



# European Geosciences Union General Assembly 2018

Vienna | Austria | 8–13 April 2018

EGU.eu



**EGU 2018 – Session HS1.8: History of Hydrology**

## **From mythology to science: the development of scientific hydrological concepts in the Greek antiquity**



Demetris Koutsoyiannis & Nikos Mamassis

Department of Water Resources and Environmental Engineering

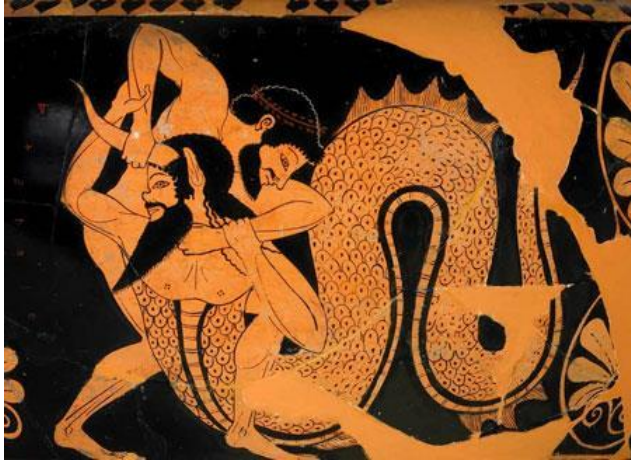
School of Civil Engineering

National Technical University of Athens, Greece

([dk@ntua.gr](mailto:dk@ntua.gr))

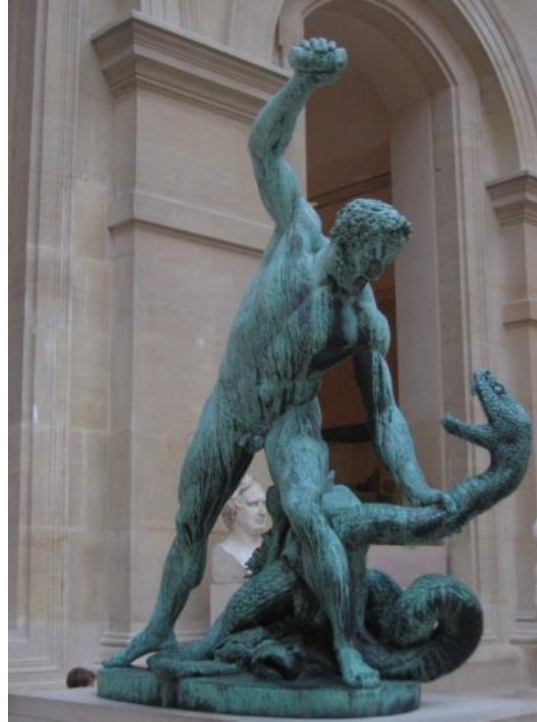
Presentation available online: <http://itia.ntua.gr/1801/>

# Ancient Greek mythology has been inspiring — even in modern times

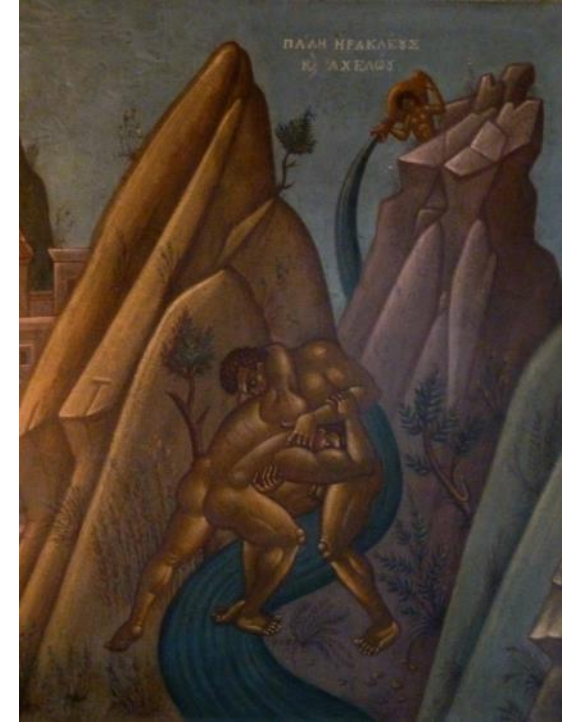


Athenian red-figure stamnos 6<sup>th</sup> BC, British Museum.

The myth of Hercules fighting Acheloos, a deity personifying the most important river of Greece, symbolizes the fight of men against the destructive power of rivers.



Hercules fighting Acheloos transformed into a snake in the Louvre; François Joseph Bosio, (1824) (wikipedia).

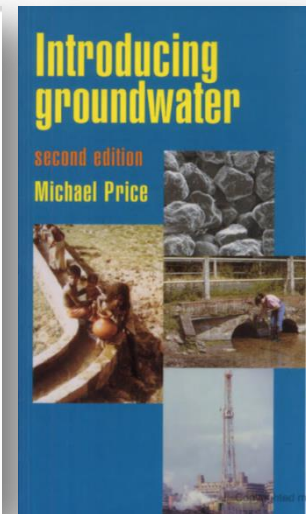


Hercules fighting Acheloos; wall painting in the Athens City Hall by Fotis Kontoglou, writer, painter and hagiographer of the 20<sup>th</sup> century.

# Modern mythology about past knowledge can also be inspiring

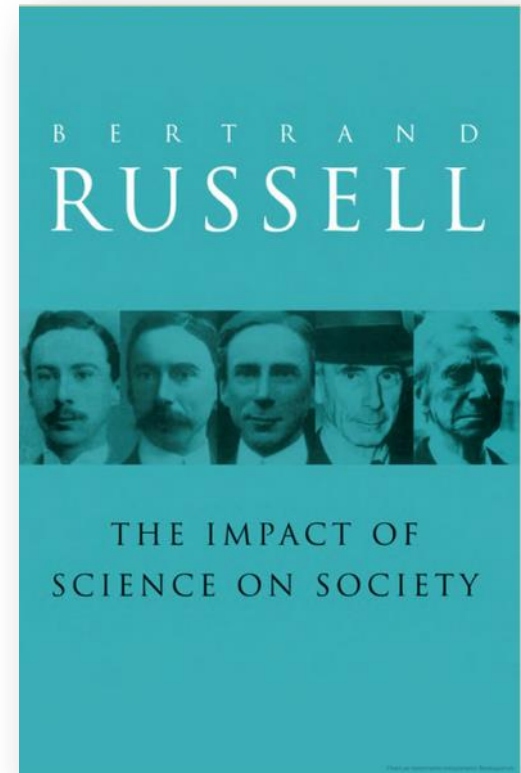
An inspiring extract from Price (1989):

*“Today, our version of the **hydrological cycle** seems so logical and obvious that **it is difficult to believe that it did not gain widespread acceptance until the 17<sup>th</sup> century**. This was caused in large part by the **tendency of the philosophers of Ancient Greece to distrust observations** and by the tendency of later philosophers to accept the opinions of the Greeks almost without question. **Plato advocated the search for truth by reasoning. He and his followers appear to have attached little importance to observations and measurements. Thus Aristotle, Plato's most famous pupil, was reportedly able to teach that men have more teeth than women, when simple observation would have dispelled this idea.** From a hydrological viewpoint, however, he had a more serious misconception – he believed that rainfall alone was inadequate to sustain the flow of rivers.”*



# Tracing back the succession of inspirations regarding Aristotle and women's teeth

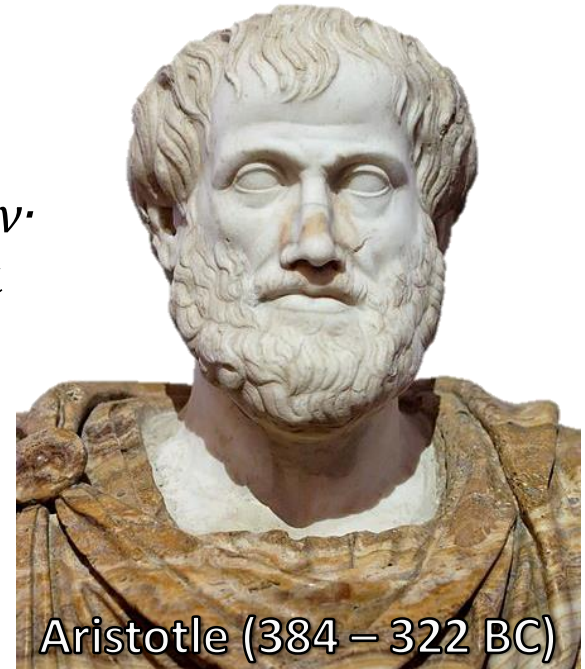
***“Observation versus Authority: To modern educated people, it seems obvious that matters of fact are to be ascertained by observation, not by consulting ancient authorities. But this is an entirely modern conception, which hardly existed before the seventeenth century. Aristotle maintained that women have fewer teeth than men; although he was twice married, it never occurred to him to verify this statement by examining his wives' mouths”*** (Russell, 1952).



# The original text by Aristotle

«Ἐχουσι δὲ πλείους οἱ ἄρρενες τῶν θηλειῶν ὀδόντας καὶ ἐν ἀνθρώποις καὶ ἐπὶ προβάτων καὶ αἰγῶν καὶ ὑῶν· ἐπὶ δὲ τῶν ἄλλων οὐ τεθεώρηται πῶ. [...] Φύονται δ' οἱ τελευταῖοι τοῖς ἀνθρώποις γόμφιοι, οὓς καλοῦσι κραντῆρας, περὶ τὰ εἴκοσιν ἔτη καὶ ἀνδράσι καὶ γυναιξίν. Ἦδη δὲ τισι γυναιξὶ καὶ ὀγδοήκοντα ἔτῶν οὔσαις ἔφυσαν γόμφιοι ἐν τοῖς ἐσχάτοις [...]»  
(Των περὶ τὰ ζῶα ιστοριῶν, Β).

*“Males have more teeth than females in the case of men, sheep, goats, and swine; **in the case of other animals observations have not yet been made** [...] The last teeth to come in man are molars called 'wisdom-teeth', which come at the age of about twenty years, in the case of both men and women. Cases have been known in women of eighty years old where at the very close of life the wisdom-teeth have come up [...]”*  
(History of Animals/Book II).



Aristotle (384 – 322 BC)

Unless otherwise noted, images depicting persons are from wikipedia.

# Some epistemological questions

- What do we mean by *observation*? Does information from school teachers, professors, books, TV, internet, climate projections for the year 3000 AD, etc., classify as *observation*?
- Is the number of teeth:
  - A constant for all individuals? (and irrespective of sex?)
  - Varying among individuals
  - Varying among individuals and also varying in time for each individual? (like in a stochastic process?)
- How did Russell know whether or not Aristotle examined his two wives' teeth?
- And did Russell's himself examine his own four wives' teeth?

# What do modern statistical data say?

**Table 46. Mean number of permanent teeth among dentate adults 20–64 years of age, by selected characteristics: United States, National Health and Nutrition Examination Survey, 1988–1994 and 1999–2004**

Characteristic	1988–1994		1999–2004	
	Mean	Standard error	Mean	Standard error
Age				
20–34 years. . . . .	26.44	0.07	26.90	0.05
35–49 years. . . . .	24.14	0.16	25.05	0.11
50–64 years. . . . .	20.39	0.22	22.30	0.22
Sex				
Male . . . . .	24.10	0.11	25.06	0.13
Female. . . . .	23.86	0.14	24.90	0.08
Race and ethnicity				
White, non-Hispanic. . . . .	24.28	0.14	25.23	0.13
Black, non-Hispanic. . . . .	22.03	0.14	23.68	0.13
Mexican American. . . . .	24.81	0.09	25.32	0.08

Official USA statistical data; Dye et al. (2007)

# A first and second reason for the difference

- (1) The number of teeth decreases with increasing age and women's life expectancy is longer by several years than men's.
- (2) Women's teeth seem to be more fragile than men's.

Official USA statistical data:  
Harvey (1981).  
Average number of decayed (D), missing (M), and filled (F) permanent teeth per person, among adults 35-74 years of age, by sex and age: United States, 1960-62 and 1971-74.

<i>Sex and age</i>	<i>DMF teeth</i>	
	<i>1960-62</i>	<i>1971-74</i>
Both sexes, 35-74 years . . . . .	19.1	20.2
Men		
35-74 years . . . . .	18.5	19.5
35-44 years . . . . .	17.2	18.4
45-54 years . . . . .	18.0	19.2
55-64 years . . . . .	20.4	20.7
65-74 years . . . . .	22.3	21.8
Women		
35-74 years . . . . .	19.7	20.8
35-44 years . . . . .	18.8	20.0
45-54 years . . . . .	19.6	20.5
55-64 years . . . . .	21.9	21.5
65-74 years . . . . .	22.8	22.5



# A third and fourth reason for the difference

(3) “**Sex Disparities.** Table 2 represents the distribution and prevalence of third molar **agenesis** [congenital lack of one or more teeth] according to sex. Frequency of third molar agenesis was higher in females than males” (Sujon et al., 2016).

Table 2. The frequency of agenesis according to sex.

Sex	n	Agenesis	Prevalence	$\chi^2$	p value
Male	2136	785	36.8%	5.02	.025*
Female	2092	839	40.1%		

\* p value <0.05 is significant

doi:10.1371/journal.pone.0162070.t002

(4) “**Hyperdontia** [increase in number of teeth in relation to the normal dental formula] is more common in males, and the degree of sex difference is greater in blacks” and “The number of extra teeth per person ranged from 1 to 8” (Harris and Clark, 2008).

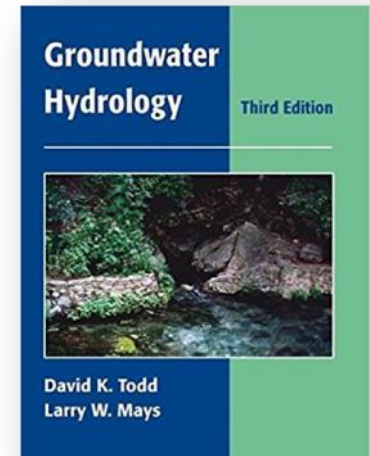
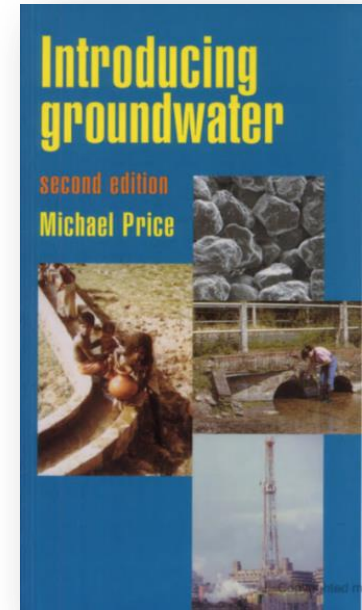
# Modern mythology about past knowledge (contd.)

Another inspiring extract from Price (1989):

*“The first person to make a forthright and unequivocal statement that rivers and springs originate entirely from rainfall appears to have been a Frenchman called Bernard Palissy, who put forward this proposition in 1580. Despite this, in the early 17<sup>th</sup> century many workers were still in essence **following the Greeks in believing that sea water was drawn into vast caverns in the interior of the Earth, and raised up to the level of the mountains by fanciful processes** usually involving evaporation and condensation. The water was then released through crevices in the rocks to flow into the rivers and so back to the sea.”*

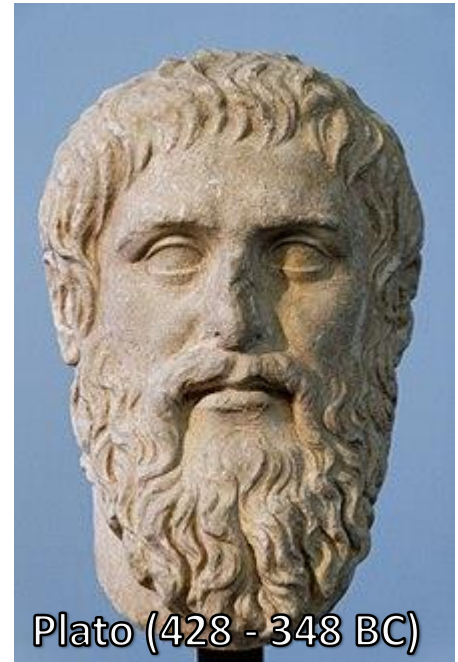
A similar extract from Todd & Mays (2005)

*“As late as the seventeenth century it was generally assumed that **water emerging from springs could not be derived from rainfall, for it was believed that the quantity was inadequate** and the earth too impervious to permit penetration of rainwater far below the surface. Thus, early Greek philosophers such as Homer, Thales, and Plato hypothesized that springs were formed by seawater conducted through subterranean channels below the mountains, then purified and raised to the surface. Aristotle suggested that air enters cold dark caverns under the mountains where it condenses into water and contributes to springs.”*



# Finding the culprit: Plato

[Σωκράτης:] «[...] τοῦτο [το χάσμα] ὅπερ Ὅμηρος εἶπε, λέγων αὐτό “τῆλε μάλ’, ἧχι βάθιστον ὑπὸ χθονός ἐστι βέρεθρον ὃ καὶ ἄλλοθι καὶ ἐκεῖνος καὶ ἄλλοι πολλοὶ τῶν ποιητῶν Τάρταρον κεκλήκασιν. εἰς γὰρ τοῦτο τὸ χάσμα συρρέουσιν τε πάντες οἱ ποταμοὶ καὶ ἐκ τούτου πάλιν ἐκρέουσιν: γίνονται δὲ ἕκαστοι τοιοῦτοι δι’ οἷας ἂν καὶ τῆς γῆς ῥέωσιν. [...] ὅταν τε οὖν ὑποχωρήσῃ τὸ ὕδωρ εἰς τὸν τόπον τὸν δὴ κάτω καλούμενον, τοῖς κατ’ ἐκεῖνα τὰ ρεύματα διὰ τῆς γῆς εἰσρεῖ τε καὶ πληροῖ αὐτὰ ὥσπερ οἱ ἐπαντλοῦντες: ὅταν τε αὖ ἐκεῖθεν μὲν ἀπολίπη, δεῦρο δὲ ὀρμήσῃ, τὰ ἐνθάδε πληροῖ αὖθις» (Φαίδων, 14.112α).



