

# **«Развитие представлений и моделирование условий термического комфорта населения на фоне современных климатических изменений».**



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устойчивого развития городской среды  
в условиях глобальных изменений»

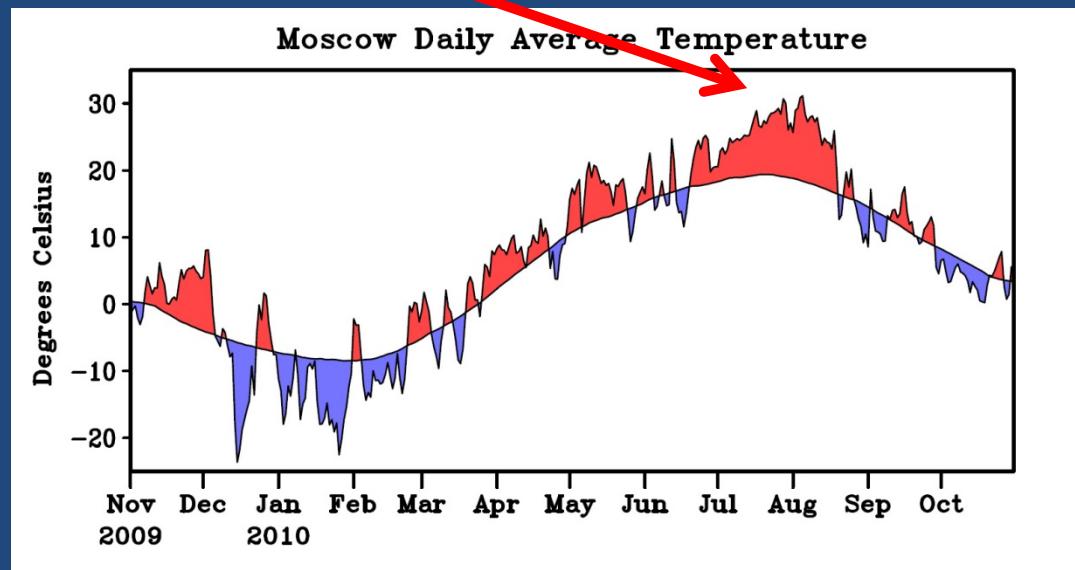
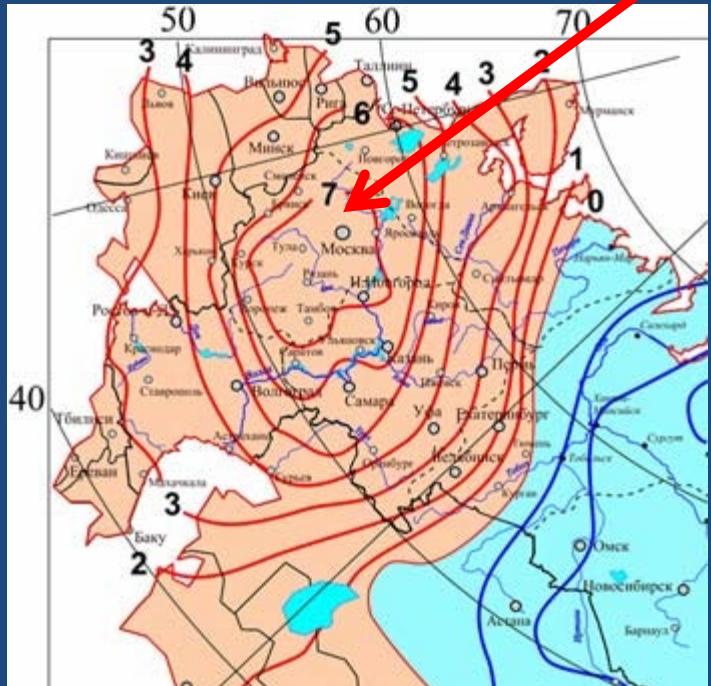
**РУДН**

# Когда мы вспоминаем о термическом комфорте?



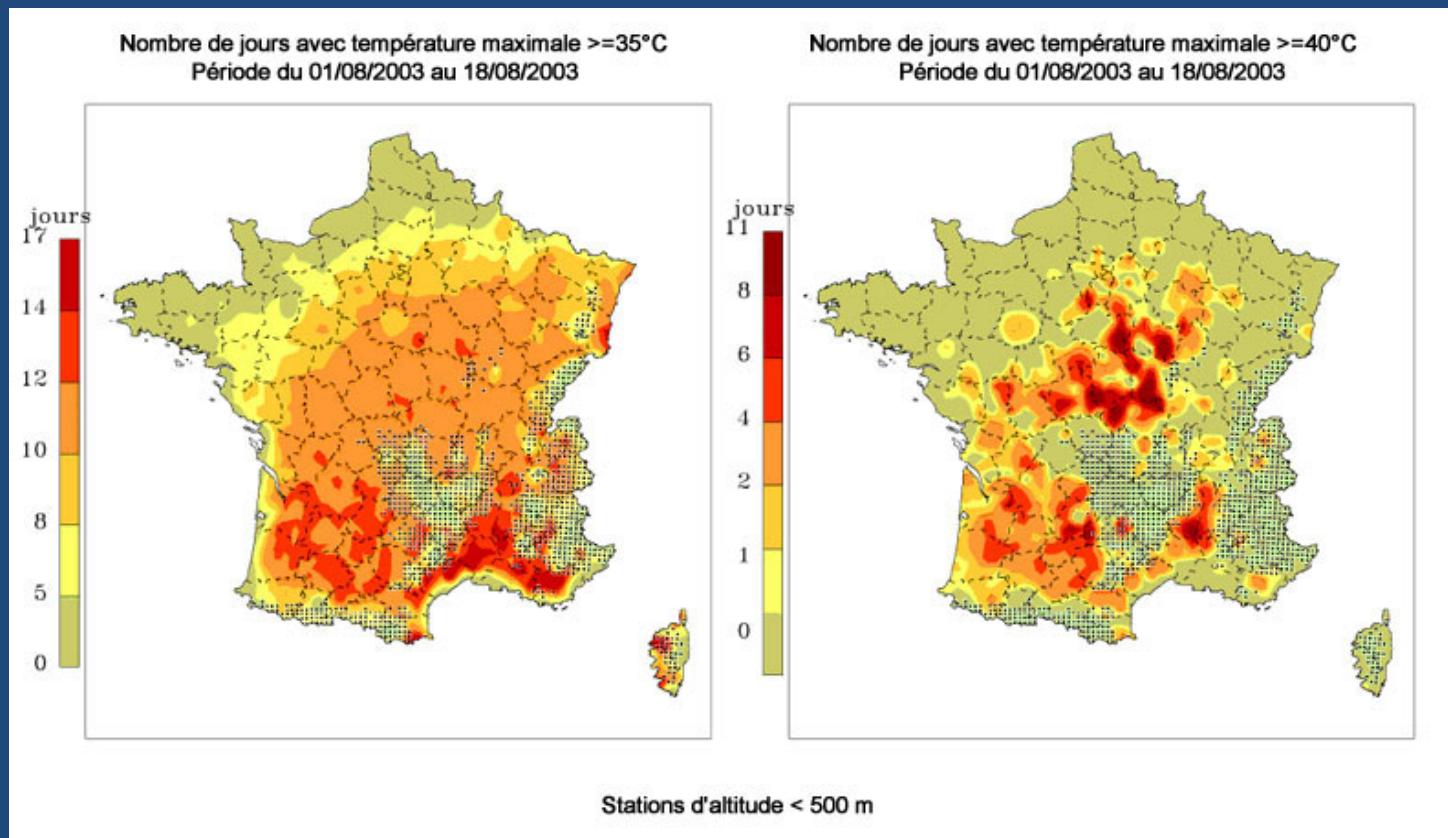
# Moscow's 2010 heat wave

Tmax=38,1 C



The exceptional heat over such a long duration, combined with poor air quality from wildfires increased deaths by at least 11,000 in Moscow (Shaposhnikov et al, ,2014)

# European Heat Wave



During August, 2003 much of Europe experienced unusually high temperatures. The extent of the extremes and their effect was greatest in France. The maps below show the number of days where air temperature exceeded 35C and 40C, respectively. The impact was greatest in cities where the temperature was raised and the population was vulnerable.

By G.Mills, 2010 WMO, Pune

# Холод ничуть не лучше

The screenshot shows a news article from Deccan Chronicle. At the top, there's a banner with the text "IN INDIA" and a large green virus-like cell graphic. The banner displays COVID-19 statistics for Maharashtra (907212 total cases, 644400 recoveries, 26604 deaths) and Andhra Pradesh (498125 total cases, 3940 recoveries). Below the banner, the URL is shown as [Nation » Current Affairs » 11 Jan 2018 » 143 deaths due to se ...](#). The main headline reads "143 deaths due to severe cold wave in Uttar Pradesh". The article is attributed to DECCAN CHRONICLE. It was published on Jan 11, 2018, at 2:09 am IST and updated on Jan 11, 2018, at 2:39 am IST. A social sharing bar is present below the headline, featuring icons for various platforms like Facebook, Twitter, LinkedIn, and WhatsApp.

NATION, CURRENT AFFAIRS

## 143 deaths due to severe cold wave in Uttar Pradesh

DECCAN CHRONICLE.

Published Jan 11, 2018, 2:09 am IST Updated Jan 11, 2018, 2:39 am IST

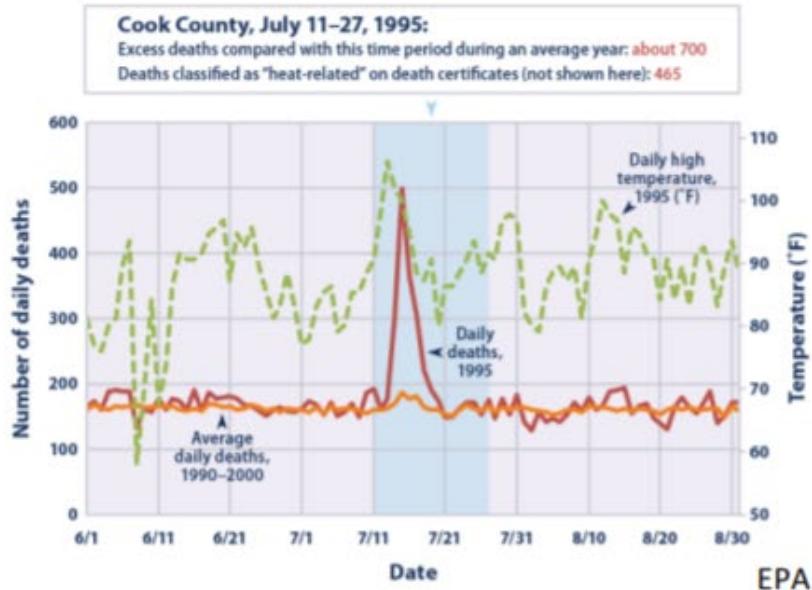
A six-year-old boy Satyam, who had gone to school in Barabanki, started shivering and died, due to cold, said sources.

# Первая тревожная “heat-wave”

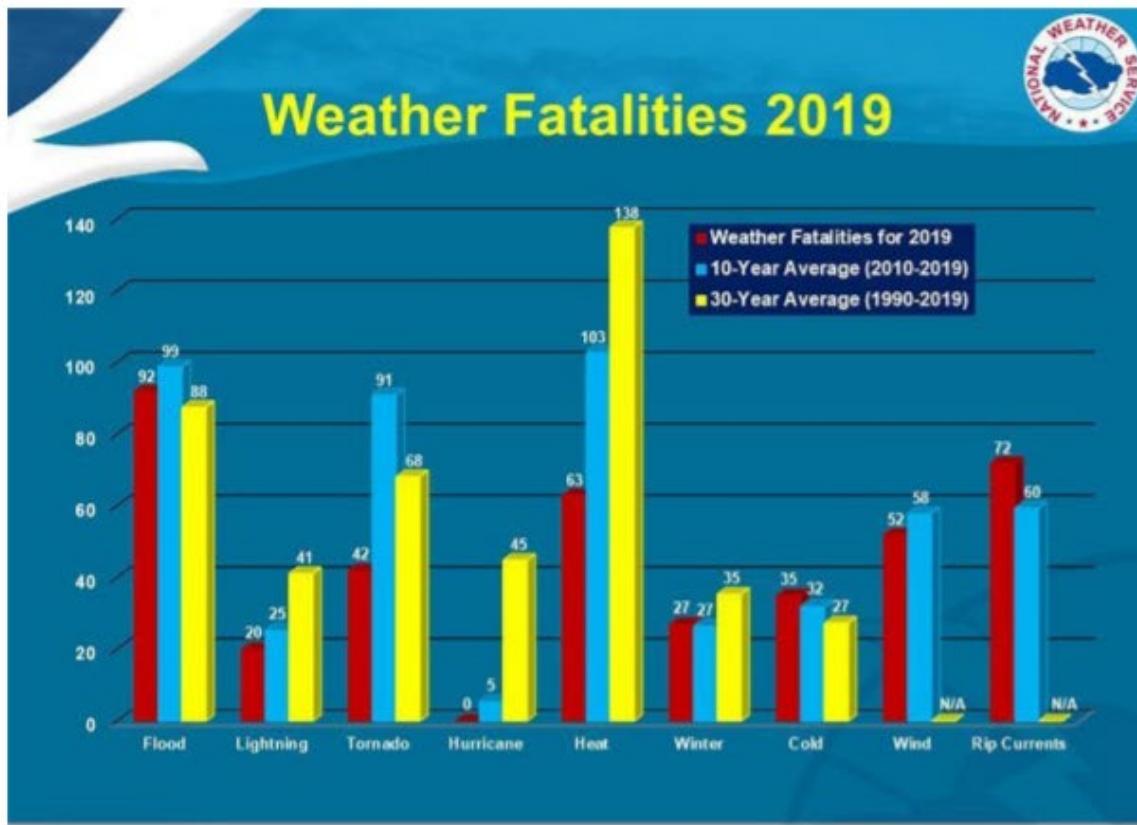
## Human Stories: Chicago 1995



Chicago Tribune



# Ущерб от погодных событий США



Nursing home where 12 died after Hurricane Irma loses license

S By ROBERT GOLDBECK - June 07, 2019 — 10:44 PM



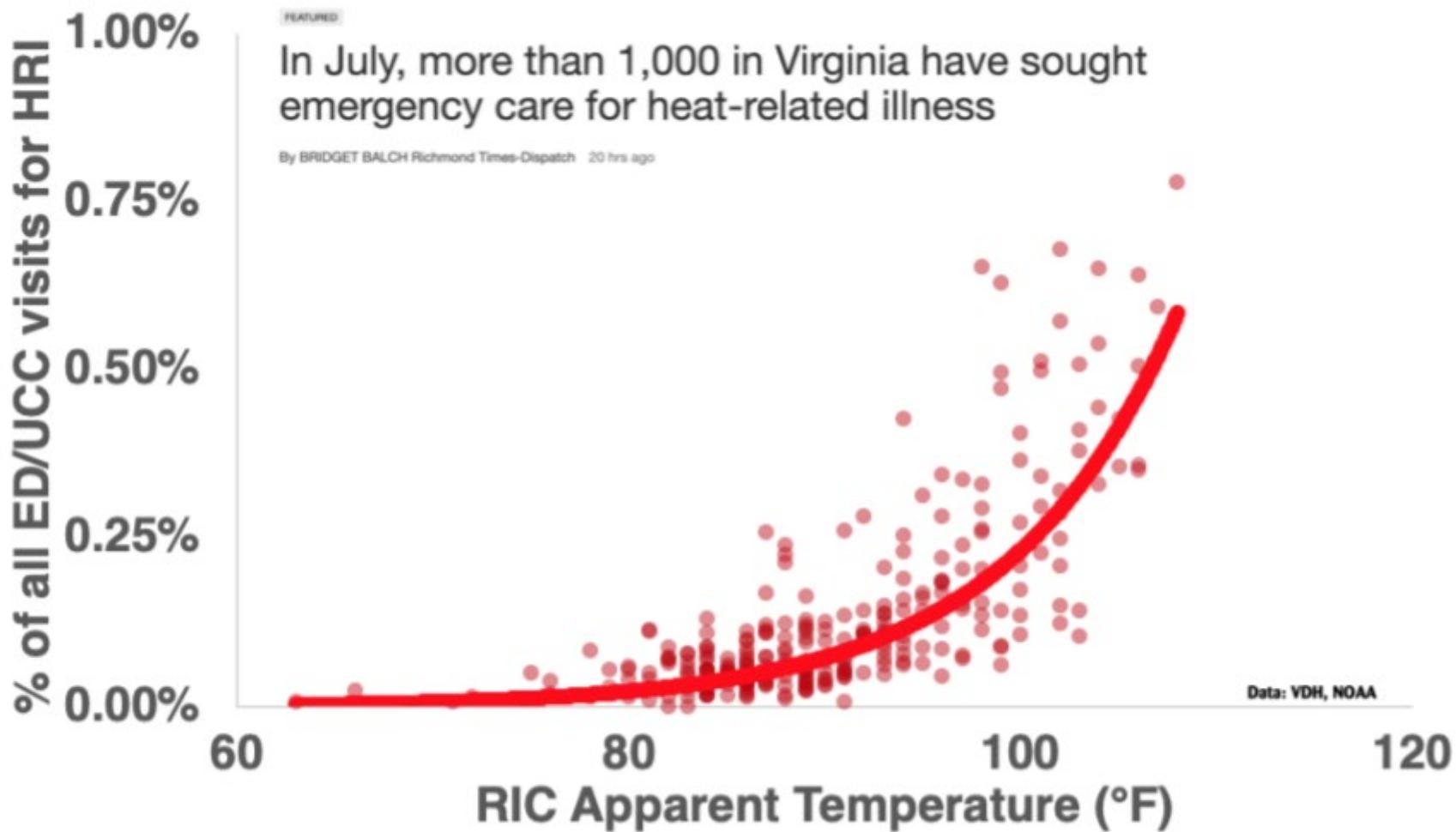
Danville Utilities asks residents to curb power usage during heatwave

DANVILLE, Va. (WSET) — There's a heatwave in effect in Central Virginia, and so far, one electricity provider is asking residents to curb ...



