P2B.5

APPLIED RESEARCH STUDIES IN PROGRESS AT RSMC LA REUNION -1- MICROWAVE IMAGERY DATABASE RELATED TO TROPICAL CYCLONES -2- ESTIMATION OF TROPICAL CYCLONE GENESIS PROBABILITY OVER THE SOUTH-WEST INDIAN OCEAN WITH ECMWF ENSEMBLE PREDICTION FORECAST

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1. A TC-RELATED MICROWAVE IMAGERY DATABASE AIMING TO ASSESS THE POTENTIAL FOR IMPROVING REMOTELY BASED INTENSITY ANALYSIS TECHNIQUES.

Introduction

The Dvorak Technique is currently the most universally used tool to estimate tropical cyclones intensity. It is based on manual or digital treatment of EIR and VIS imagery. Since the advent of the microwave instruments, new data and products are available and have demonstrated being of major interest in tropical cyclone monitoring, showing in particular clear value for intensity changes depiction.

In order to supplement the Dvorak Technique in its visual concept, the project is to try and include more formally the valuable information provided by the microwave imagery in this technique.

Data and methodology

To deal with this project, objective comparison between TC intensities provided by "*in situ"* observations and microwave imagery was required.

The most reliable *in situ* observations available come from aircraft reconnaissance flights ("recon") conducted by the 53rd Weather Reconnaissance Squadron of the air Force Reserve Command and by the National Oceanic and Atmospheric Administration (NOAA) Aircraft Operations center on the northern Atlantic. This is the reason why this study focuses on this basin, the only basin on which aircraft reconnaissance flights are still routinely operated. The microwave imagery from DMSP/SSMI, TRMM/TMI, NOAA/AMSU, AQUA/AMSRE, Coriolis/Windsat satellites imagers is available on the Naval Research Laboratory website. 85 (89 and 91) GHz imagery was first used as this "upper level" channel is available since 1997, and shows brightness temperature range, allowing deep convection brightness temperature comparison. Comparison between this imagery and the corresponding closest "recon" led to insufficient samples and pointed at some problems: storm past intensity was not considered, and the imagers have not the same brightness temperature scales nor the same spatial resolutions. Therefore, no configuration related to a specific intensity could emerge. The need for including "low-level" information was also identified.

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To overcome these problems, a database was built, gathering more than 2000 cases and more than 6500 images taking into account the different available channels (the aforementioned "upper level" ones plus "lower level" channels – at 36 or 37 GHz, depending on the imager) and associated products.

The intensities of reference to which the images are compared with, are extracted form different sources. One is the air flight reconnaissance data (RECON) taken from "vortex" messages. Another comes from the tropical cyclones best-track database HURDAT maintained by the National Hurricane Center (NHC), whose intensities rely mostly on air recon data. Dvorak current intensity numbers, "Ci", are derived from HURDAT through a correspondence to a range of maximum winds. This intended choice is justified by the systematic use of Dvorak intensities in the basins where no aircraft reconnaissance flights are conducted.

On a similar approach, AODT data (Advanced Objective Dvorak Technique) from the Cooperative Institute for Meteorological Satellite Studies (CIMSS) have been incorporated in this microwave database as T and Ci Dvorak numbers are directly available.

Comparisons between microwave images and intensities can be therefore conducted thanks to HURDAT, RECON and AODT. The database allows the user to choose between weakening or deepening systems, to set the rate of intensification/deepening, and to decide which imagers and which channels to work with. Regarding the weakening systems, a 12h-time lag is applied between "T" and "Ci". The search of matching images can be done within a 3-hours interval.

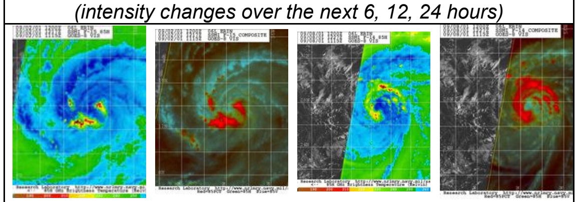
First results

Microwave imagery can actually display very different patterns for the same intensity. The primary interest of the microwave imagery is then to give clues for intensity changes.

The following results are related to deepening systems. Currently available samples do not allow to illustrate every single Dvorak intensity.

For a given T-Dvorak number, a few cases are shown to illustrate the microwave patterns leading either to an effective intensification or to stationary intensity cases or limited intensification instances.

