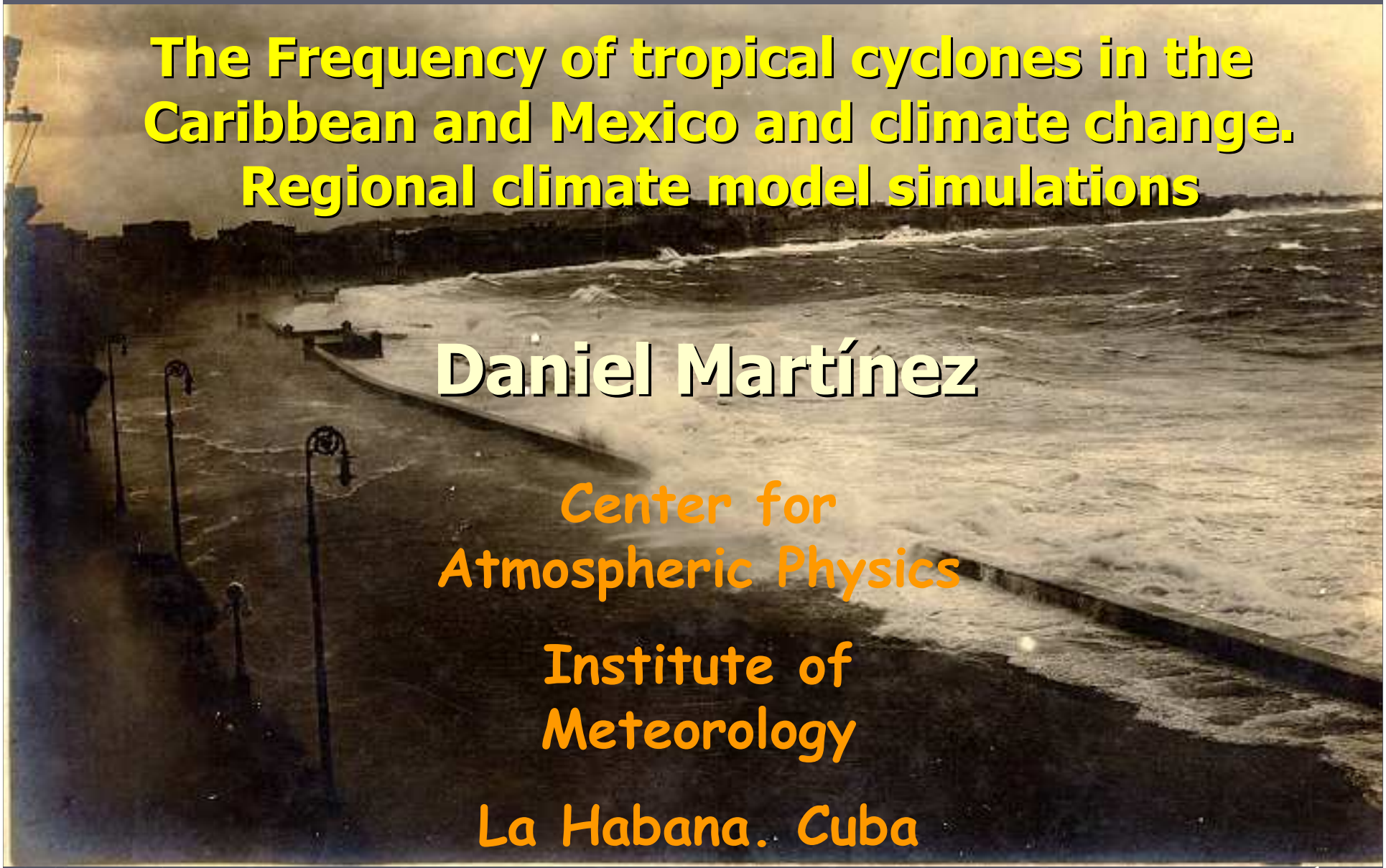
The Frequency of tropical cyclones in the Caribbean and Mexico and climate change. Regional climate model simulations



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Work Team

Israel Borrajero

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Regional Climate Modeling

The main goal of regional climate models (RCMs) is to reproduce the main climatic features in complex terrain, where mesoscale forcing becomes important and coarse-resolution global climate models (GCMs) are not sufficient for assessing local climate variability.

The Caribbean islands and adjacent territories are an example of the usefulness of RCM.

The use of RCMs in the assessment of tropical storm climatology behavior in a changing climate.

Approaches:

1- High resolution TC models with inserted vortex in GCM output to study changes in intensity and other internal characteristics of the storms in a changing climate.

Knutson et al. 1998, Science

Knutson and Tuleya, 1999, Clim. Dyn.

Knutson and Tuleya, 2004, J Clim.

Results: Global warming induces significant, but small increase in TS intensity, and greater increase in precipitation.

2. RCM nested in GCM output. Identification of **tropical cyclone-like vortices (TCLV)** following a set of criteria.

Walsh and Watterson, 1997. J. Climate

Walsh and Katzfey, 2000. J. Climate

Nguyen and Walsh, 2001. J. Climate

Walsh, Nguyen and McGregor, 2004. Clim. Dyn.

Results:

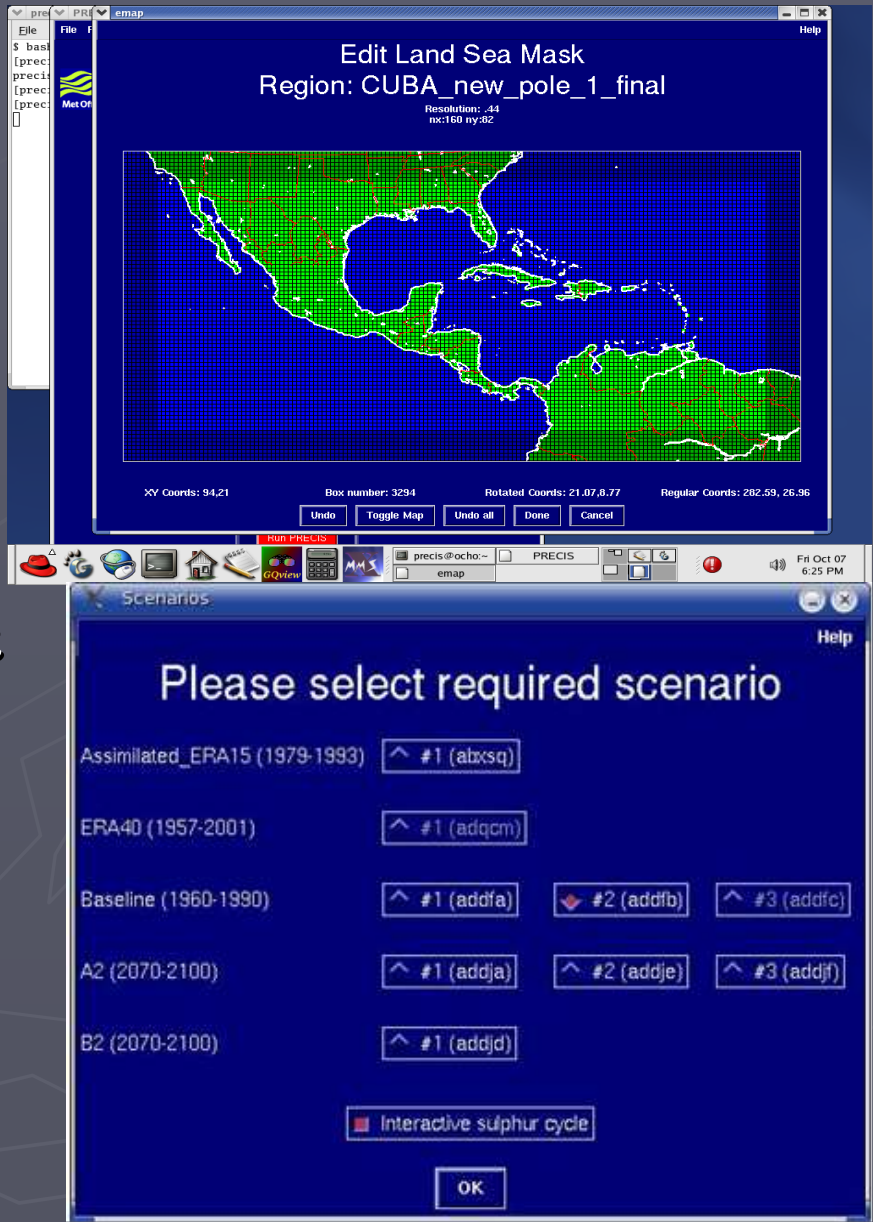
Numbers of TCLVs formed, occurrence and regions of formation don't change much in a warmer climate.

Significant increases in the number of intense TCLVs.

