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On the Role of Topography in the Description of Surface-Atmosphere Exchange

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Fate of Anthropogenic CO_2 Emissions (2010)

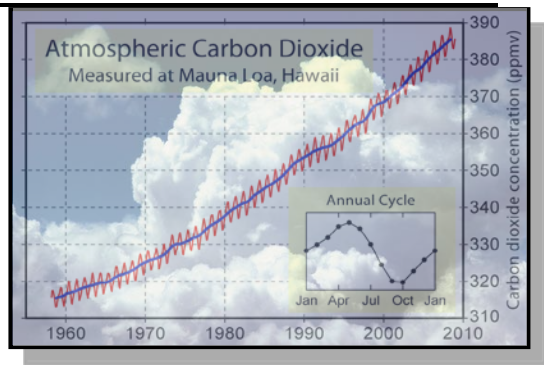
9.1 ± 0.5 PgC y^{-1}

+

0.9 ± 0.7 PgC y^{-1}

5.0 ± 0.2 PgC y^{-1}

50%



2.6 ± 1.0 PgC y^{-1}

26%

Calculated as the residual of all other flux components

24%

2.4 ± 0.5 PgC y^{-1}

Average of 5 models

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

Land surface carbon uptake

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Overall:

→ about equal shares go to oceans / land surface

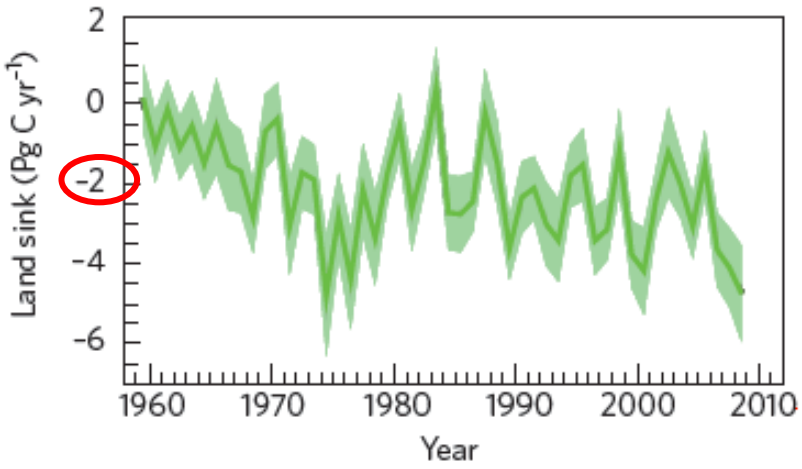
→ uncertainty of ocean uptake relatively small

→ that of land uptake: same order as 'residual' itself

→ land uptake modeled vs. residual: up to ± 2.1 PgC y^{-1}

(Le Quere et al. 2009)

→ modeled on average 'too small' (± 0.7 PgC y^{-1})



modeled land uptake
(Le Quere et al 2009)

