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5200 Auth Road Room 207
Camp Springs, MD 20746

Technical Note

MMAB Marine Hazard Summary Product[†].

Robert Grumbine [‡]
Environmental Modeling Center
Marine Modeling and Analysis Branch

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[†] MMAB Contribution No. 275.
[‡] e-mail: Robert.Grumbine@NOAA.gov

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1 Abstract

The Ocean Prediction Center used to produce a grahical summary product for marine hazards [Burroughts 1988, Burroughs 1995]. It is unclear when this was discontinued, but likely with the progress of the AWIPS era [Feit, personal communication 2008]. As models reach ever-higher resolutions in both time and space, there is again a use for a summary product, now digital, which will provide a quick look through time at areas which might be expected to have hazardous conditions. Users may then retrieve more complete model output for those hazards and areas which they are interested in.

2 The hazard product

The Marine Modeling and Analysis Branch (MMAB) of the Environmental Modeling Center (EMC) produces a number of global model guidance and analysis products of marine interest, including wave conditions [Tolman, 1991; Tolman et al., 2002], ocean visibility [Burroughs, 2004], vessel icing [Burroughs, 2004], and sea ice cover [Grumbine, 1996]. The EMC also provides guidance for global wind conditions [GCWMB, 2003 et seq.]. Retrieving full output of all of these is a matter of over a gigabyte to cover the 7 days of their forecasts (sea ice is currently an analysis only, persisted in this product to 7 days).

The marine hazard summary provides a more compact, single, file, 1.7 Mb compressed, 67 Mb uncompressed, for forecasters and other users to get a quick look at whether there are hazardous conditions in their area of interest, at what times, which hazard(s) may be involved, and how severe the condition may be. It could also be used to make ensemble-based estimates of the probabilities of hazards occurring. The hazards are coded into a 2 byte integer, and can then be read back. On some systems, including Pentium-based Linux, it will be necessary to first run dd conv=swab on the files. The grid is 1/3rd degree latitude-longitude spacing, global, with fields every 3 hours to 7 days (168 hours). It is currently constructed only 1 time per day, for the 00 UTC cycle, though this could easily be made 4 times per day. A sample program to interrogate the grids, interrog.C, is provided along with the output grids, on the experimental server at ftp://polar.ncep.noaa.gov/pub/hazards/ Figure 1 gives a sample of the current summary output. Table 1: Hazard Levels and Their Flags

Parameter	Flag Name	Flag Value	Flag Level
sea ice	ICEFLAG	1	15% concentration
vessel icing	LOW_ICING	2	0.1 inches per 3 hours
vessel icing	MED_ICING	4	0.8 inches per 3 hours
vessel icing	HIGH_ICING	8	2.4 inches per 3 hours
wind	GALE	16	34 knots
wind	STORM	32	48 knots
wind	HURRICANE	64	64 knots
visibility	LOW_VIS	128	3.0 nautical miles
visibility	POOR_VIS	256	1.0 nautical miles
visibility	HAZARD_VIS	512	0.5 nautical miles
waves	SMALLWAVE_ADV	1024	2.5 meters
waves	MEDWAVE_ADV	2048	4.0 meters
waves	HIGHWAVE_ADV	4096	6.0 meters

The flags are set sequentially, such that a wave height of 10 meters would turn on all three advisories, giving a sum of 7168. If it were also under hurricane force winds, 112 would be added. And so on. Users unconcerned about medium or less waves need only test the 12th bit to see whether it is turned on. More generally, they may add the flag values for all hazards they are concerned with and perform a bitwise logical AND to see whether (and when, and where) their hazards of concern are occurring. The interrogate program takes that sum as an argument and returns grids flagged for whether there are hazards present.

Since the fields are encoded into a 2 byte integer and only 13 bits are currently used, there is room for an additional 3 hazards, or hazard levels, without requiring reprogramming.

3 Characterizing the output

The archive of output for this field is short, but does include a full seasonal cycle, 25 January 2008 to 5 Feburary 2009. Though this is insufficient to establish a climatology, it does provide insight to seasonality. The two aspects summarized are the area under each flag, and the colocation of hazards. As only the winds have an internationally established progression of hazard levels [Joe Sienkiewicz, personal communication 2005], we could consider adjusting the warning levels so that there is a progression of areas flagged, say 10%, 3%, 1%, for low, medium, high levels. Significant wave heights in the previous significant weather summary were at every 8 feet starting at 8 feet [Burroughts, 1989], for instance. As more than one hazard may exist in the same area, the sum of areas flagged may exceed the area of the ocean, and certainly exceeds the area of hazardous conditions.

