Computing the Acclimatization Thermal Stress Index (ATSI) for Miami Dade, Florida

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Abstracts

The response of humans to weather changes might be estimated through the Acclimatization Thermal Stress Index (ATSI) introduced by Grigorieva, et.al. Such index is the ratio of the difference of heat exchanges and the exchange based on the normal for the specified region expressed as a percentage. It includes convective as well as radiative exchange and it is computed including main weather parameters as ambient temperature, humidity levels, saturated vapor pressure, wind speed, solar radiation at the geographical location. Negative values are indicative of a cold stress while positive values point into a hot stress. The merit of this index is that it unifies in a single body different approaches seem in the biometeorology community to describe the effect of extreme conditions on human health and that usually are treated separately. Additionally it is a relative index, which makes it useful for comparing different climatic zones and to find common pathways in the human response to adverse weather.

J2.3 – 95th American Meteorological Society Annual Meeting, Phoenix, Arizona 2015.

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Motivations

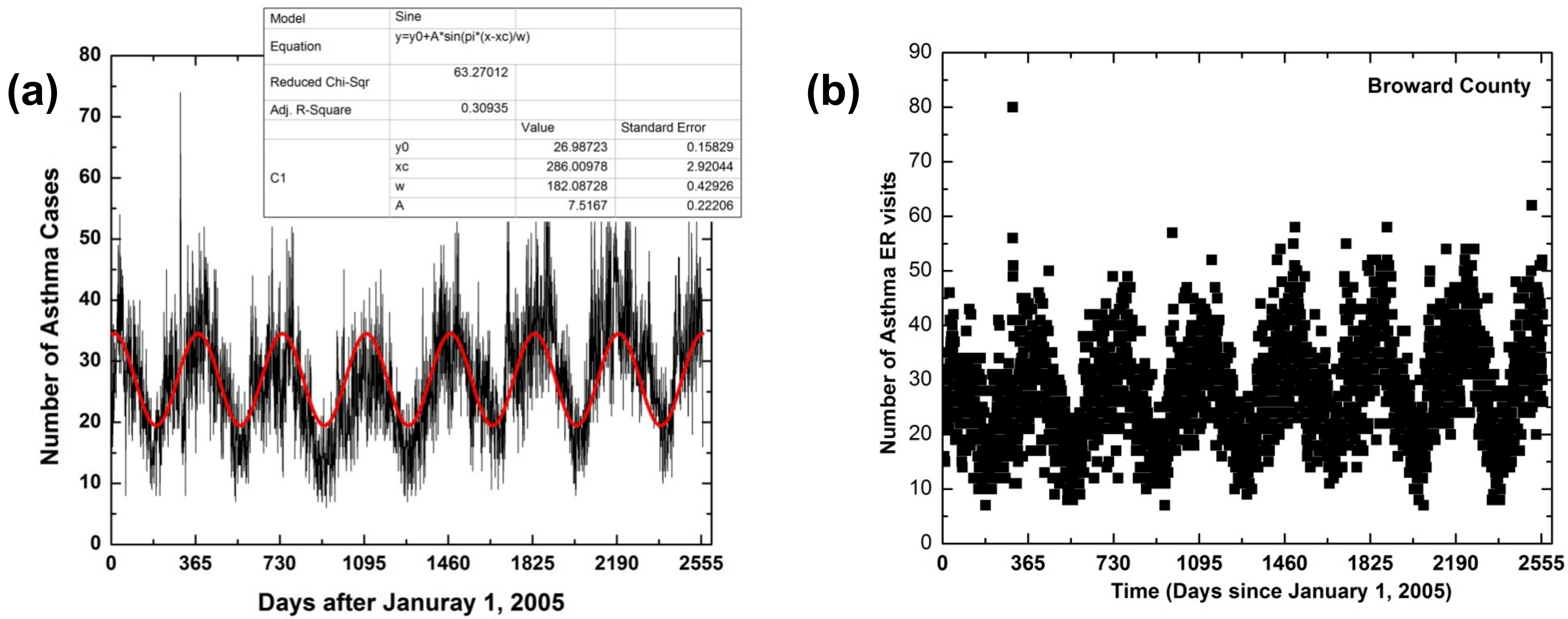

Fig. 1: Daily number of asthma cases reported at Emergency Departments in Miami Dade (a) and Broward (b) Counties in South Florida from January 1, 2005 through December 31, 2011. Horizontal axis is plotted in units of time since January 1, 2005.

