

L'inquinamento luminoso nel mondo ed in Italia: situazione attuale e futuro prevedibile

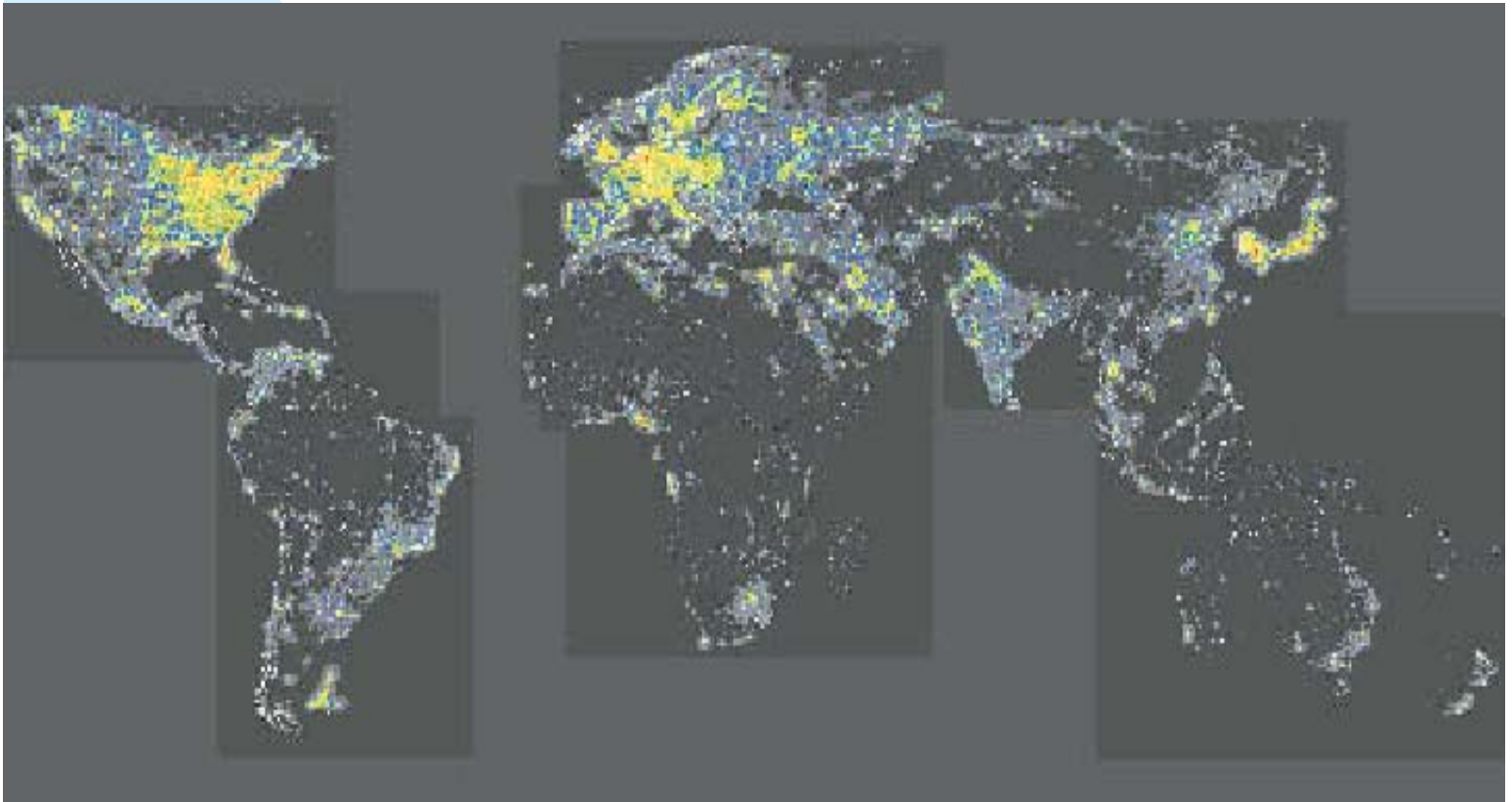
- “Gli abitanti delle nostre città moderne non possono nemmeno vedere le stelle.

Non è sorprendente che l'uomo abbia perso l'orientamento, che abbia perso le tracce di chi sia veramente e di che cosa sia davvero la sua vita”

da *Viaggi* di Michael Crichton

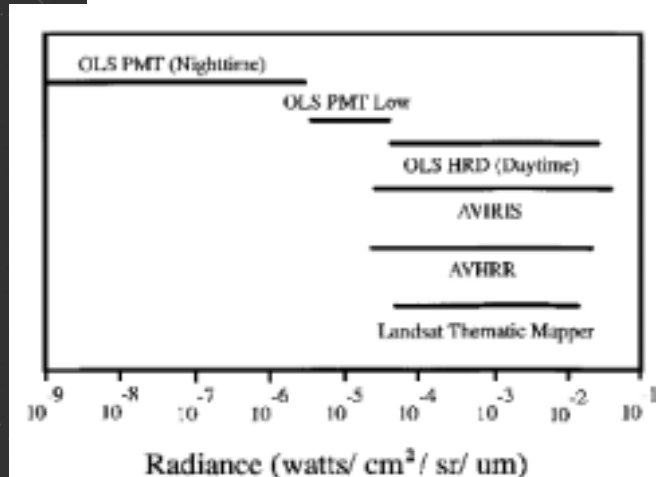
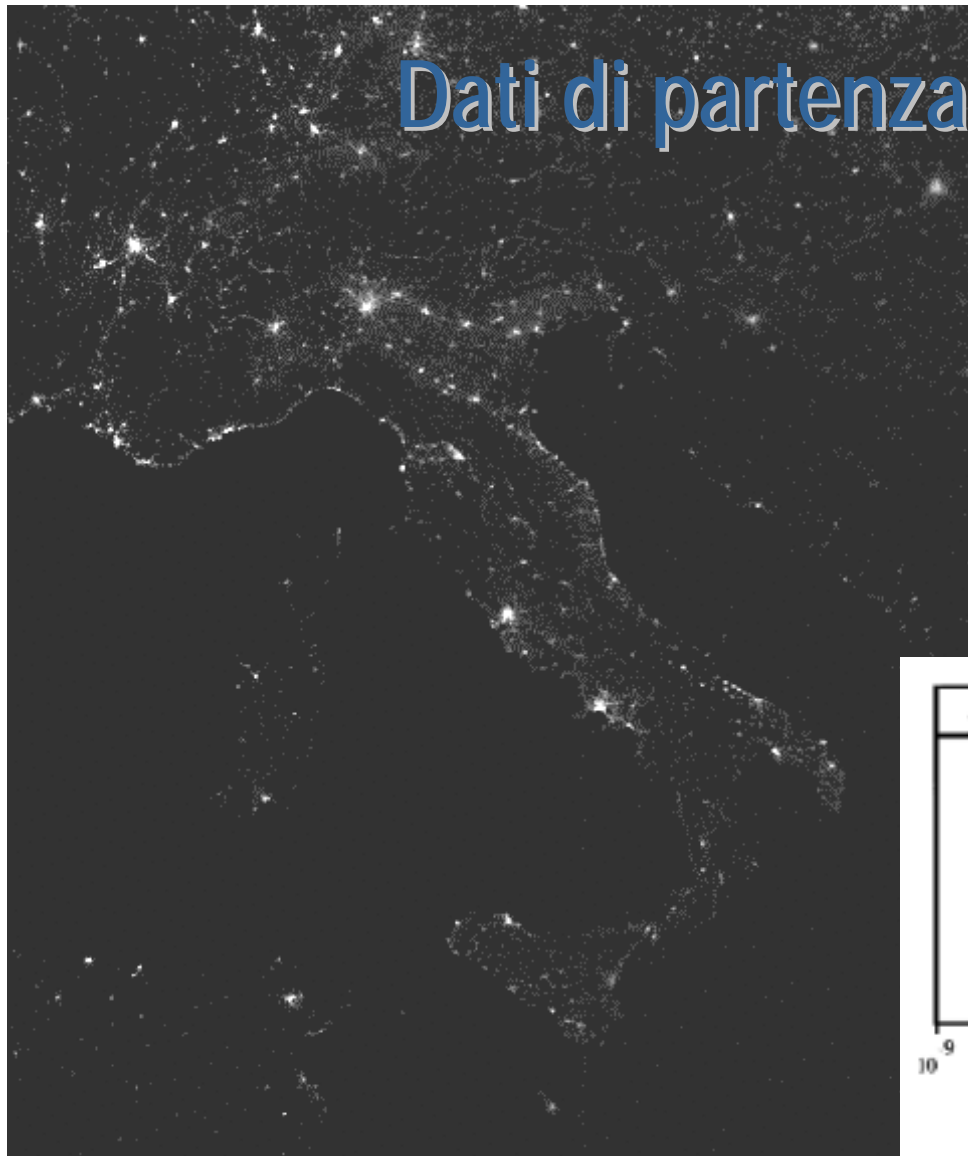
Osservatorio Astronomico G. V. Schiaparelli - Campo dei Fiori - Varese
Pianura Lombarda verso l'Aeroporto della Malpensa (foto Andrea Aletti - Oss. Schiaparelli)

La situazione attuale nel mondo: l'atlante della brillantezza artificiale del cielo notturno (Cinzano, Falchi, Elvidge 2000)

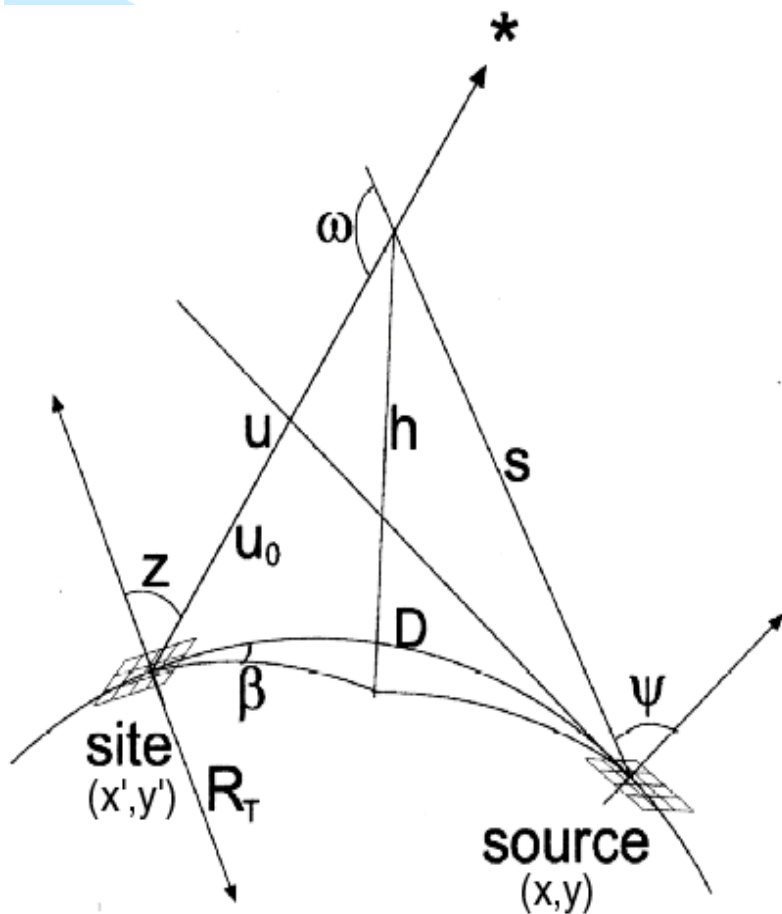


Dati di partenza: Upward flux

Dati di radianza dei satelliti del Defense Meteorological Satellite Program dell'U.S. Air Force



Calcolo della brillantezza artificiale del cielo



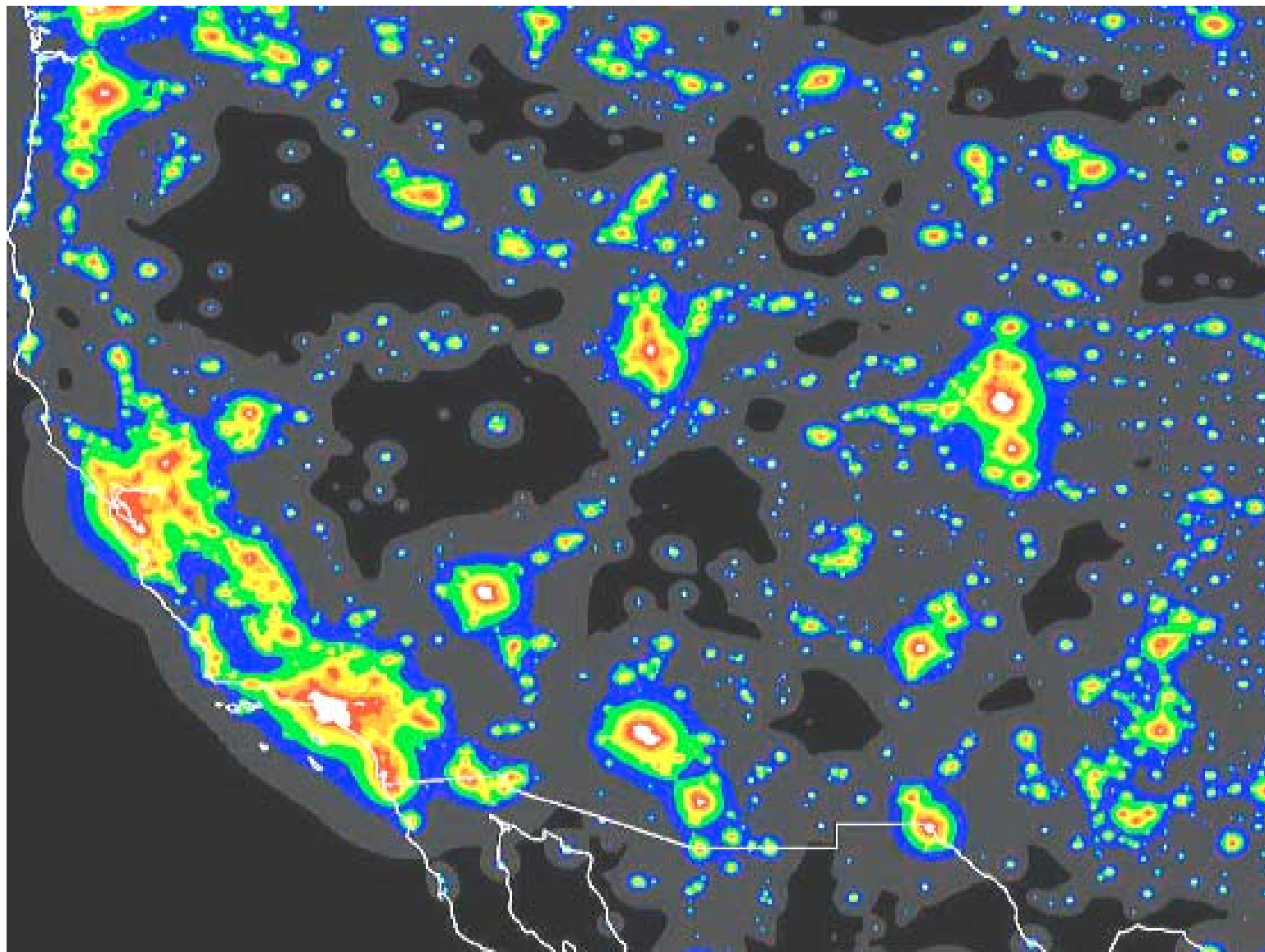
- per ogni sito integrazione del contributo delle sorgenti nel raggio di 200 km
- dati di flusso delle sorgenti rilevati dai satelliti DMSP dell'US Air Force
- calibrazione con OLS
- controllo brillantezza con misure da terra