- Healthcare costs
- Energy Costs
- Worker Productivity
- Poor Air Quality

# Связь с опасностью для здоровья



# Уязвимость от волн жары

## Vulnerability

- Elderly
- SES
- Chronic conditions
- Outdoor workers
- Tourists



**abc3NEWS**

**'Sleeping in puddles of their own sweat': Loved ones say Va. inmates suffering during heatwave**

*Former corrections officer shares conditions at Virginia's prisons*

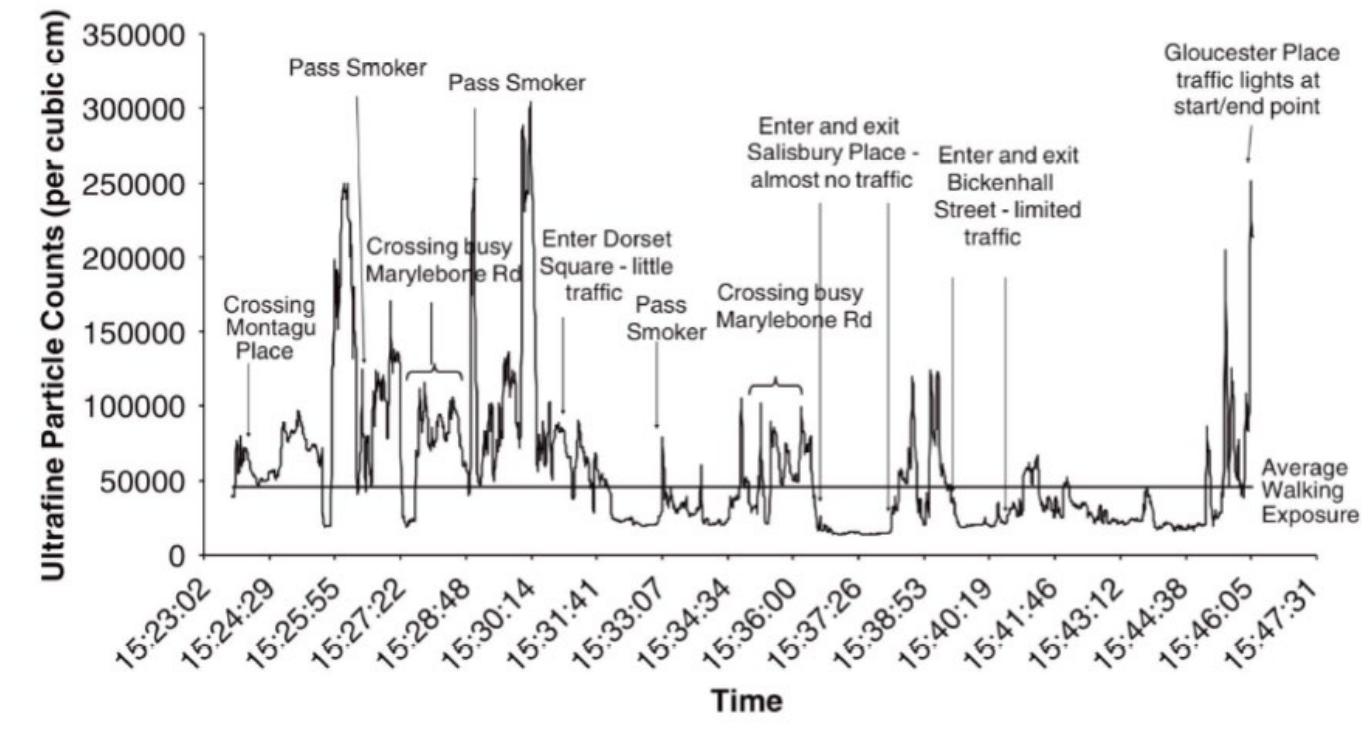
By: Kelli O'Brien  
Posted: Jul 23, 2019 / 07:15 PM EDT / Updated: Jul 23, 2019 / 10:03 PM EDT



Howe et al. 2019; Gronlund et al. 2015; Hondula et al. 2012; Reid et al. 2009

# Персональный комфорт

*One person's experience of an urban concentration field*



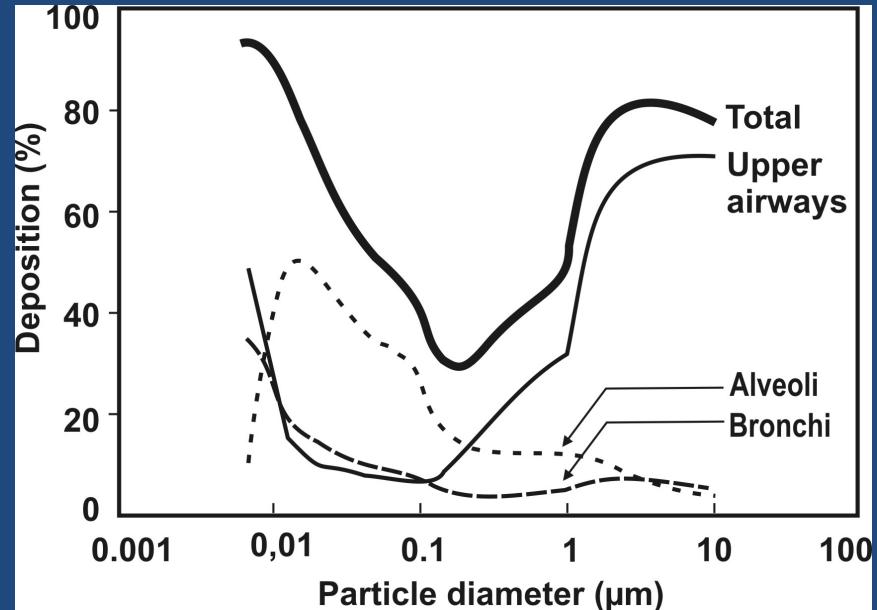
The urban effect modifies the environment to which humans are exposed, often worsening natural stresses by reducing wind-speed, raising temperature and diminishing air quality.

By G.Mills, 2010 WMO, Pune

# Air quality

Air quality is a very large subject about which there is a substantial literature. Here we will just identify issues that are related to the nature of the urban surface, rather than chemistry of the atmosphere.

The dispersion of pollutants depends upon One of the features of the urban surface is its

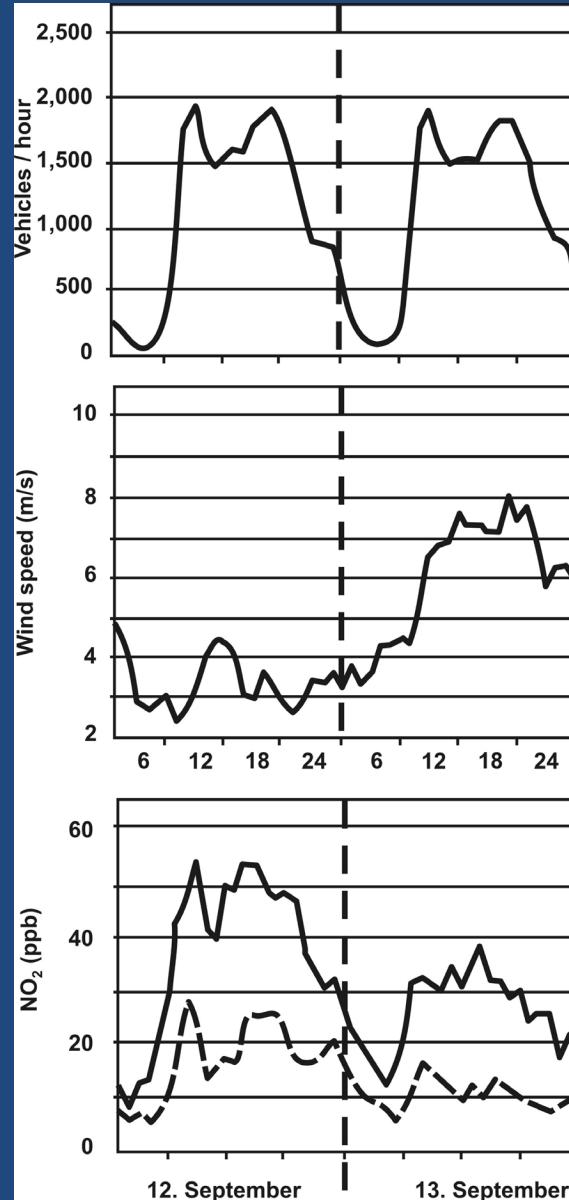


The impact of pollutants depends very much on their composition and their size.

# Emissions

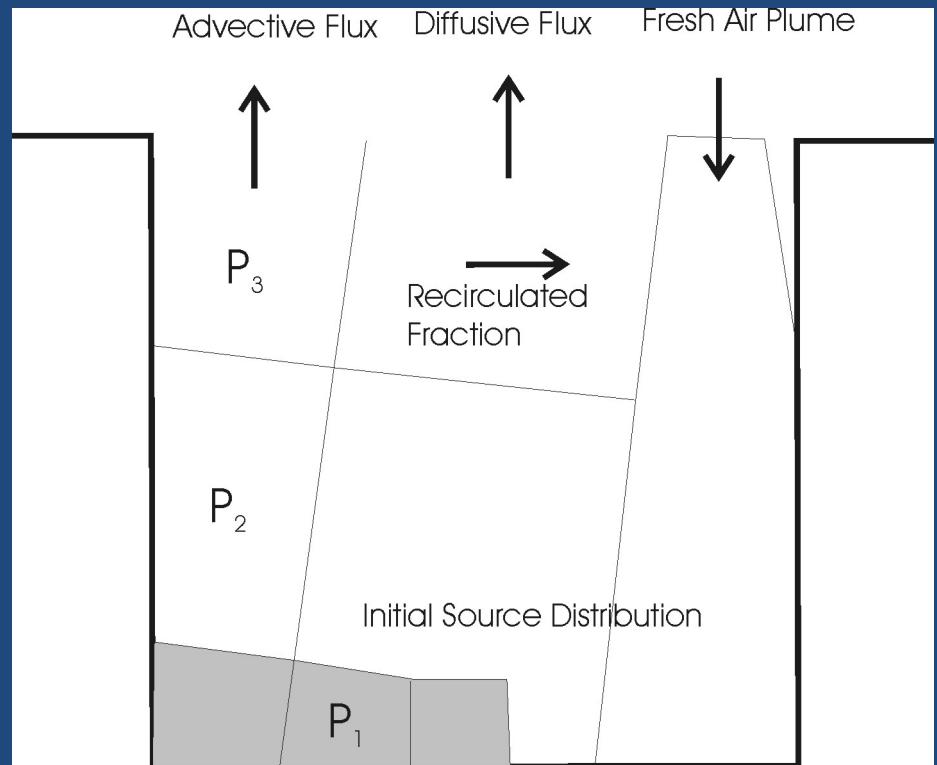
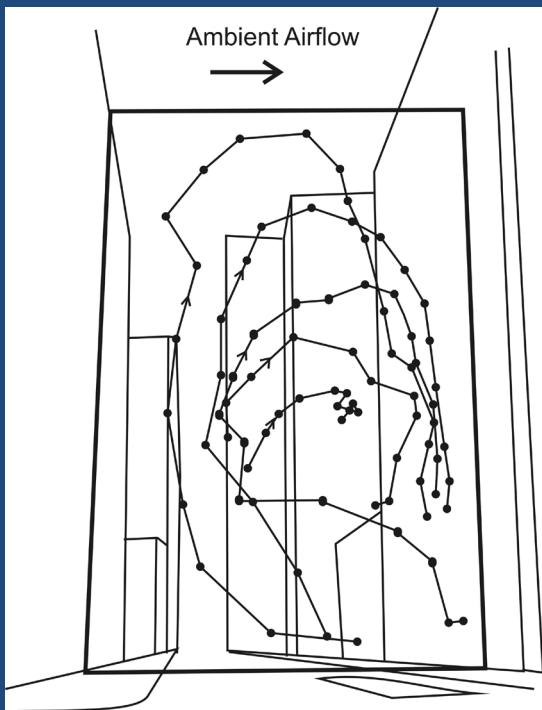
Emissions have distinct patterns in space and time. Urban areas are characterised by the density of pollutant sources. For many places, air quality is closely tied to vehicle emissions that have diurnal patterns.

These emissions occur within city streets that inhibit air motion and may generate re-circulating flows, thus trapping vehicular emissions and limiting their dispersion.



By G.Mills, 2010 WMO, Pune

# Dispersion



DePaul, F.T., Sheih, C.M., 1986.  
Measurements of wind velocities  
in a street canyon. Atmospheric  
Environment 20, 45-459

# Немного определений

Humans are homeotherms with a deep body temperature ( $T_B$ ) of 37°C. This temperature must be maintained at a near constant value to maintain health. This is accomplished by regulating exchanges at the outer envelope of the body (the skin and/or clothing surface) to achieve a net energy exchange of zero.

## TERMS

*Comfort* refers to conditions where this balance can be achieved with the least effort.

*Discomfort* is a measure of the degree of departure from comfort.

# Уравнение энергетического баланса человека

$$Q^* + Q_M - (Q_H + Q_E + Q_G) = \Delta Q_S$$

$Q^*$	Net radiation. Intercepted and reflected short-wave and absorbed and emitted long-wave radiation.
$Q_M$	Metabolic heat generated internally by the body
$Q_H$	Turbulent sensible heat exchange at the outer surface
$Q_E$	QE is turbulent latent heat exchange at the outer surface
$Q_G$	QG is sensible heat transfer by conduction
$\Delta Q_S$	Heat stored in the body volume.

As homeotherms (warm-blooded creatures), with a near-constant deep body temperature of 37°C,  $\Delta Q_S$  should be close to zero. All of actions (whether conscious or unconscious) of the body attempts to minimise  $\Delta Q_S$

# Metabolic Heat Rate ( $Q_M$ )

The energy generated by the body is a function of the levels of activity. This level is comprised of a basal rate ( $70\text{Wm}^{-2}$ ) and a work rate.

The amount of energy the body needs to dispose of depends upon the internal heat generated, which can be regulated.

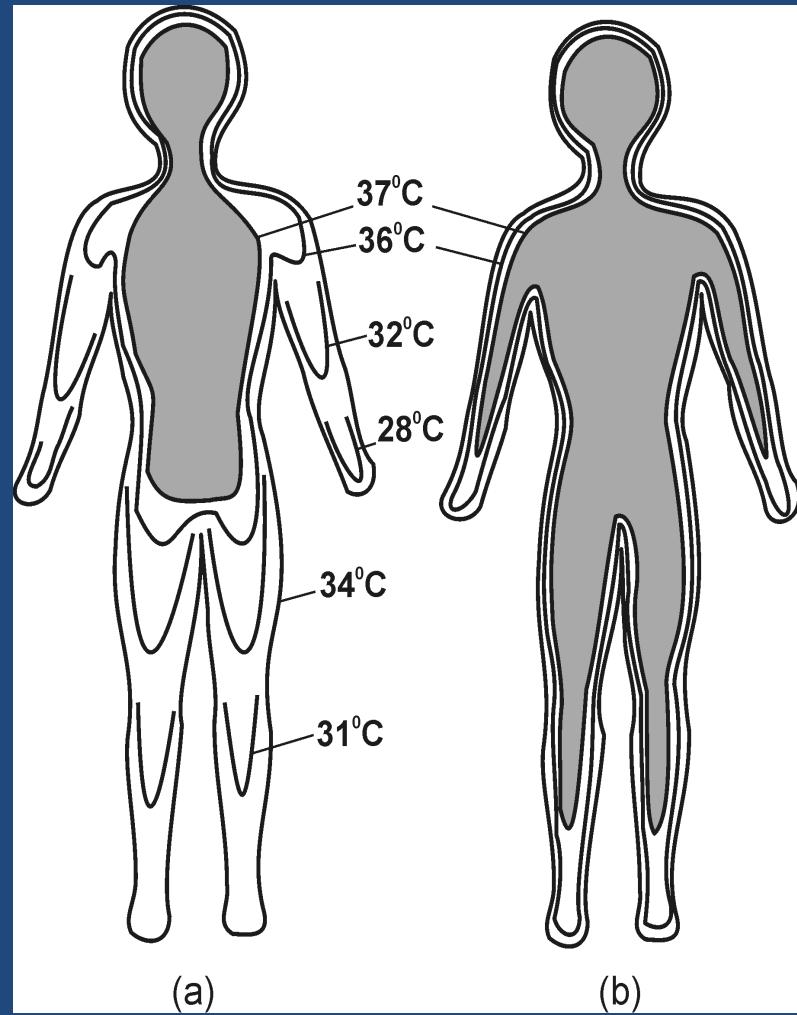
Activity	$\text{Wm}^{-2}$
Resting	
Sleeping	40
Seated, quiet	60
Standing relaxed	70
Walking on a level surface	
$0.9\text{ms}^{-1}$	115
$1.8\text{ms}^{-1}$	220
Office	
Writing	60
Walking about	100
Lifting/packing	120
Occupational	
Cooking	95 to 115
Housecleaning	115 to 200
Handling 50kg bags	235
Pick and shovel work	235 to 280
Leisure	
Dancing	140 to 255
Tennis	210 to 270
Basketball	290 to 440

