New perspectives on the synoptic development of the severe October 1992 Nome storm

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[1] Understanding the characteristics of storms that impact the Alaska region is of importance to emergency planning. The 5–7 October 1992 storm was a severe event which cost Nome, a town in Alaska, $6 million dollars. We will explore its characteristics with the aid of two established cyclone tracking schemes: the NOAA CPC current operational algorithm and the University of Melbourne algorithm. Manual tracking was performed as a control. The essential features are captured by both algorithms, but they differ in the genesis and lysis location. The NOAA algorithm broke the storm into two separate events. Synoptic development of the storm was influenced by a blocking high that affected how the tracking algorithms handled the event. A synoptic re-examination of this storm is presented in terms of the depth, Laplacian and radius of the system. These new results present a fresh perspective on the intensity and longevity of this dramatic storm. **Citation:** Mesquita, M. d. S., D. E. Atkinson, I. Simmonds, K. Keay, and J. Gottschalck (2009), New perspectives on the synoptic development of the severe October 1992 Nome storm, *Geophys. Res. Lett.*, *36*, L13808, doi:10.1029/2009GL038824.

1. Introduction

[2] One of the predicted effects of climate change is an increase in storm activity (frequency and intensity [*Simmonds et al.*, 2008]) in the North Pacific, Bering Sea and Arctic Ocean [*Graham and Diaz*, 2001]. Strong storms are an annual occurrence in the Bering Sea and Gulf of Alaska, with peak activity in the fall/winter season [*Fathauer*, 1978]. Relatively few of these storms form locally; instead they consist of "old" systems that have moved into the region from the North Pacific and which have undergone a process of re-energization. They represent a serious hazard to users of these marine regions, subsistence and commercial alike, as well as to coastal communities. Nome, a community on coastal western Alaska (Figure 1), is frequently affected: storm-surge accounts from newspapers from 1899 to 1993 indicate severe storms occur most often in October–November, with frequency peaks of catastrophic and property-damaging events occurring in 1900, 1913, 1945–46, 1974 and 1992 [*Mason et al.*, 1996].

[3] For this paper the powerful event of 1992 is examined: it registered average winds of 29 mph (47 km/h) and maximum winds of 59 mph (95 km/h), with a central pressure minimum of 962 hPa (12 Z 06 October). The rapidity of its re-energization is indicated by a minimum pressure of 974 hPa only 12 hours earlier. This storm event caused one of the most significant flooding episodes in Nome since that of November 1974 [*Fathauer*, 1975], and represents the highest storm surge since the Nome water level gauge data became available in 1992 [*Blier et al.*, 1997]. This surge placed the peak water level only 1.8 m below the top of the town seawall, which is about 8.3 m high (7.9 m in the business district).

[4] Storms research has focused on tracking individual events to identify typical trajectories and intensities in what is termed a "quasi-Lagrangian" approach [*Simmonds et al.*, 2008]. They identify local minima/maxima of storm diagnostic parameters, such as sea level pressure, within blocks of grid points [*Murray and Simmonds*, 1991; *Serreze et al.*, 1993; *Sinclair*, 1994; *Zhang et al.*, 2004]. Arguably the most commonly applied algorithm for the Alaska region is that operated at NOAA/CPC (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/stormtracks/mstrack.shtml), which uses the method of *Serreze et al.* [1993] and *Serreze* [1995] ("GS" hereafter).

[5] An alternative approach was developed at The University of Melbourne [*Murray and Simmonds*, 1991; *Simmonds et al.*, 1999; *Simmonds and Keay*, 2000], hereafter the "Melbourne" algorithm. This approach, like GS, analyses MSLP. However, open lows are incorporated into the storm lifecycle which prevent possibly inappropriate timeseries breaks if temporary weakening to an open-low state occurs. It has been applied to studies in both hemispheres [*Murray and Simmonds*, 1991; *Simmonds and Keay*, 2000; *Pinto et al.*, 2005; *Simmonds et al.*, 2008] but not specifically for Alaska.

[6] The primary goal of the present paper is to study the evolution of this dangerous storm from the perspective of two robust storm-tracking algorithms. Selection of a storm-tracking algorithm that can handle a broad range of storm life cycle phases is an important first step to better serve Alaskans in this time of potentially increasing storm activity [*Mesquita et al.*, 2008].

