Parameterizations (fluxes, convection)

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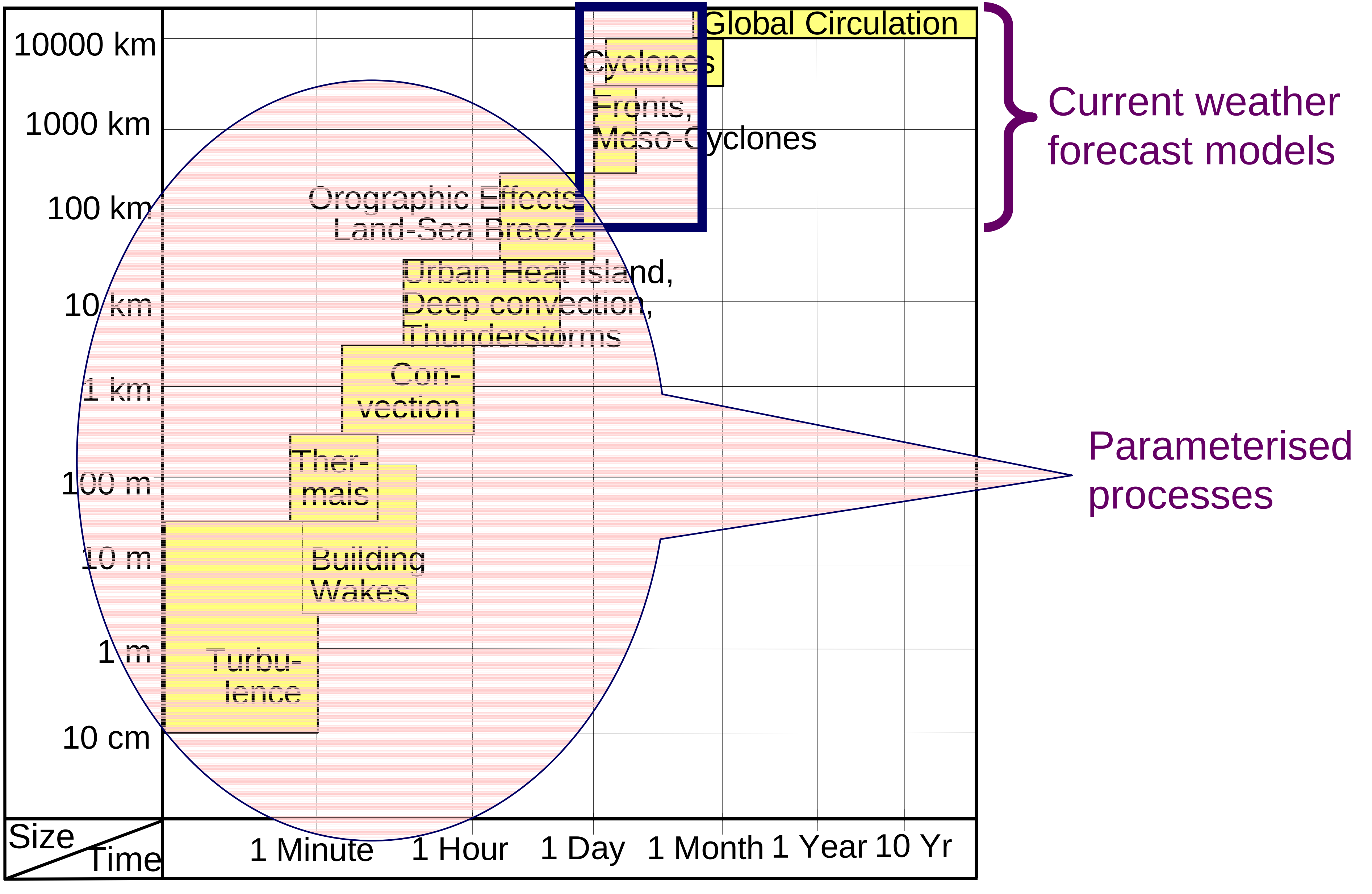
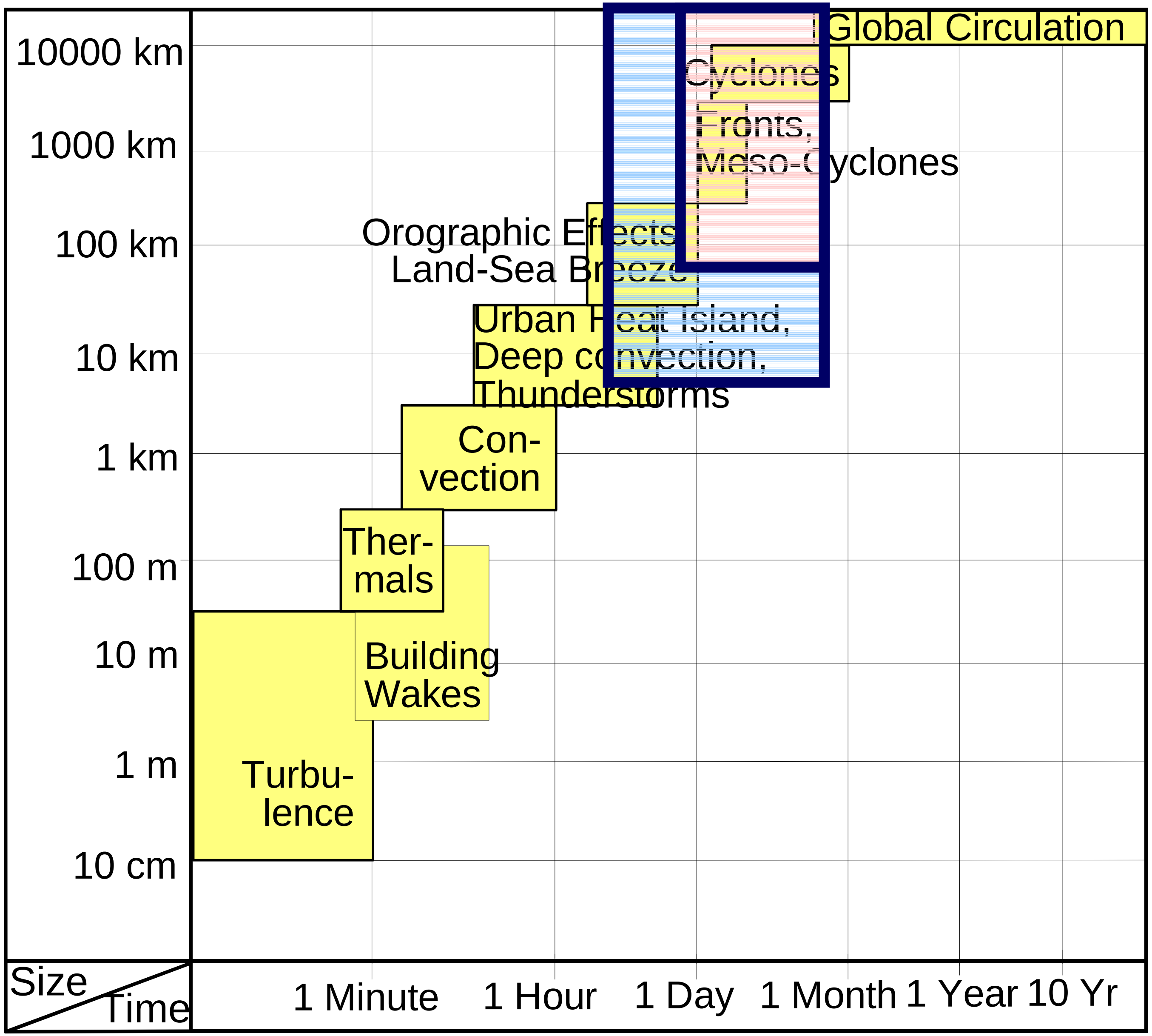
- **New resolutions - new challenges**
- **What is the current status?**
  - **Surface fluxes**
  - **Convection**
- **Towards improving parameterisations**

