Welcome
to the

Air Quality Module

Virendra Sethi
Professor

Environmental Science & Engineering Department
IIT Bombay

2023

In Service
of
YOU

In Honour
of
YOU
as
Future Leaders
and
Decision Makers

For this Module
Please Create a Game
where

YOU

are

Accountable for the Air Quality

in

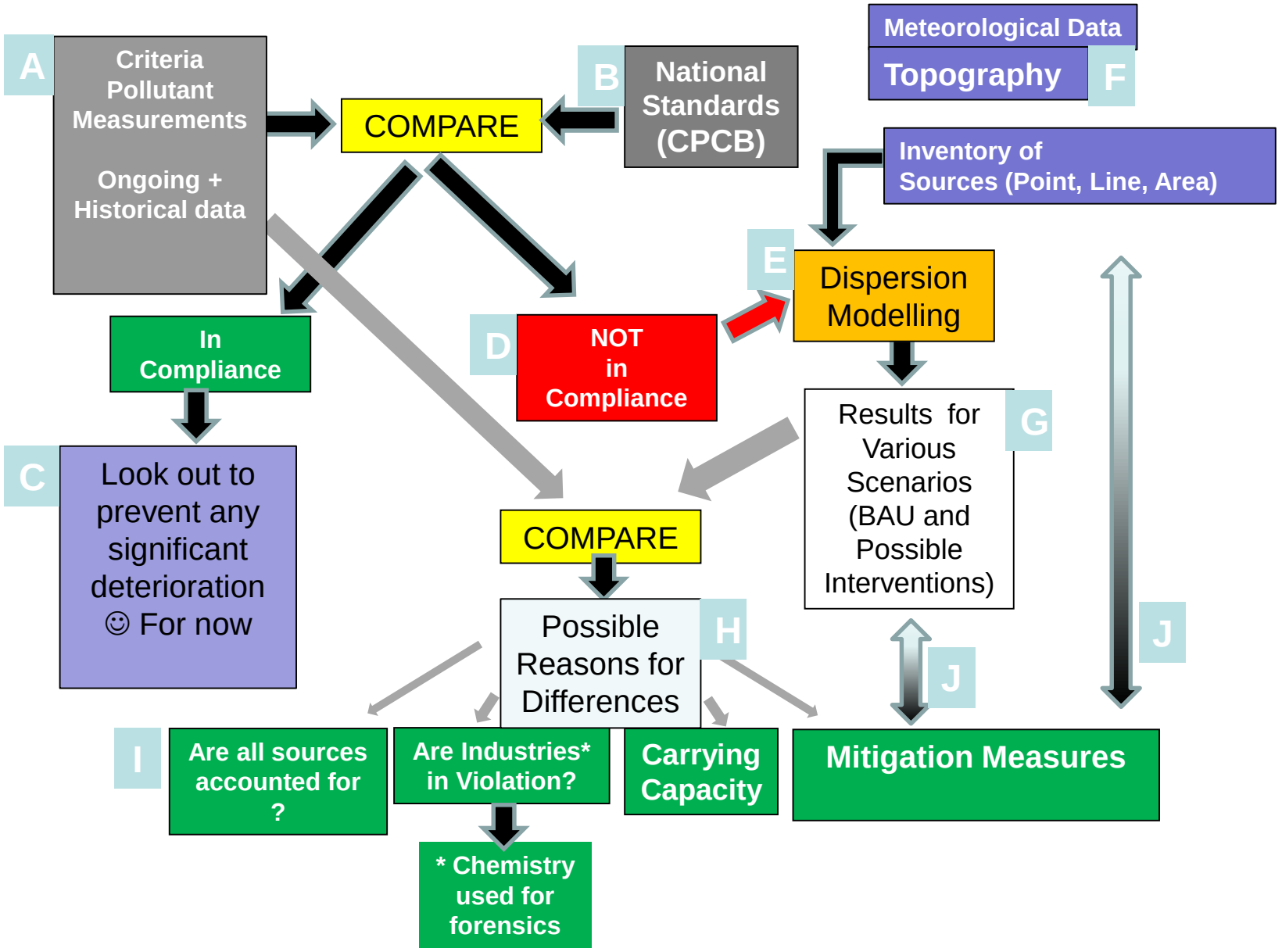
Your City

(The Appropriate Questions will Arise Naturally in that Game)

Module Objective

AQM

Air Quality Management


A
Criteria Pollutant Measurements
Ongoing + Historical data
COMPARE
B
National Standards (CPCB)
Meteorological Data
Topography
F
Inventory of Sources (Point, Line, Area)
E
Dispersion Modelling
In Compliance
D
NOT in Compliance
C
Look out to prevent any significant deterioration
☺ For now
Results for Various Scenarios (BAU and Possible Interventions)
G
COMPARE
Possible Reasons for Differences
H
J
J
I
Are all sources accounted for ?
Are Industries* in Violation?
Carrying Capacity
Mitigation Measures
* Chemistry used for forensics

Further Resources for the AQM Process

A. Air quality is routinely measured by :
   a. Hi-volume samplers in RSPM in the National Air Monitoring Program (NAMP) network of stations (twice a week) for
      i. RSPM (Respirable Suspended Particulate Matter ie size < 10 μm)
      ii. Oxides of Nitrogen
      iii. Oxides of Sulphur
      iv. eg Please see : http://www.cpcbenvis.nic.in/air_quality_data.html

   b. More recently also using CAAQMS(Continuous Ambient Air Quality Monitoring Stations)
      i. MPCB has one on campus near SAMEER Y-Point
      ii. eg Please see http://www.cpcb.gov.in/CAAQM/frmCurrentDataNew.aspx?StationName=MPCB%20Bandra&StateId=16&CityId=310

B. National Ambient Air Quality Standards

a. Please see : http://cpcbenvis.nic.in/air_pollution_main.html#

Standards are based on time of exposure. For example 8 hours standards or annual standard. You can be exposed to a higher concentration level for a short time.

C.These are the pollutants that are monitored for air pollution levels. If the levels are below these concentration levels, then the city is in compliance.

D.Else, it is in violation of the standards.

E. In case of non-compliance, efforts are made to understand the problem by using DISPERSION Modelling (For FUTURE reference you can see : https://www.sciencedirect.com/science/article/pii/S1352231006006339

F. Inputs required for DISPERSION Modelling are
   a. Meteorological conditions (wind speed, wind direction, vertical mixing) Please see wind rose : https://en.wikipedia.org/wiki/Wind_rose
   b. Topography
   c. Sources
      i. Point sources eg Industries (Chimneys)
      ii. Line sources eg Vehicles
      iii. Area sources eg coal mines

G. The model permits simulation of different scenarios such as
   a. Seasonal variations due to Meteorological conditions
   b. Turning on some sources and turning off other sources of pollution
   c. Adding new sources to study the impact of a new plant (eg coal power plant)
   d. Impact of introducing electric vehicles instead of petrol/diesel vehicles

H. Quite often, the results of the model do not compare with the measurements in A, and then further investigations are required.

I. Possible reasons could be
   a. Some sources are not included (eg road dust during dry seasons)
   b. Unexplained regional sources (dust storms, long distance agricultural burning)
   c. Industries may be violating the permitted levels of emissions
   d. Uncertainties in Met data and or the resolution of data (spatial and temporal)
   e. Diurnal variation of wind conditions and carrying capacity of the region

J. Results can be used to design mitigation measures and control strategies

Questions Arising in your Accountability

- Whether your home city is in compliance for NAAQS or not.
- What is the wind rose in your home city (or any city nearest to you)
- What are the key Point, Line and Area sources in your Home city ?
- What can be done to improve air quality in your home city ?

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Learnings

Three things learnt at Harvard **(Late Prof. Arcievala)**

1. Quantification
2. Library work
3. Apprenticeship

What is Air Pollution ?

- Perception
  - Visible
  - Odour

- What is clean air ?
  - 78% Nitrogen + 21% Oxygen + 1% Trace
  - 340 ppm CO_2 (0.034%)

- 340 ppm ?

Lifecycles/Statistics

- Capacity of the earth system as a sink
  - Feasibility (thermodynamics)
  - Proximity
- Characteristic times
  - Kinetics
  - Sulphur, Carbon, Nitrogen, Halogen Containing Compounds Cycles
- Statistics

Scales and Fate

- Local > Regional > Global
- Earth : Apple :: Atmosphere : Skin
- Ambient : Indoor
- Dispersion and Mixing

Module Objective

Air Quality Standards

&

Concentration Estimates

CPCB
National Ambient Air Quality Standards
(NAAQS)

1. Concentration

2. Exposure duration

Revised National Ambient Air Quality Standards (NAAQS)

[NAAQS Notification dated 18th November, 2009]

S. No.	Pollutants	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
			Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (notified by Central Government)	
1	Sulphur Dioxide (SO_2), µg/m^3	Annual*	50	20	1. Improved West and Gaeke 2. Ultraviolet Fluorescence
		24 Hours**	80	80	
2	Nitrogen Dioxide (NO_2), µg/m^3	Annual*	40	30	1. Modified Jacob & Hochheiser 2. Chemiluminescence
		24 Hours**	80	80	
3	Particulate Matter (Size <10µm) or PM_{10} µg/m^3	Annual*	60	60	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours**	100	100	
4	Particulate Matter (Size <2.5 µm) or $PM_{2.5}$ µg/m^3	Annual*	40	40	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours **	60	60	
5	Ozone (O_3), µg/m^3	8 hours**	100	100	1. UV photometric 2. Chemiluminescence 3. Chemical Method
		1 hours **	180	180	
6	Lead (Pb), µg/m^3	Annual *	0.50	0.50	1. AAS/ICP Method after sampling using EPM 2000 or equivalent filter paper 2. ED-XRF using Teflon filter
		24 Hour**	1.0	1.0	
7	Carbon Monoxide (CO),	8 Hours **	02	02	Non dispersive Infra Red (NDIR)

https://cpcb.nic.in/upload/NAAQS_2019.pdf

Exercise

- Given : Regulatory Limit for SO_2 in Ambient Air is
  - 80 $\mu g/m^3$ (0.03 ppm) for 24-hour average
  - 1300 $\mu g/m^3$ (0.5 ppm) for 3-hour average

- How many grams of Sulphur, if burnt in the room you are in, would exceed this 3-hour limit?

