IDROLOGIA DEL LAGO TRASIMENO

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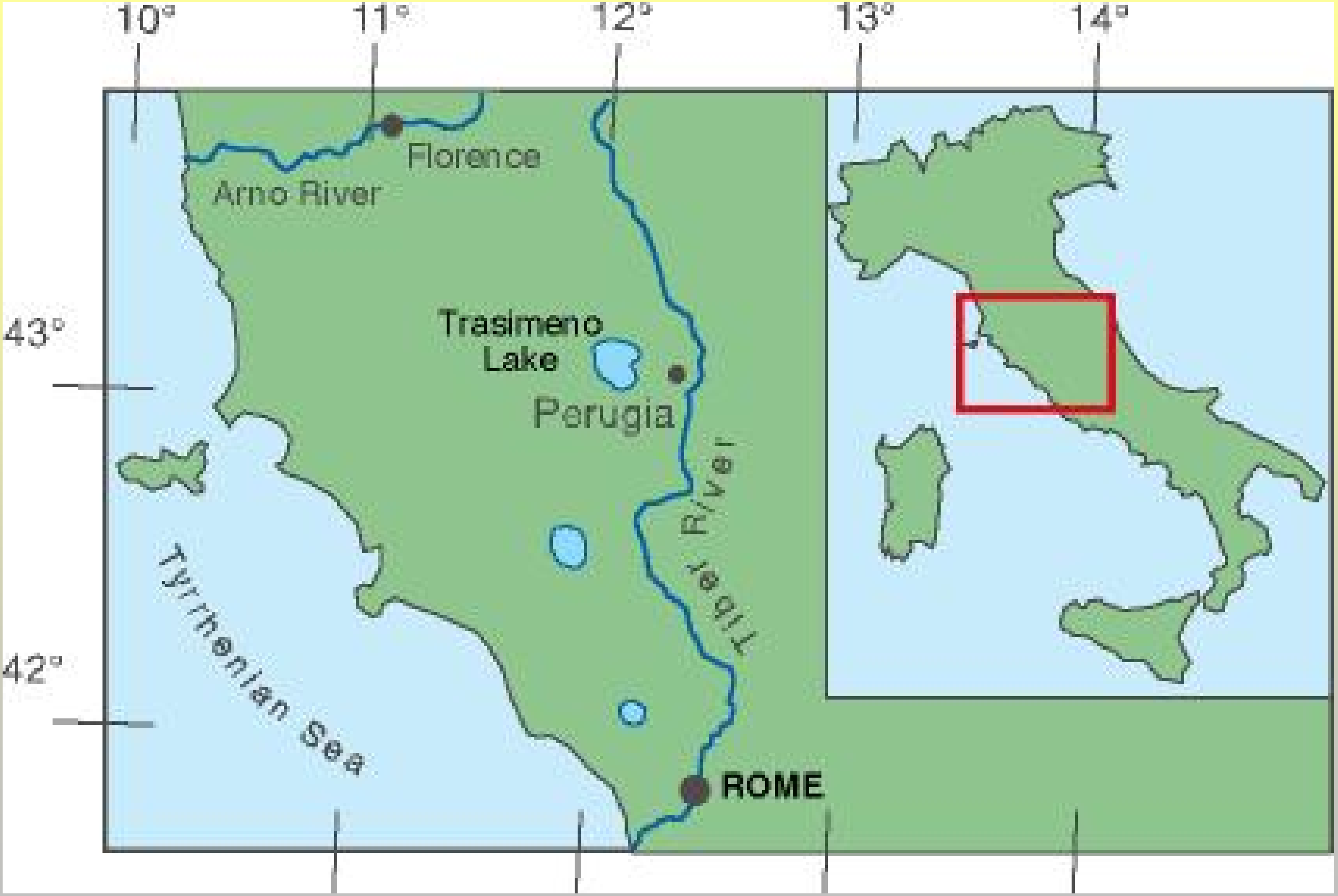
Progetto fondato in parte dalla Provincia of Perugia e dalla Fondazione Cassa di Risparmio di Perugia, progetto 2010.011.0442

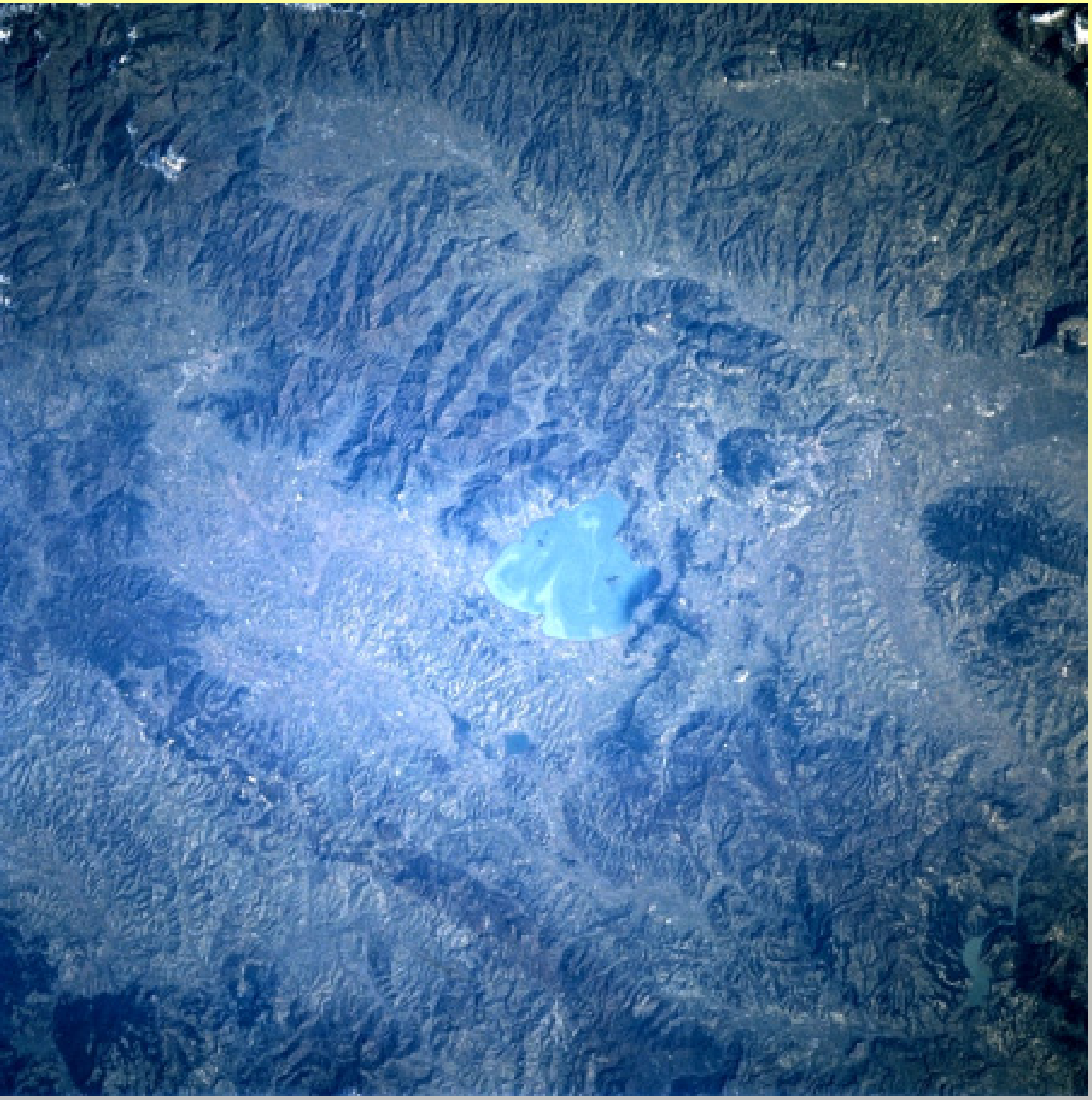
WEBINAR: **IL TRASIMENO, UN OSSERVATORIO SUI CAMBIAMENTI CLIMATICI.** 26 AGOSTO, 2020. ORE 10.30, Sala Riunioni ARPA UMBRIA (Perugia)

Questa presentazione comprende una sintesi di un più dettagliato lavoro, scritto in collaborazione con due miei ex studenti, Cecilia Giontella e Massimo Melillo (Dragoni W., Melillo M., Giontella C. -2012- Bilancio idrico del Lago Trasimeno. In "Tutela Ambientale del lago Trasimeno", a cura di Martinelli A., Libri/Arpa Umbria:
https://www.dropbox.com/sh/4f6ujjc079pt265/AAAOKj7uESVBtCJvUA4fwaMga?dl=0
http://www.arpa.umbria.it/AU/pubblicazioni/trasimeno_book.pdf ***)***

Desidero inoltre ricordare Laura Deffenu e Vittorio Castellani: con questi cari amici e colleghi, prematuramente scomparsi, ho scritto a cavallo degli anni 1970-1980 alcuni lavori sul Trasimeno, anch'essi inglobati in questa presentazione.

LOCATION OF TRASIMENO LAKE

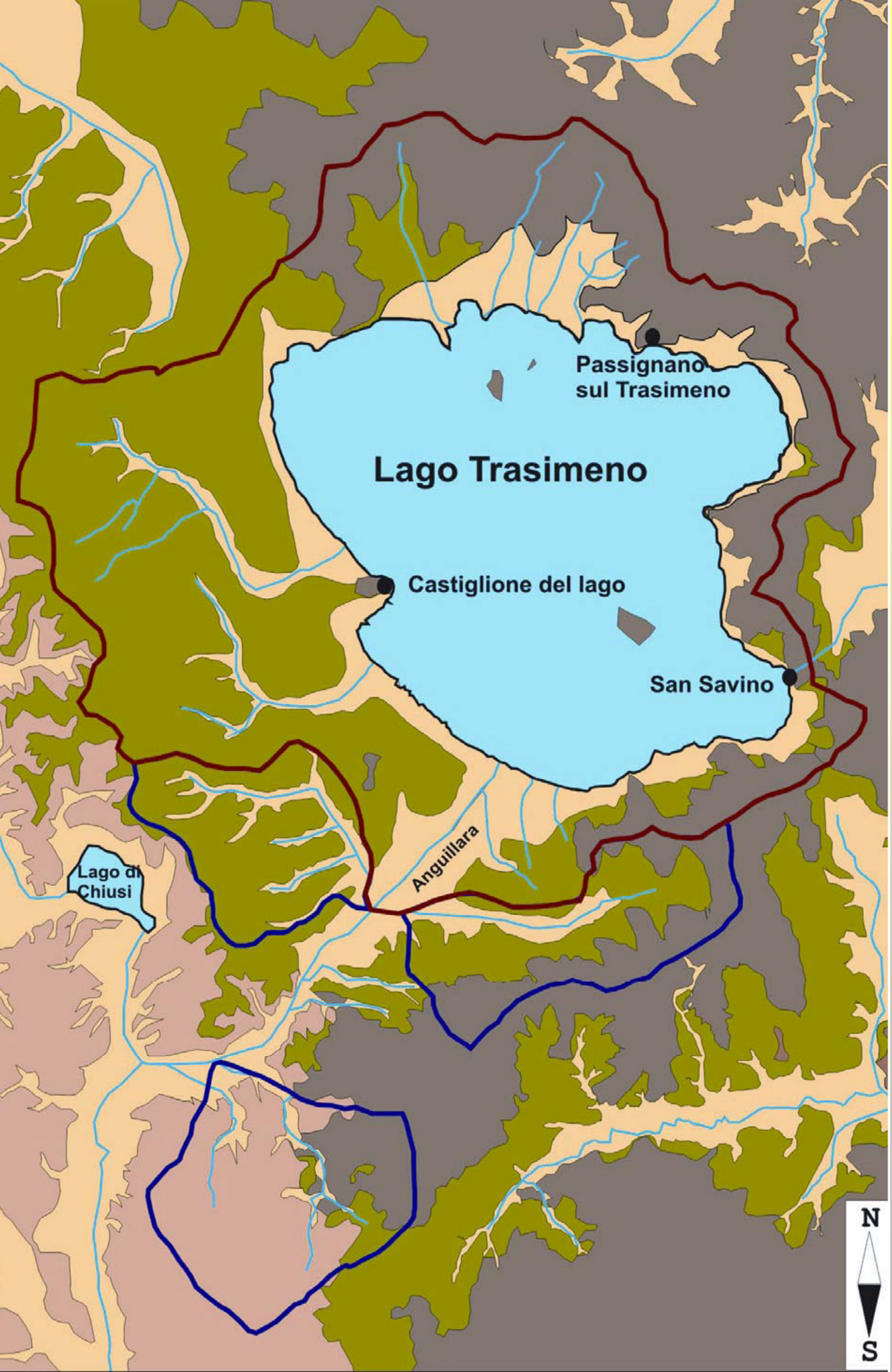


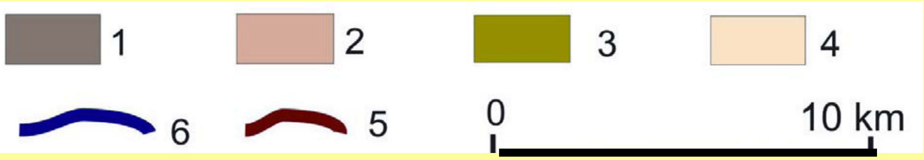


L. Trasimeno

Lake Area ~ 121 km^2
Catchment ~ 262 km^2
Max depth ~ 5 m
No natural outlets

About 1/3 of the rainfall falls on the lake





1 - Turbidites (Oligocene - Miocene);

2 – Coastal deposits (Pliocene);

3 - Fluvial and lacustrine alluvial deposits (Pleistocene);

4 - Recent and present alluvial deposits;

5 - Natural catchment basin;

6 - Artificially-joined basins.