Plato (428 - 348 BC)

[Socrates:] “[...] *One of the chasms of the earth is greater than the rest, and is bored right through the whole earth; this [chasm] is the one which Homer means when he says ‘Far off, the lowest abyss beneath the earth’ and which elsewhere he and many other poets have called Tartarus. For all the rivers flow together into this chasm and flow out of it again, and they have each the nature of the earth through which they flow. [...] And when the water retires to the region which we call the lower, it flows into the rivers there and fills them up, as if it were pumped into them; and when it leaves that region and comes back to this side, it fills the rivers here*” (Phaedo, 14.112a).

# Is this extract from Phaedo what the Greek philosophers said about the hydrological cycle?

While the view expressed in Phaedo was adopted by many thinkers and scientists from Seneca (ca. 4 BC–65 AD) to Descartes (1596-1650), **it is a just a poetic metaphor**, as indicated by the reference to Homer. It has a **symbolic meaning** as the philosophical subject of the dialogue Phaedo is the **immortality of the soul**. It is not representative of Greek philosophers' views on Nature, not even Plato's. In other dialogs Plato offers more consistent theories:

«τὸ κατ' ἐνιαυτὸν ὕδωρ ἐκαρποῦτ' ἐκ Διός, οὐχ ὡς νῦν ἀπολλῦσα ῥέον ἀπὸ ψιλῆς τῆς γῆς εἰς θάλατταν, ἀλλὰ πολλὴν ἔχουσα καὶ εἰς αὐτὴν καταδεχομένη, τῇ κεραμίδι στεγούσῃ γῆ διαταμιευομένη, τὸ καταποθὲν ἐκ τῶν ὑψηλῶν ὕδωρ εἰς τὰ κοῖλα ἀφιεῖσα κατὰ πάντας τοὺς τόπους παρείχετο ἄφθονα κρηνῶν καὶ ποταμῶν νάματα» (Πλάτων, Κριτίας, 111δ).

*“Moreover, it was enriched by the **yearly rains** from Zeus, which were not lost to it, as now, by flowing from the bare land into the sea; but the **soil** it had was deep, and therein it received the water, **storing it up in the retentive loamy soil** and by drawing off into the hollows from the heights the **water that was there absorbed, it provided all the various districts with abundant supplies of springwaters and rivers**” (Plato, Critias, 111d).*

# Hydrology at the birth of science

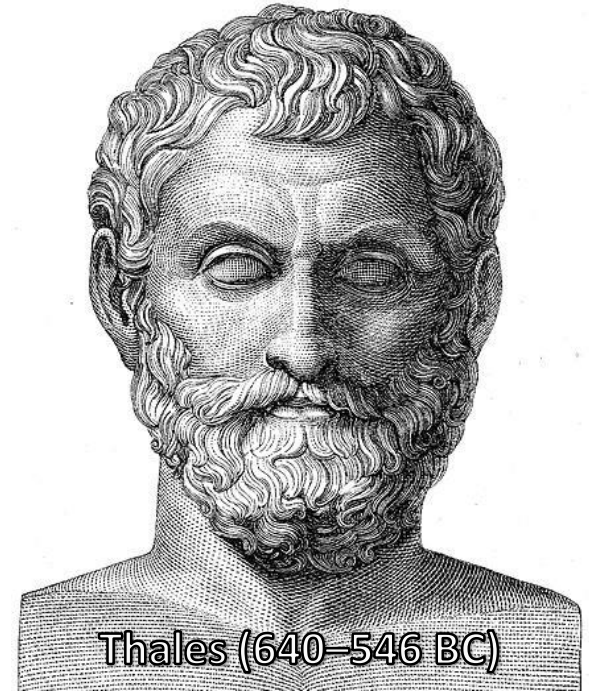
Thales of Miletus, one of the Seven Sages of Greece, is regarded as the **father of natural philosophy and science**. In addition to his scientific achievements on geometry and astronomy, he dealt with the *paradox of the Nile* (see below) thus highlighting the **importance of hydrology in the birth of science**.

His successor Anaximander is the first to dare write a book «Περὶ Φύσεως» (“On Nature”; lost), rejecting mythological and religious views. He understood the relationship of rainfall and evaporation:

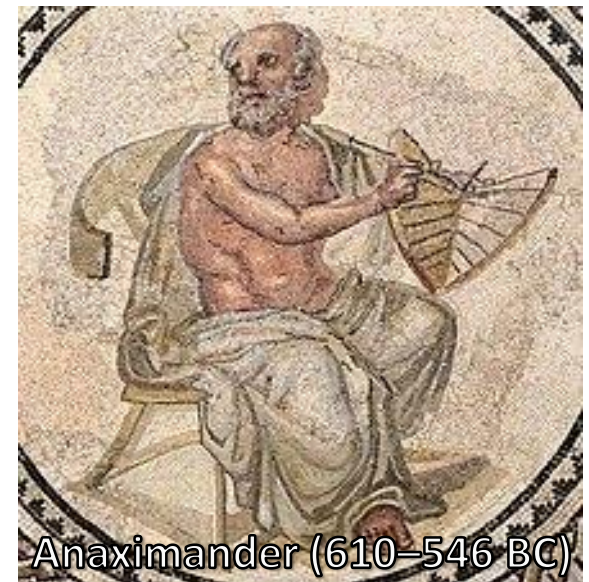
«ὕετους δὲ [γίγνεσθαι] ἐκ τῆς ἀτμίδος τῆς ἐκ γῆς ὑφ’ ἥλιον ἀναδιδομένης» (Ἰππόλυτος, Φιλοσοφούμενα ἢ Κατὰ Πασῶν Αἰρέσεων Ἔλεγχος, I, 5).

“*Rain is created from the vapours which rise from earth by the sun*” (Hippolytus of Rome, Refutation of All Heresies, I, 5;

<https://books.google.gr/books?id=9HCOCwAAQBAJ>).



Thales (640–546 BC)



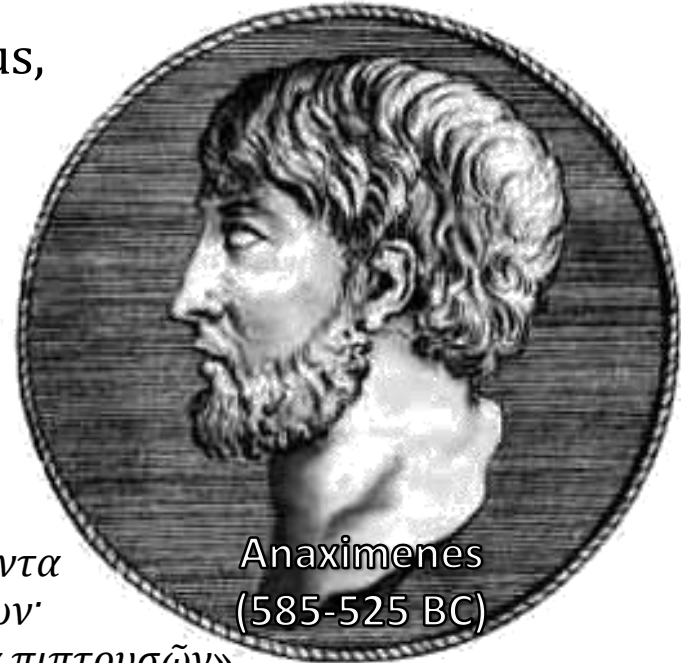
Anaximander (610–546 BC)

# Atmospheric phenomena and Anaximenes

Anaximenes was another philosopher from Miletus, who proclaimed Air as the “Arche” (origin) of the universe; naturally, thus, he devised logical explanations for the formation of wind, clouds, rain and hail:

«[...] ἀνέμους δὲ γεννᾶσθαι, ὅταν ἐκ <μέρους> πεπυκνωμένος ὁ ἀήρ καὶ ἀρθεῖς φέρηται· συνελθόντα δὲ καὶ ἐπὶ πλεῖον παχυνθέντα νέφη γεννᾶσθαι καὶ οὕτως εἰς ὕδωρ μεταβάλλειν. χάλαζαν δὲ γίνεσθαι, ὅταν ἀπὸ τῶν νεφῶν τὸ ὕδωρ καταφερόμενον παγῆ· χιόνα δέ, ὅταν αὐτὰ ταῦτα ἐνυγρότερα ὄντα πῆξιν λάβῃ. ἀστραπὴν δ' ὅταν τὰ νέφη διυστῆται βίαι πνευμάτων· [...]. Ἴριν δὲ γεννᾶσθαι τῶν ἡλιακῶν αὐγῶν εἰς ἀέρα συνεστῶτα πιπτουσῶν»  
(Ἰππόλυτος, Φιλοσοφούμενα ἢ Κατὰ Πασῶν Αἰρέσεων "Ἐλεγχος, I, 6)

*“[...] the winds arise when the air becomes partially condensed and is lifted up; and when it comes together and more condensed, clouds are generated, and thus a change is made into water. And hail is produced when the water precipitating from the clouds freezes; and snow is generated when these clouds, being more moist, acquire congelation; and lightning is caused when the clouds are parted by force of the winds; [...]. And a rainbow is produced from solar rays falling on condensed air”* (Hippolytus, Refutation of All Heresies, I, 6).



# The entire hydrological cycle and Xenophanes

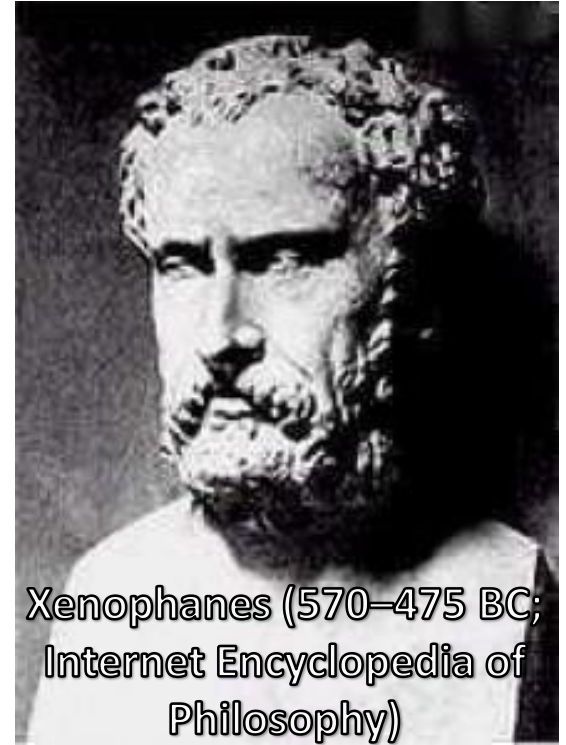
Xenophanes, another Ionian philosopher, supported his theory by the discovery of fossilized marine organisms at three island locations. Hippolitus attributes to him a theory of alternating periods of flood and drought. Xenophanes expressed his philosophy in poetic form (hexameters, elegies, iambics), as in the following fragment:

«πηγή δ' ἐστὶ θάλασσ' ὕδατος, πηγή δ' ἀνέμοιο·  
οὔτε γὰρ ἐν νέφεσιν <γίνοιτό κε ἰς ἀνέμοιο  
ἐκπνεύοντος> ἔσωθεν ἄνευ πόντου μεγάλοιο  
οὔτε ῥοαὶ ποταμῶν οὔτ' αἰ<θέρος> ὄμβριον ὕδωρ,  
ἀλλὰ μέγας πόντος γενέτωρ νεφέων ἀνέμων τε καὶ ποταμῶν»  
(Ξενοφάνης ἐν τῷ Περὶ φύσεως· Απόσπασμα Β 30·

[http://www.poesialatina.it/\\_ns/Greek/testi/Xenophanes/Fragmenta.html](http://www.poesialatina.it/_ns/Greek/testi/Xenophanes/Fragmenta.html))

*“The sea is the source of water and the source of wind;  
for neither in the clouds <would there be nor any blasts of wind  
blowing forth> from within, **without the mighty sea,  
nor river flows nor rain water from the sky.***

***The mighty sea is father of clouds and of winds and of rivers”*** (Fragment B 30,  
recovered from Geneva Scholia on Homer; [https://en.wikisource.org/wiki/Fragments\\_of\\_Xenophanes](https://en.wikisource.org/wiki/Fragments_of_Xenophanes))



Xenophanes (570–475 BC;  
Internet Encyclopedia of  
Philosophy)

# Anaxagoras bringing science to Athens

Anaxagoras of Clazomenae lived and taught in Athens for ~30 years and transplanted the ideas of Ionic philosophers to Athenians, having prominent students such as Pericles, Euripides, Sophocles, and Herodotus. He proposed a theory of “everything-in-everything,” and was the first to give a correct explanation of eclipses.

While his scientific theories were mostly related to astronomy, including the claims that the sun is a mass of red-hot metal and the moon is earthy, they also include hydrology:

«*τοὺς δὲ ποταμοὺς καὶ ἀπὸ τῶν ὄμβρων λαμβάνειν τὴν ὑπόστασιν καὶ ἐξ ὑδάτων τῶν ἐν τῇ γῆ· εἶναι γὰρ αὐτὴν κοίλην καὶ ἔχειν ὕδωρ ἐν τοῖς κοιλώμασιν*» (Ἰππόλυτος, Φιλοσοφούμενα ἢ Κατὰ Πασῶν Αἰρέσεων Ἔλεγχος, I, 7).

***“The rivers receive their contents from the rains and from the waters in the earth; for the earth is hollow and has water in its hollow portions”***  
(Hippolytus, Refutation of All Heresies, I, 7).



Anaxagoras (510 – c. 428 BC) – from a coin of Klazomenae (~ 190-30 BC) seated on globe, (<http://www.ancientcoinage.org/poets-philosophers-astronomers-etc.html>)



# Aristotle and the phase change of water

Aristotle was student of Plato, but his theories were influenced by Ionic philosophers. His theories expand to all aspects of knowledge; in particular his treatise *Meteorologica* offers a great contribution to the explanation of hydrometeorological phenomena:

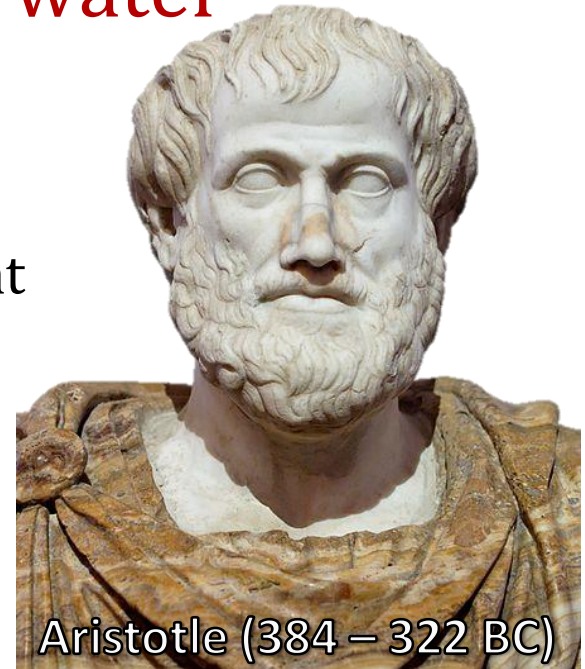
«ἔτι δ' ἡ ὑπὸ τοῦ ἡλίου ἀναγωγὴ τοῦ ὑγροῦ ὁμοία τοῖς θερμαινομένοις ἐστὶν ὕδασιν ὑπὸ πυρός» (Μετεωρολογικά, Β2)

*“the sun causes the moisture to rise; this is similar to what happens when water is heated by fire”*

(*Meteorologica*, II.2, 355a 15)

«συνίσταται πάλιν ἡ ἀτμίς ψυχομένη διὰ τε τὴν ἀπόλειψιν τοῦ θερμοῦ καὶ τὸν τόπον, καὶ γίγνεται ὕδωρ ἐξ ἀέρος· γενόμενον δὲ πάλιν φέρεται πρὸς τὴν γῆν. ἔστι δ' ἡ μὲν ἐξ ὕδατος ἀναθυμίασις ἀτμίς, ἡ δ' ἐξ ἀέρος εἰς ὕδωρ νέφος»

*“the vapour that is cooled, for lack of heat in the area where it lies, condenses and turns from air into water; and after the water has formed in this way it falls down again to the earth; the exhalation of water is vapour; air condensing into water is cloud”* (ibid., I.9, 346b 30).



