J8J.2 USING SYNTHETIC APERATURE RADAR (SAR), MODELING, AND A SARJET FIELD STUDY TO UNDERSTAND THE TERRAIN-ENHANCED FLOWS ALONG THE SOUTHEAST ALASKAN COAST

Brian A. Colle and Joseph B. Olson
Stony Brook University / SUNY

Nathaniel S. Winstead
Johns Hopkins University Applied Physics Laboratory

Kenneth Loescher and George Young
Pennsylvania State University

Nicholas Bond
JISAO – University of Washington.

1. INTRODUCTION

The low-level flow near steep coastal terrain is often complex and can be quite intense. This is particularly the case for the Gulf of Alaska, where frequent, landfalling storms, local terrain, and cold, Arctic air from interior Alaska interact to produce strong coastal winds to near hurricane force at times. Specific phenomena that produce these winds include gap flows, barrier jets, and the interaction between them. The resulting locally severe winds clearly pose a significant hazard to the marine and general aviation interests in coastal Alaska but unfortunately there are limited observations in the coastal zone to now-cast such winds.

During the cool season, extratropical cyclones over the Pacific Ocean frequently make landfall along the southeast coast of Alaska. Interaction of these synoptic scale disturbances with the steeply rising coastal terrain (see Fig. 1) can result in the development of high winds oriented primarily in the along coast direction. Such flows are classically referred to as barrier jets (Parish 1982, Doyle 1997). Barrier jets are induced when stably stratified air directed toward a terrain barrier becomes blocked and accelerated down the along-barrier pressure gradient.

Corresponding author address:
*Dr.*Brian A. Colle, Inst. For Terrestrial and Planetary Atmospheres, Stony Brook Univ. / SUNY, Stony Brook, NY 11794-5000
e-mail: brian.colle@stonybrook.edu

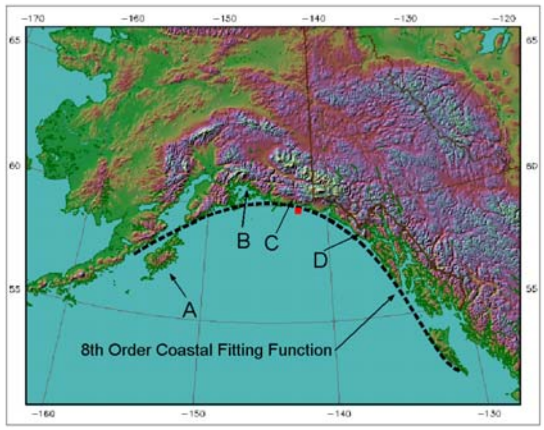

Figure 1. Topographical map of southern Alaska. The solid line is the coastal fitting function created for use in computing the spatial distribution of barrier jets. Locations A, B, C, and D, correspond to Kodiak Island, Prince William Sound, Valdez-Cordova mountains to the northwest of Yakutat, and Mount Fairweather near Glacier Bay National Park, key features in the creation of many barrier jets and hybrid jets. The red square at 60°N 142.5°W is the location of the NCEP reanalysis data point used for the analyses in section 3 (figure 1 from Loescher et al 2005).

2. CLIMATOLOGY

While the basic processes governing barrier jets have been long understood, there are multiple outstanding issues regarding the specific morphology of these phenomena for more three-dimensional terrain – particularly when they interact with other phenomena such as gap flows. The coastal terrain of southeast Alaska has numerous fjords (gaps) and isolated peaks (Fig. 1); making Alaska the ideal place to study barrier jets and their interactions with other mesoscale phenomena. Recently, the authors have completed a climatology of barrier jets in the Gulf of Alaska based on a long record of synthetic aperture radar imagery over the Gulf of Alaska. Details of this climatology work can be found in Loescher et al (2005) and Colle et al (2005); however, the major findings are summarized here.