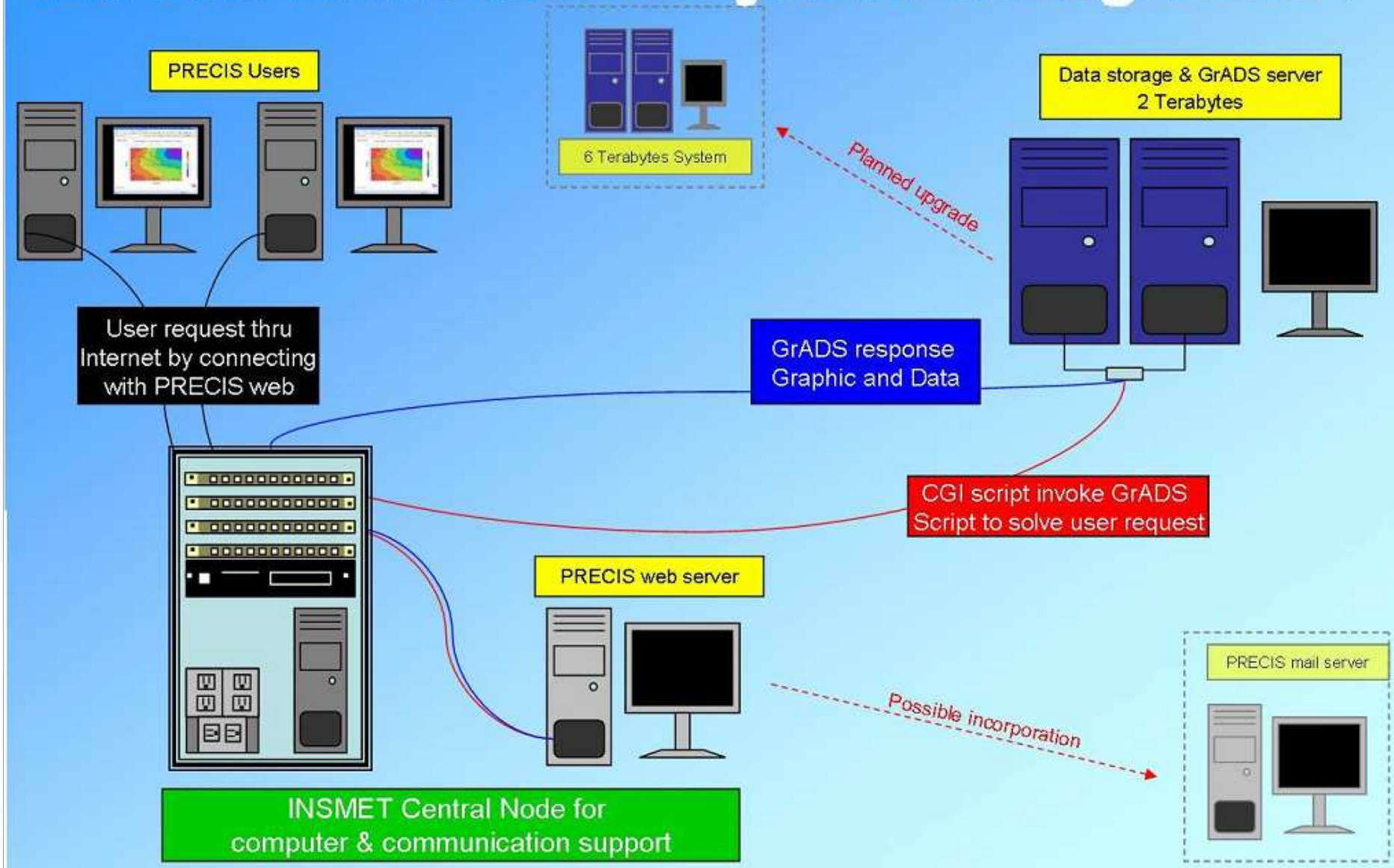
PRECIS

(Providing REgional Climates for Impact Studies)

- PRECIS (Providing REgional Climates for Impacts Studies) is a PC-based regional climate model developed by the Hadley Centre of the Meteorological Office of the United Kingdom for use by non-Annex I Parties to the United Nations Framework Convention on Climate Change.



PRECIS Data Access System Configuration



The PRECIS Regional Climate Model (RCM)

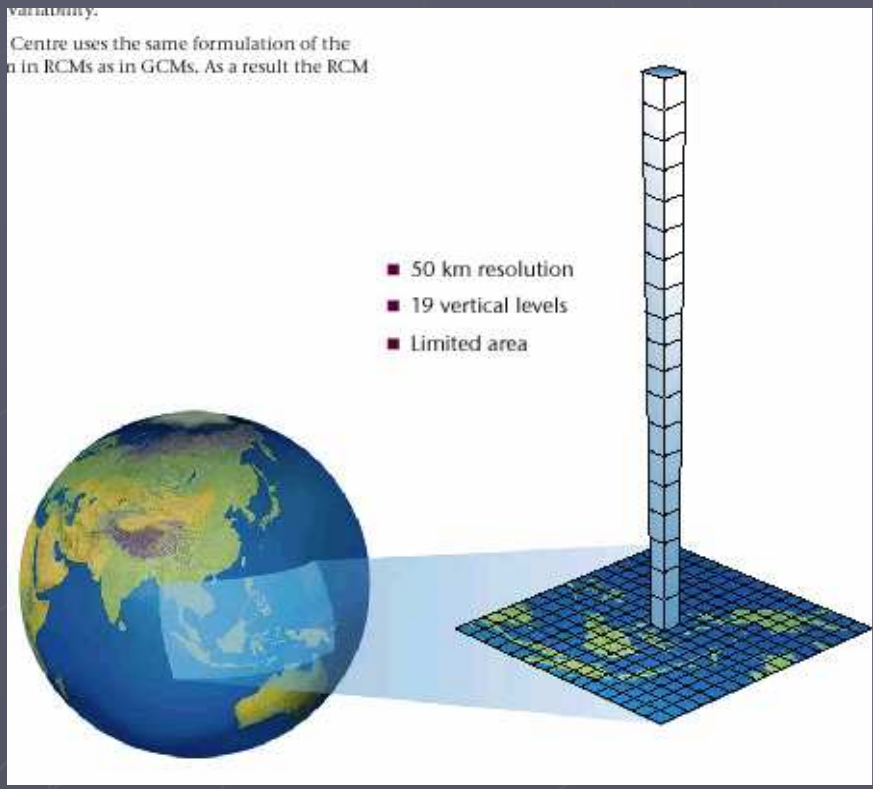
- An atmospheric and land surface model of limited area and high resolution locatable over any part of the globe.
- The Hadley Centre's most up to date model: HadRM3P
- Hadley Center's driving model HadAMP3 using emission scenarios developed for IPCC-SRES

Boundary conditions

- The model requires prescribed surface and lateral boundary conditions (P,U,V,T,RH). Surface boundary conditions are only required over water, where the model needs time series of surface temperatures and ice extents.
- These lateral boundary conditions are updated every six hours; surface boundary conditions are updated every day.

Model description

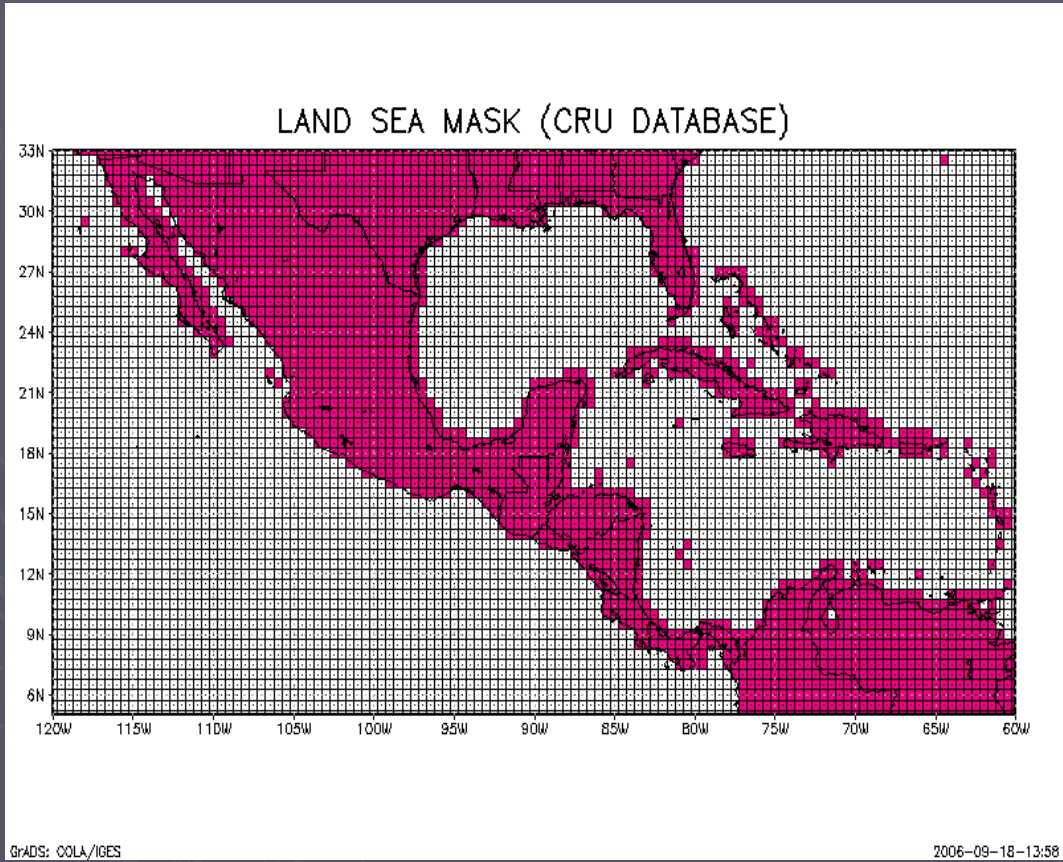
- Hydrostatic
- Complete Coriolis force
- Regular latitude-longitude grid in the horizontal and a hybrid vertical coordinate.
- 19 vertical levels, the lowest at ~50m and the highest at 0.5 hPa with terrain-following -coordinate used for the bottom four levels, purely pressure coordinates for the top three levels and a combination in between