Aristotle (384 – 322 BC)

# Aristotle and mass conservation

Aristotle recognized the principle of mass conservation within the hydrological cycle:

«ὥστε [τὴν θάλατταν] οὐδέποτε ξηρανεῖται· πάλιν γὰρ ἐκεῖνο φθήσεται καταβὰν εἰς τὴν αὐτὴν τὸ προανεληθόν».

*“Thus, [the sea] will never dry up; for [the water] that has gone up beforehand will return to it” (ibid., II.3, 356b 26).*

«κἂν μὴ κατ’ ἐνιαυτὸν ἀποδιδῶ καὶ καθ’ ἐκάστην ὁμοίως χώραν, ἀλλ’ ἐν γέ τισιν τεταγμένοις χρόνοις ἀποδίδωσι πᾶν τὸ ληφθέν».

*“Even if the same amount does not come back every year or in a given place, yet in a certain period all quantity that has been abstracted is returned” (ibid., II.2, 355a 26).*

# Aristotle and Change

Aristotle penetrated into the concept of “change”. He was fully aware that the landscape changes through the ages and that rivers are formed and disappear in the course of time:

«ἀλλὰ μὴν εἴπερ καὶ οἱ ποταμοὶ γίνονται καὶ φθείρονται καὶ μὴ ἀεὶ οἱ αὐτοὶ τόποι τῆς γῆς ἔνυδροι, καὶ τὴν θάλατταν ἀνάγκη μεταβάλλειν ὁμοίως. τῆς δὲ θαλάττης τὰ μὲν ἀπολειπούσης τὰ δ' ἐπιούσης ἀεὶ φανερόν ὅτι τῆς πάσης γῆς οὐκ ἀεὶ τὰ αὐτὰ τὰ μὲν ἔστιν θάλαττα τὰ δ' ἥπειρος, ἀλλὰ μεταβάλλει τῷ χρόνῳ πάντα».

*“But if rivers are formed and disappear and the same places were not always covered by water, the sea must change correspondingly. And if the sea is receding in one place and advancing in another it is clear that the same parts of the whole earth are not always either sea or land, but that all changes in course of time” (ibid., I.14, 353a 16).*

# Aristotle and experimentation

Aristotle also understood by experiment that salt contained in water is not evaporated:

«ὅτι δὲ γίγνεται ἀτμίζουσα πότιμος καὶ οὐκ εἰς θάλατταν συγκρίνεται τὸ ἀτμίζον, ὅταν συνιστῆται πάλιν, πεπειραμένοι λέγωμεν»

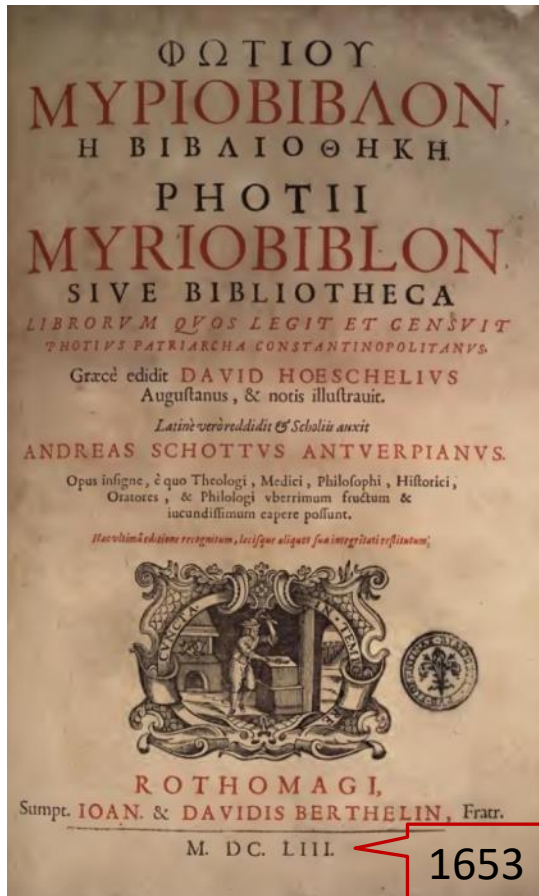
*“Salt water when it turns into vapour becomes drinkable [freshwater] and the vapour does not form salt water when it condenses again; **this I know by experiment**”* (ibid., II.3, 358b).

This has certainly found technological application in desalination (removal of salt from sea water), useful in a country with scarcity of fresh water and many shores and islands. Thus, we learn from a commentary on Aristotle’s *Meteorologica II*, written by Olympiodorus (the peripatetic philosopher, 495 – 570 AD), that:

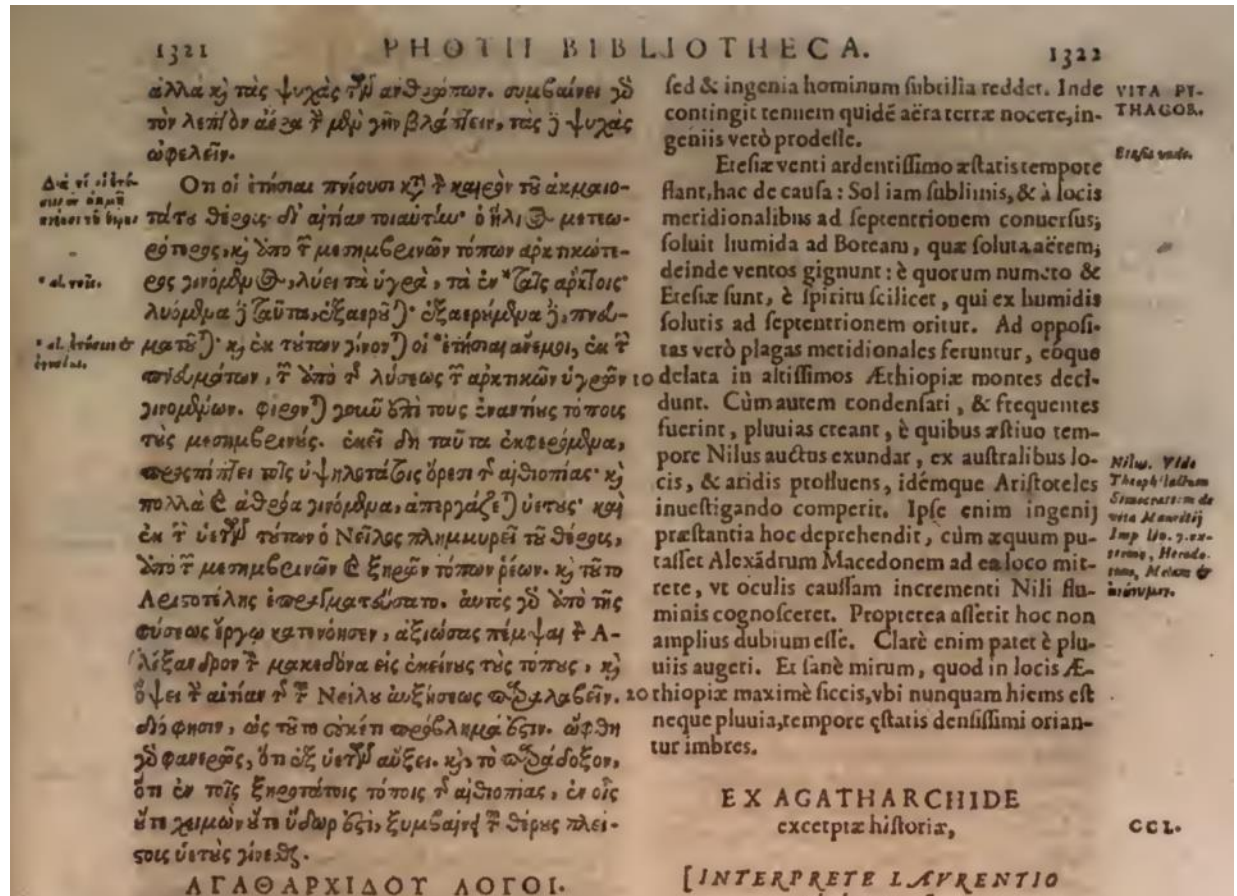
*“Sailors, when they labour under a scarcity of fresh water at sea, boil the sea-water, and suspend large sponges from the mouth of a brazen vessel, to imbibe what is evaporated, and in drawing this off from the sponges, they find it to be sweet [fresh] water”* (Morewood 1838; see also quotation by Alexander of Aphrodisias, peripatetic philosopher, fl. 200 AD, in Forbes, 1970).

# Aristotle and the solution of the Nile paradox

Aristotle's treatise «Περὶ τῆς τοῦ Νείλου ἀναβάσεως» [De inundacione Nili] is lost. However, a work by an anonymous author contained in Patriarch Photios' (~810/820 –893) Bibliotheca, which was published in 1653, gives important information about Aristotle's decisive contribution in solving the Nile paradox.



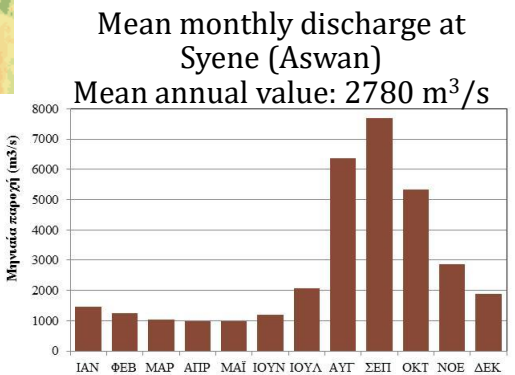
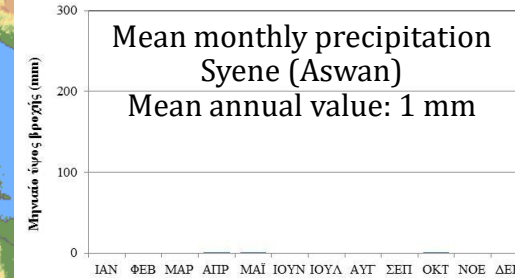
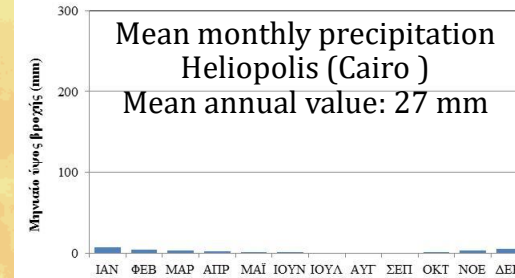
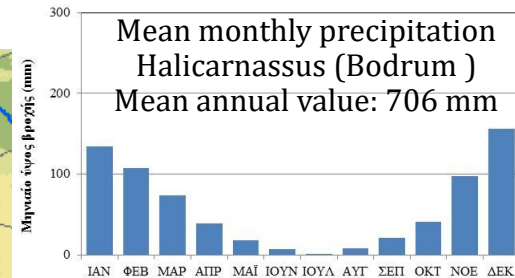
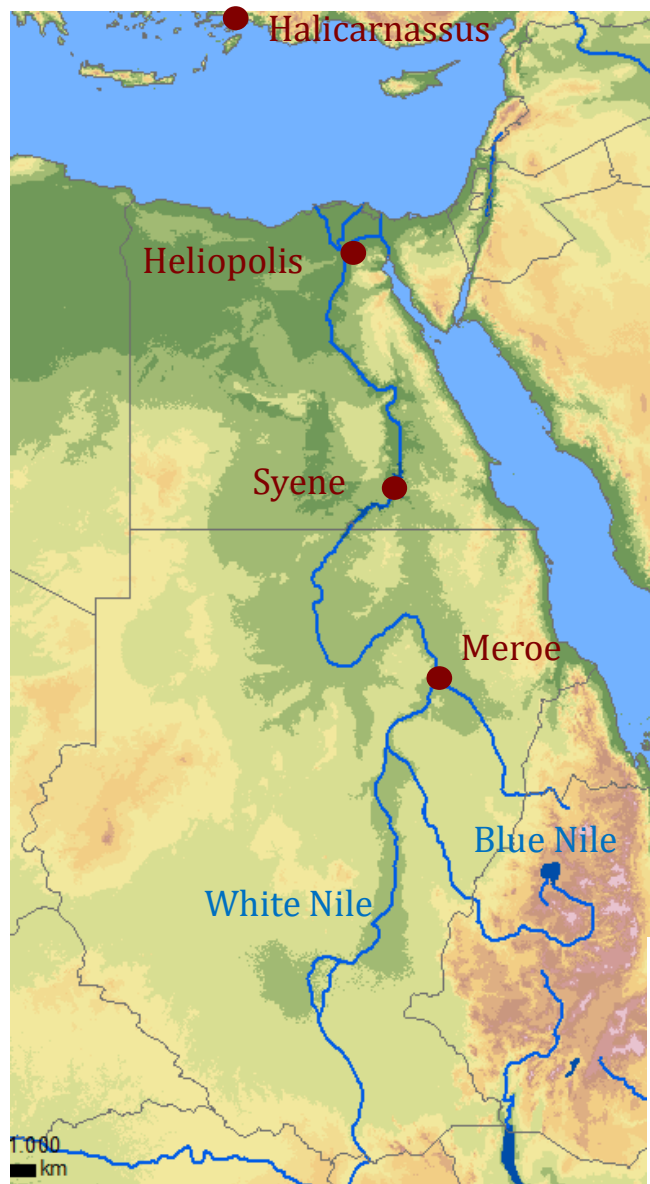
1653



# What was the Nile paradox?

The first great problem related to a natural behaviour and put in scientific terms was the cause of the Nile floods. It was debated for almost three centuries (Burstein, 1976).

What puzzled Greek thinkers was the different hydrological regime compared to other Mediterranean rivers: the Nile floods occur in summer rather than during winter.



# Problem statement by Herodotus

«τοῦ ποταμοῦ δὲ φύσιος πέρι οὔτε τι τῶν ἱρέων οὔτε ἄλλου οὔδενός παραλαβεῖν ἐδυνάσθην. πρόθυμος δὲ ἕα τάδε παρ' αὐτῶν πυθέσθαι, ὃ τι κατέρχεται μὲν ὁ Νεῖλος πληθύνων ἀπὸ τροπέων τῶν θερινέων ἀρξάμενος ἐπὶ ἑκατὸν ἡμέρας, πελάσας δὲ ἕς τὸν ἀριθμὸν τουτέων τῶν ἡμερέων ὀπίσω ἀπέρχεται ἀπολείπων τὸ ῥέεθρον, ὥστε βραχὺς τὸν χειμῶνα ἅπαντα διατελέει ἐὼν μέχρι οὗ αὗτις τροπέων τῶν θερινέων. τούτων ὧν πέρι οὔδενός οὔδεν οἷός τε ἐγενόμην παραλαβεῖν παρὰ τῶν Αἰγυπτίων, ἱστορέων αὐτοὺς **ἦντινα δύναμιν ἔχει ὁ Νεῖλος τὰ ἔμπαλιν πεφυκέναι τῶν ἄλλων ποταμῶν**: ταῦτά τε δὴ τὰ λελεγμένα βουλόμενος εἰδέναι ἱστόρεον καὶ ὃ τι αὔρας ἀποπνεούσας μῦθος ποταμῶν πάντων οὐ παρέχεται» (Ηροδότου Ἱστορία, 2, 19).

*“Concerning the nature of the river, I was not able to gain any information either from the priests or from others. I was particularly anxious to learn from them why the Nile, at the commencement of the summer solstice, begins to rise, and continues to increase for a hundred days—and why, as soon as that number is past, it forthwith retires and contracts its stream, continuing low during the whole of the winter until the summer solstice comes round again. On none of these points could I obtain any explanation from the inhabitants, though I made every inquiry, wishing to know what was commonly reported—**they could neither tell me what special virtue the Nile has which makes it so opposite in its nature to all other streams, nor why, unlike every other river, it gives forth no breezes from its surface**” (Herodotus, The Histories, 2, 19).*

# First explanation described by Herodotus

«ἀλλὰ Ἑλλήνων μὲν τινὲς ἐπίσημοι βουλόμενοι γενέσθαι σοφίην ἔλεξαν περὶ τοῦ ὕδατος τούτου τριφασίας ὁδοῦς: τῶν τὰς μὲν δύο τῶν ὁδῶν οὐδ' ἀξιῶ μνησθῆναι εἰ μὴ ὅσον σημῆναι βουλόμενος μοῦνον».