Loescher et al (2005) describes the morphology and structure of the surface marine expressions of each of several types of barrier jets (Fig. 2). Loescher et al found that the majority of coastal barrier jets occur during the cool season (September – March) with the coastline near Mount Fairweather and the Valdez-Cordova Mountains experiencing the greatest number. They noted a subclass of barrier jets, hybrid jets, which are observed when cold, continental air from interior Alaska is fed into coastal barrier jets through gaps in the local terrain, especially during the cool season. The favored locations for hybrids are west of Cross Sound, Yakutat Bay, and Icy Bay. Loescher et al also found another subclass, shock jets, whose offshore wind speed gradient is much sharper than the classical barrier jet conceptual model. These results are summarized in Figure 3. Finally, variable jets are marked by significant horizontal variability along the offshore edge.

Colle et al (2005) constructed large-scale and sounding composites for all barrier jets objectively identified around Yakutat, AK (YAK) using the daily NCAR reanalysis and twice-daily soundings at YAK and Whitehorse, YT (YXY) located a few hundred kilometers to the northeast. They found that each type of jet has a significant large-scale and thermodynamic signal, which may be useful for forecasting these events. Some key findings include:

- Jet events are associated with an anomalously deep upper-level trough approaching the Gulf of Alaska and an anomalous ridge over western Canada and interior Alaska. (Figs. 4 and 5)
- Large cool and dry anomalies exists over the interior at YXY, especially for shock events.
- Variable jets are associated with weaker low-level stability

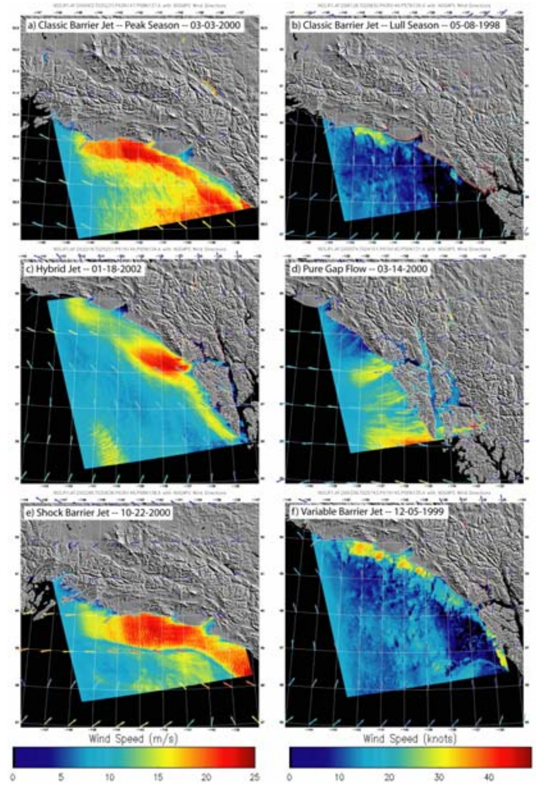

Figure 2. *SAR derived surface wind speed analysis of: (a) A classic barrier jet in March 2000 (b) A lull season barrier jet. (c) A hybrid jet. (d) Pure gap flow. (e) A shock barrier jet. (f) A variable jet. (Fig. 2 from Loescher et al 2005)*

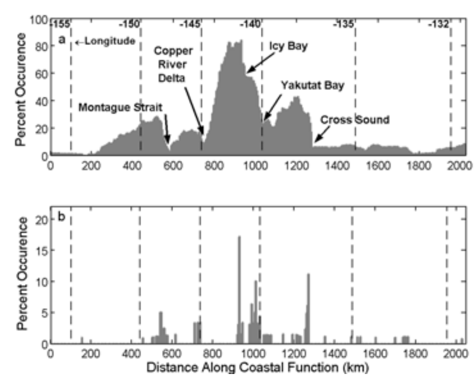

Figure 3. Spatial climatology of hybrid jets shown as the percent of all such cases found at each location along the coastal function (a). The percent of all hybrid jets that started at a particular location is shown in b (from Loescher et al 2005)

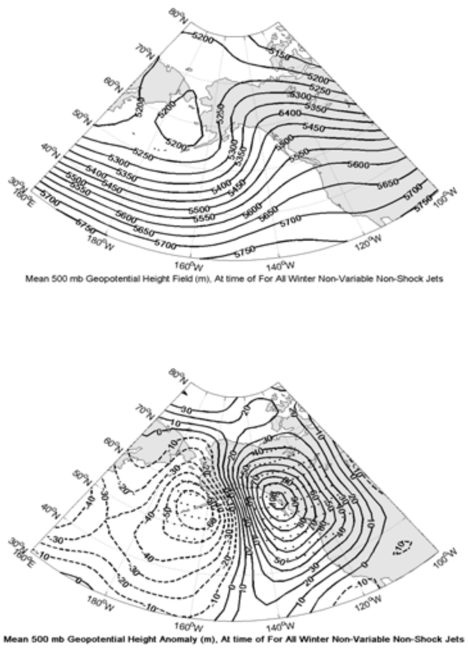

Figure 4. 500 mb height field (a) and anomaly (b) associated with non-variable, non-shock jet events during the winter months (Fig. 3c and 3d from Loescher et al 2005).

