NOAA CREST Strategies for Urban Coastal Areas

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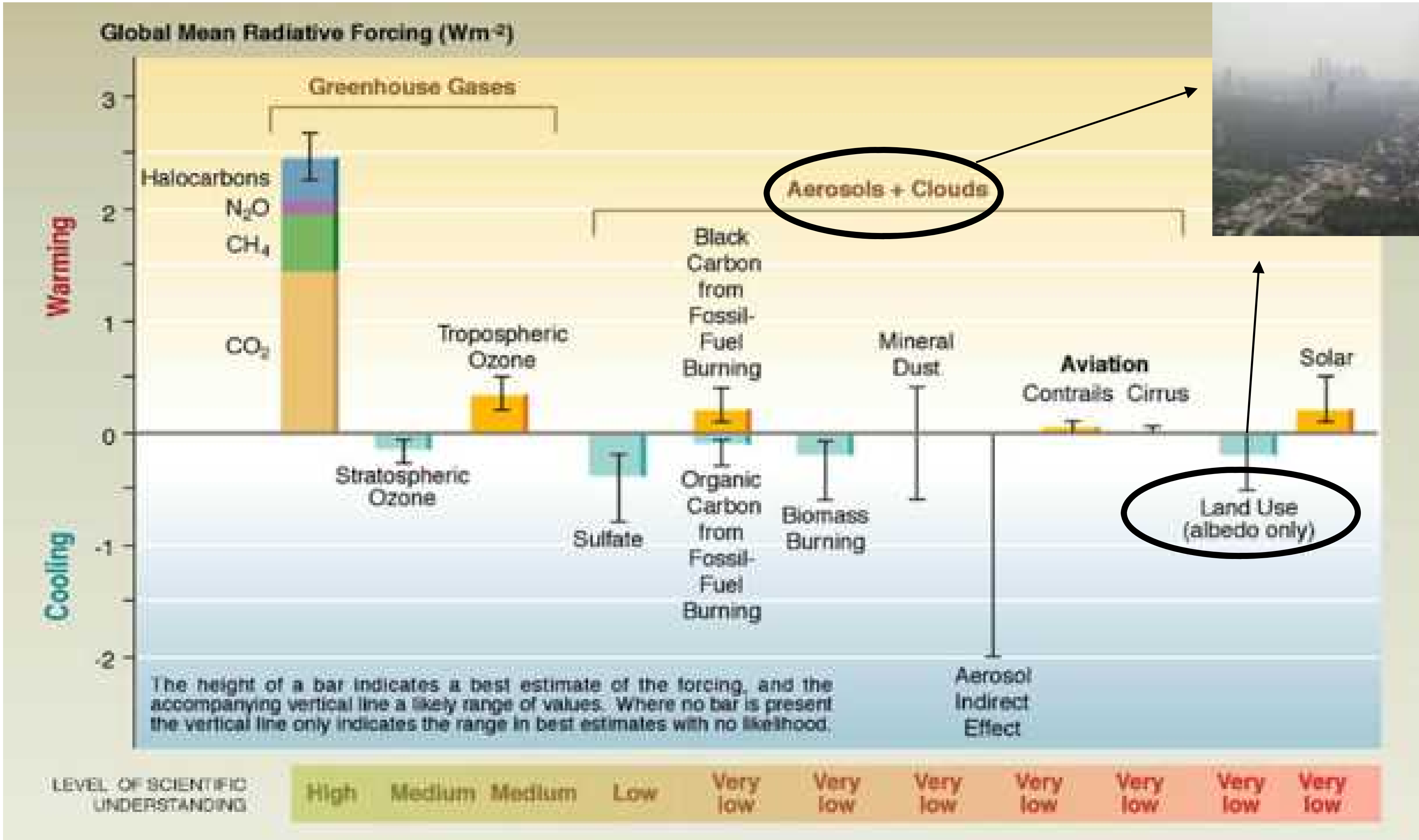


US Climate Change Science Program
www.climatescience.gov

Questions & Strategies

- The changing land-sea interaction for urban areas.

- Relationship of aerosols on clouds & precipitation in urban coastal areas.

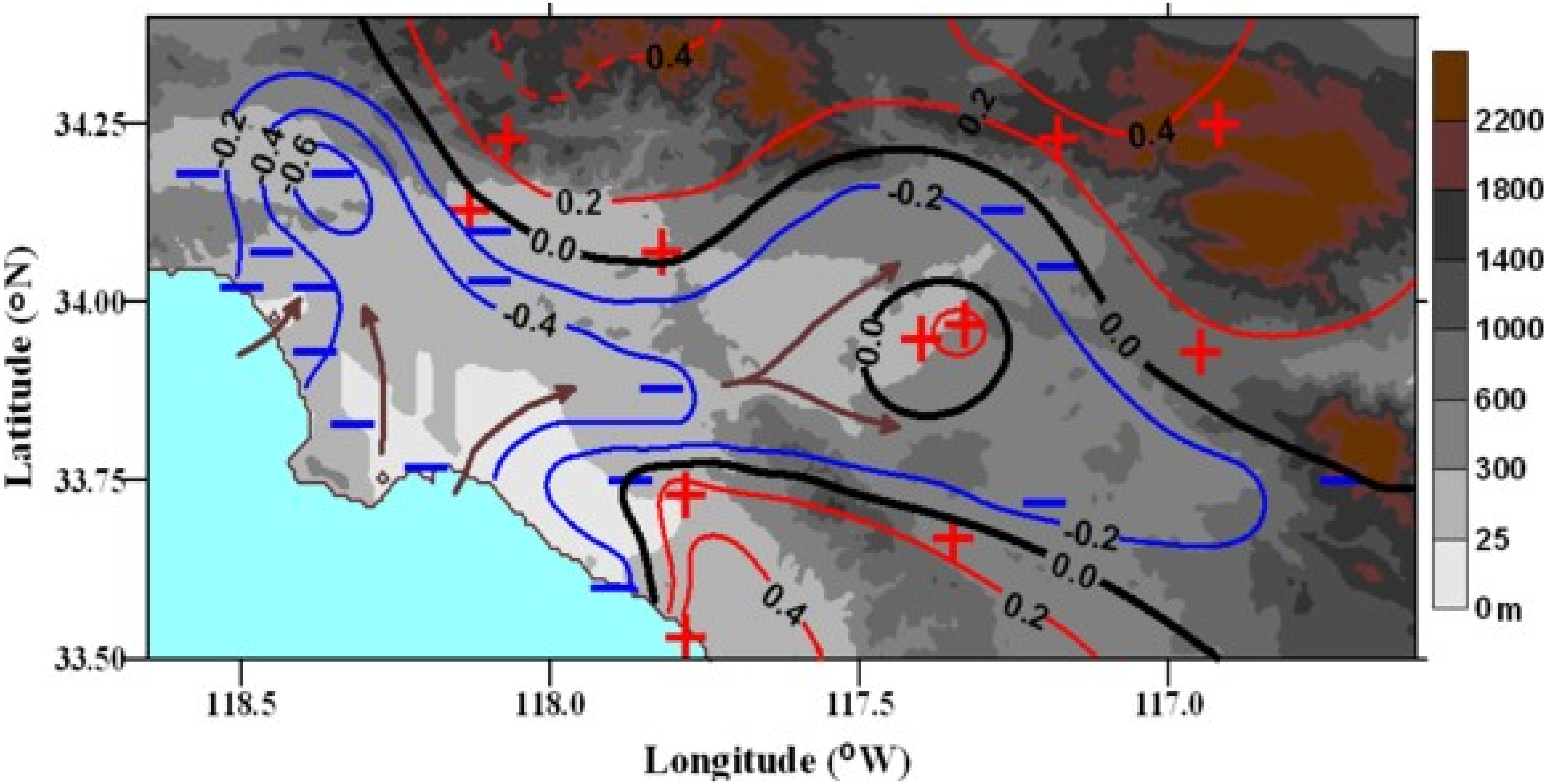
The (LCLU + GW) Question on Urban Coastal Areas

1. What is the relative climatic impacts of global climate change in urban coastal regions?
2. Under these conditions of LCLU and global climate change, what are the combined effects in sea breezes, surface temperatures, precipitation, and extreme events?

Continental case: Lebassi et al. (1 July 2009), J. of Climate

Observed 1970-2005 CA JJA max-Temp (^{0}C/decade) trends in SFBA & SoCAB (below) showed concurrent

> low-elevation coastal-cooling & > inland-warming



Current Hypothesis

INCREASED INLAND WARMING →

INCREASED HORIZONTAL T-GRADIENTS (COAST TO INLAND)→

INCREASED SEA BREEZE: FREQ, INTENSITY, PENETRATION, &/OR DURATION →

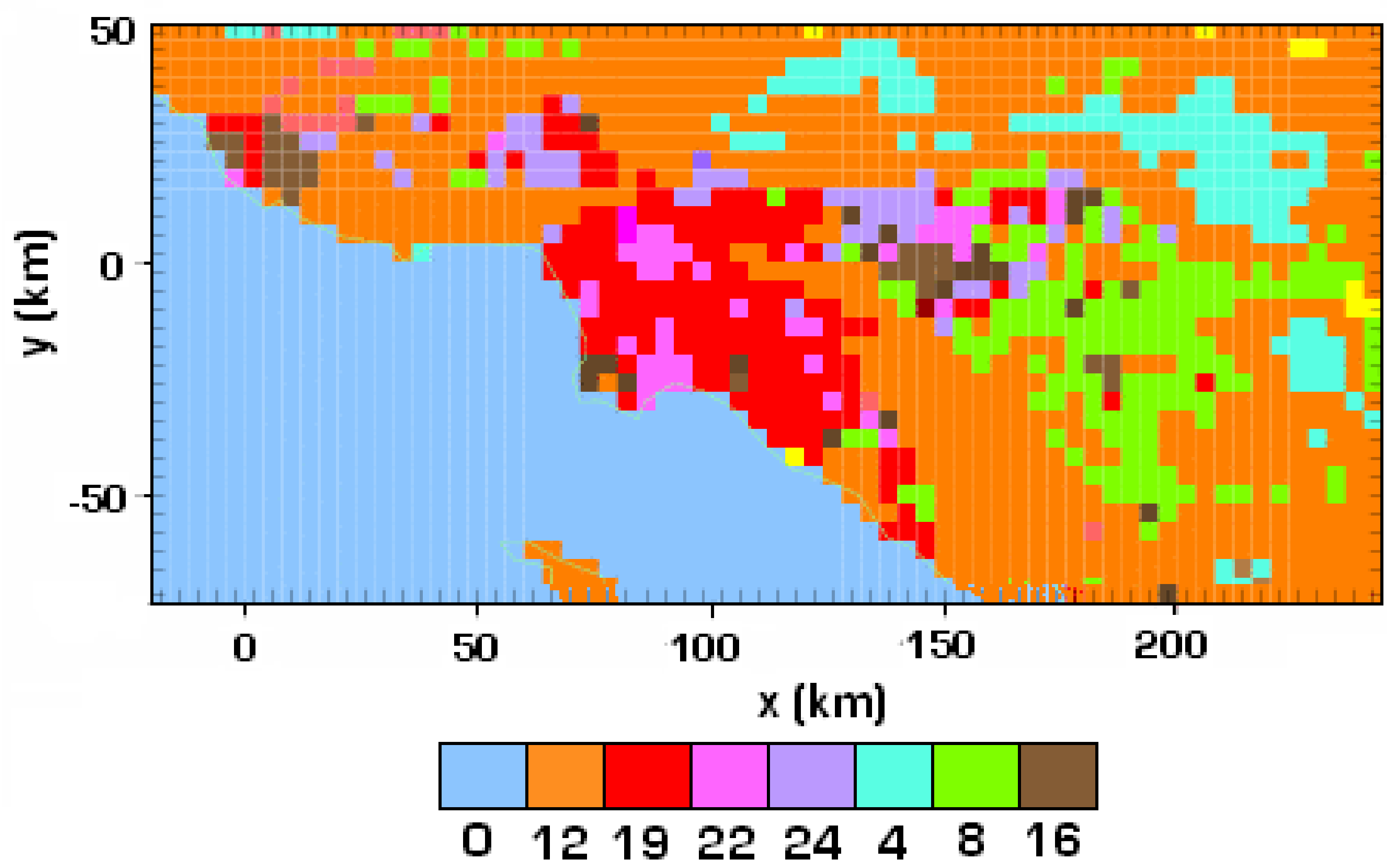
COASTAL REGIONS SHOULD THUS EXPERIENCE COOLING TEMPS DURING SUMMER DAYTIME PERIODS

Methodology

- **Current goal:** **separate out effects of urbanization & LULC changes on observed temp-trends and on sea breeze flow patterns by use of numerical simulations**
- **Regional Atmospheric Modeling System (RAMS) model**
  - **Runs 1 vs. 2:**
    - **Research question: Effects of urbanization?**
    - **Both runs: JJA 2002 climate**
    - **Run 1: current urban LULC (NOAA 2002, at 30 m resolution**
    - **Run 2: pre-urban LULC (all urban turned to dominant class, i.e., scrubland)**
  - **Runs 1 vs. 3:**
    - **Research question: Effects of global climate change?**
    - **Run 3: uses**
      - **Run 1 (Current) LULC**
      - **Past JJA 1970 climate (only for August 1-10, 2002 for now)**

Grid 2 (4 km) LCLU-classes: present case (2002)

- Input: 30 m NOAA LULC mapped into Leaf-3 RAMS classification
- Output: dominant class, with parameter values as weighed averages
- Urban Classes 19 (red) , 22 (pink), & 24 (grey)