Florida Asthma Coalition

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BRACE project

Building Resilience Against Climate Effects

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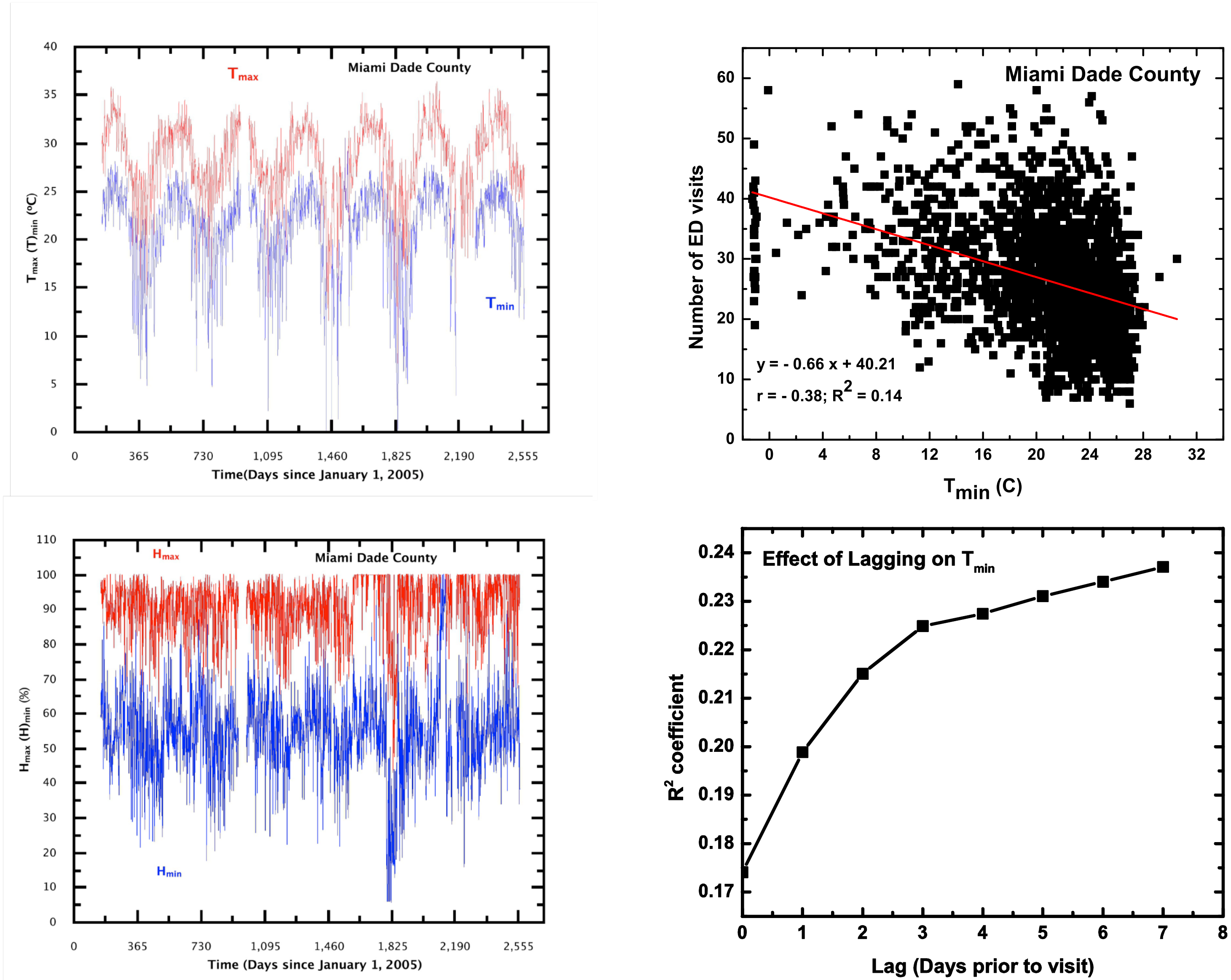

Fig. 2: Time – series of temperature and humidity (left panels) and linear correlation analysis (right panels)

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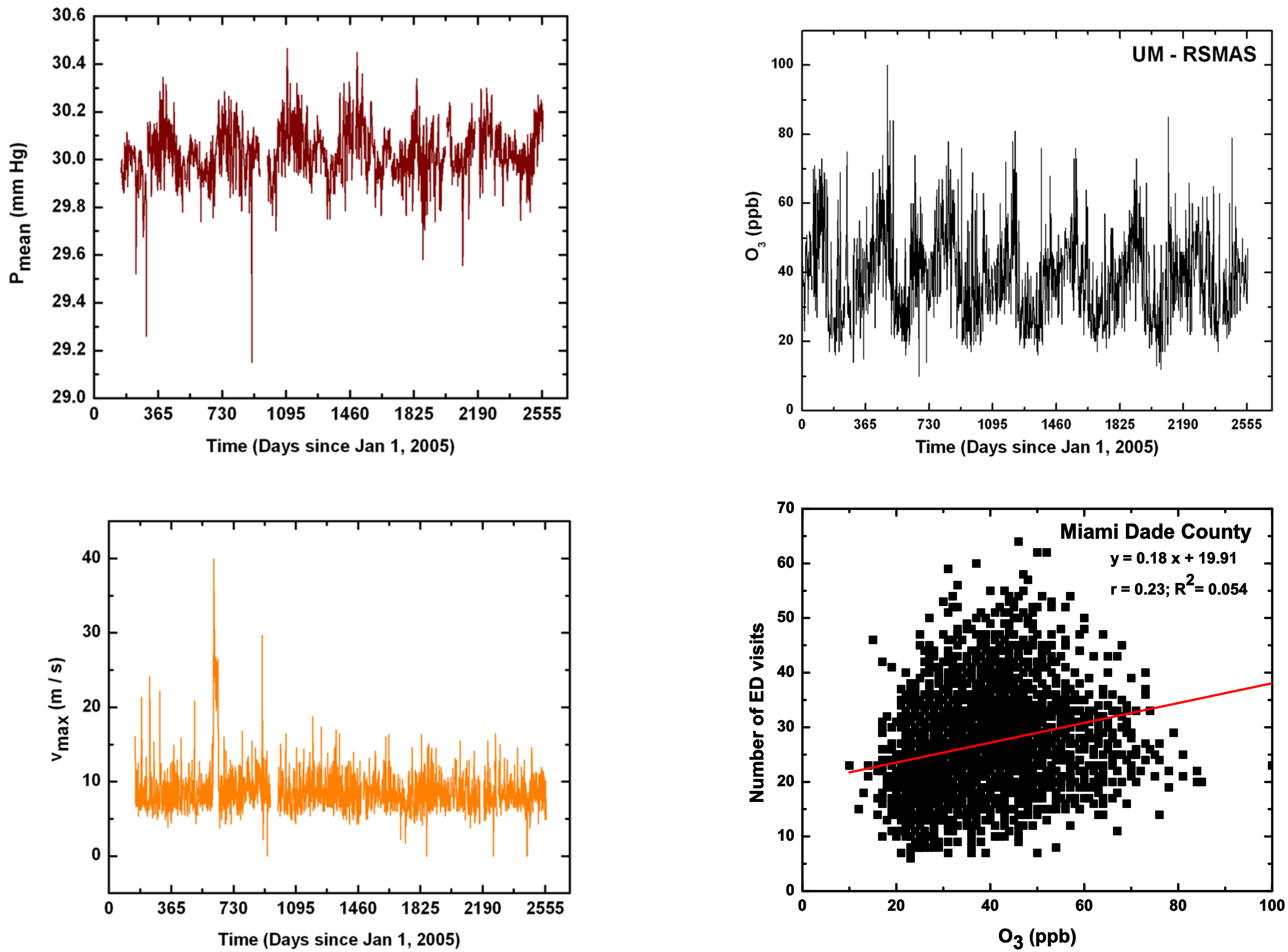

