JP1.11 RAMS SIMULATED AND SAR OBSERVED FLOW INTERACTION IN THE LOWER COOK INLET, ALASKA

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1. INTRODUCTION

Weather in the North Gulf of Alaska is characterized by a high frequency of deep synoptic-scale low pressure systems, especially during the cold season. The strong pressure gradients of these storms interact with the extremely rugged terrain of the coastal mountains to produce a variety of channeled flows (e.g., Macklin et al. 1990, Bond and Macklin 1993). Located in the north Gulf of Alaska (Fig. 1), Cook Inlet and Shelikof Strait are two connected northeast-southwest trending channels that are important to local marine and aviation traffic. Cook Inlet is bounded on the west by the massive Aleutian Range and on the east by the Chugach and Kenai Ranges. Shelikof Strait is bounded by the Alaska Peninsula on the west and rugged Kodiak Island to the east. The topographic heights of most of the mountain ranges are between 1000—2000 m. During the winter storm season, strong atmospheric pressure gradients occur across this region as cyclones transit the north Gulf. The various resultant channeled winds strongly affect these activities. The lower Cook Inlet of Alaska is prone to severe surface winds all year around. Although the strong westerly surface jet occurs most frequently, strong wind can blow from any direction in this region (Macklin et al. 1980). Especially in winter, strong wind from upper Cook Inlet pours into the lower Cook Inlet and interacts with the strong easterly wind from the North Gulf of Alaska, causing more variability to the winds and severe sea surface surge. Numerical models often captures these local wind events (e.g., Olsson et al. 2004). The station observations are a source of verification of the model results, but meaningful spatial verification is limited by the coarse observations. The Synthetic Aperture Radar (SAR)-derived winds available occasionally give very high resolution "snapshots" of the surface winds (Monaldo, 2000) and can be used to verify model output (e.g. Sandvik and Furevik, 2002; Pan and Smith, 1999).This study reports several events of interaction between strong gap winds and/or barrier jets.

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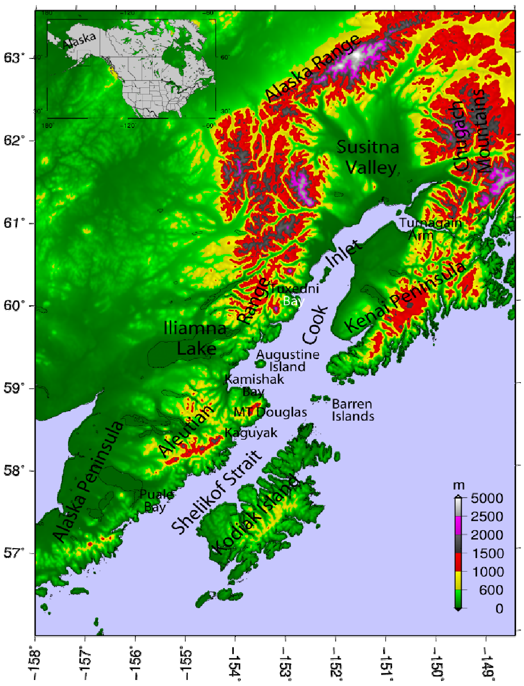

Fig. 1. Topography of Cook Inlet and Shelikof Strait. The location of Alaska is depicted by the small print of the US map.