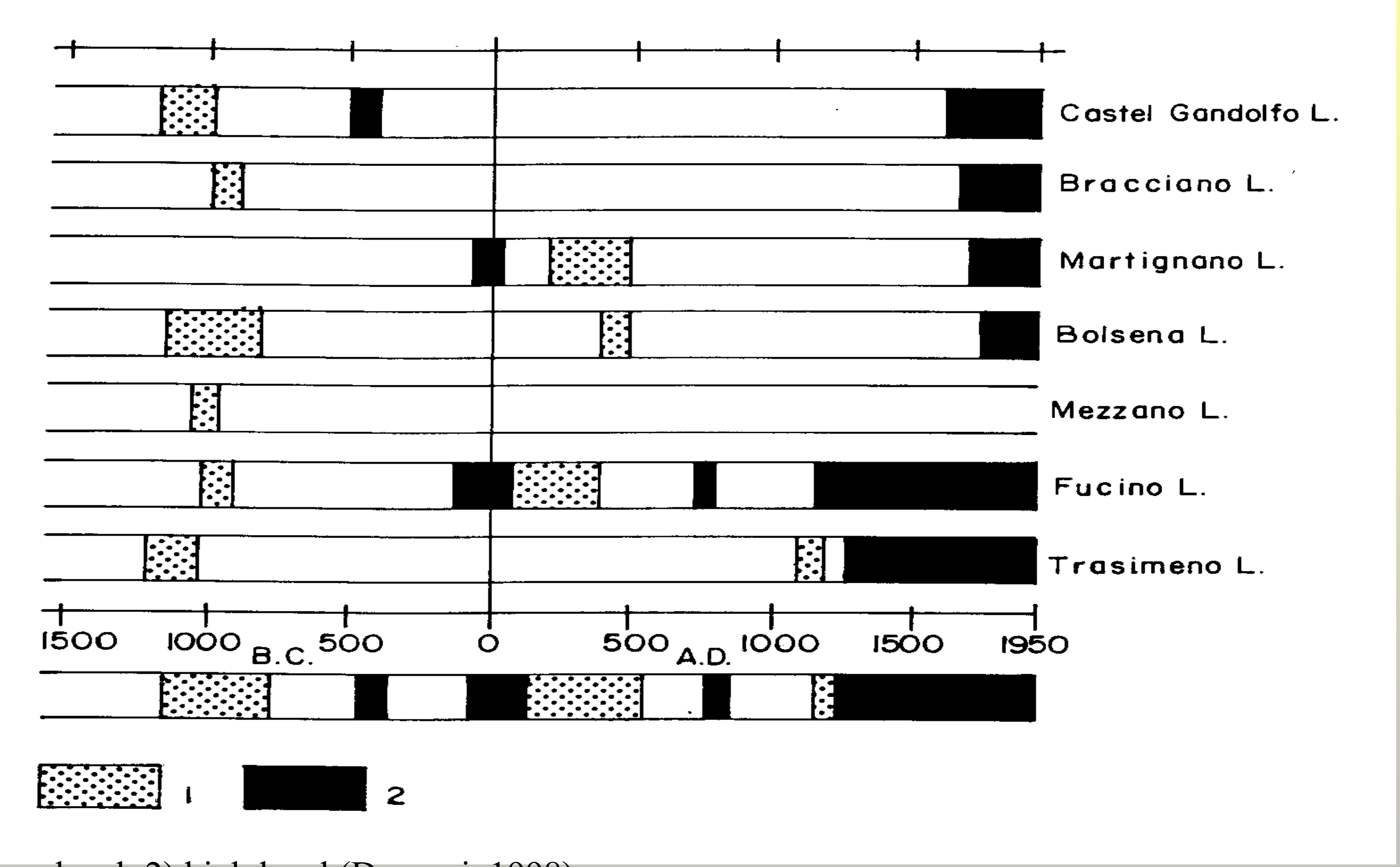
-Closed Lake, i.e no natural outlets

- About 1/3 of the rainfall falls directly on the lake

- Low permeability rocks.

Because of all these characteristics, the lake level varies considerably and is strictly linked to local rainfall* CLIMATIC CONDITIONS *which are not constant.

LEVEL OF THE LAKES IN CENTRAL ITALY IN THE PAST 3000 YEARS



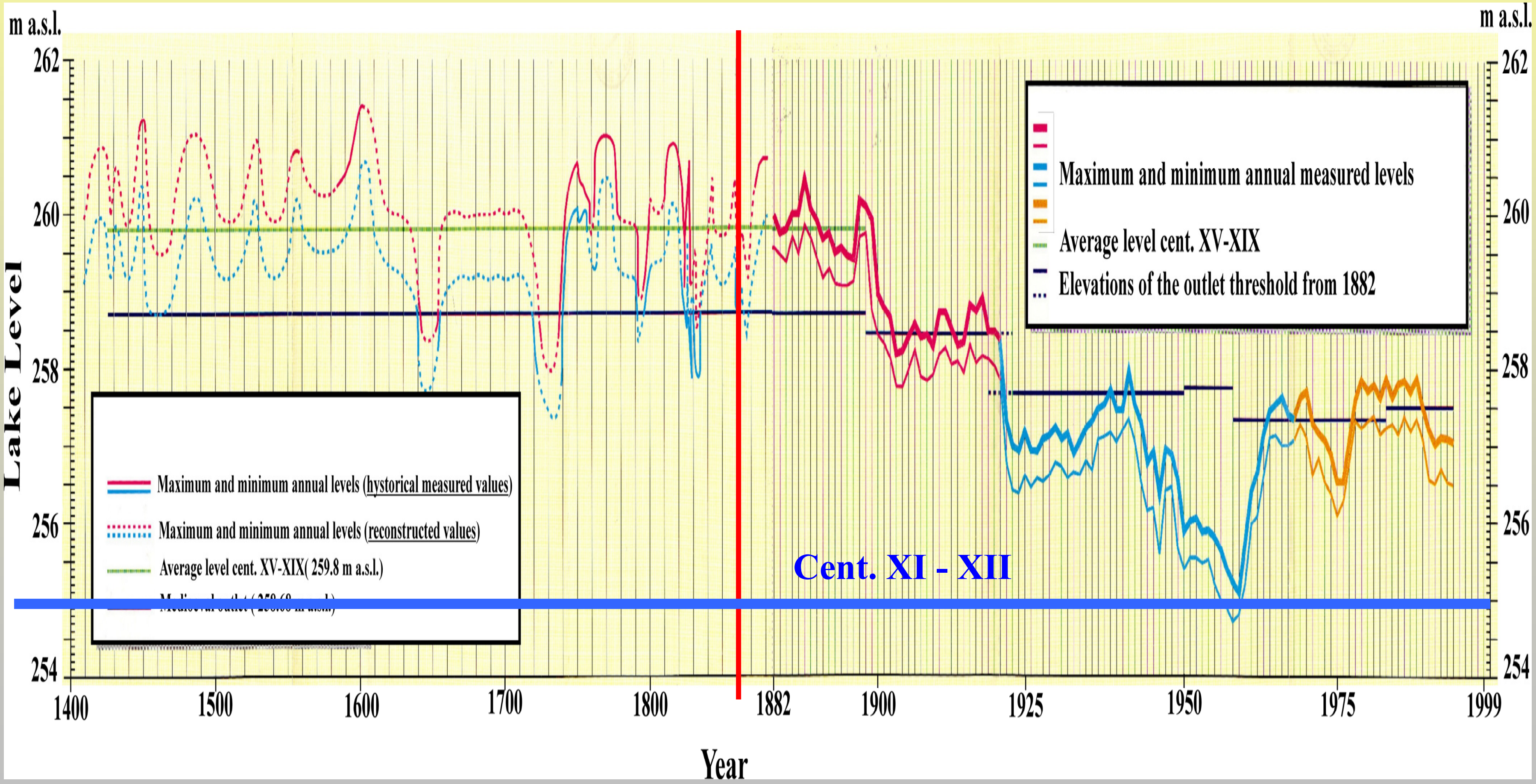
1) Low level; 2) high level (Dragoni, 1998)

- ❖ Several hydraulic works have been made, probably since the Roman age, to regulate lake levels

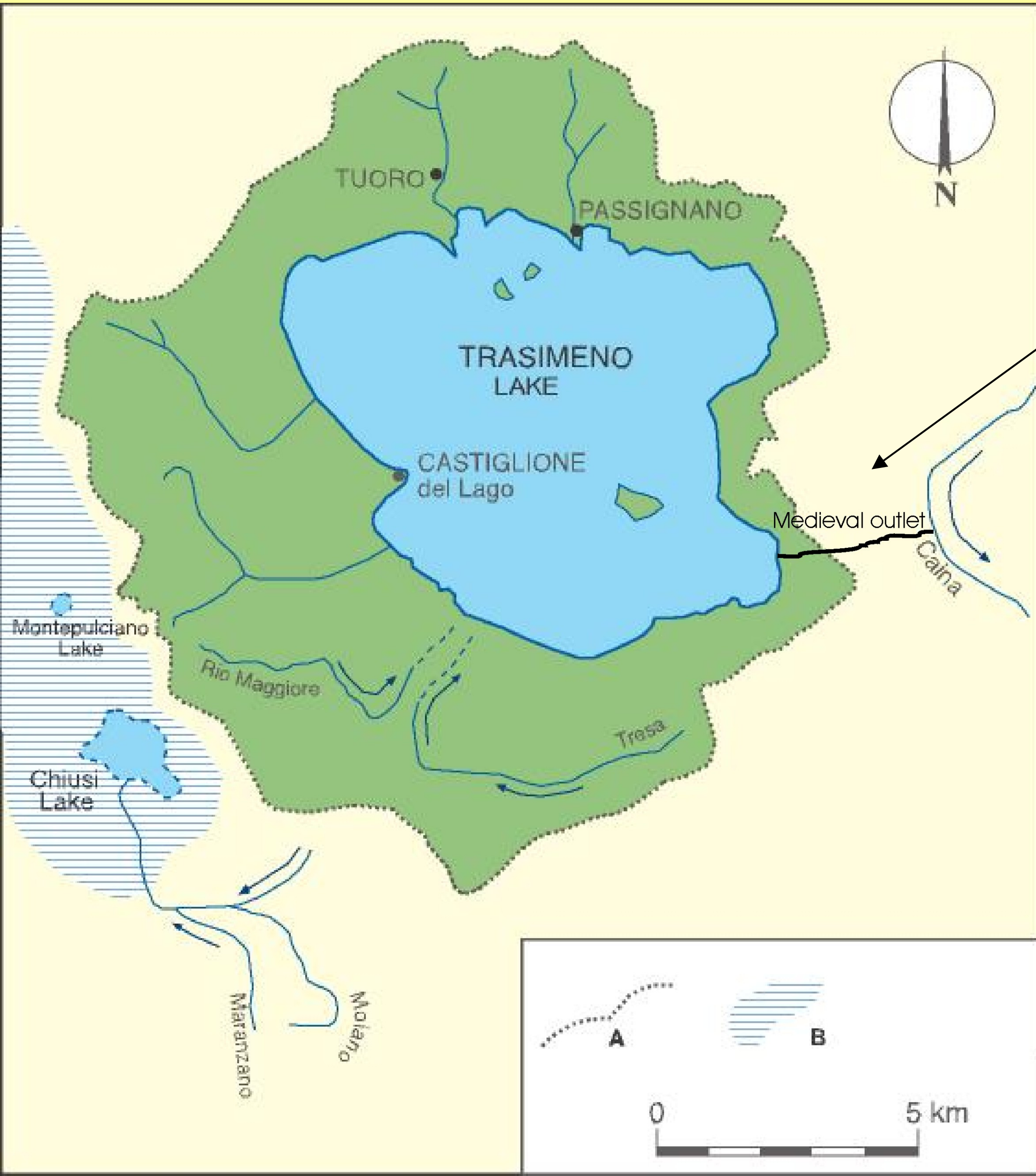
- ❖ According to Strabo in Roman times the Trasimeno was linked to the River Tiber: this was possible only if there was an artificial outlet, but not sure evidences have been found.

Maximum and minimum levels of lake Trasimeno from 1400 to 1999

(after Gambini, 2002)



Situation of the Trasimeno basin between 1420 and about 1482



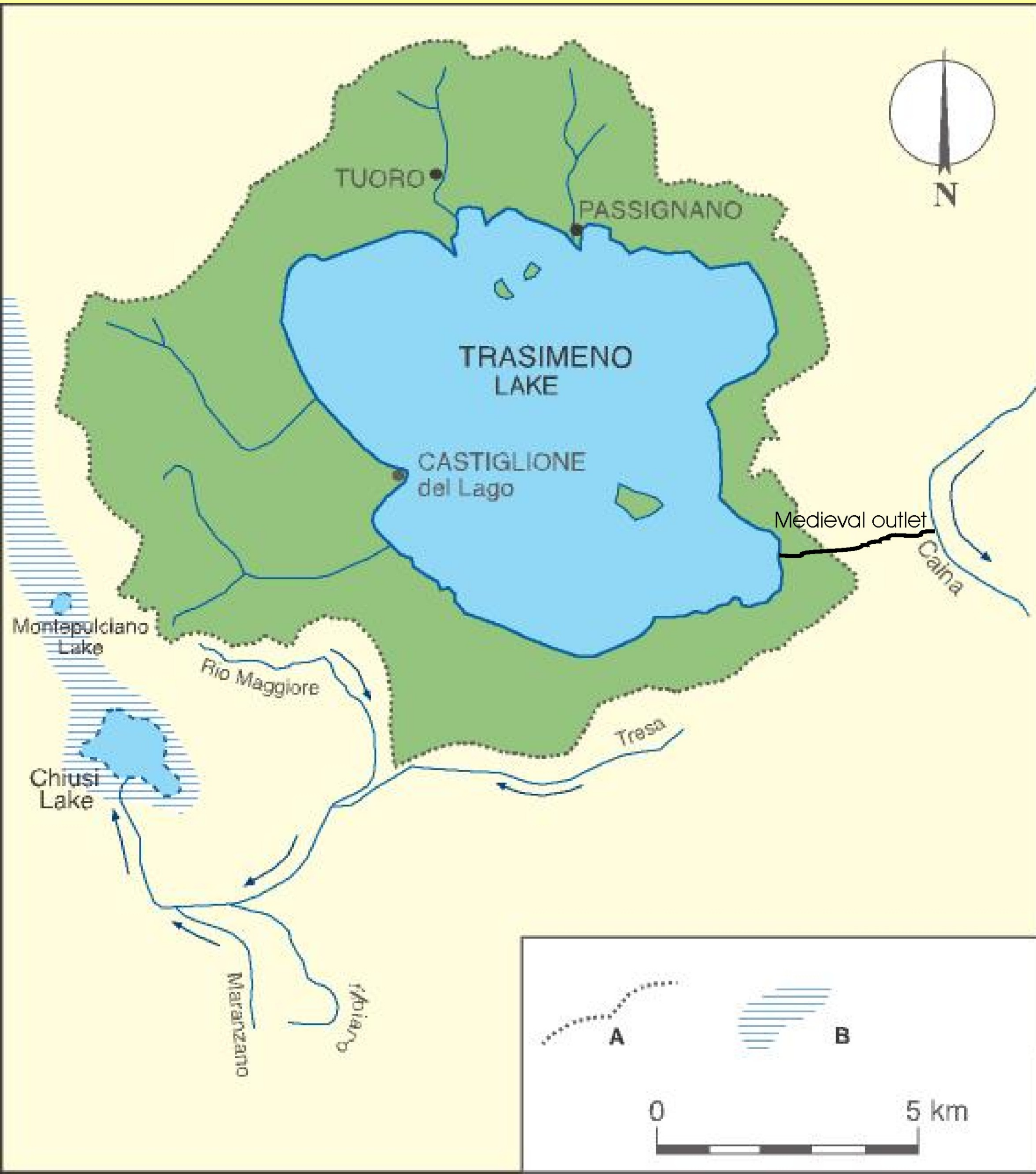
Medieval outlet channel (for about 900 m underground)