New Tech: determination of urban Veg, Rooftop, & Street fractions

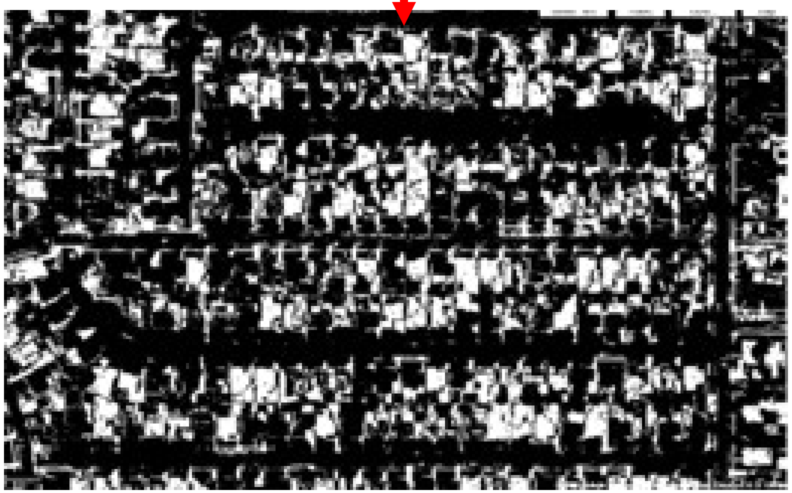
(a)

Initial visible Google map for typical urban class 19

(b)

Resulting 16 color visible image: 32% is veg & 68% is roof + street

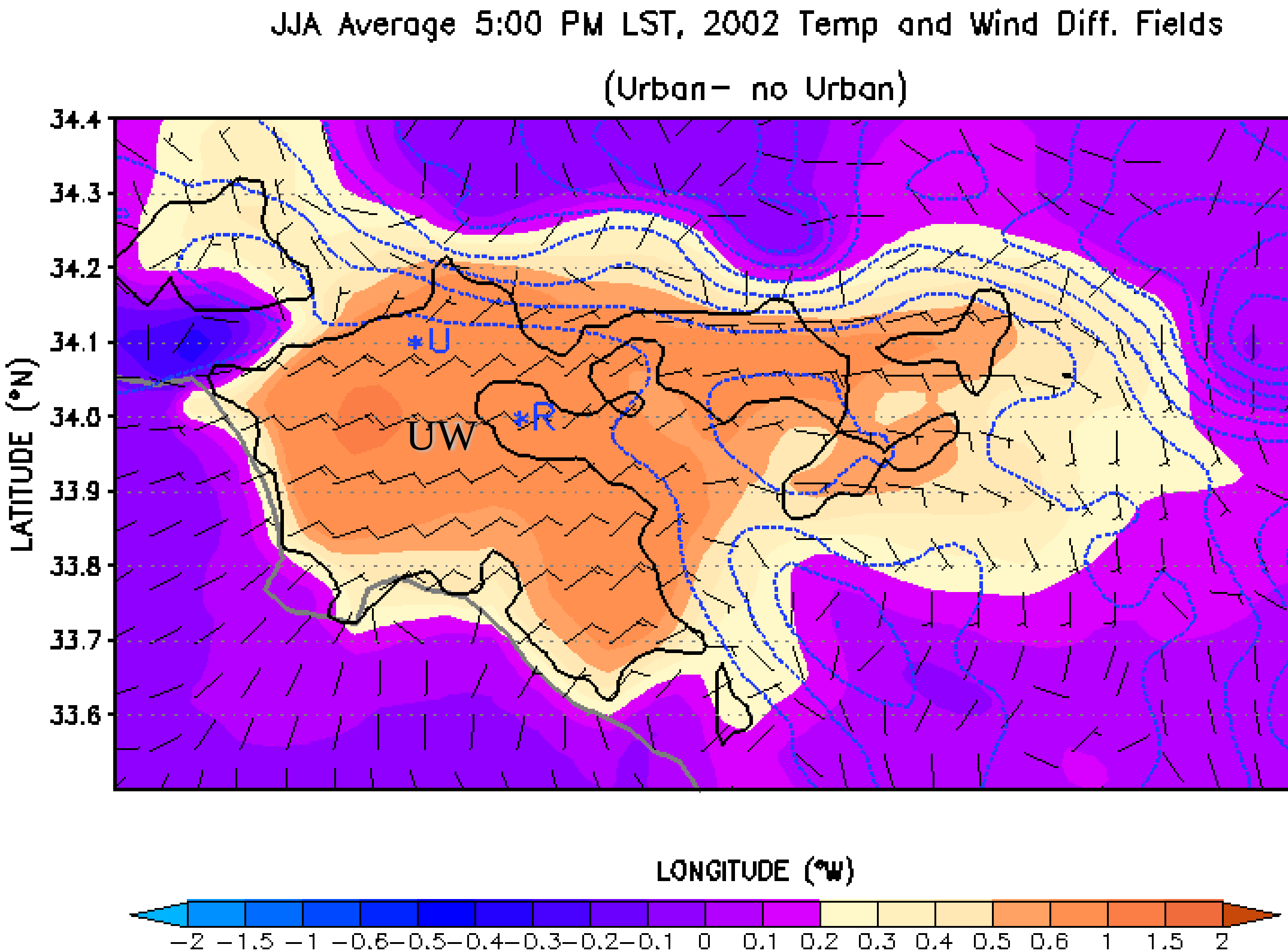
(c)



> Resulting 2 color visible image: building are white (52%): &
vegetation + streets are black (48%) ➔
> Thus (48-32%=) 16% are streets

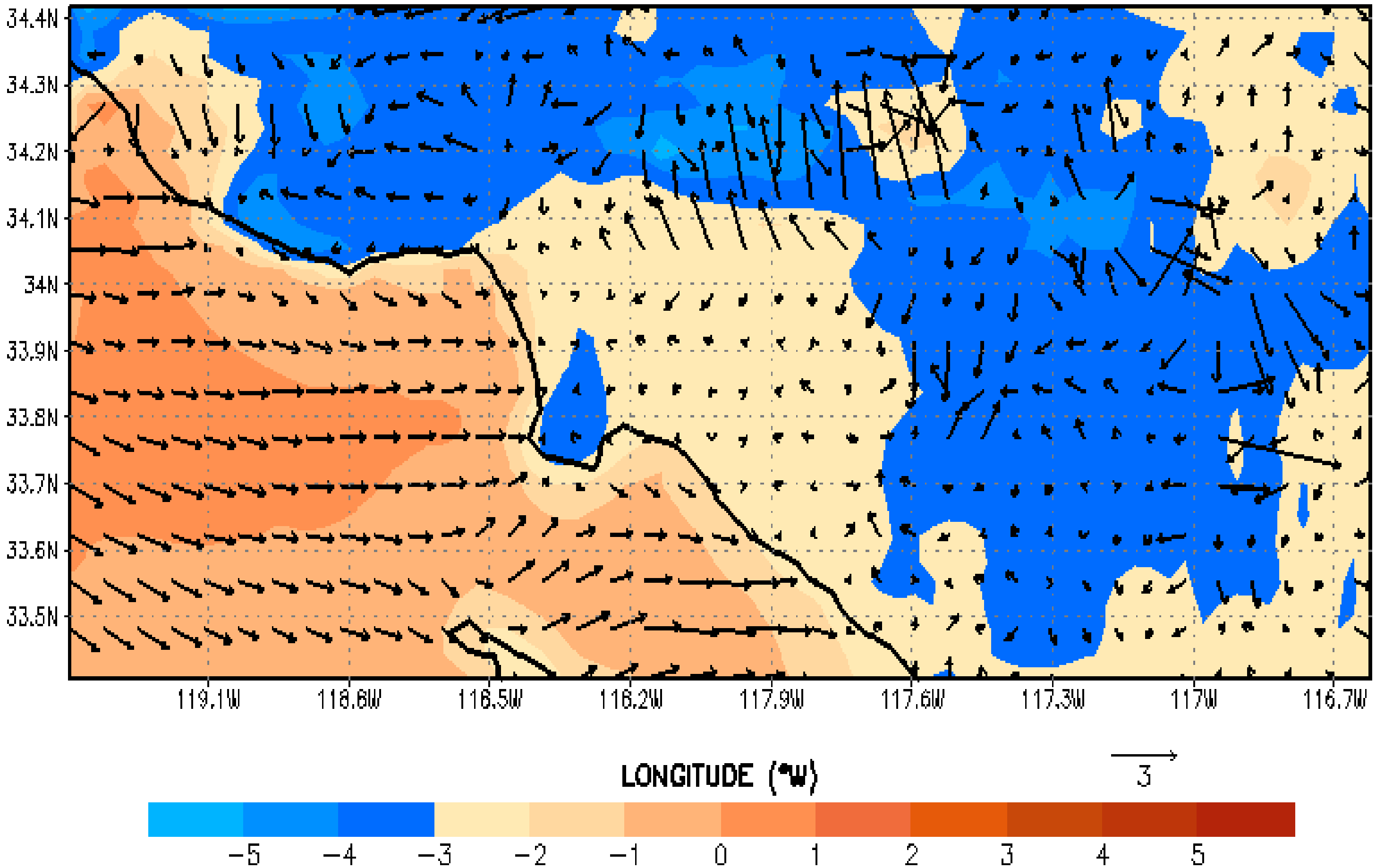
Methodology:

- Start w/ visible Google map for typical urban area (map-a)
- Change map-a to 16-color image (map-b) & count fraction of green pixels (32%)
- Change map-a to 2-color image (map-c)
  - > where white fraction is rooftop & black fraction is thus veg + streets
  - > Street fraction is thus black fraction minus green fraction (from map-b)
- Only veg fractions can be input into current RAMS lookup table



Run 1 minus Run 2, 5 PM key: JJA
Urban: urban has large warming (UW) area and counter-flow (Run-1 vector is onshore & difference vector is offshore due to z0-deceleration)
Rural: low elevation has smaller warming due to adv; interior has cooled due to induced secondary-circulations

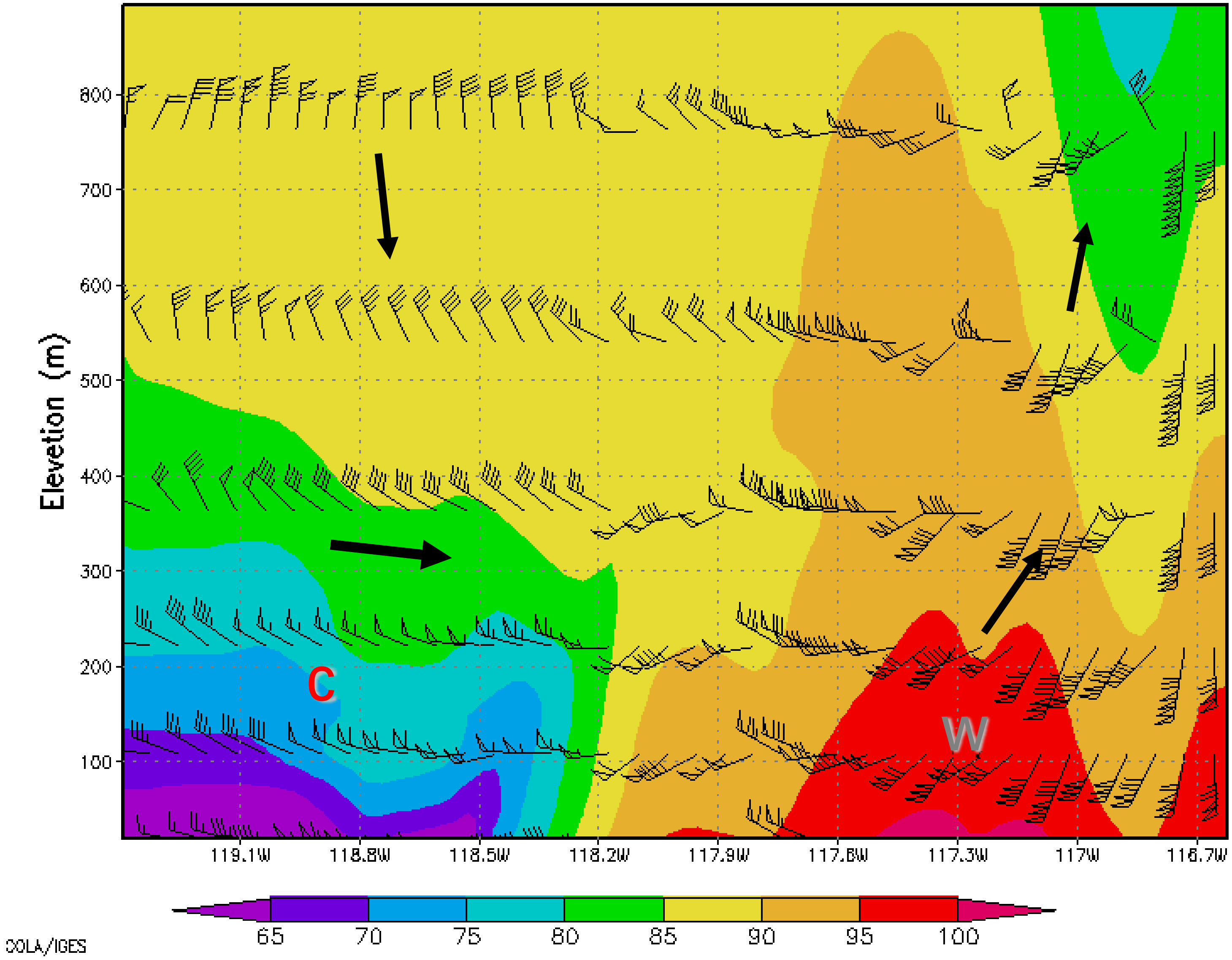
5 PM Aug 1-10 average change (current-2002 minus past-1970): temp (colors) and speed vectors (m/s)

