Vertical range of urban 'heat island' in Moscow

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Urban ‘heat island’ phenomenon

RESULTS IN FIGURES.

Average and difference of Day and Night for each month.

Mo.	Mean of greatest heat by Day.	Mean of greatest cold by Night.	Difference.
1. Jan.	40·28	31·36	8·92
2. Feb.	44·63	33·70	10·93
3. Mar.	48·08	35·31	12·77
4. April	55·37	39·42	15·95
5. May	64·06	46·54	17·52
6. June	68·36	49·75	18·61
7. July	71·50	53·84	17·66
8. Aug.	71·23	53·94	17·29
9. Sept.	65·66	48·67	16·99
10. Oct.	57·06	43·51	13·55
11. Nov.	47·22	36·49	10·73
12. Dec.	42·66	33·90	8·76

Extremes of the Climate. Greatest heat in 10 years 96°: greatest cold—5 (below zero). Difference of *night* from *day* sometimes 30° or 35°; seldom less than 6°. Night is 3.70 *warmer* and day 0.34° *cooler* in the city than in the country. Thus the latter has 4° more variation.

Mean Temperature of each Month, on an average of observations continued from 1807 to 1816.

Mo.	In the Country.	In London.	London warmer.
1. Jan.	34·16°	36·20°	2·04
2. Feb.	39·78	41·47	1·69
3. Mar.	41·51	42·77	1·26
4. April	46·89	47·69	0·80
5. May	55·79	56·28	0·49
6. June	58·66	59·91	1·25
7. July	62·40	63·41	1·01
8. Aug.	61·35	62·61	1·26
9. Sept.	56·22	58·45	2·13
10. Oct.	50·24	52·23	1·99
11. Nov.	40.93	43·08	2·15
12. Dec.	37·66	39·40	1.74

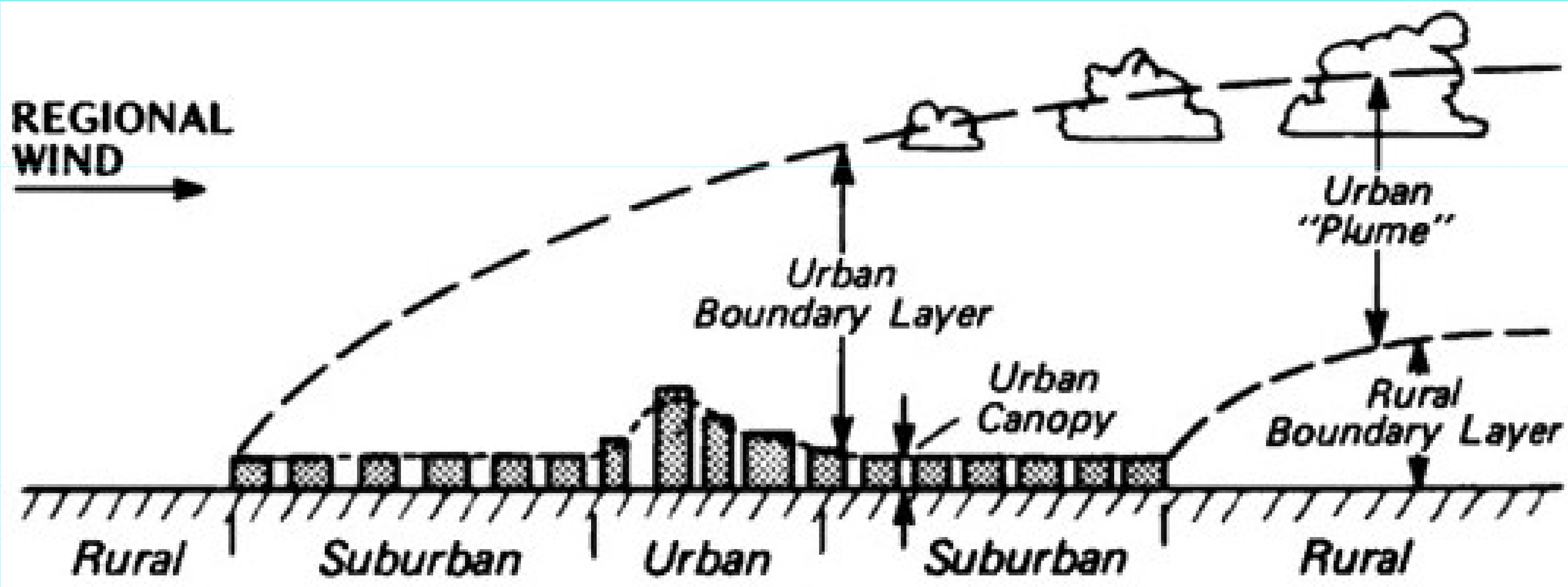
By this Table, the reader who makes daily observations on the temperature for a month may compare his mean result with a fixed standard.

Famous Table of Luke Howard for London city from his book “The Climate of London”, 1820 (cited by Helmut E.Landsberg, 1981).

Luke Howard (1772-1864) – pioneer of the ‘heat island’ studying.

The urban atmosphere scheme
(vertical structure of ‘heat island’)

Oke T. Boundary Layer Climates. London, UK, 1978.



Experimental results: “cross-over effect”.

Duckworth F.S. and Sandberg J.S., 1954. The effect of cities upon horizontal and vertical temperature gradients. Amer. Meteor. Soc. Bulletin, Vol. 35, No. 5, pp.198-207.

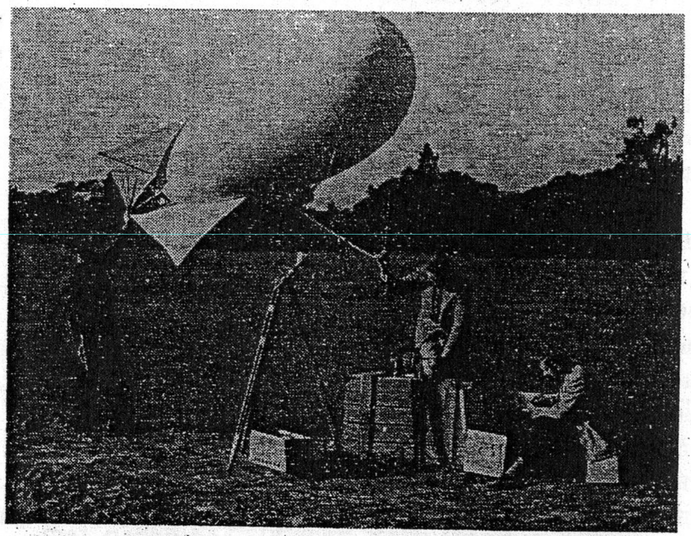


FIG. 2. Wiresonde equipment. Thermistor element is carried aloft by Kytoon. Conducting cable, unwound from reel, transmits electrical impulses to balanced-bridge indicating unit, shielded in metal box on ground. Hand and mounted clinometers measure blow-down angle.

Tethered balloons

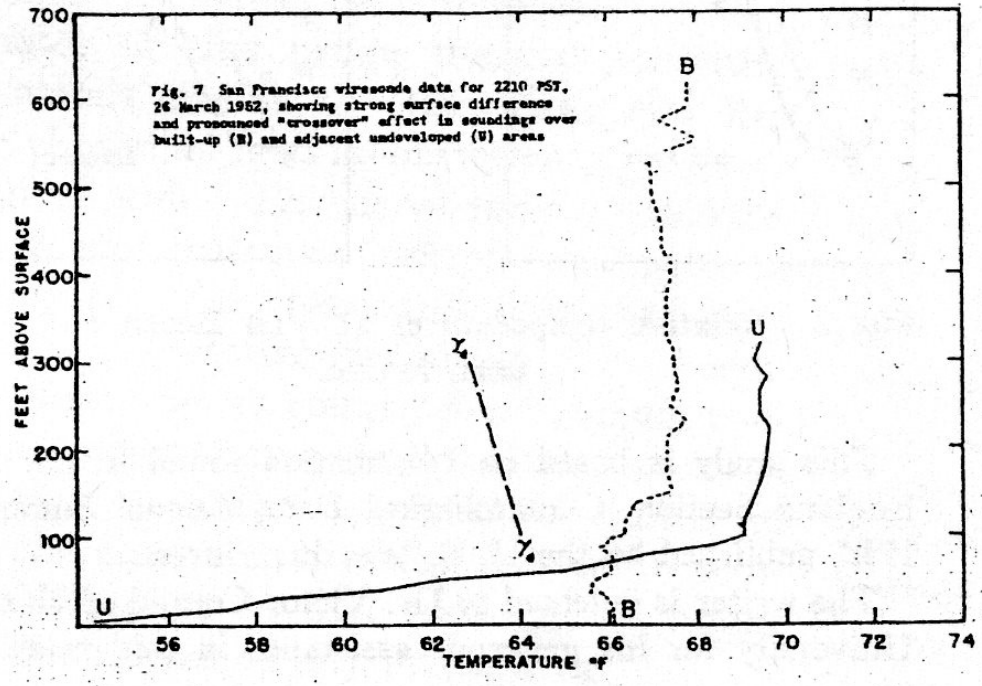


FIG. 7. San Francisco wiresonde data for 2210 PST, 26 March 1952, showing strong surface difference and pronounced “crossover” effect in soundings over built-up (B) and adjacent undeveloped (U) areas.

Experimental results: “cross-over effect”.

Landsberg H.E., 1981: The Urban Climate. Academic Press, New York.

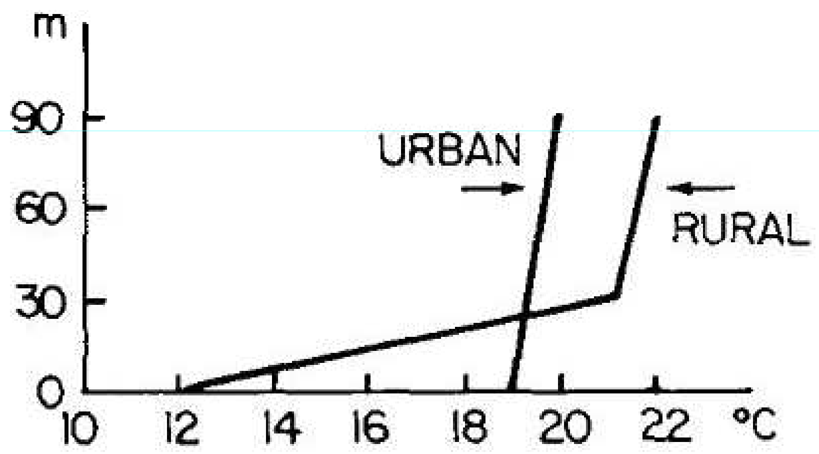


Fig. 5.18 Typical nocturnal vertical temperature structure over an urban and adjacent rural area, showing the so-called crossover effect.

Experimental results: “cross-over effect”.

**Landsberg H.E., 1981: The Urban Climate.
Academic Press, New York.**

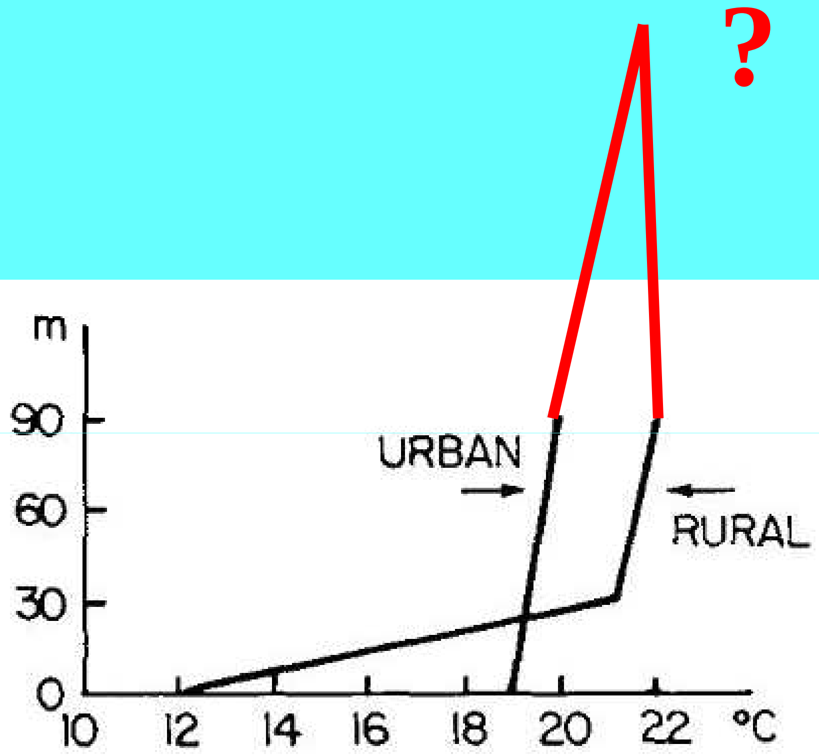
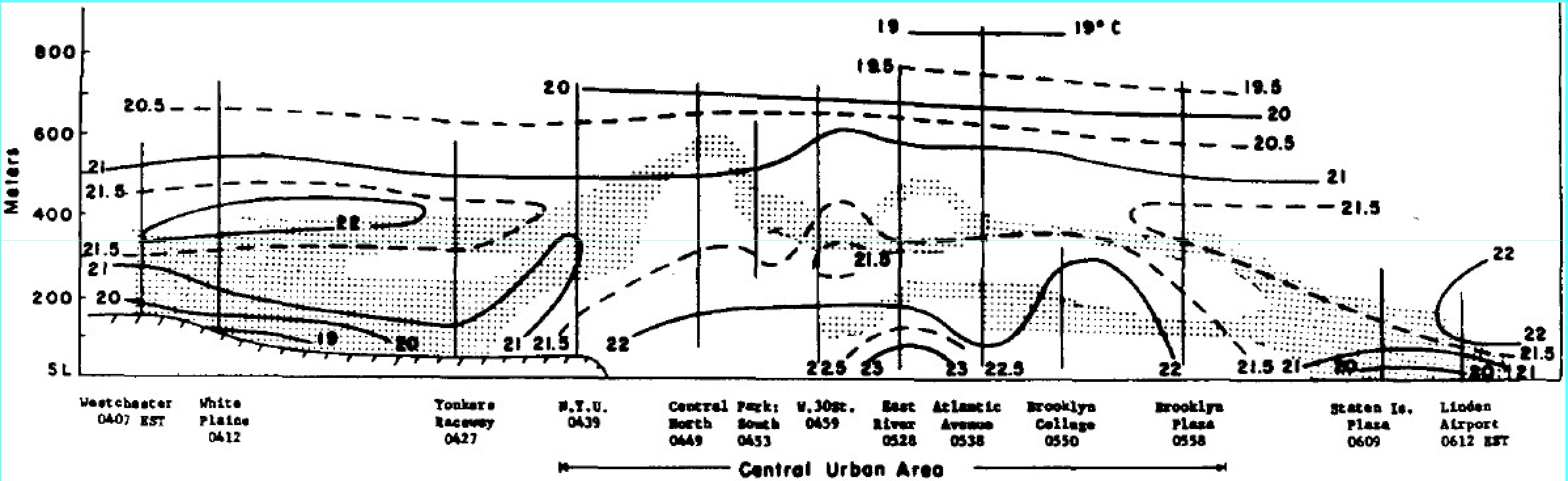


Fig. 5.18 Typical nocturnal vertical temperature structure over an urban and adjacent rural area, showing the so-called crossover effect.

