# Controlled Hurricane Weakening via Marine Cloud Brightening

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## Summary.

The basic idea is to cool ocean surface waters in regions in which the genesis and early development of hurricanes occurs. This would be achieved by seeding – with copious quantities of seawater cloud condensation nuclei (CCN) - low-level maritime stratocumulus clouds covering either these regions, or ones from which ocean currents flow to them. As a consequence, the cloud droplet number concentration within the clouds increases, thereby enhancing their reflectivity for incoming sunlight, and possibly their longevity. This approach is therefore a more localised application of the Marine Cloud Brightening global cooling technique (MCB). Herein, we demonstrate, by utilising the climate ocean / atmosphere coupled HadGEM1 model, that – subject to defined caveats - judicious seeding of maritime stratocumulus clouds could substantially reduce sea surface temperatures (SSTs) in oceanic regions where hurricanes often develop. Thus the seeding might reduce hurricane intensity. The extent to which the magnitude of this effect could be controlled is yet to be determined. Rough calculations based on observationally-based relationships between SST and maximum wind-speed together with the SST-reduction values emanating from our computations, suggest that cooling produced by MCB may be able to achieve a 1-category reduction of hurricane intensity, and prevent the formation of a significant number of hurricanes.

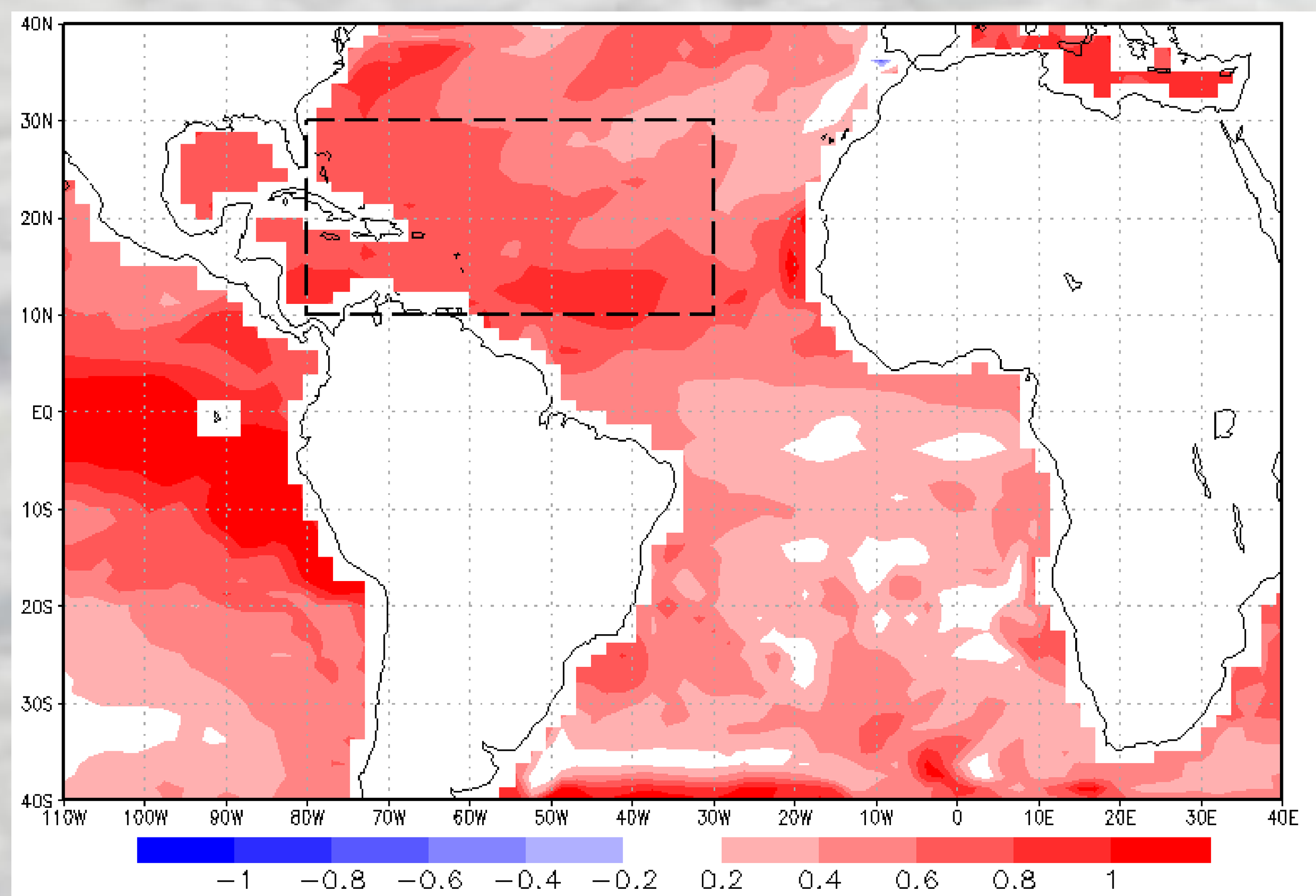


*Figure 1. Sea surface temperature (SST) differences (°C) between conditions 2xCO$_2$ and 1xCO$_2$, within an area bounded by latitudes 30 degrees North & 30 degrees S and longitudes 110 degrees West and 60 degrees East. There is no seeding. The inner, dashed rectangle defines the hurricane development region HDR. The average difference in SST (from Control) is 0.66°C in the HDR and 0.53°C globally.*

