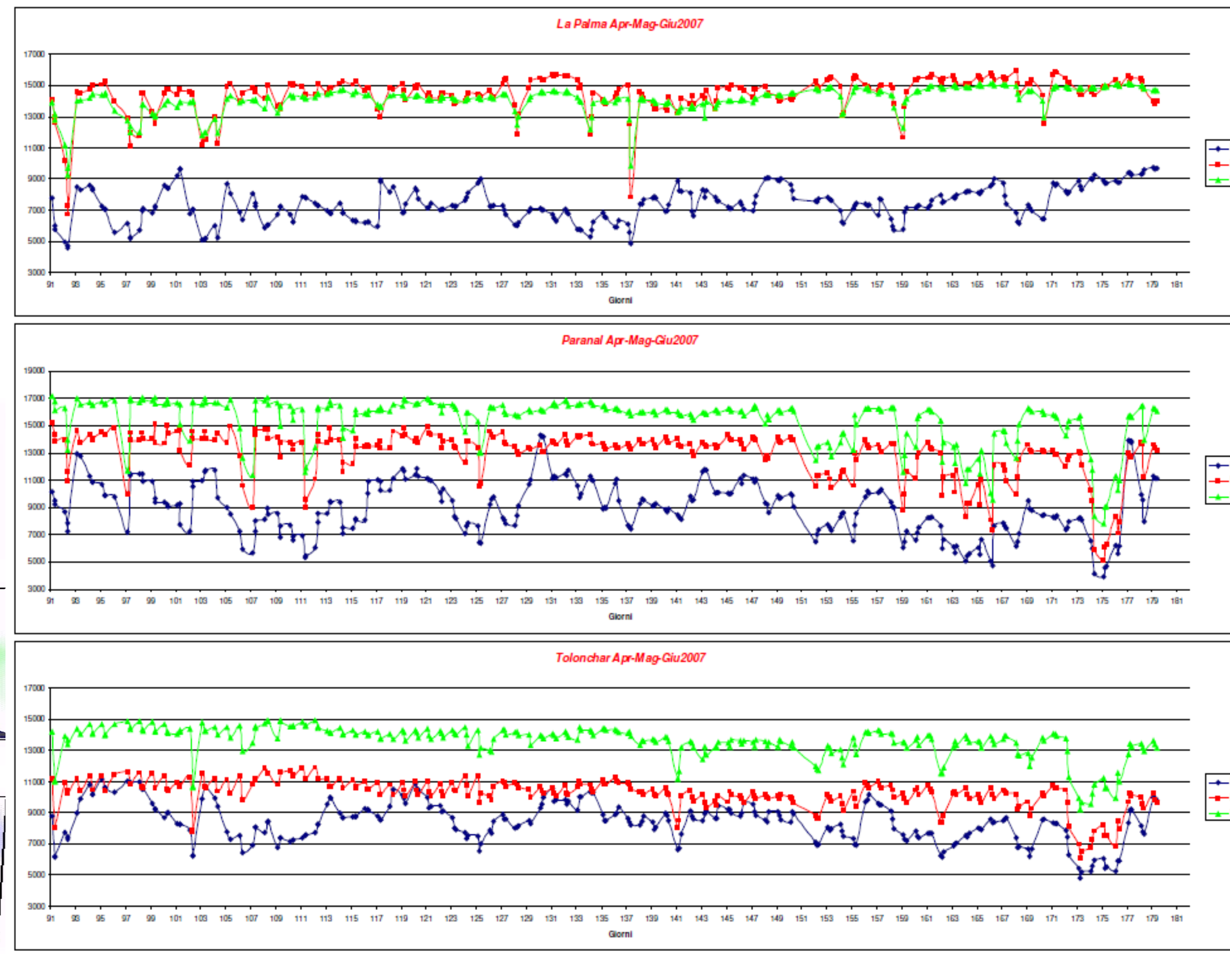
B3, B4 and B6 bands (6.7, 10.7 and 13.3 µm; h=8000, 4000, 3000m)

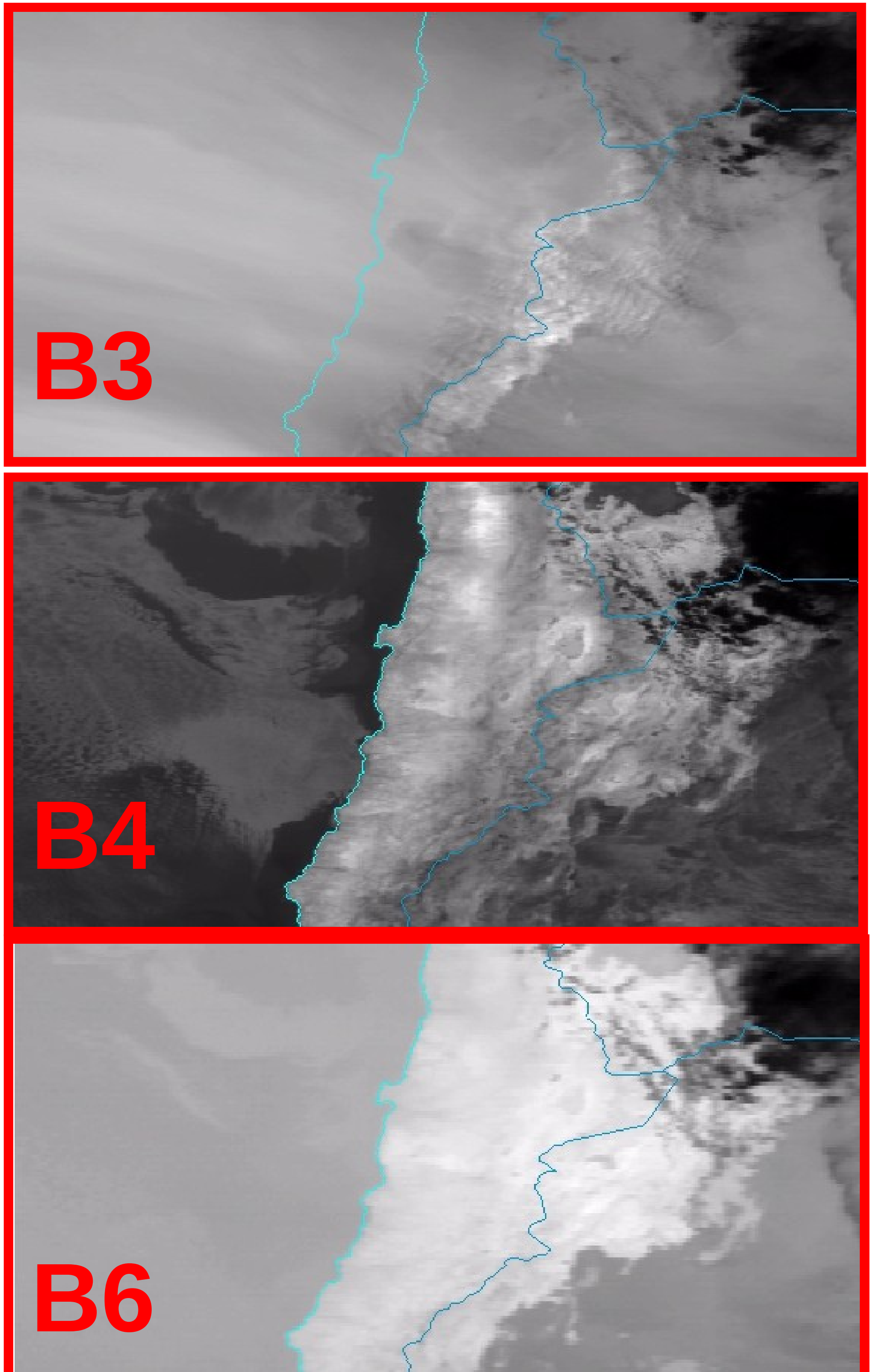


Are some data “wrong” ?

Does it make “mistakes” ?

