How is subcanopy moisture transport related to wind stability in a typical even-aged, plantation conifer forest?

Increasing daytime stability enhances downslope moisture transport in the subcanopy of an even-aged conifer forest in Western Oregon, USA

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Do summer temperatures affect moisture and heat movement in, out, and within forest canopies and subcanopies? Researchers examined how the transport of moisture and heat into, out of, and within a forest subcanopy were influenced by summertime heating of the upper canopy. They measured moisture concentration, heat, and airflow. This study focused on a plantation forest in a steep mountain valley, which the authors considered to be representative of many Pacific Northwest managed forests.

Did wind direction and speed change with time of day?

Above canopy winds moved down valley during the night and up valley during the day and were more turbulent than below canopy winds. Below canopy winds moved down valley or down slope during the daytime as well as during the night.

Wind patterns fell into four time categories: daytime flow, evening transition, night conditions, and morning transition. Wind speed increased during daytime flow and decreased during night conditions.

Did wind flow direction differ between sites based on their location relative to the valley axis?

Below canopy winds moved down valley at sites aligned with the axis of the main channel or its tributaries. However, below canopy wind flow was downslope at sites above the valley axis. The site in a canopy opening had variable wind direction.

How was stability, or canopy inversion strength, related to wind speed?

Wind speed is positively related to stability on days with high stability. There is no relationship between wind speed and static stability on low stability days. The standard deviation of vertical wind speed is higher on low stability days. Therefore, more mixing through the canopy may occur on low stability days.

Above canopy winds influenced below canopy winds on low stability days. On high stability days below canopy winds were decoupled from above canopy winds.

Was stability related to water transport or temperature?

On high stability days, the difference in water vapor concentrations below and above the canopy was greater. With less mixing, more water vapor remained below the forest canopy, resulting in greater downslope movement of moisture for a given subcanopy wind speed.

On high stability days, wind speed was positively related to the temperature difference between the up-channel and down-channel sampling sites.

Do regional climate models accurately reflect the airflow, water transport, and temperature gradients found in this study?

Basin-scale sampling by ERA5 Land products do not effectively capture above canopy wind speed or direction and do not accurately describe below canopy wind state for the study area. However, they can be used to differentiate between high stability and low stability days.

How can these findings be used to improve predictions of forest response to climate change?

The results of this study increase understanding subcanopy wind movement and moisture transport that can be used to inform large scale climate models, especially related to predictions about how even-aged plantation forests will respond to changing climate conditions.

A main finding to be incorporated is that the uniform canopy structure of plantation forests increases the likelihood that the subcanopy winds result in net moisture transport out of the watershed.

Research Approach/Methods

- The researchers deployed sensors on tripods at four locations in each of three sub-domains along the valley axis to measure air flow, heat, and water vapor concentrations July through September 2012 in a subbasin of Lookout Creek, a 45 year old, single layer conifer plantation on a steep hillside.
- Additional sensors were mounted on a nearby tower to sample winds above the canopy and to determine subcanopy stability. Researchers composited tower data to determine features that occur at the same time daily.
- Researchers examined how moisture fluxes within and through the canopy are influenced by subcanopy winds and inversions.
- They also utilized basin-scale data collected at five permanent environmental data collection sites in the forest to determine how subcanopy dynamics were related to basin-wide wind patterns.

Keywords subcanopy heat transport, subcanopy moisture transport, subcanopy airflow subcanopy inversions, static stability, regional climate change, downslope airflow, water vapor advection, water vapor transpiration