Fig. 3: Time – series of pressure, average wind speed (left panels) and surface ozone (right panels)

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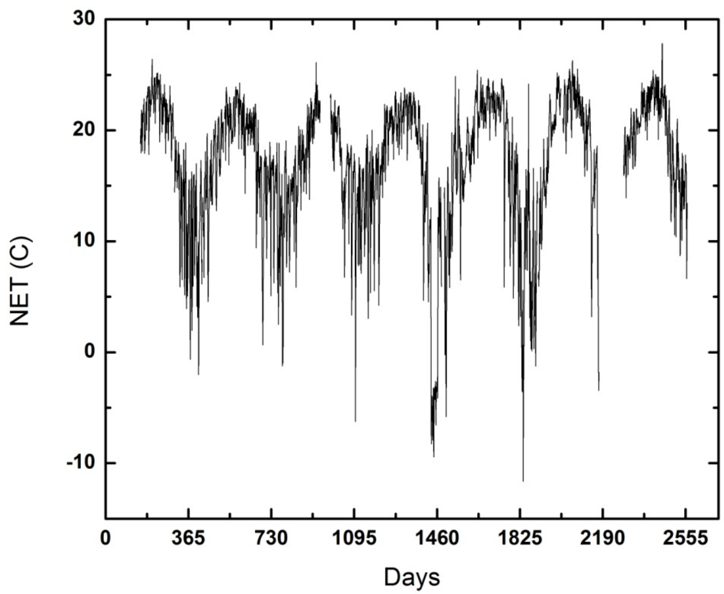
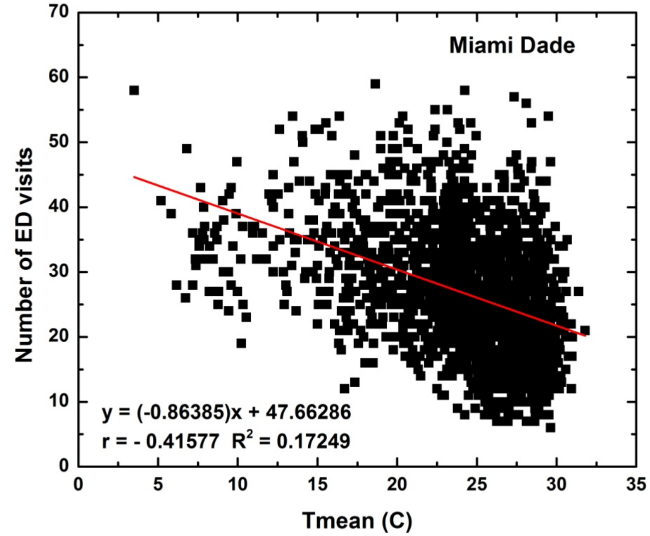
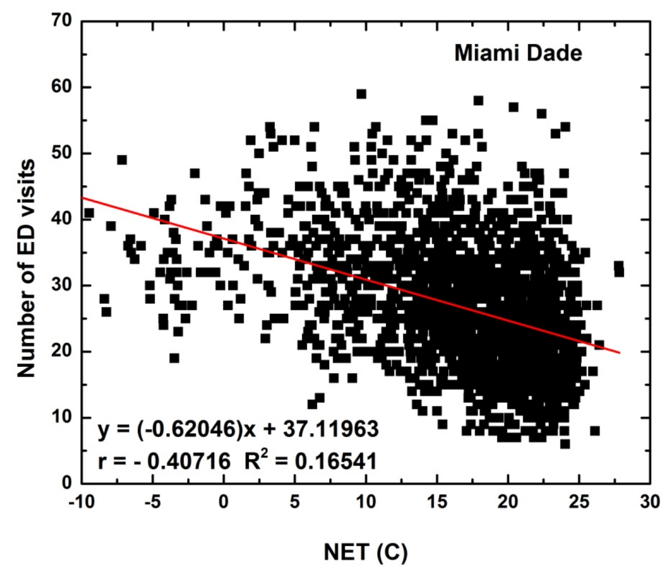
Net Effective Temperature (NET)

$$NET = 37 - \frac{37 - T}{0.68 - 0.0014RH + \frac{1}{1.76 + 1.4v^{0.75}}} - 0.29T(1 - 0.01RH)$$

P.W. Li and S.T. Chan, Meteorol. Appl. 7, 369 – 375 (2000)







Even though both **NET** and **Tmean** follow the same trend as the **number of ED visits** neither one alone is able to go beyond a **moderate level** of correlation, being the Tmean, the parameter with slightly better results.

