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# Nonlocality of tropical cyclone activity idealized climate simulations

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# 1 Introduction

**What does nonlocality of tropical cyclone activity mean?**

- The observed frequency and intensity of tropical cyclones (TCs) correlates better with the anomaly of sea surface temperature, SSTa, than with its absolute value, STT (Swanson 2008).

  Definition: SSTa = SST - <SST> (<SST> Area average of tropical SST)

- Therefore, a nonlocal dependency of TC activity on SST exists, that is, the SST has an influence on tropical cyclones in remote ocean basins.

**Question**

- Which mechanism of the climate system is responsible for this phenomenon?

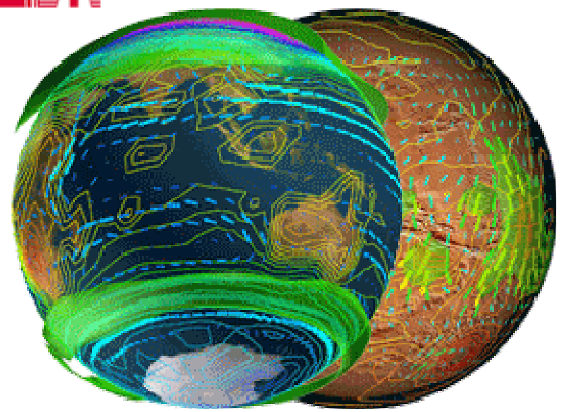
  We tried to answer this question under idealized conditions by using the climate model Planet Simulator.

# 2 Model and experimental design

## Experiments are conducted with PlanetSimulator (PLASIM)

PLASIM

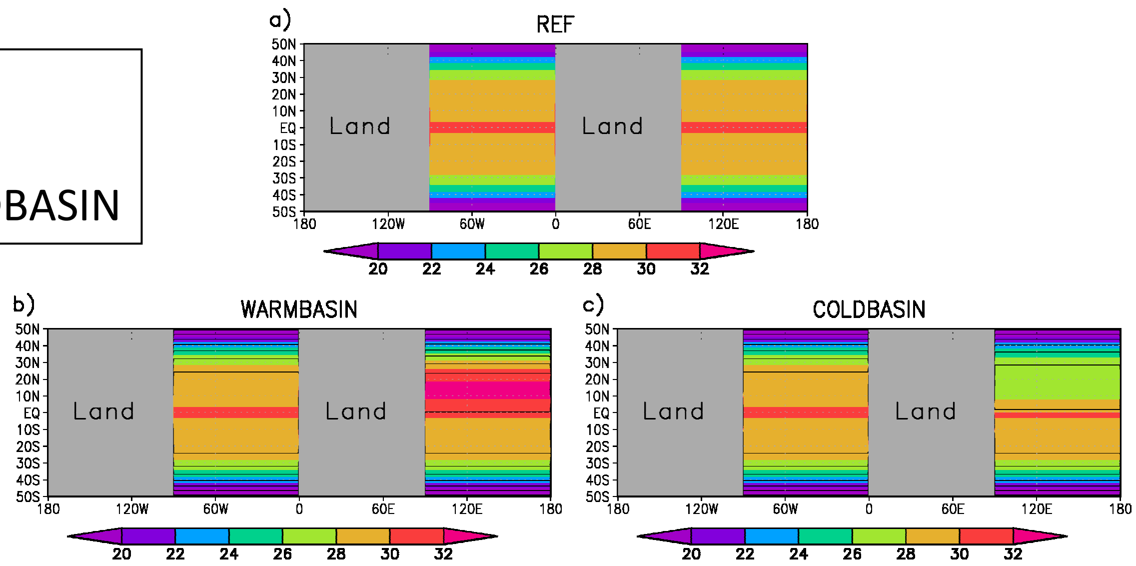
- PLASIM (Fraedrich et al. 2005) is a global atmospheric climate model.
- A spectral primitive equation model forms the dynamical core of PLASIM.
- Modules to include ocean, land ice, soil and vegetation dynamics.
- In this study fixed boundary conditions except for soil are included.
- 28 model layers are adopted.