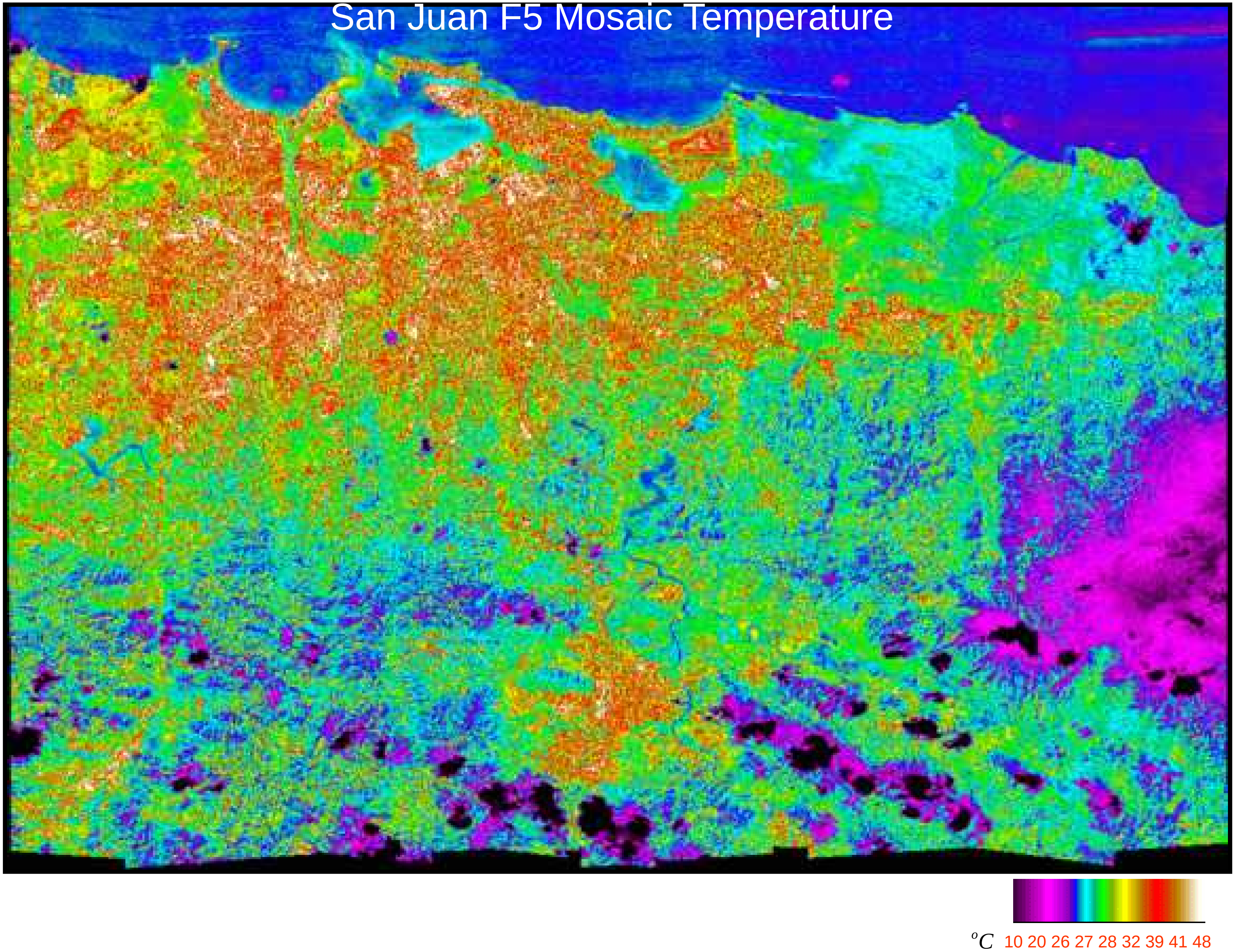


Temps: GHG warming (W) over Ocean (2 K) increases sea breeze flow (2-3 m/s), which cools (C) temps over rural area (3-4 K), while the UHI counters this sea breeze induced-cooling (as city only cools by 2-3 K).

Winds: Stronger HPGF accelerates (A) over-ocean flow (by 2 m/s), but urban z_0 retards (R) on-shore flow over the city by 1 m/s

9 July, 5 PM LST: u, 100-w as f(x, z) at 34ºN

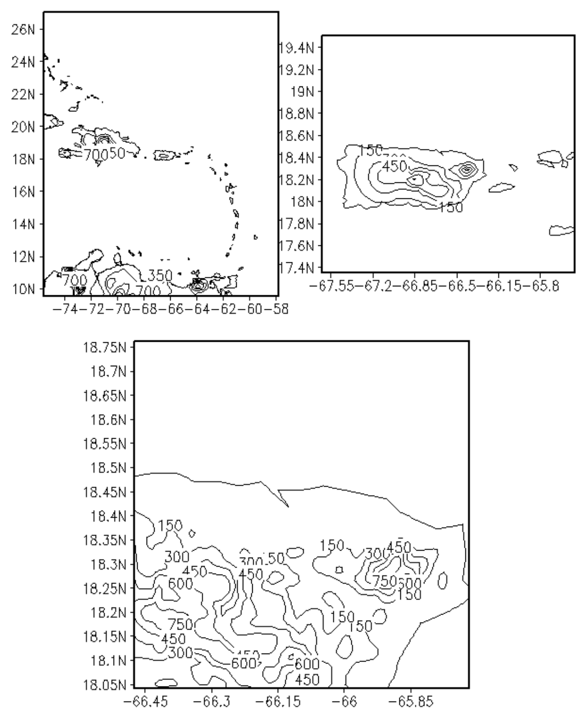


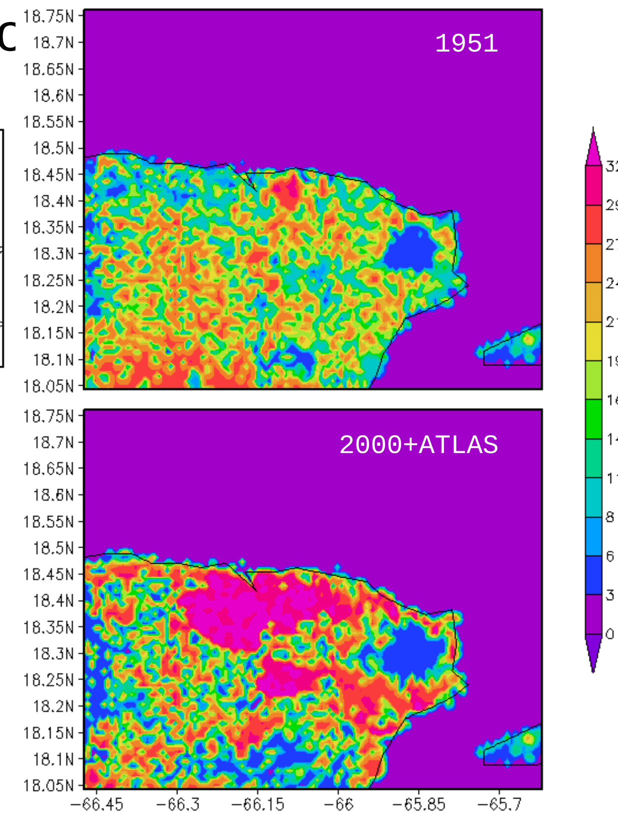

San Juan F5 Mosaic Temperature
°C 10 20 26 27 28 32 39 41 48

Tropical Coastal Areas

In order to answer these questions for tropical coastal areas a series of numerical atmospheric simulations are proposed to separate the signals of LCLU change and global climate change. The Regional Atmospheric Modeling System (RAMS) is the main research tc

General Model Configuration			
	Grid 1	Grid 2	Grid 3
$\Delta x = \Delta y$	25km	5km	1km
vertical	σ-coordinate $\Delta\sigma$ = 30mts near sfc until $\Delta\sigma$ = 1km, model top at ~25km		
CPU time	Approximately 5 to 6 days for a 30-day simulation		





Model grids w/ topography and surface characteristics for the two scenarios analyzed

Table 1: Numerical Experimental Matrix

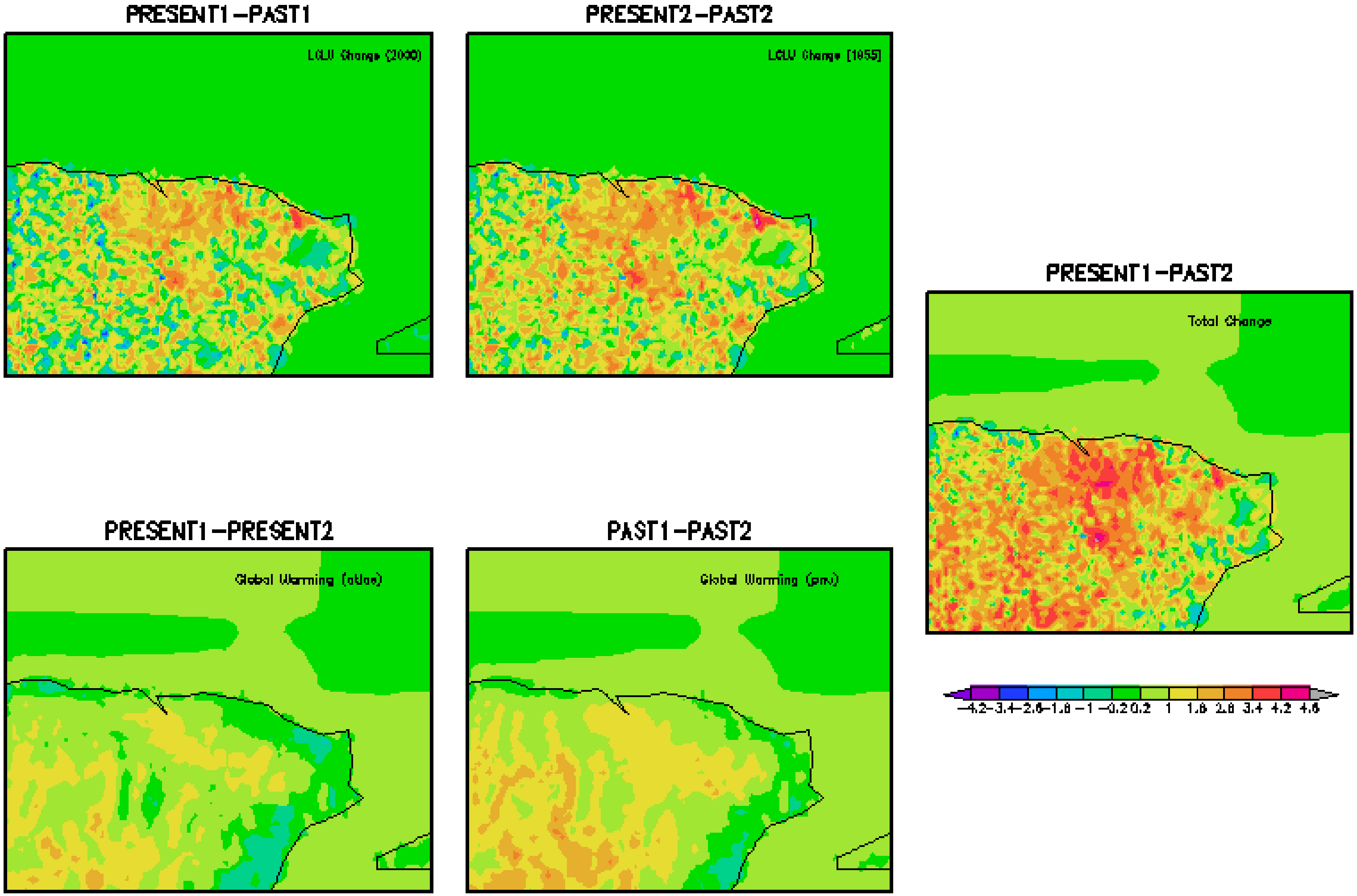
Run ID	LCLU	Driving Conditions**	Questions
Present1*	ATLAS	Present Clim. & GHG concentration	1, 2, 3, 4+
Present2	ATLAS	Past Clim. & GHG concentration	2, 3, 4+
Past1	PNV	Present Clim. & GHG concentration	1, 3, 4+
Past2	PNV	Past Clim. & GHG concentration	3, 4+