Hypothesis

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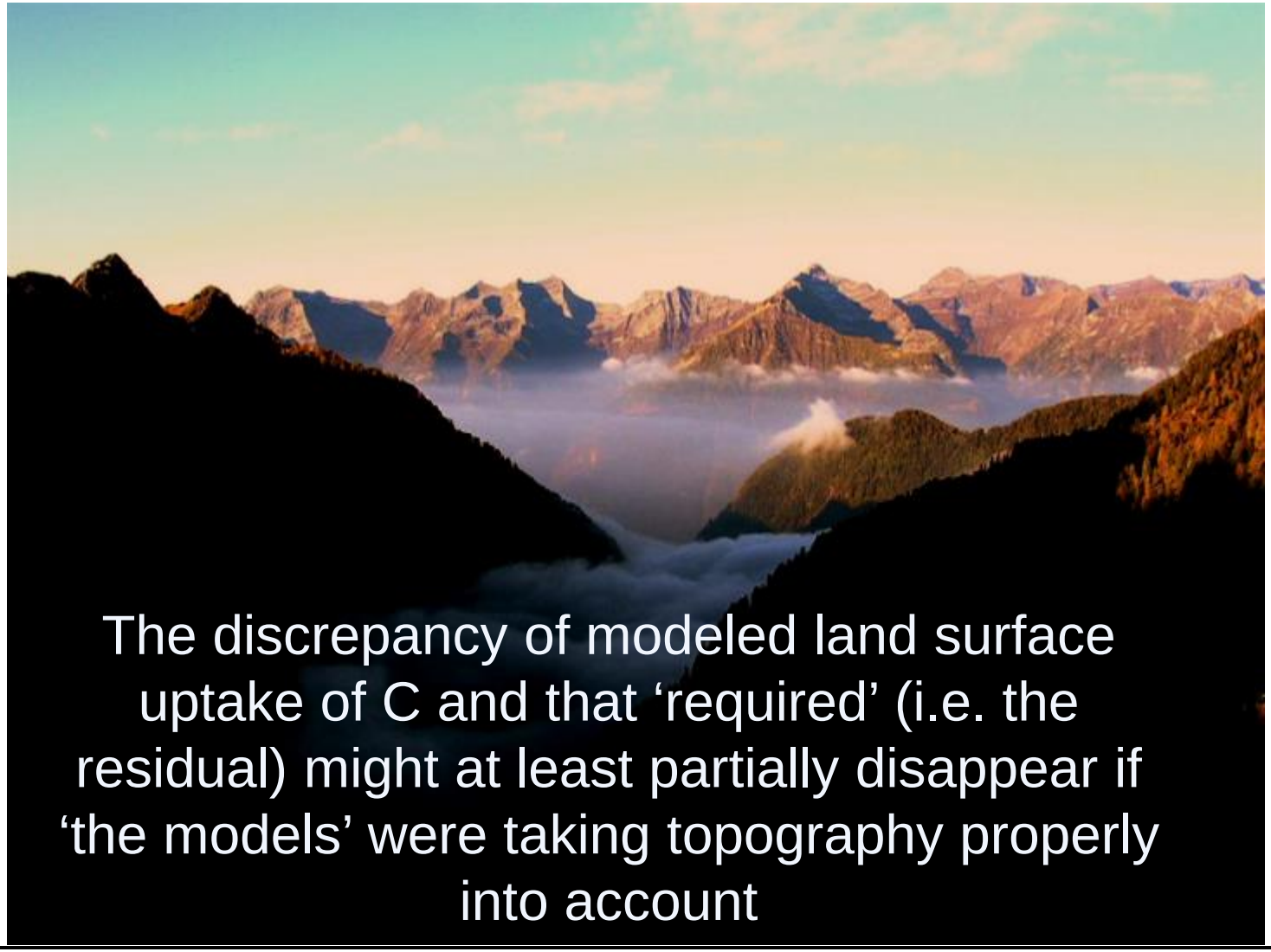

Modeled land surface uptake

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Four approaches

- inventory based
- atmospheric inverse modeling
- ecosystem modeling
- upscaling from ‘flux towers’