3.1 Area flagged

Figures 2-5 shows the areas which are flagged for different hazards. Figure 2 shows low (2.5 meters, 8 feet) and medium (4.0, 13 feet), and high (6.0 meters, 20 feet) wave height hazards. Figure 3 shows the sea ice coverage, and reduced (3 nautical miles or less) visibility. Figure 4 shows moderately and highly reduced visibility (1.0 and 0.5 nautical miles or less, respectively), low vessel icing rates, and gale force (34 kts) winds. Finally, figure 5 shows the areas of medium (0.8 inches per 3 hours) and high (2.4 inches per 3 hours) vessel icing rates, storm force (48 kts) winds, and hurricane force (64 kts) winds. Each figure shows progressively less area affected by the given conditions.

In terms of conditions exceeding the minimum or maximum hazard level, both criteria show the progression of most to least area affected being waves, sea ice, visibility, vessel icing, and winds. All parameters are flagged when outside the model's domain (for non-global models, such as the waves) or on what the model considers to be land. The area of waves above warning levels is 15-20 million km^2 too large compared to the real ocean because all areas north of 78 N are flagged for high waves because the zone is outside the model domain. In nature, the sea ice pack will likely suppress waves to below the warning levels.

3.2 Colocation of hazards

Colocation is taken to be the fraction of area of flag i which is also flagged for j (a conditional probability). This is not a symmetric matrix as, for example, all high wave conditions will also have medium wave conditions, but the converse is not true. Table 2 gives the conditional probabilities. The rows give the condition that is true; sea ice being present is the first row. The columns show the fraction of the area with that condition which also has the second condition. Row 1 column 2 shows us that only 7% of the area with sea ice also has low vessel icing rates.

Table 2: Probability that warning condition and level in the column occurs in the same place as the warning condition and level in the row.

Parameter	Sea ice	Icing			Winds		
Sea Ice	1.00	0.05	0.02	0.01	0.01	0.00	0.00
Low Icing	0.23	1.00	0.36	0.12	0.01	0.00	0.00
Med Icing	0.28	1.00	1.00	0.32	0.01	0.00	0.00
High Icing	0.36	1.00	1.00	1.00	0.01	0.00	0.00
Gale	0.08	0.02	0.01	0.00	1.00	0.02	0.00
Storm	0.18	0.04	0.01	0.00	1.00	1.00	0.00
Hurricane	0.39	0.01	0.00	0.00	1.00	1.00	1.00
Low Red. Vis.	0.01	0.00	0.00	0.00	0.02	0.00	0.00
Med Red. Vis.	0.00	0.00	0.00	0.00	0.02	0.00	0.00
High Red. Vis.	0.00	0.03	0.00	0.00	0.02	0.00	0.00
Low Wave	0.10	0.02	0.01	0.00	0.01	0.00	0.00
Med Wave	0.18	0.02	0.01	0.00	0.01	0.00	0.00
High Wave	0.39	0.03	0.01	0.00	0.01	0.00	0.00

Parameter	Red.	Vis.		Waves		
Sea Ice	0.01	0.00	0.00	0.76	0.75	0.75
Low Icing	0.01	0.00	0.00	0.72	0.50	0.27
Med Icing	0.00	0.00	0.00	0.75	0.53	0.30
High Icing	0.01	0.00	0.00	0.78	0.57	0.33
Gale	0.10	0.06	0.05	0.60	0.34	0.16
Storm	0.12	0.06	0.04	0.63	0.41	0.25
Hurricane	0.19	0.10	0.08	0.81	0.53	0.33
Low Red. Vis.	1.00	0.57	0.46	0.79	0.45	0.06
Med Red. Vis.	1.00	1.00	0.80	0.81	0.46	0.05
High Red. Vis.	1.00	1.00	1.00	0.83	0.47	0.05
Low Wave	0.05	0.03	0.02	1.00	0.52	0.24
Med Wave	0.05	0.03	0.03	1.00	1.00	0.46
High Wave	0.02	0.01	0.01	1.00	1.00	1.00