LEGEND

A – Natural catchment basin

B – Swampy area (Chiana valley)

Situation of the Trasimeno basin between 1482 and about 1898

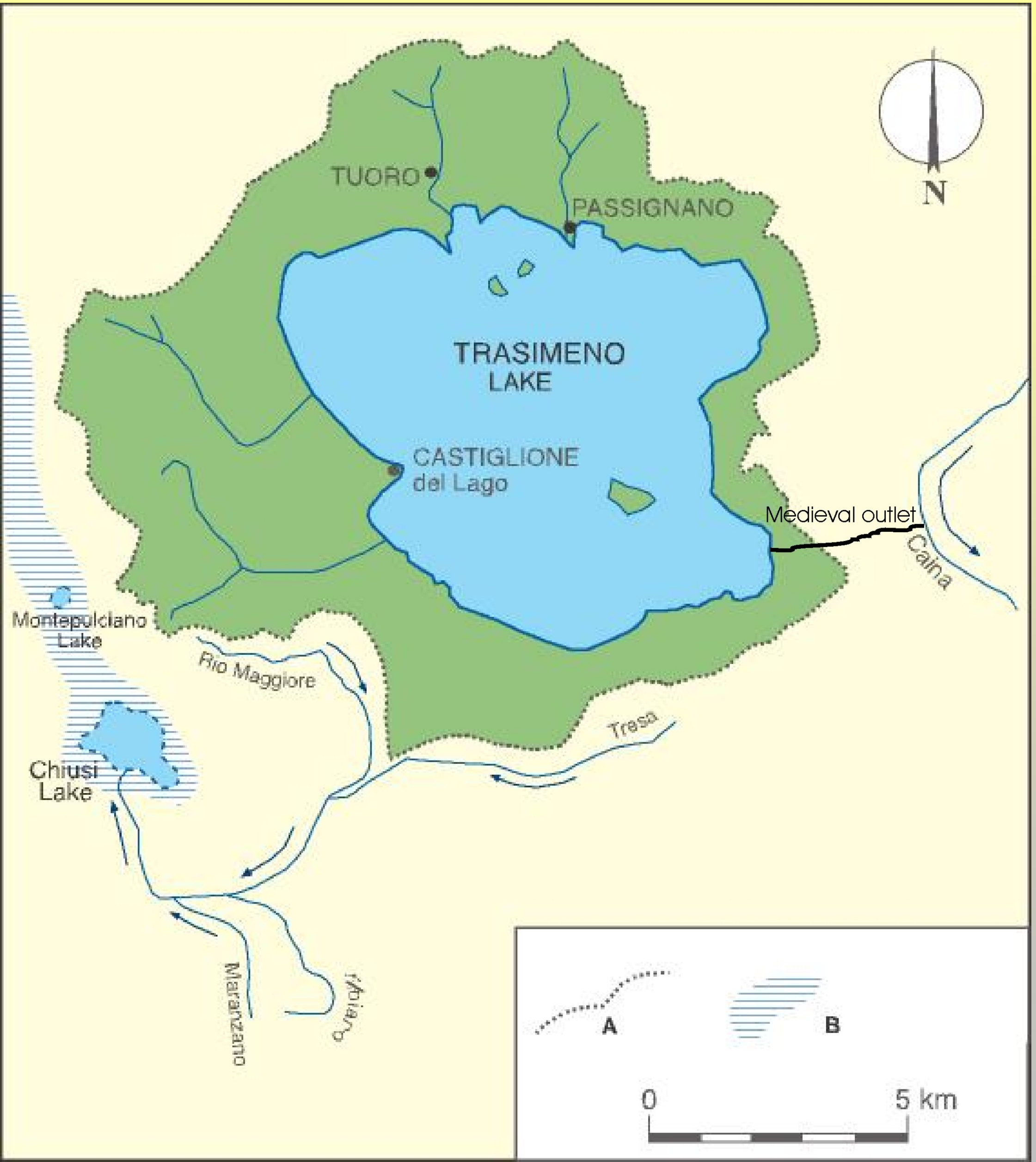


LEGEND

A – Natural catchment basin

B – Swampy area (Chiana valley)

Situation of the Trasimeno basin between 1482 and about 1898



LEGEND

A – Natural catchment basin

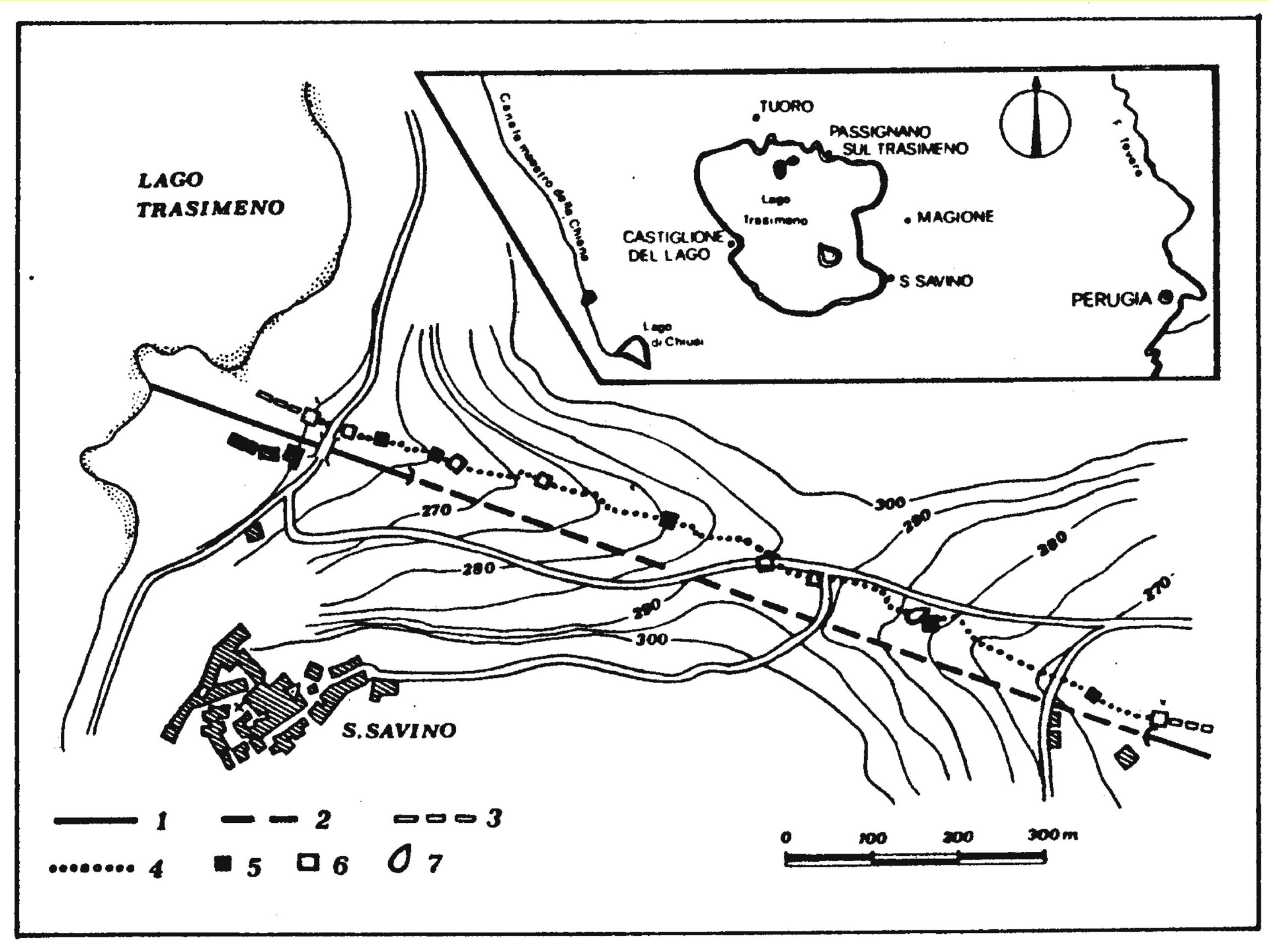
B – Swampy area (Chiana valley)

Leonardo Da Vinci – Trasimeno e Val di Chiana (ca. 1502-1503)

Passignano
sul Trasimeno
Lago Trasimeno
Castiglione del lago
San Savino
Anguillara
Lago di
Chiusi
N
S

The medieval outlet could not have succeeded in controlling the lake level because it was undersized: in fact, the outlet's theoretical maximum discharge was about 1 m^3/s, corresponding to about 32 x 10 m^3/year, i.e. about 1/3 of the volume of water coming into the lake in rainy years. This implies that the tunnel frequently went under pressure, with water at high velocity and frequent collapses and so it had a flow much smaller than 1 m^3/s.

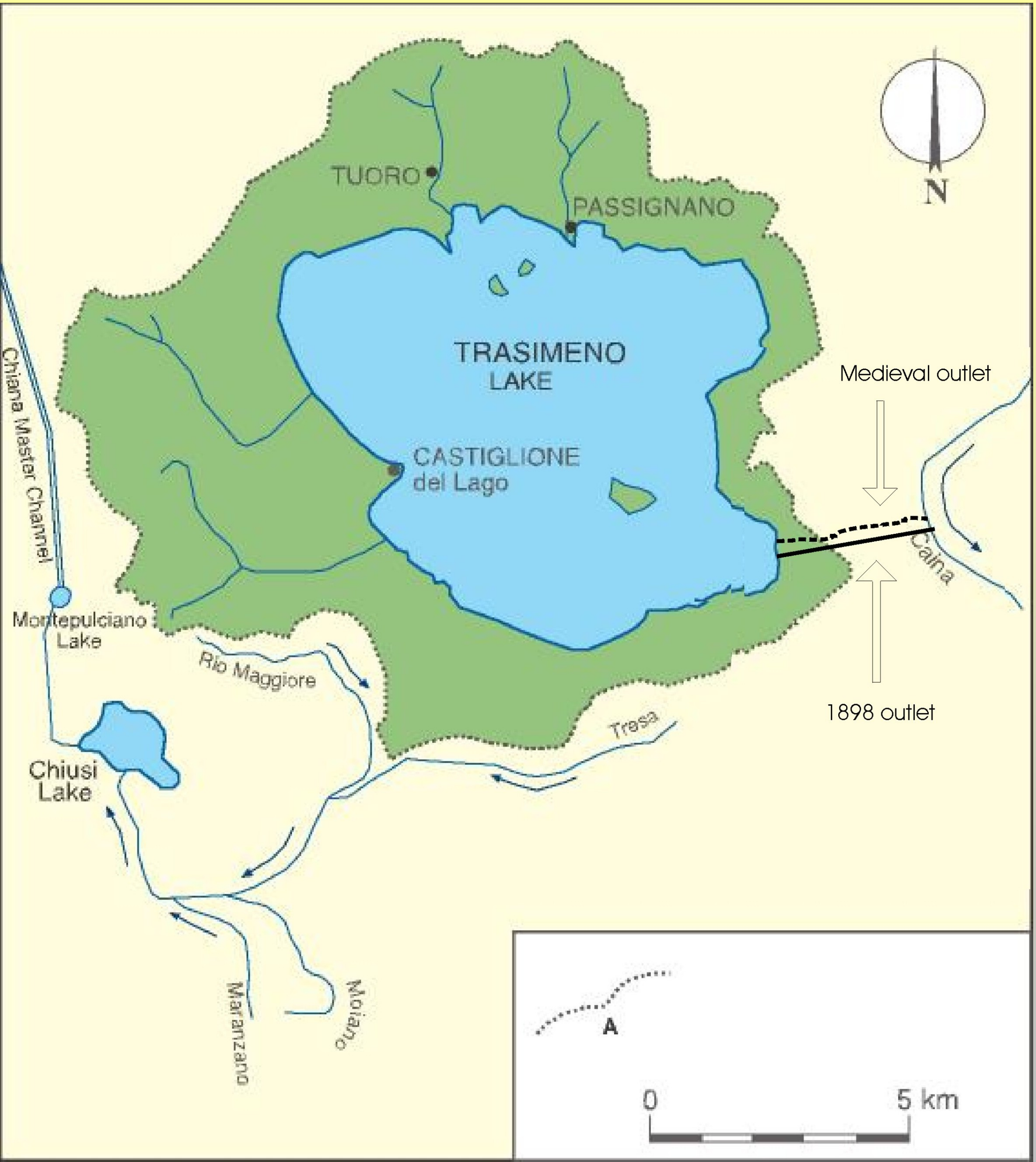
In 1898 a new outlet was built. This outlet, still in use today, is about 7300 m long, about 900 m of which are underground. The maximum discharge is about 12 m^3/s.