- $S + O_2 = SO_2$
- 32 gm S gives 64 gm of SO_2

- X gm will give 2X gm

- Mixed in how much volume ? Will lead to exposure concentration…

The REAL Question then is …

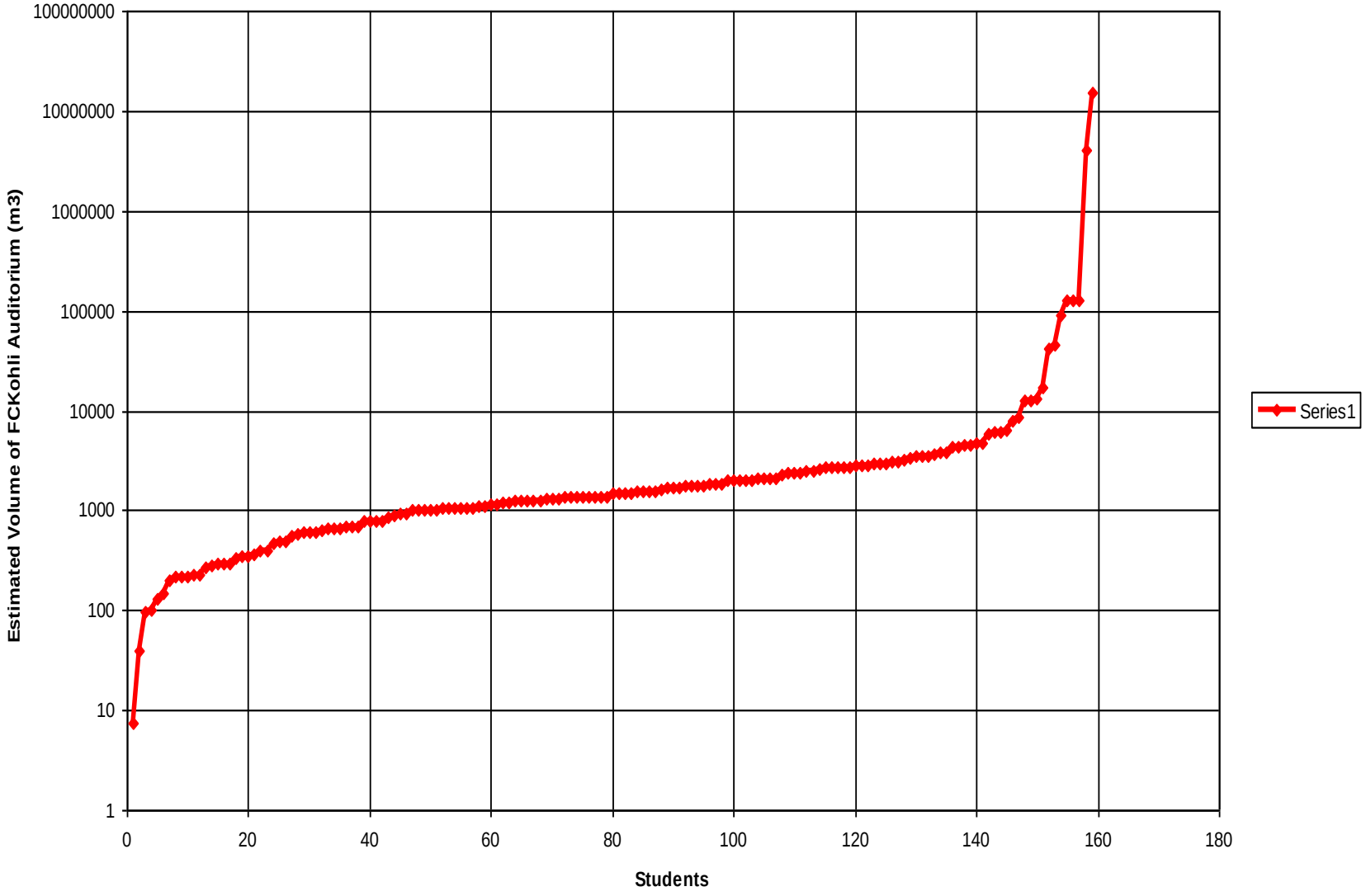
- What is the volume of air in your room (in m^3) ?

How Close were You ?

- Make an estimate of the length, breadth and height of your room.
- Now measure these with a measuring tape/scale
- How close was your estimate ?
- In a closed room, all dimensions are well defined. However, in the ambient, these are open. Uncertainty of measurements is HIGH.

Caution

Results from a Class Exercise



Consequences of a Bad Estimate

- RANGE
  - 20 mg to 8 kg of Sulphur
  - 20 mg : panic buttons for no reason
  - 8 kg : major error that can be fatal
- Actual measurements are IMPORTANT

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How do we Manage Air Quality ?

- At the source itself
  - Industry
  - Vehicles
  - Dust
  - Home cooking (Natural/Forced ventilation)
- After the source
  - Dispersion and Mixing

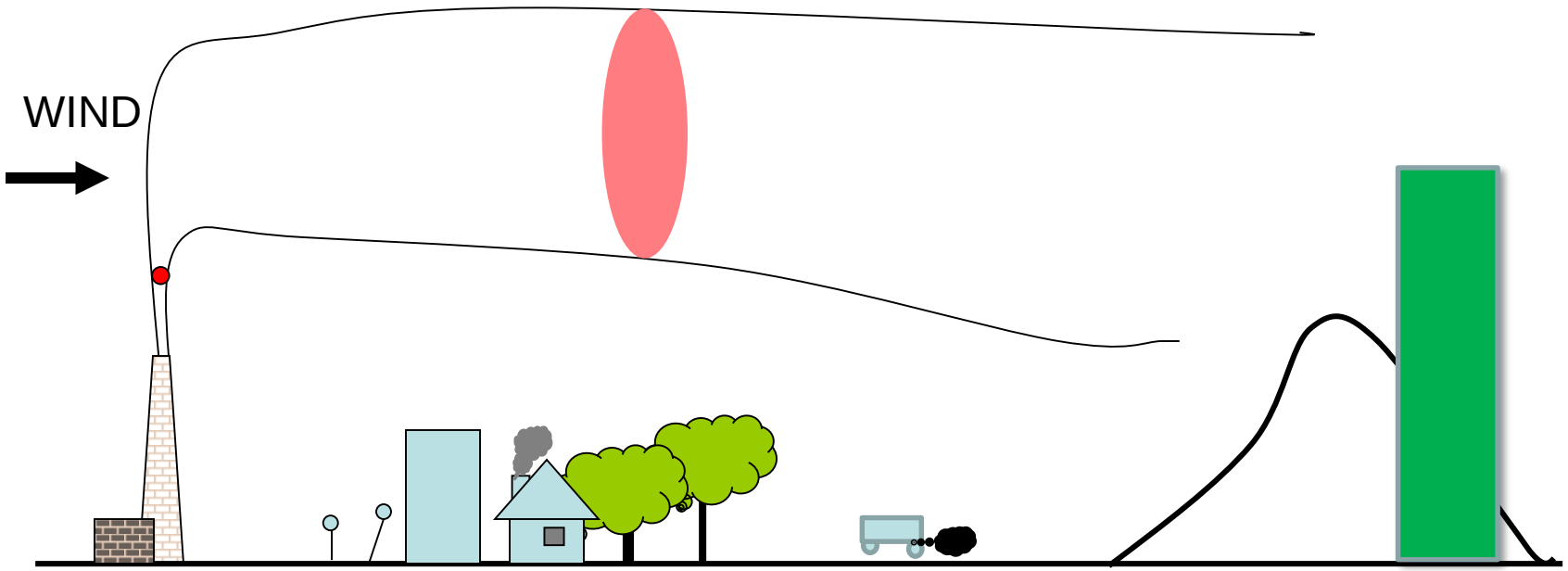
Three Kinds of Sources

- Point
- Line
- Area

https://pixabay.com/photos/environment-industry-4787978/

https://www.google.com/imgres?imgurl=https%3A%2F%2Fimg.rawpixel.com%2Fprivate%2Fstatic%2Fimages%2Fwebsite%2F2022-05%2Fpx757683-image-

Dispersion – Gaussian Plume



Mixing/Dispersion

- Meteorology
  - Horizontal
    - Wind
      - Speed
      - Direction
  - Vertical
    - Temperature
      - Lapse Rate

4, 5 & 6

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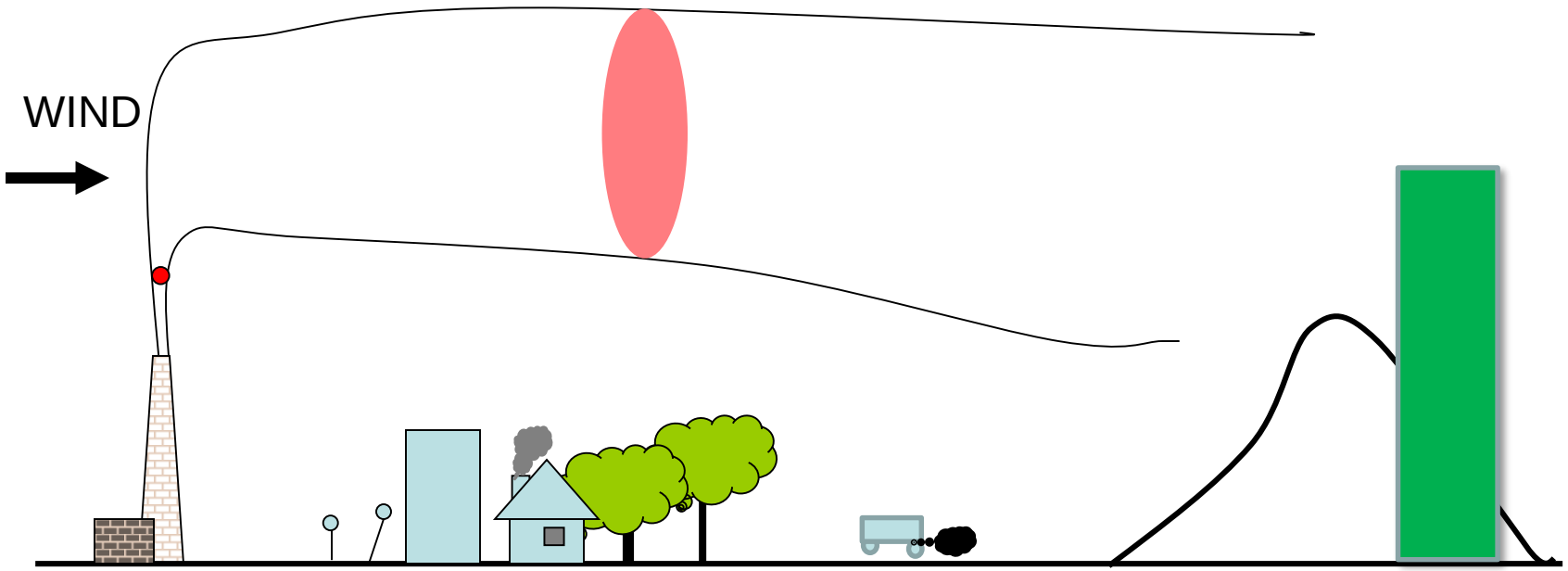
Dispersion – Gaussian Plume

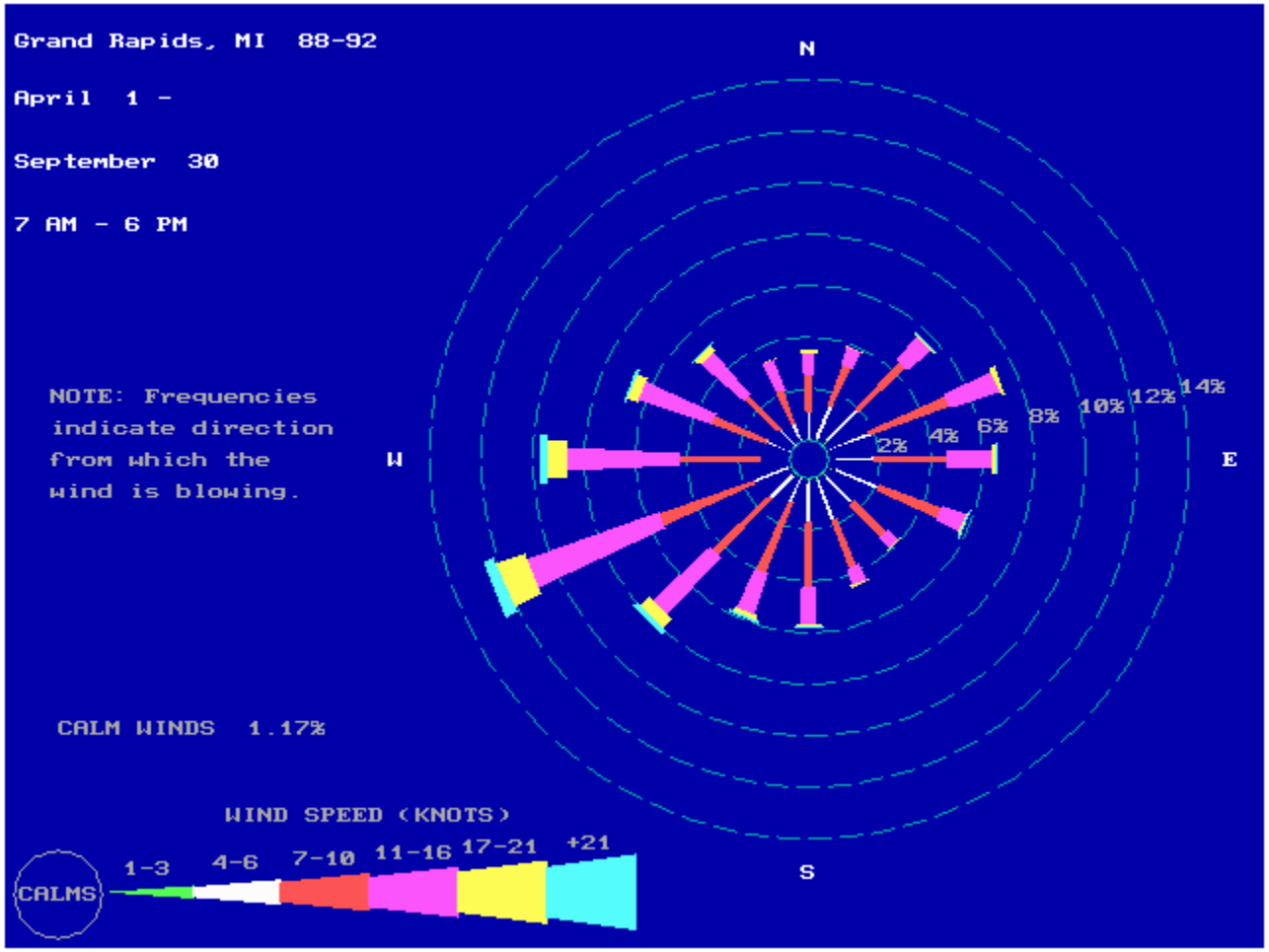


Mixing/Dispersion

- Meteorology
  - Horizontal
    - Wind
      - Speed
      - Direction
  - Vertical
    - Temperature
      - Lapse Rate