**возможно ли с  
точки зрения  
закона  
сохранения  
энергии  
существование  
Мальчика-с-  
пальчика?**



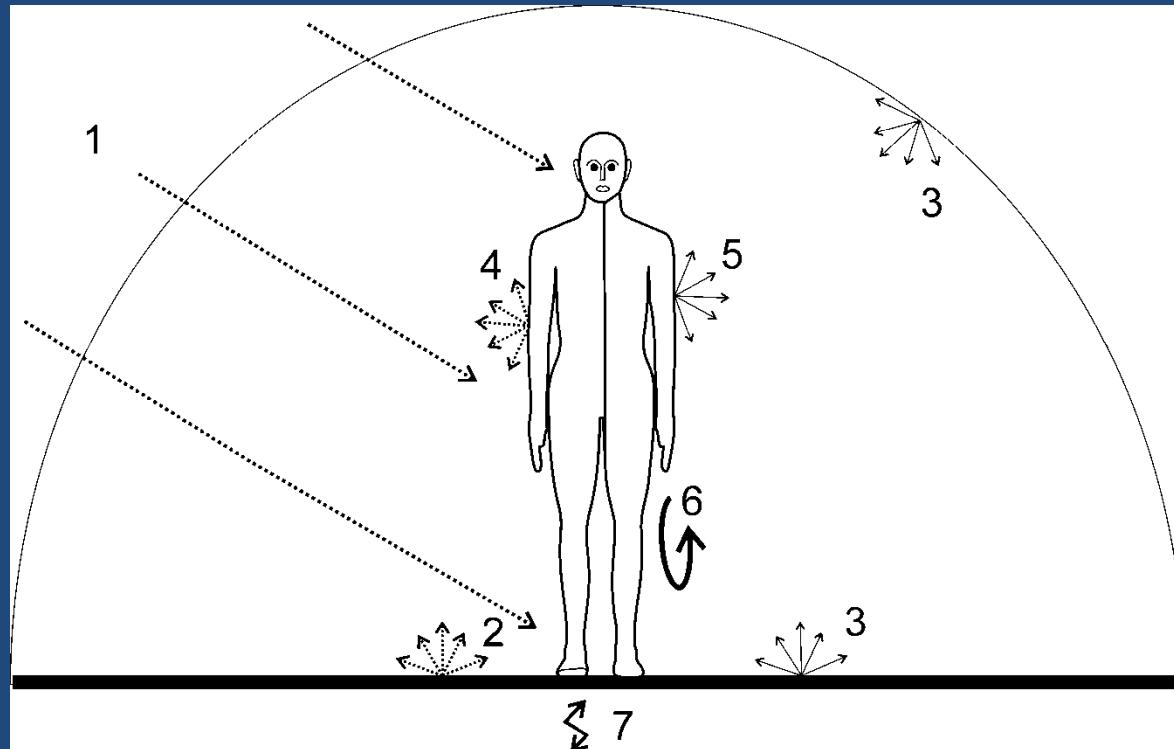
# Регуляция комфорта

Energy exchanges with the atmosphere occurs primarily at the skin surface. Heat transfer from the transfer within the body occurs from the centre to the skin surface. The exchange is regulated the intervening resistance provided by the tissues close to the skin.



Mount L.E. (1979) Adaptation to thermal environment : man and his productive animals. London : Edward Arnold,

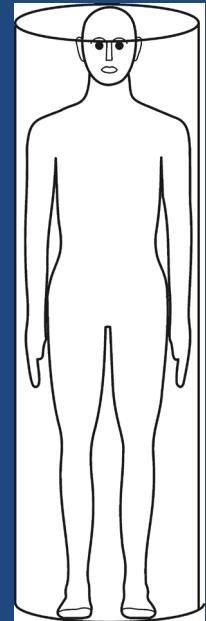
# Моделирование термического климата



The energy budget of a human must account for all the exchanges at the exposed surface. This includes direct solar radiation (1), diffuse short- and long-wave radiation from the sky and ground (2 & 3), reflected short-wave radiation (4) and emitted long-wave (5) radiation, convective sensible and latent heat exchanges that result from surface-air exchanges (6) and the conduction of heat into the substrate (7).

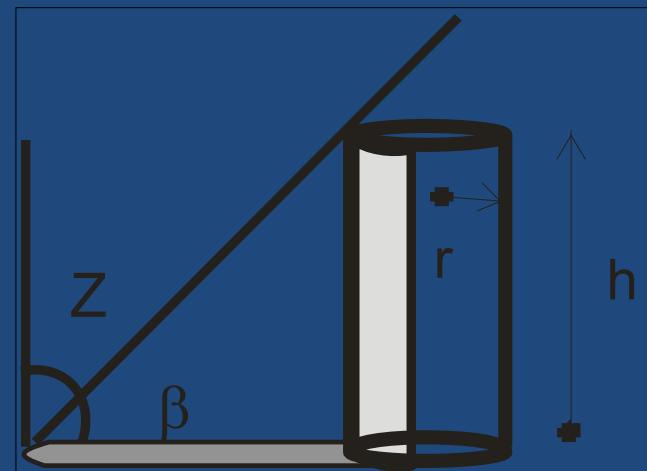
# «Огонь, мерцающий в сосуде» ?

The surface area of an upright average man is  $1.8\text{m}^2$  enclosing a mass of 70kg. However the effective area at which exchanges occur can be altered by a change in posture and clothing. A cylinder with a height of 1.65m and a radius of 0.12m may be used to crudely represent this human form.



This simplification can be used effectively to examine radiation and surface-air exchanges. For example, the direct radiation ( $S$ ) can be determined from that received on a horizontal surface multiplied by the shadow area generated by the beam,

$$2rh \cot(\beta) + \pi r^2$$



# Радиационный обмен

Net radiation consists of both short- (K) and longwave (L) radiation incident on the surface and reflected and emitted from the surface.

$$Q^* = K \downarrow - K \uparrow + L \downarrow - L \uparrow$$

Shortwave radiation receipt ( $K \downarrow$ ) consists of both direct and diffuse components. Seeking shadow removes the direct component. Reflected radiation ( $K \uparrow$ ) depends on the albedo of the body, which can be regulated through clothing selection.

Longwave radiation receipt ( $L \downarrow$ ) depends on the temperatures of the surrounding surfaces and their emissivity. The outgoing longwave radiation consists of a small proportion of reflected  $L \downarrow$  and primarily emitted radiation, which is a function of surface temperature.

# Mean Radiant Temperature

One of the most useful concepts in biometeorology is that of a uniform surface temperature surrounding the body that generates the same radiative load as that experienced in reality – this is the Mean Radiative Temperature ( $T_{MRT}$ )

$$T_{MRT} = \sqrt[4]{K^* + L \downarrow}$$

This value is employed in indoor circumstances where surface temperatures may be regulated. Applying it in outdoor circumstances is more difficult and requires that the contributions of all the surfaces ‘seen’ by the body are accounted for and weighed proportionately. Its advantage is that it aggregates the radiation contributions.

# Non-radiative exchanges (1)

The conductive heat flux ( $Q_G$ ) can usually be ignored for humans. The remaining terms are the convective sensible ( $Q_H$ ) and latent ( $Q_E$ ) fluxes.

The sensible heat exchange results from the temperature difference between the outer surface ( $T_{sk}$ ) and adjacent air temperature ( $T_a$ ). Its magnitude is related to the size of the difference and the intervening wind speed through a heat transfer coefficient ( $h_c$  in  $\text{Wm}^{-2} \text{K}^{-1}$ ). The inverse of  $h_c$  is insulation.

$$Q_H = h_c(T_{sk} - T_a)$$

Skin temperature can be regulated by the body through vasodilation and vasoconstriction. The effect of clothing is to insulate the skin by providing a layer of static air adjacent to the body surface

# Теплосберегающие свойства одежды

Garment	Insulation $\text{m}^2 \text{ K W}^{-1}$	Clothing Ensembles	Insulation $\text{m}^2 \text{ K W}^{-1}$
Underpants T-Shirt	0.006 (0.2) 0.012 (0.5)	Walking shorts, short-sleeved shirt	0.056 (2.2)
Long-sleeved shirt Sweat shirt	0.045 (1.8) 0.053 (2.1)	Sweat pants, sweat shirt	0.115 (4.5)
Trousers Overalls	0.031 (1.2) 0.048 (1.9)	Knee-length skirt, short-sleeved shirt, panty hose, sandals	0.084 (3.3)
Single-breasted jacket Long-sleeved sweater	0.063 (2.4) 0.048 (1.9)	Ankle-length skirt, long-sleeved shirt, suit jacket and panty hose	0.172 (6.7)
Skirt Dress	0.029 (1.1) 0.059 (2.3)	Insulated coveralls, thermal underwear	0.213 (8.3)

Information extracted from ASHRAE (2009). Values in parentheses are percentages and represent a comparison between the insulation of the garment with that of still air, which has a value of approximately  $3.85 \times 10^{-5} \text{ m}^2 \text{ KW}^{-1}$ .

# Non-radiative exchanges (2)

Latent heat exchange ( $Q_E$ ) between the body and the environment occurs through three mechanisms:

1. Breathing – exhaled air is more humid than that inhaled.
2. Diffusion of water through the skin surface
3. Regulatory sweating.

The latter is most important from the viewpoint of thermoregulation as it can be managed by the body itself. When sensible heat exchange cannot dispose of sufficient heat, the body will sweat as a response. The body will not sweat otherwise.

# Non-radiative exchanges (2)

Latent heat exchange is governed by the difference in vapour pressure between the skin and the adjacent air modulated by a transfer coefficient, which depends on airflow

$$Q_E = h_v(e_{sk} - e_a)$$

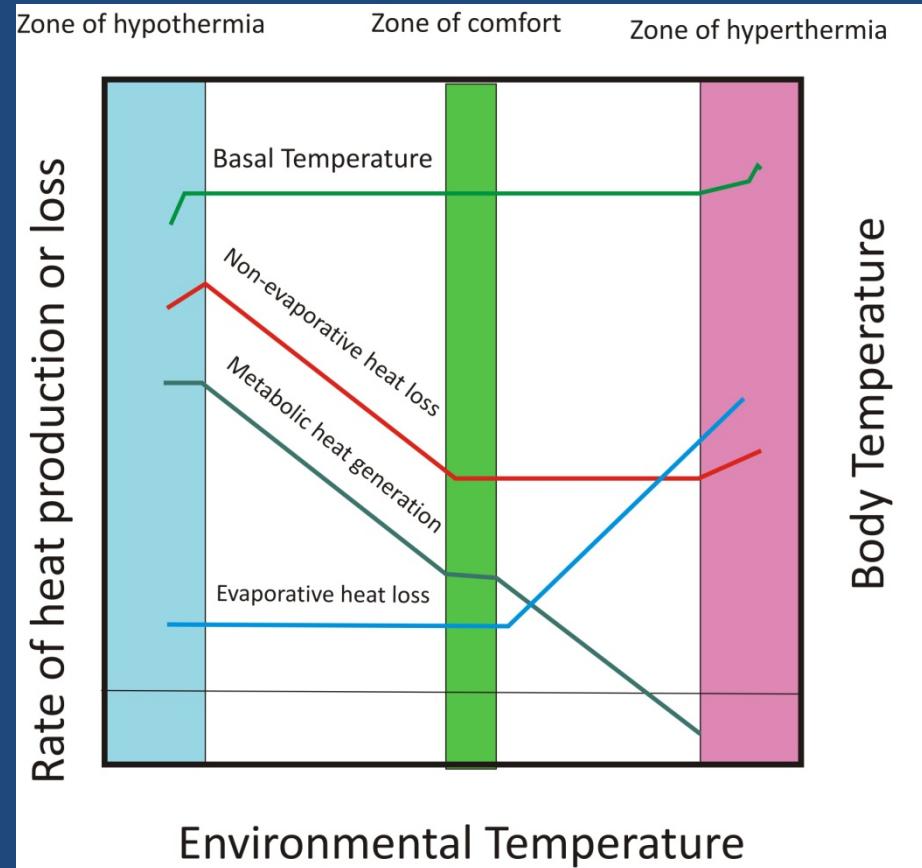
In practice this term is difficult to assess because the body can regulate vapour pressure at the skin surface.

A common practice is to establish the maximum flux based on the assumption that the skin surface is saturated at  $T_{sk}$  and determine what proportion of the body's surface needs to be 'wet' to achieve thermal equilibrium.

# Thermal Equilibrium

The body can manage equilibrium ( $\Delta Q_s=0$ ) exchanges over a range of environmental temperatures through modifying the magnitudes and nature of heat loss and generation. At the limits the body cannot dispose of sufficient heat (hyperthermia) or generate sufficient heat (hypothermia).

Comfort is a relatively narrow zone where the body has to do least work to maintain equilibrium



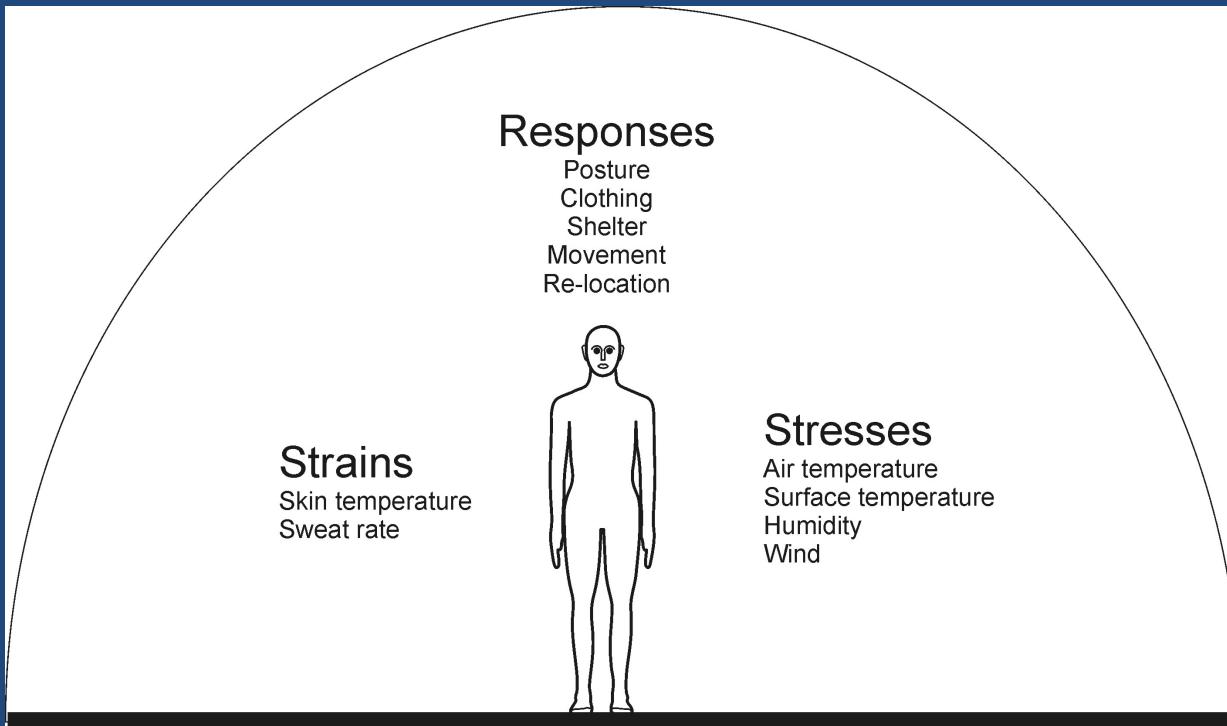
Buildings are designed to achieve comfort.

# Термическое воздействие - стресс

Conditions exterior to the body such as temperature or humidity may be referred to as *stresses*. In a given set of circumstances, environmental elements can combine to create either heat or cold stresses. Many simple measures exist that evaluate these stresses for outdoor conditions.

The physical response of the body to these stresses, such as elevated skin temperature or sweating, may be referred to as *strains*.

# Достижение термического равновесия



Apart from thermo-physical responses (which can be used as measures of strain, humans can make conscious decisions to deal with the stresses imposed by the environment. Many simple measures exist that employ readily available meteorological data.

