TROPICAL CYCLONE INTENSITY ESTIMATION USING TEMPORAL ANALYSIS AND SPATIAL FEATURES IN SATELLITE DATA

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Abstract

- Developing new automated techniques to estimate the TC intensity and to overcome the existing errors in estimation is still a challenge
- We have developed and tested an automated method to estimate TC intensity based on the existing historical data.
- The intensity estimation algorithm has two parts: temporal analysis and image feature analysis.
- The focus of this study is on the temporal analysis.
- Temporal information provides a priori estimates of TC intensity before using any satellite analysis.
- It uses the age of the cyclone, 6, 12 and 24 hours prior intensities as predictors of the expected intensity.
- Several tests are implemented to statistically validate the proposed algorithm using k-Fold Cross-Validation.
- The proposed technique has an average improvement in *Mean Absolute Error* (MAE) intensity estimation of 55% compared to Dvorak technique.

Goal/Motivation

- Tropical cyclones (TCs) are a significant threat to life and property.
- Hypothesize that discovering unknown regularities and abnormalities that may exist in the large group of past observations could help human experts interpret TC intensity changes from various points of view.
- Provide a data mining tool that increases the ability of human experts to analyze huge amount of historical data for TC intensity estimation.

Introduction

- Estimating tropical cyclone intensity (INT) from:

$$INT = f(g(x,y),t)$$

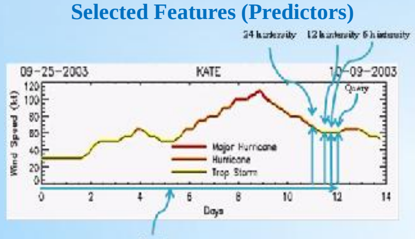
- In this mapping, the spatial interpretation of satellite imagery (g) is constrained in time (t) by some function, f.
- This is similar to Dvorak intensity estimation, where T-numbers are constrained in time to estimate current intensity (CI).
- The primary focus of this poster is on the temporal constraint function, f.

Temporal Estimation

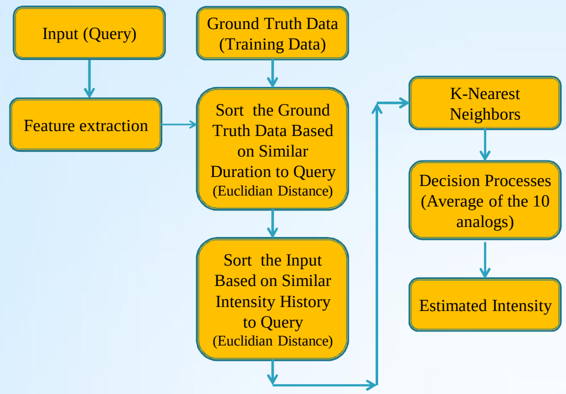
- TC intensity may describe as a function of the prior *maximum sustained wind* (MSW) speed.

$$INT = f\,(MSW_{t-6}, MSW_{t-12}, MSW_{t-24}, AGE)$$

Selected Features (Predictors)



Procedure

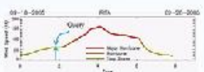


North Atlantic HURSAT-B1 used as Database

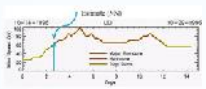
Product	Hursat-B1	HURSAT-AVHRR	HURSAT-MW	GridSat
Temporal span	1978 - 2009	1978 - 2009	1988 - 2009	1979 - 2009
Spatial span	Storm-centric: 10.5° from center for all global TCs	Storm - centric: 10.5° from storm for all global TCs	Storm-centric: 10.5° from center for all global TCs	Global
Temporal resolution	3 hourly	Varying (6-12 hourly)	Varying (6-12 hourly)	3 hourly
Gridding resolution	8km	4km	8km	8km
Data source	ISCCP B1	AVHRR GAC	DMSP SSM/I	ISCCP B1
Channels available	IRWIN (11μm) IRWVP (6.7μm) (0.65μm)	All AVHRR channels	All SSM/I channels	IRWIN(11μm) IRWVP(6.7μm) (0.65μm)
Calibration	Clim. – IRWIN, ISCCP - IRWVP,	Climate calibrated	Operational calibration	Clim. – IRWIN, ISCCP–IRWVP,
Yearly size (GB)	< 6.5	40-60	4	200
Format	NetCDF	NetCDF	NetCDF	NetCDF
Current version	4.0	Beta	Beta	Beta
Imagery	Movies	BD Imagery	Imagery	Planned

Detailed specification of HURSAT data (Knapp and Kossin 2007)

Example



Query entry selected from Rita storm (2005)



Nearest neighbor from Lili storm (1996)

Distribution of Ground truth data and Query data for first test

Classified Ground truth data from North Atlantic storms (1978-1996 & 2004 – 2006 storms)

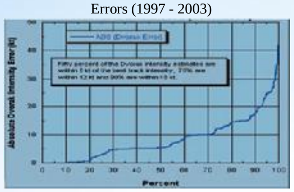
Class	T1	T1.5	T2	T2.5	T3	T3.5	T4	T4.5	T5	T5.5	T6	T6.5	T7	T7.5	T8
Total	1759	16	1854	1323	2474	1739	1530	1043	964	343	363	203	105	49	6

Classified Query data from North Atlantic storms 1997 – 2003 storms

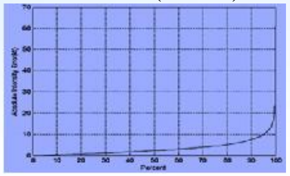
Class	T1	T1.5	T2	T2.5	T3	T3.5	T4	T4.5	T5	T5.5	T6	T6.5	T7	T7.5	T8
Total	649	5	652	606	951	788	632	398	420	172	196	82	57	11	0

