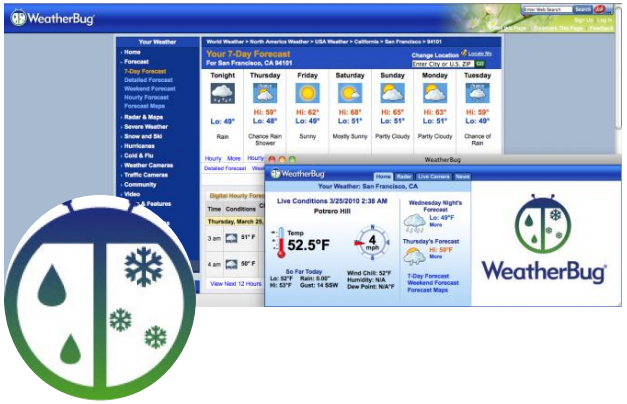
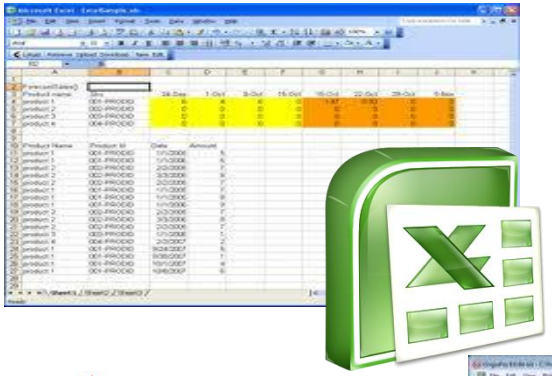
About the use of WeatherBug Achieve in entry level research undergraduate projects: Combining weather, physiology, engineering, and mathematics

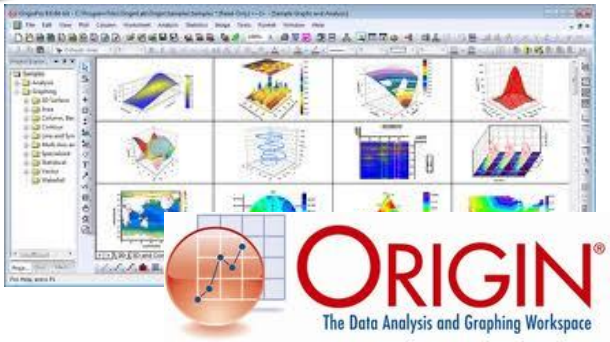
D. Quesada, G. Gonzalez, S. Gonzalez, V. Iglesias, H. Castro,
A. Perez, Y. Davila, and H. Rodriguez-Gallo
School of Science, Technology, and Engineering Management,
St. Thomas University, 16401 NW 37 Ave. Miami Gardens, FL 33054





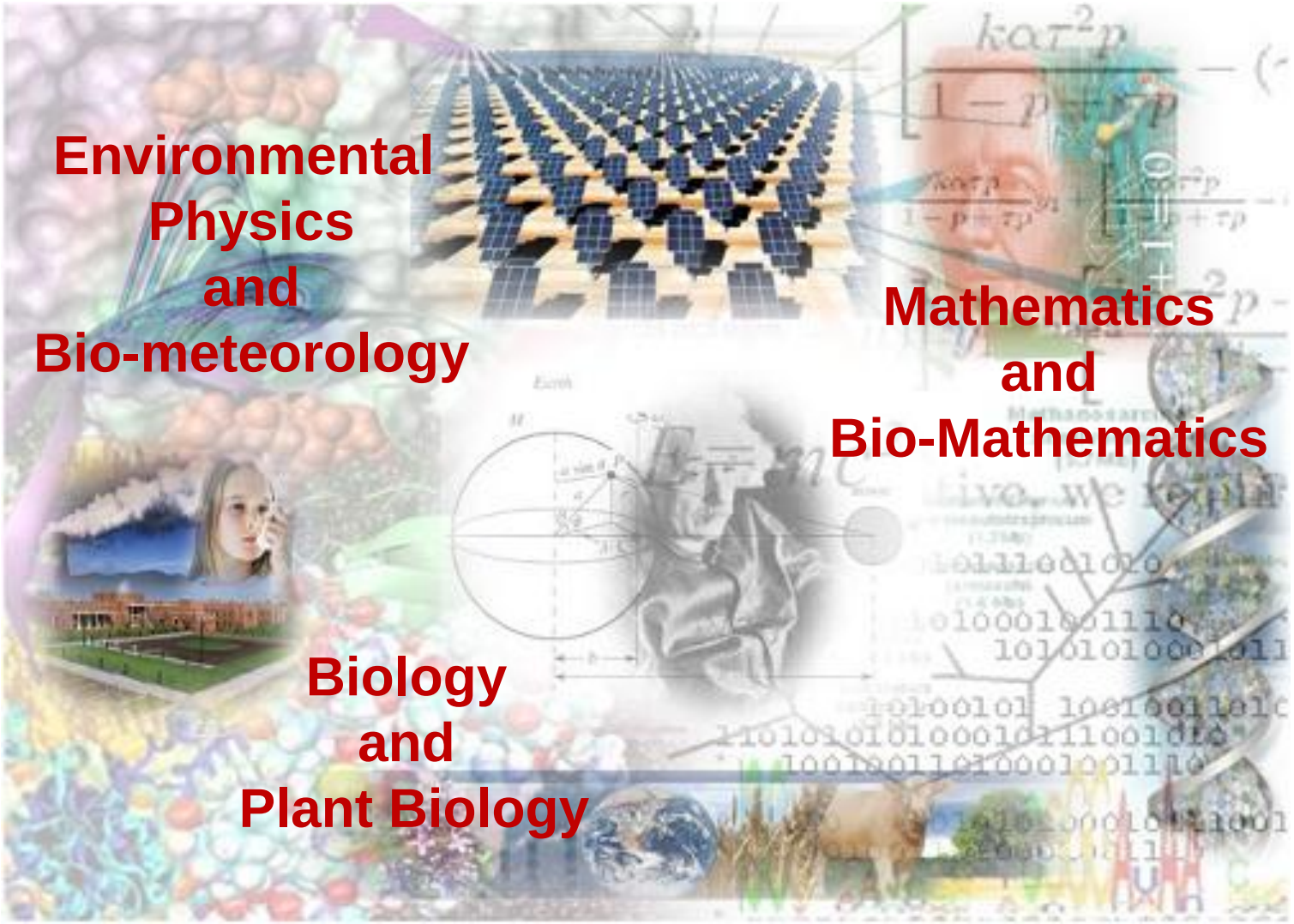
ST.THOMAS UNIVERSITY
School of SCIENCE, TECHNOLOGY & ENGINEERING MANAGEMENT

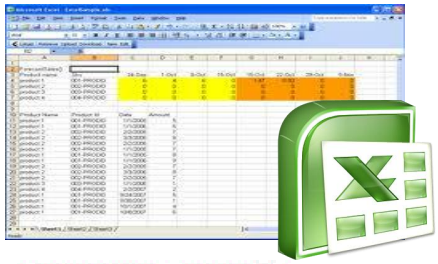
Wolfram Mathematica 8



Saint Thomas University

School of Science, Technology and Engineering Management



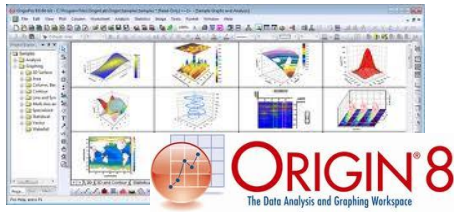


Topics of Interest

- Bio-Meteorology of Asthma in South Florida
- Air quality vs weather, Sugarcane burning
- Micro-meteorology
- Urban meteorology and Urban island effect
- Trigonometry regression and time series
- CO_2 dynamics modeling
- O_3, NO_x and PAH models
- ENSO modeling

Pre-Processing

- Import data from WxBug
- Sorting and data mining



Post-Processing

- Graphing
- Regression analysis
- Correlation analysis

Student + Mentors Presentations

- School Research Symposium
- State' s Academy of Science Annual Meetings and Articles

Mathematical Modeling

- Model's build-up
- Differential Equations
- WRF + Chem

Python

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WeatherBug & WeatherBug Achieve

Weather Parameters

WeatherBug Your Weather Just Got Better.®

Weather Laboratory

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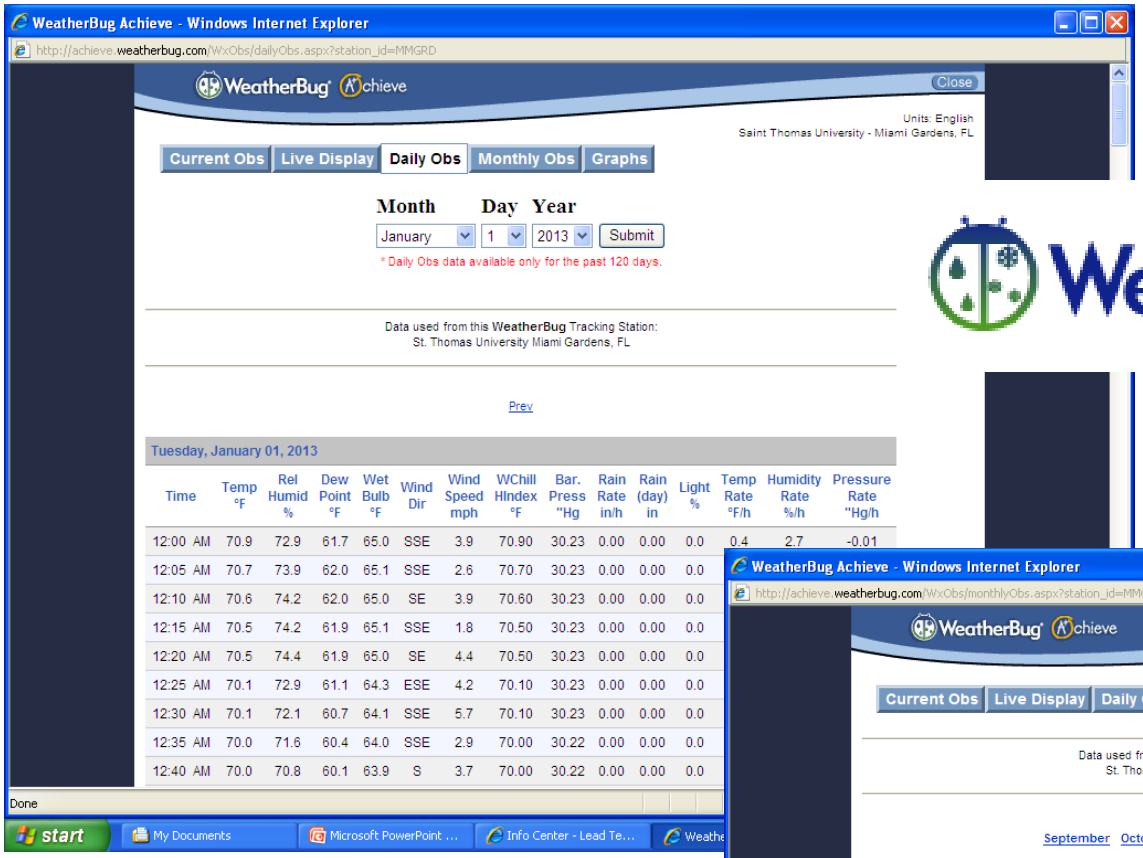
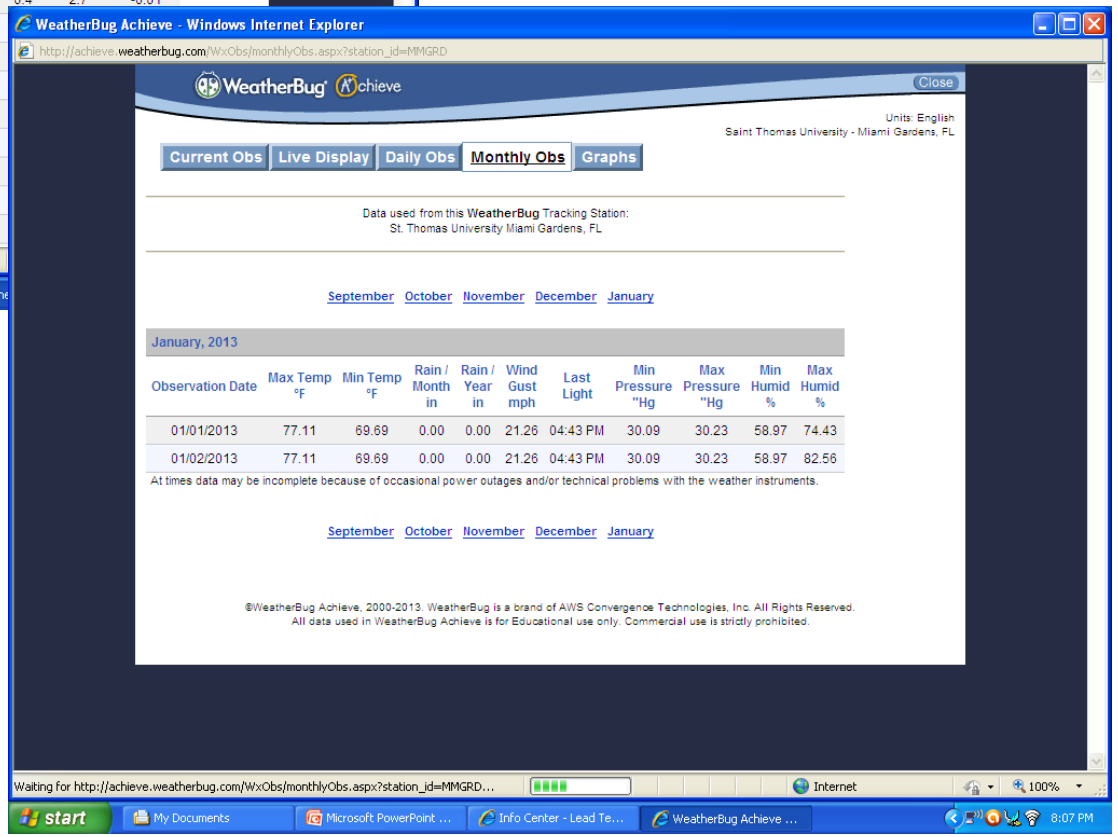
Leaders Make the Discoveries That Build Our Future

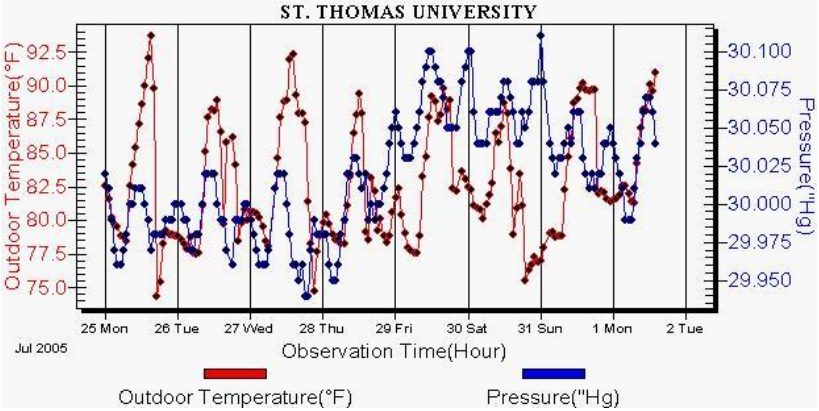
Feature	Range (English)	Accuracy (English)	Range (Metric)	Accuracy (Metric)
Temperature	-55F – 150F	+/- 1F	-45C – 60C	+/- 0.5C
Relative Humidity	0 – 100%	+/- 2%	0 – 100%	+/- 2%
Wind Speed	0 – 125 mph	+/- 2 mph	0 – 275 kph	+/- 4 kph
Wind Direction	0 – 360 deg	+/- 3 deg	0 – 360 deg	+/- 3 deg
Barometric Pressure	28 – 32” Hg	+/- 0.05”Hg	900 – 1100 mbar	+/- 5 mbar
Rainfall	Unlimited	+/- 2%	Unlimited	+/- 2%
Light Intensity	0 – 100%	N/A	0 – 100%	N/A

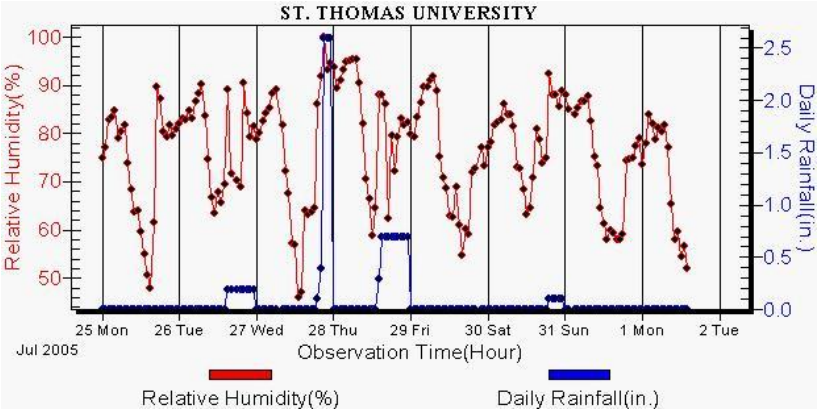


WeatherBug Achieve



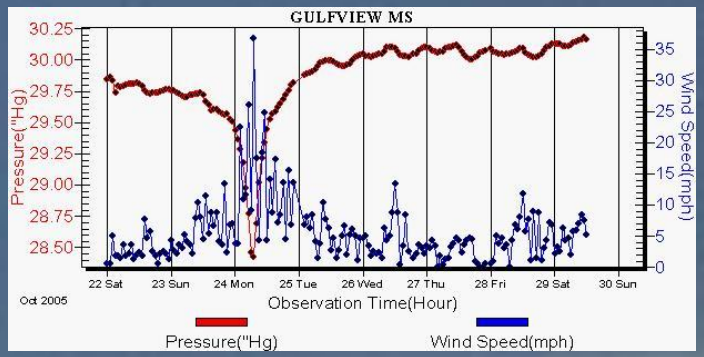
Data collected by the weather tracking station in campus. It is interesting to notice; how many parameters may be correlated at once by looking at these graphics.

