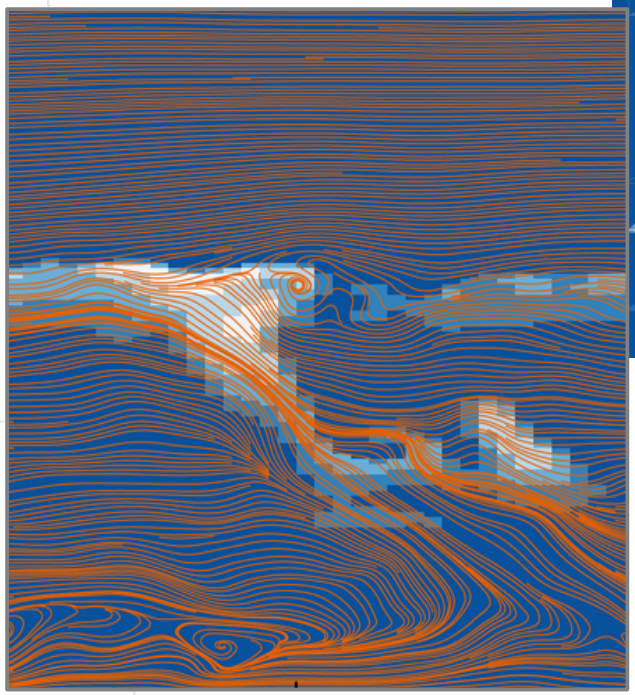
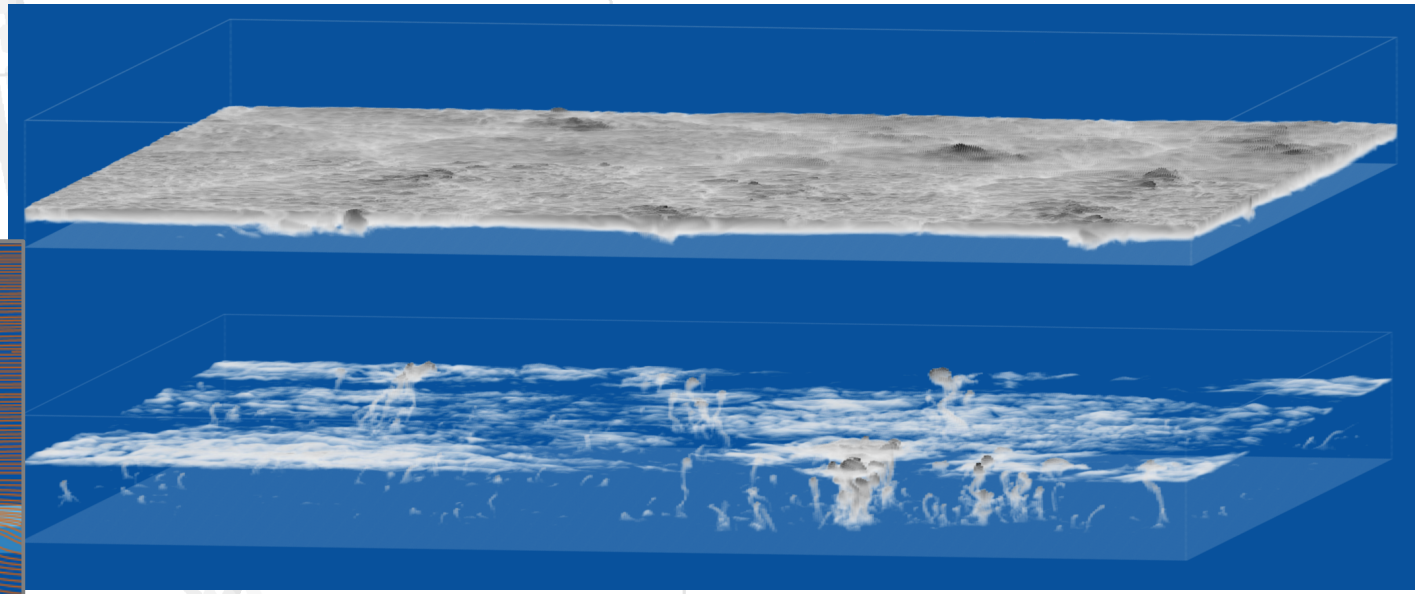
Status of the ASTEX LES intercomparison study





Johan van der Dussen
Stephan de Roode
Pier Siebesma

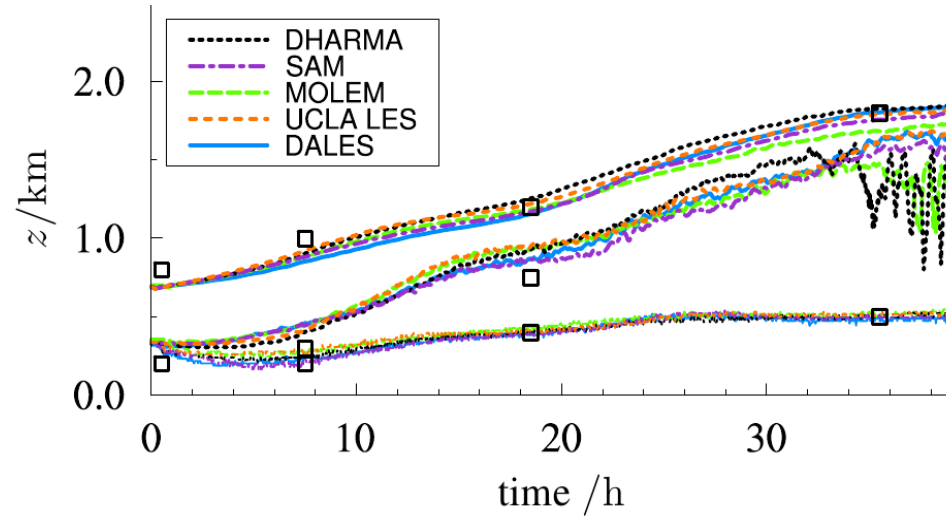
Andy Ackerman
Peter Blossey
Adrian Lock
Irina Sandu

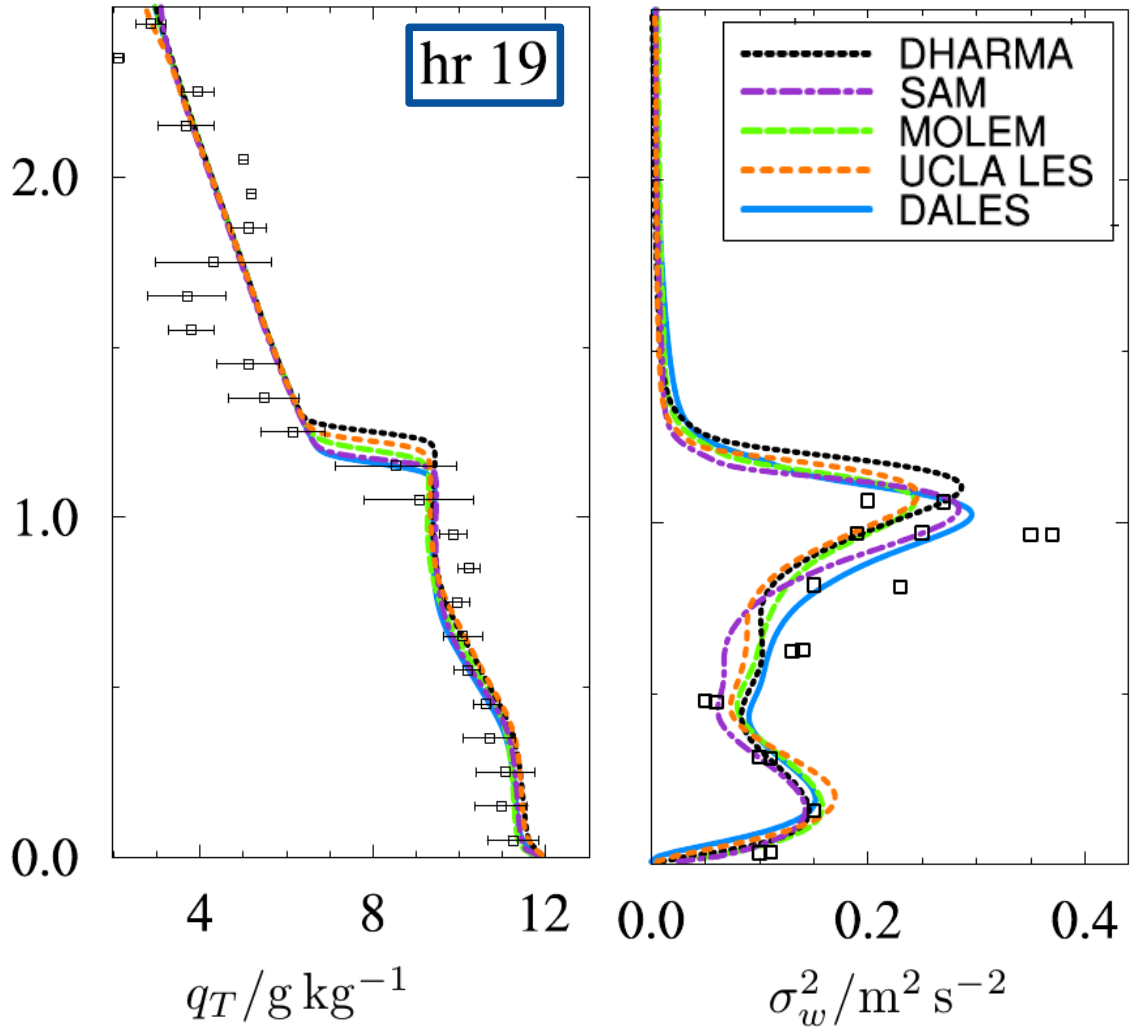
ASTEX model intercomparison

Final results of all participants have been received

Agreement among models is exceptionally good

Observations are very well reproduced





Transition analysis

Detailed analyses of the LES and SCM results for ASTEX and the two GPCI columns	D3.3

