TEMPORAL AND SPATIAL CHANGES OF CLIMATE ELEMENTS IN HUNGARY

EVAPOTRANSPIRATION, AIR HUMIDITY, FOG, CLOUDINESS

EVAPOTRANSPIRATION

- Evapotranspiration is a change of phase, for which energy is provided by solar radiation absorbed by the surface.

- In meteorological sense evapotranspiration is the process, when water from large-scale natural or atificial surface gets into the atmosphere.

- Evapotranspiration has two components:

  1. A process when water gets into the atmosphere from pure soil surface and/or water surface (evaporation).

  2. A process when water gets into the atmosphere through plant metabolism (transpiration).

- Water amount got into the atmosphere from a unit surface and unit time (mm/year).

- Water cen get to the atmosphere through two processes:

1. In case of given climatic conditions a given water amount that may be potentially vaporized: **potential evapotranspiration (PET)**.

2. A given water amount that is actually vaporized during a unit time **actual evapotranspiration (AET)**. In every case AET $\leq$ PET.

- Annual course of AET follows the annual course of temperature: minimum in January, maximum in July.

- Its geographical distribution follows that of radiation budget and temperature: Alföld: 800-850 mm; a narrow belt along the Dráva River: 900 mm; a substantial part of Dunántúl: 700-750 mm; mountainous regions: around 600 mm.

Air humidity characteristics determining evaporation

- **absolute humidity (s):** mass of water vapour in a unit volume of moist air (= density of water vapour): ($g \cdot m^{-3}$);
- **specific humidity (q):** mass of water vapour in a unit mass of moist air (–);
- **vapour pressure (e):** partial pressure of water vapour in the air (mb);
- **saturated vapour pressure (E):** at a given temperature, the partial pressure of the maximum admissable water vapour in the air (mb);
- **saturation deficit (d):** it shows the difference between the saturated vapour pressure at a given temperature and the actually observed vapour pressure at the same temperature: d=E–e (mb);
- **relative hunmidity (RH):** it expresses the actual vapour pressure in percentage of the saturation vapour pressure belonging to the observed temperature: RH=e/(E*100) (%);
- **dew point (t_d):** this is the temeprature to which the unsaturated air, comprising water, should be cooled on constant pressure for reaching saturation (°C);
- **dew point depression (Δ):** this is the difference between the actual temperature and the dew point: $\Delta = t - t_d$ (°C);

Ways of calculations

- Computation I.
  - heat budget method

$$P = \frac{R_n - Q_{tal}}{L(1+\beta)}$$

$$ahol\ \beta : Bowen\ \ arány$$

  - aerodynamic method – Dalton formula:

$$P = f\left(E - e; szél\right)$$

Computation II.

- water balance method

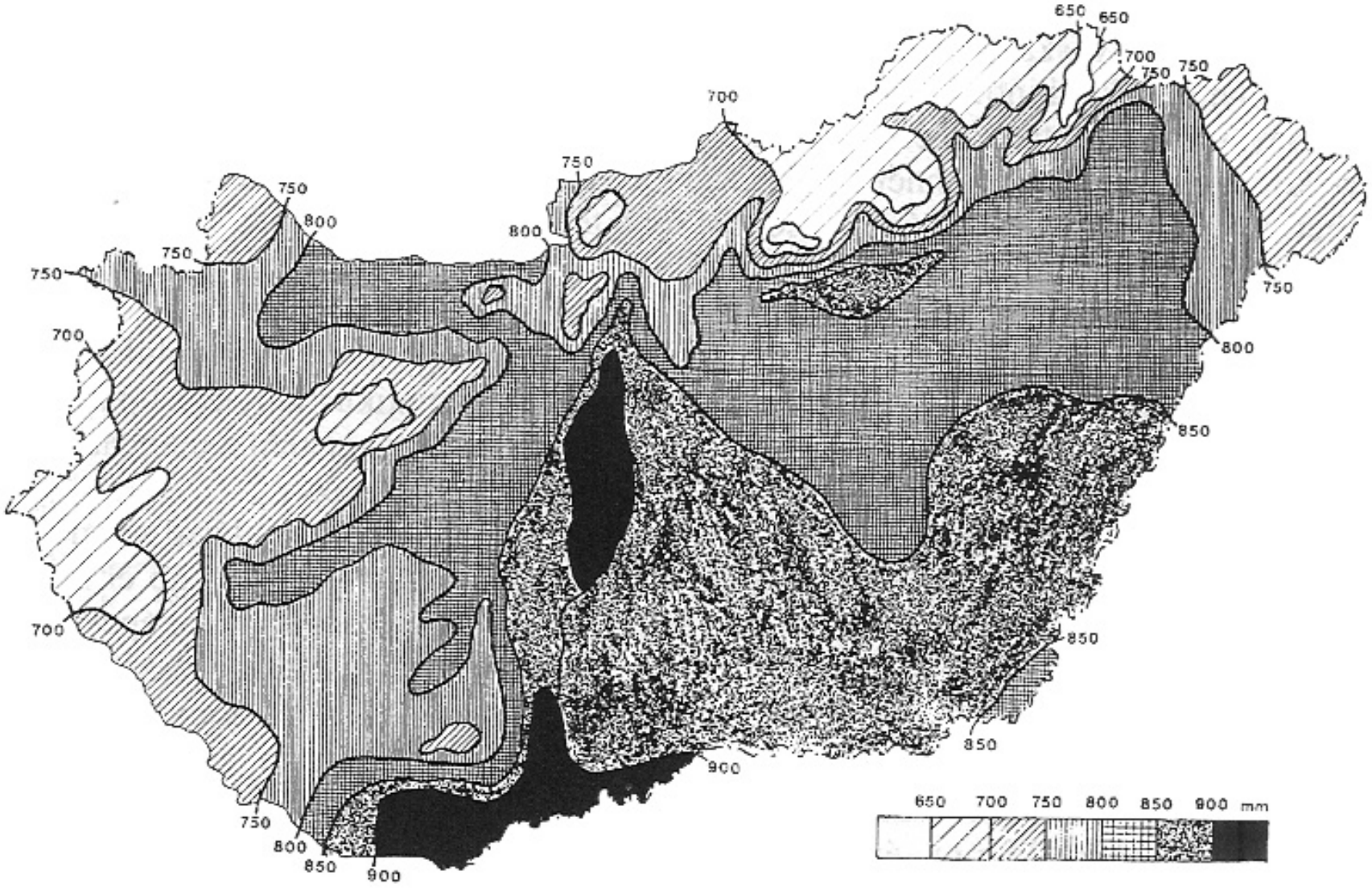
$$P = W_1 + Csap. - W_2$$

- empirical procedures

- measurement – by evaporation bath (principle)

Mean monthly and annual sums of potential evapotranspiration, mm, 1901-1950

Station	J.	F.	M.	Á.	M.	J.	J.	A.	Sz.	O.	N.	D.	year
M. magyaróvár	0	0	20	40	93	116	131	114	77	41	13	1	656
Pécs	0	2	23	53	95	122	143	129	83	44	16	3	713
Budapest	0	2	22	52	98	124	142	125	81	43	14	2	705
Kecskemét	0	0	19	51	96	123	140	122	78	41	12	1	683
Szeged	0	1	22	53	98	124	145	127	83	46	16	2	717
Szarvas	0	1	19	49	99	123	142	126	81	44	14	1	699
Debrecen	0	0	18	51	98	122	141	122	80	40	12	1	685
Kékestető	0	0	1	33	77	97	115	101	70	34	3	0	531

