Cluster analysis of simulated TC tracks in the North Atlantic basin

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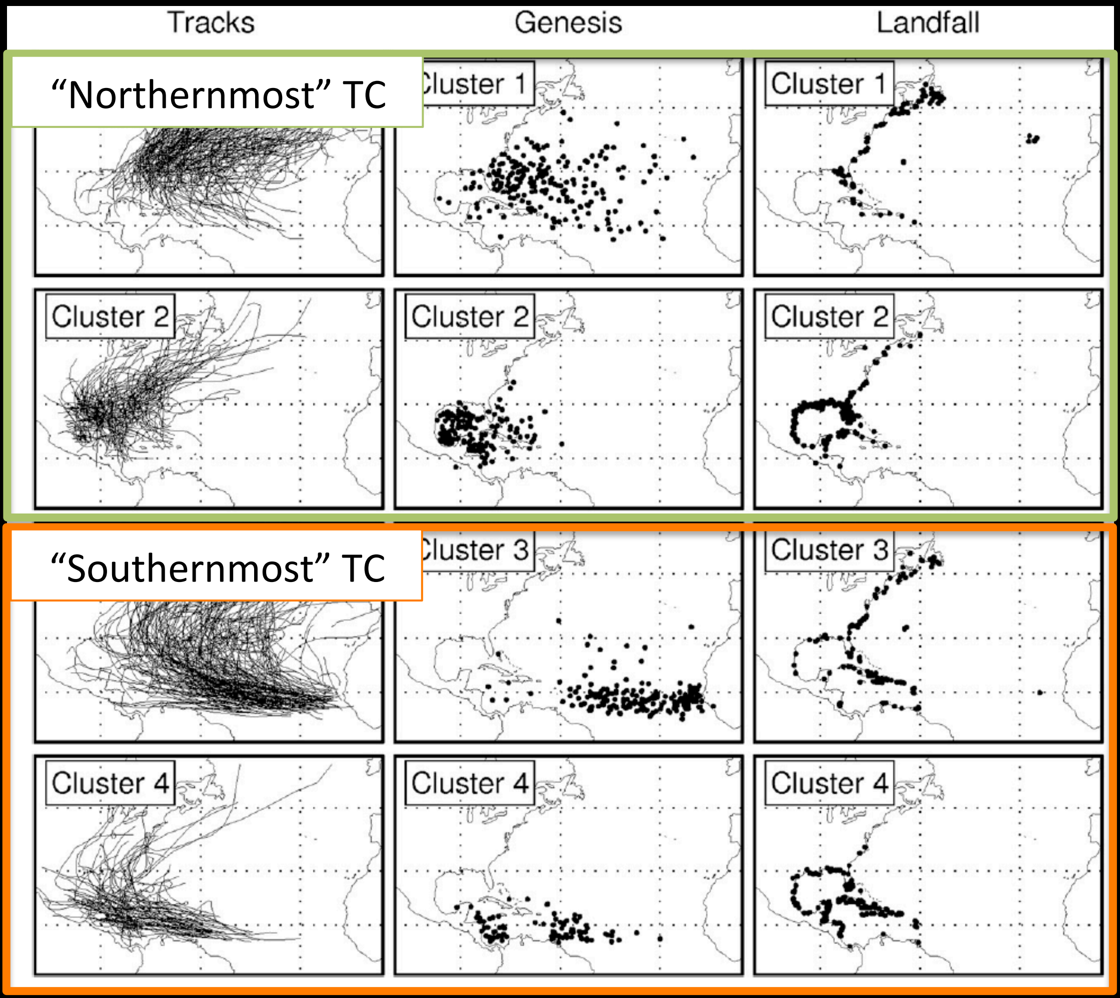
Background on cluster analysis

Observations (HURDAT) 1950-2007
Kossin et al. 2010



- Cluster analysis

  Meridionally and zonally separates tropical cyclones (TCs) into groups which share similar characteristics.