Let us first examine the flags within a parameter. For ocean waves, 52% of the area which has low waves has medium waves. 46% of the area that has medium waves has high waves. For vessel icing, the respective figures are 36% and 32%. In reduced visibility, the progression is 57% and 80%. This seems like the flag levels aren't very helful. If we have medium level visibility reduction, we very likely have high level reduction. For that matter, if we have at least low level visibility reduction, almost half the time (46%) we have highly reduced visibility. In a future version of the summary, we might want to either change the level definitions, or reduce to only 2 flags. For winds, very little of the area with gale force winds reach storm force, 2%. And less than 0.5% of the area with storm force reach hurricane force. It might also signal that the model under-predicts the areas of such high winds. Only 19 days of the 378 examined had any area of hurricane speed winds, and the maximum area (globally) was only $6.03 * 10^4$ km^2. Again, for a model-based product, we might want to reconsider the levels shown and their progression.

The current graphic simply shows the highest warning level in any given grid point due to any parameter. There is no distinction between the different parameters. Consideration of the degrees to which warning levels are colocated suggests that a fairly simple method may suffice to distinguish the different parameters.

Sea ice and high waves (the table notwithstanding) are geographically distinct. They are also (figures 2-5) the parameters which cause the greatest areas of warnings. Visibility has the next highest area. We see that less than 3% of the area of reduced visibility occurs in areas with sea ice, vessel icing, or high winds. Conversely, reduced visibility accounts for less than about 10% the area of any other warning. Reduced visibility is very likely to occur in areas of at least warning levels of wave heights, but it is 5% or less of the area of the wave warnings. This suggests that we could simply replace wave warning indicators with visibility warnings. The domain of the wave warning should be simply inferrable from the pattern established by the 90+% of the area which hasn't been modified by the second flag.

Similarly, vessel icing occurs in little of the area which is occupied by any other warning, and accounts for little of the area of those other warnings. Except, again, that a significant fraction of the icing warnings are in areas of high waves. Similarly for high winds.

So a method for display of the hazard type can be a 'painter's algorithm' of first painting in the waves warnings, then sea ice, visiblity, vessel icing, and finally winds, each in their own distinctive pattern or color.

4 Conclusions

This hazard summary was a simple effort at constructing a field to display marine hazard levels. As simple as it is, the animations and quantitative grids nevertheless provide insight to conditions and areas of concern. We might, for instance, want to re-examine hazard levels for some parameters, or to re-investigate the performance of the Global Forecast System for high wind conditions.

There are a number of simple improvements which can be made to the product and its display at this point:

- run for each model cycle (the models run 4 times a day, but the summary is done only once)
- display different hazards in different colors
- use improved graphics which display the valid time on each frame
- add a user comment form to the display and move to the experimental side of the MMAB web site
- construct a file which concatenates all the inputs to the hazard product, for users who wish to use their own levels
- add the wave steepness hazard

Less simple, but valuable:

- reconsider the warning levels with the MMAB, Ocean Prediction Center, and USCG Search and rescue
- make higher resolution but more limited area summary grids as well
- establish a Java applet to let users set their own limits interactively on the web page
- add a hazard representing winds which are against ocean current directions
- construct probabilities of exceeding warning levels using ensemble models where available
- transition to operational usage with the Ocean Prediction Center using this field as an automated first guess and then editing to a public summary graphic using NAWIPS software.

5 Acknowledgements

My thanks to Joe Sienkiewicz for review of the paper and discussion of the Wave, Freezing Spray, Visibility, and wind speed criteria, Hendrik Tolman for waves, Lawrence Burroughs for Freezing Spray and Visibility. And David Feit for discussion of the history of the earlier hazard summary. Helpful comments on the resulting product from Arthur Allen of the USCG.