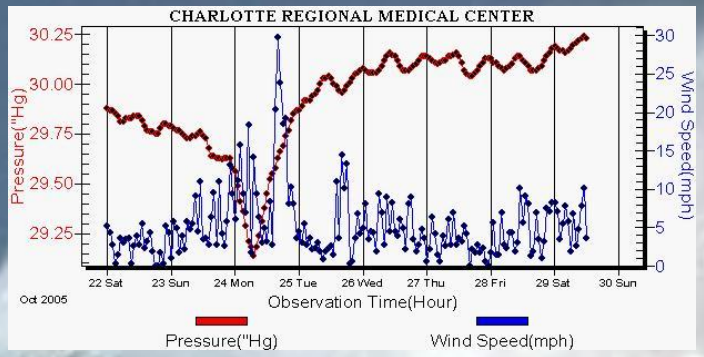


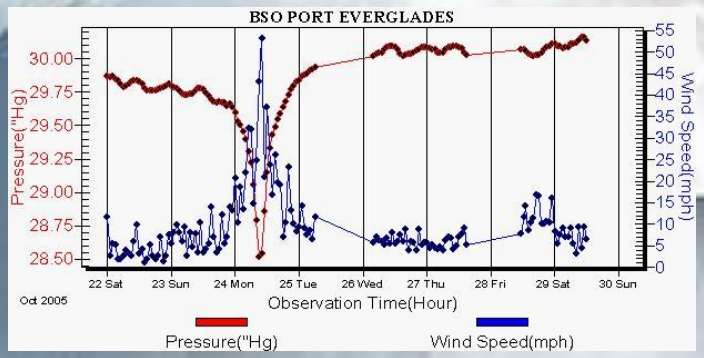


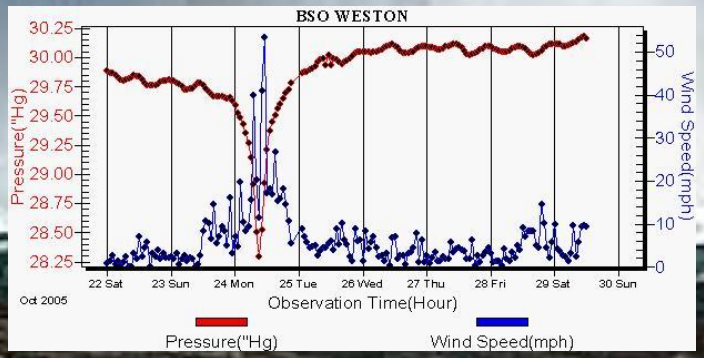
Hail storm took place on May 26, 2005 in the area of Miami Gardens and Opa-Locka. Hails of size an inch and a half were collected that day.

Hurricane Wilma
Graphs – Wilma's path from West to East Florida
Background: Havana's harbor fortress "El Morro"

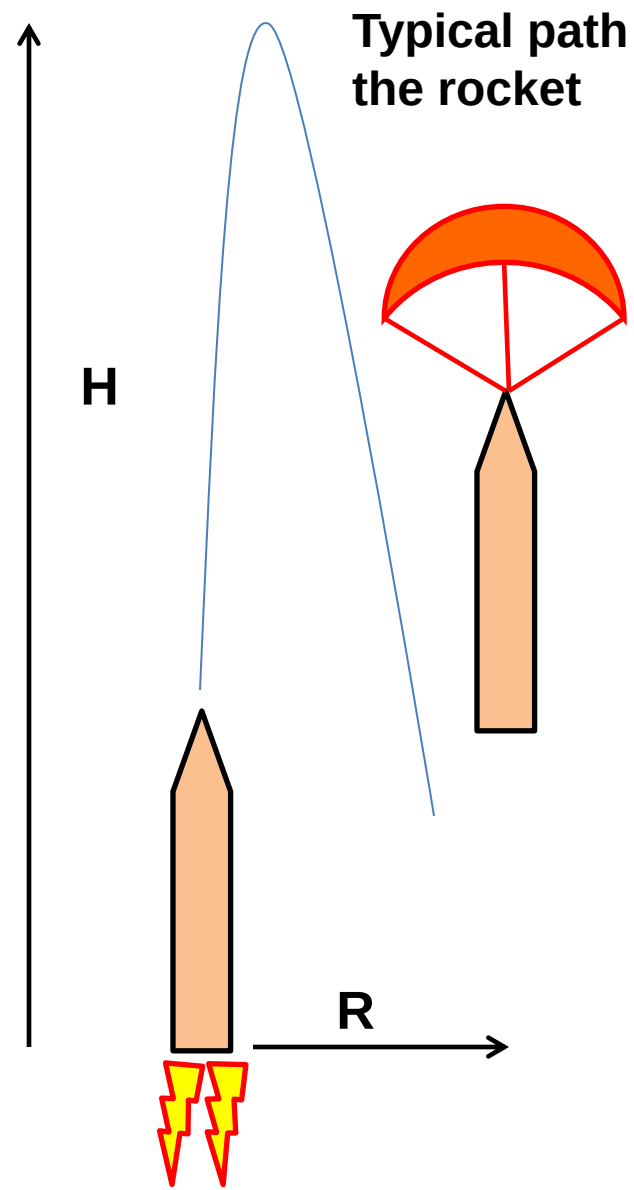








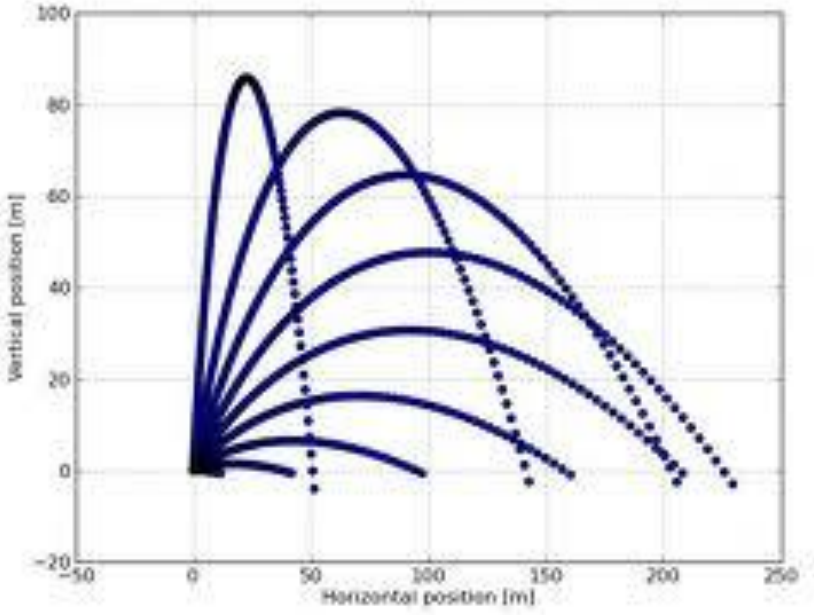
Rocketry's Club: The path from School to NASA



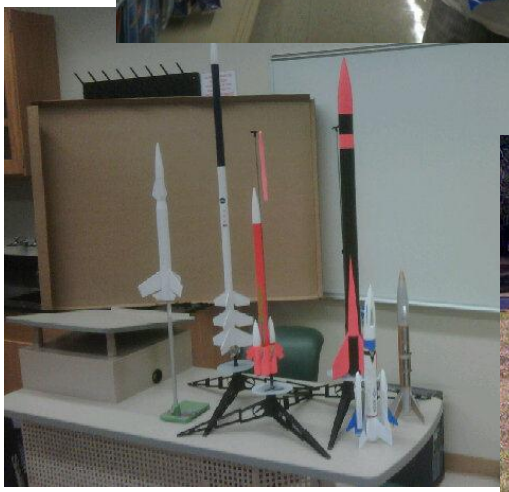
The Physics of Projectile Motion

Laws of Projectile Motion

$$\mathbf{F} = (-mg)\,\mathbf{z}$$

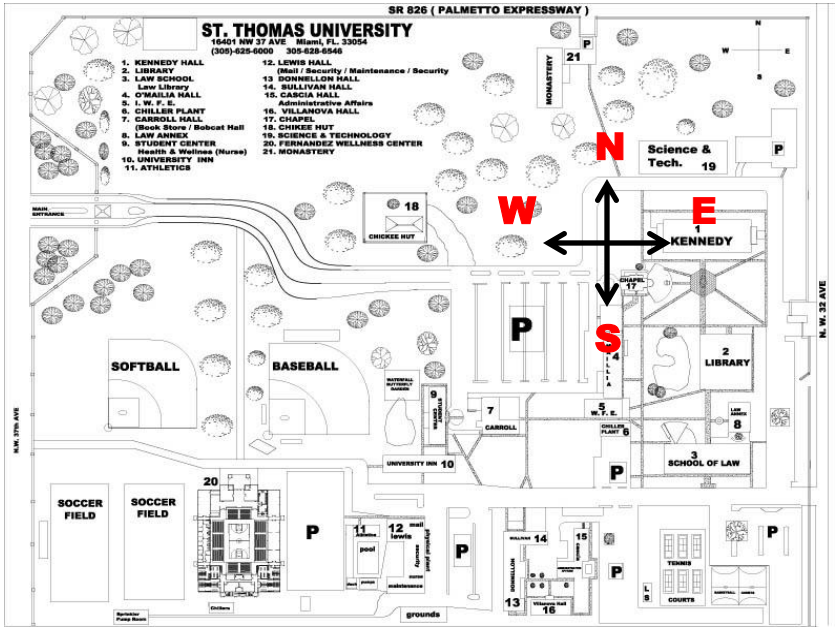


From the Hobby Store to the launching pad



Where is the Weather Component?

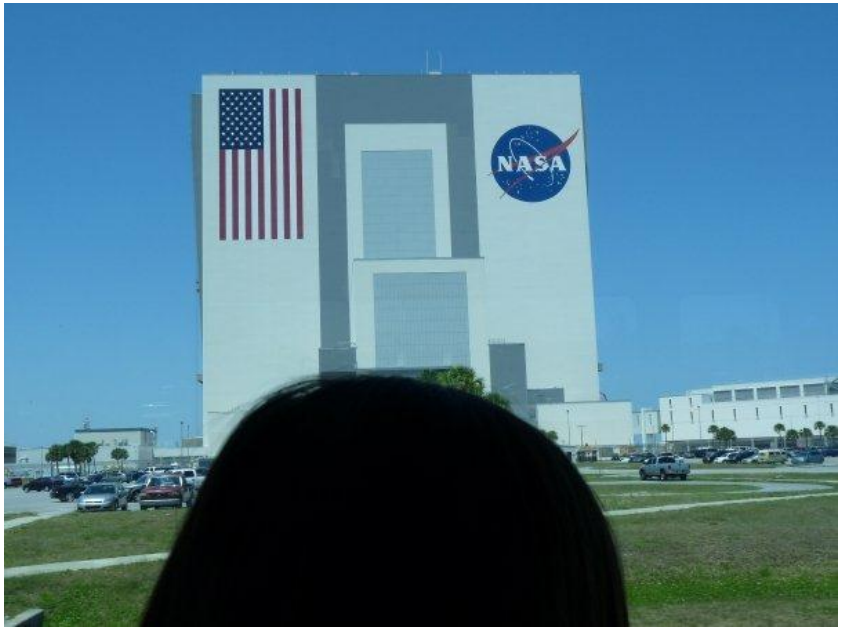
- Surface winds – speed and direction
- High level (between 300 and 600 ft) winds – speed and direction.



If **a mistake** is made about the right moment for the launch, the rocket might land either into:

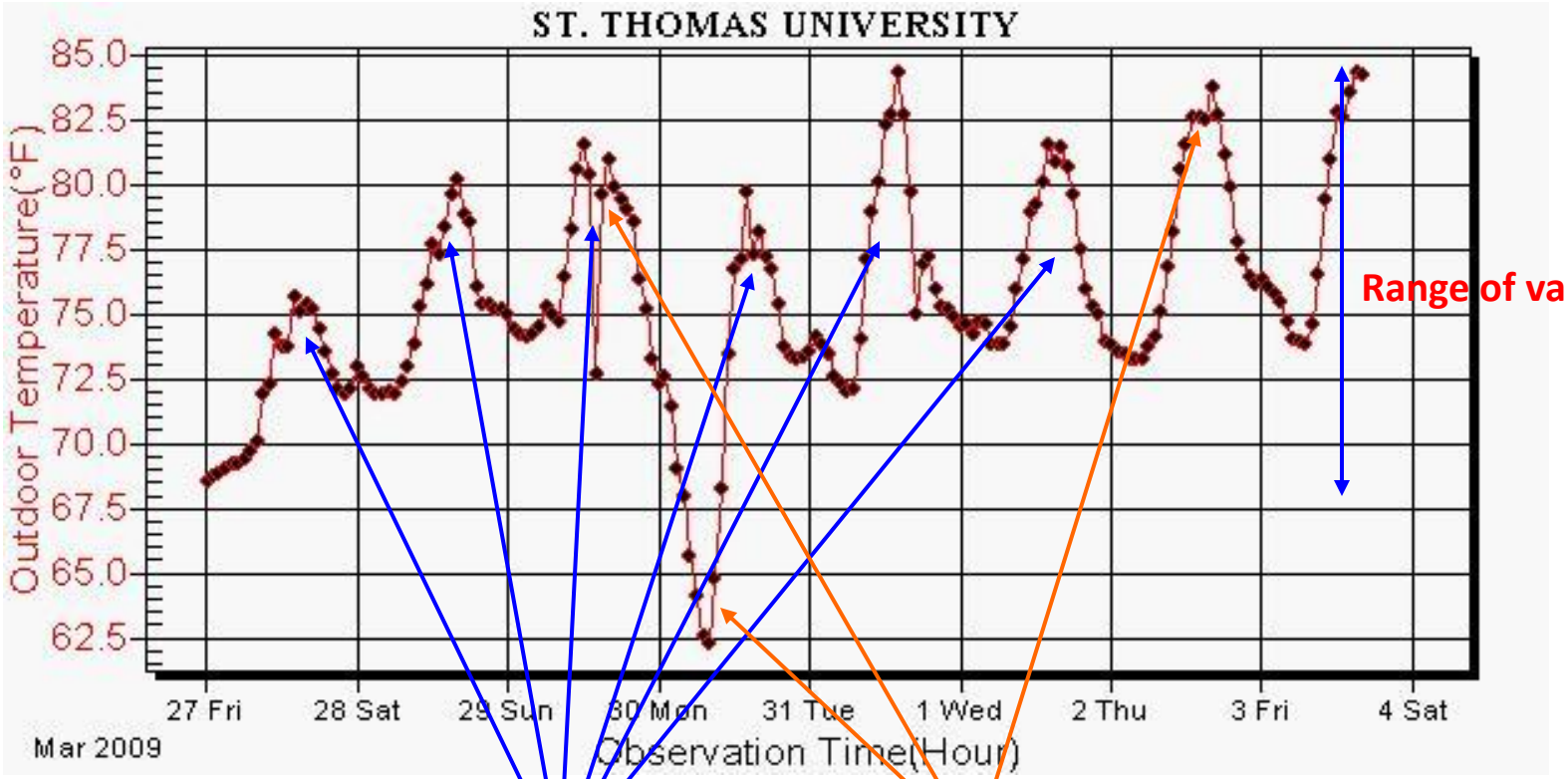
- The Palmetto Expressway
- 32 or 37 Avenues
- Forest within campus

Rocketry's Club: The path from School to NASA



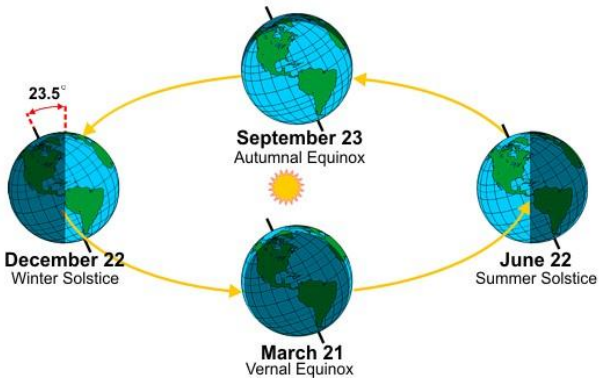
Climate and Weather Variability

Slopes, Trigonometric Functions, Average Values, and Global Warming



It is worth to notice the periodicity (24 hrs) of these peaks; however it is clear the irregular shape of all these peaks too – Why?

Cloudiness and Random Fluctuations in the weather are responsible for these irregularities



Climate and Weather Variability

Periodic Patterns in Nature and its Graphical Representation

$$y = A\sin(Bx + C) + D$$

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Steps for fitting data to a Sine function

- **Step1:** Determine A, the Amplitude of the function

A = (largest data value – smallest)/2

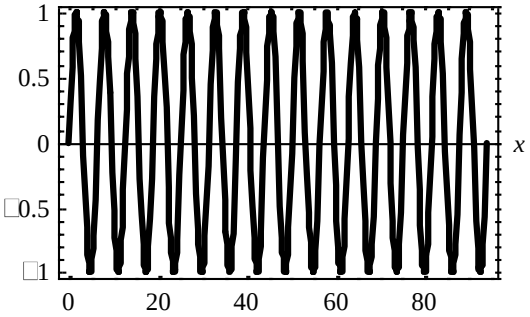
- **Step2:** Determine D, the vertical shift of the function

D = (largest data value + smallest)/2

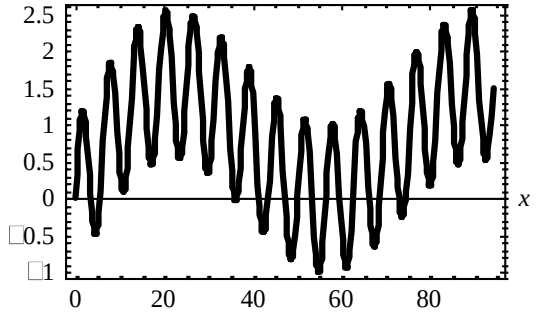
- **Step3:** Determine B, the frequency.

Since B = 2π / T, where T is the period. Check for periodicity.

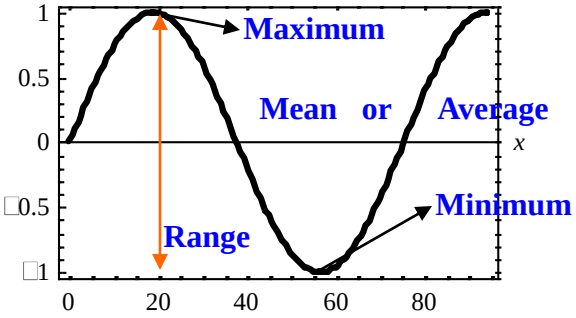
- **Step4:** Determine C, the horizontal shift.