# Design of the experiments with PLASIM

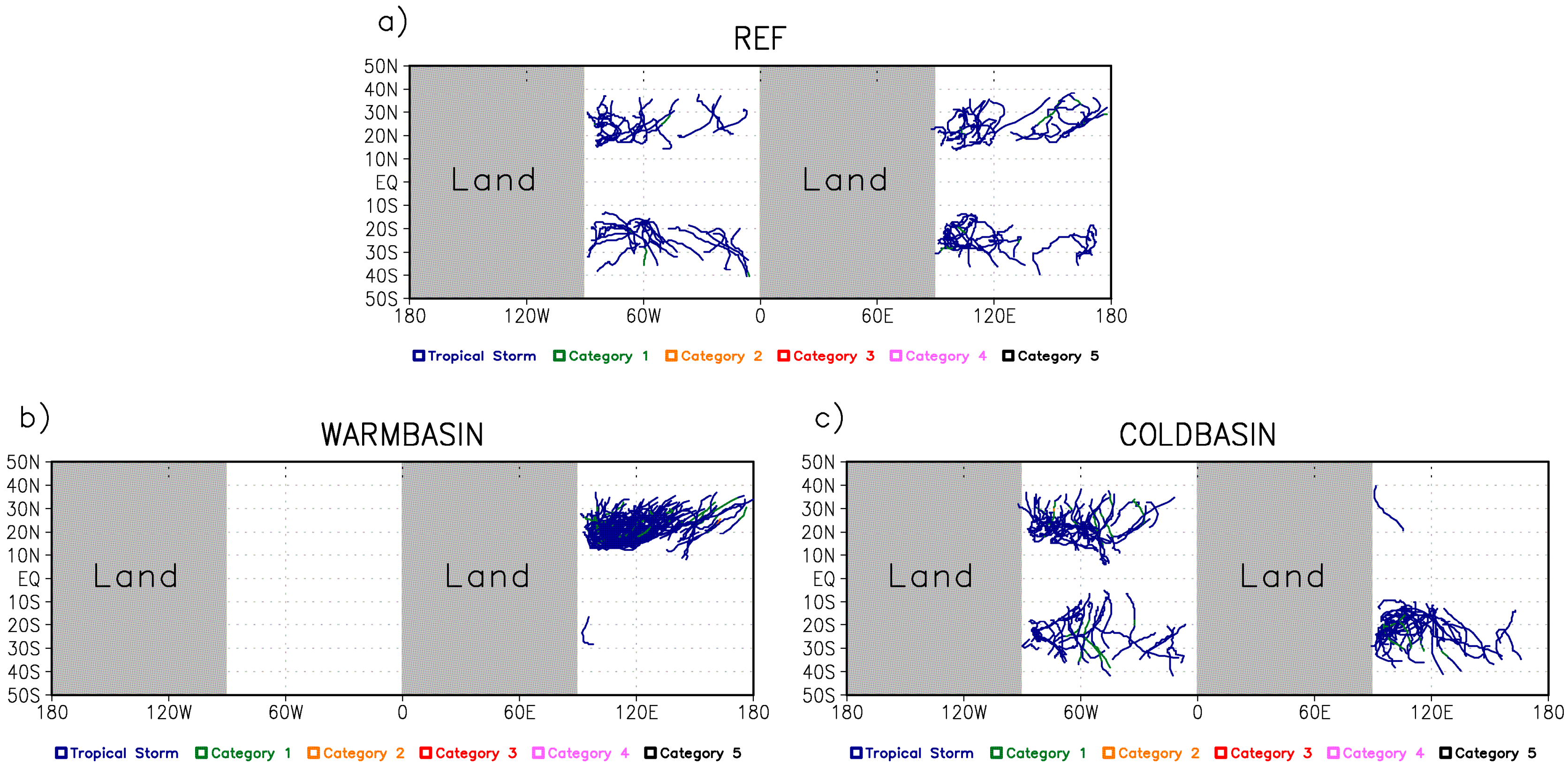
- Prescription of SST-fields in three experiments
- 10 year spinup at the spectral resolution T42L28
- 2 years simulation at the spectral resolution T170L28

SST und land sea mask
in the idealized experiments
REF, WARMBASIN and COLDBASIN



# 3 Results

## Detected hurricane tracks for the three model experiments



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## ACE-Index und number of hurricanes in the various ocean basins

Definition of Accumulation Cyclone Energy (ACE) Index (Bell et al. 2000):

$$ACE = \sum_{n=1}^{N} \left( \frac{V_n}{100\text{m/s}} \right)^2$$

$V_n$ denotes the maximum 1000hPa wind speed of the cyclone $n$

**Table:** 1. Entry: ACE Index, 2. Entry: Number of hurricane tracks

| | REF | | WARMBASIN | | COLDBASIN | |
|---|---|---|---|---|---|---|
| | West | East | West | East | West | East |
| North | 93.5 / 18 | 121.9 / 22 | 0 / 0 | 633.0 / 120 | 216.3 / 35 | 4.3 / 1 |
| South | 85.5 / 19 | 114.8 / 19 | 0 / 0 | 2.6 / 1 | 138.0 / 23 | 177.7 / 39 |

A significant nonlocal response arises in WARMBASIN and COLDBASIN. It is more pronounced in COLDBASIN.

