On the diurnal development of Sundowner winds in coastal Santa Barbara, CA

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1) Motivation

Coastal Santa Barbara occasionally experiences strong and gusty downslope winds that locally are referred to as **Sundowner winds**. These winds occur on the southern-facing slopes of the Santa Ynez Mountains (**SYM**). Unlike other downslope windstorms (e.g. Bora, Chinook, Foehn winds), Sundowners have a tendency to intensify **near sunset.** It is unknown what drives this typical timing.

The goal of this **study is** to investigate what drives the diurnal manifestation of Sundowner winds. We hypothesize that the 'Sundowner' behavior is explained by interactions between the synoptic flow with the San Rafael Mountains (**SRM**) and boundary layer processes upstream in the Santa Ynez Valley (**SYV**). We investigate this by using WRF 4.0.1 model in the setup of Duine et al. 2019, and by:

- Comparing two case studies with different synoptic conditions driving Sundowners with distinct regional characteristics (hereafter referred to as **western** and **eastern regimes**).
- Gradually removing terrain features upstream of SYM: **Default**, and **terrain reduction** in the range 25-90% of original terrain elevation (see Fig. 1 and 2).
- Increasing **soil moisture values** in the SYV to trigger different PBL structures upstream of SYM.

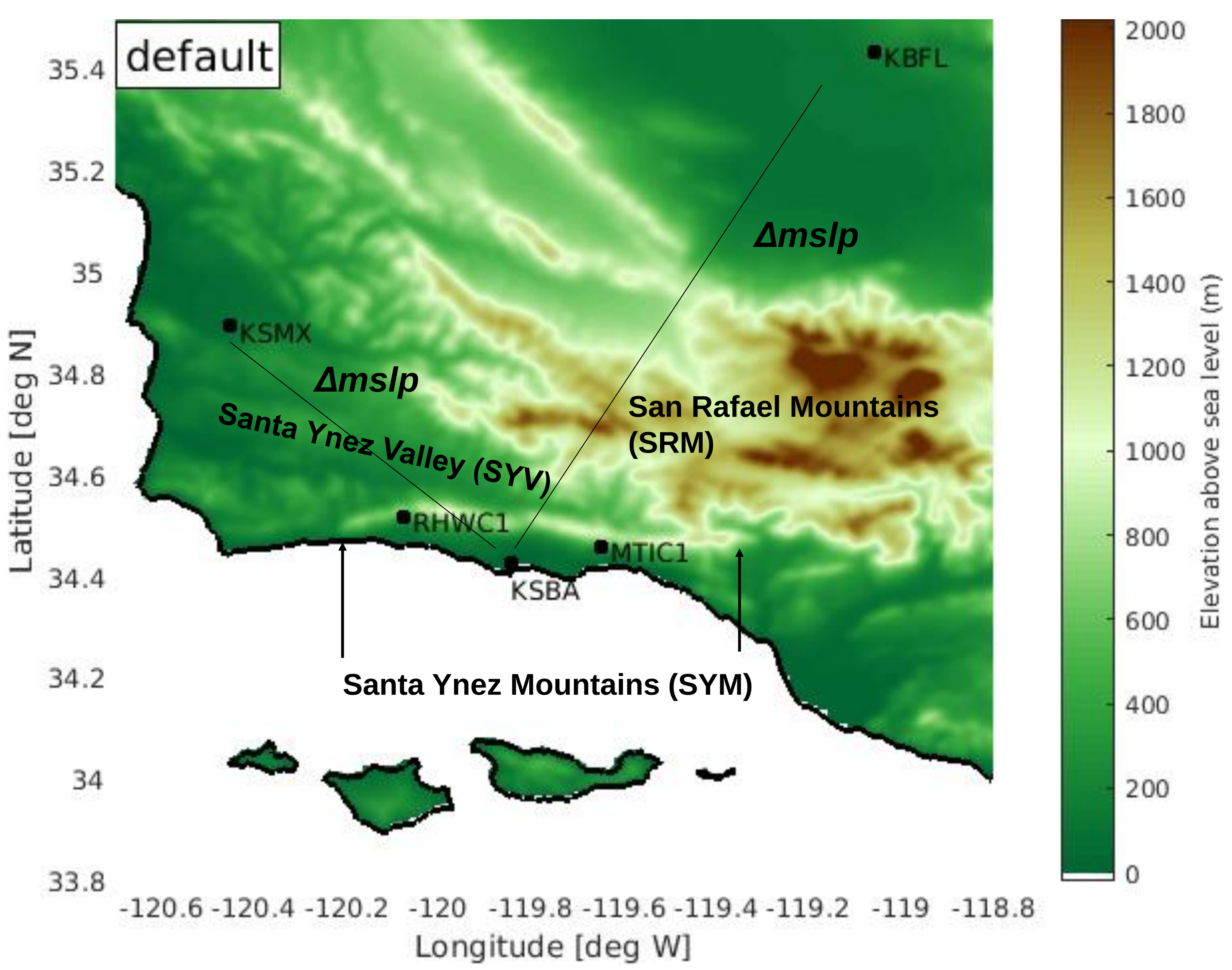

Fig. 1. Terrain elevation of the study area, with important features and locations used in this study.

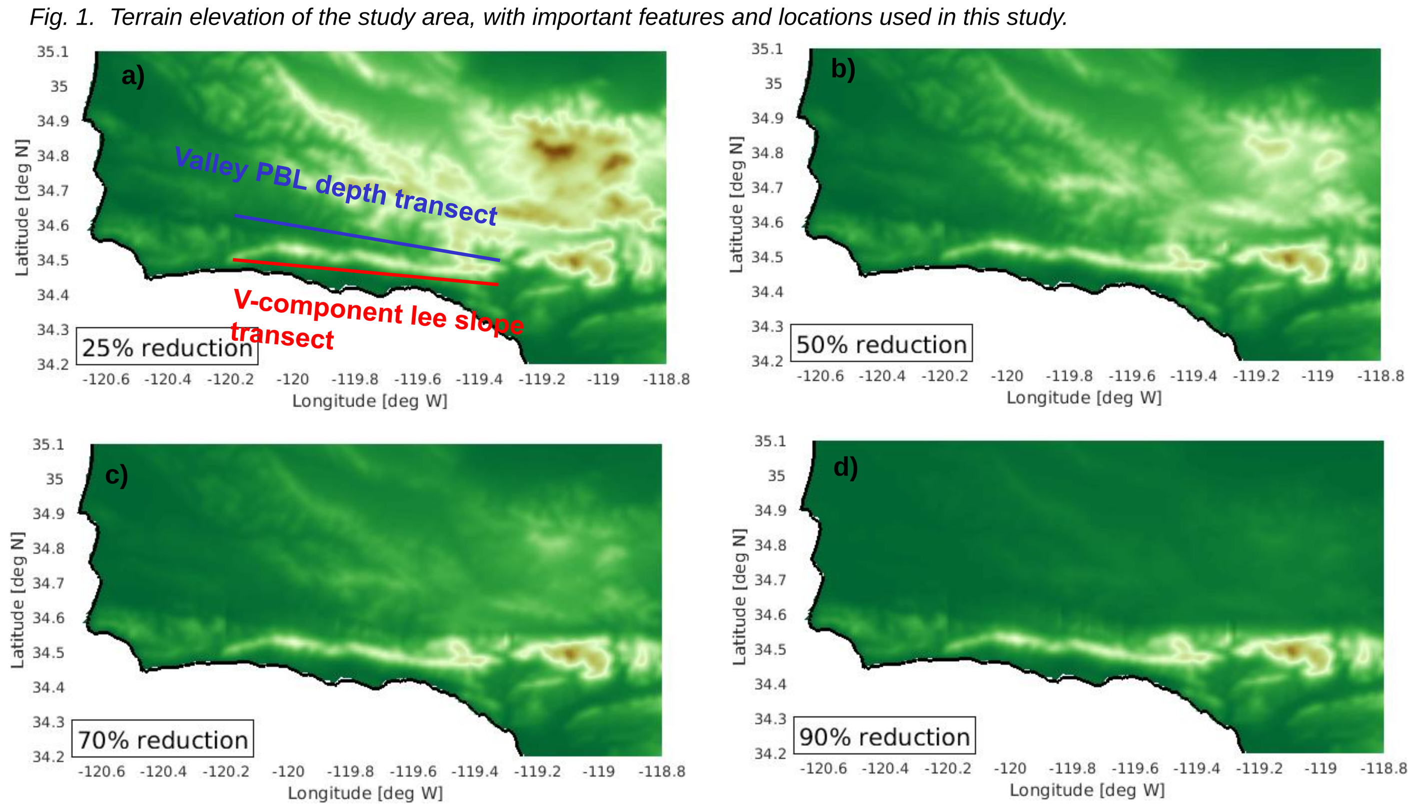

Fig. 2. Sensitivity experiments with reduced terrain elevation for San Rafael Mountains. Transect locations for hovmuller plots are shown in 2a).