Scales of atmospheric phenomena



(based on Orlanski, 1975; Randerson, 1976; Tangermann-Dlugi, 1982; Schlünzen, 1996)

Scales of atmospheric phenomena



Current weather forecast models

Future weather forecast models

Parameterisations need to be adjusted

(based on Orlanski, 1975; Randerson, 1976; Tangermann-Dlugi, 1982)

Requirements for ~2km resolution models

- **No parameterisations needed (resolved):**
  sea breeze, urban heat island, thunderstorms, (orography effects, deep convection).

- **Remaining sub-grid-scale processes:**
  Convection, thermals, building wakes, turbulence, (orographic effects, deep convection).

➢ **Challenge:**
Parameterisations for 1 to 10 km resolution!

  ➢ Sub-grid-scale land-use effects (incl. heat island),
  ➢ Sub-grid scale orography effects,
  ➢ Convection (shallow towards deep, thunderstorms).

Current status

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Surface fluxes:
Effects of main land-use in numerical models

- **Different surface temperatures arise over different soils / land-uses.**
- **Horizontal temperature gradients develop.**
- **Advectives flow is generated (reduces temperature / pressure difference).**

➢ **Reduced grid size with same land-use (and horizontal temperature difference) increases horizontal flow.**

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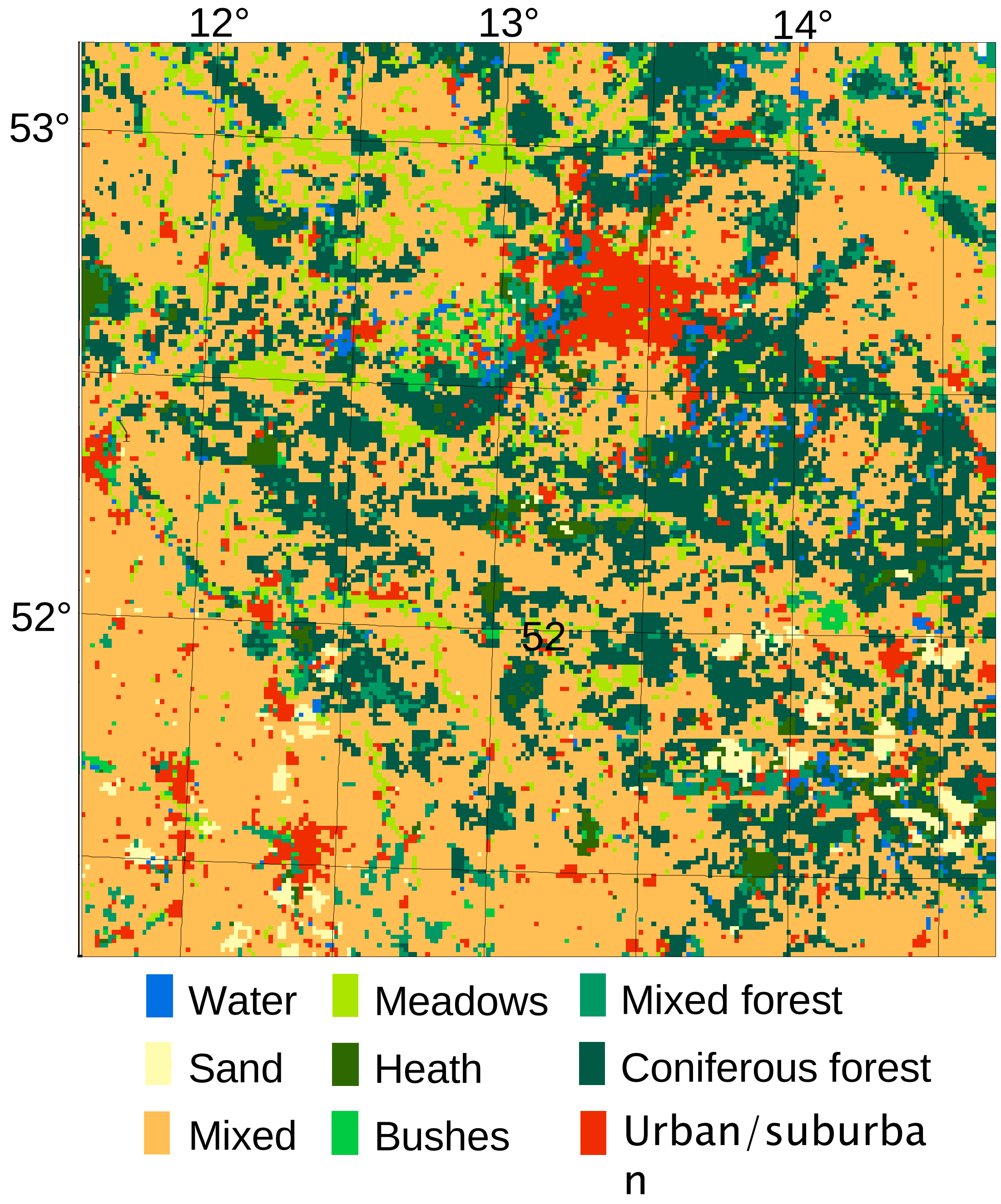
Sub-grid-scale land-use considered in METRAS, data resolution 1km