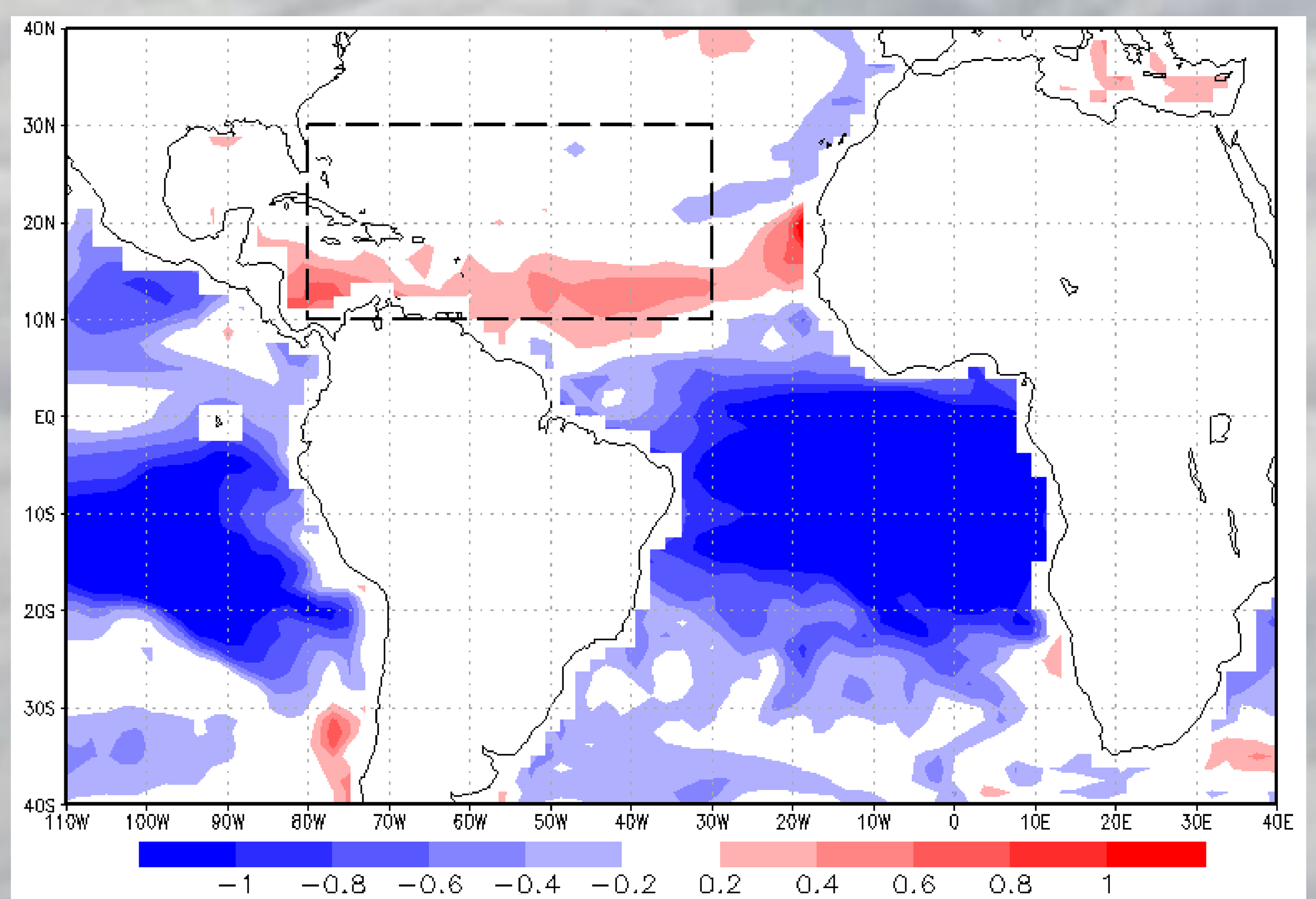


*Figure 2. SST differences between patchy seeding at 2xCO$_2$ and Control (1xCO$_2$, no seeding). The average difference in SST (from Control) is 0.13°C in the HDR and -0.11°C globally*

| Figure | $CO_2$ | Seed | HDR | Global |
|---|---|---|---|---|
| 1 | x2 | None | 0.66 | 0.53 |
| 2 | x2 | 3*Patch | 0.13 | -0.11 |
| 3 | x2 | Full | -4.00 | -5.04 |
| 4 | x1 | Full | -4.61 | -5.38 |

Table 1. Departures (°C) of average Sea Surface Temperature (SST) values from Control (no seeding, 1xCO$_2$) for the four figures (*Fig. 1-4* ) presented below. ***Seed*** is the type of seeding, ***HDR*** is the Hurricane Development Region (defined in the text), and the atmospheric CO$_2$ concentration is either the current value (Control) or twice the pre-industrial value.

## Results:

Each of the four figures presented below shows values of sea surface temperature (SST) differences (°C) between specified conditions within a geographical area bounded by latitudes 40° North & 40° South and longitudes 110° West & 40° East. The inner, dashed rectangle, present in all four figures, defines the Hurricane Development Region [HDR] chosen for the present study, since highly energetic and damaging hurricanes commonly develop in or around this region of the Tropical North Atlantic, to the East of the Gulf of Mexico in a box 10 - 30° North, and 30 - 80° West. Some previous work shows that the region between 10 – 40° North, and 30 - 100° West is prone to an increase in the frequency of high intensity hurricanes [(1)]. Other work suggests that hurricanes develop within the bounds of 10-20 degrees North and 30 – 45° West [(2)]. The HDR covers a large portion of both of these regions. If the sea surface temperature within this region is cooled by our proposed cloud seeding below about 26°C, hurricanes may not form. Figures 1-4 show the SST differences compared with the "Control" , current day values, for a double CO2 scenario, a 3 patch seeding for a double CO2 scenario, a full seeding scenario and full seeding for the current CO2 levels.

## Discussion:

The modelling results indicate that the sea-surface temperature in regions where hurricanes develop could be significantly reduced by such cloud seeding, thereby raising the possibility of appreciably weakening hurricane development, thus lessening the damage that hurricanes wreak. The magnitude of the cooling produced in relevant oceanic regions is dependent on the fraction of suitable cloud cover seeded, and the location and amount of the seeding, all of which could be controlled to a significant extent. The "patchy" seeding, which involves the three oceanic regions of most persistent stratocumulus cloud coverage, which have been employed in several GCM studies of marine cloud brightening [(3,4,5)], is found (see previous section) to produce an SST reduction which roughly compensates for the warming resulting from CO$_2$-doubling. Seeding all suitable clouds produces major over-compensation.