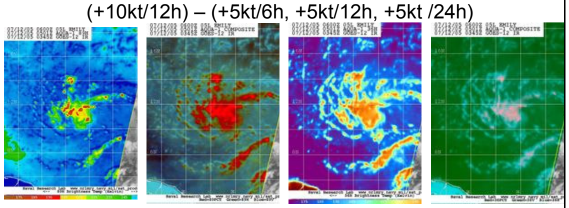
T3.0 / 45kt	
Dvorak Number / Vmax (1 min sustained winds)	
(+15kt/12h) (+0kt/6h, +0kt/12h,+5kt/24h)	(+10kt/12h) (+15kt/6h, 30kt/12h,50kt/24h)
(Intensification over the last 12 hours) *(intensity changes over the next 6, 12, 24 hours)*	



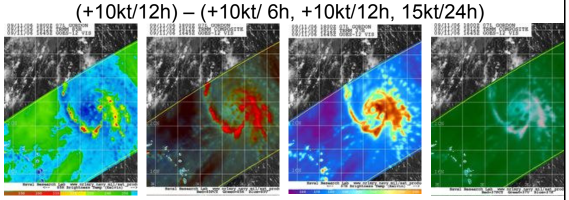
Concerning these cases, only "upper level" channel and associated product are available. For a similar past intensification, deep convection shows better organization on the right figures, with a curved band or hook shape pattern, compared to the disorganized patchwork of scattered deep convection on the left.

T3.0 / 40kt

(+10kt/12h) – (+5kt/6h, +5kt/12h, +5kt /24h)



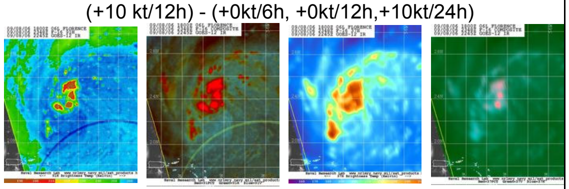
(+10kt/12h) – (+10kt/ 6h, +10kt/12h, 15kt/24h)



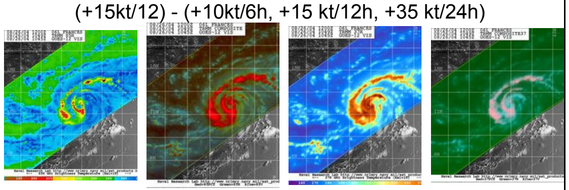
When "low level" channels show a well-depicted Low Level Circulation Center (LLCC), generally associated to the formation of a rain-free area or eye-like feature still indistinguishable on the "upper level" channels at this stage, this is generally a harbinger sign of rapid or faster intensification to occur.

T3.5/50-55kt

(+10 kt/12h) - (+0kt/6h, +0kt/12h,+10kt/24h)



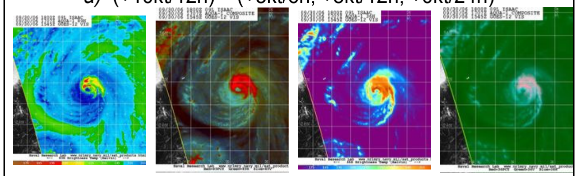
(+15kt/12) - (+10kt/6h, +15 kt/12h, +35 kt/24h)



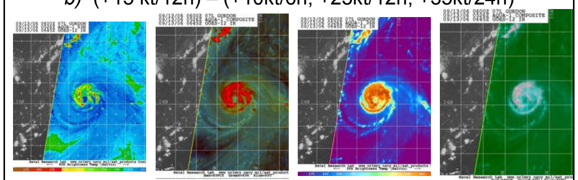
Curved band pattern versus "dotted" convection: sign of rapid intensification.

T4.0 / 70 kt

a) (+10kt/12h) – (+5kt/6h, +5kt/12h, +0kt/24h)



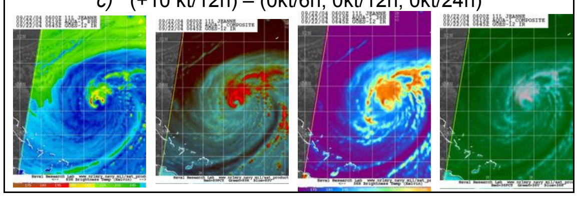
b) (+15 kt/12h) – (+10kt/6h, +25kt/12h, +35kt/24h)



The upper case (a) – and the T 5.0 case below (c) – show a typical sign of an intensification phase on the verge of being leveled off through increased ventilation: at low and high levels, the "eye" appears eroded or opened upshear. Opposite situation corresponds to an "eye" showing a closing in trend (above, b).

T5.0 / 85kt

c) (+10 kt/12h) – (0kt/6h, 0kt/12h, 0kt/24h)



Imagery source: NRL Monterey
Legend: Dvorak Number/Vmax (1 min sustained winds) (Intensification over the last 12 hours) – (intensity changes over the next 6, 12, 24 hours).

