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This bulletin, prepared by Dr. R. W Grumbine of the Ocean Modeling Branch, Environmental Modeling Center, National Centers for Environmental Prediction, describes the automated sea ice drift guidance for the polar regions of the Earth which is provided in alphanumeric form. This guidance was implemented in the late 1970s at the request of the National Ice Center and uses the Skiles (1968) model to predict sea ice drift direction and distance out to 6 days at 207 fixed points in the Arctic region.

Since April 1993, new guidance has been implemented experimentally. The new guidance uses the ice models of Thorndike and Colony (1982) for the Northern Hemisphere and Martinson and Wamser (1990) for the Southern Hemisphere. It includes the Skiles fixed prediction points, but also include points along the Arctic and Antarctic ice edges which vary from week to week and are provided by the National Ice Center. Evaluations have been made of both prediction systems, and the new system has been found to be better than the old system. The new prediction system was implemented operationally in 1996.

This is the first Technical Procedures Bulletin on the Subject

SEA ICE DRIFT GUIDANCE

by R. W. Grumbine

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1. INTRODUCTION

In the late 1970s, the National Centers for Environmental Prediction (NCEP) implemented the Skiles (1968) sea ice drift model at the request of the National Ice Center (NIC). This model provides sea ice drift direction and speed forecast guidance for the Arctic region at 207 fixed points from 24- through 144-h at 24-h intervals. The positions of the points are given in Table 1. In April 1993, a newer model (Thorndike and Colony 1982) was implemented experimentally for the northern hemisphere. This model makes predictions at the Skiles points and also at a variable set of points along the northern hemisphere ice edge. The latter set of points is taken from the current northern hemisphere ice edge analysis. The number of points and their location varies weekly with the NIC analysis cycle. A sea ice model for the southern hemisphere (Martinson and Wamser 1990) was also added. Prediction points for this model come only from the NIC weekly southern hemisphere analysis.

A comparative evaluation of the operational and experimental forecasts at the Skiles points has been done and is explained in detail in section 5.

2. METHOD

The method used to derive all the sea ice drift models is statistical. The model differences lie in the variables used for the prediction equations and the associated coefficients and constants derived through regression techniques.

3. DEVELOPMENT AND DEFINITIONS

Sea ice drift models are based on the observation that sea ice tends to drift at an angle to the geostrophic wind direction and at a fraction of the geostrophic wind speed. In the Skiles model, the drift speed is a function of the "roughened" geostrophic wind speed. The roughened geostrophic wind speed is determined by adding to the original pressure field terms proportional to the second derivative of the pressure field. The drift direction is a function of both the geostrophic wind direction and the roughened geostrophic wind speed. In Thorndike and Colony and Martinson and Wamser, the drift speed is strictly a function of the geostrophic wind speed, and the drift direction is a function of the geostrophic wind direction only.

a. NCEP Computers and File Names

Table 2 gives the NCEP computer or workstation and data set name for the experimental global ice drift point forecasts and the Alaska subset of these data.

When the NAS - 9000 computer is decommissioned, the files currently on that machine will also disappear. The operational Skiles model will also cease producing its output. When the moratorium on implementing products is lifted, the experimental products will replace the Skiles products. For a time, the only way to receive these data will be from the Cray machines or by ftp (file transfer protocol) to the address given in Table 2 over the INTERNET.

b. Formats for Operational and Experimental Data

The operational Skiles sea ice drift forecasts are sent daily to the weather forecast offices in Anchorage and Fairbanks on a dedicated circuit, the NIC, and a Fleet Weather and Oceanography Facility at Keflavik, Iceland. The bulletins to Alaska are sent out with a WMO header of FQGA40 KWBC on an X.25 dedicated communications line. They contain only the forecast points for Alaska. The bulletins sent to Keflavik contain only forecast points of interest to them.
The experimental guidance contains forecasts at the Skiles points and along the ice edges in the northern and southern hemispheres (see Fig. 1). The file contains a title for each forecast which gives the projection day (1 - 6) of the forecast and the date the forecast was made (day zero). This line is followed by the guidance at the Skiles points and the guidance at the ice edge points as indicated.