- Northernmost TC = clusters 1 + 2

  = Baroclinic and hybrid TCs

  Southernmost TC = clusters 3 + 4

  = Deep TCs

- Clusters 3 storms = most intense storms

Data and Methodology

CLIVAR-hurricane working group

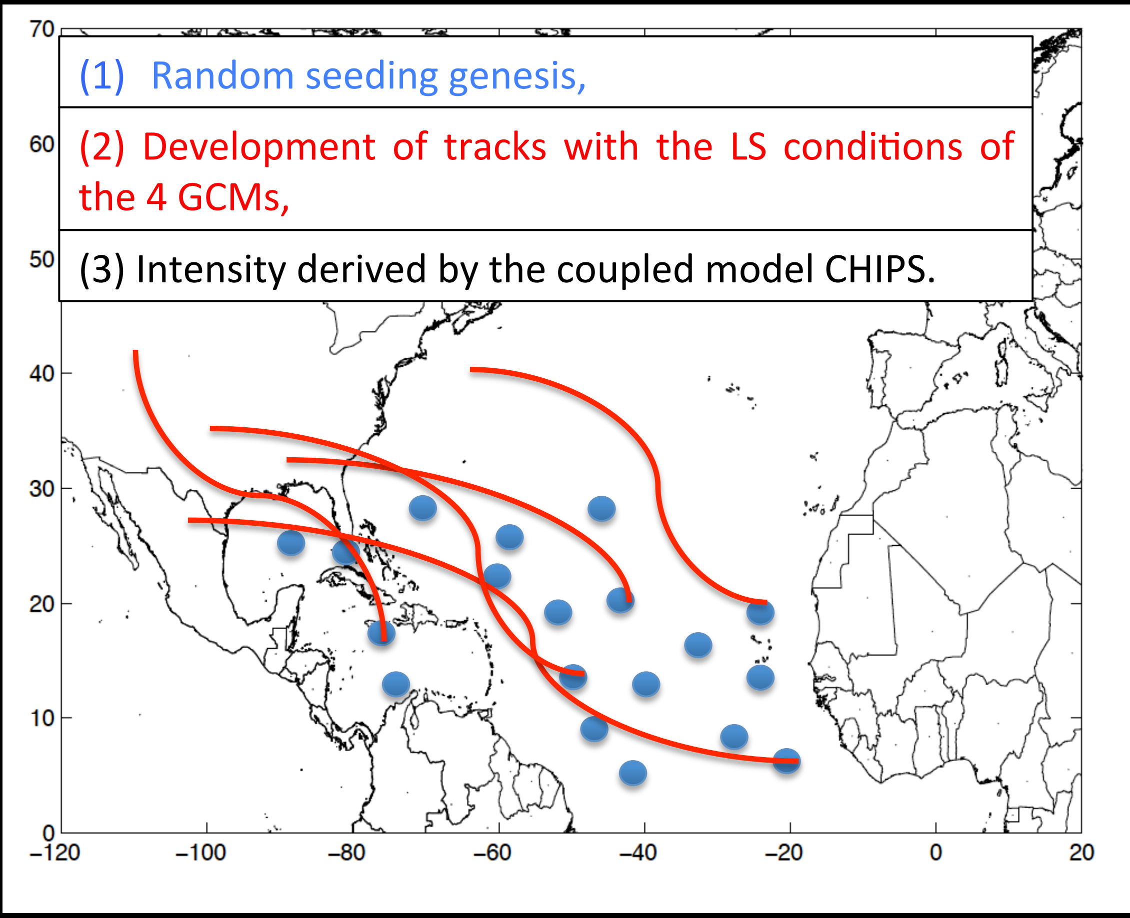
Explicit tracks (8 models)

Simulation	Spatial resolution	Number of years
GFDL_E	0.5°	20
GISS_E	1°	20
CMCC_E	0.75°	10
CAM5_E	1°	10

- Tracking algorithm detecting tropical cyclones when dynamic and thermodynamic variables meet specified criteria,
- Different tracking algorithm for each model,
- Forced by a climatology of Hadley's Sea Surface Temperature.