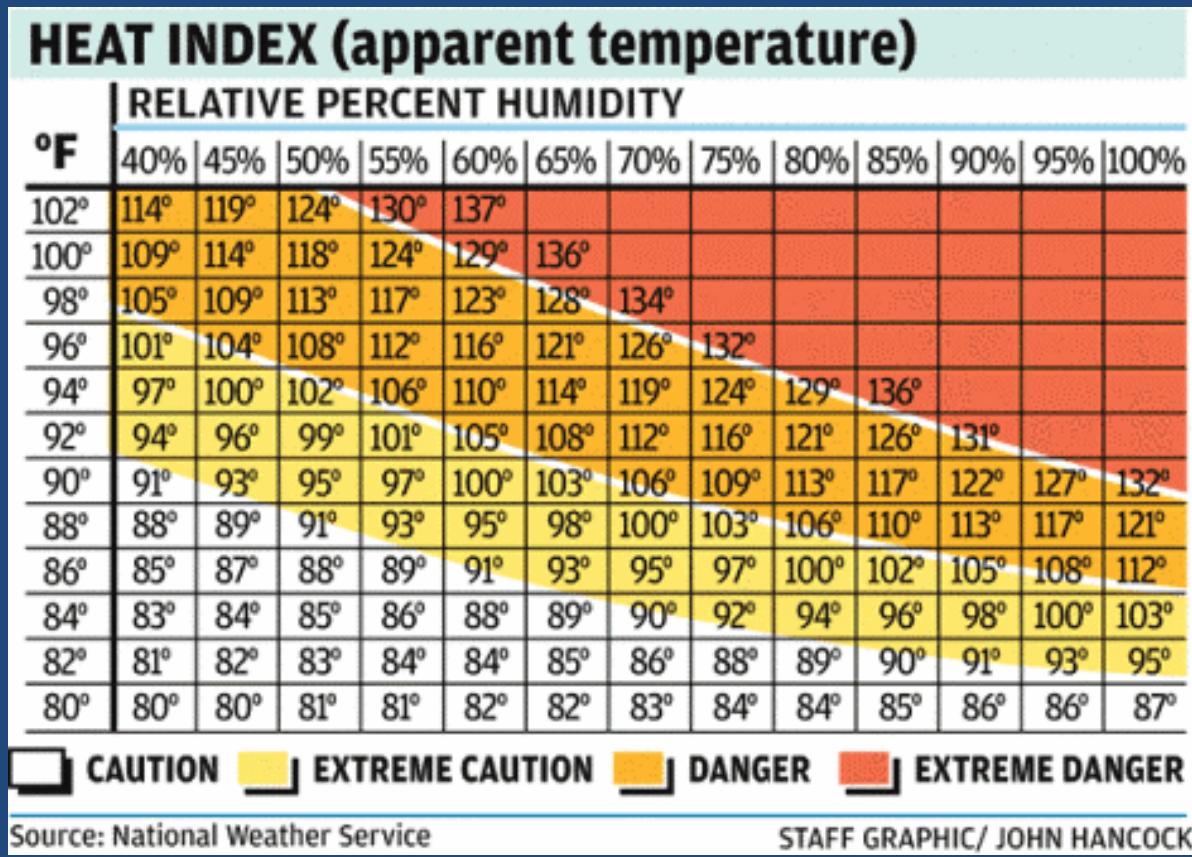


«Физик Вальтер Нернст увлекался разведением карпов. Однажды кто-то глубокомысленно заметил: “Странный выбор. Кур разводить и то интереснее”. Нернст невозмутимо ответил: «Я развозжу таких животных, которые находятся в тепловом равновесии с окружающей средой. Разводить теплокровных – это значит обогревать на свои деньги мировое пространство”

# Индексы термического комфорта.

От простого к сложному

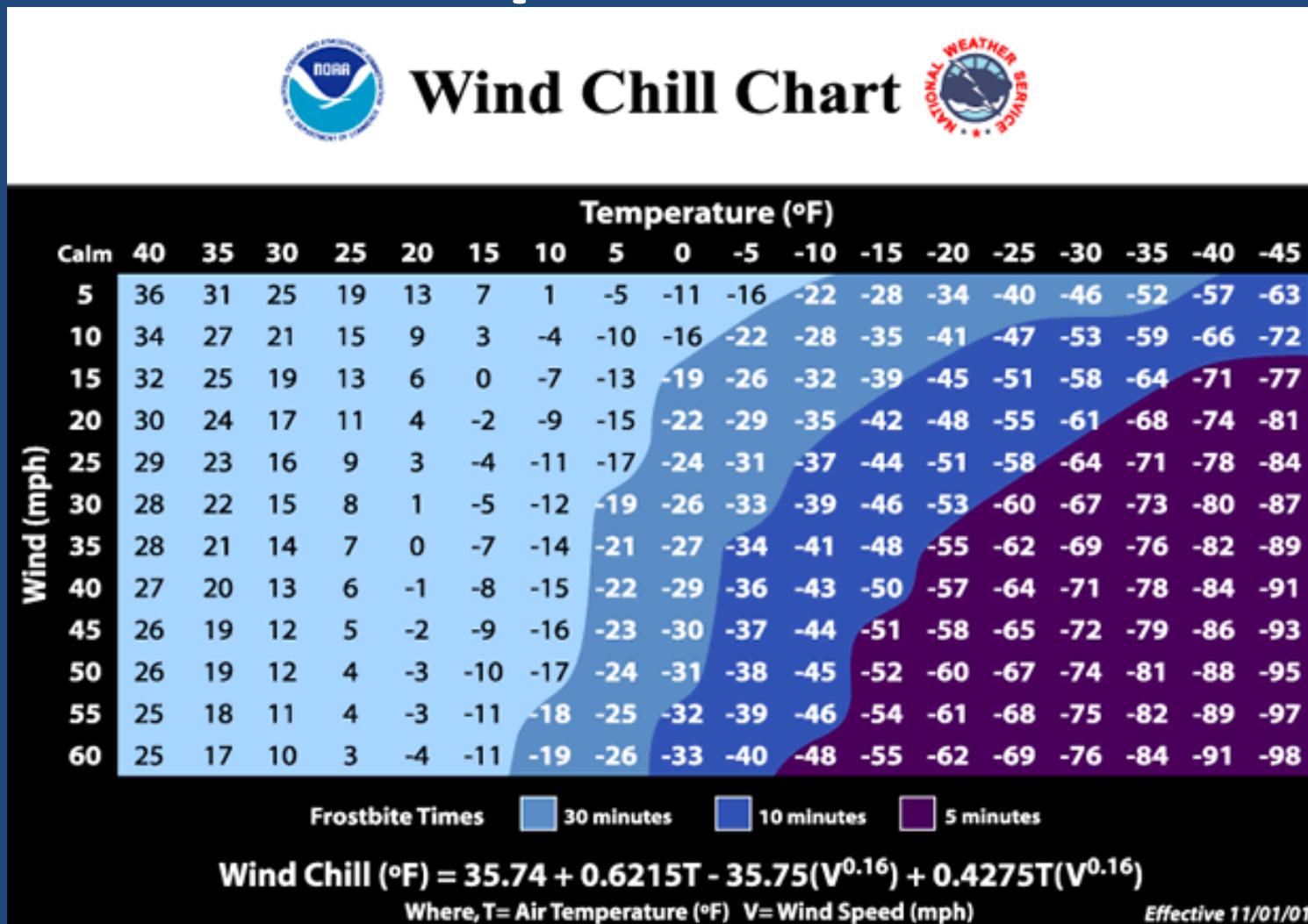
# Example: Heat stress



This is an example of a heat stress index. Note that it is a derived apparent temperature that accounts for the combined effect of just two variables, air temperature and relative humidity.

$$\begin{aligned} \text{Heat Index} = & -42.379 + \\ & 2.04901523T + \\ & 10.14333127R - \\ & 0.22475541TR - 6.83783 \\ & \times 10^{-3}T^2 - 5.481717 \times 10^{-2}R^2 + 1.22874 \times 10^{-3}T^2R + \\ & 8.5282 \times 10^{-4}TR^2 - 1.99 \times \\ & 10^{-6}T^2R^2 \end{aligned}$$

# Example: Cold stress



This is a wind chill chart. It presents a ‘wind chill’ temperature that accounts for the joint effect of air temperature (below freezing) and wind, which enhances heat loss.

# Эквивалентно-эффективная температура (ЭЭТ °).

- По А.Миссенарду :

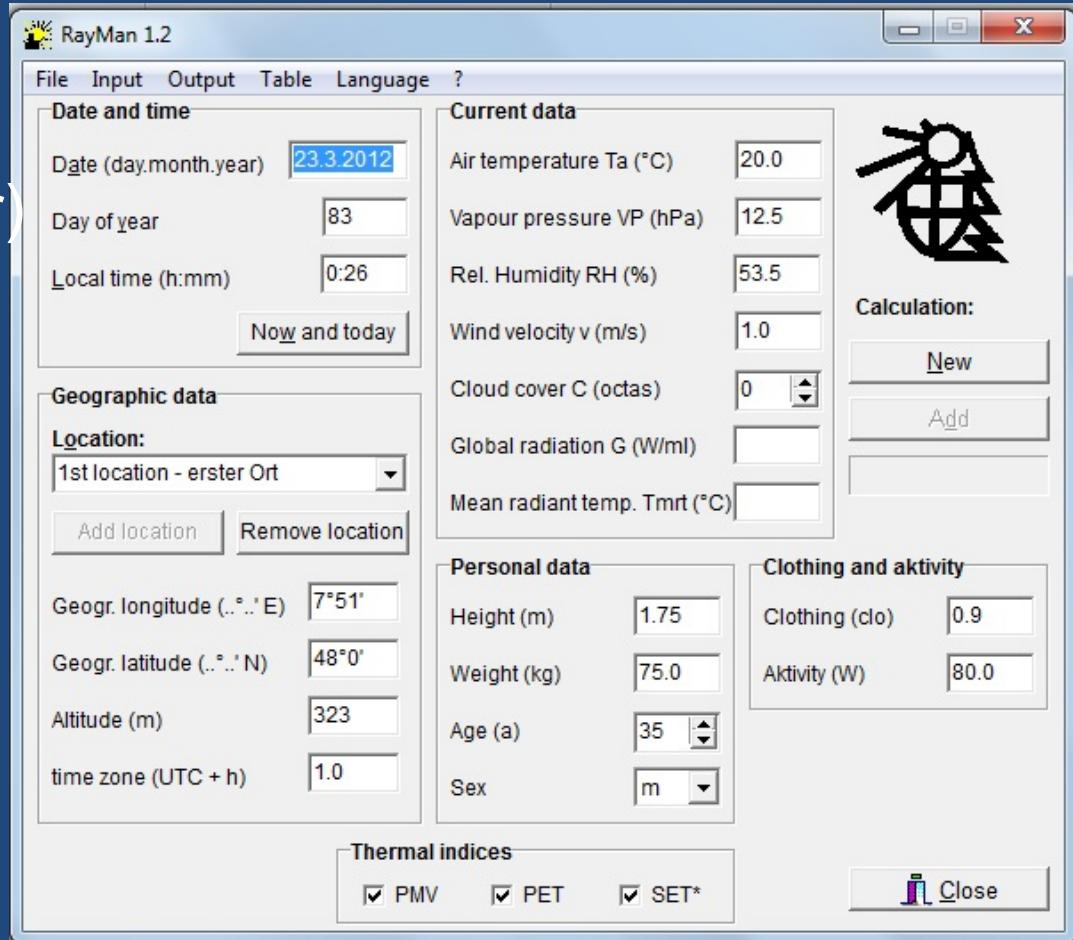
$$ET = 37^{\circ}\text{C} - \frac{37^{\circ}\text{C} - T}{0.68 - 0.0014f + \frac{1}{1.76 + 1.4V^{0.75}} - 0.29T(1 - \frac{f}{100})}$$

- По Б.А. Айзенштату:

$$\begin{aligned} & \text{ЭЭТ} \\ &= T[1 - 0,003(100 - f)] \\ & - 0,385v^{0.59}[(36,6 - T) + 0,622(V - 1)] \\ & + [(0,0015V + 0,008)(36,6 - T) - 0,0167](100 - f) \end{aligned}$$



# PET index derived from Rayman model (Matzarakis, Rutz, Mayer)

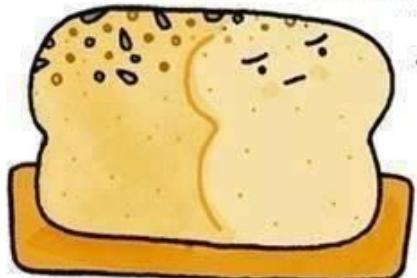


- Matzarakis, A., Rutz, F. (2005) Application of RayMan for tourism and climate investigations. Annalen der Meteorologie 41: Vol. 2, 631-636.
- Matzarakis, A.; Rutz, F.; Mayer, H. (2000) Estimation and calculation of the mean radiant temperature within urban structures. In: Biometeorology and Urban Climatology at the Turn of the Millennium (ed. by R.J. de Dear, J.D. Kalma, T.R. Oke and A. Auliciems): Selected Papers from the Conference ICB-ICUC'99, Sydney. WCASP-50, WMO/TD No. 1026, 273-278.
- Matzarakis, A., Rutz, F., Mayer, H. (2007) Modelling Radiation fluxes in simple and complex environments – Application of the RayMan model. Int. J. Biomet. 51: 323-334.

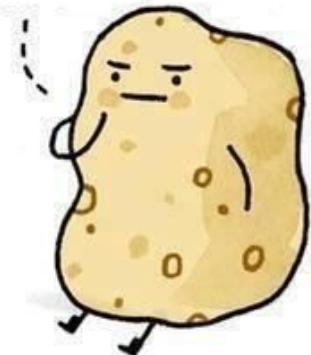
MONDAY PUNDAY

BY GEMMA CORRELL  
WWW.GEMMACORRELL.COM

Отличается ли мое  
мировосприятие от  
восприятия его другими?



В чём моя цель?



В чём причина  
бытия?



Есть ли в жизни смысл?



Сложные углеводы

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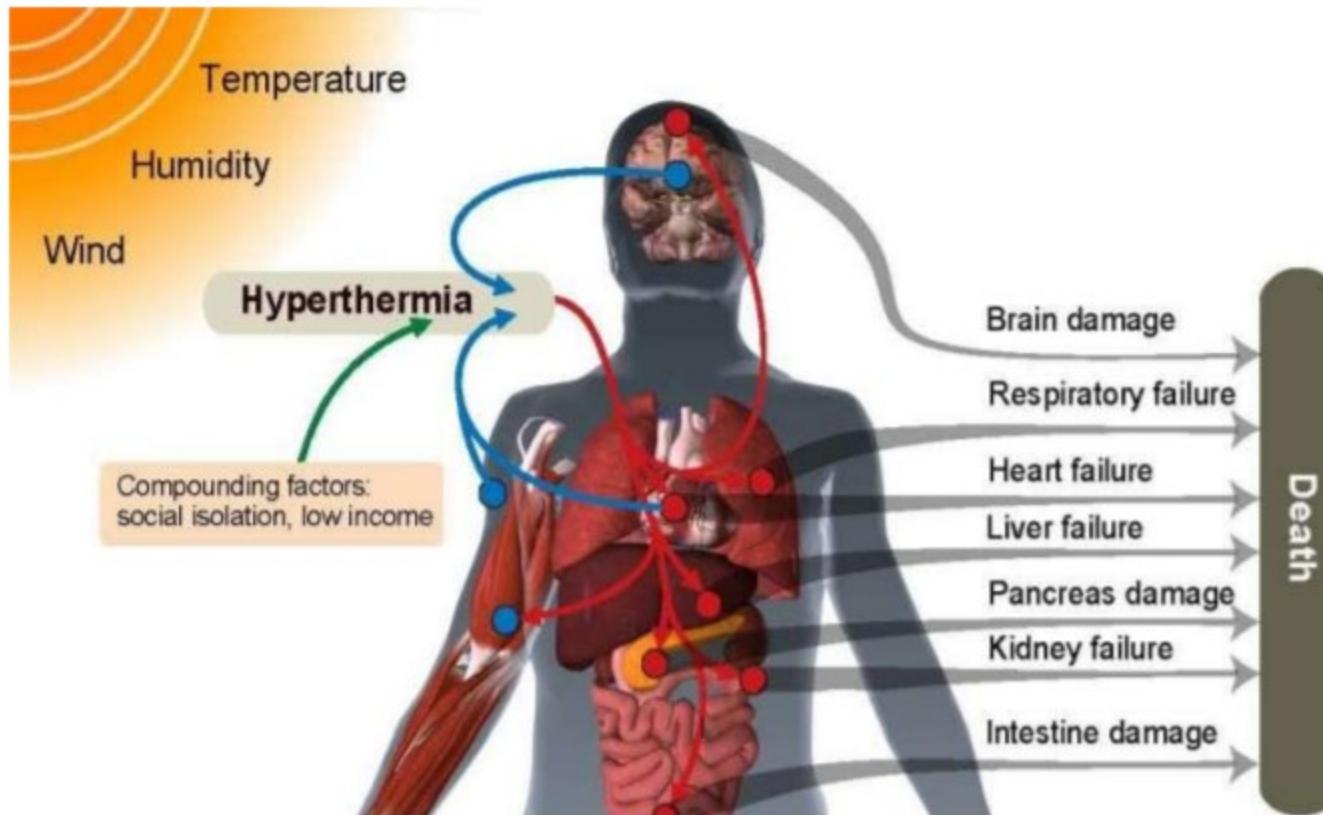
joyreactor.cc

Помимо  
простых  
индексов  
существуют  
также более  
сложные.

(как углеводы)

# Влияние на организм

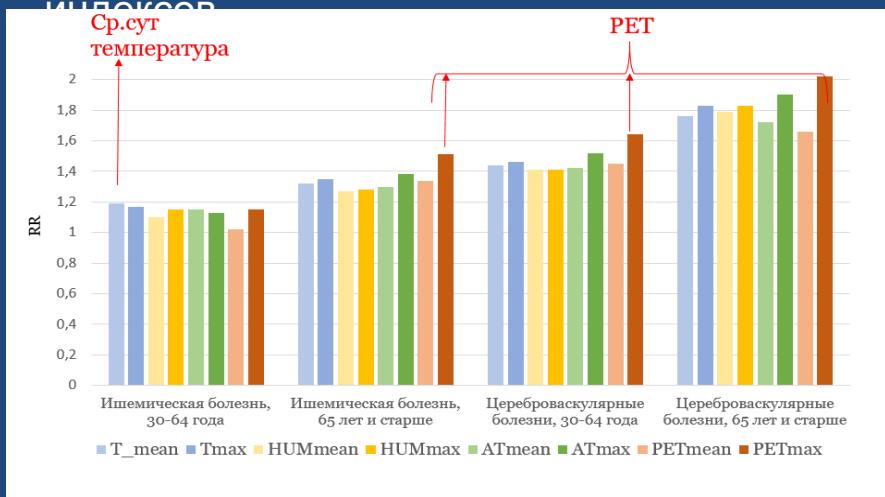
## Health Impacts



C. Mora

# На основе моделей теплового баланса человека

1) **PET** (Physiologically Equivalent Temperature) (Höppe, 1984) – физиологически эквивалентная температура. Параметр определяется как мера теплоощущения человека, находящегося в состоянии спокойствия. На сегодняшний день PET считается одним из наиболее популярных индексов.