Wind Rose

1 knot = 1.82 km/hr



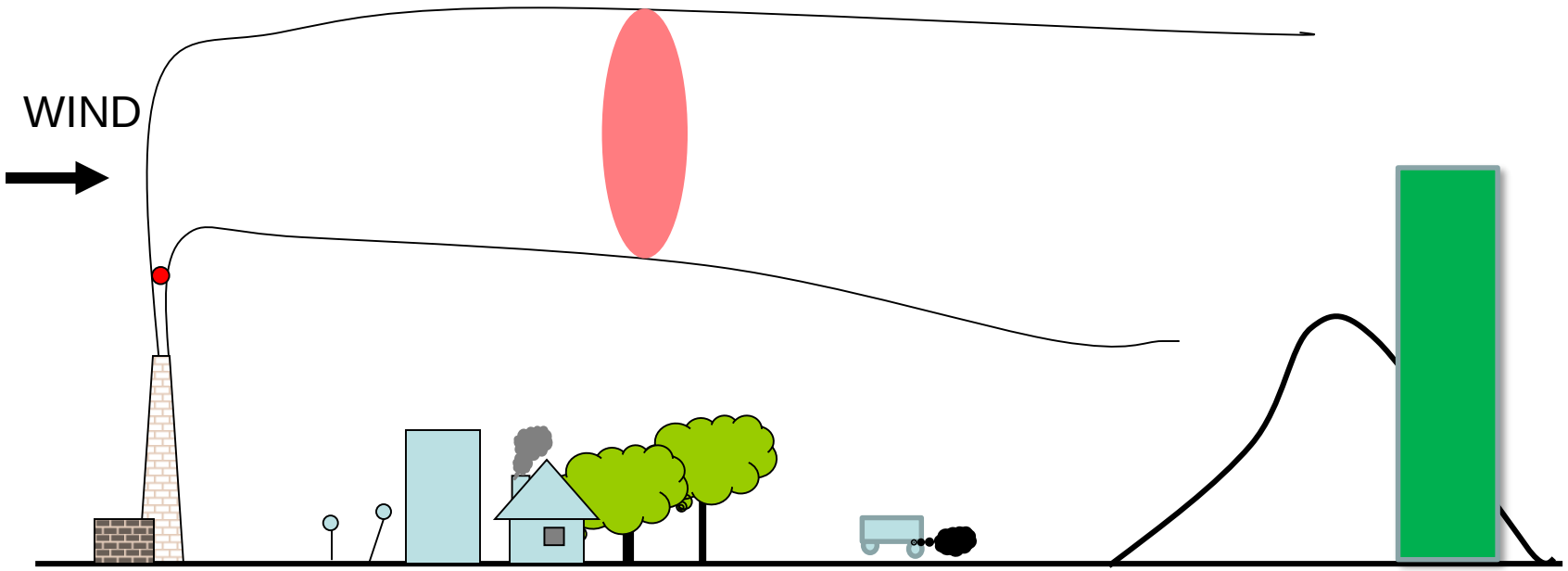
http://www.epa.gov/ttn/naaqs/ozone/areas/wind.htm#dlfi

- Wind roses are divided into 16 wind directions
- Each wind direction is divided into wind speeds
- As the percent of time the wind blows from a particular directions gets larger, the portion of the bar representing the wind speed gets larger both in length and width

Mixing/Dispersion

- Meteorology
  - Horizontal
    - Wind
      - Speed
      - Direction
  - Vertical
    - Temperature
      - Lapse Rate

Dispersion – Gaussian Plume

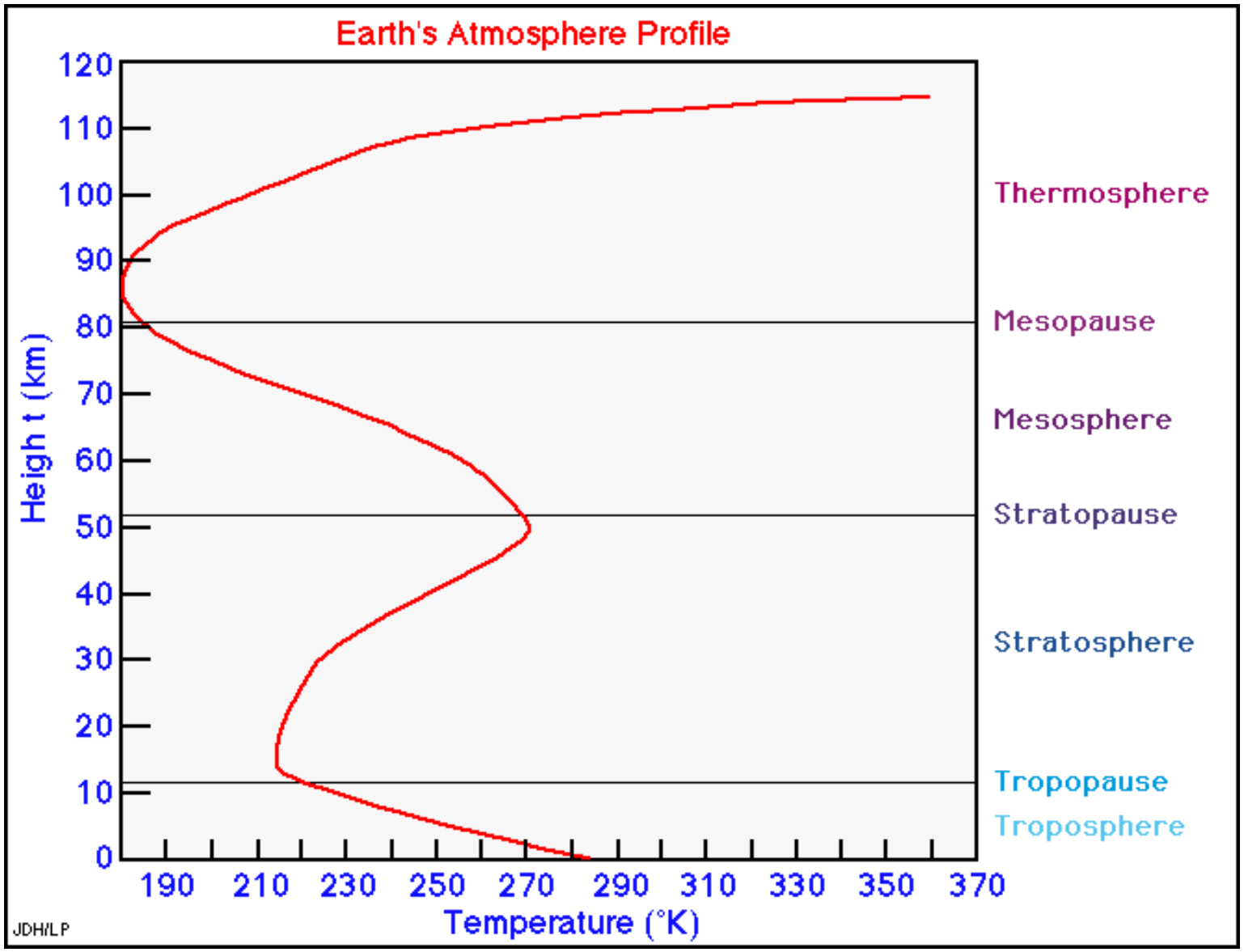


Volume of your Room

The mixing height is known

In the atmosphere **it changes**

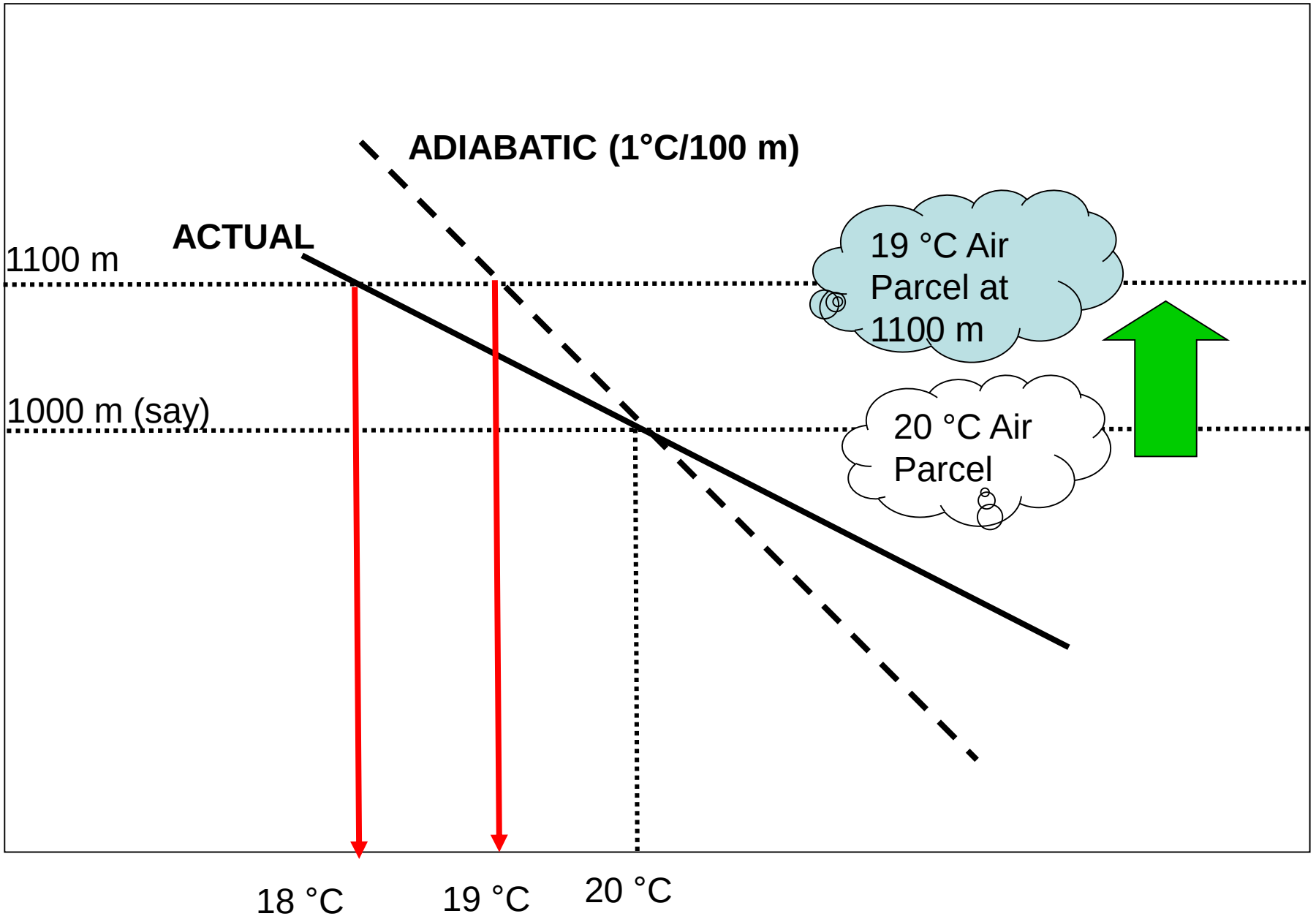
So the volume available for mixing (and dilution of the pollutants) also changes