Downscaled tracks (4 models)

Emanuel 2005



Objectives of the study

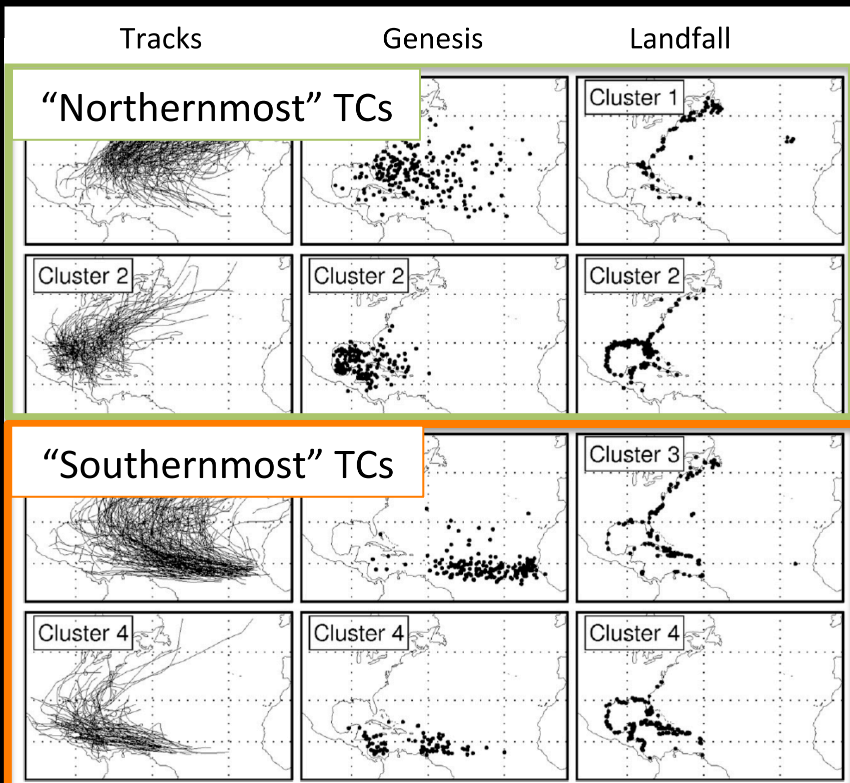
1) Determine the ability of explicit and downscaled simulation to represent the climatology of tropical storms clusters.

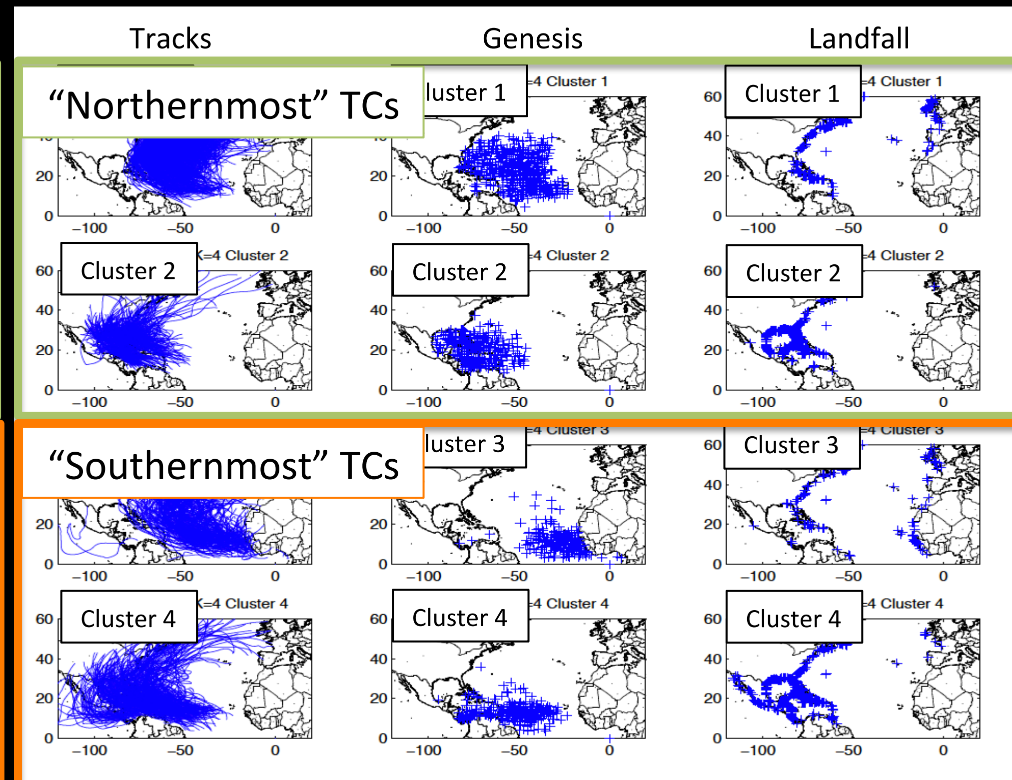
2) Examine the future changes in frequency and intensity of the clusters.