2) Sensitivity to upstream terrain

With a greater reduction of the San Rafael Mountains, the diurnal pattern of Sundowner winds diminishes (Figs. 3,4). This depends however on the location, i.e. western (RHWC1) or eastern (MTIC1) slopes of SYM. This is a consequence of the more open terrain upstream of western SYM relative to eastern SYM. Note the NE and NW orientation of both winds, depending on the 'Sundowner regime'.

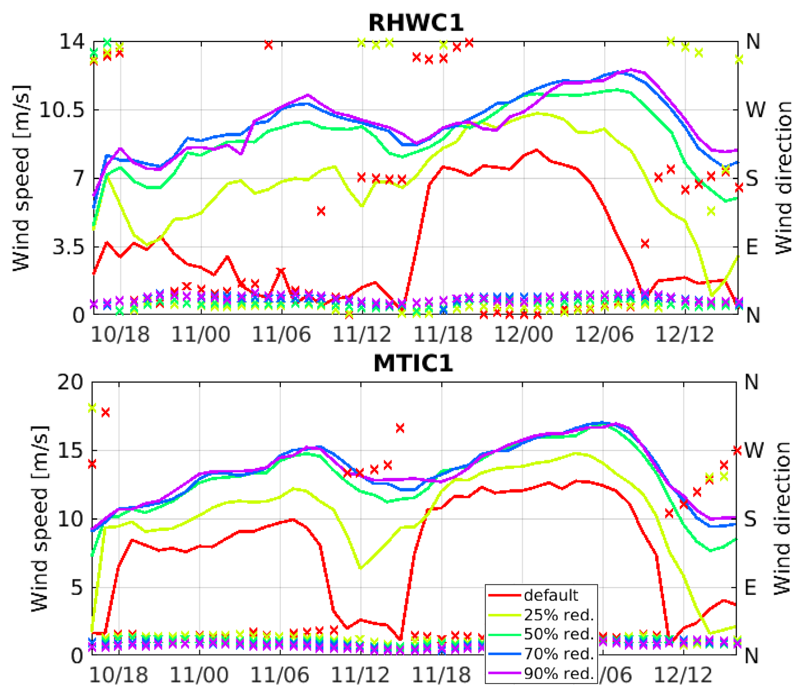

Fig. 3. Winds at RHWC1 and MTIC1 locations for different terrain removal simulations during the eastern regime event