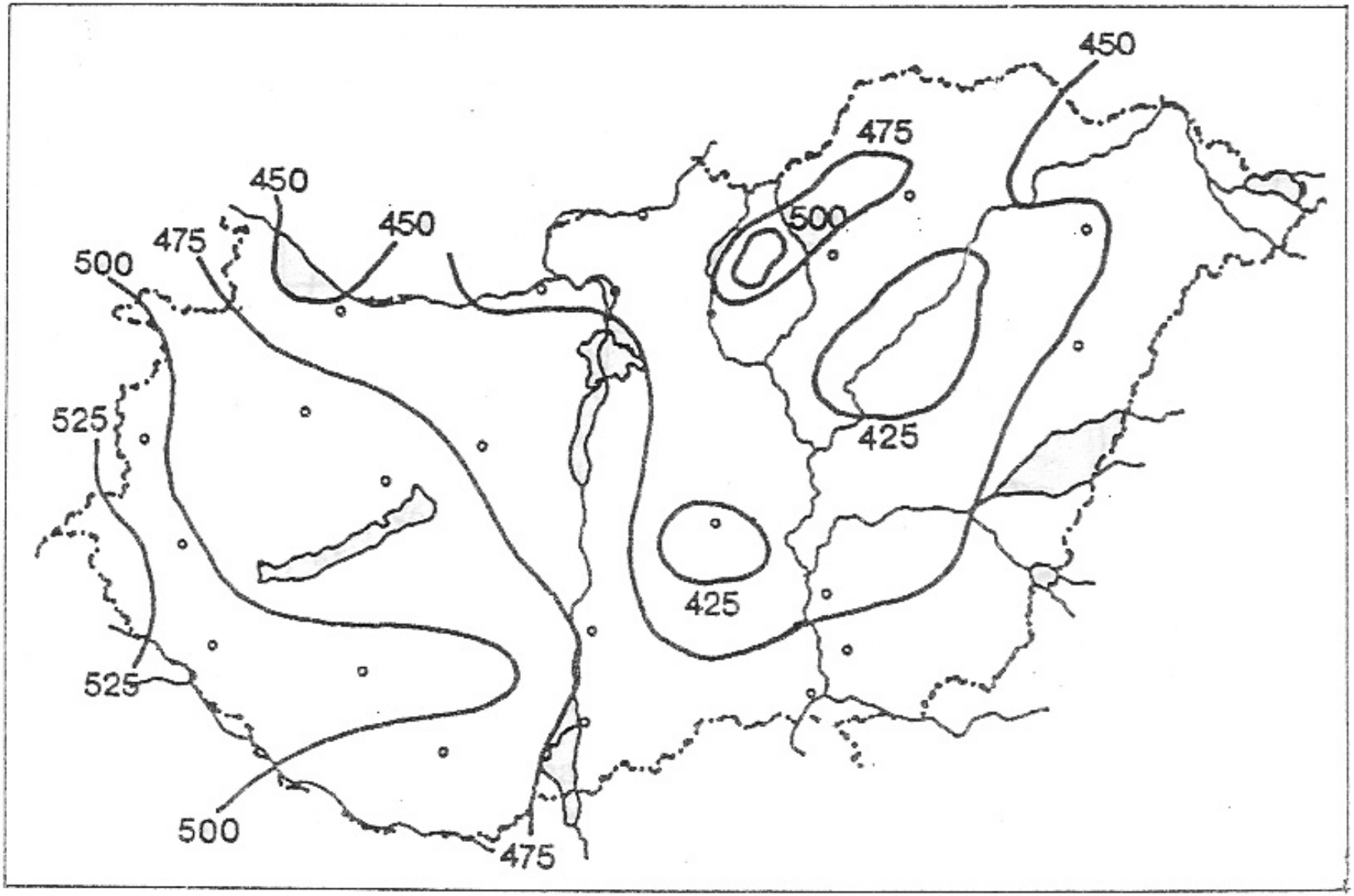


Areal distribution of the annual sums of potential evapotranspiration in Hungary

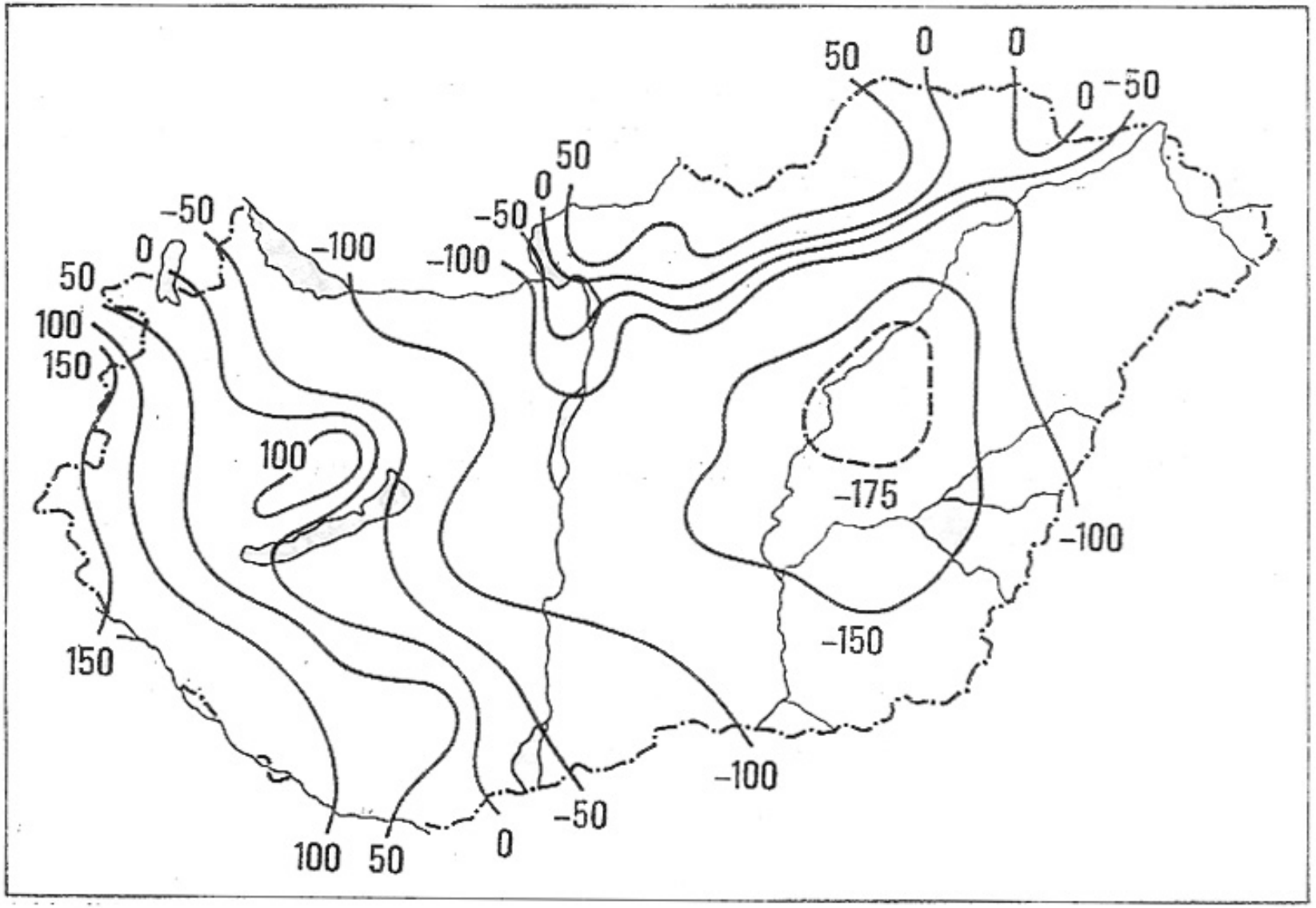
- The temporal course of AET is also similar: maximum is in July, minimum is in January.
- Its mean value is 450-550 mm in Hungary.
- Its regional distribution is significantly different from PET, since its amount is determined by the precipitation and the resources of the soil for a given area.
- Its minimum is in Alföld, while its maximum is in West-Dunántúl and the mountainous regions.
- Regarding relative changes of PET and AET, their value is the same from October to May, due to the substantial moisture supply of the soil. However, between June and September, because of the desiccaroion of the soil, AET legs behind the PET values.
- Maximum values of AET differ in various regions of Hungary, since the dates of high temperature and high precipitations do not coincide either.