→ all rely on measurements: [CO_2] or $\overline{w'CO_2'}$

Flux tower sites

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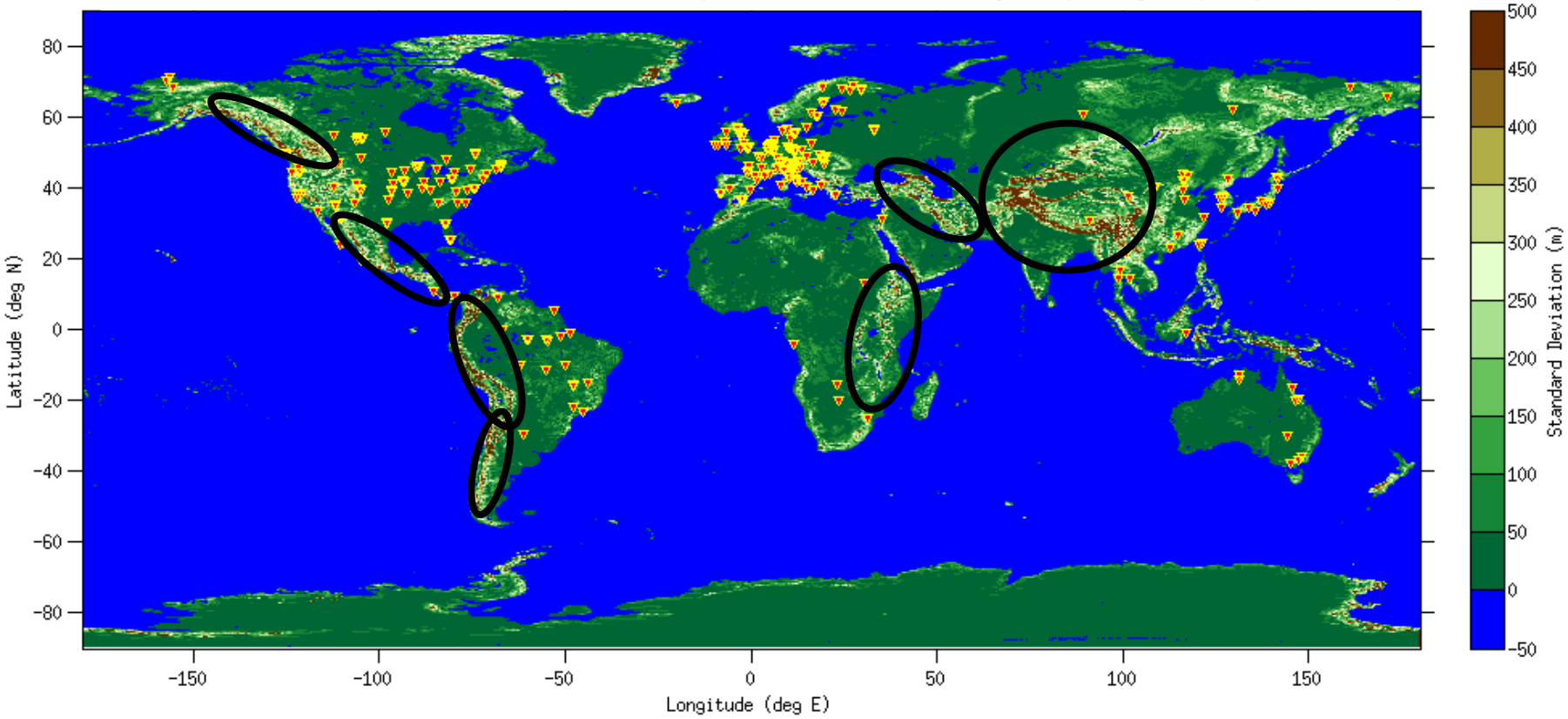
Standard deviation subgrid-scale topography (20km)