Available methods for considering sub-grid-scale land-use effects

- **Parameter averages.**
- **Average surface fluxes.**
- **Mosaic method.**

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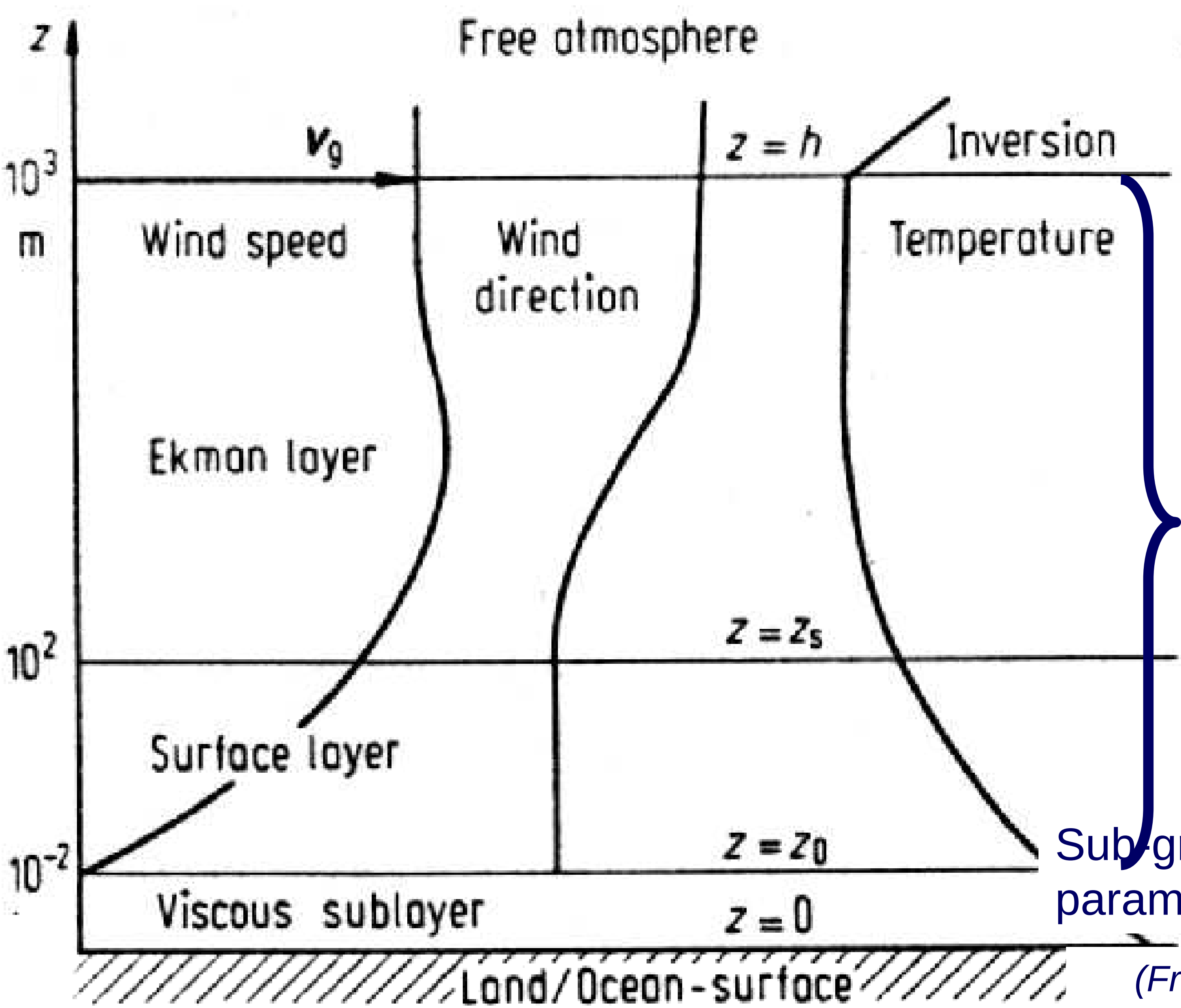
Available methods for considering sub-grid-scale orography effects