## Global ACE-Index

Response to local SST Change

| Experiment | ACE |
|---|---|
| COLDBASIN | 536 (+120) |
| REF | 416 |
| WARMBASIN | 635 (+219) |

Response to global SST Change

| Experiment | ACE |
|---|---|
| SST COOLING by 2.5 K | 323 (-93) |
| REF | 416 |
| SST WARMING by 2.5 K | 432 (+16) |

Global response to local SST anomalies is larger than to a globally uniform SST change.

# 4 Analysis of cyclogenesis indices

**For diagnosis we evaluated the following well-known cyclogenesis indicators:**

- Gray's Seasonal Genesis Parameter SGP (Gray 1978)

$$SGP = 30\underbrace{f\left(\zeta_{950}\times 10^6 + 5\mathrm{s}^{-1}\right)\left(|\mathbf{v}_{200}-\mathbf{v}_{950}|+3\mathrm{m/s}\right)^{-1}}_{\text{Dynamic potential}}\underbrace{(T_s - 299.15K)(\theta_{e1000}-\theta_{e500}+5K)\frac{R_{700}+R_{500}-80\%}{60\%}}_{\text{Thermodynamic potential}}$$

- Genesis potential index GPI (Emanuel und Nolan 2004)

$$GPI = 10^5|f+\zeta_{850}|^{3/2}\left(\frac{R_{700}}{50\%}\right)^3\left(\frac{V_{pot}}{70\mathrm{m/s}}\right)^3\left(0.1|\mathbf{v}_{200}-\mathbf{v}_{850}|+1\mathrm{m/s}\right)^{-2}$$

Notation

$f$ Coriolis-parameter, $\zeta$ relative vorticity, $\mathbf{v}$ horizontal wind, $T_s$ SST, $R$ relative humidity, $\theta_e$ equivalent-potential temperature, $V_{pot}$ potential intensity (PI, Bister und Emanuel 2002). The index refers to the pressure in hPa of the selected isobaric surface.