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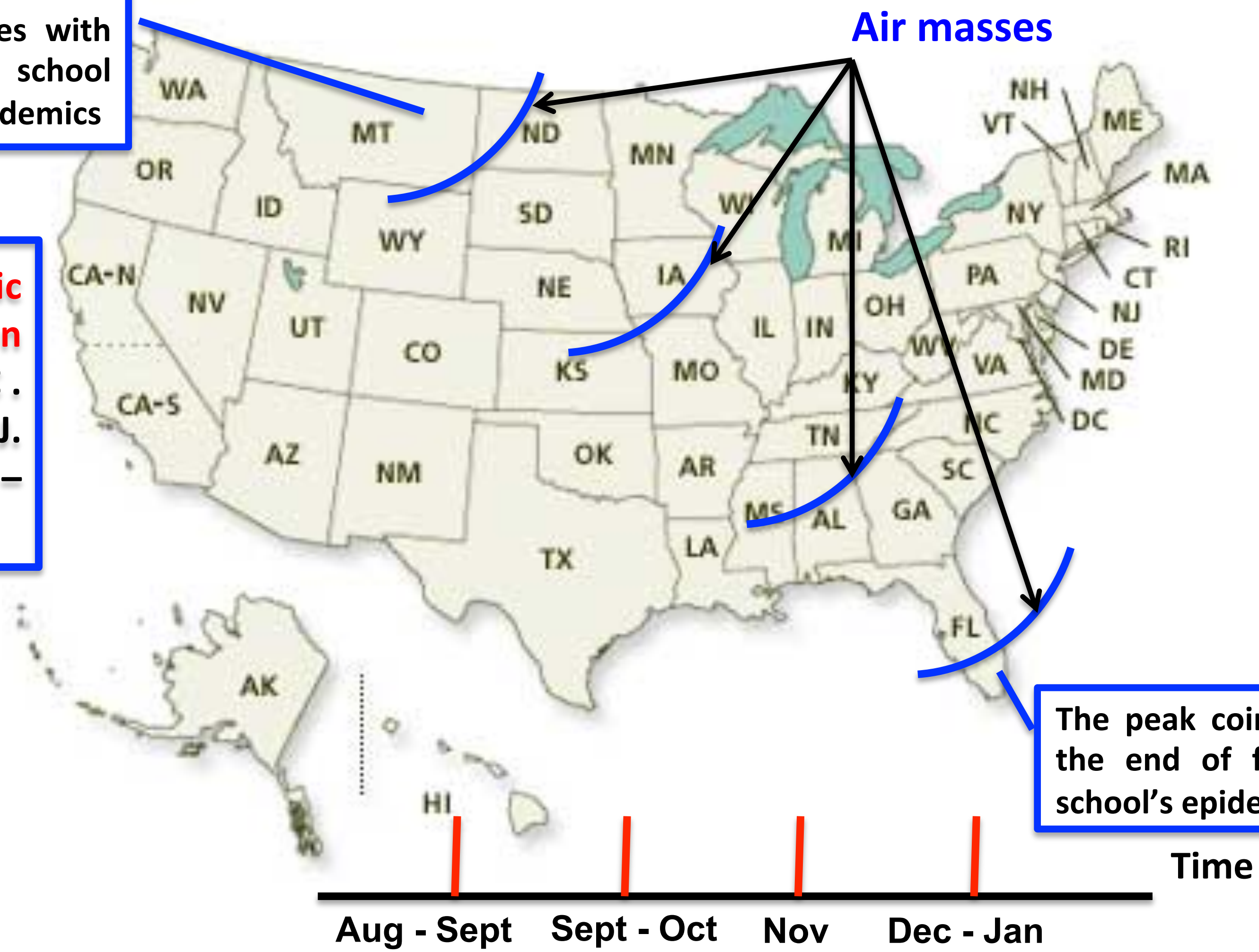
The peak coincides with the beginning of school year – school's epidemics

Spatial Synoptic Classification (SSC) – SC. Sheridan, Int. J. Climatol. 22, 51 – 68, (2002).



The peak coincides with the end of fall term – school's epidemics still??

Fig. 4: Shift of the seasonality peak due to asthma reported cases at Emergency Departments across the continental USA. Notice, how it moves from northern states to southern Florida.