→ represent ecosystems

→ but not topography

Flux tower sites

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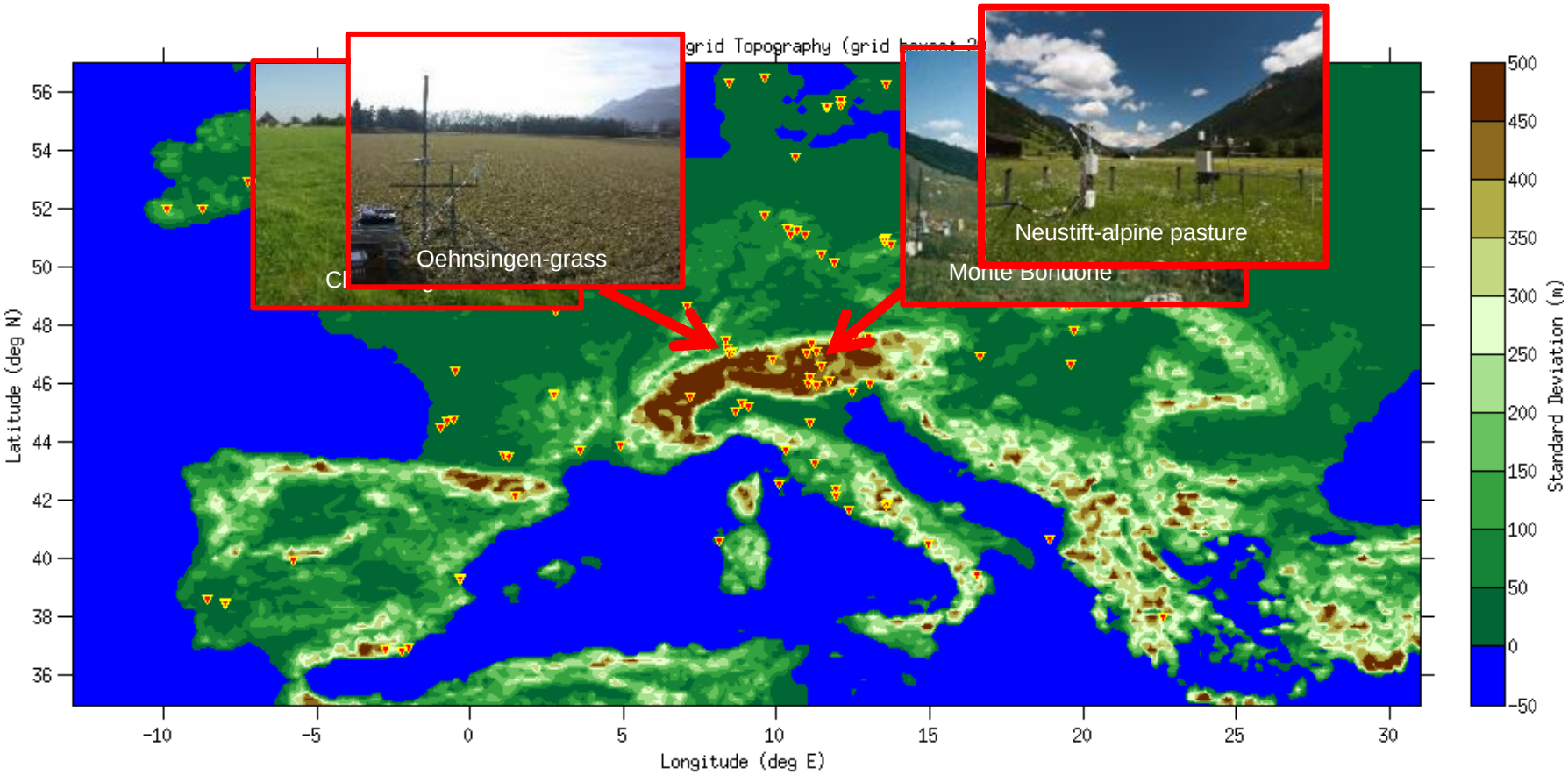

→ represent ecosystems

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Modeled land surface uptake

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Four approaches

- inventory based
- atmospheric inverse modeling
- ecosystem modeling
- upscaling from ‘flux towers’

} → rely on ‘boundary layer exchange’