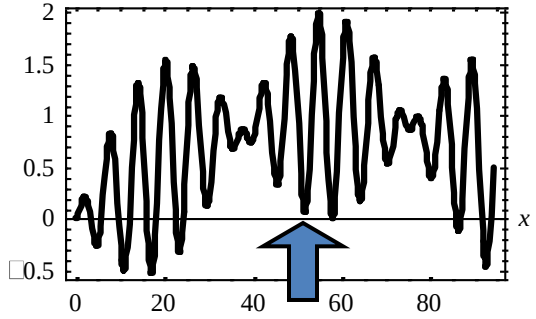


Daily variations – Days and Nights
Period = T = 24 hr

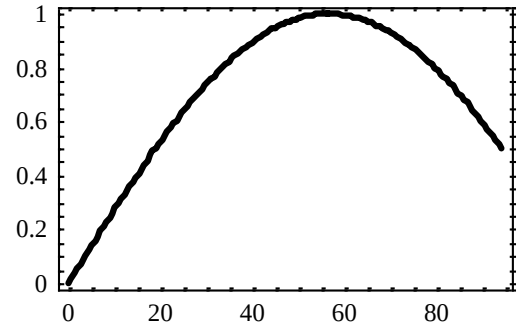


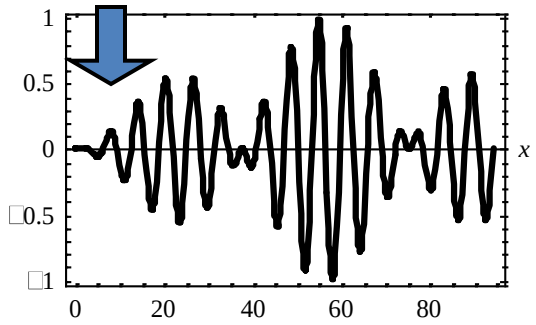
Daily, monthly, and yearly variations - three periods T_1= 24 hr, T_2= 90 days, T_3= 365 days



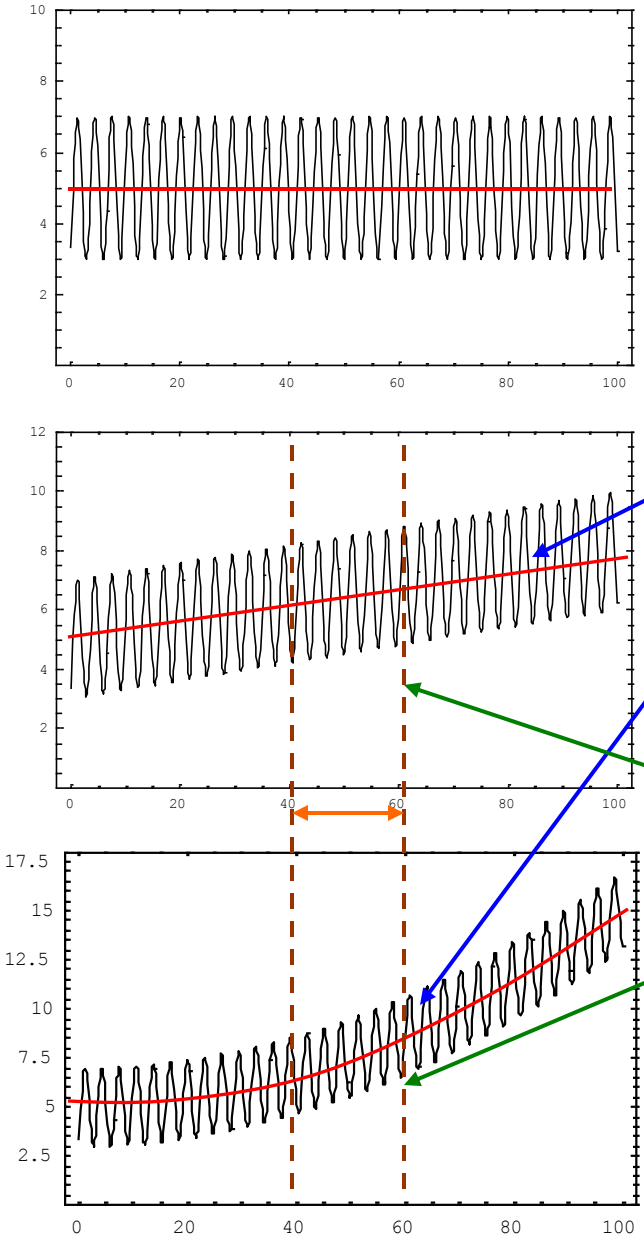


More complicated behaviors are indicators of hidden dynamical processes to be studied





Slopes, Trigonometric Functions, Average Values, and Global Warming



$$T(t) = T_M Sin(\omega t - \delta) + T_0(t)$$

$$T_0(t) = T_0 = 5$$

It is worth to notice how the trigonometric function oscillates around the main value function $T_o(t)$.

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$$T_0(t) = T_0 + at = 5 + 0.03t$$

A minimum of 30 years it is needed to make a conclusion about a warming Climate. It is worth to notice also how , short Cold intervals may coexist with a warming trend.

$$T_0(t) = T_0 + at^2 = 5 + 0.001t^2$$

Slopes, Trigonometric Functions, Average Values, and Global Warming

$$T(t) = T_M Sin(\omega t - \delta) + T_0(t)$$

Trigonometric Interpolation

$$T_0(t) = T_0$$

Case 1: The free term T_o is a constant

$$T_0(t) = T_0 + at$$

Case 2: The free term T_o is a linear function of time

$$T_0(t) = T_0 + at^2$$

Case 3: The free term To is a quadratic function of time

Weather is all about the values of these Functions at some moments of time, known as the time series

$$T_{ave} = \frac{1}{\Delta\tau} \int_{\tau_i}^{\tau_f} T(t)\, dt$$

Climate is all about the value of this Integral, known as the average value

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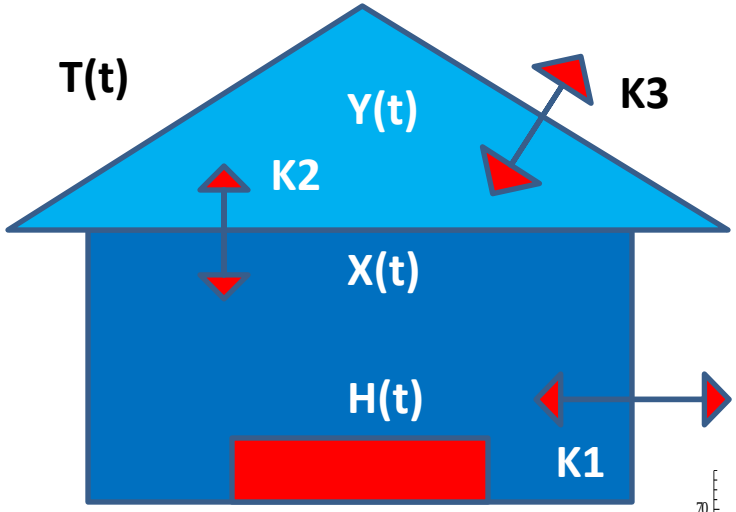
Environmental Engineering and Home Acclimatization

(Junior project)

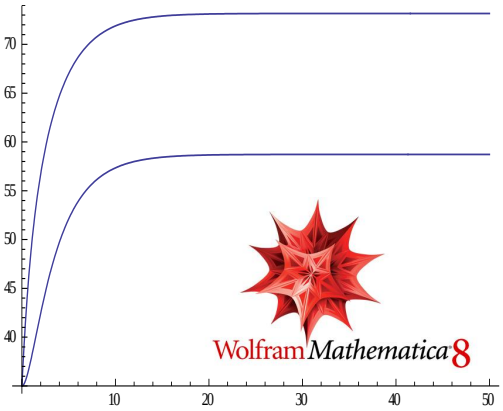


Newton's Law of Cooling

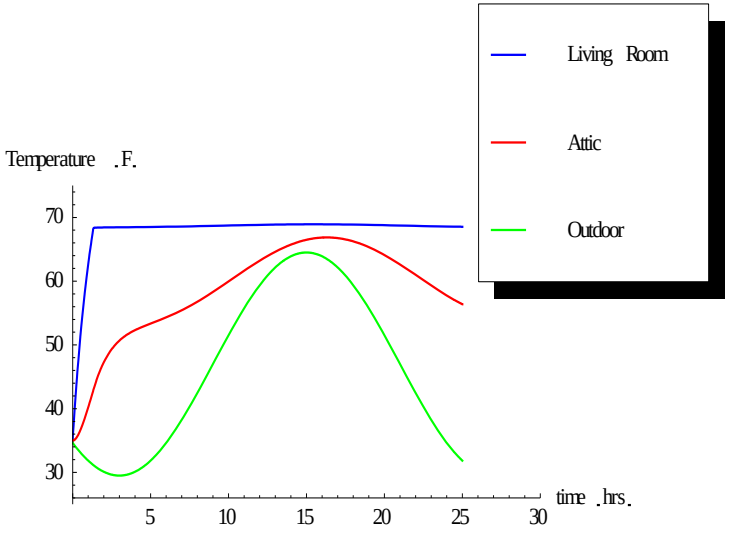
$$X'(t)=k_1[T(t)-x(t)]+k_2[y(t)-x(t)]+H(t)$$
$$Y'(t)=k_2[x(t)-y(t)]+k_3[T(t)-y(t)]$$

$k_1=0.35$, $k_2=0.46$, $k_3=0.28$

$T(t)=35$, $H(t)=20$



t	x_1	x_2
5.53	67.955	53.122
5.54	67.972	53.140
5.55	67.988	53.157
5.56	68.005	53.175
5.57	68.021	53.192
5.58	68.37	53.209

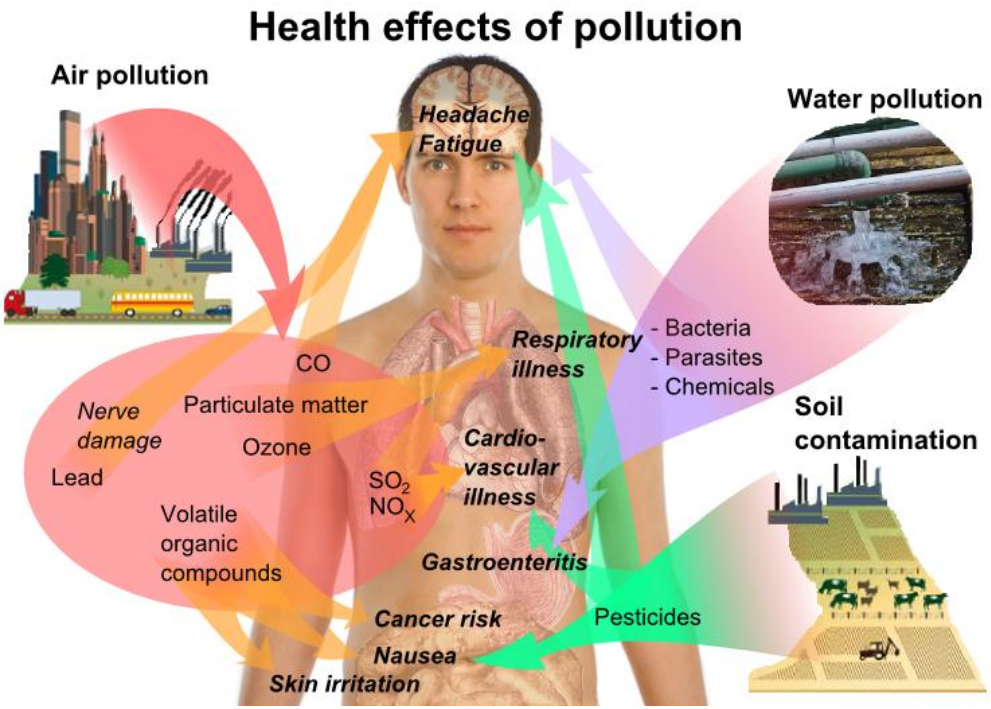


Action of the Thermostat :

H(t) = 20 if x(t)<68

0 if x(t)≥68

Outdoor Temperature: $T(t)=-17.5\sin(\pi/12)(t+3)+47$



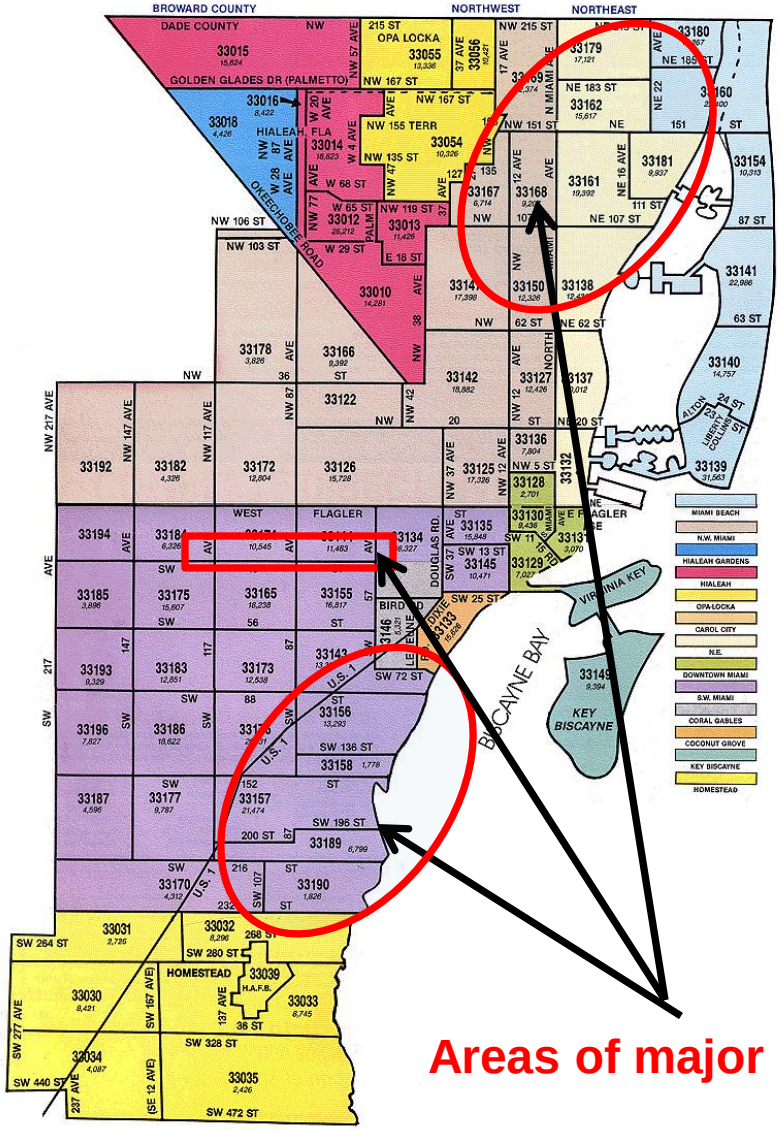
Integrated Science

- Atmospheric Chemistry
- Physiology
- Atmospheric Physics
- Statistics
- Mathematical Modeling
- Bio-Physics and Bio-Meteorology

Bio – Meteorology of Asthma

- Weather data
- Air Quality data (Ozone, Particulate Matter)
- Health data

Miami Dade Asthma Snapshot



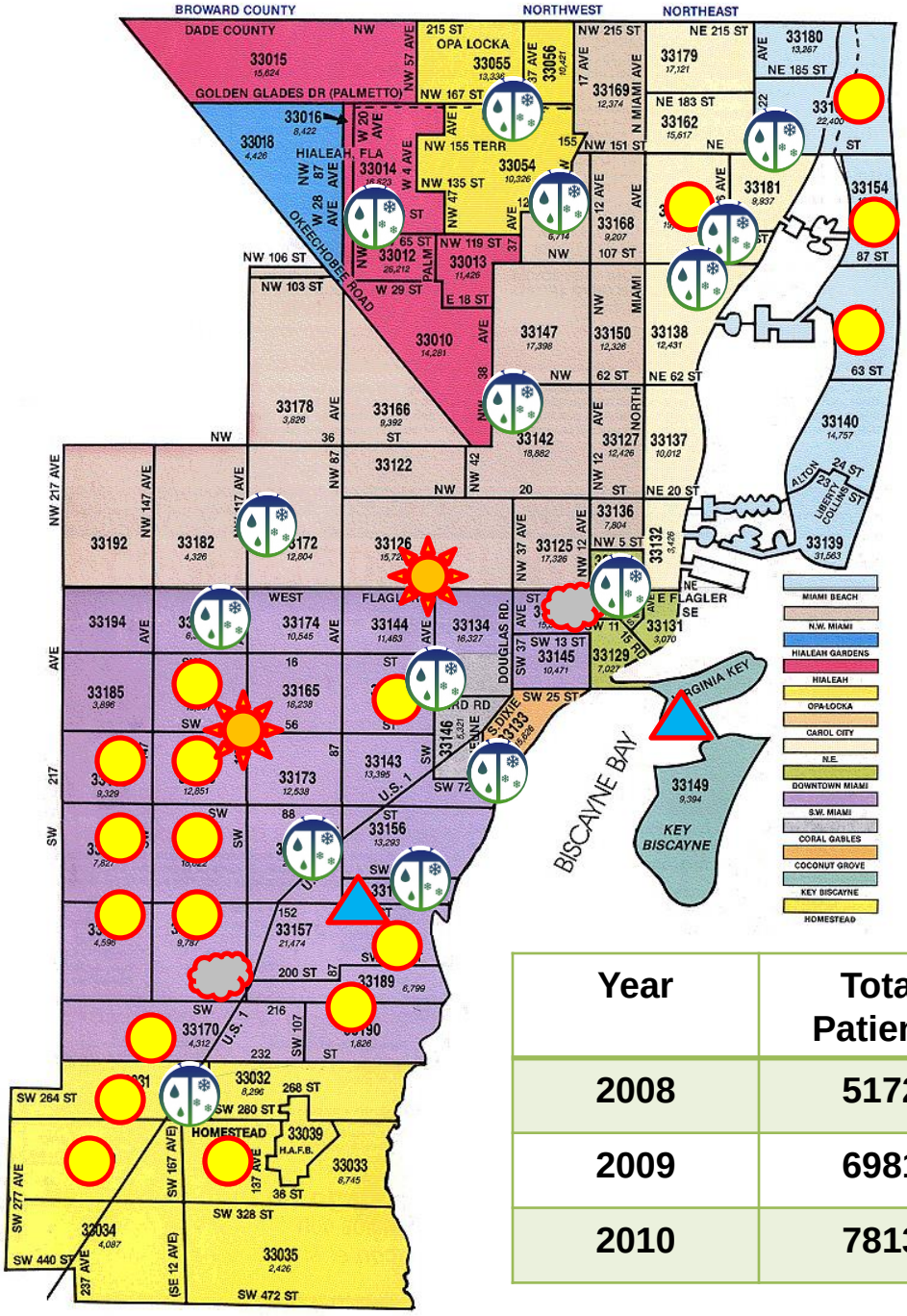
Asthma Statistics Worldwide

Number of people diagnosed: more than 150 M
Europe: the # of cases has doubled
USA: the number of cases has increased more than 60%
India: between 15 and 20 M
Africa: between 11 and 18% population
Number of deaths yearly: around 180,000