*“Some of the **prominent Greeks, however, wishing to get a reputation for wisdom, have offered explanations of the phenomena of the river, for which they have accounted in three different ways. Two of these I do not think it worth while to speak of, further than simply to mention what they are**” (ibid. 2, 20).*

«τῶν ἡ ἑτέρη μὲν λέγει τοὺς ἑτησίας ἀνέμους εἶναι αἰτίους πληθύνειν τὸν ποταμόν, κωλύοντας ἐς θάλασσαν ἐκρέειν τὸν Νεῖλον. πολλάκις δὲ ἑτησία μὲν οὐκὼν ἔπνευσαν, ὁ δὲ Νεῖλος τῷ τὸ ἐργάζεται. πρὸς δέ, εἰ ἑτησία αἰτίοι ἦσαν, χρῆν καὶ τοὺς ἄλλους ποταμούς, ὅσοι τοῖσι ἑτησίησι ἀντίοι ῥέουσι, ὁμοίως πάσχειν καὶ κατὰ τὰ αὐτὰ τῷ Νείλῳ, καὶ μᾶλλον ἔτι τοσοῦτῳ ὅσῳ ἐλάσσονες ἐόντες ἀσθενέστερα τὰ ρεύματα παρέχονται. εἰσὶ δὲ πολλοὶ μὲν ἐν τῇ Συρίῃ ποταμοὶ πολλοὶ δὲ ἐν τῇ Λιβύῃ, οἳ οὐδὲν τοιοῦτο πάσχουσι οἷόν τι καὶ ὁ Νεῖλος.»

*“**One says that the Etesian [i.e. monsoon] winds cause the rise of the river by preventing the Nile-water from running off into the sea. But in the first place it has often happened, when the Etesian winds did not blow, that the Nile has risen according to its usual wont; and further, if the Etesian winds produced the effect, the other rivers which flow in a direction opposite to those winds ought to present the same phenomena as the Nile, and the more so as they are all smaller streams, and have a weaker current. But these rivers, of which there are many both in Syria and Libya, are entirely unlike the Nile in this respect**” (ibid. 2, 20).*



## Second explanation described by Herodotus

«ἡ δ' ἑτέρα ἀνεπισημονεστέρα μὲν ἐστὶ τῆς λελεγμένης, λόγῳ δὲ εἰπεῖν θωμασιωτέρα: ἢ λέγει ἀπὸ τοῦ Ὠκεανοῦ ῥέοντα αὐτὸν ταῦτα μηχανᾶσθαι, τὸν δὲ Ὠκεανὸν γῆν περὶ πᾶσαν ῥέειν. [...] ὁ δὲ περὶ τοῦ Ὠκεανοῦ λέξας ἐς ἀφανὲς τὸν μῦθον ἀνεναίκα οὐκ ἔχει ἔλεγχον: οὐ γὰρ τινὰ ἔγωγε οἶδα ποταμὸν Ὠκεανὸν ἔοντα, Ὅμηρον δὲ ἢ τινὰ τῶν πρότερον γενομένων ποιητῶν δοκέω τὸ οὔνομα εὐρόντα ἐς ποίησιν ἐσενείκασθαι.»

*“The second opinion is even more unscientific than the one just mentioned, and also, if I may so say, more marvellous. **It is that the Nile acts so strangely, because it flows from the ocean, and that the ocean flows all round the earth.** [...] As for the writer who attributes the phenomenon to the ocean, his account is involved in such obscurity that it is impossible to disprove it by argument. For my part I know of no river called Ocean, and I think that Homer, or one of the earlier poets, invented the name, and introduced it into his poetry” (ibid. 2, 21&23).*

# Third explanation described by Herodotus

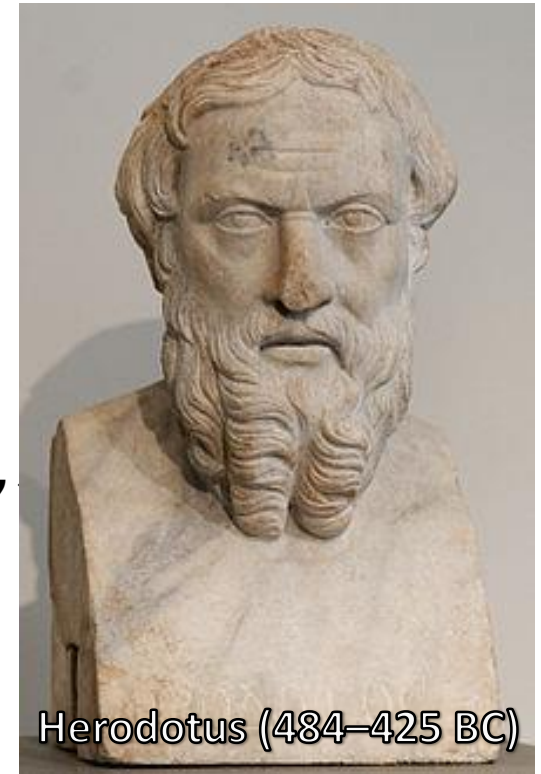
«ἡ δὲ τρίτη τῶν ὁδῶν πολλὸν ἐπιεικεστάτη ἐοῦσα μάλιστα ἔψευσται: λέγει γὰρ δὴ οὐδ' αὐτὴ οὐδέν, φαμένη τὸν Νεῖλον ῥέειν ἀπὸ τηκομένης χιόνος: ὃς ῥέει μὲν ἐκ Λιβύης διὰ μέσων Αἰθιοπῶν, ἐκδιδοῖ δὲ ἐς Αἴγυπτον. κῶς ὦν δῆτα ῥέει ἂν ἀπὸ χιόνος, ἀπὸ τῶν θερμοτάτων ῥέων ἐς τὰ ψυχρότερα τὰ πολλά ἐστι; ἀνδρὶ γε λογίζεσθαι τοιοῦτων πέρι οἴω τε ἐόντι, ὡς οὐδὲ οἶκος ἀπὸ χιόνος μιν ῥέειν, πρῶτον μὲν καὶ μέγιστον μαρτύριον οἱ ἄνεμοι παρέχονται πνέοντες ἀπὸ τῶν χωρέων τουτέων θερμοὶ: δεύτερον δὲ ὅτι ἄνομβρος ἡ χώρα καὶ ἀκρύσταλλος διατελεῖ ἐοῦσα, ἐπὶ δὲ χιόνι πεσοῦση πᾶσα ἀνάγκη ἐστὶ ὕσαι ἐν πέντε ἡμέρησι, ὥστε, εἰ ἐχιόνιζε, ἕτεο ἂν ταῦτα τὰ χωρία: τρίτα δὲ οἱ ἄνθρωποι ὑπὸ τοῦ καύματος μέλανες ἐόντες. ἰκτῖνοι δὲ καὶ χελιδόνες δι' ἔτεος ἐόντες οὐκ ἀπολείπουσι, γέρανοι δὲ φεύγουσαι τὸν χειμῶνα τὸν ἐν τῇ Σκυθικῇ χώρῃ γινόμενον φοιτῶσι ἐς χειμασίην ἐς τοὺς τόπους τούτους. εἰ τοίνυν ἐχιόνιζε καὶ ὅσον ὦν ταύτην τὴν χώραν δι' ἧς τε ῥέει καὶ ἐκ τῆς ἄρχεται ῥέων ὁ Νεῖλος, ἦν ἂν τούτων οὐδέν, ὡς ἡ ἀνάγκη ἐλέγχει.»

*“The third explanation, which is very much more plausible than either of the others, is positively the furthest from the truth; for there is really nothing in what it says, any more than in the other theories. **It is, that the inundation of the Nile is caused by the melting of snows.** Now, as the Nile flows out of Libya, through Ethiopia, into Egypt, how is it possible that it can be formed of melted snow, running, as it does, from the hottest regions of the world into cooler countries? Many are the proofs whereby any one capable of reasoning on the subject may be convinced that it is most unlikely this should be the case. The first and strongest argument is furnished by the winds, which always blow hot from these regions. The second is that rain and frost are unknown there. Now whenever snow falls, it must of necessity rain within five days, so that, if there were snow, there must be rain also in those parts. Thirdly, it is certain that the natives of the country are black with the heat, that the kites and the swallows remain there the whole year, and that the cranes, when they fly from the rigors of a Scythian winter, flock thither to pass the cold season. If then, in the country whence the Nile has its source, or in that through which it flows, there fell ever so little snow, it is absolutely impossible that any of these circumstances could take place” (ibid. 2, 22).*

## Herodotus' own explanation

«εἰ δὲ δεῖ μεμψάμενον γνώμας τὰς προκειμένας αὐτὸν περὶ τῶν ἀφανέων γνώμην ἀποδέξασθαι, φράσω δι' ὃ τι μοι δοκέει πληθύνεσθαι ὁ Νεῖλος τοῦ θέρους: τὴν χειμερινὴν ὥρην ἀπελαυνόμενος ὁ ἥλιος ἐκ τῆς ἀρχαίης διεξόδου ὑπὸ τῶν χειμῶνων ἔρχεται τῆς Λιβύης τὰ ἄνω. ὡς μὲν νυν ἐν ἐλαχίστῳ δηλῶσαι, πᾶν εἴρηται: τῆς γὰρ ἂν ἀγχοτάτῳ τε ἢ χώρης οὗτος ὁ θεὸς καὶ κατὰ ἦντινα, ταύτην οἶκός διψῆν ὑδάτων μάλιστα καὶ τὰ ἐγχώρια ῥεύματα μαραίνεσθαι τῶν ποταμῶν.»

*“Perhaps, after censuring all the opinions that have been put forward on this obscure subject, one ought to propose some theory of one's own. I will therefore proceed to explain what I think to be the reason of the Nile's swelling in the summer time. During the winter, the sun is driven out of his usual course by the storms, and removes to the upper parts of Libya. This is the whole secret in the fewest possible words; for it stands to reason that the country to which **the Sun-god approaches the nearest, and which he passes most directly over, will be scantest of water, and that there the streams which feed the rivers will shrink the most**” (ibid. 2, 24).*



# Who supported the three explanations discussed by Herodotus?

Aetius, the 1<sup>st</sup>- or 2<sup>nd</sup>-century AD doxographer and Eclectic philosopher, reveals the supporters of the three explanations.

Interestingly, **the first explanation is attributed to Thales**, which highlights the strong link of hydrology with science (or natural philosophy), at the dawn of the latter:

«Θαλῆς τοὺς ἐτησίαις ἀνέμους οἶεται πνέοντας τῇ Αἰγύπτῳ ἀντιπροσώπους ἐπαίρειν τοῦ Νείλου τὸν ὄγκον διὰ τὸ τάς ἐκροάς αὐτοῦ τῇ παροιδήσει τοῦ ἀντιπαρήκοντος πελάγους ἀνακόπτεσθαι» (Αἰτίος IV, 1, 1).

*“Thales thinks that the Etesian winds (monsoons), blowing straight on to Egypt, raise up the mass of the Nile’s water through cutting off the outflow by the swelling of the sea coming against it”* (Aetius IV, 1, 1).

The second was supported by Euthymenes of Massalia (Εὐθυμένης ὁ Μασσαλιώτης; fl. early 6<sup>th</sup> century BC), a Greek explorer from Massilia (Marseille), who explored the coast of West Africa.

The third seems to have been supported by Anaxagoras and in another version by Democritus (460–370 BC).

# The solution of the paradox by Aristotle

«Ὅτι οἱ ἐτήσιαι πνέουσι κατὰ τὸν καιρὸν τοῦ ἀκμαιοτάτου θέρους δι' αἰτίαν τοιαύτην. Ὁ ἥλιος μετεωρότερος καὶ ἀπὸ τῶν μεσημβρινῶν τόπων ἀρκτικώτερος γινόμενος λύει τὰ ὑγρά τὰ ἐν ταῖς ἄρκτοις· λυόμενα δὲ ταῦτα ἐξαεροῦται, ἐξαερούμενα δὲ πνευματοῦται, καὶ ἐκ τούτων γίνονται οἱ ἐτήσιαι ἄνεμοι [...]. Ἐκεῖ δὴ ταῦτα ἐκφερόμενα προσπίπτει τοῖς ὑψηλοτάτοις ὄρεσι τῆς Αἰθιοπίας, καὶ πολλὰ καὶ ἀθρόα γινόμενα ἀπεργάζεται ὑετούς· καὶ ἐκ τῶν ὑετῶν τούτων ὁ Νεῖλος πλημμυρεῖ τοῦ θέρους, ἀπὸ τῶν μεσημβρινῶν καὶ ξηρῶν τόπων ῥέων. Καὶ τοῦτο Ἀριστοτέλης ἐπραγματεύσατο· αὐτὸς γὰρ ἀπὸ τῆς φύσεως ἔργῳ κατενόησεν, ἀξιώσας πέμψαι Ἀλέξανδρον τὸν Μακεδόνα εἰς ἐκείνους τοὺς τόπους καὶ ὄψει τὴν αἰτίαν τῆς τοῦ Νεῖλου αὐξήσεως παραλαβεῖν. Διὸ φησιν ὡς τοῦτο οὐκέτι πρόβλημά ἐστιν· ὥφθη γὰρ φανερώς ὅτι ἐξ ὑετῶν αὖξει. Καὶ <λύεται> τὸ παράδοξον, <ὅτι> ἐν τοῖς ξηροτάτοις τόποις τῆς Αἰθιοπίας, ἐν οἷς οὔτε χειμῶν οὔτε ὕδωρ ἐστί, ξυμβαίνει τοῦ θέρους πλείστους ὑετούς γίνεσθαι» (Ανώνυμος, Βίος Πυθαγόρου, στο Φωτίου, Μυριόβιβλον, Anon, [https://el.wikisource.org/wiki/Μαρτυρία\\_\(Αριστοτέλης\)](https://el.wikisource.org/wiki/Μαρτυρία_(Αριστοτέλης))).

*“The Etesian winds [i.e., monsoons] blow during the peak of the summer for this reason. The sun, at the zenith passing from south to north, disintegrates the moisture from the arctics and once this moisture is disintegrated, it evaporates and gives rise to monsoons [...] When they reach the high mountains of Ethiopia and concentrate there, they produce rains. These rains in full summer cause the flood of the Nile and make it overflow, while it flows at the northern arid regions. **This was analysed by Aristotle, who, by the superiority of his mind, understood it. He demanded to send Alexander of Macedonia to these regions, and to find, by sight, the cause of the flooding of the Nile. That's why they say there is not a problem anymore. It became apparent by sight that the flow is increased by these rains. And this solved the paradox that in the driest Ethiopian [i.e. African] places where there is no winter nor rain, it happens that in the summer strong rainfalls occur**” (Anonymus, *Life of Pythagoras*, in Photios, *Bibliotheca*, <http://remacle.org/bloodwolf/erudits/photius/pythagore.htm>)*

# Verification of the story by other philosophers

«Ἐρατοσθένης δὲ οὐκέτι φησὶν <πρόβλημα εἶναι> οὐδὲ ζητεῖν χρῆναι περὶ τῆς αὐξήσεως τοῦ Νείλου, σαφῶς καὶ ἀφικομένων τινῶν εἰς τὰς τοῦ Νείλου πηγὰς καὶ τοὺς ὄμβρους τοὺς γιγνομένους ἑωρακότων, ὥστε κρατύνεσθαι τὴν Ἀριστοτέλους ἀπόδοσιν» (Πρόκλος ο Λύκιος, Σχόλια, Πλάτωνος Τίμαιος, 22 E—I 121, 8 Diehl).