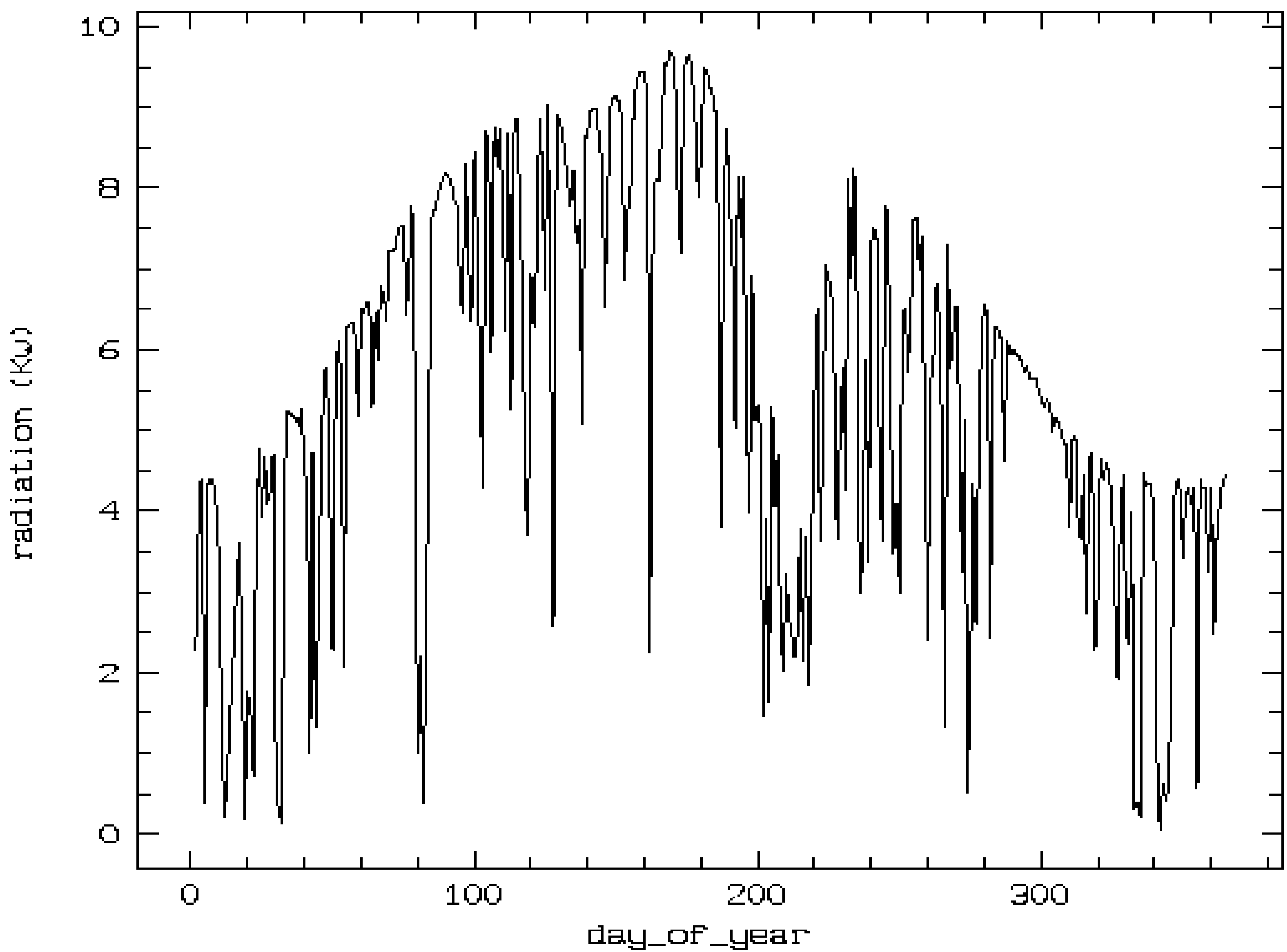




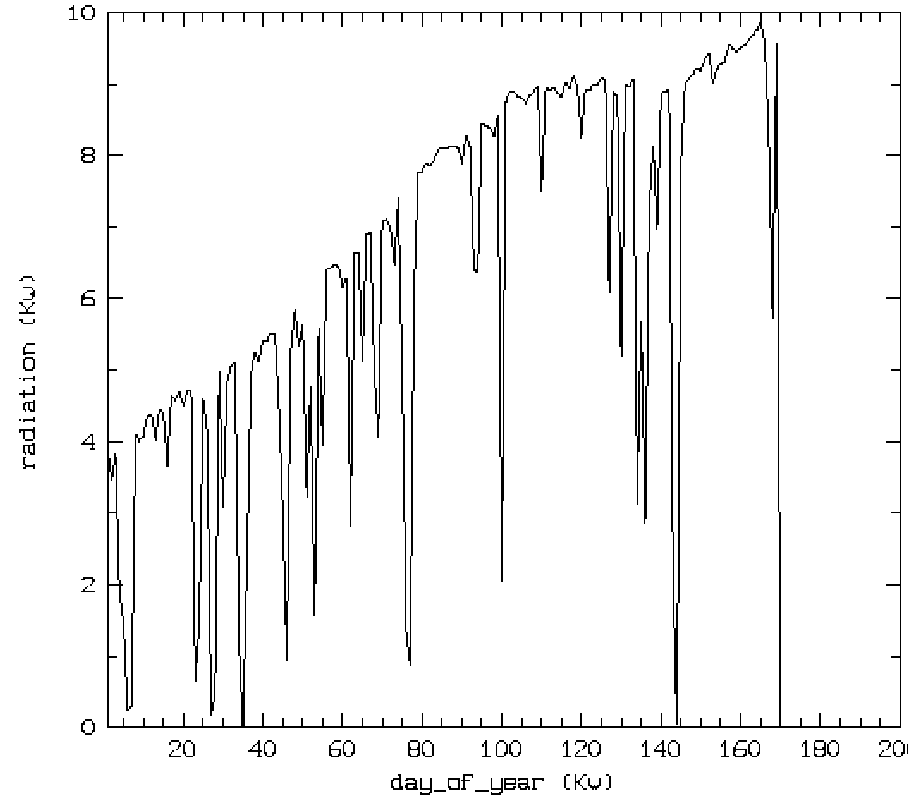


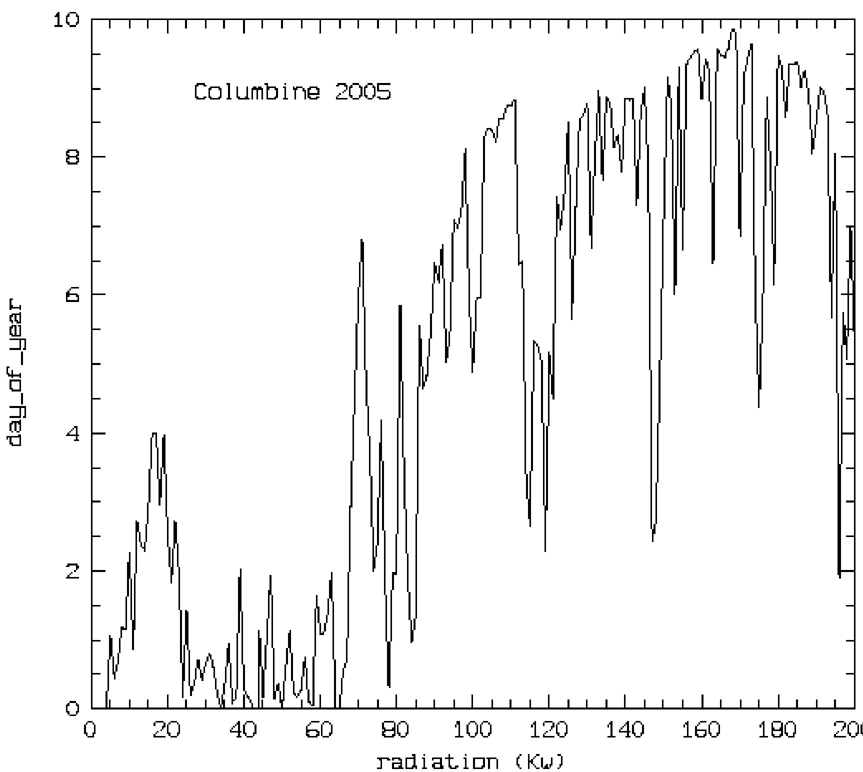
Bands of GOES12

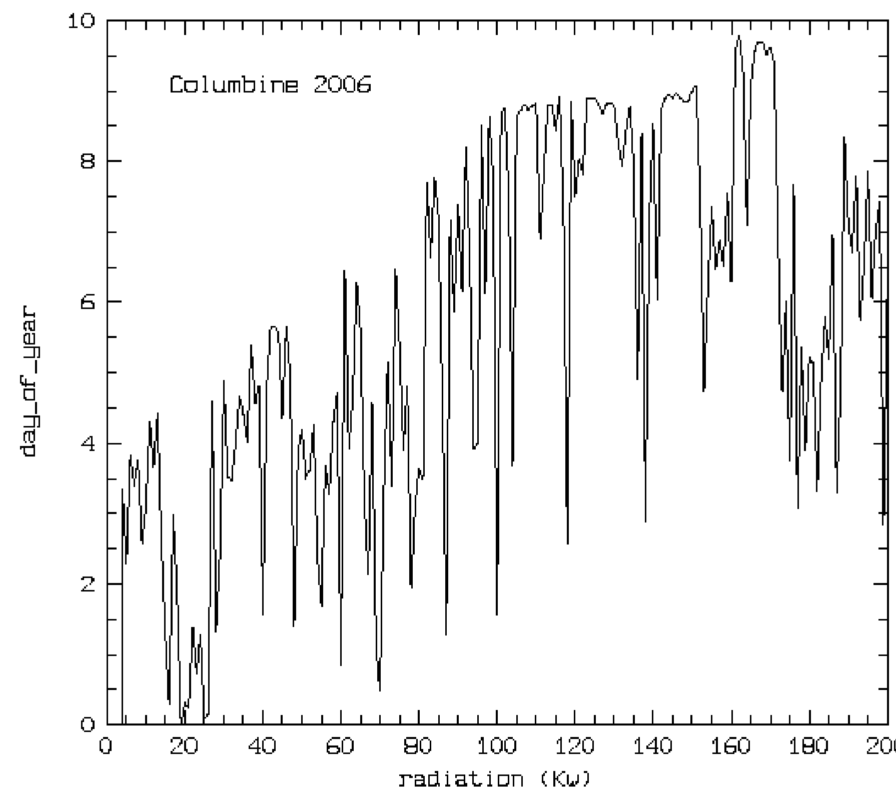
An alternative, very simple approach: Mt. Graham, Sun radiation year distribution, winter storms and summer monsoon (Culombine data, 2008)



Mt Graham: year to year changes, 2008 is the best







A check of the Sun radiation and rainfall at Mt. Graham (della Valle et al., 2009)

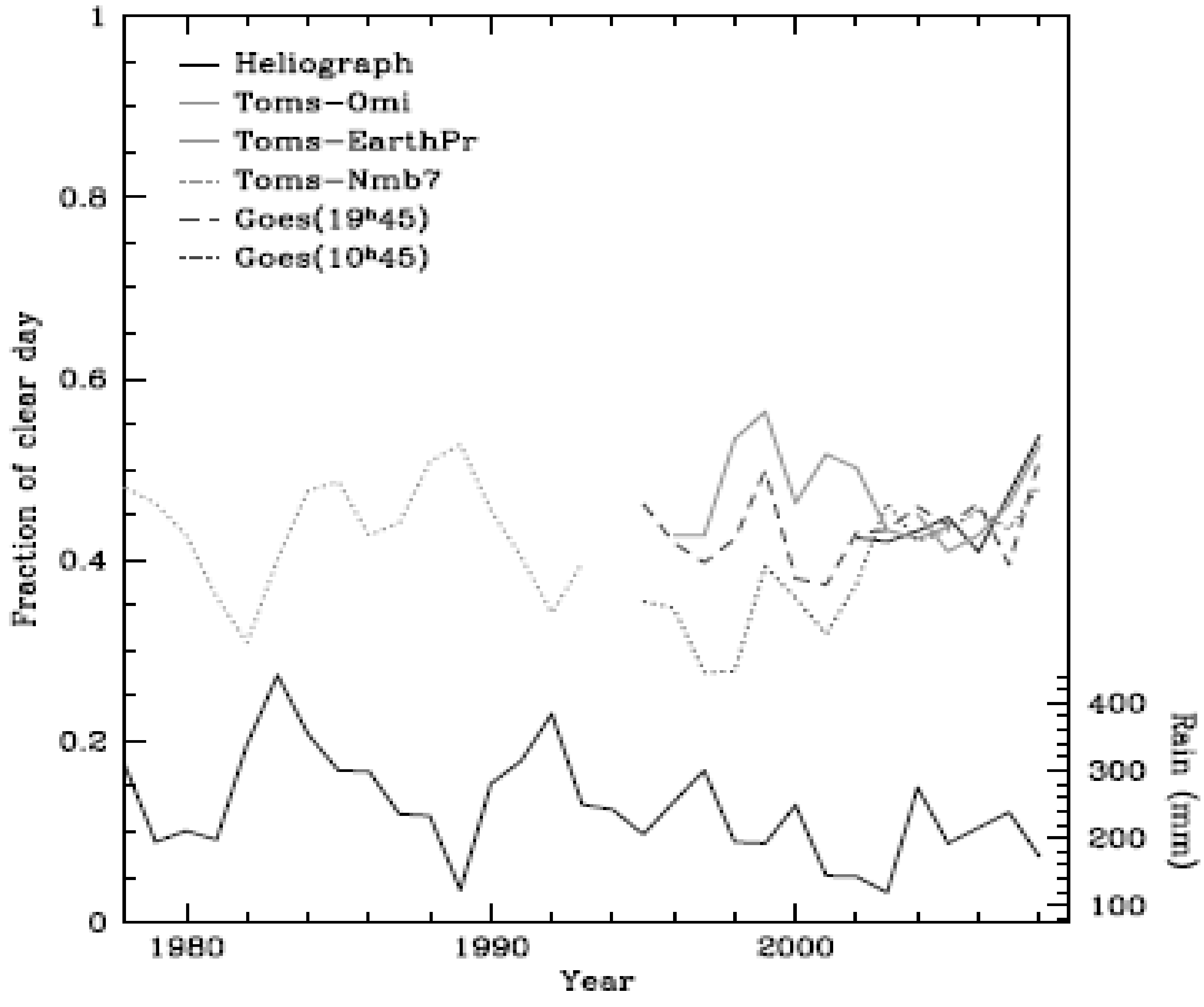
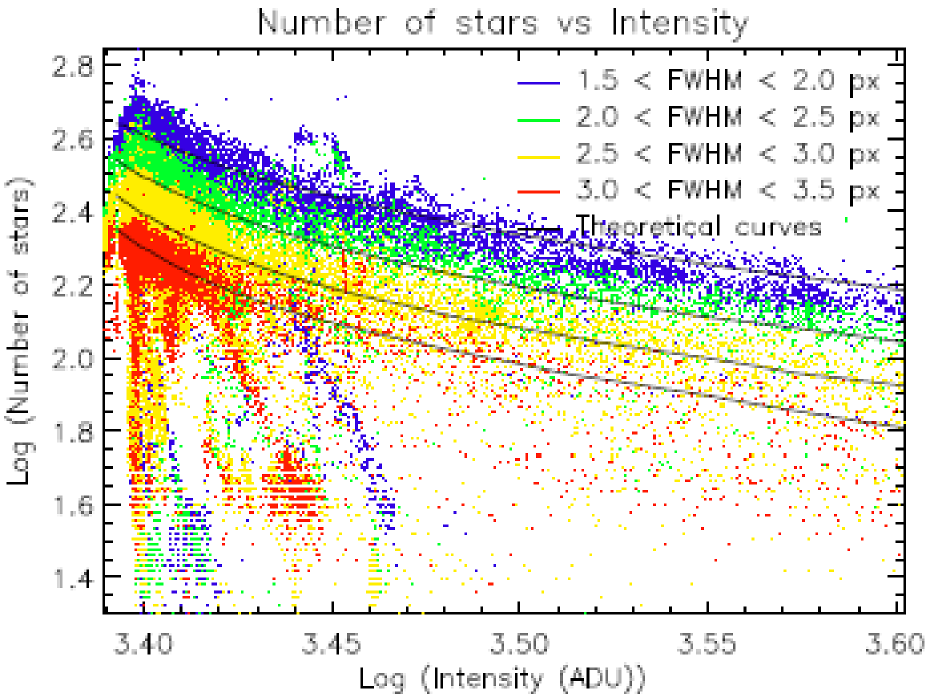


Figure 18. Composite yearly mean distribution of clear nights at Mt. Graham

Counting stars (Dome C, Crouzet et al., 2010)

Other examples, all sky cameras, by Shamir and Nemiroff (2005)



All sky cameras (Martinis et al., 2013)

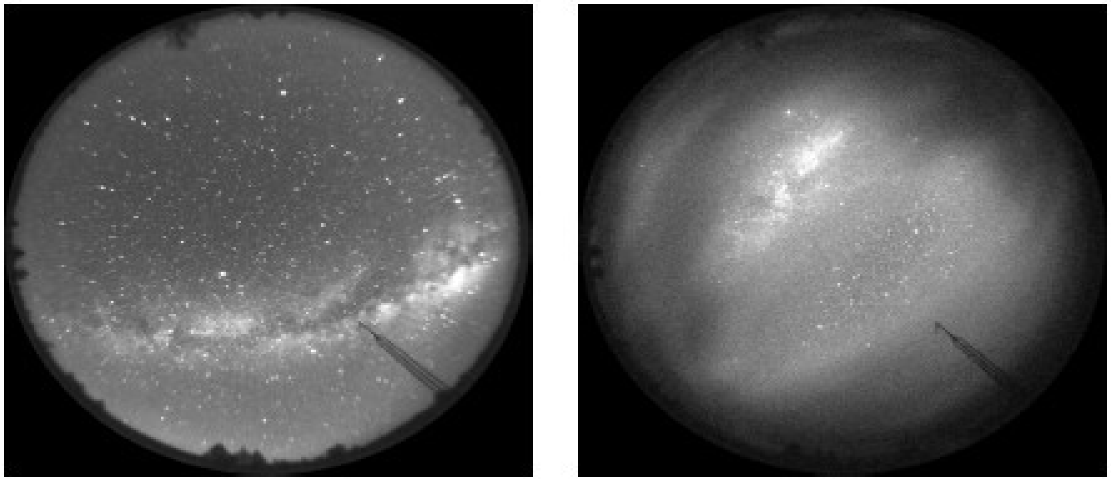


Figure 2: Left: Image of clear night sky. Right: Partly cloudy night skies. Moon and clouds are visible close to horizon.

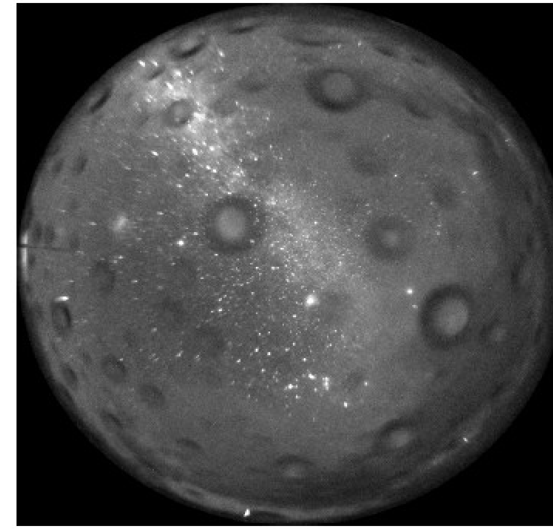


Figure 15: Lens of the ASC covered with water drops.