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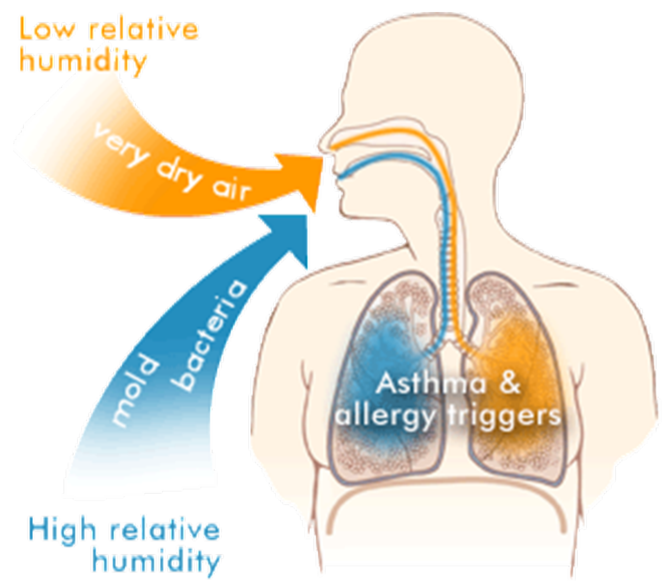
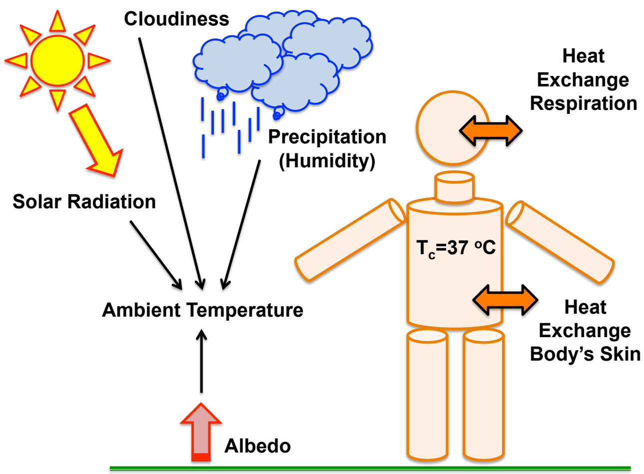
The respiratory organs are not protected and humans can do nothing to prevent the ambient air entering into the body's core area, the lungs, through airways.



Why negative thermal loading is so relevant?

- Keystone in the etiology of acute respiratory diseases.
- Respiratory heat losses above the norm (15 W – effective heat loss) lead to high frequency of respiratory diseases in children.
- High heat losses from respiratory organs make it easier for pathogenic micro-flora to penetrate the protective barrier of lungs and may be the reason for increased morbidity.



$$ATSI = \frac{Q_{daily} - Q_{normal}}{Q_{normal}} \cdot 100\%$$

Q – heat exchanged during respiration

- Daily refers to the heat exchange computed based on daily averages.
- Normal refers to the heat exchange expected to happen according to climatological normal for a given area.

C.R. de Freitas, E.A. Grigorieva, Int. J. Biometeorol (2009) 53: 307 – 315

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$$Q = C + E$$

Heat dissipated during respiration

$$C = 1.17 \times 10^{-3}\, M\, (T_{core} - T)\, A$$

Convective Heat Exchange

$$E = 2.3 \times 10^{-3}\, M\, (e_a - e_s)\, A$$

Evaporative Heat Exchange

M – Metabolic heat rate == **90 W / m^2 person standing relaxed**
A – DuBois body area == **1.8 m^2**
T_{core} – Body core temperature == **37 ^{o}C**
T – ambient air temperature (^{o}C), or the Net Effective Temperature (^{o}C)
e_s – saturated vapor pressure of ambient air (mm Hg)
e_a – saturated vapor pressure of core air == **44 mm Hg**

$$e_s(T) = 4.5827\, exp\left(\frac{17.625\, T}{T + 243.04}\right)$$ **Magnus – Tetens approximation**

Since the ATSI involves a difference, the contributions from clothing and radiation cancel out because they are almost the same.

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	Month	T_{min} (ºC)	T_{max} (ºC)	T_{mean} (ºC)	V_{mean} (m/s)	RH_{max} (%)	RH_{min} (%)	RH_{mean} (%)
1	January	15.3	24.3	19.8	4.24	85	60	72.5
2	February	16.1	25.0	20.5	4.47	84	58	71
3	March	17.9	26.5	22.2	4.65	88	57	72.5
4	April	20.1	28.2	24.1	4.69	79	54	66.5
5	May	22.3	29.9	26.1	4.24	80	59	69.5
6	June	23.9	31.3	27.6	3.90	84	66	75
7	July	24.7	32.0	28.3	3.53	83	63	73
8	August	24.9	32.2	28.6	3.53	85	65	75
9	September	24.4	31.3	27.8	3.66	87	67	77
10	October	22.4	29.5	25.9	4.11	86	63	74.5
11	November	19.8	27.0	23.4	4.34	84	62	73
12	December	16.6	24.9	20.7	4.07	84	60	72

Table 1: Normals for Miami International Airport (41 years average)