2. Methodology and Data Sets

[7] The two tracking algorithms, GS and Melbourne, are contrasted using a specific case study, the event of September–October 1992. Both algorithms were run using 6-hourly mean sea level pressure data from the NCEP/NCAR reanalysis (R1) [*Kistler et al.*, 2001] for 1992.

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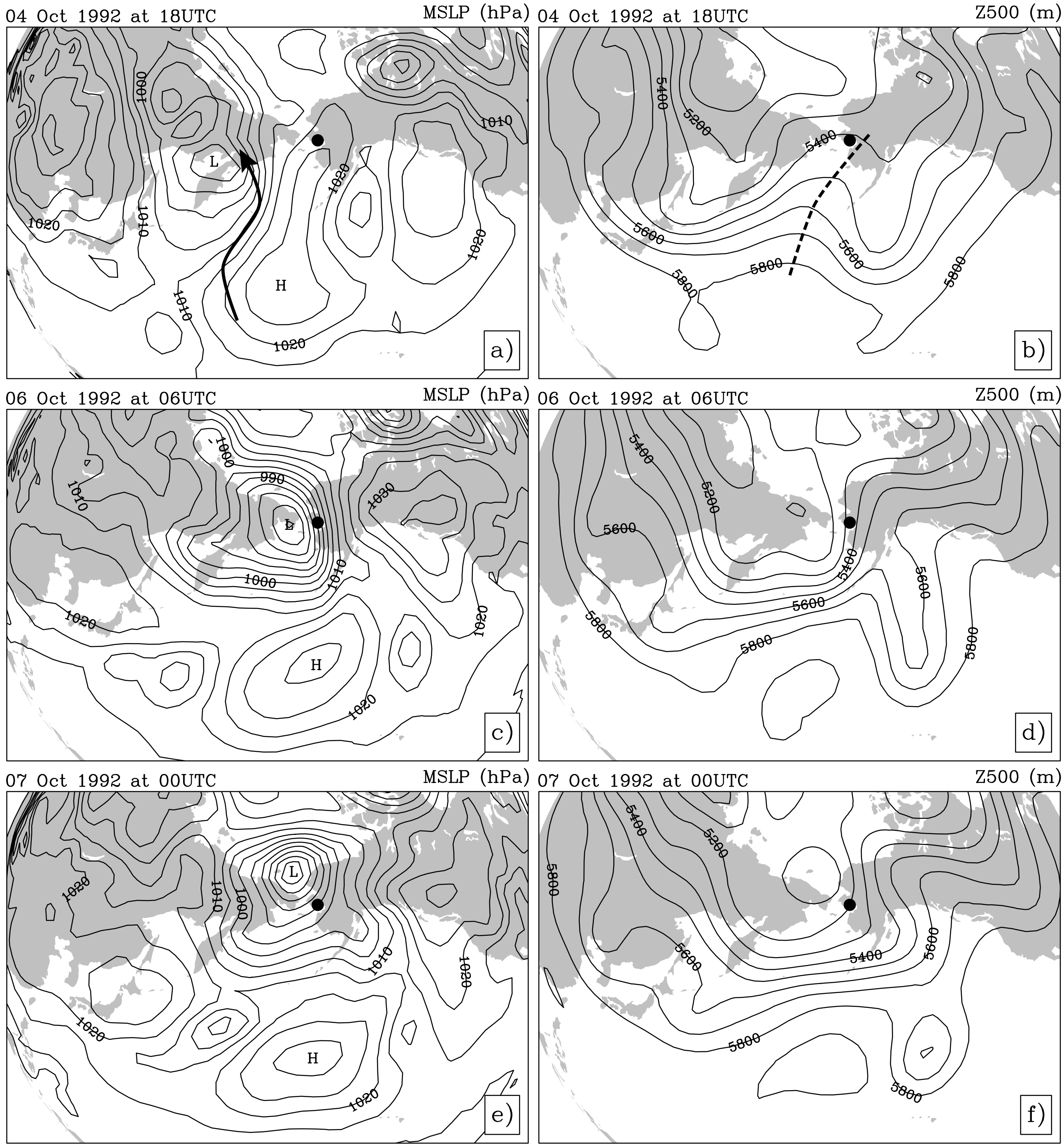