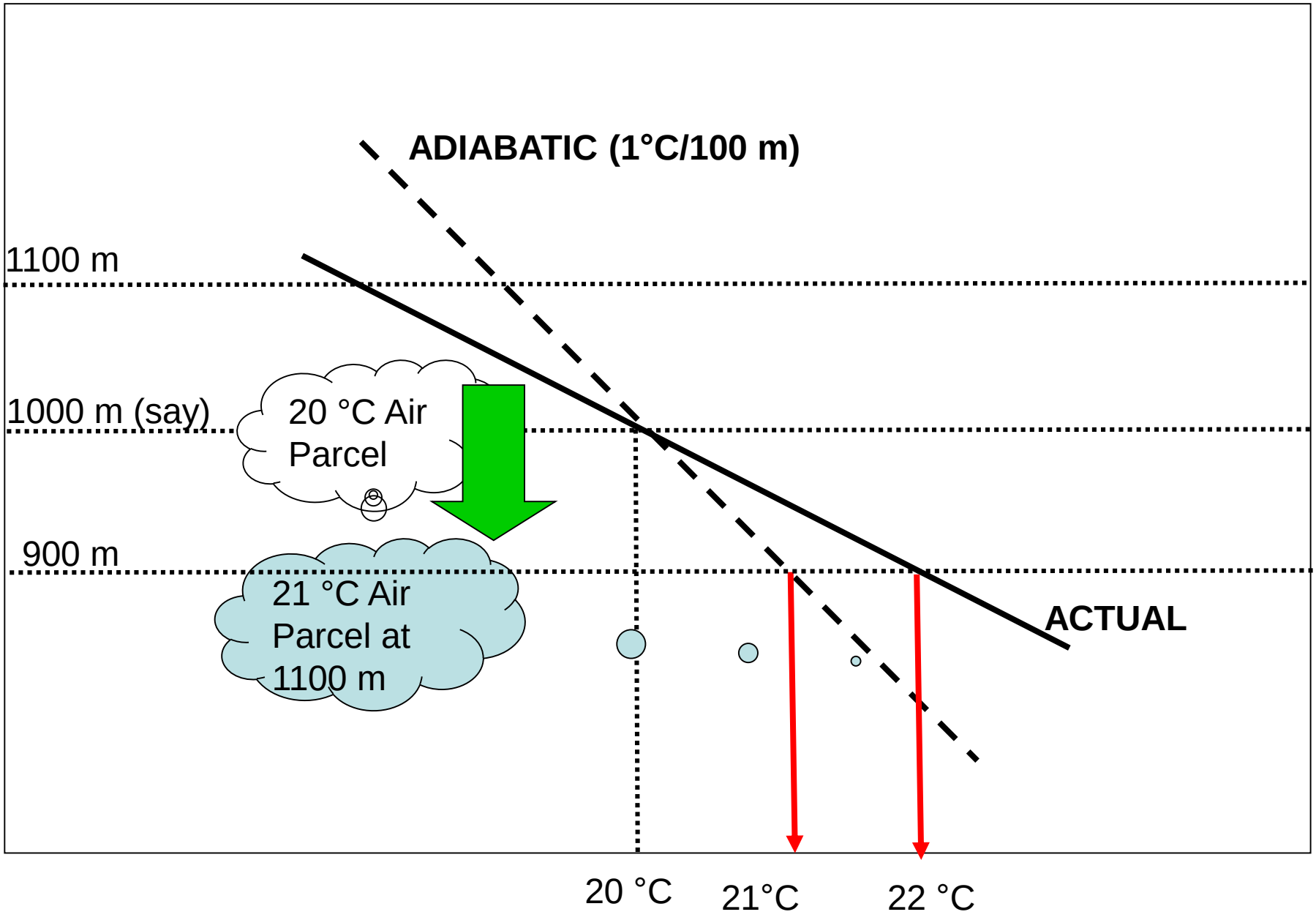


http://www.ldeo.columbia.edu/edu/dees/ees/climate/slides/atmprofile.gif

Lapse Rates

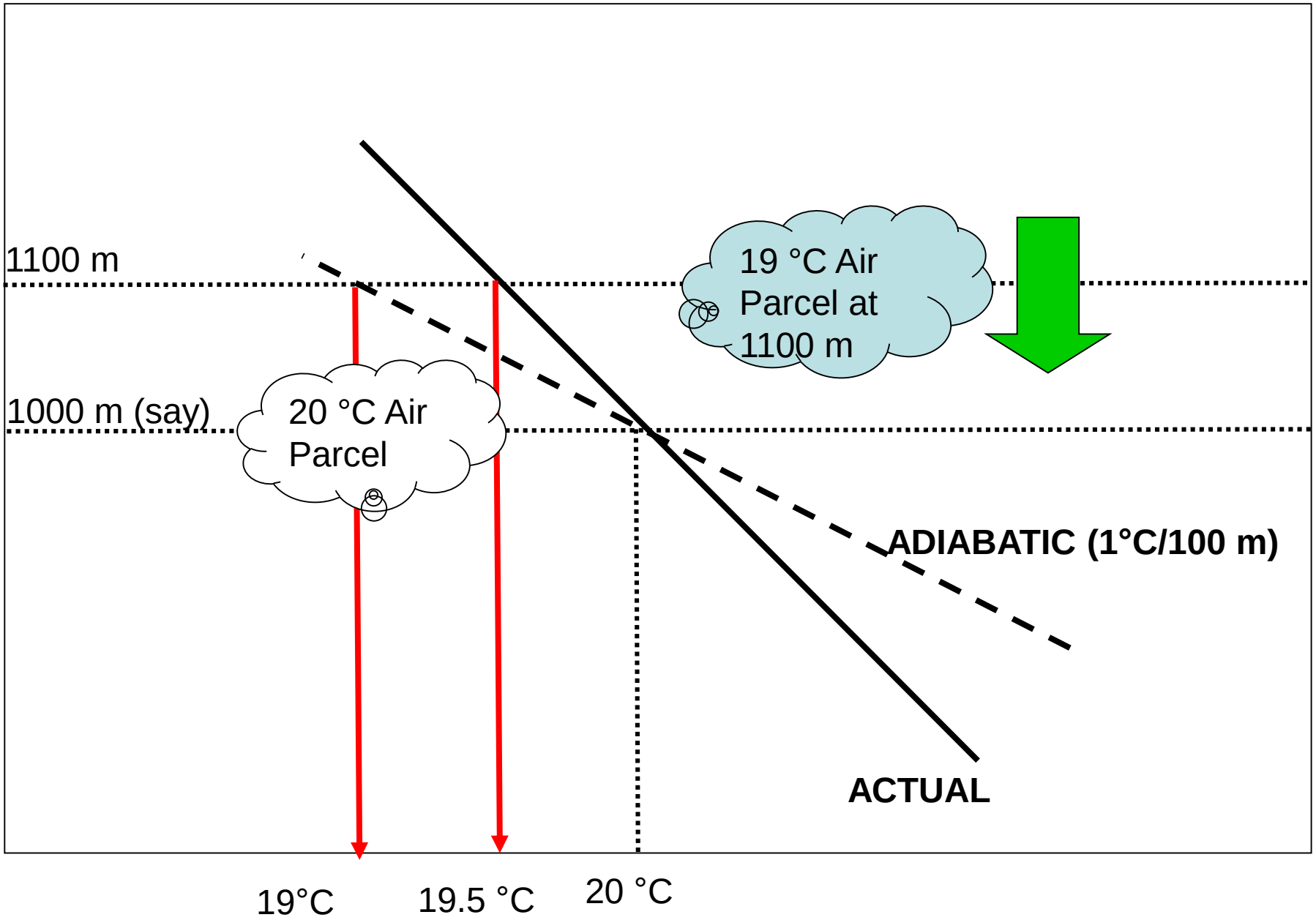
- Atmosphere cools with height
  - What rate ?
    - Dry (Adiabatic) 10°C/km
    - Wet (Adiabatic) 6°C/km
      - (Release of heat with condensation)

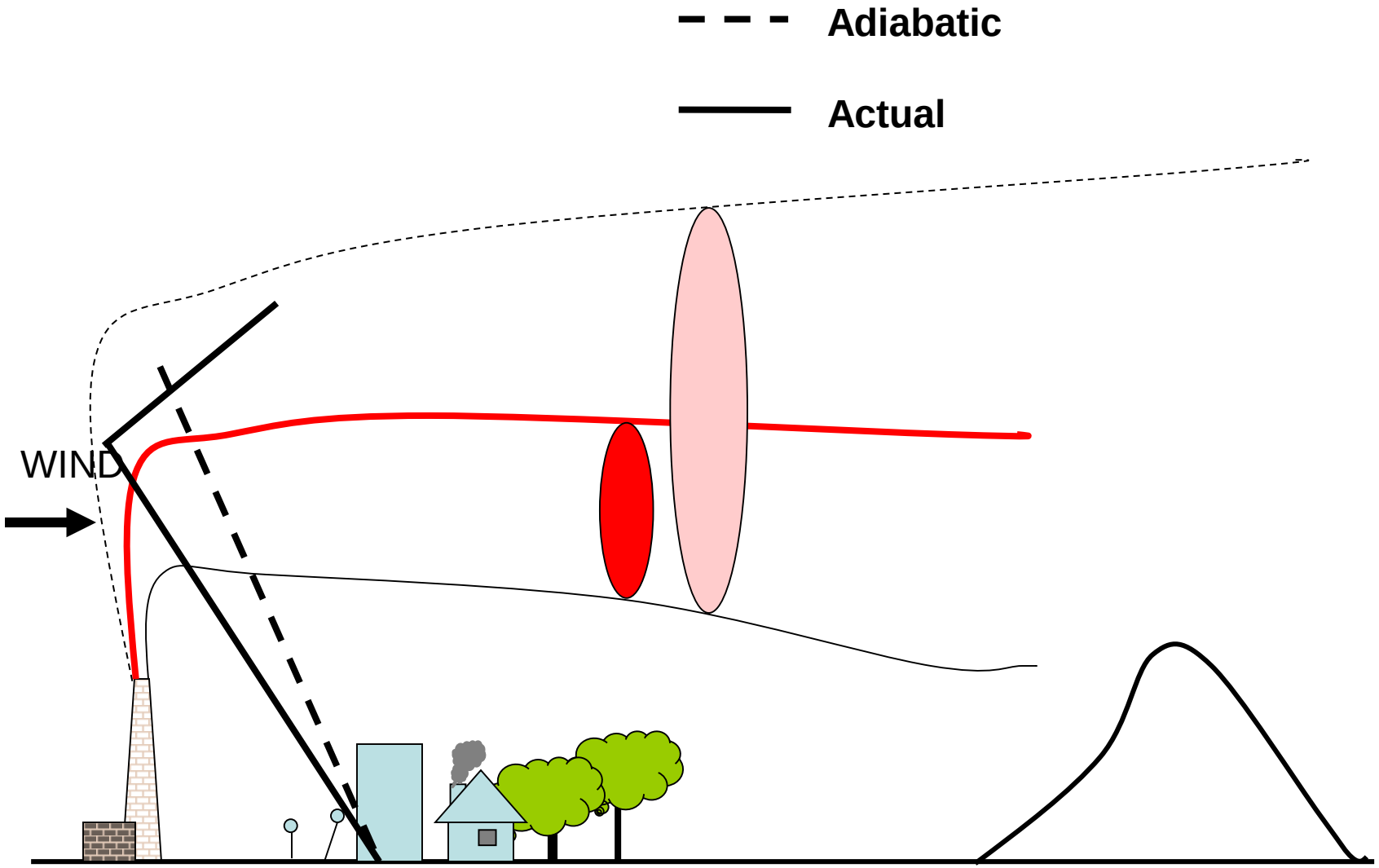

ADIABATIC (1°C/100 m)
ACTUAL
1100 m
1000 m (say)
19 °C Air Parcel at 1100 m
20 °C Air Parcel
18 °C
19 °C
20 °C