* Control run

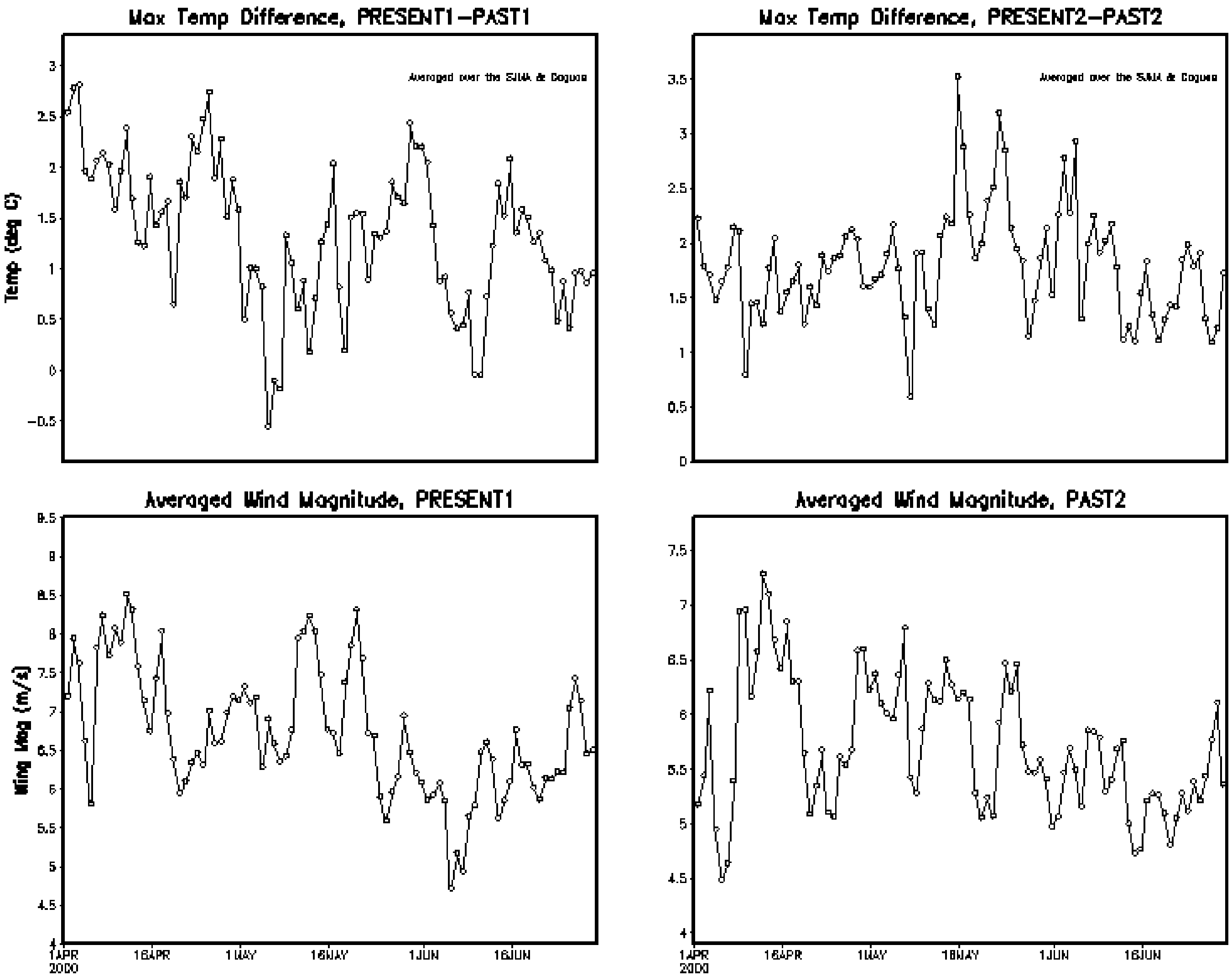
** The timeframe for the present and past climatologies will be selected as to reduce the influence of the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) on the Caribbean Early Rainfall Season (ERS) climate, as identified by previous studies, and in accordance with historical LCLU changes.

\+ The fourth question arose while analyzing the urban/vegetation canopy modeling parameterization and is presented later.

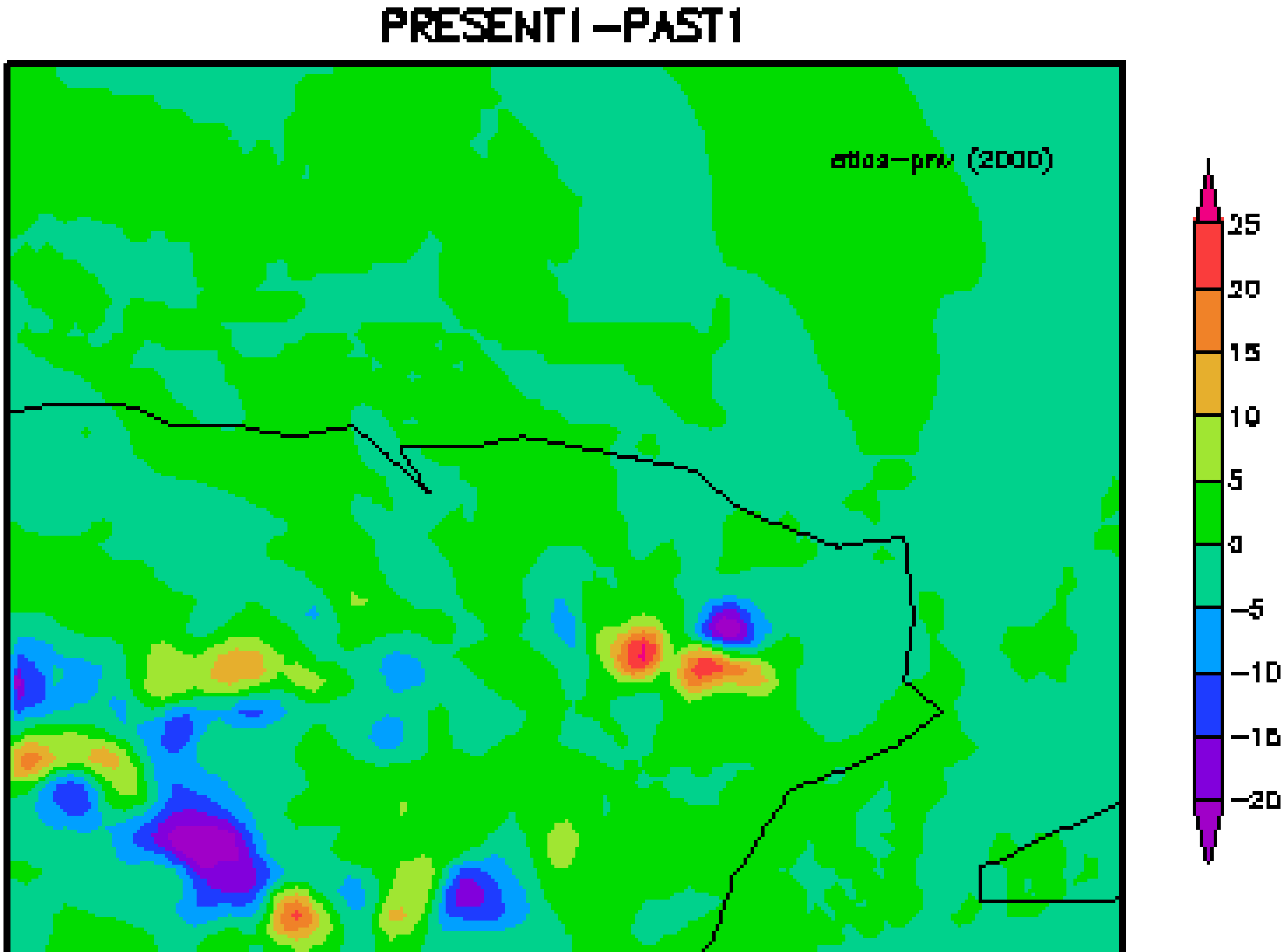
Model Results: Impacts on Max Temperature



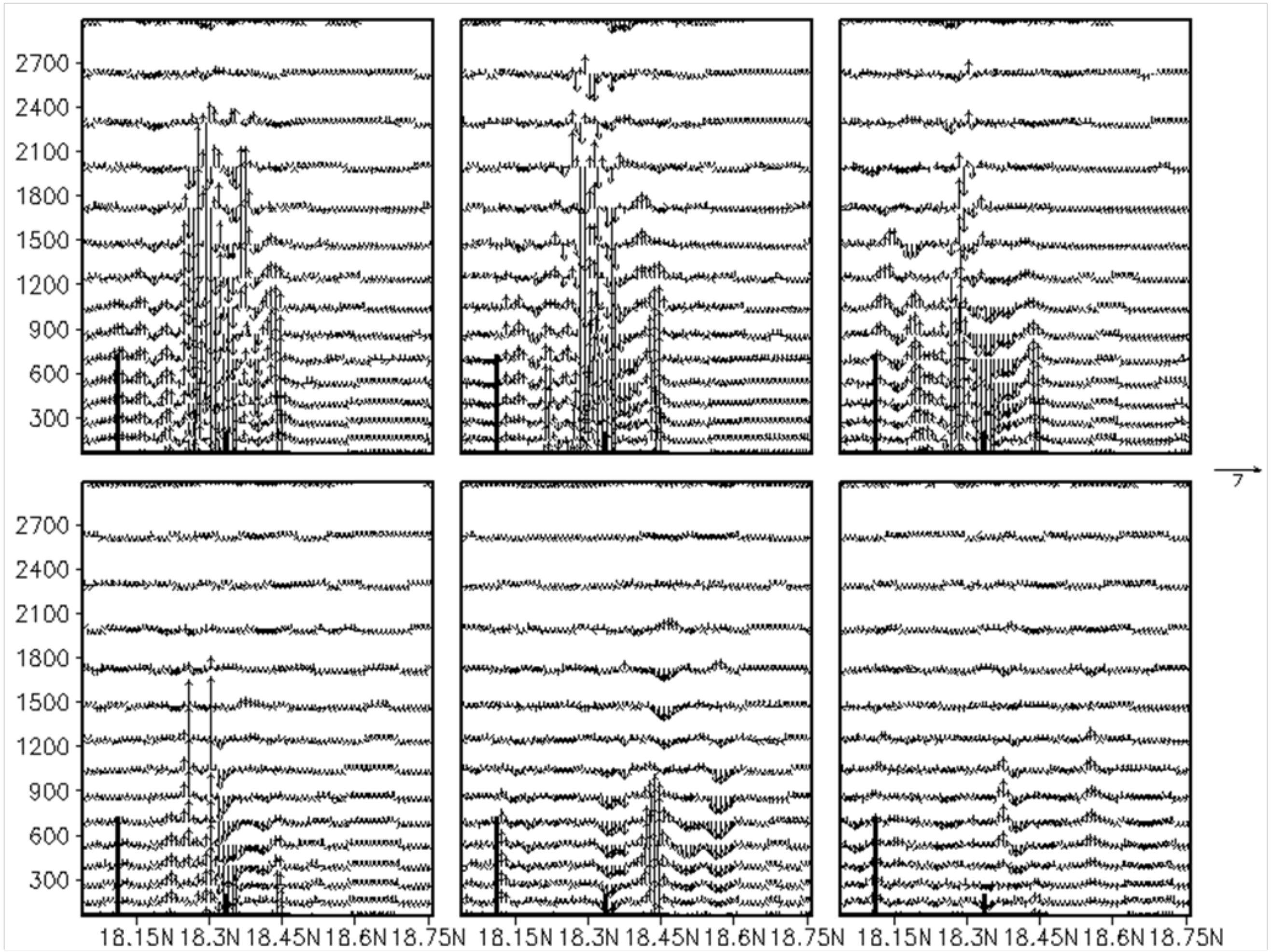
Model Results: LCLU Change
DT vs. Wind Magnitude



Preliminary Results:
ERS 2000, LCLU Change Impact



Precipitation Difference



North-south vertical cross-sections of wind vectors difference between the Urban and Natural run for the average 12, 14, and 16 (top row, left to right), and 18, 20, and 22 (bottom row, left to right) local time. The thick horizontal line at the bottom of each panel depicts the presence of land, and the two thick vertical lines represent the two reference topographic peaks of ~ 700 and 200m.

Summary/Conclusions on LCLU/GW Questions

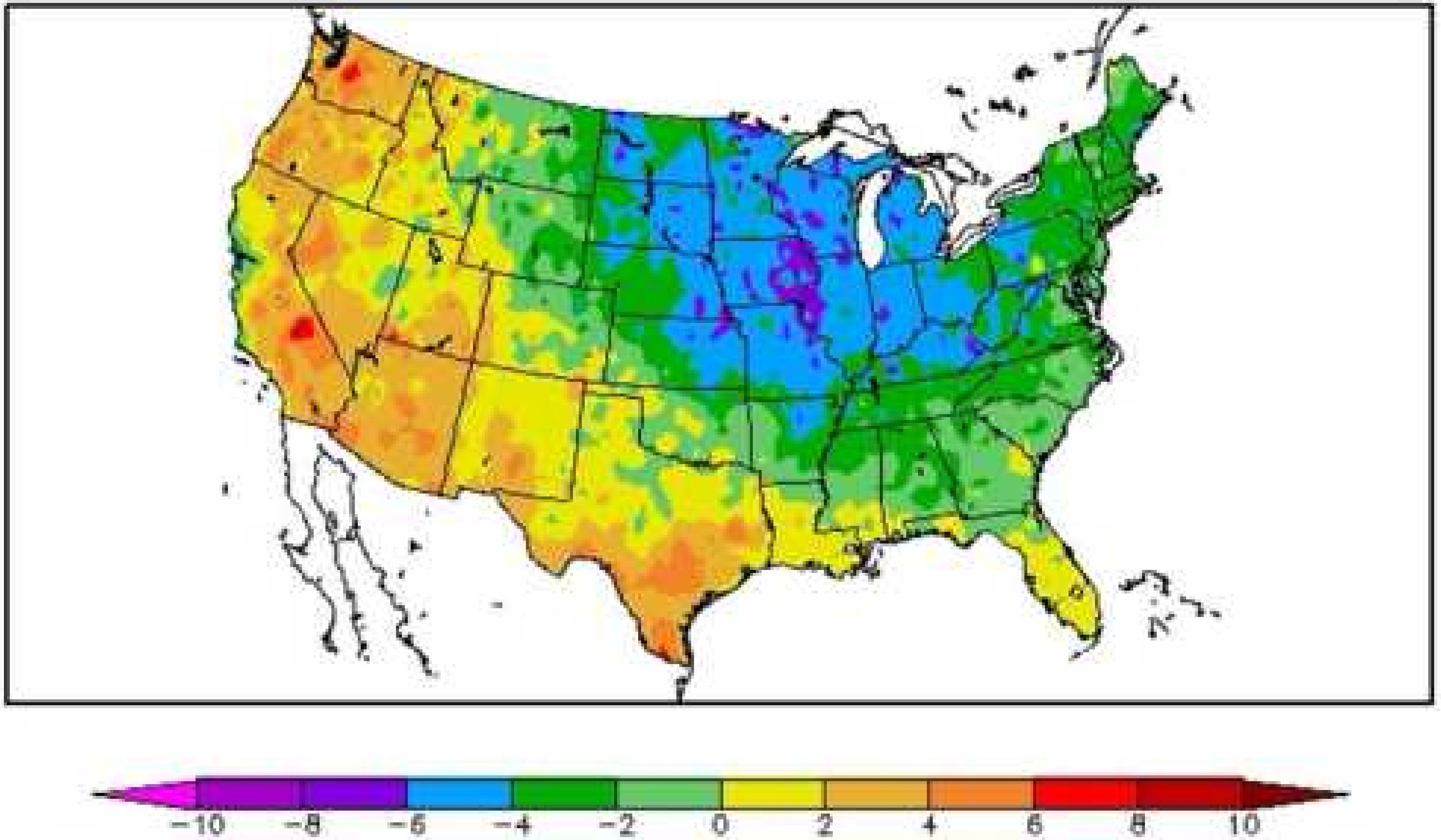
Summary:

- Evidence of climate changes on urban coastal areas of study, as reflected by asymmetric warming, increase sea breeze changes, and possible changes in precipitation.
- Environmental impacts attributed to LCLU may have been (in reality) consequence of combined effects GHG+LCLU.
- LCLU impacts reflect in maximum surface temperature increases, while GW in minimum temperatures.
- Combined effects (LCLU+GW) are unknown for precipitation.