The EUCLIPSE LES model intercomparison of the Stratocumulus to Cumulus transition as observed during ASTEX

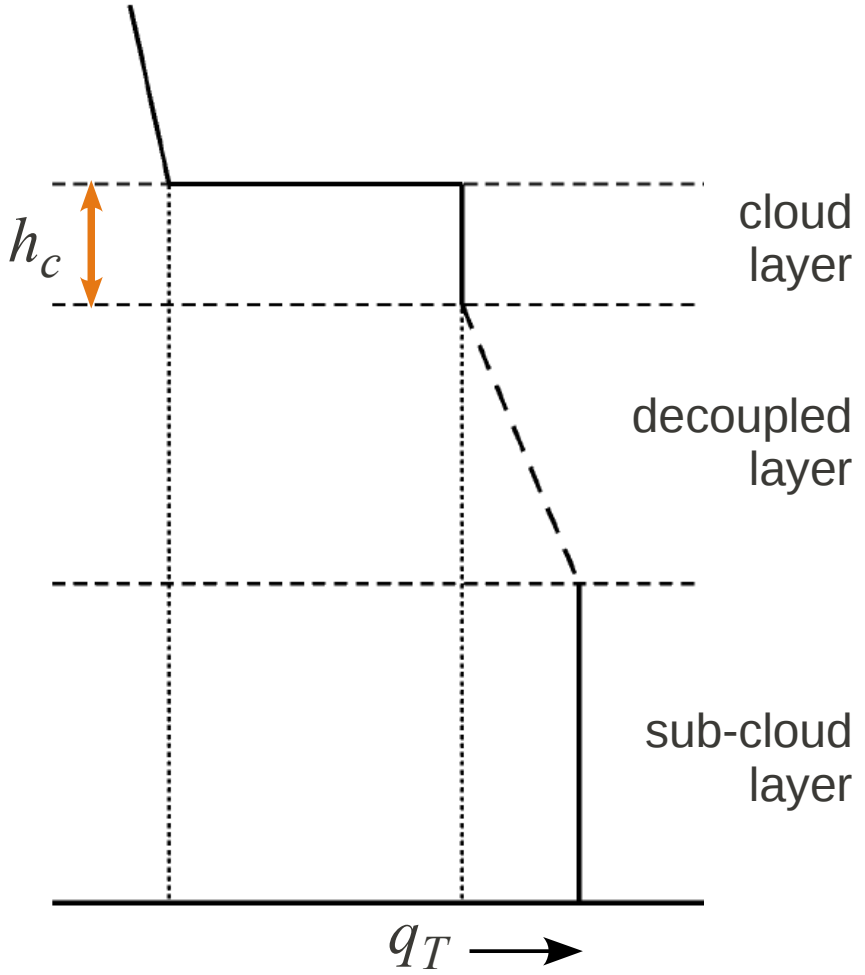
Quart. J. Roy. Meteor. Soc., *to be submitted*

Analysis of transition results

Relevant quantity for cloud break-up is: $\frac{\partial h_c}{\partial t}$

Assume well-mixed cloud layer, then:

$$q_{L,\text{top}} \approx \Gamma_{q_L} h_c$$



(Randall, 1984)

(Wood and Bretherton, 2004)

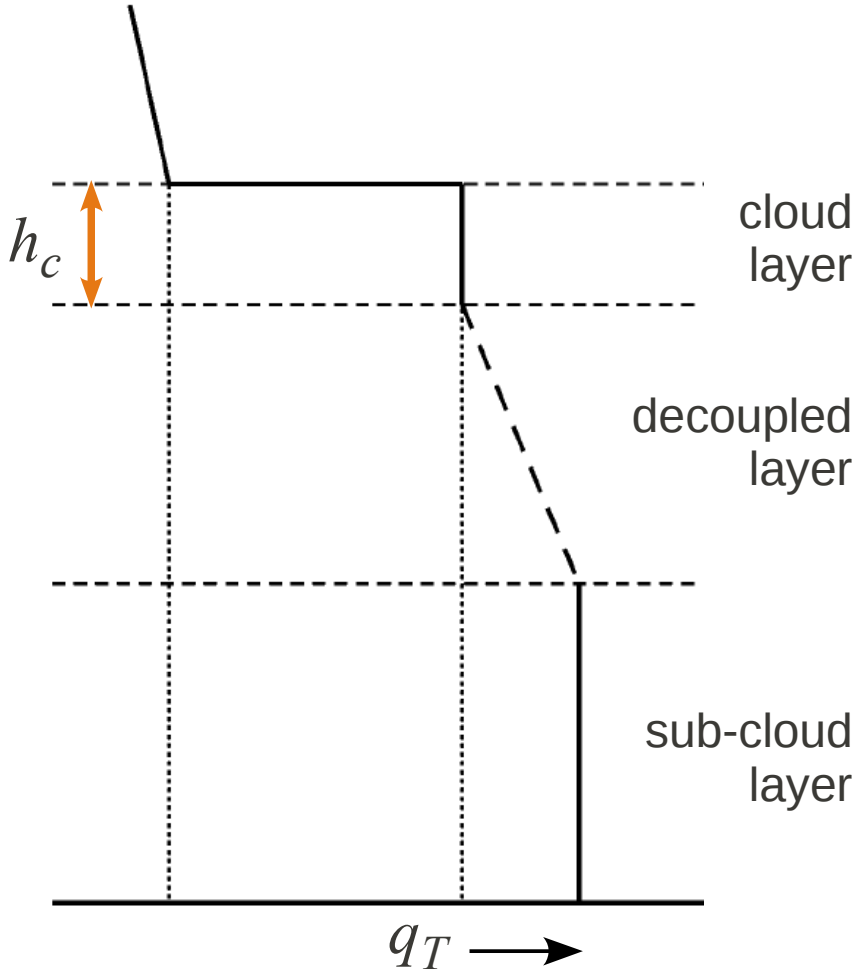
Analysis of transition results

Relevant quantity for cloud break-up is: $\frac{\partial h_c}{\partial t}$

Assume well-mixed cloud layer, then:

$$q_{L,\text{top}} \approx \Gamma_{q_L} h_c$$

$$q_{L,\text{top}} = f(q_T, \theta_L, z_i)$$



(Randall, 1984)

(Wood and Bretherton, 2004)

Tendency of cloud layer thickness

$$\Gamma_{q_L} \frac{\partial h_c}{\partial t} = \left(\frac{\partial q_L}{\partial q_T}\right)_{\theta_L, z_i} \frac{\partial q_T}{\partial t} + \left(\frac{\partial q_L}{\partial \theta_L}\right)_{q_T, z_i} \frac{\partial \theta_L}{\partial t} + \left(\frac{\partial q_L}{\partial z_i}\right)_{\theta_L, q_T} \frac{\partial z_i}{\partial t}$$

- Budget equations for q_T and θ_L tendencies

$$\frac{\partial \varphi}{\partial t} = -\frac{\partial \overline{w'\varphi'}}{\partial z} + \frac{\partial S_\varphi}{\partial z}$$

- Inversion height evolution is sum of entrainment and subsidence

$$\frac{\partial z_i}{\partial t} = w_e + \overline{w}(z_i)$$

Tendency of cloud layer thickness

$$\Gamma_{q_L} \frac{\partial h_c}{\partial t} = \left(\frac{\partial q_L}{\partial q_T}\right)_{\theta_L, z_i} \frac{\partial q_T}{\partial t} + \left(\frac{\partial q_L}{\partial \theta_L}\right)_{q_T, z_i} \frac{\partial \theta_L}{\partial t} + \left(\frac{\partial q_L}{\partial z_i}\right)_{\theta_L, q_T} \frac{\partial z_i}{\partial t}$$

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Tendency of cloud layer thickness