*“Eratosthenes, however, says, it is no longer requisite to investigate the cause of the increase of the Nile, once some have reached at the springs of the Nile and saw the rains that occur there, so as to corroborate what is said by Aristotle”* (Proclus, Commentary on Plato’s Timaeus, 22 E—I 121, 8 Diehl)

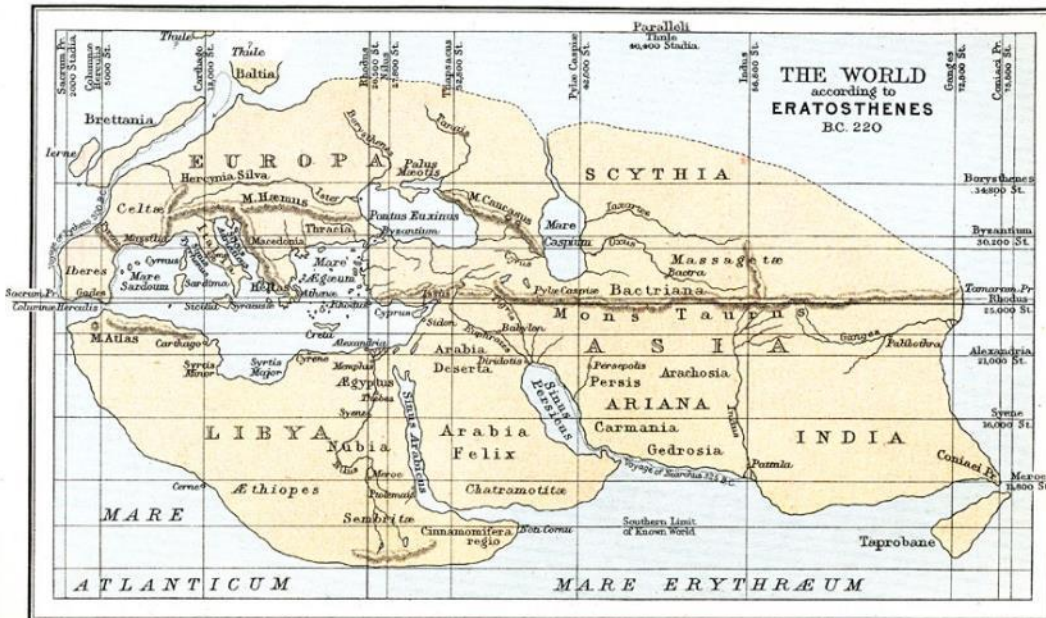
«τῆς γὰρ Αἰθιοπίας ὑψηλοῖς παρὰ τὰ καθ’ ἡμᾶς ὄρεσι διεζωσμένης ὑποδεχομένης τε τὰς νεφέλας πρὸς τῶν ἔτησίων ὠθουμένας, ἐκδιδόναί τὸν Νεῖλον. ὡς καὶ <Καλλισθένης> ὁ Περιπατητικὸς ἐν τῷ τετάρτῳ βιβλίῳ τῶν Ἑλληνικῶν (124 F 12) <φησὶν ἑαυτὸν συστρατεύσασθαι Ἀλεξάνδρῳ τῷ Μακεδόνι, καὶ γενόμενον ἐπὶ τῆς Αἰθιοπίας εὐρεῖν τὸν Νεῖλον ἐξ ἀπείρων ὄμβρων κατ’ ἐκείνην γενομένων> καταφερόμενον» (Ἰωάννης Λαυρέντιος ὁ Λυδός, De mensibus, 4, 107).

*“For since Ethiopia is girdled by mountains higher than ours, as it receives the clouds that are driven by the Etesian [winds], the Nile swells. As Callisthenes the Peripatetic also says in the fourth book of his Hellenica that he campaigned with Alexander the Macedonian, and when he was in Ethiopia he found that the Nile is driven down by the endless rain-storms that take place in that [area]”* (John the Lydian, On the Months, 4, 107).

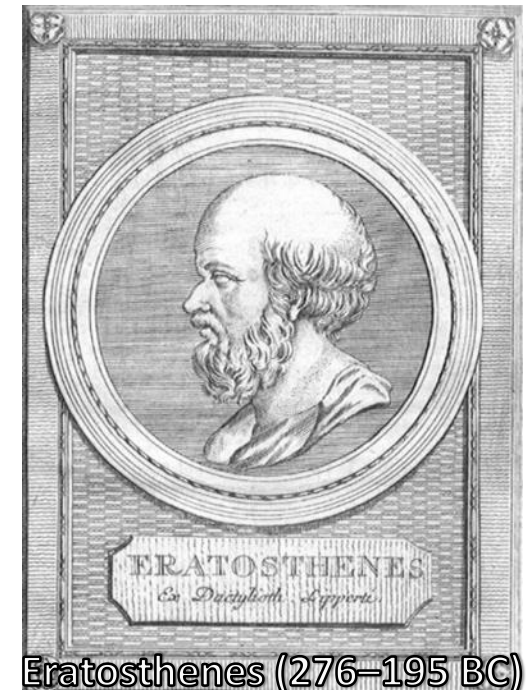
# What about Eratosthenes?

Eratosthenes, head of the Library at Alexandria, among other achievements, calculated the Earth's circumference by measuring, at the noon of the day of summer solstice, the shadow cast by a gnomon at Alexandria and the distance between Alexandria and Syene, where the latter is situated exactly under the Tropic of Cancer.

Eratosthenes also calculated, in following the windings of the Nile, the distances between several points on the Nile up to Meroe (Strabo, Geography, 17.1.2; Rawlins, 1982). Perhaps because of this, he is often credited by several authors (regrettably including Koutsoyiannis, 2014) for solving the paradox of the Nile. However, in view of the information provided here (Proclus, see previous slide), his achievement seems to be no more than a further verification of Aristotle's theory. He also seems to have been aware of the earlier expedition to the Nile sources for the purpose of proving Aristotle's theory (Burstein, 1976).

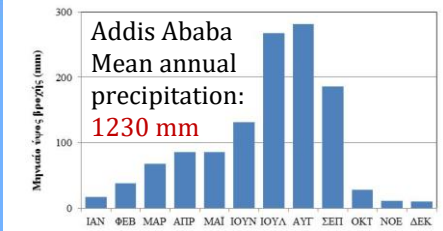
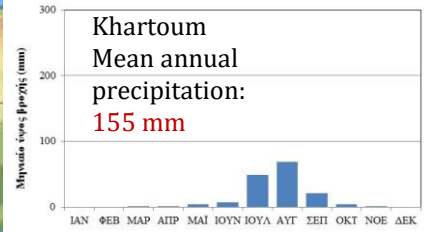
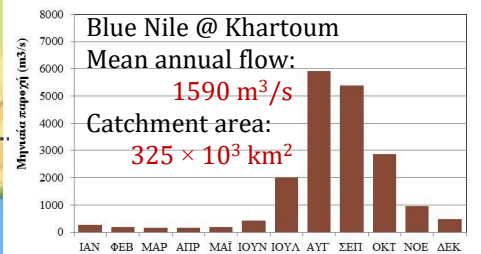
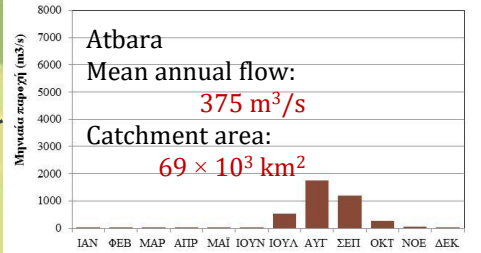
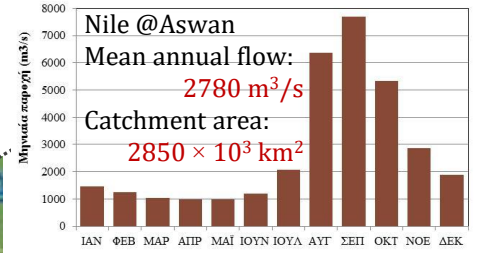
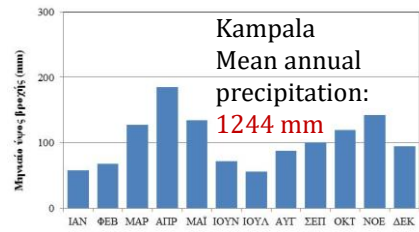
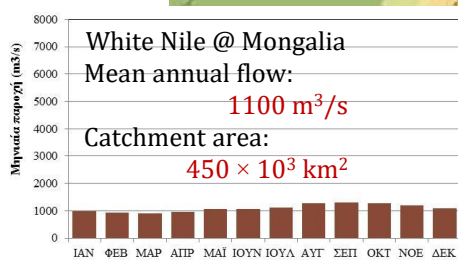
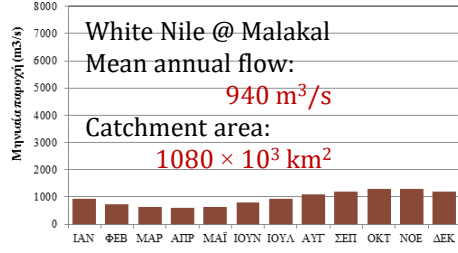
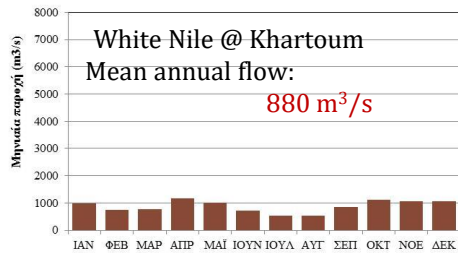


Map of the World according to Eratosthenes (reproduced by Rhys, 1912)



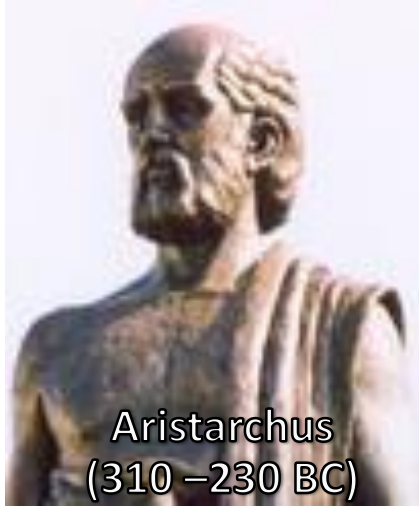
Eratosthenes (276–195 BC)

# The Nile (non)paradox in modern terms





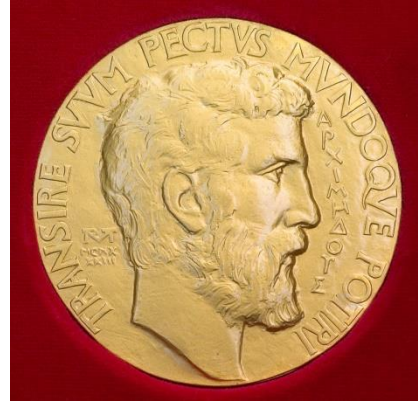
# Prominent scientists of the Hellenistic period with relevance to geosciences and hydrology



Aristarchus  
(310 –230 BC)

Heliocentric model for the solar system 1800 years before Copernicus

Calculations on the relative sizes of the Sun, Earth and Moon

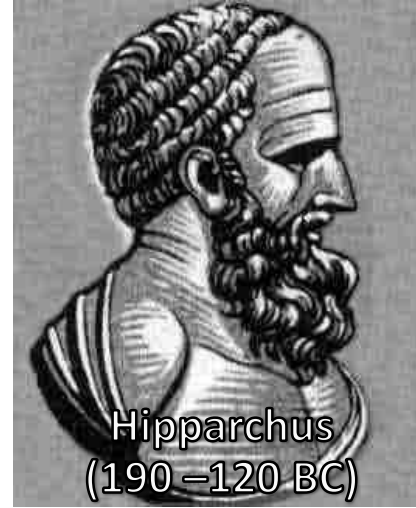


Archimedes  
(287 - 212 BC)

Archimedes' principle and hydrostatics

Archimedes' screw (still in use for pumping)

Infinitesimals and a first version of integral calculus



Hipparchus  
(190 –120 BC)

Introduction of the term Κλίμα (pl. Κλίματα = Climate(s), meaning the inclination angle of the incoming sunbeams

Classification of Earth's climates



Hero of Alexandria  
(fl. ~150 BC\* or ~50 AD)

\*see Woodcroft (1851)

Use of the term Υδραυλικόν (*hydraulic*) ὄργανον (for a musical instrument)

Notion of *discharge* and its measurement

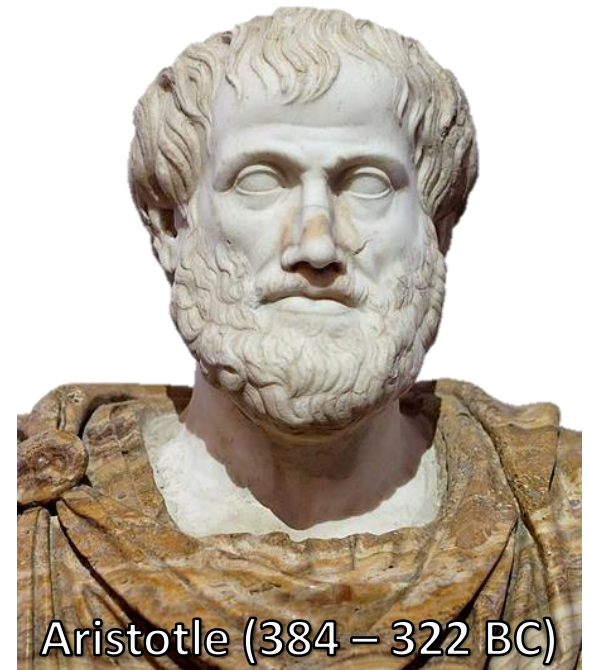
Study of pressure; Steam machines; Pneumatics

# Back to Aristotle: importance of seeking the truth

«φίλος μὲν Σωκράτης, ἀλλὰ φιλτάτη ἡ ἀλήθεια»

(Latin version: “*Amicus Socrates, sed magis amica veritas*”)

“*Socrates is dear (friend), but truth is dearest*” (Ammonius, Life of Aristotle)



«δόξειε δ' ἂν ἴσως βέλτιον εἶναι καὶ δεῖν ἐπὶ σωτηρίᾳ γε τῆς ἀληθείας καὶ τὰ οἰκεῖα ἀναιρεῖν, ἄλλως τε καὶ φιλοσόφους ὄντας: ἀμφοῖν γὰρ ὄντοιν φίλοιν ὅσιον προτιμᾶν τὴν ἀλήθειαν»

“*Still perhaps it would appear desirable, and indeed it would seem to be obligatory, especially for a philosopher, to sacrifice even one’s closest personal ties in defense of the truth. Both are dear to us, yet it is our duty to prefer the truth*” (Aristotle, Nicomachean Ethics 1096a11).

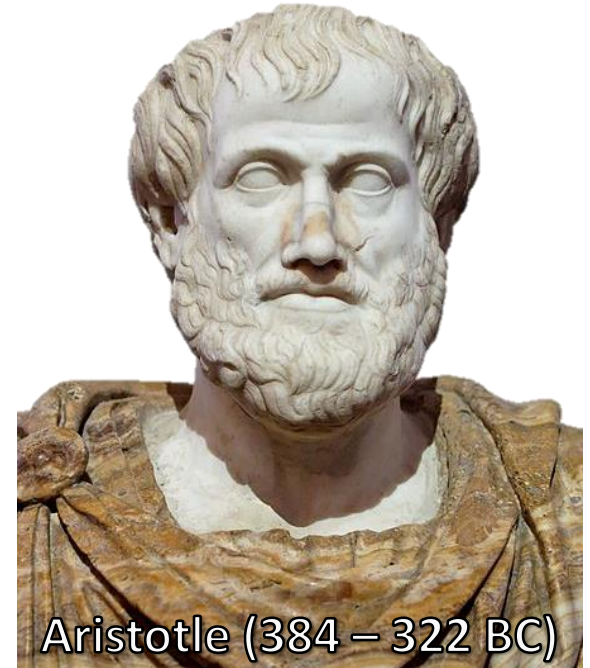
## Other contributions by Aristotle: logic, precision, change

Λογική, συλλογισμός, επαγωγή  
Logic, deduction, induction  
(Aristotle, Organon)

«... τοσοῦτον τάκριβες ἐπιζητεῖν καθ’  
ἕκαστον γένος, ἐφ’ ὅσον ἡ τοῦ  
πράγματος φύσις ἐπιδέχεται»

“... look for precision in each class of  
things just so far as the nature of the  
subject admits”

(Aristotle, Nicomachean Ethics, 1094b)



Aristotle (384 – 322 BC)

«Μεταβάλλει τῷ  
χρόνῳ πάντα»  
“All is changing in the  
course of time”

(Aristotle; Meteorologica,  
I.14, 353a 16)

# Hydrology is the science of change and randomness; Heraclitus described the nature of each in a few words

«Πάντα ῥεῖ»

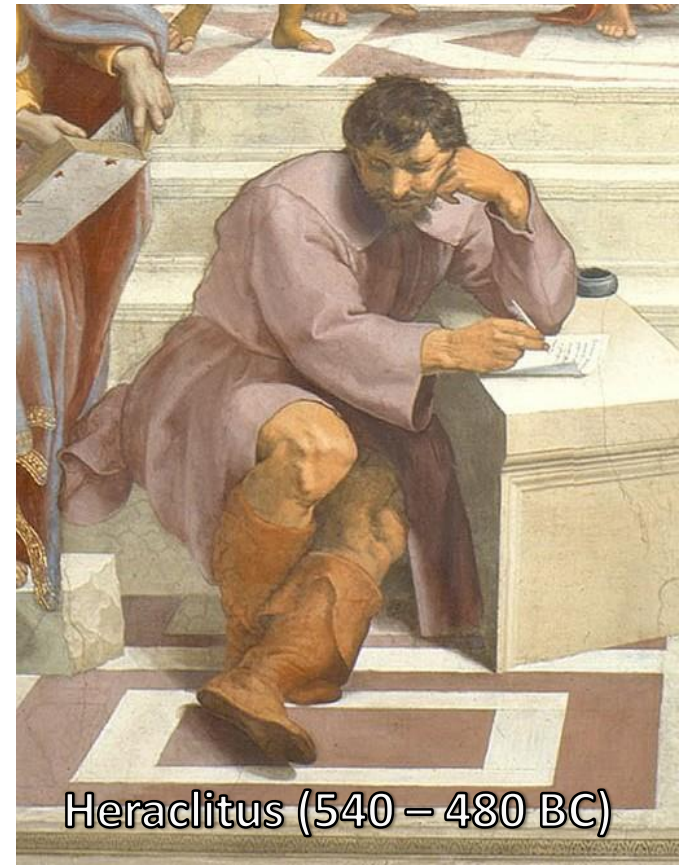
*“Everything flows”*

(Heraclitus; quoted in Plato’s  
Cratylus, 339-340)

«Αἰὼν παῖς ἔστι παίζων πεσσεύων»

*“Time is a child playing, throwing dice”*

(Heraclitus; Fragment 52)



# It takes courage to formulate scientific theories —now as well as then

«ὁ γὰρ πρῶτος σαφέστατόν τε πάντων καὶ θαρραλεώτατον περὶ σελήνης καταυγασμῶν καὶ σκιᾶς λόγον εἰς γραφὴν καταθέμενος Ἄναξαγόρας οὐτ' αὐτὸς ἦν παλαιὸς οὔτε ὁ λόγος ἔνδοξος, ἀλλ' ἀπόρρητος ἔτι καὶ δι' ὀλίγων καὶ μετ' εὐλαβείας τινὸς ἢ πίστεως βαδίζων. οὐ γὰρ ἠνείχοντο τοὺς φυσικοὺς καὶ μετεωρολέσχας τότε καλουμένους, ὡς εἰς αἰτίας ἀλόγους καὶ δυνάμεις ἀπρονοήτους καὶ κατηναγκασμένα πάθη διατρίβοντας τὸ θεῖον, ἀλλὰ καὶ **Πρωταγόρας ἔφυγε, καὶ Ἄναξαγόραν εἰρχθέντα μόλις περιεποιήσατο Περικλῆς, καὶ Σωκράτης**, οὐδὲν αὐτῶ τῶν γε τοιούτων προσῆκον, ὅμως ἀπώλετο διὰ φιλοσοφίαν» (Πλουτάρχου Βίοι Παράλληλοι, Νικίας, 23).