Miami Dade County , Florida

7.1% Middle and HS children were reported with asthma
The number of hospitalizations due to asthma has doubled.
The number 1 cause of school absences and 35 % of parents missed work

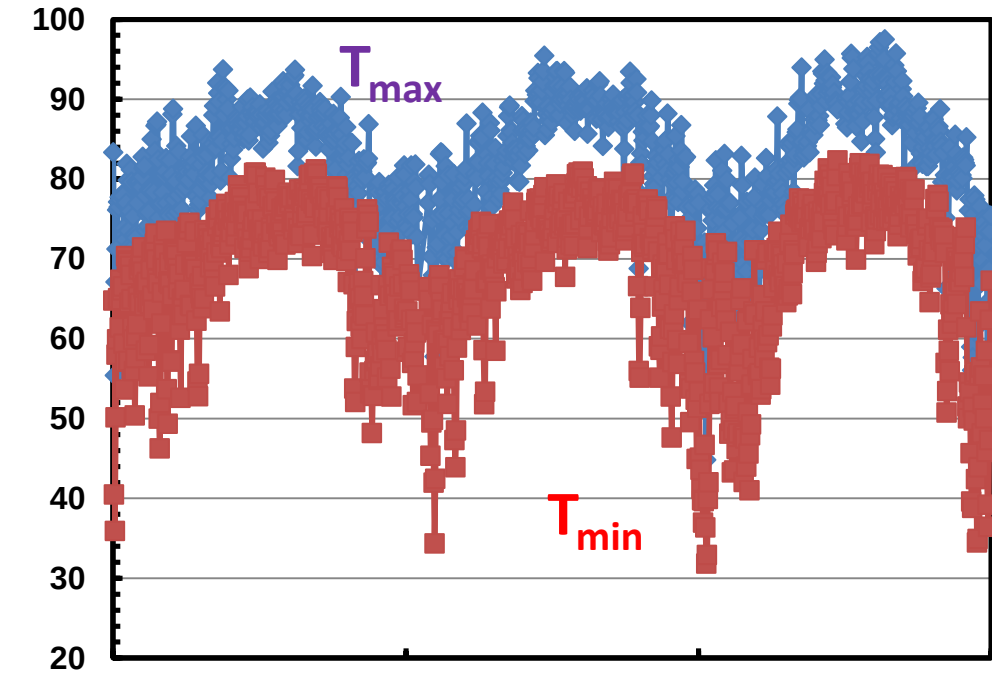
Areas of major incidence

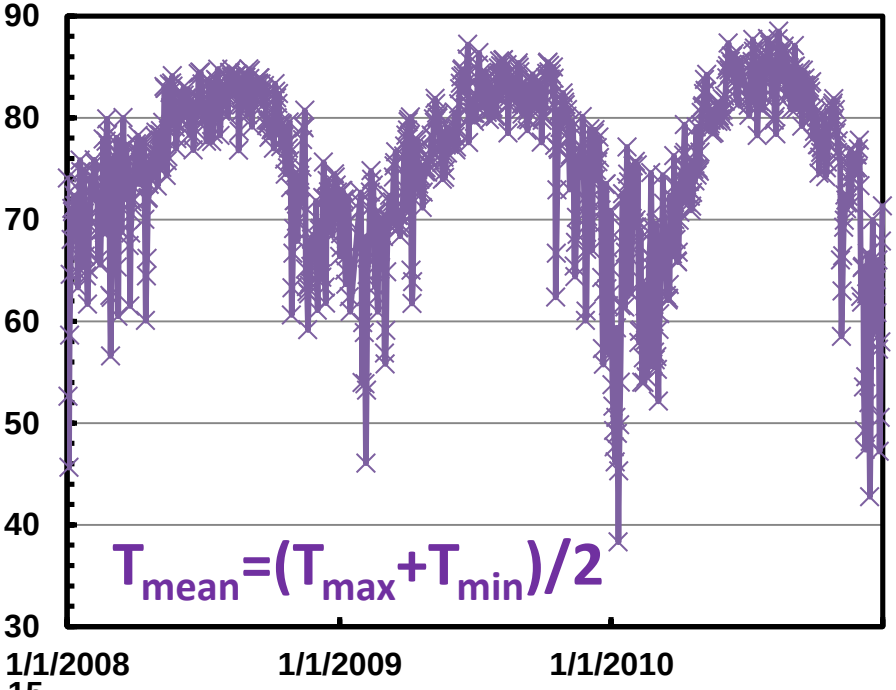


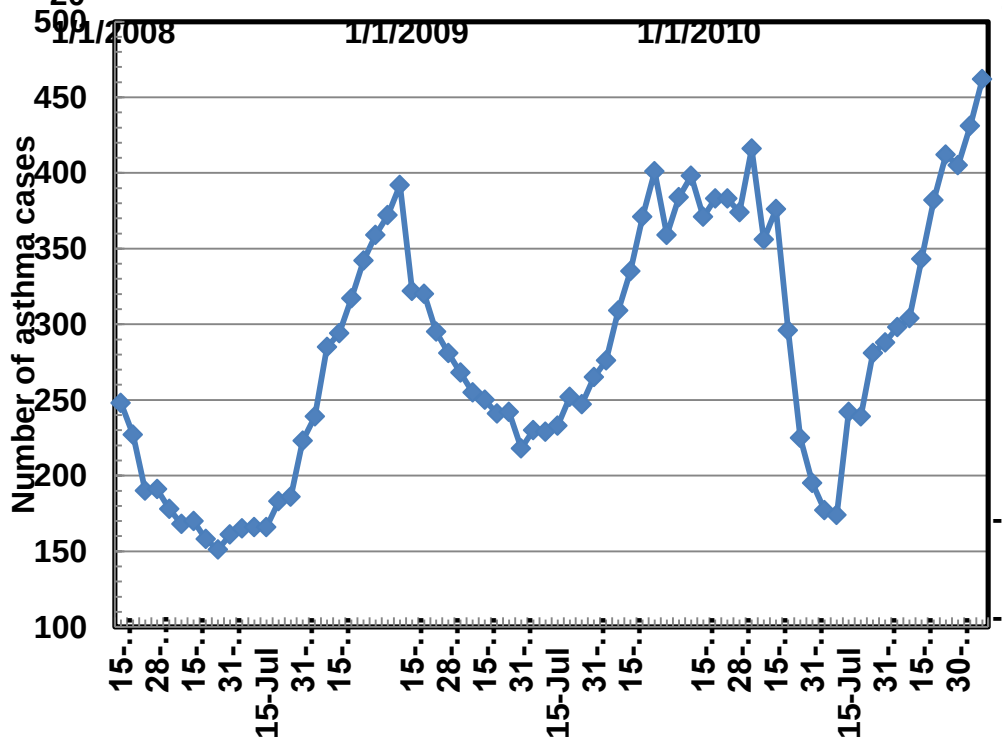
- Zip codes patients came from
- WeatherBug Mesonet stations
- NWS stations, MIA & Tamiami
- Ozone measuring stations
  - UM, RSMAS
  - Purdue Medical Center
- Particulate Matter $PM_{2.5}$
  - Fire Stations # 5, & Homestead

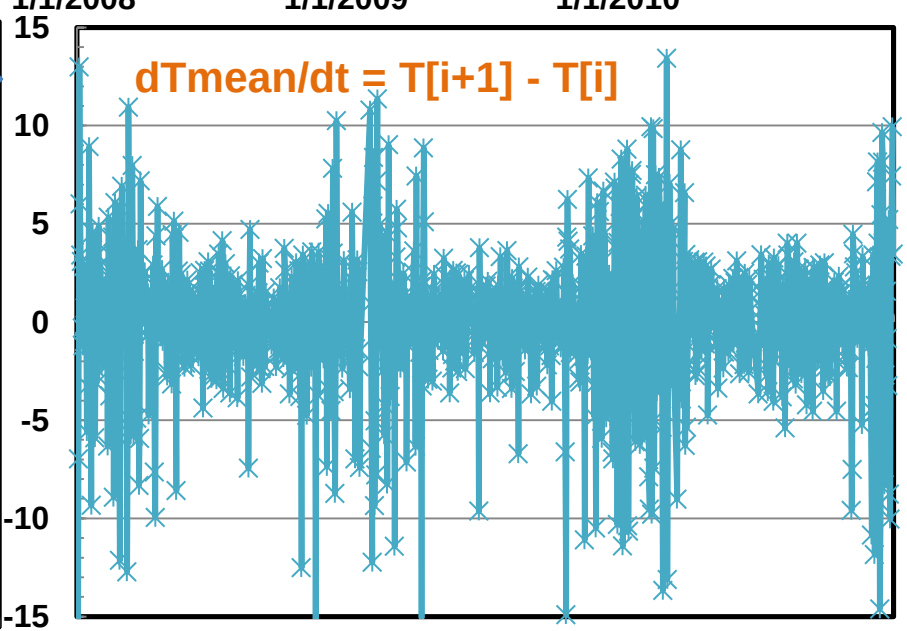
Year	White	White Hispanic	Non White Hispanic	African American
2008	490	505	820	510
2009	350	256	650	525
2010	528	495	605	657

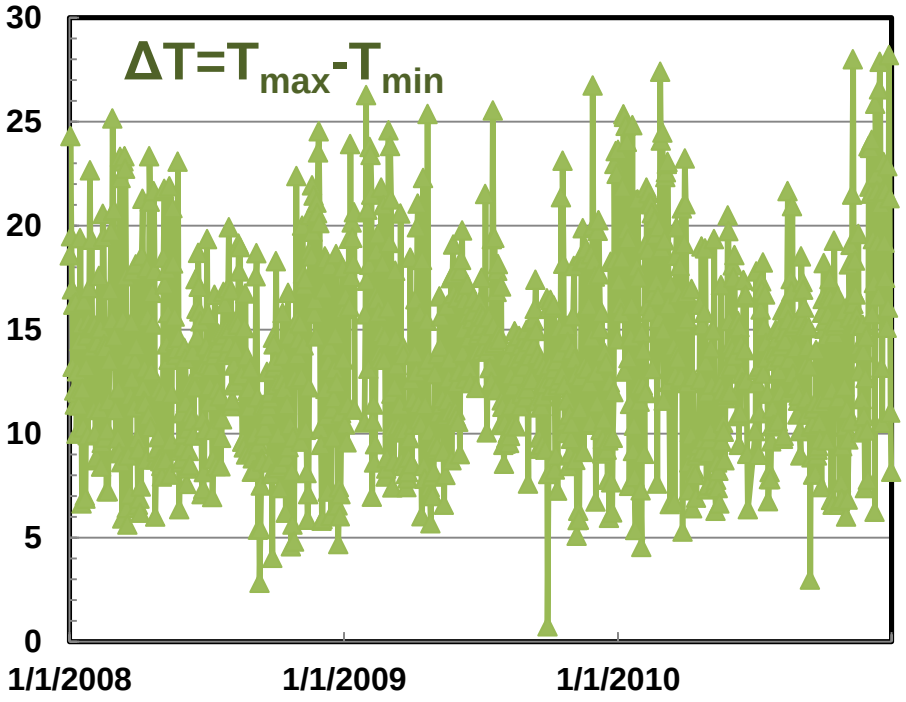
Year	Total Patients	Total Respiratory	Total Asthma	% of asthma
2008	5172	2950	2222	43
2009	6981	4301	2680	38
2010	7813	4960	2853	37

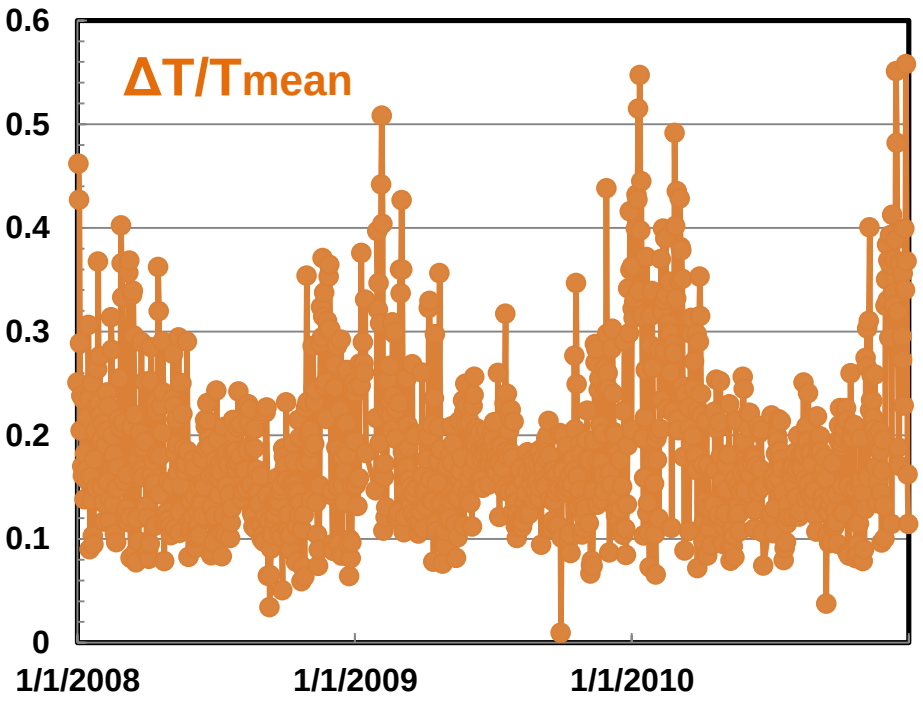

T_{max}
T_{min}

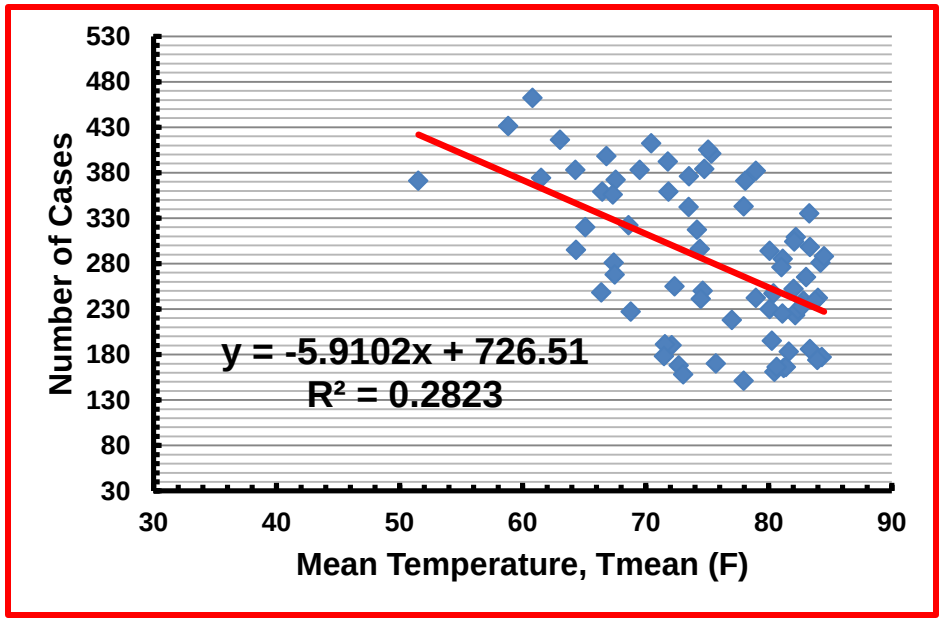

$T_{mean}=(T_{max}+T_{min})/2$
1/1/2008
1/1/2009
1/1/2010


Number of asthma cases
1/1/2008
1/1/2009
1/1/2010


dTmean/dt = T[i+1] - T[i]







Linear Regression Model

Independent Variable: T_{mean}

Dependent Variable: # of Cases

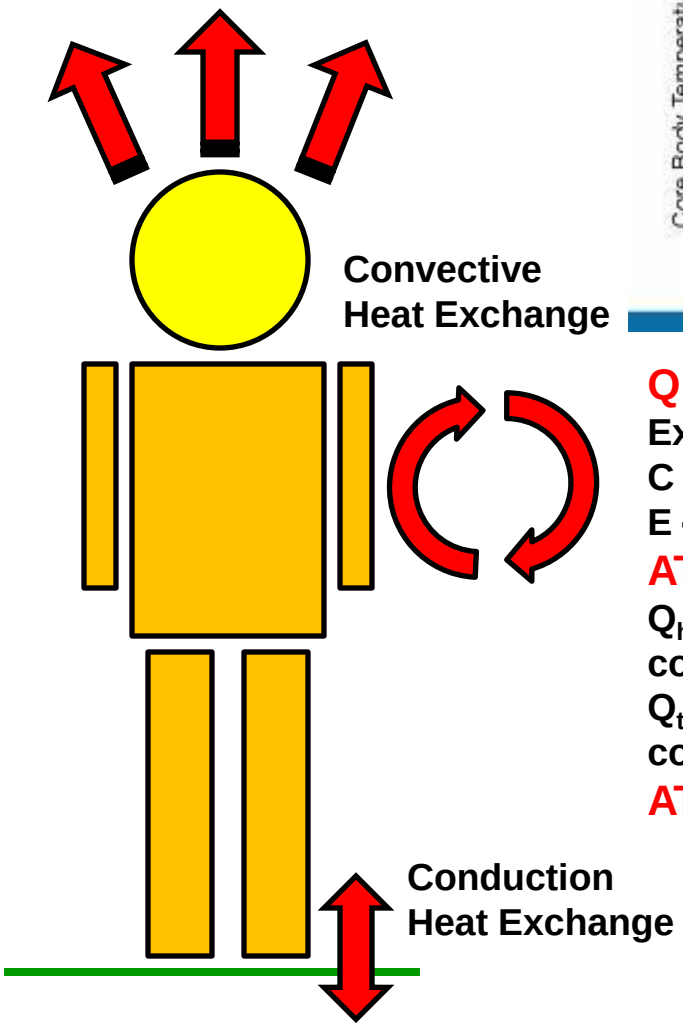
Correlations between the number of cases and the given set of variables