Experimental results: vertical range of UHI

Bornstein R.D. Observations of the urban heat island effect in New York City. Journal of Applied Meteorology, 1968, Vol.7, pp.575-582.



Vertical and horizontal temperature distribution over the New York City area on 16 July 1964 from 0407–0612 EST.

Helicopter sounding

Experimental results: vertical range of UHI

Bornstein R.D. Observations of the urban heat island effect in New York City. Journal of Applied Meteorology, 1968, Vol.7, pp.575-582.

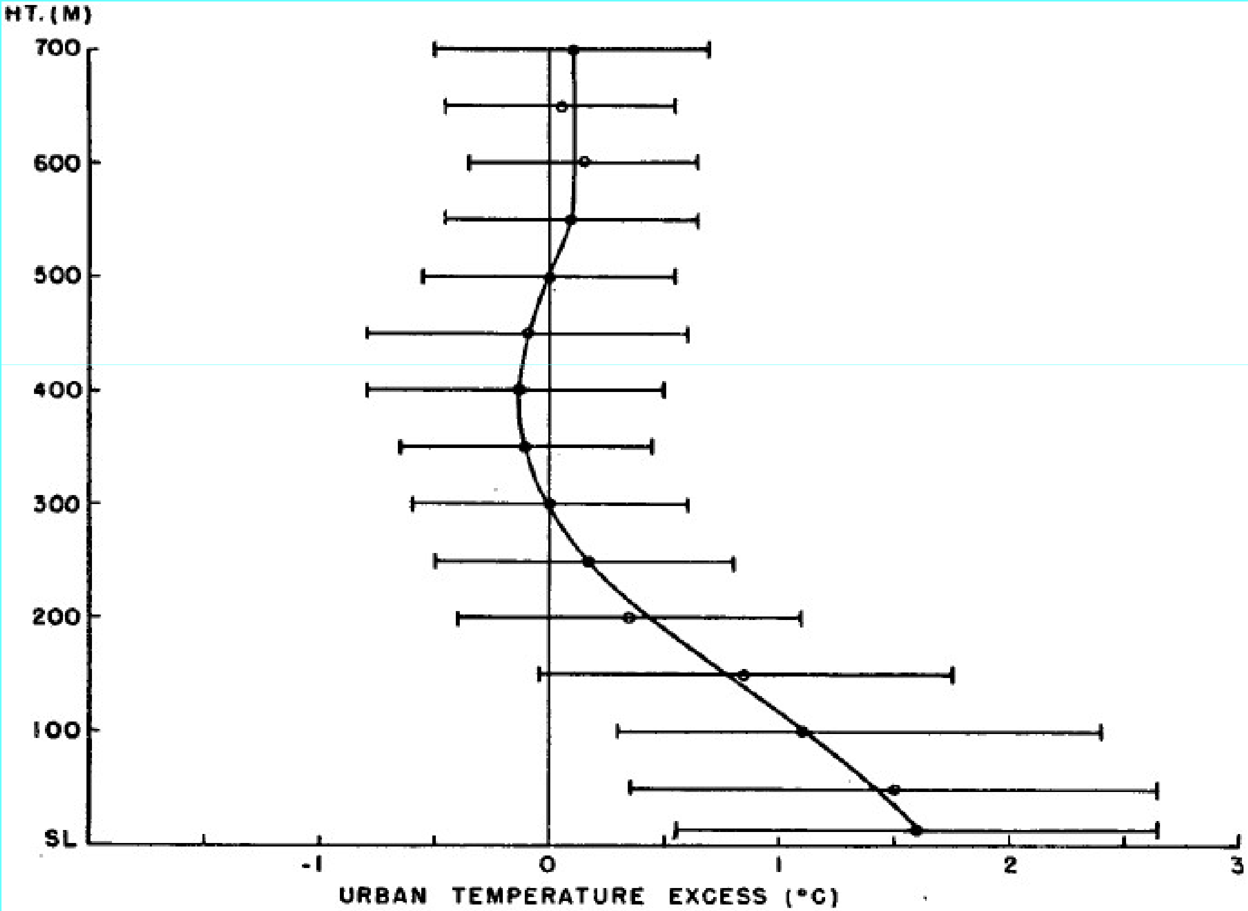
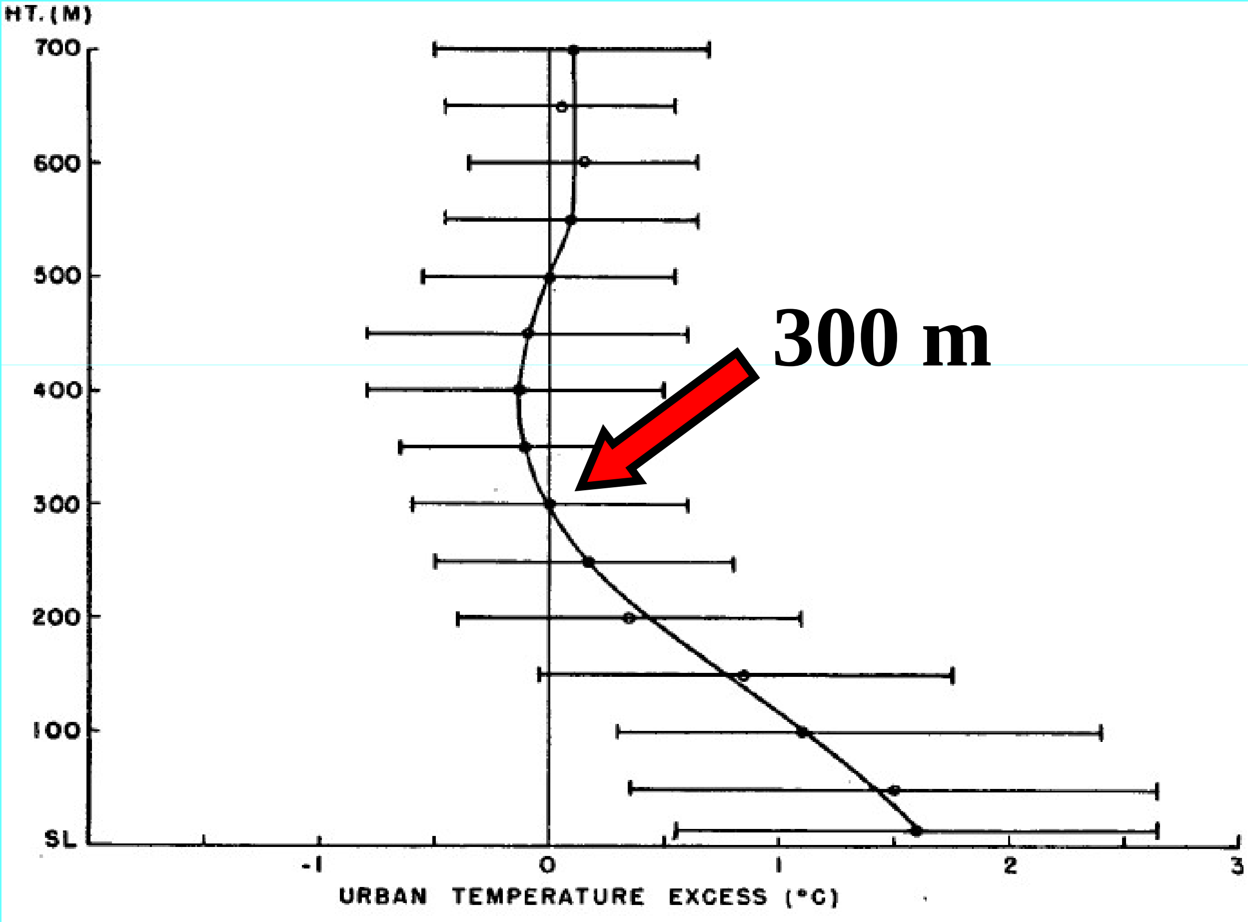


FIG. 7. Height variation of the magnitude of the urban heat island of New York City during the hours near sunrise. Range of plus and minus one standard deviation is also shown.

Helicopter sounding

Experimental results: vertical range of UHI

Bornstein R.D. Observations of the urban heat island effect in New York City. Journal of Applied Meteorology, 1968, Vol.7, pp.575-582.



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Helicopter sounding

Experimental results: vertical range of UHI

Kadygrov E.N. et al. Transactions (Doklady) of the Russian Academy of Sciences / Earth Sciences Section, Vol.385, No.6.

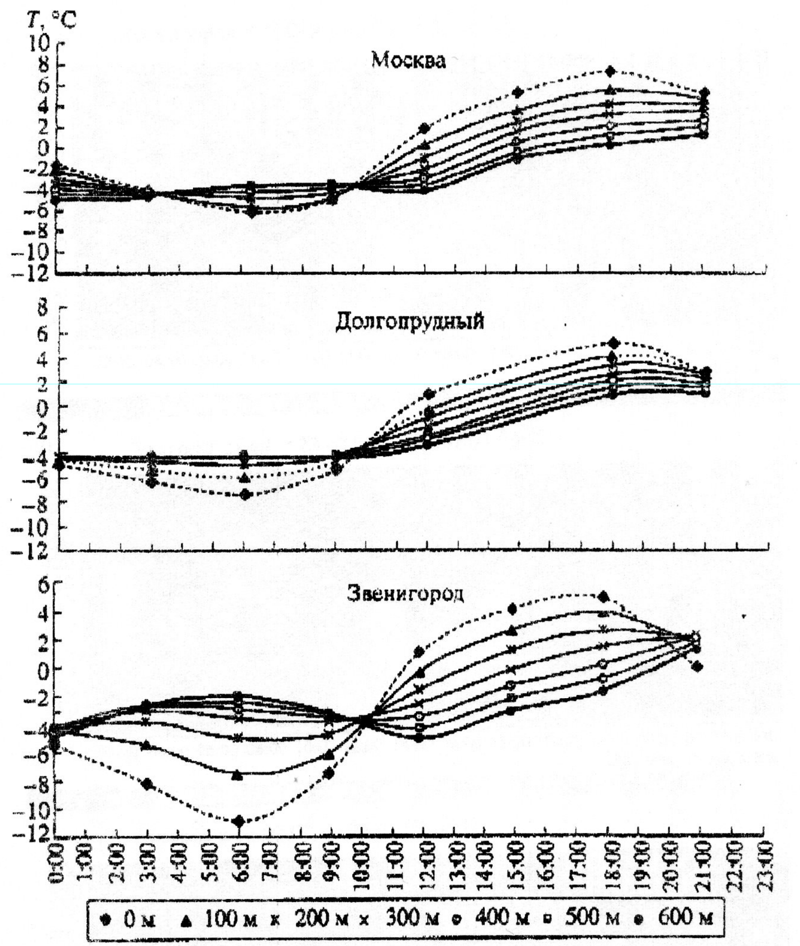
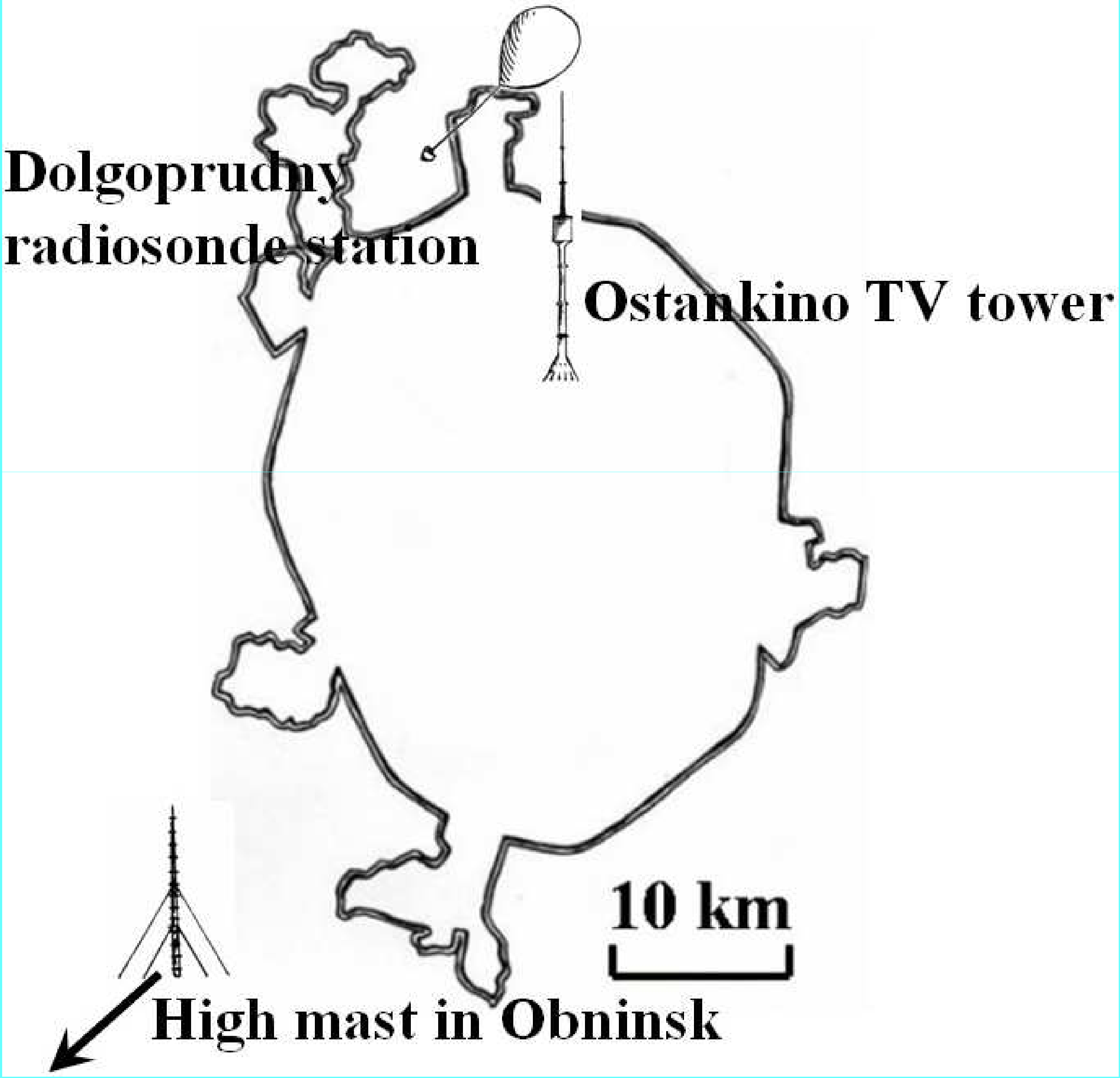