Clusters in downscaled simulations

Observations (HURDAT)
Kossin et al. 2010

GFDL_D (downscaled)





Very good representation of the clusters for all the downscaled simulations in terms of tracks, genesis and landfalls.

Climatology of "downscaled" clusters

Northernmost TCs Southernmost TCs

20C	Dataset	Cluster 1	Cluster 2	Cluster 3	Cluster 4
TC count	HURDAT	203	153	183	84
	GFDL_D	496	296	238	285
	CMCC_D	149	157	103	135
	CAM5_D	117	154	99	156
	GISS_D	176	242	96	151
Mean LMI per TC ($m.s^{-1}$)	HURDAT	35	35	44	45
	GFDL_D	41	31	42	41
	CMCC_D	39	33	38	34
	CAM5_D	34	33	36	39
	GISS_D	37	34	40	42
Mean duration per TC (days)	HURDAT	4.9	3.3	8.30	5.4
	GFDL_D	8.9	6.4	12.3	10.6
	CMCC_D	8.3	7.3	13.6	9.9
	CAM5_D	8.0	7.4	11.3	10.3
	GISS_D	8.7	8.0	13.5	9.5
Mean PDI per TC (10^{10} $m^3.s^{-2}$)	HURDAT	1.5	1.1	4.6	3.0
	GFDL_D	2.2	0.9	3.7	2.9
	CMCC_D	1.6	1.0	3.1	1.5
	CAM5_D	1.2	1.1	2.2	2.7
	GISS_D	1.6	1.3	3.1	2.6