Mean monthly and annual sums of the actual evapotranspiration, mm, 1901-1950

Állomás	J.	F.	M.	Á.	M.	J.	J.	A.	Sz.	O.	N.	D.	Év
M. magyaróvár	0	0	20	50	91	105	108	88	64	41	13	1	581
Pécs	0	2	23	53	94	112	114	94	66	44	16	3	621
Budapest	0	2	22	52	97	114	107	89	59	43	14	2	601
Kecskemét	0	0	19	50	84	95	89	71	55	41	12	1	517
Szeged	0	1	22	52	90	106	100	79	59	46	16	2	573
Debrecen	0	0	18	51	93	110	110	90	60	40	12	1	585
Kékestető	0	0	1	33	77	97	113	97	69	34	3	0	524

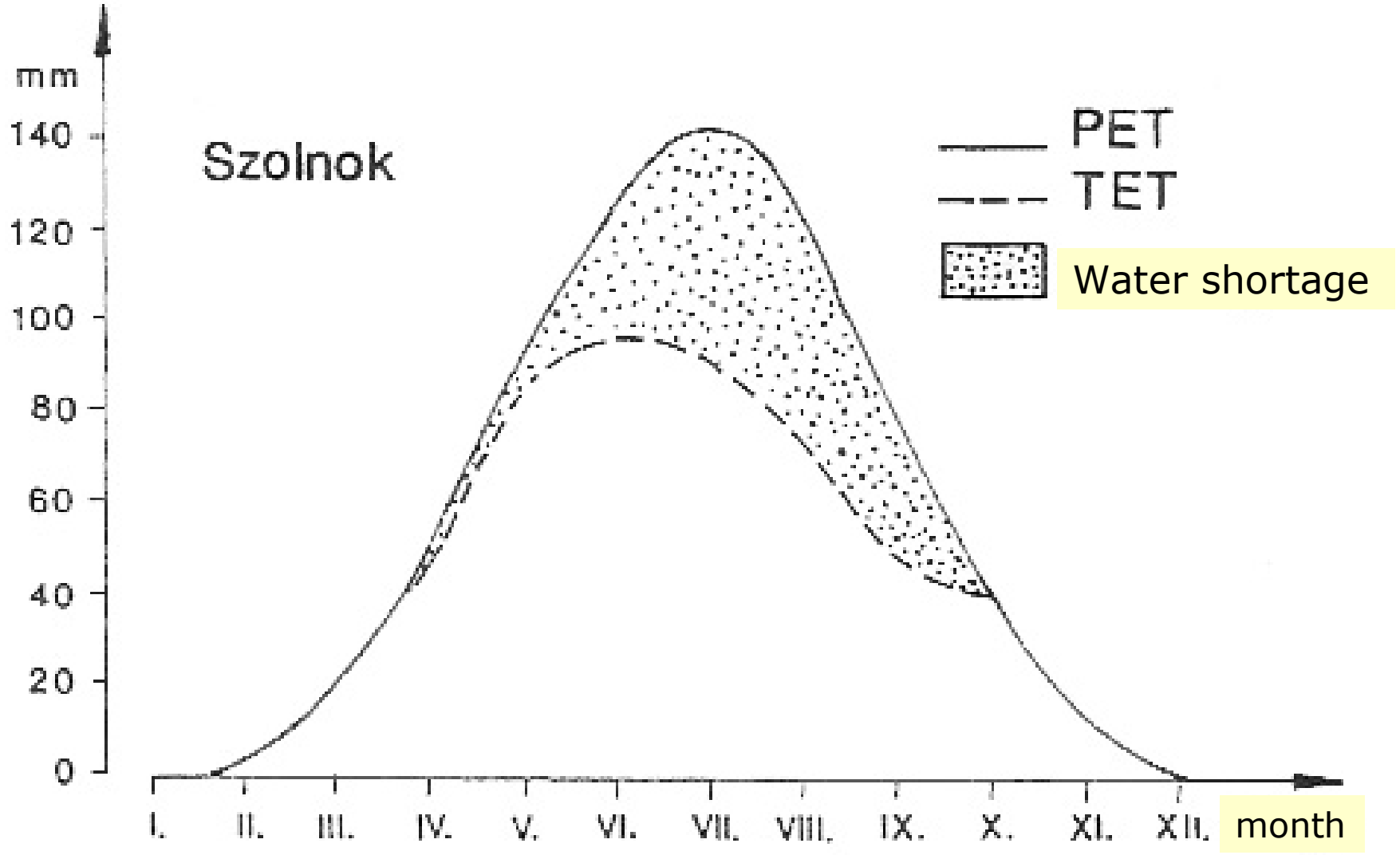


Mean annual sums of the actual evapotranspiration, mm, Hungary

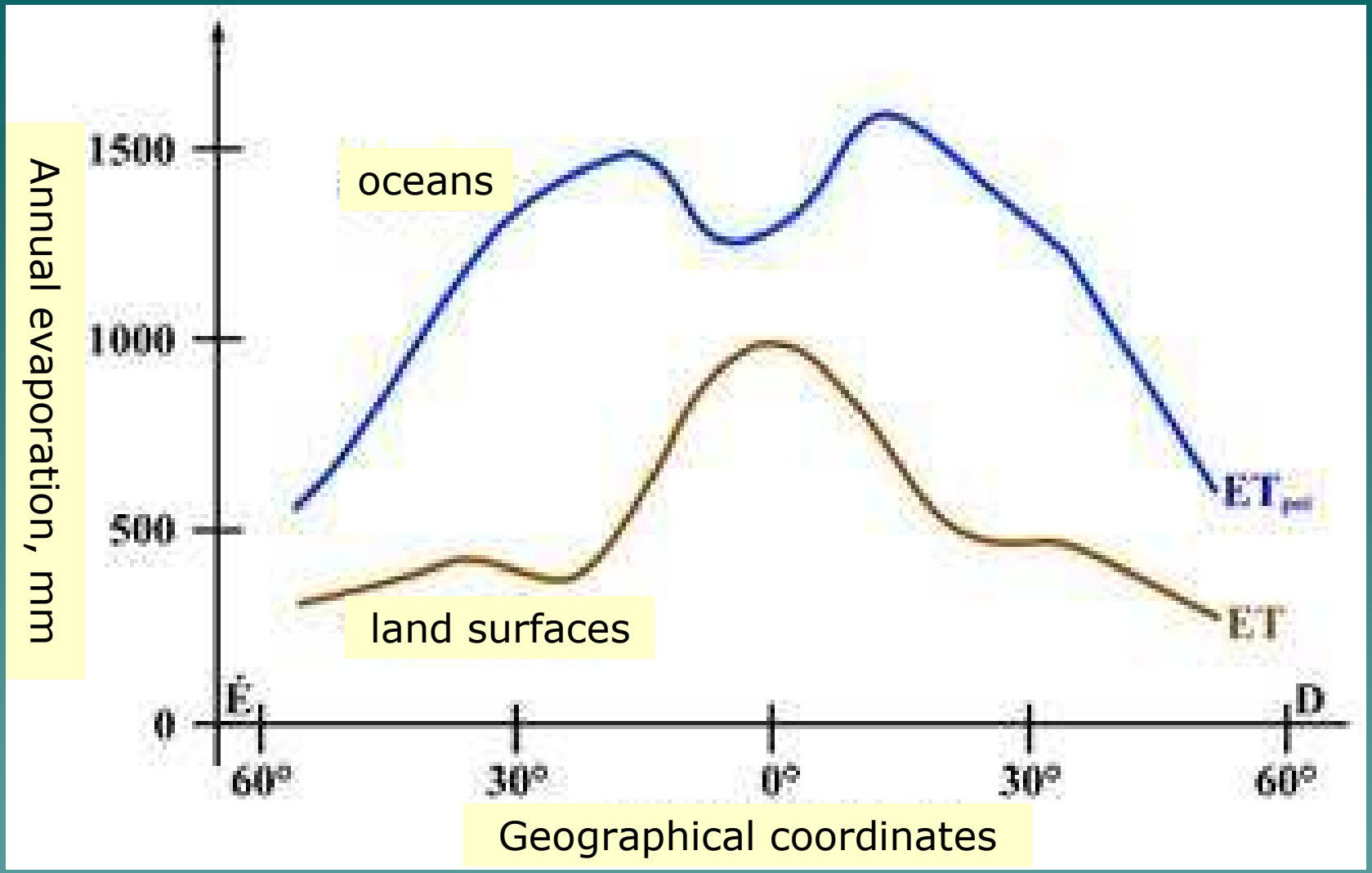


Mean annual value of the climatic water budget, mm, Hungary

Climatic water budget = annual sum of precipitation – annual sum of PET



Relationship of PET and AET during the year