Modern outlet : 1) above ground; 2) underground. Medieval outlet : 3) above ground; 4) underground; 5) wells, still visible today, on the vertical of the medieval outlet; 6) wells not visible; 7) landslide inside the medieval tunnel (Castellani e Dragoni, 1981)

1898 outlet

Situation of the Trasimeno basin between 1898 and about 1960

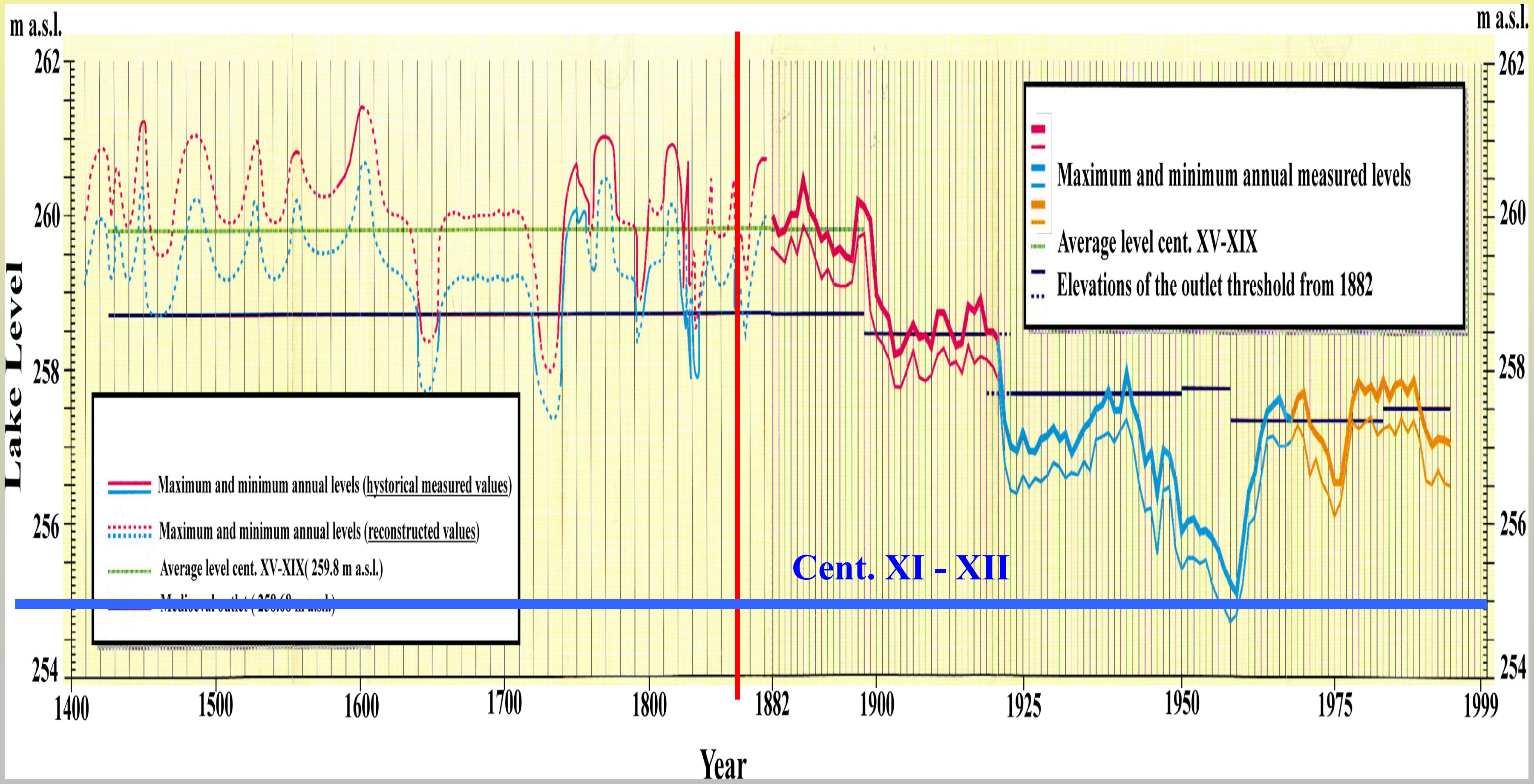


LEGEND

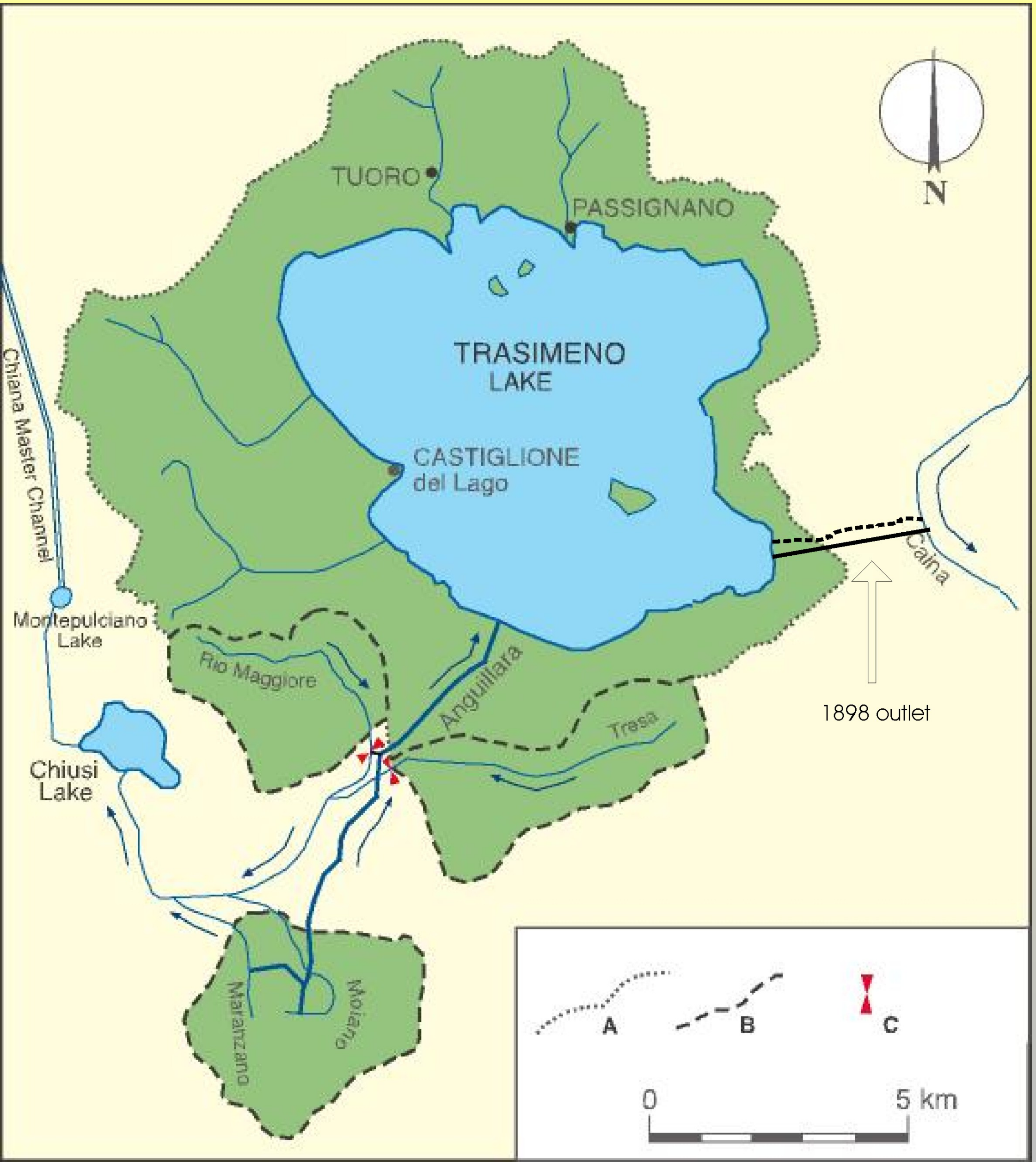
A – Natural catchment basin

Maximum and minimum levels of lake Trasimeno from 1400 to 1999

(after Gambini, 2002)



Present situation of the Trasimeno basin (since 1960)

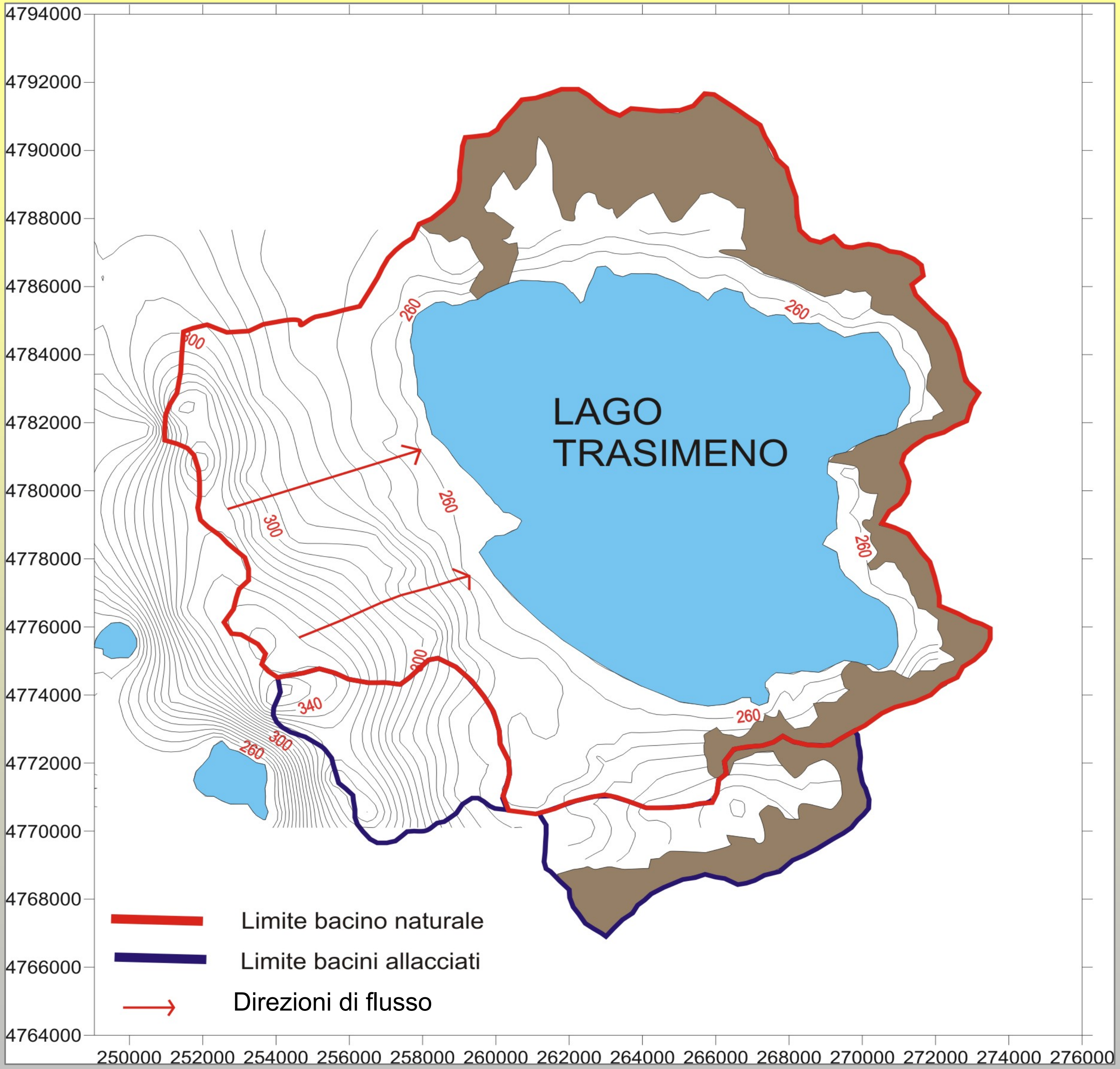


LEGEND

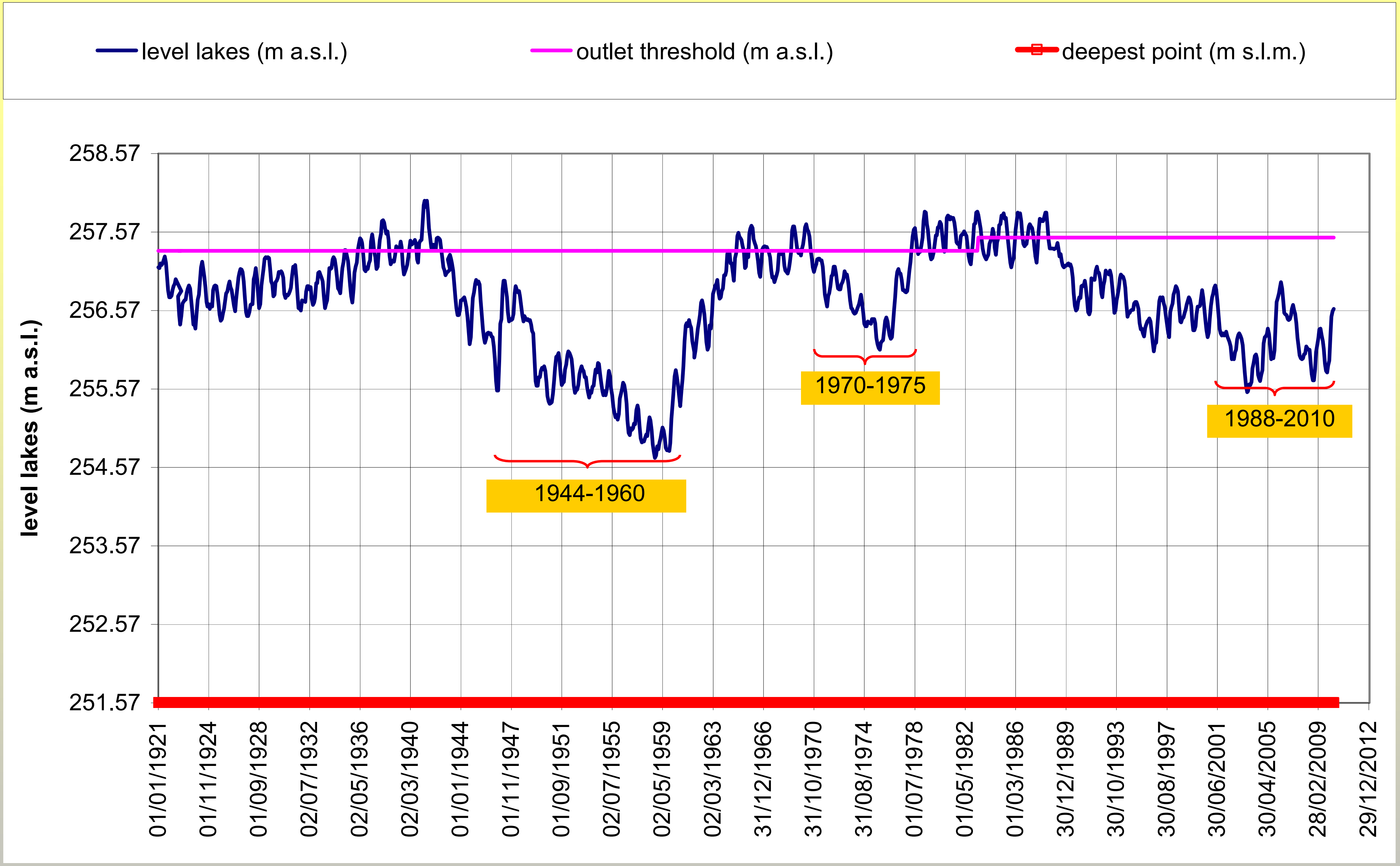
A – Natural catchment basin

B – Artificially joined basins

C – Sluice gates on the artificially joined channels


LAGO
TRASIMENO
260
300
340
4794000
4792000
4790000
4788000
4786000
4784000
4782000
4780000
4778000
4776000
4774000
4772000
4770000
4768000
4766000
4764000
250000 252000 254000 256000 258000 260000 262000 264000 266000 268000 270000 272000 274000 276000
Limite bacino naturale
Limite bacini allacciati
Direzioni di flusso

