MECHANISMS OF WIND CHANNELING IN THE HUDSON VALLEY, NY.

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1. Introduction:

This study presents preliminary results from the Hudson Valley Ambient Meteorology Study (HVAMS). One of the goals of HVMAS is to understand the surface wind regime in this region. The above predominant climatological winds are westerly, but in the Valley most of the surface winds are in the along valley direction. This channeling is related to an along valley pressure gradient (Fitzjarrald and Lala, 1989). Previous studies have focused on the mechanisms for wind channeling in valleys (Gross and Wippermann, 1987; Whiteman and Doran, 1993; Webber and Kaufmann, 1998). Whiteman and Doran (1993) identified four mechanisms responsible for wind regimes in a valley: thermally driven, forced channeling, pressure driven, and downward momentum transport. In this study, we will focus on pressure driven and forced channeling, since there is no evidence of diurnal/nocturnal changes in the valley wind direction and that there is no wind channeling when the vertical mixing is too strong. We aim to detect the controlling surface pressure gradients (along and cross valley) using data from a network of surface weather stations.

2. Location and instrumentation:

The study region, the mid Hudson Valley, is located from –74.1 to –73.6 ^{0}W and 41.6 to 42.8 ^{0}N. Valley walls range mostly from 200-300m with the highest peak reaching over 1000m in the West wall (the Catskill Plateau) (figure 1). The valley is about 40 km wide and its aspect ratio is similar to the valleys Whiteman and Doran (1993) and Grossman and Wipperman (1987) investigated. The along valley axis has an azimuth angle of 8.517^0. During September to October 200 a network of 9 flux towers (PAM stations) from NCAR/ISFF group (www.atd.ucar.edu/rtf/projects/hvams03/) were assembled in the valley.

Among other instruments, the PAM stations collected wind data using 3D sonic anemometers (Campbell Sci., model CSAT3) at 7 m.

The transmission factor (TF) can be used to assess obstructions, such as buildings and trees, to the flow that will affect the wind field (Fujita and Wakimoto, 1982). In this case, the TF is used to assess the sheltering of each station in comparison to the whole network. This technique compares the wind at a given station from a given direction to the maximum wind observed in the network from that direction. Thus, a TF=1 indicates an open direction, and TF=0 an obstructed direction. Figure 2 shows the TF for the entire PAM network, and all stations present along valley wind channeling but station 7. According to figure 1, station 7 is most sheltered station by the West wall.

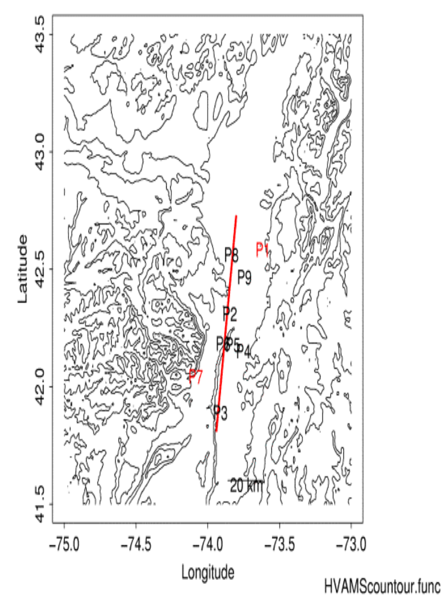

Figure 1: Topography of the study region and location of the surface stations. Numbers 1 to 9 correspond the location of PAM towers. The thick straight line is the along valley axis.