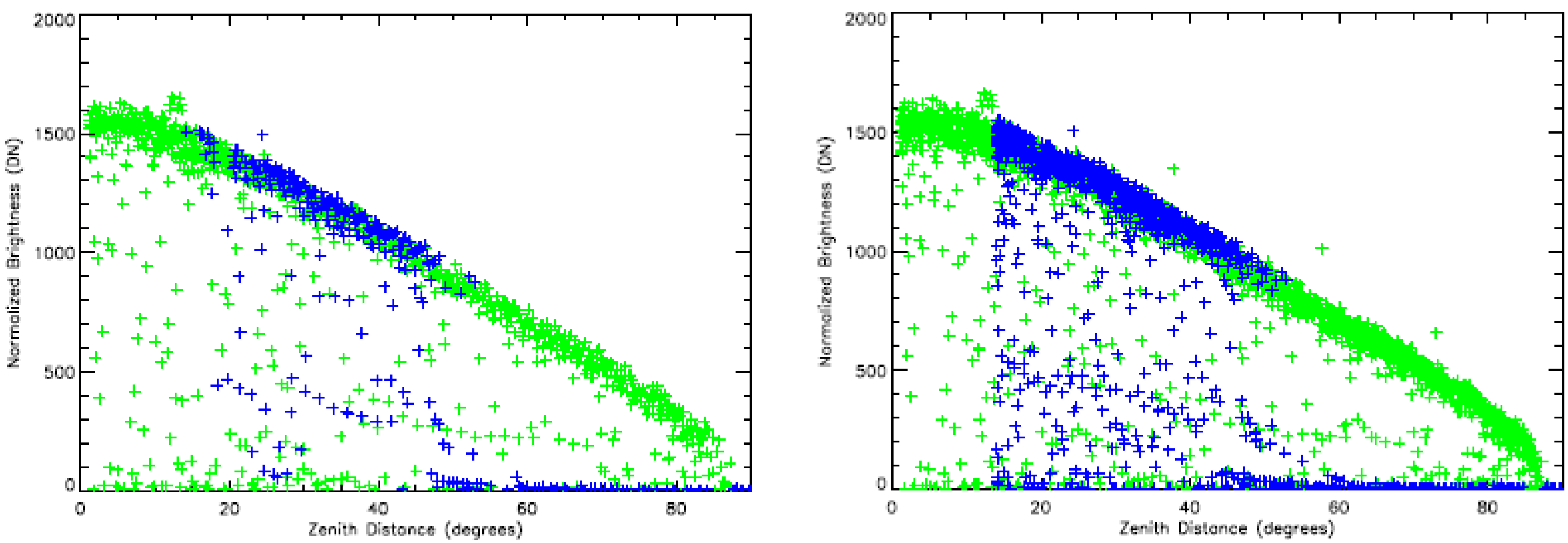
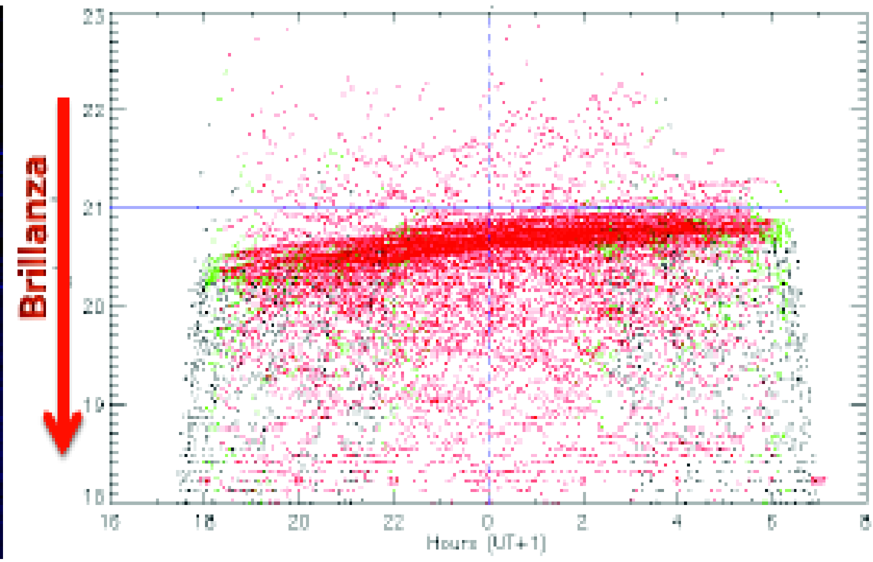


FIG. 3.—*Left*: Example of the scattering in the data leading to the formation of a 'clear sky band' using 1 month worth of data for two stars, Sirius (*blue crosses*) and Fomalhaut (*green crosses*). Values have been normalized to a data number of 1000 at 45° ZA; *Right*: Similar to the left panel, but now using data from 3 months. See the online edition of the *PASP* for a color version of this figure.

The SQM data for the cloud coverage ? (Vedovato, thesis 2013; Garstang, 2007)



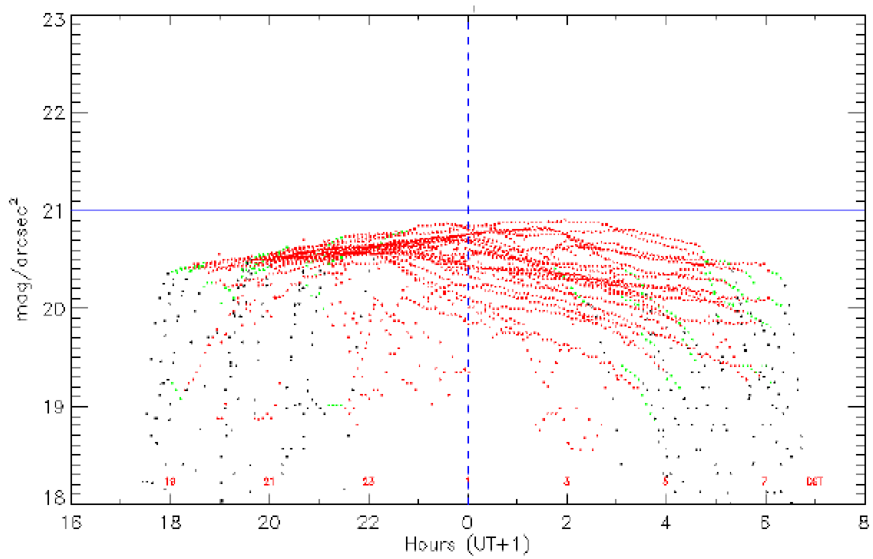


Fig. 13-3 Sovrapposizione delle notti di ultimo quarto di Luna selezionate da maggio 2011 ad aprile 2013

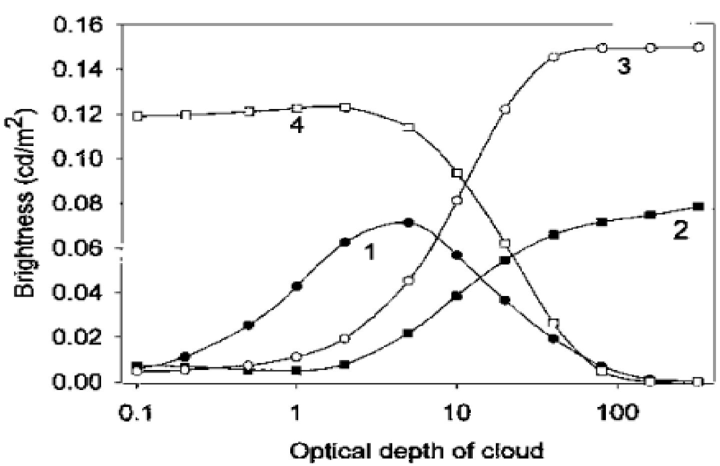
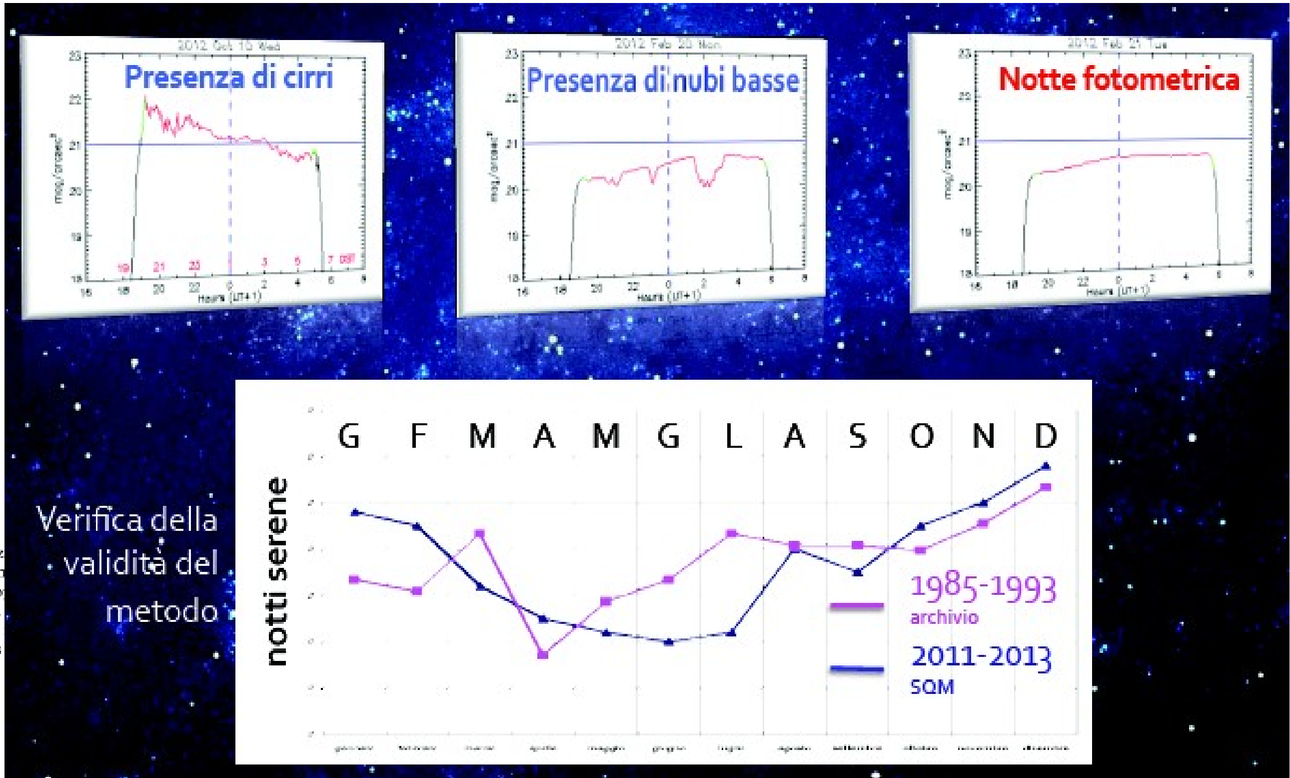


FIG. 3

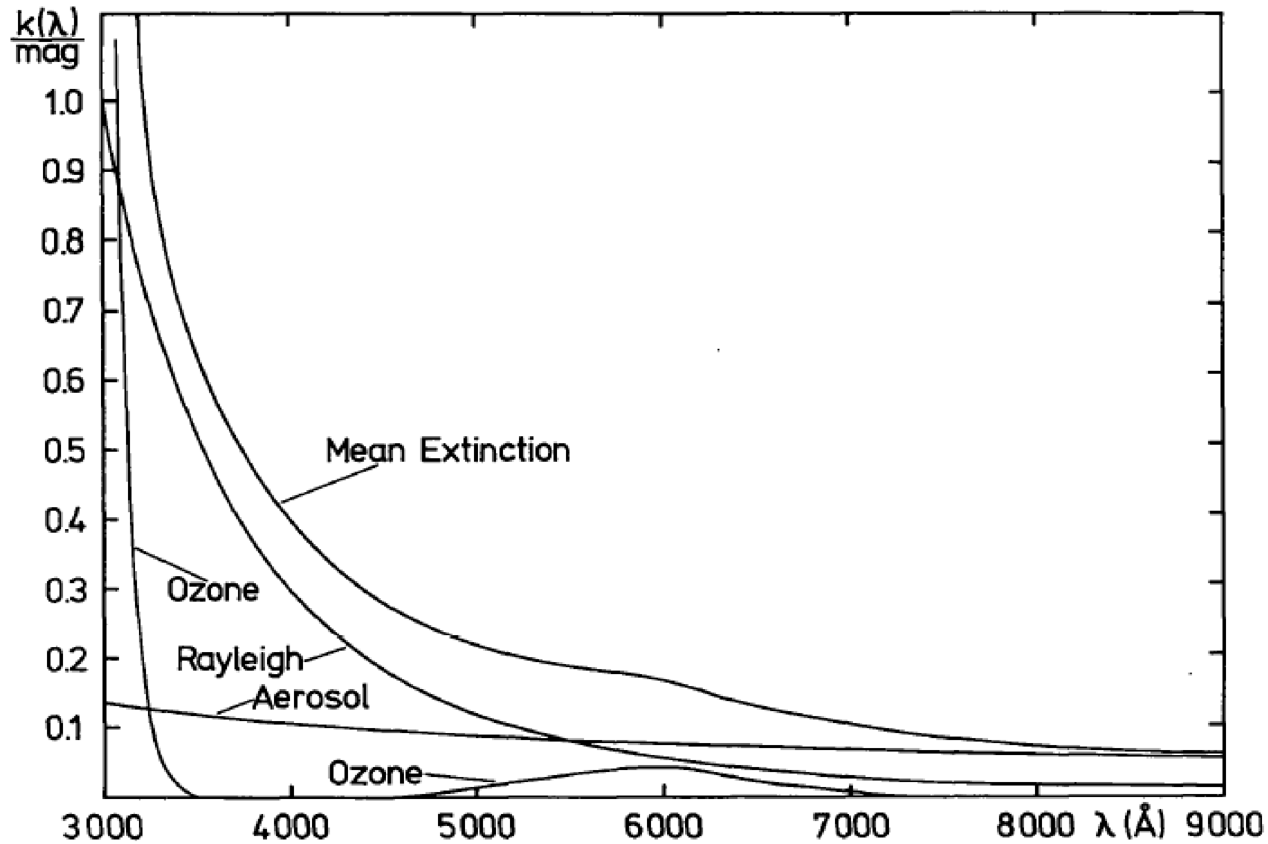
Brightness of clouds due to full moon (Moon near zenith at $\mu_0 = 0{\cdot}9$): curve 1 as seen in the z direction from the ground, curve 2 as seen from a satellite looking vertically downwards. For com son with the brightness of a city without moonlight, curve 3 shows the brightness of a city with po tion 100 000 and radius 3·162 km seen at the zenith from the centre of the city and curve 4 as seen a satellite looking vertically downwards at the city centre. An observer at the centre of this city on a of full moon would see a brightness given by adding curves 1 and 3; an observer looking downwards a satellite would see a brightness given by adding curves 2 and 4.