Относительные риски смертности (RR) во время аномально-жаркой погоды, идентифицированной по различным биоклиматическим индексам (Shartova et al., 2018)

PET показывает наибольшие значения по методу максимизации относительных рисков (RR) во время аномально-жаркой погоды, поэтому является основным предиктором смертности (Shartova et al., 2018).

2) **UTCI** (Universal Thermal Climate Index) (Jendritzky et al., 2012) – универсальный тепловой индекс климата. В отличие от PET данный параметр рассчитывается с обязательным учётом воздействия ветра, то есть предполагается, что происходит теплоотдача в окружающую среду за счёт движения человека.

# PET

**PET** – это мера теплового ощущения находящегося в покое человека. Индекс рассчитывается с учётом уравнения теплового баланса человека:

$$M + W + R + C + ED + ERe + ESw + S = 0$$

, где

M - скорость обмена веществ (внутренняя выработка энергии),

W – теплоотдача при физической работе,

R – радиационный баланс тела,

C - конвективный поток тепла,

ED- скрытый поток тепла, расходуемый на потоотделение,

ERe - сумма тепловых потоков для нагревания и увлажнения выхлопного воздуха,

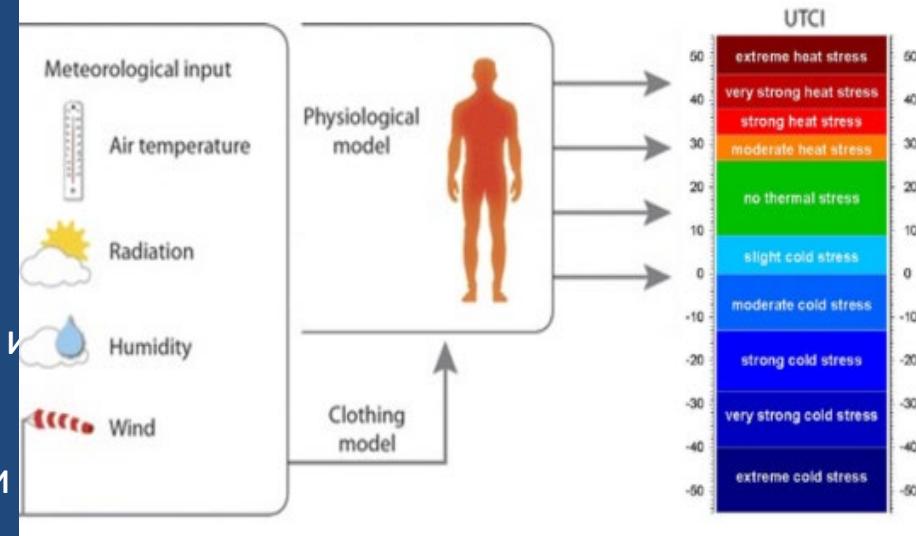
ESw – поток тепла, расходуемый на испарение пота

S - поток тепла, который сохраняется для нагревания или охлаждения масса тела

Индекс PET	Теплоощущение человека	класс физиологического воздействия
4	крайне холодно	экстремальный холодовой стресс
8	очень холодно	сильный холодовой стресс
13	холодно	умеренный холодовой стресс
18	прохладно	слабый холодовой стресс
23	комфортно	отсутствие теплового воздействия
29	умеренно тепло	легкое тепловое воздействие
35	тепло	умеренное тепловое воздействие
41	жарко	сильное тепловое воздействие
	очень жарко	экстремальное тепловое воздействие

# UTCI

- **UTCI** – это универсальный индекс теплового комфорта. Он был разработан в качестве концепции «эквивалентной температуры»: он включает определение базового условия, с которым будут сравниваться все другие климатические условия. Упрощенно говоря, индекс UTCI может быть определен в качестве эквивалентной температуры для данной комбинации ветра, радиации, влажности и температуры воздуха, впоследствии сравниваемый с температурой воздуха в эталонных условиях влажности, радиации и скорости ветра, которая дает одно и тоже значение «индекса деформации» или шкалы ощущений

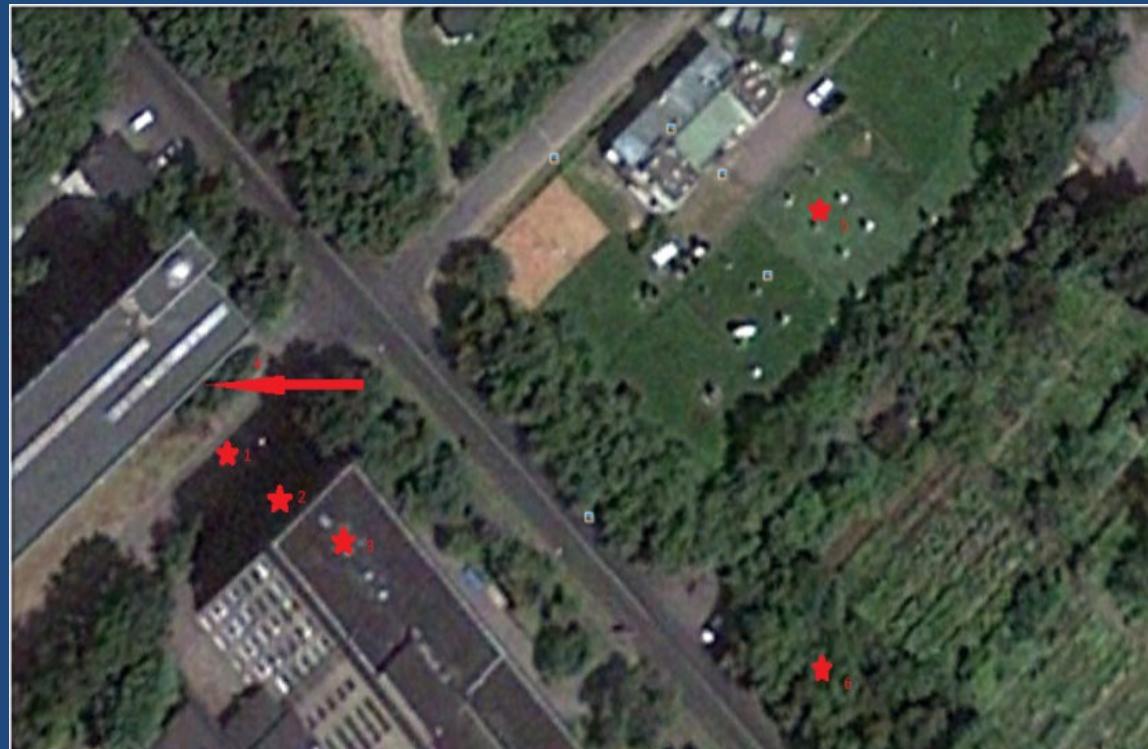


# mPET

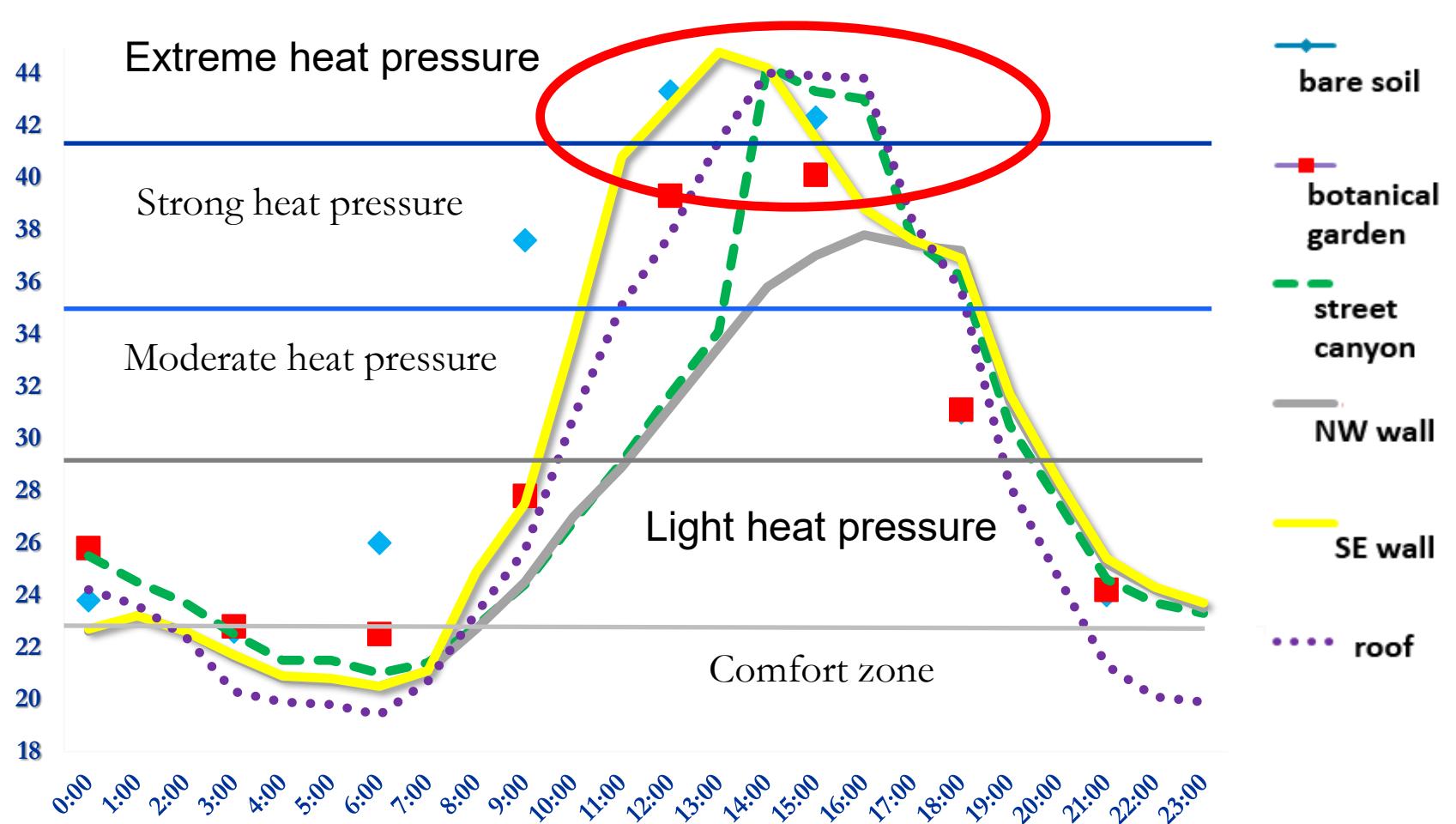
- **mPET** – самый современный тепловой индекс, основанный на физиологических параметрах человека. Он преобразован из индекса PET, но основан на другом уравнении теплового баланса человека и он лучше оценивает влажность и теплоизоляционные свойства одежды.
- Сейчас это самый универсальный индекс, который лучше всего оценивает термический комфорт **в разных климатических зонах** и **в разные периоды года**

# Heat pressure in different urban landscapes

1. At the lane (between two buildings)
2. Balcony on the wall faced northwestward
3. At the roof of a building
4. Balcony on the wall faced southeastward
5. Weather shelter of MSU observatory
6. Botanical garden



# Diurnal course of PET 29.07.2010

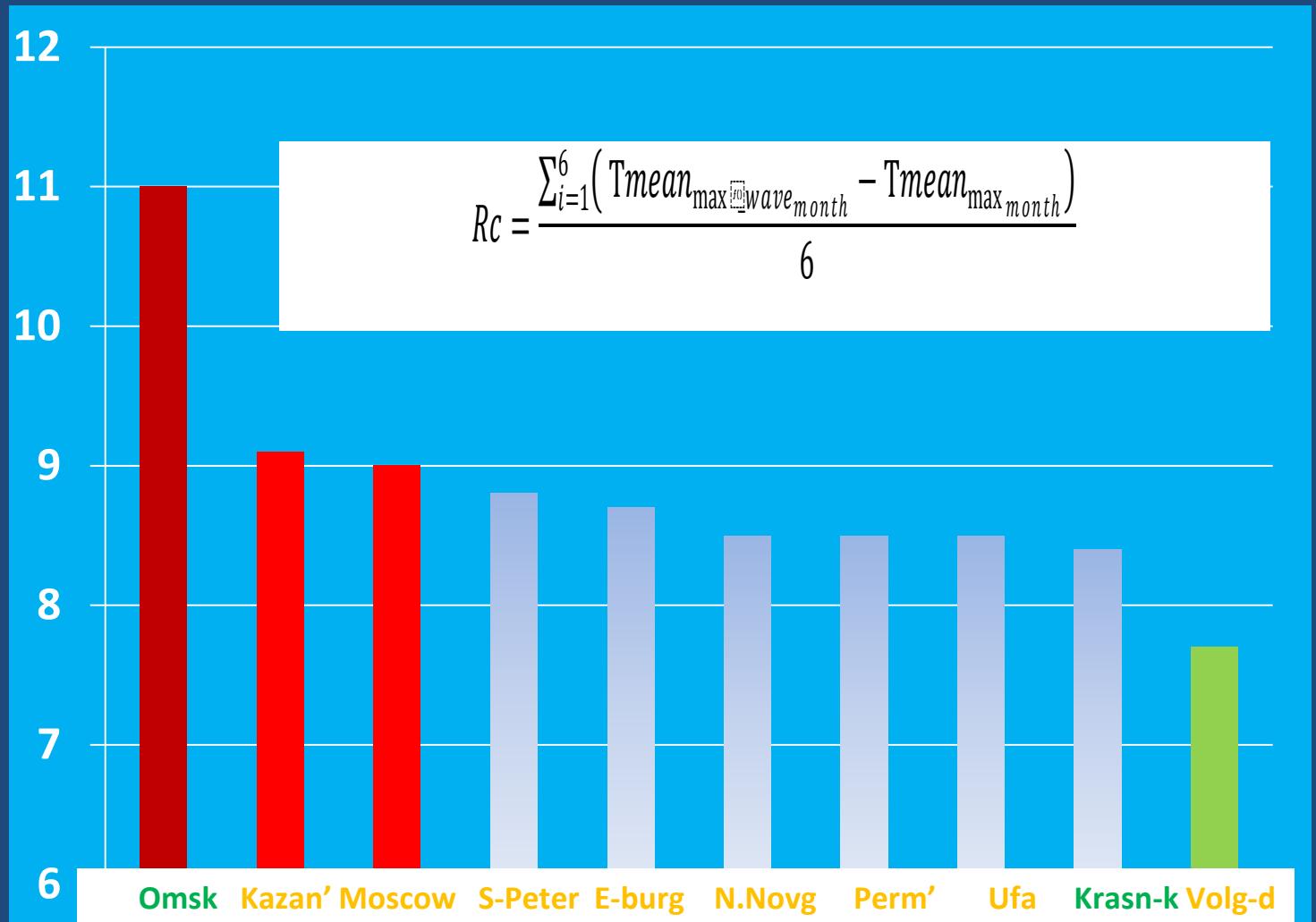


Point name	Duration of extreme heat pressure Period of extreme heat pressure	Duration of extreme heat pressure Period of extreme heat pressure
The lane	3 hours	13:30 – 16:30
Wall faced northwestward	Not observed	Not observed
The roof	3,5 hours	13:00 – 16:30
Wall faced southeastward	4 hours	11:00 – 15:00  Heat syncope is possible
Botanical garden	Not observed	Not observed

# Heat-wave intensity

	April	May	June	July	August	September	mean Tc
<b>Ekaterinburg</b>	10,1	9,0	7,8	7,9	8,4	9,2	<b>8,7</b>
<b>Kazan'</b>	10,5	8,6	8,1	10	8,4	9	<b>9,1</b>
<b>Krasnoyarsk</b>	9,6	10,1	7,5	7	7,9	8,1	<b>8,4</b>
<b>Moscow</b>	<b>12,4</b>	8,5	7,7	8,1	9,2	8,3	<b>9,0</b>
<b>Nizhnij Novgorod</b>	9	8,7	7,7	7,9	9,3	8,6	<b>8,5</b>
<b>Omsk</b>	11,2	<b>12,3</b>	<b>11,2</b>	<b>11</b>	<b>9,9</b>	<b>10,5</b>	<b>11,0</b>
<b>Perm'</b>	10,1	8,8	8	6,8	8,3	8,7	<b>8,5</b>
<b>Volgograd</b>	8,4	7,4	7,9	7,6	8	7,1	<b>7,7</b>
<b>Sankt-Petersburg</b>	10	9,4	<b>8,6</b>	<b>8,5</b>	7,7	8,6	<b>8,8</b>
<b>Ufa</b>	10,3	8	8	7,9	8,1	8,6	<b>8,5</b>

# «Strangeness» of heat wave events



Где это находит свое  
применение?