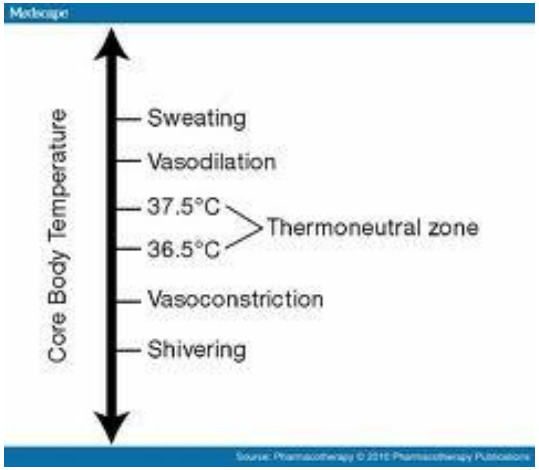
	Tmax	Tmin	ΔT	Tmean	dT/dt	ΔT/Tmean
Pearson (r)	- 0.524	- 0.529	0.357	- 0.531	- 0.122	0.487
P - value	0.000	0.000	0.002	0.000	0.306	0.000
Kendall - τ	- 0.325	- 0.301	0.159	- 0.311	- 0.122	0.264
P - value	0.000	0.000	0.048	0.000	0.132	0.002
Spearman - ρ	- 0.485	- 0.463	0.224	- 0.475	- 0.148	0.375
P - value	0.000	0.000	0.059	0.000	0.215	0.001

	ΔP	Pmean	dP/dt	ΔP/Pmean	ΔH	Hmean	dH/dt	ΔH/Hmean
Pearson (r)	0.367	- 0.021	0.082	0.42	0.452	- 0.213	- 0.015	0.445
P - value	0.002	0.862	0.491	0.000	0.000	0.073	0.899	0.000
Kendall - τ	0.269	0.008	0.045	0.291	0.282	- 0.052	0.006	0.264
P - value	0.001	0.922	0.579	0.000	0.000	0.521	0.938	0.001
Spearman - ρ	0.388	0.001	0.063	0.415	0.402	-0.091	0.003	0.373
P - value	0.001	0.996	0.600	0.000	0.000	0.445	0.979	0.001

The Acclimatization Thermal Strain Index – ATSI

(following ideas suggested by C.R. de Freitas and E.A. Grigorieva
International Journal of Biometeorology (2009) 53: 307 – 315)

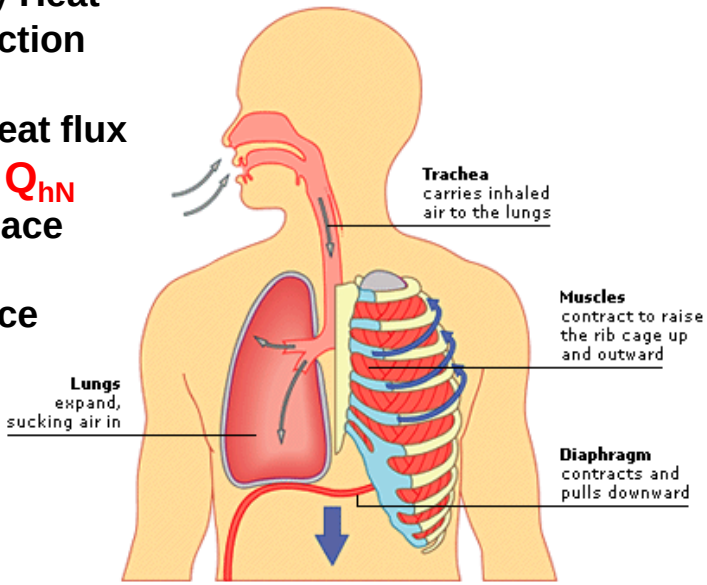


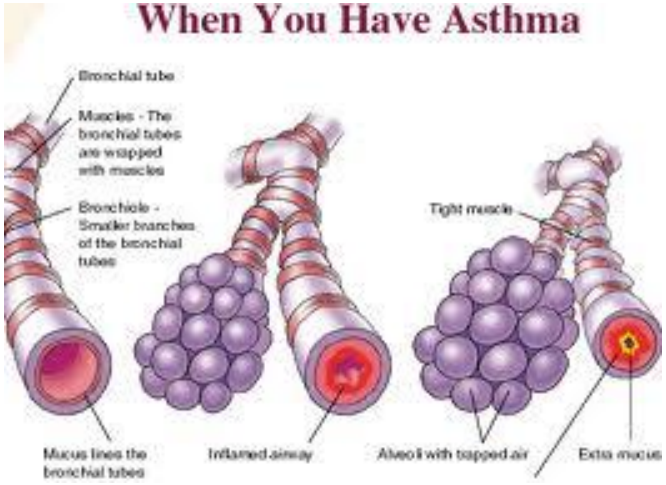


Heat loss from the skin can account for most of the heat loss from the human body, but the skin is usually covered by clothing, then insulated

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

$Q = C + E$ --- Respiratory Heat Exchange, Forced Convection
C – Dry heat flux
E – Evaporative (latent) heat flux
$ATSI = 100\ (Q_{hN} - Q_t) / Q_{hN}$
Q_{hN} – heat exchange in place computed from Normals
Q_t – heat exchange in place computed at moment t
ATSI < 0 cold strain





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 microflora to penetrate the protective barrier of lungs and may be the reason for increased morbidity.**

$Q = C + E$

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

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

M – Metabolic heat rate (W / m^2)

A – DuBois body area (m^2)

$\mathbf{T_{core}}$ **–** Body core temperature (^oC)

T – ambient air temperature (^oC)

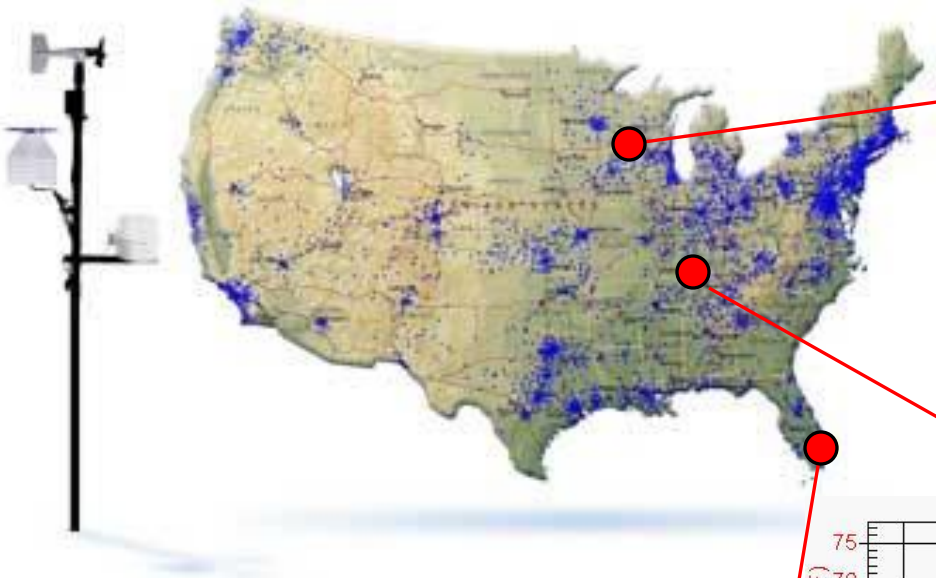
e – vapor pressure of ambient air (mm Hg)

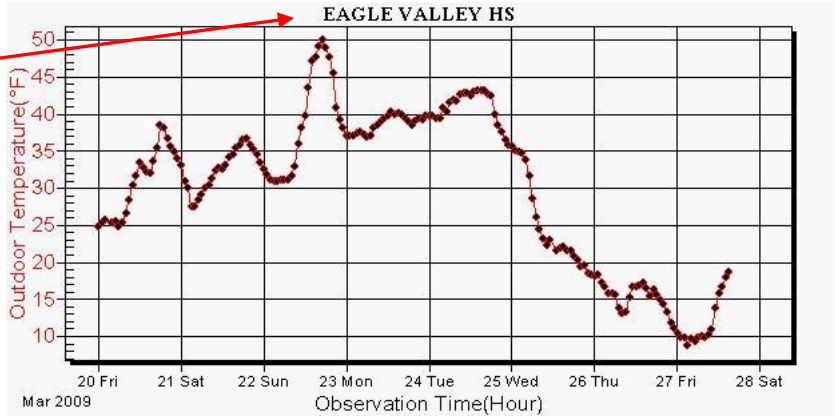
$\mathbf{e_a}$ **–** vapor pressure of core air (mm Hg)

M = 90 W / m^2 person standing relaxed

$\mathbf{e_a}$ **= 44 mm Hg**

$\mathbf{T_{core}}$ **= 37 ^oC**

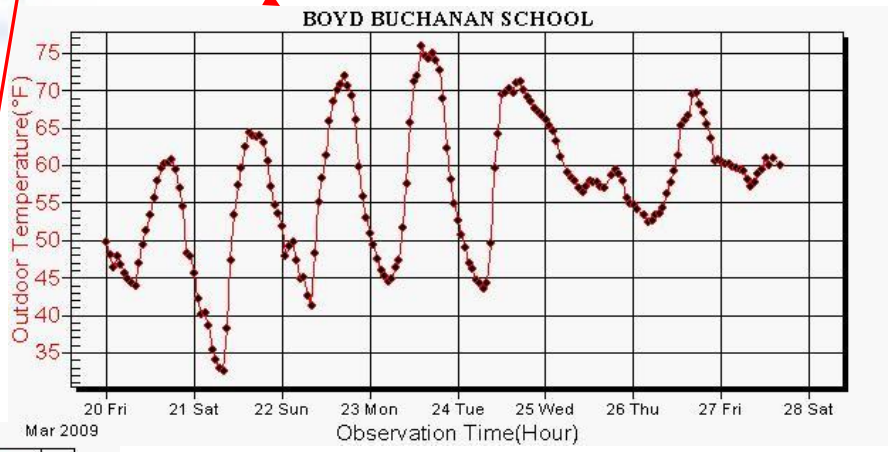




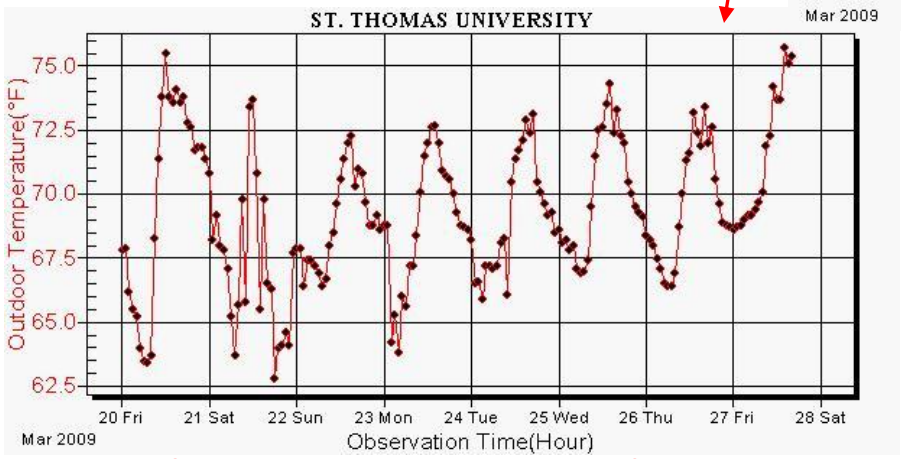
Eagle Valley HS, Eagle Bend, MN

Tourism and Recreation

Involves either traveling to distant places or participating in activities that are quite different from those one has become accustomed to at Home.



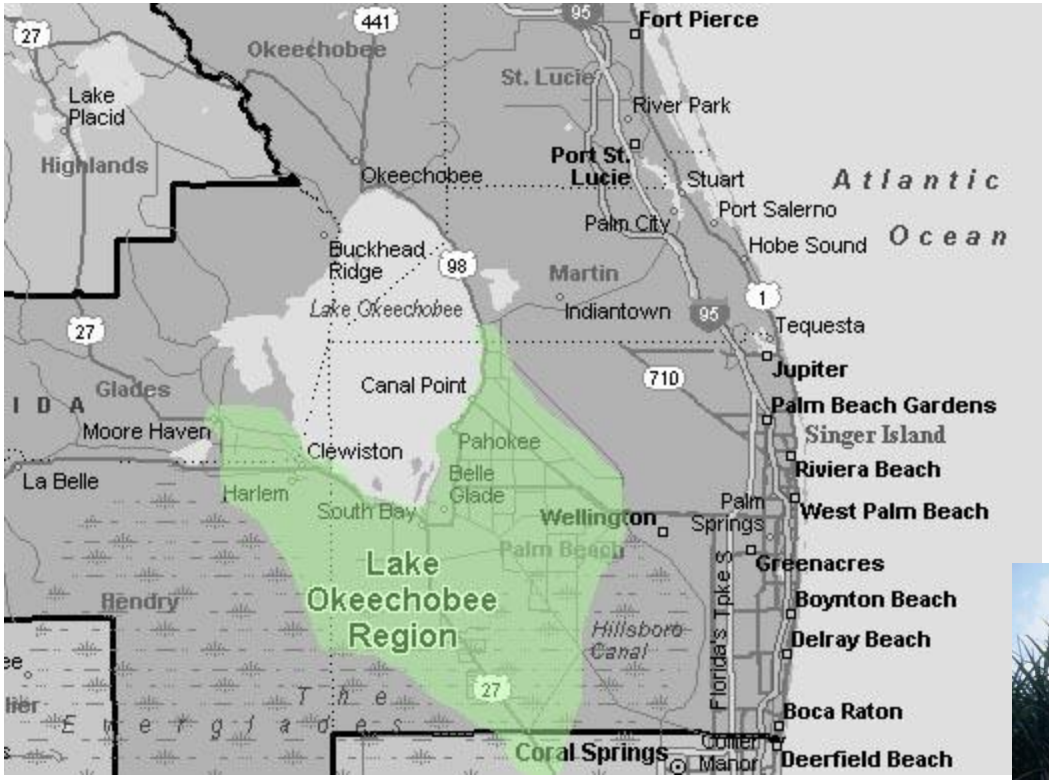
Boyd Buchanan, Chattanooga, TN



St. Thomas University, Miami Gardens, FL

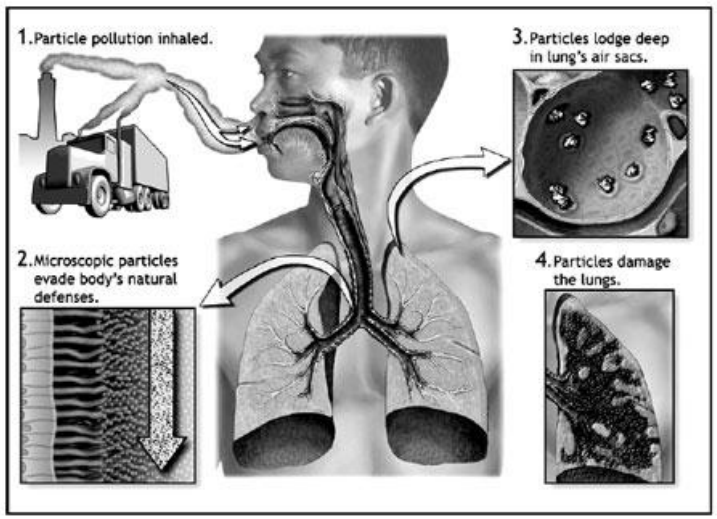
Adaptation to Changing Weather

Involves the acclimatization to new weather conditions in a given season, it may be cold weather or hot weather. It also might include the response to Heat wave passage or strong freezing Conditions. It might occur at the same place, and no traveling is necessary.