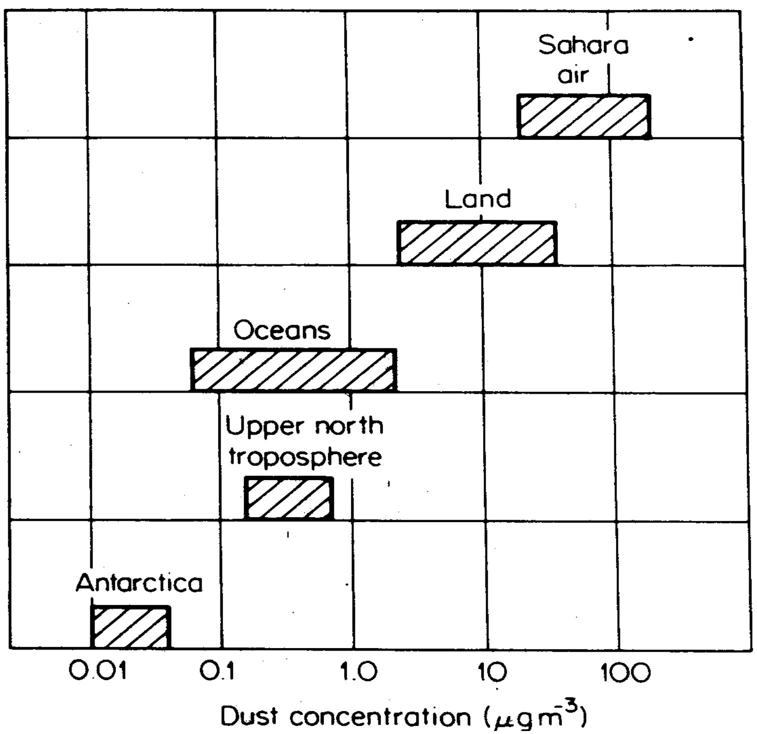
Mean extinction components: Rayleigh scattering dominates in the blue, but the aerosols (from 1 to 10 μ) are the short time variable component.

$$K = K_{ray} + K_{mie} + K_{O3}$$

$$I/I0 = cost.\ (1 + \cos^2\phi) / \lambda^4$$



The Sahara is the major source of dust on the Earth (200×10^6 t/year) (Murdin, 1986, see also Sicard et al., 2010)



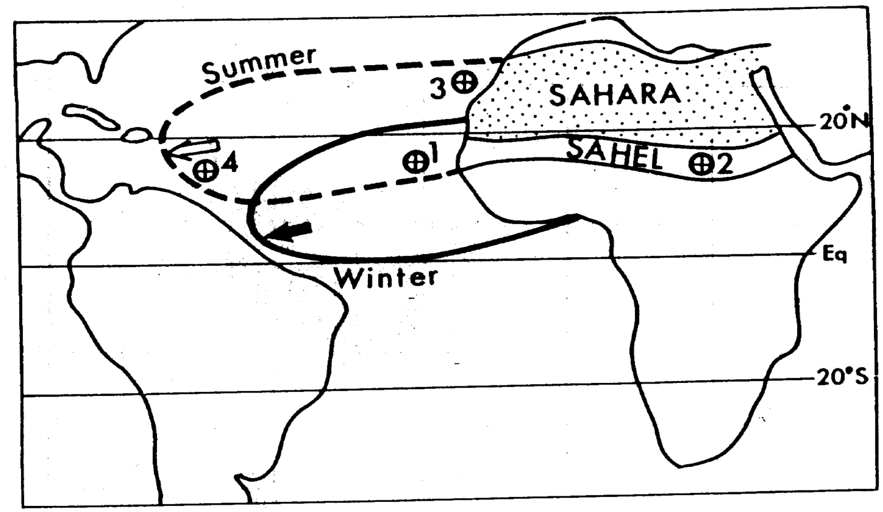


Figure 3.3 Dust transport over the Atlantic (after Rapp, 1974)
3 ~~1~~ = Tenerife
2 = Jebel Marra Mountains, Sudan
1 ~~3~~ = Cape Verde Islands
4 = Barbados

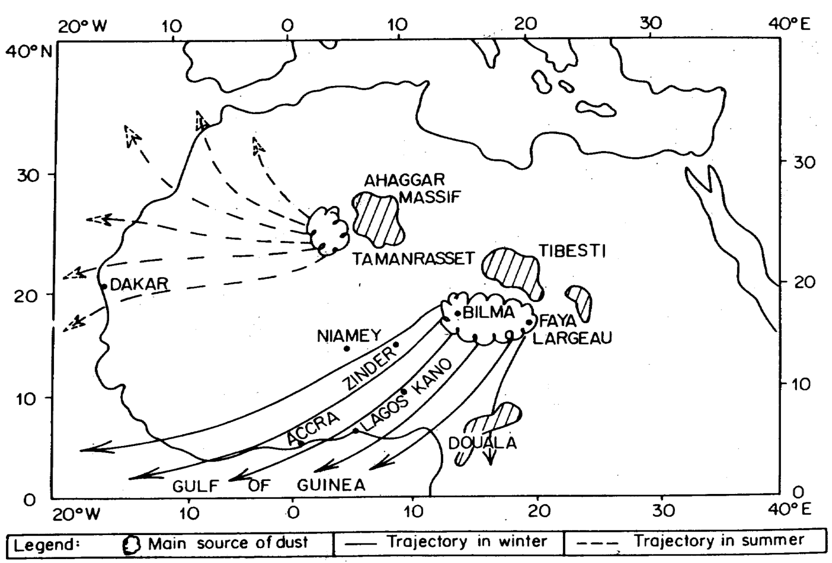
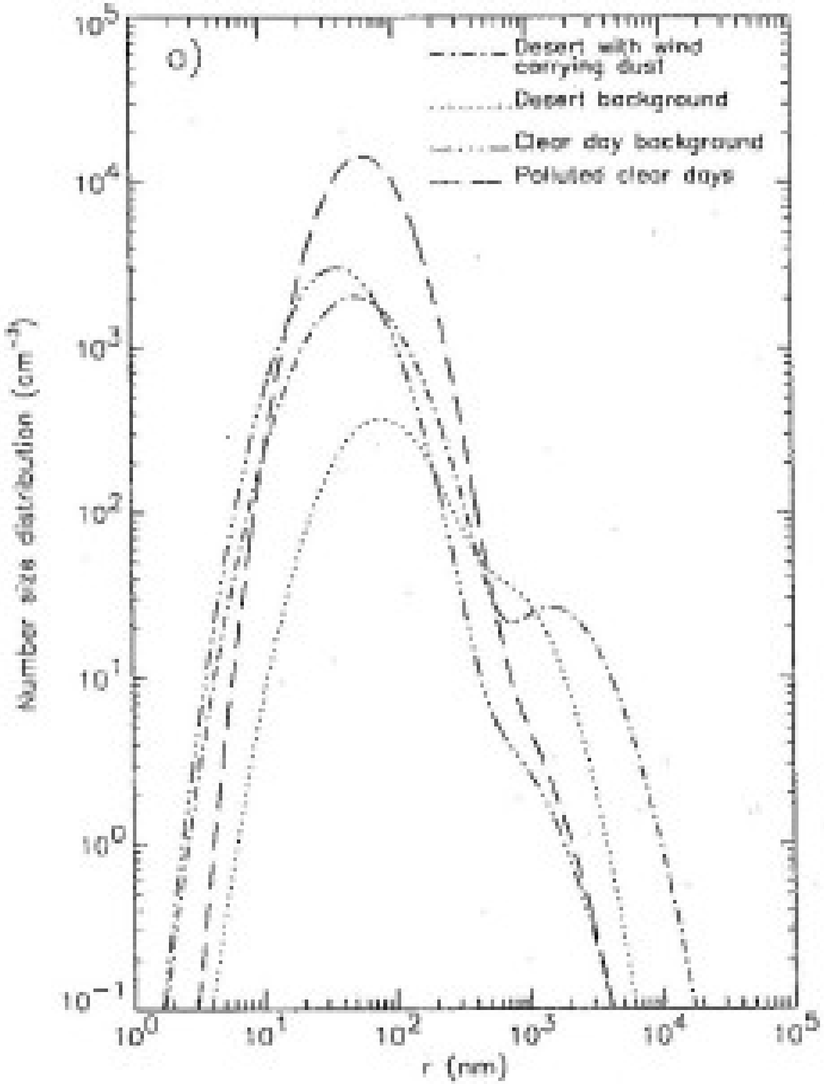
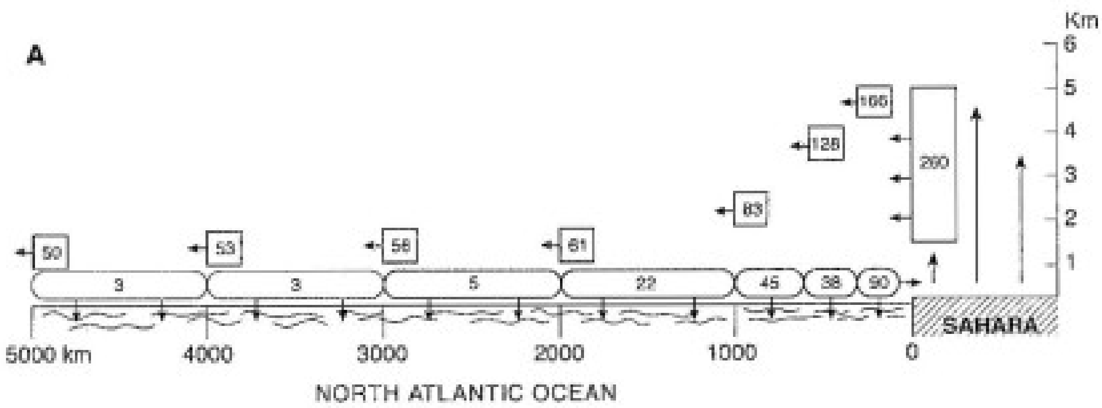


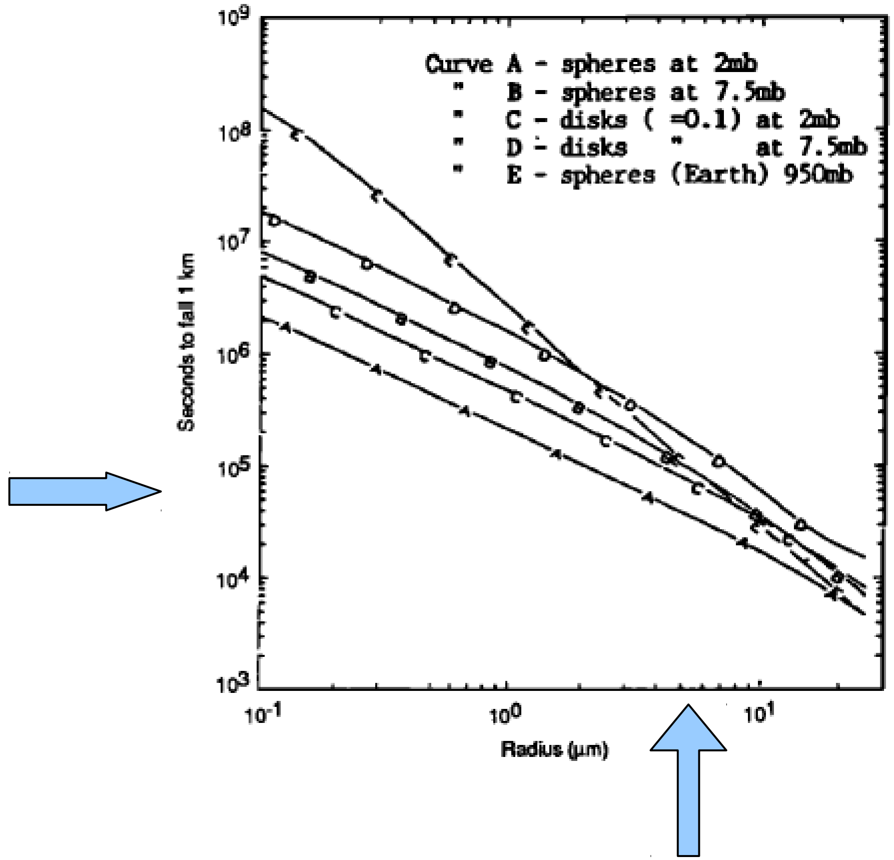
Figure 5.1 Saharan dust trajectories across West Africa

Aerosol typical distribution and transport of dust from Sahara (Bertolin thesis, 2005)





Size and settlement of the dust: typical height 6 km, settlement time (1 km) up to 50 days (1 μ)