Рис. 1. Температура в 600-метровом слое в трех разнесенных пунктах при ясной погоде вблизи центра антициклона 31 марта 2001 г.

Microwave radiometers at several locations

Measurements of temperature profiles in Moscow region



Sources of used data:

Since 1941 – Aerologic station at Dolgoprudny (2 km to the North from Moscow)

Sources of used data:

Regular measurements on 2, 121 and 301 m

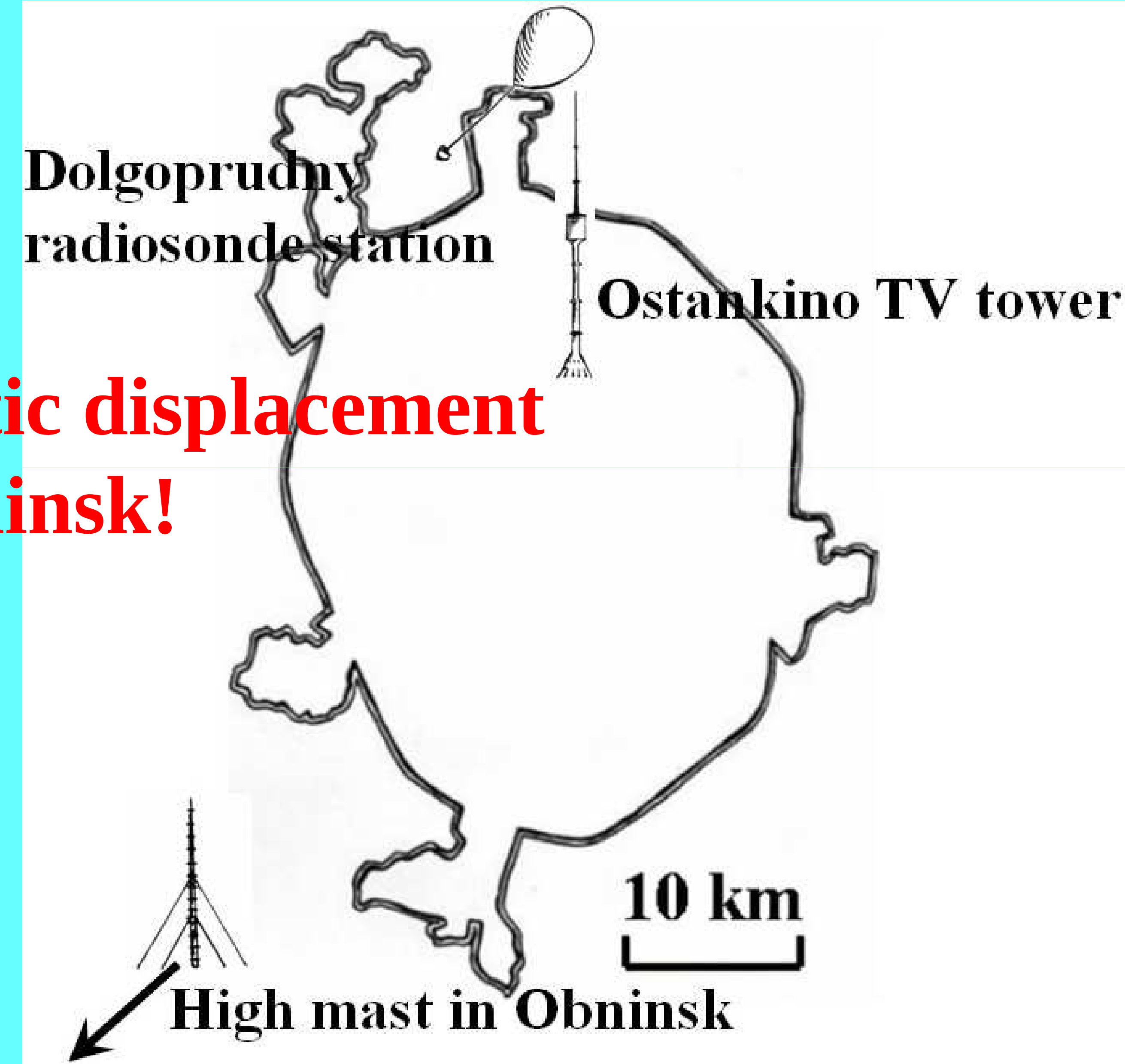
Since 1958 – 310 m High meteorological mast in Obninsk (96 km to the South from Moscow)

Sources of used data:

Regular measurements on 2, 85, 128, 201, 253, 305, 385 and 503 m

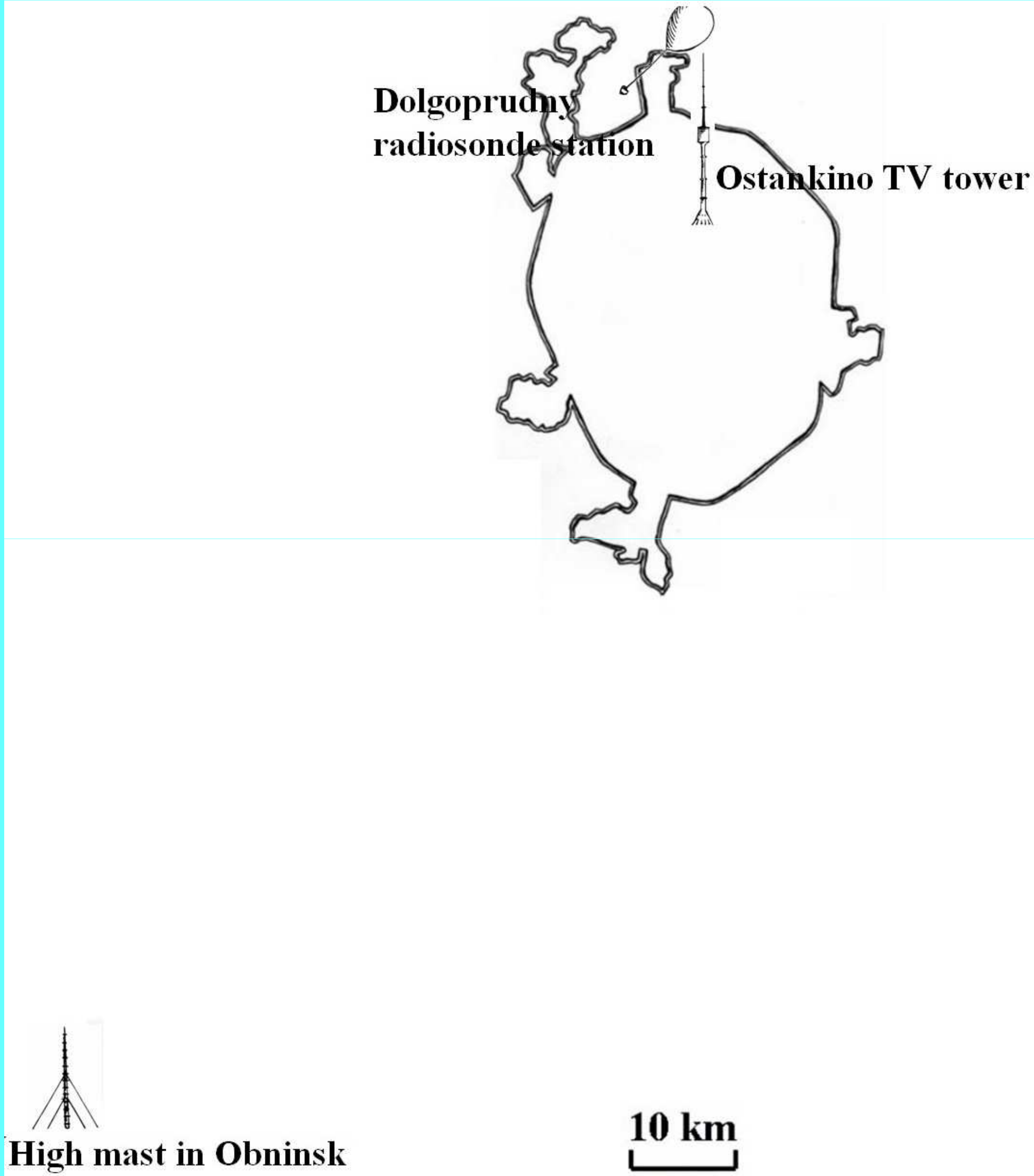
Since 1968 – 540 m TV Tower in Ostankino district of Moscow (7 km from the city centre)

Methodical problems

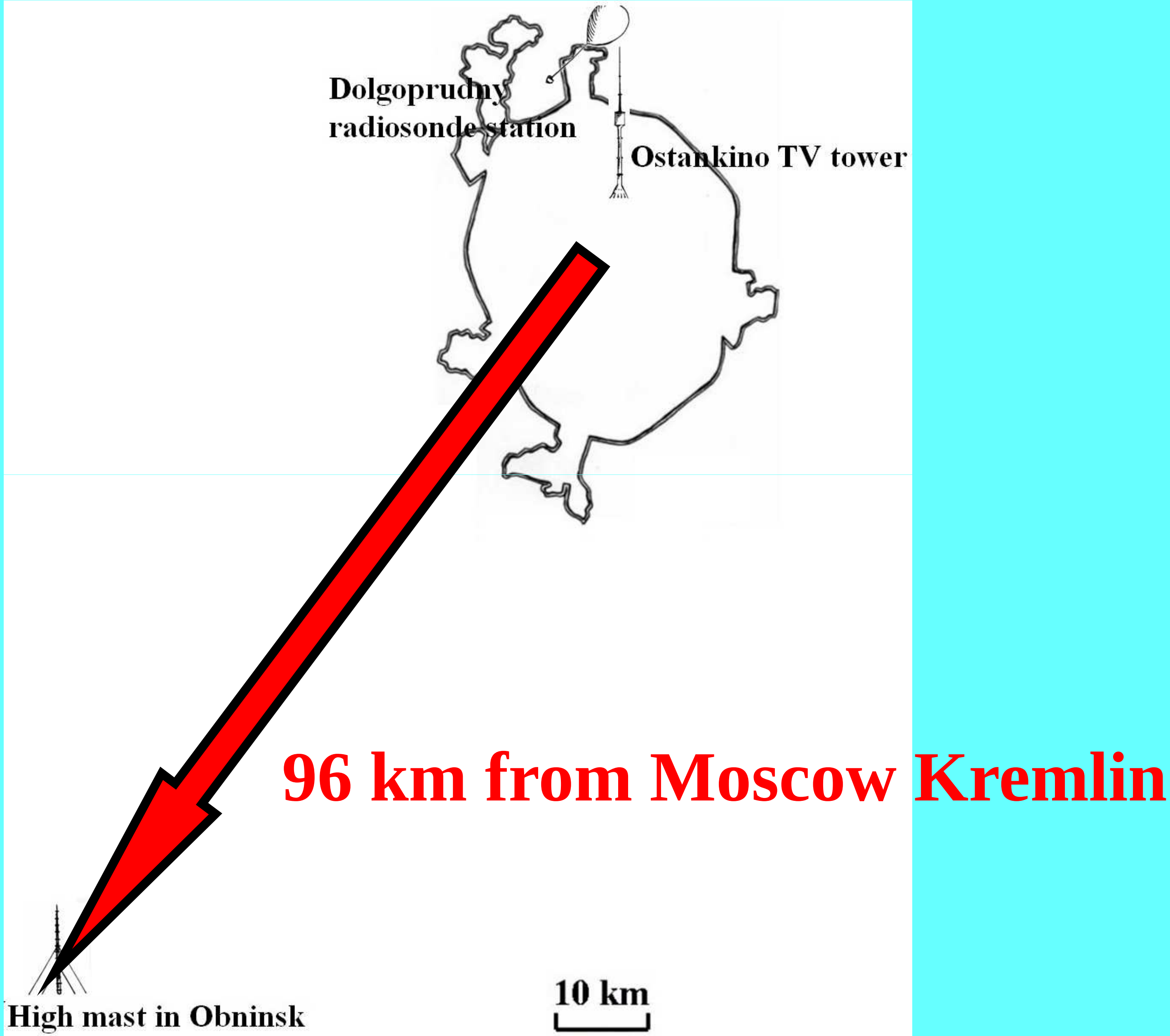


Climatic displacement of Obninsk!