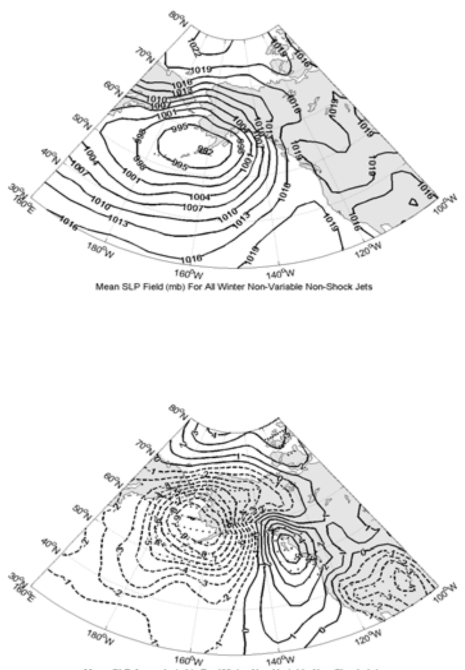

Figure 5. Mean sea-level pressure (a) and anaomaly (b) associated with non-variable, non-shock jet events during the winter months (Fig. 4c and 4d from Loescher et al 2005).

3. SARJET CASE STUDIES

The new subclasses of barrier jets identified by the climatology suggest that the dynamics associated with barrier jets is substantially more complicated than the classical model. As a result, the Southeast Alaska Regional Jet Experiment (SARJET) field campaign was conducted between 24 September and 21 October 2004. The objective of this field work was to obtain *in situ* observations of the boundary layer flow using flight measurements obtained from the University of Wyoming's King Air research aircraft. The King Air was well-suited for this type of work – its measurements of not just the mean flow, but also turbulent and cloud microphysical properties, are allowing unprecedented characterization of the important aspects of coastal barrier jets documented in the climatology papers summarized in section 2.

SARJET was very successful. There were a total of 11 IOP's, four of which included double flights by the King Air. In this paper we highlight preliminary results from just two of the IOPs.

The PSU-NCAR MM5 (version 3.6) was used to simulate several of the IOPs at 36, 12, and 4-km grid spacing using a one-way nest interface and 33 vertical sigma levels. The 6-h GFS analyses were used to initialize the MM5 and supply boundary conditions. In addition, four-dimensional data assimilation (nudging) was applied to the MM5 at 36- and 12-km grid spacing during the 36-h forecast using the GFS analyses in order to mitigate model drift in the synoptic field. The MM5 was run using the Eta (Mellor-Yamda-Janic) PBL, simple ice microphysics, and Grell convection parameterization on the 36- and 12- km grids.

Two SARJET cases are briefly contrasted here to illustrate the differences between a classical-like jet on 26 September 2004 and a well-defined hybrid jet 12 October 2004. Figure 5 shows an IR satellite image, GFS sea-level pressure analysis, and surface observations at 1200 UTC 26 September 2004. There was a 986 mb cyclone over the Gulf of Alaska, with a strong pressure gradient and southeasterly flow to the southeast of the cyclone along the coast. In contrast, for the 1800 UTC 12 October 2004 event (Fig. 6b), the cyclone was located farther offshore and there was colder air over the interior northeast of YAK. As a result, the coastal flow for the October event was directed more offshore (easterly).