- **Envelope method.**
- **Increased roughness length.**

➢ **No method for considering sub-grid-scale shading, insolation and coherent structeres forced by sub-grid-scale orography.**

Atmospheric structure



Convective boundary layer

Sub-grid-scale parameterisations

(From Etling, 1987)

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Surface layer

Scaling values wíthout convection:

$$u_*, \quad \overline{\theta' w'}, \quad \overline{q' w'}, \quad z, \quad g/\theta, \quad L = -\frac{u_*^{\,3}}{\kappa \frac{g}{\theta} \overline{\theta' w'}}$$

Free convection scaling:

$$w_* = \left(\frac{g}{\theta} \overline{\theta' w'} \cdot z_i \right)^{1/3}, \quad \overline{\theta' w'}, \quad \overline{q' w'}, \quad z_i, \quad g/\theta$$

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Sub-grid-scale land-use schemes (friction velocity)

Flux Averaging:

$$u_* = \kappa U(z) \sqrt{\sum_{i=1}^{n} \frac{f_i}{\left(\mathit{ln}\left(z/z_{0i} \right) - \psi_m \left(z/L_i \right) \right)^2}}$$

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Convection in Ekman layer

Several schemes, including counter gradient schemes:

$$\overline{w'\theta'} = - K_{\theta v}\left(\frac{\partial\overline{\theta}}{\partial z} - \Gamma\right)$$

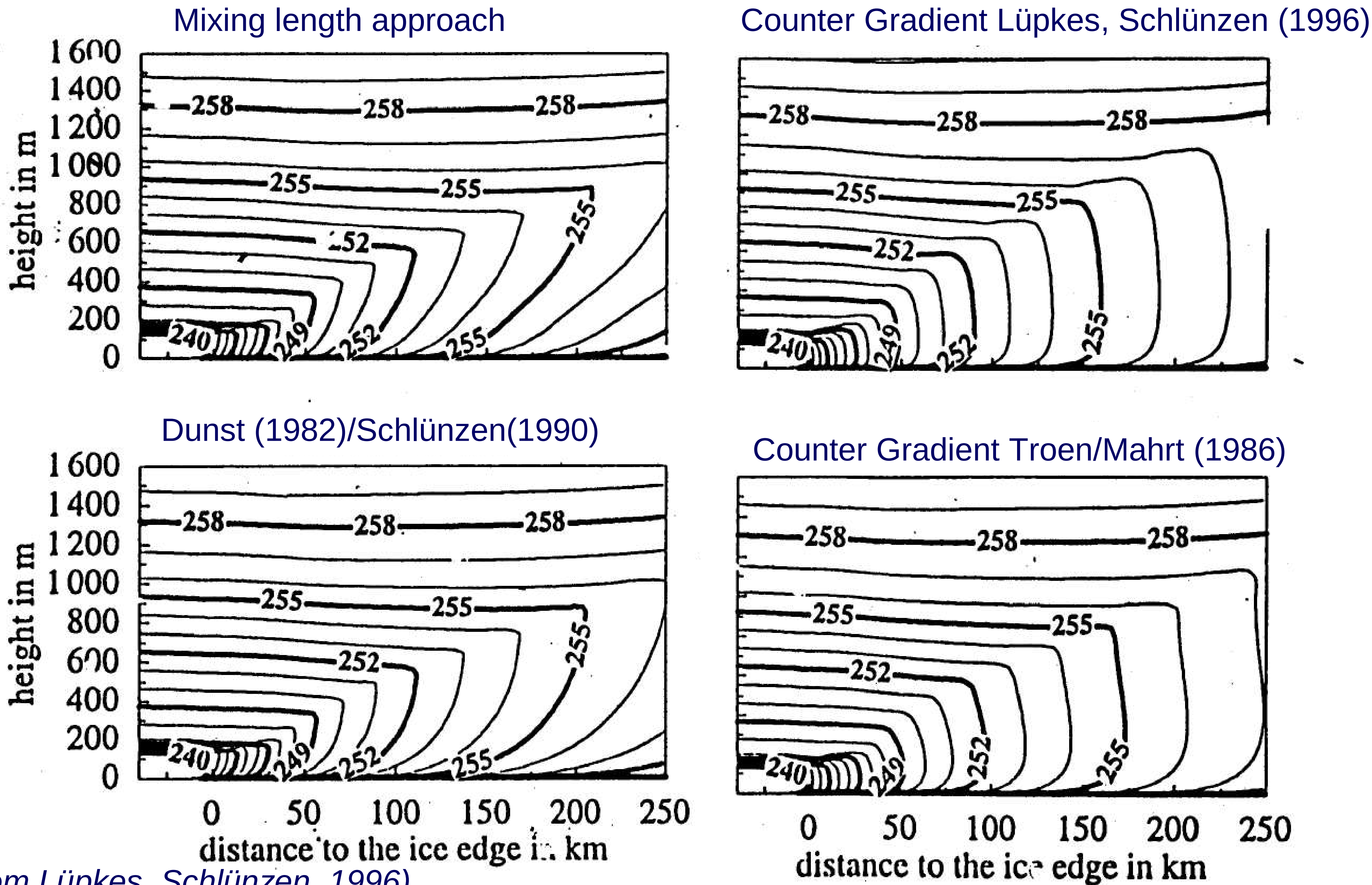
Postulated in 1947 by Priestley and Swinbank, first values for Γ by Deardorff (1972), LES-derived values for Γ by Troen and Mahrt (1986), Holtslag and Moeng (1991); parameter adjustments thereafter (e.g. Lüpkes and Schlünzen, 1996).