ADIABATIC (1°C/100 m)
1100 m
1000 m (say)
20 °C Air Parcel
900 m
21 °C Air Parcel at 1100 m
ACTUAL
20 °C
21°C
22 °C

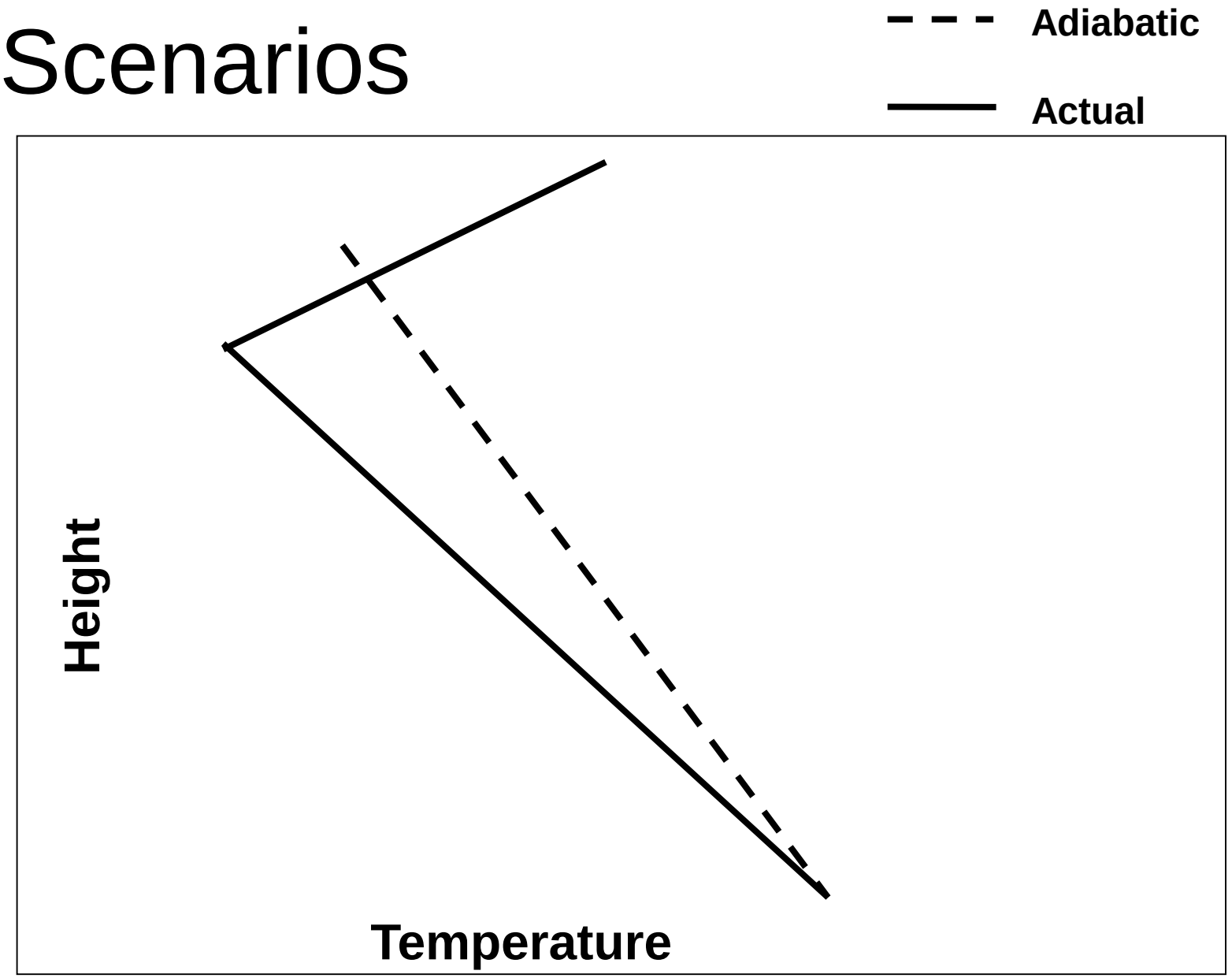
Change of (Relative Slope) Environmental Lapse Rate

(Adiabatic lapse rate slope does not change)

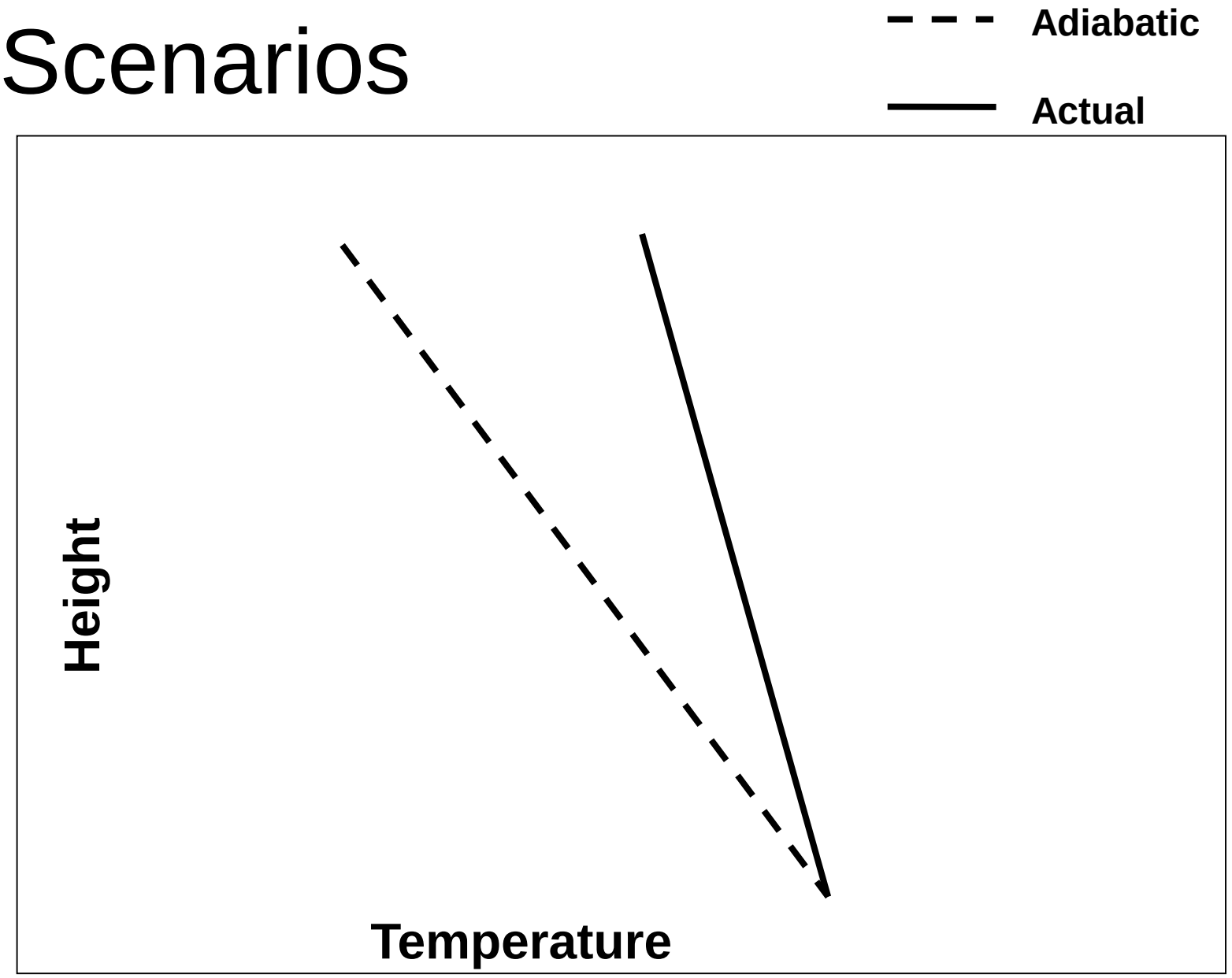

1100 m
1000 m (say)
19 °C Air Parcel at 1100 m
20 °C Air Parcel
ADIABATIC (1°C/100 m)
ACTUAL
19°C
19.5 °C
20 °C