Figure 1. NCEP/NCAR mean sea level pressure and 500 hPa geopotential height at three times in the life of the Nome storm: (a, b) 04 October 1992 at 18 UTC, (c, d) 06 October 1992 at 06 UTC and (e, f) 07 October 1992 at 00 UTC. Contour interval: 5 hPa for MSLP and 100 m for Z500. Only the case-study storm and the stationary high are labelled in the plot: 'L' and 'H' respectively. The thick arrow shows moisture flow trajectory. The thick dashed line shows 500 ridge axis. Nome is indicated with the dot.

[8] The GS algorithm tracks storms by finding the center of a "closed low" pressure system, i.e., a grid point is surrounded by points with higher values and appears as a closed line on a mean sea level pressure map. A threshold of 1 mb was selected as the minimum difference between the central point and the surrounding ones. A choice of threshold below 2 mb is ideal [*Eichler and Higgins*, 2006]. There are two possible weaknesses with the 'GS' method: mean storm count can be overestimated because it does not account for the entire storm life-cycle [*Pinto et al.*, 2005], and that it only considers the average value of MSLP between 9 grid points with thresholds [*Gulev et al.*, 2001]. GS does not track the system when the storm center is no longer closed. This can be problematic because "open-low" systems, i.e., a low pressure at a weakening stage when a grid point is not completely surrounded by higher