*“The first man to put in writing, most clearly and most courageously of all, the explanation of the moon’s illumination and darkness, was Anaxagoras. But he was no ancient authority, nor was his account in high repute. It was still under seal of secrecy, and made its way slowly among a few only, who received it with a certain caution rather than with confidence. For people did not tolerate the natural philosophers and stargazers, as they were then called, because they reduced the divine agency down to unreasoning causes, blind forces, and necessary incidents. Even **Protagoras was exiled, Anaxagoras was imprisoned and with difficulty rescued by Pericles, and Socrates, though he had nothing whatever to do with such matters, nevertheless lost his life because of philosophy**” (Plutarch, Nicias, 23; cf. I. Velikovsky, Anaxagoras, <http://www.varchive.org/ce/orbit/anax.htm>; note, Anaxagoras was charged of impiety, and he was sentenced to death by the Athenian court. He avoided this penalty by leaving Athens, and he spent his remaining years in exile).*

# Concluding remarks

- **Scientific theories are mostly wrong.** It is a matter of time for any theory to be replaced by a better one.
- Naturally, all theories developed in the dawn of science (2600 years ago) have been replaced. **This does not make them non-scientific.**
- It is a good practice to study the history of science, recognize the past contributions and give credit to those who made them. (Notifications: (a) consulting original texts is useful; (b) humour is different from arrogance).
- This study –of the history of hydrology in particular– is useful as it reveals the **effectiveness of thought and logic**, which were the basic tools of ancient philosophers, in compiling a sensible world vision with some admirable elements, even though other elements are inconsistent according to modern knowledge.
- As the information provided here shows, in addition to thought and logic, **experimentation, measurement, and observation** were all used by ancient philosophers, particularly by Aristotle.
- As evident from our terminology (*meteorology, climate, hydraulics*), **modern science is not independent from the ancient one**; advances of the Greek antiquity have been particularly seminal for the modern science after the Renaissance.

# References

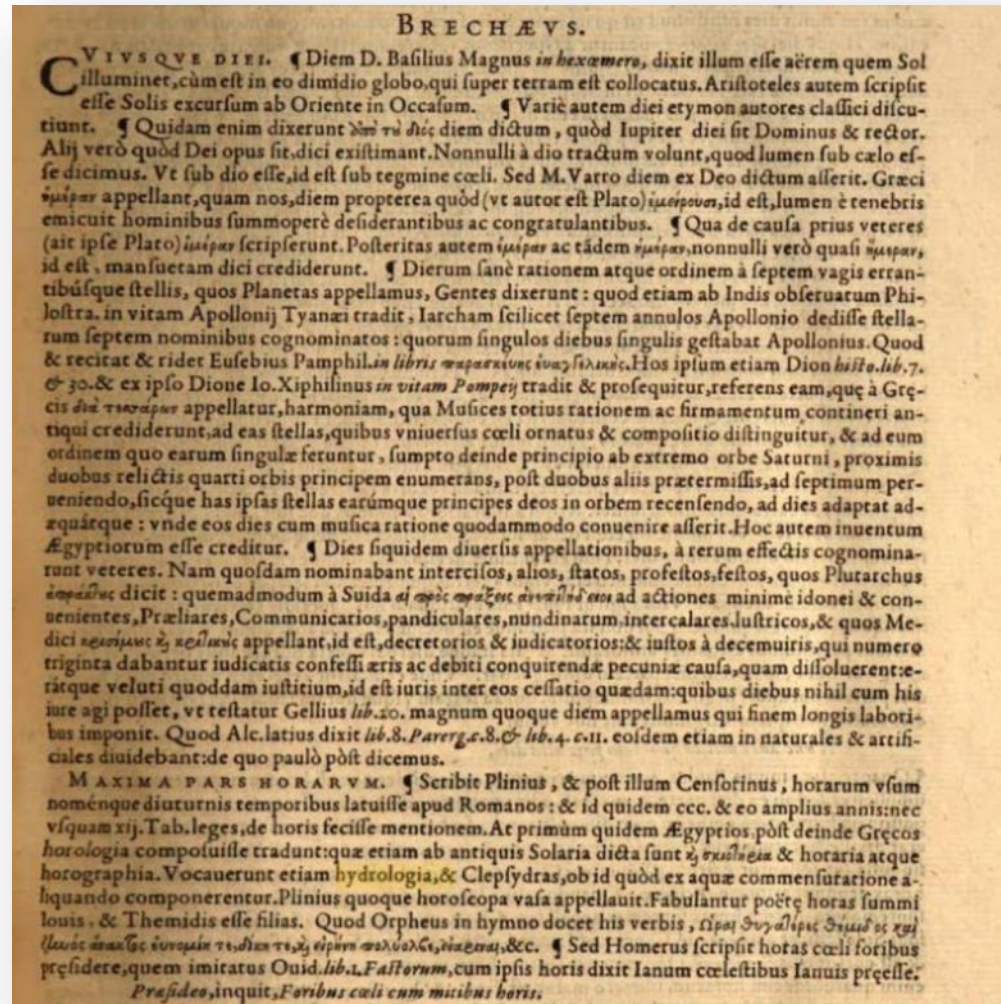
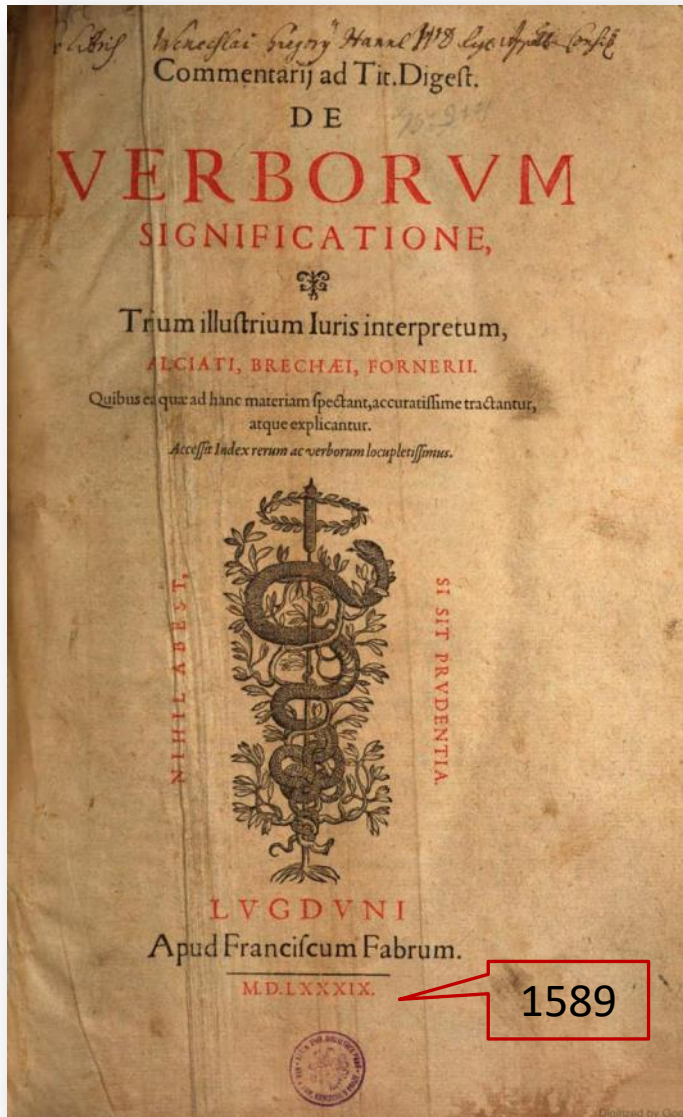
- Burstein, S.M. (1976). Alexander, Callisthenes and the Sources of the Nile. *Greek, Roman And Byzantine Studies*, 17, 135.
- Dye, B.A., Tan, S., Smith, V., Lewis, B.G., et al. (2007), Trends in oral health status: United States, 1988–1994 and 1999–2004, National Center for Health Statistics. *Vital Health Stat* 11(248).
- Forbes, R.J. (1970), *A Short History of the Art of Distillation*, Brill, Leiden, Netherlands, 405 pp.
- Harris, E.F., and Clark, L.L. (2008), An Epidemiological study of hyperdontia in American blacks and whites, *The Angle Orthodontist*, 78 (3), 460-465.
- Harvey, C.R. (1981), Decayed, missing, and filled teeth among persons 1-74 years, United States 1971-75, DHHS Publication No. (PHS) 81-1673, U.S Department of Health and Human Services, Public Health Service, National Center for Health Statistics, Hyattsville, Md, USA.
- Koutsoyiannis, D. (2014), Reconciling hydrology with engineering, *Hydrology Research*, 45 (1), 2–22, doi:10.2166/nh.2013.092.
- Morewood, S. (1838), A philosophical and statistical history of the inventions and customs of ancient and modern nations in the manufacture and use of inebriating liquors: with the present practice of distillation in all its varieties: together with an extensive illustration of the consumption and effects of opium, and other stimulants used in the East, as substitutes for wine and spirits year. W. Curry, Jun. & Co., W. Carson, Dublin.
- Price, M. (1989) *Introducing Groundwater*, Chapman & Hall.
- Rawlins, D. (1982), The Eratosthenes-Strabo Nile Map: Is It the Earliest Surviving Instance of Spherical Cartography? Did It Supply the 5000 Stades Arc for Eratosthenes' Experiment?, *Archive for History of Exact Sciences*, 26 (3), 211-219.
- Rhys, E. (Ed.) (1912), *A Literary and Historical Atlas of Asia*, E.P. Dutton & Co., New York, NY.
- Russell, B. (1952), *The Impact of Science on Society*, New York: Columbia University Press, 64 pp.
- Sujon, M.K., Alam, M.K., Rahman, S.A. (2016), Prevalence of third molar agenesis: associated dental anomalies in non-syndromic 5923 patients, *PLoS ONE*, 11 (8): e0162070, doi: 10.1371/journal.pone.0162070.
- Todd, D., and Mays, L. (2005), *Groundwater Hydrology*, John Wiley & Sons.
- Woodcroft, Bennet (1851), *The Pneumatics of Hero of Alexandria Publisher*, Taylor Walton and Maberly, London.

# Appendix: The appearance of the term *hydrology*

- Several terms related to hydrology appear in ancient Greek literature. Specifically:
  - The conveyance of water or liquids is termed ὑδραγωγία (ἡ), and a person (or device) related to it ὑδραγωγός.
  - The modern term ὑδραυλική (*hydraulics*) stems from ὑδραυλικὸν (*hydraulic*) ὄργανον, a musical instrument operated by hydraulics and invented by Ctesibius; it is also known as ὑδραυλις (ἡ), which is played by a musician called ὑδραύλης.
  - The actions of drawing, fetching or distributing water are termed ὑδρεία, ὑδρευσις and ὑδροπαροχία; a person related to them is termed ὑδροπάροχος and a guard or inspector of aqueducts or irrigation works ὑδροφύλαξ.
  - The action or art of seeking or discovering water is termed ὑδροσκοπία, ὑδροσκοπική or ὑδροφαντική (verb: ὑδροσκοπέω); a person related to it is ὑδρόσκοπος, ὑδρογνώμων or ὑδροφάντης and a related instrument is ὑδροσκόπιον.
  - The term *meteorology* stems from μετεωρολογία, which in turn stems from μετέωρα (meteors; note, in the ancient literature, in addition to hydrometeors, meteors include the heavenly bodies); a person who studies μετεωρολογία is μετεωρολόγος or μετεωρολογικός (cf. Plato's Phaedro 270a and Aristotle's Meteorologica).
  - The term *climate* stems from κλίμα (meaning the inclination angle of the incoming sunbeams; pl. κλίματα); a property pertaining to κλίμα is κλιματικός.
- *Hydrology* is also a Greek word, i.e. ὑδρολογία, but it does not appear in the ancient Greek literature; a close match is ὑδρολόγιον (pl. ὑδρολόγια), which however is a water-clock; as a scientific term with the modern meaning, *hydrologia* appeared after the Renaissance in Latin, Italian and Spanish (*hydrologie* in French and German and *hydrology* in English).