2. MODEL DESCRIPTION

The mesoscale model Regional Atmospheric Modeling System (RAMS) was configured to run over three two-way nested grids in this study. Developed at Colorado State University and Mission Research Corporation, RAMS is a multipurpose numerical simulation system (Pielke et al., 1992a; Cotton et al., 2002). RAMS is well suited to simulate mesoscale phenomena including gap events (Jackson, 1994; Doran and Zhong, 2000). For this study, grid 1 has 50 by 50 grids points with a grid spacing of 64 km, sufficient to capture the synoptic-scale storm events. Grid 2 has 74 by 70 grid points with a spacing of 16 km, and the grid 3 has 122 by 134 grid points with a spacing of 4 km (Fig. not shown). Grid 3 covers the entire area of Cook Inlet and Shelikof Strait and is fine enough to simulate the details of major gap flows in this region. Vertically, all three domains have the same 36 levels. The vertical grid spacing starts at 50 m at the surface and stretches by a factor of 1.15 for each successive level above the surface, to a maximum separation of 1200 m. This gives a vertical domain height of 23.5 km above mean sea level. The sea surface temperature (SST) is from NCEP weekly SST. The land and vegetation, and topography data are from the standard RAMS data sets. The simulation was carried out in 36 hour forecast mode with initial and lateral forcing data from the NCEP Eta model. RAMS often captures the interaction between CId and ILAr at the lower Cook Inlet . Here we present 3 cases with SAR observations. The goal is to depict the interaction between the two strong surface wind features.

3. THREE EVENTS

Under certain circumstances, the down Cook Inlet jet (CId) and easterly jet in lower Cook Inlet (ILAr) occur at the same time and converge in lower Cook Inlet. This situation often rises when a low system traverses through the North Gulf of Alaska. Fig. 2 Shows the Eta surface analysis at 00Z on 7, 17 and 24 Feb. 2005, all periods in which CId and ILAr coexisted. They are typically characterized by a low pressure system or trough in the western Gulf of Alaska , easterly flows in the lower Cook Inlet and down Inlet winds in the rest of Cook Inlet. The pressure in the Alaska interior is relatively higher than the coastal region that the pressure gradients are directing channeled flows down Cook Inlet. The events on 7 and 17 Feb have more intense pressure gradients In the east side of the Kenai Peninsula. The lower level easterly flows blocked by the coastal mountains tends to form a localized ridge parallel to the coast which induce a barrier jet.

Fig. 3 gives SAR-derived and RAMS simulated wind for the above three events, depicting interacting CId and ILAr lower Cook Inlet. The SAR images were taken at about 3 UTC Feb. 07, 17 and 24 2005. The RAMS winds are those closest in time to the SAR images. (The color scale of the RAMS plots is very similar to the SAR image.) The overall patterns of surface wind shown on SAR images and resolved by RAMS model are similar. The northeasterly CId and easterly ILAr meet in lower Cook Inlet and create a narrow convergence zone which may cause strong turbulence not resolved at these grid scales and present a hazard to general aviation traffic. The barrier jet induced by the blocking of the coastal mountains to the on shore flow is apparent on the plots for both 7 (Fig. 3a) and 17 (Fig. 3b) Feb. The highest wind is just off the end of the barrier. The easterly flow of 24 Feb does not show barrier jet characteristics on RAMS simulation more closely resembles a gap flow. The flow has a moderate speed (12 ms^{-1}) before entering the lower Cook Inlet and accelerates through the gap between the Kenai Peninsula and the Kodiak Island. Here we conclude that the easterly jet is likely the result of the channeling of the gap between the Kenai Peninsula and Kodiak Island of the strong easterly flow from the North Gulf of Alaska.