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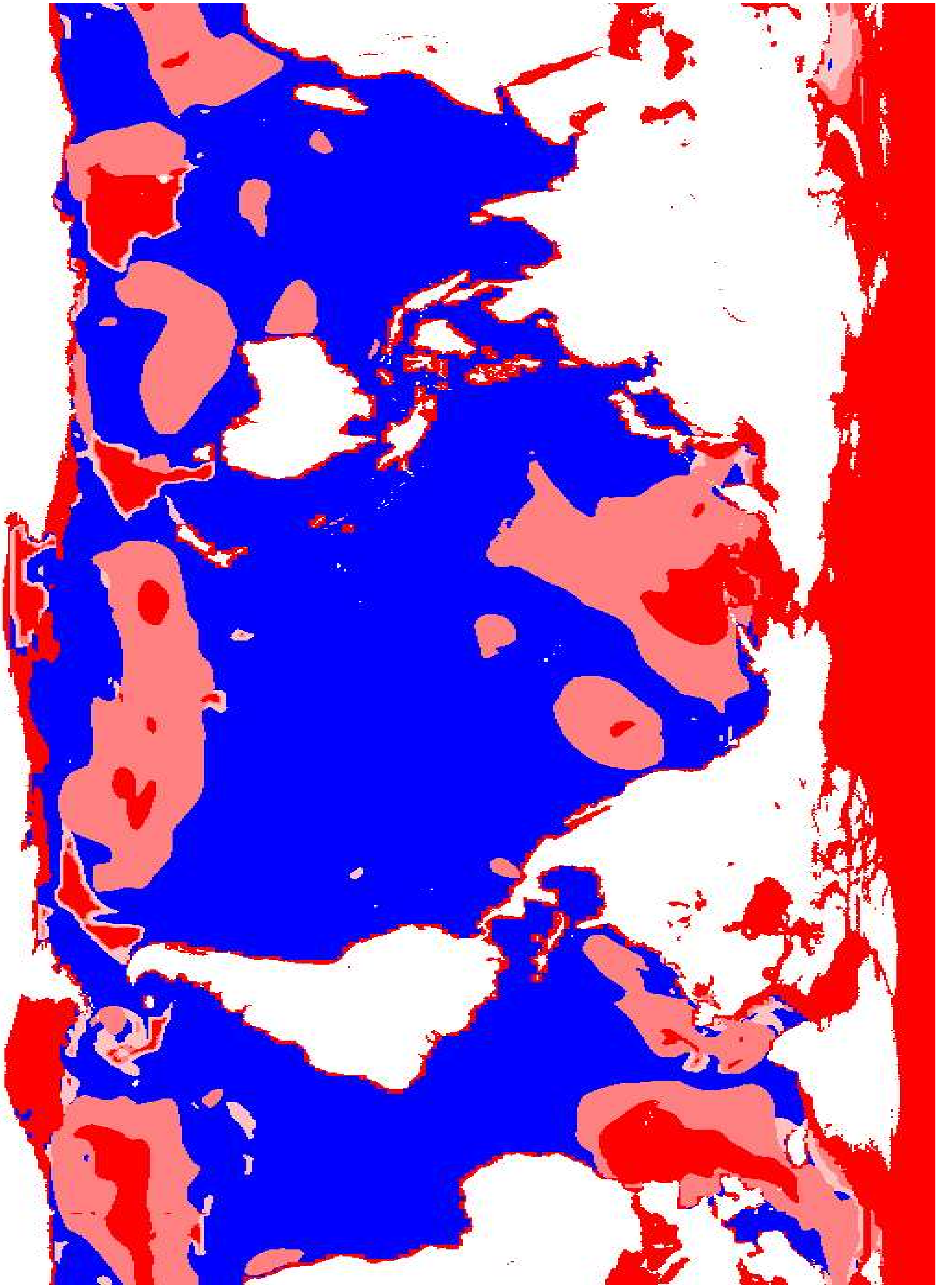