Images

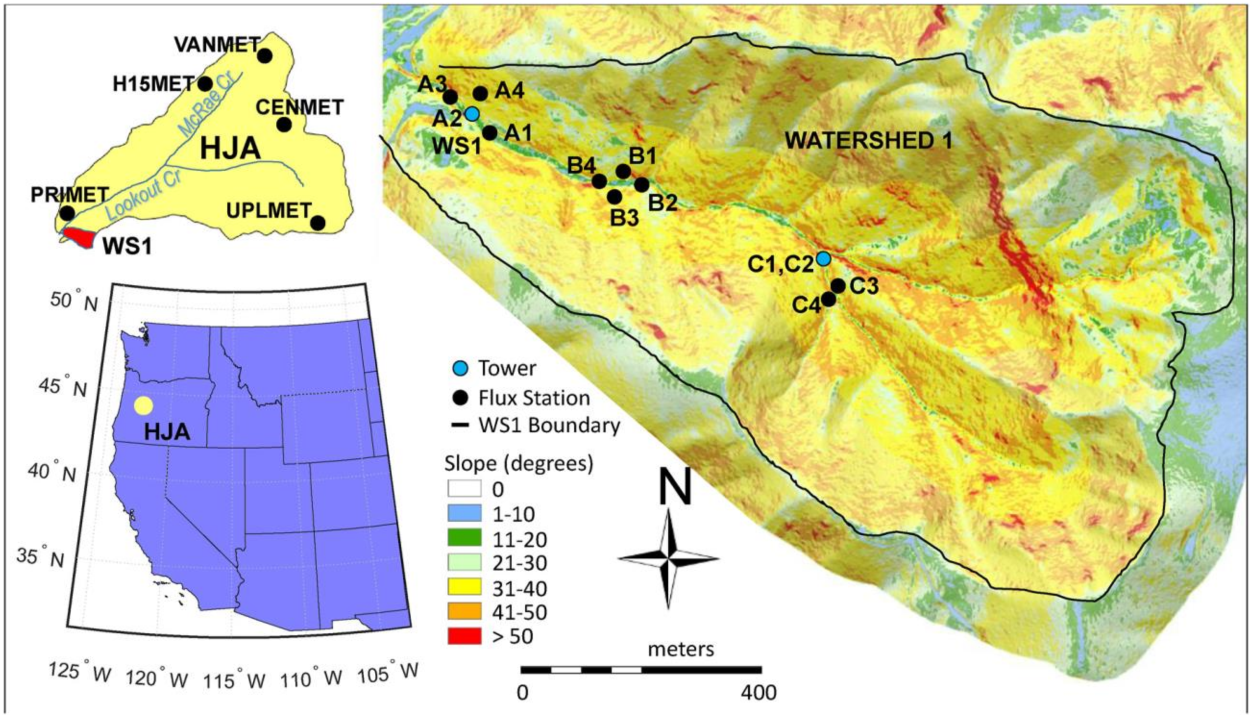

Figure 1 in Drake et al. 2022. Overview maps show the location of the HJ Andrews Experimental Forest in Oregon, the locations of benchmark stations and the Watershed 1 (WS1) tower within the HJ Andrews domain, and flux station locations within WS1 (source: Theresa Valentine, Corvallis Forest Science Laboratory). The WS1 stream drains into Lookout Creek 150 m below station A3.