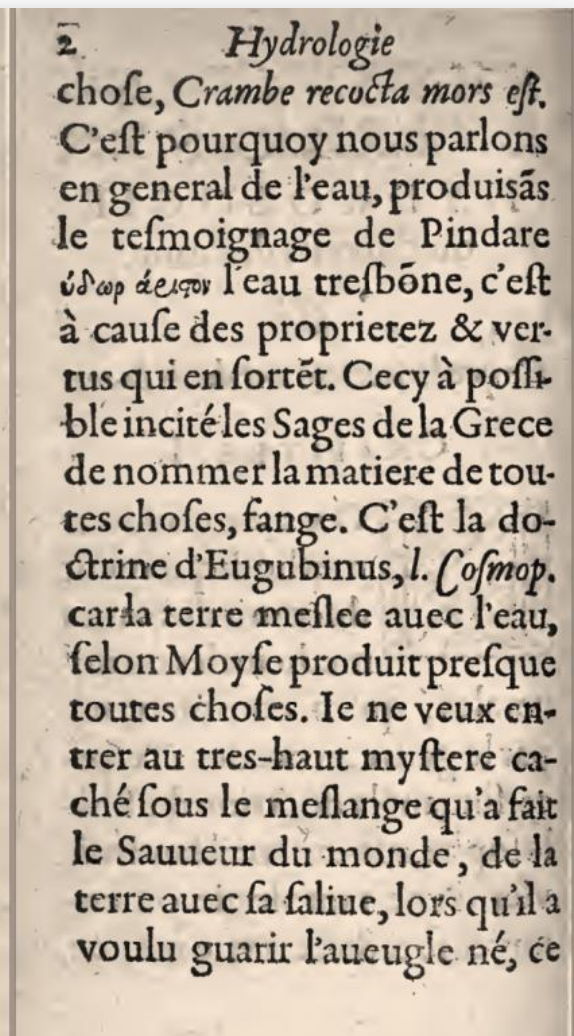
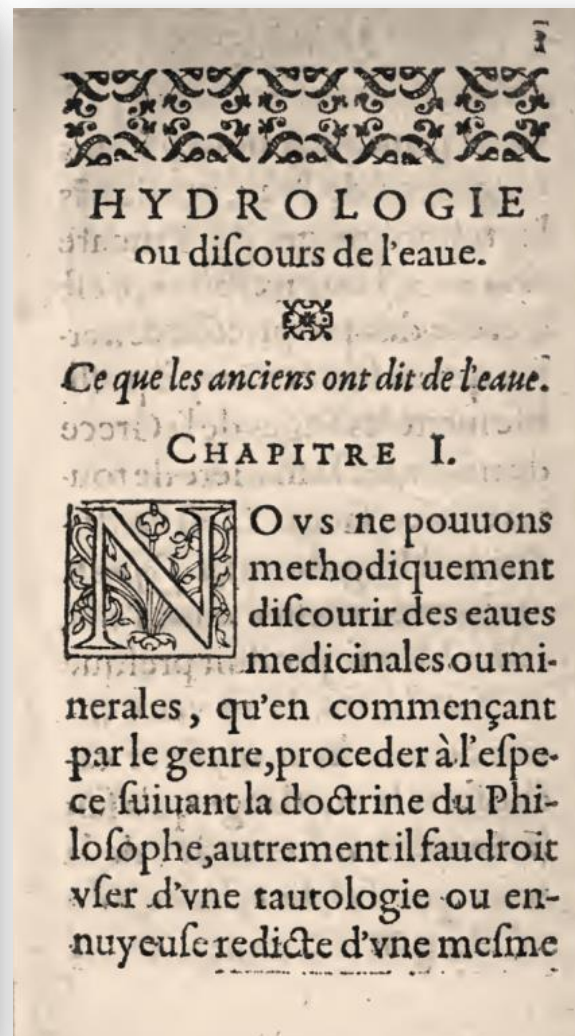
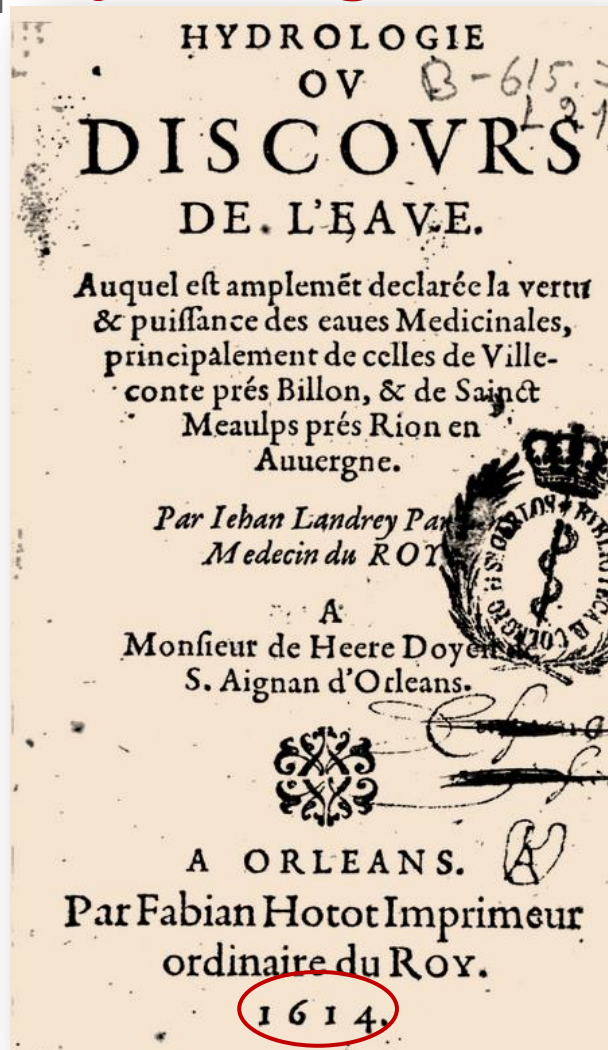


# First appearance of “hydrologia” in a book in print



Here hydrologia seems to be plural of hydrologion, i.e. Clepsydra – hourglass)

# Hydrologie ou Discours de l'Eaue

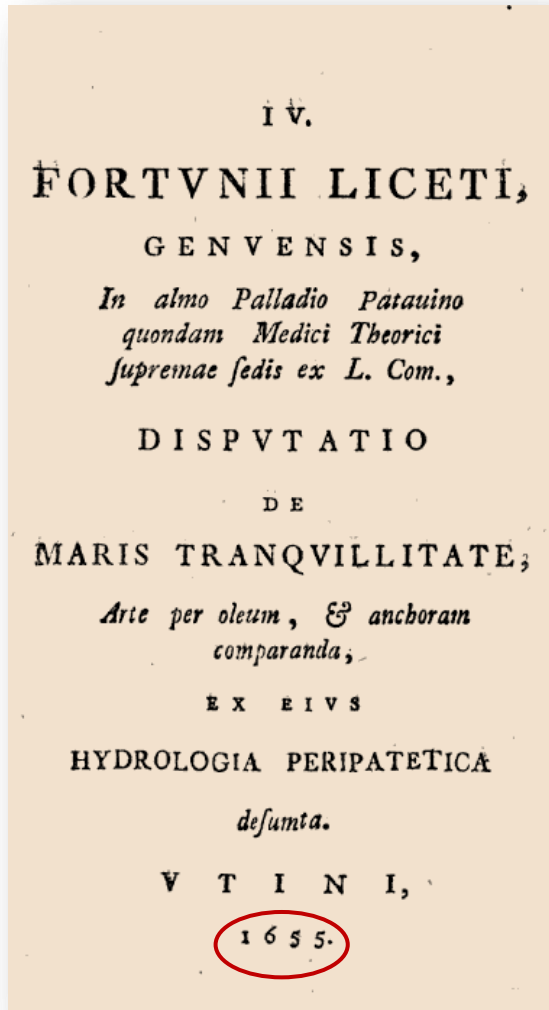


[https://archive.org/details/BIUSante\\_30326](https://archive.org/details/BIUSante_30326)

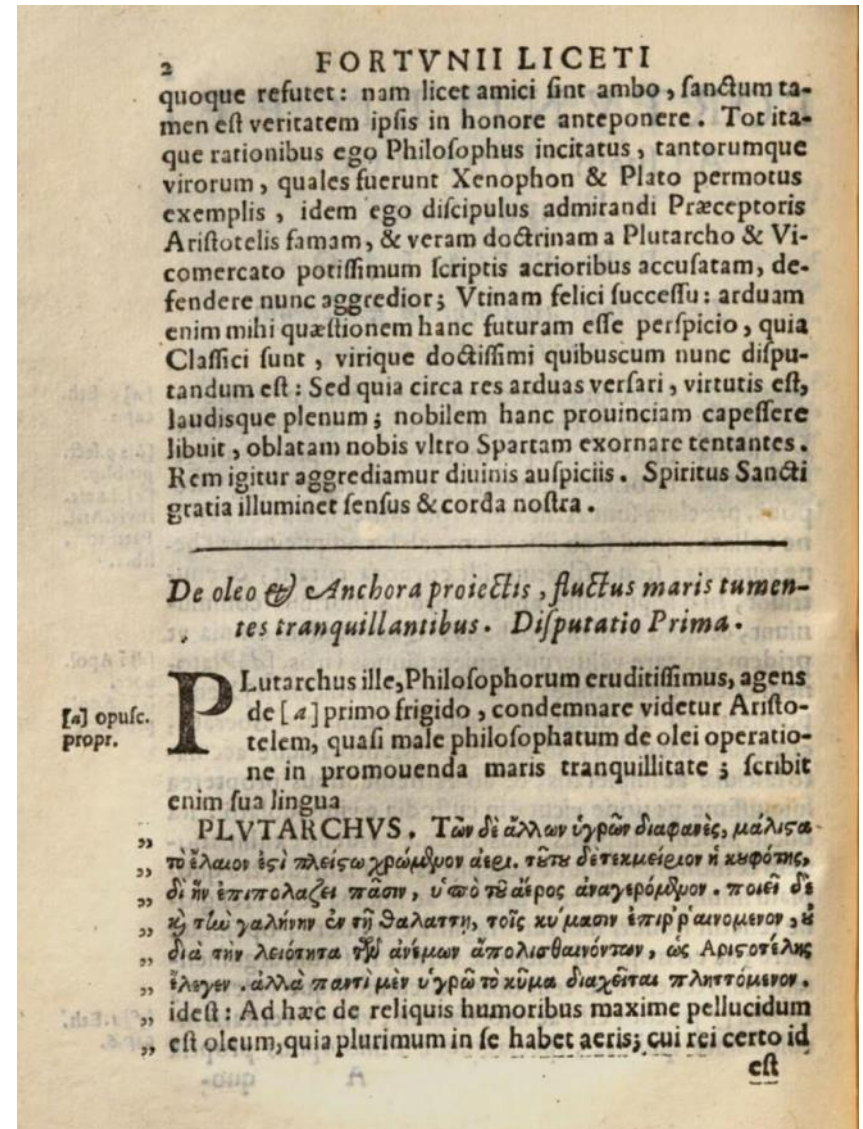
In most of the early uses of *hydrology*, its content is related to medicine and physiology.



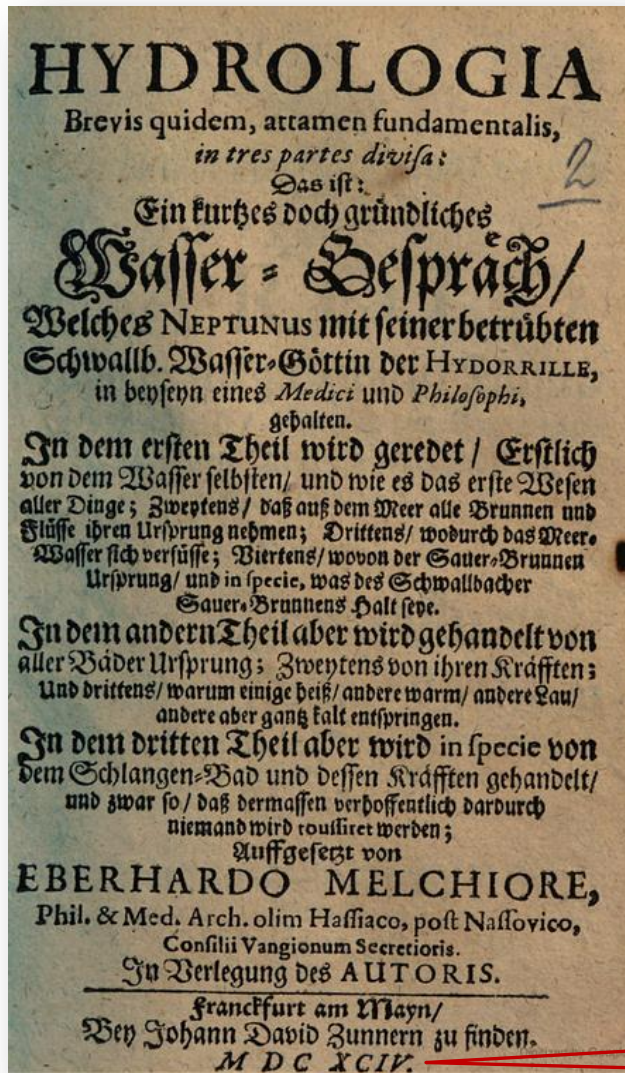
# A book about Hydrologia Peripatetica



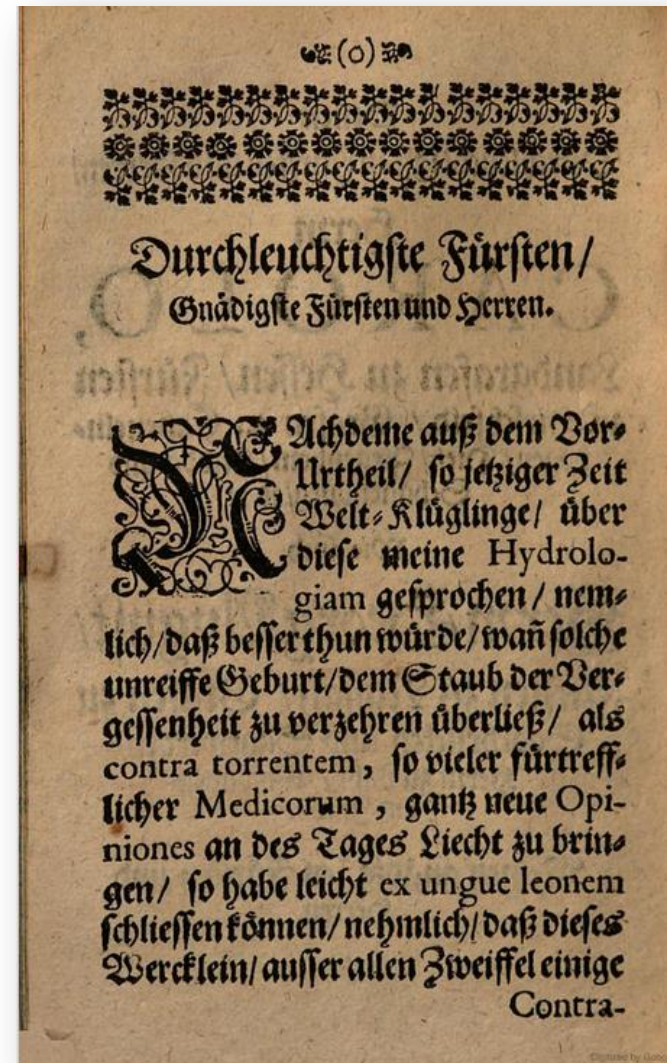
Fortunius LICETUS (or Fortunio Liceti, 1577–1657, an Italian physician and philosopher).



# Hydrologia in tres partes



1694



<https://books.google.com/books?id=HqAVcgAACAAJ>

# British Hydrology in Latin

THE  
PHILOSOPHICAL  
TRANSACTIONS

(From the Year 1700 to the Year 1720.)

ABRIDG'D,

AND

Dispos'd under GENERAL HEADS.

In Two VOLUMES.

By HENRY JONES, M. A. and

Fellow of King's College in CAMBRIDGE.

VOL. IV. Containing

Part I. The MATHEMATICAL Papers.

Part II. The PHYSIOLOGICAL Papers.

THE SECOND EDITION.

L O N D O N :

Printed for J. and J. Knapton, D. Midwinter and A. Ward, A. Bettesworth and C. Hitch, W. Innys, F. Fayram and T. Hatchett, J. Osborn and T. Longman, J. Pemberton, C. Rivington, F. Clay, J. Batley, and R. Hett 1731.

100106-B

## CHAP. II.

### Hydrology.

I. QUANDO quidem admiranda nonnulla & insolita de Lacu *Vettero O-*  
*laus Magnus*, aliiq; referant Scriptores; operæ pretium duxi in  
dicti *Lacus* indolem, & Scriptorum Fidem penitus inquirere: Inque iis  
quæ propriis Observationibus experiri non liceret, eorum indagare Te-  
stimonia, qui in Viciniâ habitantes, & antiquâ commendati fide, veris  
Narrationibus meis satisfacere possent Quæstionibus.

An Account of  
the Lake Vetter, in Swe-  
den; by Dr.  
Urban Hearnæ.  
n. 298. p.  
1938.

Lacus *Vetteri* a Septentrione Meridiem usque vergens de *Askersfundio*  
*Nericie* ad *Jonekopiam Smolandie* 14 *Suecica* metitur Milliaria, quorum  
quodlibet 5 vel 6 Milliaria *Anglica*, & decem unum fere conficiunt  
Gradum: Latitudine vero 3, nonnunquam vix 2 superat Milliaria.  
Lacus ob elevatiores Montium colles, qui hunc in ipso littore sæpius  
ambiunt, nonnunquam paulo remotiores prominent, adstantibus semper  
apparet ad latera depressus. Profunditate gaudet insigni, adeo  
vero inæquali, ut aliquibus in locis ad 80, in confiniis vero *Ostrogo-*  
*thie* diversis, paucisq; *Westrogotthie* ad trecentas usq; orgyas nullum re-  
perias fundum. Civis quidam *Vadstenensis* *Benedictus Amberni*, qui ut  
ad littora Civitatis *Grennensis Vetteri* exploraret profunditatem, aliquot  
Orgyarum funes, securi loco ponderis appensa, demiserat, fundo au-  
tem nusquam reperto, cum funes iterum collegerat, securi deperditâ,  
cranium equi chordæ exactè alligatum obtinuit. Similis item abyssus  
ad præcipitia montis *Obmensis*, quæ *parietis Occidentalis* nomine infig-  
niuntur,

4 P 2

# Spanish Hydrologia & German Hydrologie

## HYDROLOGIA, <sup>(3)</sup>

O TRATADO

DE LAS AGUAS  
FERRUGINEAS,  
RUBRAS,

VULGARMENTE DICHAS  
DE LA VIRGEN

DE LA CINTA  
DE TORTOSA,

DE SUS ADMIRABLES EFECTOS,  
y methodo para su buen uso.

SU AUTHOR

EL DOCTOR VICENTE VINAYMA,  
Medico en la misma Ciudad.

Conlicencia de los Superiores, en Valen-  
cia, por Joseph Garcia, en la Plaza  
de Calatrava, año 1738.