Future Tasks and Overall Research Plan

- Extend the work to other large urban coastal regions.
- Incorporate other relevant effects; i.e. aerosols and pollution.
- Extend the work to all seasons (winter/snow).
- Perform simulations for different IPCC emissions-based climate change scenarios and future projections of LCLU change.

Departure from Normal Temperature (F)
7/1/2009 - 7/31/2009



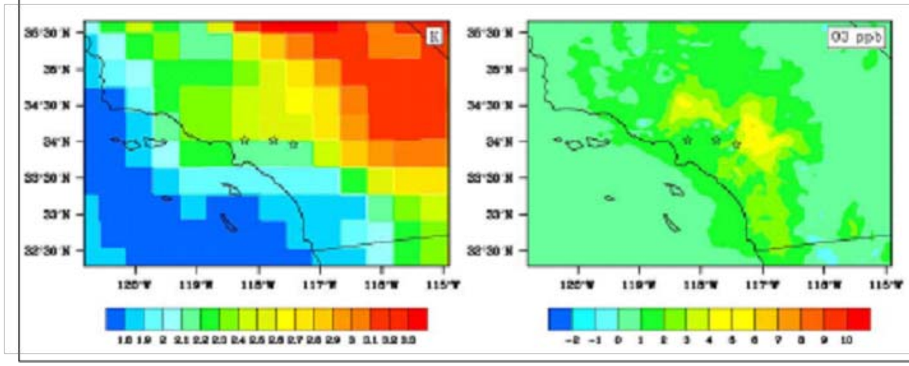
Generated 8/5/2009 at HPRCC using provisional data.

NOAA Regional Climate Centers

Implications of Coastal Urban Climate Changes

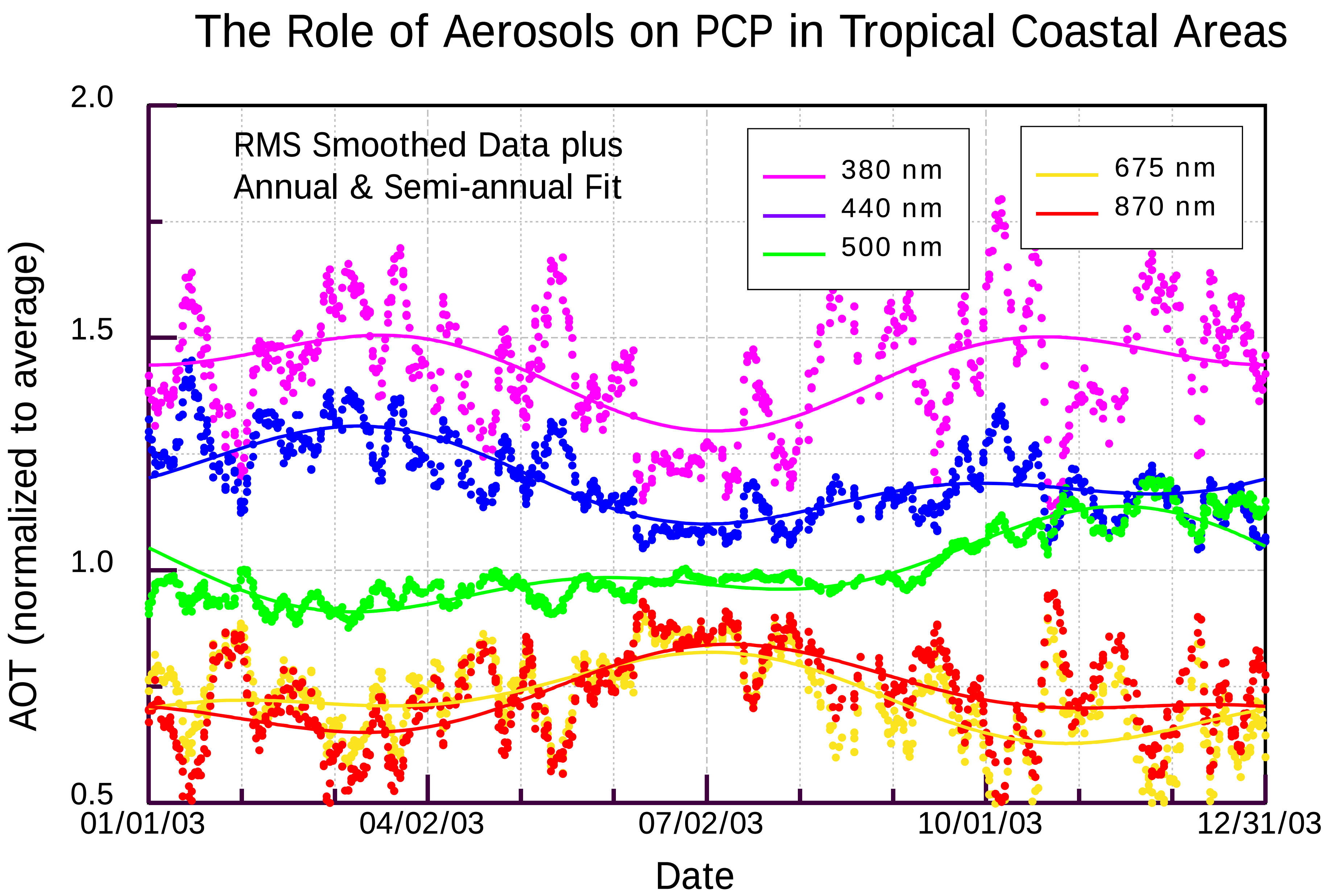
Air quality
Energy demands
Fog production
Heat waves (intensity, frequency)

Air Quality-Difference between future and base case temperatures, and resulting changes in weekday-average ozone concentrations at 15:00 h LT.



•Need for RS Data & Products

H-R surface winds & pressure (PBL)
H-R SST's (<10 kms; hourly)
H-R land classes
& skin temperatures (~ 1 km; LANDSAT, ASTER, HysPIRI)
Sea-Land temperature records
Validation campaigns



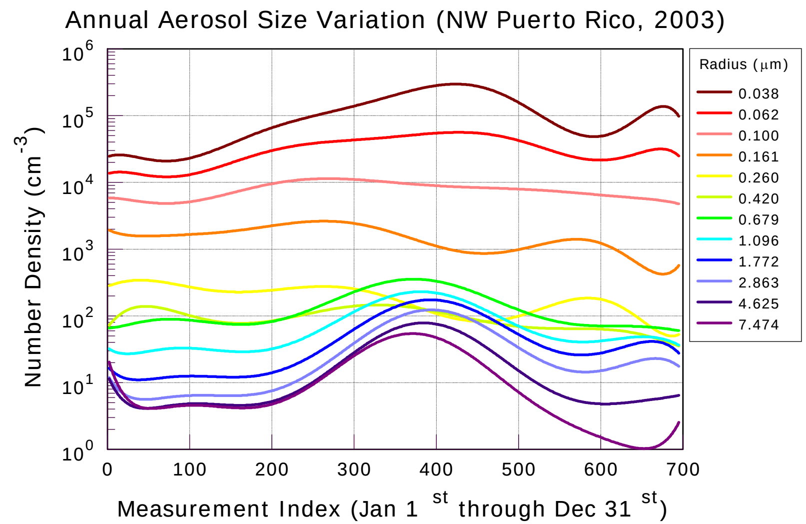
The Role of Aerosols on PCP in Tropical Coastal Areas
RMS Smoothed Data plus
Annual & Semi-annual Fit
380 nm
440 nm
500 nm
675 nm
870 nm
2.0
1.5
1.0
0.5
AOT (normalized to average)
01/01/03
04/02/03
07/02/03
10/01/03
12/31/03
Date

Background of Aerosol effects on PCP

- The link between cloud microphysics and the tropical climate should be investigated using in-situ observations and modeling tools capable of directly resolving micro-scale and mesoscale processes and dynamics.
- Previous studies of cloud-resolving atmospheric modeling have used domain-wide, horizontally homogeneous aerosol data to drive the cloud microphysics package, whether it is explicitly resolved or bin parameterizations.
- This expresses the need of data, and in conducting intensive experimental campaigns designed to build an extensive, vertical and horizontally varying, aerosol data sets.

Simulating a Precipitation Event in Arecibo – Exp. 1 Setup

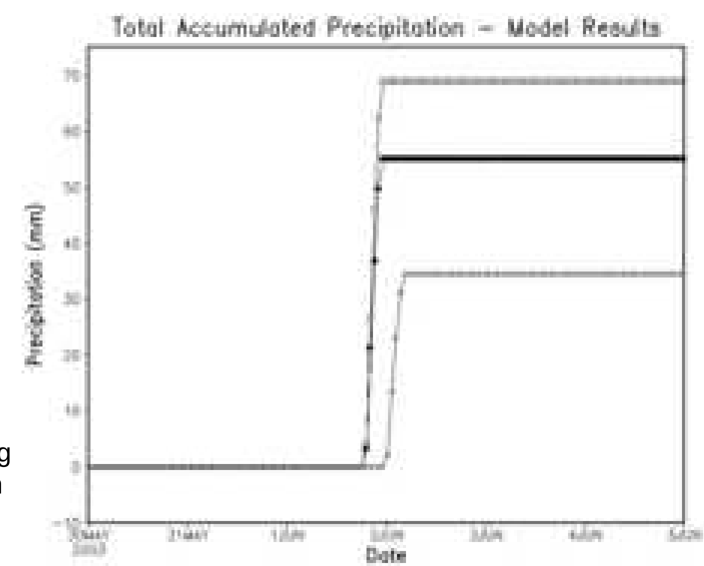
A new microphysics module is being investigated along with the observations by the AO. In order to better separate the different influences on the results The simulations were performed following the table shown below



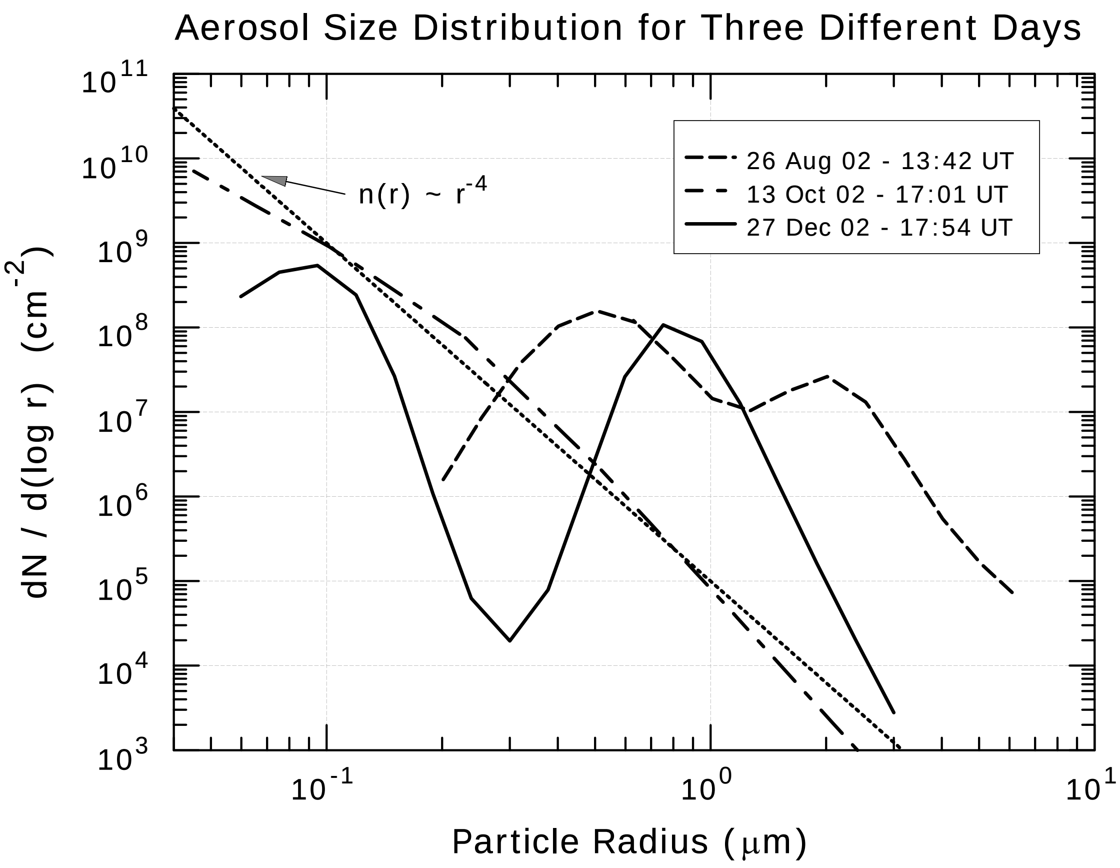
Aerosol info by the Arecibo Observatory

	Microphysics Information	
Model Version	**Arecibo Observations**	**Old Cloud Spectrum**
RAMS w/CCN activation	**run1**	**run2**
RAMS 4.3	**na**	**run3**