Methodical problems

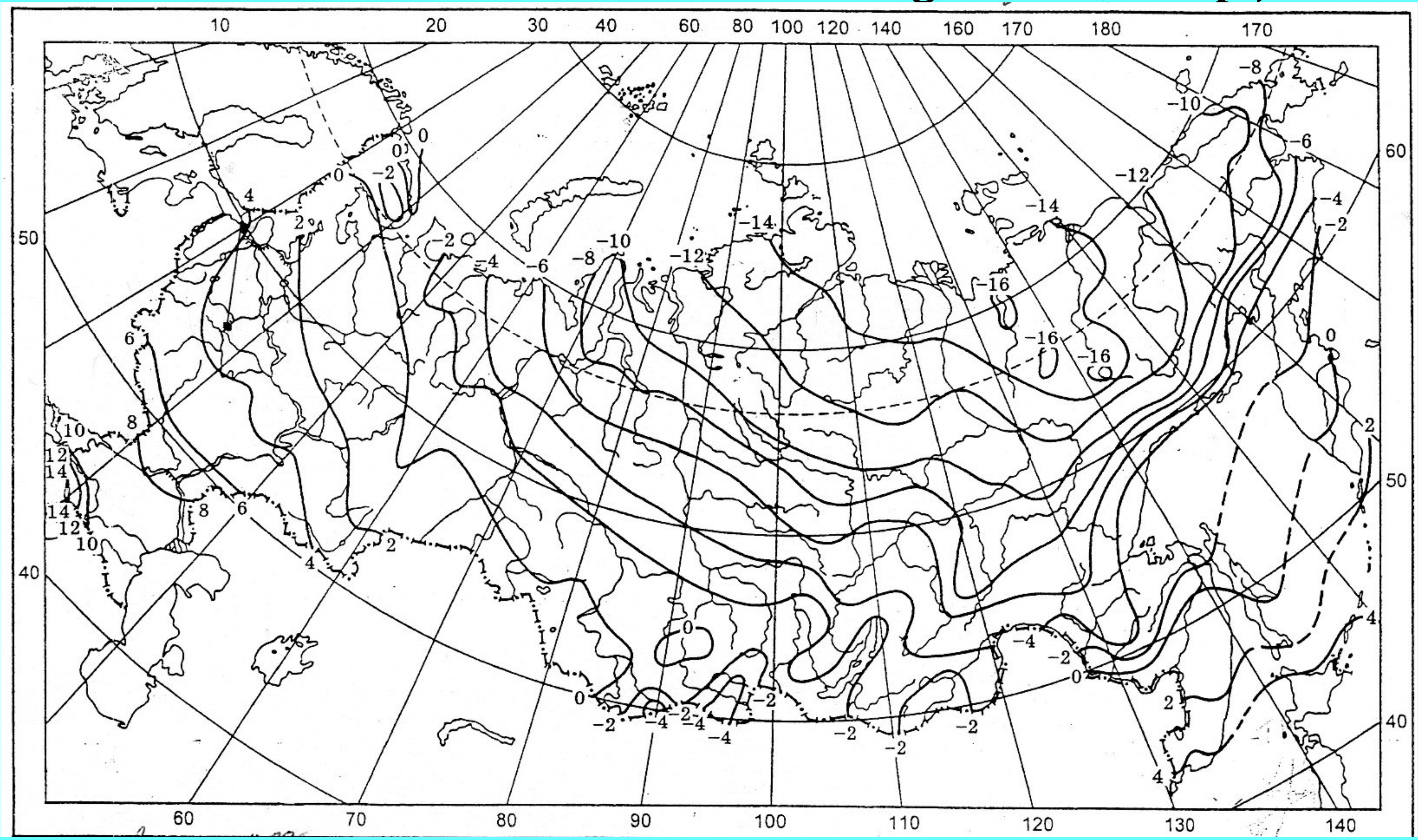


Methodical problems



Map of the mean-annual isotherms in Russia

(Kobysheva N.V. (Ed.), 2001: The Climate of Russia. Gidrometeoizdat Publ., St.Petersburg, Russia, 656 p.).



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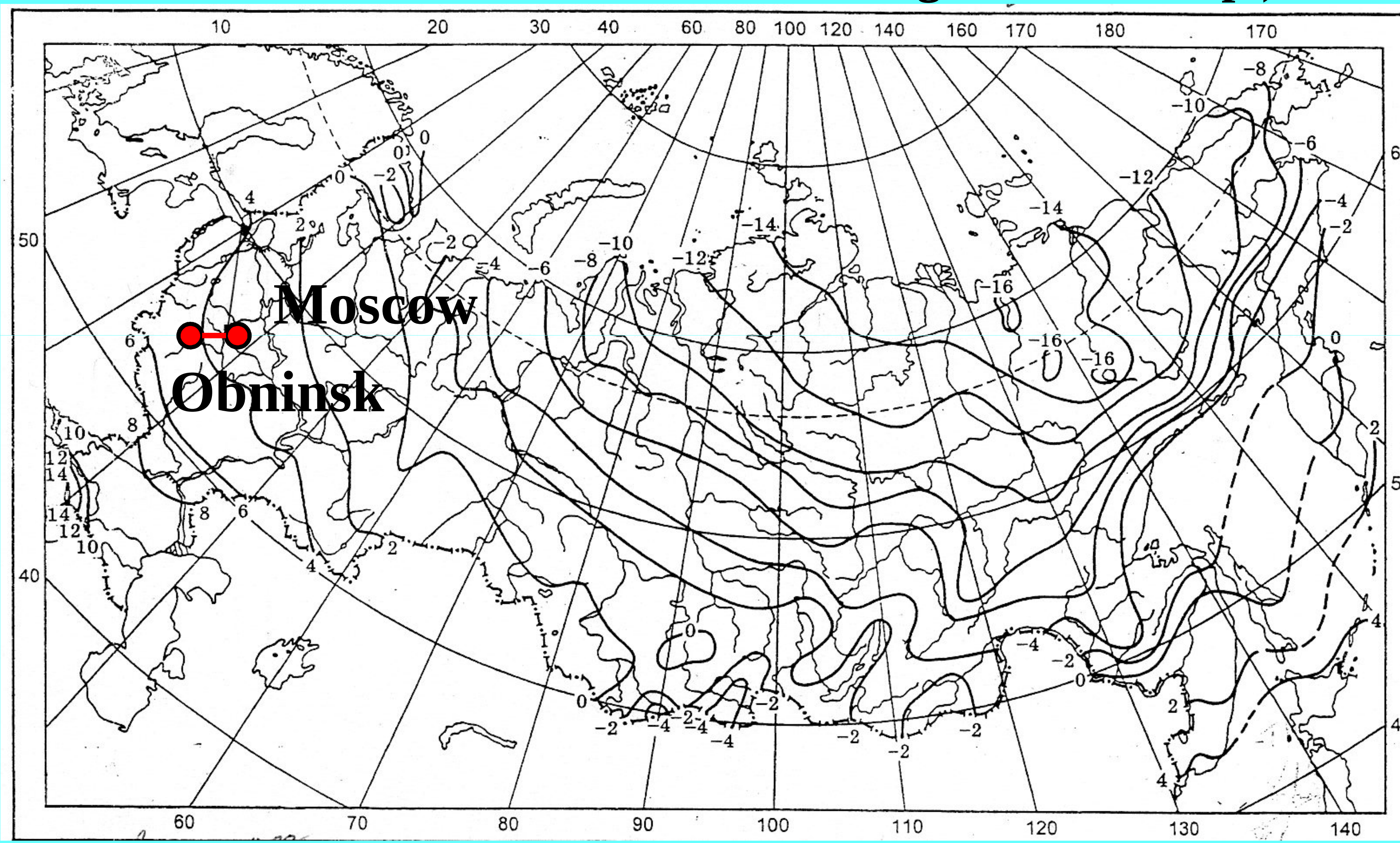

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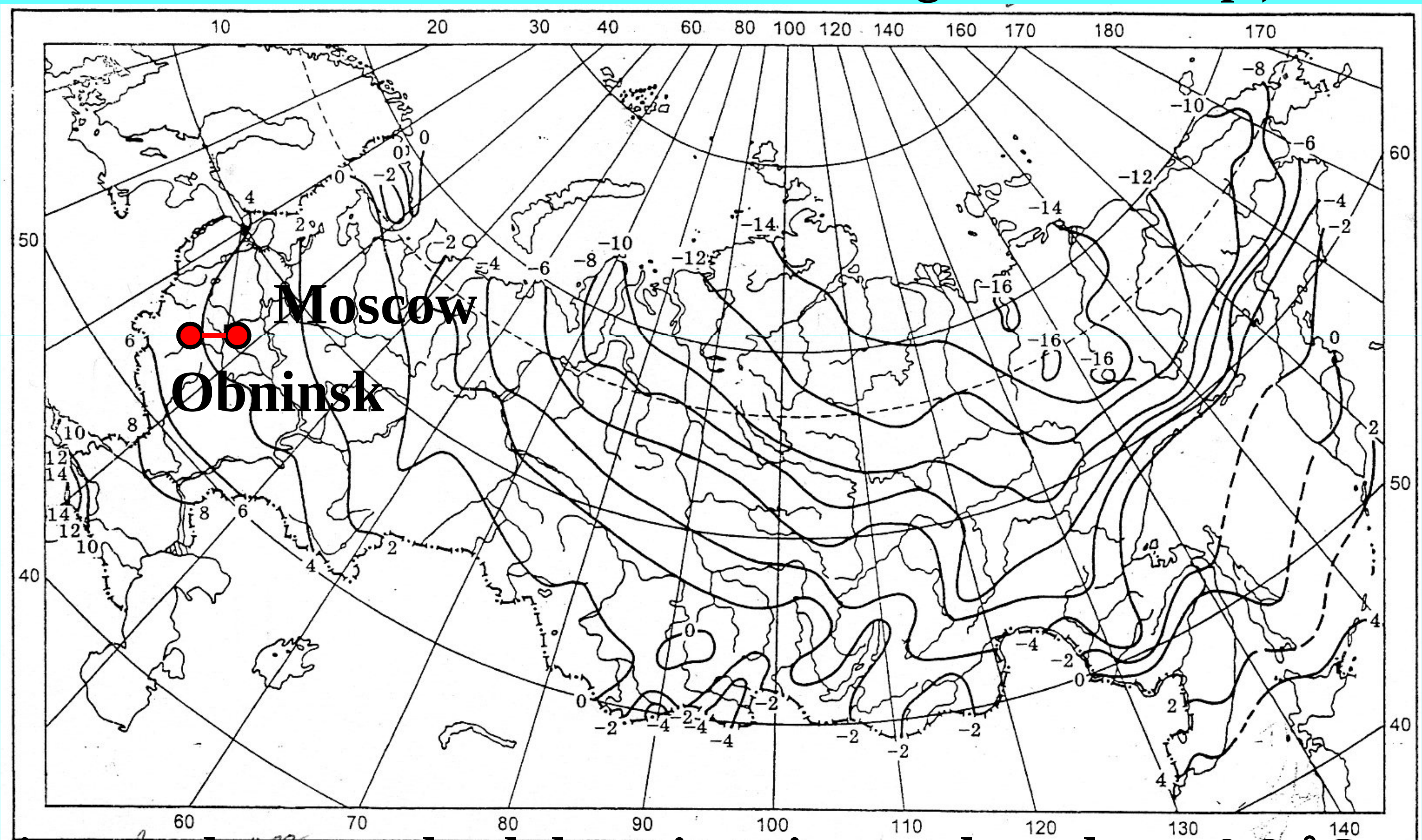
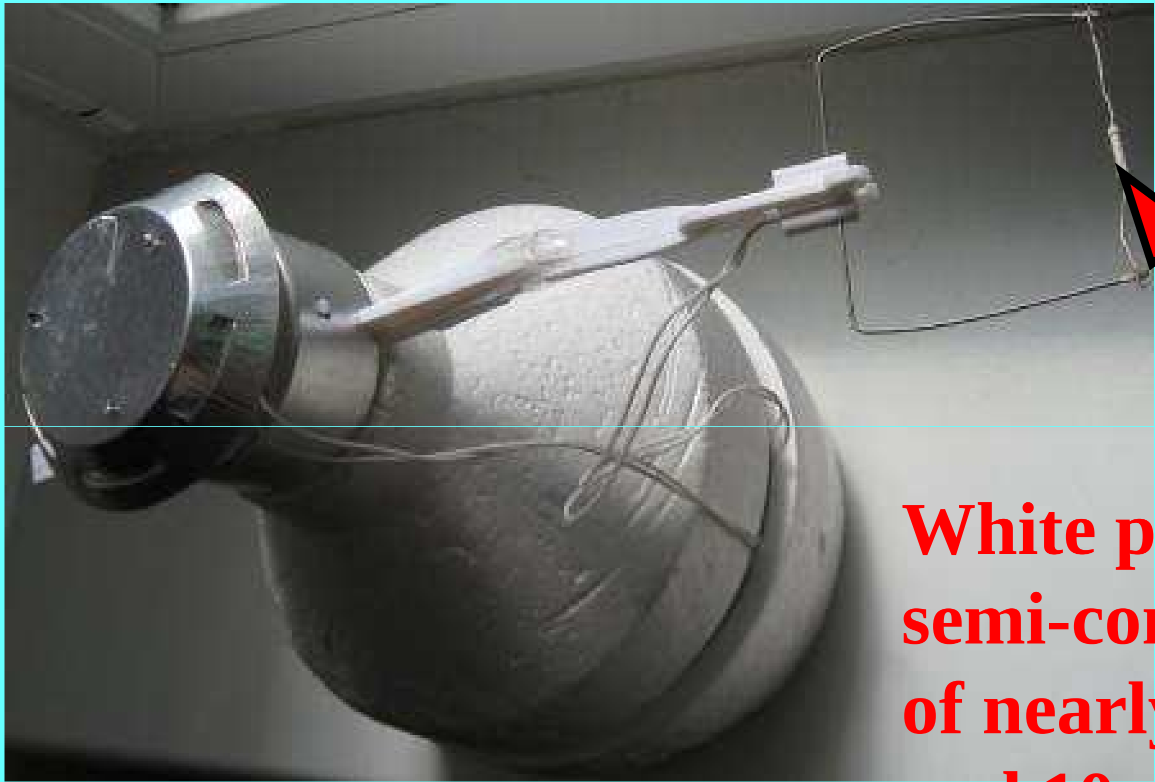


Distance between both locations is equal to about 0.3 °C

Methodical problems

Soviet (Russian) radiosonde MRZ

Methodical problems



White painted rod
semi-conducted thermistor
of nearly 2 mm diameter
and 10 mm length

Soviet (Russian) radiosonde MRZ

Methodical problems

Time constant α = 5-6 s (Kokovin, 1966) or 7 s (Ivanov et al., 1991)

Soviet (Russian) radiosonde MRZ

Methodical problems

Inevitable inertia?