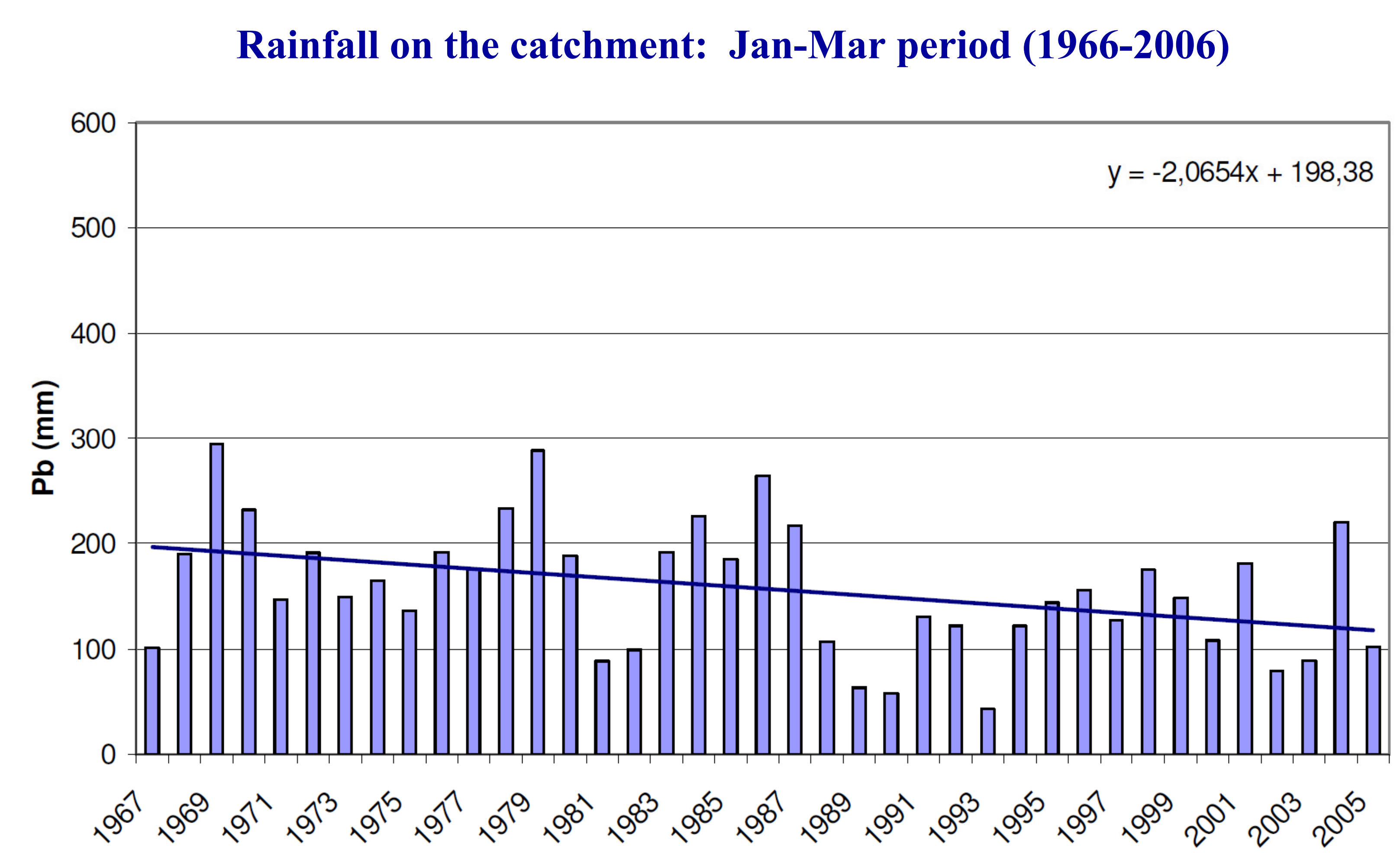
Main characteristics of Lake Trasimeno (1984-2006). Considering of the approximation of the data, the rains have been rounded to 5 mm, areas to 0.5 km^2	
Surface of basin + lake (km^2)	**383,5**
Average Surface of basin (km^2)	**264.5**
Average Surface of Lake (km^2)	**120,5**
Max. Surface of Lake (km^2)	**124,5**
Min. Surface of Lake (km^2)	**116,5**
Average monthly temperature (°C)	**14,3**
Average Rain over the Lake (mm/year)	**700**
Average Rain over the basin (mm/year)	**730**
ETR according to Turc (mm/year)	**555**
Volume stored in the Lake (Mm^3)	**490**
Maximum depth (m)	**5.5**
Average elevation (a. s.l.m)	**257.1**



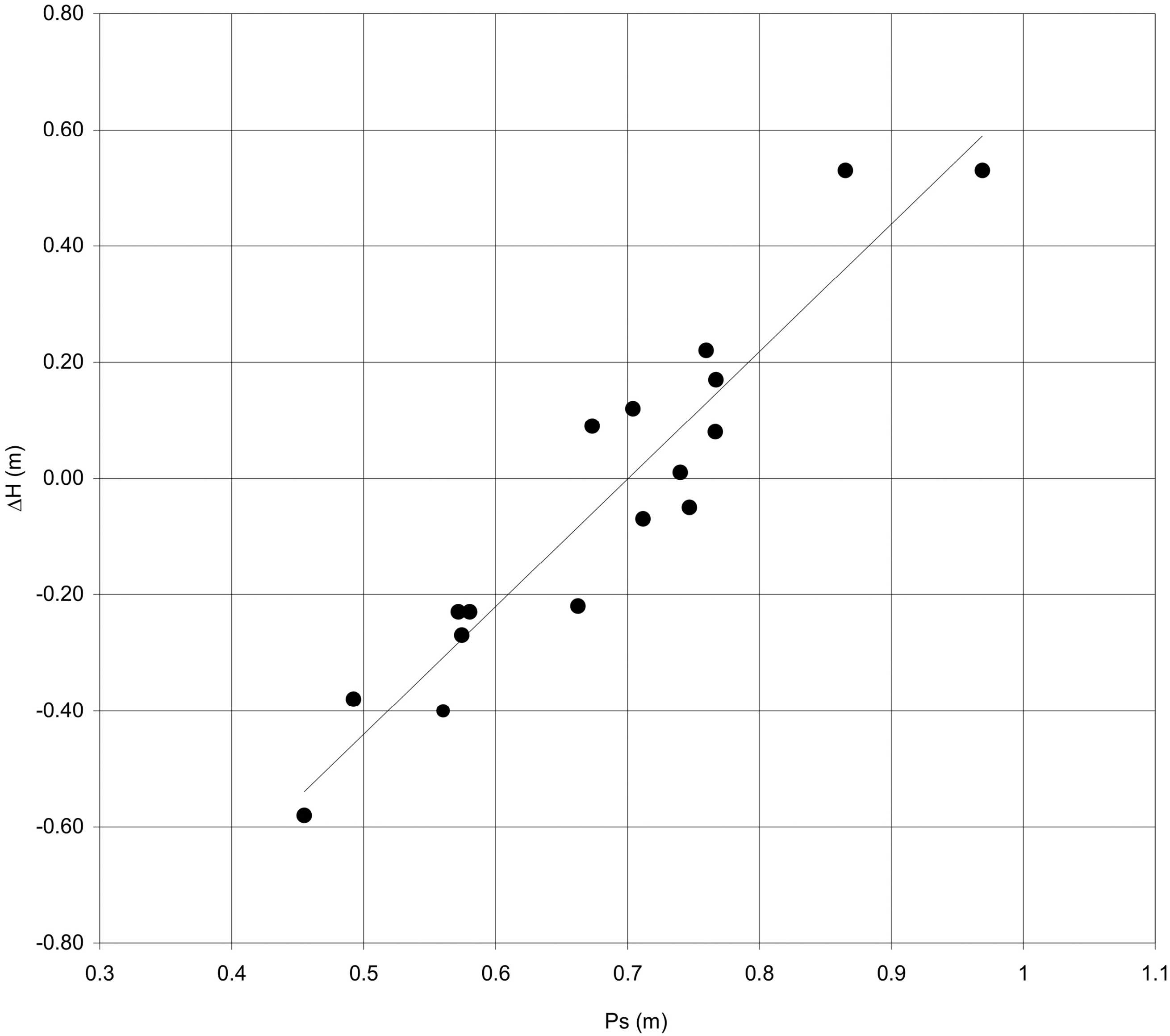
level lakes (m a.s.l.)
outlet threshold (m a.s.l.)
deepest point (m s.l.m.)
level lakes (m a.s.l.)
258.57
257.57
256.57
255.57
254.57
253.57
252.57
251.57
1944-1960
1970-1975
1988-2010
01/01/1921
01/11/1924
01/09/1928
02/07/1932
02/05/1936
02/03/1940
01/01/1944
01/11/1947
01/09/1951
02/07/1955
02/05/1959
02/03/1963
31/12/1966
31/10/1970
31/08/1974
01/07/1978
01/05/1982
01/03/1986
30/12/1989
30/10/1993
30/08/1997
30/06/2001
30/04/2005
28/02/2009
29/12/2012

Trasimeno Lake: Rainfall on the basin - trends

Rainfall on the catchment (Jan-Mar period)	
1° period (1966-1984)	183 mm
2° period (1984-2006)	135 mm
Δ%	**-26%**