Zonal averages of the annual actual evapotranspiration (AET) over land surfaces, as well as those of the annual potential evaporation (ET_{pot}) over oceanic surfaces (Potential evaporation over oceanic surfaces equals to the potential evapotranspiration) (after Budiko, 1956)

AIR HUMIDITY

- Air humidity is the water vapour content of the air. **It has two sources:**
  1. **Evaporation** and **transpiration** from the components of clouds and precipitations, as well as from the surface
  2. **Water vapour advection** from distant lands. Air masses of marine origin coming from the direction of the Icelandic minimum (+), as well as the continental air masses (-) caused water vapour advection.
- Among the several parameters **water vapour** and **relative humidity** are used to characterize air humidity in climatology.

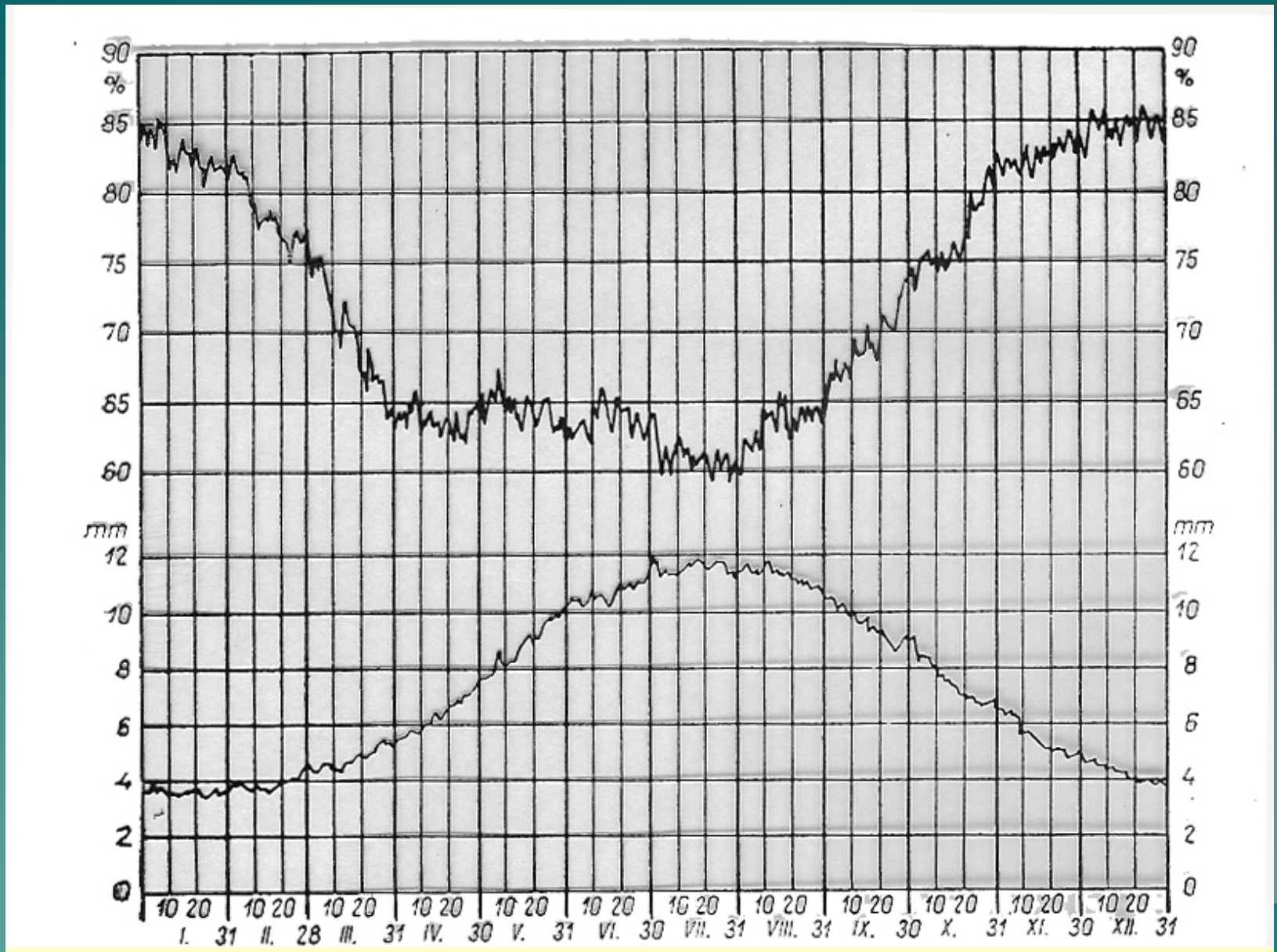
Monthly and annual averages of water vapour (hPa) and relative humidity (%), 1901-1950