Distribution of the classification errors

Distribution of Dvorak classification Errors (1997 - 2003)



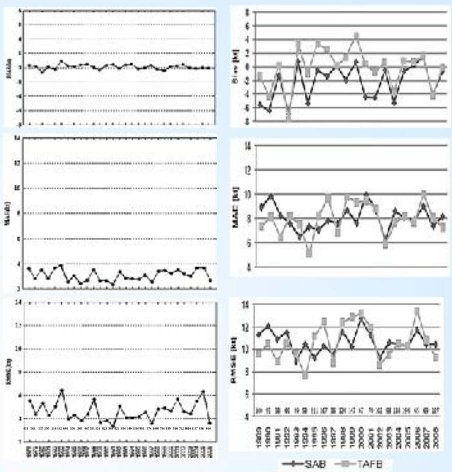
Distribution of proposed technique classification errors (1997 - 2003)



Results	50%	75%	90%
DVT	5kt	12kt	18kt
Proposed	2.4kt	4.4kt	7.5kt
Percent Improvement	52%	63.3%	58.3%

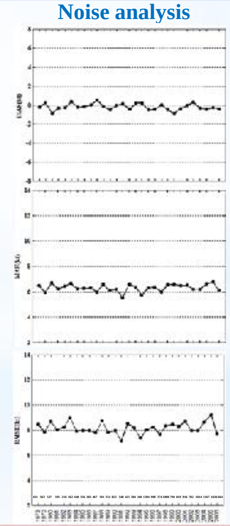
Inter-annual statistics

Proposed technique results / Dvorak results (Knaff et al. 2010)



- Mean Bias values of the proposed technique are almost zero.
- For DT the Bias values changes from -8 to 4 kt.
- MAEs and RMSEs of DT are with mean values of approximately 8 and 11 kt respectively.
- MAEs and RMSEs of proposed technique are with mean values of approximately 3 and 5 kt respectively.

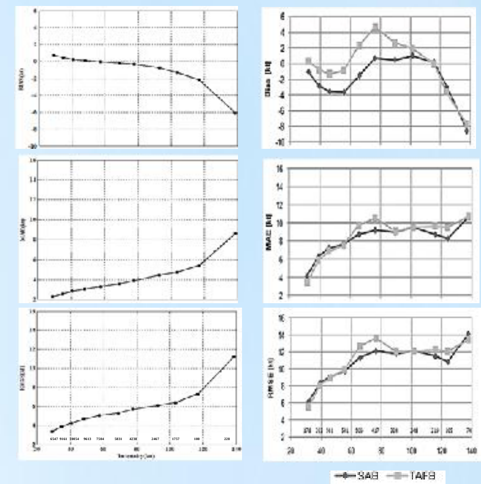
Noise analysis



- Noise with a Gaussian distribution having a zero mean with 5 knot and 6 hour standard deviations for prior intensities and duration, respectively.
- The biases are not changed.
- With added noise, the average RMSE of the proposed technique is around 8.2 kt which is still less than Dvorak error of 11.7 kt.

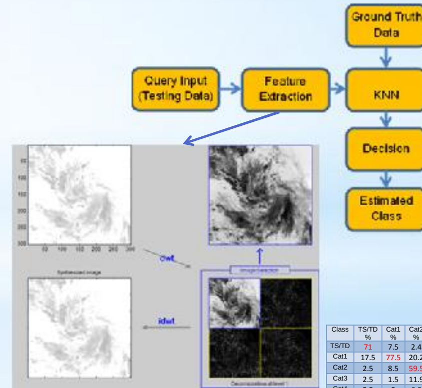
Biases and errors as a function of intensity

Proposed technique results / Dvorak results (Knaff et al. 2010)



- The biases show that the DT underestimates intensities when TCs have intensities between 35 and 55 kt and greater than 125 kt.
- DT overestimation of intensities occurs between 75 and 105 kt.
- For the proposed technique the underestimates occur especially for intensities greater than 115 kt.
- The MAEs and RMSEs are lower for weak storms and larger for the higher intensities which are similar for both techniques

Preliminary Spatial Analysis



Sample Discrete Wavelet transform of a satellite image, the approximation component is selected.

Category	Wind speed (mph)
Five	>= 156
Four	131-155
Three	111-130
Two	96-110
One	74-95

Saffir-Simpson Hurricane scale

Class	TS/TD	1	2	3	4	5
Ground truth	800	800	336	291	244	60
Testing	200	200	84	73	61	15
Total	1000	1000	420	364	305	75

Number of training and testing images from Northern Atlantic storms 1995 – 2005

Confusion Matrices

Class	TS/TD %	Cat1 %	Cat2 %	Cat3 %	Cat4 %	Cat5 %
TS/TD	71	7.5	2.4	0	0	0
Cat1	17.5	77.5	20.2	6.8	3.3	0
Cat2	2.5	8.5	59.5	13.7	0	0
Cat3	2.5	1.5	11.9	64.4	9.8	0
Cat4	5.5	5	6.0	15.1	83.6	33.3
Cat5	1	0	0	0	3.3	66.7

Average accuracy is71%

Class	TS/TD	C1/C2	C3
TS/TD	71%	6%	0%
C1/C2	20%	84%	11%
C3(Cat3, 4,5)	9%	10%	89%

Average accuracy is 81.3%

Conclusion/Future work

- The proposed technique has a great potential to provide new temporal constraints on satellite analyses (e.g., the Dvorak technique). The current analysis has the ability to decrease the Dvorak error from 11.7 kt to nearer the current temporal estimate of 8.2 kt, as an upper limit. It shows improvement between 30% to 55%.
- We will fuse temporal analysis with satellite image analysis for more accurate TC intensity estimation.

References

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