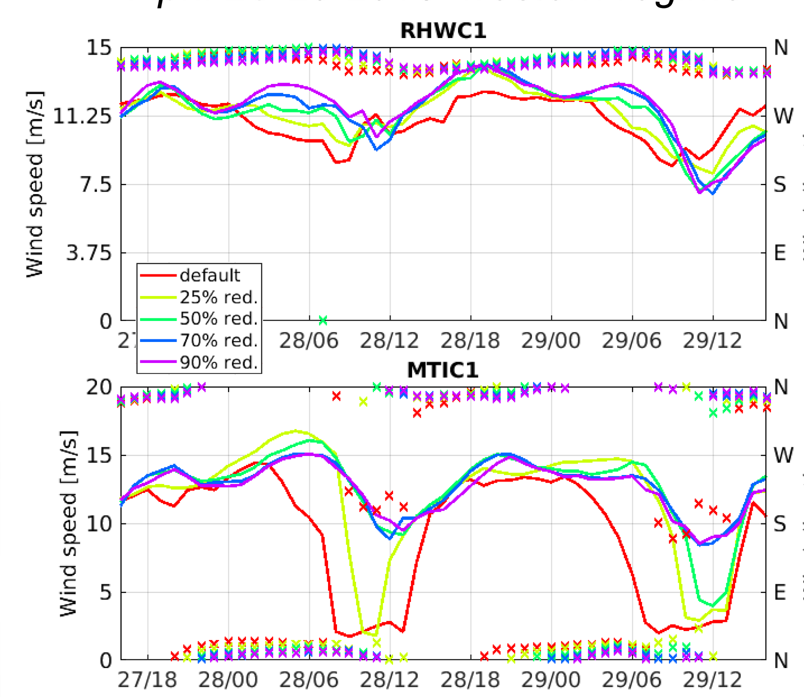

Fig. 4. Same as Fig. 3 but for western regime event

Horizontal pressure differences ***Δmslp<-2* hPa** between KSBA and KSMA or KBFL pre-determine the synoptic set-up for a Sundowner to occur (Ryan 1996), see Figs. 5,6. Removing the terrain alters *Δmslp*, but does not bear a correlation with resulting downslope winds (i.e., in both cases of more negative and less negative values for *Δmslp*, stronger downslope winds occur). *Δmslp* also does not determine the timing or diurnal variability of a downslope wind.

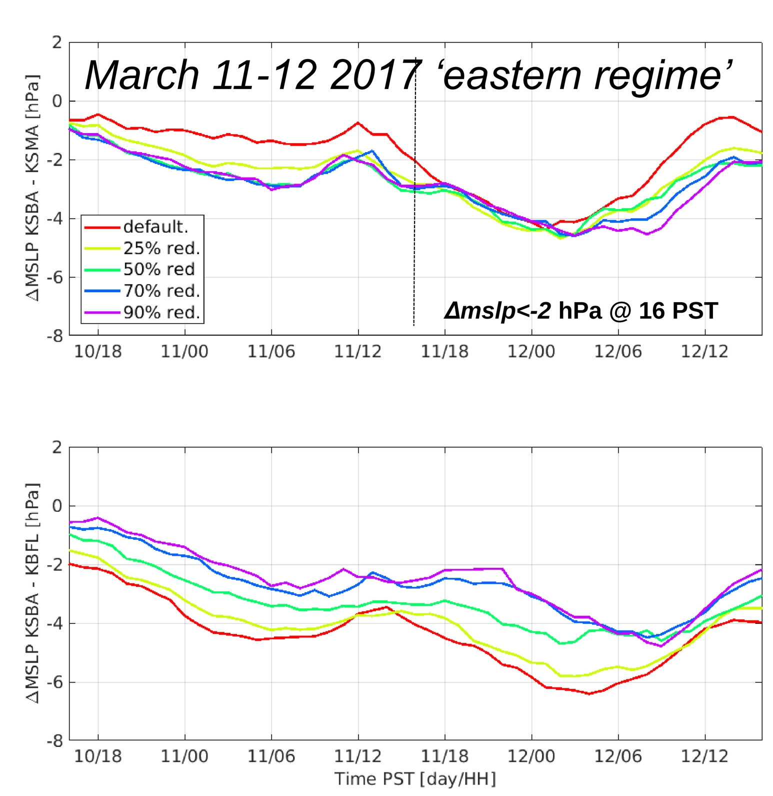

Fig. 5. MSLP difference between KSBA and KSMA (upper panel), and KSBA and KBFL (lower panel) locations for the eastern regime event and different simulations