Water vapour

station	J.	F.	M.	Á.	M.	J.	J.	A.	Sz.	O.	N.	D.	year
M. magyaróvár	6,3	6,8	8,5	11,2	16,1	18,9	20,2	19,3	16,4	13,0	9,7	7,6	12,8
Keszthely	6,0	6,5	8,5	10,8	16,1	19,4	21,4	20,5	17,6	13,6	9,6	7,4	13,0
Pécs	6,4	6,9	8,9	11,8	16,1	19,7	20,7	20,0	17,6	14,0	10,2	7,8	13,3
Budapest	6,4	6,8	8,5	11,2	16,0	18,9	20,1	19,8	17,0	13,3	9,8	7,8	12,9
Szeged	6,8	7,0	8,9	11,2	16,0	19,3	20,2	19,4	16,8	13,4	10,2	8,0	13,0
Túrkeve	6,0	6,8	8,5	10,8	16,1	19,4	21,4	20,3	17,2	12,9	10,0	7,6	13,0
Nyíregyháza	5,9	6,8	8,9	11,3	16,2	20,2	21,8	21,4	17,6	13,0	9,6	7,4	13,3

Relative humidity

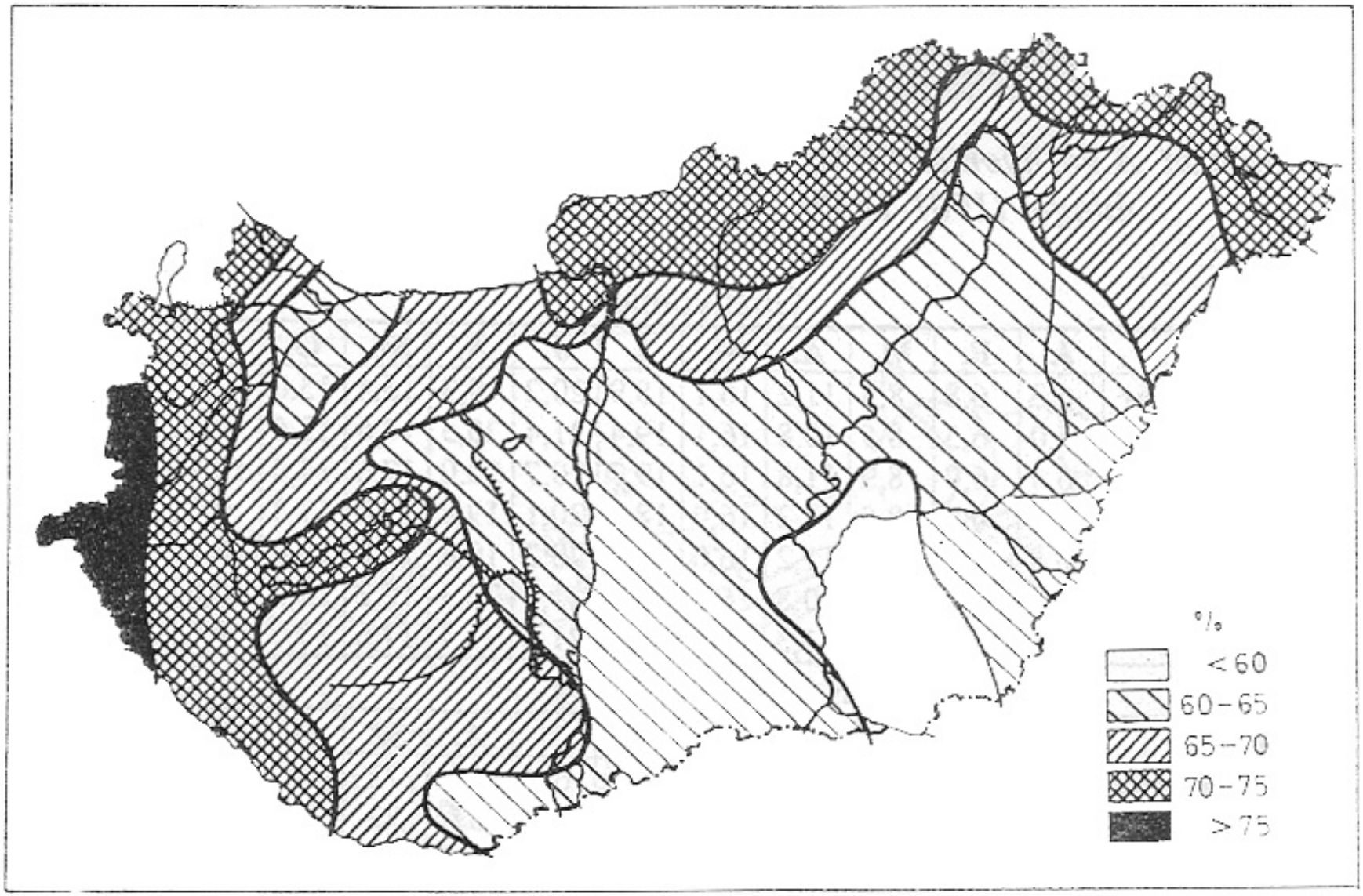
station	J.	F.	M.	Á.	M.	J.	J.	A.	Sz.	O.	N.	D.	year
M. magyaróvár	79	76	75	70	69	67	68	69	72	74	78	79	73
Keszthely	81	75	72	65	68	67	67	67	73	78	79	81	73
Pécs	83	78	70	64	66	64	62	63	67	75	81	83	71
Budapest	81	76	67	60	62	62	60	62	65	74	81	83	69
Szeged	83	79	73	66	64	62	58	59	65	73	82	84	71
Túrkeve	83	79	73	68	68	66	65	65	70	76	85	85	74
Nyíregyháza	85	84	70	71	69	69	67	70	76	79	85	87	78



Annual course of relative humidity (%) and water vapour (mm)
based on the 80-year averages of the daily mean values,
Budapest, 1871-1959 (after Kakas)