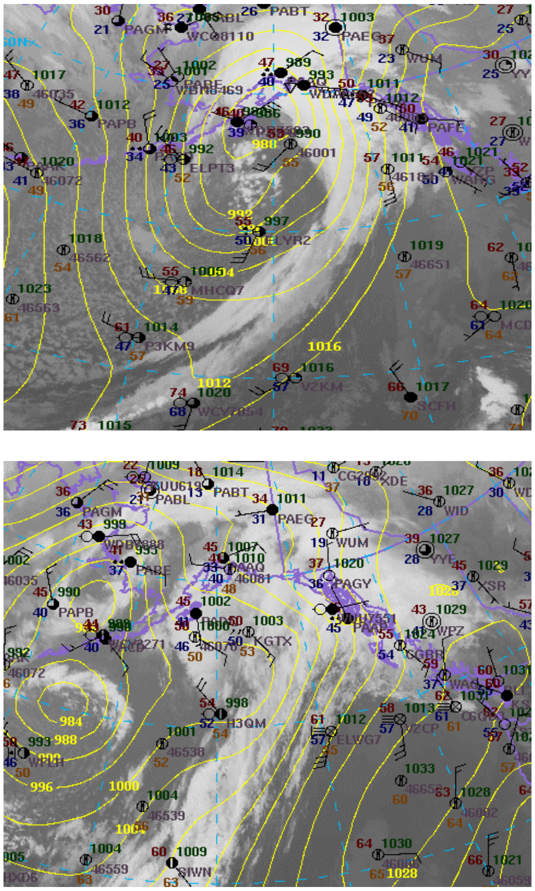

Figure 6. (a) IR satellite, surface observations, and the GFS analysis from (a) 1200 UTC 26 September 2004 and (b) 1800 UTC 12 October 2004.

Some of the mesoscale differences between the two cases are highlighted using the King Air flight-level data. Figure 7 shows the flight-level winds and temperatures at 150 m MSL as well as the MM5 near-surface wind speed and vectors for the IOP area. The observed flow is generally southeasterly at around 20 m s^{-1}, with a few m s^{-1} enhancement near the steepest coastal terrain. The temperatures were around 10 ^{o}C, with little variation away from the coast. The MM5 realistically simulated both the temperatures and winds at this level for this IOP.

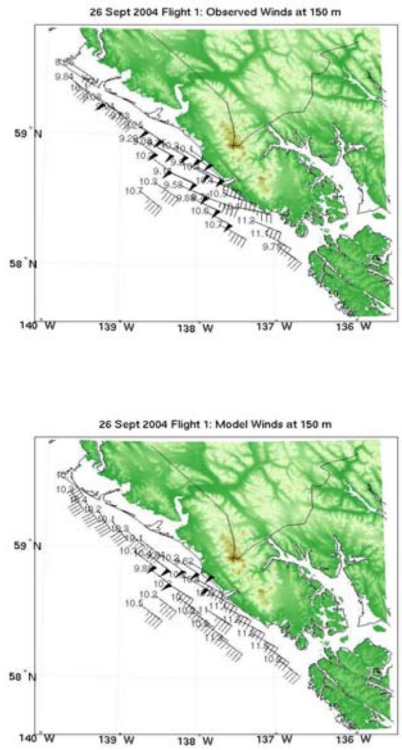

Figure 7. a) IOP07 Flight 1 flight level winds at 150 m altitude around 1800 UTC 12 October 2004, (b) same as (a) except for the 4-km MM5.

In contrast, during the 12 October 2004 IOP at 1800 UTC (Fig. 8), both the model and observations had offshore (easterly) flow out of the Cross Sound gap. The lowest level potential temperatures were also observed in the exit of this gap. However, unlike the classic conceptual model of a barrier jet, there was a warm anomaly along the terrain, not a cold anomaly induced by advection or upslope flow. Model surface winds suggest that easterly flow descended the coastal terrain to create this warm anomaly (Fig. 9). The winds rapidly veered to become coast-parallel along the steepest terrain in both the observations and model. Overall, the comparison between MM5 and the flight-level data is quite good; however, later on in the event the MM5 maintained the cold air and east-southeasterlies too long along the coast (not shown).