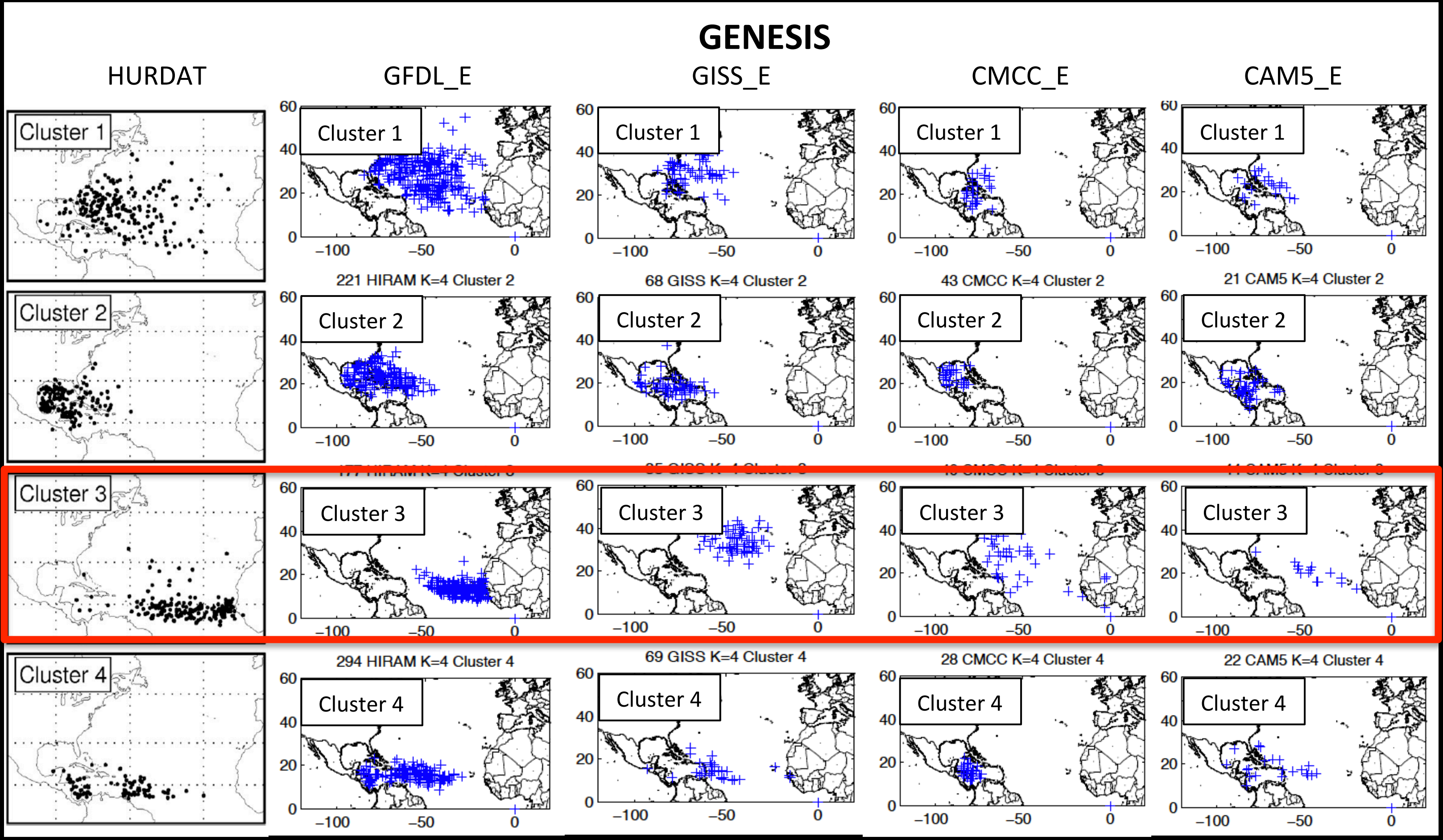
- Southernmost TCs present:
  - Higher LMI*,
  - Longer duration,
  - Higher mean PDI**.
- Cluster 3 presents:
  - High intensity,
  - Longest duration,
  - Highest mean PDI.
- Cluster 3 storms should present the highest total PDI, but due to bias in proportions this is not the case.

Very good representation of the climatology of cluster memberships by the downscaled simulations.

** LMI = Lifetime Maximum Intensity*

***PDI = Power Dissipation Index*

Clusters in explicit simulations



GFDL_E clearly gives the best representation of the clusters in terms of tracks, genesis and landfalls.

Factors creating differences: spatial resolution, AEWs (?).