## References:

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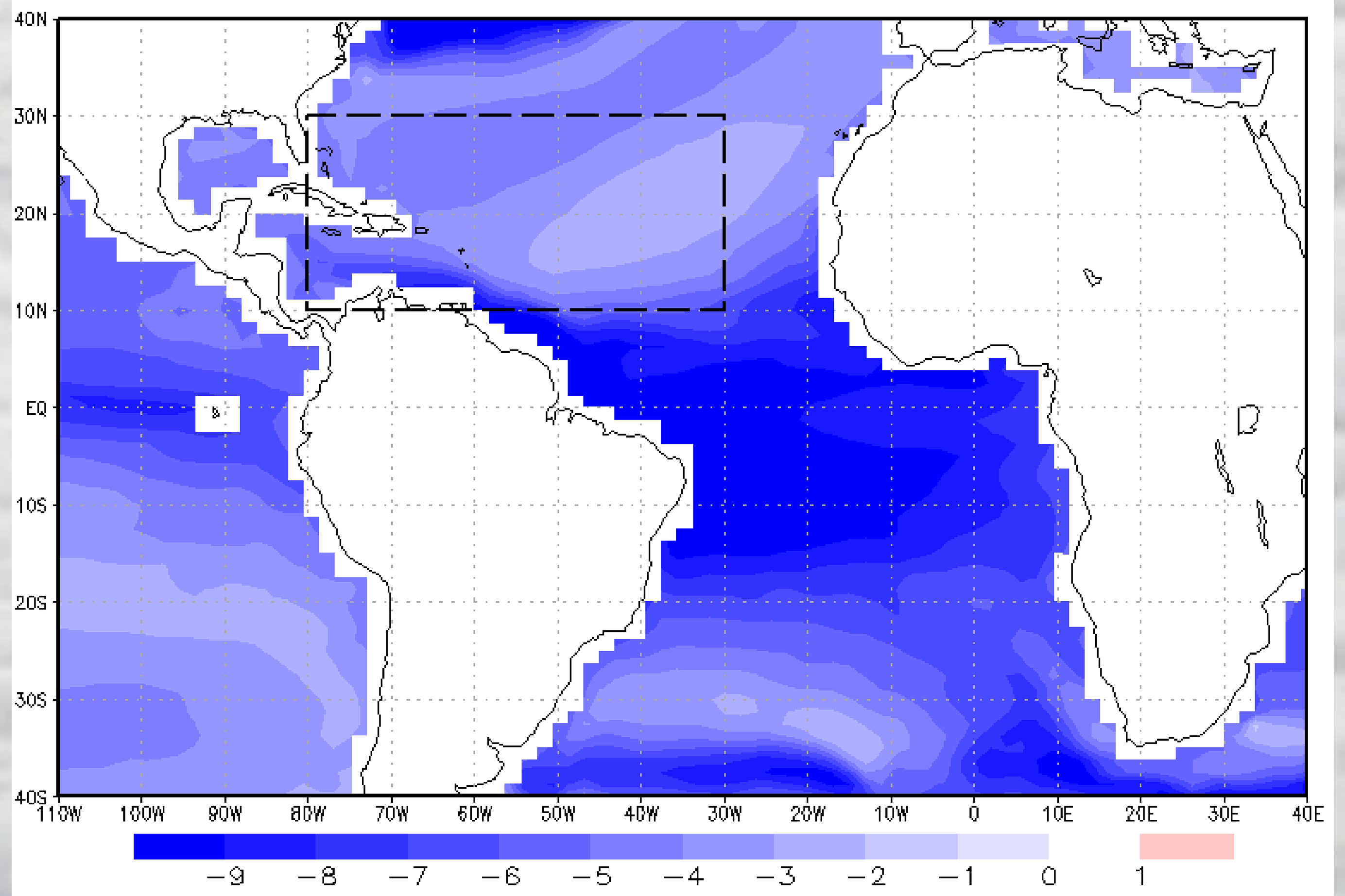


*Figure 3. SST differences between full seeding at 2xCO$_2$ and Control (1xCO$_2$, no seeding). The average difference in SST (from Control) is -4.0°C in the HDR and -5.04°C globally*