Model description

- The model equations are solved in spherical polar coordinates and the latitude-longitude grid is rotated so that the equator lies inside the region of interest in order to obtain quasi-uniform grid box area throughout the region. The horizontal resolution is 0.44°x0.44°, which gives a minimum resolution of ~50 km at the equator of the rotated grid. Due to its fine resolution, the model requires a time step of 5 minutes to maintain numerical stability.
- Prognostic variables: Psurf, U,V, θ,Qtot
- Arakawa B grid: the momentum variables (u and v)are offset by half a grid box in both directions from the thermodynamic variables (p*, L, qT). The aerosol variables also lie on the thermodynamic grid.
- Five chemical species which are used to simulate the spatial distribution of sulphate aerosols [gaseous sulphur dioxide (SO2), dimethyl sulphide (DMS) and three modes of sulphate aerosol (SO4)]
- The radiation scheme includes the seasonal and diurnal cycles of insolation, computing short wave and long wave fluxes which depend on temperature, water vapour, ozone (O3), carbon dioxide (CO2) and clouds (liquid and frozen water being treated separately), as well as a package of trace gases (O2, N2O, CH4, CFC11 and CFC12). The calculations are split into 6 short wave bands and 8 long wave bands.

Preliminary results of PRECIS validation for the Caribbean



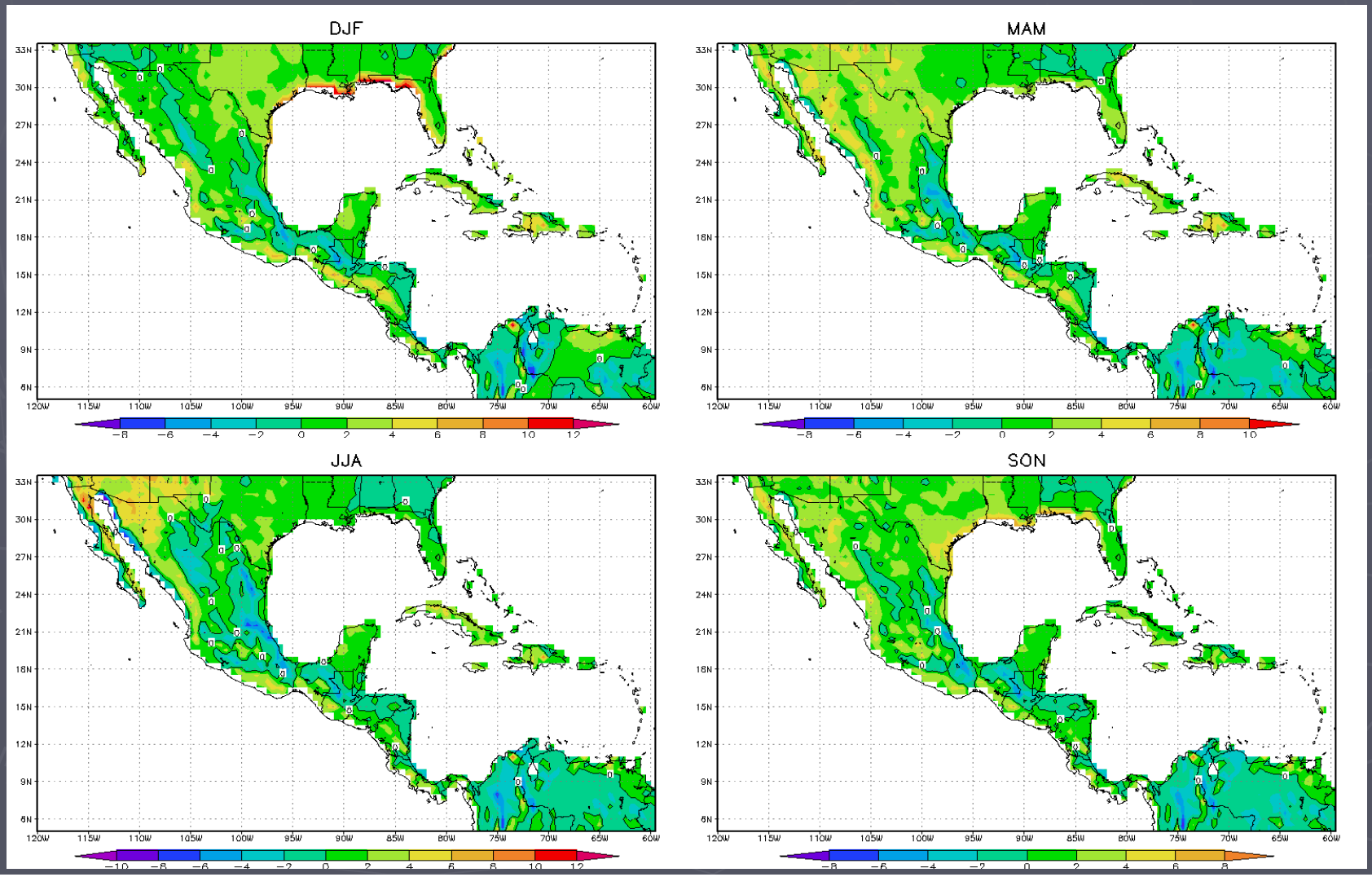
Temperature and Precipitation over land areas

1. Quasi-observed climate RCM driving by ERA15 Reanalysis
2. RCM driven by CGM control run (CON)
3. CRU data over land areas

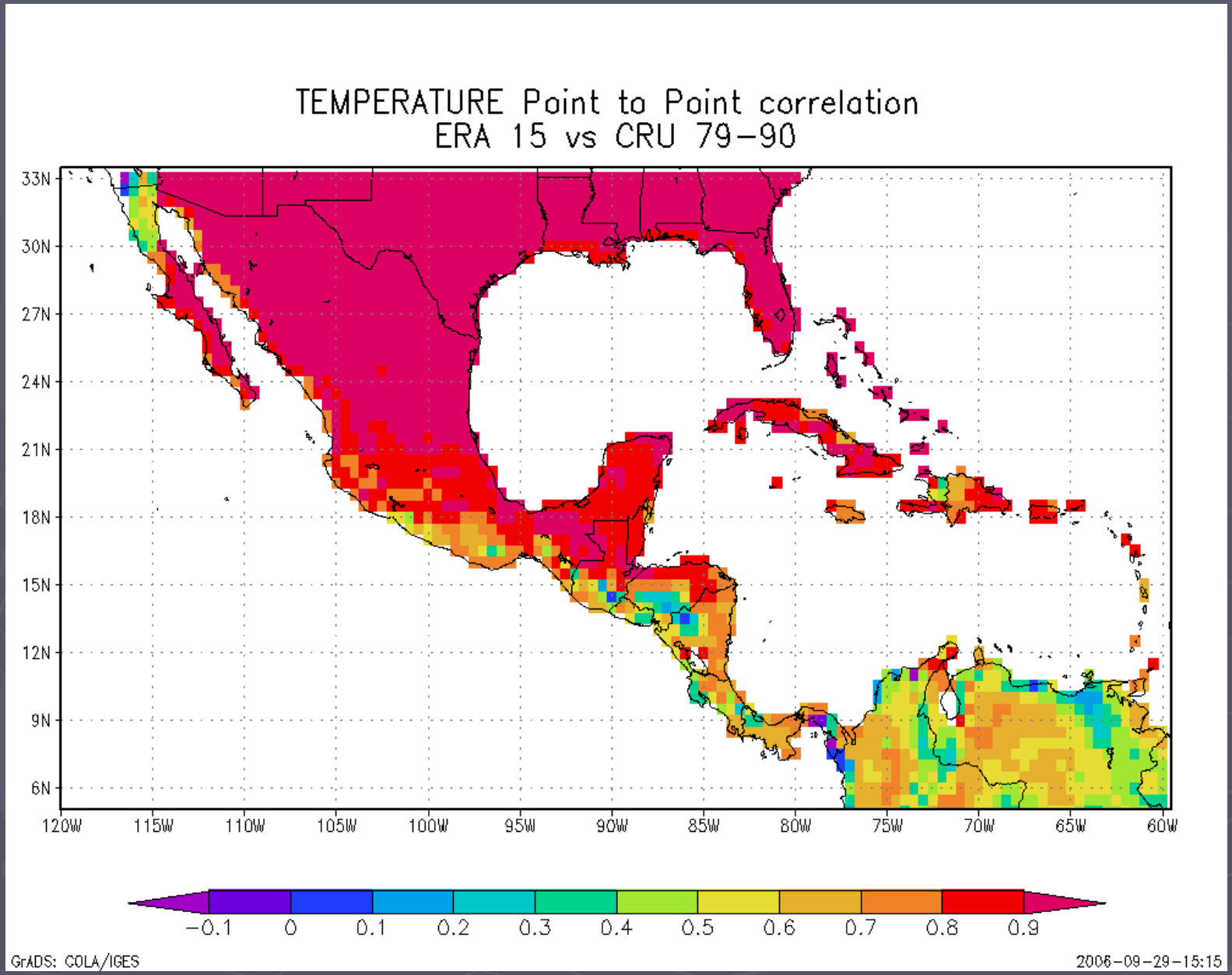
General Statistics

TEMPERATURE				
RCM_ERA vs CRU Statistics				
	DJF	MAM	JJA	SON
Mean_Obs	18.03	22.49	25.64	22.47
Mean_RCM	18.85	23.36	26.01	22.80
Dif_RCM-Obs	0.63	0.81	0.31	0.18
RCM Spatial STD	5.56	3.54	2.77	3.22
RMS_error_RCM-Obs	2.11	2.07	1.96	1.81
S.Correlat	0.94	0.86	0.81	0.87