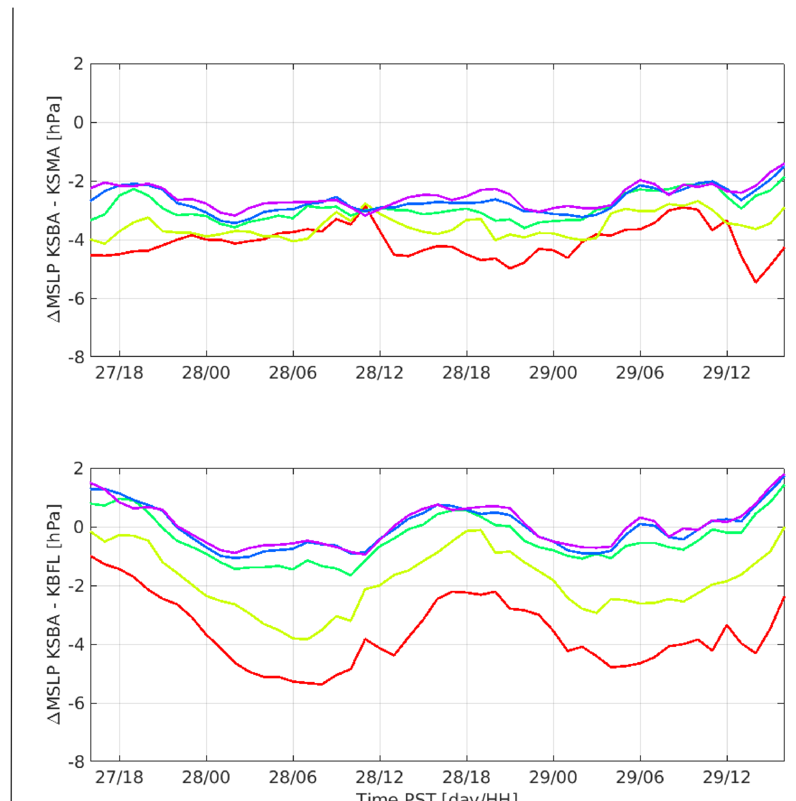

Fig. 6. MSLP difference between KSBA and KSMA (upper panel), and KSBA and KBFL (lower panel) locations for the eastern regime event and different simulations

Hovmoller plots of V-component along the southern-facing lee slope of SYM for both cases (Fig. 7,8) indicate that diurnal variability diminishes over the full range of SYM after removal of the SRM upstream. The connection to sunset seems unclear, and depends upon other factors than the sunset transition. However, the intensification of the lee slope jet is closely tied to sunset transition **explaining the origin of the name Sundowner**.

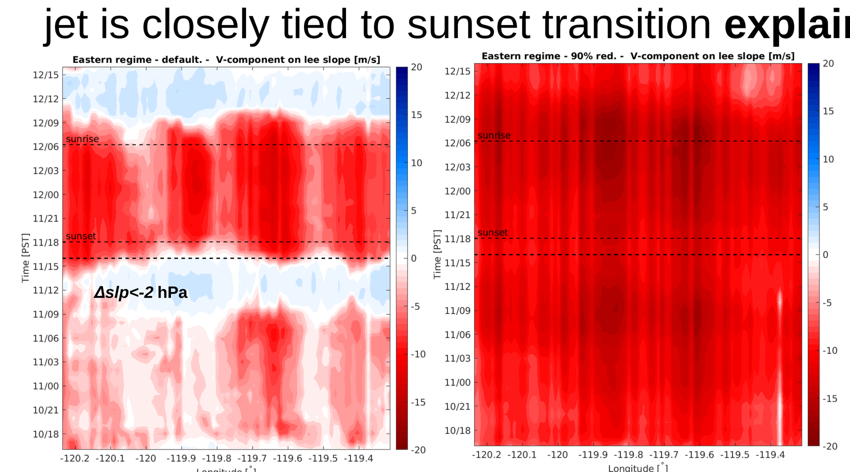

Fig. 7. Hovmoller plots of V-component for default (left) and 90% reduction along the southern-facing lee slopes of SYM for eastern regime event. See Fig. 2a for location.

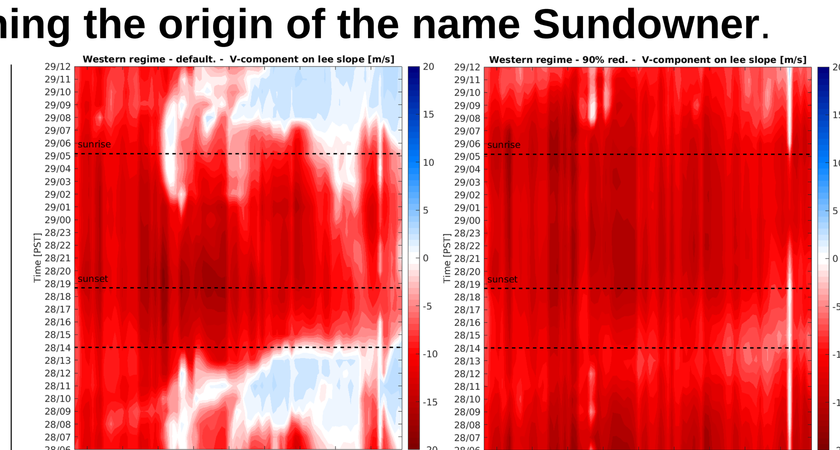

Fig. 8. Hovmoller plots of V-component for default (left) and 90% reduction along the southern-facing lee slopes of SYM for western regime event

3) Sensitivity to upstream inversion depth

a) Relation between valley PBL depth and V-component lee slope

Therefore, what causes the onset of Sundowners for especially the *eastern side* of SYM? A crucial component appears to be the collapse of the CBL in the valley upstream of SYM. Both case studies show a simultaneous timing of PBL collapse in the valley, and onset of strong winds on the lee-slope.