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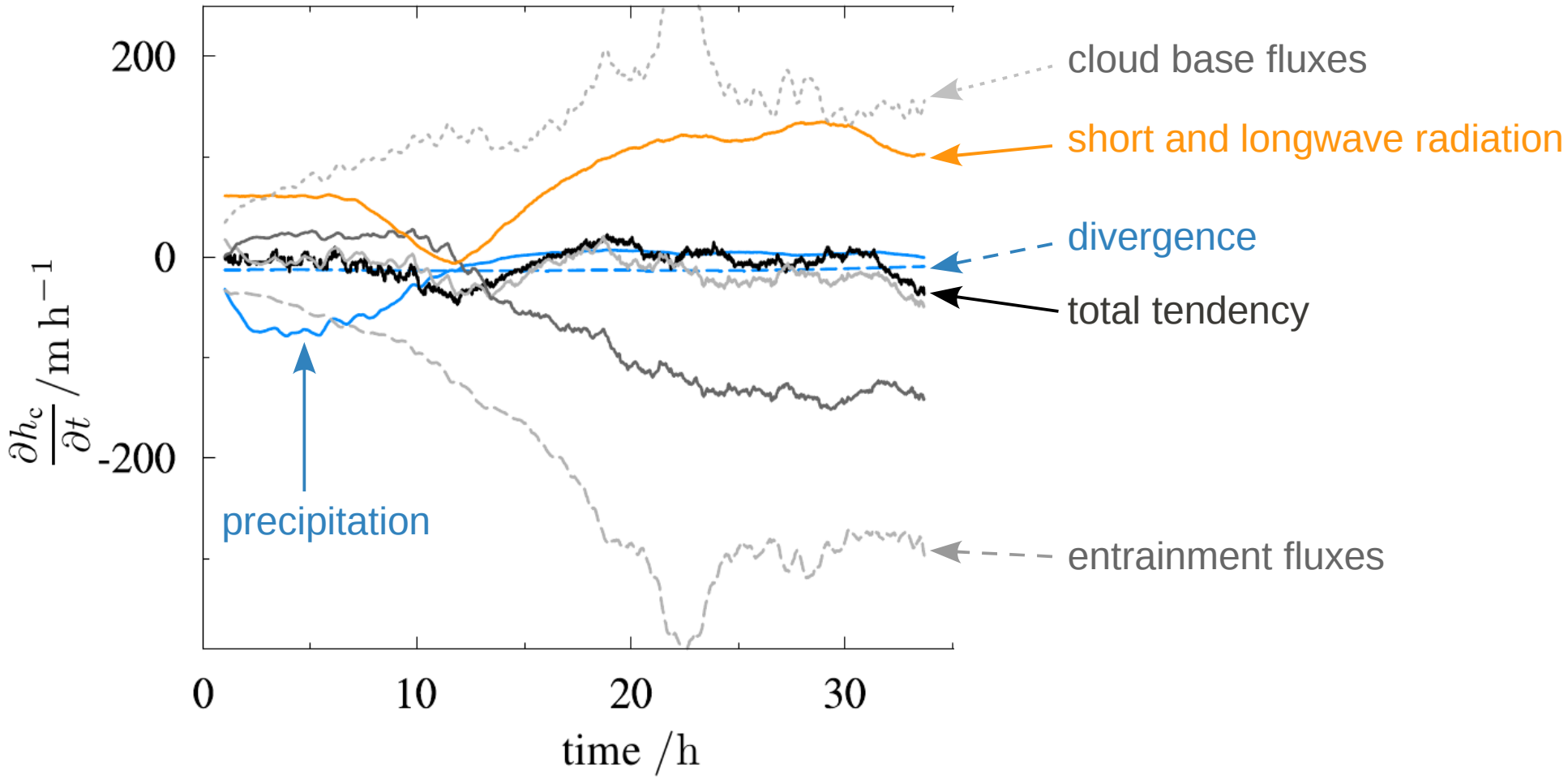
Thermodynamics

Result: analysis of cloud thickness tendency during ASTEX

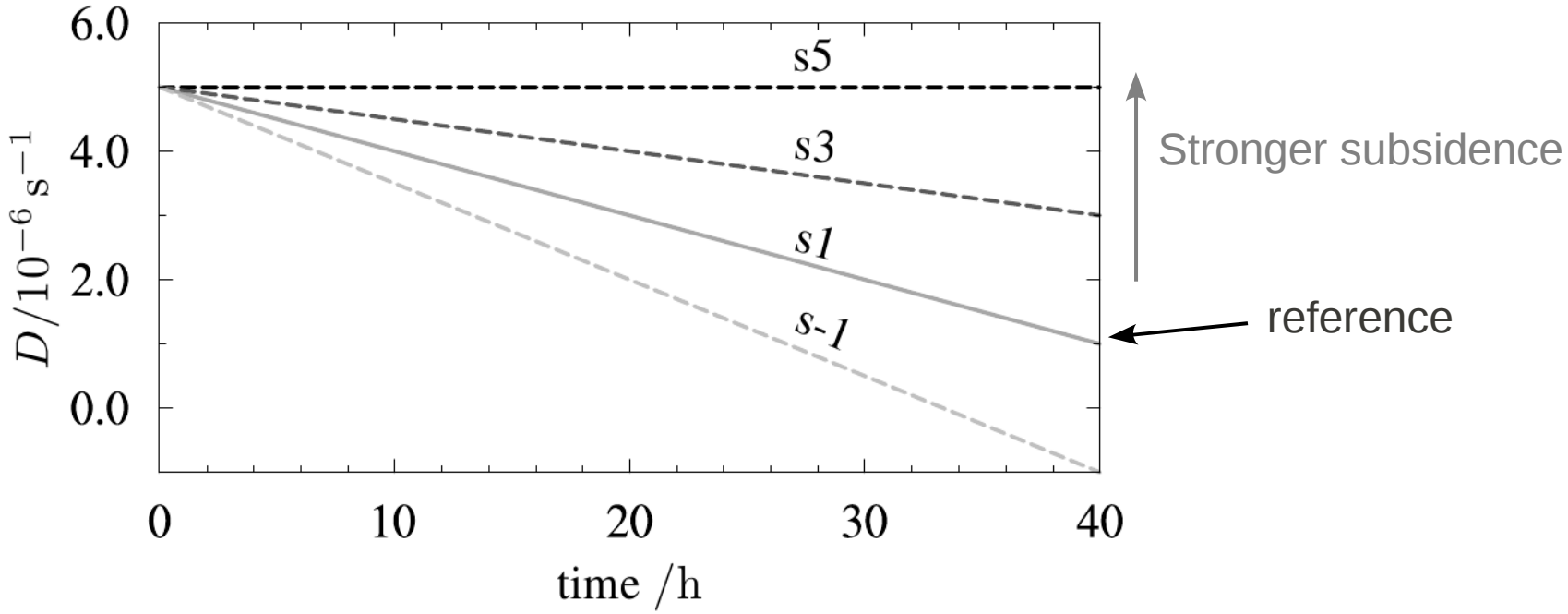


Sensitivity experiments: divergence

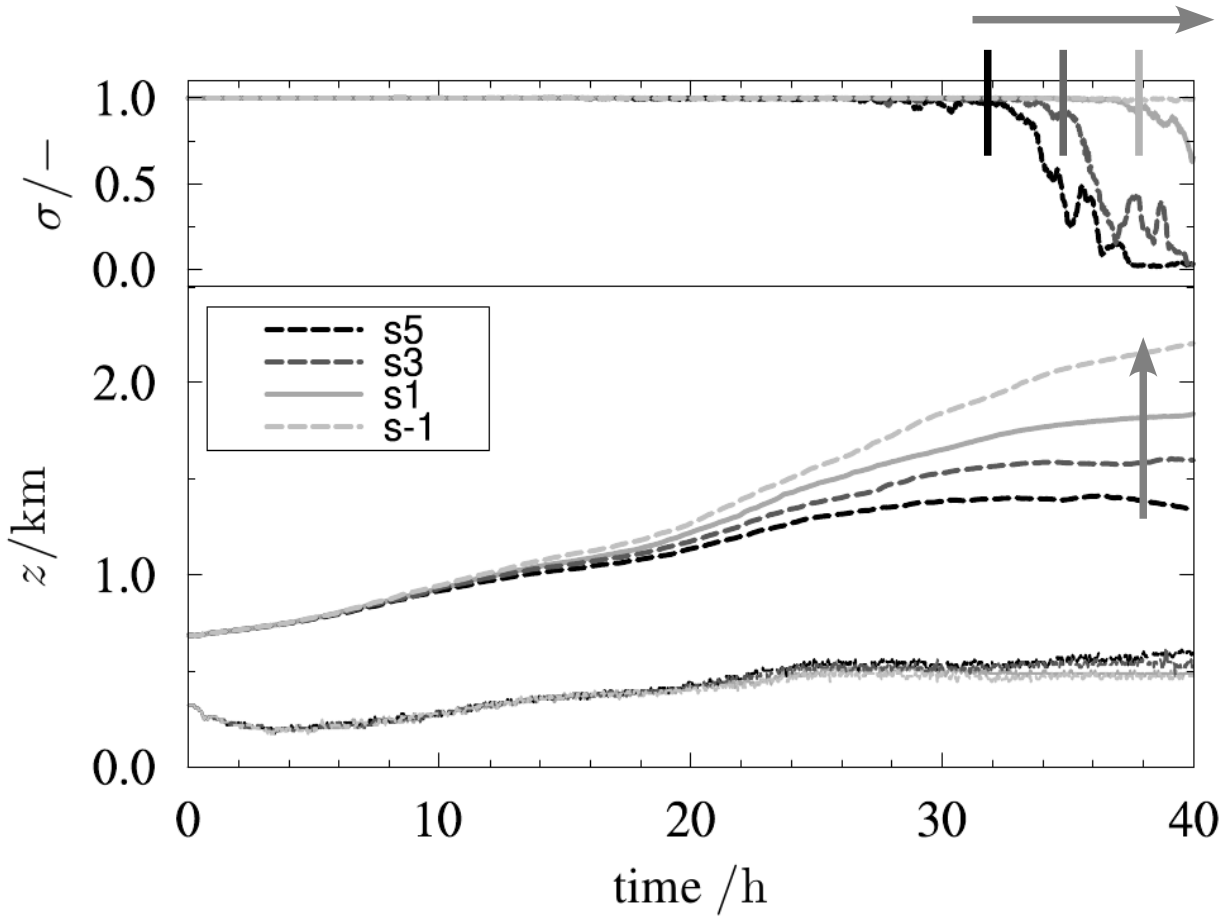
Sensitivity experiments: divergence

Transitions were previously shown to be slowed down by lower divergence
(De Roode and Van der Dussen, 2010; Sandu and Stevens, 2011)