The guidance at the Skiles points contain the point number, the Thorndike and Colony drift direction in degrees and drift in nautical miles, and the Skiles drift direction and drift distance for comparative purposes. When the new guidance becomes operational the Skiles sea ice drift will no longer be computed. The drift direction follows the meteorological convention for wind direction, ie., "270" means drift from 270 degrees (west) to 090 degrees (east).
The ice edge point guidance consists of a point number, the initial longitude, the initial latitude, the drift direction in degrees, and the drift distance in nautical miles. The drift direction is in the same sense as at the Skiles points. The ice edge points change in position and number from week to week with the sea ice edge analysis schedule at the NIC. A negative latitude means the latitude is south of the equator. The longitude is reckoned from 0 degrees to 360 degrees east of

5. EVALUATION

A comparative evaluation of the Thorndike and Colony and Skiles sea ice drift models was carried out from April 1993 through January 1995. No evaluation of the Martinson and Wamser sea ice drift model could be done due to a lack of observation data and lack of any other co-located model data to compare. Forecasts of sea ice drift were verified by comparison with drift observed by drifting buoys which are set on ice floes. Buoys had to be within plus or minus 3 hours of the valid time of the forecast and within 0.5 degrees of the position of the point at the valid time of the forecast.

Forecast skill was measured by three different means: correlation of forecast drift distance with observed, index of agreement between forecast drift distance and observed, and vector correlation between forecast drift vector and observed. The index of agreement ranges from 0 to 1 and measures the forecast error relative to the observation. If the forecast is wrong by 2 n mi, and the observed drift is only 2 n mi, this is penalized more than a 2 n mi error on a 20 n mi observation. The vector correlation has the same character as a linear correlation, except for being in two dimensions, and that we use the squared correlations. The two-dimensional nature gives a range of 0 to 2, rather than 0 to 1 that ordinary correlation squared would have.

Figure 1 shows model skill as a function of the forecast length. We see that regardless of the skill measure, the model skill had essentially no dependance on forecast length. We also see that the Thorndike and Colony model appears to be superior to the Skiles model at all forecast lengths and by all measures except for the vector correlation at day 1, where it is slightly worse. Figure 2 shows the model skill at day 6 from April 1993 through January 1995, excluding July 1994 which experienced an archive failure. The Thorndike and Colony model is consistently superior to the Skiles model. By index of agreement, it is better in 18 of the 21 months. The correlation is better 16 months and ties once. The vector correlation is better in 15 of the 21 months. Since the index of agreement is the measure which shows the greatest model to model differences, it is the preferred skill measure.

6. REFERENCES

Martinson, D. G. and C. Wamser, 1990: Ice drift and momentum exchange in winter Antarctic pack ice. J. Geophys. Res., 95, 1741-1755.

Skiles, F., 1968: Empirical wind drift of sea ice. Arctic Drifting Stations, *Arctic Institute of*

Table 1. - Positions of Skiles sea ice prediction locations. Longitudes are east from the Prime Meridian. Accuracy of latitudes and longitudes is plus or minus 8 seconds of arc.

Point No.	Latitude	Longitude
1	48.88	299.98
2	46.24	308.61
3	54.46	280.00
4	50.57	306.57
5	49.02	310.96
6	47.27	314.99
7	57.63	273.66
8	57.82	280.00
9	56.18	298.43
10	54.97	303.96
11	53.48	309.05
12	51.76	313.69
13	49.86	317.88
14	60.39	265.96
15	61.03	272.88
16	61.24	280.00
17	61.03	287.12
18	60.39	294.04
19	59.37	300.56
20	58.01	306.57

26	63.74	295.95
27	62.57	303.20
28	61.03	309.74
29	59.18	315.54
30	57.08	320.60
31	67.08	261.57
32	67.94	270.54
33	68.23	280.00
34	67.08	298.43
35	65.73	306.57
36	63.98	313.69
37	61.90	319.81
38	59.58	325.00
39	68.83	249.04
40	70.42	258.20
41	71.44	268.69
42	71.79	280.00
43	71.44	291.31
44	70.42	301.80
45	64.46	325.00
46	61.90	330.19
47	69.45	235.00
48	71.79	243.13

53	73.69	306.57
54	66.81	331.34
55	63.98	336.31
56	68.83	220.96
57	71.79	226.87
58	74.51	235.00
59	76.82	246.31
60	78.43	261.57
61	79.02	280.00
62	71.79	333.13
63	68.83	339.04
64	65.73	343.43
65	62.57	346.80
66	70.42	211.80
67	73.69	216.57
68	76.82	223.69
69	79.64	235.00
70	81.80	253.44
71	82.67	280.00
72	81.80	306.57
73	76.82	336.31
74	73.69	343.43
75	70.42	348.20