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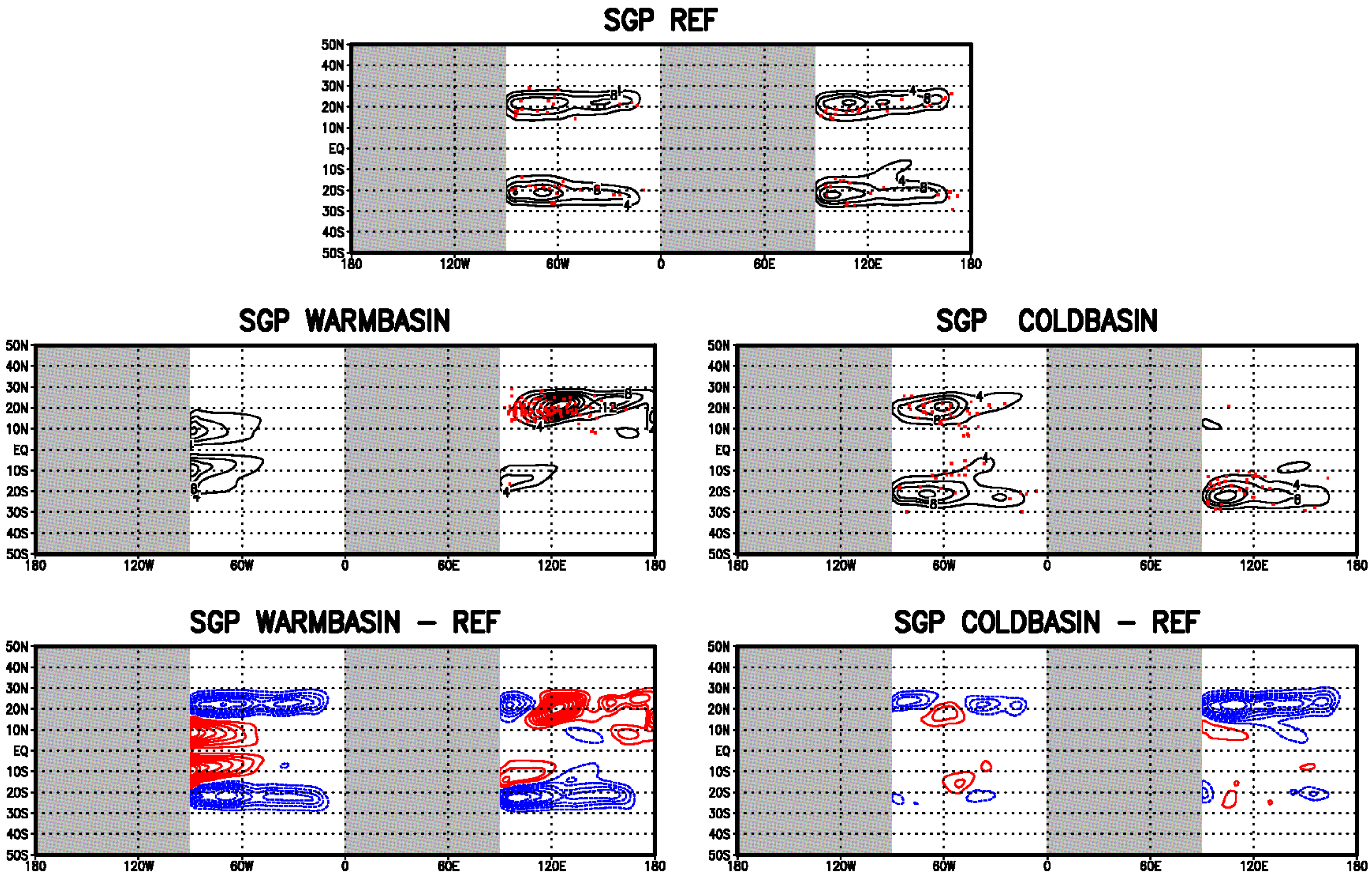
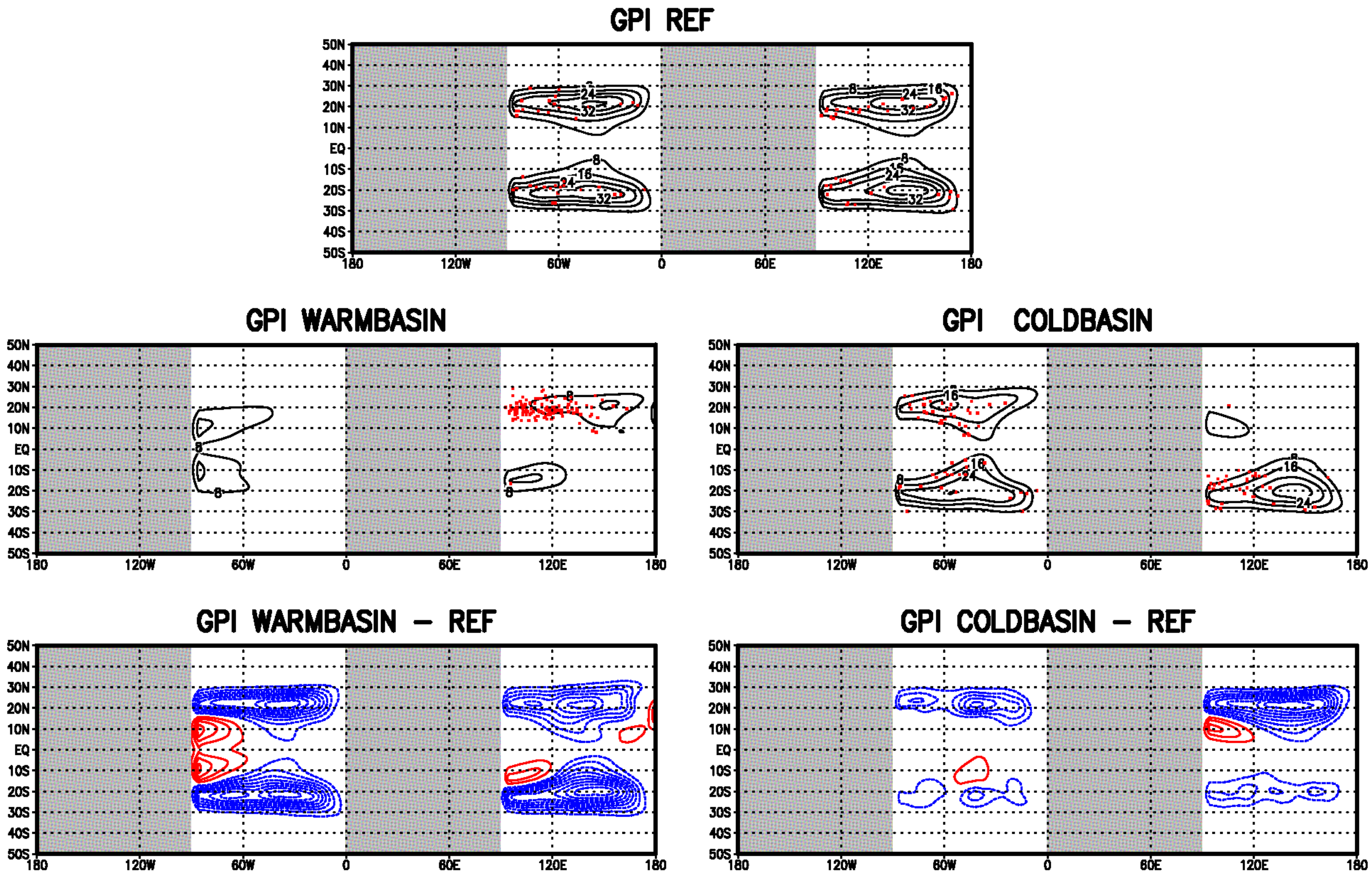
# SGP distribution and its difference to REF; red dots display cyclogenesis locations