Adiabatic
Actual
WIND

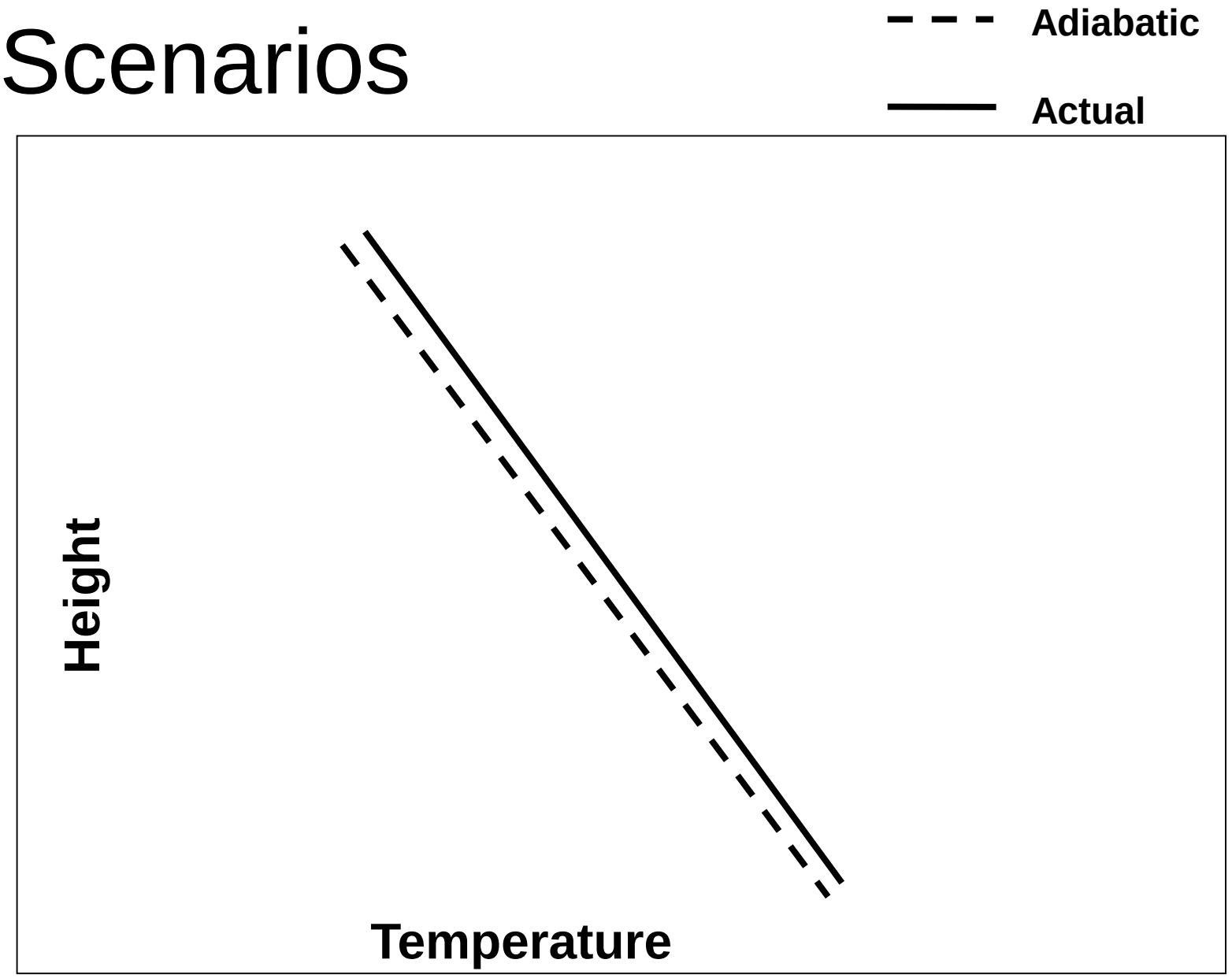
Scenarios



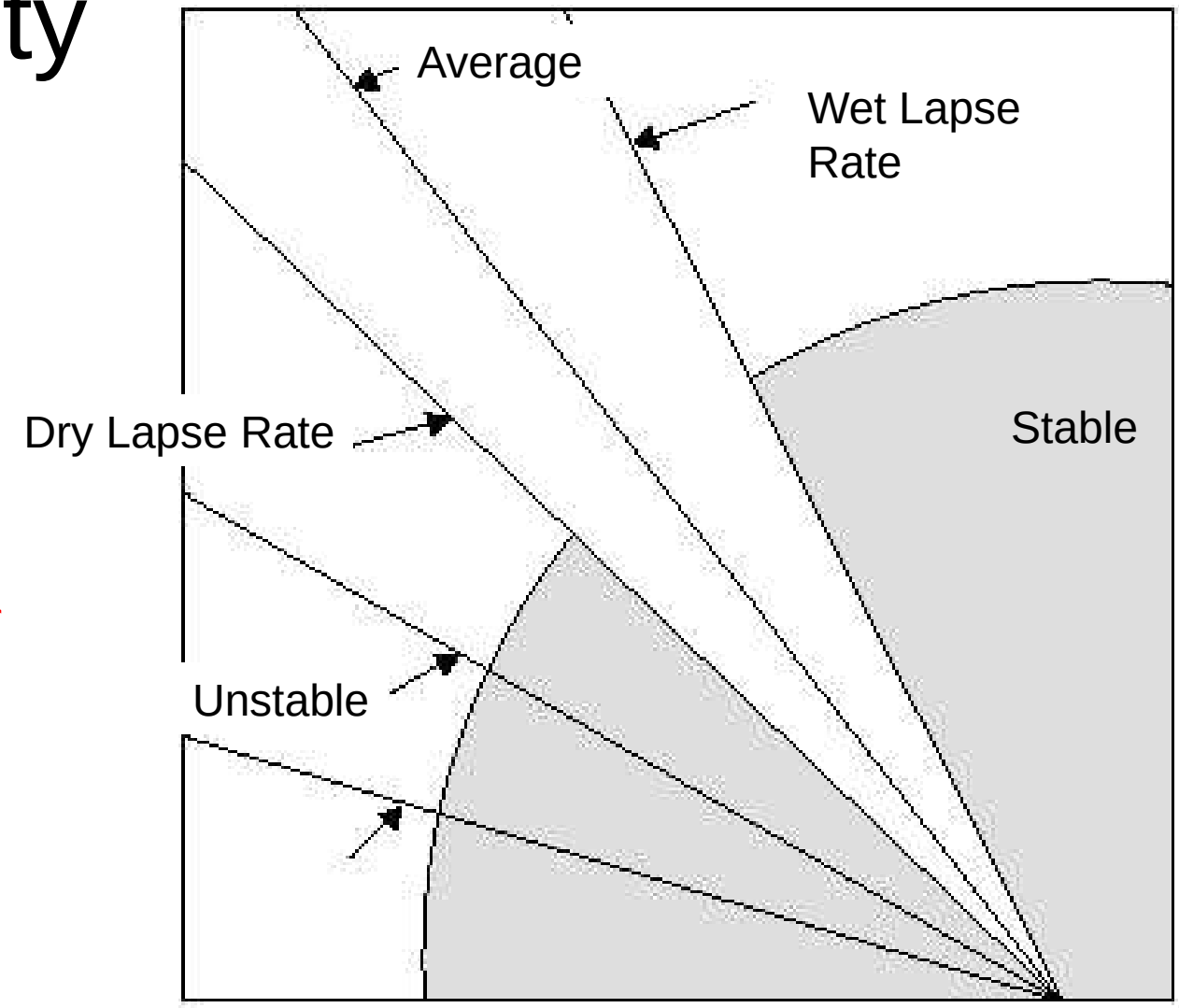
Scenarios



Scenarios

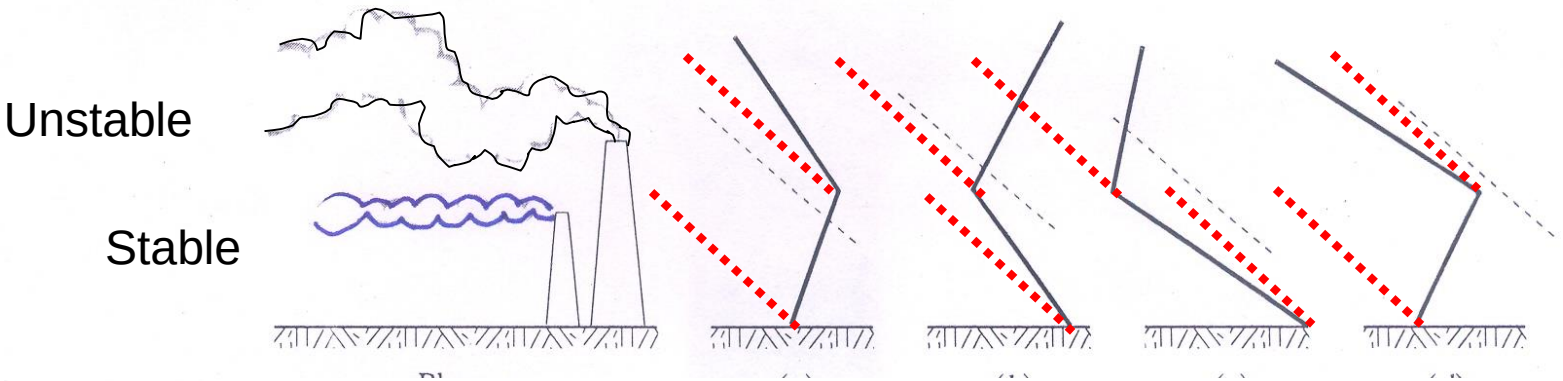


Stability



http://www.tpub.com/content/aerographer/14312/css/14312_47.htm

Exercise : Match the Likely Temperature Profile



(Adapted from Masters, 1997)

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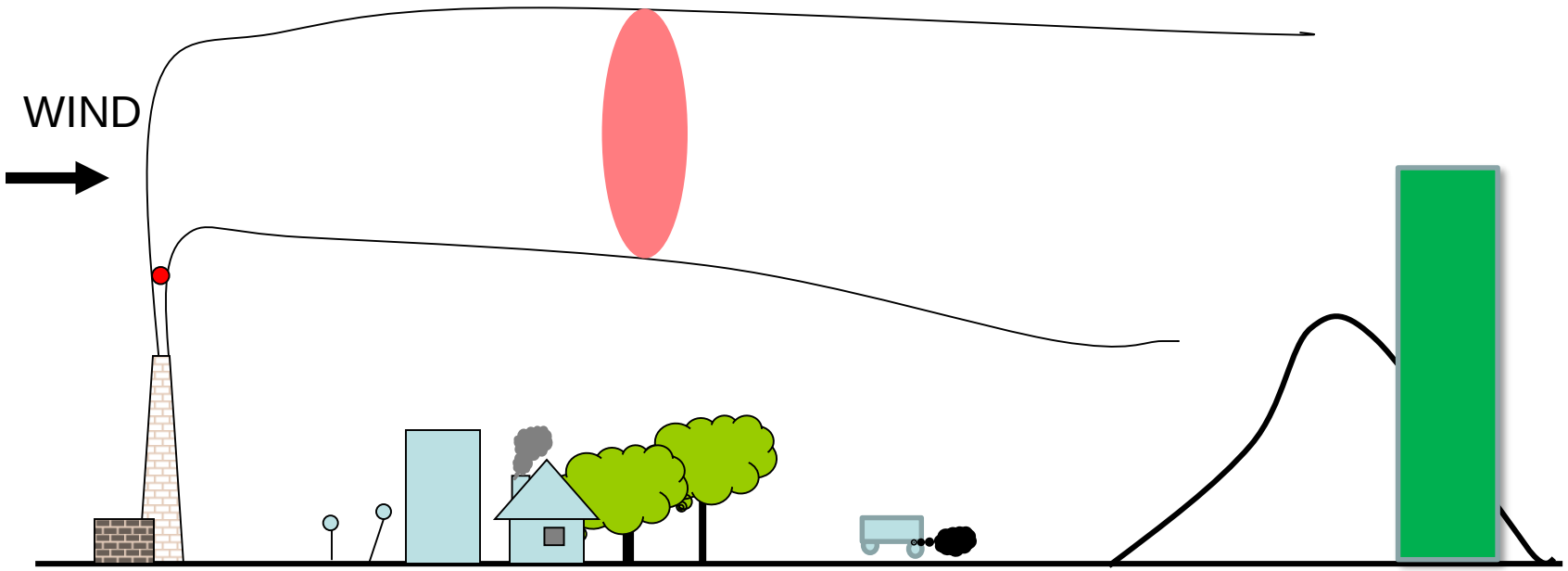
Dispersion – Gaussian Plume



Review

Dispersion and Mixing Influenced by :

- Wind
  - Speed
  - Direction
  - Wind Rose
- Temperature Lapse Rates
  - Dry adiabatic
  - Wet Adiabatic
  - Stability

Why are we doing all of this ?

- **If you want to set up a new industry, it implies adding a new source of pollutant(s)**
- **This source is PERMITTED to emit after it has applied the Best Available Control Technology (BACT) on their processes**
- **AFTER leaving the chimney, the concentrations on ground is determined by the meteorology**

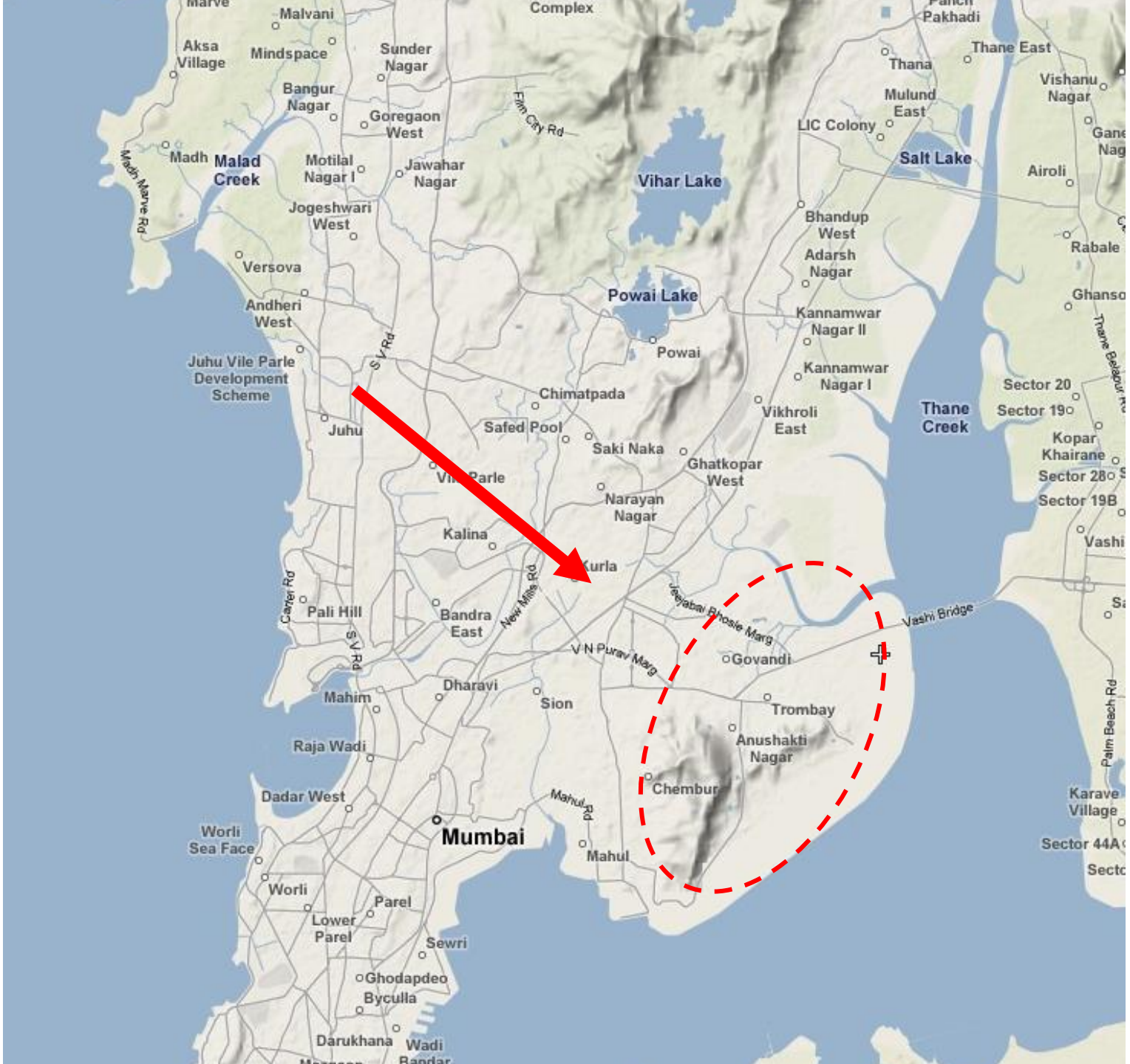
Why are we doing all of this ?