80	64.46	198.13
81	67.94	199.46
82	71.44	201.31
83	74.95	204.04
84	78.43	208.44
85	81.80	216.56
86	84.81	235.00
87	86.33	280.00
88	84.81	325.00
89	81.80	343.43
90	78.43	351.57
91	74.95	355.96
92	71.44	358.69
93	54.46	190.00
94	57.82	190.00
95	61.24	190.00
96	64.71	190.00
97	68.23	190.00
98	71.79	190.00
99	75.39	190.00
100	79.02	190.00
101	82.67	190.00
102	86.33	190.00

107	75.39	010.00
108	71.79	010.00
109	57.82	010.00
110	54.46	010.00
111	54.30	184.29
112	57.63	183.66
113	61.03	182.88
114	64.46	181.87
115	67.94	180.54
116	71.44	178.69
117	74.95	175.96
118	78.43	171.56
119	81.80	163.44
120	84.81	145.00
121	86.33	100.00
122	84.81	055.00
123	81.80	036.57
124	78.43	028.43
125	74.95	024.04
126	71.44	021.31
127	61.03	017.12
128	57.63	016.34
129	54.30	015.71

134	73.69	163.44
135	76.82	156.31
136	79.64	145.00
137	81.80	126.56
138	82.67	100.00
139	81.80	073.43
140	79.64	055.00
141	76.82	043.69
142	73.69	036.56
143	70.42	031.80
144	63.74	025.95
145	60.39	024.04
146	57.08	022.53
147	56.18	171.56
148	59.37	169.44
149	71.79	153.13
150	74.51	145.00
151	76.82	133.69
152	78.43	118.44
153	79.02	100.00
154	78.43	081.56
155	76.82	066.31
156	74.51	055.00

161	54.97	166.04
162	58.01	163.44
163	61.02	160.26
164	71.79	136.87
165	73.69	126.56
166	74.95	114.04
167	74.95	085.96
168	73.69	073.43
169	71.79	063.13
170	69.45	055.00
171	66.81	048.66
172	45.87	028.43
173	42.90	027.10
174	53.48	160.95
175	59.18	154.46
176	70.42	078.20
177	68.83	069.04
178	66.81	061.34
179	44.77	032.62
180	41.89	031.04
181	49.02	159.04
182	51.76	156.31
183	54.46	153.13

188	47.27	155.01
189	49.86	152.12
190	52.38	148.81
191	54.80	145.00
192	57.08	140.60
193	45.37	151.34
194	47.80	148.37
195	50.14	145.00
196	52.38	141.19
197	54.46	136.87
198	43.35	148.01
199	45.62	145.00
200	47.80	141.63
201	45.37	138.66
202	42.90	136.03
203	40.39	133.69
204	42.00	130.26
205	39.36	128.30
206	37.96	123.20
207	39.05	119.65

Table 2. List of NCEP computers/workstations and associated file names for sea ice drift forecasts.

NCEP Computer/Workstation	File Name
Alaska Ice Drift Forecast Subset	
NAS - 9000	USR.AK.FORECAST.DRIFT
polar.wwb.noaa.gov[1]	pub/ice/ak.out
Global Ice Drift Forecast	
NAS - 9000	USR.JIC.FORECAST.DRIFT
cray3	/ombptmp/ice/driftfore/sk2.yymmdd[2]
cray4	/marine/ice/driftfore/sk2.yymmdd[2]
polar.wwb.noaa.gov[1]	pub/ice/drift.out

[1]Use this address to ftp sea ice drift file on INTERNET.
[2]yymmdd is the date in 6 digit format