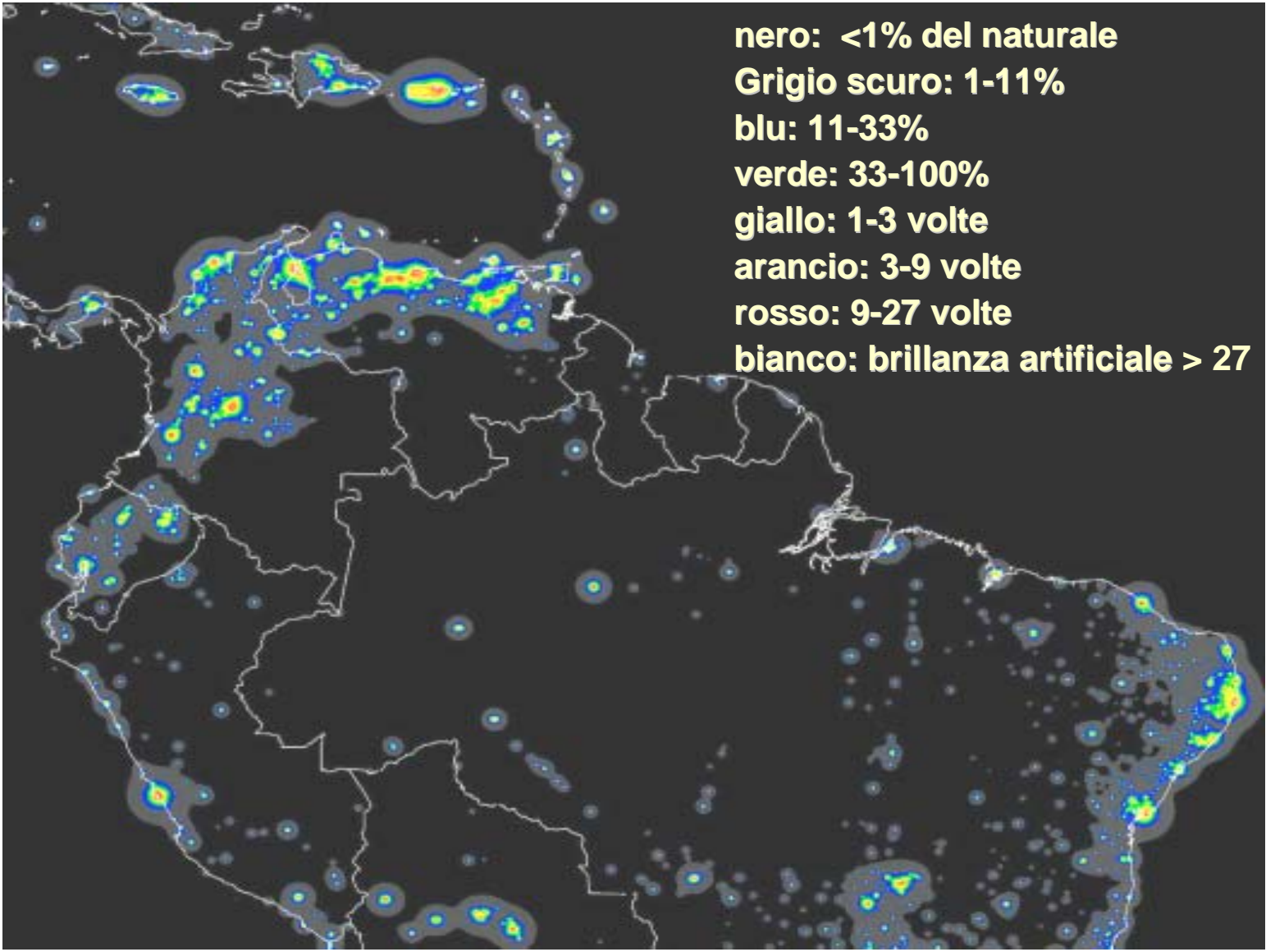
Approfondimento

Mappe della brillantezza artificiale del cielo

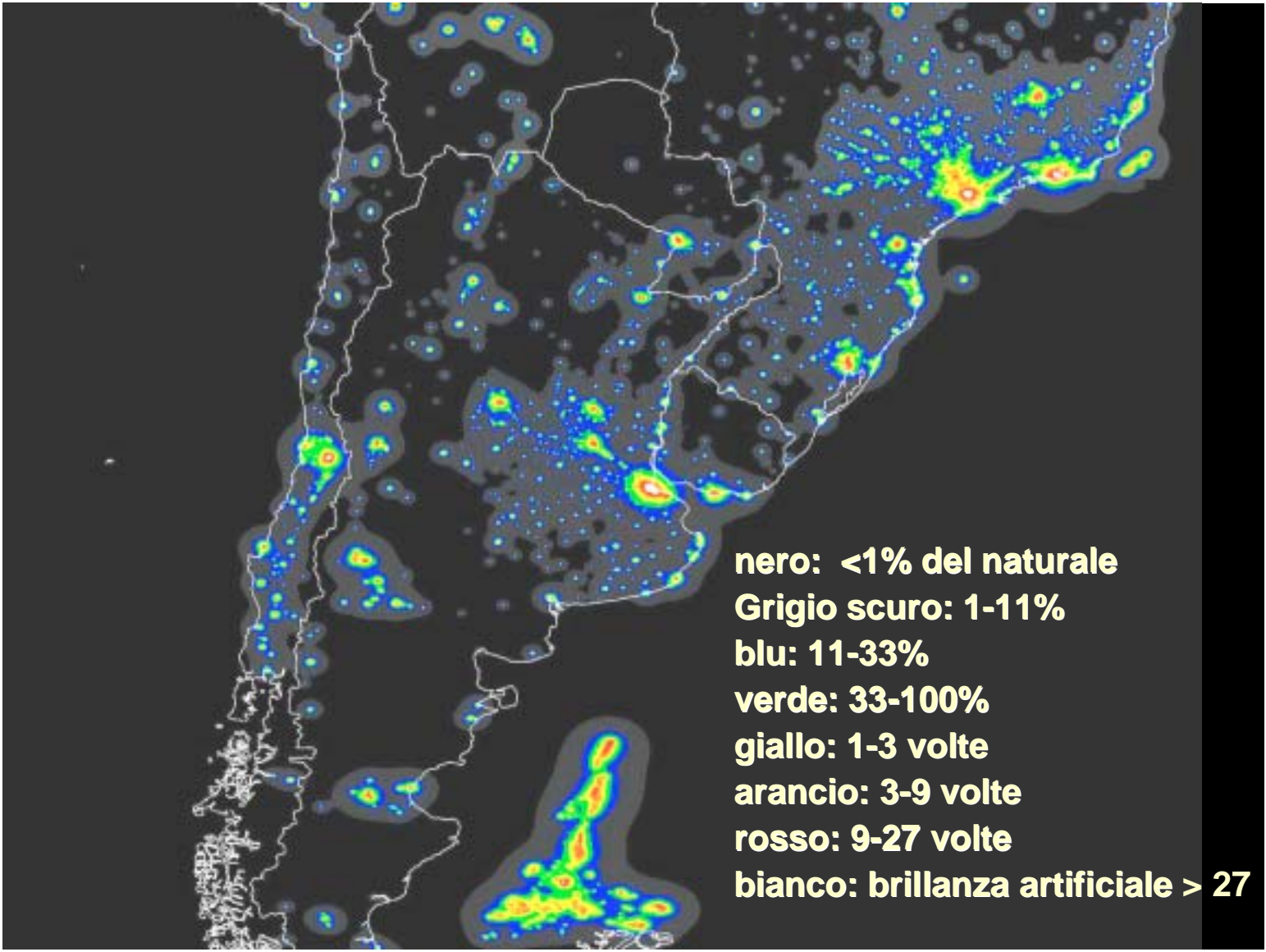
- Calcolate per un'estinzione di 0.33 mag nella banda V
- La brillantezza naturale è assunta essere di 21.6 mag/arcsec² nella banda V
- Il livelli, confrontati con la brillantezza naturale, sono:
 - ◆ nero: brillantezza artificiale <1% di quella naturale
 - ◆ grigio scuro: 1-11%
 - ◆ blu: 11-33%
 - ◆ verde: 33-100%
 - ◆ giallo: 1-3 volte
 - ◆ arancio: 3-9 volte
 - ◆ rosso: 9-27 volte
 - ◆ bianco: brillantezza artificiale > 27 di quella naturale