RCM ERA-CRU



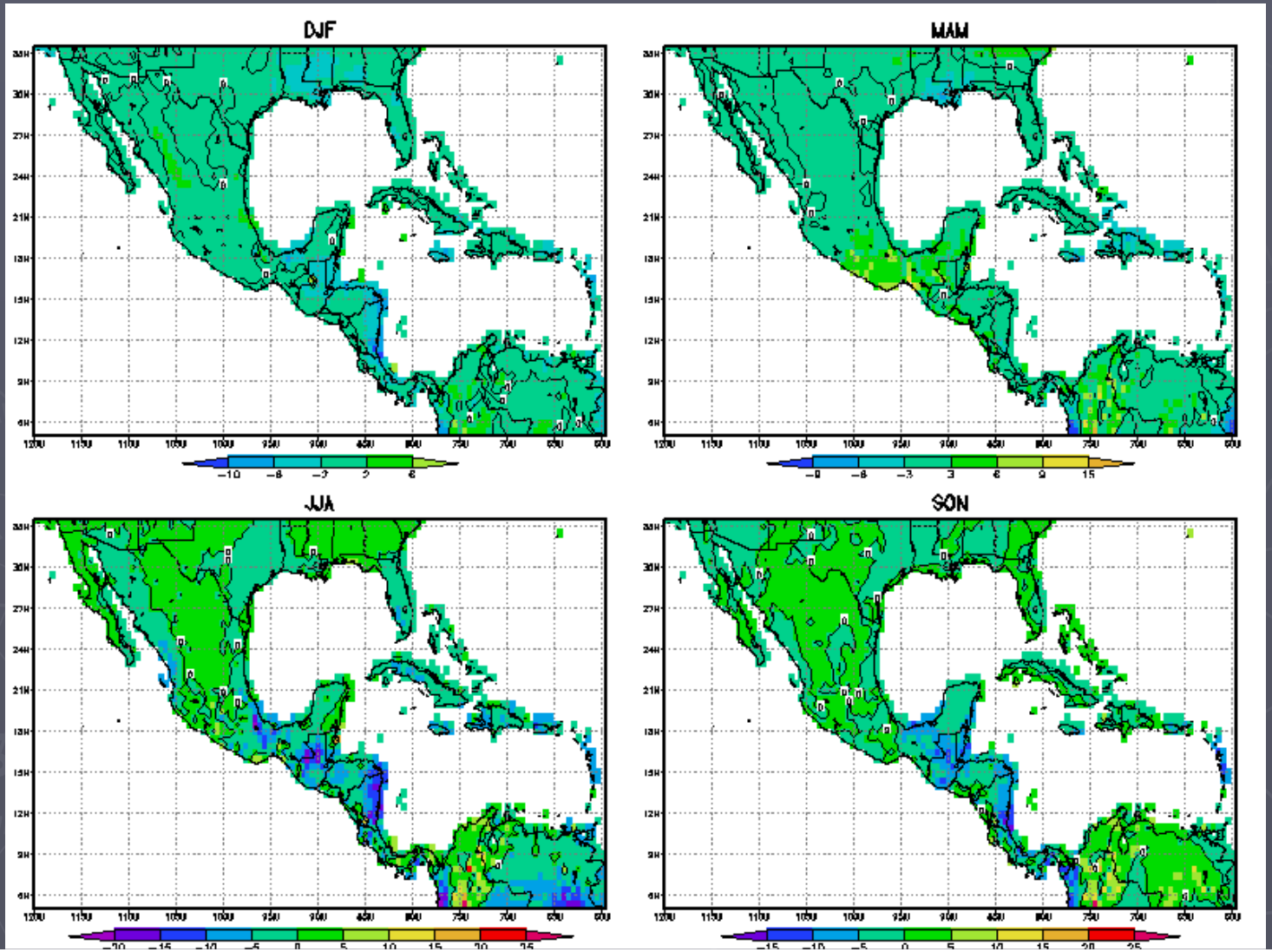
Time correlations



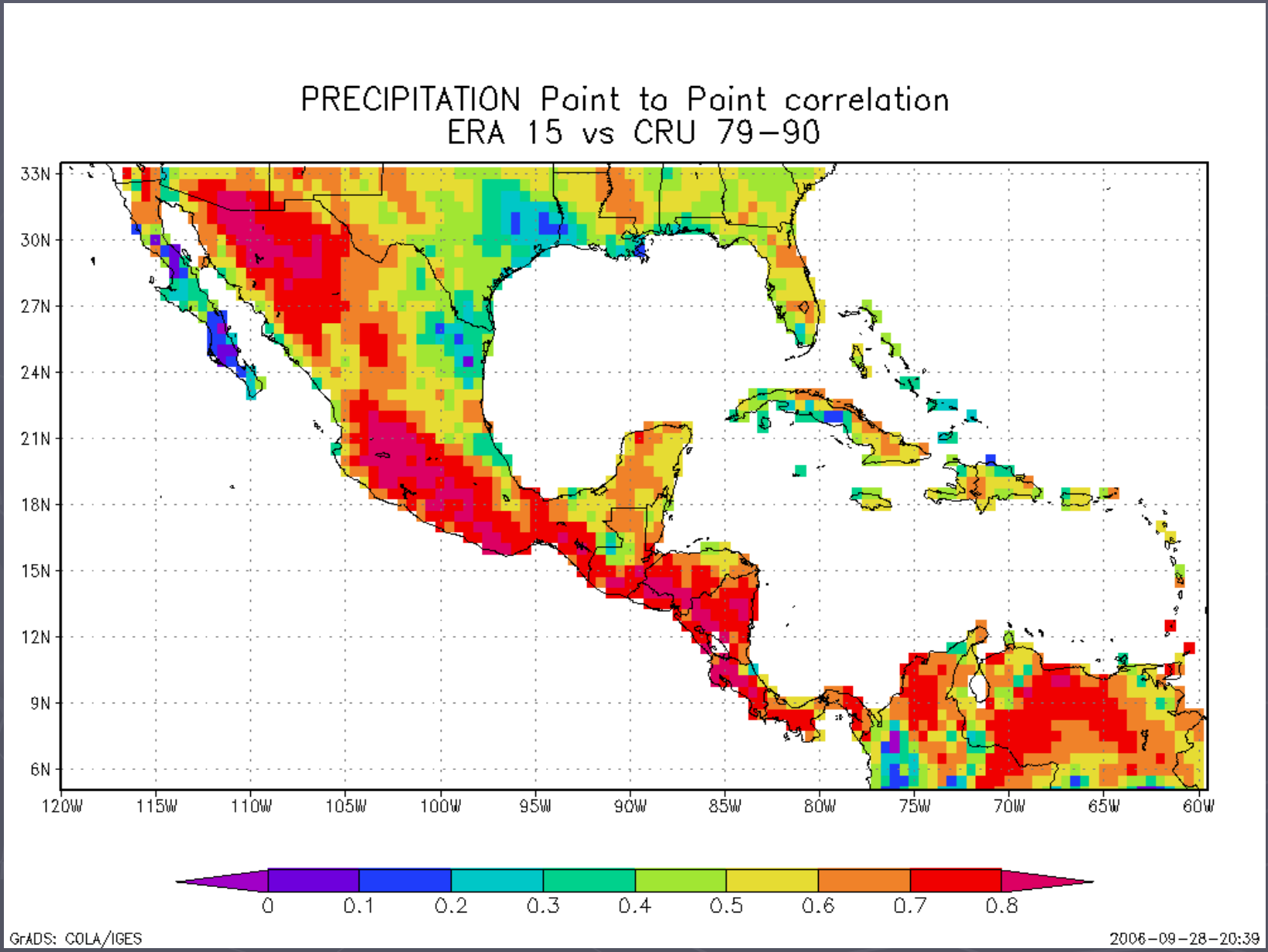
General Statistics

RCM ERA-CRU

PRECIPITATION				
RCM-ERA vs CRU Statistics				
	DJF	MAM	JJA	SON
Mean_Obs	1.77	2.69	5.64	4.39
Mean_RCM	1.65	2.81	4.57	3.89
Dif_RCM-Obs	-0.12	0.14	-1.05	-0.52
RCM Spatial STD	1.98	3.14	4.01	4.10
RMS_error_RCM-Obs	1.33	1.61	2.70	2.37
S.Correlat	0.52	0.71	0.57	0.63