Cloud microphysics used in previous modeling efforts obtained in maritime cumulus clouds in Hawaii (from Rogers & Yau, 96)



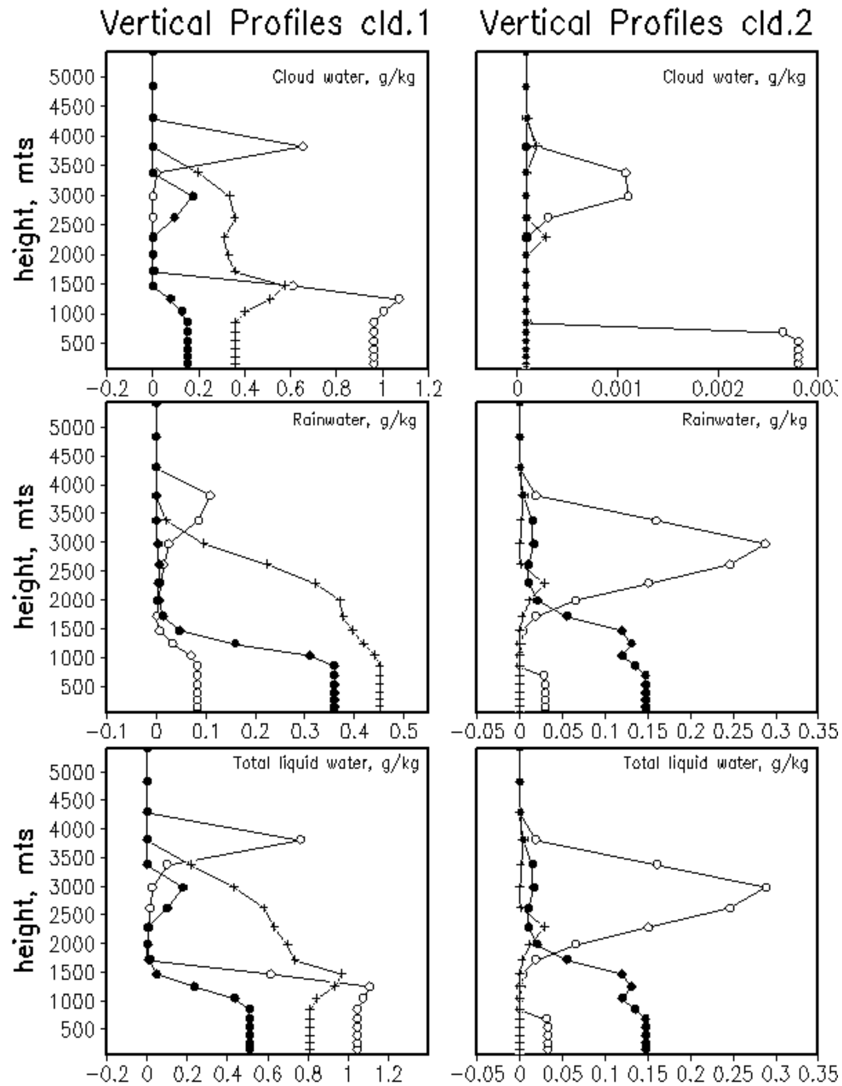
Effects of Atmospheric Particles on Cloud Microphysics for Urban Coastal Areas



Log-radius number distribution for aerosols as a function of particle radius measured from northwest Puerto Rico on three days

Effects of Atmospheric Particles on Cloud Microphysics – Exp. Results

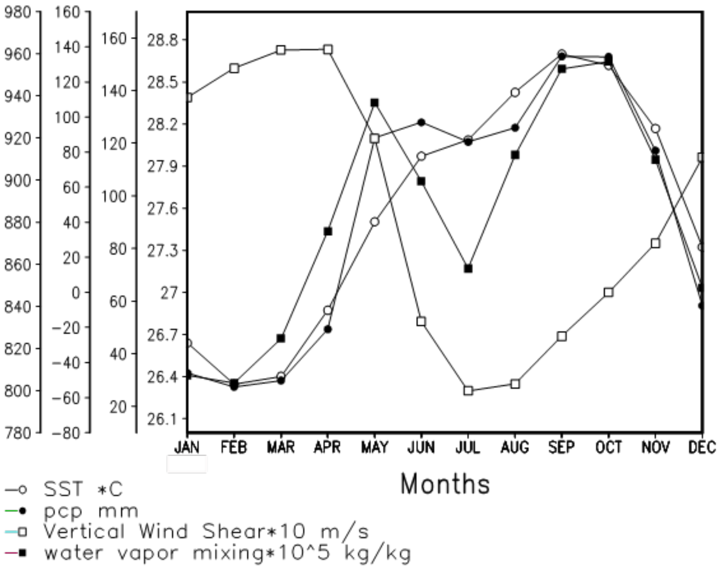
- The cloud water mixing ratio field follows the same pattern in the two experiments.
- The cloud droplet production is significantly larger at low levels (below 1500 m), and at higher levels (between 3 and 4 km) in polluted air than in clear skies.
- Rainwater mixing ratio in polluted air is less than a third of that in clear air for the cld.1 runs, and almost non-existent in the cld.2 experiment.

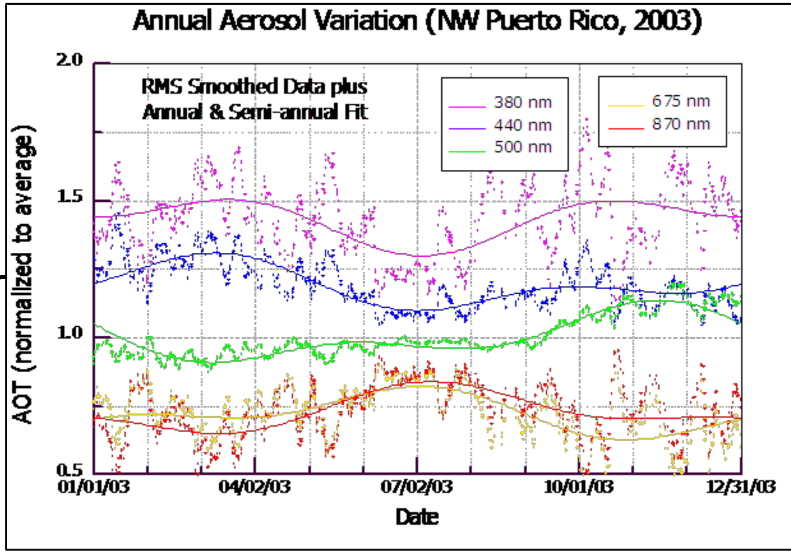


(+) control, (o) high, and (•) low, in all panels

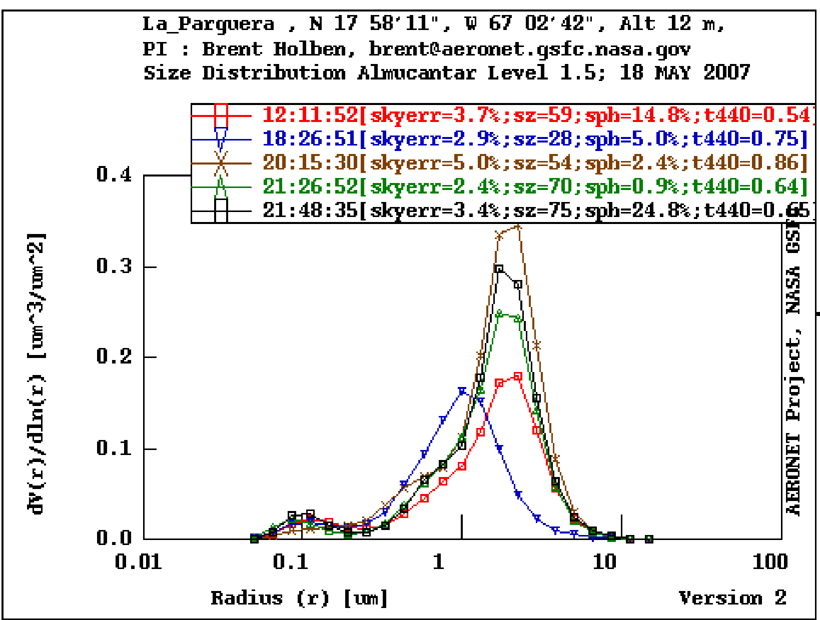
Aerosols and Precipitation Suppression

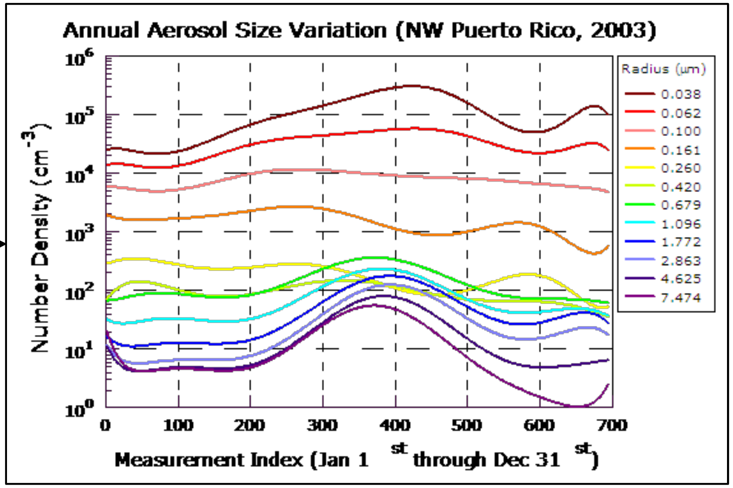
Puerto Rico Island-wide Features





Inversion Algorithm (AOT to size dist.)

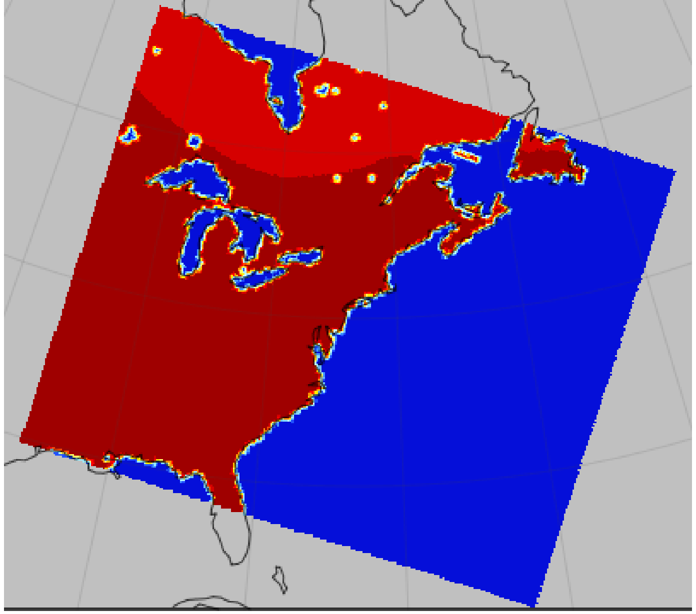




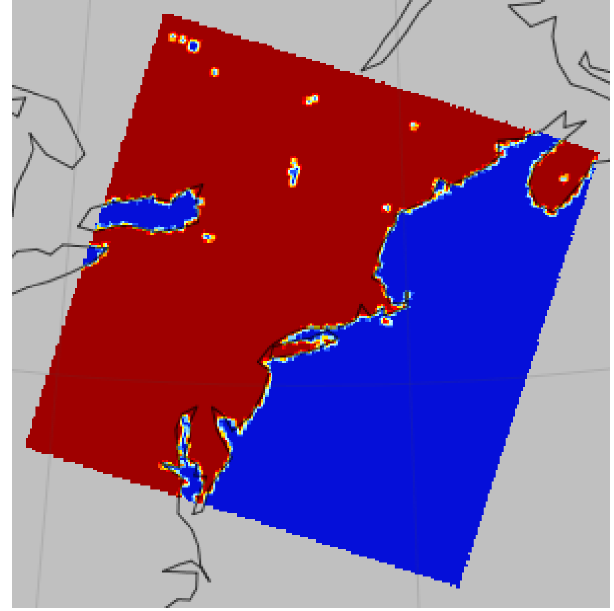
Volume Concentration to Density Number

Suggestions for Aerosols on PCP

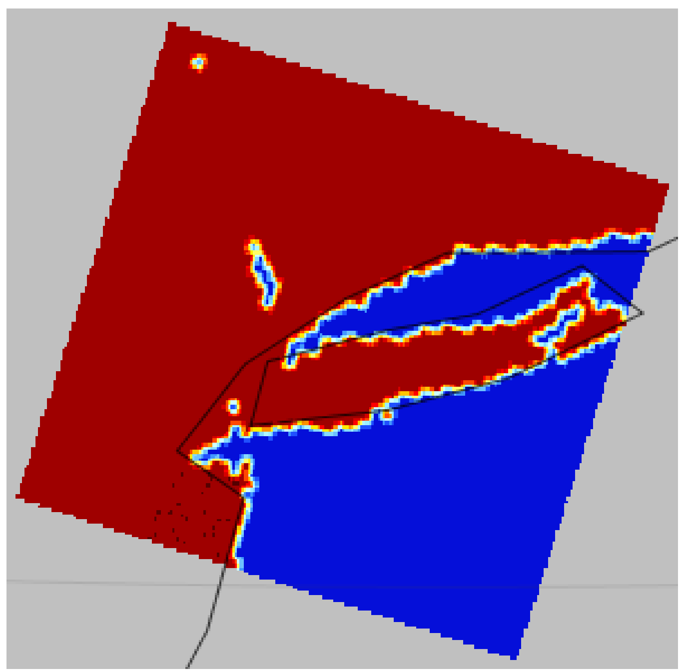
- There is an imperative need to further our understanding of cloud formation and aerosol dynamics in general.
- A new set of observations are required to describe the 4-D distribution of aerosols that will eventually lead to better prediction of weather and climate events.
- Remote sensors are an invaluable tool to observe cloud and aerosol dynamics such as MODIS-2 and the *A-Train* series (Aura, CALIPSO, CloudSat, PARASOL, and Aqua).
- A combination of field campaigns, ***development of algorithms***, and data ingestion into models is suggested.