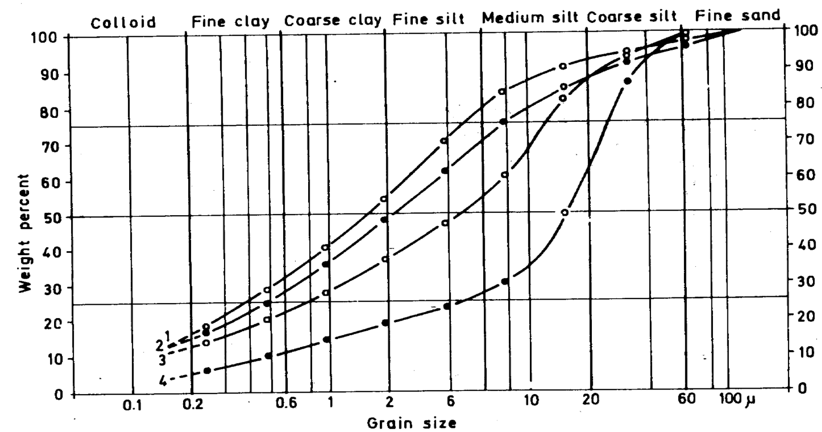
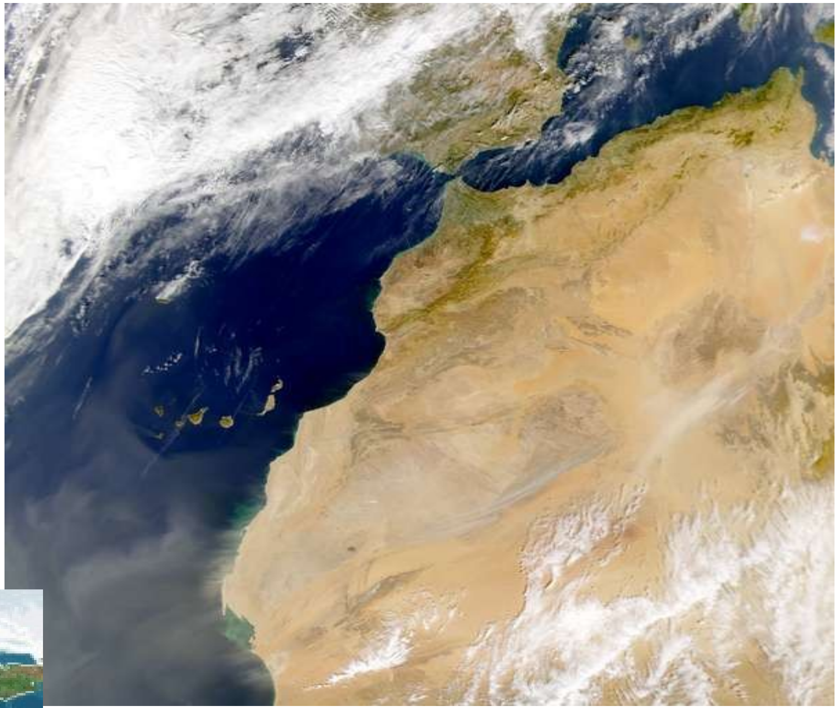
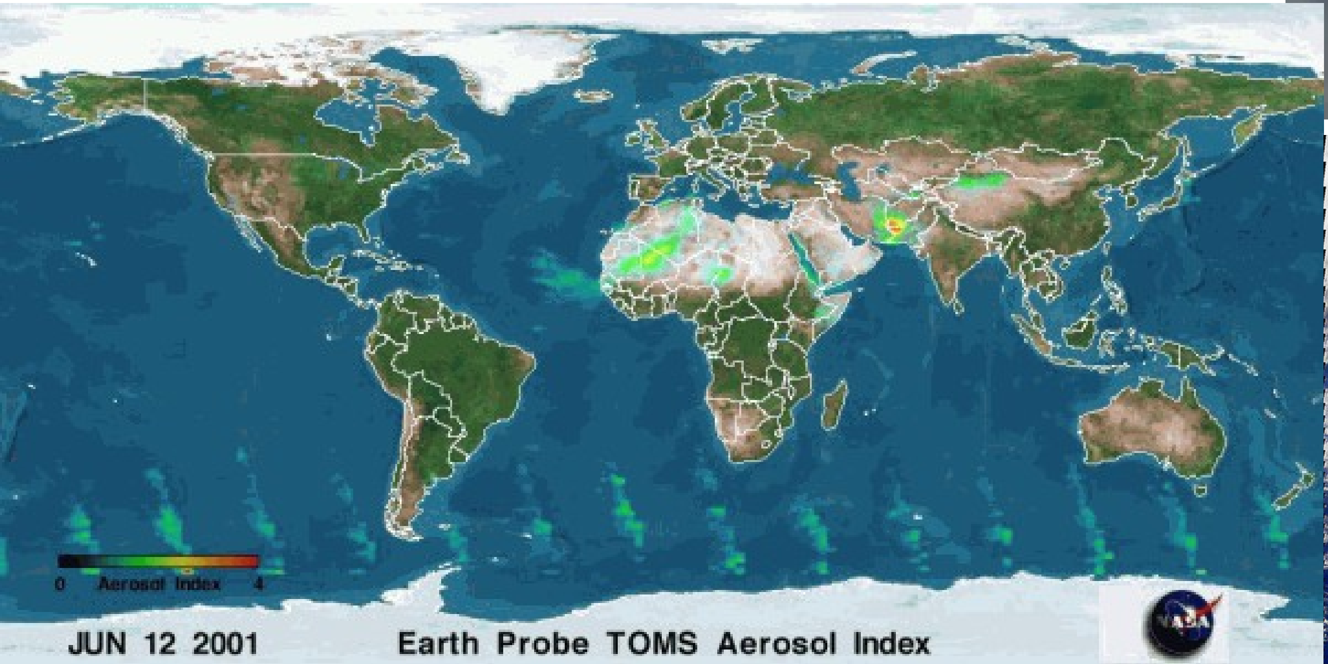


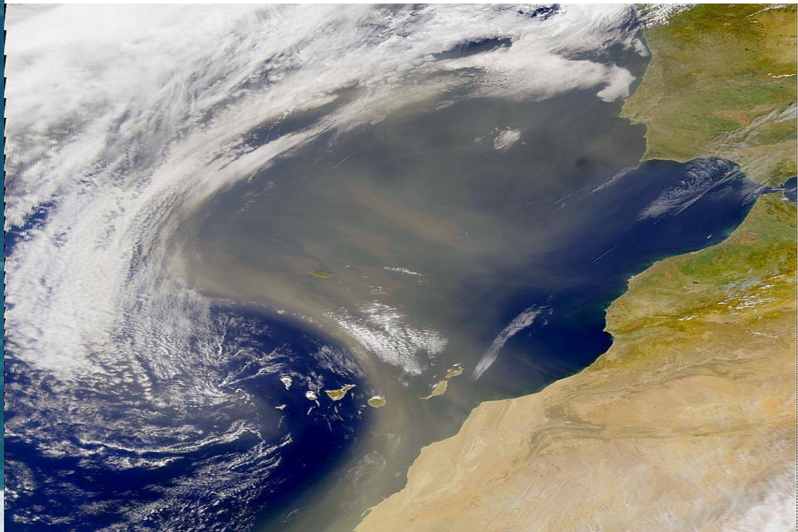
Figure 10.4 Cumulative curves of sediments from Core No. 210
(1) Ordinary, homogeneous sediment; mean of 77 pipette analyses.
(2) Ordinary, heterogeneous sediment; mean of 22 pipette analyses
(3) Microstratified wind-borne sediment; mean of 8 pipette analyses from bed 312.0–284.0 cm.
(4) Microstratified wind-borne sediment; sample 309.5 cm

With an average speed of 10 m/s the dust can be transported up to a distance of 10.000 km before settlement. Most of subtropical sites are affected. Obviously higher sites are in a better position

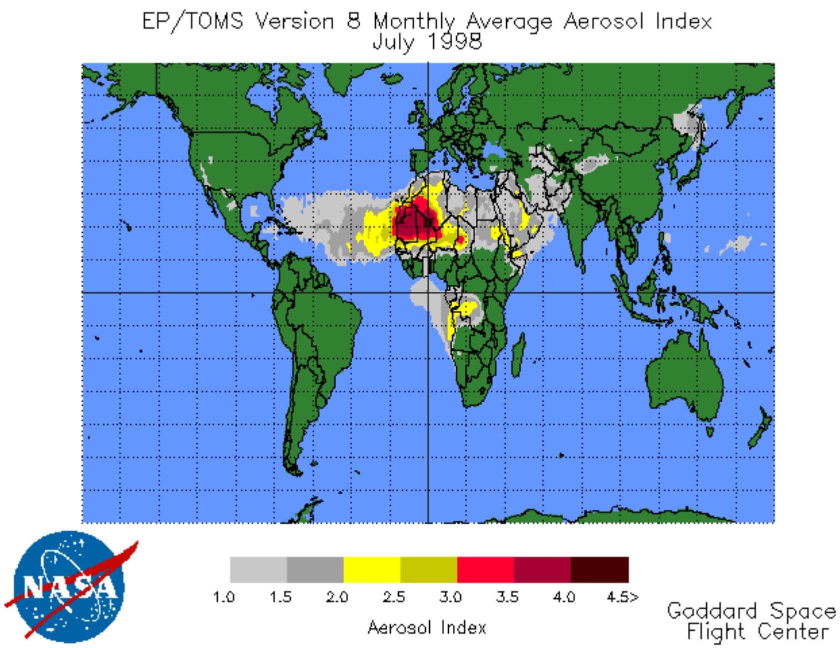
In the north the atmospheric dust content is maximum in summer: sources are Sahara, Arabian Peninsula, Tibet, other deserts affected before the summer peak (Arizona...)

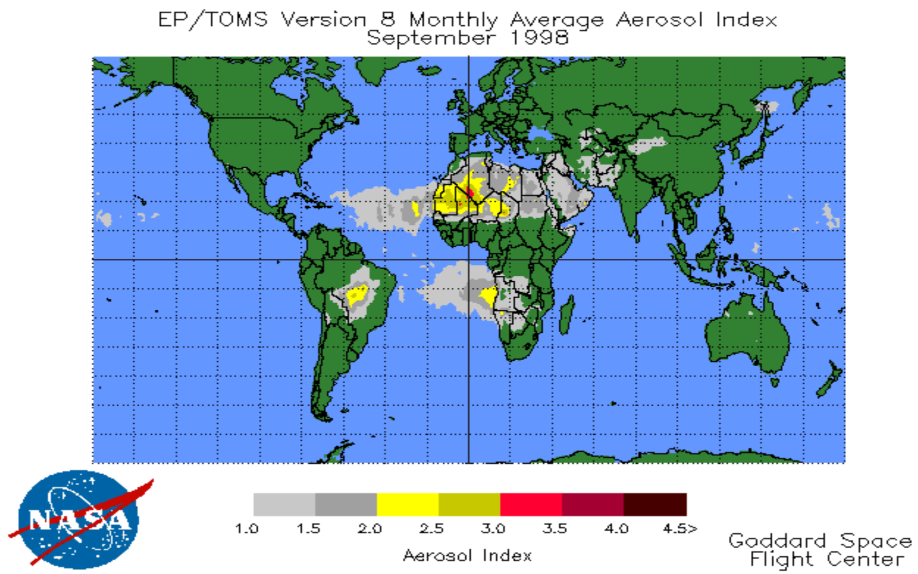


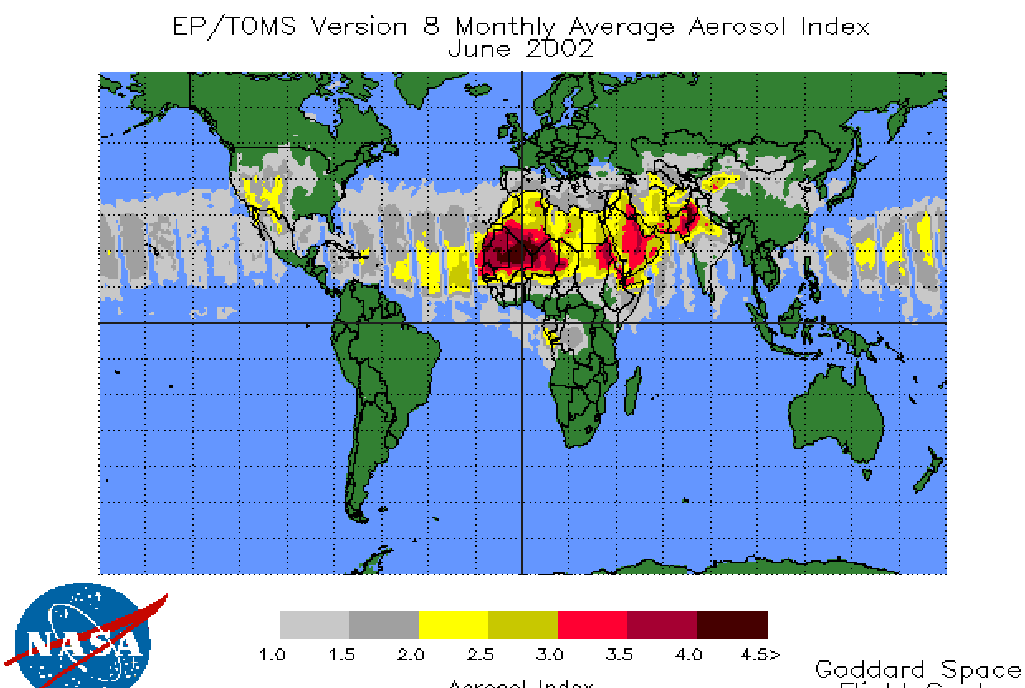


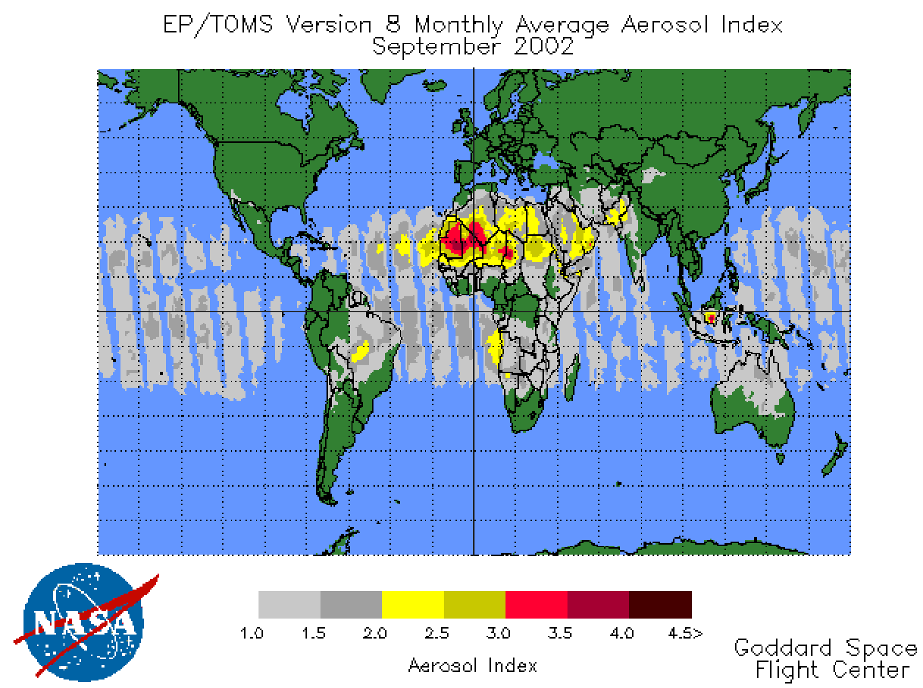


Aerosols (dust) in June-July and September TOMS (Earth Probe) satellite data: in September there is the highest activity in the south