# Точки особого риска – города!

Самый жаркий день в Москве



# Не только в реальных городах

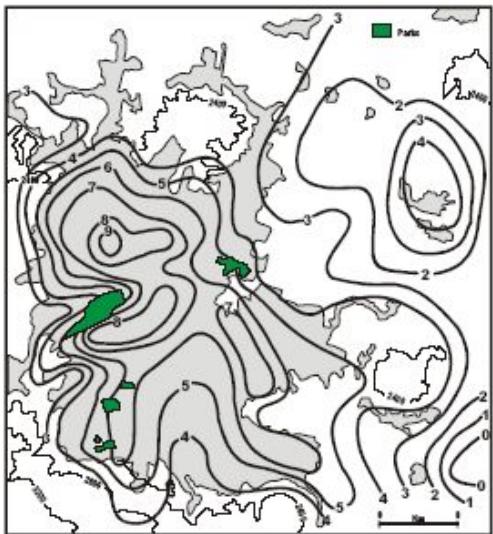
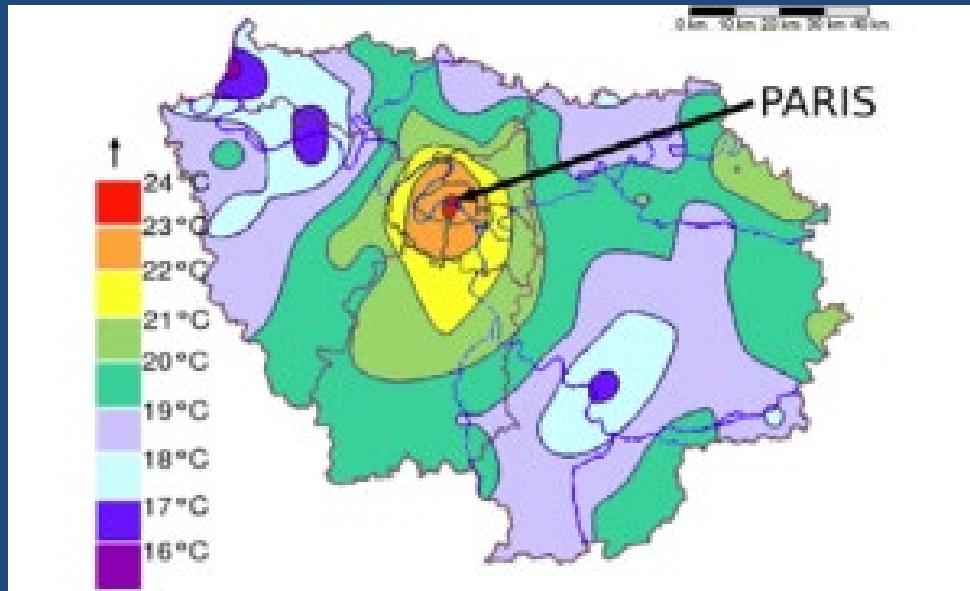


Figure 2: Mean minimum temperature for November 1981 in Mexico City. Redrawn from [4].



# „The King’s Landing Effect“

or

transforming social inequalities into  
environmental problems on an example  
of urban climate of a fantasy city

# Imaginary city King's Landing



King's Landing - Game of Thrones



<http://gameofthrones.wikia.com/>



[http://commons.wikimedia.org/wiki/File:Dubrovnik\\_crop.jpg](http://commons.wikimedia.org/wiki/File:Dubrovnik_crop.jpg)

Dubrovnik, Croatia



<http://editorsense.com/2013/05/30/travel/game-of-thrones-tours/>

# Model Setup

**Domain:** 10.1 km x 7.6 km x 0.5 km

**Resolution:** 60 m horizontal, 10-50 m vertical

**Grid points:** 168x126x25

**Land use:** 14 classes

**Max elevation:** 100 m

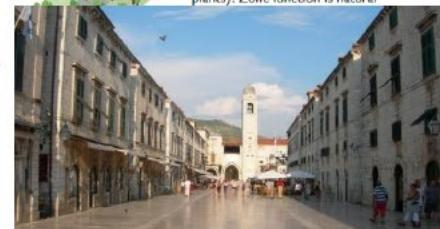
16 idealized simulations, 24 h duration, two wind directions (NW and SE) for low and high wind speed, temperature and relative humidity conditions.

## Local Climate Zone (LCZ) classification system

(Stewart and Oke, 2012)

Built types	Definition	Land cover types	Definition
1. Compact high-rise	Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials.	A. Dense trees	Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
2. Compact midrise	Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	B. Scattered trees	Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural
3. Compact low-rise	Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.		

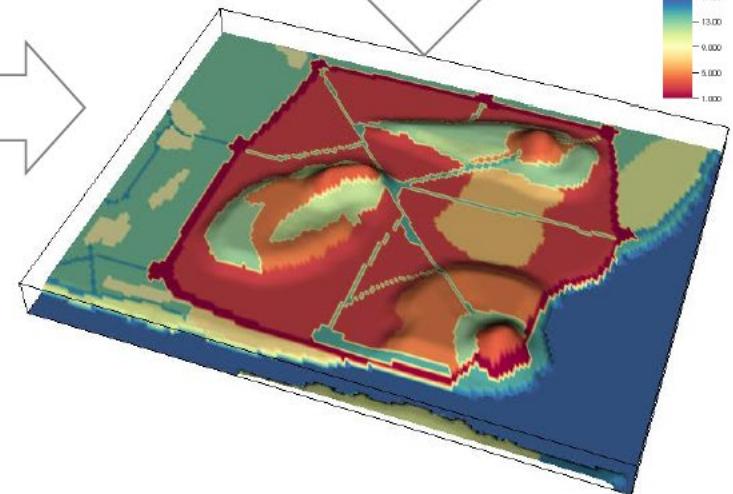
**+ Building structure  
and climate data  
from Dubrovnik**



<http://static.panoramio.com/photos/original/371519.jpg>



Map digitalization

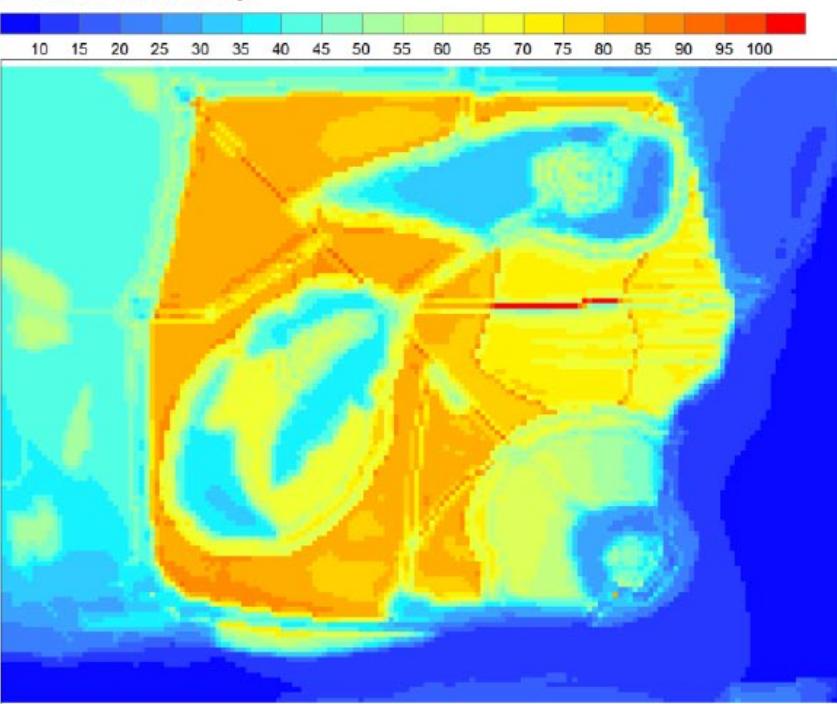


## Model results for King's Landing

DAY

Annual number of hot days

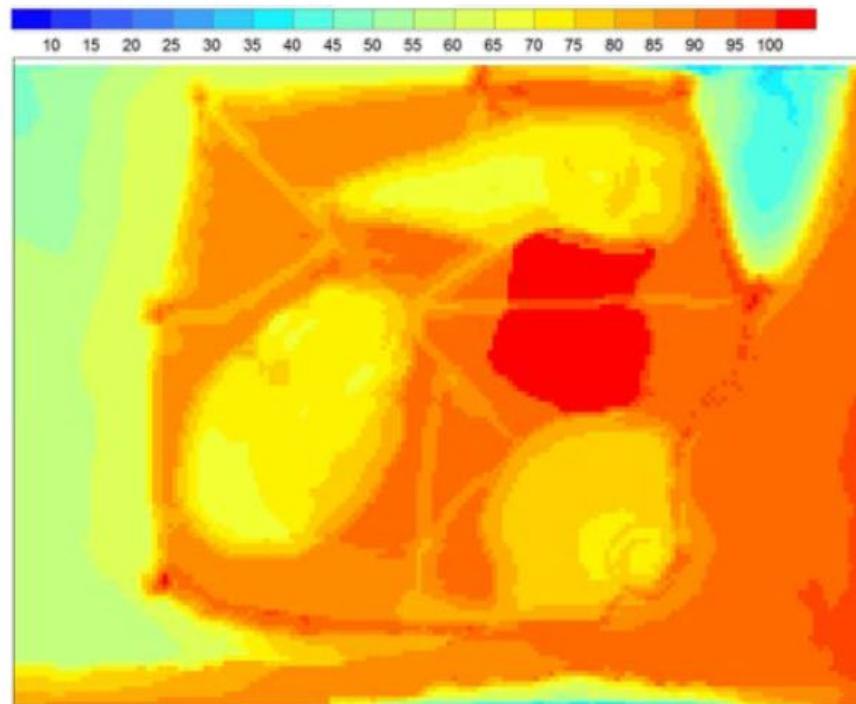
0 500 1,000 1,500 2,000 2,500 Metres



NIGHT

Annual number of tropical nights

0 500 1,000 1,500 2,000 2,500 Metres

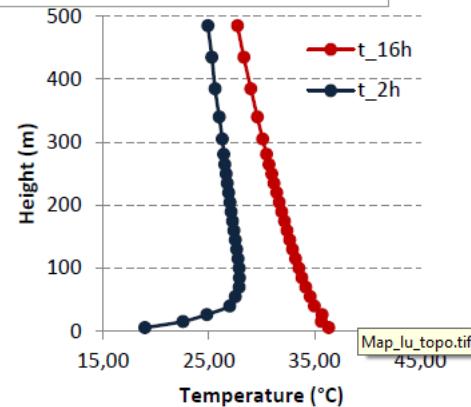


**Day:** high heat load in the built-up area within the walls, higher head load values towards inland

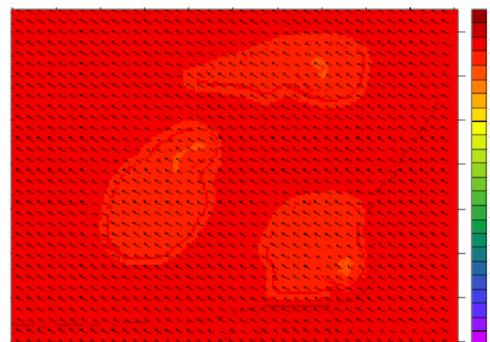
**Night:** high heat load towards sea and maximum heat load in the area of the poor

## Natural Factors

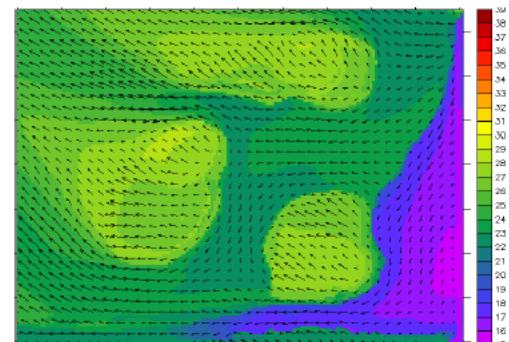
### Orography



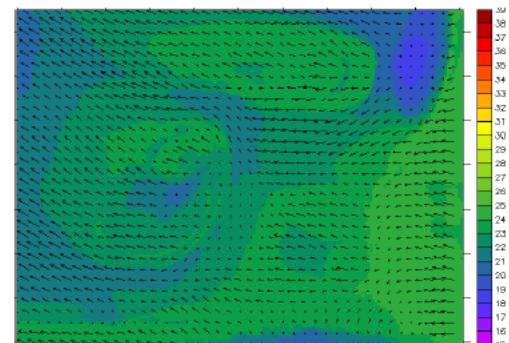
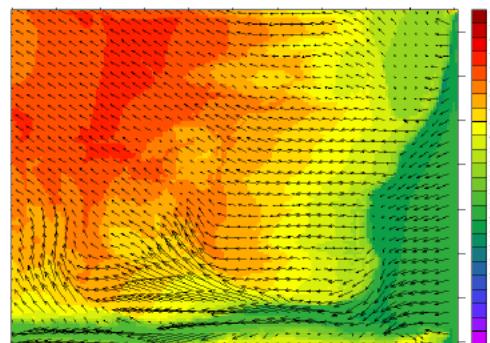
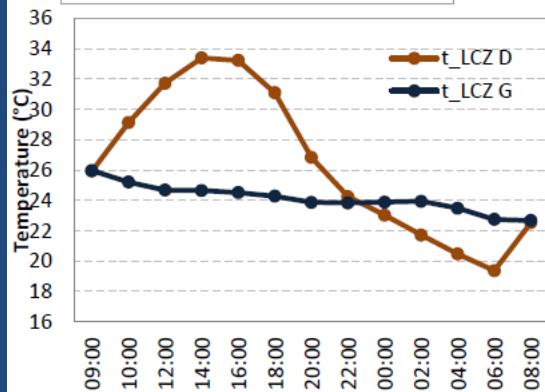
DAY



NIGHT



### Landuse



# Antropogenic Factors

Local Climate Zone (LCZ)  
0 100 200 300 400 Miles  
1 2 3 4 5 6 7 8 9 10 A B C D E F G

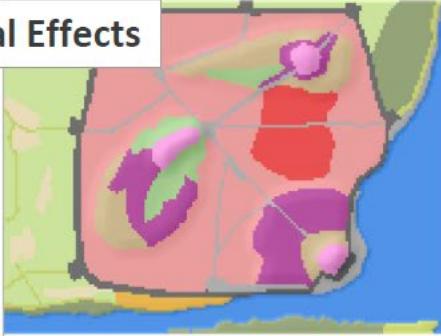
Wall



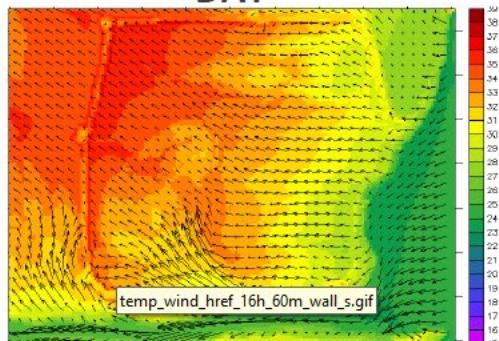
Buildings



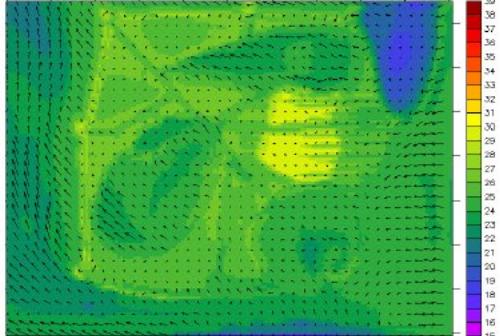
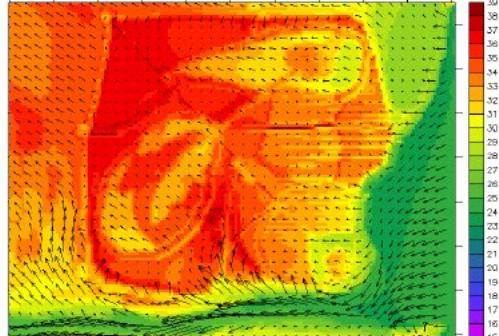
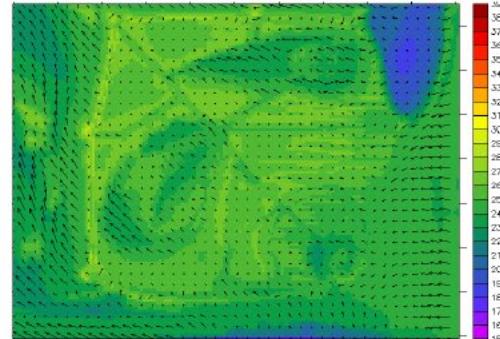
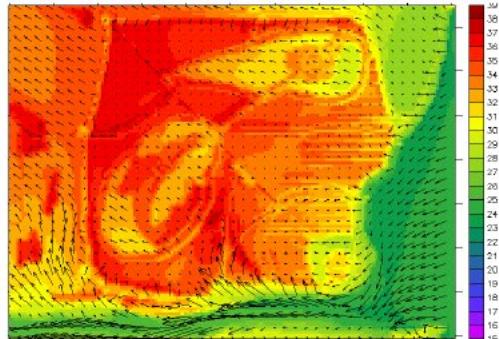
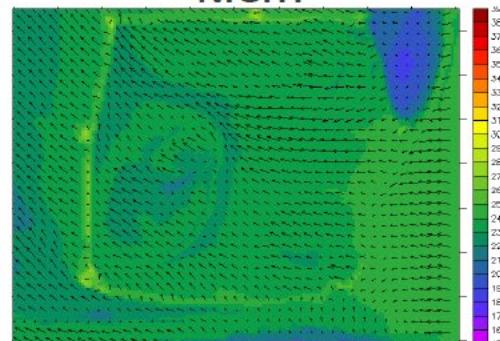
Social Effects



DAY



NIGHT

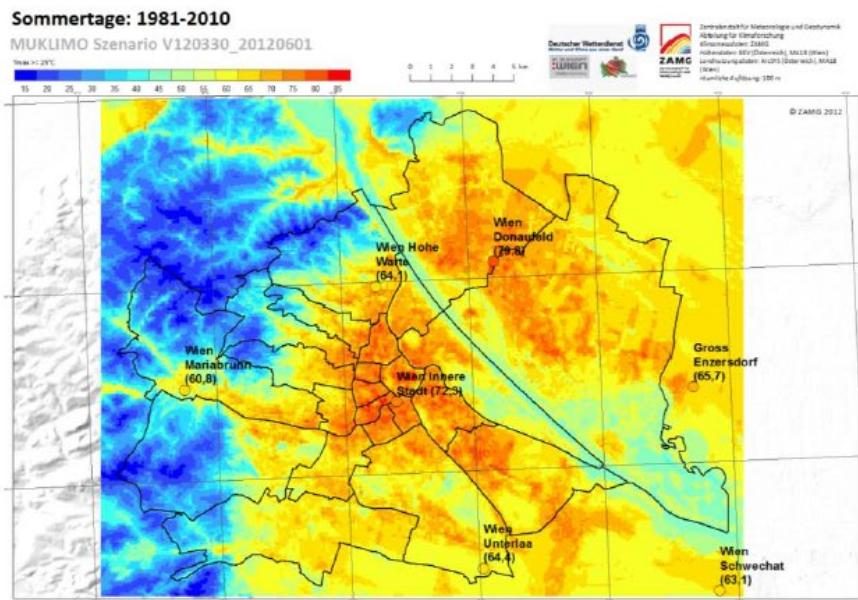


## The King's Landing Effect

- Excessive heat load can be formed in the socially unprivileged areas as a **result of natural and human induced factors**.
- **Basic mechanism that relates social inequalities with environmental problems** in urban areas:
  - naturally advantageous areas are expected to be populated by higher classes and maintain good quality due to careful planning
  - less favorable areas are expected to be inhabited by lower social classes and can further lose their quality due to inappropriate planning
- An example of an imaginary city serves as an illustrative example that does not deal with any actual city, but **the concept of the city itself**.
- The fantasy books describe social relationships, while environmental processes and related **climatic consequences are not intentional, but develop as a result of social division**.