Time correlations

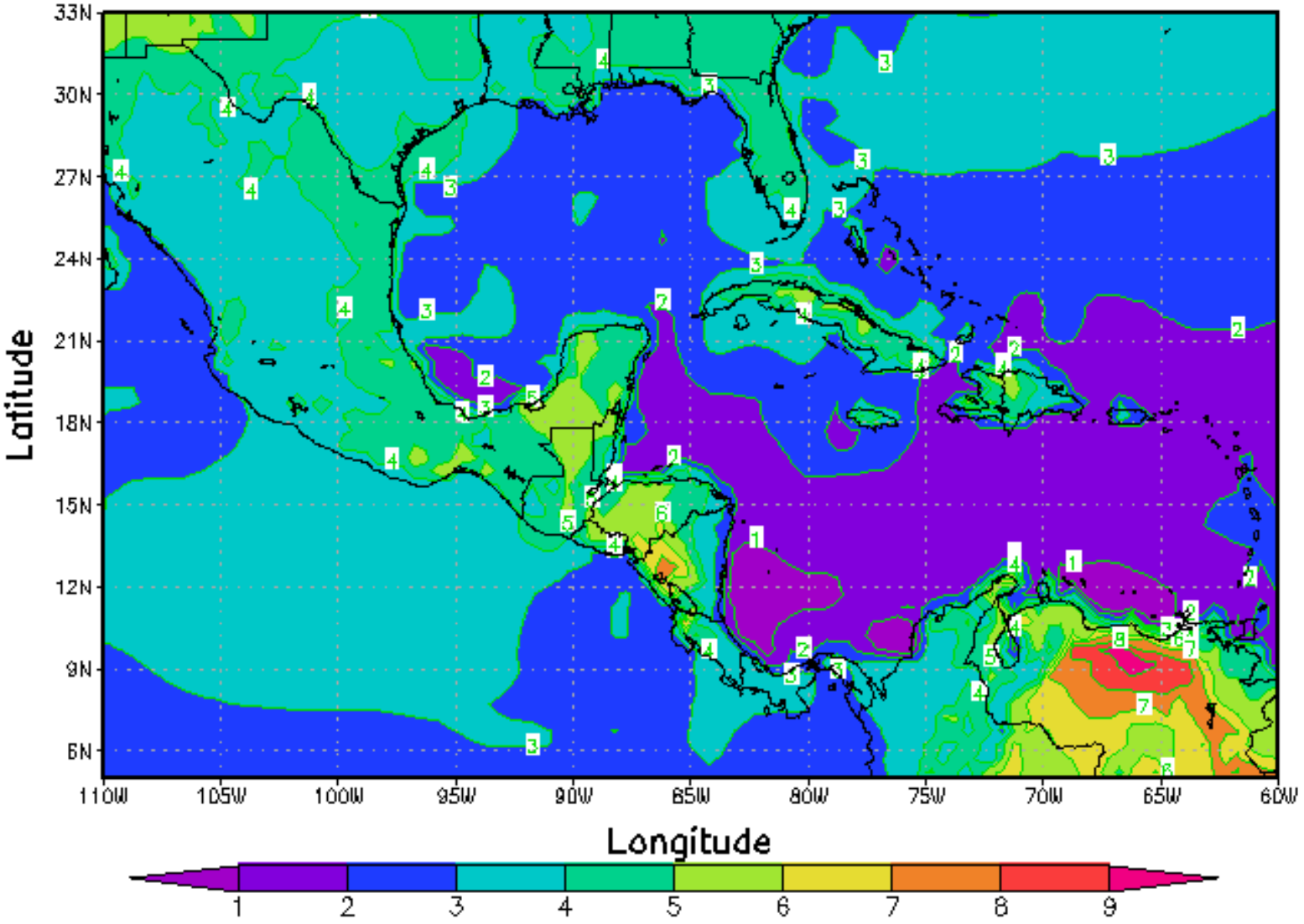


Numerical experiments

- 30 Years Baseline (Control Experiments) 1961-1990 (Sulphur).
- 30 Years of future scenario (A2) 2071-2100 (Sulphur).
- Output: Daily means of prognostic and diagnosis variables

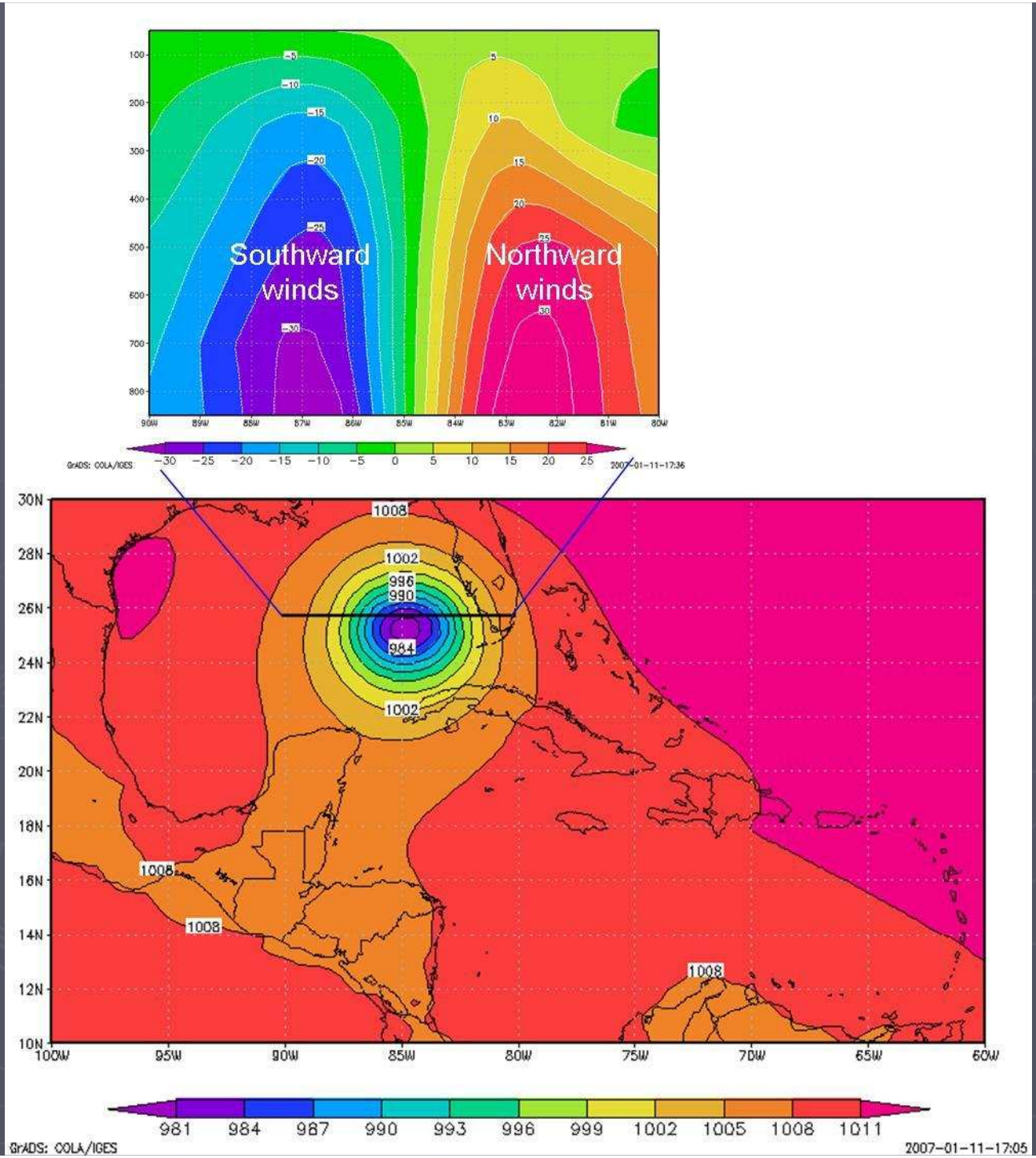
Changes in Mean surface temperature A2 Scenario