‚Near-surface' exchange

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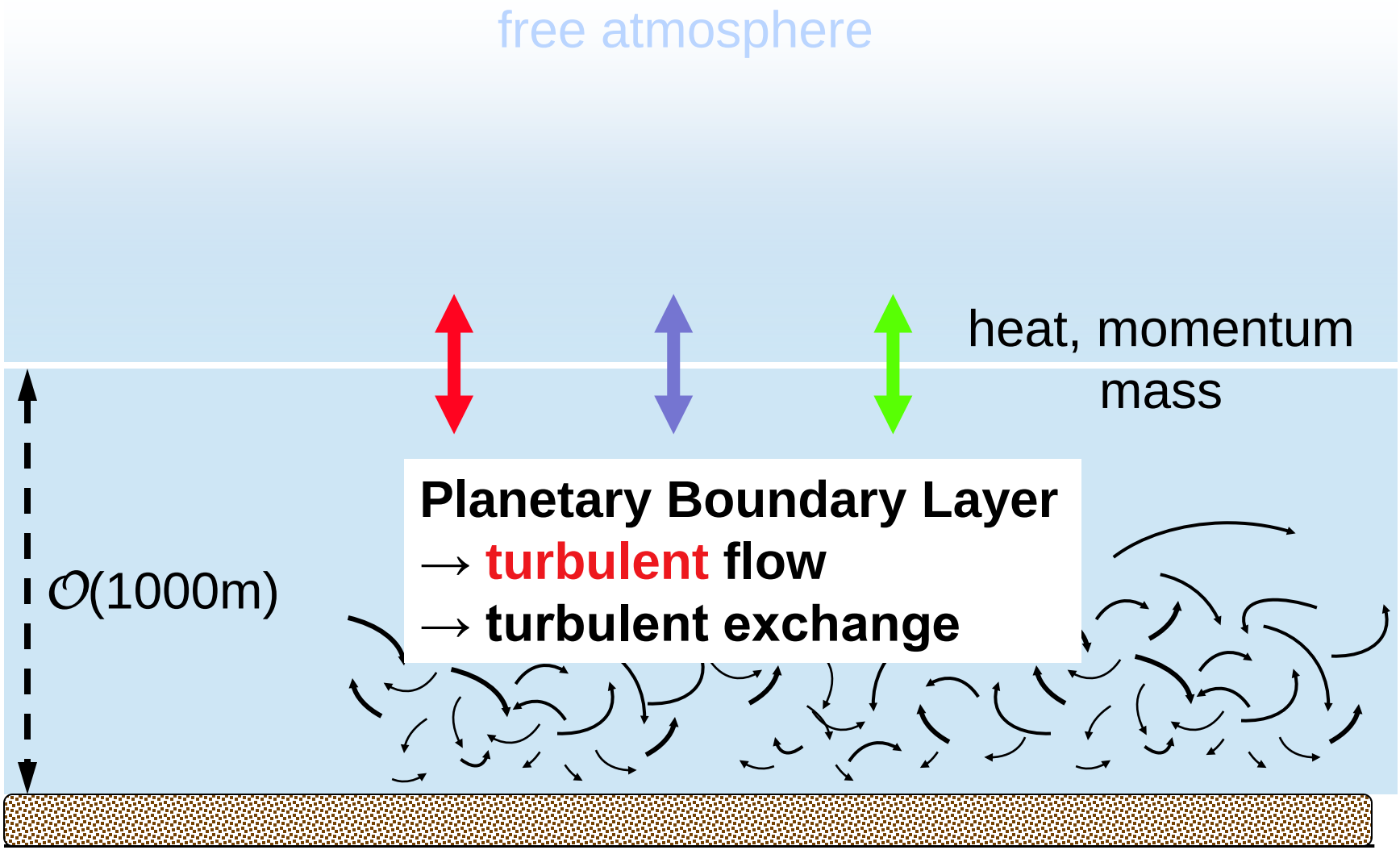