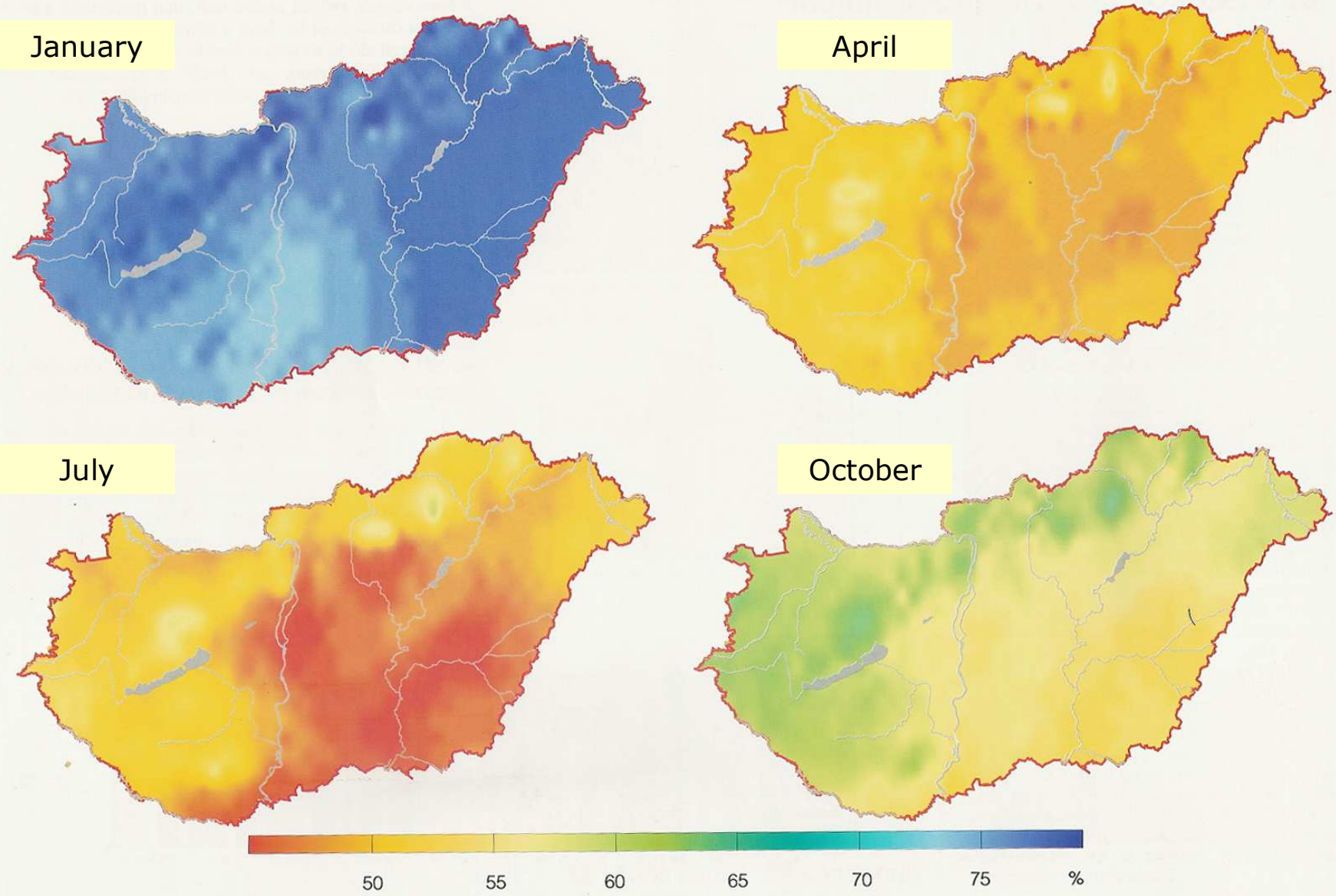
- Annual course of water vapour is cahracterized by July maximum and January minimum, since the increase of temperature enhances surface evapotranspiration.
- The summer vapour pressure maximum substantially contributes to the development of summer precipitation maximum.
- Contrary to this, relative humidity reacges its maximum in December-January, and its minimum in July.
- This is because with the increase of air temperature, the saturation vapour pressure also increases; therefore, smaller water vapour amount at lower temperature can induce greater relative saturation.
- Monthly and annual averages of water vapour show rather uniform picture for the whole area of Hungary, this is why it is not worth to display this map.

- Spatial distribution of relative humidity shows a much more interpretable regional picture.
- During the winter months relative humidity is uniformly high across the country, with values around 75%.
- During the summer months, due to the invasion of oceanic and continental air masses of different humidity, the regional distribution of relative humidity is much more varied.
- In Dunántúl area, from west to east, parallel to the weakening of the oceanic effect decreasing values stand out (75-60%)
- In Alföld area, a concentric distribution due to the basin character with values of 55-70% occur.
- When Mediterranean air masses come from south-east, 10-15% relative humidity may happen in the south-east part of Alföld in summer.



Geographical distribution of mean relative humidity (%), July, Hungary

Relative humidity in the middle months of the seasons, (%)



FOG

- When precipitated within volume, suddenly a large number of tiny water droplets and/or ice crystals are formed which will obscure the clear air.
- Then fog or cloud is generated, depending on whether the process develops on the ground or in high altitude air.
- Thus, there is no physical difference between the two phenomena: cloud or fog are referred to as a coherent part of the atmopshere, in which the very small water droplets and/or ice crystals are floating in such a large number that they make an obstacle to the path of the solar radiation.
- Foggy day is considered the day, when the visiibility is less than 1 km due to the former reason, for any length of time.

- The air cools by contact, when flowing over a colder surface (frozen soil, snow cover). This process results in flowing fog. It is also called *advective, or frontal fog,* because such situation develops in the case of front-associated moisture advection.

- As a result of surface radiation, the air cooled at night above the soil may cool to its dew point, or below, on which water vapour becomes saturated. In this way, condensation generally takes place only in a thin layer close to the ground; so, radiation fog is generated.

- Condensation can occur by mixing so that two air masses of different temperature and close to saturation mix together. The resulting joint temperature will be lower than the warmer air. Thus, it is saturated with water vapour, and mixing fog or cloud is formed.

Mean monthly and annual number of foggy days, 1940-1954

station	J.	F.	M.	Á.	M.	J.	J.	A.	Sz.	O.	N.	D.	year
Szombathely	4,6	2,8	1,7	0,6	0,6	0,4	0,2	0,5	1,6	4,0	6,8	7,2	31,0
Pécs	5,7	4,2	1,5	0,6	1,1	0,7	0,6	0,9	1,3	1,7	5,3	7,9	31,5
Budapest	10,1	7,5	3,4	0,7	0,2	0,1	0,0	0,1	0,6	2,5	7,7	10,9	48,8
Nagykőrös	5,0	4,3	1,8	0,2	0,2	0,2	0,1	0,1	0,9	2,6	5,0	8,0	28,4
Szeged	7,6	6,5	2,1	0,8	0,2	0,4	0,0	0,3	1,2	1,7	6,6	9,8	37,2
Nyíregyháza	6,5	5,1	2,1	1,0	0,5	0,5	0,2	0,5	1,2	3,8	6,0	7,4	35,2
Kékestető	13,3	10,4	10,3	8,0	6,7	5.3	3,0	4,2	4,5	12,2	17,0	15,0	109,9

- Frequency of fogs is associated with the annual course of relative humidity of around 100%, and varies opposite to temperature.
- The most foggy period is December 6-12 (in the mountains December 12-15) where daytime is also foggy. Secondary and tertiary maxima are autumn and sprong, respectively. Summer is practically fog-free.
- Daily course of fog frequency is opposite to that of temperature: the most foggy is dawn, while the least foggy period is around noon.
- Regarding geographical distribution, the least foggy areas are the most windy Kisalföld and the region between Duna and Tisza (20-30 foggy days on annual average).
- At several regions in Alföld and Dunántúl areas 40-60 foggy days per year are characteristic.
- Mountain valleys are the most foggy areas: with 60-120 foggy days on annual average.