$\Delta H = 2.195\ Ps - 1.538$ $R^2 = 90\%$



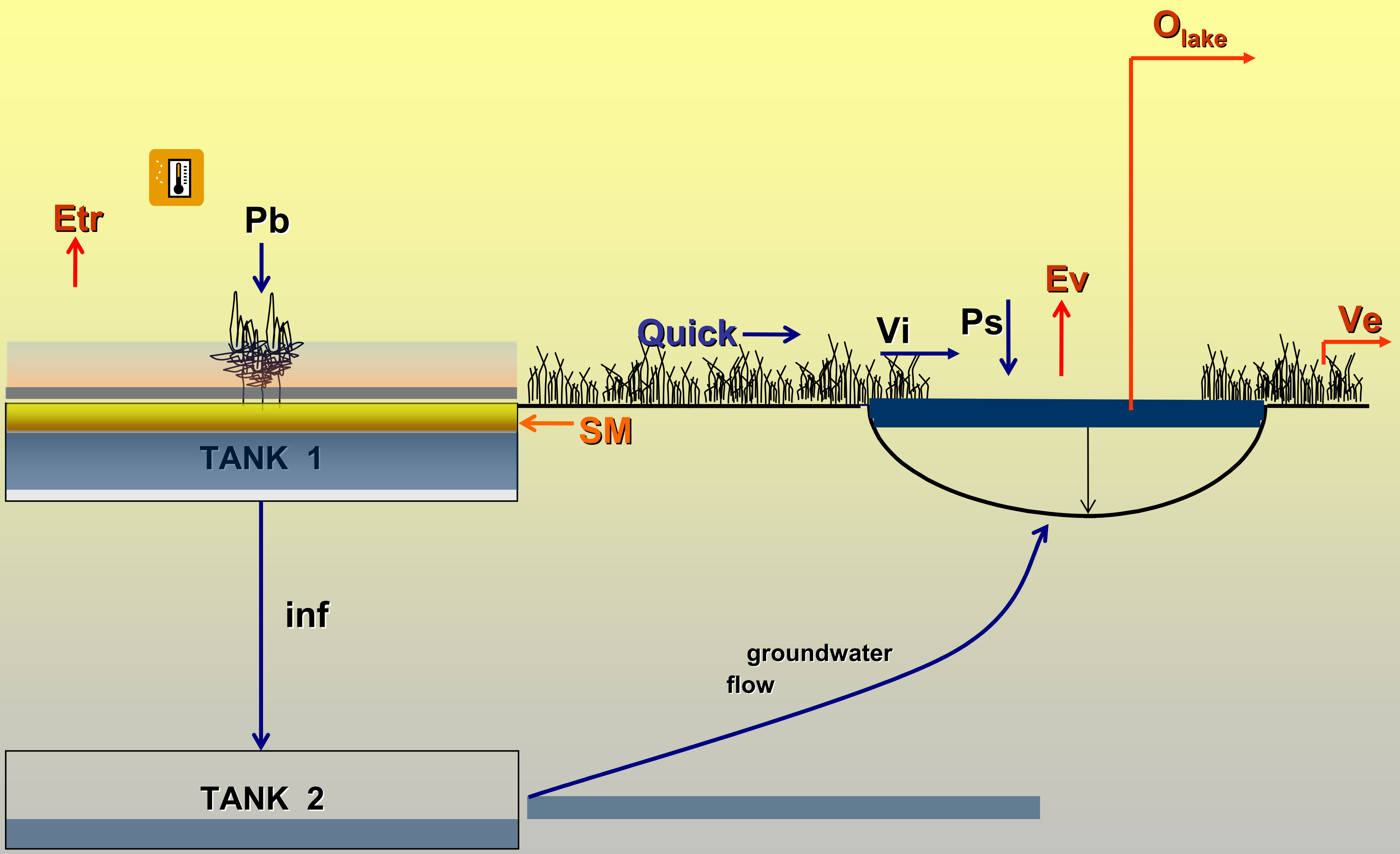
Trasimeno Lake - Summer 2003

Trasimeno Lake - Spring 1983

Trasimeno Lake - 2003

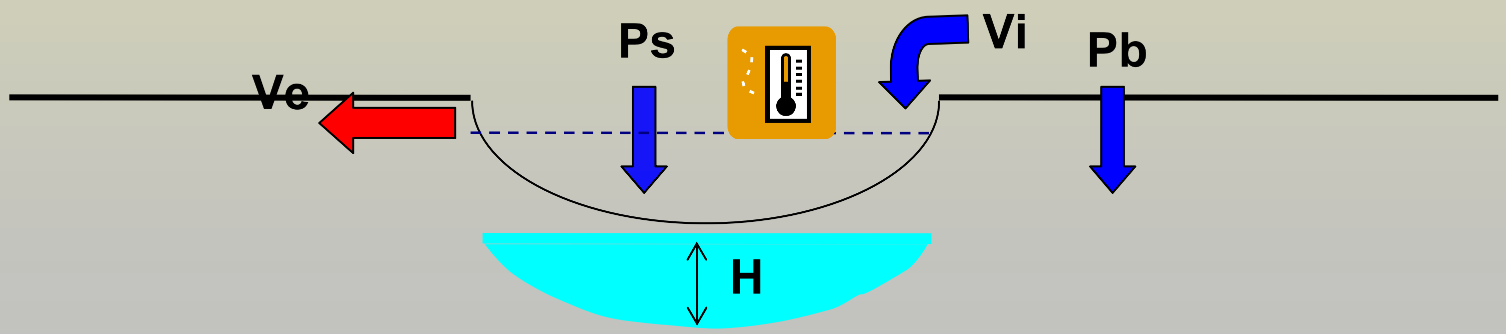
Problems of eutrophication, navigability, ecology, tourism, irrigation, aesthetics.
When the outlet is not working the only natural outflow is EVAPORATION, i.e.:
concentration of salinity & pollutants…

”LAGO” is a lumped model (simple!)



REQUIRED INPUT DATA

- ✓ **Total area of the basin (km²)**
- ✓ **Relation between depth, surface and stored Lake volume (hypsographic curve)**
- ✓ ***Curva ipsografica L,S,V=f (L,S,V)*** ***Database*** **Livello-Superficie-Volume**
- ✓ **Month by month rain on Basin & Lake (mm)**
- ✓ **Month by month average air temperature (C°)**
- ✓ **Month by month Outflow from outlet canal (m^3)**
- ✓ **Month by month Lake level (1° day, measured from Lake bottom, only for calibration) (m)**



Water budget month by month:

$$\Sigma I + \Sigma U = \pm \Delta R$$

MODEL OUTPUT		
Evaporation	**Calibrated semi-empirical equation**	**Dragoni & Valigi, 1994**
Evapotranspiration	**Calibrated semi-empirical equation**	**Dragoni & Valigi, 1994**
Quick flow to the lake	**Calibrated empirical equation**	**Vandewiele G.L., Xu C-Y, Win N-L, (1992)**
Groundwater recharge		
Groundwater flow to the Lake	**Calibrated Darcy equation**	
Water intake for irrigation	**Calibrated empirical equation**	

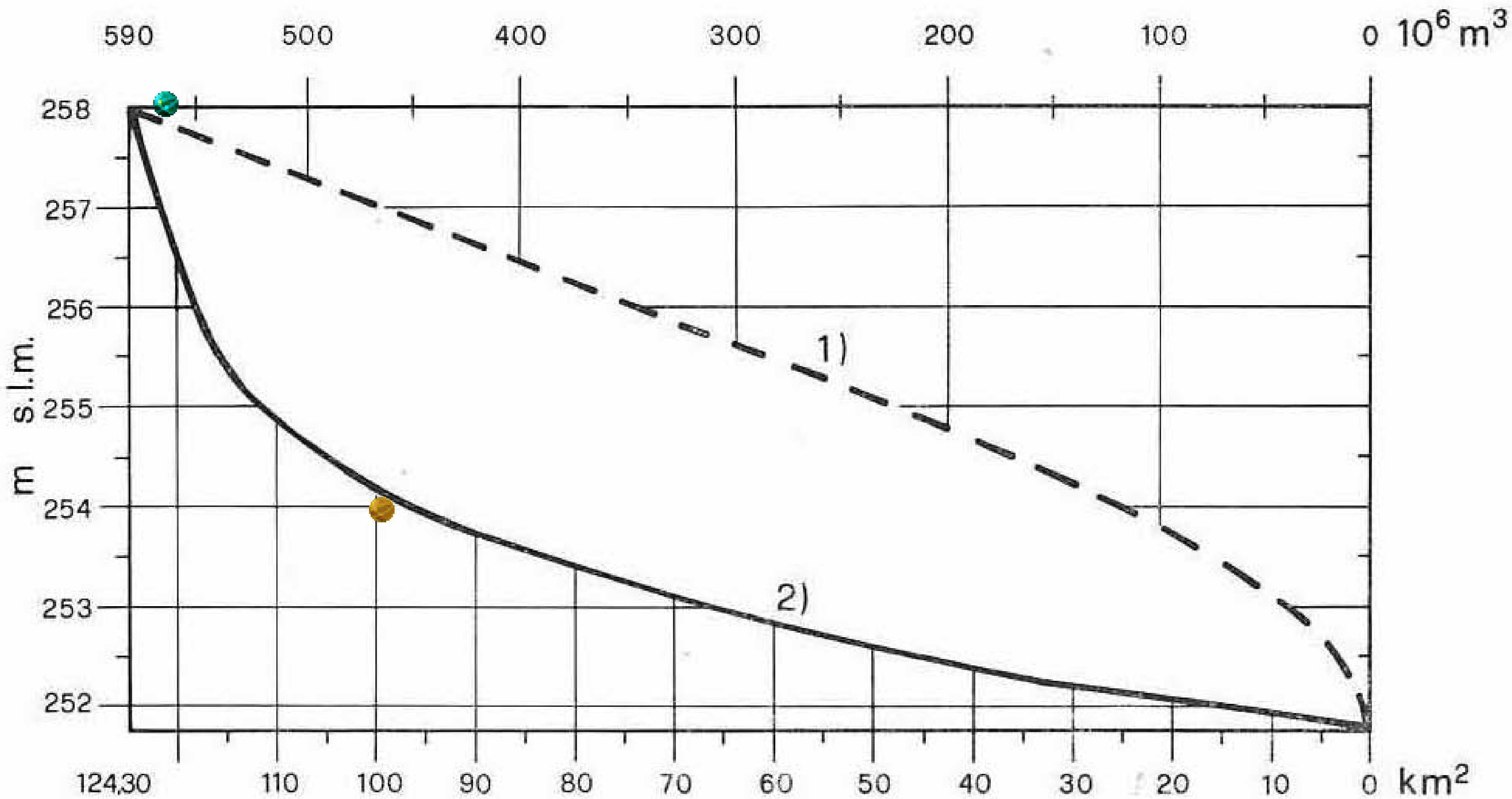
Calibration:

$$Err = \sqrt{\frac{\sum_{1}^{n}(V - V')^2}{N - n}}$$

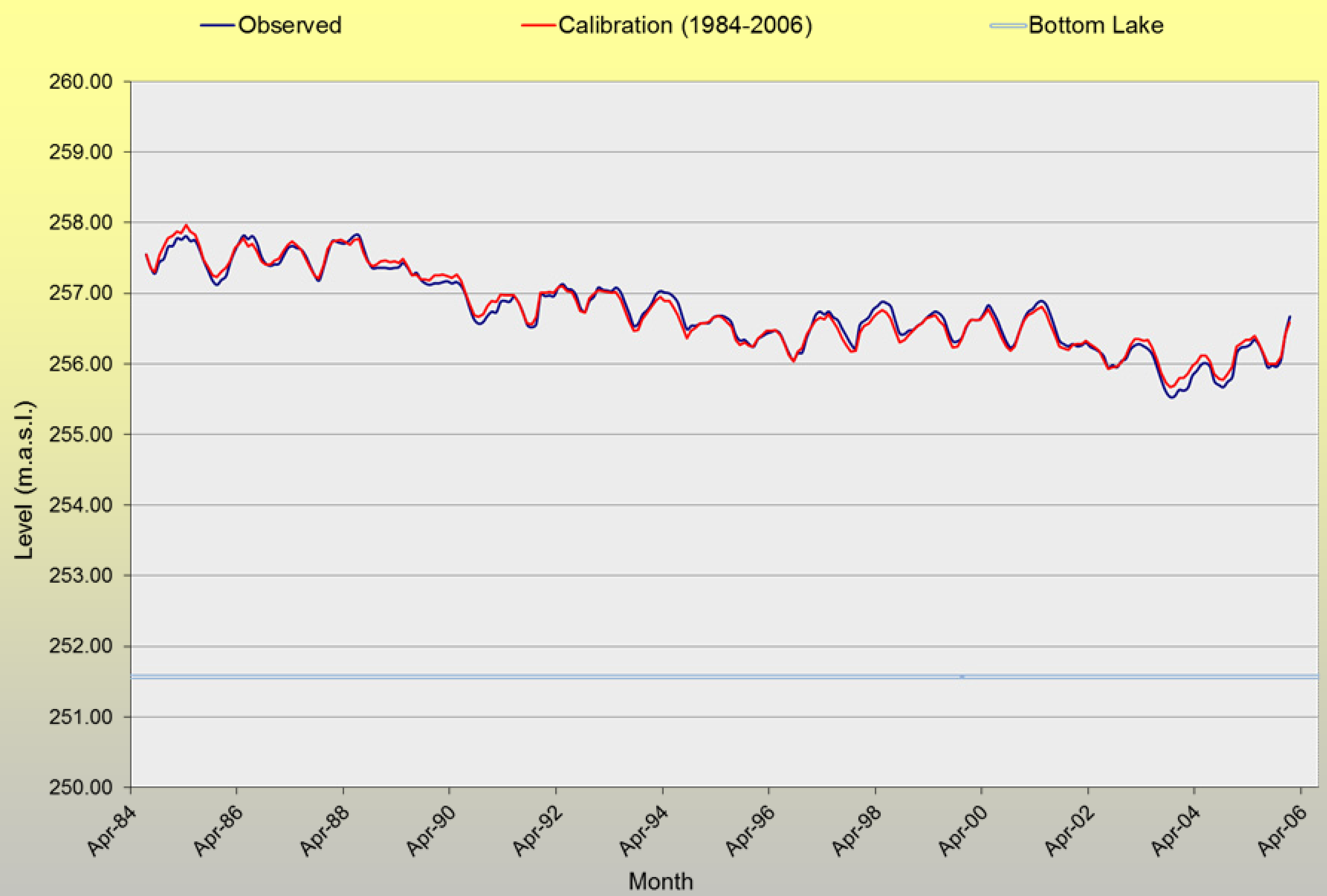
V e V'= stored actual volume and simulated stored volume
N = number of months; n = number of calibrated coefficients

Error minimization routine: <u>Annealing</u> (Aarts e Koerst, 1990)

The computed stored water volume, on the 1° day of each month, is transformed in Lake level elevation by means of the hypsographic curve.



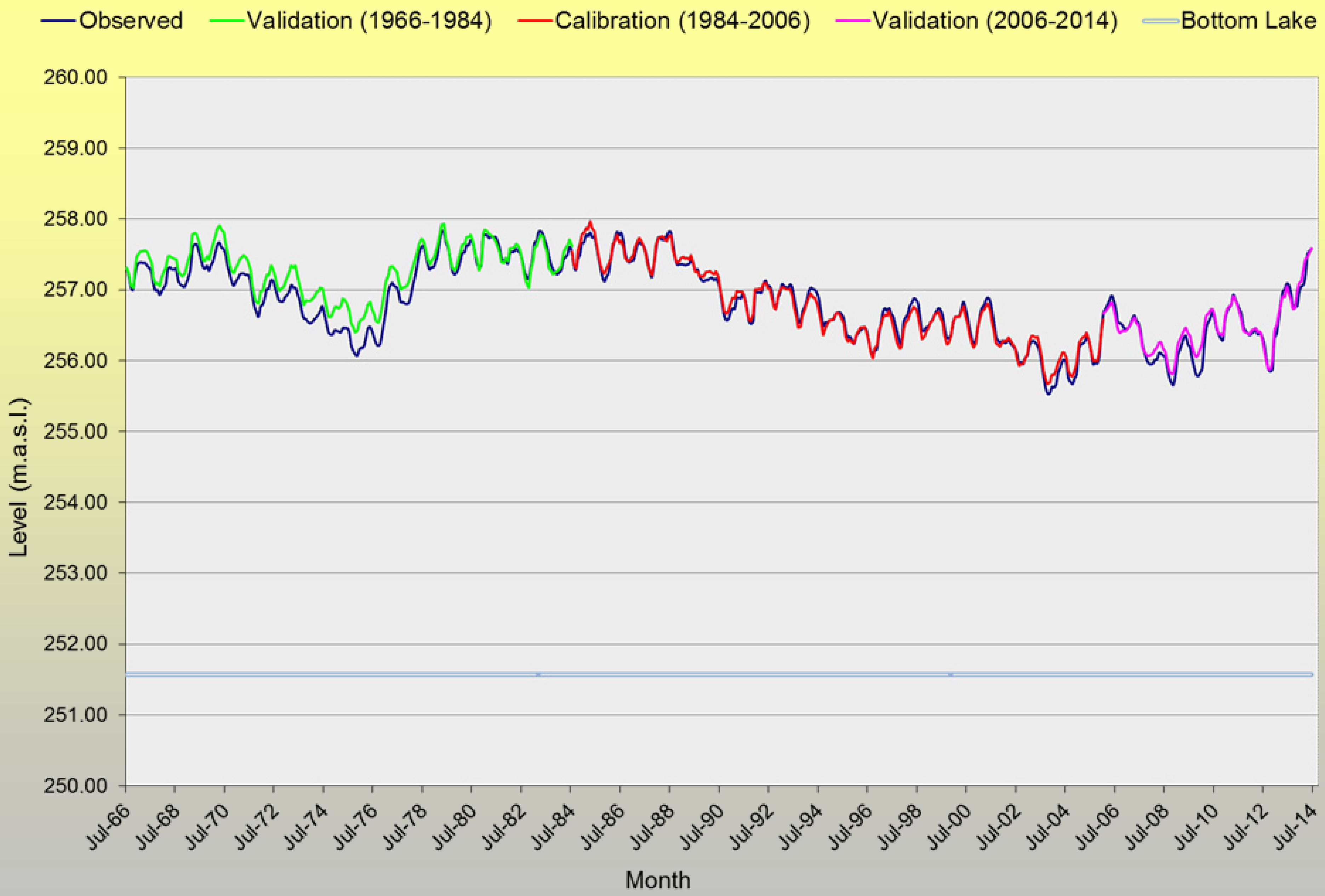
Relation between elevation of the water in the Lake, surface and volume
1 – volume (Mm^3) 2- surface of the Lake (km^2)
(Carollo, 1969)



