**From:** Stuart Stothoff
**Sent:** Wednesday, March 21, 2007 4:10 PM
**To:** Randall Fedors; Eugene Peters
**Cc:** Hakan Basagaoglu; 'Robert Lenhard'; 'cmanepally@swri.edu'
**Subject:** RE: SPAM::Re: mountain evaporation

Randy

I was aware that Ed Weeks had done some work, and in fact the blowing borehole reference was offered by Ed at the UZFM expert elicitation.

The Weeks (1987) paper mentions that during the winter the UZ-6 and UZ-6S boreholes consistently exhaled at 3 m/s, but the direction of flow fluctuated several times a day during the summer and atmospheric air penetrated to approximately 30 m. Weeks attributes the winter exhaling to the density difference between cold atmospheric air and warm mountain air forming a circulation in at low elevation and out on the crest, but expects that summer should see exactly the opposite pattern. Interestingly, the YMP-2 met station shows the strongest east-west pattern in the summer, which would induce the strongest upward flow. Upward flow appears to be dominant in the afternoon (when winds are strong) and downward flow is dominant at night (when winds are calm and the atmosphere is most stratified). This suggests that the two factors are roughly equal in magnitude. It also suggests that evaporation due to air movement may be most significant during the winter.

The North Ramp document reports some heat and gas flow simulations near the end of the document, considering topography-induced pressure changes (but not wind-induced changes) with annual-average temperatures. The North Ramp document also notes that condensation would occur under the ridges. The cited value for vapor flux corresponds to 0.006 mm/yr. If Weeks' analysis is correct, the implication is that winter fluxes and summer fluxes may be much larger, but in opposite directions. The wind hypothesis would tend to counter the large fluxes in summer, implying that net fluxes may be much larger than the North-Ramp analysis suggests. Nevertheless, even an increase of three orders of magnitude is less than the equivalent of 1 mm/yr of flux.

stu

> -----Original Message-----
> **From:** Randall Fedors [mailto:RWF@nrc.gov]
> **Sent:** Wednesday, March 21, 2007 12:07 PM
> **To:** Stuart Stothoff; Eugene Peters
> **Cc:** Hakan Basagaoglu; Robert Lenhard; cmanepally@swri.edu
> **Subject:** SPAM::Re: mountain evaporation
>
> Did you check out the field work by the USGS (Ed Weeks) on the paired boreholes near Highway Ridge road. This is documented in an AGU monograph (thanks to Bradbury), 2nd edition. Also, I think the North Ramp Study mentions the zones of decreased saturation where there is no soil cover. There might be some observations worth assembling from that study.
>
> If need be, I can follow up with more complete references.

--Randy

>>> Stuart Stothoff <sstothoff@cnwra.swri.edu> 03/21/2007 1:58 PM >>>
Gene, Randy

I've done just a little back-of-the-envelope thinking on the issue of mountain evaporation. I find it implausible that there would be a significant reduction in deep percolation due to evaporation in the Tiva Canyon formation.

Two processes may induce bulk air movement within the bedrock or enhance vapor movement. Wind flowing over the mountain may induce bulk air movement through the fractured bedrock, which would advect vapor from the mountain. Barometric pumping may slosh air in and out of the mountain, which effectively increases the diffusion of vapor within the air phase. In either case, air moving into the soil will tend to be relatively dry and air moving out of the soil will tend to be essentially vapor-saturated.

In the case of bulk air movement, the dry incoming air becomes vapor-saturated very quickly as soon as it passes into a region of soil or bedrock that has appreciable moisture. Vapor saturation probably occurs within the rooting zone. Appreciable vapor-pressure lowering due to capillarity requires that the conditions are quite dry, and I would have a hard time imagining that significant vapor-pressure lowering occurs more than a meter into the bedrock if there is any soil cover at all. Once the air is vapor saturated, the only reason for appreciable change in vapor density is due to temperature changes. If the air moves from cold to hot, evaporation occurs; from hot to cold, condensation occurs. So the net effect of bulk movement of air is to remove moisture from the rooting zone, where air enters and saturates, plus some evaporation or condensation due to thermal changes.

In the case of barometric pumping, air moves in and out, but the volume of air moving is probably quite small since air is almost incompressible. This pumping again tends to remove moisture from the surface of the mountain where entering air first saturates.

The dominant wind patterns at YM depend on local effects, and are typically aligned with dominant wash directions. In Fortymile Wash, for example, winds are almost always north-south, whereas YMP stations 1 and 2 (NTS 60 and northern Yucca Crest, respectively) are more affected by the large washes north of YM and have some easterly and westerly components as well as the north-south component.

Two wind patterns are of interest. A pure north-south wind would tend to primarily influence the ridges on the east flank of YM, whereas an east-west or diagonal wind would tend to have a larger influence due to the exposed

Solitario Canyon face, potentially influencing all of the Tiva Canyon.

Perhaps the largest influence would occur during a wind from the east, even though this may not be prevalent. Kaushik tells me that in this case, wind moving up the east flank would form a vortex in Solitario Canyon, thus the tendency would be for air moving up the west flank as well. Continuity requires that the pressure drops from the base of the mountain to the crest (this is true on both flanks), and the drop in velocities on the west flank implies that pressures are larger on the west flank than on the east. I ran a test case qualitatively describing the exposed TCw with a no-flow boundary for the PTn and dirichlet conditions qualitatively agreeing with this pressure scenario. Perhaps not surprisingly, air flow within the mountain tended to follow the direction of air movement at the ground surface, with inflow all along both flanks and outflow at the crest. The trend is for air to move from hot to cool, based on the geothermal gradient. Accordingly, I would expect that whenever air comes from the east or southeast there will be a tendency to dry the surface crust, condense a small fraction of this vapor within the mountain due to the geothermal gradient, and carry the remainder out the crest.

The one data point I have is an anecdote about strongly upward flowing air in one or more open boreholes along the crest, consistent with the simulation.

It's not so clear that the situation is completely analogous when wind comes from the west, because of the shape of the mountain and because of Jet Ridge, but I would expect some of the same analysis to hold with greatly reduced flows. And for purely north-south winds, the effect would be limited to the ridgetops on the eastern flank because the topography shelters the washes, so the effect may be even less important.

So all in all there is little basis to expect that the process of evaporation would cause deep percolation to be significantly reduced relative to the net amount of water passing into the bedrock below the rooting zone, and if anything bulk air movement would tend to increase the water in the bedrock away from the rooting zone.

However, enhanced evaporation due to air movement may play a role in reducing infiltration relative to current numerical models, because the current models do not account for enhanced drying of the soil due to bulk air movement. Such drying would tend to reduce the antecedent water saturation for individual storms, which would increase storage capacity and reduce infiltration. I suspect that this is not a huge player in the overall balance, since infiltration is dominated by large winter storms or storm sequences and such drying may not be important in this case.

I hope this helps clarify the situation. Give me a buzz with questions.

stu

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**From:** Stuart Stothoff

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