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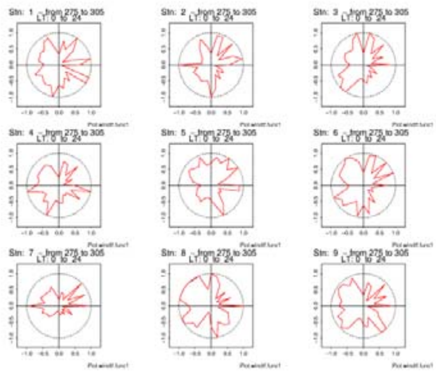

Figure 2: Transmission factor for the PAM network

On six PAM stations (stations 2, 3, 4, 6, 8, and 9) high-resolution microbarographs at 2 m (Setra, model 270) were installed with static pressure heads (Vaisala, model SPH10) to minimize the dynamic pressure. Before the field installation, an intercomparison among the microbarographs was performed. In the lab, an accuracy of 0.05 mbar among the instruments was attained. According to the manufacturer, the SPH10 reduces the error of the dynamic pressure to less than 0.1 mbar if the wind is less than or equal to 10 m/s and the attack angle of the flow is between –10 to 10^0.

3. Data Analysis.

During the field experiment, about 81% of the surface wind directions were aligned with the valley axis. However, winds aloft usually have another direction (figure 3). This along-axis channeling in the valley can be explained by 2 major mechanisms. The first mechanism is forced channeling; the cross-valley component is blocked or reduced by the valley walls. Thus, the along-valley component will determine the wind direction in the valley. The second mechanism is pressure driven channeling. As the air aloft enters the valley, it decelerates and the imbalance in the geostrophic wind will force a leftward deflection in the wind direction (Eckman, 1998). The pressure driven mechanism is the only one that explains counter currents or valley reversal flows, i.e., the wind direction in the valley is the opposite of the wind direction aloft. Table 1 shows the distribution of the surface southerly and northerly winds in the valley. For 850 mb Westerly winds, there are more valley northerly winds, indicating that forced channeling prevails over the pressure driven mechanism. The presence of the Mohawk Valley on the Northwest wall also helps for this scenario. However, counter currents indicate the presence of the pressure driven mechanism as well. In 8 cases there is no explanation of the wind behavior. In all cases the mean wind speed of the entire network was less than 1 ms^{-1} indicating that local effects are more important.

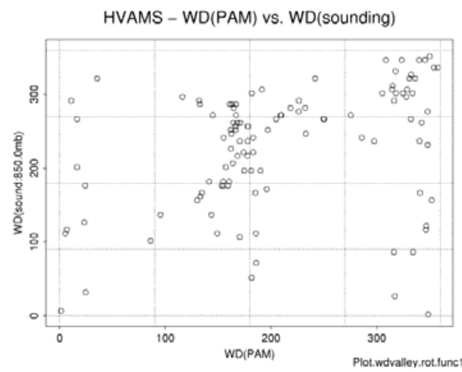

Figure 3: Scater plot of the 850 mb meteorological wind direction from air soundings launched in Albany airport versus the mean PAM network surface wind direction. Both wind direction are rotated to the axis valley (fig. 1), so a 0^0 wind direction comes from the North of the valley (northerly) and 180^0 from the South of the valley (southerly).

Table 1: Occurrence of southerly and northerly valley winds. WD(850) is the wind direction at 850 mb, "FC" is forced channeling, "PD" is pressure driven, "?" represents unknown mechanism. "*" represents the counter current events.

WD(850)	Northerly	Southerly
0 to 90^0	6 (FC, PD)	2 (?)
90 to 180^0	8(PD) *	9 (FC)
180 to 270^0	6 (?)	28 (FC, PD)
270 to 360^0	20 (FC)	11 (PD) *