# GPI distribution and its difference to REF; red dots display cyclogenesis locations



**Calculation of the contribution to the change of SGP and GPI due to the various factors**

Both cyclogenesis indicators can be written in factorised form

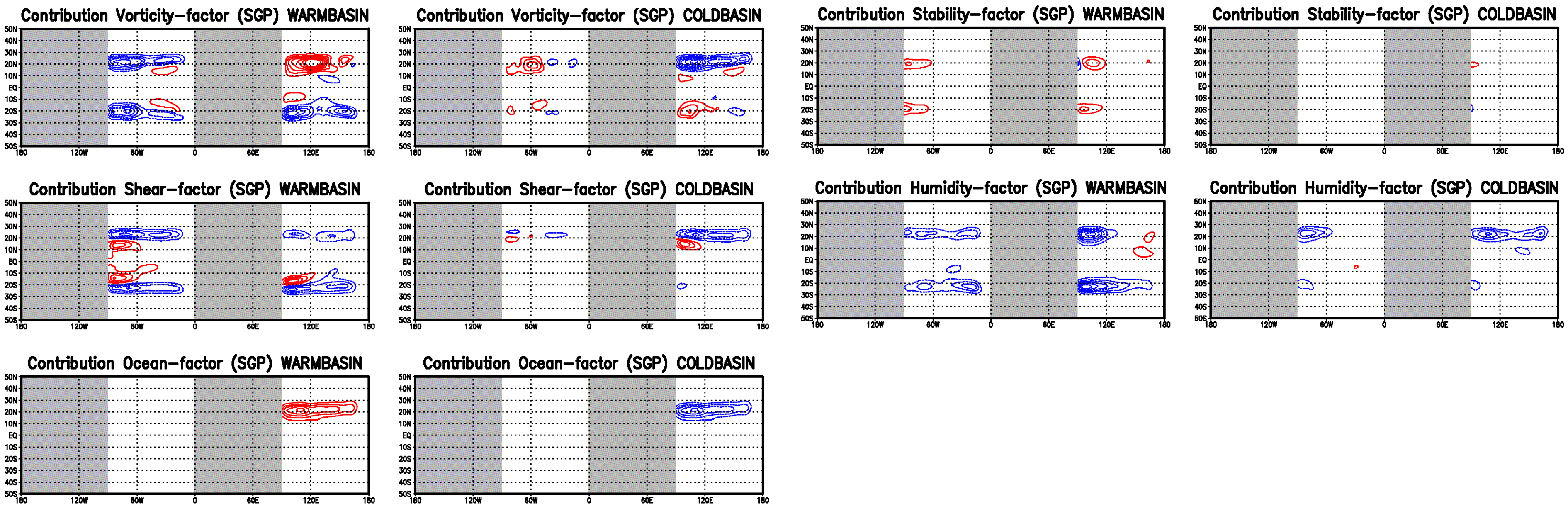
$$Y = \prod_{n=1}^{N} X_n$$

The contribution of one factor to the change of the indicator can be estimated by the sensitivity $\partial Y / \partial X_n$ . Taylor expansion up to the first (linear) order leads to:

$$\Delta Y \approx \sum_{n=1}^{N} \frac{\partial Y}{\partial X_n} \Delta X_n = \sum_{n=1}^{N} \left( \prod_{n' \neq n} X_{n'} \right) \Delta X_n$$