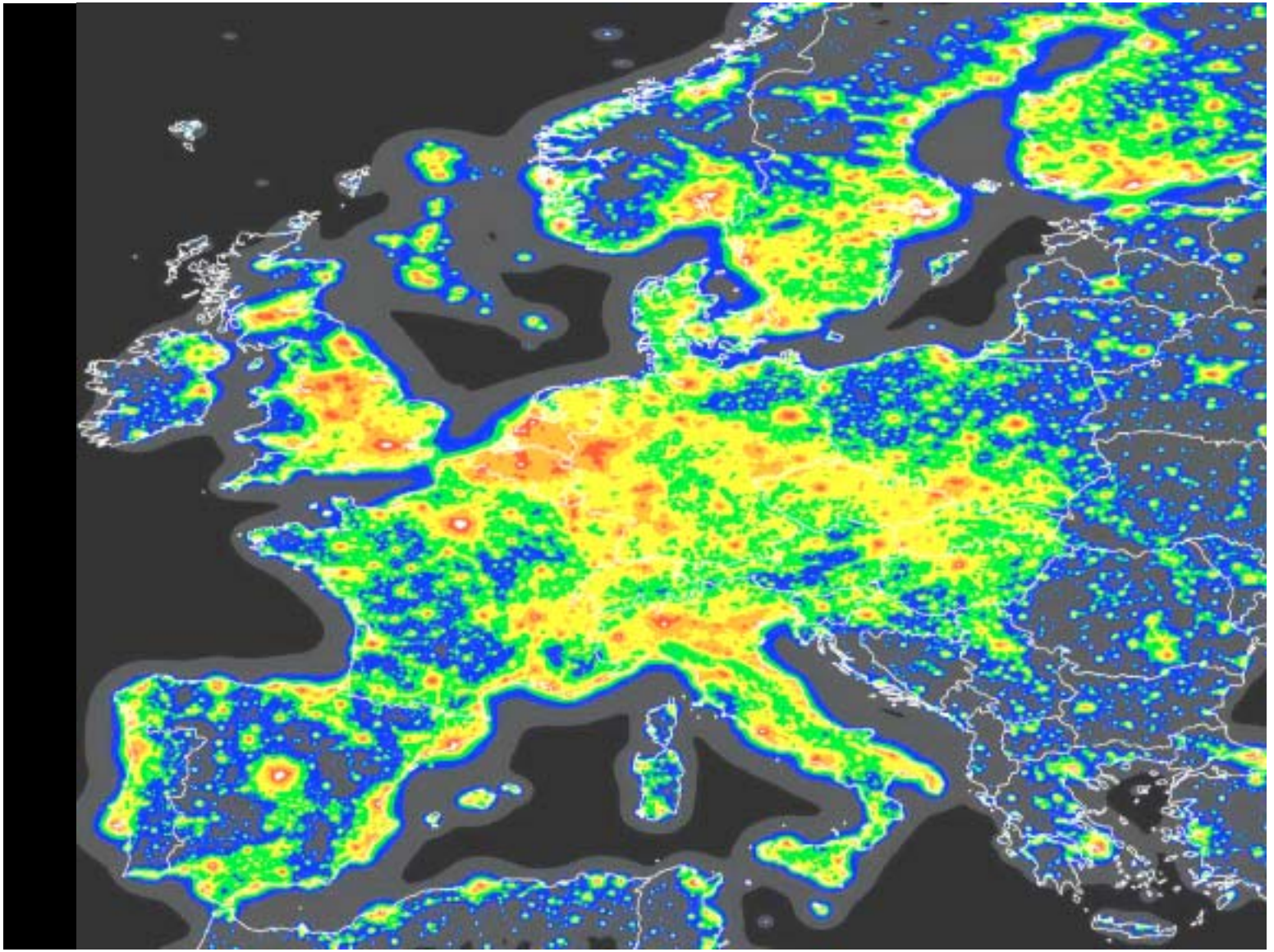


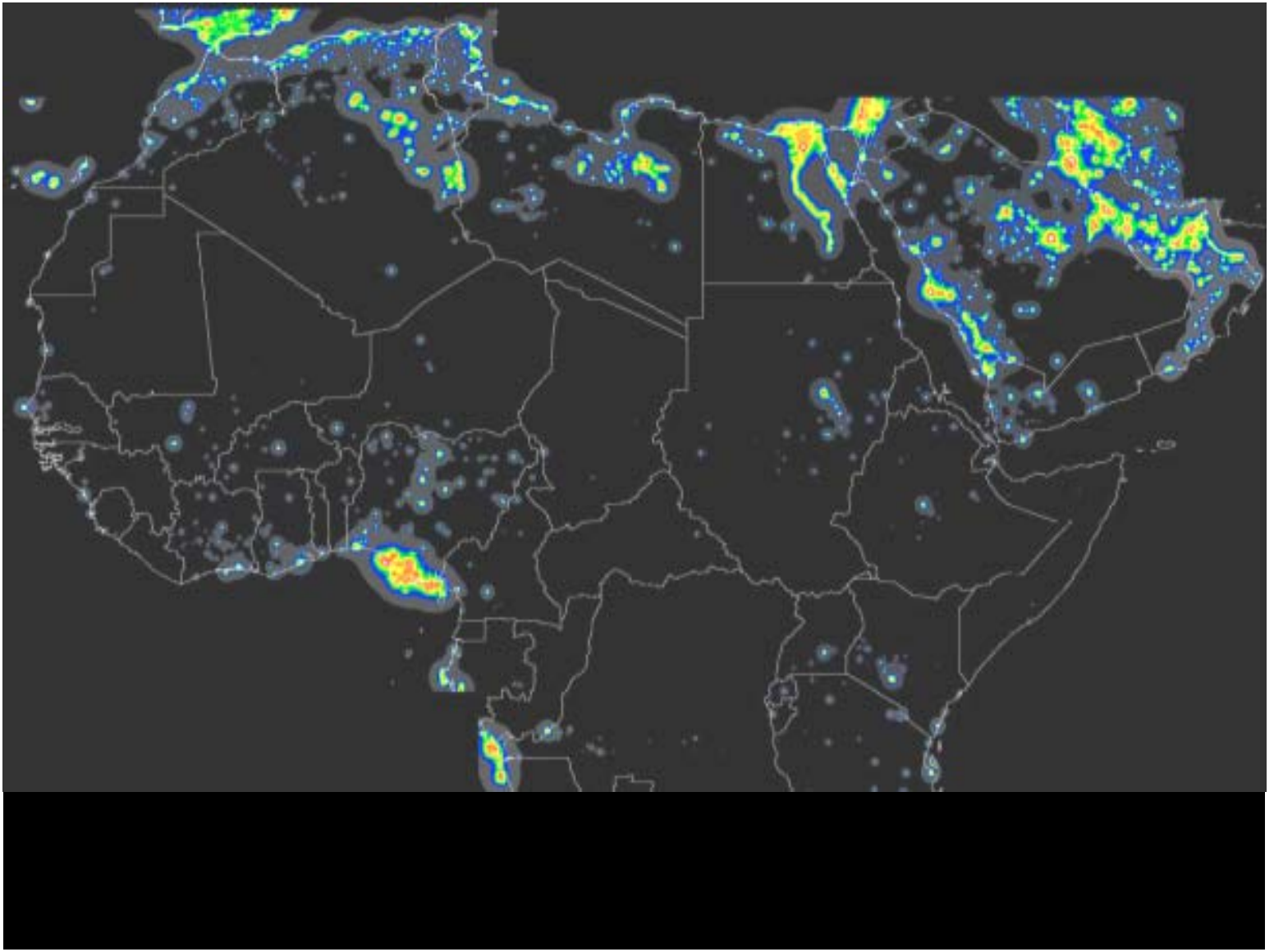


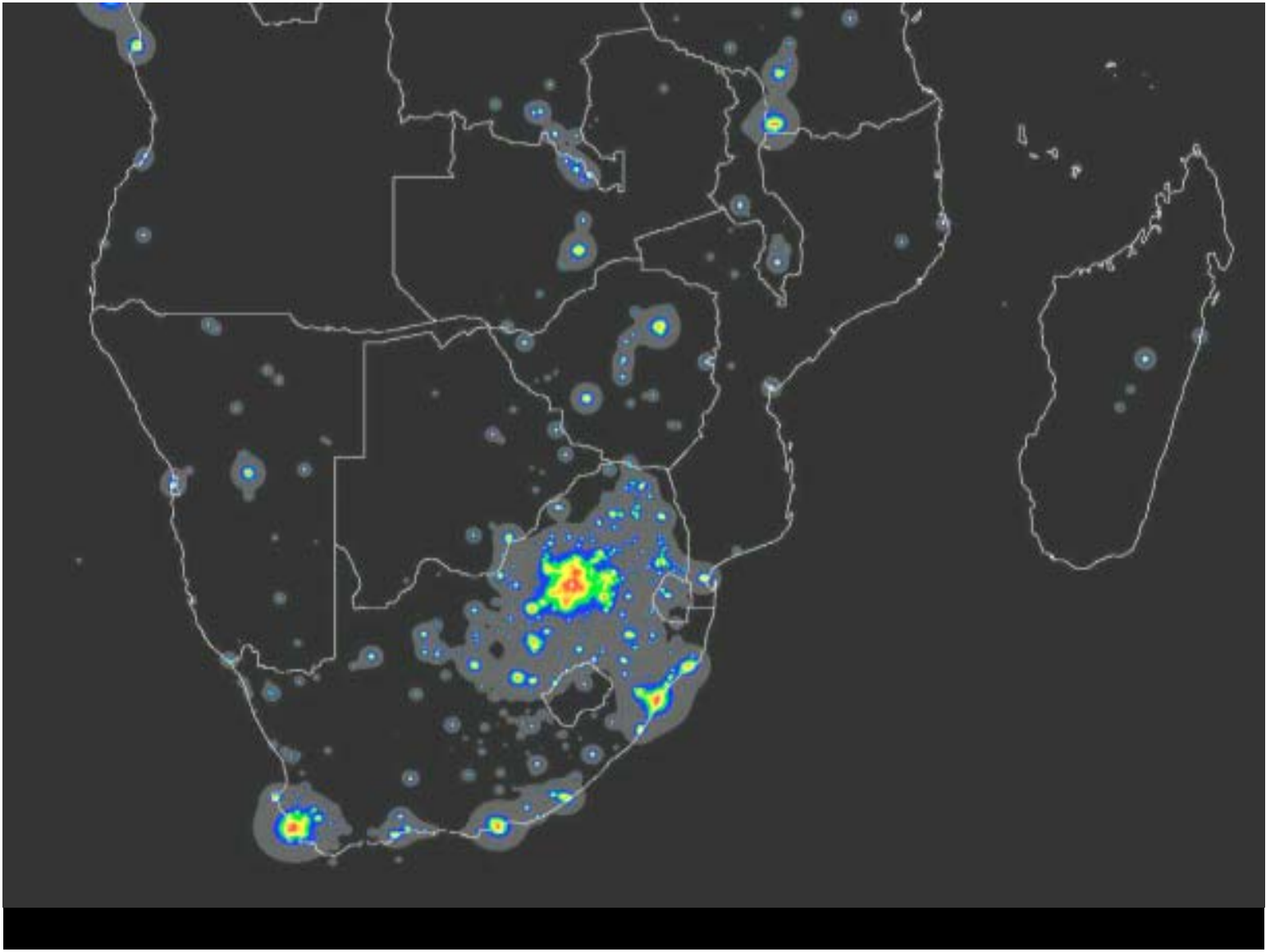
nero: <1% del naturale
Grigio scuro: 1-11%
blu: 11-33%
verde: 33-100%
giallo: 1-3 volte
arancio: 3-9 volte
rosso: 9-27 volte
bianco: brillantezza artificiale > 27

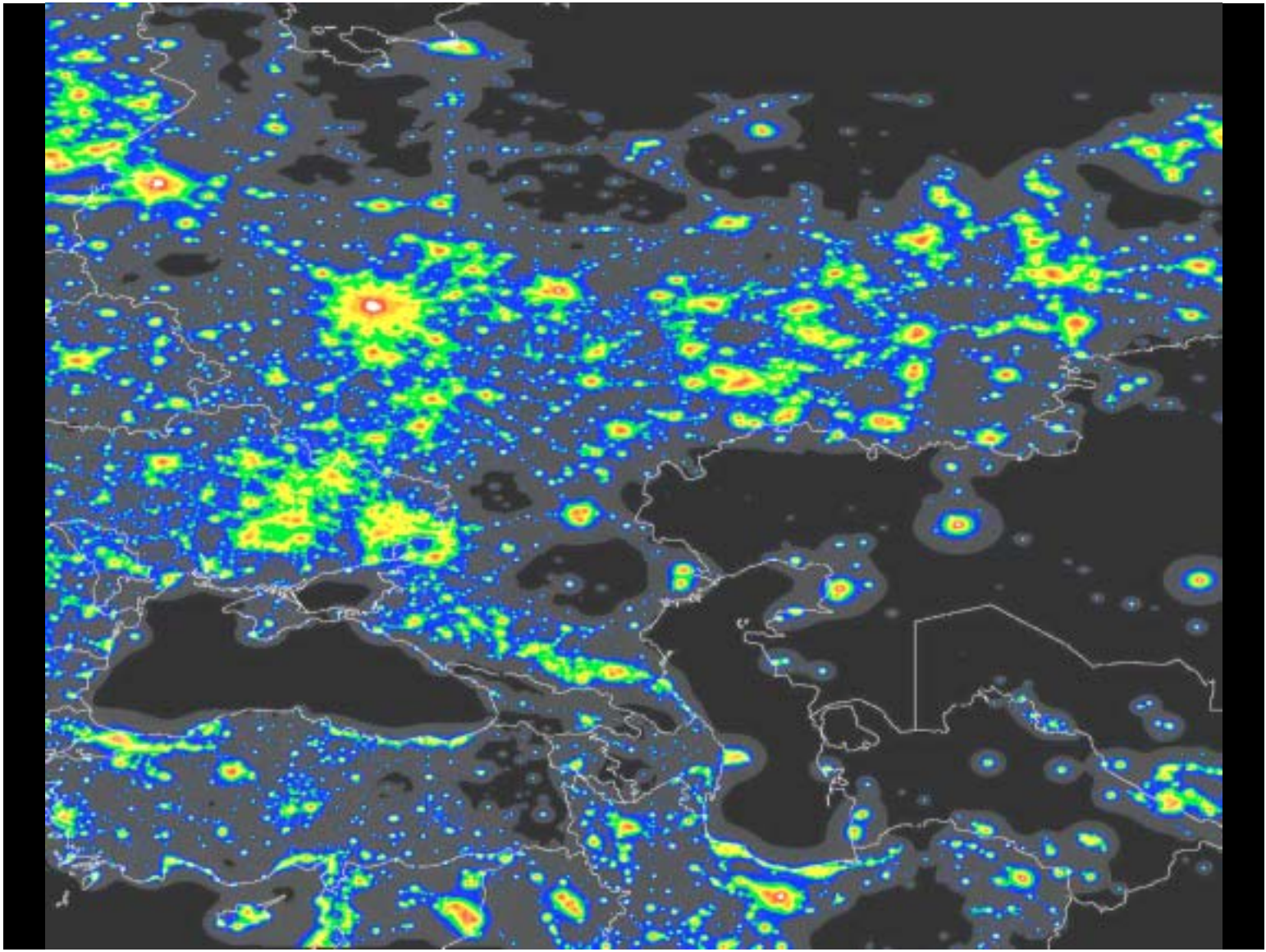


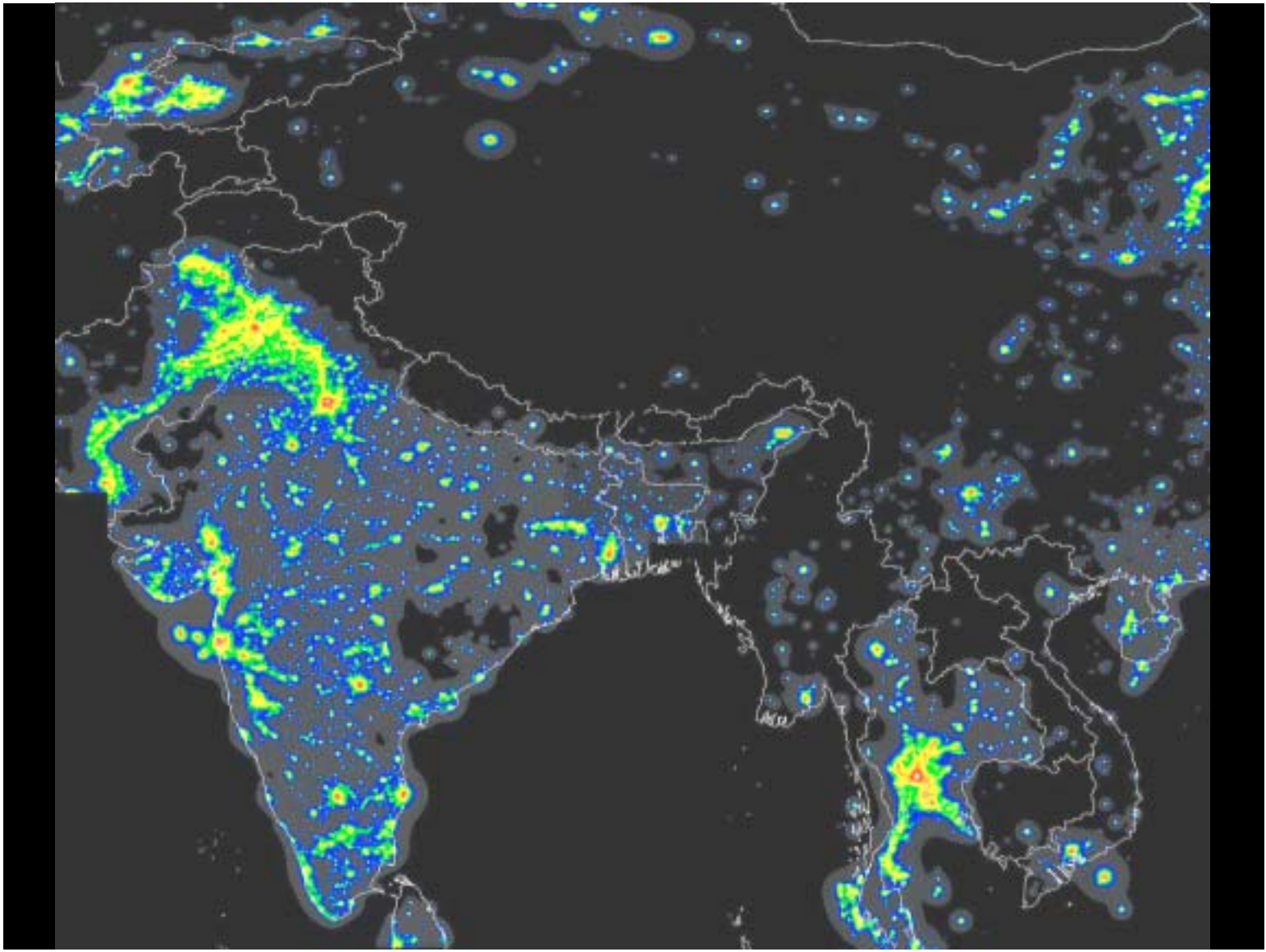
nero: <1% del naturale
Grigio scuro: 1-11%
blu: 11-33%
verde: 33-100%
giallo: 1-3 volte
arancio: 3-9 volte
rosso: 9-27 volte
bianco: brillantezza artificiale > 27