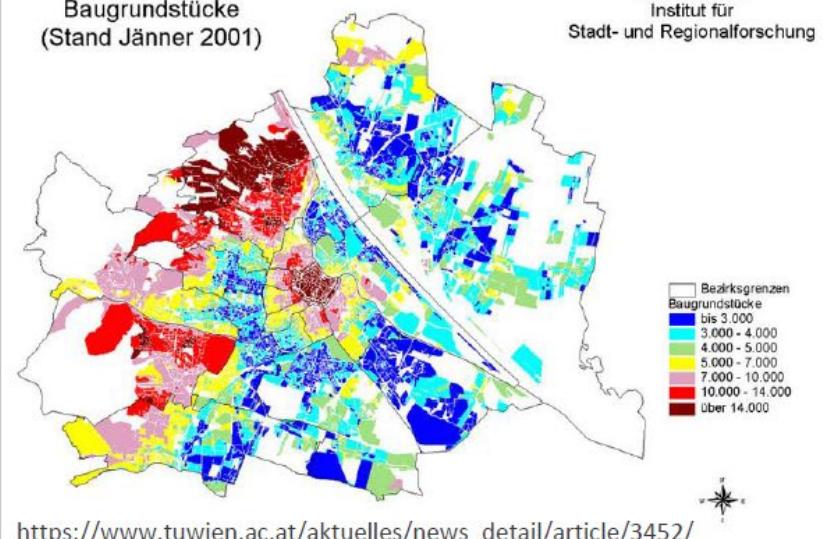
# Is there a King's Landing effect in Vienna?

## Urban heat load



## Real-estate prices

Preise für  
Baugrundstücke  
(Stand Jänner 2001)



Climate Change question: in which direction are we driving the system?

В каких областях мы это  
применяем?

# 1. Изучение влияния преобразования городской среды (Urban Greening etc.)

# Пример: прогноз термического стресса в Москве. 13 июля 2010 года 19:00 (волна жары)

Территория без деревьев



Экстремальный тепловой стресс

Территория с деревьями

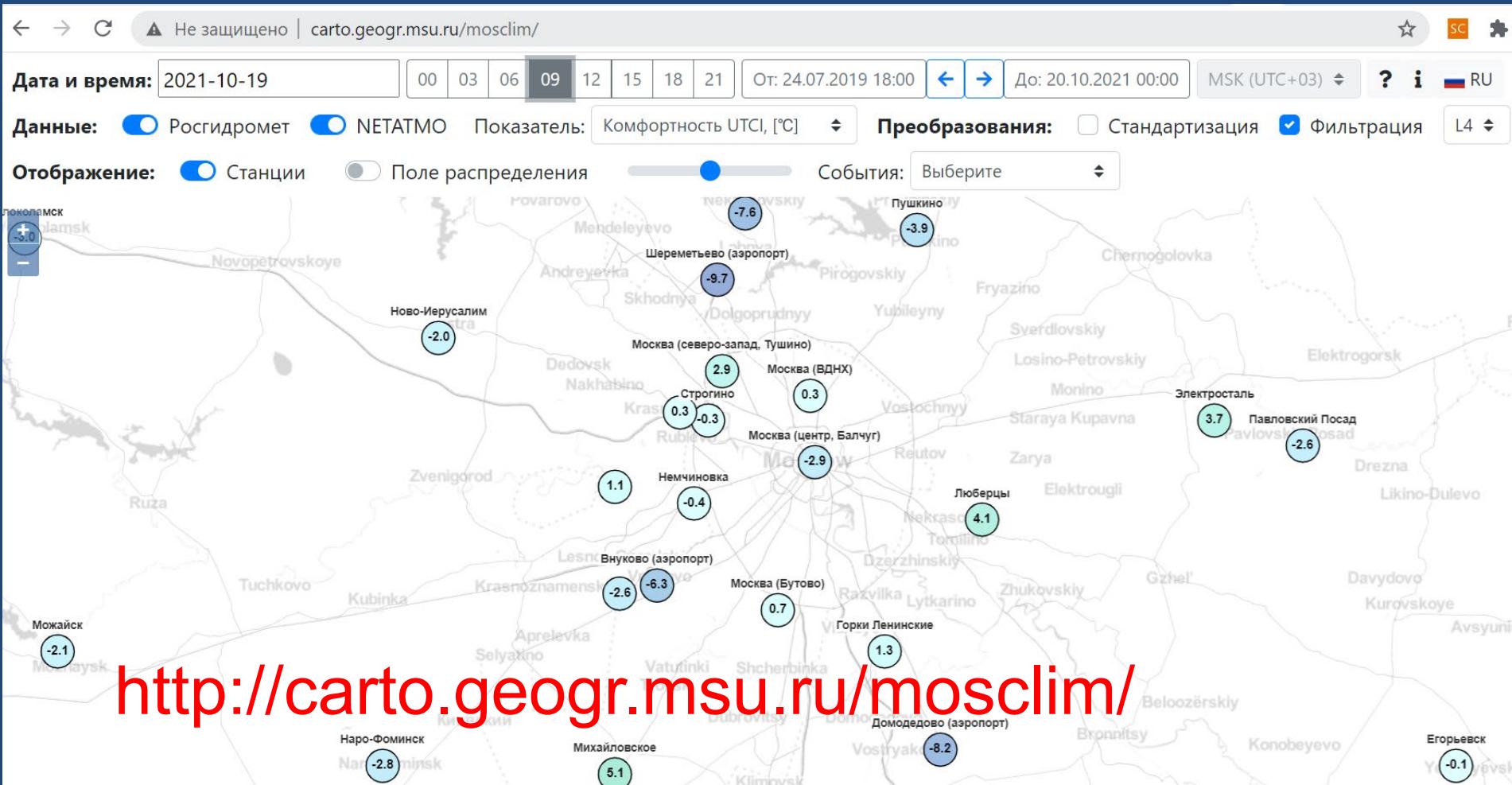


Сильный тепловой стресс

А если этот  
стресс  
длится >3 часов,  
то это уже  
увеличение  
смертности !

## 2. Онлайн-прогнозирование условий термического комфорта

*Визуализация значений индекса UTCI на территории Москвы и прилегающих регионов (18 апреля 2020 г.)* <http://carto.geogr.msu.ru/mosclim/>



### 3. Прогнозирование условий термического комфорта на масштабе России

ЛЕТО В ГОРОДЕ  
**HEAT2020**  
БЕРЕГИСЬ ЖАРЫ



## ЖАРА В ГОРОДАХ РОССИИ

\*ПО ДАННЫМ ОПЫТНОЙ ТЕХНОЛОГИИ ПРЕДСКАЗАНИЯ ТЕПЛОВОГО СТРЕССА ДЛЯ 30 КРУПНЕЙШИХ РОССИЙСКИХ ГОРОДОВ

Самые жаркие города в предстоящие сутки\*

1	Ростов-на-Дону
2	Краснодар
3	Ялта

Максимумы теплового стресса в предстоящие сутки\*

1	Ростов-на-Дону
2	Краснодар
3	Ялта

Самые комфортные города в предстоящие сутки\*

1	Нижний Новгород
2	Ульяновск
3	Ярославль

Самые прохладные города в предстоящие сутки\*

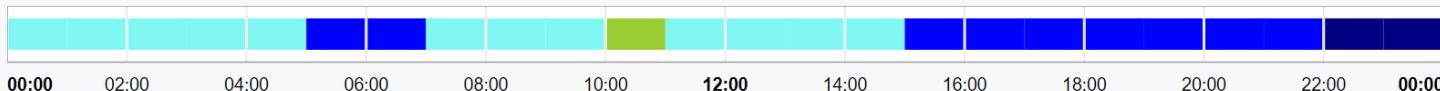
1	Омск
2	Барнаул
3	Красноярск

1 МОСКВА

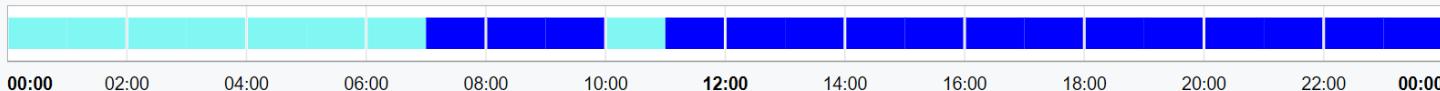
Население: 12 290 700 чел (2019)

Подходящее время для прогулок/пробежек : с 10:00 до 11:00

условия термического комфорта в естественных условиях освещенности - "на солнце"



условия термического комфорта без прямых солнечных лучей - "в тени"



Прохладно\*   Слегка прохладно\*   Комфортно\*   Слегка тепло\*   Тепло\*   Жарко\*   Очень жарко\*  
Холодно\*   \*теплоощущение человека, одетого в летнем стиле (плотная футболка/рубашка + брюки/юбка)

\*\*согласно фактору теплового стресса/комфорта, без учета вероятности выпадения осадков

Наверх

28 ТОМСК

Население: 575 352 чел (2019)

Подходящее время для прогулок/пробежек : 12:00-13:00

условия термического комфорта в естественных условиях освещенности - "на солнце"



условия термического комфорта без прямых солнечных лучей - "в тени"



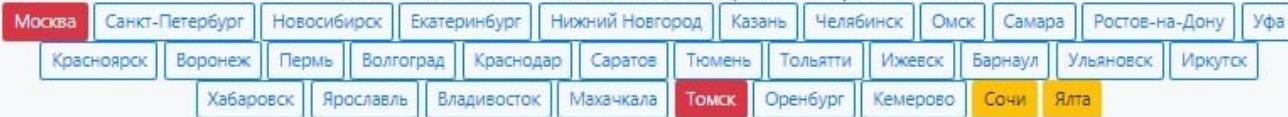
Прохладно\*    Слегка прохладно\*    Комфортно\*    Слегка тепло\*    Тепло\*    Жарко\*    Очень жарко\*

Холодно\*   \*теплоощущение человека, одетого в летнем стиле (плотная футболка/рубашка + брюки/юбка)

# ОЖИДАЕМЫЕ УСЛОВИЯ 24 ИЮНЯ 2021 ГОДА:

в крупнейших городах странах в порядке уменьшения количества населения: для быстрого перехода кликните на город

\*\* Хотите чтобы мы отдельно считали и для вашего города? Нет проблем - напишите нам!

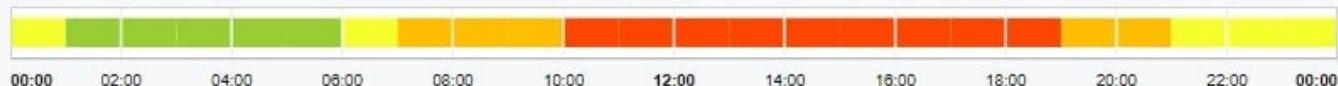


1 МОСКВА Население: 12 290 700 чел (2019) Подходящее время для прогулок/пробежек : с 5:00 до 6:00 и с 22:00 до 24:00

условия термического комфорта в естественных условиях освещенности - "на солнце"



условия термического комфорта без прямых солнечных лучей - "в тени"

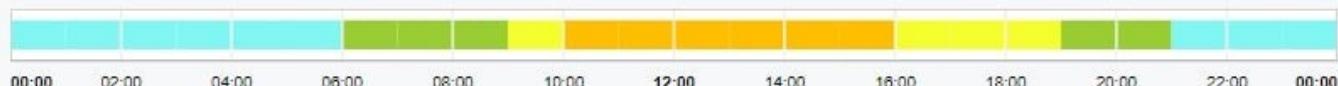


Прохладно\* Слегка прохладно\* Комфортно\* Слегка тепло\* Тепло\* Жарко\* Очень жарко\*  
Холодно\* \*теплоощущение человека, одетого в летнем стиле (плотная футболка/рубашка + брюки/юбка)

\*\*согласно фактору теплового стресса/комфорта, без учета вероятности выпадения осадков

[Наверх](#)

2 САНКТ-ПЕТЕРБУРГ Население: 5 383 890 чел (2019) Подходящее время для прогулок/пробежек : с 6:00 до 9:00 и с 19:00 до 21:00



Прохладно\* Слегка прохладно\* Комфортно\* Слегка тепло\* Тепло\* Жарко\* Очень жарко\*  
Холодно\* \*теплоощущение человека, одетого в летнем стиле (плотная футболка/рубашка + брюки/юбка)

\*\*согласно фактору теплового стресса/комфорта, без учета вероятности выпадения осадков

[Наверх](#)



Экстремальный тепловой стресс в  
2 сентября

Краснодаре

По материалам <http://heat2020.ru>

16 КРАСНОДАР

Население: 918 145 чел (2019)

Подходящее время для прогулок/пробежек : 7:00-8:00 и 22:00-24:00



Прохладно\* Слегка прохладно\* Комфортно\* Слегка тепло\* Тепло\* Жарко\* Очень жарко\*  
Холодно\* \*теплоощущение человека, одетого в летнем стиле (плотная футболка/рубашка + брюки/юбка)

\*\*согласно фактору теплового стресса/комфорта, без учета вероятности выпадения осадков

[Наверх](#)

**Физиологически-эквивалентная (PET) - «ощущаемая» человеческим организмом  
температура в районе 12:00 может превысить +50 градусов !**

# 4. Климатическая оценка изменений термического комфорта

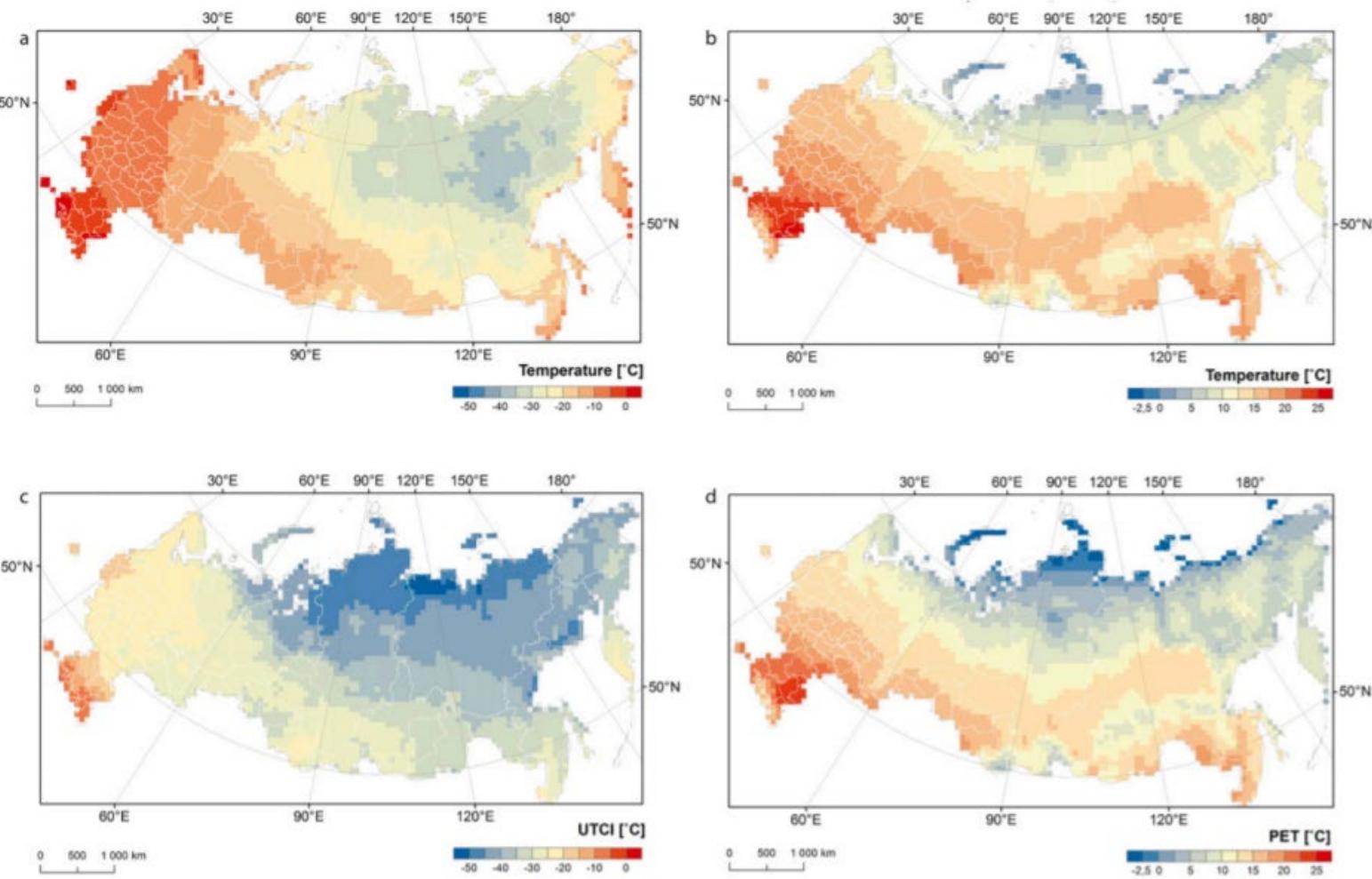


FIG. 1. Spatial distribution of mean (a) winter and (b) summer air temperatures for Russia, as well as the (c) mean winter UTCI and (d) mean summer PET, for 1981–2010.