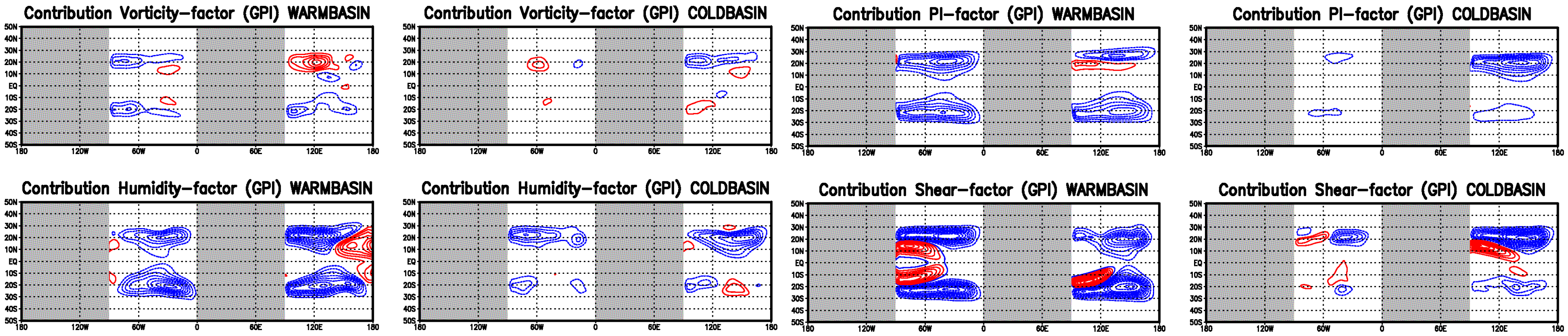
Each summand yields the linear contribution to the change due to the respective factor. The importance of a certain factor can be estimated by this method.

# Contributions to the SGP




- Only the vorticity factor supports nonlocality in both sensitivity experiments.
- The humidity and shear can provide an explanation in experiment WARMBASIN.