Approximate value of the T systematic overestimation by radiosondes in the afternoon and inside inversions is:

$\Delta T = \alpha \cdot V \cdot \partial T/\partial z = 0.2\text{–}0.4\ ^\circ C$,

where V is a typical rate of sonde's ascent.

Methodical problems

However!

Results of the international radiosonde comparisons in Dzhambul, USSR in 1989:
T values by the Soviet thermistor despite of its big time constant were mostly lower (in average on 0.2-0.4 ˚C) than T values by Finnish RS80-15N and by USA VIZ-1392 thermistors having less time constant (2.5–3.0 s). Thus, radiation cooling of the thermistor surface seems to be stronger than its expected inertia.

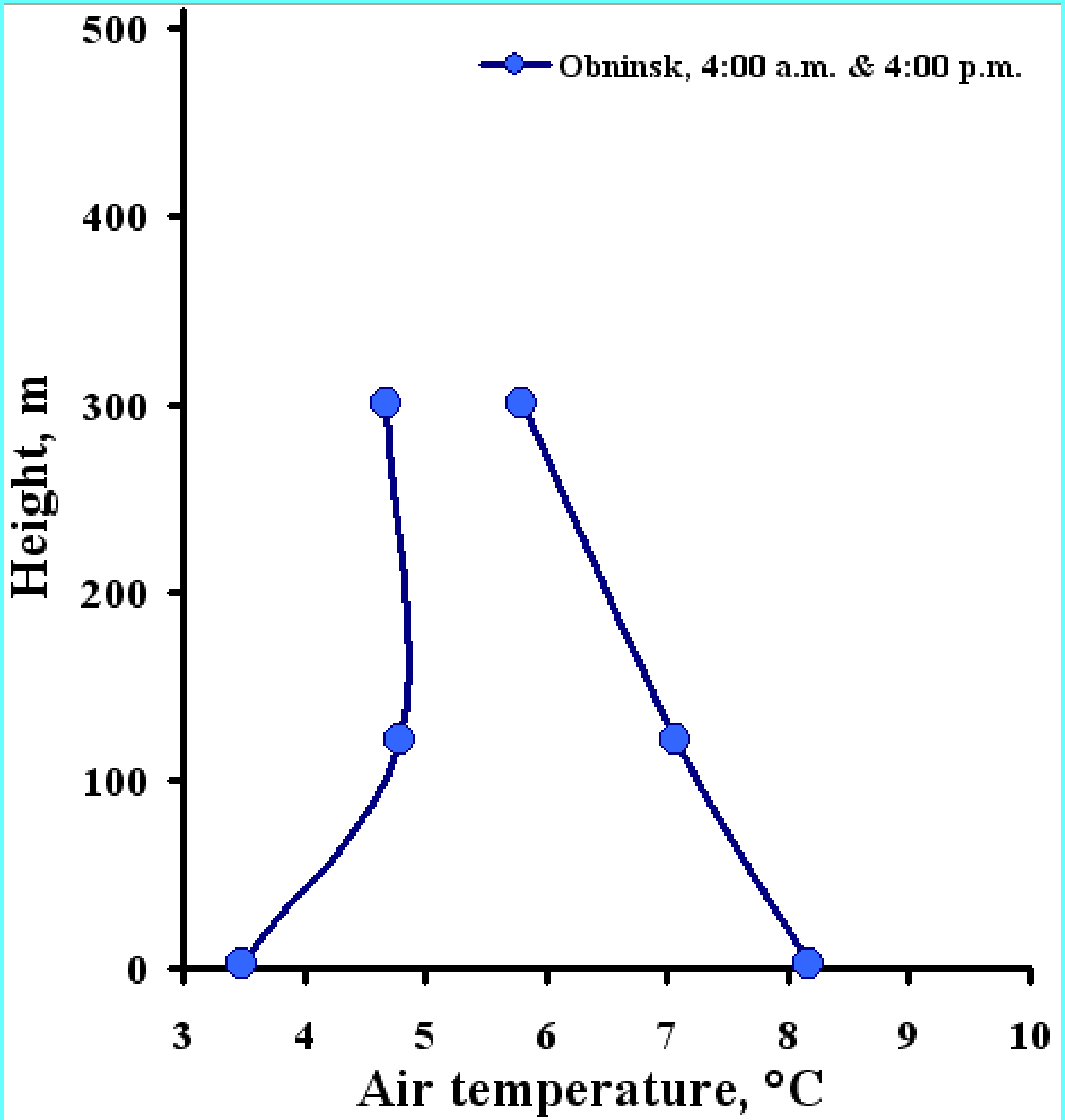
Data about air temperature are available:

by radiosondes in Dolgoprudny –
since 1991 till 2013;

by high mast in Obninsk –
since 1993 till 2013;

by TV tower Ostankino in Moscow –
since 2006 till 2013

Average profiles of T for the period 2006-2013



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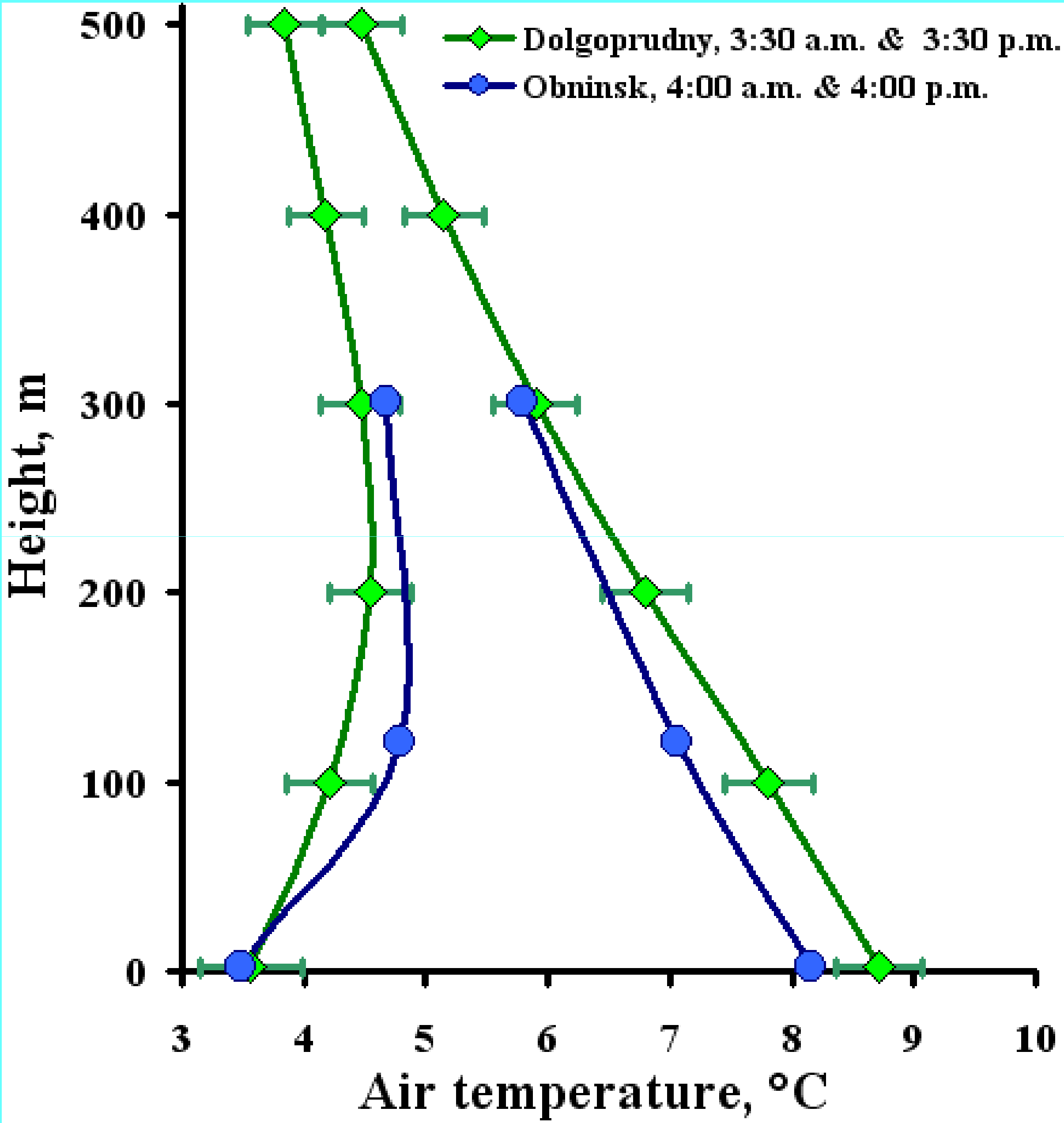

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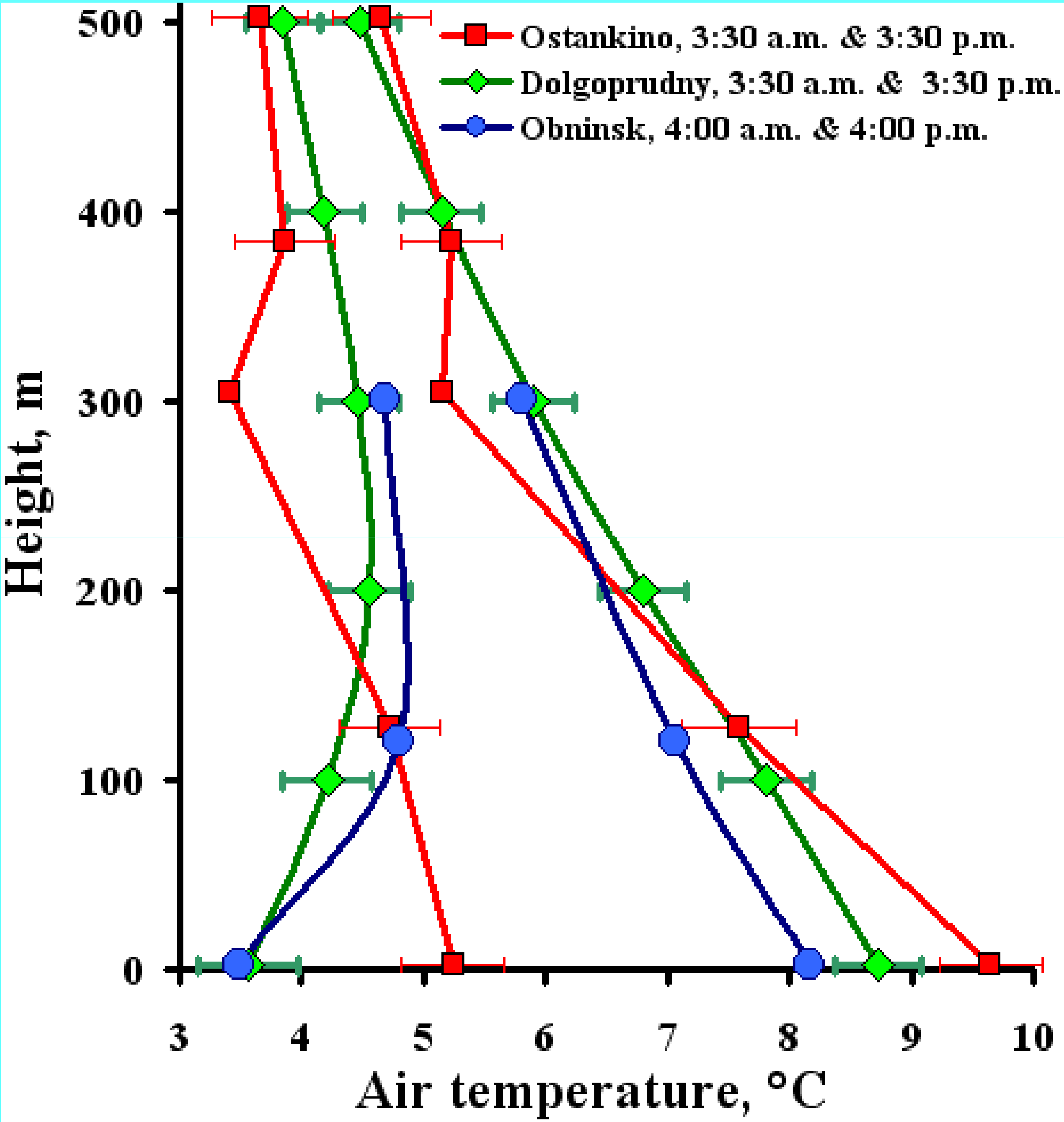