Fig. 6.1 : Sample of Hazard Summary Product

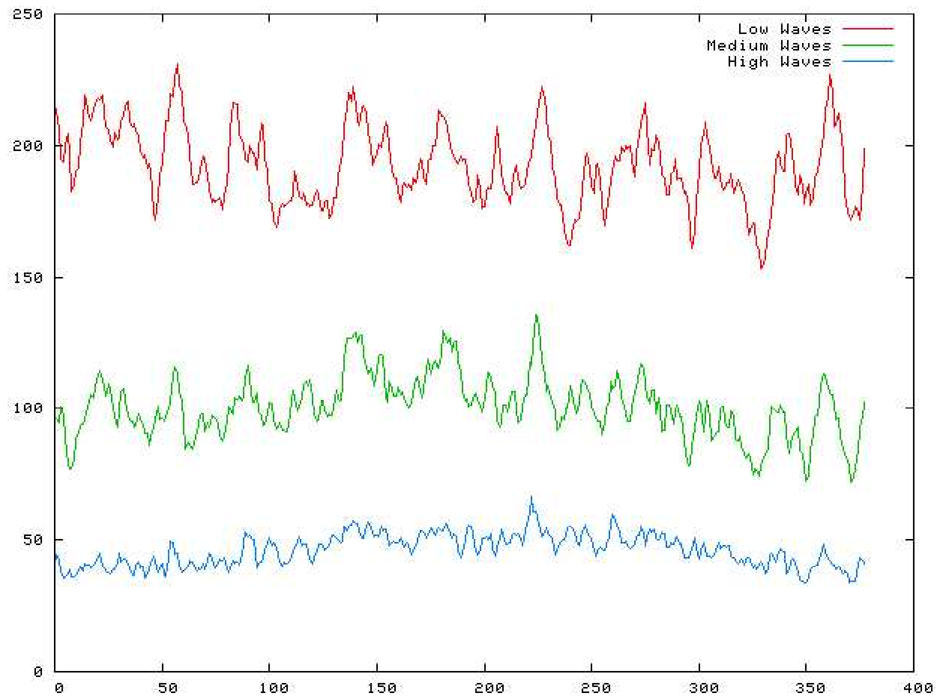

Fig. 6.2 : Areas in Million km^2 of Wave Hazard Conditions versus days since January 25, 2008

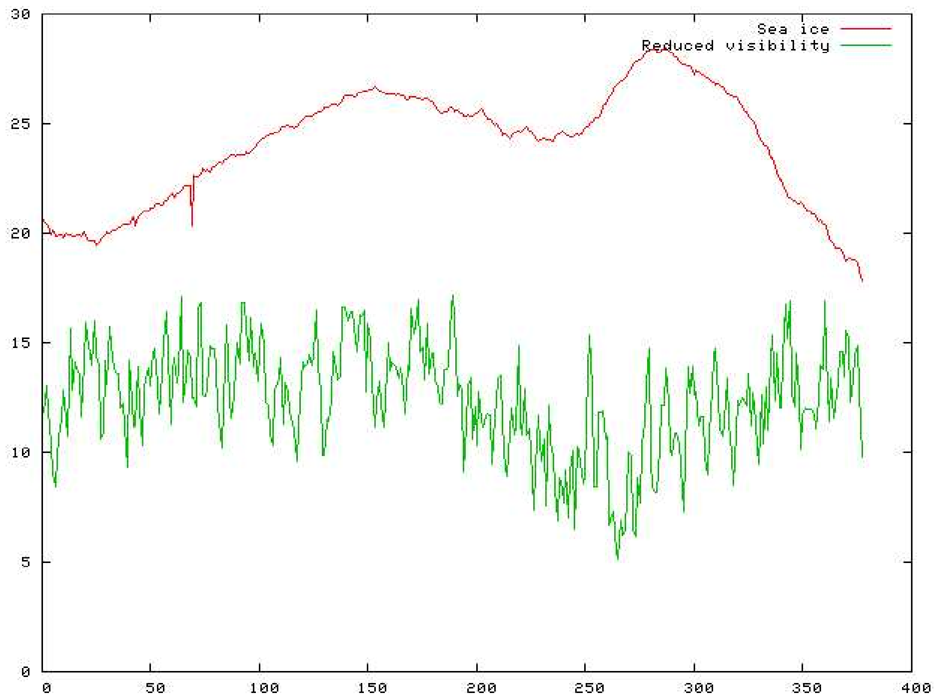

Fig. 6.3 : Areas in Million km^2 of Sea ice and Reduced Visibility versus days since January 25, 2008