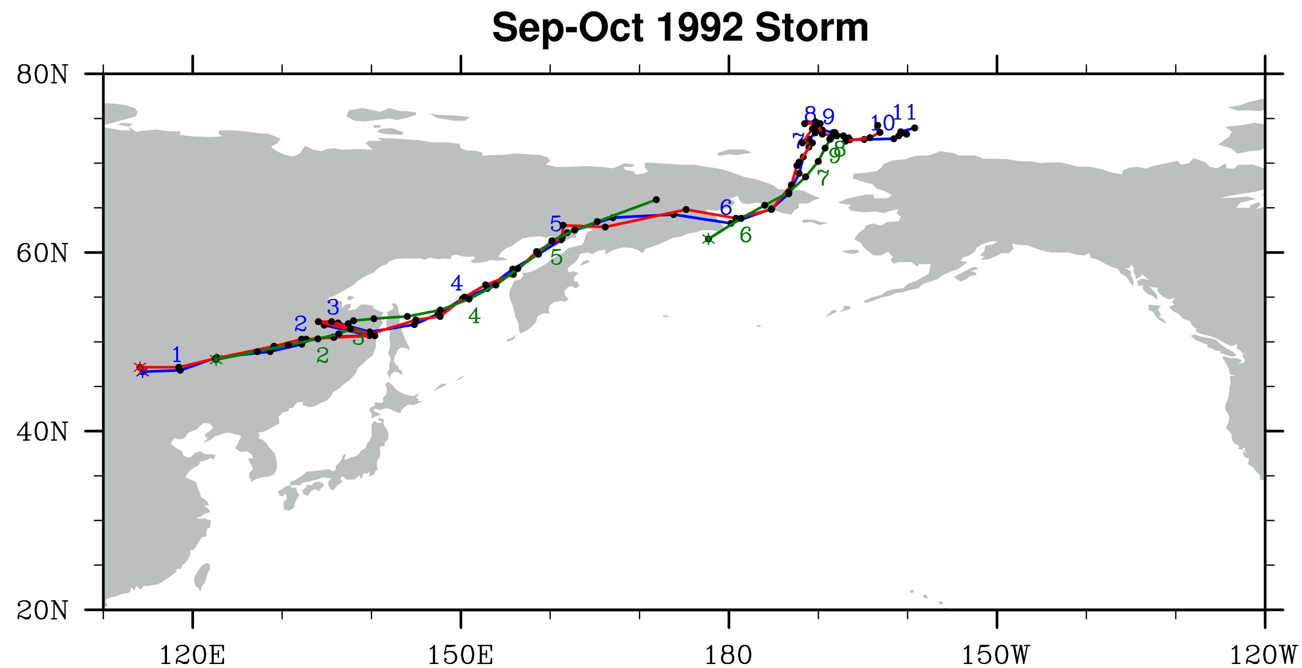

Figure 2. The September–October 1992 storm represented by three tracking techniques. The manually tracked system (red line) persists from 30 September 1992 at 18 Z through 10 October 1992 18 Z. The Melbourne algorithm (blue line) shows the storm persisting from 30 September 1992 at 18 Z through 11 October 1992 at 00 Z. The GS algorithm (green line) shows two separate systems: the first starting 06 Z 01 Oct. 1992 through 18 Z 05 Oct. 1992, and the second starting at 18 Z 05 Oct 1992 through 12 Z 09 Oct. 1992. The stars indicate the start point of the storms, the dots represent 6 h-interval time steps and the numbers represent the days in October 1992 at 00 Z.

value points, may continue to cause damage and they may also reenergize into closed systems [*Bergeron*, 1950]. In the latter case, GS could return erroneously high storm counts. Thus an algorithm that accounts for open low systems should return storm climatology results that better approximate reality.

[9] The Melbourne tracking algorithm provides information about system type – open/closed – and relative strength – weak/strong. An open/closed system is defined by comparing the Laplacian of pressure at each grid point with its neighbors [*Murray and Simmonds*, 1991; *Simmonds et al.*, 2008]. When a possible low is found, the location of the pressure minimum is interpolated by iterative approximation to the center of an ellipsoid of best fit to the pressure surface. An open system is searched for when a closed center cannot be determined by the ellipsoid. A system is classified as "weak/strong" based on the "concavity criterion" [*Simmonds et al.*, 2008]: when the average value of the Laplacian exceeds 0.2 hPa ($^\circ$ lat)$^{-2}$ over a radius of 2° lat, the storm is included in the count. If the Laplacian value is between 0.2 and 0.7 hPa ($^\circ$ lat)$^{-2}$, the storm is considered "weak", and higher than 0.7 hPa ($^\circ$ lat)$^{-2}$, "strong". The depth (in hPa) and the Laplacian of the pressure [in hPa ($^\circ$ lat)$^{-2}$ where 1° lat (degree latitude) is approximately 111 km] will be shown for the Melbourne algorithm in order to describe the lifetime of this storm. Finally, manual tracking was also performed to act as a control for this event.

3. Results

3.1. Storm of 5–7 October 1992

[10] The low formed initially over eastern China while a large blocking high was sitting over the North Pacific (01 October 1992 at 12 UTC, not shown). Between 01 October and 04 October the storm strengthened and moved towards the Sea of Okhotsk and the blocking high became larger, developing a ridge extending from the North Pacific up through the state of Alaska (Figures 1a and 1b, 04 October 1992 at 18 UTC). The surface low was accompanied at the 500 hPa level by a ridge extending north into the Bering Sea (Figure 1b). Between 04 October and 06 October the low came under the influence of the high and was diverted northward, over far eastern Russia (Figure 2). By 06 October the blocking system has weakened and the 500 hPa ridge displaced eastward, allowing the storm to strengthen and move into the north Bering Sea (Figures 1c and 1d, 06 October 1992 at 06 UTC). Eighteen hours later the storm has moved into the south Chukchi Sea (Figures 1e, 1f, 07 October 1992 at 00 UTC) with a gradient presentation favourable for development of large surge at Nome.

[11] This event was tracked using three different methods (Figure 2). The GS track starts twelve hours later and finishes (one) two days earlier than the (manual) Melbourne track. All three tracks exhibited similar features and positions throughout their lifecycles. The retrograde shift of 02–03 October was well represented by manual and Melbourne, less so by GS.