Three extra simulations were performed to investigate this effect



Delayed cloud break up by lowering divergence

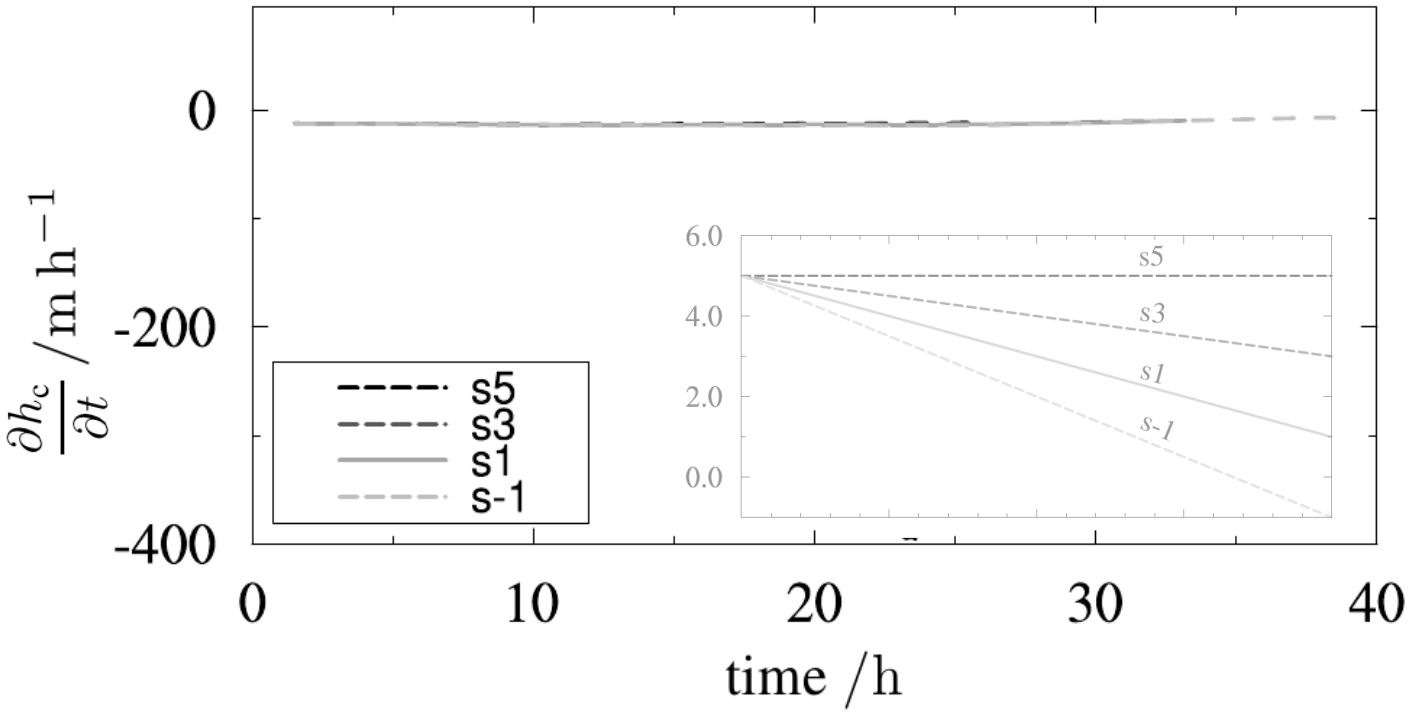


$$\frac{\partial z_i}{\partial t} = w_e + \overline{w}$$

Inversion height increases due to:

- less negative $\overline{w}$ (~ 2/3)
- increased w_e (~ 1/3)

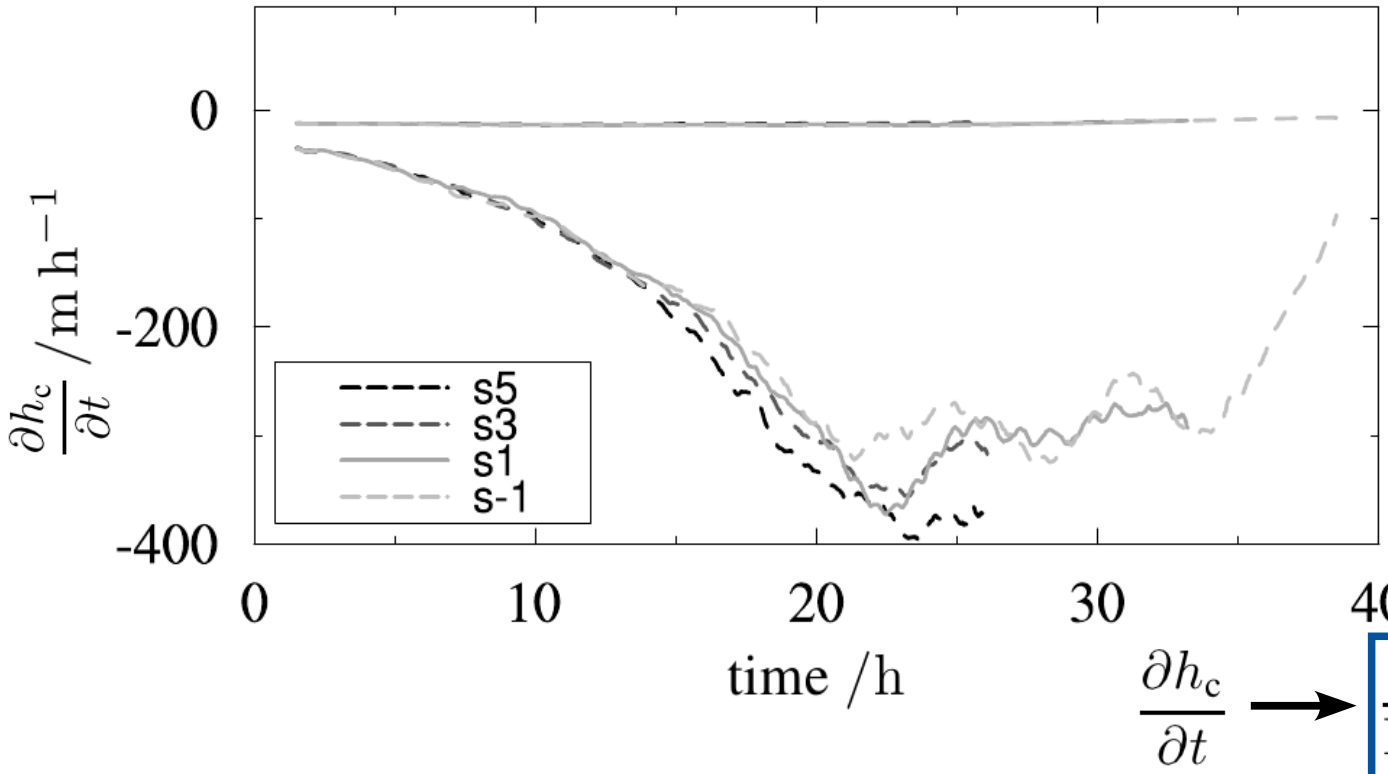
Tendency due to divergence hardly changes



Divergence:

$$\frac{\partial h_c}{\partial t} \rightarrow -Dz_i$$

Tendency due to entrainment becomes less negative



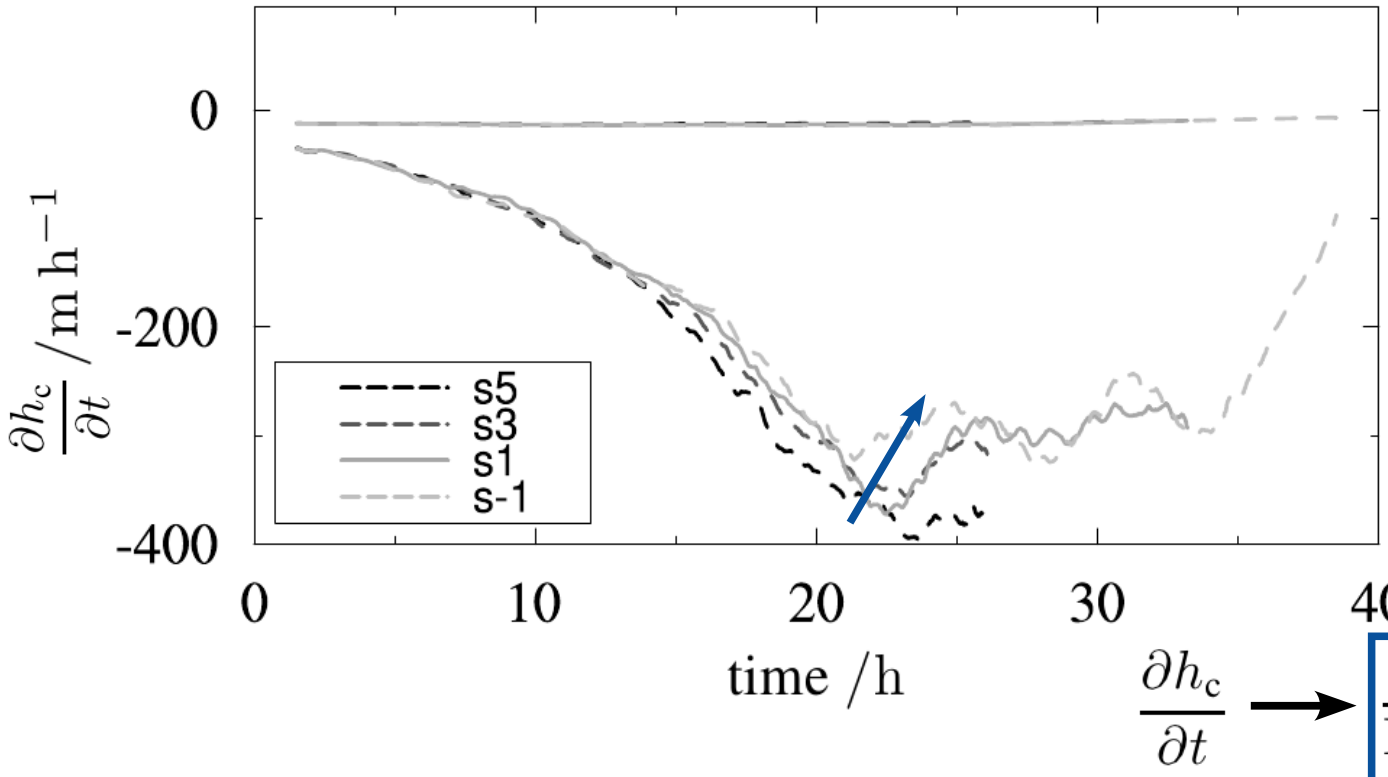
Divergence:

$$\frac{\partial h_c}{\partial t} \rightarrow -Dz_i$$

Entrainment:

$$\frac{\partial h_c}{\partial t} \rightarrow \frac{\eta w_e}{\Gamma_{q_L} h_c}\left(\Delta_i q_T - \Pi\gamma\Delta_i\theta_L\right) + w_e$$