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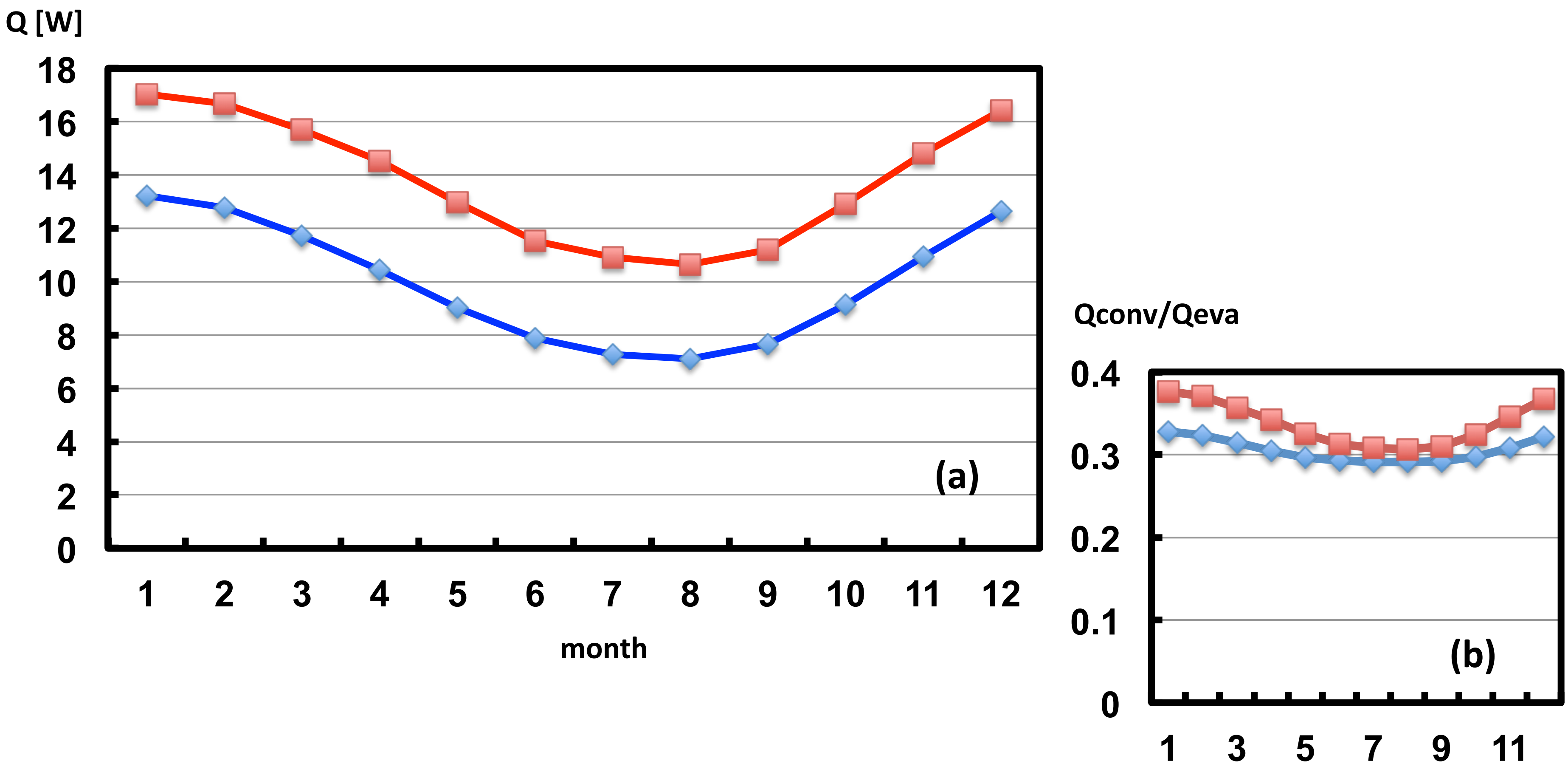

Fig. 5: Computed heat losses Q including the convective and evaporative contributions (a) and their ratios (b). The curve in blue is obtained using only the mean temperature while the curve in red uses the net effective temperature. Notice the close to (above) threshold (15 W) values during winter months.

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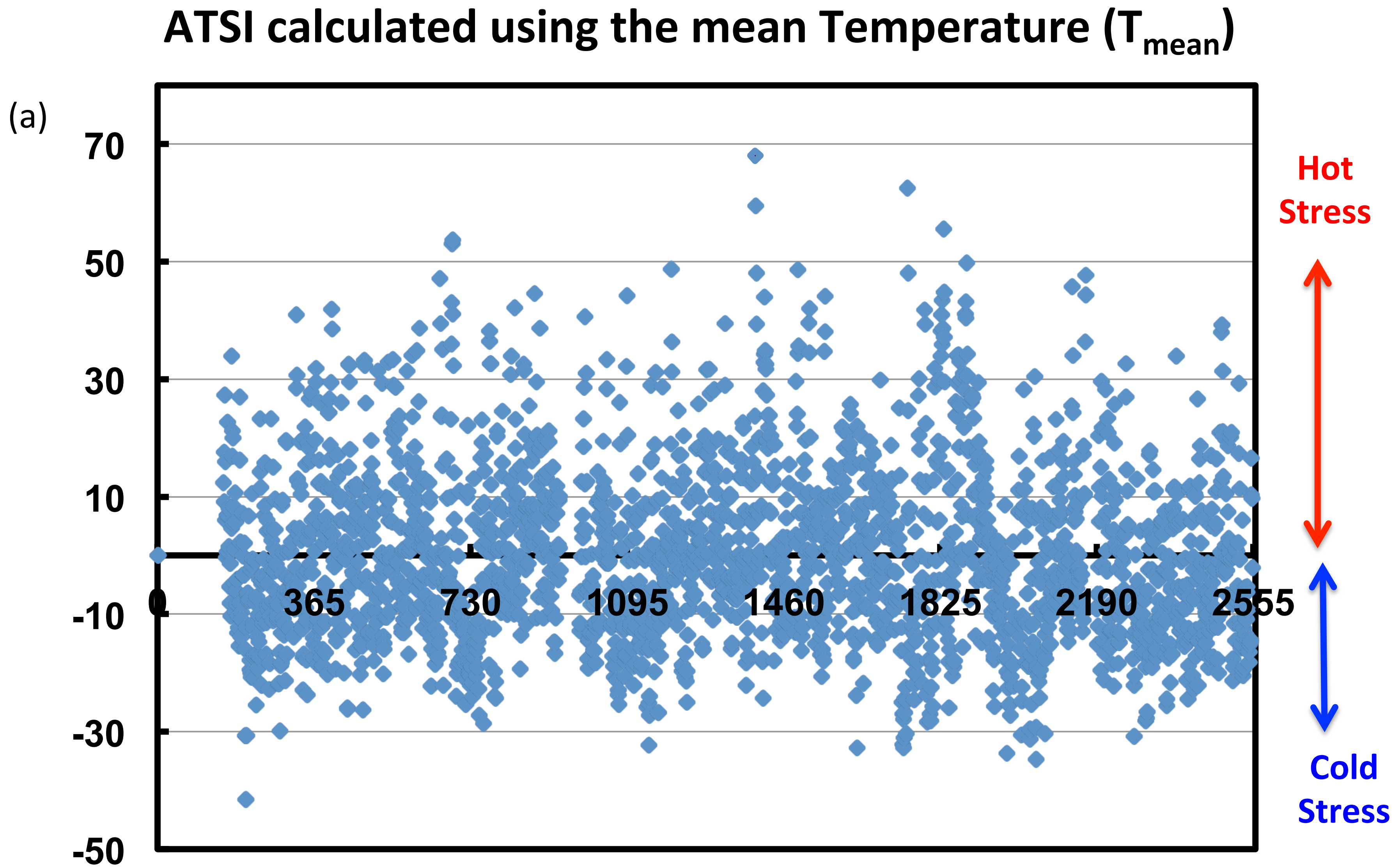