No 3-d measurements for verification over heterogeneous land use!

Challenge:

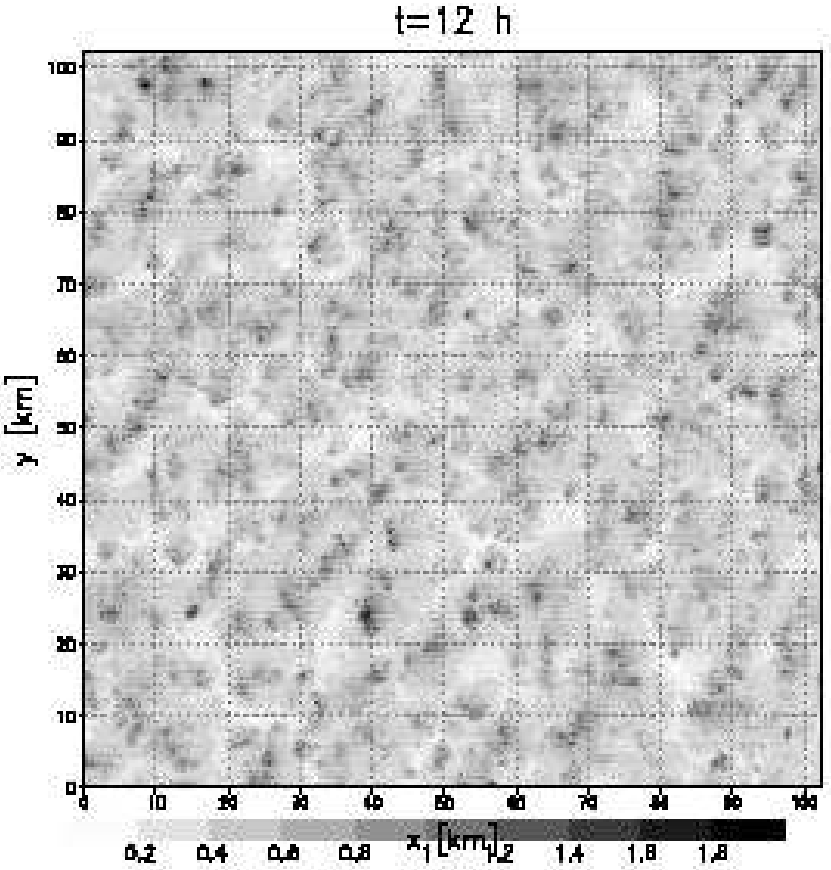
Determine Γ 60 years after postulation.