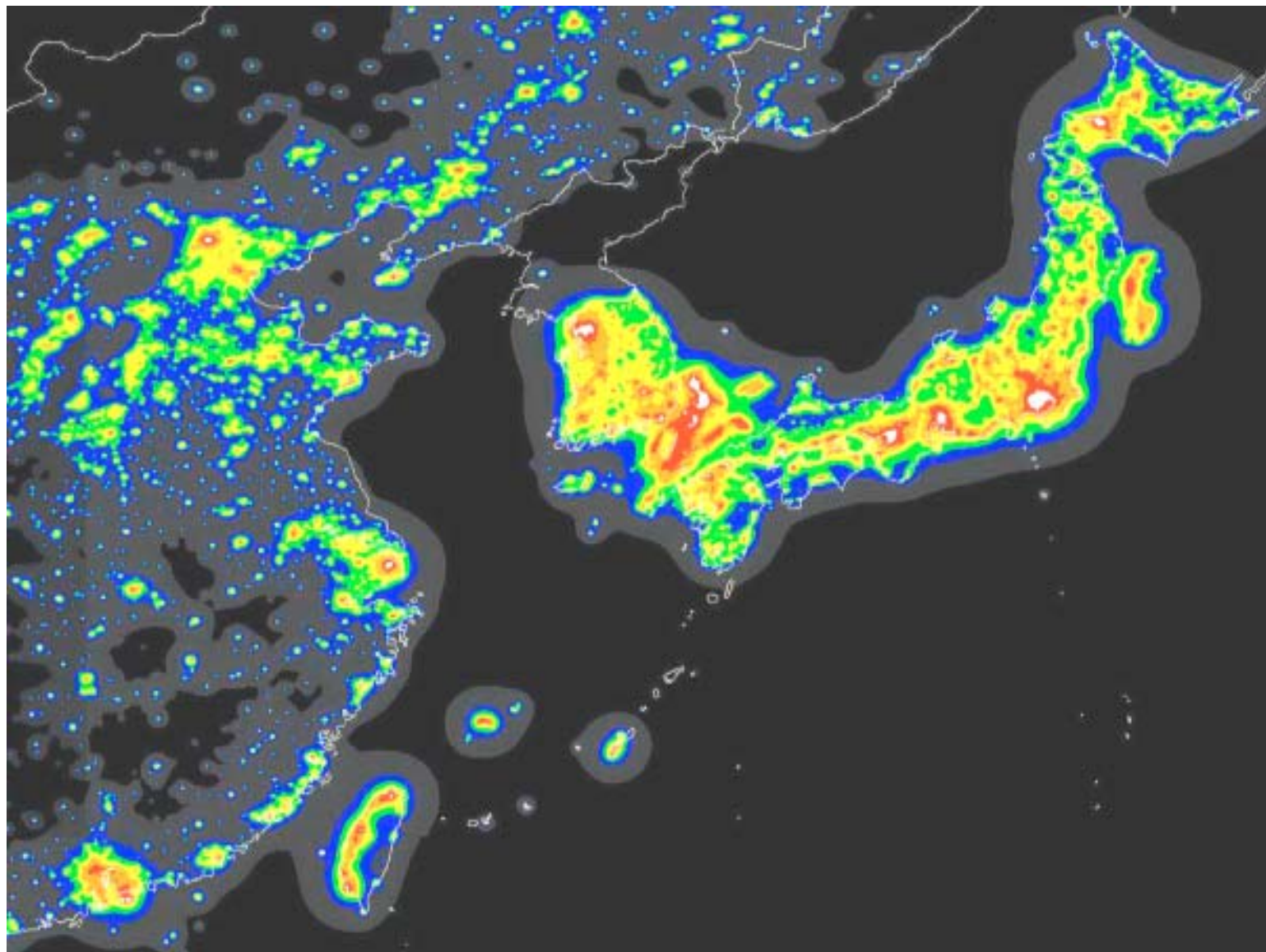


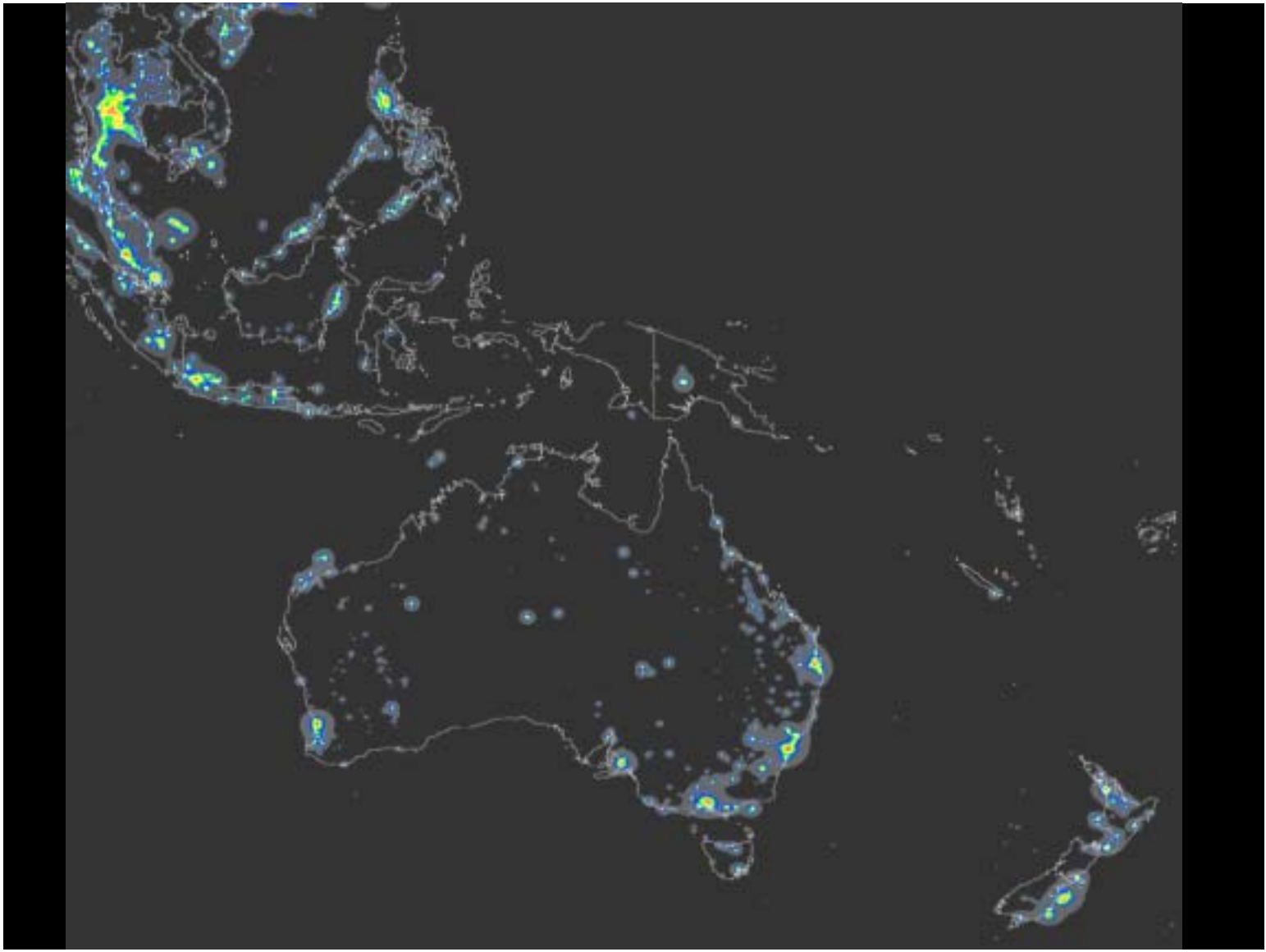


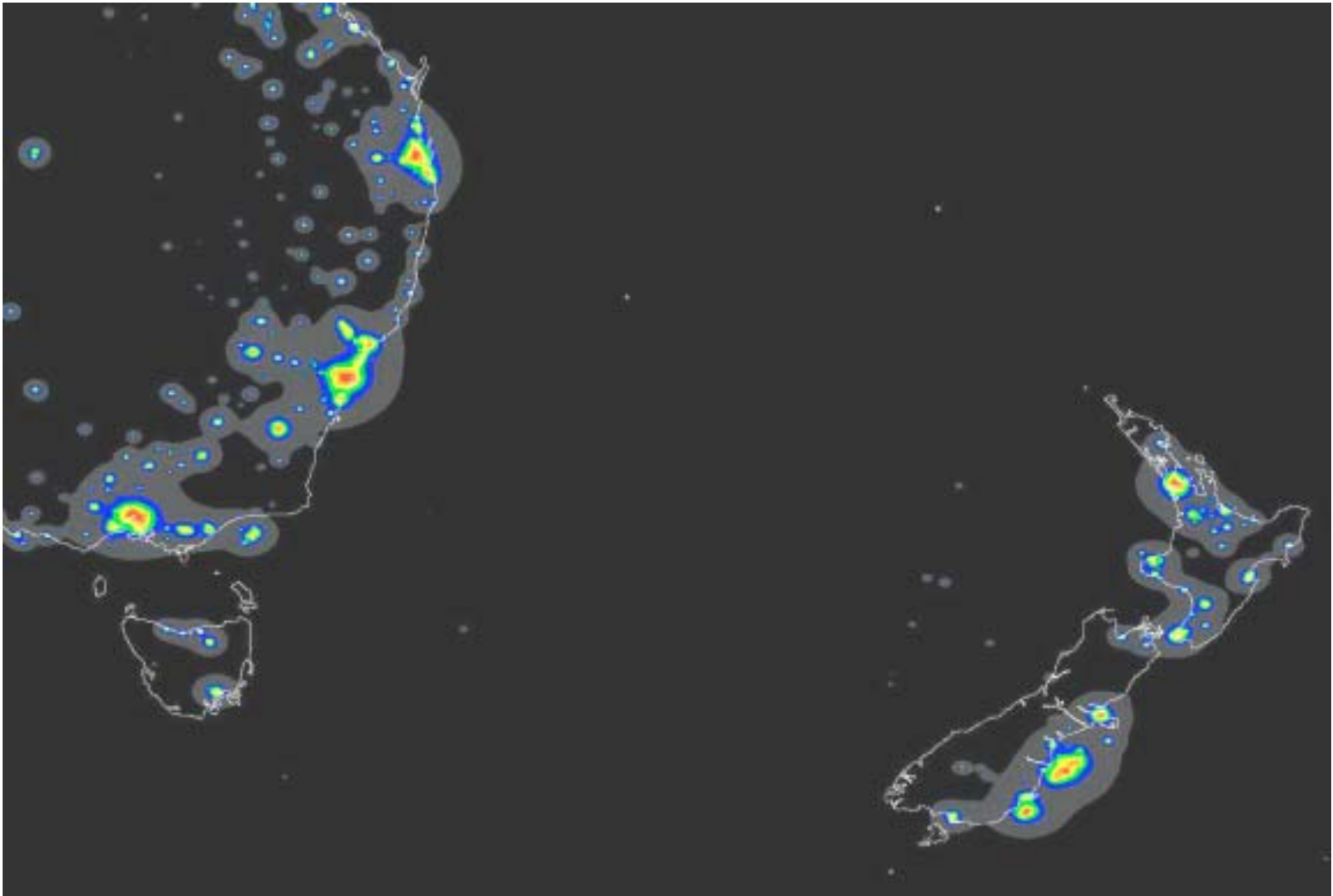












Altri tipi di mappe

Statistiche di superficie e popolazione

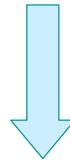
- Confrontando le mappe con il data base della densità di popolazione Landscan 2000 DOE abbiamo ottenuto, per ogni nazione (e per l'Italia, per ogni provincia):
 - ◆ La percentuale di popolazione che vive sotto cieli di una data brillantezza artificiale
 - ◆ La percentuale di territorio con cielo che supera una data brillantezza artificiale

Statistiche di popolazione

Brillanza del cielo	> 0.11	> Bn	> 27	> B mw
NAZIONE				
Italia	100	95	6	50
Giappone	100	96	27	73
Russia	87	73	8	44
U.S.A.	99	93	30	71
Europa (E.U.)	99	90	8	51
Mondo	62	43	6	21