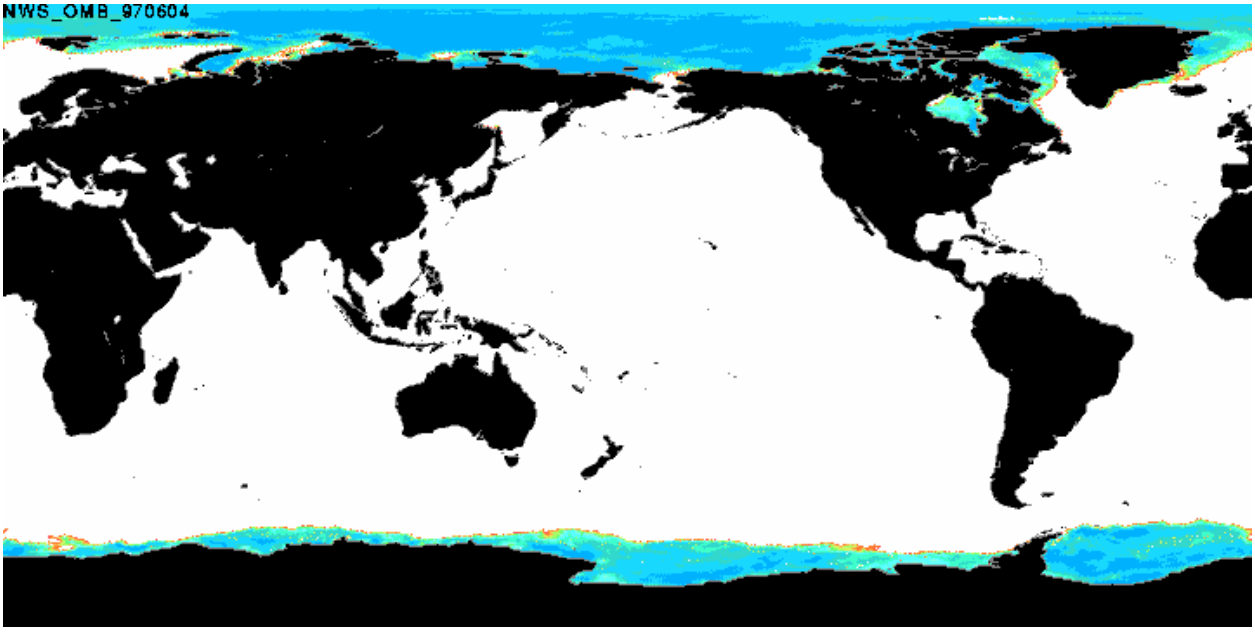
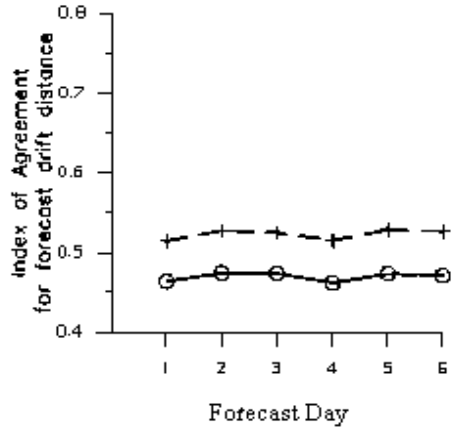