Climatology of "explicit" clusters

Northernmost TCs | Southernmost TCs

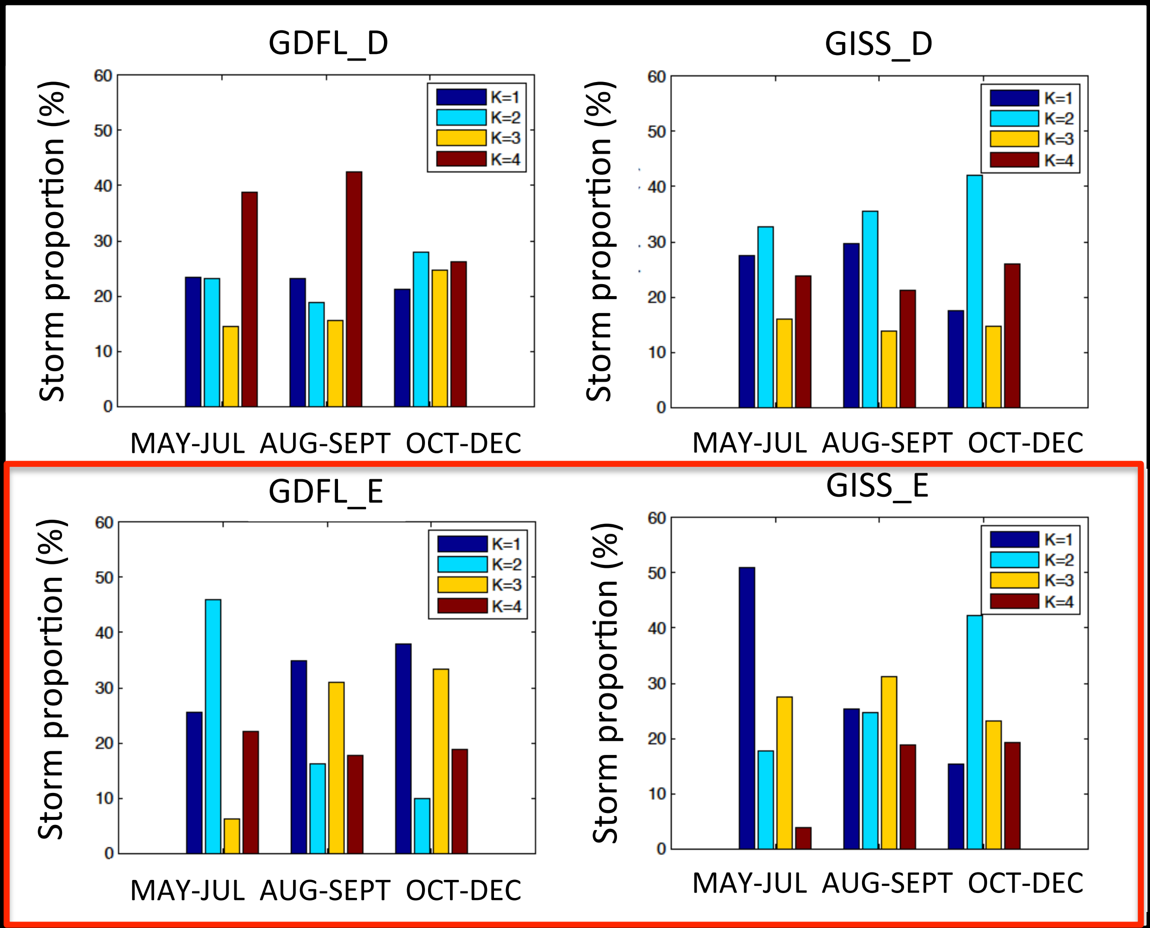
All runs	Dataset	Cluster 1	Cluster 2	Cluster 3	Cluster 4
TC count	HURDAT	203	153	183	84
	GFDL_E	294	177	221	159
	CMCC_E	28	40	40	43
	CAM5_E	22	44	14	21
	GISS_E	68	66	69	35
Mean LMI per TC ($m.s^{-1}$)	HURDAT	35	35	44	45
	GFDL_E	23	23	22	22
	CMCC_E	33	32	32	32
	CAM5_E	18	16	18	19
	GISS_E	8	7	8	6
Mean duration per TC (days)	HURDAT	4.9	3.3	8.3	5.4
	GFDL_E	2.1	2.4	2.7	2.7
	CMCC_E	1.0	0.9	0.7	1.4
	CAM5_E	2.4	2.3	3.3	3.3
	GISS_E	3.0	2.5	3.1	2.2
Mean PDI per TC (10^{10} $m^3.s^{-2}$)	HURDAT	1.5	1.1	4.6	3.0
	GFDL_E	1.1	1.2	1.5	1.3
	CMCC_E	0.3	0.3	0.2	0.4
	CAM5_E	0.4	0.3	0.7	0.7
	GISS_E	0.1	0.03	0.1	0.02

- Southernmost TCs present:
  - Higher LMI,
  - Longer duration,
  - Higher mean PDI.

- Cluster 3 presents:
  - High intensity,
  - Longest duration,
  - Highest mean PDI.

Poor representation of the climatology of cluster memberships by the explicit simulations compared to the downscaled simulations and the observations.