Tendency due to entrainment becomes less negative



Divergence:

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$$\frac{\partial h_c}{\partial t} \rightarrow \frac{\eta w_e}{\Gamma_{q_L} h_c}\left(\Delta_i q_T - \Pi\gamma\Delta_i\theta_L\right) + w_e$$

Contribution due to entrainment decreases, even though the entrainment rate increases

Hypothesis: extra decoupling decreases magnitudes of jumps

Lower divergence

↓

More decoupled boundary layer

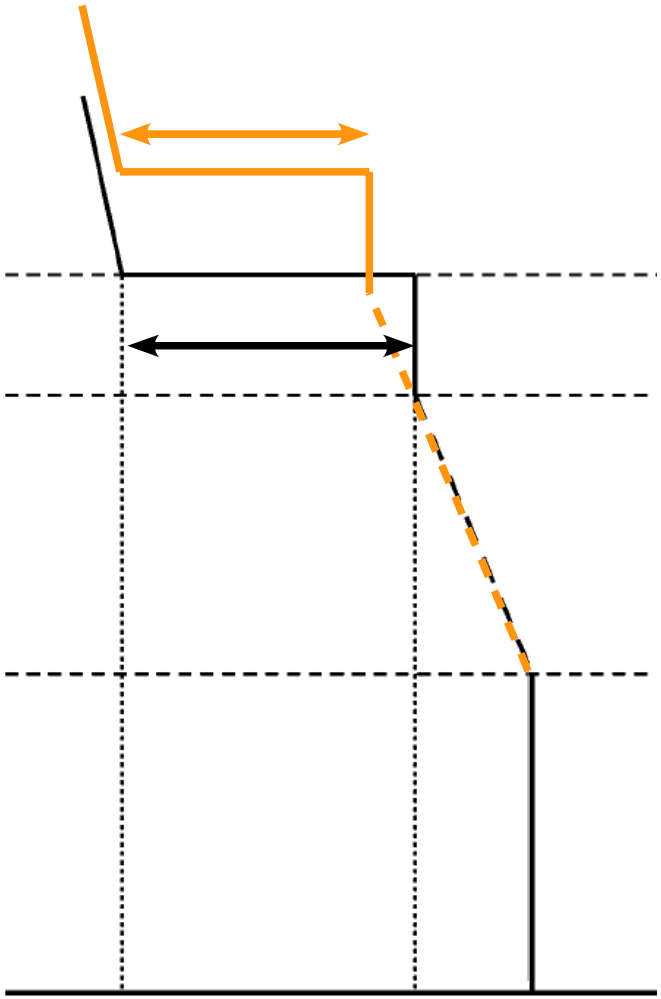
(Park etal, 2004; Wood and Bretherton, 2004)