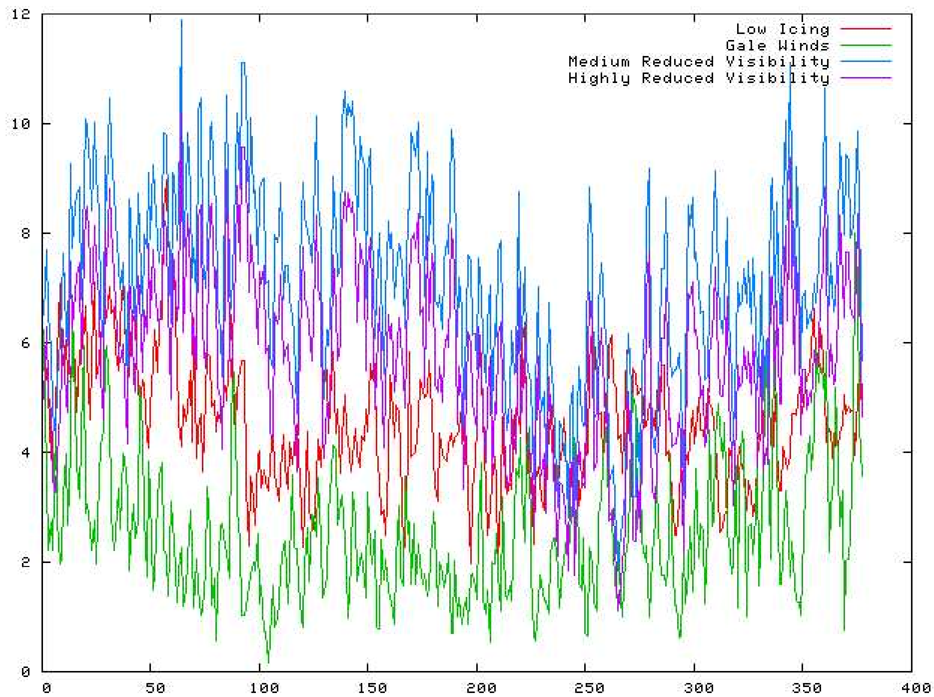

Fig. 6.4 : Areas in Million km^2 of Low Icing, Gale Winds, and Medium or Highly Reduced Visibility versus days since January 25, 2008

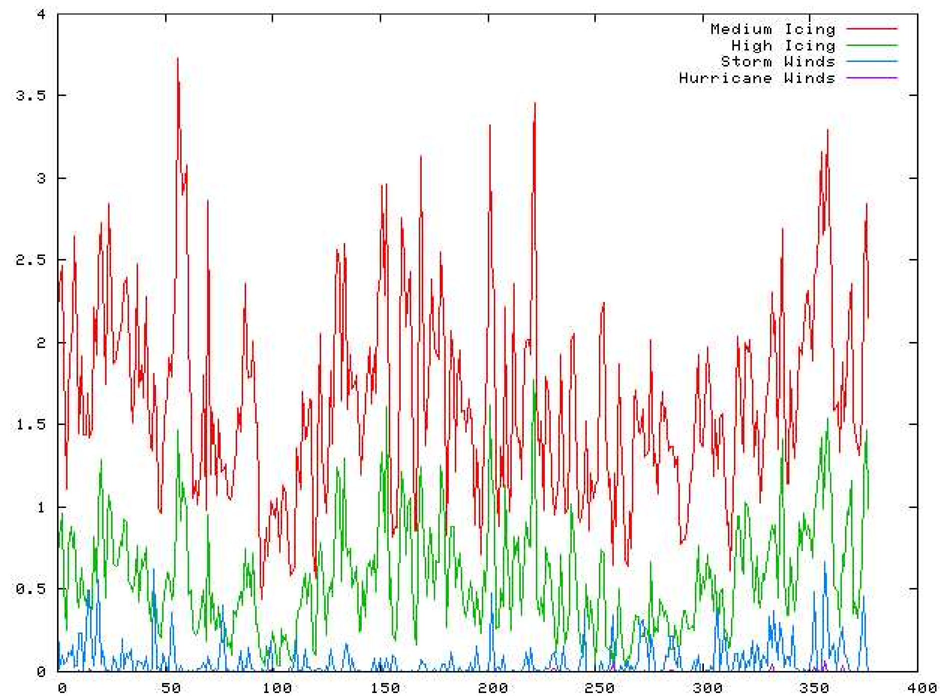

Fig. 6.5 : Areas in Million km^2 of Medium or High Vessel Icing Rates, Storm Force Winds, Hurricane Force Winds versus days since January 25, 2008