The western side is less affected by diurnal variability of PBL, as the upstream conditions are more open (i.e., no elevated topographic barriers exist – Fig. 1).

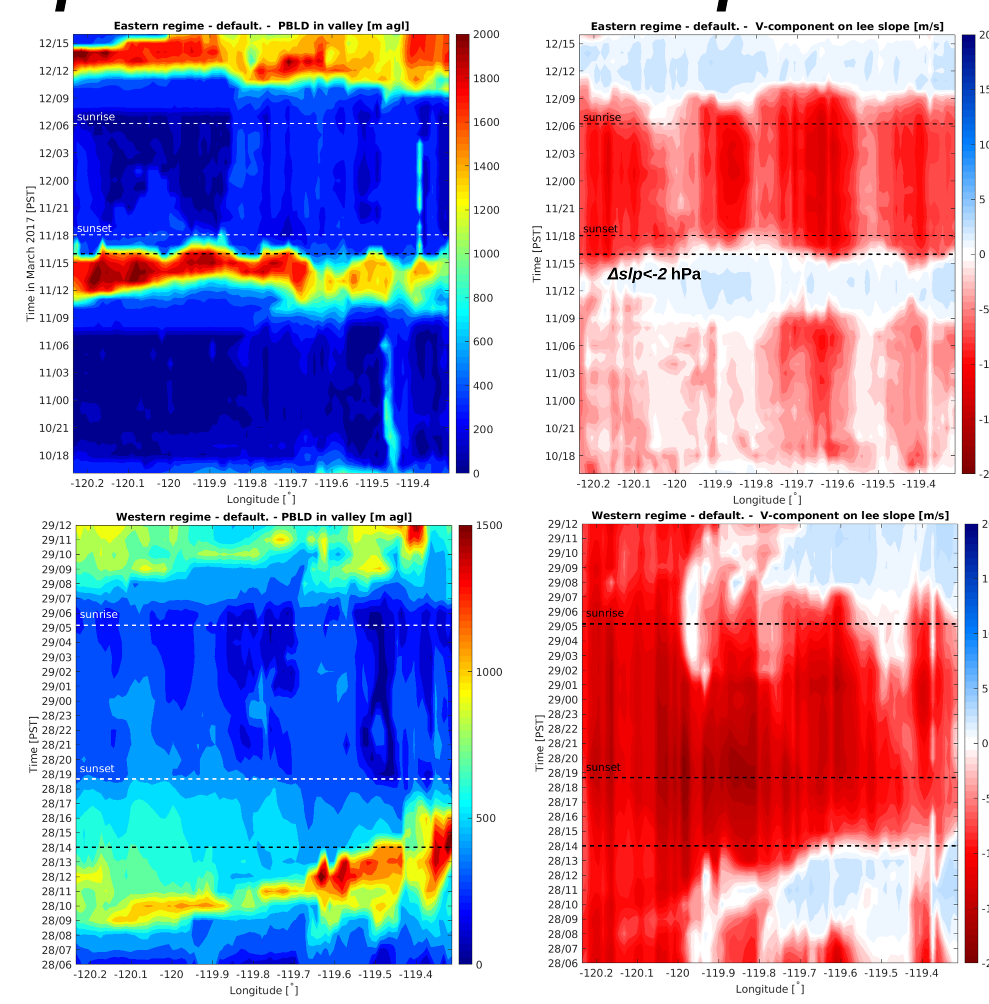

Fig. 9. Hovmoller plots of PBL depths in the SYV (left panels) and V-component on the lee slope (right panels), for the eastern (upper panels) and western (lower panels) regime events. See Fig. 2a for locations of transects

b) Influence of decreased soil moisture values

The influence of the PBL depth in the valley is further investigated by increased **soil moisture** in SYV. This lowers the CBL depth, and advances the collapse of a CBL in time. At those locations where the collapse of the PBL is earlier, a slightly earlier onset of downslope windstorm is simulated.