↓

Smaller inversion jumps

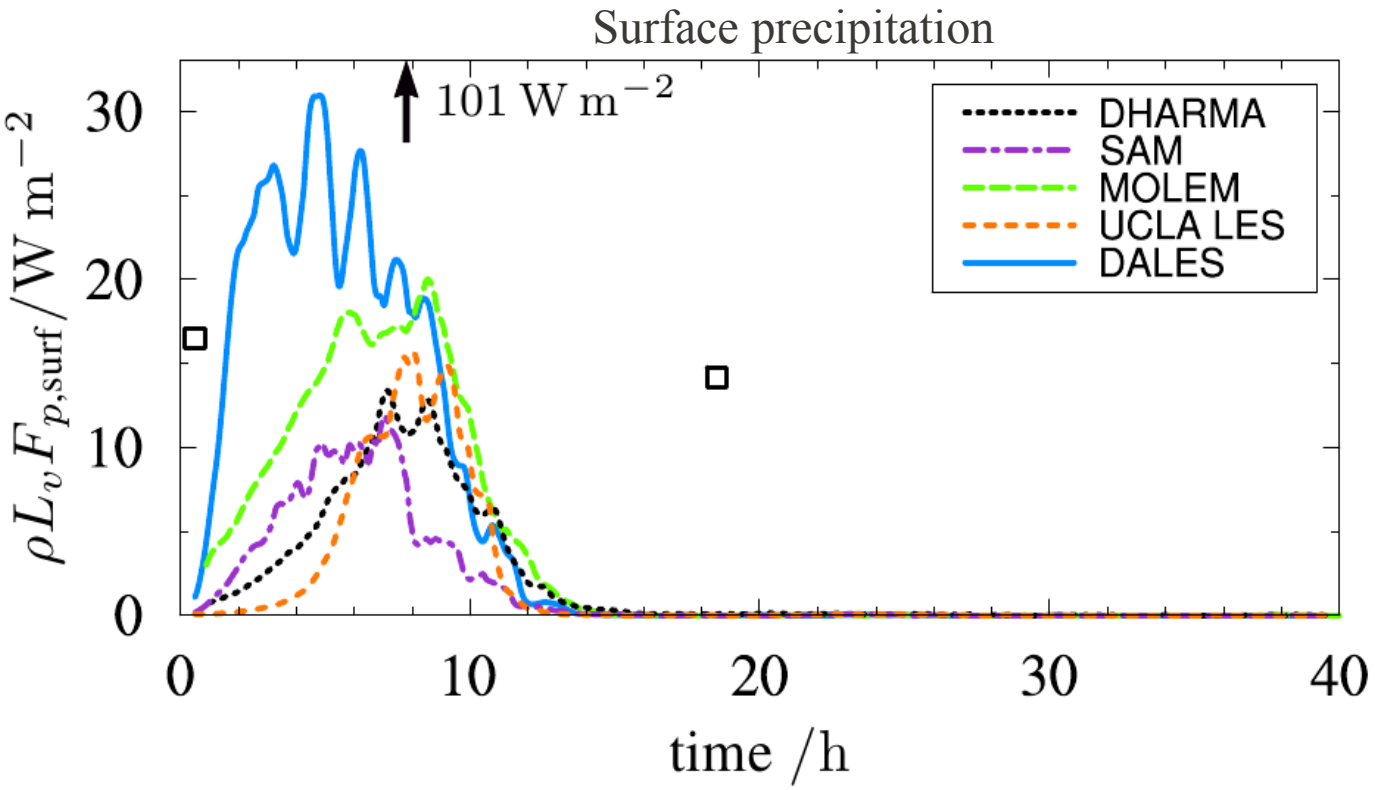
↓

Less warming/drying due to entrainment

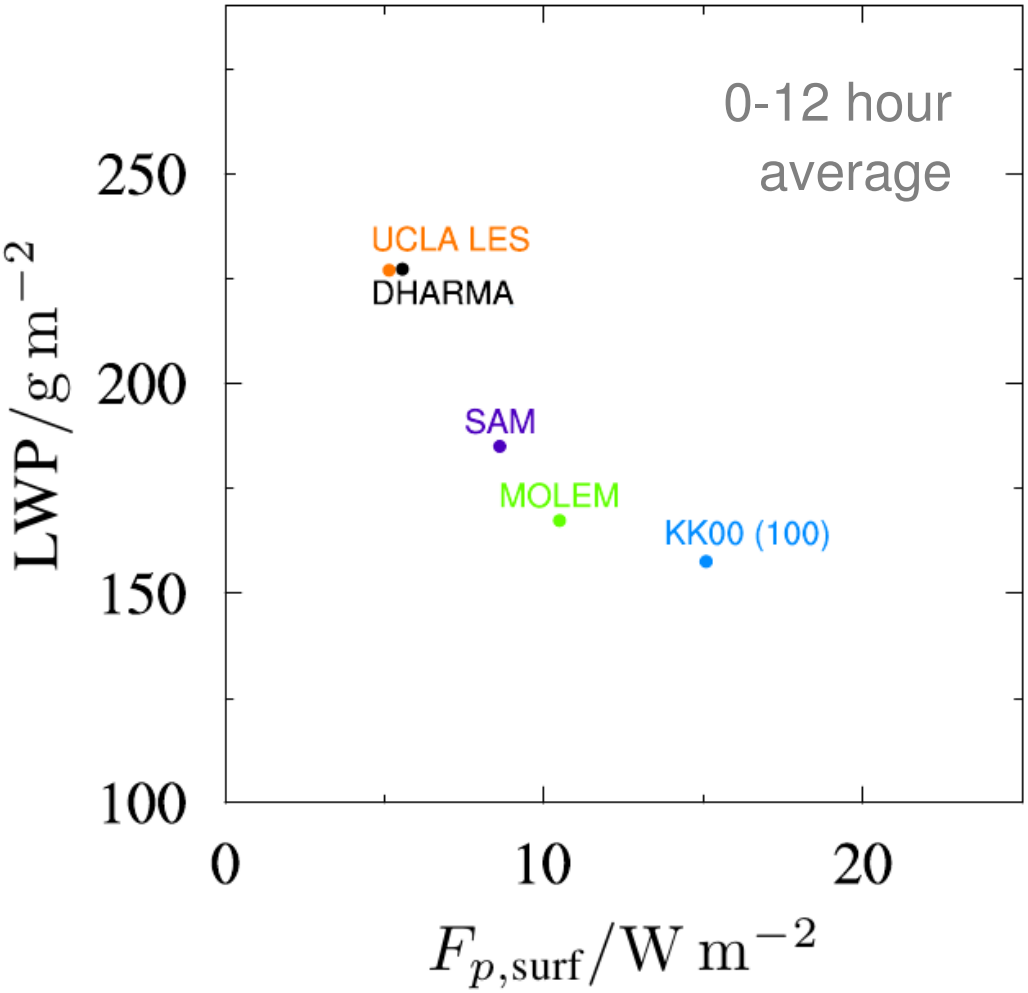


Sensitivity experiments: Cloud droplet number density

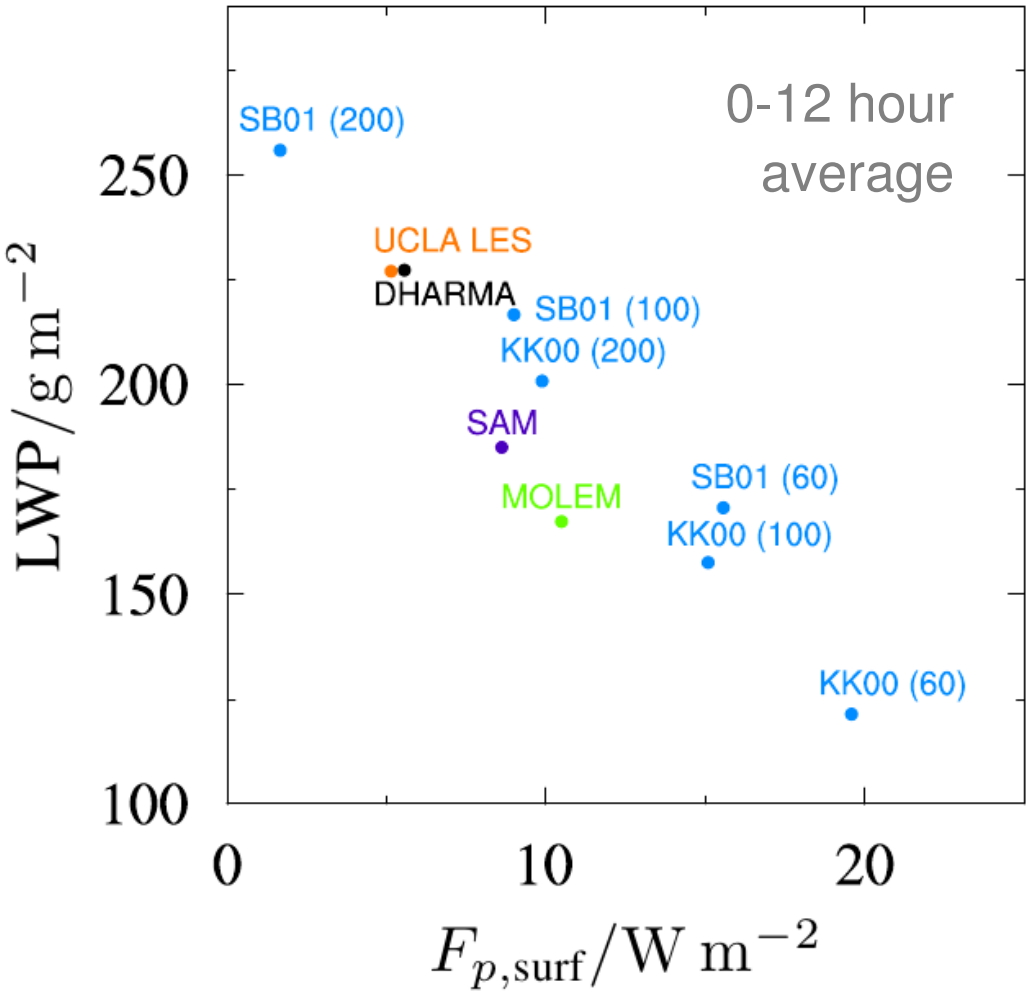
Relatively large precipitation differences



Precipitation rate differences related to LWP



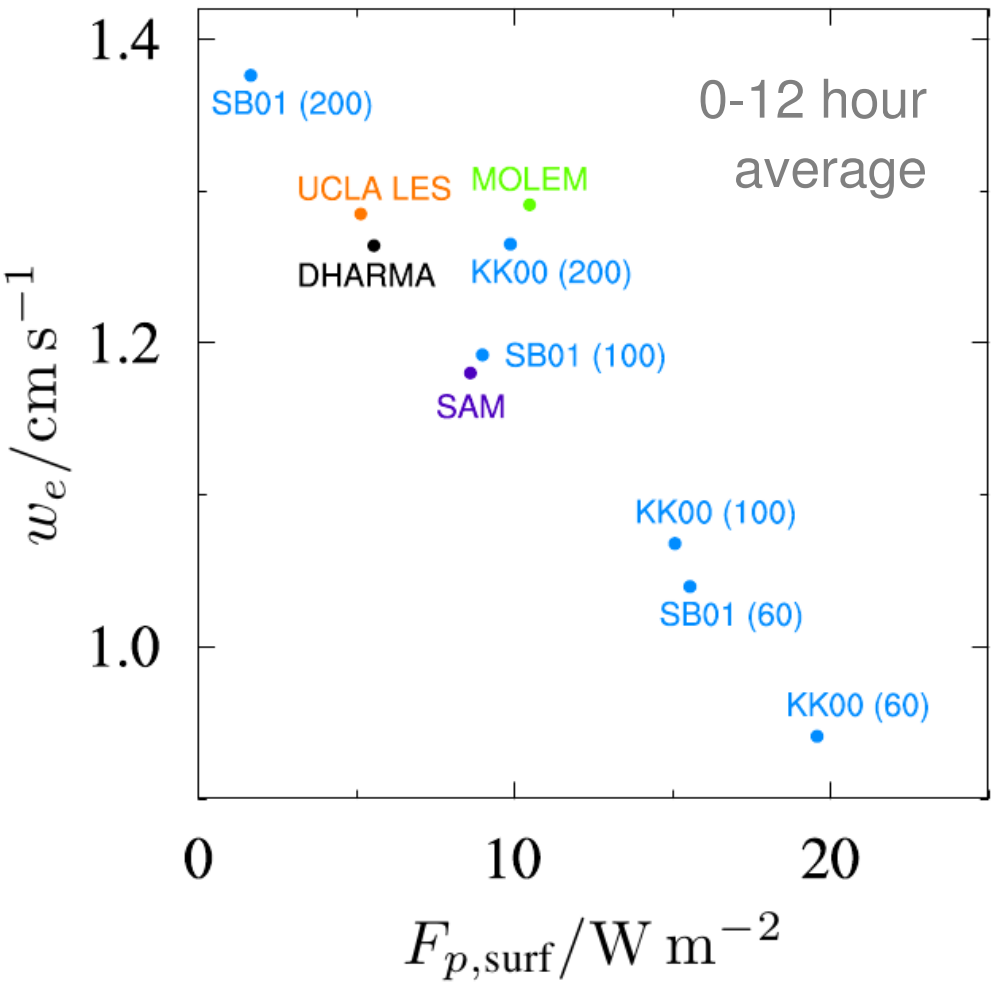
Sensitivity experiments: precipitation



Additional simulations using DALES confirm relation

- N_c = 60, 100 and 200 cm^{-3}
- Khairoutdinov and Kogan (2000)
  Seifert and Beheng (2001)

Entrainment rate sensitive to change in cloud droplet number



Lower entrainment rate (up to 30 %) when decreasing N_c

Opposite relation has been reported for the composite cases

Entrainment contribution:

$$\frac{\partial h_c}{\partial t} \rightarrow \boxed{\frac{\eta w_e}{\Gamma_{q_L} h_c} \left(\Delta_i q_T - \Pi \gamma \Delta_i \theta_L\right) + w_e}$$

For ASTEX, jumps are small and contribution hardly changes

In the composite cases, q_T jump is factor of 4 larger

Parametrisation statistics

Identification and comparison of the key quantities used in ESM parametrisation schemes with LES results and observations	D3.4

Next step: parametrisation statistics

Example: conditionally sampled w-budget

$$\frac{\partial w_s}{\partial t} = \underbrace{B_s}_{\text{Buoyancy}} - \underbrace{\frac{1}{2}\frac{\partial w_s^2}{\partial z}}_{\text{Advection}} - \underbrace{\frac{\epsilon_w w_s^2}{1-\sigma_s}}_{\text{Entrainment}} - \underbrace{\frac{1}{\sigma_s}\frac{\partial \sigma_s \overline{w'' w''}^s}{\partial z}}_{\text{Subplume}} - \underbrace{\left[\frac{\partial p}{\partial z}\right]_s}_{\text{Pressure}} + \underbrace{2\Omega u_s \cos\phi}_{\text{Coriolis}}$$