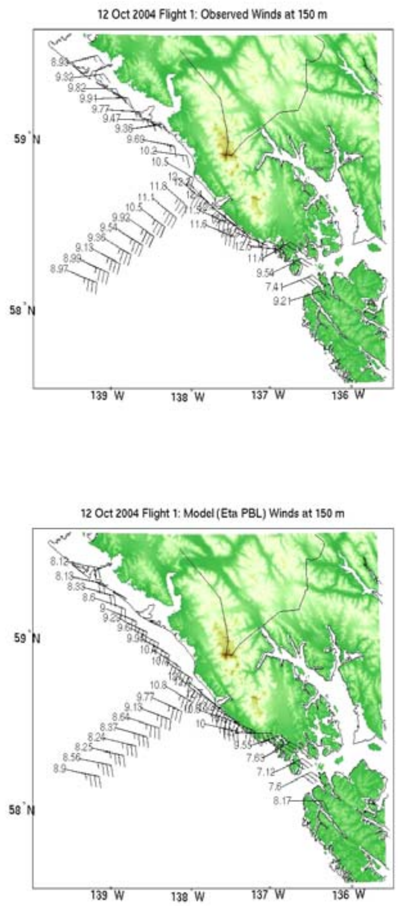

Figure 8. (a) IOP7 Flight 1 flight level winds at 150 m altitude around 1800 UTC 12 October 2004, b) same as (a) except for the 4-km MM5. MM5.

The enhanced area of high winds located just offshore of Mount Fairweather is a hybrid barrier jet. The wind vectors show offshore flow from Cross Sound turning and accelerating down the coast.

4. CONCLUSIONS

Barrier jets in the Gulf of Alaska display a remarkable degree of horizontal and spatial variability and they do not tend to follow the classical conceptual model of terrain blocking. Several new classes of jets have been identified – classical, hybrid, shock and variable jets. Hybrid and shock jets are associated with stronger cool, dry anomalies

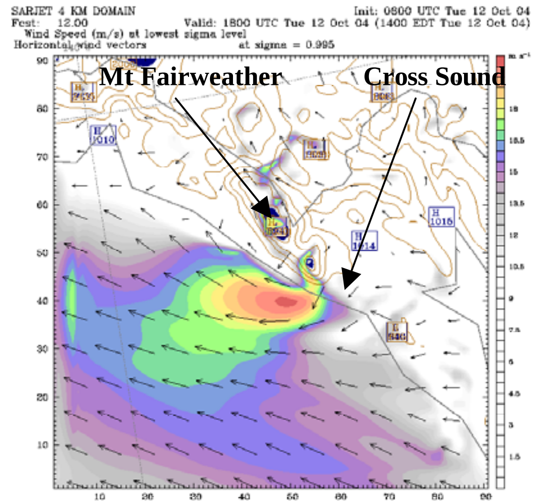

Figure 9. MM5 30-m winds from 1800 UTC 12 Oct 2004 (during flight 1)

on the inland side of the terrain barrier, while variable jets are associated with somewhat weaker low-level static stability.

Using King Air aircraft data from the SARJET field study, preliminary results from 26 September 2004 and 12 October 2004 are presented contrasting some of the differences between a more classical jet (26 Sept) and a pronounced hybrid jet (12 Oct) downstream of Cross Sound and upwind of Mount Fairweather. The MM5 realistically simulated these events, although the model overpredicted the cold anomaly later in the 12 October event. Future work will use the model to better understand the momentum budget of air parcels exiting the gap as they turn and accelerate. Additional future work will involve exploring the role that the PBL parameterization has on the model response as well as further understanding of the dynamics associated with these hybrid jets.

5. ACKNOWLEDGEMENTS

This work was supported by the National Science Foundation – grants ATM-0240869 and ATM-0240402.

6. REFERENCES

Colle, B. A., K. A. Loescher, G. S. Young, and N. S. Winstead, 2005: Climatology of barrier jets along the Alaskan Coast, Part II: Large-scale and sounding composites. *Mon. Wea. Rev.* In Press.

Doyle, J. D., 1997: The influence of mesoscale orography on a coastal jet and rainband. *Mon. Wea. Rev.*, **121**, 1493-1513.

Loescher, K. A., G. S. Young, B. A. Colle and N. S. Winstead, 2006: Climatology of barrier jets along the Alaskan Coast, Part I: Spatial and temporal variations. *Mon. Wea. Rev.* In press.

Parish, T. R., 1982: Barrier winds along the Sierra Nevada Mountains. *J. Appl. Meteor.*, **21**, 925-930.