The impact of valley geometry on thermally driven flows and vertical heat fluxes

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Outline

1. Introduction
2. Goals
3. Simulation results
4. Conclusion
1. Introduction

2. Goals

3. Simulation results

4. Conclusion
Atmospheric boundary layer (BL)

- Convective boundary layer over flat terrain
Slope and valley winds $\Rightarrow$ BL structure

- Change of BL structure due to mesoscale slope/valley winds?
- Impact of thermally driven flows on vertical transport?
- Difference: valley BL $\Rightarrow$ plain BL?
Change of BL structure due to mesoscale slope/valley winds?
Impact of thermally driven flows on vertical transport?
Difference: valley BL \( \Rightarrow \) plain BL?
Operational NWP- and climate models do not resolve valleys properly. \( \Rightarrow \) **Error** in vertical profiles \( \Rightarrow \) **Parameterization**
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Boundary layer over complex terrain

- Systematically vary valley topography.
- Compute bulk flux profiles (heat, moisture, mass, ...).
- Impact of valley depth/width on bulk profiles?
- Difference between valley and plain profiles.

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Model set-up (Schmidli 2013)

Model set-up

- WRF model (version 3.4)
- 40 x 10 x 1.5 km
- dx = dy = 50 (100) m
- dz = 8 to 50 m
- SGS turbulence: Deardorff-type TKE
- Periodic lateral boundaries
- 5 hours simulation
- Online statistics module

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Initialisation/Forcing

- Atmosphere at rest
- $\frac{\partial \theta}{\partial z} = 3 \text{ K km}^{-1}$
- Constant forcing: $HFX = 150 \text{ W m}^{-2}$
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LES Output
Subgrid, resolved, mean variables

- Fully turbulent variable: $\tilde{\psi}$
- Model-gridbox averaged variable: $\overline{\psi}$

$$\tilde{\psi} = \overline{\psi} + \psi'_{SGS}$$

- LES output: $\overline{\psi}$

$$\overline{\psi} = \langle \overline{\psi} \rangle + \psi''_{RES}$$

- Averaging operator (Schmidli 2013)

$$\langle \cdot \rangle = \frac{1}{TL_y} \int \int \overline{\psi} dy dt$$

- $T = 40$ min, $L_y = 10$ km

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Reference run: mean flow

Valley geometry and thermally driven flows

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Heat flux profile: plain ⇔ valley

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Heat flux profile: plain ⇔ valley

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Variation of valley depth: $<U>$

Valley geometry and thermally driven flows

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Valley depth: bulk profiles

Heat Flux

Pot. Temperature

Heating Rate
Outline

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Conclusions

The deeper the valley the stronger the...

- valley inversion
- heat flux at mountain top
- superposed circulation cells
Conclusions

The wider the valley the...

- stronger the valley inversion
- weaker the heat flux at mountain top
- weaker the superposed circulation cells
Conclusions

Existence of along valley wind:
- stronger valley inversion
- stronger upslope-winds
- deeper + colder valley BL
Thank you for your attention!

Schmidli, J., 2013: Daytime heat transfer processes over mountainous terrain, sub.
Heat flux profile: plain ⇔ valley

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Heat flux profile: plain ⇔ valley

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Heat flux profile: plain ⇔ valley

RES+SGS:

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Variation of valley width: \( <U> \)
Valley width:bulk profiles

Heat Flux

BULK HFX

Pot. Temperature

BULK Theta

Heating Rate

BULK Tend

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Valley-plain: bulk profiles

Heat Flux

Pot. Temperature

Heating Rate

Valley geometry and thermally driven flows

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Vertical profiles: <U>

Comparison WRF ⇐⇒ ARPS (Schmidli, 2013)

Valley geometry and thermally driven flows
Valley depth: bulk heat flux profiles

Valley geometry and thermally driven flows
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Valley depth: bulk profiles

Heat Flux

Pot. Temperature

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Valley width: bulk heat flux profiles

SGS

RES

MEAN

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Valley-plain topography

- Valley plain topography: evolution of along valley winds
- Symmetric boundary conditions in along valley direction
Valley-plain topography: $<U>$, $<W>$<T>
Valley-plain: bulk heat flux profiles

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