‚Near-surface' exchange

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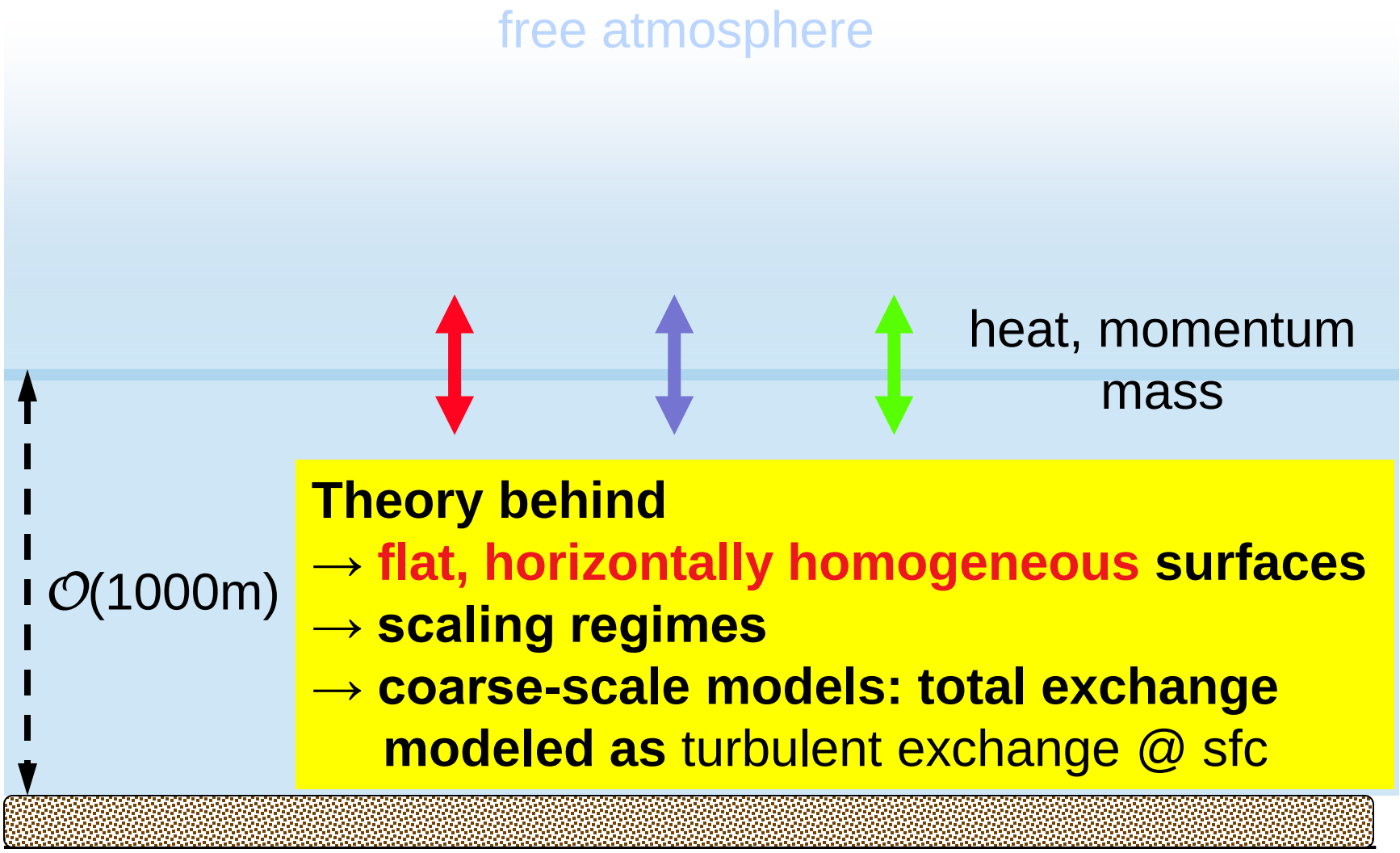

Exchange over topography

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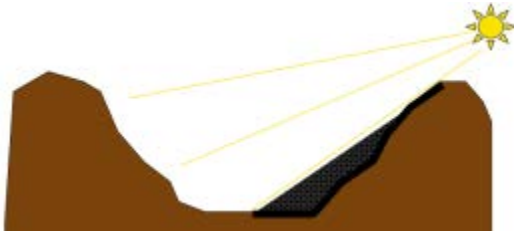
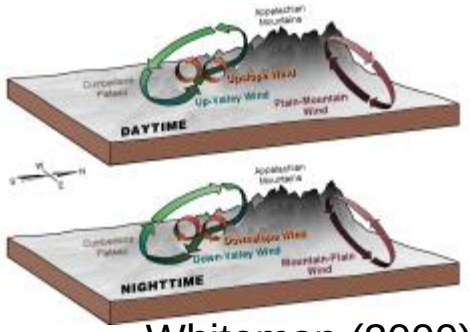
- Boundary layer is inhomogeneous by construction

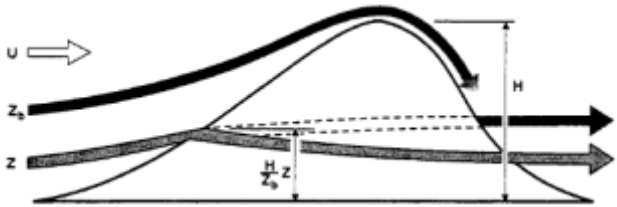


- thermally induced circulations
  → slope / valley flows
  → mountain venting



Whiteman (2000)

- dynamic modification (gravity wave drag, etc)



Lott and Miller (1996)