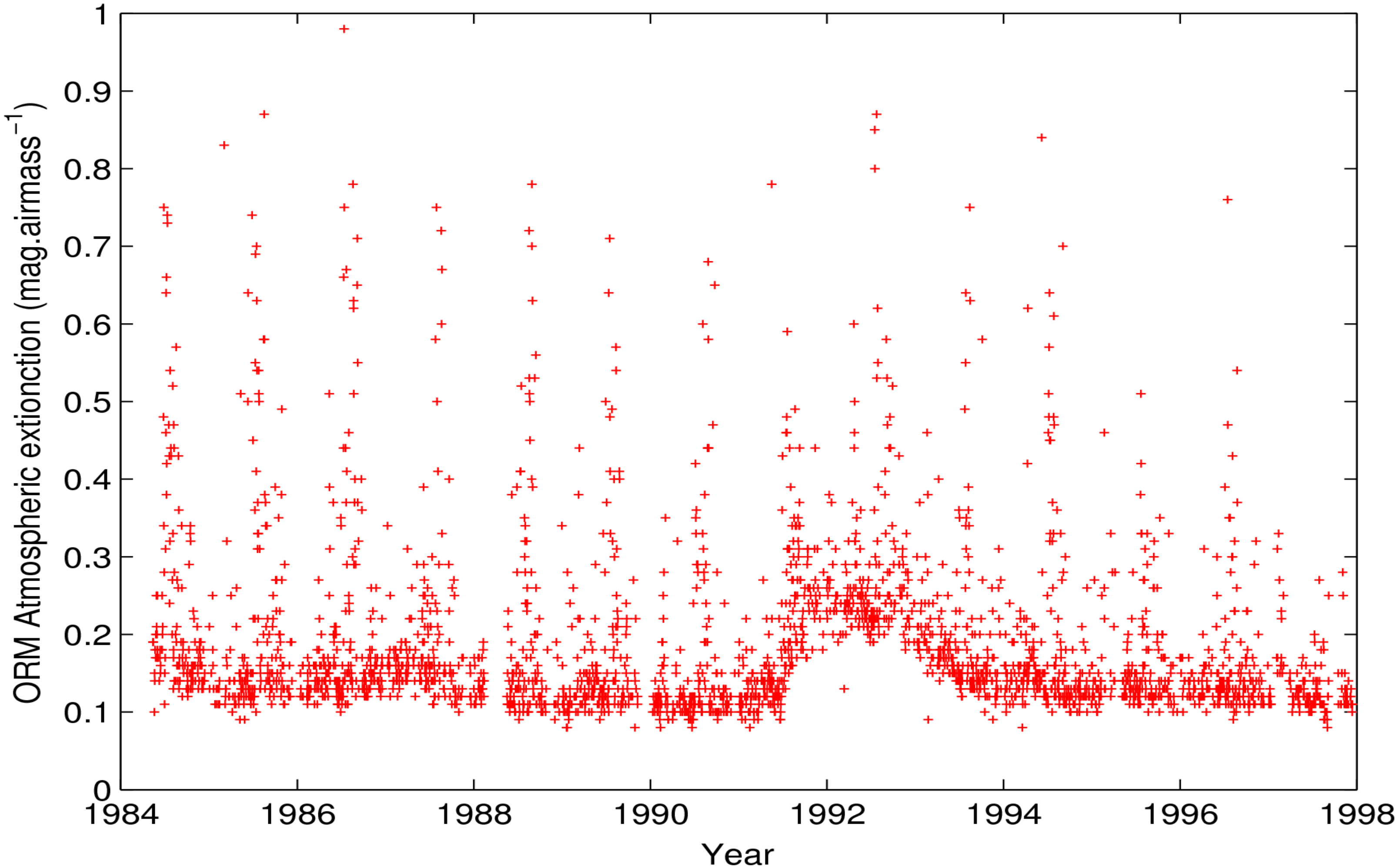








La Palma extinction (CAMCT): sahara dust + Pinatubo eruption (1992)



Dust distribution in the dust storm conditions (Lombardi et al., 2010, 2008)

Table 2. Dust background in [N m^{-3}] at TNG and Paranal in wintertime and summertime.

	wintertime		summertime	
	TNG	Paranal	TNG	Paranal
0.3 μm	1.0×10^6	–	3.7×10^6	–
0.5 μm	1.2×10^5	2.1×10^5	3.7×10^5	2.3×10^5
1.0 μm	3.6×10^4	–	1.1×10^5	–
3.0 μm	2.7×10^3	–	5.2×10^3	–
5.0 μm	1.0×10^3	0.1×10^3	1.5×10^3	0.2×10^3
10.0 μm	1.2×10^2	–	0.7×10^2	–

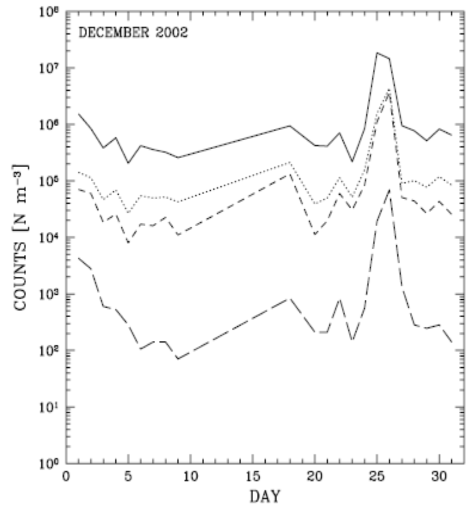


Fig. 3. Dust storm event of 2002 December 25 and 26: 0.3 μm (solid), 0.5 μm (dots), 1.0 μm (short-dashes) and 5.0 μm (long-dashes).

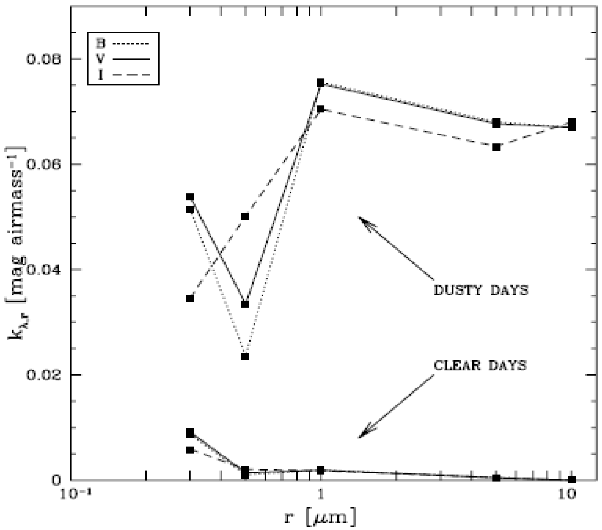


Fig. 8. Median aerosol atmospheric extinction in *B*, *V*, and *I* in typical dust background conditions and in typical dust-storm conditions for each particle size. The biggest particles are dominant with respect to sub-micron particles.

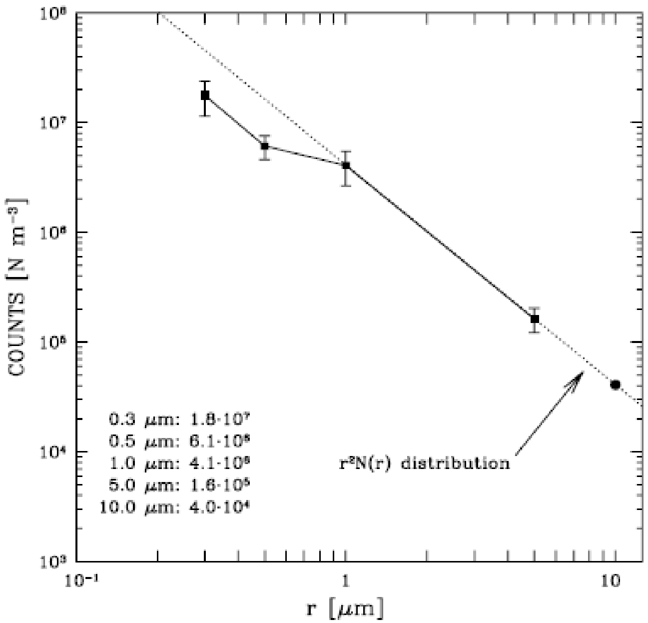
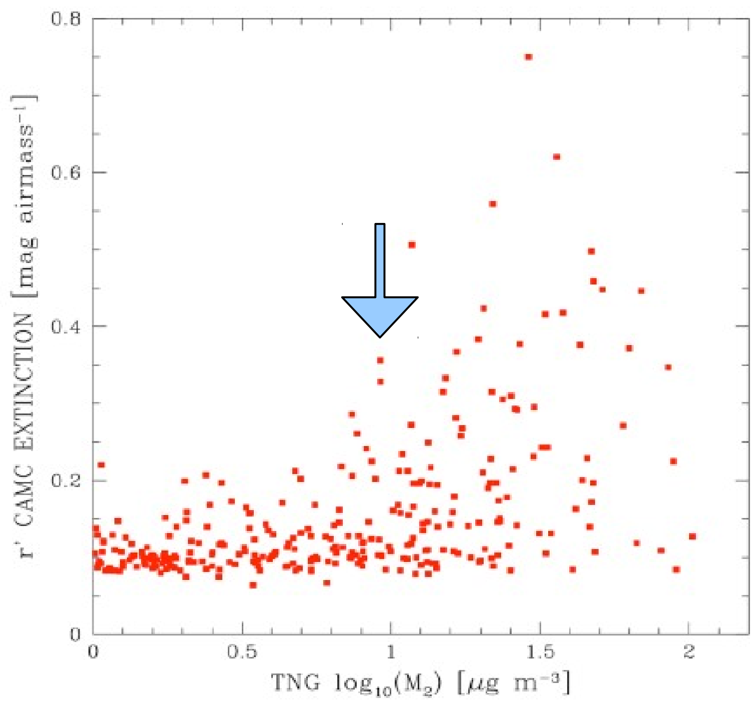


Fig. 4. Distribution of the median dust counts during dust storms. Particles ≥1.0 μm are treated as if they follow an $r^2N(r)$ power law.

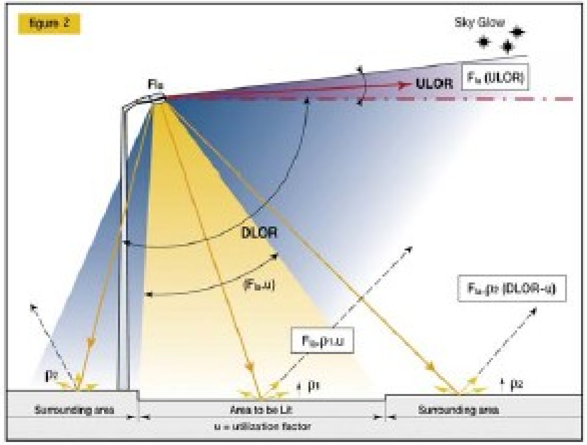


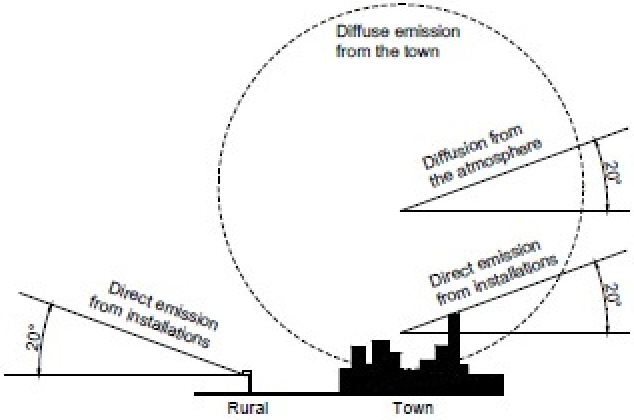
The dust particle number increases at smaller sizes
The optical effect is greater for bigger particles
During dust storms bigger particles density increases