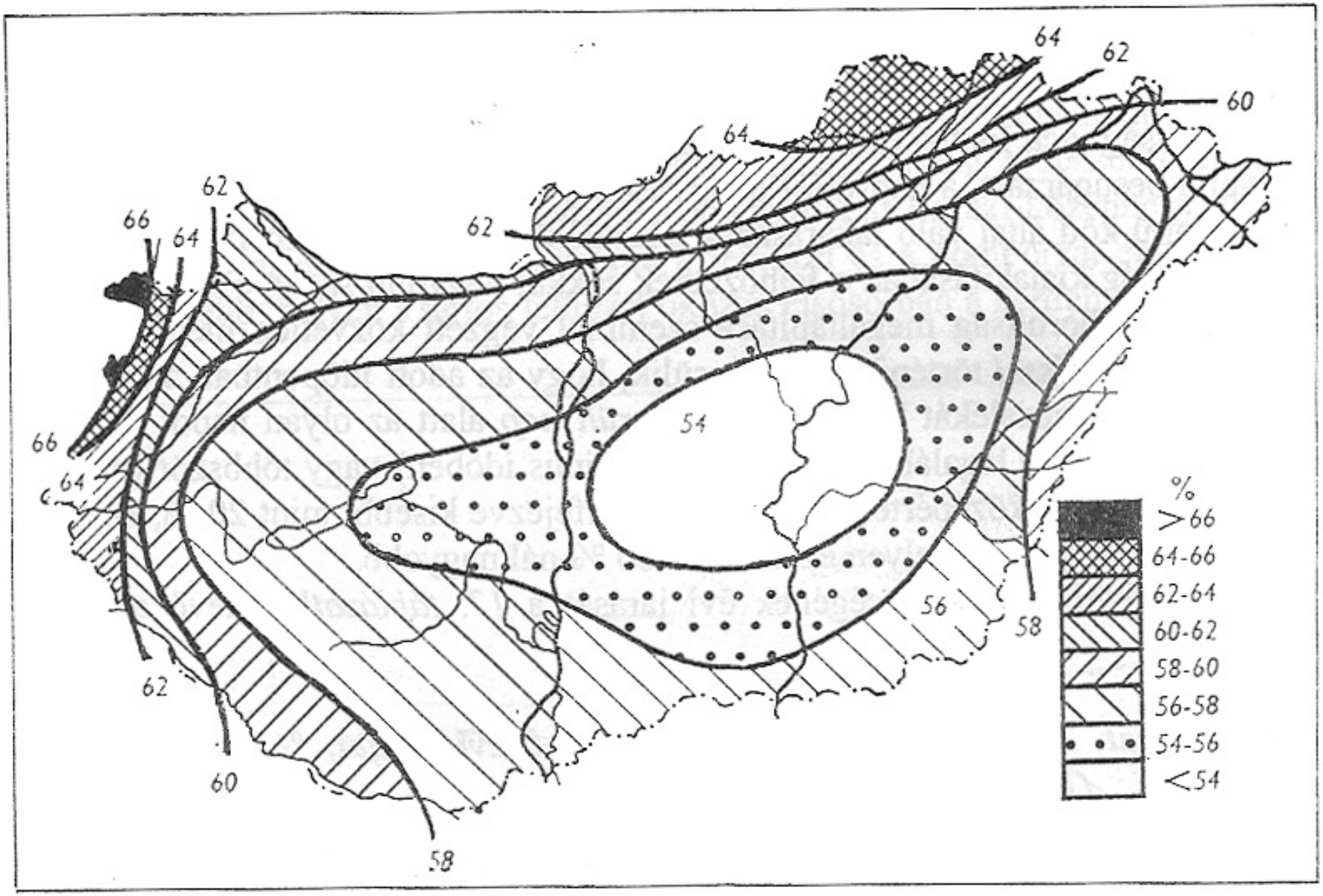
CLOUDINESS

- Cloudiness has a fundamental importance in forming sunshine duration.
- Under cloudiness, we understand coverage of the sky by clouds and/or thick fog, expressed in percentage or octa.
- Its value can be estimated, without using instrumenation. Te sky is divided imaginary into eight equal parts and it is determined that how big part is covered by clouds.
- The completely cloudless sky is indicated by 0 (0%), the completely covered sky by 8 octa (100%). At night cloud coverage is assessed on how many eigth of the sky is free of stars.
- When observing clouds, their height, type, quantity and pass should also be considered.

Monthly and annual averages of cloudiness,
%, 1901-1950

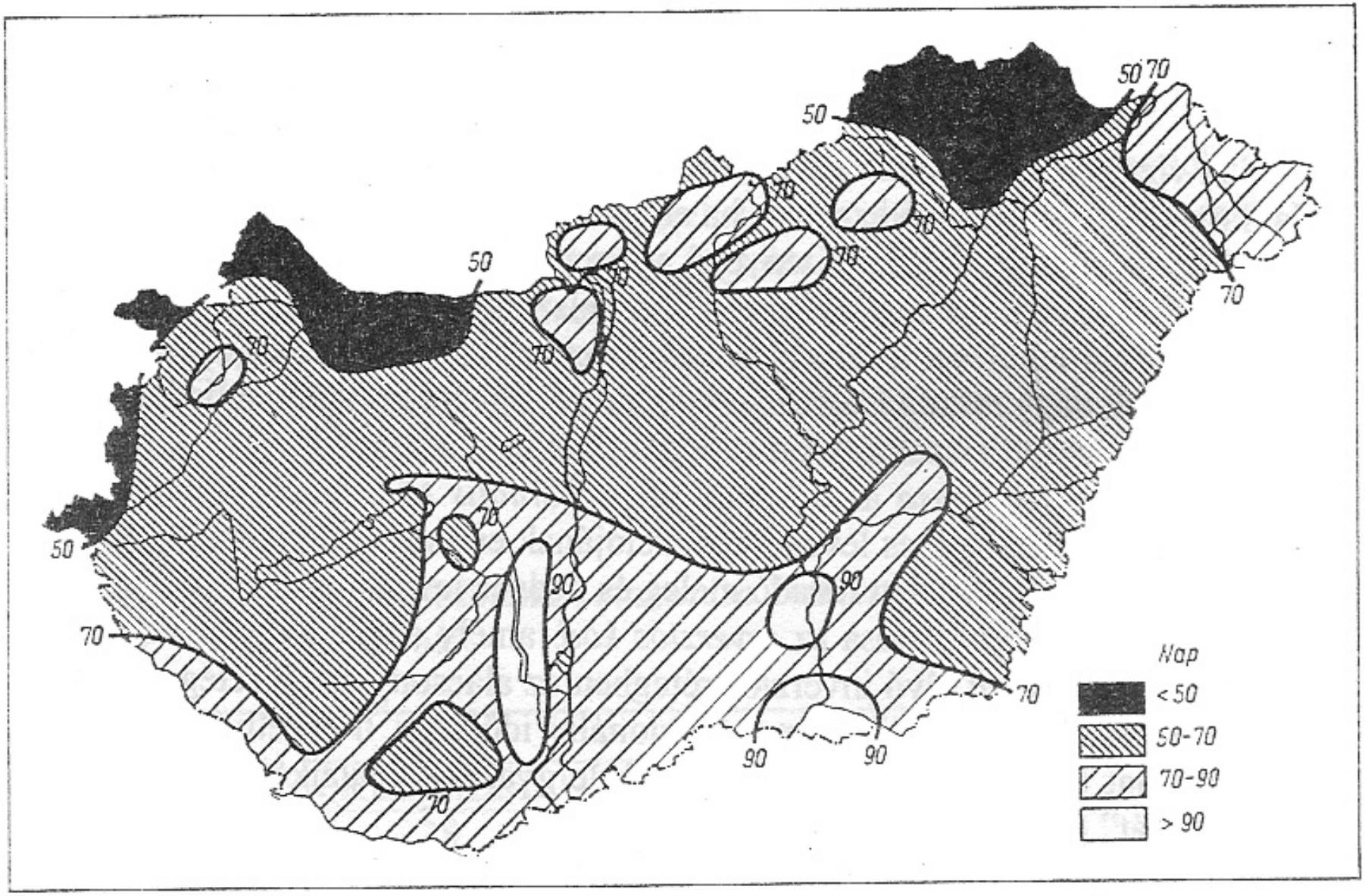
station	J.	F.	M.	Á.	M.	J.	J.	A.	Sz.	O.	N.	D.	year
M. magyaróvár	74	68	61	61	55	55	51	49	51	60	74	78	61
Keszthely	71	64	58	58	54	52	47	44	47	57	71	76	58
Pécs	70	64	60	60	53	51	44	40	46	56	70	74	57
Budapest	70	65	59	58	54	52	46	43	46	57	71	77	58
Kecskemét	68	61	55	54	50	48	42	39	42	51	64	71	54
Szeged	71	65	59	59	53	51	42	39	42	54	69	75	57
Békéscsaba	72	67	59	58	52	50	41	39	43	54	69	77	57
Nyíregyháza	70	65	56	55	52	53	47	43	45	53	68	74	57
Kékestető	62	63	52	54	49	51	46	35	40	53	64	64	53