[12] By 09 October at 18 Z the storm was still a strong closed system, transitioning to a weak closed system by 10 October at 00 Z. From there on until 11 October at 00 Z, it became a weak open system until lysis. The last time steps of the Melbourne track show the most discrepancy when compared to manual, largely because use of the Laplacian of the pressure allows the algorithm to track more accurately

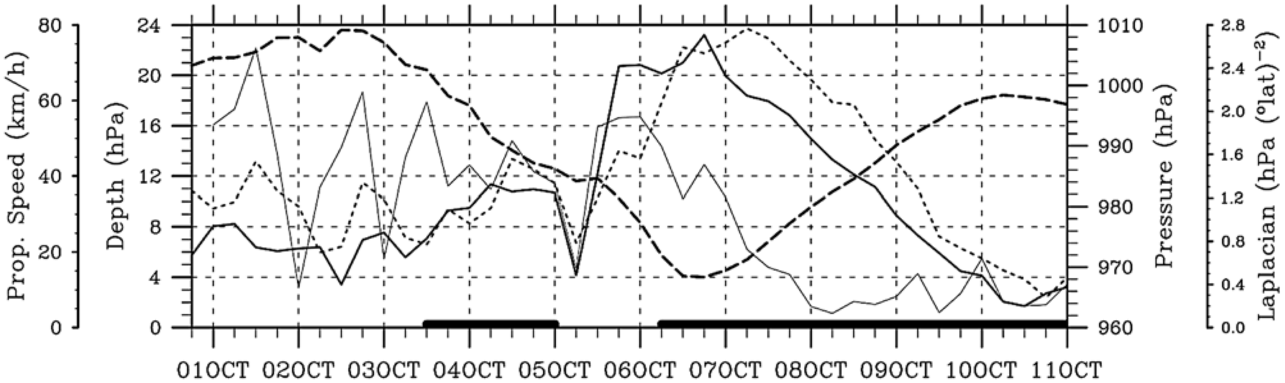

Figure 3. The life history of the September–October 1992 storm calculated using the Melbourne algorithm. The storm started on 30 September 1992 at 18 Z through 11 October 1992 at 00 Z. The solid line represents the depth of the storm in hPa. The thin solid line is the propagation speed in km/h. The dashed lines indicate the central pressure of the storm in hPa. The dotted line shows the Laplacian of the pressure field given in hPa (° lat)$^{-2}$. The spacing in the x-axis is for every 6 hours, starting at 00 Z for each day. The thick lines on the x-axis represent the time when the storm passed over the sea.

the position of the storm center as compared to the manual tracking of the system, which was based on visual assessment of contours.

[13] The most apparent difference amongst the tracks is the break identified by GS on 05 October (Figure 2). The tracking break, situated over the Chukotka region in Russia at 18 Z 05 October, was likely triggered in the GS algorithm by a temporary weakening of the system to a strong open system caused by interaction with orography as described in section 4.

[14] Figure 3 shows the life history of the storm track. The pressure time series (dashed line) shows that the storm started with a central pressure of 1003 hPa and then it had a slight increase of 6 hPa in 42 hours. After that, the central pressure dropped to its minimum value of 968 hPa on 06 October at 18 Z. This represented a drop of 41 hPa from the maximum value within 102 hours. During the period of weakening it increased again to 998 hPa by 10 October at 06 Z. After a brief drop to 996 hPa the system dissipated.

[15] The depth and the Laplacian parameters (Figure 3) represent a measure of storm intensity [*Simmonds et al.*, 2008]. From the beginning of the storm until 05 October at 06 Z, the intensity oscillated without showing an overall trend. It is from that point on that both the depth and the Laplacian rapidly increased over 24 hours. The maximum depth value (23.21 hPa) occurred on 06 October at 18 Z; 36 hours earlier the minimum value was 4 hPa. The maximum Laplacian value occurred on 07 October at 06 Z (2.77 hPa (° lat)$^{-2}$). Both the depth and the Laplacian dropped in value until close to the end of the storm lifetime.

[16] The propagation speed (Figure 3) shows a similar pattern to the intensity parameters. As the storm moved from sea to land between 05 October and 06 October, the speed decreased and increased afterwards, covariant with the Laplacian and depth parameters.

3.2. Role of the Blocking High

[17] The main reason the storm weakened to an open system was due to the influence of a high-pressure system located along Alaska, the Aleutian Islands and part of the North Pacific Ocean in a SW-NE axis (Figure 1a). Continued progression of the storm northeastward along its maritime track was interrupted as it was diverted by the blocking high system until 05 October at 12 Z. The high and its ridge, however, then set the stage for the initial phase of the rapid storm strengthening. As the low moved up against the high a strong gradient was established along the west side of the high/ridge in which a strong southerly flow developed (see arrow in Figure 1a) that brought destabilizing warmth and water vapour to the storm at lower levels.