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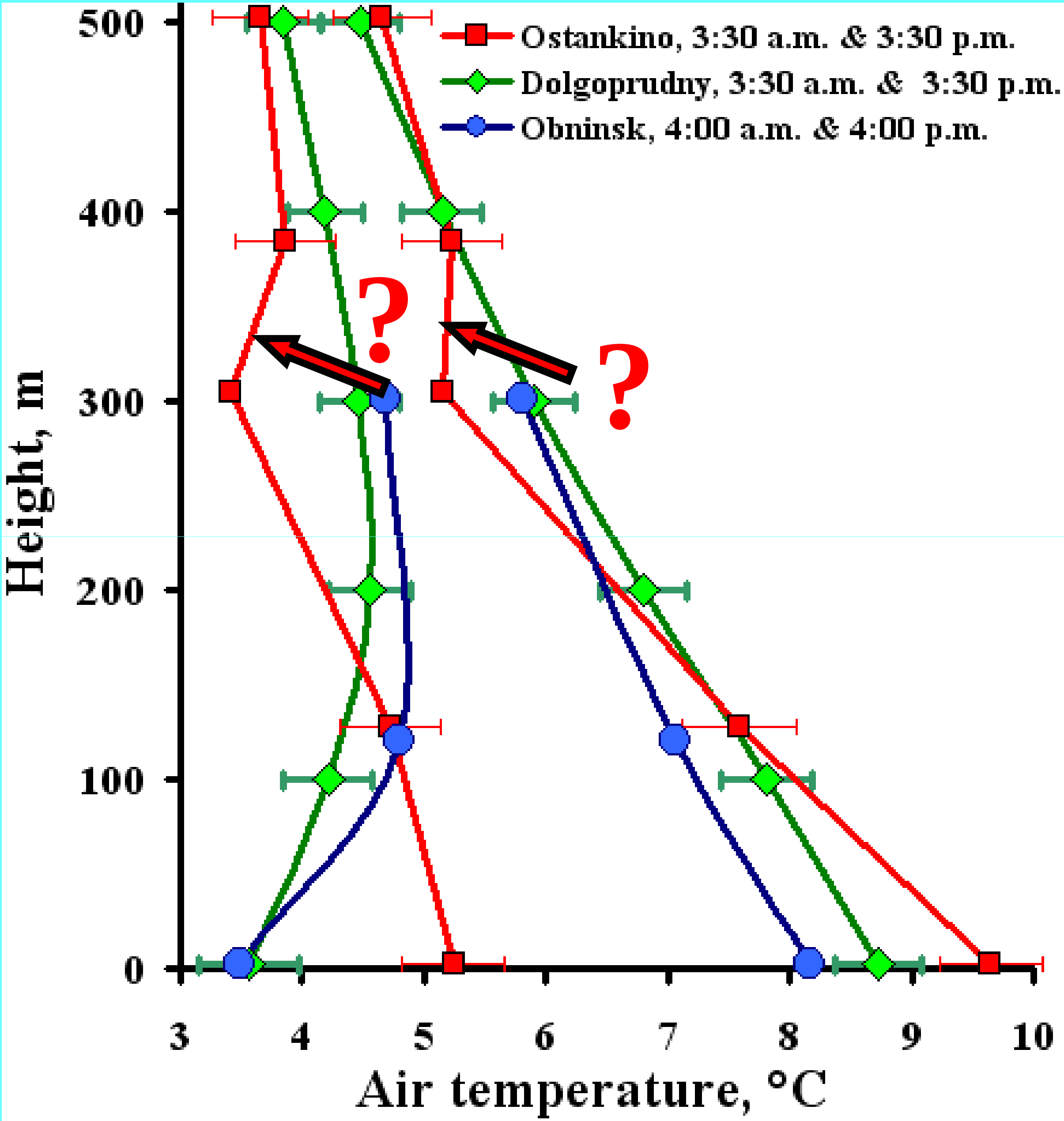


The constant elevated inversion in Ostankino – real phenomenon or phantom?

Long history of the question

Lokoshchenko M.A. et al. Russian Meteorology and Hydrology, 1993, Vol.18, No.9, pp.13-24

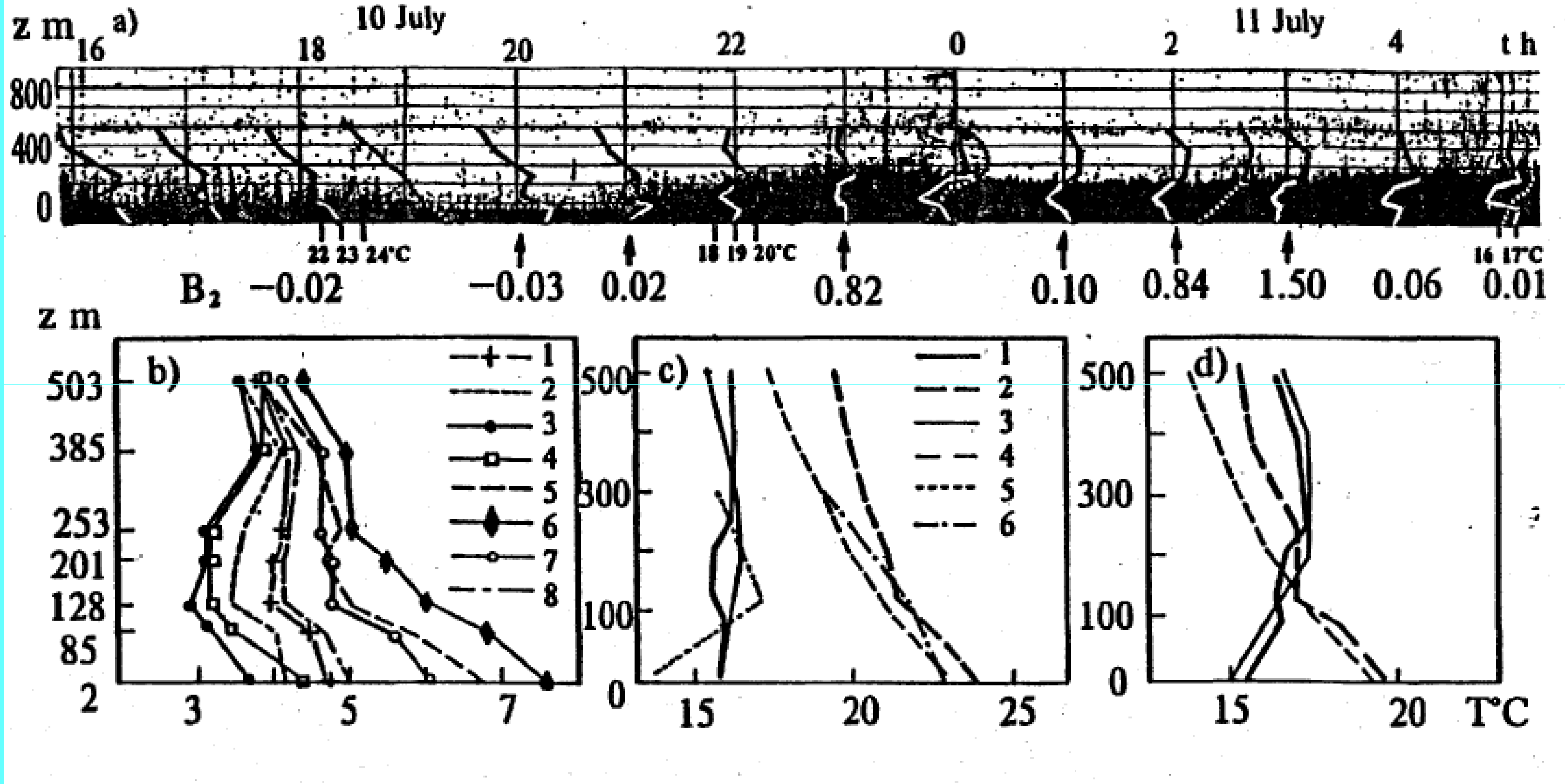
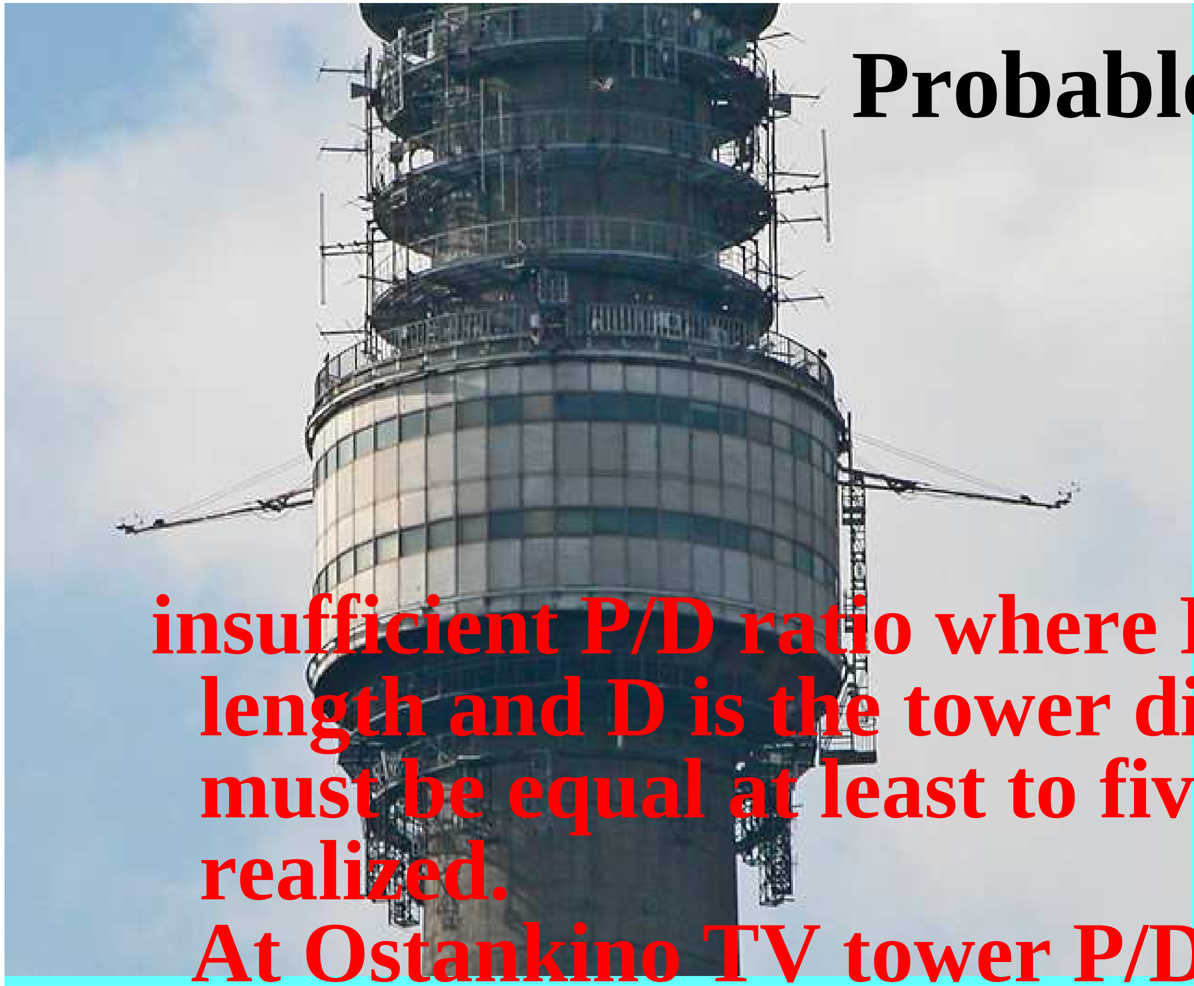


Fig. 1. Vertical temperature profiles from different measurements: a) Ostankino TV tower sensors (solid lines) and radiosounding in Dolgoprudnyi (dots) superposed on a facsimile record of the Ostankino sodar on 10–11 July 1991. The shadowed layer on the record at night corresponds to a temperature inversion area; below are presented the values of the parameter B_2 from the results of gradient measurements at Ostankino; b) TV tower measurements averaged for October of 1990, at 00:00 (1), 03:00 (2), 06:00 (3), 09:00 (4), 12:00 (5), 15:00 (6), 18:00 (7), and 21:00 (8); c) measurements by three techniques averaged for the time of the experiment at Ostankino at 03:00 (1) and 15:00 (2), in Dolgoprudnyi at 02:30 and 14:30, in Obninsk at 03:00 (5) and 15:00 (6); d) measurements on the TV tower and radiosounding data during the experiment (the legend is presented in Fig. 1c).