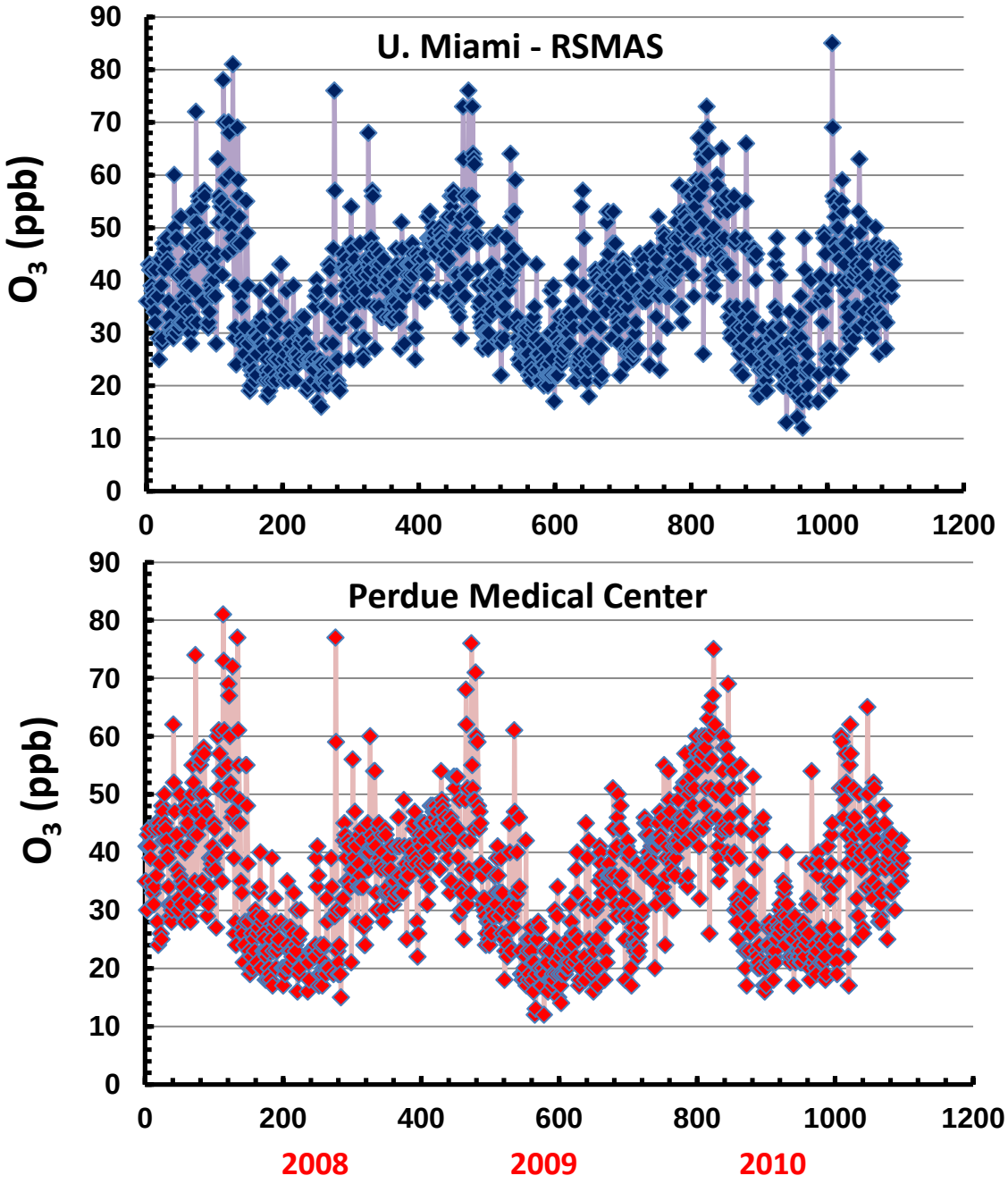


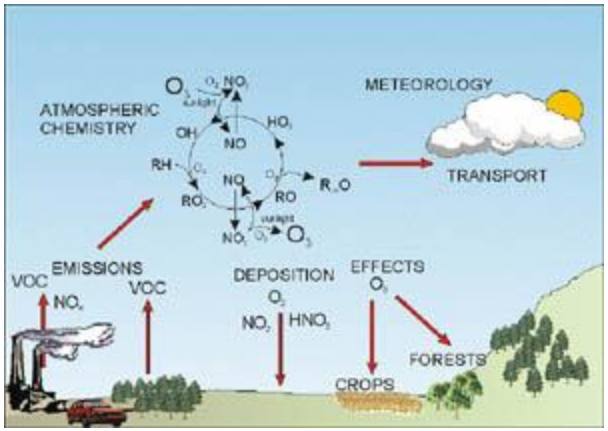
Sugarcane burning and Air quality

- **Weather conditions**
- **Air quality indicators $PM_{2.5}$**

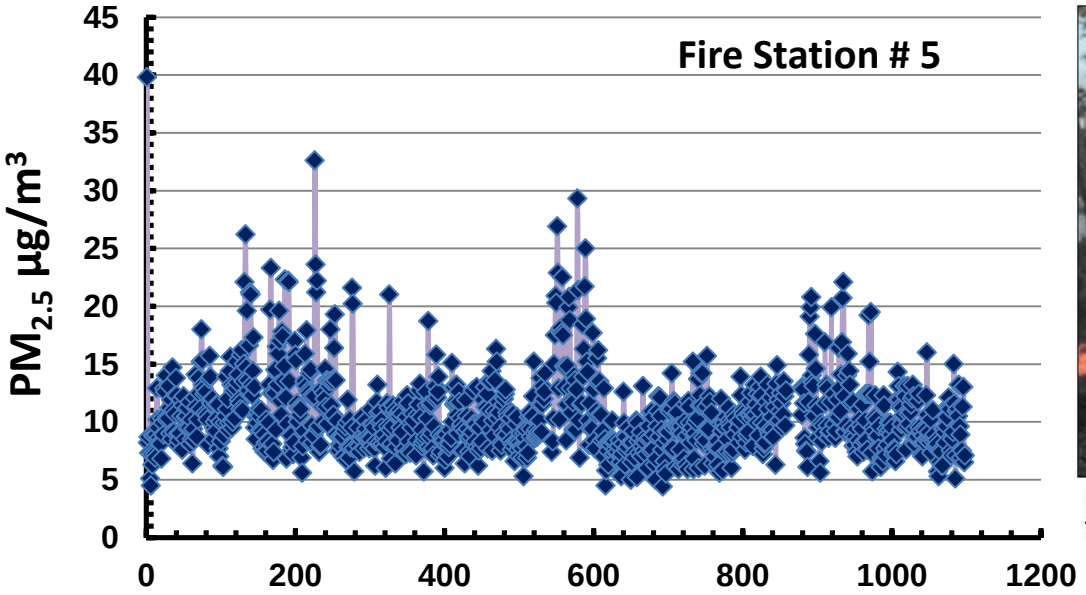


Surface Ozone Level Miami Dade





Particulate Matter $PM_{2.5}$



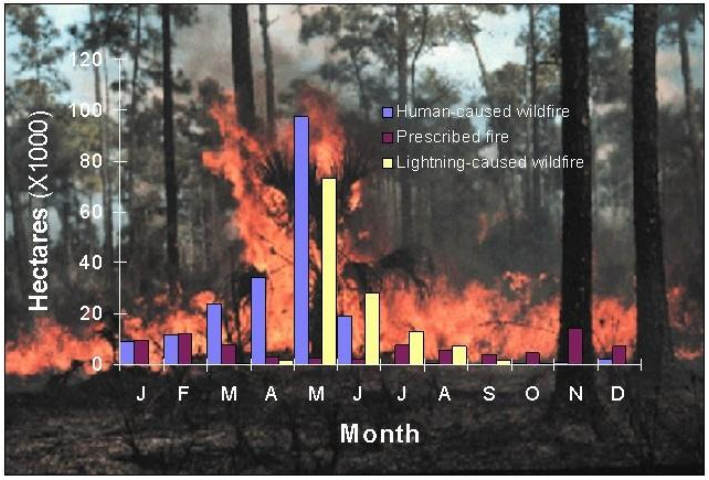
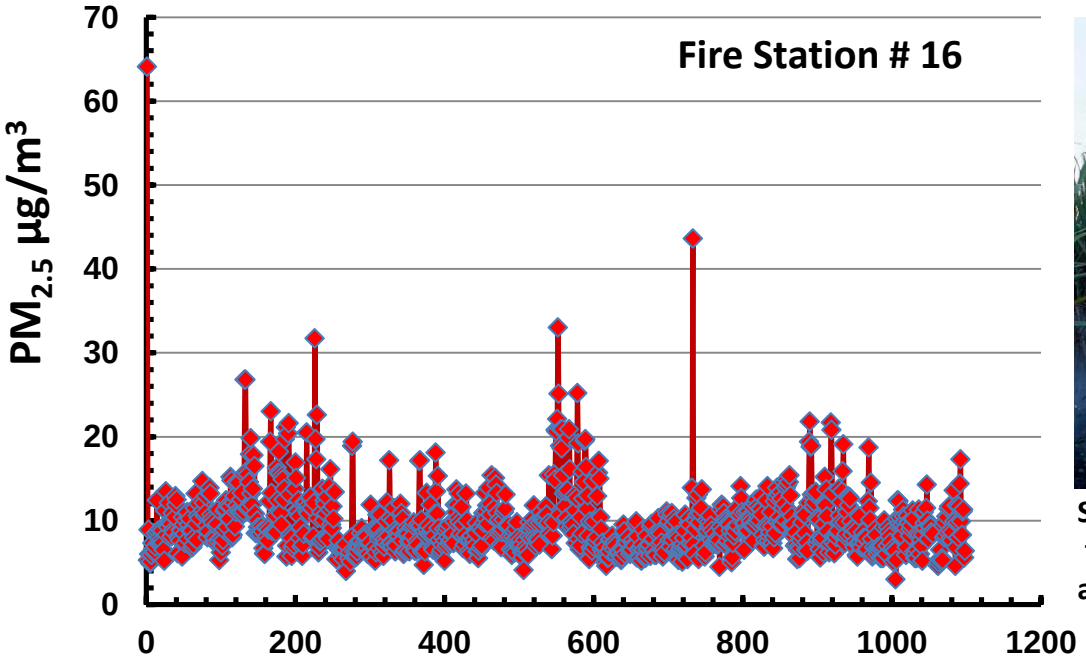


Figure 2. Monthly distribution of area burned by cause. Data from Everglades National Park, 1948-1997.



Sugarcane controlled burning in preparation for harvest. Sugarcane plantations are around the east side of the Lake Okeechobee

Prevailing Winds Over the Years

December – February 2006, 2009, 2012 (Month data)

ORIGIN 8
The Data Analysis and Graphing Workspace

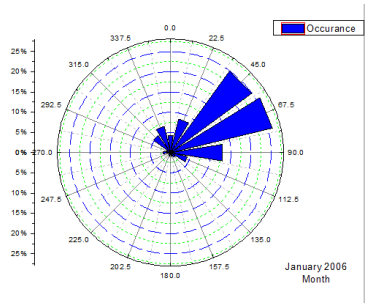
2006

December 2005

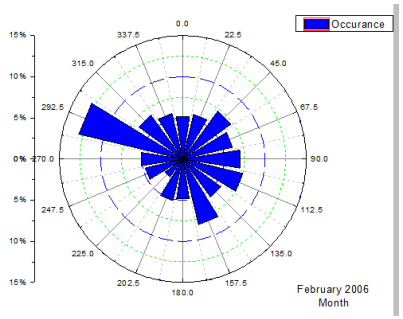
Data Unavailable

Daily Obs values for 2006 produced the average

January 2006

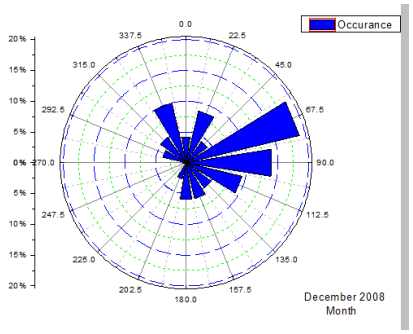


February 2006

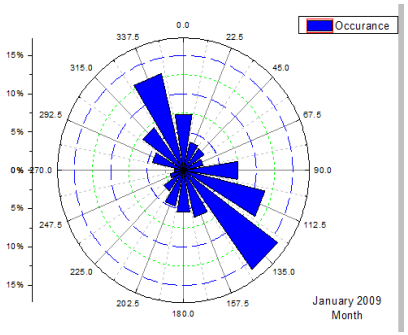


2009

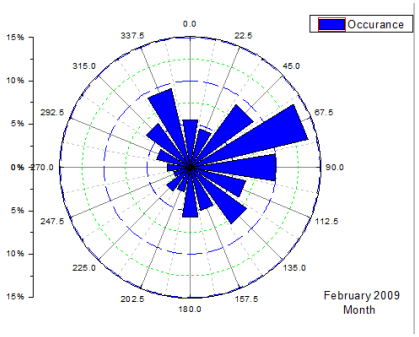
December 2008



January 2009

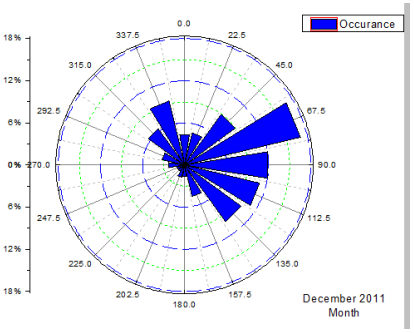


February 2009

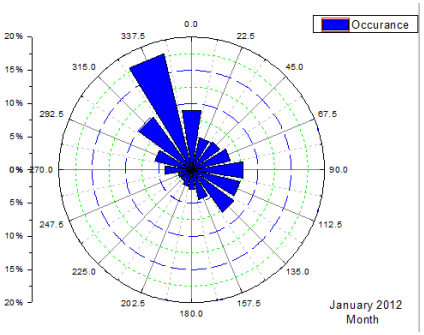


2012

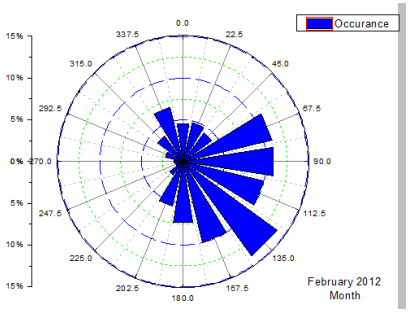
December 2011



January 2012



February 2012



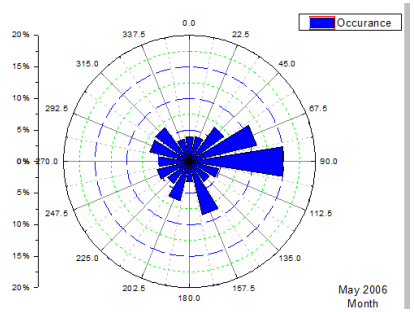
Prevailing Winds Over the Years

May – July 2006, 2009, 2012 (Month data)

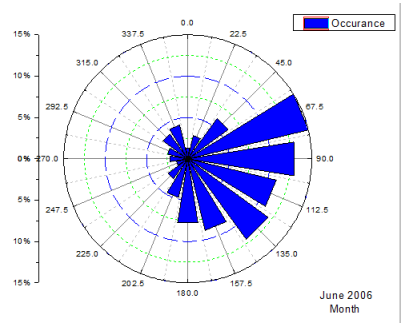
ORIGIN 8 The Data Analysis and Graphing Workspace