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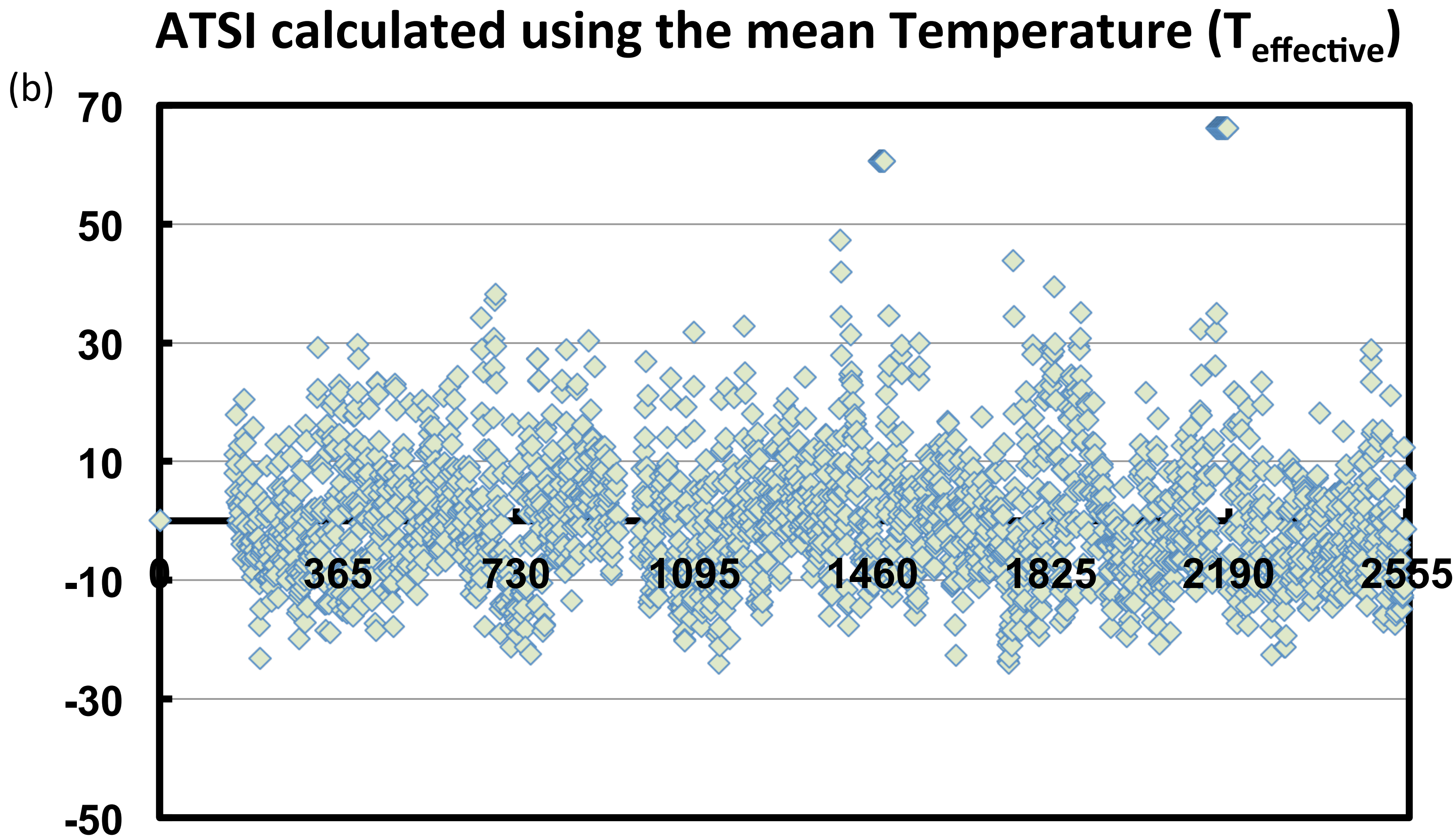

Fig. 6: Calculated ATSI for Miami Dade County using the mean temperature (a) and the net effective temperature (NET) (b). The NET leads to a more stability in term of heat (cold) stress compared to T_{mean} case. Notice also the particular behavior of Miami, rapid variations in terms of thermal stress.