Suggested attempts to explain imaginary elevated inversion:

- **Gusev M.A., 1975: heating as a result of adiabatic compression due to constant downward air flows;**
- **Novikova E.N. et al., 1975: smoke from forest fires in time of heat wave in 1972;**
- **Pogosyan Kh.P., 1975: influence of real elevated inversions in morning time;**
- **Pharaponova G.P., 1989: thermal effect from industrial haze layer above the city;**
- **Different authors: heated plumes from chimneys of urban plants; etc.**



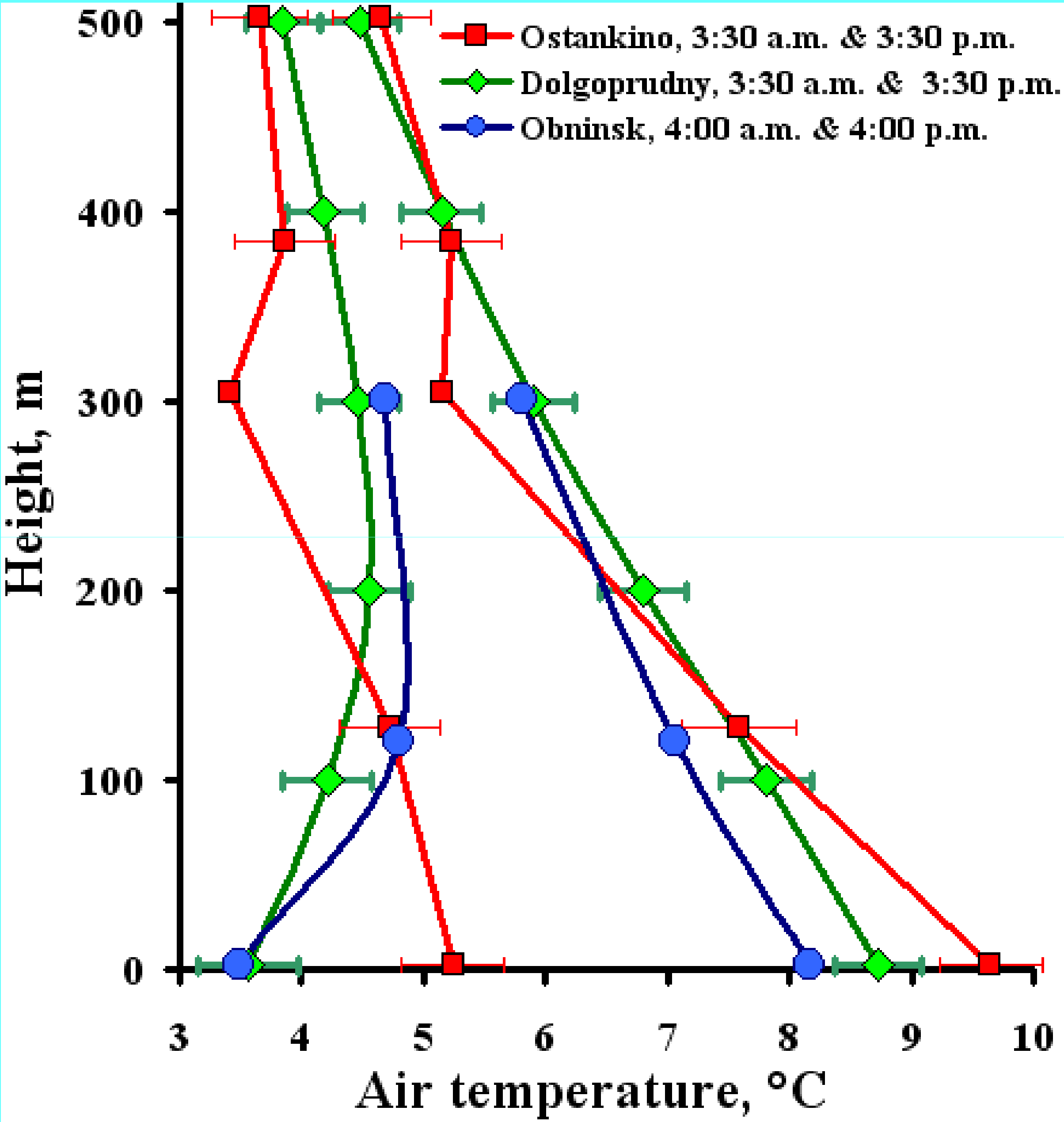
Probable explanation:

insufficient P/D ratio where P is radial line's length and D is the tower diameter. This ratio must be equal at least to five, but it is hardly realized.

At Ostankino TV tower P/D ratio is only about 1.0–1.5 at all levels except only the highest one (503 m) where it is equal to 6.9 (with the account of balcony width – even 9.0).

- Probably, dynamic and thermal influence of tower construction on T sensors is inevitable.

Average profiles of T for the period 2006-2013



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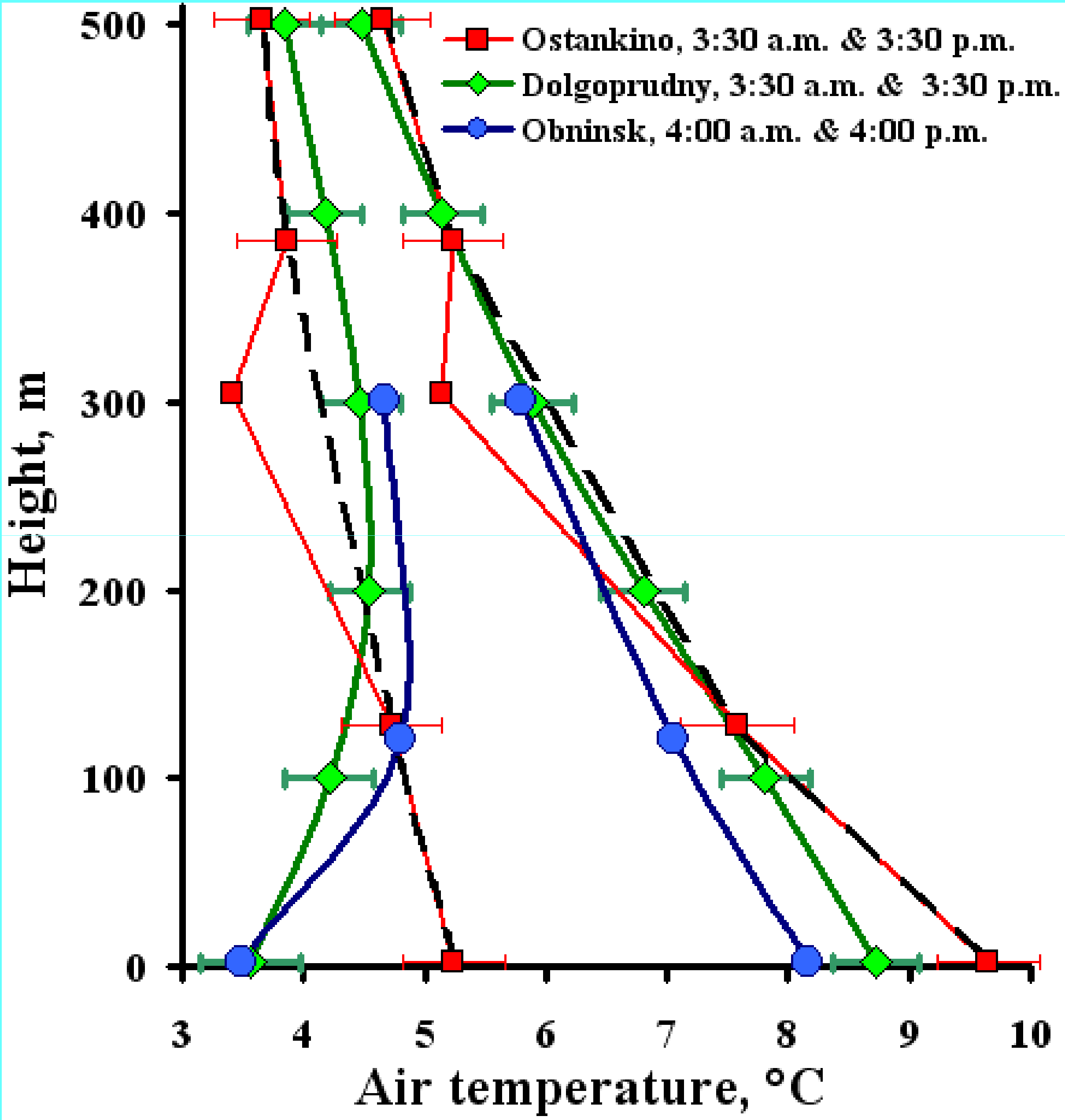
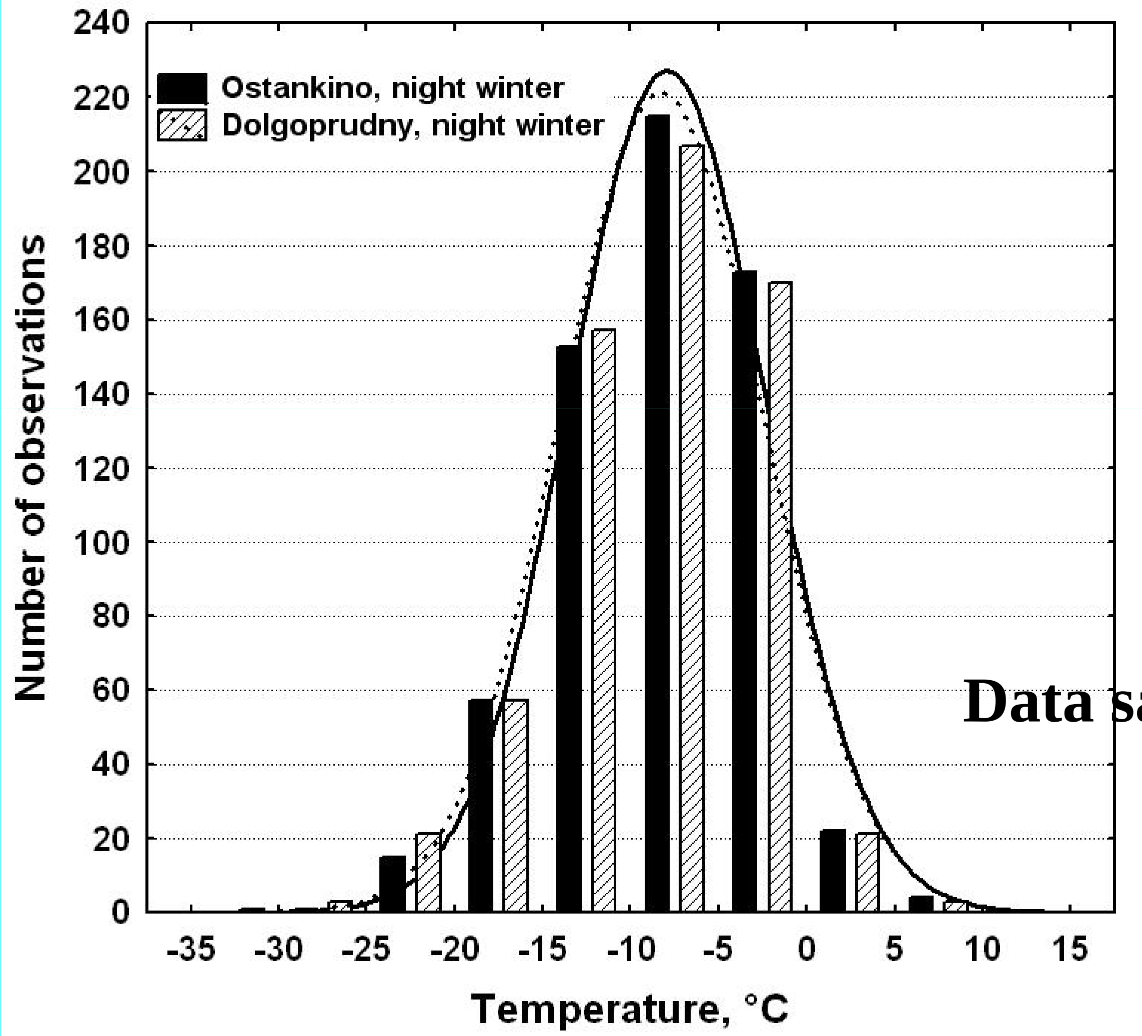


Average daily air temperature at heights from 2 to 500-503 m for the period 2006-2013

Height, m	City centre (TV tower)	City periphery (sondes)	Rural zone (Obninsk)
2	7.3	5.9	5.9
100–128	6.0	5.8	6.0
300–305	4.9*	4.9	5.2
385–400	4.4	4.4	
500–503	4.0	3.9	

** This value has been interpolated between 128 and 385 m.*

Statistical distributions of the T values on 500-503 m by TV tower and radiosonde data at 3:30 a.m. in winter for the period since 2006 till 2013.



Data sampling is 640

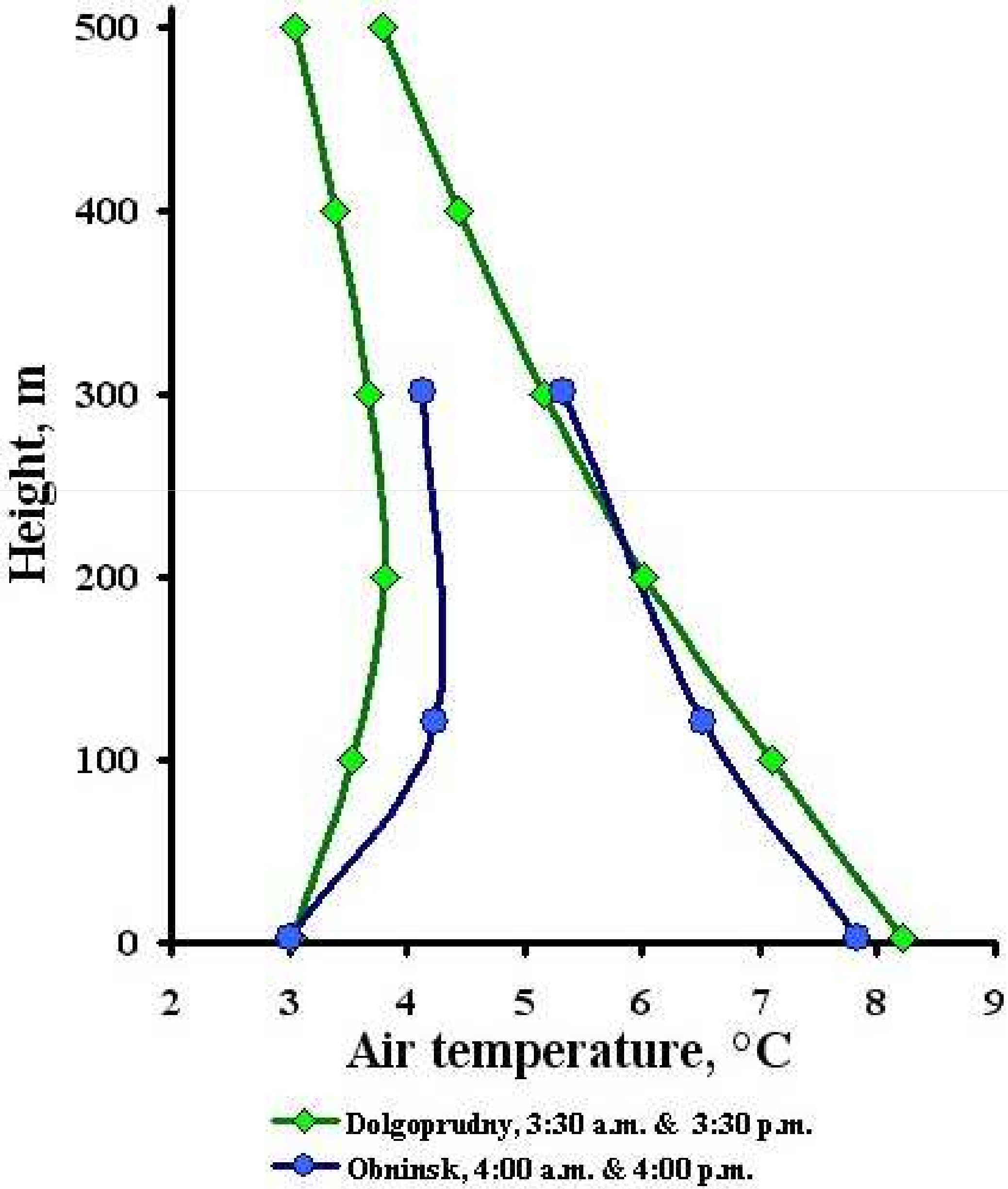
Solid lines represent the normal law distributions for both places.