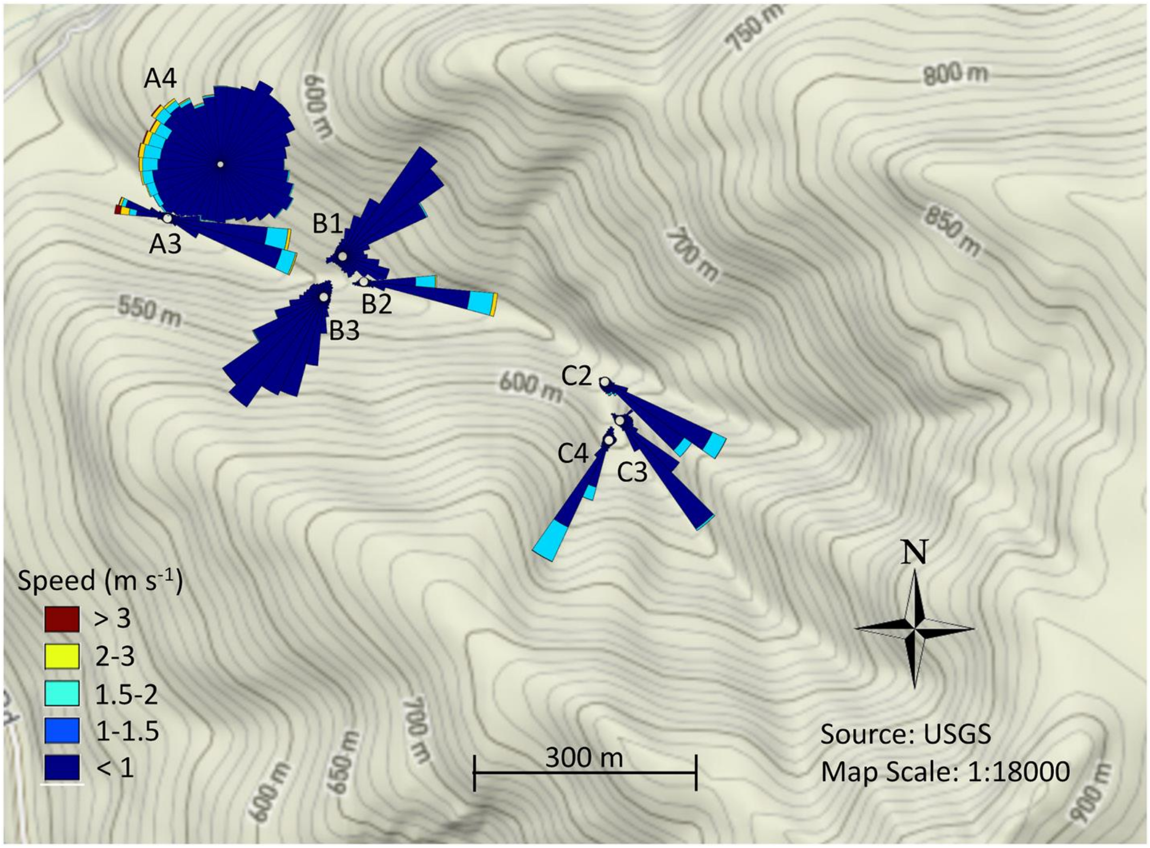

Figure 5 in Drake et al. 2022. Windroses of 1-min averaged winds at 2 m nominal height for subcanopy stations A3, A4, B1, B2, B3, C2, C3, and C4 in Watershed 1. Stations A1 and B4 have very similar windrose shapes as station A3 in Figure 5 but are not rendered to avoid overlapping. Windrose bin sizes are rescaled to avoid overlap and highlight features described in the text (Map source: USGS).