- **So,**
  - **If you want to know WHERE to put the new industry**
  - **If you want to know the pollution levels under the worst case scenario of STABLE conditions and low wind speeds**
  - **If you want to know what height does the chimney need to be**
  - **QUANTIFICATION of horizontal movement and vertical mixing becomes essential**

Why are we doing all of this ?

- **Gaussian Plume (Dispersion) Model (GPM) is used to estimate the Ground Level Concentrations for pollutants coming from a Chimney**

- **INPUTS to GPM**
  - **Height of chimney and Source Strength**
  - **Wind Rose Data**
  - **Atmospheric Stability of the region**

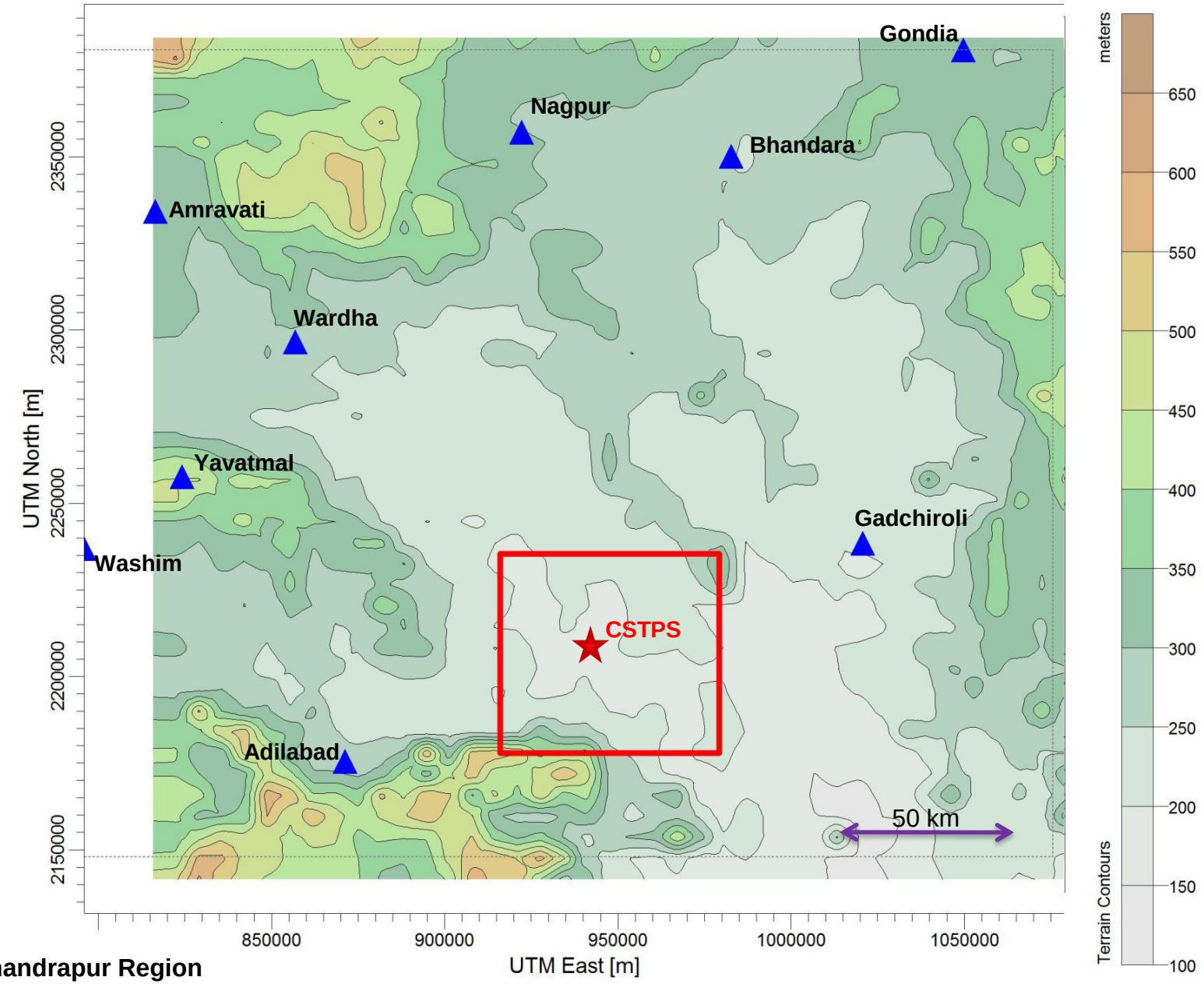

Malvani
Aksa Village
Mindspace
Sunder Nagar
Bangur Nagar
Goregaon West
Fifth City Rd
Madh
Malad Creek
Madh Marve Rd
Motilal Nagar I
Jawahar Nagar
Jogeshwari West
Versova
Andheri West
Juhu Vile Parle Development Scheme
S V Rd
Juhu
Complex
Vihar Lake
Powai Lake
Powai
Chimatpada
Safed Pool
Saki Naka
Kalina
Narayan Nagar
Kurla
New Mills Rd
Carter Rd
Pali Hill
Bandra East
S V Rd
Mahim
Dharavi
Sion
V N Purav Marg
Jeejabai Bhosle Marg
Govandi
Vashi Bridge
Trombay
Anushakti Nagar
Chembur
Mahul Rd
Mahul
Raja Wadi
Dadar West
Mumbai
Worli Sea Face
Worli
Parel
Lower Parel
Sewri
Ghodapdeo
Byculla
Darukhana
Wadi Bandar
Panch Pakhadi
Thane East
Thana
Vishanu Nagar
Mulund East
LIC Colony
Salt Lake
Airoli
Bhandup West
Adarsh Nagar
Rabale
Kannamwar Nagar II
Kannamwar Nagar I
Vikhroli East
Ghatkopar West
Thane Creek
Sector 20
Sector 19
Kopar Khairane
Sector 28
Sector 19B
Vashi
Palm Beach Rd
Karave Village
Sector 44A

Fun Exercise

- **Find the Wind Rose for**
  - **Mumbai**
  - **Your home city**
  - **Does IMD have a Met Station near your City ?**

Case Study
for
Wind Roses

Terrain Map of Chandrapur with 9 neighboring IMD stations

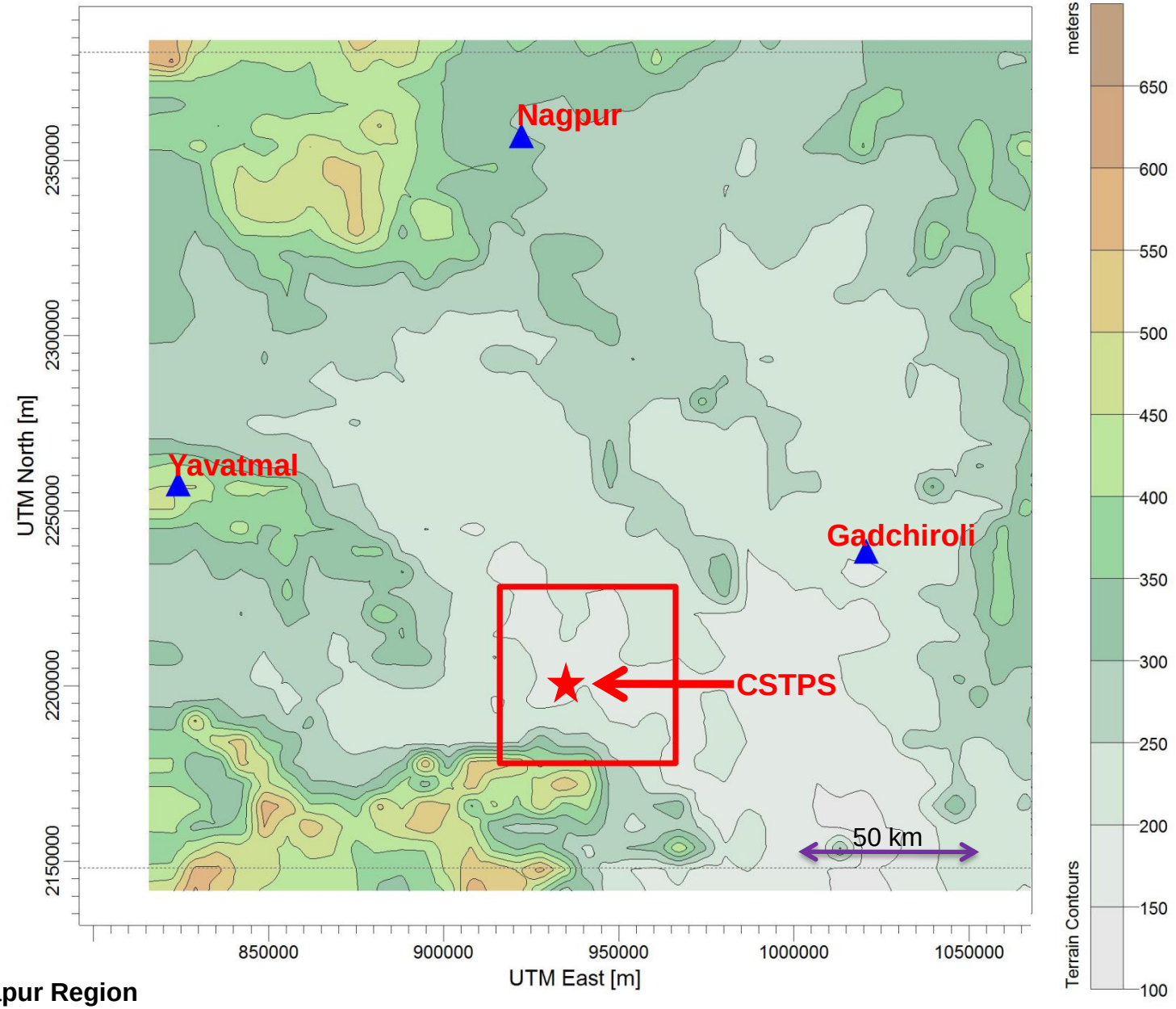


Chandrapur Region

- Three IMD stations were selected to eliminate possible influence of terrain on local scale wind patterns :