Observed
Calibration (1984-2006)
Bottom Lake
260.00
259.00
258.00
257.00
256.00
255.00
254.00
253.00
252.00
251.00
250.00
Level (m.a.s.l.)
Apr-84
Apr-86
Apr-88
Apr-90
Apr-92
Apr-94
Apr-96
Apr-98
Apr-00
Apr-02
Apr-04
Apr-06
Month

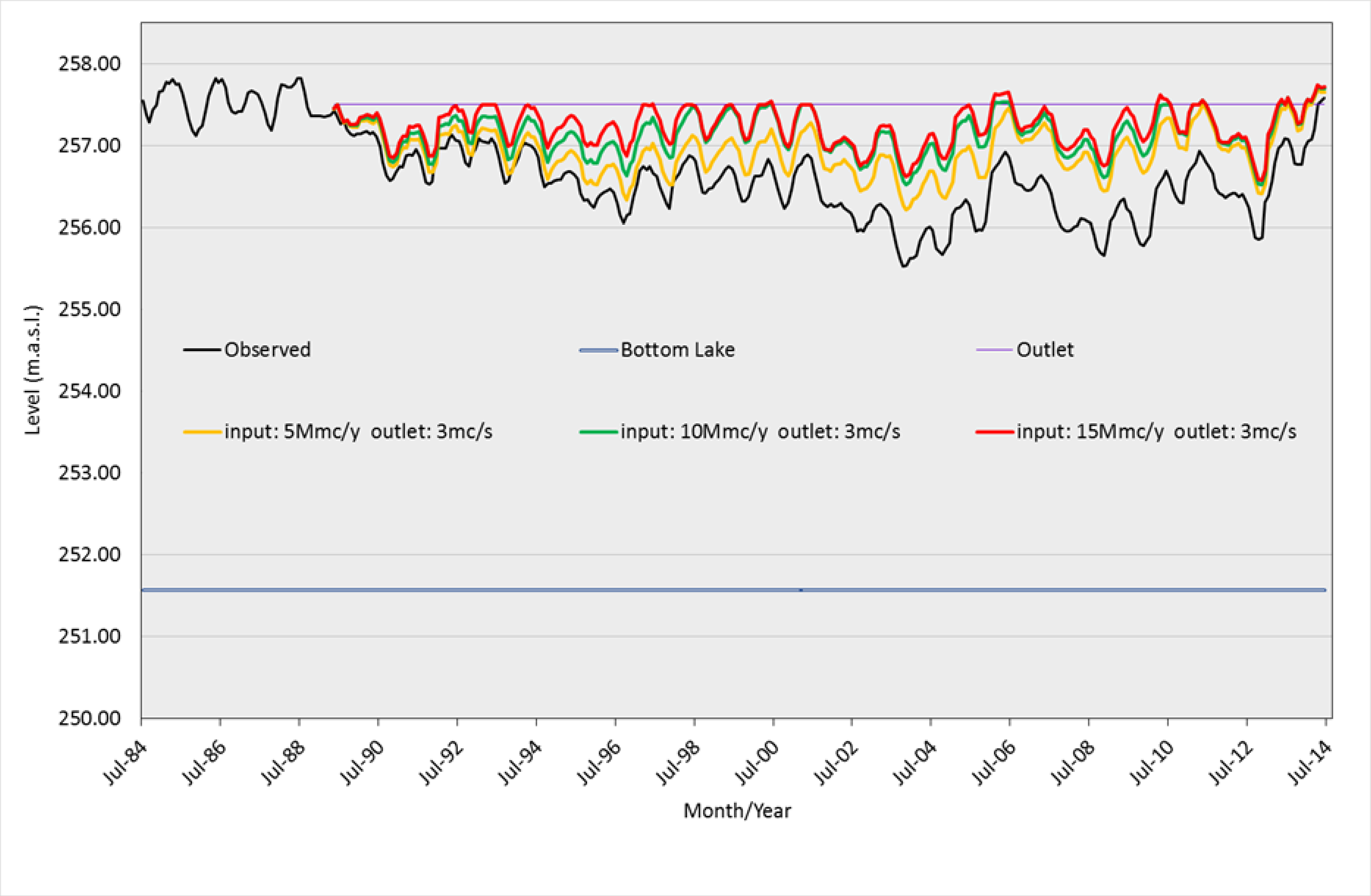
Results out of the model (calibration, 1984 – 2006)

Rain on the Lake (measured)	*700 (mm/year)*	*84.30 (Mm^3/year)*
Rain on the basin (measured)	*730 (mm/year)*	*192.04 (Mm^3/year)*
ETR according to the model	**535 (mm/year)**	**140.74 (Mm^3/year)**
ETR according to TURC	**555 (mm/year)**	**146.00 (Mm^3/year)**
Quick flow	**160 (mm/year)**	**42.09 (Mm^3/year)**
Aquifer Recharge	**23 (mm/year)**	**6.05 (Mm^3/year)**
Total Runoff Coefficient	**0.251**	**----**
Evaporation from the Lake	**1030 (mm/year)**	**124.05 (Mm^3/year)**
Withdrawals from the Lake	**91 (mm/year)**	**11.00 (Mm^3/year)**
Withdrawals from the aquifer	**--**	**0.40 (Mm^3/year)**

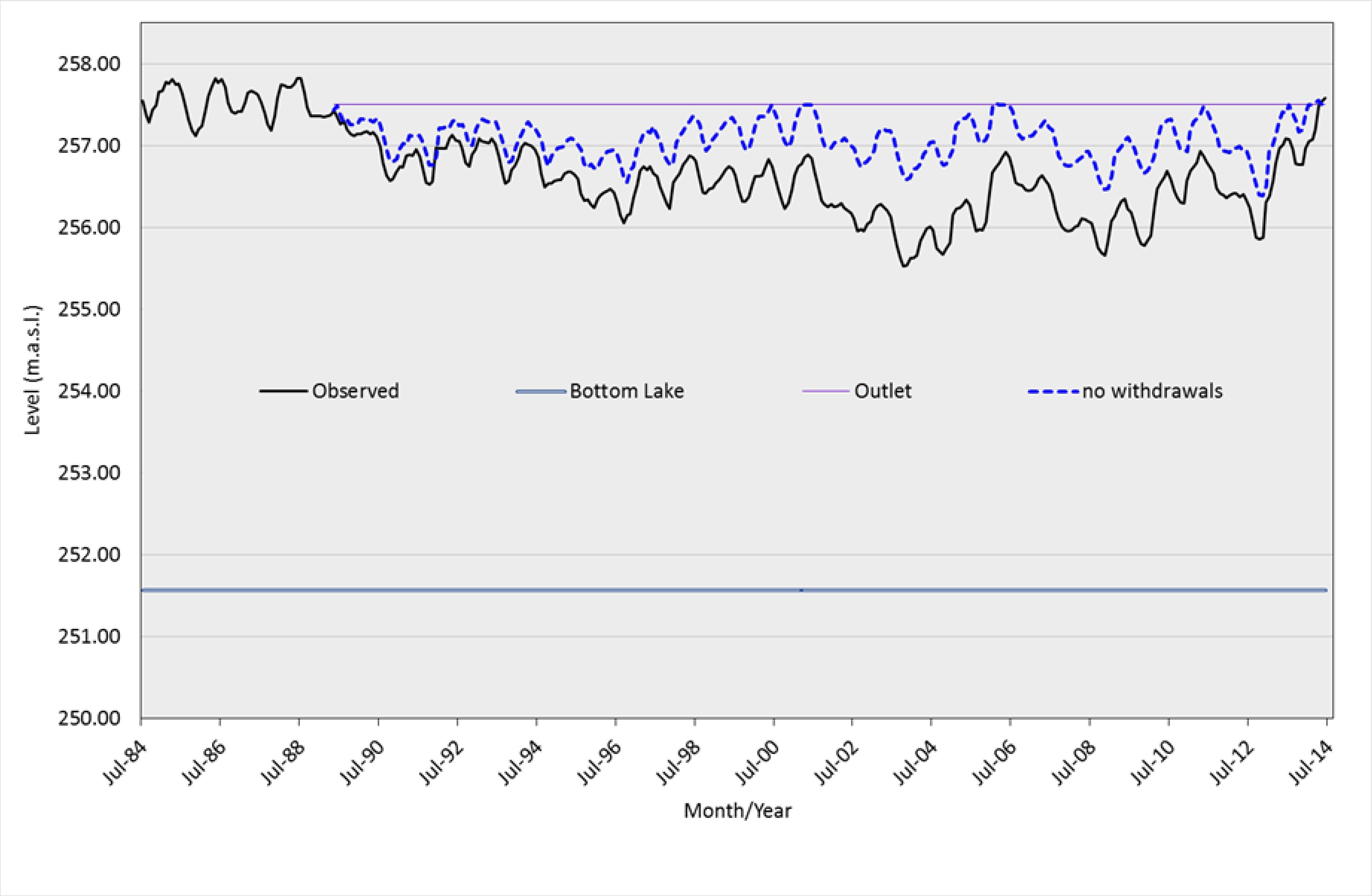


Observed
Validation (1966-1984)
Calibration (1984-2006)
Validation (2006-2014)
Bottom Lake
Level (m.a.s.l.)
260.00
259.00
258.00
257.00
256.00
255.00
254.00
253.00
252.00
251.00
250.00
Jul-66
Jul-68
Jul-70
Jul-72
Jul-74
Jul-76
Jul-78
Jul-80
Jul-82
Jul-84
Jul-86
Jul-88
Jul-90
Jul-92
Jul-94
Jul-96
Jul-98
Jul-00
Jul-02
Jul-04
Jul-06
Jul-08
Jul-10
Jul-12
Jul-14
Month

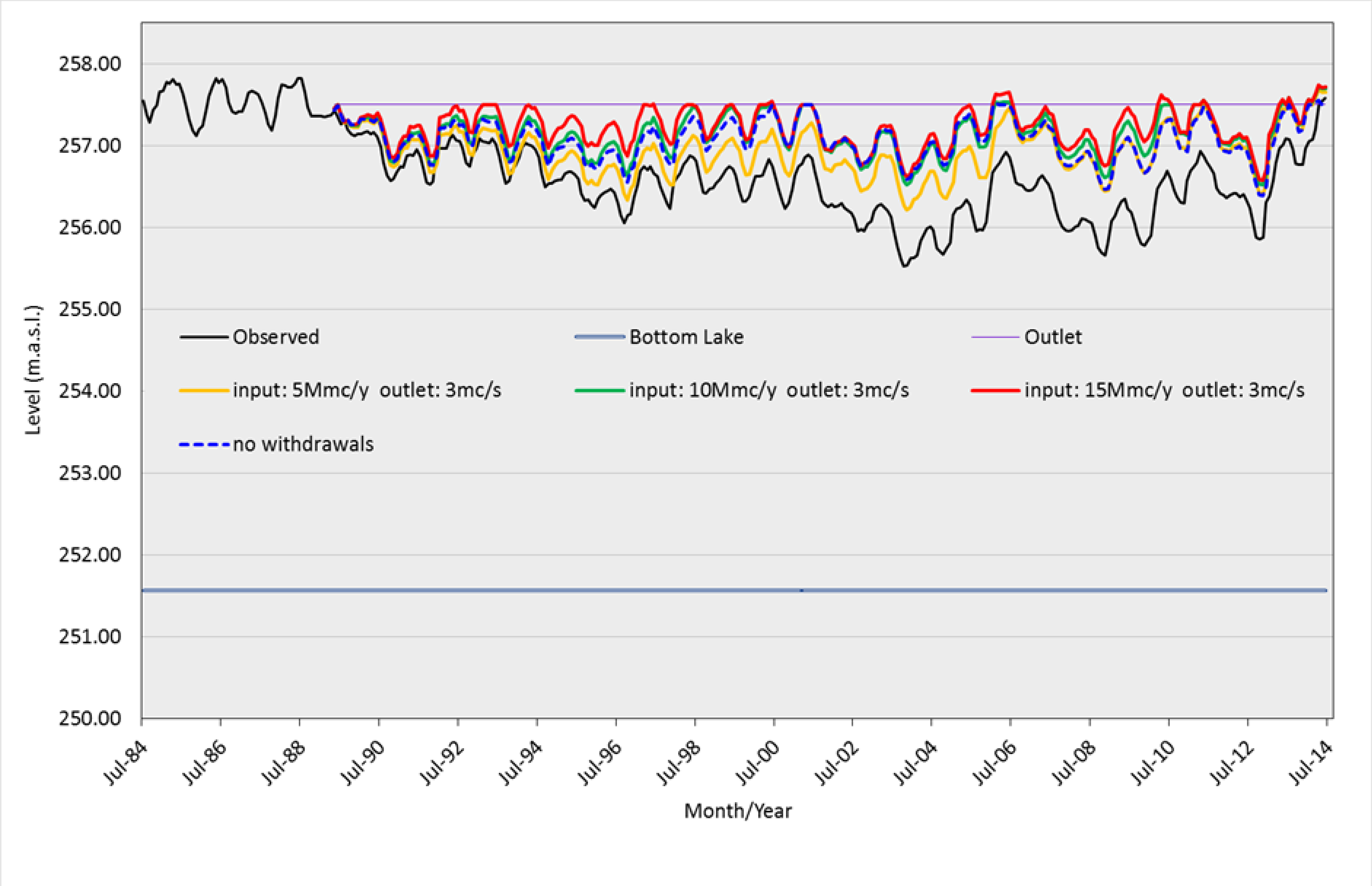
Simulation of the Lake Levels if … water was diverted into the Lake from the Tiber river