The pressure regime within the valley is also investigated. To reduce the microbarograph pressure data into a reference level, an average for a day or more was performed on each station. The use of the pressure perturbation, or the difference between the observed pressure and its mean, levels the studied signal for the entire network. Also, this procedure has the advantage avoiding the problem of instrument offsets, such as for temperature and humidity, and uncertainties regarding station height. The disadvantage is that the reference level is unknown. Gradients are obtained from the regression line of the scatter plot of the pressure perturbation and the location of the stations. Figure 4 shows the pressure gradients and the wind components for the along (v,dp/dy) and cross valley (u,dp/dx). There is an opposite pattern of the along and cross valley gradients. Also it can be seen that dp/dy is inversely proportional to the along wind component. This is consistent with the balance of forces at the surface (figure 5). For instance, if the valley wind vector is negative (v<0), then the gradient pressure should be positive (dp/dy>0), and due to the Coriolis force, the cross valley gradient is also positive. This supports Fitzjarrald and Lala (1989) who especulated the presence of cross valley gradients in the valley. Thus, the presence of this cross valley gradient is associated with a baroclinic layer over the valley, i.e., there is a tilt at some pressure levels leading to one side of the Valley to be cooler than other.

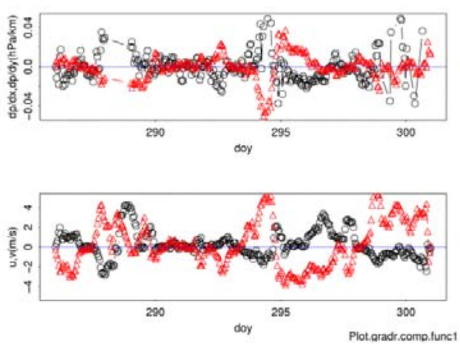

Figure 4: Time series of cross valley (circles) and along valley (triangles) pressure gradients (top). Cross valley (circle) and along valley (triangles) wind components (bottom). "doy" stands for day of the year.

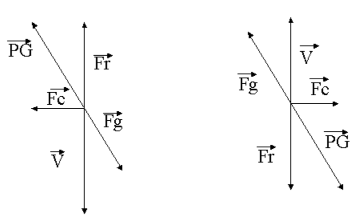

Figure 5: Schematics of the channeled wind and its forcings in the Valley. V is wind velocity, Fc is the coriolis force, Fr is the friction force, Fg is the pressure gradient force, and PG is the pressure gradient.

4. Summary and Future work:

The along valley axis is the preferred wind direction, even when the wind over the valleys has a different direction. Pressure driven and forced channeling mechanisms seem to be the major processes. For southerly valley flow both mechanisms seem to be important. However, for valley northerly wind directions there is a preponderance of forced channeling.

The microbarograph network allowed studying the pressure regime within the valley. The surface wind channeling is accompanied with the along valley gradient pressure. This result is qualitatively consistent with the balances of forces at the surface. The opposite pattern of the cross gradient indicates that there is a tilt in pressure levels in the cross valley section.

Continuing efforts will concentrate on analyzing upper air andother data resources (soundings, sodar, and aircraft data). It will also focus on determining the presence of the tilting pressure levels and the directional shear of the wind. Also, we are going to quantitatively determine magnitudes of the surface balance of forces.

5. Acknowledgments:

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6. References:

Eckman, R.M., 1998. Observations and numerical simulations of winds within a broad forested valley. *J. App. Meteo.*, **37**, 206-219.

Fitzjarrald, D.R., Lala, G.G., 1989. Hudson Valley fog environments. *J. App. Meteo.*, **28**, 1303-1328.

Fujita, T.T., and Wakimoto, R.M., 1982. Effects of miso- and mesoscale obstructions on PAM winds obtained during project NIMROD. *J. App. Meteo.*, **21**, 840-858.

Gross, G. and Wippermann, F., 1987. Channeling and countercurrent in the upper Rhine valley: numeric simulations. *J. of Clim. and App. Meteo.*, **26**, 1239-1304.

Whiteman, C.D., and Doran J.C., 1993. The relationship between overlying synoptic-scale flows and winds within a Valley. *J. App. Meteo.*, **32**, 1669-1682.

Webber, R.O., and Kaufmann, P., 1998. Relationship of synoptic winds and complex terrain flows during MISTRAL field experiments. *J. App. Meteo.*, **37**, 1468-1496.