La crescita dell'inquinamento luminoso

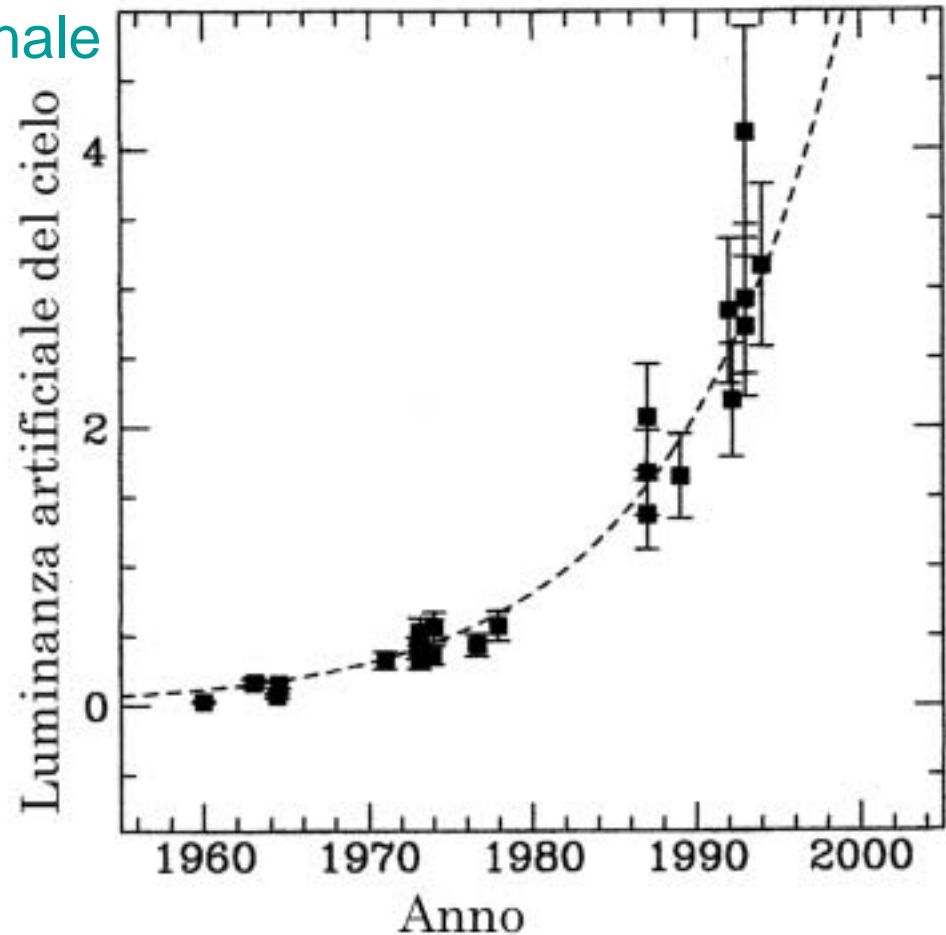
- Nel mondo si assiste ad una crescita generalizzata del flusso installato
 - ◆ +10% annuo in Canada (Berry, 1976)
 - ◆ +10% annuo in Italia (Cinzano, 2000)
 - ◆ +10-20% annuo in Giappone (Isobe e Hamamura, 1998)

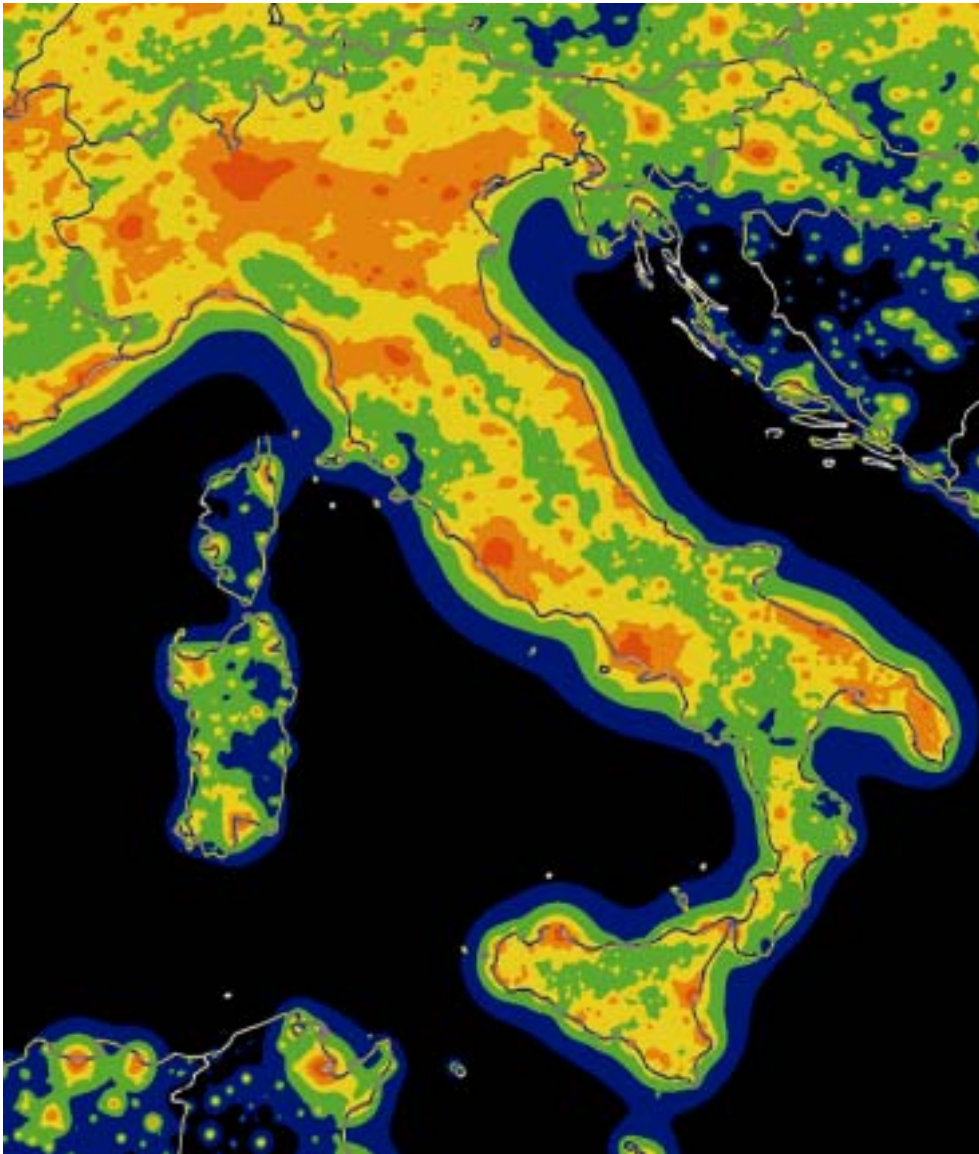


- Crescita esponenziale della brillantezza artificiale del cielo e degli effetti negativi dell'inquinamento luminoso

Crescita in Italia

- +10% annuo dal 1960 (Cinzano Mem. S.A.It., vol 71, n.1, 2000)
- Raddoppio decennale



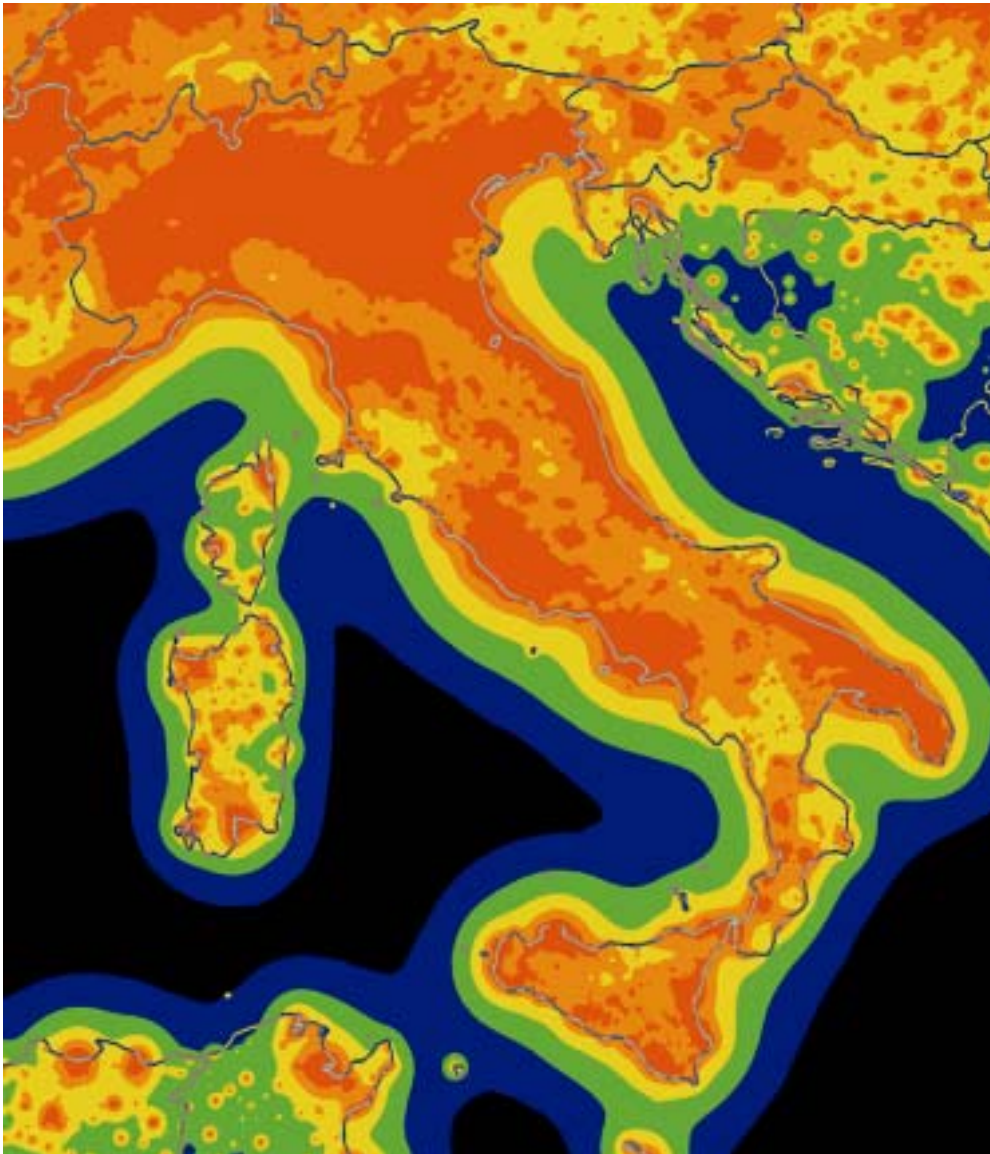


Luminanza artificiale

- Calcolata per il 1998
- Espressa in rapporto a quella naturale:
 - ◆ nero: <0.1 volte
 - ◆ blu: 0.1-0.3
 - ◆ verde: 0.3-1
 - ◆ giallo: 1-3
 - ◆ arancio: 3-9
 - ◆ rosso: >9 volte

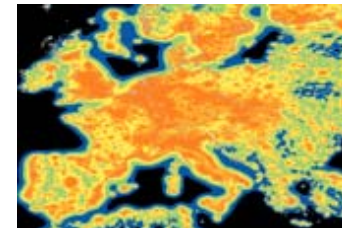


Luminanza artificiale nel 2025

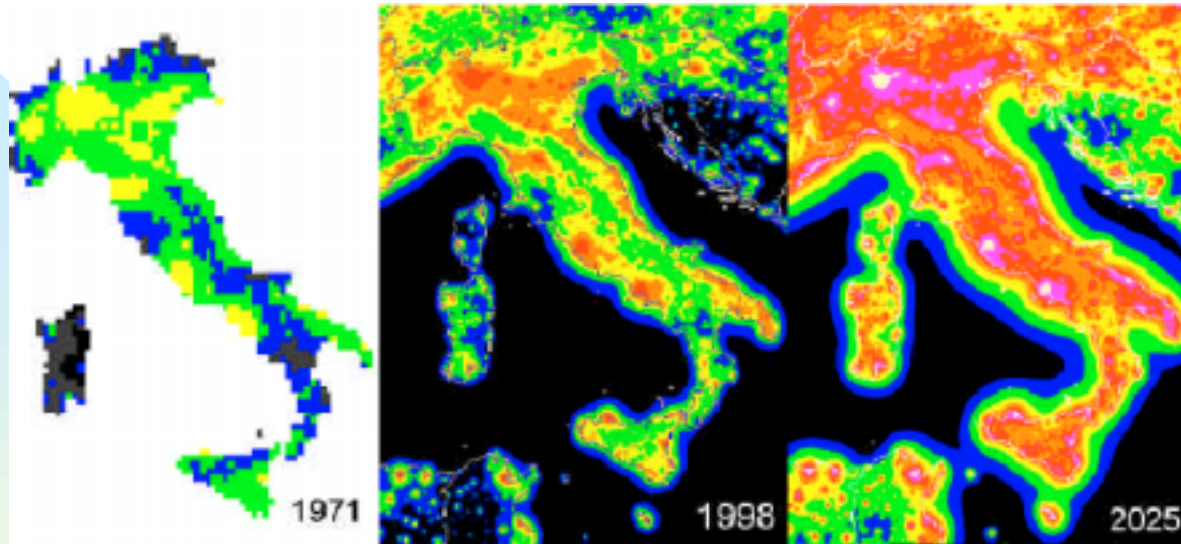


■ **Espressa in rapporto a quella naturale:**

- ◆ nero: <0.1 volte
- ◆ blu: 0.1-0.3
- ◆ verde: 0.3-1
- ◆ giallo: 1-3
- ◆ arancio: 3-9
- ◆ rosso: >9 volte