Conclusion and future work

The primary interest of the microwave imagery is to give clues for intensity changes – deepening or weakening – at short range.

Some further investigation has to be done for "eyewall replacement cycle" cases and weakening stages. Database has to be completed with 2007 season data in order to increase the sampling.
ADOT data will also be utilized to compare with the imagery.

Aknowledgements

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2. ESTIMATION OF TROPICAL CYCLONE GENESIS PROBABILITY OVER THE SOUTH-WEST INDIAN OCEAN WITH ECMWF ENSEMBLE PREDICTION FORECAST

The operational and daily issue of 72-hour range tropical cyclone outlooks require model-based objective information providing guidance about 'suspect areas' and able to discriminate between “developing” and “non developing” convective areas. Despite recent improvements, the current operational forecast models do not always 'react' pertinently to tropical cyclogenesis. The ECMWF ensemble prediction forecast is based on 50 perturbed analyses that influence both the physics and the dynamics of the model ; this leads to a large spectrum of “solutions” and to probabilistic information. In this project, the goal is to build a composite, operational and objective estimation of the cyclogenesis potential based on the ECMWF ensemble prediction forecast, *i.e.* to give prominence to the areas where the dynamic, thermodynamic and energetic conditions are deemed favorable for a tropical cyclogenesis by the model.

A basic approach of this issue brings to the fore 4 (model) parameters : the 850 hPa vorticity, the CAPE index, the 700 hPa relative humidity (to confirm the water vapor content), and the DGP (Daily Genesis Parameter) defined as ζ_{850}-ζ_{200}, to impose a vertical structure within the environment associated with low-level cyclonic and upper-level anticyclonic circulations. From a detailed analysis of the ECMWF ensemble prediction forecast 'reaction' to the 2004/2005 cyclone season cyclogeneses characteristic thresholds for each of the 4 parameters were extracted. To sum up, these 4 parameters and their associated thresholds define the ECMWF typical model features associated with a standard ‘average’ cyclogenesis.

ζ_{850hPa}	8.10^{-5} s^{-1}
CAPE	1400 J/kg
HU_{700hPa}	85%
DGP	8.10^{-5} s^{-1}

TABLE 1. Characteristic thresholds based on the 2004/2005 cyclone season cyclogeneses over the Southwest Indian Ocean

The operational composite tropical cyclone genesis probability is computed by mixing the 4 parameters : over a specific grid point, the genesis index represents the probability that the 4 parameters exceed simultaneously their respective threshold within a 4 degrees latitude square centered on this point.
This tropical cyclone genesis probability was then tested by the operational RSMC La Réunion tropical cyclone forecasters during the 2006/2007 cyclone season. An objective control based on the 35 cyclogeneses confirms the skill of the index for cyclogenesis detection: the forecast probability is about 80% from 24-hour to 72-hour range, and remains above 50% up to 168-hour range.
The CAPE index, confirmed as a prominent parameter, sometimes leads to a reduction of the detection skill when underestimated or misplaced by the model. Besides, still considering the 2006/2007 cyclone season over the southwestern Indian Ocean, the 'false alarm' rate is about 30% from tau 24 to tau 120hr.

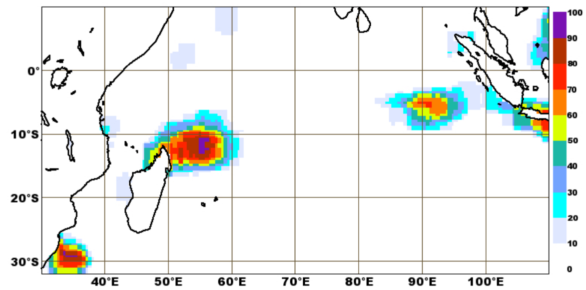

FIG. 1. Déc. 30 2006, « CLOVIS » cyclogenesis (12.5°S/56.0°E). Tropical cyclone genesis probability forecast based on Dec. 28, 2006 ECMWF ensemble prediction forecast, tau 48.

This tropical cyclone genesis probability, based on 4 basic predictors derived from the ECMWF ensemble prediction forecast, highlights the areas potentially favorable for cyclogenesis with a good detection skill up to 120-hour range; this signal often appears before a significant model predicted mean sea level pressure deepening. This encouraging ‘start’ is to be confirmed and improved: the perspectives include integration of more pertinent parameters (such as an integrated relative humidity), systematic adjustment of the thresholds... Besides, taking account of limiting factors such as the vertical wind shear should reduce the 'false alarm' rate and improve the discrimination between “developing” and “non developing” tropical cyclones.

Aknowledgements
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