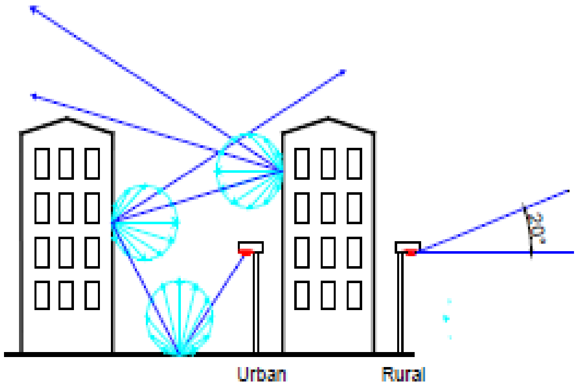
Aurora and auroral light from space

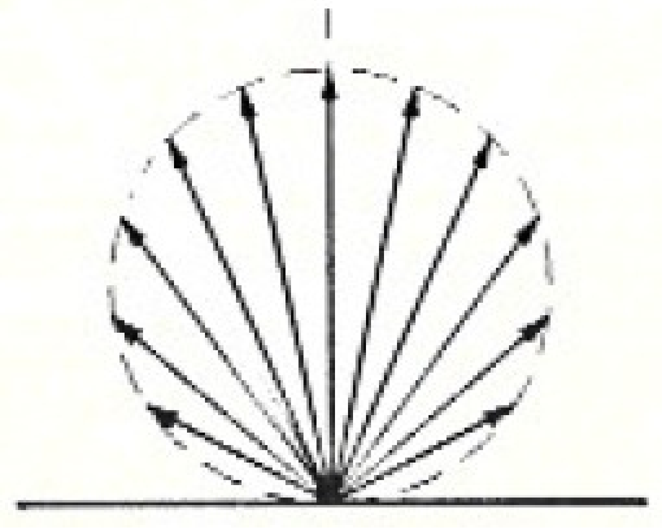
Zodiacal light, La Silla – La Palma

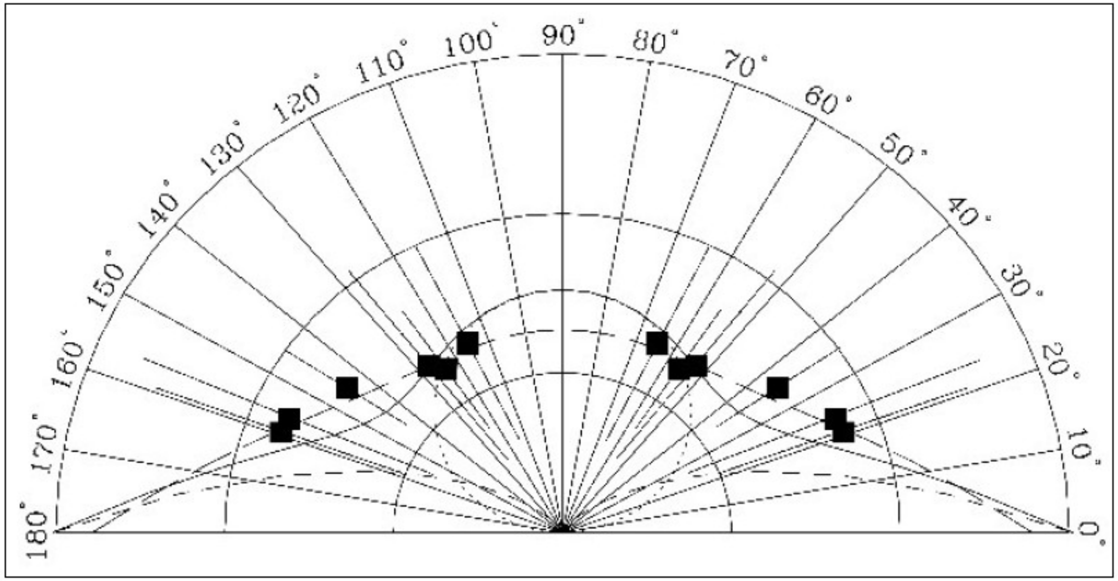
Soardo, 2008; Cinzano, 2008





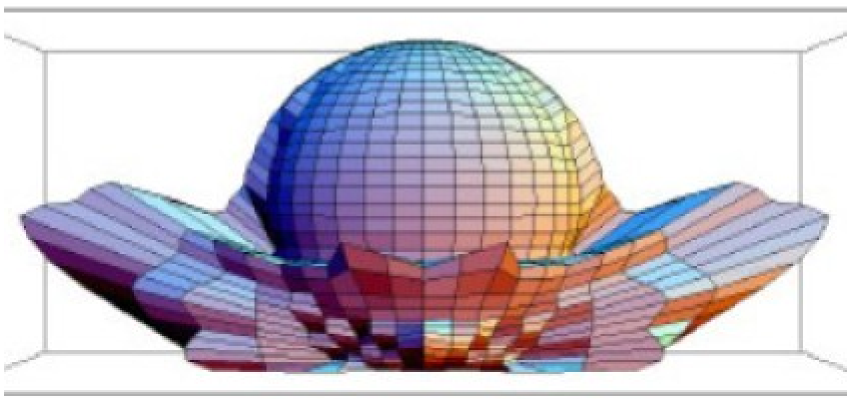


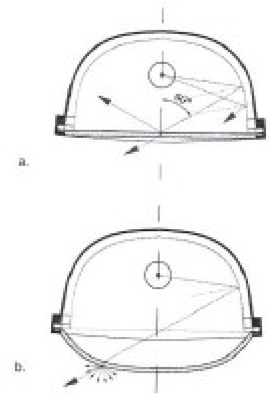


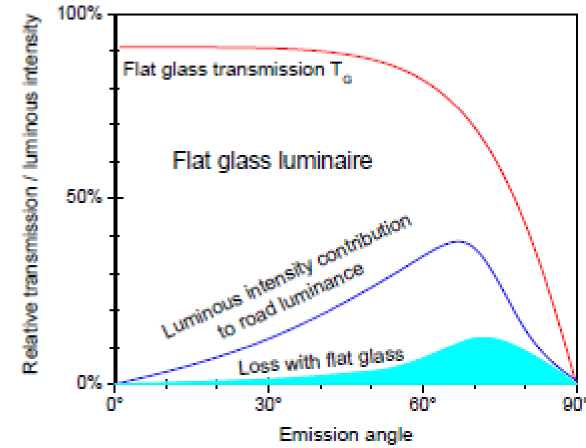


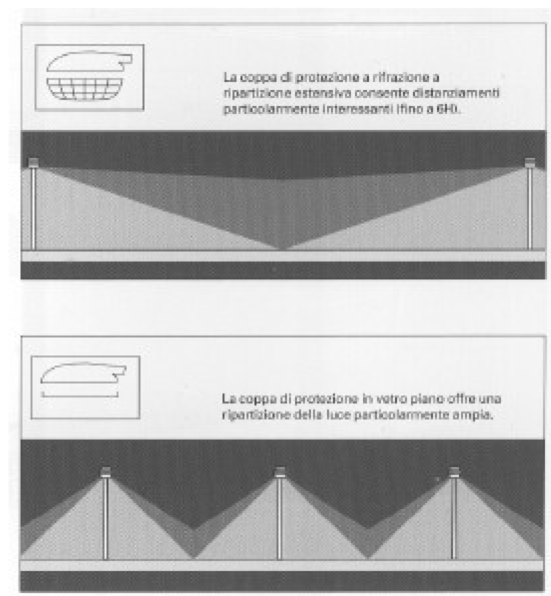
Hollan, J.; Cinzano, P., 2003

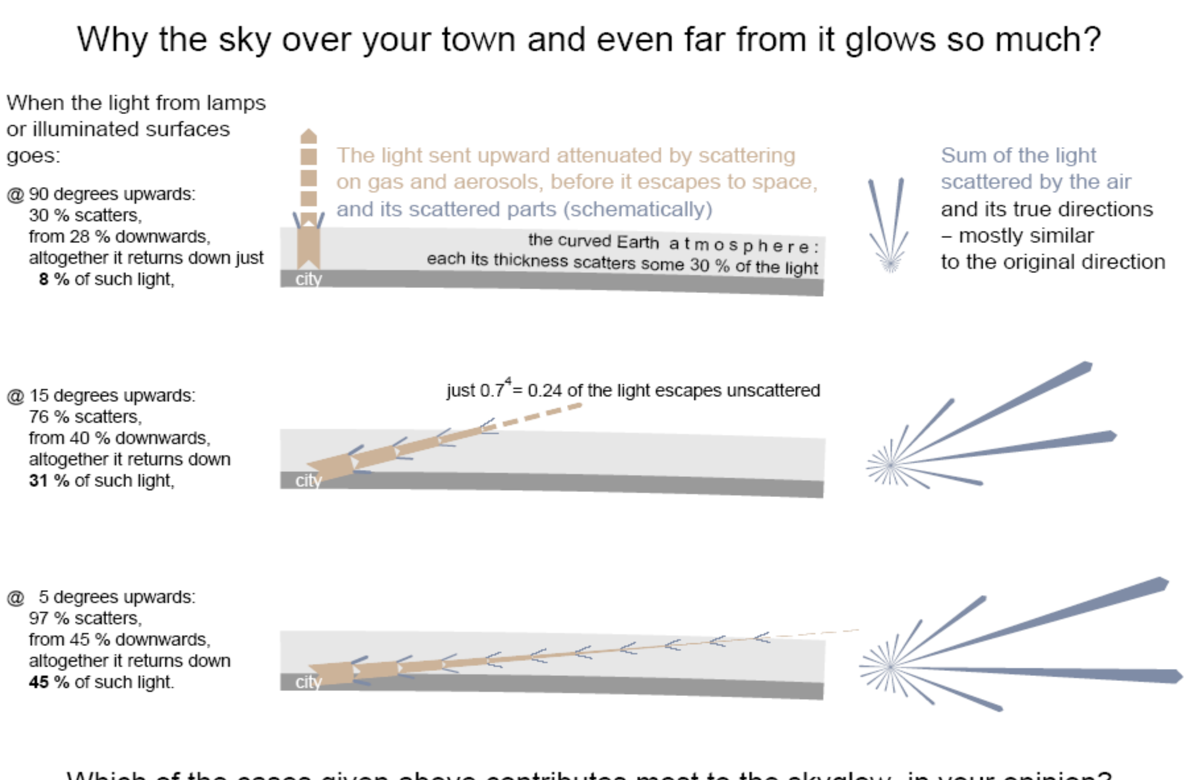
(2% upward lamp plus ground)

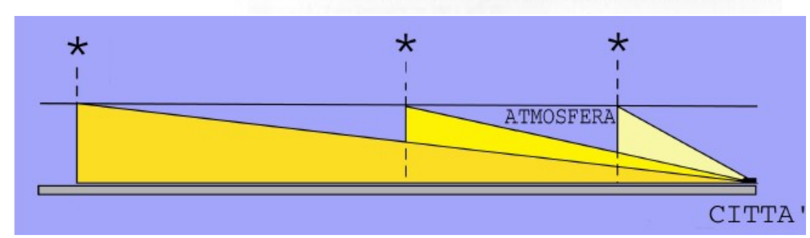






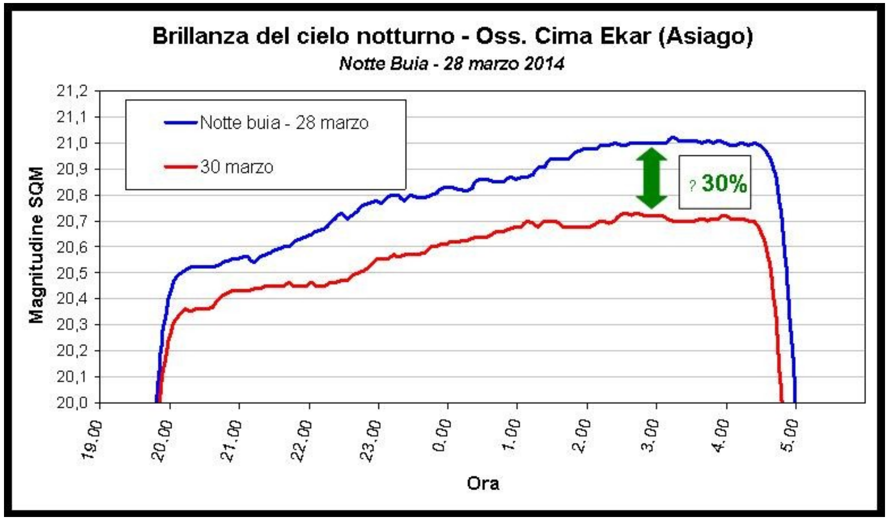






A unique experiment at Asiago Observatory: about 5000 street lamps off in the night of March 28°, involving 15000 people in a 500 km2 area.

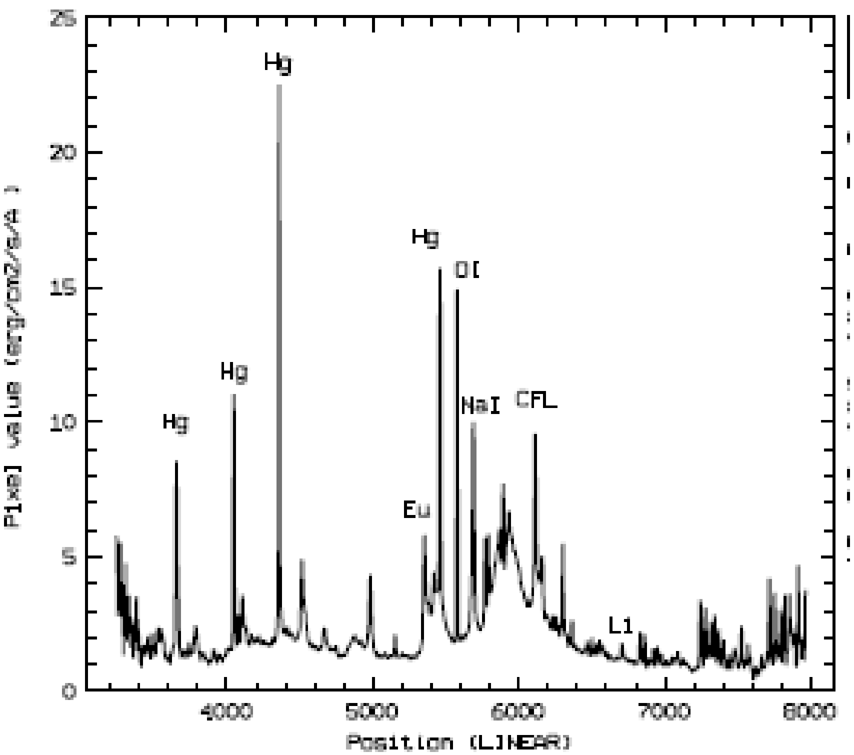
A limited gain (30%) on the sky brightness at Ekar observatory, still a factor 3 above the natural sky.

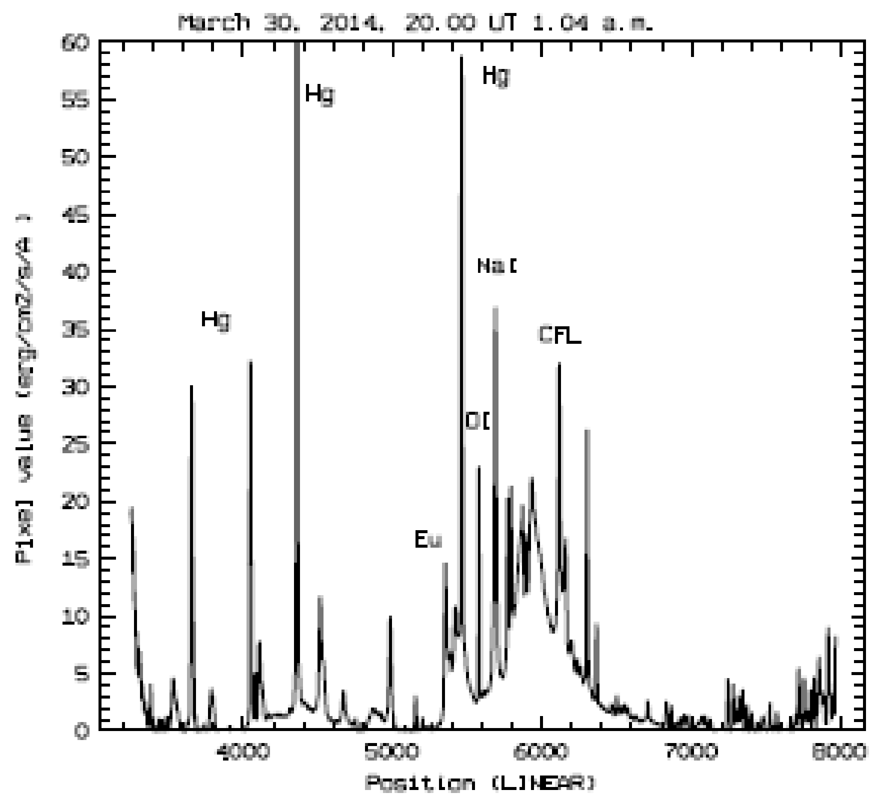


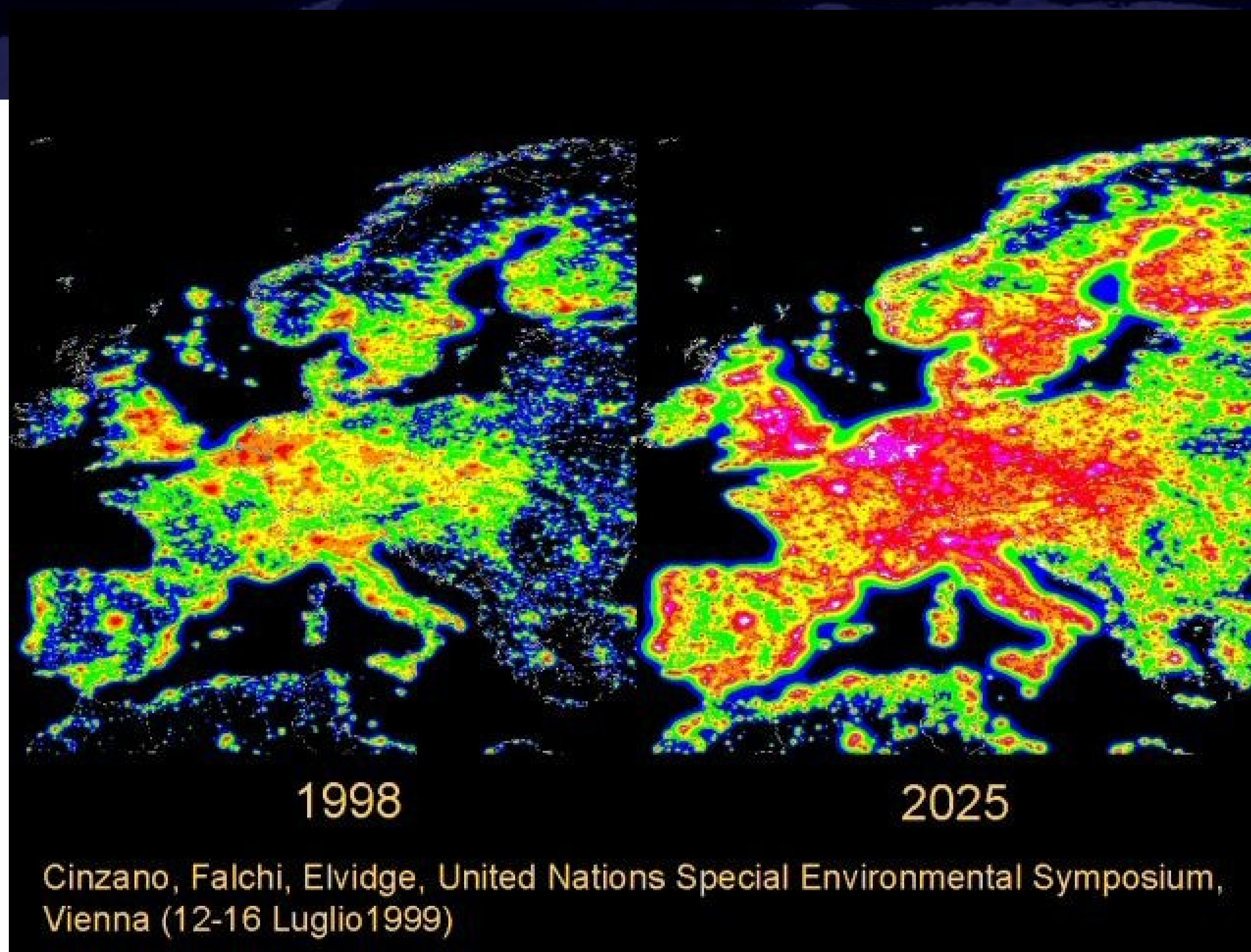
A wrong statement:

“No norm is better for observing the sky than the lack of lighting: observatories should be surrounded by dark zones (the so-called **“star parks**”), where lighting installations should not be allowed.”

Who is polluting the sky ? Hg, Na, CFL and LED lamps. The dark night vs. a “normal” night. Street lights are acutally dominated by Na and Hg (LED ?):






1998
2025
Cinzano, Falchi, Elvidge, United Nations Special Environmental Symposium,
Vienna (12-16 Luglio1999)

All the sites are affected by some light pollution: Cile (Paranal-Armazones), the darkest site, San Pedro Martir, North Arizona (Meteor Crater), Tenerife (Izana)

Contrails

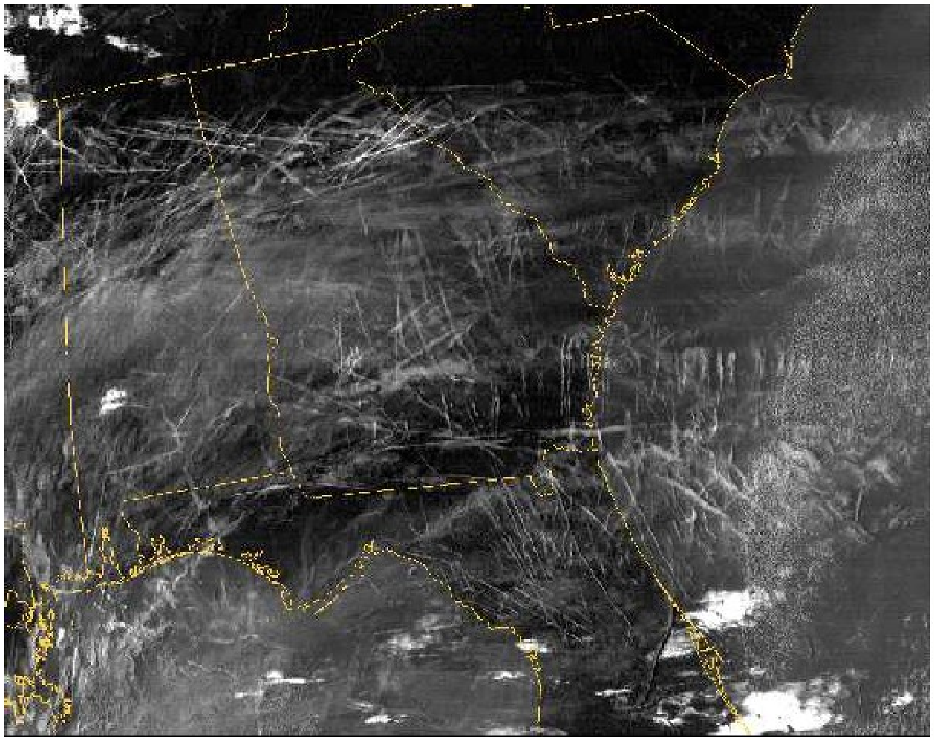


Figure 1. Contrails over North America, as detected by NASA's Terra satellite on January 29, 2004.
http://earthobservatory.nasa.gov/Newsroom/NewImages/Images/contrails_southeast_lrg.gif

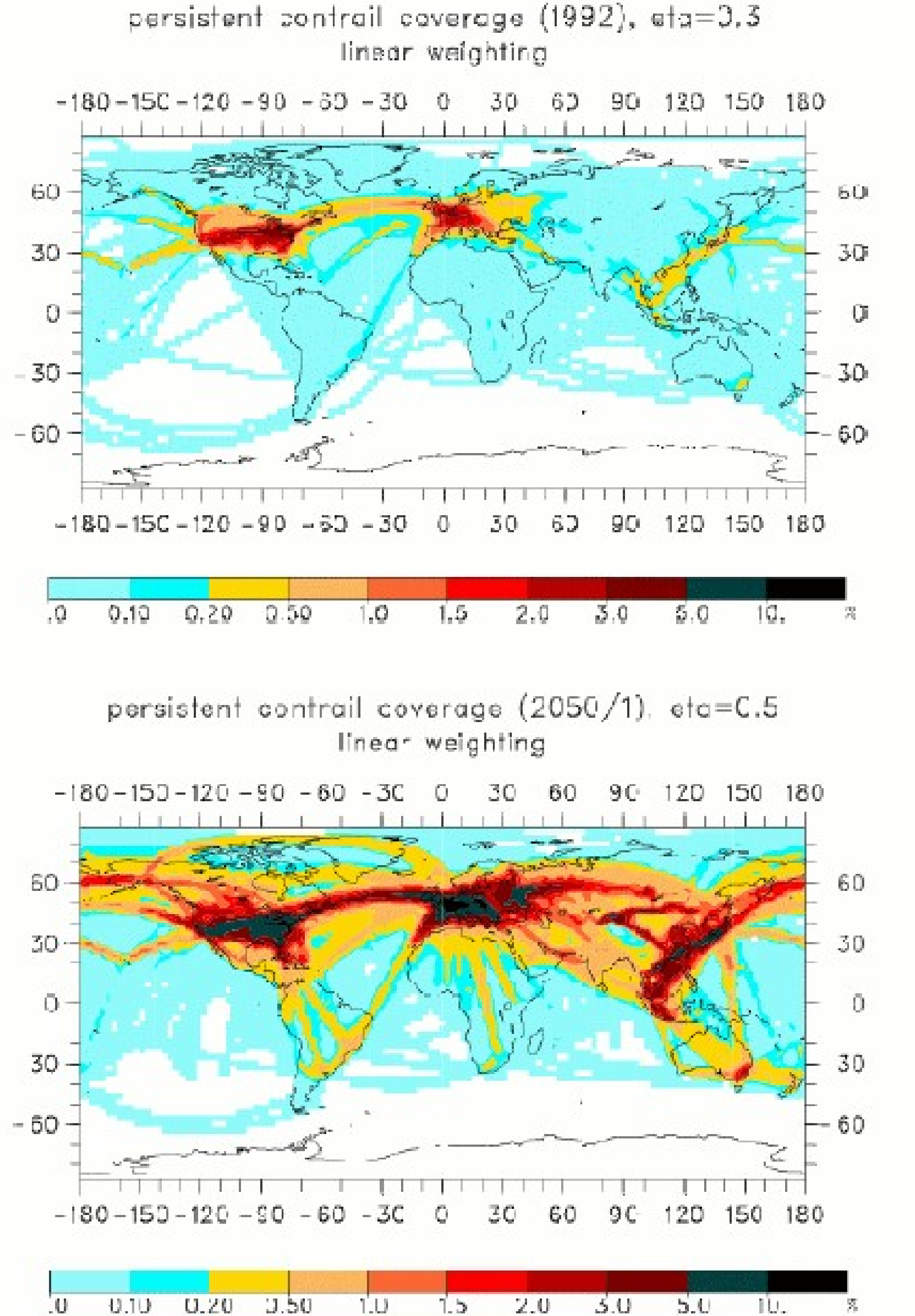
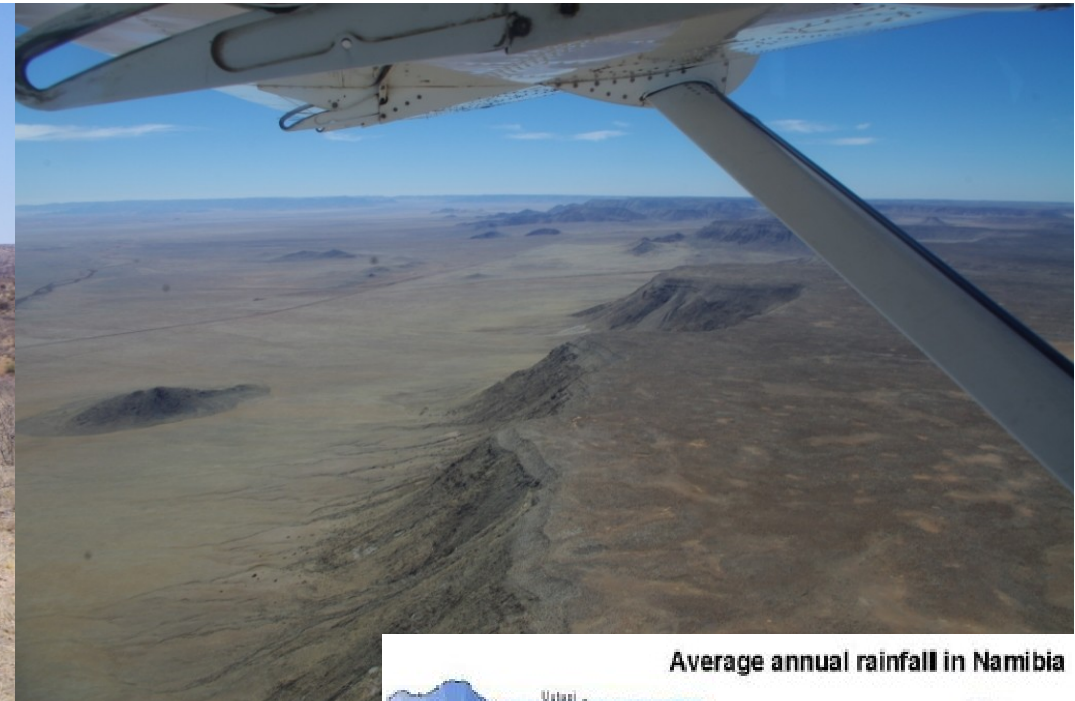


Figure 14-7: World map of jet aircraft contrails in 1992 (top), and predicted for 2050 (bottom), from [72]

Namibia, Hess (sinistra) e Aar. In basso la zona costiera



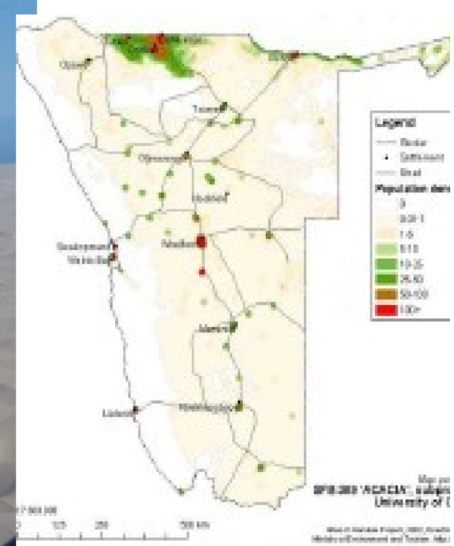
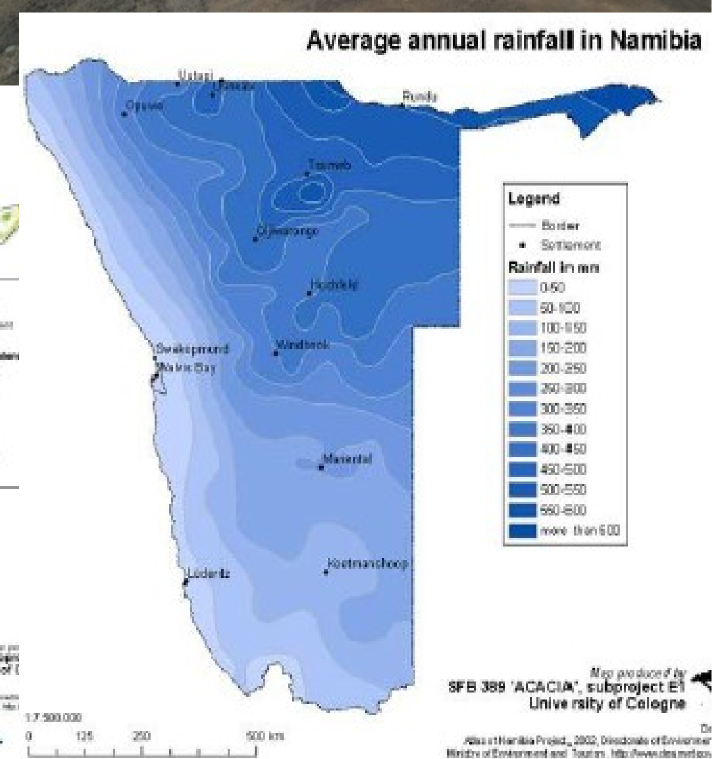


Figure 1: Population density of Namibia.



Argentina: S. Antonio de los Cobres (4000m) e El Leoncito (2500m)

Paranal sky

Cambiamenti climatici importanti in astronomia: andamento notti fotometriche a Paranal e a La Silla in 20 anni