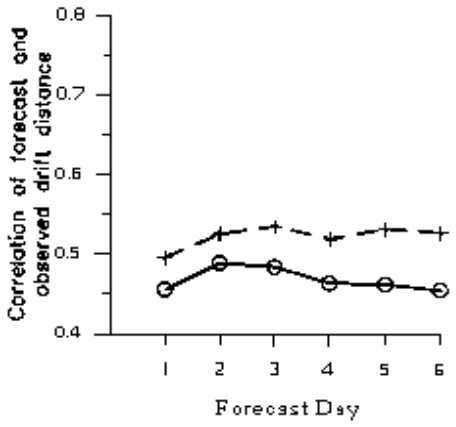
Figure 1 -

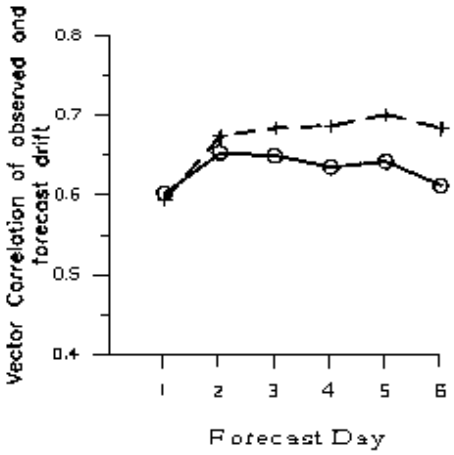
VIRTUAL FLOW ICE DRIFT FORECAST MODEL

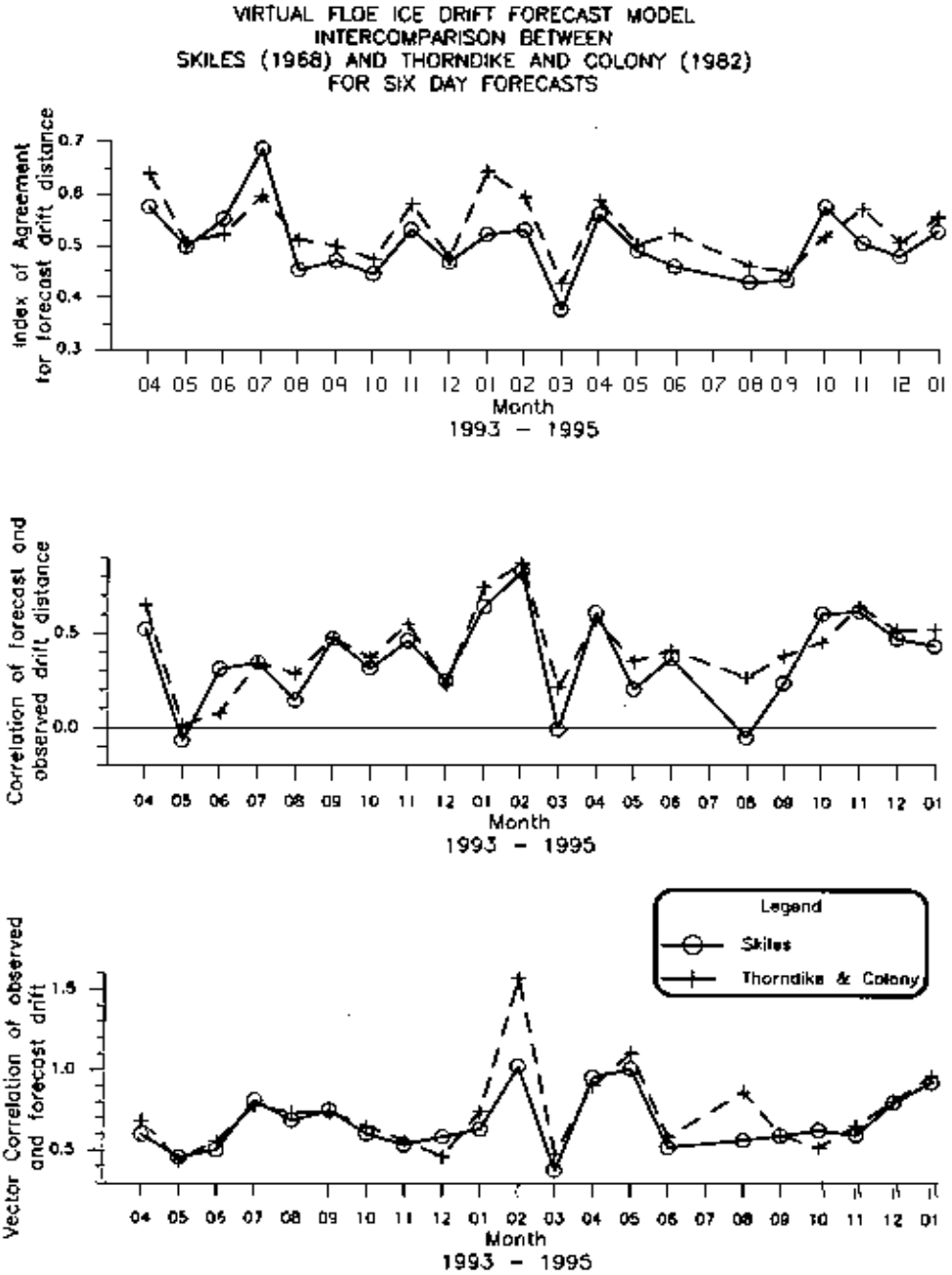
INTERCOMPARISON BETWEEN

Skiles (1968) and Thorndike and Colony (1982)








VIRTUAL FLOE ICE DRIFT FORECAST MODEL
INTERCOMPARISON BETWEEN
SKILES (1968) AND THORNDIKE AND COLONY (1982)
FOR SIX DAY FORECASTS
Index of Agreement for forecast drift distance
0.7
0.6
0.5
0.4
0.3
04 05 06 07 08 09 10 11 12 01 02 03 04 05 06 07 08 09 10 11 12 01
Month
1993 - 1995
Correlation of forecast and observed drift distance
0.5
0.0
04 05 06 07 08 09 10 11 12 01 02 03 04 05 06 07 08 09 10 11 12 01
Month
1993 - 1995
Legend
Skiles
Thorndike & Colony
Vector Correlation of observed and forecast drift
1.5
1.0
0.5
04 05 06 07 08 09 10 11 12 01 02 03 04 05 06 07 08 09 10 11 12 01
Month
1993 - 1995