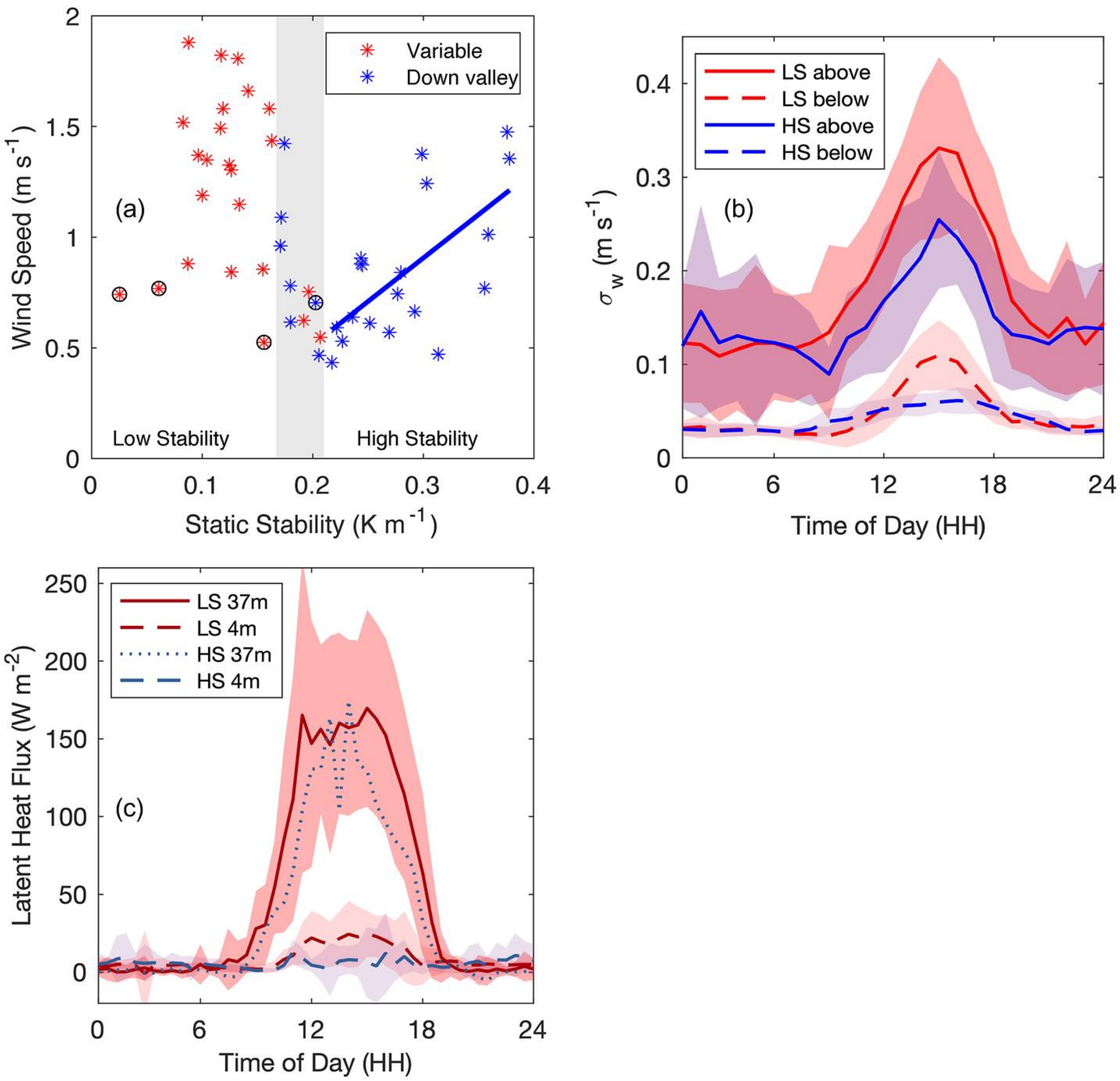

Figure 7 in Drake et al. 2022. Relationship of composite 4 m wind speed to static stability (a); composite σ_ω over the day (b), and composite latent heat flux over the day (c). Panel (a) shows Watershed 1 tower 4-m mean wind speed versus canopy static stability over the 1- to 23-m layer during the time period 13:30 to 14:30 for each of the 50-day IOP. Wind speed is coded by dominant daily wind direction (variable = red or downvalley = blue). Overcast days are circled. (b) Composite standard deviation of the vertical wind speed component by time of day computed at 37 m (above canopy) and 4 m (below canopy) heights for low static stability (LS) and high static stability (HS) days indicated in panel (a). (c) Composite latent heat flux at 4-m and 37 m heights for LS and HS days. Shading in panels (b) and (c) represent ± one standard deviation from the composite.