2006

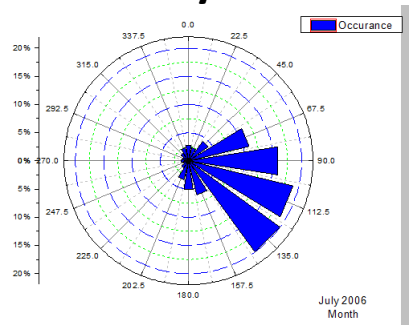
May 2006



June 2006

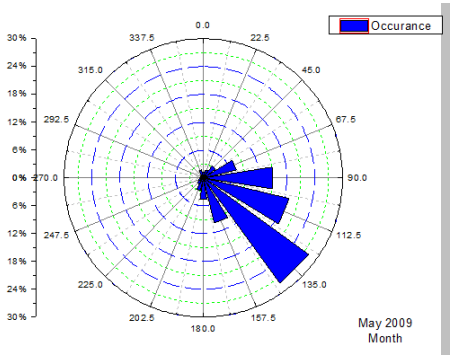


July 2006

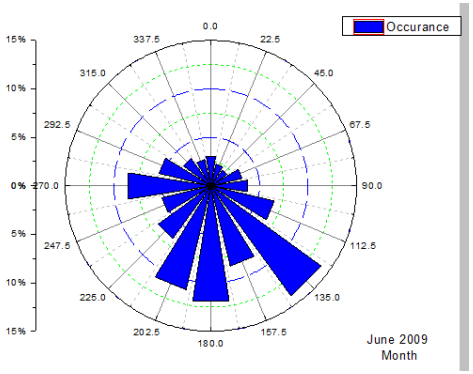


2009

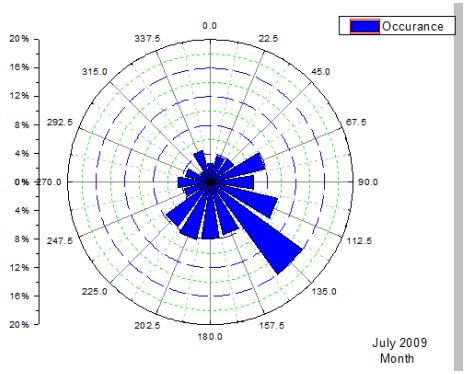
May 2009



June 2009

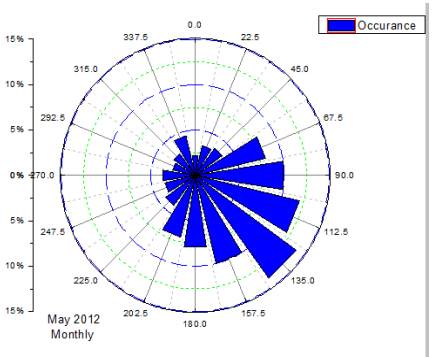


July 2009

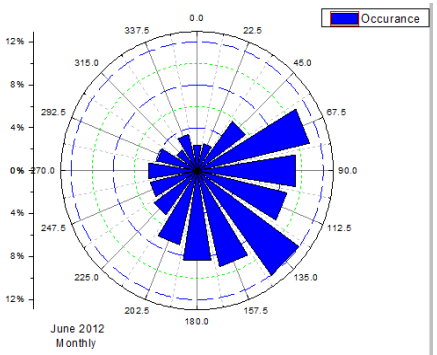


2012

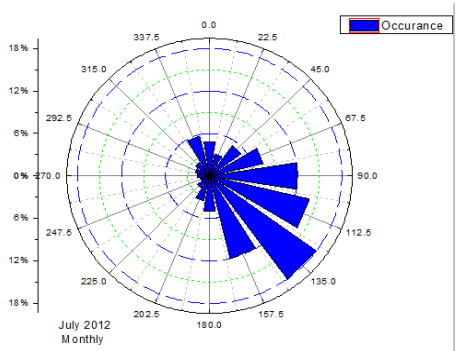
May 2012

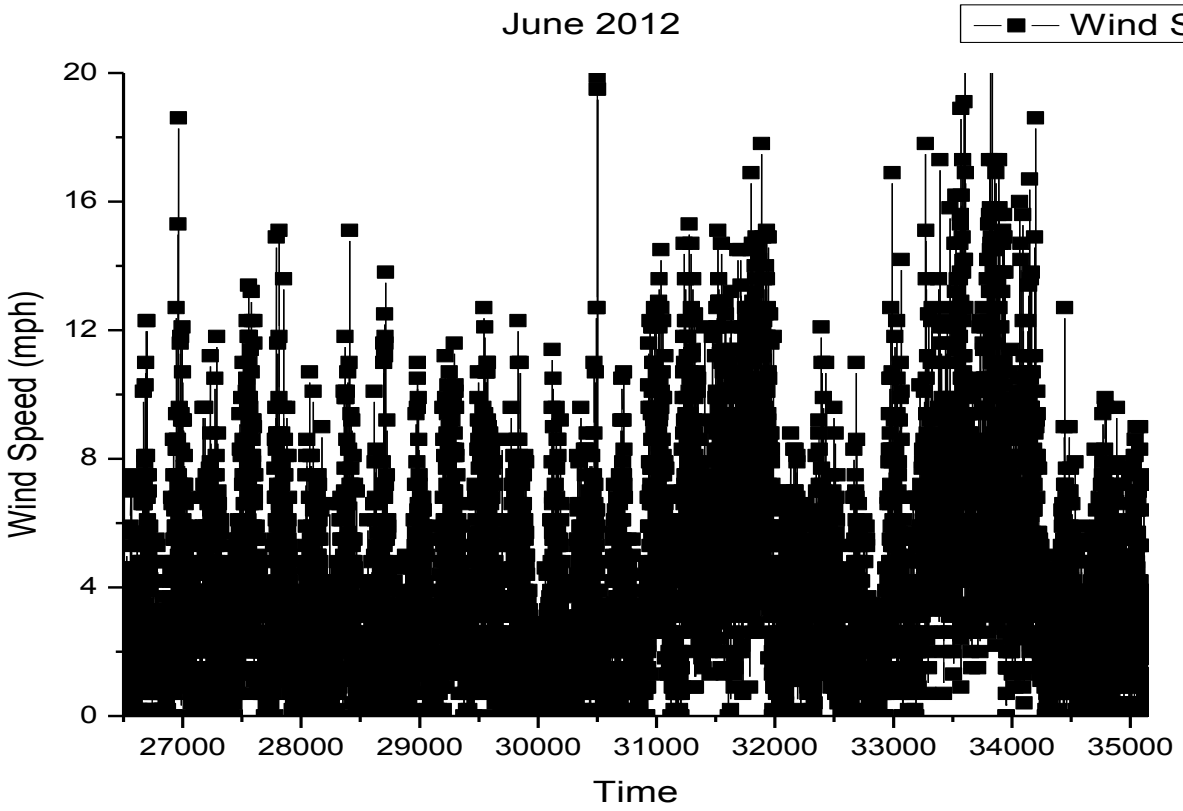


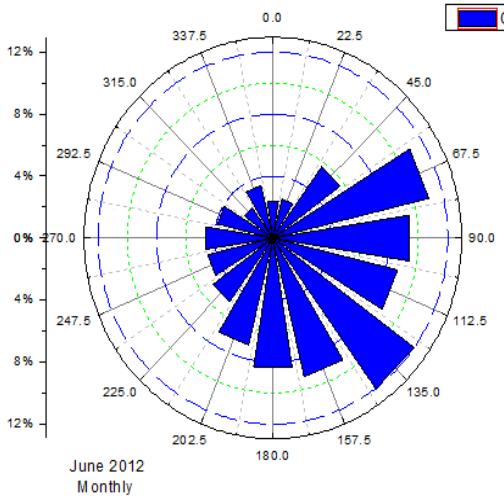
June 2012



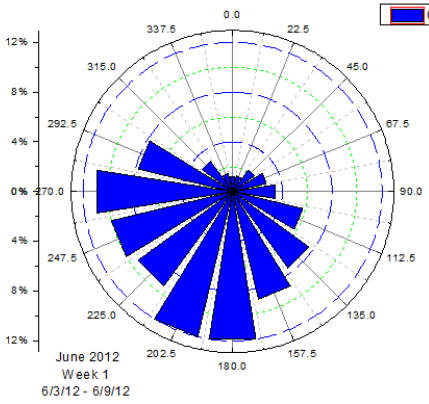
July 2012





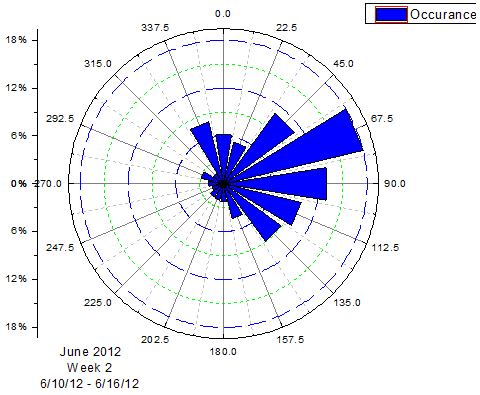


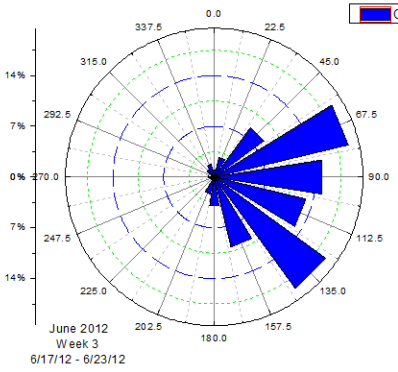
Month



Week 1

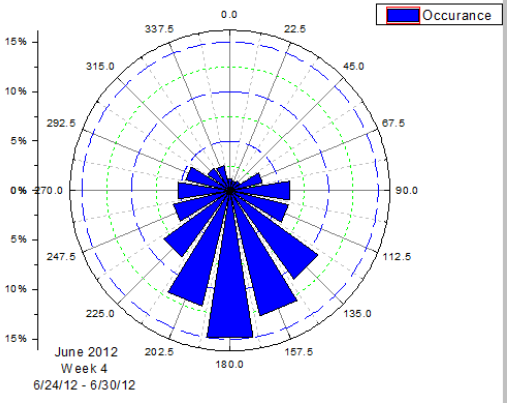
Week 2

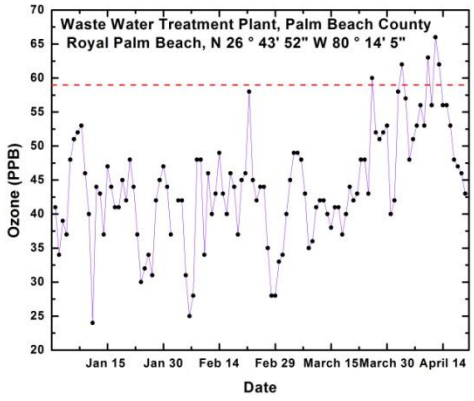


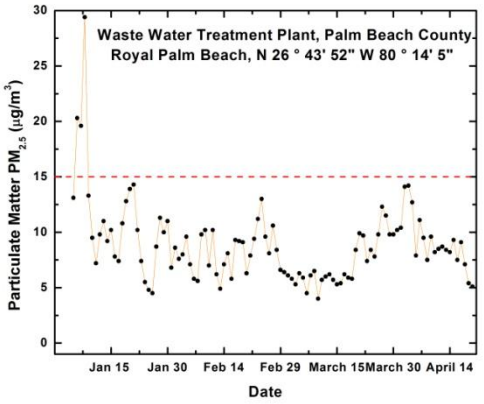


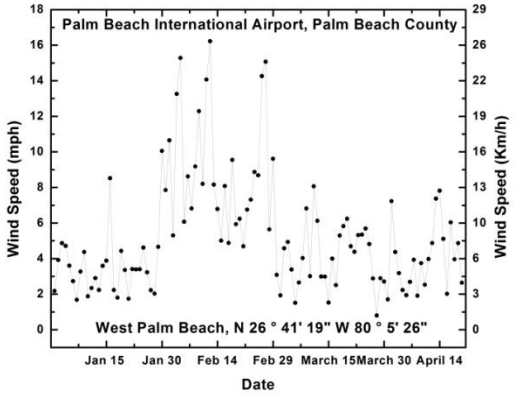
Week 3

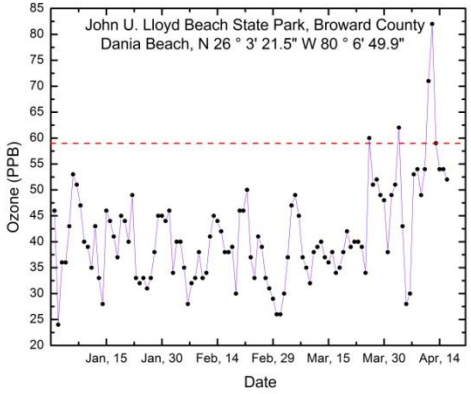
Week 4

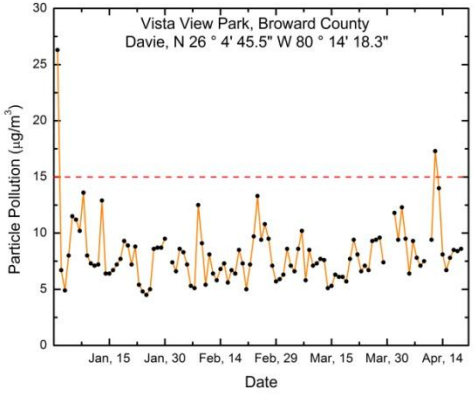


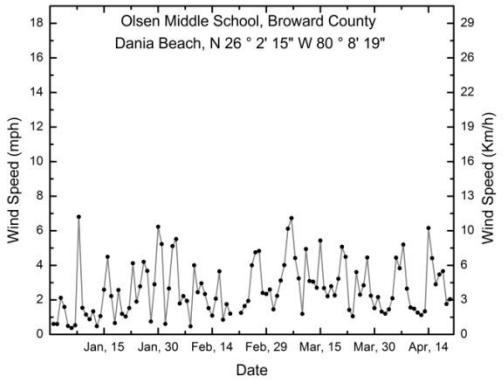

Waste Water Treatment Plant, Palm Beach County
Royal Palm Beach, N 26 ° 43' 52" W 80 ° 14' 5"
Ozone (PPB)
Date
Jan 15
Jan 30
Feb 14
Feb 29
March 15
March 30
April 14

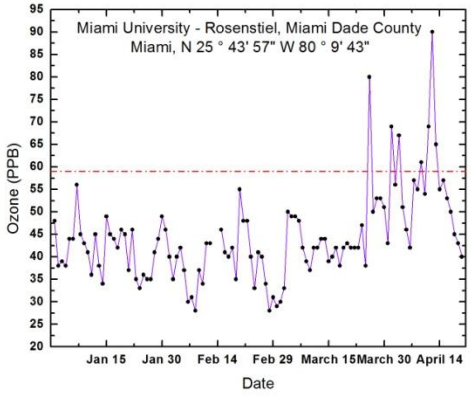

Waste Water Treatment Plant, Palm Beach County
Royal Palm Beach, N 26 ° 43' 52" W 80 ° 14' 5"
Particulate Matter PM2.5 (µg/m3)
Date
Jan 15
Jan 30
Feb 14
Feb 29
March 15
March 30
April 14

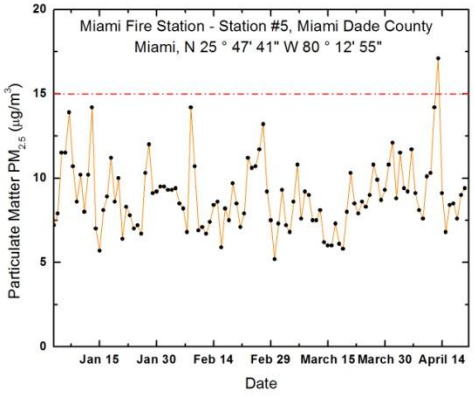

Palm Beach International Airport, Palm Beach County
West Palm Beach, N 26 ° 41' 19" W 80 ° 5' 26"
Wind Speed (mph)
Wind Speed (Km/h)
Date
Jan 15
Jan 30
Feb 14
Feb 29
March 15
March 30
April 14

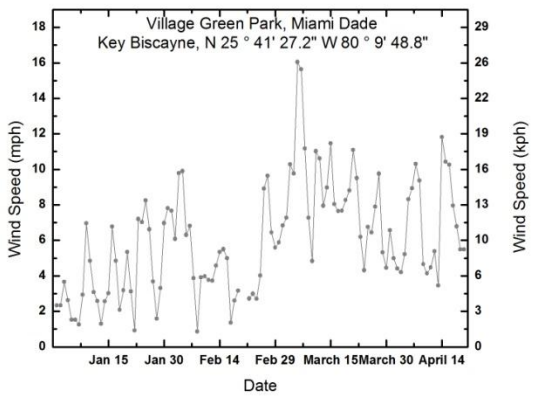

John U. Lloyd Beach State Park, Broward County
Dania Beach, N 26 ° 3' 21.5" W 80 ° 6' 49.9"
Ozone (PPB)
Date
Jan, 15
Jan, 30
Feb, 14
Feb, 29
Mar, 15
Mar, 30
Apr, 14

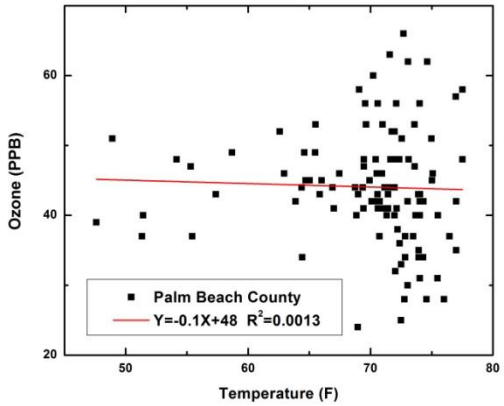

Vista View Park, Broward County
Davie, N 26 ° 4' 45.5" W 80 ° 14' 18.3"
Particle Pollution (µg/m3)
Date
Jan, 15
Jan, 30
Feb, 14
Feb, 29
Mar, 15
Mar, 30
Apr, 14

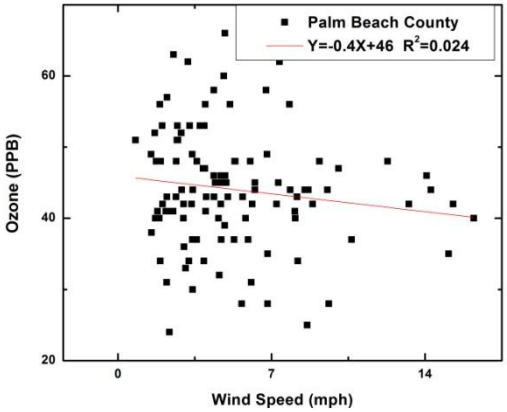

Olsen Middle School, Broward County
Dania Beach, N 26 ° 2' 15" W 80 ° 8' 19"
Wind Speed (mph)
Wind Speed (Km/h)
Date
Jan, 15
Jan, 30
Feb, 14
Feb, 29
Mar, 15
Mar, 30
Apr, 14

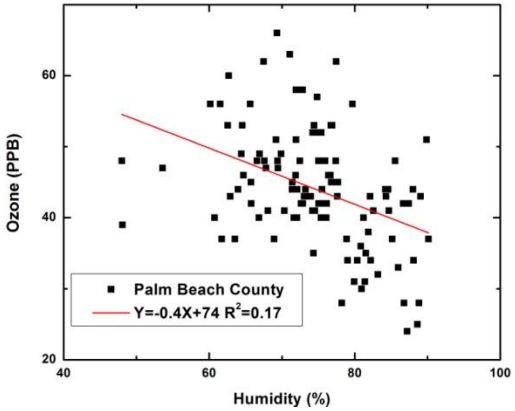

Miami University - Rosenstiel, Miami Dade County
Miami, N 25 ° 43' 57" W 80 ° 9' 43"
Ozone (PPB)
Date
Jan 15
Jan 30
Feb 14
Feb 29
March 15
March 30
April 14

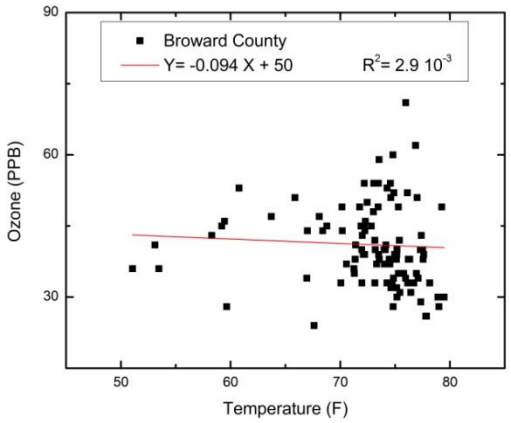

Miami Fire Station - Station #5, Miami Dade County
Miami, N 25 ° 47' 41" W 80 ° 12' 55"
Particulate Matter PM2.5 (µg/m3)
Date
Jan 15
Jan 30
Feb 14
Feb 29
March 15
March 30
April 14

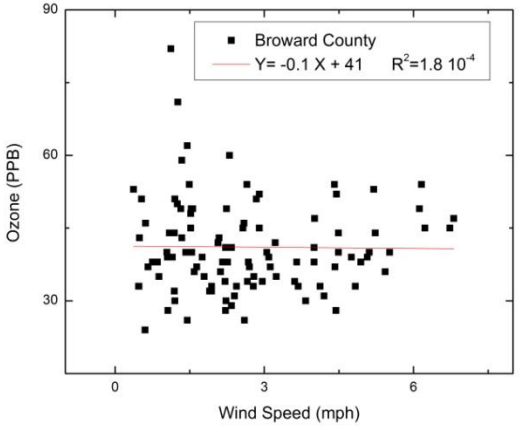

Village Green Park, Miami Dade
Key Biscayne, N 25 ° 41' 27.2" W 80 ° 9' 48.8"
Wind Speed (mph)
Wind Speed (kph)
Date
Jan 15
Jan 30
Feb 14
Feb 29
March 15
March 30
April 14

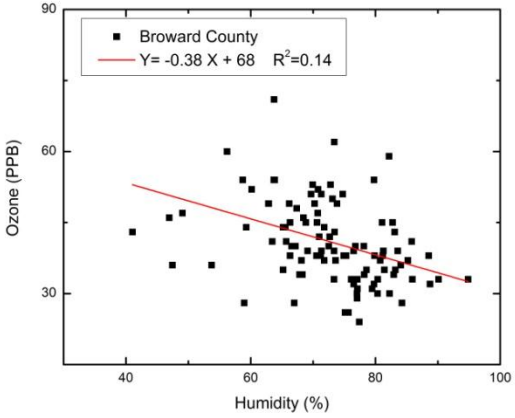

Ozone (PPB)
Temperature (F)
Palm Beach County
Y=-0.1X+48 R2=0.0013

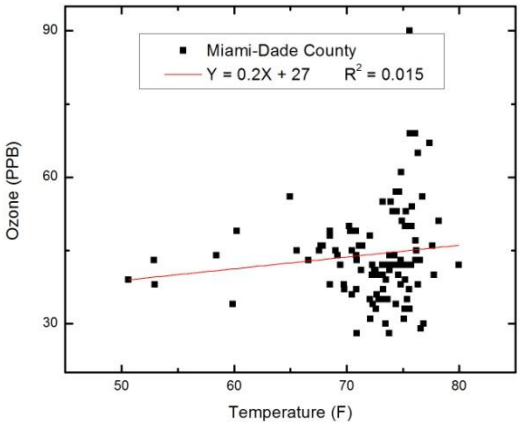

Ozone (PPB)
Wind Speed (mph)
Palm Beach County
Y=-0.4X+46 R2=0.024

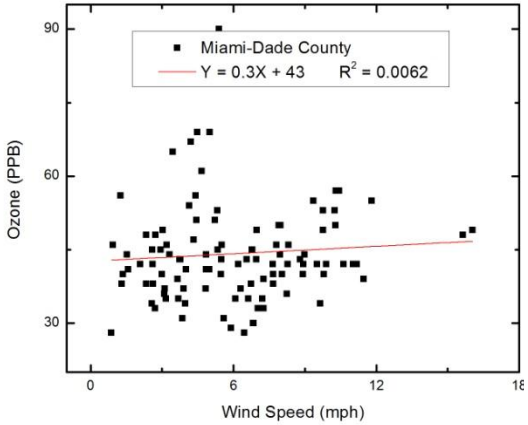

Ozone (PPB)
Humidity (%)
Palm Beach County
Y=-0.4X+74 R2=0.17

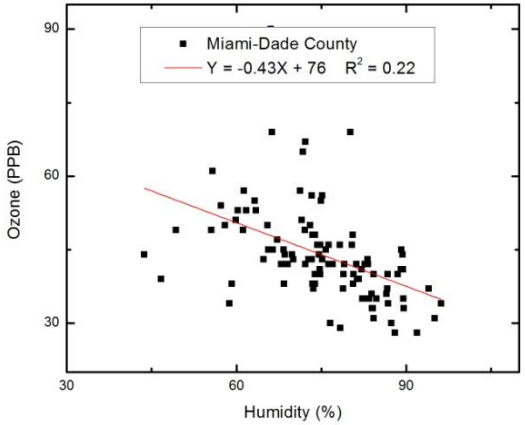

Ozone (PPB)
Temperature (F)
Broward County
Y= -0.094 X + 50 R2= 2.9 10-3


Ozone (PPB)
Wind Speed (mph)
Broward County
Y= -0.1 X + 41 R2=1.8 10-4


Ozone (PPB)
Humidity (%)
Broward County
Y= -0.38 X + 68 R2=0.14


Ozone (PPB)
Temperature (F)
Miami-Dade County
Y = 0.2X + 27 R2 = 0.015


Ozone (PPB)
Wind Speed (mph)
Miami-Dade County
Y = 0.3X + 43 R2 = 0.0062


Ozone (PPB)
Humidity (%)
Miami-Dade County
Y = -0.43X + 76 R2 = 0.22

Comparing Compartmental and Lotka-Volterra models for modeling CO_2 dynamics (senior level project)

$$\begin{cases} \frac{dT}{dt} = aT - bT[CO_2]_A + Asin(wt) \\ \frac{d[CO_2]_A}{dt} = -c[CO_2]_A + dT[CO_2]_A - e[CO_2]_A[CO_2]_O \\ \frac{d[CO_2]_O}{dt} = -f[CO_2]_O + g[CO_2]_A[CO_2]_O \end{cases}$$