Total result:

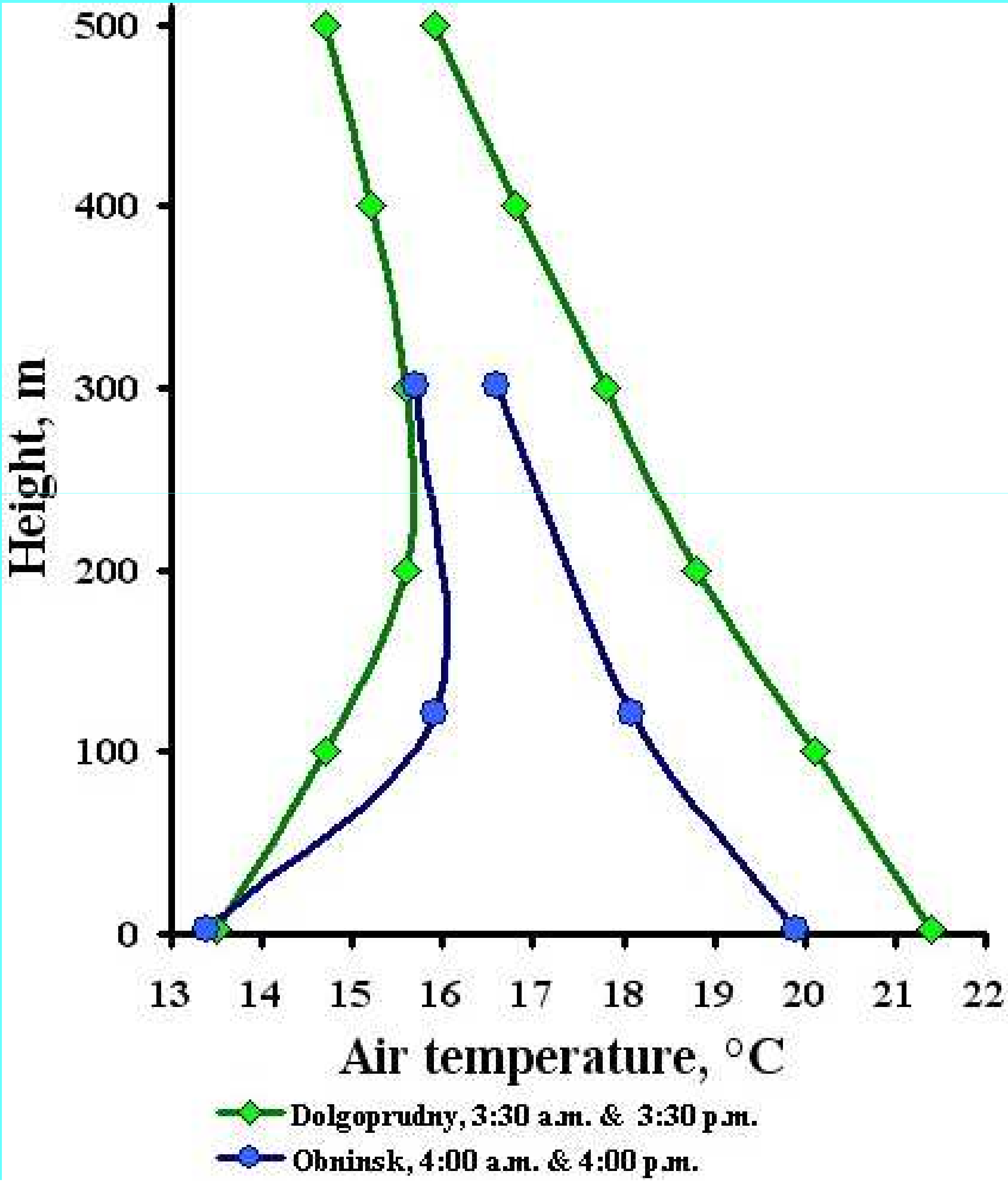
- Since the level of 400 m frequencies of T values are close to each other at all histogram gradations.
- Statistical differences between mean values of T at both locations according to Student criteria are statistically insignificant even with the confidence probability of 0.95.

$$Z = \frac{(\bar{X} - \bar{Y})}{\sqrt{\sigma^2(X)/n + \sigma^2(Y)/m}}$$

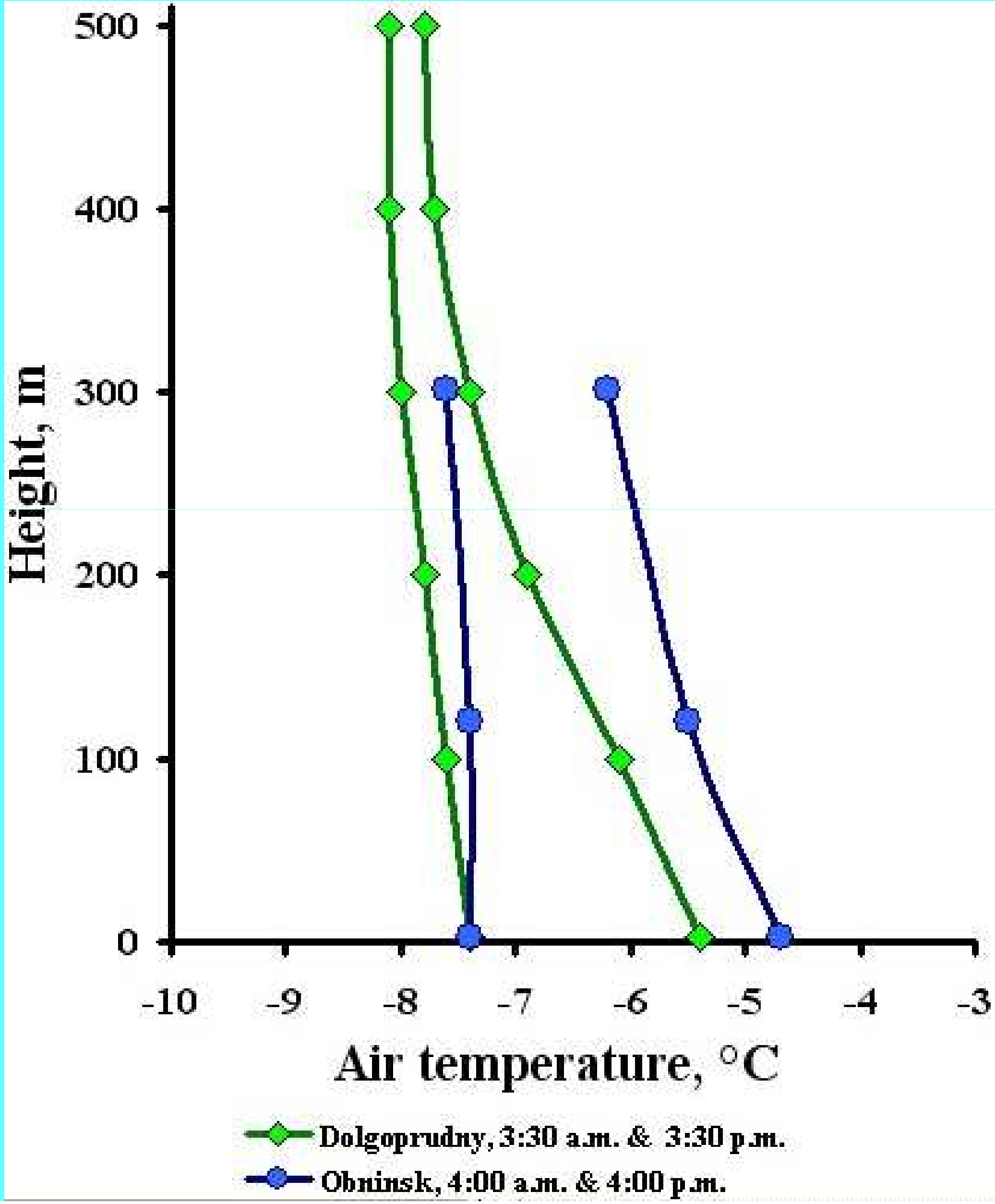
Average mean-annual profiles of T for the period 1993-2013



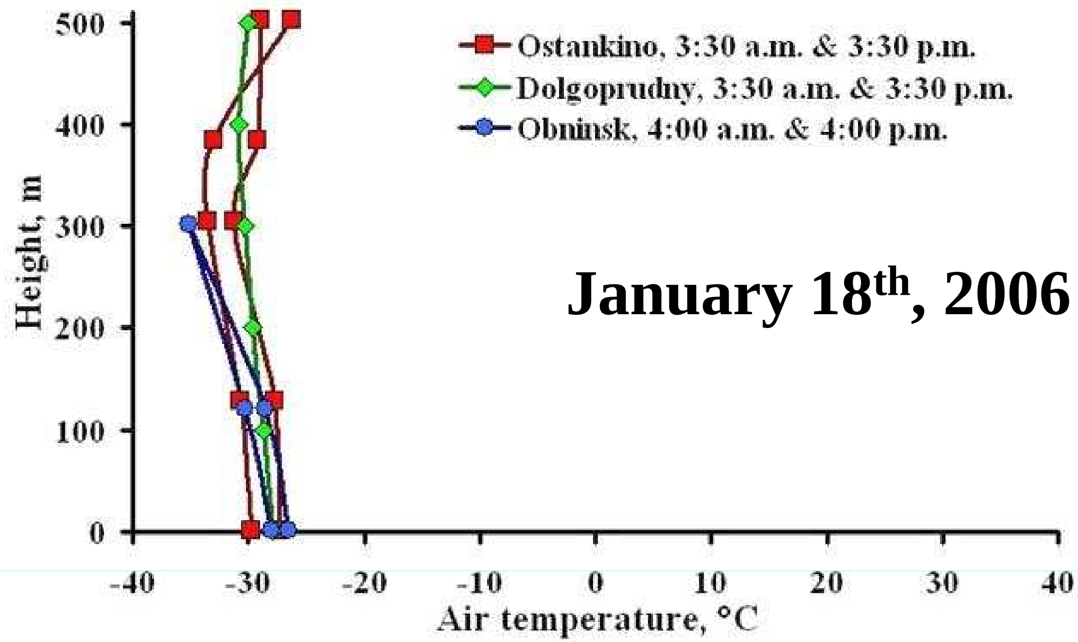
Average summer profiles of T for 1993-2013



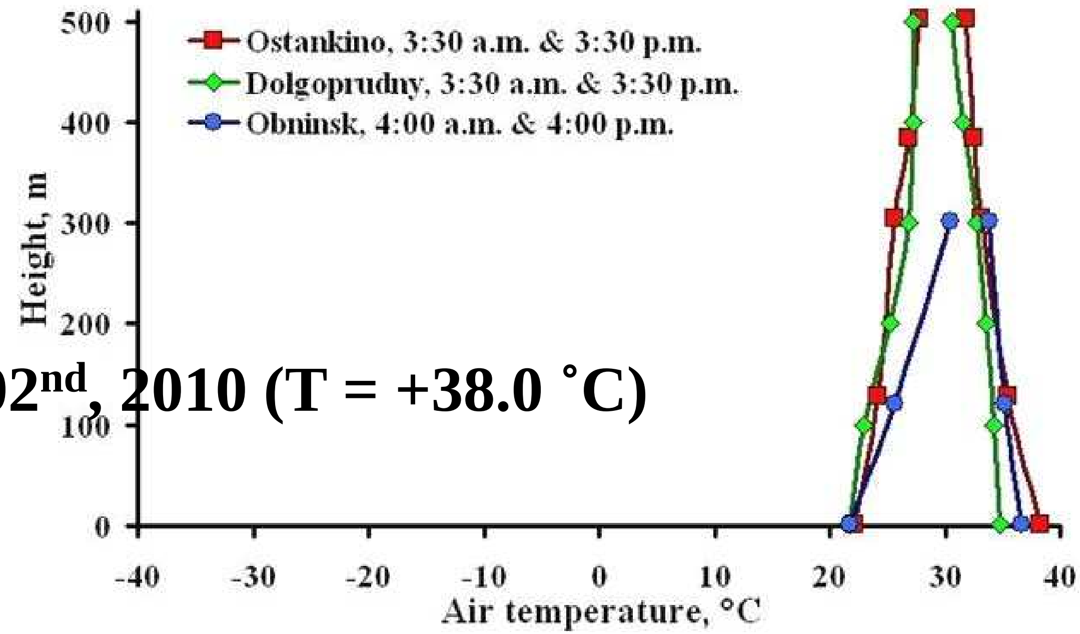
Average winter profiles of T for 1993-2013



Case studying



January 18th, 2006 (T = –30.1 ˚C)



August 02nd, 2010 (T = +38.0 ˚C)

Conclusions:

1. **Above big city (Moscow) a thermal anomaly exists as ‘heat island’ effect in daytime at least up to 500 m height and in nighttime up to 100 m. Above 100 m at night ‘cool island’ is a result of the ‘cross-over’ effect.**
2. **The intensity of both ‘heat island’ and elevated ‘cool island’ gradually goes to zero with a height. At 400-500 m spatial differences between nocturnal and diurnal air temperature are statistically insignificant.**
3. **The 300 m level may be considered as the vertical range of the urban thermal anomaly in average of a day.**
4. **The urban ‘heat island’ intensity strongly depends on weather conditions including thermal advection.**