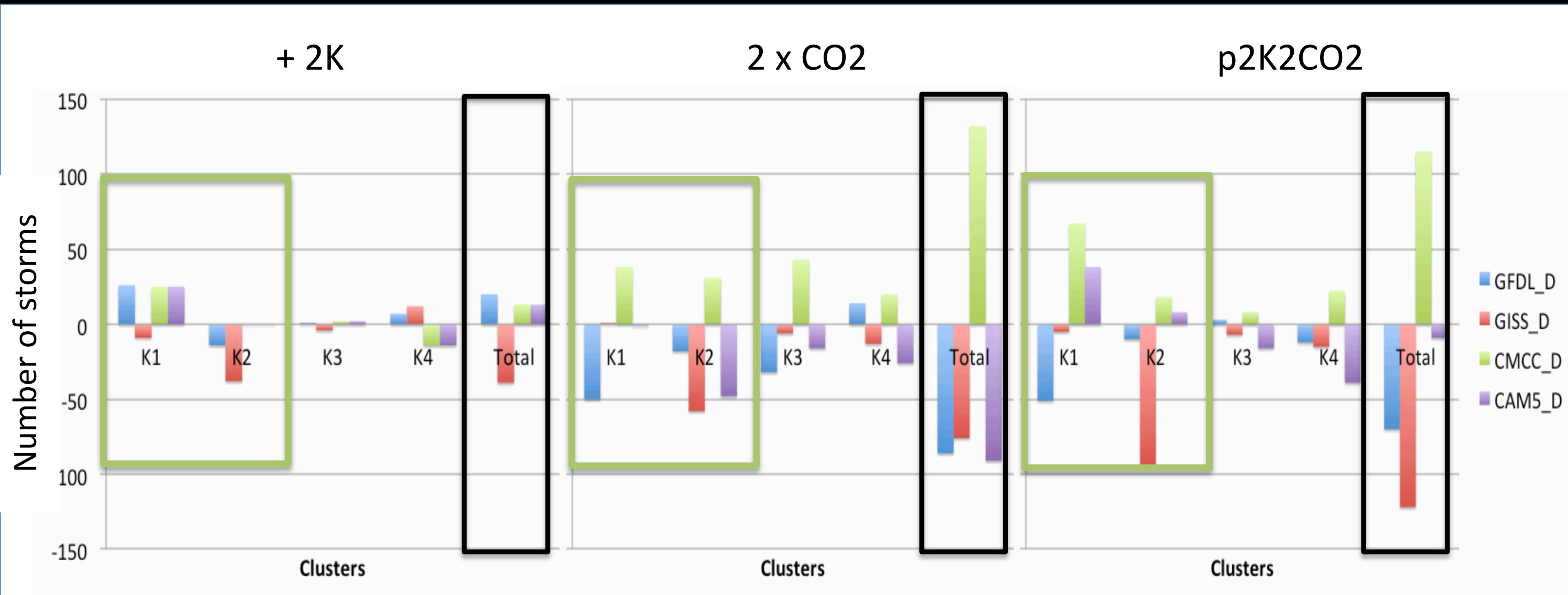
Seasonality of cluster memberships



- The seasonal cycle for the total number of storms (before cluster analysis) is well simulated by both types of simulations.
- In the observations
  - MAY-JUL = cluster 1 & cluster 2
  - AUG-SEPT = clusters 3
  - OCT-DEC = cluster 1 & cluster 2

- The seasonal cycle of cluster memberships is very poorly simulated by downscaled simulations due to biases in the proportion of storms per cluster.
- The downscaling technique can degrade the seasonal cycle.