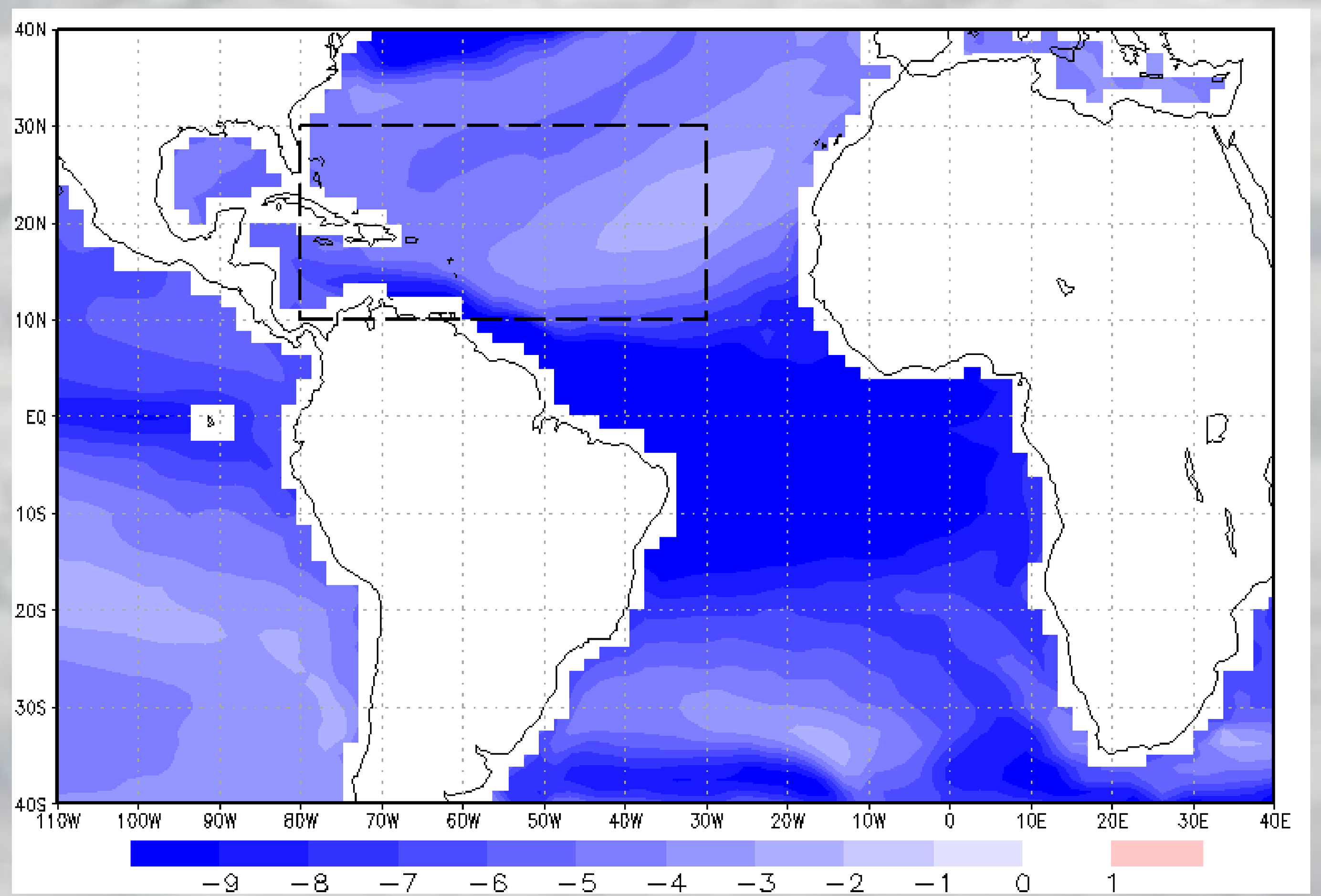


*Figure 4. SST differences between full seeding at 1xCO$_2$ and Control (1xCO$_2$, no seeding). The average reduction in SST produced by seeding is -4.6°C in the HDR and -5.38°C globally*

## Acknowledgements.

This work made use of the facilities of HECToR, the UK's national high-performance computing service, which is provided by NCAS / NERC supercomputing facility. Support for elements of this research was provided by the Fund for Innovative Climate and Energy Research, FICER, at the University of Calgary. This does not constitute endorsement of deployment in any form of Cloud Albedo Modification by the funding agency