Temperature for polar cold air outbreak



(From Lüpkes, Schlünzen, 1996)

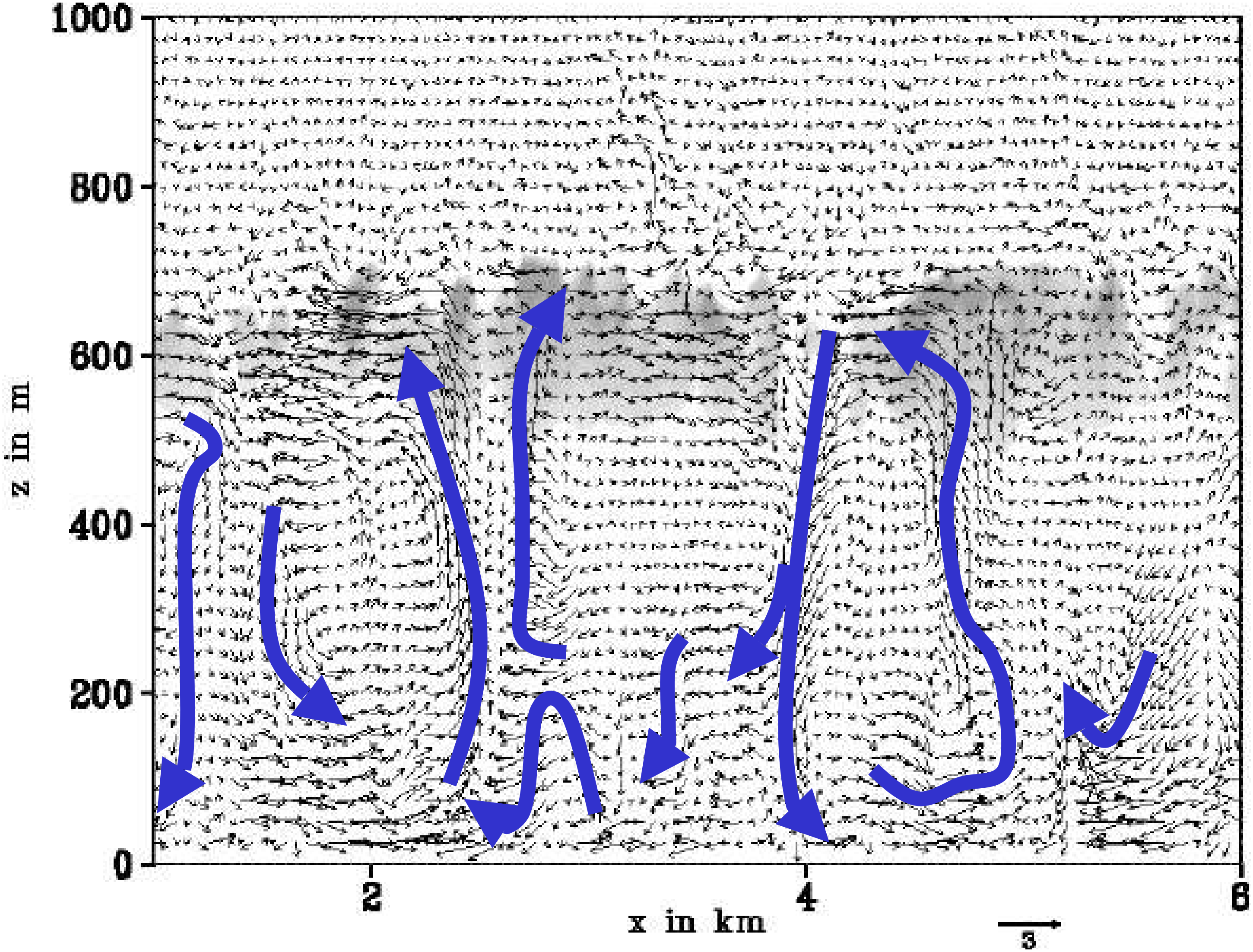
Temporal development of liquid water path (mm)



(results of model PALM by Jansen et al., 2004)