- geometrical effects (e.g., narrowing / widening) for mass

Coarse models

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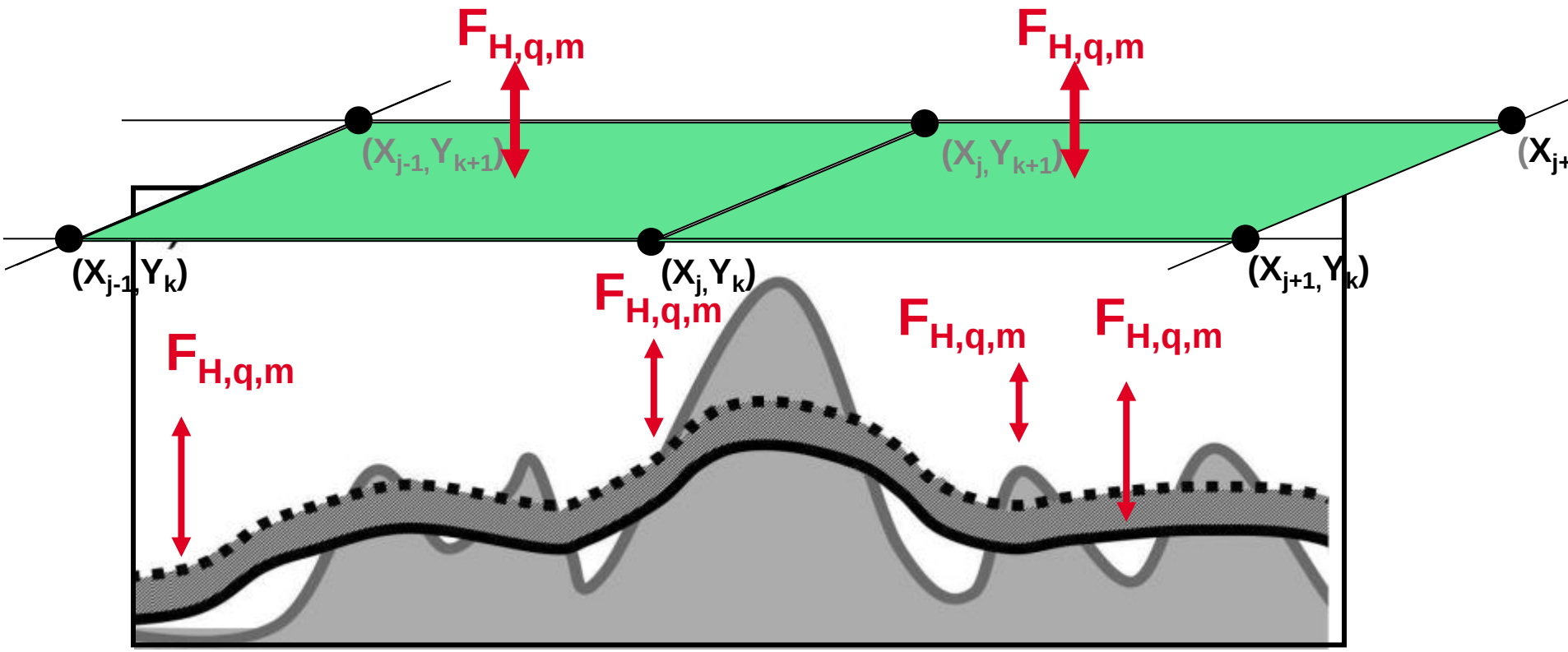
→ high spatial resolution required $\mathcal{O}$(100m)

→ climate modeling: $\mathcal{O}$(100km) …. (regional $\mathcal{O}$(10km)



Rotach and Zardi (2007)

Earth-atmosphere exchange

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Determined by

→ ‘input’ from surface exchange
(coarse models have it)