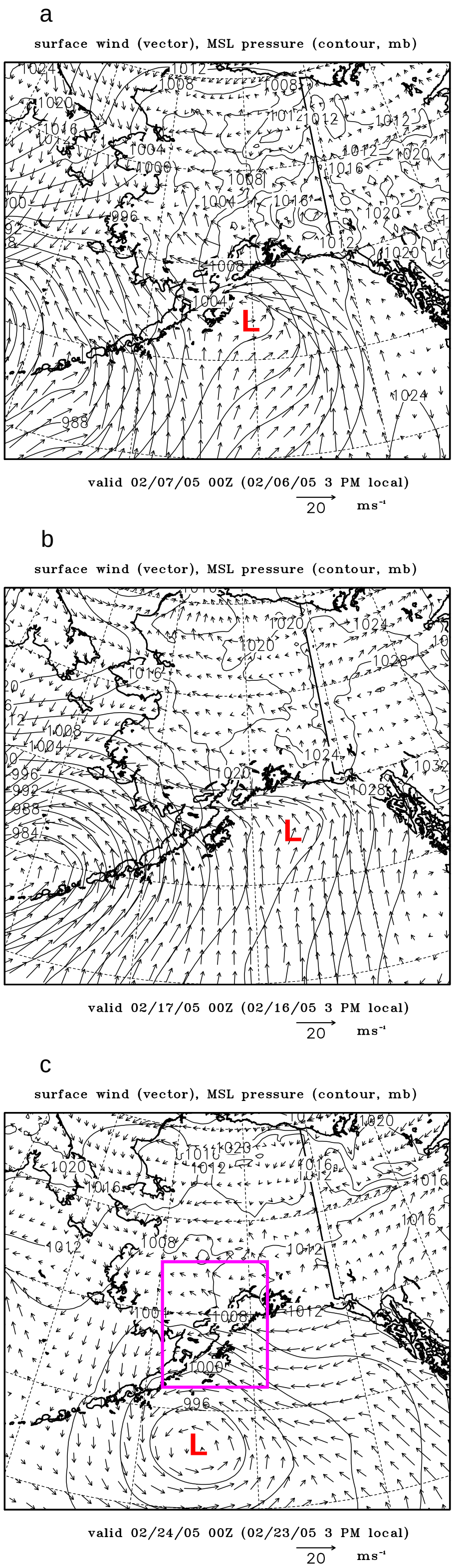

Fig. 2. Eta surface analysis at 00Z on 7 (a), 17 (b) and 24 (c) Feb. 2005. The magenta rectangle in c shows the geo-location of Fig. 1.