- When studying annual course of cloudiness, the most clear sky is characteristic at the end of summer (frequent anticyclonic large-scale weather situations),
- Due to frequent fog formation, associated with cyclonic large-scale weather situations, the most cloudy is December.
- Daily course of cloudiness is specific. The least cloudy is late evening in every season. However, the time of greatest cloudiness differs between winter and summer.
- In the summer, due to the intensive cloud (cumulus) formation, early afternoon is the most cloudy.
- In the winter, due to the frequent fog- and low stratus formation, as a result of nocturnal radiation, dawn and morning are the most cloudy.

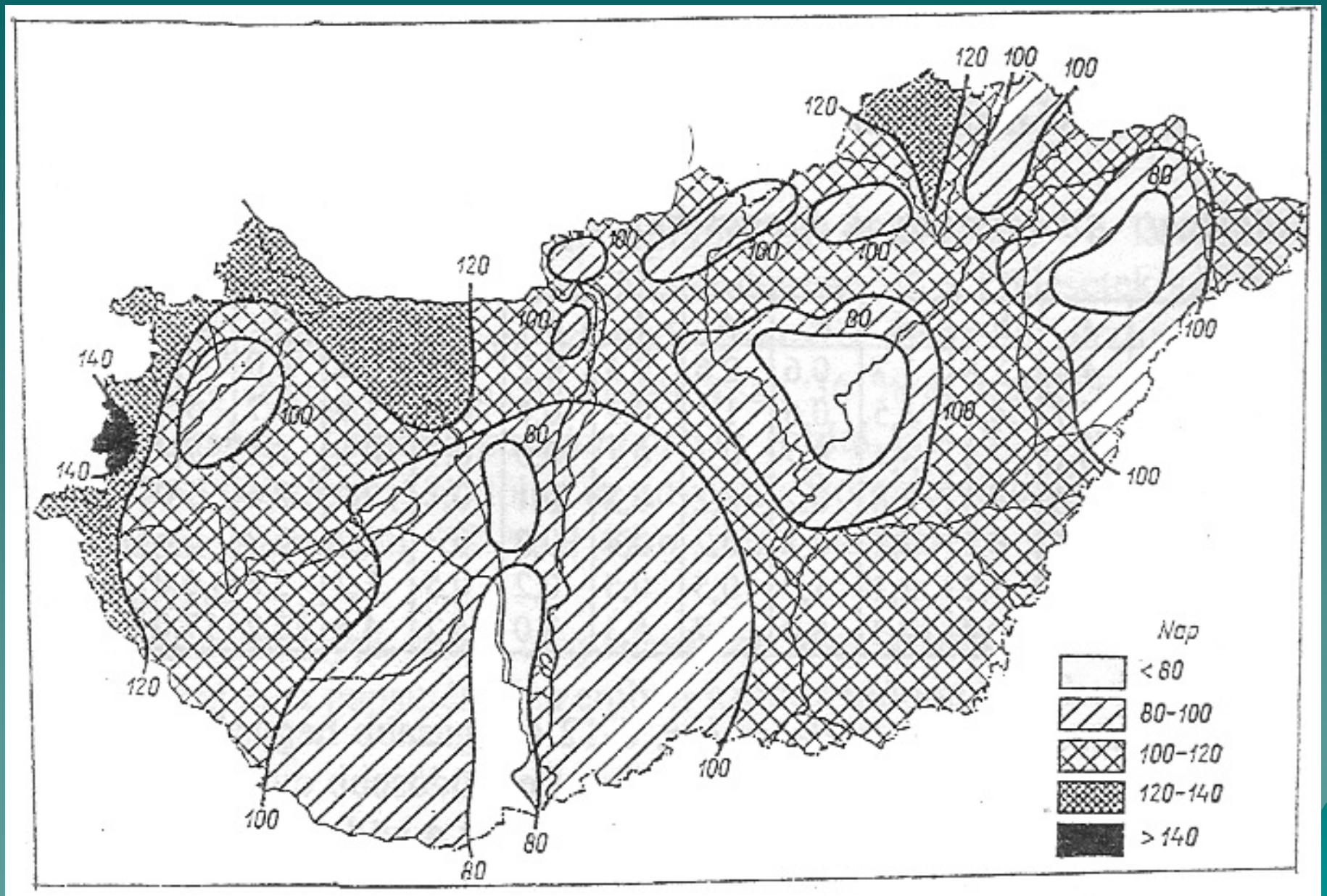


Geographical distribution of mean annual cloudiness (%) in Hungary

- Based on the annnual average of cloud coverage (%), the smallest cloudiness occurs in the middle part of Alföld area (>50 %), due to the basin character.
- Towards the edges of the basin, cloudiness is gradually inreasing except for the southern foreground of the Northern Medium-high Mountains, where due to winds of foehn character low clloudiness is characteristic, similarly to Alföld area.
- The most cloudy region is the edge area at West Hungary, where cloud coverage reaches 70%.
- For characterizing cloudiness, the number of clear (cloud cover < 20%) and cloudy (cloud cover > 80%) days are used.
- The most clear region occurs in the middle of Alföld area (Kecskemét: 90 days), while the most cloudy is Zempléni Mountain and the Foothill of the Alps (Sopron: 40 days).
- The mean annual number of cloudy days vary between 80 (Kecskemét) and 140 (Sopron).



Geographical distribution of the mean annual number of clear days in Hungary



Geographical distribution of the mean annual number of cloudy days in Hungary

Always look on the bright side of things!

We finished for today, goodbye!

ямарваа нэг зүйлийн гэгээлэг
талыг нь үргэлж олж харцгаая

өнөөдөртөө ингээд дуусгацгаая, баяртай

让我们总是从光明的一面来看待事物吧！

今天的课程到此结束，谢谢！

دعونا ننظر دائما إلى الجانب المشرق من الأشياء!

انتهينا لهذا اليوم، وداعا!