Crescita in Italia: 1971-2025



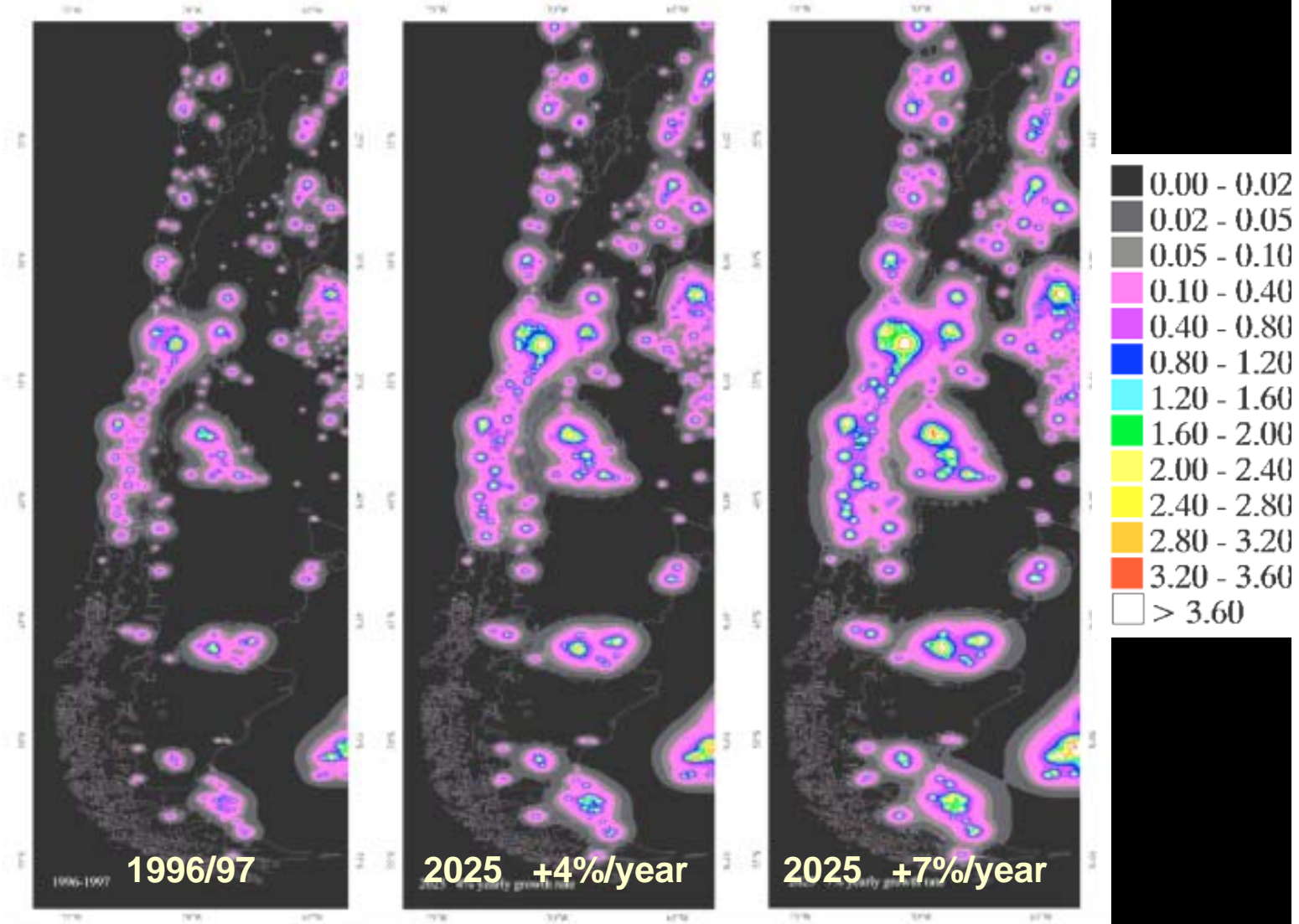
mappa 1971 (Bertiau et al.)		mappa 1998		mappa 2025	
<5%	nero	<11%	nero	<11%	nero
6-15%	grigio				
16-35%	blu	11-33%	blu	11-33%	blu
36-110%	verde	33-100%	verde	33-100%	verde
>1.1	giallo	1-3	giallo	1-3	giallo
		3-9	arancio	3-9	arancio
		>9	rosso	9-27	rosso
				27-81	violetto
				>81	bianco

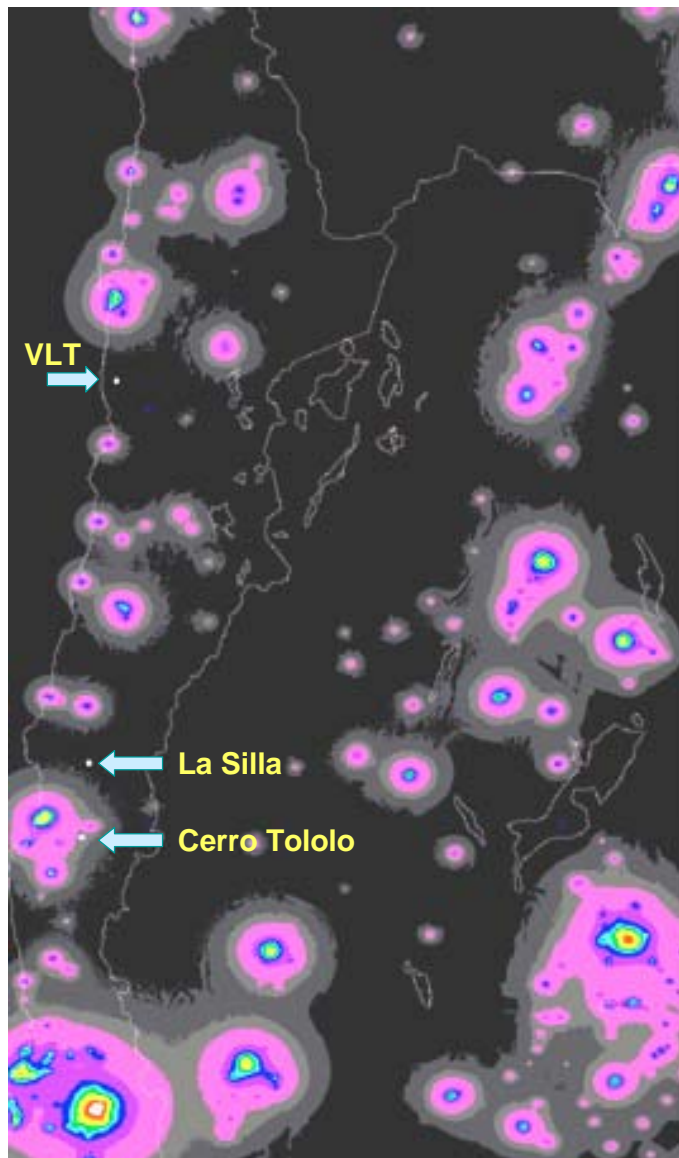
Crescita della brillantezza artificiale in Cile

(da Cinzano et. Al., in 'Light Pollution: The Global View', Kluwer Academic Publishers, 2003)

- Mappe calcolate tenendo conto dell'altitudine
- Proiezioni per l'anno 2025:
 - ◆ + 4% di crescita annua del flusso verso l'alto (stima prudentiale)
 - ◆ + 7% / anno (stima realistica)
 - ◆ No leggi/norme anti inquinamento luminoso

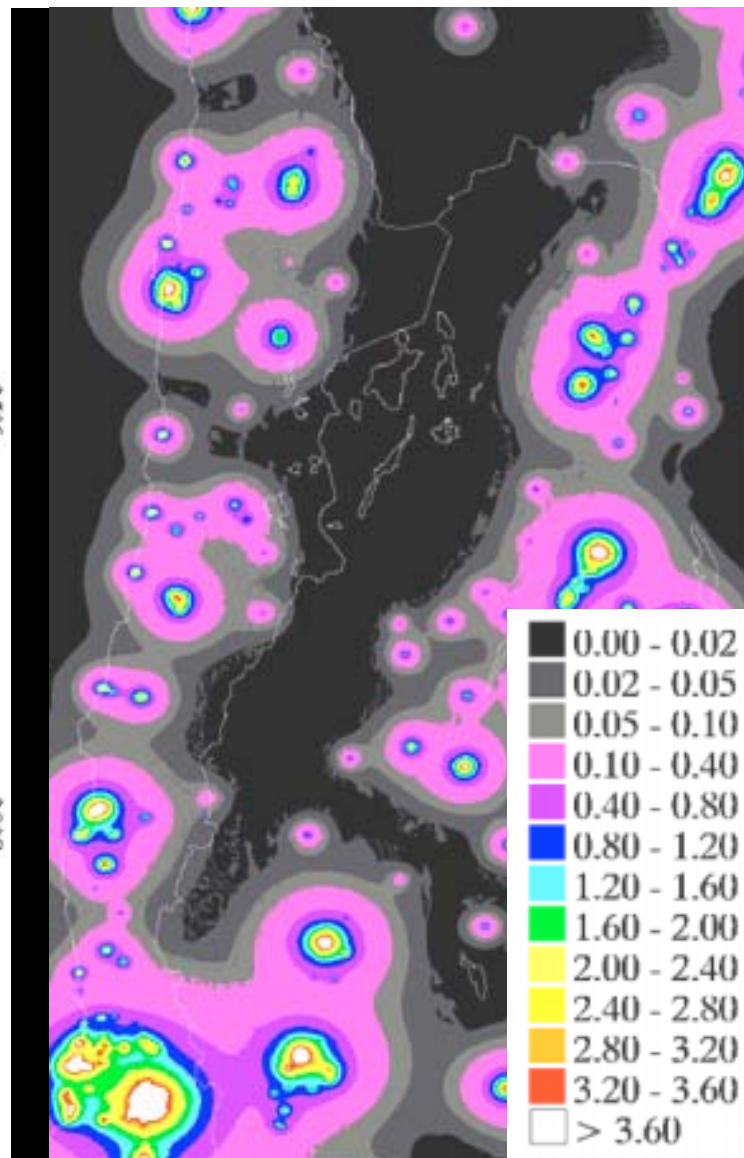
Night Sky Brightness in Chile due to Light Pollution





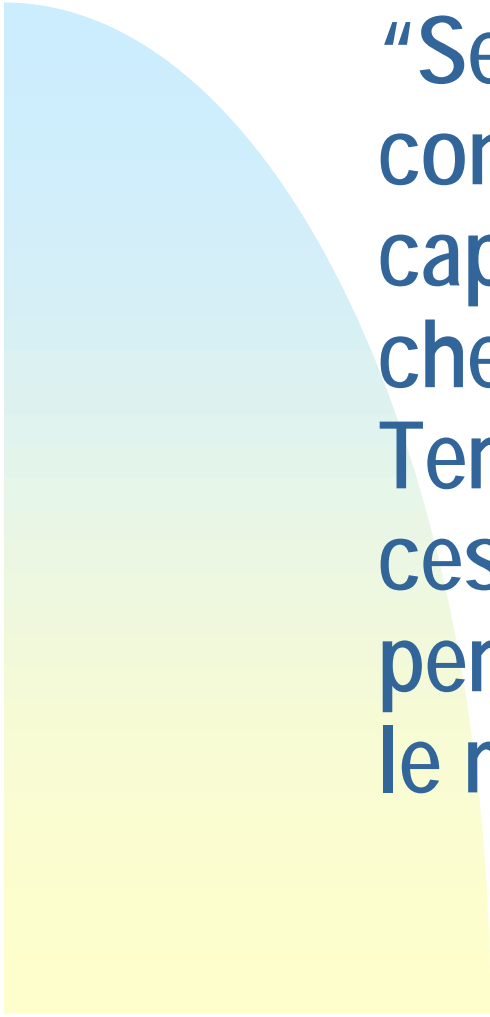
25°S

30°S



25°S

30°S



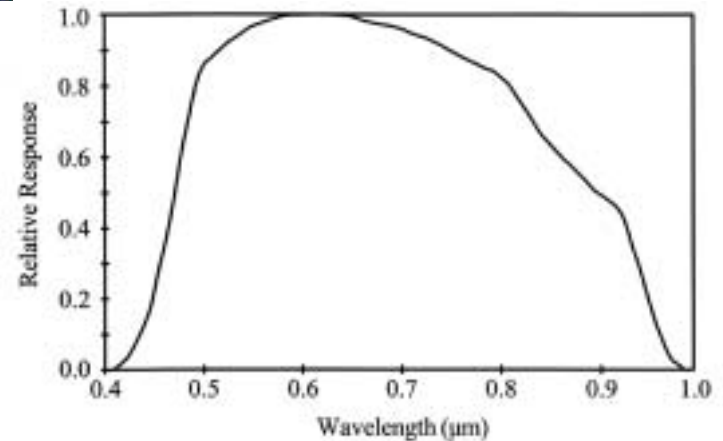
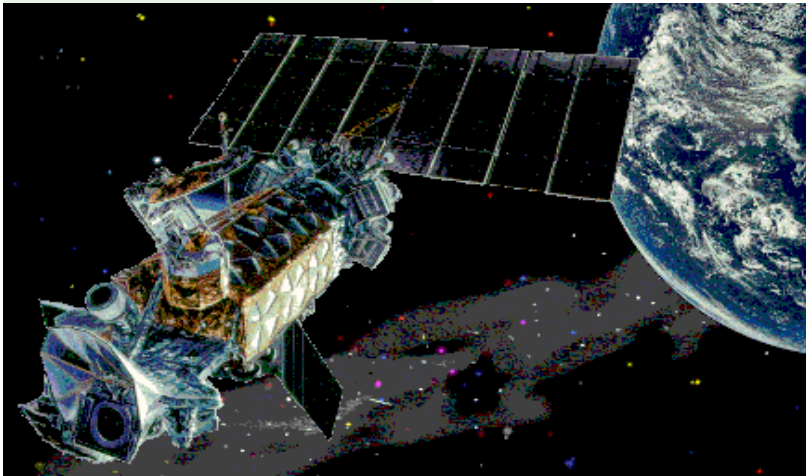
“Se le stelle, anziché brillare continuamente sul nostro capo, non si potessero vedere che da un solo punto della Terra, gli uomini non cesserebbero dal recarvisi per contemplare ed ammirare le meraviglie dei Cieli”

Seneca

Defense Meteorological Satellite Program

Air Force and Missile System center

- altitude 830 km, period 101^m, 14 orbit/day
- positioning by radar+orbital mechanics
- instruments: OLS+PMT (visible), OLS+TIR (infrared)
- nominal resolution 2.8km GSD, EIFOV 2.2-5.4km
- fine resolution (future studies)
- PMT sensitivity $10^{-10} \text{ W cm}^{-2}\text{sr}^{-1}\mu\text{m}^{-1}$
- PMT spectral range 470-900 nm FWHM