Mikhail Varentsov, Natalia Shartova, Mikhail Grischenko, and Pavel Konstantinov. Spatial patterns of human thermal comfort conditions in russia: Present climate and trends. WEATHER CLIMATE AND SOCIETY, 12(3):629–642, 2020.

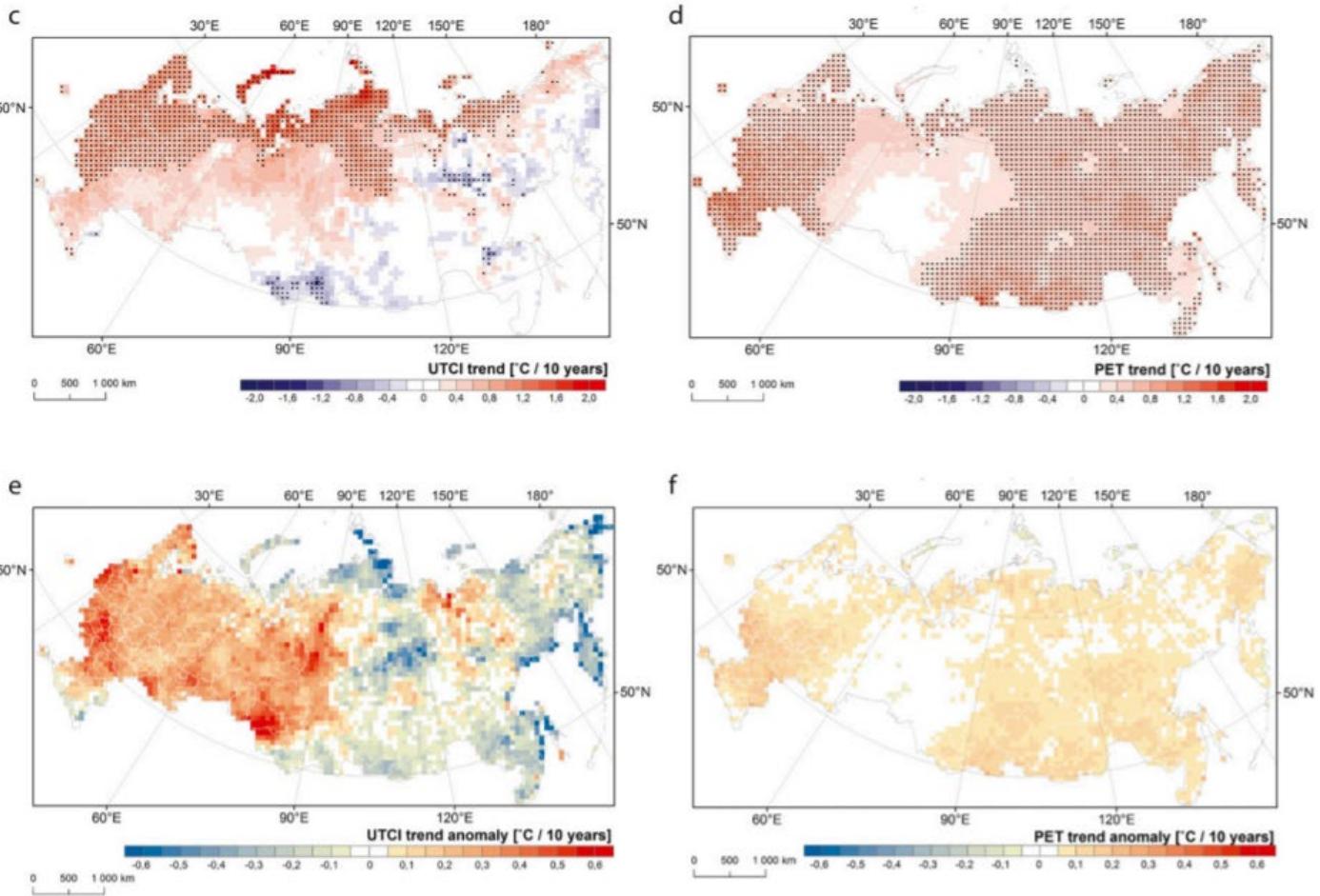
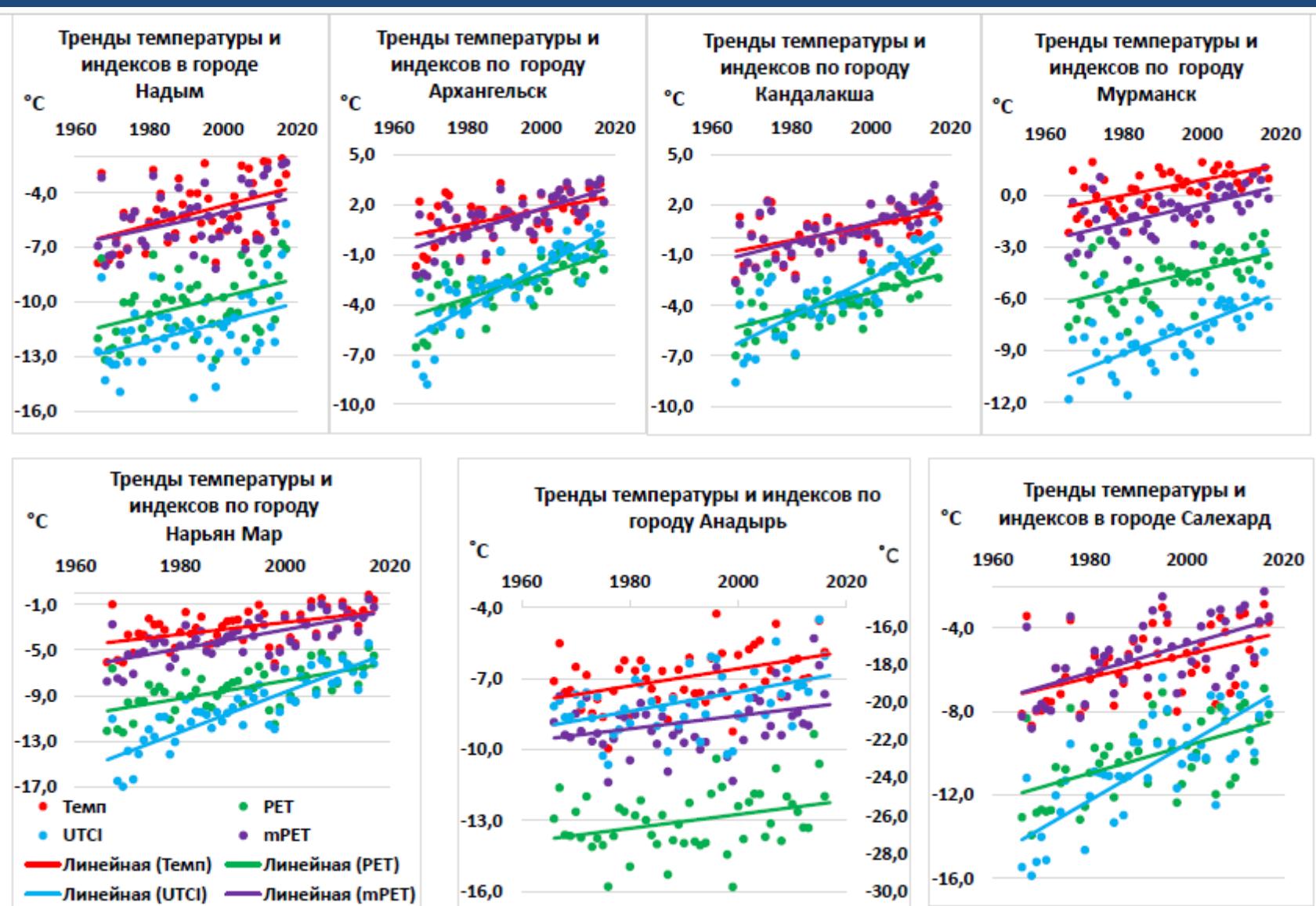


FIG. 3. Spatial distribution of Sen's slope coefficients of linear temperature trends for (a) winter and (b) summer, (c) UTCI for winter, (d) PET for summer, (e) trend anomaly defined as the difference between the UTCI trend slope and the temperature trend slope for winter, and (f) PET trend slope and temperature trend slope for summer for 1979–2018. Stippling in (a)–(d) indicates grid cells for which the trend was significant at  $p < 0.05$  according to the Mann-Kendall test.

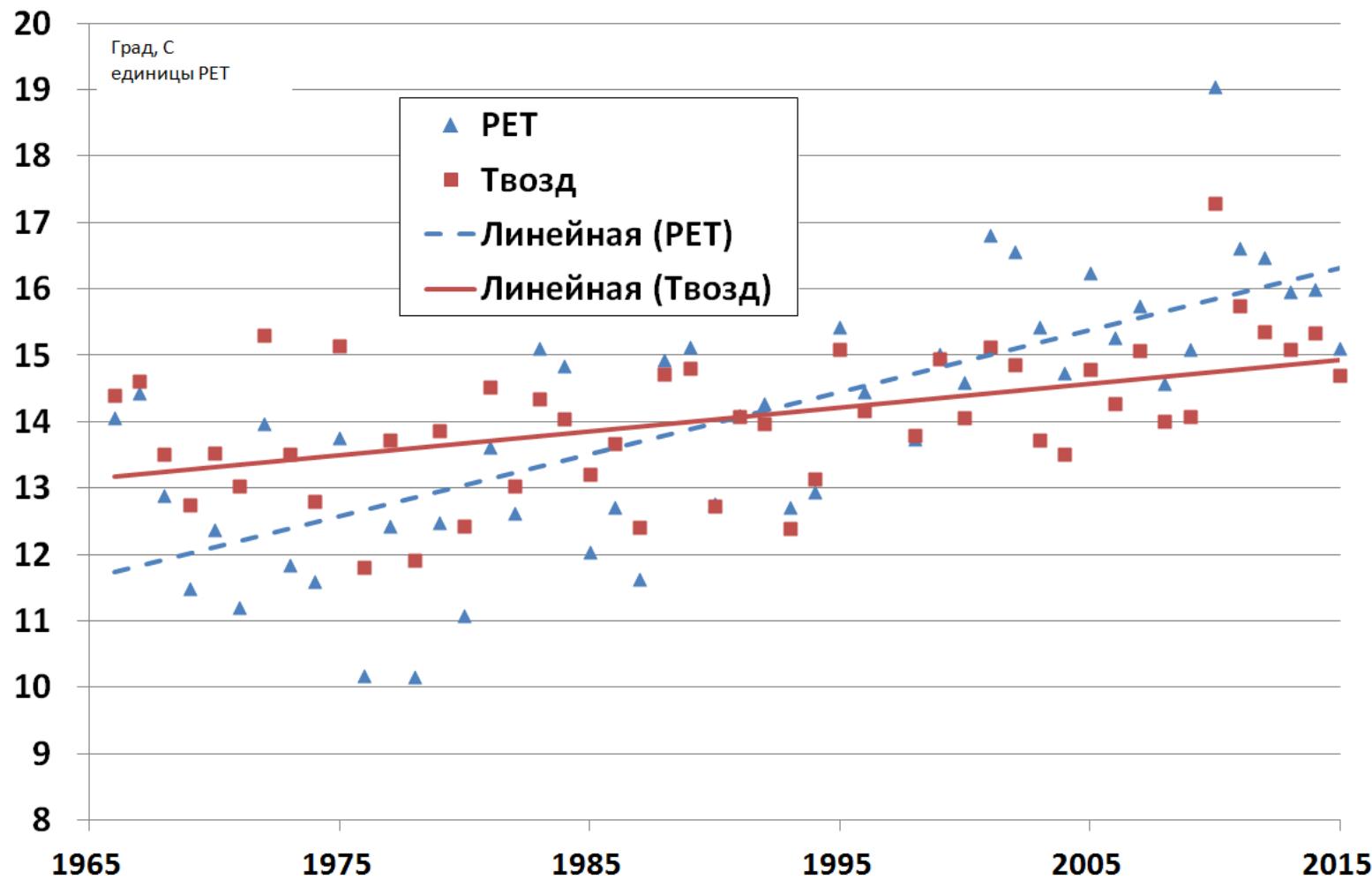
Mikhail Varentsov, Natalia Shartova, Mikhail Grischenko, and Pavel Konstantinov. Spatial patterns of human thermal comfort conditions in russia: Present climate and trends. WEATHER CLIMATE AND SOCIETY, 12(3):629–642, 2020.

## 5. Изменение климата Арктики



A. A. Semenova, P. I. Konstantinov, M. I. Varentsov, and T. E. Samsonov.  
 Modeling the dynamics of comfort thermal conditions in arctic cities under  
 regional climate change. IOP Conference Series: Earth and Environmental  
 Science, 386:012017, 2019.

# Тенденции последних 50 лет. Москва



# **ВМЕСТО ЗАКЛЮЧЕНИЯ**

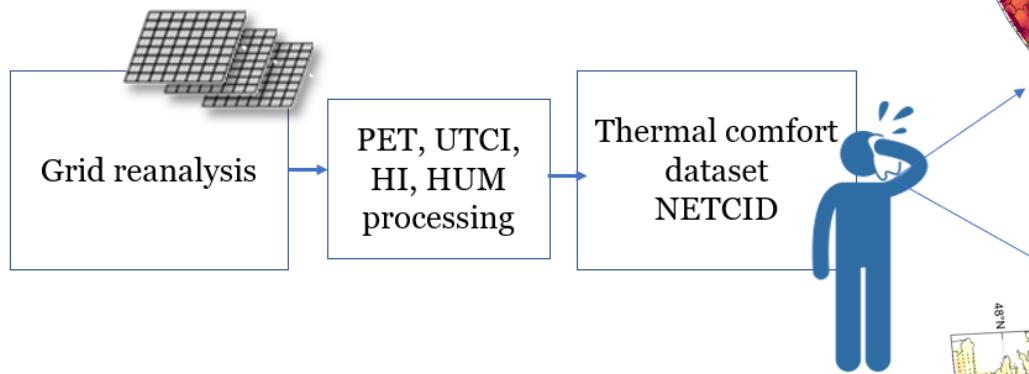
**КОМФОРТ УХУДШАЕТСЯ БЫСТРЕЕ, ЧЕМ  
ТЕПЛЕЕТ КЛИМАТ**

# COMING SOON

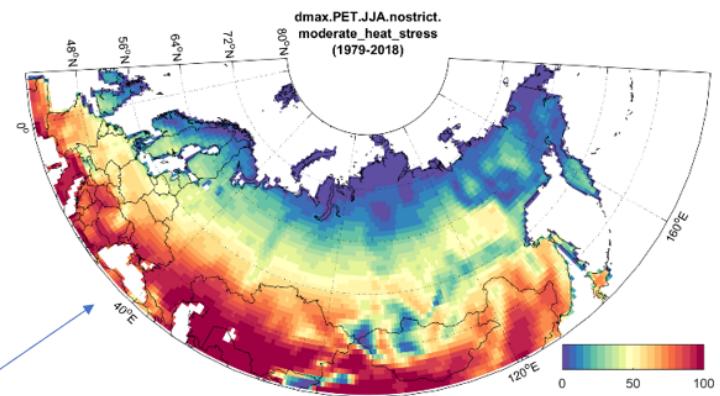
North Eurasian Thermal Comfort Indices Dataset (NETCID): New Gridded Database for the Biometeorological Studies

Created By Pavel Konstantinov, Mikhail Varentsov and Natalia Shartova

The new way to learn climatology of different thermal indices for the territory of Northern Eurasia  
In Earth sciences



NETCID – gridded dataset of 6 thermal comfort indices with horizontal resolution of  $0.75^\circ \times 0.75^\circ$  time resolution of 3 hours for the period 1979-2018



Spatial visualization