Non – linear terms, Simulating saturation

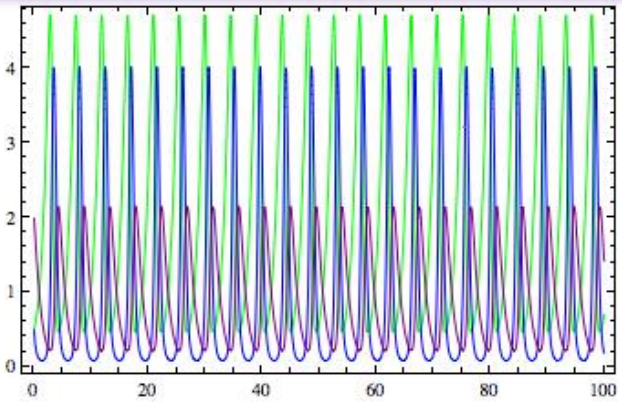
Growth rate for species 1

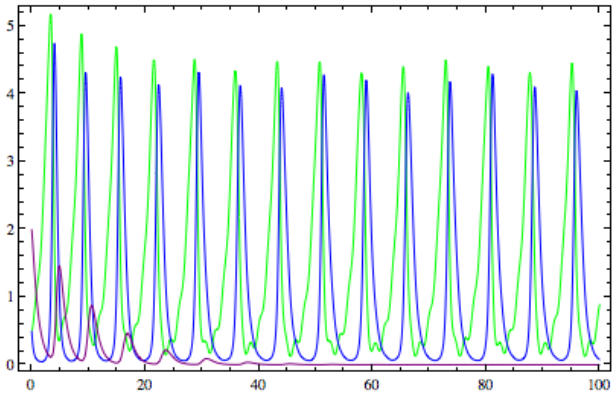
$$\frac{dN_1}{dt} = r_1 N_1 \left(1 - \frac{N_1}{K_1} - \frac{\alpha_{12} N_2}{K_1}\right)$$

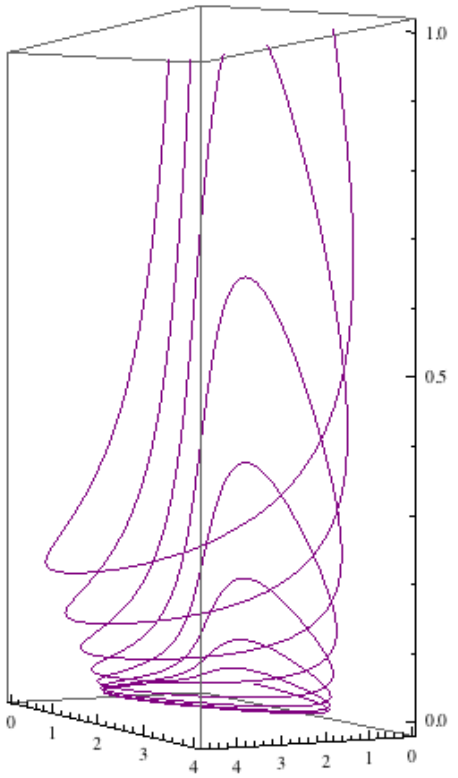
Growth rate for species 2

$$\frac{dN_2}{dt} = r_2 N_2 \left(1 - \frac{N_2}{K_2} - \frac{\alpha_{21} N_1}{K_2}\right)$$

$$\begin{cases} x' = a_1 x - a_2 xy \\ y' = -b_1 y + b_2 xy \end{cases}$$







Modeling El Nino Southern Oscillation with the Delayed Action Oscillator (senior level project)

Wolfram Mathematica 8

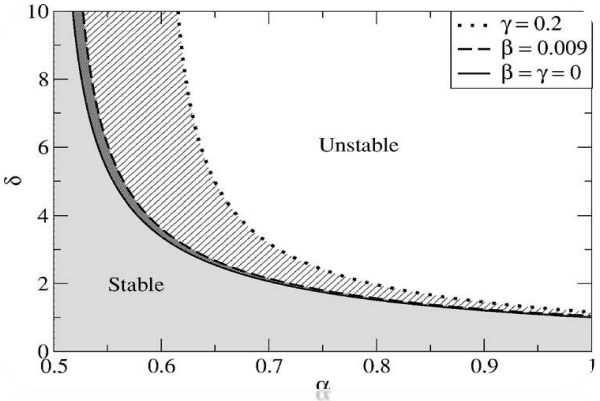
The Delayed Action Oscillator (DAO)

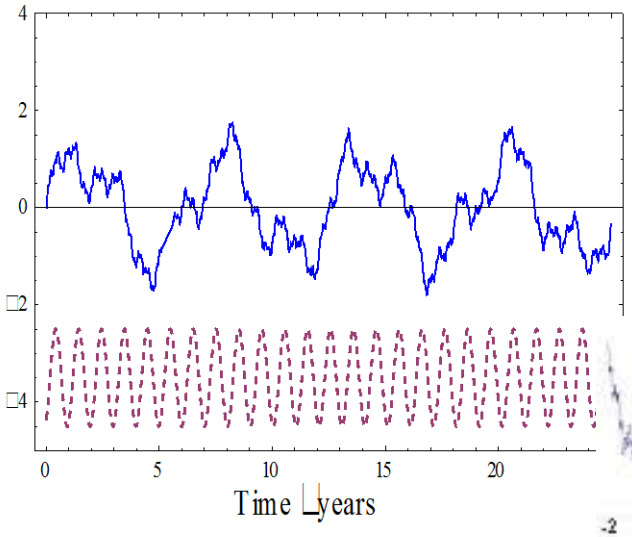
A non-linear first order differential equation to model El Niño oscillation in the sea surface temperature (SST) anomalies.

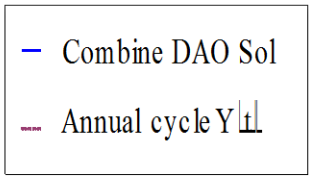
Original equation : $dT/dt = kT - bT^3 - AT[t-\Delta] + C + Y[t]$

- kT — Newton's Law of Cooling
- bT^3 — Non-linear term (dissipation)
- $AT[t-\Delta]$ — Delayed action
- C — Warming
- $Y[t]$ — Stochastic

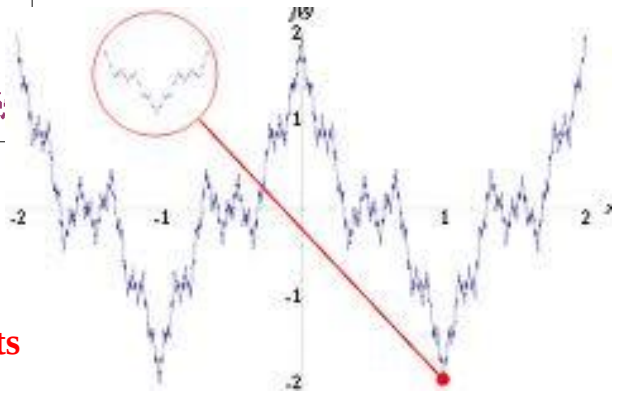
```
h1[x_,t_]=
  y[x,t]/.NDSolve[
 {D[y[x,t],t, t] == c^2*D[y[x,t],x,x]
  y[x,0]==ic[x],iv[x] == 0,
  y[0,t]==0, y[L,t] == 0},
  y,{x,0,L},{t,0,1},
 MaxSteps->100000
][[1]];
```





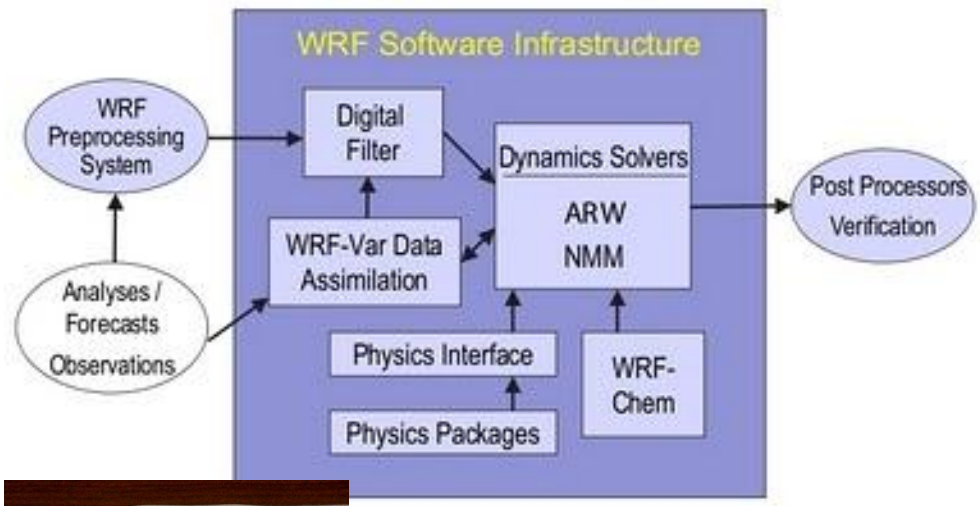


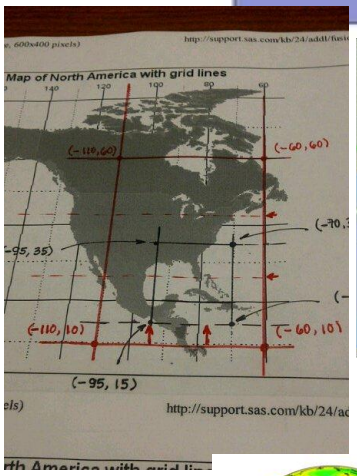
Weierstrass function

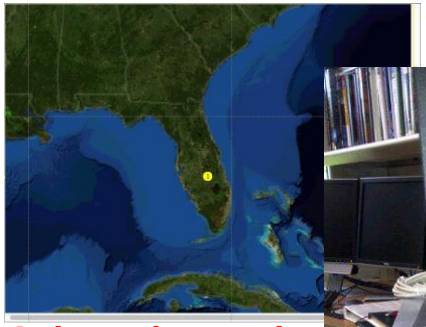


Global Warming will not affect the oscillations, and hence El Niño events will continue to occur.

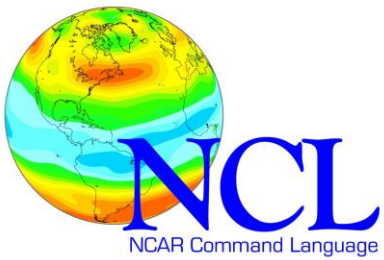
Using WRF + Chem to determine the Ozone concentration and its vertical profile in South Florida (senior level project)







Selected Domain



Goals

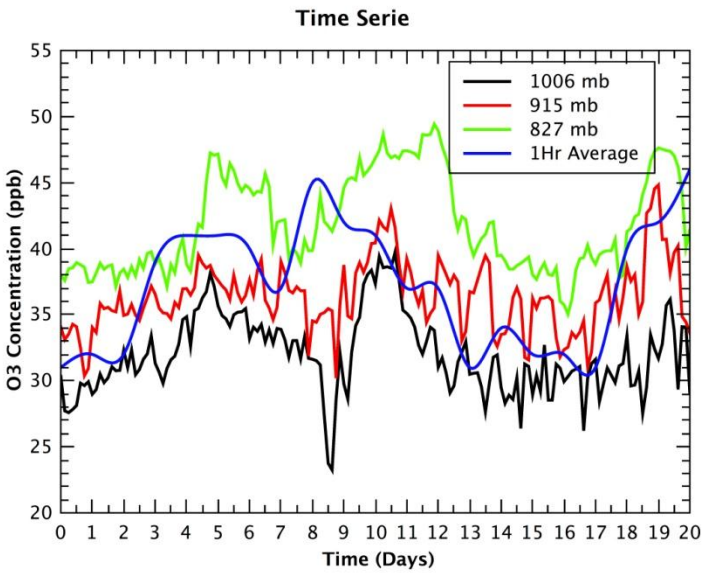
Being introduced to Mathematical Methods in Atmospheric modeling:

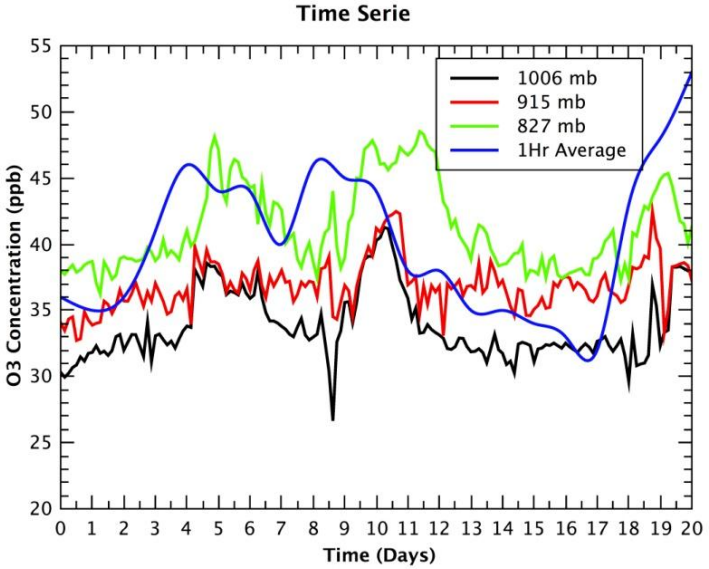
- Spline interpolation
- Numerical solutions
- Pre- and Post – processing
- NCL language and Python apps.

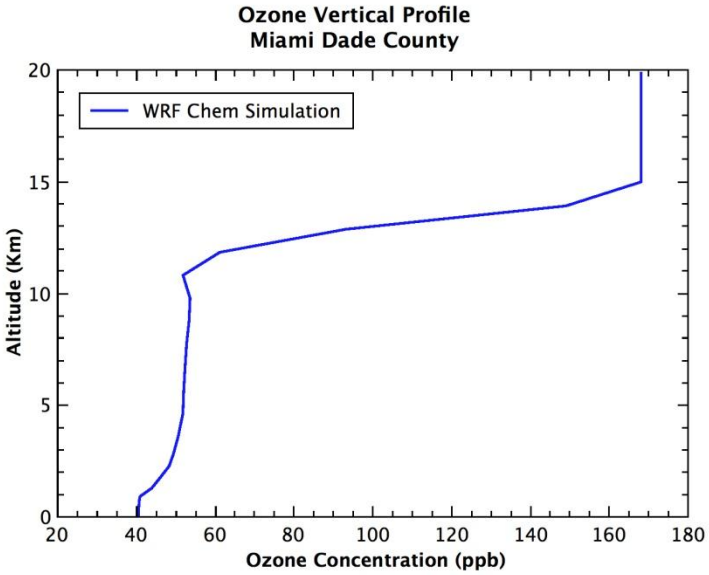
How to get there?

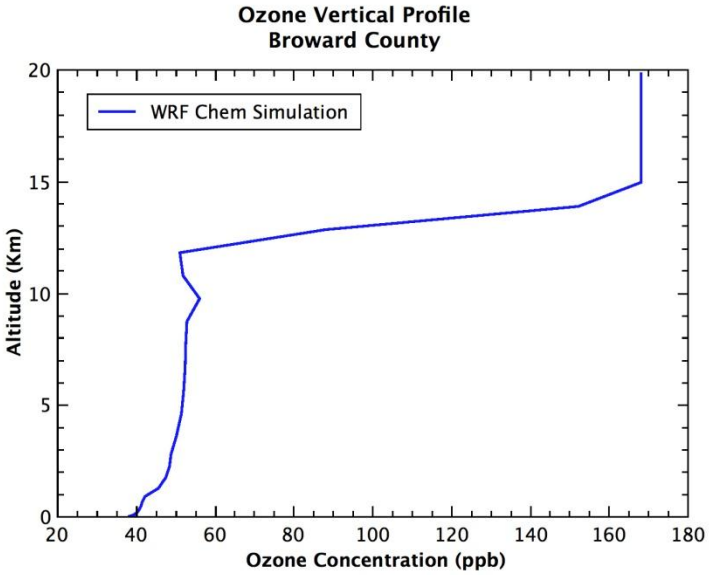
- Internship at NCAR – Foothills Labs
- Dell Quad-core (12 threads) + 2 Dells Dual Core

Using WRF + Chem to determine the Ozone concentration and its vertical profile in South Florida (senior level project)









Conclusions

- **WeatherBug databases may be used for with high level of confidence**
- **Students may take advantage of WeatherBug Achieve for a diverse range of projects**

Bio-Meteorology of Asthma

- **African Americans and Non White Hispanics seem to be more affected by asthma.**
- **Zip codes from Miami Dade with the major incidence seem to be related with socio-economic background and proximity to highways.**
- **A seasonal pattern of Emergency Department visits due to Asthma has been documented.**
- **Among weather variables, Tmean, ΔT, Tmin, and ΔH appear to correlate better with the number of asthma cases.**
- **The effect of the weather is clear, 30 % of the Mean Temperature variance may explain the changes in visits due to asthma.**
- **Low values of temperatures during late Fall and Winter along with calm winds (less than 10 mph) predominantly from the north may produce temperature Inversions, trapping pollutants in urban areas.**
- **In Spring and Summer, sea and land Breezes take pollutants either to Everglades or open Ocean, preventing people to be exposed to them.**
- **The observed patterns seem to be originated in the thermoregulation response to cold weather (homeostasis), rather than in allergic pathways. Temperature, as well as air quality seem to act as environmental stressors on immune system, favoring inflammatory response in individuals with genetic pre-disposition to asthma (topic to be studied through modeling)**
- **A delayed action on asthma occurrence seems to happen pointing to a cumulative effects of stressors and elasticity of immune response.**

Acknowledgments

- **Oscar Hernandez M.D. and Elizabeth Fontora, Medical Group, Miami Dade, FL**
- **School of Science, St. Thomas University**