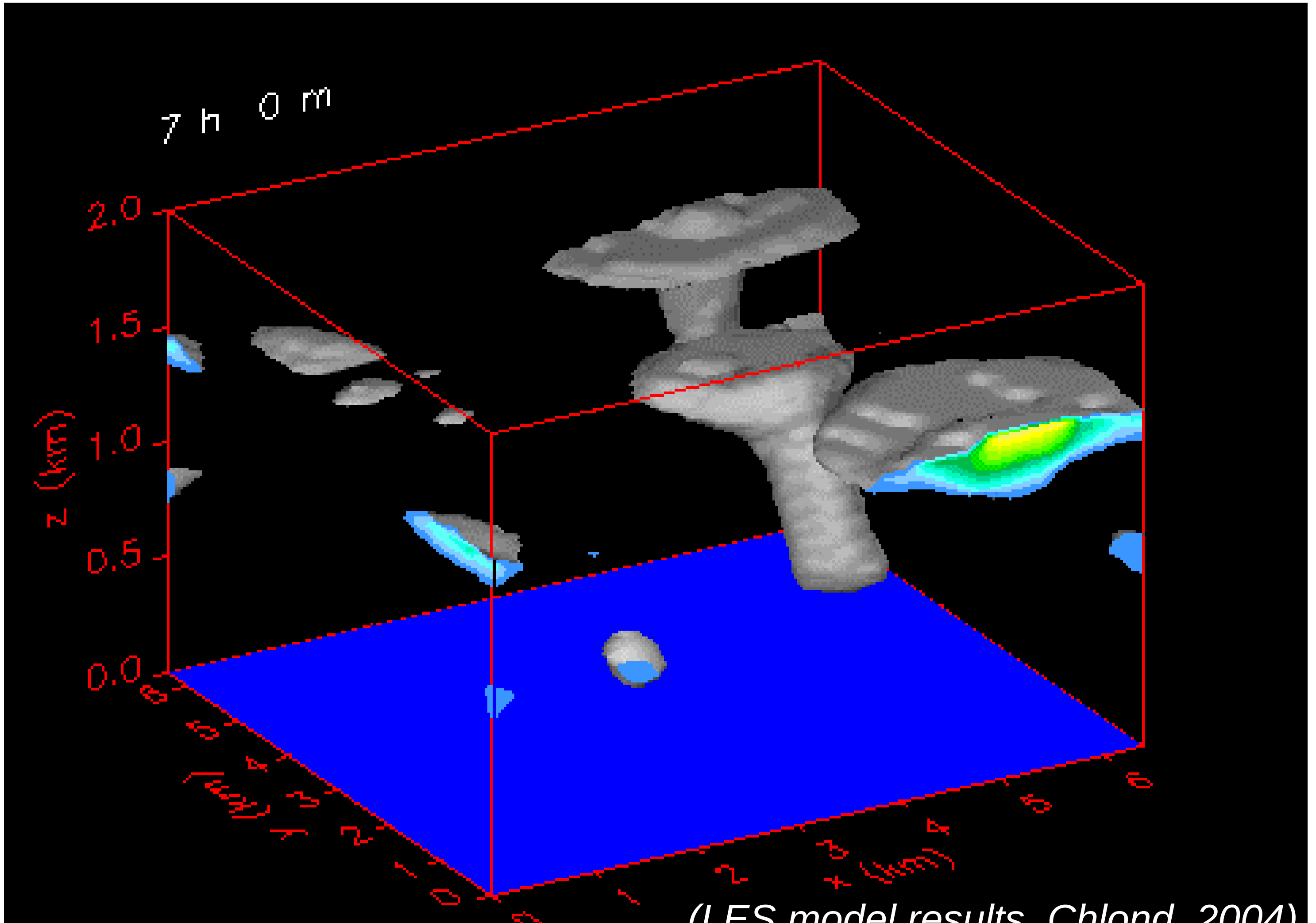
Wind field and cloud water content

Vertical cross section 120km downwind of the ice edge



(results of model PALM by Gryschka & Raasch, 2004)

Cumulus cloud development over homogeneous terrain



(LES model results, Chlond, 2004)

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Summarizing current status

- **Mesoscale models with different parameterisations for turbulence incl. convection and sub-grid-scale fluxes.**
- **LES models with/without chemistry.**
- **2-D measurements over the oceans for relatively simple surface conditions.**

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Improving parameterisations –

What is needed (sub-grid-scale land-use & convection)

- **4-D measurements (incl. spectra) of**
  - sensible and latent heat fluxes,
  - liquid water content and
  - momentum fluxes

  over heterogeneous terrain for convective situations.
- **PBL-height (3-D).**
- **Detailed land-use information [~100 metres, 2-D] incl.**
  - soil water content,
  - LAI and
  - small scale orography information.
- **(Entrainment / detrainment & mixing in clouds – 4-D).**
- **LES models for detailed simulations (4-D).**
- **Mesoscale models for testing available and new (LES and measurement based) parameterisations (4-D).**

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