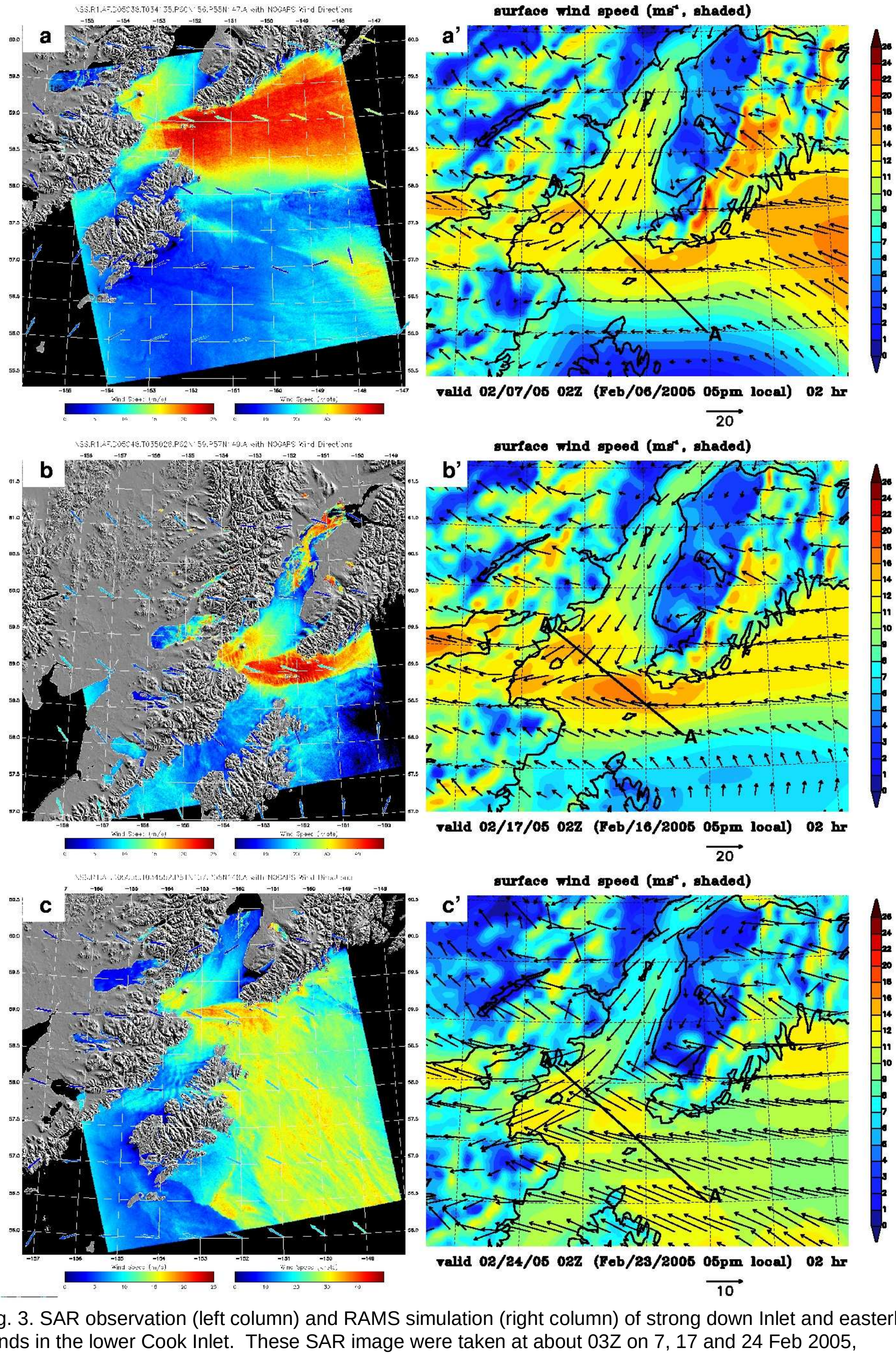

Fig. 3. SAR observation (left column) and RAMS simulation (right column) of strong down Inlet and easterly winds in the lower Cook Inlet. These SAR image were taken at about 03Z on 7, 17 and 24 Feb 2005, corresponding RAMS winds are at 02Z.