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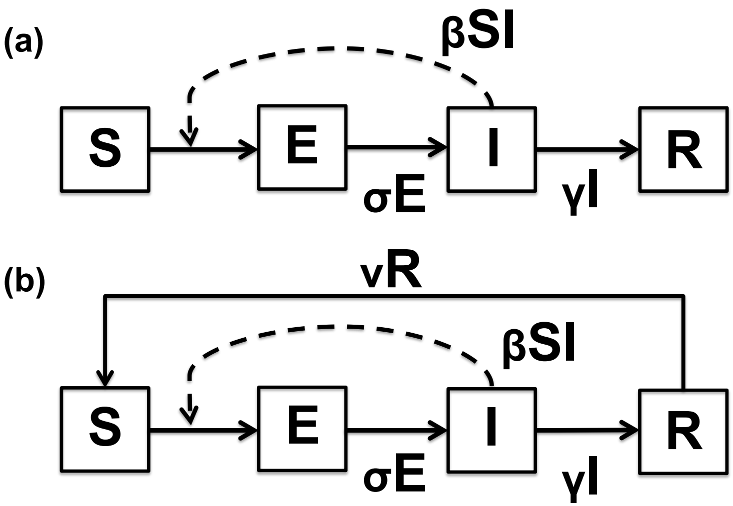
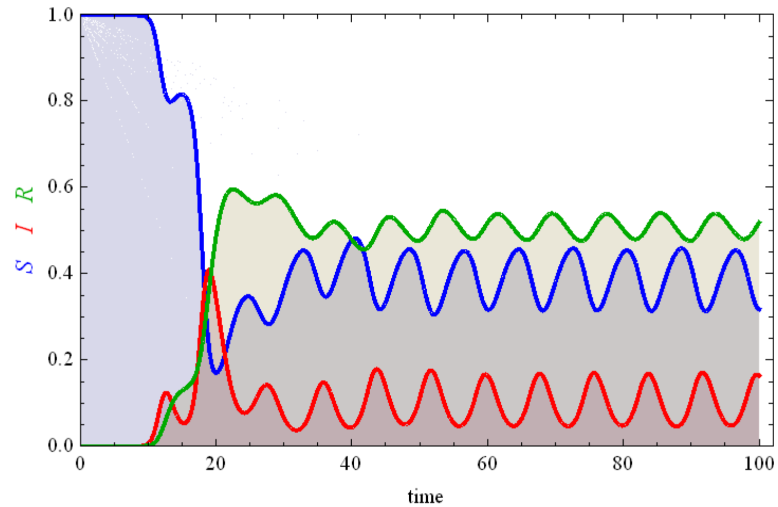
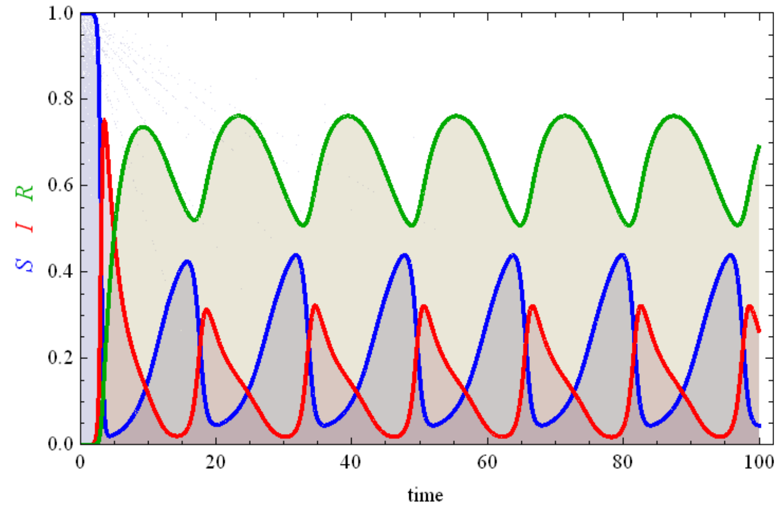


Schematic representation of the SEIRS model, where S – susceptible, E – exposed, I – infected, R – recovered individuals, β(t) is the seasonally forced infection rate used to model the seasonal incidence of epidemics affecting asthmatic patients, σ is the rate exposed individuals are becoming infected, while γ is the recovery rate.

$$\beta(t) = \beta(0)\,(1 + \mathrm{Sin}[2\pi t/T])$$

Seasonally forced infection rate





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Conclusions

- Asthma is a complex respiratory disorder showing nonlinear dependence between the number of cases reported at Emergency Departments and weather parameters.
- Seasonality in asthma occurrence is hard to explain appealing only to weather parameters and/or using multi-linear statistical regressions.
- ATSI does not correlate significantly with the number of cases neither. Positive and negative values are found even within the same season.
- ATSI calculated using the Net Effective Temperature results in more thermal comfort than when it is calculated using the mean temperature for a day.
- Asthma seems to be triggered rather by epidemic outbreaks with the same seasonality as the former than by individual meteorotropic effect. Weather conditions seems to facilitate the spread of the seasonal viruses.
- Biophysical modeling is needed in order to understand the complex interaction between weather and respiratory health, as well as the robustness (stability of a system to perturbations) of the respiratory system.