4. Discussion and Conclusion

[18] The fact that the blocking high system helped shape the Nome storm of 1992 is in agreement with *Blier et al.* [1997]. This seems to be the case for storms that cause flooding in Nome and other areas of Alaska [*Fathauer*, 1975, 1978; *Blier et al.*, 1997]. Other authors confirm that the North Pacific storms 'frequently' move into the Chukchi Sea as blocking ridges develop over the Aleutian Islands [*Wilson and Overland*, 1987; *Salmon*, 1992; *Mason et al.*, 1996]. This cyclone-anticyclone configuration is similar to the 'classic' type of events associated with cold outbreaks south of Australia [*Simmonds and Rashid*, 2001]. Thus in the North Pacific context it would appear that a blocking high with ridge serves to a) interact with an approaching low to develop a relatively steep pressure gradient along the ridge west side, b) entrain warmth and moisture in the ensuing strong southerly flow and advect it into the low, and to c) deflect these now revitalized storms to the northeast, towards the Aleutian Islands and Bering Sea. Sea surface temperature plots for 1992 (not shown) suggested anomalous SST warmth in the September–October period in the mid-North Pacific. On 05 October at 12 Z, the storm weakened and became an open system. The weakening was caused by its trajectory over land and interaction with orography.

[19] The strengthening of the storm during 05–06 October displaced the surface ridge to the east. In addition to the mechanisms described above it is possible that storm re-energization was also facilitated by a drawing of kinetic energy from the background flow associated with

the ridge break up process. Storm re-energization may have been further aided by increased local availability of water vapour as it traversed several water bodies: the Sea of Okhotsk and the Gulf of Anadyrsk. As the system progressed towards the Bering Sea the southerly moisture and heat flow dissipated with the disruption of the ridge but favourable conditions developed aloft, specifically, a shortwave trough with vorticity and divergence maxima to the east, positioned over the center of the surface low.

[20] GS and Melbourne captured the main trajectory features of the 1992 Nome storm. They differ in the genesis and lysis location, which is not unusual when using different algorithms [*Raible et al.*, 2008]. The fact that GS split the storm into two is not necessarily in error and may point to an alternate explanation of event evolution; that is, that there were in fact two separate systems. As the storm moved from the Sea of Okhotsk, it died as it reached the cold land temperatures over Russia. A separate system started over the Bering Sea moving towards the Chukchi Sea – a region of high baroclinicity due to the gradient of temperature in that region, akin to processes along the US eastern seaboard.

[21] *Blier et al.* [1997, Figure 4] show the event as one system and not two. In the present case study it is felt that the Melbourne algorithm provides additional insights into the storm evolution, in terms of its genesis location and longevity, via the description of open and closed centers, as well as variables like Laplacian and depth.

[22] The concept of what a "storm" really is represents an important issue when considering automated classification methods. The way a tracking algorithm defines a "storm" clearly sets the context for the tracking results. In this paper, we do not advocate one system as being better than the other but instead echo *Leonard et al.* [1999, p. 180]: "In carrying out an intercomparison of depression tracking schemes great care must be taken not to draw misleading conclusions about the merits and value of a particular scheme, since different users of the software will have different requirements." Hence, a scheme should be chosen according to the user's needs and type of research.

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References

Bergeron, T. (1950), *De Tropiska Orkanernas Problem*, Kungl. Boktr. P. A. Norstedt and Soener, Stockholm.

Blier, W., et al. (1997), Storm surges in the region of western Alaska, *Mon. Weather Rev.*, *125*, 3094–3108, doi:10.1175/1520-0493(1997)125<3094:SSITRO>2.0.CO;2.

Eichler, T., and W. Higgins (2006), Climatology and ENSO-related variability of North American extratropical cyclone activity, *J. Clim.*, *19*, 2076–2093, doi:10.1175/JCLI3725.1.

Fathauer, T. F. (1975), The great Bering Sea storms of 9–12 November 1974, *Weatherwise*, *28*, 76–83.

Fathauer, T. F. (1978), A forecast procedure for coastal floods in Alaska, *NOAA Tech. Memo., NWS AR-23*, 27 pp.