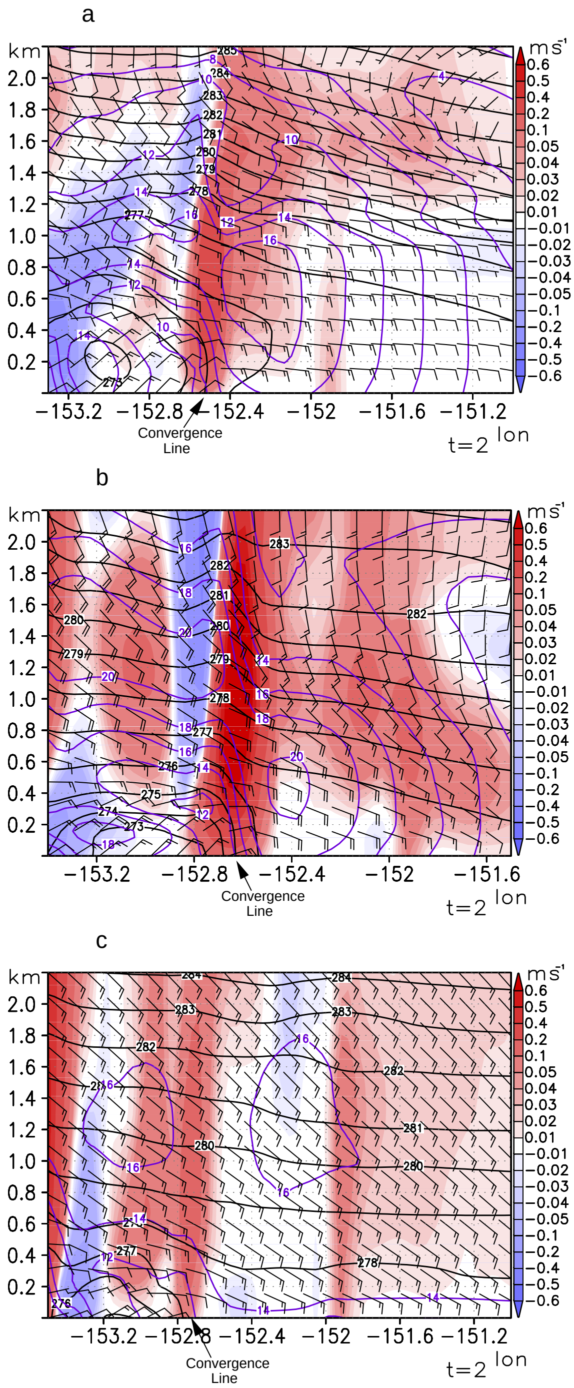

Fig. 4. Vertical cross-section for 07 (a), 17 (b) and 24 (c) Feb. 2005. The location is shown on Fig. 2 by lines AA'. The solid lines are isentropes, the dotted line is wind (ms^{-1}); the shades is the vertical velocity (ms^{-1}).

There are two automated surface observations (C-man stations) at the Augustine Island and the Barren Islands respectively. Table 1 and 2 show the surface wind observations at these two locations Augustine Island and Barren Islands (see Fig. 1 for the location). Note the SAR-wind speed is estimated from the SAR-wind image so only a possible range is given.

There are some differences between the C-man observations, RAMS wind and SAR wind. It seems there is more agreement at Augustine Island. Overall, the direction differences are within 30 deg which is within the error range of 45 deg of onshore and offshore observation (Hsu, 1998). Note that the simulations seem to under-predict wind speed at these locations.

Fig.4 gives the cross-section of these three events at lines AA' on Fig. 3. The location is chosen such that the cross section is normal to the convergence zone between CId and ILAr.

Table1. Wind at Barren Islands at 03Z on February 7, 17 and 24 2005.

Date	C-man WSPD (ms^{-1})	C-man WD (deg)	RAMS WSPD (ms^{-1})	RAMS WD (deg)	SAR WD (ms^{-1})
07/Feb/05	17.5	64	12.4	93	24-25
17/Feb/05	17.0	67	12.8	103	22-23
24/Feb/05	9.7	95	10.3	105	15-16

Table 2. As Table 2 but Augustine Island.

Date	C-man WSPD (ms^{-1})	C-man WD (deg)	RAMS WSPD (ms^{-1})	RAMS WD (deg)	SAR WD (ms^{-1})
07/Feb/05	14.4	49	12.6	71	14-15
17/Feb/05	13.3	48	13.5	61	15-16
24/Feb/05	11.8	54	10.8	69	12-13

Fig. 4a gives a view of flows on 7 Feb from the surface to the height of more than 2000 m. The surface convergence line is at about 152.5W, above which the upward vertical velocity is vigorous. The flows have the same direction above 500 m which indicates the depth of CId. Similarly, Fig. 4b is for 17 Feb. 2005. The surface convergence line is at 152.7W, the depth of CId is about 400 m. The high resolution simulation (1 km grid spacing) will show more details in the next section. Fig. 4c is for 24 Feb. 2005. This is a weak event, the depth of CId is less than 200 m height. The surface convergence line is at 152.7W.

4. VERY-HIGH-RESOLUTION SIMULATION

Fig. 4 shows some characteristics of the surface front: zero-order discontinuities in density (temperature) and wind velocity (Shapiro and Keyser, 1990) in the convergence zone for all three cases. However, the fine structure along the convergence zone is dim, e.g. the vertical velocity is less than 0.8 ms^{-1}. From the plot of observed cases (Shapiro and Keyser, 1990), the scale of these fine structures is on the order of a few hundred meters to 1 km. Therefore, we conducted a very high-resolution (1km grid spacing) simulation for the case of 17 Feb. 2005. The fourth nested grid of 202 by 202 points covering the whole lower Cook Inlet region was included in addition to the previous 3 nested grids. The plots from the model output are shown on Fig. 5.