Next step: parametrisation statistics

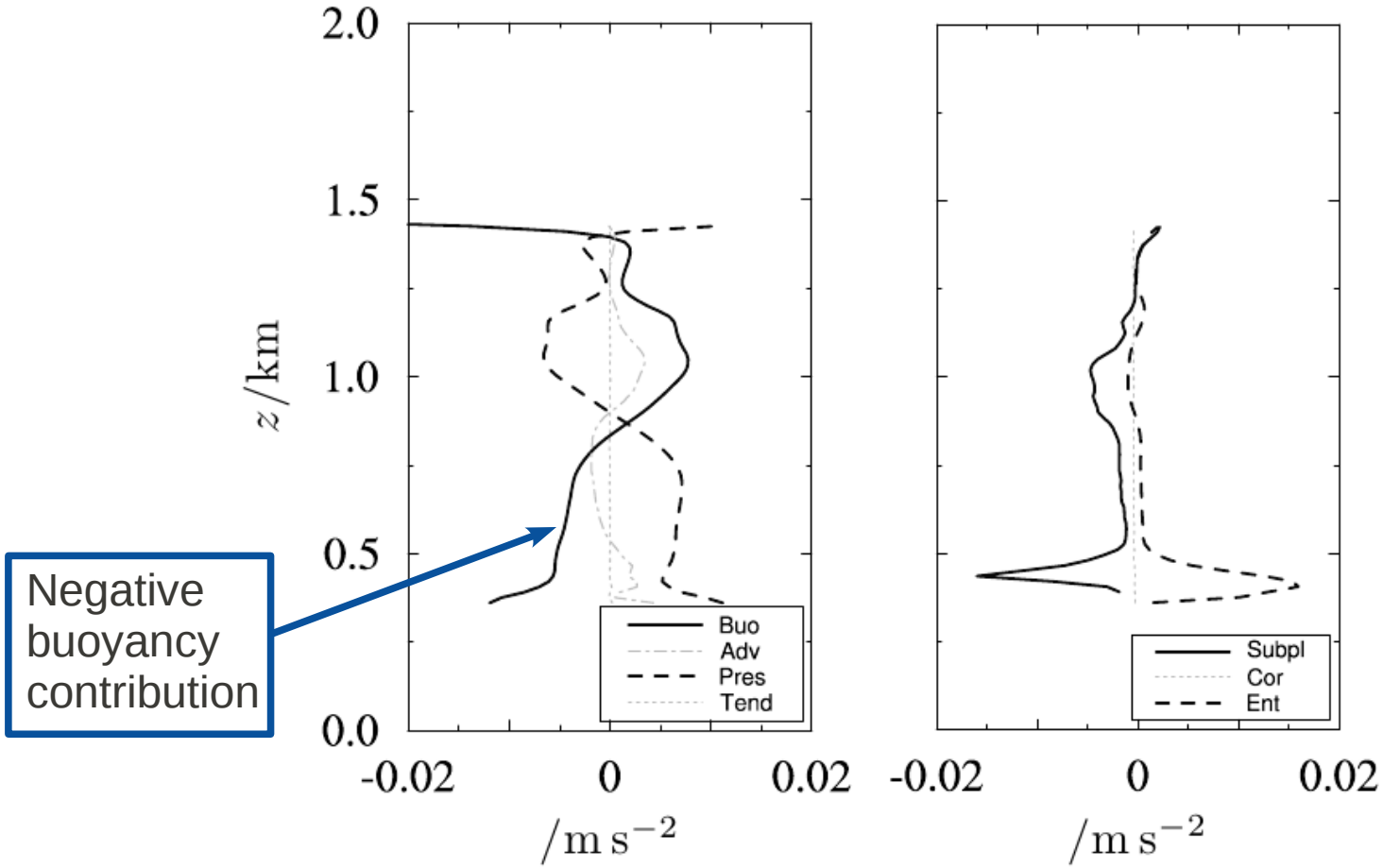
Example: conditionally sampled w-budget

$$\frac{\partial w_s}{\partial t} = \underbrace{B_s}_{\text{Buoyancy}} - \underbrace{\frac{1}{2}\frac{\partial w_s^2}{\partial z}}_{\text{Advection}} - \underbrace{\frac{\epsilon_w w_s^2}{1-\sigma_s}}_{\text{Entrainment}} - \underbrace{\frac{1}{\sigma_s}\frac{\partial \sigma_s \overline{w'' w''}^s}{\partial z}}_{\text{Subplume}} - \underbrace{\left[\frac{\partial p}{\partial z}\right]_s}_{\text{Pressure}} + \underbrace{2\Omega u_s \cos\phi}_{\text{Coriolis}}$$

Typically parametrised as:

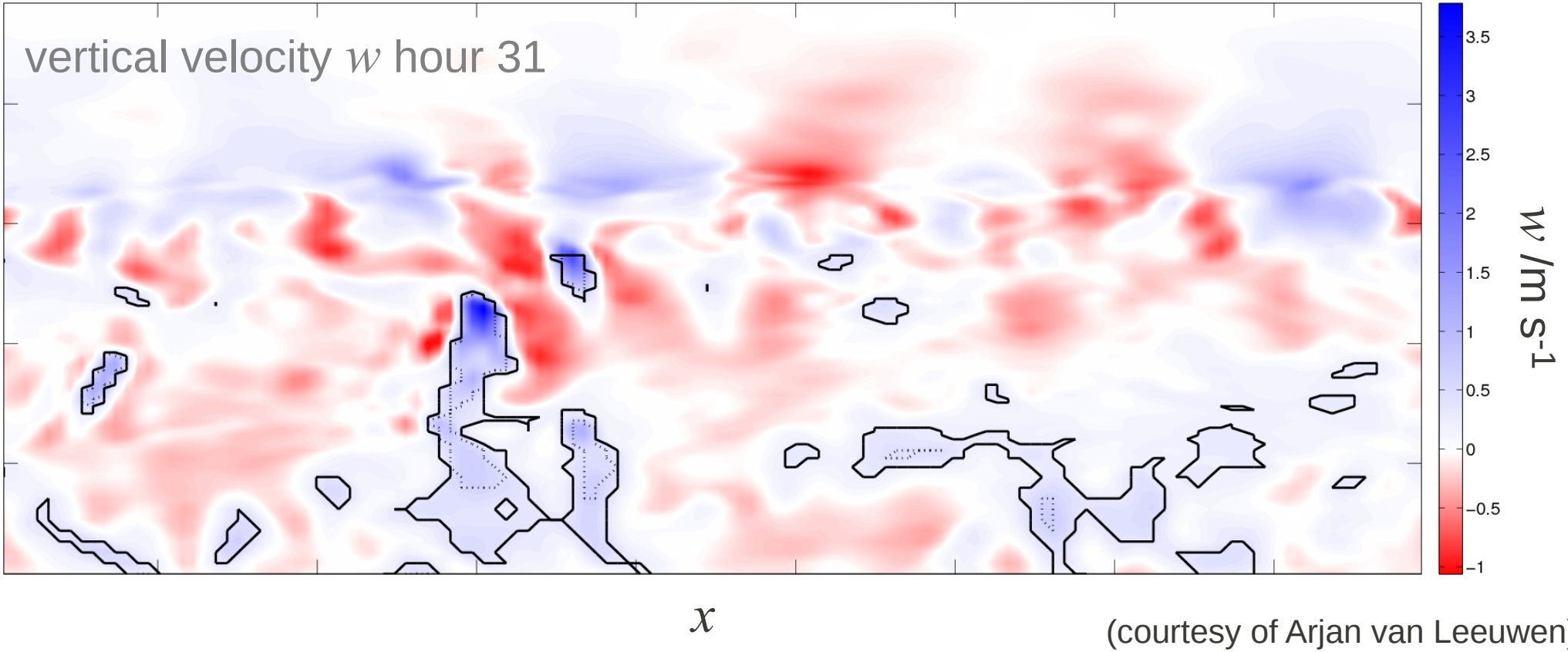
$$\frac{1}{2}\frac{\partial w_s^2}{\partial z} = aB_s - b\epsilon_q w_s^2$$

Unexpected results for cloud updraft sampling



Test sampling criteria using 3D LES data

Storage of instantaneous 3D LES fields and key statistical variables in a public archive	D3.2



(courtesy of Arjan van Leeuwen)

Publicly accessible 3D LES fields to test sampling criteria

EUCLIPSE *European Union Cloud Intercomparison, Process Study & Evaluation Project*

Home | Projectinfo | WP1 | WP2 | WP3 | WP4 | Deliverables

Intercomparison cases

- ASTEX Lagrangian
- Composite Cases
- CGILS
- Radiation intercomparison study

Meetings

- EUCLIPSE WP3 meeting Toulouse, 5-6 April 2012
- EUCLIPSE-GCSS/BLCWG meeting De Bilt, 27-30 September 2010

Links

- Cloud Feedback MIP
- GEWEX Cloud System Study

Instantaneous 3D LES fields for the ASTEX case as obtained with DALES

Below is a list of file names astex_3D_hhmmss.nc, with hh indicating the hour, mm the minute, and ss the seconds.

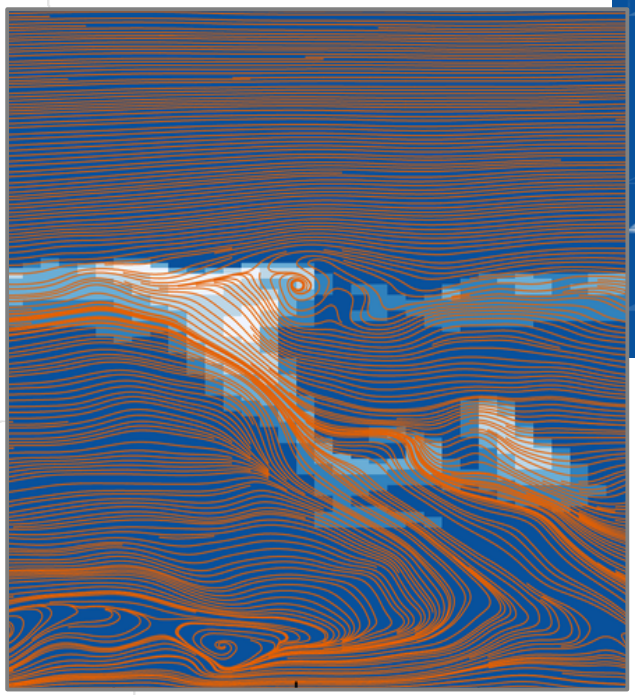
- astex_3D_020000.nc
- astex_3D_020500.nc
- astex_3D_021000.nc
- astex_3D_021500.nc
- astex_3D_022000.nc
- astex_3D_022500.nc
- astex_3D_023000.nc
- astex_3D_023500.nc
- astex_3D_024000.nc
- astex_3D_024500.nc
- astex_3D_025000.nc
- astex_3D_025500.nc
- astex_3D_030000.nc
- astex_3D_070000.nc
- astex_3D_070500.nc
- astex_3D_071000.nc
- astex_3D_071500.nc
- astex_3D_072000.nc
- astex_3D_072500.nc