Mean for OCT 2071–2099 vs 1961–1990



GrADS Image

INSMET


Southward winds
Northward winds
GrADS: COLA/IGES
2007-01-11-17:36
1008
1002
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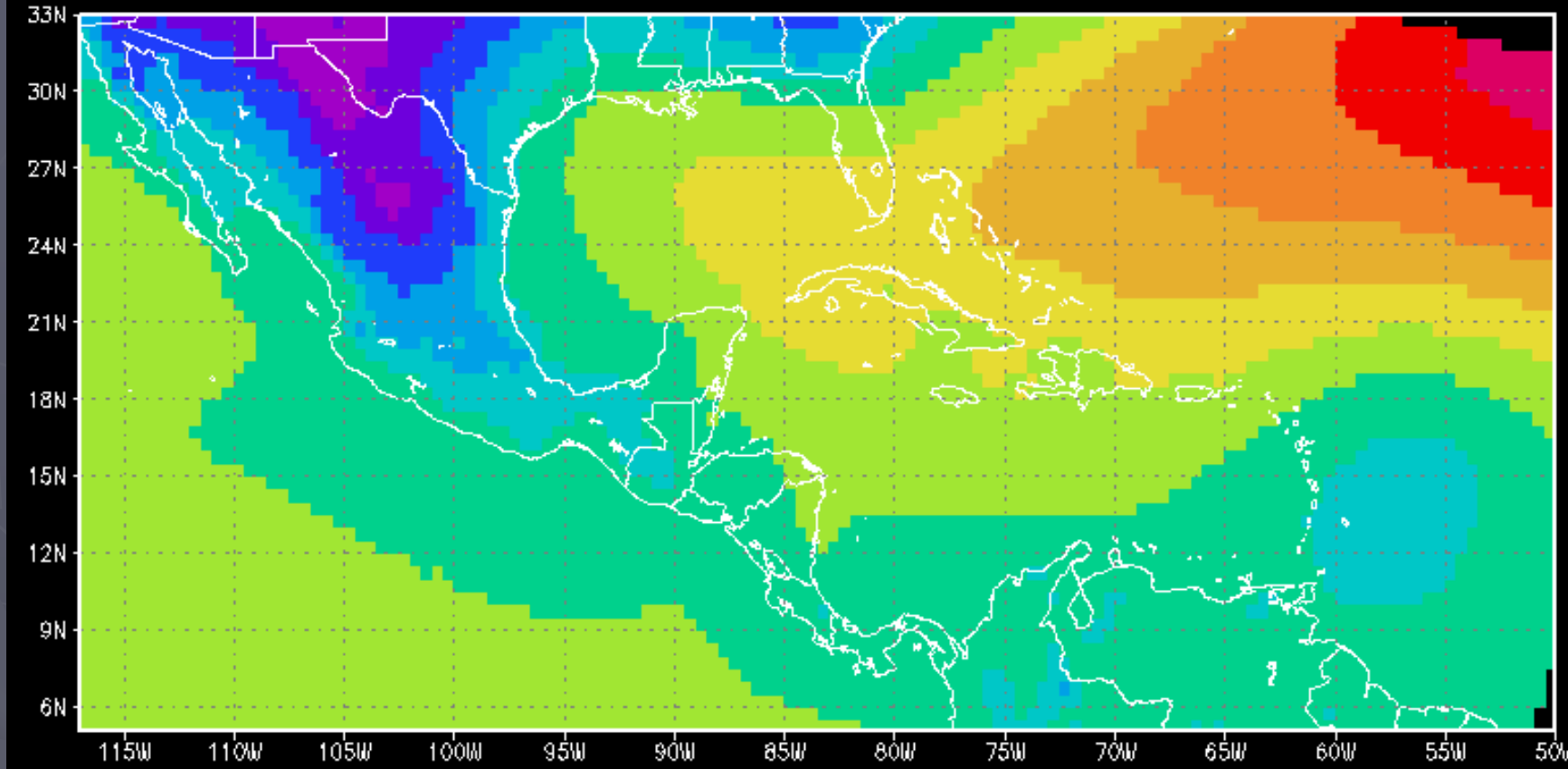
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TCLVs detection methodology

- It is designed to work with daily means
- On a grid of 0.44^{o} (50 km), a point of minimum in surface pressure is sought so that the averaged pressure over a circumference of 6^{o} (700 km) centered in the point is at least 5.5 hPa greater than in the point.
- The difference between the maximum and minimum values of the wind speed in a neighborhood of 3 grid points radius (1.3^{o} or 150 km) centered in the point of minimum pressure must be at least 40 km/h (11 m/s).
- The end of the track of each individual vortex occurs when in two consecutive days, the points of two consecutive TCLV position are located at a mutual distance of more than 7^{o} (800 km).
- The above criteria were adjusted in practice by trial and error based on a detailed visual analysis of the animated image sequences in the output of the model.

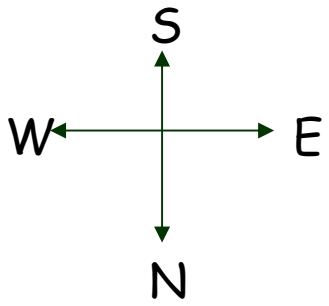
Application of the wind speed criterion to appoint the center of TCLV

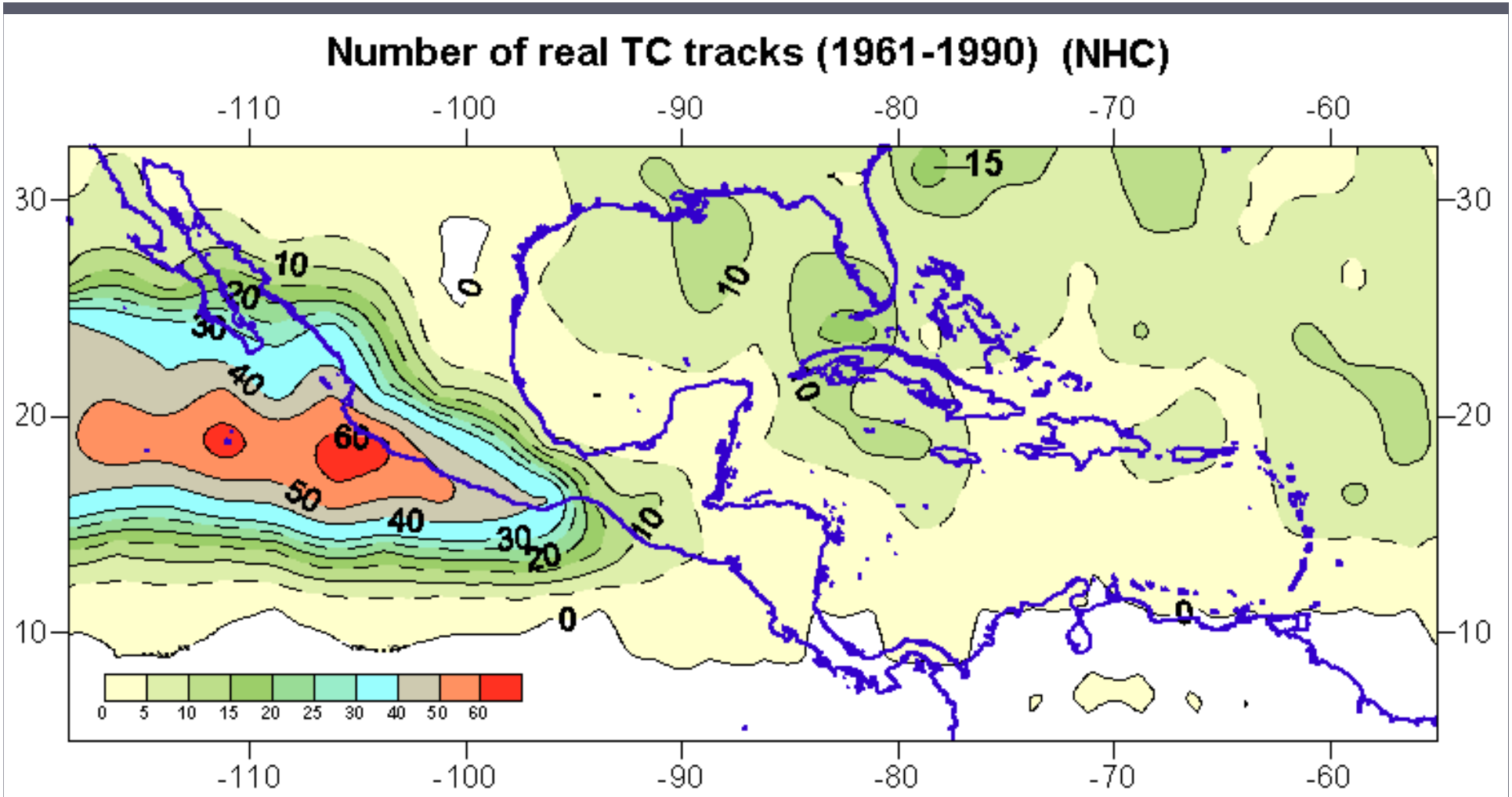
7.46	7.10	6.82	7.11	7.90	8.67	9.06	9.06	8.92	8.94
9.17	9.07	8.92	9.03	9.68	10.50	11.02	11.07	10.81	10.53
10.80	11.02	11.16	11.35	11.86	12.63	13.20	13.33	13.01	12.46
12.49	12.97	13.44	13.85	14.32	15.00	15.61	15.83	15.49	14.72
14.44	15.09	15.76	16.39	16.99	17.63	18.23	18.54	18.28	17.44
17.06	17.82	18.58	19.34	20.07	20.70	21.19	21.47	21.24	20.39
20.55	21.60	22.51	23.32	24.04	24.58	24.88	24.89	24.45	23.37
24.82	26.30	27.48	28.33	28.83	29.15	29.25	28.95	28.07	26.47
29.81	31.49	32.24	32.15	31.88	32.20	32.94	33.13	32.00	29.66
34.31	34.02	31.69	29.42	29.06	30.93	33.86	36.00	35.56	32.60
34.50	29.62	21.31	16.84	20.95	27.79	33.94	37.90	38.06	34.70
31.92	23.09	8.90	7.66	20.18	30.02	37.17	40.69	39.75	35.43
32.68	26.81	23.75	27.93	33.93	39.19	42.69	42.86	39.37	34.42
38.20	38.05	39.90	42.71	44.31	44.84	43.87	40.87	36.71	32.29
40.79	42.49	43.83	44.19	43.41	41.78	39.49	36.44	33.02	29.59
37.25	38.67	39.05	38.41	37.25	35.83	33.96	31.68	29.23	26.72
31.91	32.87	33.11	32.72	31.93	30.85	29.43	27.77	25.94	23.99
27.11	27.89	28.18	28.07	27.61	26.82	25.74	24.42	22.90	21.25
22.94	23.64	23.94	23.93	23.62	23.04	22.19	21.10	19.82	18.42
19.32	19.99	20.25	20.22	19.94	19.41	18.66	17.73	16.65	15.53
16.10	16.68	16.91	16.87	16.56	16.05	15.37	14.61	13.73	12.81
13.40	13.78	13.95	13.96	13.73	13.30	12.78	12.19	11.47	10.68
11.59	11.81	11.90	11.96	11.89	11.66	11.26	10.71	10.06	9.34
10.50	10.64	10.72	10.80	10.84	10.75	10.48	9.99	9.36	8.64
9.70	9.78	9.85	9.96	10.05	10.04	9.87	9.44	8.76	8.00