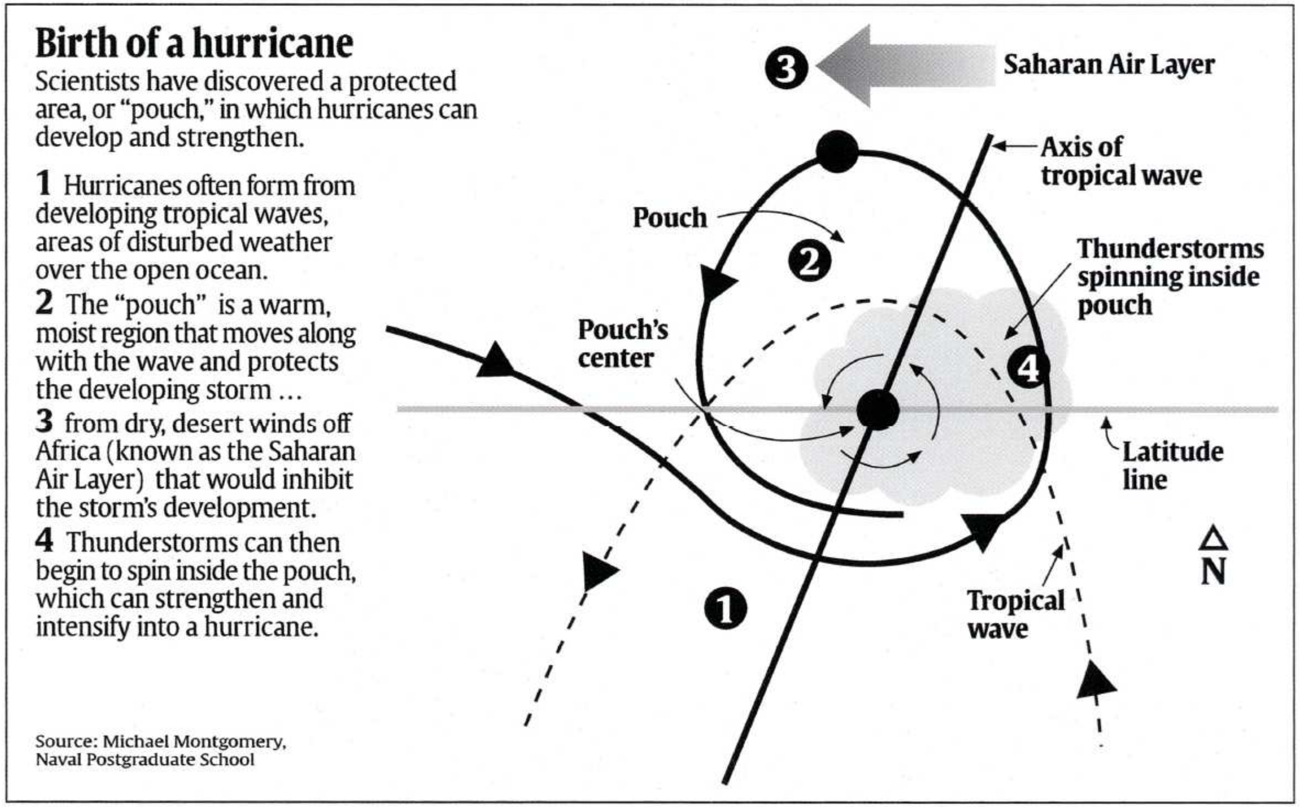
## Contributions to the GPI




- The vorticity factor supports the nonlocality effect but less pronounced.
- The relative humidity and PI factors could also explain nonlocality in WARMBASIN.
- The PI fails to explain the local increase of TC activity in WARMBASIN.

**The Marsupial Paradigma (Dunkerton et al. 2008):**

An approach to understand tropical cyclogenesis

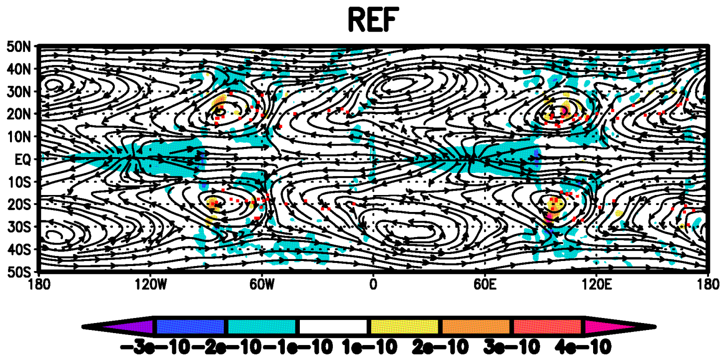


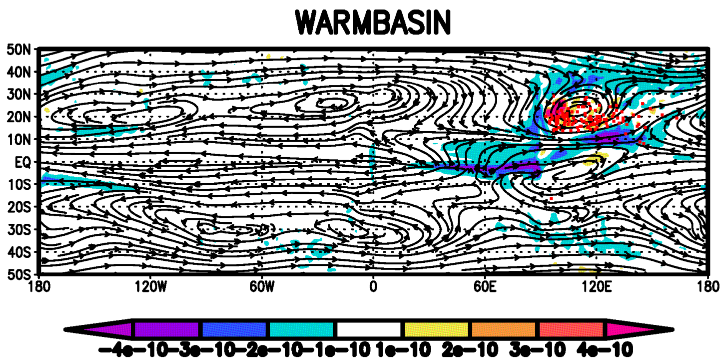

(from US-Today)

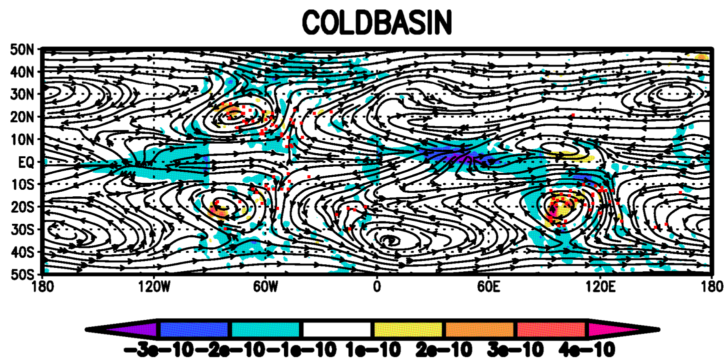
## The Okubo-Weiss parameter represents a suitable indicator for the „Pouch“´:

$$OW = \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)^2 - \left(\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}\right)^2 - \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)^2 = \zeta^2 - E^2 - F^2$$