Future changes in frequency

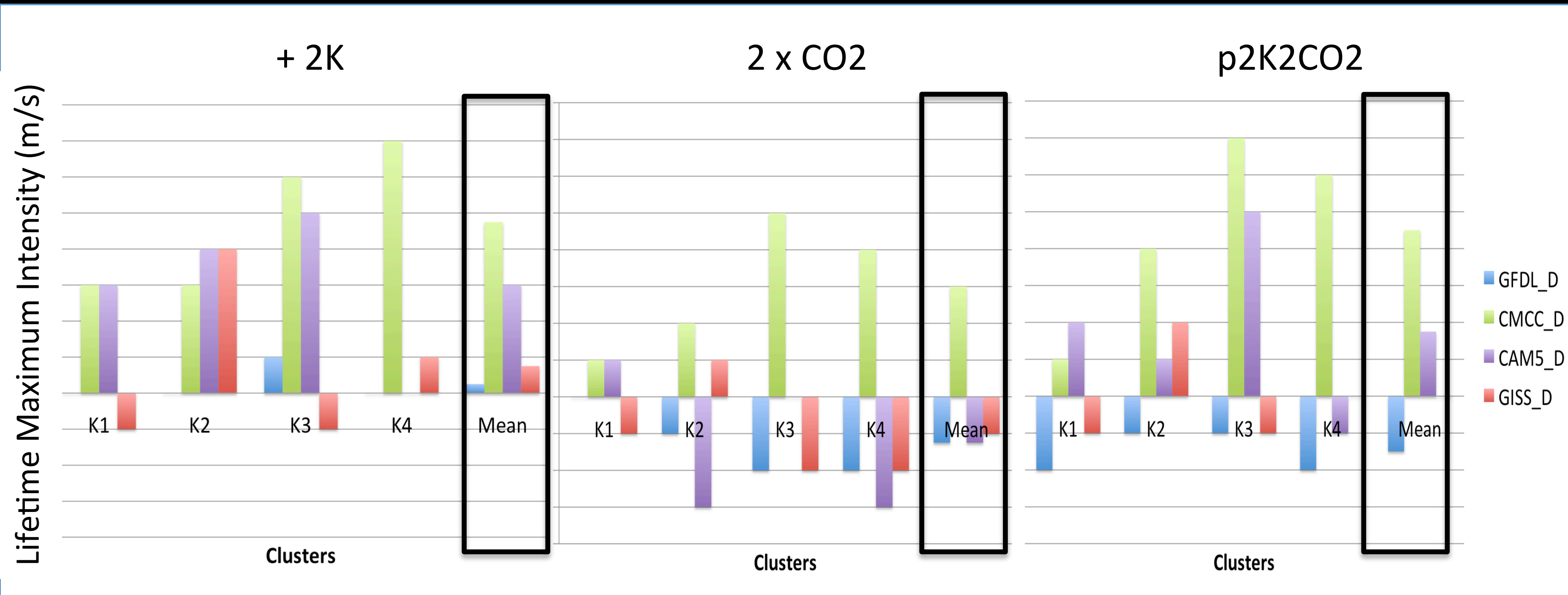


- <u>Total number of TCs</u>

For 3 models: ↗ for p2K scenario and ↘ for 2xCO2 and p2K2CO2.
For CMCC_D: ↗ of the frequency for all scenarios !!

- Changes in frequency, mostly due to changes in the number of northernmost TCs (clusters 1&2).

Future changes in intensity



- <u>Mean LMI</u>

For all the models: ↗ for p2K scenario,
For 3 models: ↘ for 2xCO2 scenario,
For 2 models: ↗ for p2K2CO2 scenario,

- Changes in intensity are distributed over all the clusters.

Conclusions

- Explicit simulations
  - All the simulations manage to correctly simulate 3 of the 4 clusters (tracks, genesis and landfalls locations),
  - High bias in terms of intensity and PDI showing the need for high spatial resolution.
- Downscaled simulations
  - All the simulations represent correctly all the clusters in terms of tracks, genesis and landfall locations !
  - Very interesting encouraging results concerning the climatology (intensity, duration, PDI ...),
  - However there is still a bias in proportion of the TCs and the seasonality of cluster memberships.

Conclusions

- Future changes in TC activity
  - Very different results depending on the different simulations and scenarios.
  - For the changes in frequency:
    - Changes mainly come from the doubling of CO_2,
    - Changes mainly come from northernmost TCs (Clusters 1 and 2)
  - For the changes in intensity:
    - Changes seems to come from the increase in SST,
    - Changes distributed overall the clusters.