→ spatial inhomogeneity

→ (thermo-)dynamic modifications

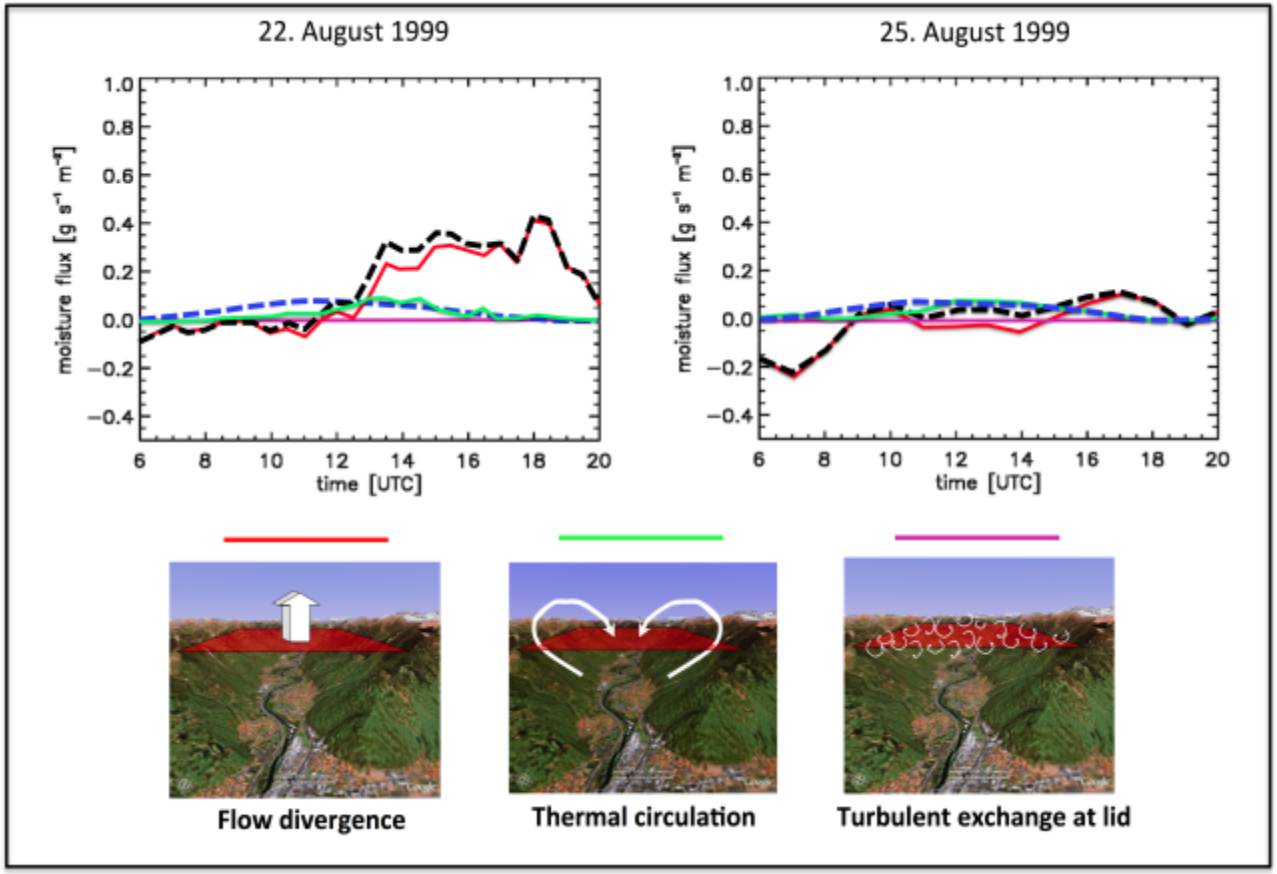
→ geometry of terrain

} coarse models (naturally) don’t have it

→ act through feedback mechanisms

One example….

- Exchange of water vapour, Riviera Valley (CH)
- high-resolution model
- ‘climate model’



LES (350m):

(= + +)

Coarse model:

Weigel et al (2007)

Summary

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- Boundary layer structure in complex topography
  → impact on total transport from/to ‘free atmosphere’
  → turbulent transport *plus* meso-scale circulation *plus* terrain effects
- important for exchange of momentum, energy, mass
- coarse models: do not resolve topography
  → only turbulent transport
  → underestimate exchange
  → might compensate for ‘missing sink’ (CO_2)
- need parameterization of subgrid-scale topography effects
  → measurements, modeling


Thank you very much for your interest!
Bild Bernd Willinger, 28.7. 2013