Minimum pressure point

Minimum wind speed

Maximum wind speed

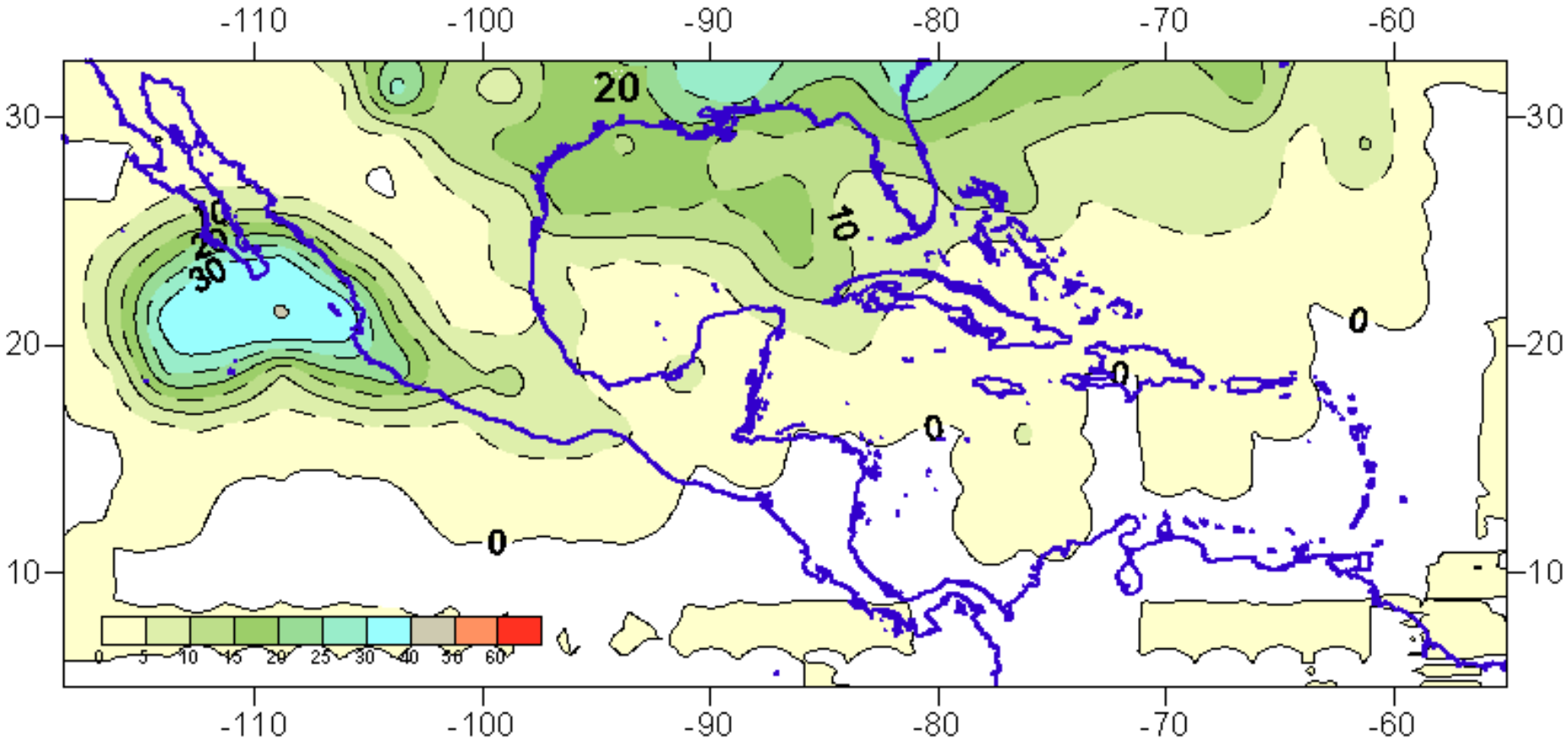




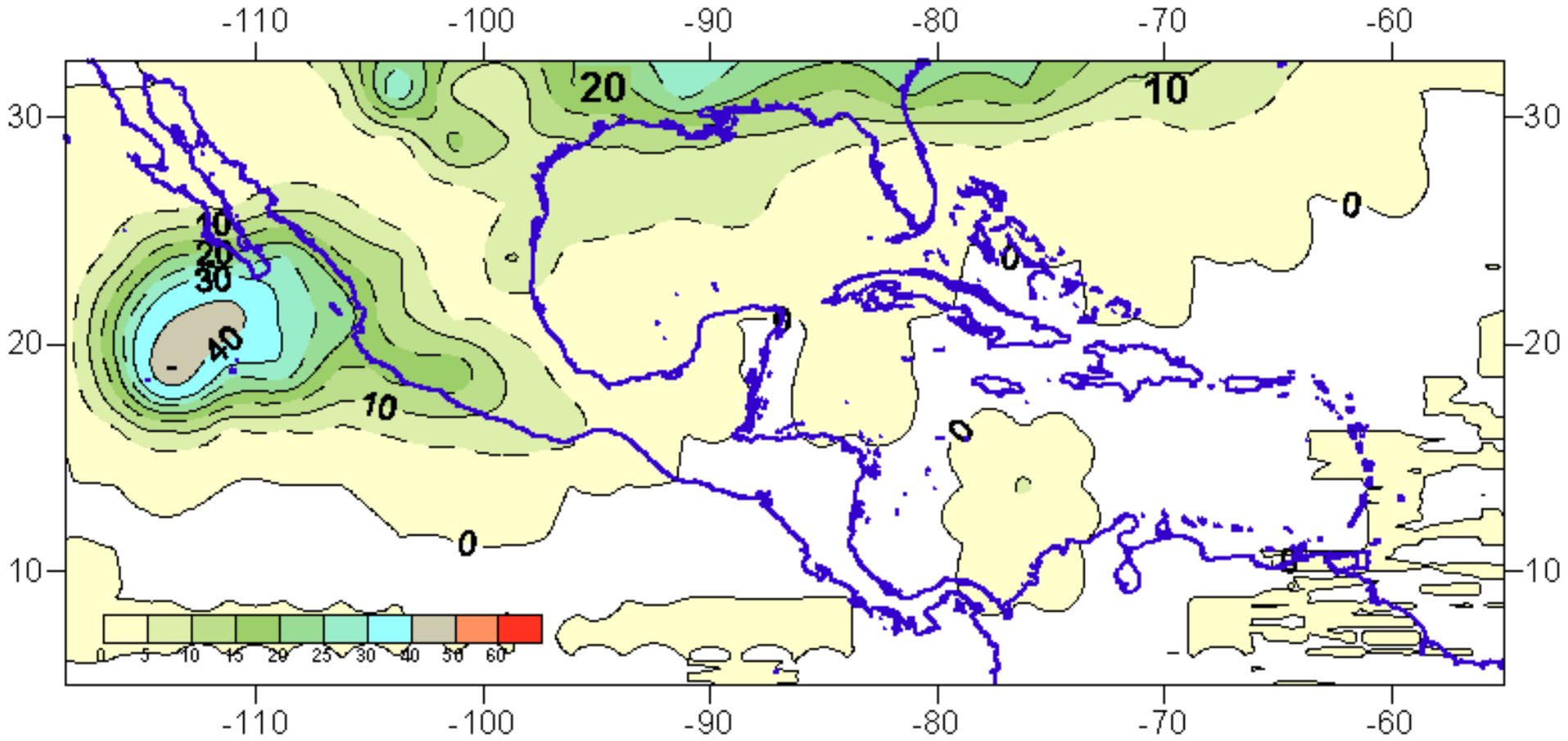
Historical North Atlantic and East-Central North Pacific Tropical Cyclone Tracks, 1851-2005