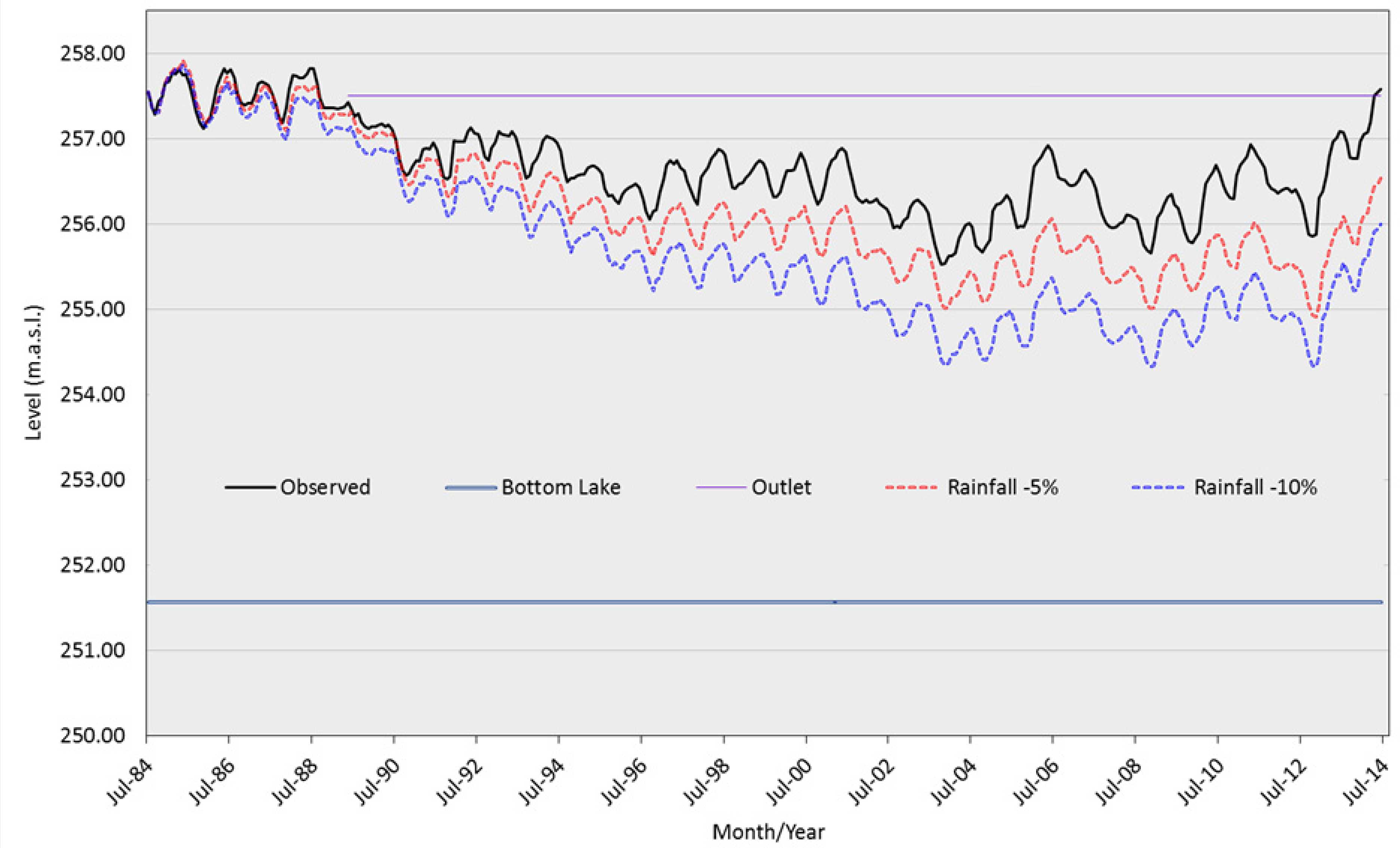
Simulation of the Lake Levels if … no withdrawals for irrigation.

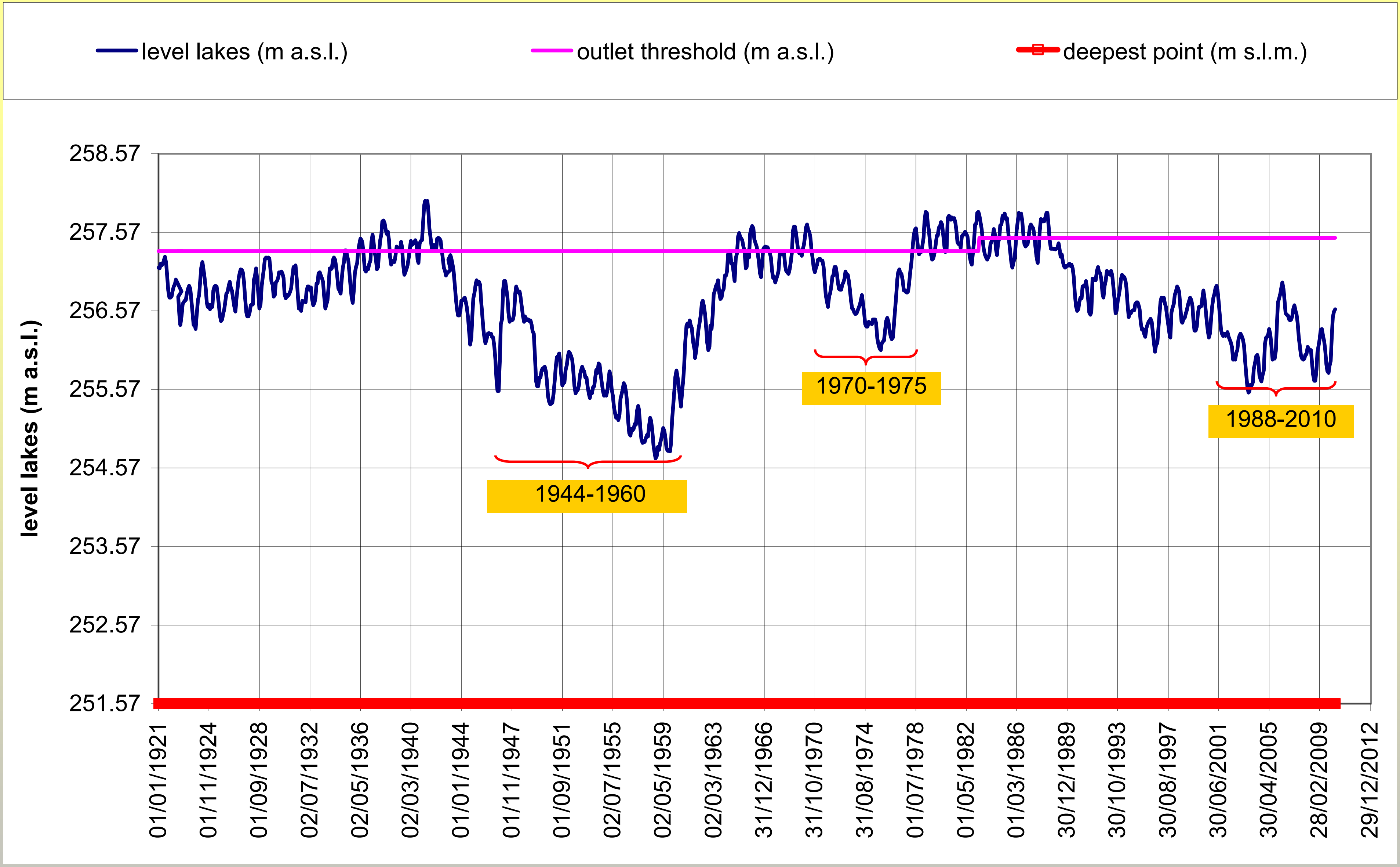


Simulation of the Lake Levels if … no withdrawals for irrigation.



Simulation of the Lake Levels if … the rains had followed the IPCC scenarios




level lakes (m a.s.l.)
outlet threshold (m a.s.l.)
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01/09/1951
02/07/1955
02/05/1959
02/03/1963
31/12/1966
31/10/1970
31/08/1974
01/07/1978
01/05/1982
01/03/1986
30/12/1989
30/10/1993
30/08/1997
30/06/2001
30/04/2005
28/02/2009
29/12/2012

Conclusions

In order to decrease the number of years with water levels below 256.5 m a.s.l., it is necessary to bring into the lake circa 14 Mm^3/year of water (Tiber?). This would assure a certain renewal of the water Lake.

IPCC forecasts on Southern Europe a decrease of rainfall up to 20%, and an increase of temperature up to 2 – 3 C: if the rainfall would decrease according to the scenarios of IPCC and other pertinent literature, inevitably the Lake would decrease its surface and thus its depth.

It is necessary to improve the quality and the number of the data: evaporation, solar radiance, meteo data.

• **Measurement of Hydrometeorological data:**

In South America measurement stations passed from 4267 a 390 in the period 1989 – 2006 (LORENZ & KUNSTMANN, 2012)

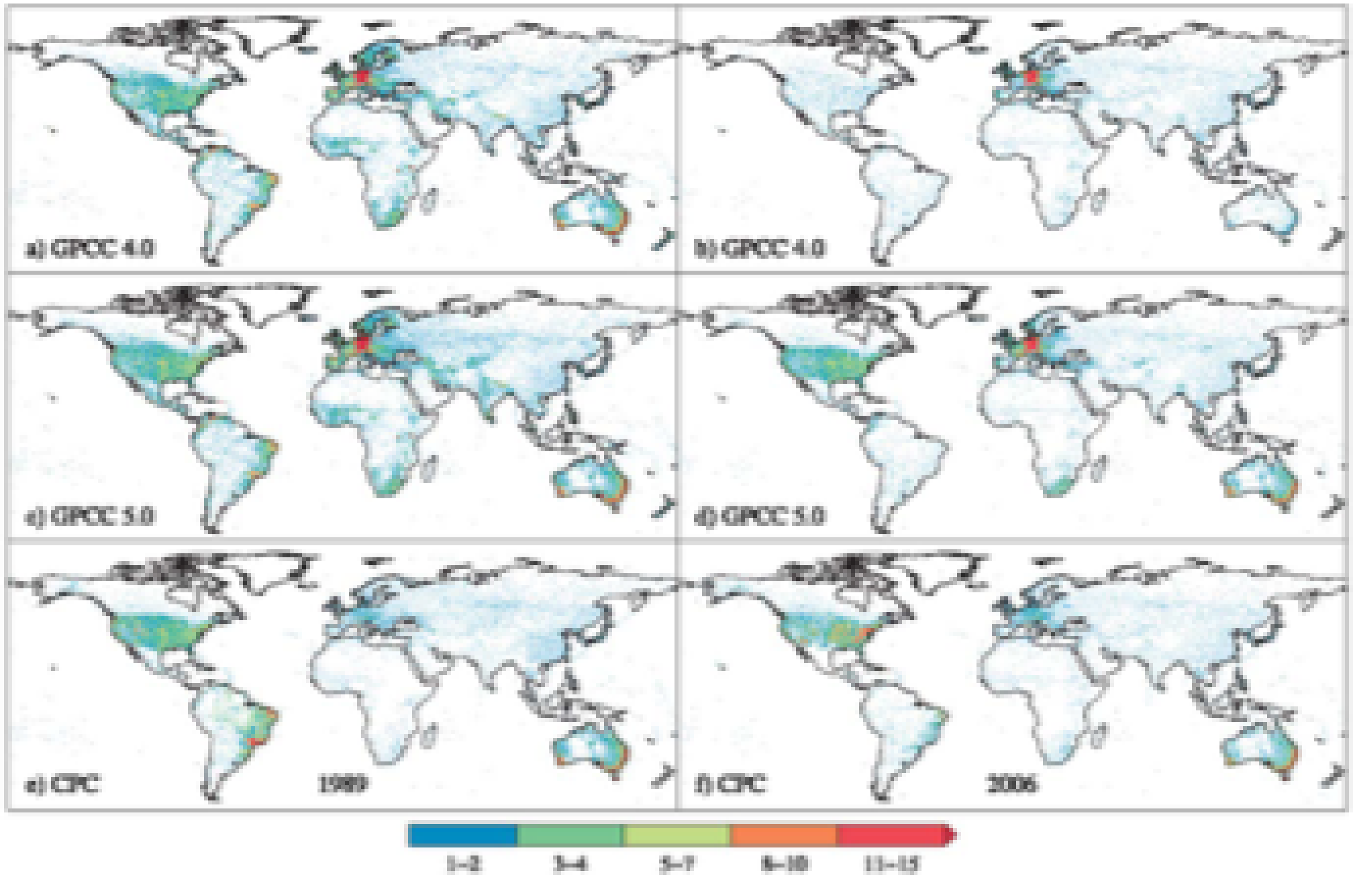

FIG. 3. Number of monitoring stations per 0.5° × 0.5° grid cell in (a),(c),(e) January 1989 and (b),(d),(f) December 2006 for the (a),(b) GPCC v4.0; (c),(d) GPCC v5.0; and (e),(f) CPC datasets. A good spatial coverage with observation stations can be observed over North America (GPCC v5.0 and CPC) and Europe (GPCC v4.0 and v5.0), while the number of gauges over North America is significantly reduced in GPCC v4.0. Over most of the tropical regions like the Congo or Amazon basin, high-latitude regions, and large parts of Asia, the three datasets use a maximum of 1–2 gauges per grid cell, whereas some areas are completely ungauged.

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Grazie per l’attenzione!