Joh. Gottschalk Wallerius,  
der Weltweisheit und Heynenkunst Doctors auf der  
königl. schwedischen Akademie zu Upsala, der medicinischen So-  
cietät zu Upsala, der kaiserlichen Akademie der Wissenschaften  
forstlicher, auch der königl. medicin. Collegii zu Stock-  
holm Mitglieds.

Hydrologie,

oder

Wasserreich,

von ihm eingetheilt und beschrieben:

mit einer Anleitung

zur Anstellung der Wasserproben:

wie auch

dessen Gedanken

Dannemarks Gesundbrunnen.

In Deutsche übersezt

von

Johann Daniel Denso,

königl. Professor am Collegio Carolingiano zu Stargard  
in Pommern, Secretaire an der Stadtkanzel, der königl. deut-  
schen Gesellschaft zu Königsb. auch der zu Königsb. Mitglieds.

Im königl. Preuss. und russisch. Kaiserl. Hoch-  
schol. und Brandenburgischen PNEUMATIK.



Berlin,

Nicolays Christlich-Verlags NICOLAI.

1751.

# Hydrology in Geography

COL. COLL. LIBRARY  
NEW YORK

A  
NEW SYSTEM  
OF  
GEOGRAPHY:

IN WHICH IS GIVEN,

A General Account of the SITUATION and LIMITS, the MANNERS, HISTORY, and CONSTITUTION, of the several KINGDOMS and STATES in the known World;

And a very particular Description of their *Subdivisions* and *Dependencies*; their *Cities and Towns, Forts, Sea-ports, Produce, Manufactures and Commerce.*

By A. F. BUSCHING, D. D.

Professor of Philosophy in the University of GOTTINGEN, and Member of the Learned Society at DUISBURG.

Carefully Translated from the last Edition of the GERMAN Original.

To the Author's Introductory Discourse are added three *Essays* relative to the Subject.

Illustrated with Thirty-six *Maps*, accurately projected on a new Plan.

IN SIX VOLUMES.

VOLUME the FIRST.

CONTAINING,

DENMARK, NORWAY, GREENLAND, SWEDEN,  
RUSSIA and POLAND.

LONDON:

Printed for A. MILLAR in the Strand.

MDCCLXII.

1762

## INTRODUCTION to GEOGRAPHY.

49

civilized. It may be observed in general, that among all people and nations of the Earth, there are some men of a reasonable, and others of an unreasonable disposition or turn of mind; as there are also in every country graceful and awkward, candid and disingenuous, virtuous and vitious, mild and austere, polite and ill-bred, noble and ignoble persons.

### Of the WATER.

§. 71. It remains, lastly, that we treat of the Water on the surface of the Earth; and this branch of Geography is by some termed Hydrography. Dr. Wallerius was the first who made accurate enquiries into the AQUEOUS KINGDOM, or Hydrology, and classed it among the other Kingdoms of Nature. We may divide the Water into two principal *Genera*, namely, into COMMON and MINERAL Water. COMMON Water, or that which is called sweet or fresh Water, has no particular taste, smell, or colour, and falls either in dew, rain, or snow from the air, whither it was conveyed from the Earth in vapours and exhalations; or else it is found on the Earth in its proper channels and cavities. Running Water is the lightest among the latter sort, and is also called living Water; of which, Spring-Water, which springs naturally out of the Earth, and continually keeps running, is a species. Springs, in all appearance, owe their origin to mountains, on which the vapours exhaled from the Earth fall in dew, rain, and snow; which, penetrating into the mountains, are collected together, and break out in springs below. Those springs which arise in sandy eminences produce the purest Water. Most springs are perennial, or flow constantly; others begin to run in spring, on the melting of the snow or ice, and cease again towards autumn, and are called temporal Springs. Others again flow only for certain hours of the day, and some of these only in summer, which must be owing to certain subterraneous cavities in the mountains from which they are supplied. Many springs emit Water as cold as ice, and yet bubble up and make a noise, like a pot boiling over the fire; which seems to be owing to the rarefied subterraneous air. Some springs rise and fall as if they were regulated by the ebbing and flowing of the sea. In many places Wells are also dug in which water is collected for use.

§. 72. Running Springs produce Brooks; and a conflux of several Brooks form a Rivulet, or Stream; and many Streams or Rivulets uniting together make one great current, called a River. Rivers have a steep or shelving bottom; and the greater the slope or declivity, the more rapid and stronger is their current. If the bed or channel of a River be very wide, its rapidity is not so great as when it is narrow. The water of Streams and Rivers often falls down from a precipice; and as the Rivers which form them happen to be smaller or greater, so are the cascades smaller or greater in proportion. Several Rivers also, at certain seasons of the year, being increased

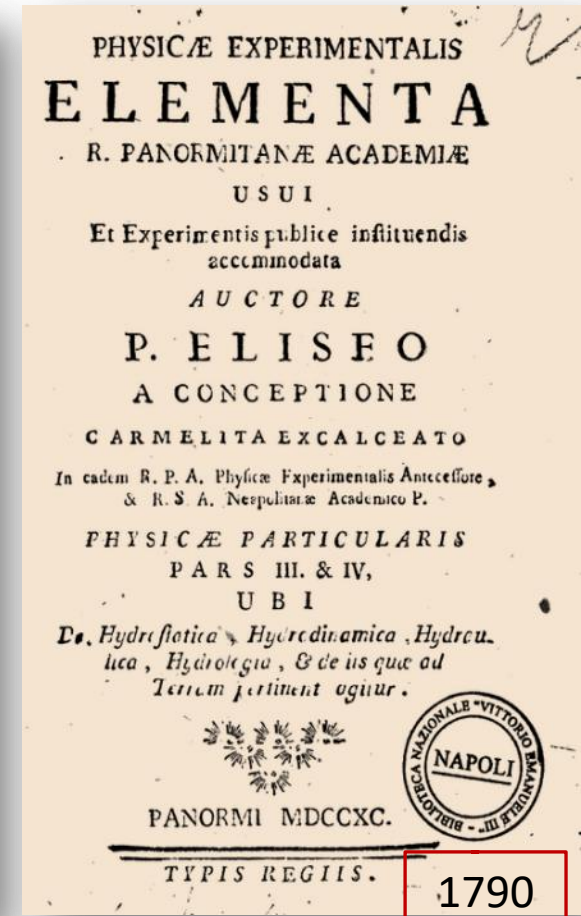
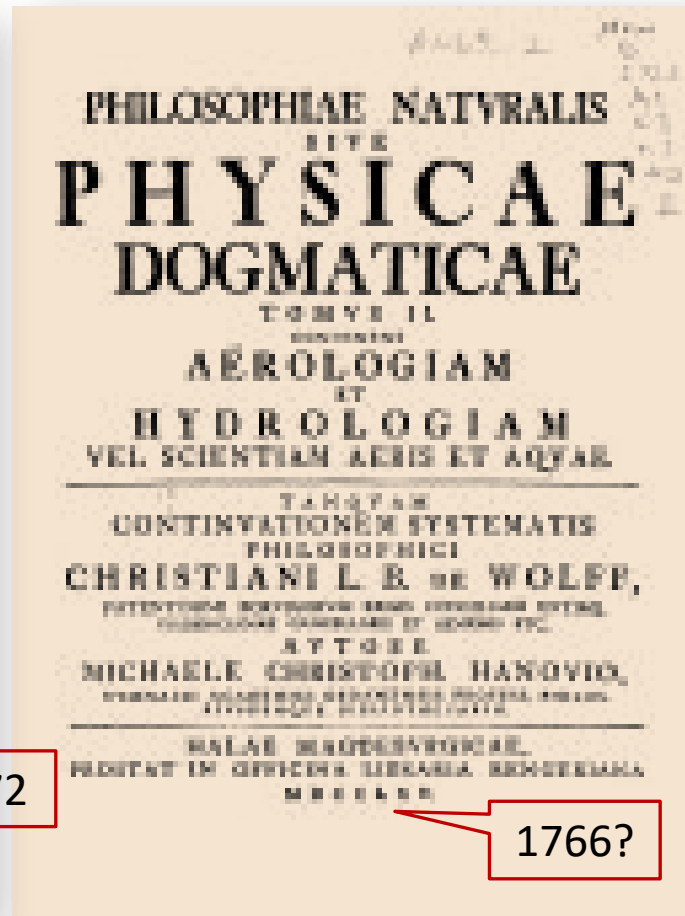
VOL. I.

H

or

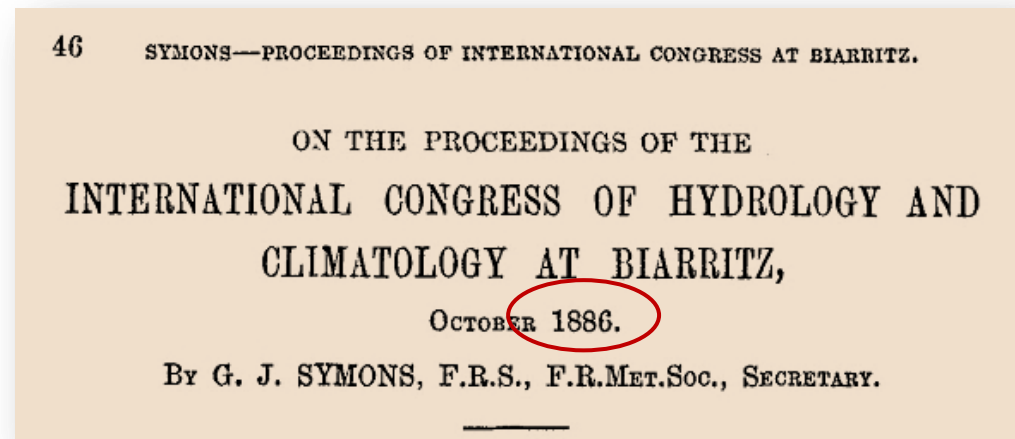
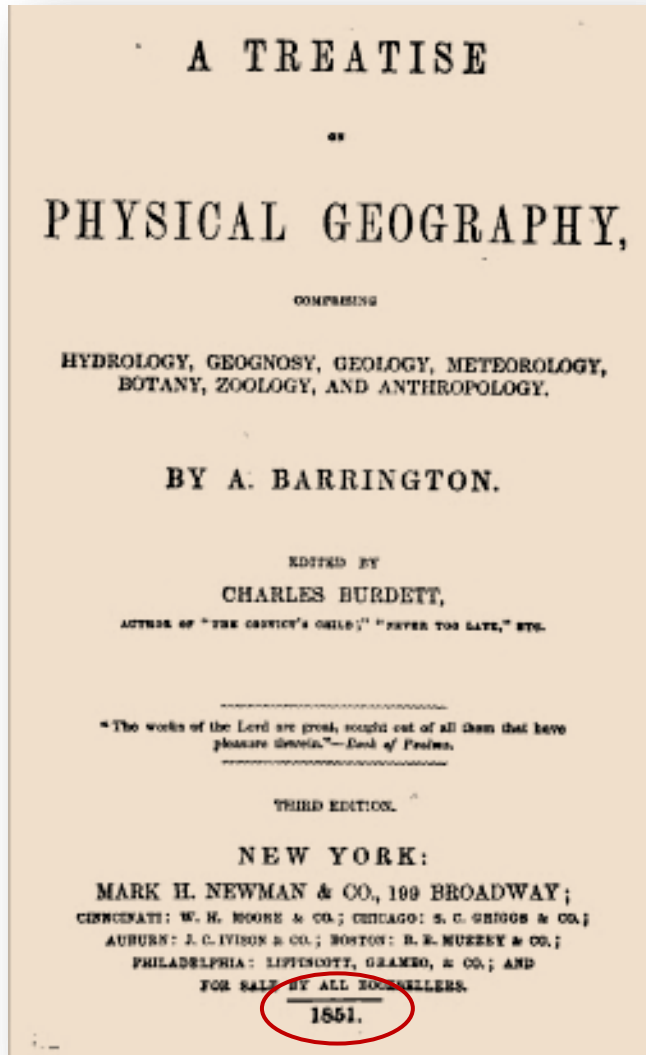


# Nouvelle Hydrologie – Physicae Dogmaticae – Physicae Experimentalis Elementa (cum hydrostatica, hydrodinamica, hydraulica, hydrologia)



# Hydrology within Physical Geography

## Scientific Hydrology vs. Medical Hydrology



- I. *Scientific Hydrology*.—Water analysis, micro-organisms, collection of mineral waters, geological influences, bathing apparatus, 34.
- II. *Medical Hydrology*.—Physiological and medical questions, 40.
- III. *Climatology, scientific and medical*, 35.

# Engineering Hydrology

## MANUAL OF HYDROLOGY:

CONTAINING

I.—HYDRAULIC AND OTHER TABLES.

II.—RIVERS, FLOW OF WATER, SPRINGS, WELLS,  
AND PERCOLATION.

III.—TIDES, ESTUARIES, AND TIDAL RIVERS.

IV.—RAINFALL AND EVAPORATION.

BY

NATHANIEL BEARDMORE,

CIVIL ENGINEER.

London:

WATERLOW AND SONS, 49, PARLIAMENT STREET,

24, BIRCHIN LANE, AND 65 to 68, LONDON WALL.

1862.

### WATER PIPES UNDER PRESSURE.—Tables 8a and 8b.

This will be seen upon reference to Mr. Leslie's paper "On the flow of water through pipes," &c, before referred to, and the discussion which ensued thereupon. For very small pipes or flat rates of inclination, or waere a closer approximation to accuracy may be desired, somewhat better results may be obtained by using Du Buât's formula, viz. :—

$$\frac{307 (\sqrt{r} - 0.1)}{\sqrt{\frac{l}{h}} - L (\sqrt{\frac{l}{h}} + 1.6)} - 0.3 (\sqrt{r} - 0.1) = \text{Velocity in inches per second.}$$

$$r = \frac{\text{dia}^2}{4} = \text{"Mean radius" or Hydraulic mean depth in inches.}$$

L = Hyperbolic Log. of the term to which it is prefixed.

Hyperbolic Log. = Common Log.  $\times$  2.30258. When reduced

### TABLE OF HEIGHTS OF MAXIMUM FLOODS OF THE PO DURING THE NINETEENTH CENTURY,

As registered at various points on the river above summer low water, which at Piacenza is 132.3 feet above the sea level; at Cremona, 104.2 feet; at Isola Pescaroli, 89.2 feet; at Casalmaggiore, 74.8 feet.

Name of Station.	Dist. from the Sea.	1801	1807	1812	1823	1827	1839	1839	1840	1841	1846	1846	1855	1857
		13th Nv.	12th Dec.	15th Oct.	16th Oct.	13th My.	30th Oct.	8th Nv.	6th Nv.	31st Oct.	20th My.	20th Oct.	1st Nv.	1st Oct.
Monticelli .....	Mls.	210.0	213.0	...	211.9	...	213.9	177.8	213.0	211.8	215.6	216.9	215.5	218.7
Piacenza .....	ft.	196.3	249.9	...	...	...	216.4	231.1	244.4	244.6	216.2	227.3	216.2	218.0
Cremona .....	ft.	171.9	199.6	...	161.1	177.2	178.7	181.3	178.7	178.4	178.3	178.8	191.2	210.8
Isola Pescaroli .....	ft.	155.9	210.6	...	191.8	177.7	178.6	191.6	191.2	178.5	178.9	210.0	191.4	211.6
Casalmaggiore .....	ft.	141.8	211.3	...	191.1	178.1	210.6	211.1	211.1	210.0	211.2	211.2	211.8	211.1
Dosolo .....	ft.	125.4	216.9	215.7	...	244.6	...	215.4	216.2	215.5	216.1	215.6	216.1	216.8
Borgoforte .....	ft.	114.5	217.6	217.0	217.0	215.6	216.9	216.5	218.1	215.5	215.8	216.7	217.1	218.2
St. Benedetto .....	ft.	100.5	215.9	216.1	217.9	217.8	218.2	217.5	219.2	216.9	217.5	217.5	218.1	218.6
Ostiglia .....	ft.	88.4	218.4	219.2	210.1	219.9	219.7	219.8	211.3	218.8	219.7	219.9	210.3	210.7
Serride .....	ft.	76.9	216.5	217.0	218.1	218.2	217.7	217.7	218.5	216.4	217.4	...	218.1	218.2
Quatrelle (Stellata) .....	ft.	66.5	216.4	217.4	218.6	218.4	218.1	218.0	219.0	217.2	217.6	218.1	218.5	218.2
Ponte Lagoscuro .....	ft.	53.9	215.2	216.0	216.8	216.6	216.8	217.3	218.1	217.1	216.5	216.6	216.8	216.9
Polesella .....	ft.	43.9	...	...	215.8	215.8	216.0	216.6	217.7	216.3	216.1	...	...	217.9
Crespino .....	ft.	36.1	...	...	214.2	214.2	214.6	214.6	215.5	215.0	214.5	...	...	215.6
Cavalladi Po .....	ft.	19.1	...	...	17.9	18.0	18.4	18.8	19.6	18.6	18.5	...	...	...
Porto Scanarello .....	ft.	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0