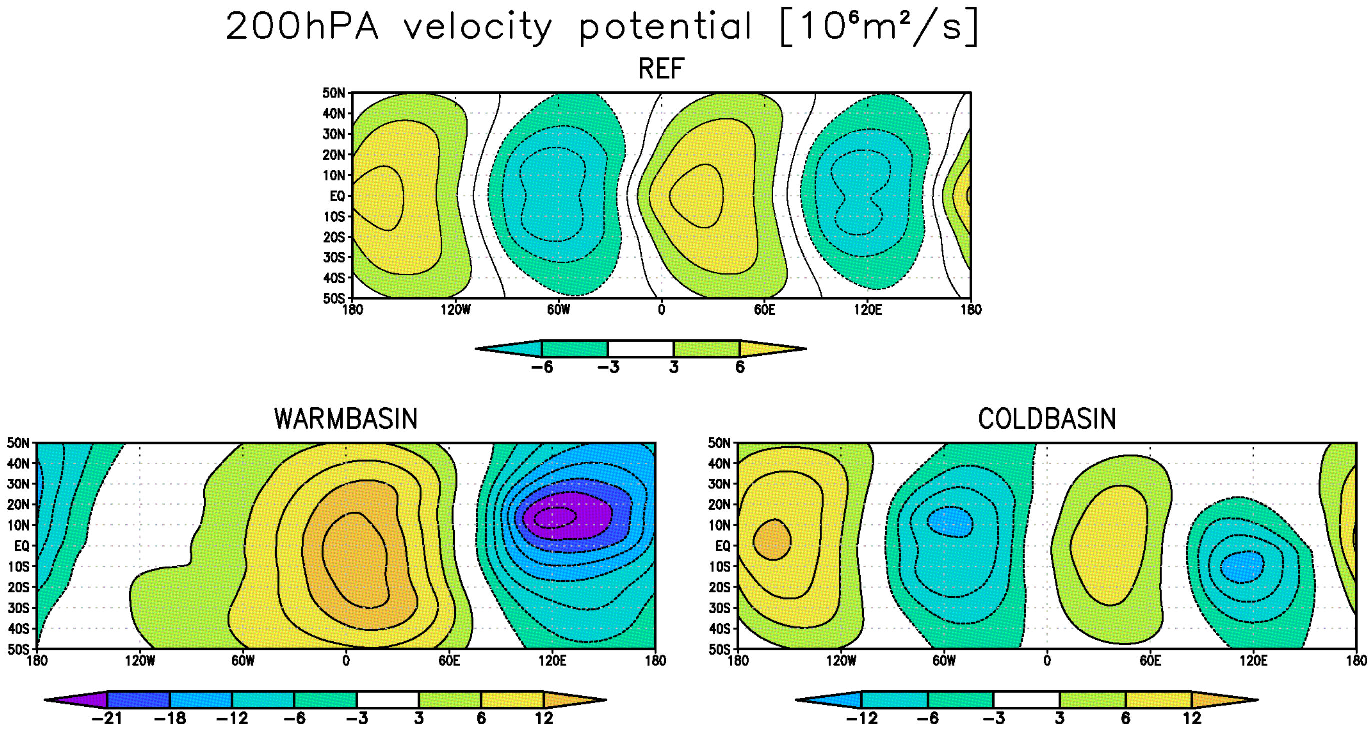
**Figure:** Time-averaged Streamlines,Okubo-Weiss parameter at 700hPa (colored shadings) and cyclo-genesis locations (red dots)



**The change of the large scale streamlines mainly results from the change of the overturning circulation as seen in the 200hPa velocity potential.**



# 5 Conclusion

- The idealized sensitivity experiments with Plasim reveal a nonlocality of TC activity due to changes in the SST distribution.
- The cyclogenesis-indicators SGP und GPI explain these results unsatisfactorily.
- Only the vorticity-factor of both indicators provides a change pattern that is consistent with the change of TC activity.
- The more far-going consideration of the Marsupial-paradigm could also explain the nonlocality of TC activity in these experiments.
- With this paradigm the TC activity in remote basins mainly changes due to a rearrangement of the large scale overturning circulation.
- The response of TC activity to a global warming of similar magnitude is smaller. This indicates the importance of regional climate change for TCs.

# 6 Outlook

- The results possibly depend on the choice of the global climate model. It would be beneficial to verify the results in other global climate models which allow for higher resolution and more sophisticated models physics.
- The results also depend sensitively on the choice of the land parameters (e.g Albedo). It would also be interesting to find out how and why land surface properties modify TC activity.

**Acknowledgments**

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