Satellite data

F-12 OLS visible data acquired with a range of gain settings

Solar Glare

17 dB

23 dB

29 dB

35 dB

41 dB

35 dB

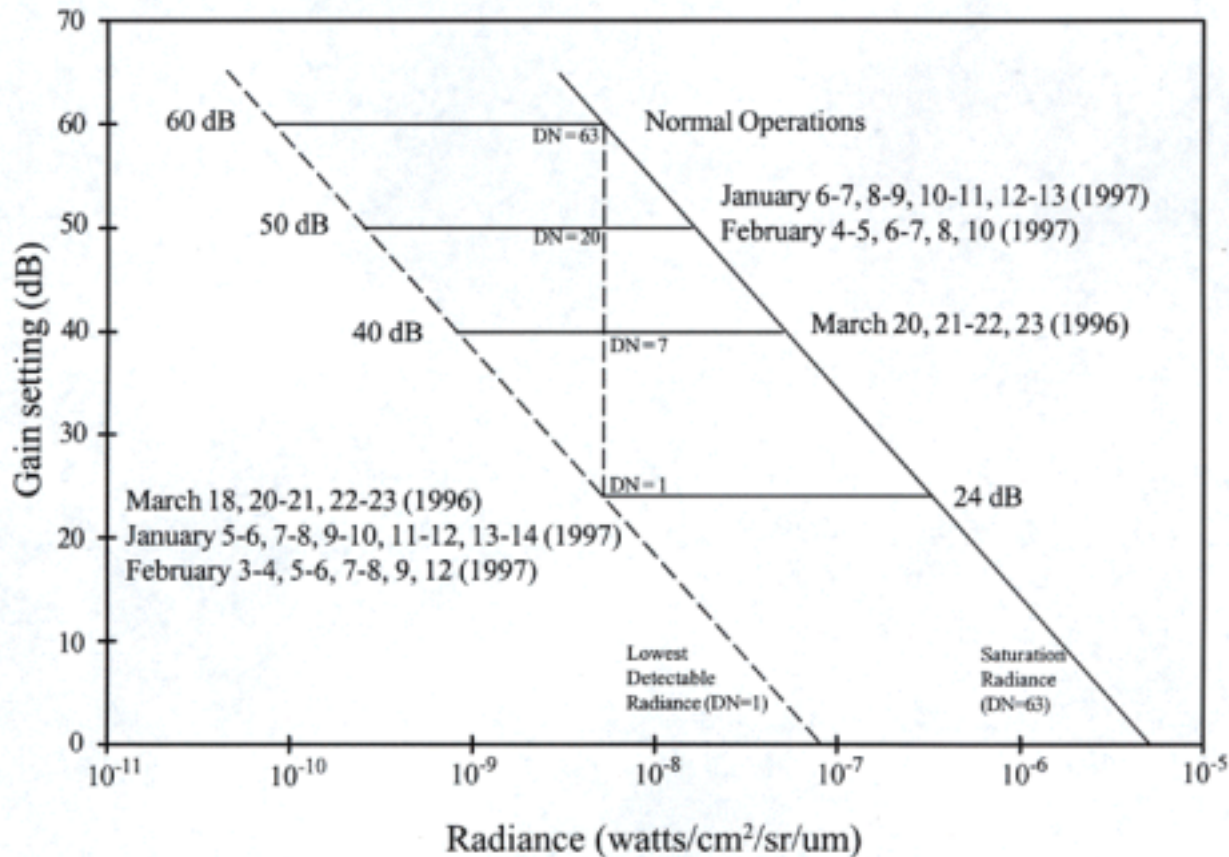
**Normal
Operations**



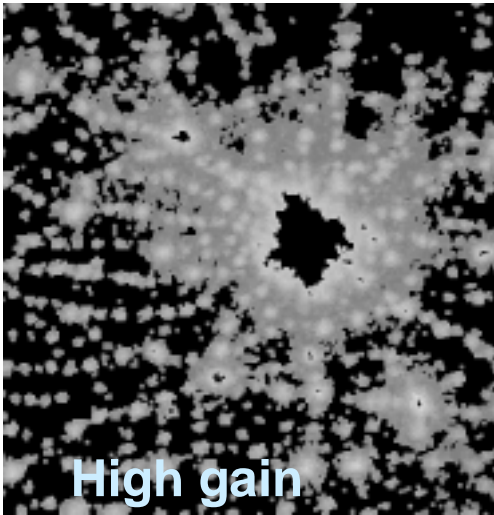
Composite satellite data

- low and medium gain **imaging** with DMSP OLS-PMT in 26 dark nights of 1996-1997
- **revision of images** from each suborbit, noise subtraction, cleaning of defective scan lines and cosmic rays, solar glare
- **cloud identification** in TIR OLS images
- **geolocation** of lights and clouds on a reference grid with finer spatial resolution than the input images (30"x30")(0.9x0.6km at 45° latitude)
- **calibration** of the 8-bit OLS data in radiance using prior to launch calibration
- determination of the **average radiance** of each land area separately for cloud-free medium gain data and for cloud free low gain data (each one has at least 3 cloud-free detections)
- **composition** of low and high gain average images computing the average radiance weighted for total number of light detections, filtering single detections (ephemeral events such as fires)

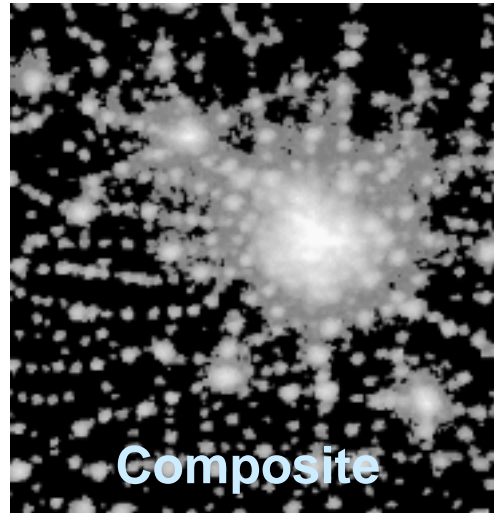
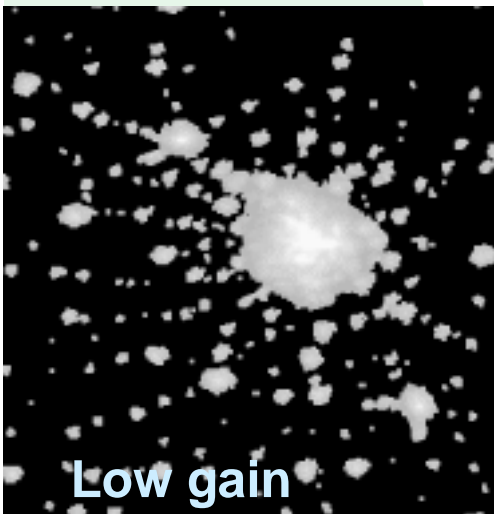
OLS PMT gain setting and radiance delivered



Radiance calibrated OLS composite data



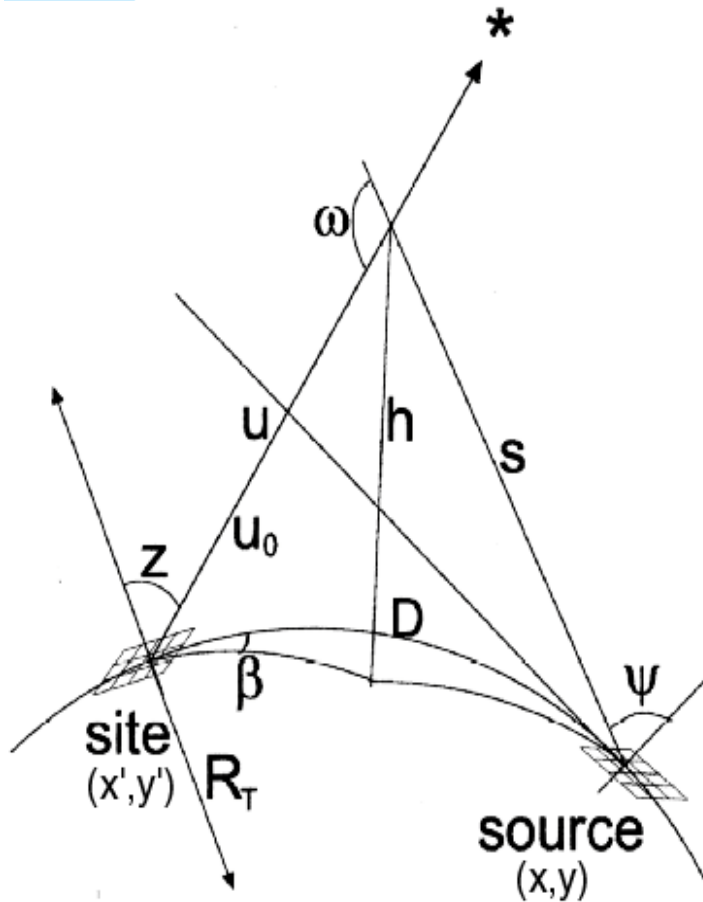
Compositing is used to overcome the dynamic range limitations of the OLS sensor



Artificial sky brightness maps computation

- we divided the surface Earth (where 98% of population lives) in land areas with the same positions and dimensions as the projections on the Earth of the pixels of the composite radiance image
- each land area is assumed to be source of light pollution with an upward emission per unit solid angle proportional to the radiance measured in the corresponding pixel multiplied by the surface area
- we computed sky brightness at the centre of each area summing contributions from all areas (as point sources) in a 200 km radius

Computation of artificial sky brightness



Modelling technique from:

Garstang(1986,1889a,1989b,1991,1999, etc.)

Cinzano(1999a,1999b,1999c)

Taking in account of Rayleigh

scattering by molecules, Mie scattering by haze aerosols, extinction along light paths, vertical distribution of molecules and aerosol, Earth curvature

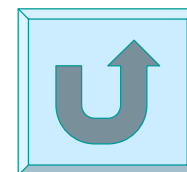
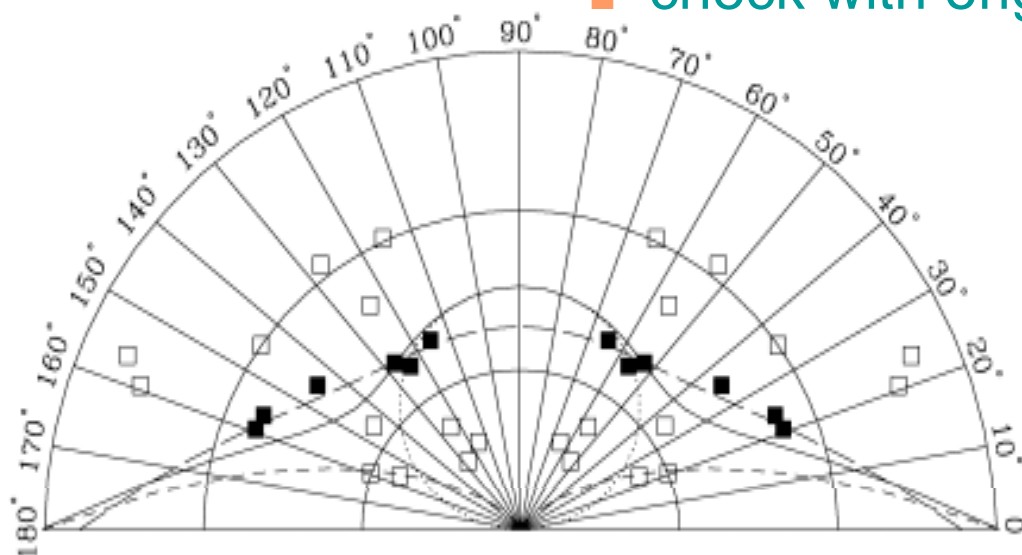
Input data: zenith distance and azimuth of line of sight, distance of the source area, its upward flux, aerosol content

Assumption:

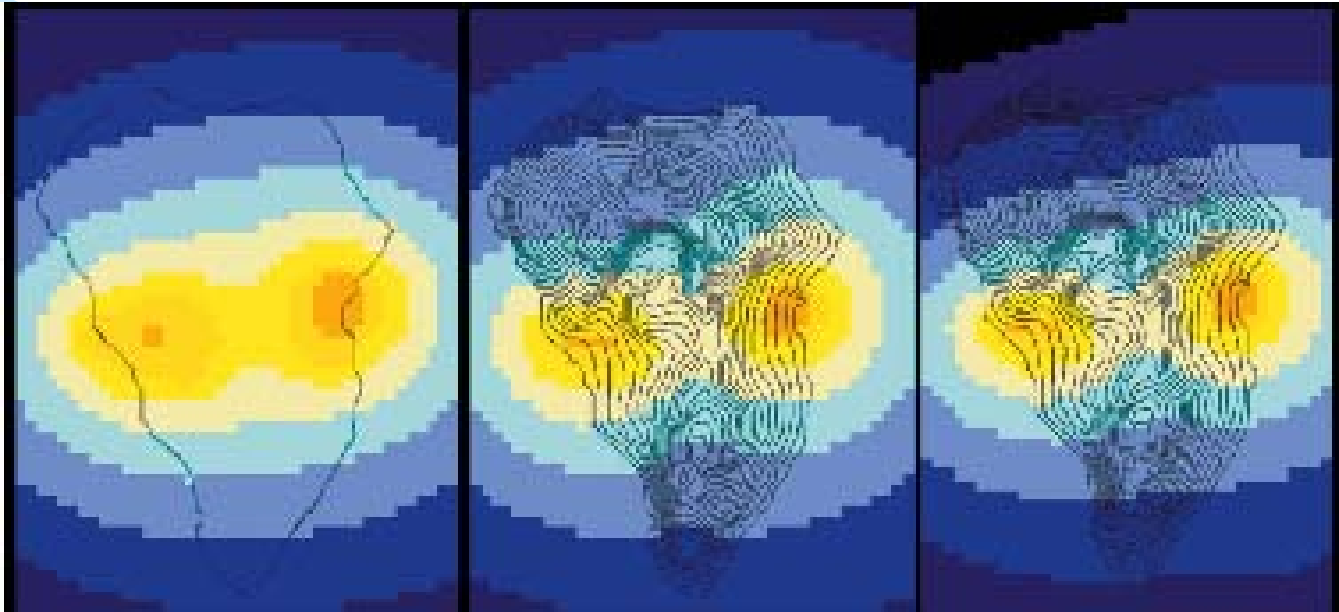
- sources at sea level
- site at sea level (except Chile's new maps)
- upward emission function with the same shape everywhere

Upward emission function

- Average upward emission function used (flux per unit solid angle)
- check with original data