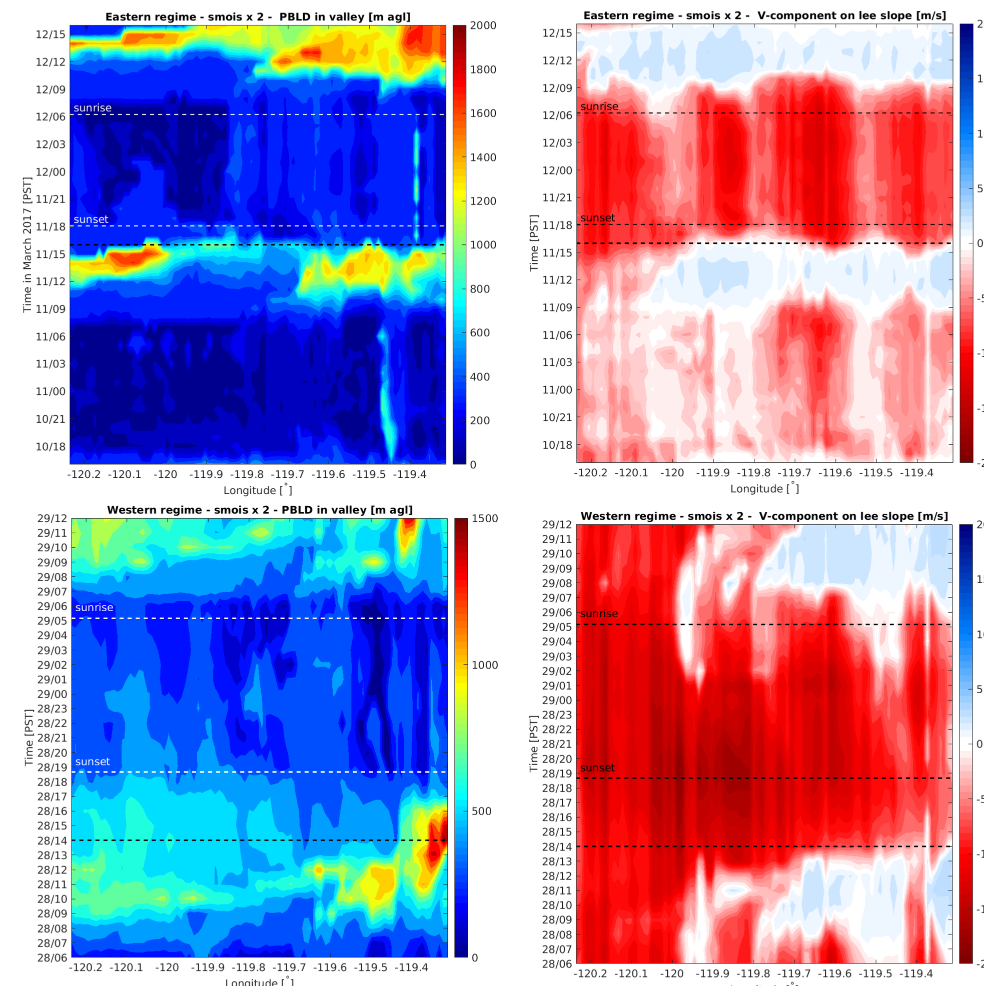

Fig. 10. Same as Fig. 9 but for increased soil moisture values in the SYV. See Fig. 2a for locations of transects

4) Summary and conclusions

A primary condition for Sundowners to develop is the synoptic forcing (expressed by the difference in MSLP) providing significant cross-mountain flow. This however does not explain the typical diurnal variability of Sundowners. Here, we show that the timing of Sundowners is related to the existence of the San Rafael Mountains upstream of SYM; its removal reduced the diurnal variability of Sundowners. It is further shown that on the eastern slopes, that is closer to the blocking SRM, the collapse of the CBL in the valley upstream is a crucial component in the onset of a Sundowner.

Literature

Duine, G.J., C. Jones, LMV. Carvalho, and RG. Fovell, 2019: Simulating Sundowner winds in coastal Santa Barbara: validation and model sensitivity. Atmosphere, 10 (3), 155.

ACKNOWLEDGMENTS

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