MEDICANES AND CLIMATE CHANGE: Analysis with two different methods

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4th International Meeting on Meteorology and Climatology of the Mediterranean
MOTIVATION

Medicanes are warm-core, surface flux-driven extreme windstorms potentially threatening the islands and coastal areas:

- Are there favoured locations for medicane development?
- How intense can they become?
- How could they react in frequency and intensity to global warming?
MEDICANE RISK ???

With an average frequency of only 1-2 events per year and given the lack of systematic, multidecadal databases, an objective evaluation of the long-term risk of medicane-induced winds is impractical with standard methods.

Database from satellite
(Tous and Romero, 2012)
**APPROACH:** Large-scale environmental proxies

Synoptic analyses of a few studied cases show that an inevitable precursor is the presence of a deep, **cut-off, cold-core** low in the upper and middle troposphere:

- **But** the infrequent occurrence of medicanes suggests that **additional and very special meteorological conditions** are necessary for these storms to occur …
**APPROACH:** Large-scale environmental proxies

Application of an empirical index of genesis:

\[ I = 10^5 \eta \left( \frac{H}{50} \right)^{3/2} \left( \frac{V_{\text{pot}}}{70} \right)^3 \left( 1 + 0.1 V_{\text{shear}} \right)^{-2} \]

GENIX parameter
(Emanuel and Nolan, 2004)

- **But** these environmental proxies behave as necessary but **no sufficient** ingredients for the successful genesis of a medicane …
FIRST METHOD: Nested climatic simulations

Detection and tracking of symmetric warm-core cyclonic disturbances generated in mesoscale simulations forced by Reanalysis and GCM data:

• But high computational cost: Limited horizontal resolution; Too few climatic realizations to permit a full sampling of the PDF of storms …
SECOND METHOD: Statistical-deterministic approach

Developed by Kerry Emanuel and his team in the context of the long-term wind risk associated with tropical cyclones:

- **Low-cost generation of thousands of synthetic storms**
- **Statistically robust** assessment of risk (e.g. return periods for winds)

- **Genesis**: Random draws from observed PDF or Random seeding
- **Track**: Randomly varying synthetic winds (respecting climatology)
- **Environment**: Previous winds + monthly-mean thermodynamic fields
- **Intensity and radial distribution of winds**: CHIPS model
ADAPTATION OF THE SECOND METHOD

The separation of timescales made in the tropics between the synthetic wind field (fast scale) and the thermodynamic environment (slow scale) is not appropriate to represent the movement, growth and decay of mid-latitude weather systems. In addition, the history of medicane genesis is far too sparse to form a reasonable PDF of genesis, and random seeding would be very inefficient:

- For each month, decomposition through PCA of 10-day synoptic evolutions of $z_{250}$, $z_{850}$, T600, R600 and PINT into the new space of independent PCs
- Random selection + random perturbation of the set of PCs
- This perturbed set of PCs is converted back into physical space
- This is tantamount to generating 10-day sequences of spatiotemporal coherent $z_{250}$, $z_{850}$, T600, R600 and PINT synthetic fields which also respect their mutual covariances

- Potential Genesis: Based on the GENIX parameter
OPEN-SEA POINT + MAX OF GENIX > 20 + ABS VOR > 10 units

**YES**

Backward (Max: 6 h) Forward (Max: 2 days over land)

\[
\begin{align*}
  u_{\text{track}} &= \alpha u_{850} + (1 - \alpha) u_{250} \\
  v_{\text{track}} &= \alpha v_{850} + (1 - \alpha) v_{250} + v_\beta
\end{align*}
\]

\[
\alpha = 0.8 \quad v_\beta = 2.5 \text{ m/s}
\]
EXEMPLE FOR A REAL EVENT
19-March-1999, 18 UTC
ERA-40
2 tracks
RND 1
1 tracks
RND 2
4 tracks
RND 3
5 tracks
RND 4
5 tracks
We synthetically generate a total of ~15000 potential tracks for each climate/model. These are simulated with CHIPS and checked for intensification above TS category (34 kt):

<table>
<thead>
<tr>
<th>Climate Scenario</th>
<th>Reanalysis or GCM</th>
<th>Successful Storms</th>
<th>Storms per century</th>
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<tr>
<td><strong>PRESENT</strong></td>
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<tr>
<td><strong>SRES A2</strong></td>
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</tbody>
</table>
Regional Distribution

- Atlantic
- West Reg
- Cent Reg
- East Reg
- Black Sea

Regions:
- Atlantic
- West Reg
- Cent Reg
- East Reg
- Black Sea

Models:
- ERA40
- CSIRO
- ECHAM
- GFDL
- MIROC
Return Period

Maximum Wind (kt)

Years

Cat 4
Cat 3
Cat 2
Cat 1

ERA40  
CSIRO  
ECHAM  
GFDL  
MIROC

Cat 4
Cat 3
Cat 2
Cat 1

[Graph showing wind speed vs. years for different models and categories.]
20C3M scenario
SRSA2 scenario
COMPARISON OF BOTH METHODS

SYNTHETIC generation

DYNAMICAL downscaling

28 101 9

60 105 45

16 64 23
CONCLUSIONS

• The statistical-deterministic approach is a good alternative to computationally expensive classical methods (e.g. dynamical downscaling of medicanes), with the extra benefit of producing statistically large populations of events.

• We attained unprecedented medicane-wind risk maps for the Mediterranean region.

• General agreement with the “known” phenomenology of medicanes in the current climate (e.g. maximum in the cold season and central Mediterranean) and between both methods.

• In spite of some geographical uncertainties, GCMs tend to project fewer medicanes at the end of the century compared to present but a higher number of violent storms, suggesting an increased probability of major economic and social impacts as the century progresses.