Altitude and screening effect



Sea level

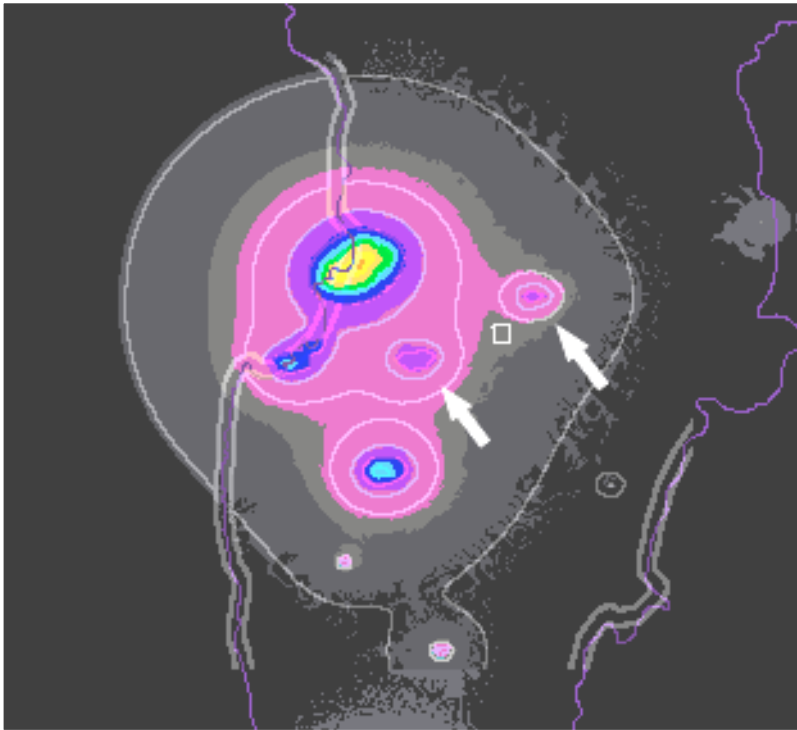
Altitude

Altitude +
screening

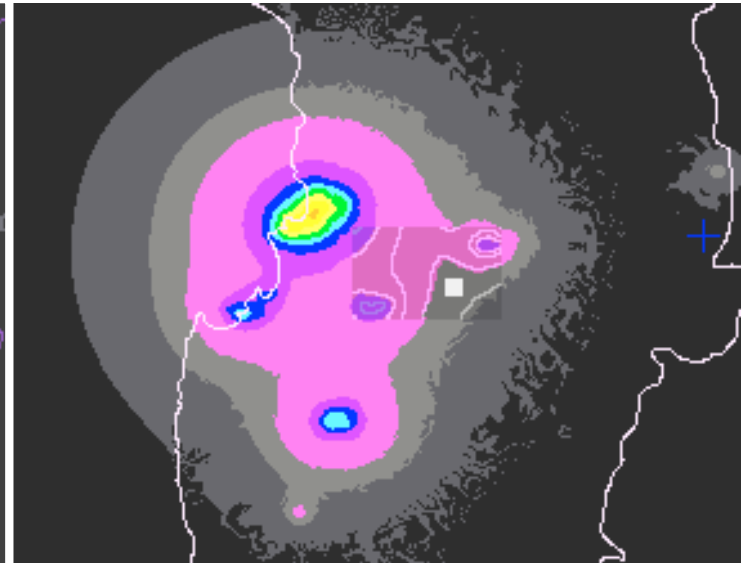
Cerro Tololo



Altitude and screening effect



Sea level
(isophotes) vs.
altitude (colors)

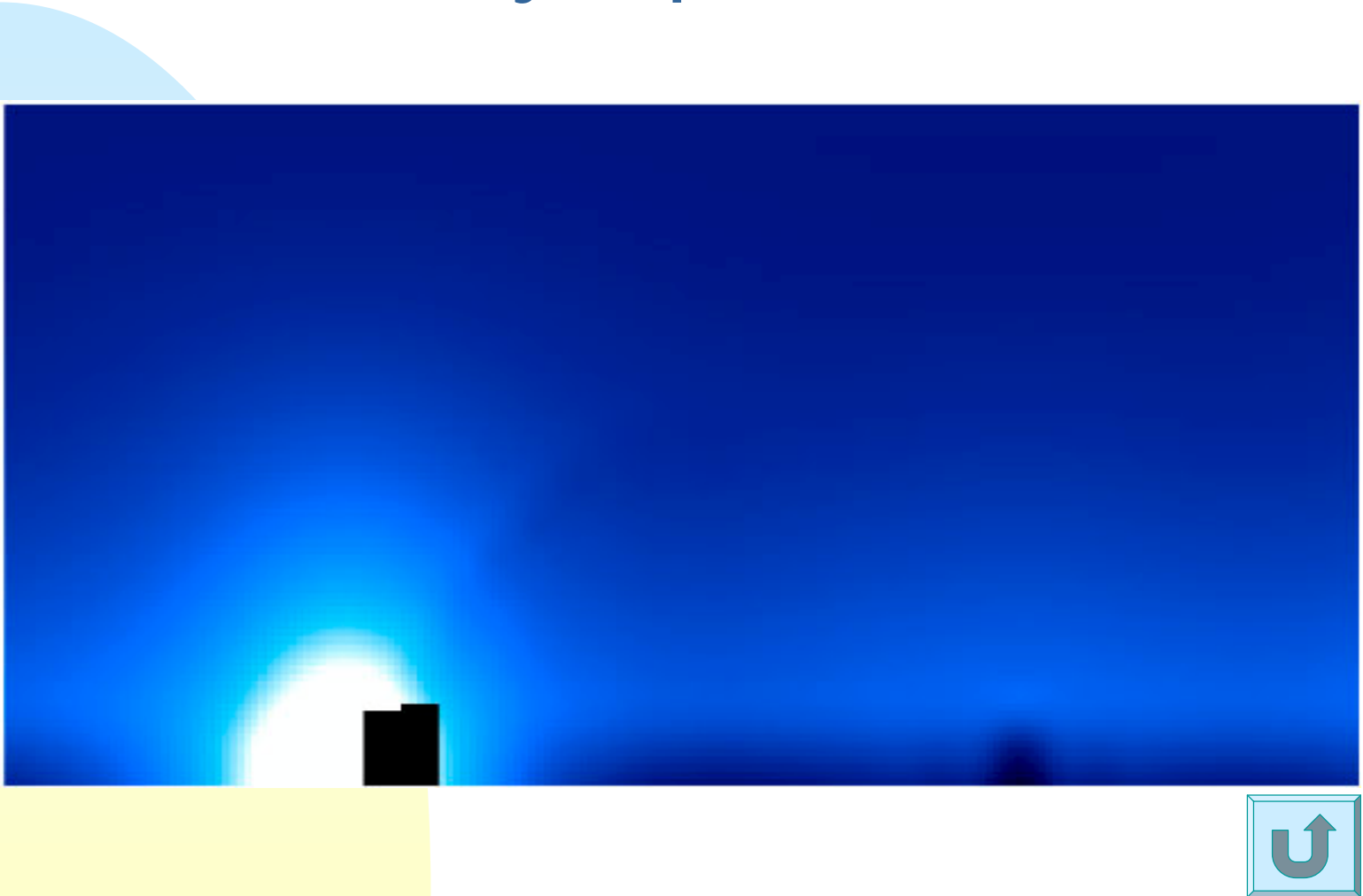


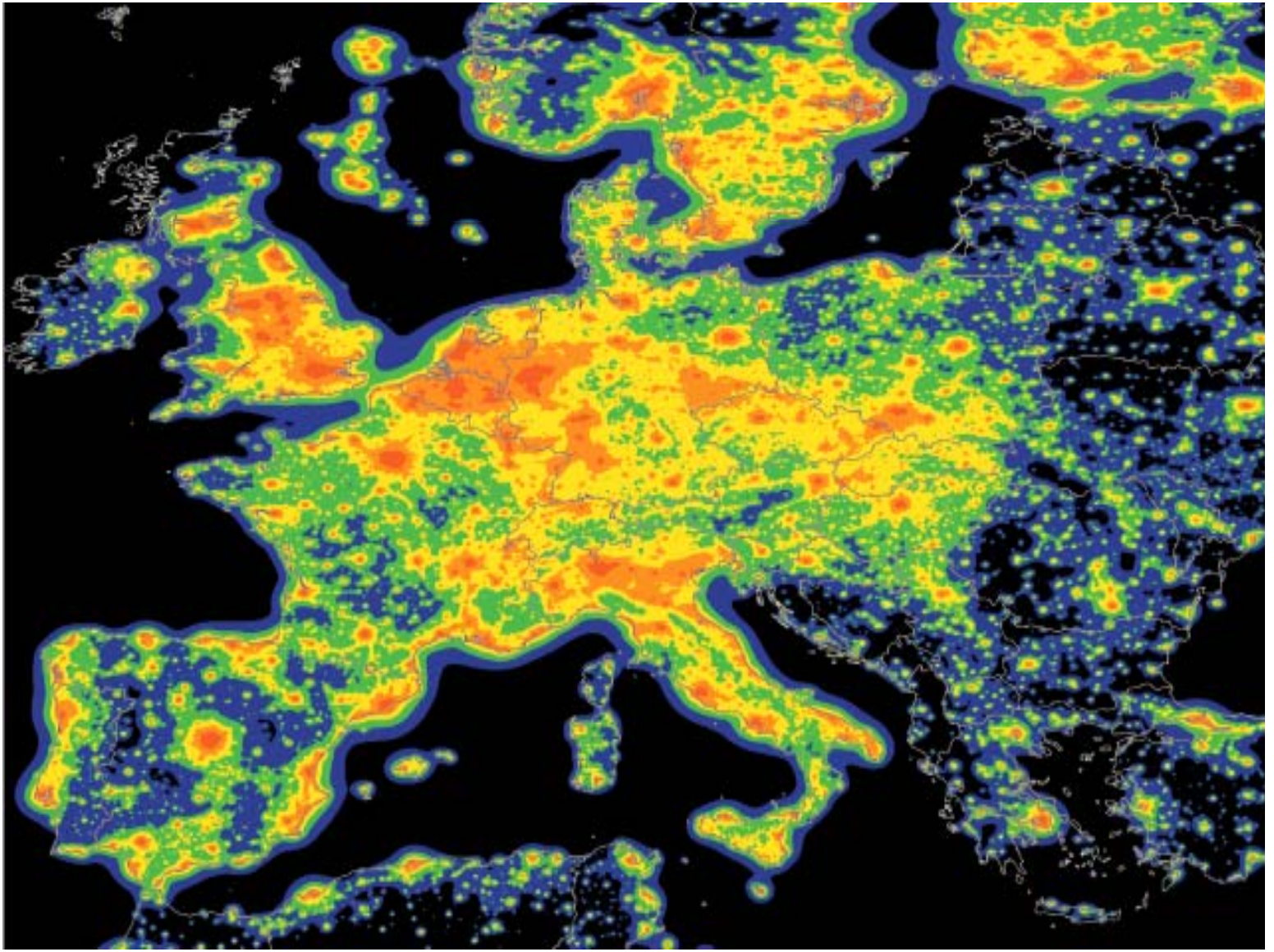
Altitude (colors) vs.
screening (isophotes)

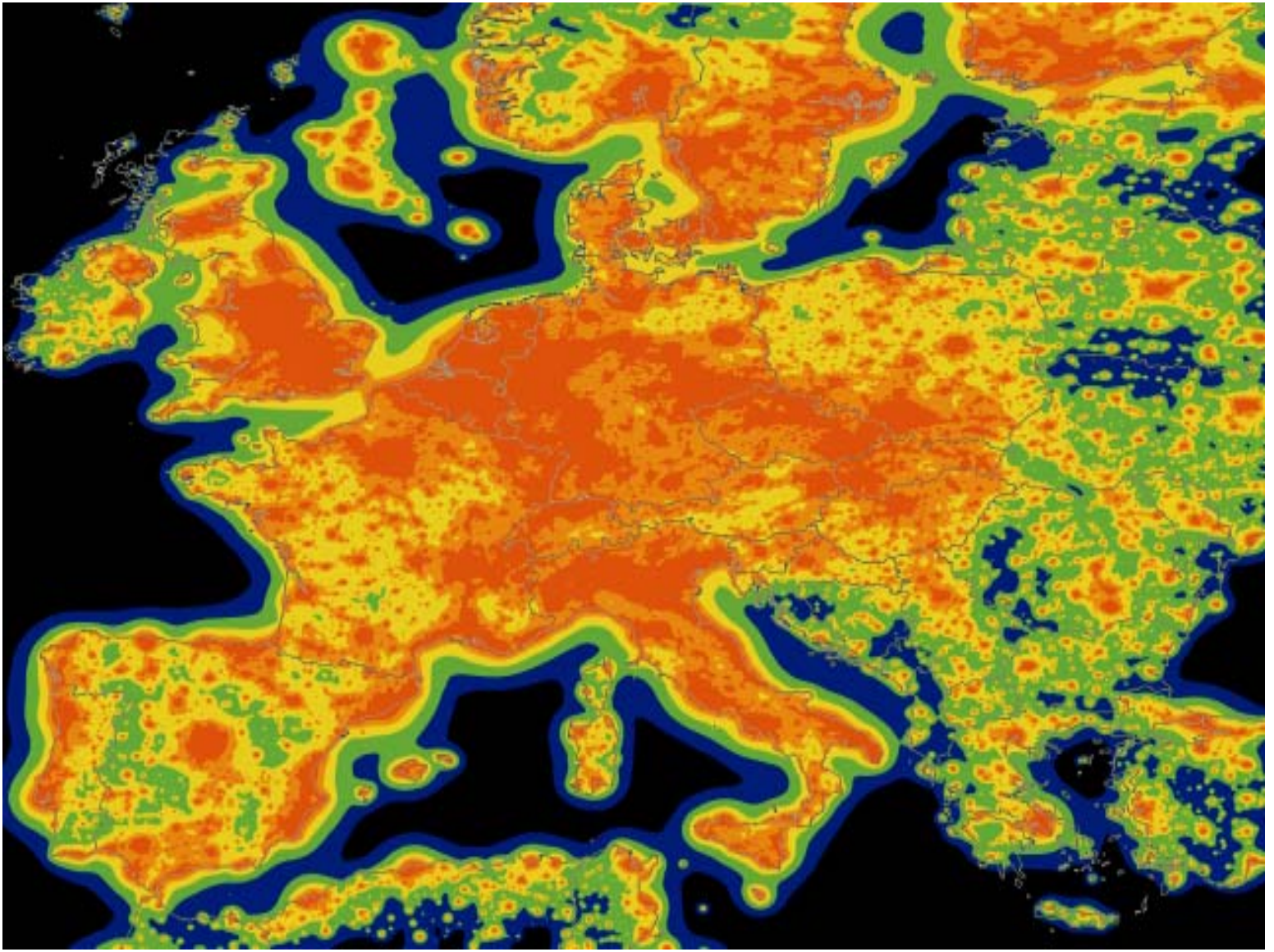
All sky map



All sky map







Further information

- Web:
 - ◆ www.lightpollution.it
 - ◆ www.istil.it