National Oceanic and Atmospheric Administration, Tropical Prediction Center/National Hurricane Center

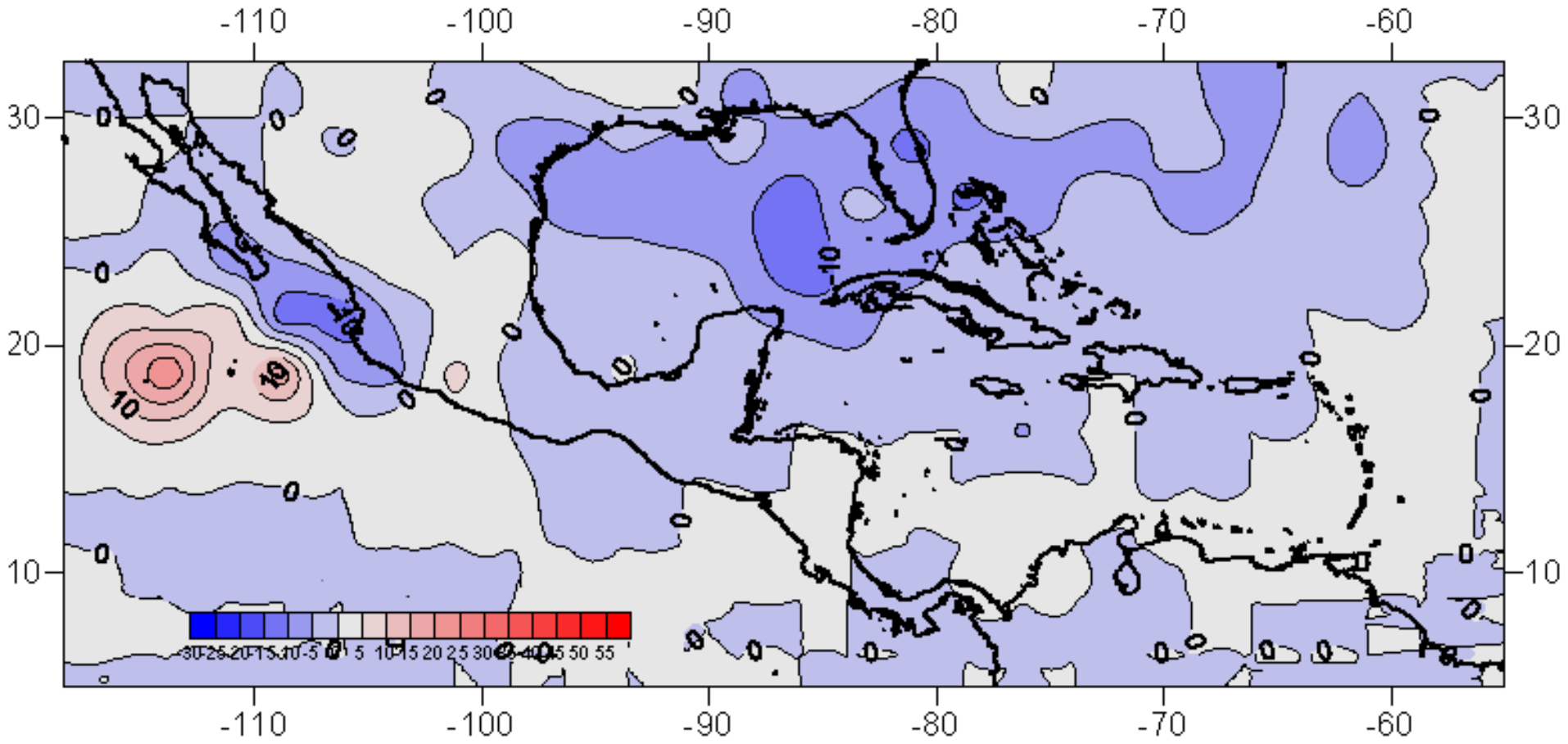
Number of TCLVs simulated for baseline (1961-1990)



Number of TCLVs projected for A2 scenario(2071-2100)

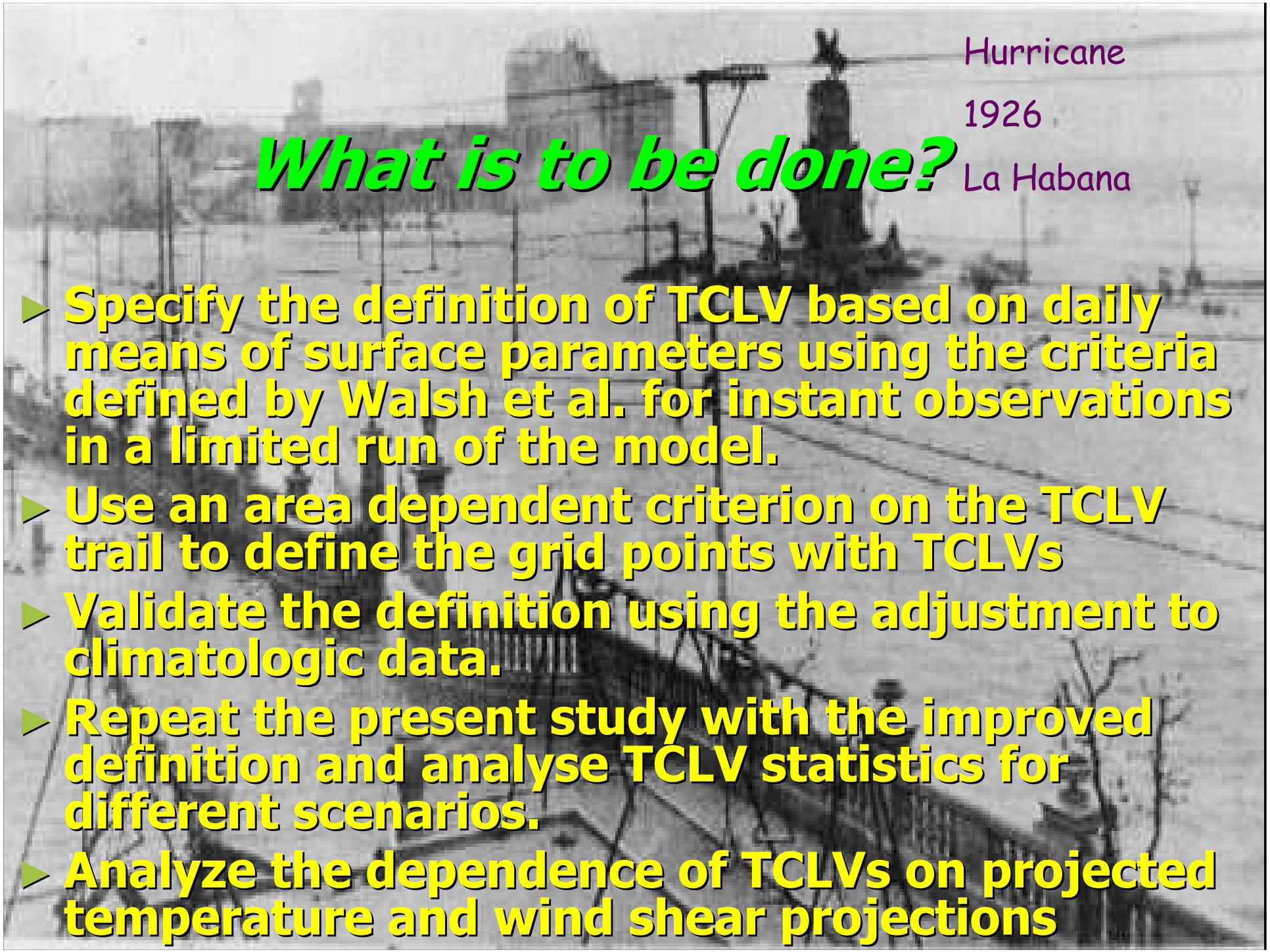


Projected increase in number of TCLVs
(A2)- Baseline



Speculation

- The projected increase in temperature in Eastern Pacific near the coast of Mexico and the smaller increase projected for Western Tropical Atlantic seem to be consistent with a greater projected increase of TCLVs for Eastern pacific.



What is to be done?

- Specify the definition of TCLV based on daily means of surface parameters using the criteria defined by Walsh et al. for instant observations in a limited run of the model.
- Use an area dependent criterion on the TCLV trail to define the grid points with TCLVs
- Validate the definition using the adjustment to climatologic data.
- Repeat the present study with the improved definition and analyse TCLV statistics for different scenarios.
- Analyze the dependence of TCLVs on projected temperature and wind shear projections


Wilma
24/10/2005
La Habana
Thank you!