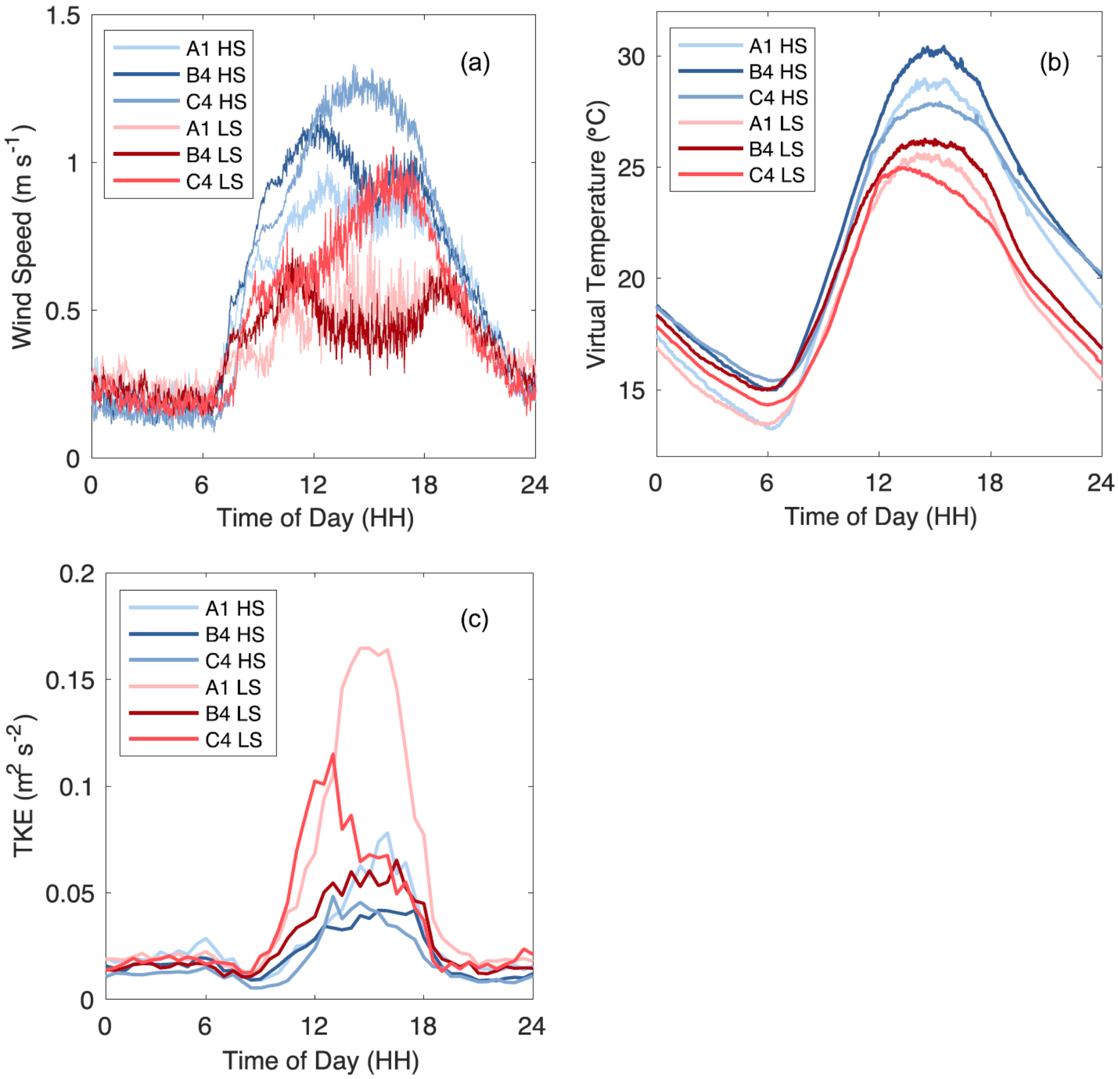

Figure 9 in Drake et al. 2022. Comparison of subcanopy wind speed during high static stability (HS) and low static stability (LS) days at selected stations in Watershed 1 (panel a). In panel (b), subcanopy 1-min averaged virtual temperatures and in panel (c) 30-min averaged Turbulence kinetic energy are compared at the same stations as in panels (a) and (b) for HS and LS days. All measurements were obtained at 2-m nominal height agl.

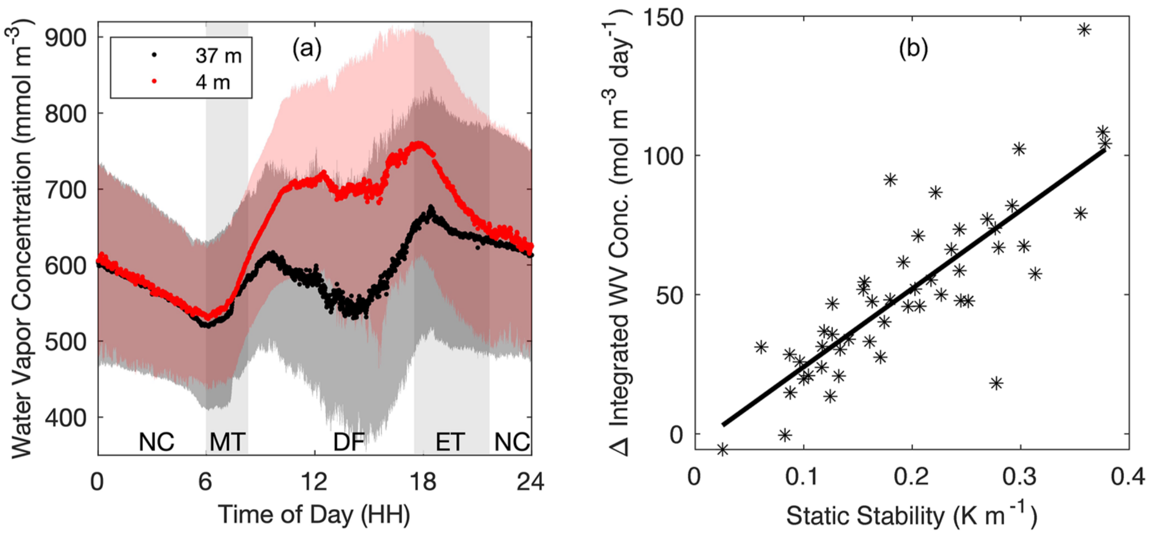

Figure 11 in Drake et al. 2022. Relationship of water vapor concentration to static stability. (a) Composited water vapor concentration over time during the day for high-stability days at 4 m (red) and 37 m (black). (b) Difference in average daily water vapor concentration, 4 m minus 37 m, versus the daily maximum stability (1 hr averaged) for all days in the study period.