Fig. 5a is the 2 dimensional plot of the horizontal wind speed, temperature and sea level pressure. A very narrow zone of about 3 km width formed between CId and ILAr in lower Cook Inlet. The CId side is 2° warmer than the ILAr side. Compared to the 4 km simulation (Fig. 3b'), the winds are stronger in the 1 km simulation that the areas with high speed are larger, the edge of convergence zone is sharper, more closely resembling the SAR-wind image.

Fig. 5b shows the near "zero-order" discontinuities in density and wind velocity between air masses from

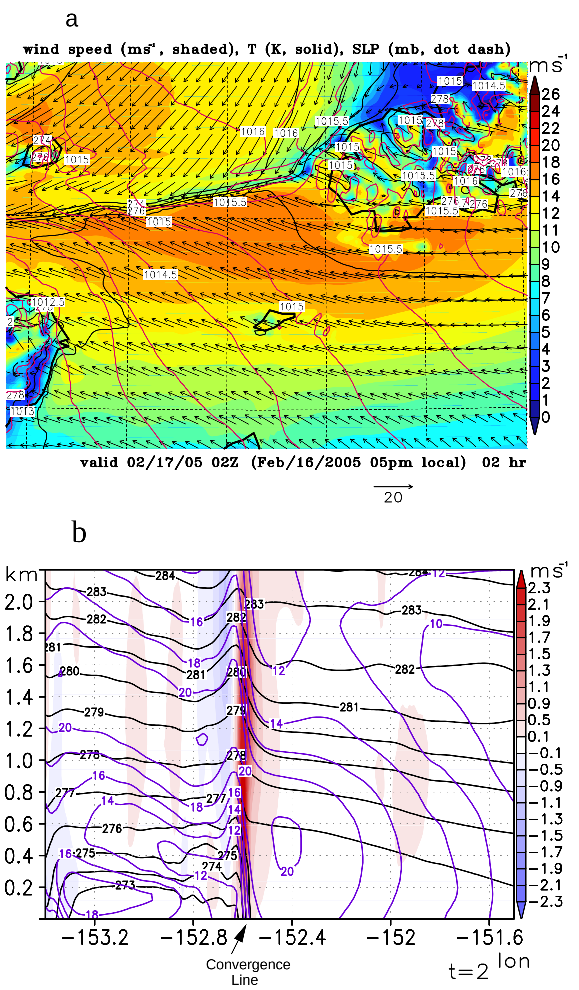

Fig. 5. The very-high-resolution simulation of the case on 17 Feb 2005. a: the horizontal plot of surface wind (shaded), temperature and sea level pressure; b: the cross-section along the same line for Fig. 4b.

CId and ILAr. It also shows the vertical velocity of as high as 2.3 ms^{-1} at the convergence zone. The high vertical movement reaches as high as 1800 m above the sea surface. It is clearly a hazard to the aviation traffic in this region.

5. CONCLUSIONS

The North Gulf of Alaska is a wind-prone area. Low pressure systems traversing through the Gulf induce strong winds in the coastal region. The three events considered here show that the strong down Inlet wind converges with the strong easterly wind in the lower Cook Inlet and create strong vertical velocities and associated turbulence up to 2000 m height which is a hazard to the local aviation. The southerly down Inlet jet is a down-gradient flow resulting from the confining terrain bounding Cook Inlet on both sides. The strong easterly wind is in some cases a barrier jet caused by the blocking of the Kenai Peninsula to the easterly flow from the Gulf and in others a gap wind crossing the gap between the Kenai Peninsula and the Kodiak Island. The depth of these down Cook Inlet jets is less than 500 m. Therefore the interaction zone is shallow. The 4 km resolution RAMS winds show similar horizontal structure as the SAR-derived wind while the 1 km very-high-resolution simulation showed more agreement.

6. ACKNOWLEDGMENT

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