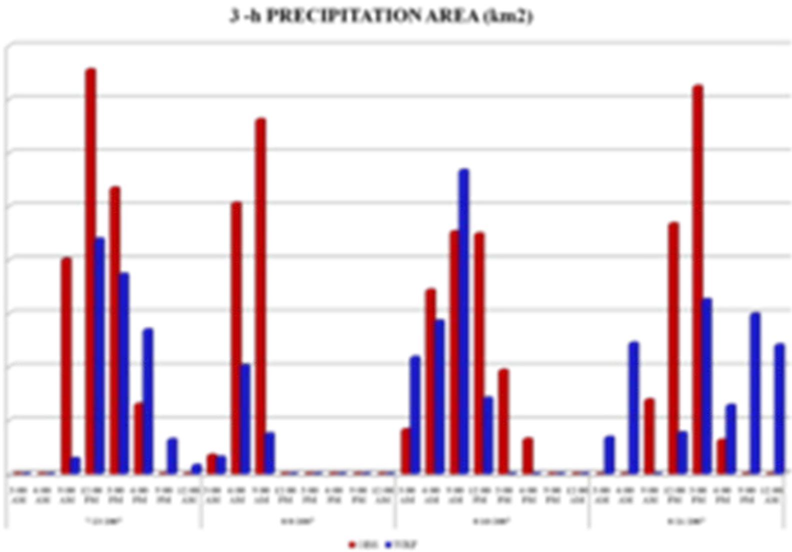
Domain 1

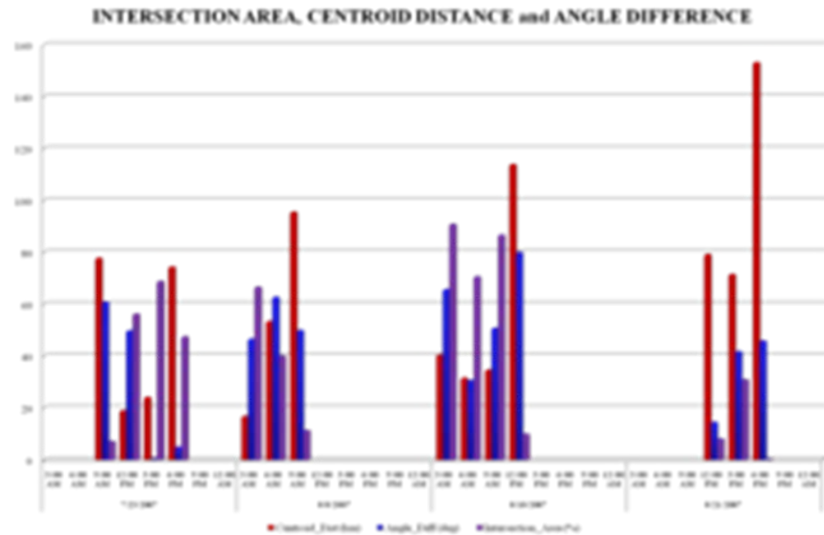


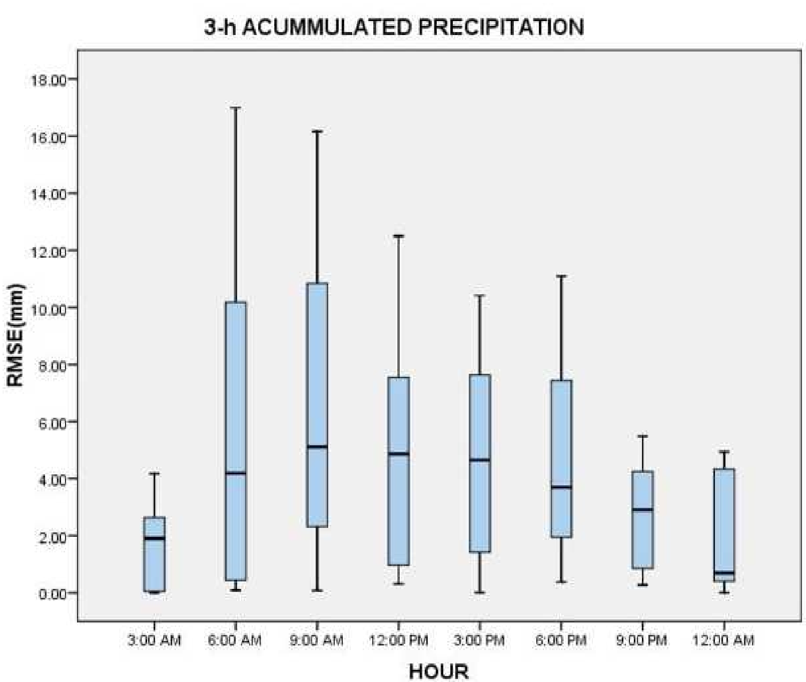
Domain 2

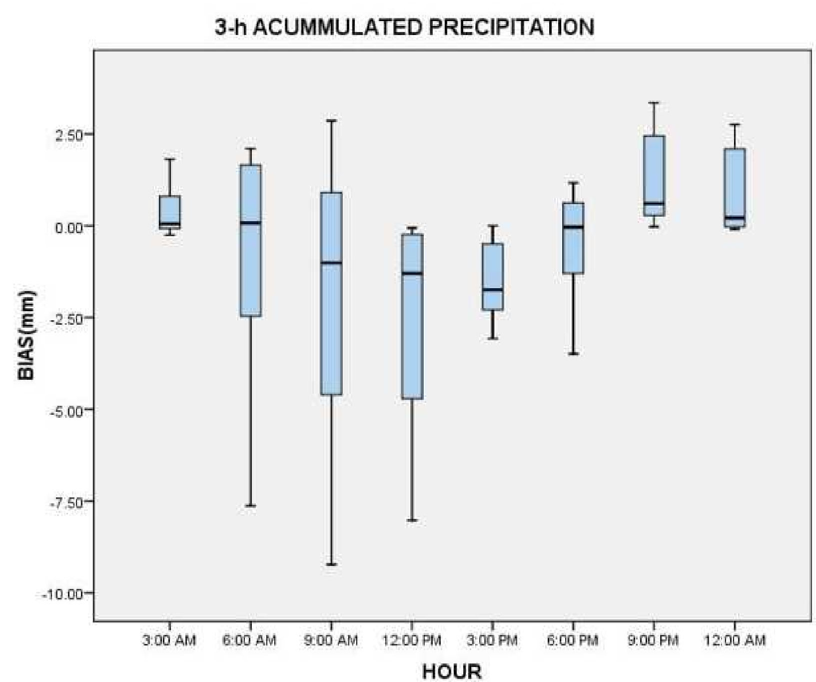


Domain 3

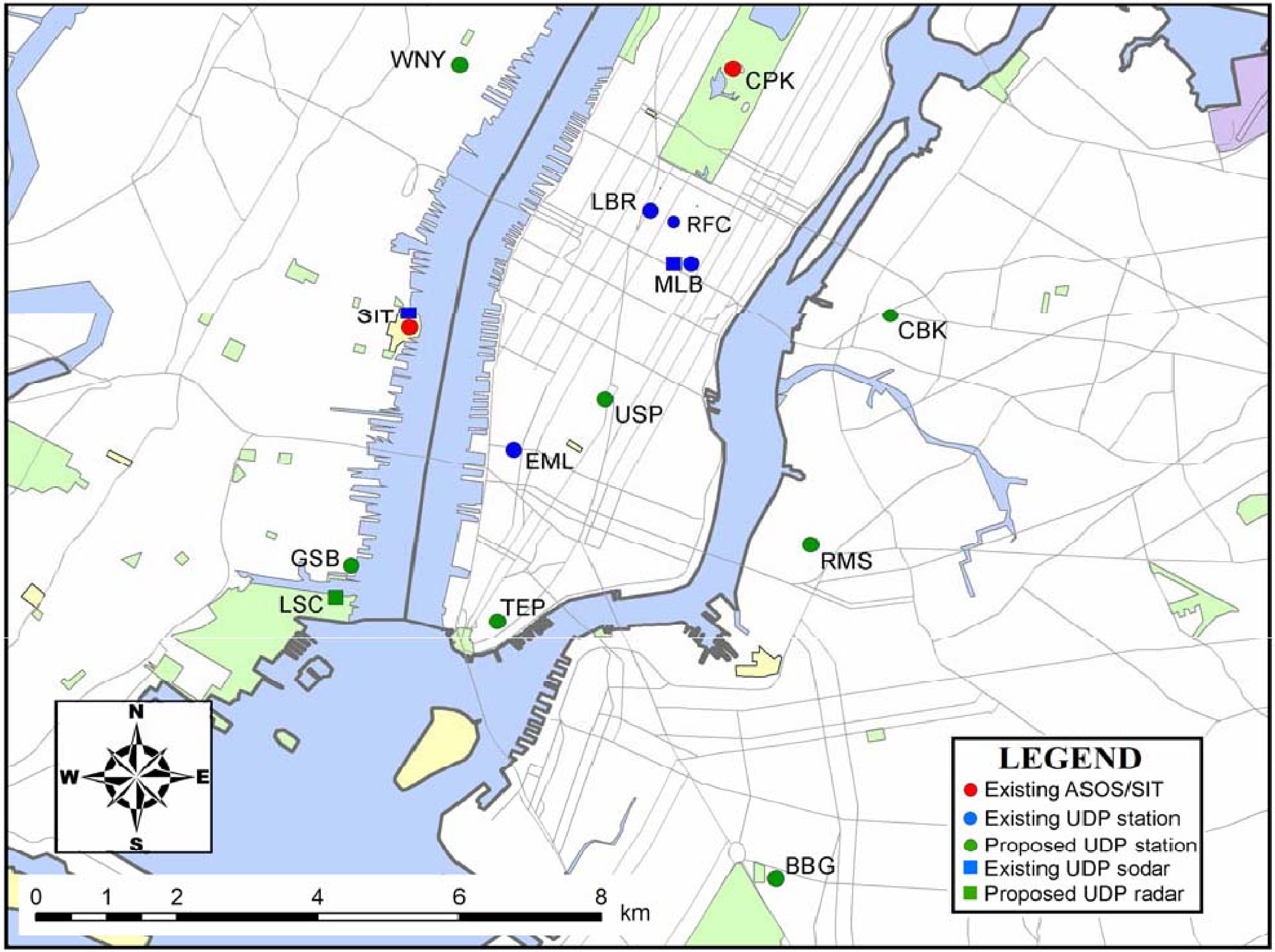

3 -h PRECIPITATION AREA (km2)


INTERSECTION AREA, CENTROID DISTANCE and ANGLE DIFFERENCE

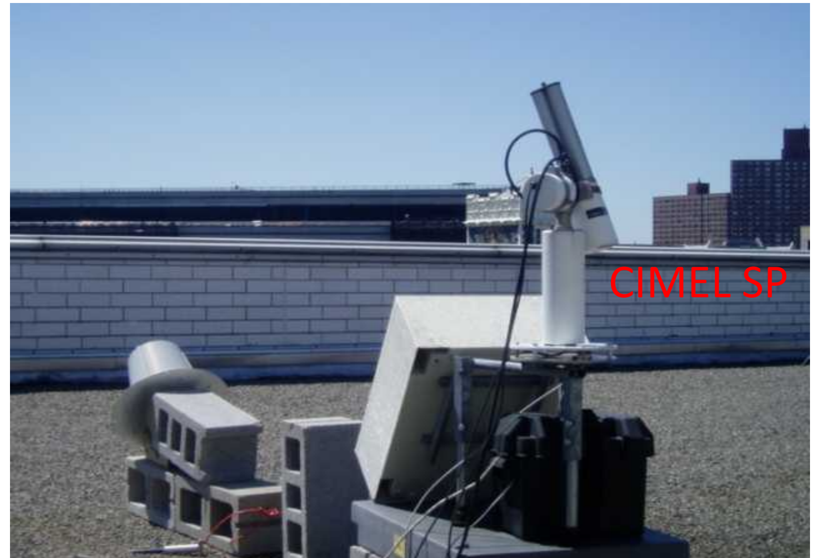

3-h ACUMMULATED PRECIPITATION
RMSE(mm)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
HOUR