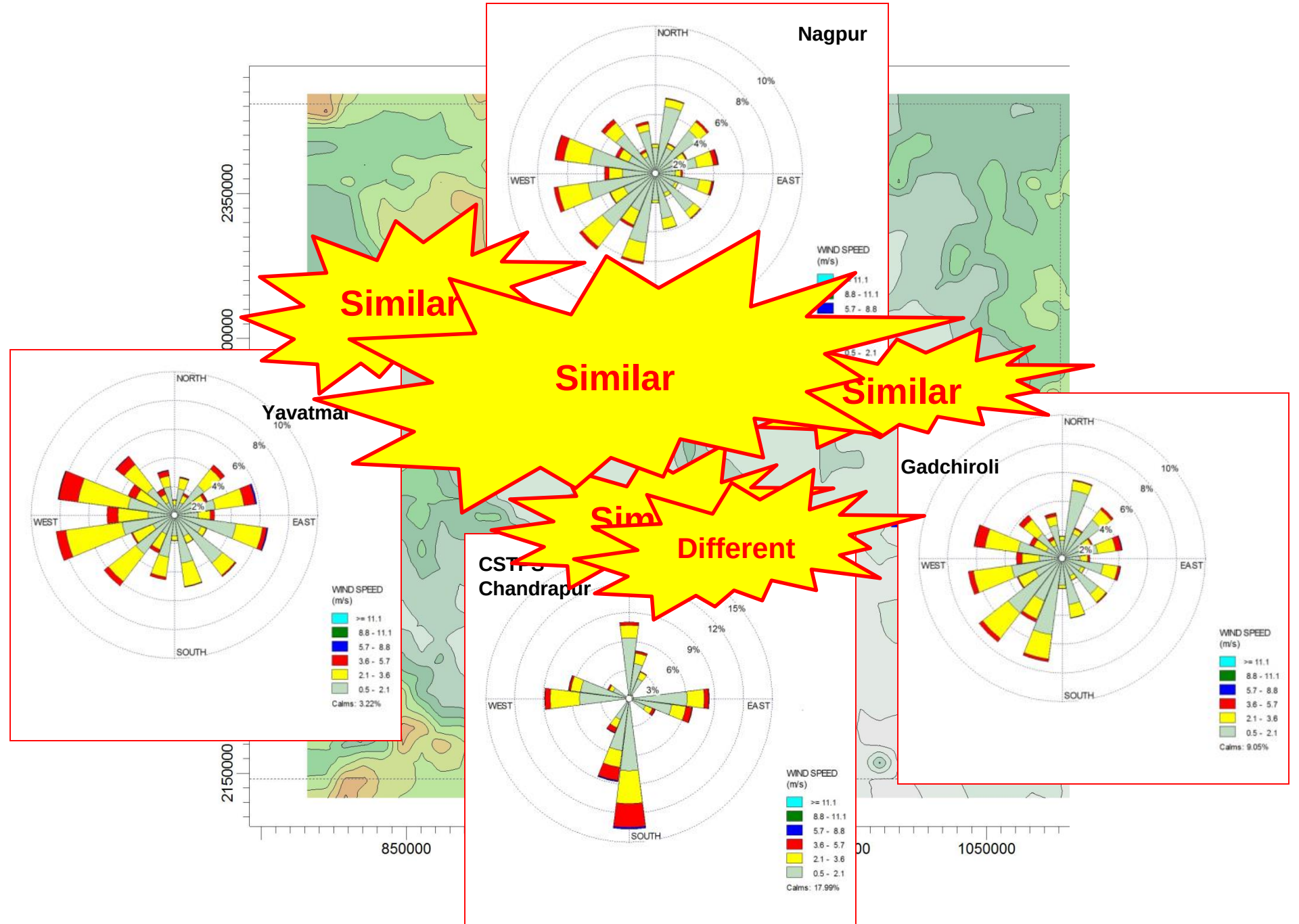
1. Nagpur
2. Gadchiroli
3. Yavatmal

Location of CSTPS met station with the 3 selected IMD stations



Chandrapur Region

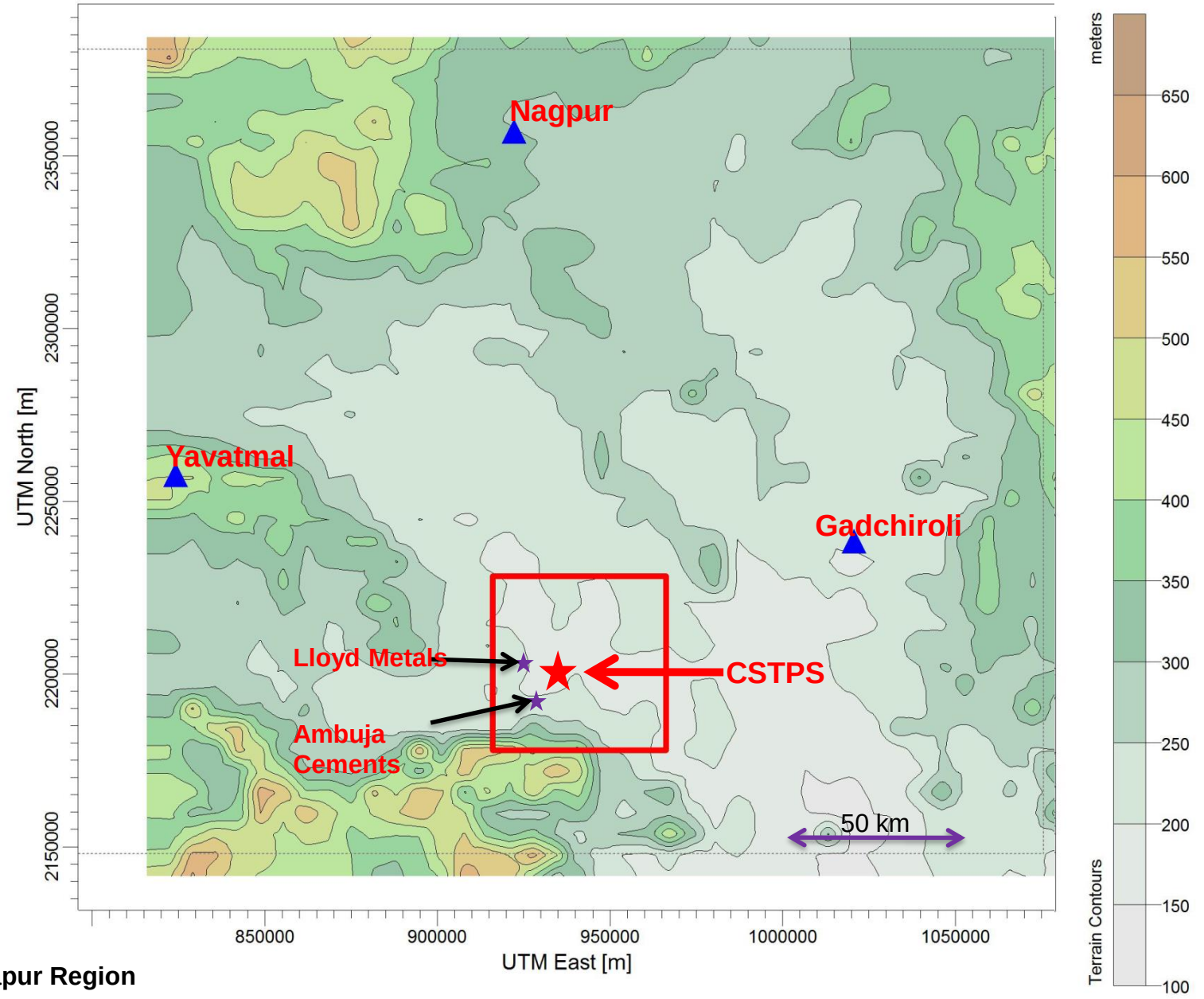
Wind conditions at 3 IMD Stations and CSTPS in Chandrapur



Conclusions

- Wind conditions are similar at the three IMD locations.
- CSTPS station by comparison is NOT similar.
- Therefore, CSTPS Met data needs to be verified with other Local Met Station Data
  - Ambuja Cement
  - Lloyd Metals

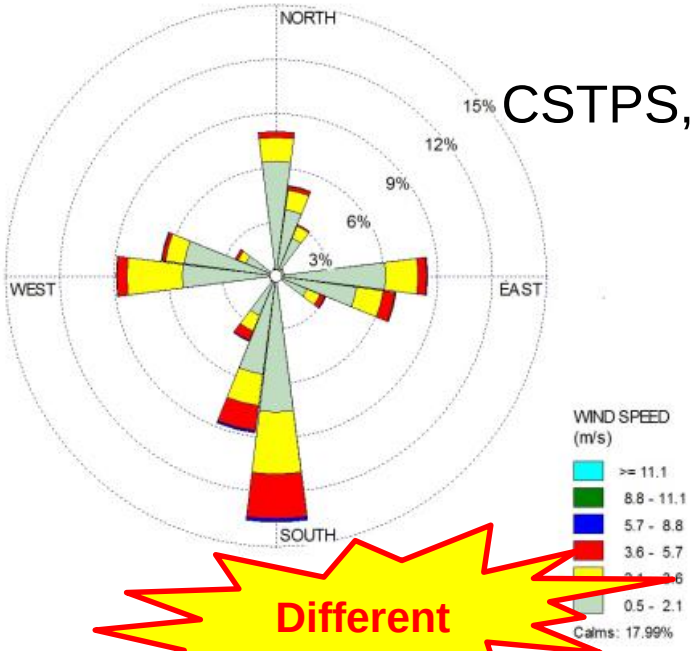
Location of CSTPS met station with other two local met stations from Lloyd Metals and Ambuja Cements



Chandrapur Region

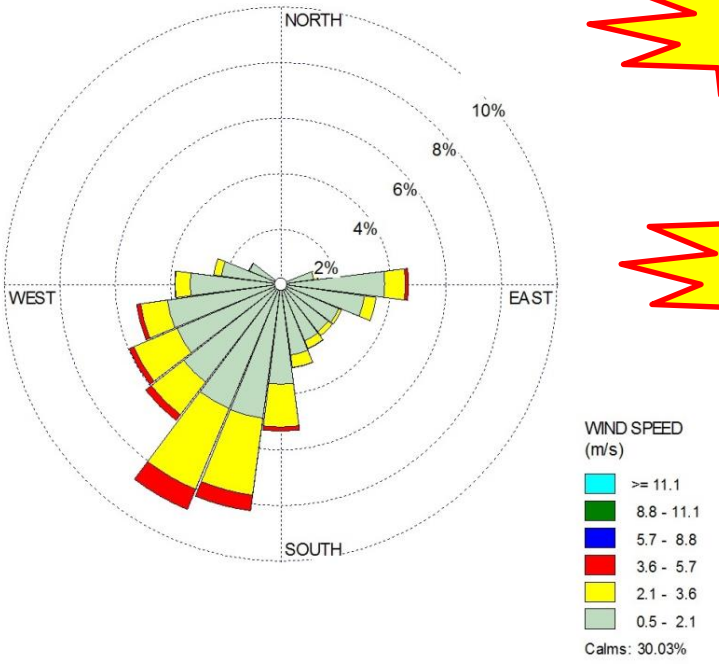
Wind condition at CSTPS for 2011, and M/s Lloyd Metals Ltd., M/s Ambuja Cements in Chandrapur for 2013

CSTPS,2011



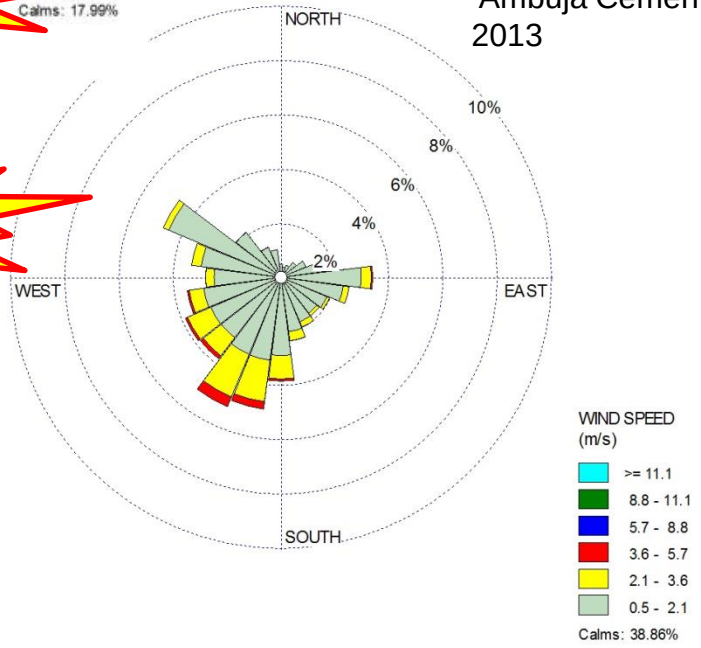
Different

Lloyd Metals, 2013



Similar

Ambuja Cements 2013



Models are only as Good as the Input Data