Graham, N. E., and H. F. Diaz (2001), Evidence for intensification of North Pacific winter cyclones since 1948, *Bull. Am. Meteorol. Soc.*, *82*, 1869–1893, doi:10.1175/1520-0477(2001)082<1869:EFIONP>2.3.CO;2.

Gulev, S. K., et al. (2001), Extratropical cyclone variability in the Northern Hemisphere winter from the NCEP/NCAR reanalysis data, *Clim. Dyn.*, *17*, 795–809, doi:10.1007/s003820000145.

Kistler, R., et al. (2001), The NCEP-NCAR 50-year reanalysis: Monthly means CD-ROM and documentation, *Bull. Am. Meteorol. Soc.*, *82*, 247–267, doi:10.1175/1520-0477(2001)082<0247:TNNYRM>2.3.CO;2.

Leonard, S. R., et al. (1999), An assessment of three automatic depression tracking schemes, *Meteorol. Appl.*, *6*, 173–183, doi:10.1017/S135048279900119X.

Mason, O. K., et al. (1996), The periodicity of storm surges in the Bering Sea from 1898 to 1993, based on newspaper accounts, *Clim. Change*, *34*, 109–123, doi:10.1007/BF00139256.

Mesquita, M. d. S., et al. (2008), Climatological properties of summertime extra-tropical storm tracks in the Northern Hemisphere, *Tellus, Ser. A*, *60*, 557–569, doi:10.1111/j.1600-0870.2008.00305.x.

Murray, R., and I. Simmonds (1991), A numerical scheme for tracking cyclone centres from digital data. Part I: Development and operation of the scheme, *Aust. Meteorol. Mag.*, *39*, 155–166.

Pinto, J. G., et al. (2005), Sensitivities of a cyclone detection and tracking algorithm: Individual tracks and climatology, *Meteorol. Z.*, *14*, 823–838.

Raible, C. C., et al. (2008), Northern Hemisphere extratropical cyclones: A comparison of detection and tracking methods and different reanalyses, *Mon. Weather Rev.*, *136*, 880–897, doi:10.1175/2007MWR2143.1.

Salmon, D. K. (1992), On interannual variability and climatic change in the North Pacific, Ph.D. dissertation, Inst. of Mar. Sci., Univ. of Alaska Fairbanks, Fairbanks.

Serreze, M. C. (1995), Climatological aspects of cyclone development and decay in the Arctic, *Atmos. Ocean*, *33*, 1–23.

Serreze, M. C., et al. (1993), Characteristics of Arctic synoptic activity, *Meteorol. Atmos. Phys.*, *51*, 147–164, doi:10.1007/BF01030491.

Simmonds, I., and K. Keay (2000), Mean Southern Hemisphere extratropical cyclone behaviour in the 40-year NCEP-NCAR reanalysis, *J. Clim.*, *13*, 873–885, doi:10.1175/1520-0442(2000)013<0873:MSHECB>2.0.CO;2.

Simmonds, I., and H. A. Rashid (2001), An investigation of a dramatic cold outbreak over southeast Australia, *Aust. Meteorol. Mag.*, *50*, 249–261.

Simmonds, I., et al. (1999), A refinement of cyclone tracking methods with data from FROST, *Aust. Meteorol. Mag.*, special issue, 35–49.

Simmonds, I., et al. (2008), Arctic climate change as manifest in cyclone behavior, *J. Clim.*, *21*, 5777–5796, doi:10.1175/2008JCLI2366.1.

Sinclair, M. R. (1994), An objective cyclone climatology for the Southern Hemisphere, *Mon. Weather Rev.*, *122*, 2239–2256, doi:10.1175/1520-0493(1994)122<2239:AOCCFT>2.0.CO;2.

Wilson, J. G., and J. E. Overland (1987), Meteorology, in *The Gulf of Alaska: Physical Environment and Biological Resources*, *Miner. Manage. Study OCS 86-0095*, edited by D. W. Hood and S. T. Zimmerman, pp. 31–56, NOAA, Silver Spring, Md.

Zhang, X., et al. (2004), Climatology and interannual variability of Arctic cyclone activity: 1948–2002, *J. Clim.*, *17*, 2300–2317, doi:10.1175/1520-0442(2004)017<2300:CAIVOA>2.0.CO;2.

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