3-h ACUMMULATED PRECIPITATION
BIAS(mm)
2.50
0.00
-2.50
-5.00
-7.50
-10.00
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
HOUR

CCNY “Met Net”


WNY
CPK
LBR
RFC
MLB
SIT
CBK
USP
EML
GSB
RMS
LSC
TEP
BBG
N
W
E
S
0
1
2
4
6
8
km
LEGEND
Existing ASOS/SIT
Existing UDP station
Proposed UDP station
Existing UDP sodar
Proposed UDP radar

CCNY multi-wavelength Raman-Mie lidar



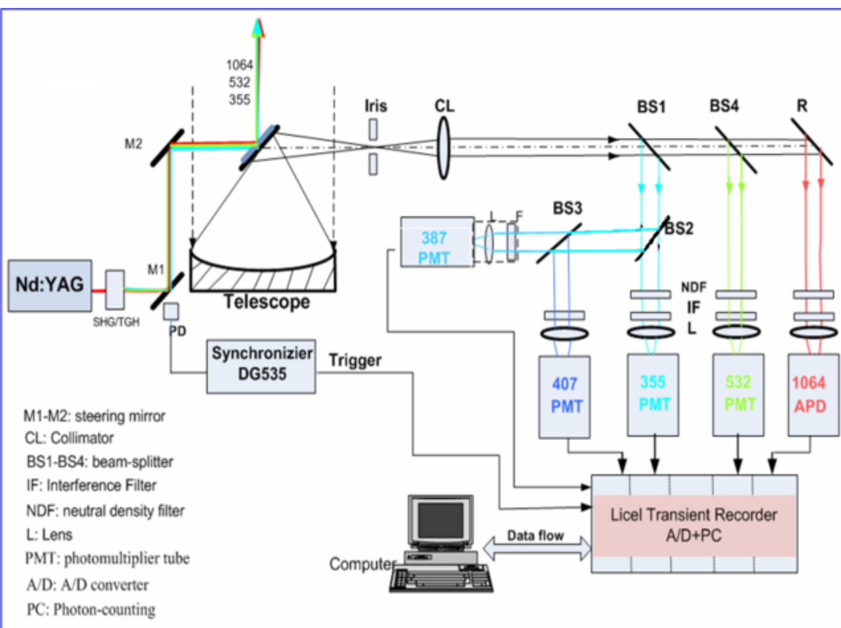
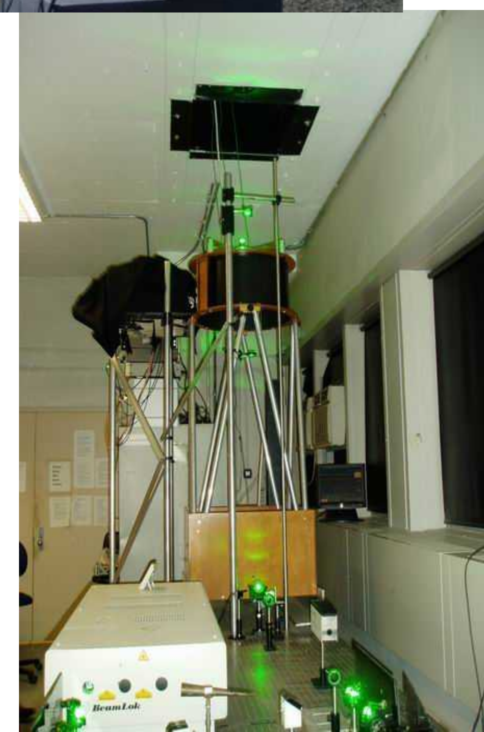


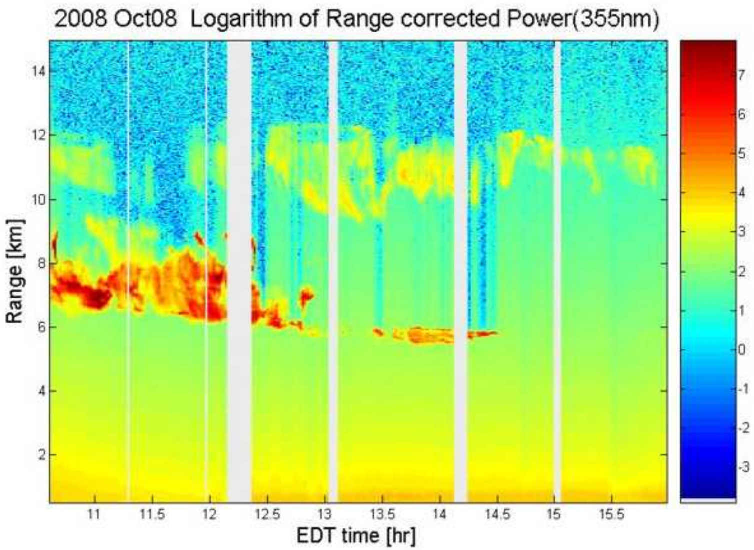
Fig.1 Schematic diagram of CCNY multi-wavelength Raman-Mie lidar

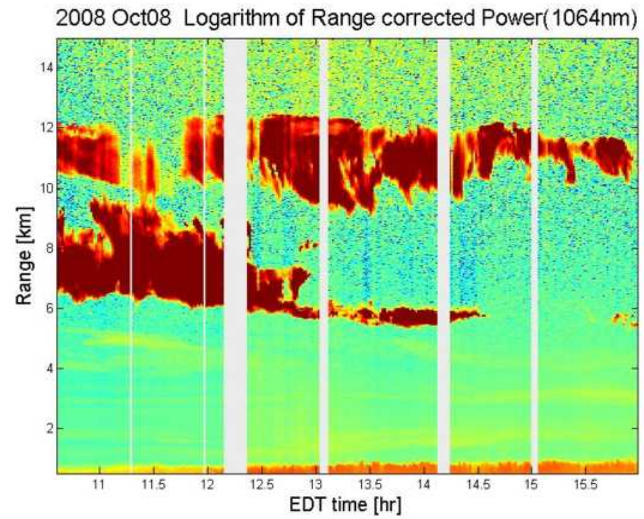
- **Three laser-beams: 1064/532/355-nm simultaneously**
- **Five-receiving channels: 3 elastic + 2 Raman channels (387-407 nm)**
- **Laser power: 9W@355-nm, Telescope: Φ50-cm**
- **Regular obs., App. 3-day/week**



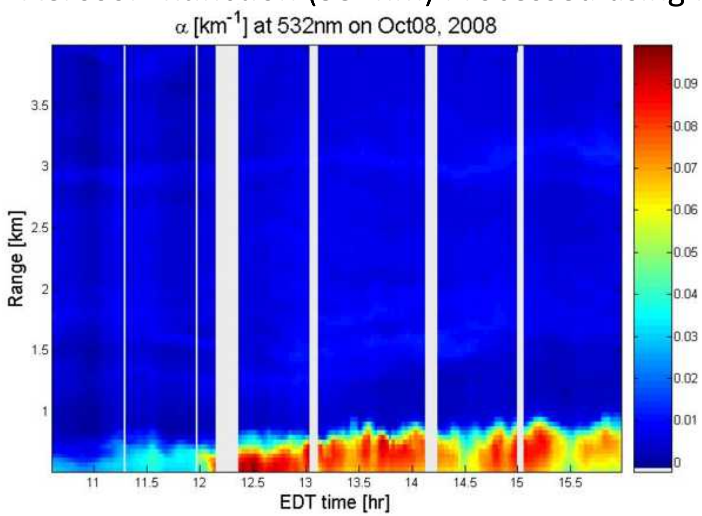
CCNY Lidar Output

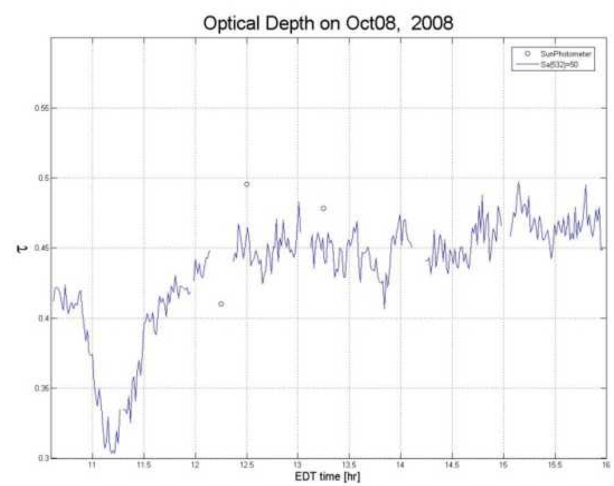
Range Corrected Powers at 1064, 355 (532 not shown)



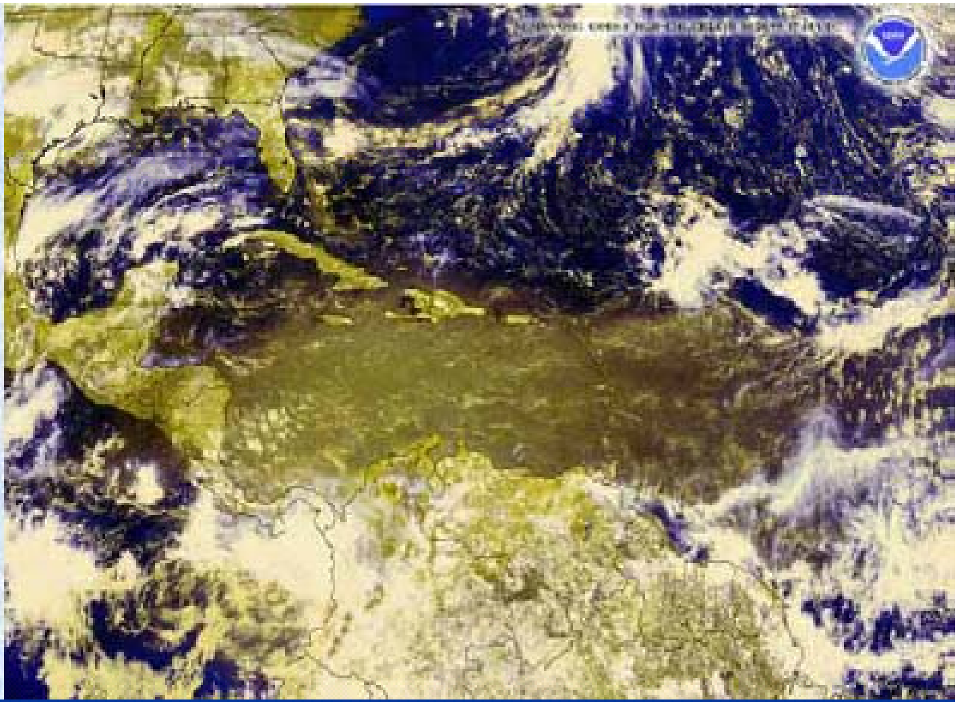


Aerosol Extinction (532nm) Processed using Fernald Method with S ratio constrained with AOD matching to Aeronet





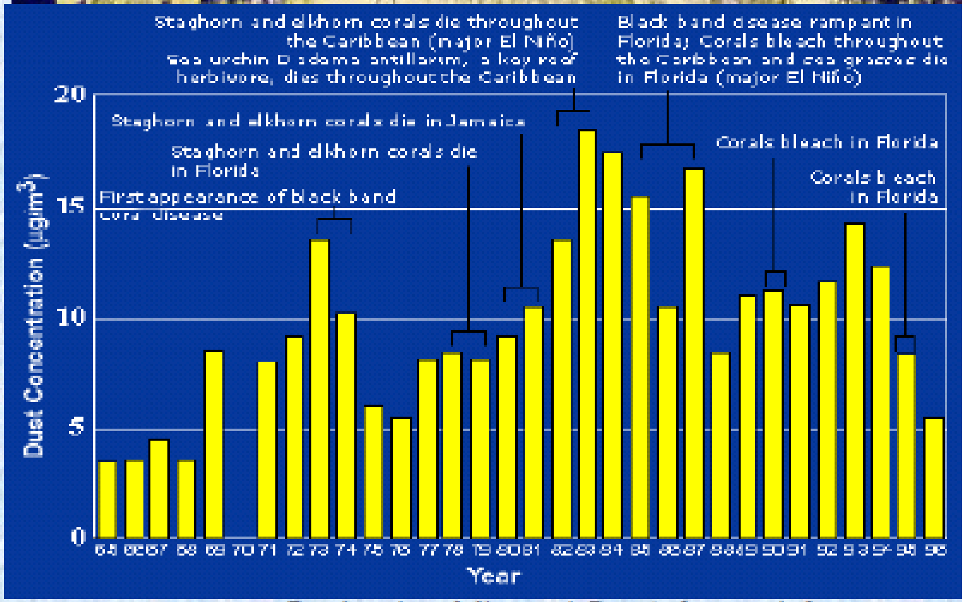
Satellite image (05/28/1999) showing dust covering the southern Caribbean, (From NOAA, Prospero and Stone, 1997)



The interactiones between clouds and aerosols

Modulation of rainfall?

a)- What is the 4-D distribution of Cloud Condensation Nuclei (CCN) in the IAS, what are their sources, variability and what are their roles in clouds formation?
b)- What is the variability of cloud heights and depths in the Caribbean as function of regional SSTs, and large scale forcings such as the ENSO, the NAO the Atlantic dipole and the Atlantic multi-decadal oscillation?
c)- What is the relationship between aerosols and seasonal climate variation in the IAS?



Barbados Mineral Dust Annual Average and Benchmark Caribbean Events (After Prospero 2002)