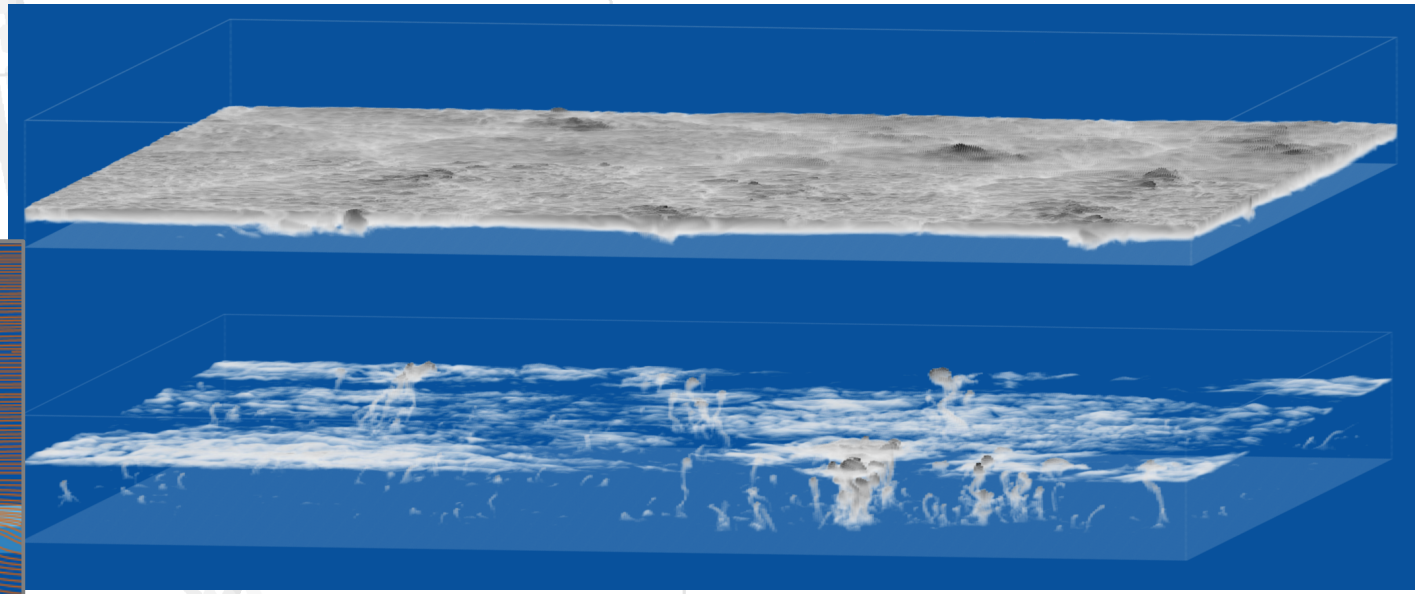
http://www.euclipse.nl/wp3/LES_Data/ASTEX/Dales/

3D fields of u, v, w, θ_L, q_T, q_L, N_r and q_r

5 minute interval during selected hours of transition

Status of the ASTEX LES intercomparison study





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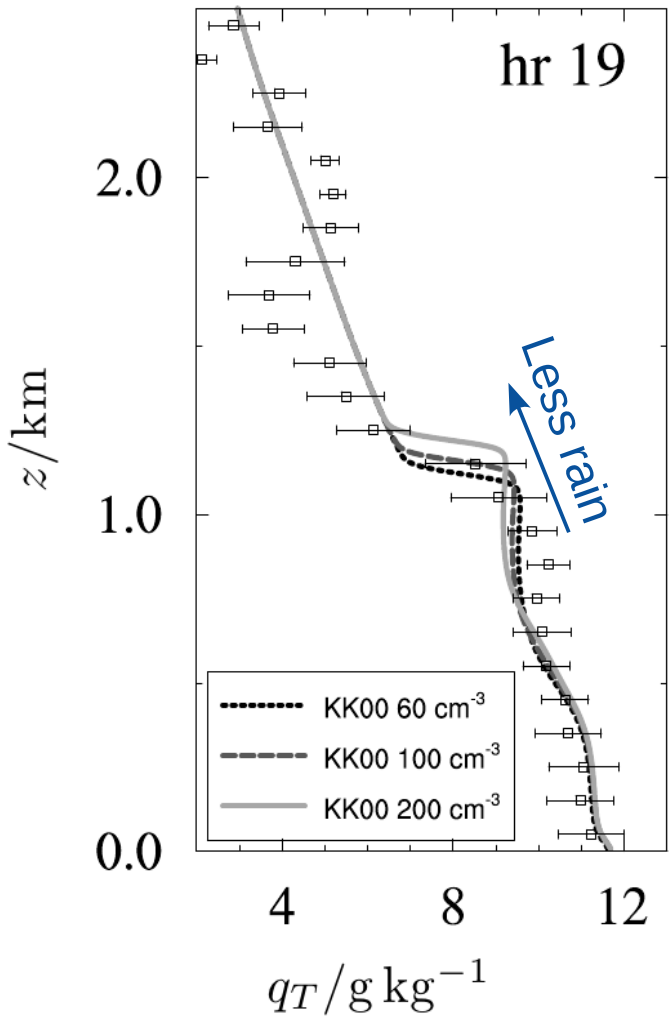
Tendency of cloud layer thickness (2)

$$\frac{\partial h_c}{\partial t} = \text{Base} + \text{Ent} + \text{Prec} + \text{Rad} + \text{Div}$$

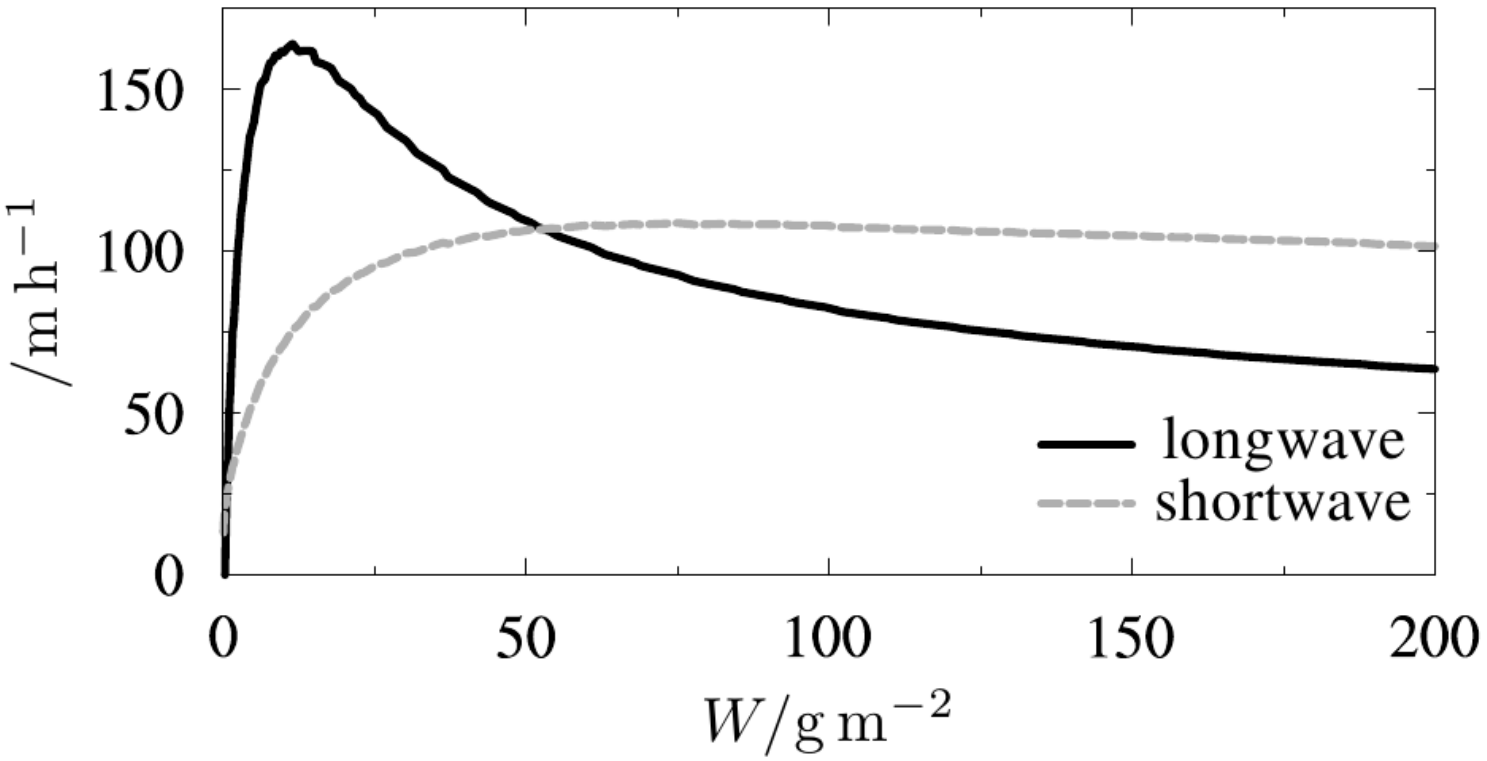
Tendency due to:

- Base: cloud base fluxes
- Ent: entrainment fluxes
- Prec: precipitation
- Rad: short and longwave radiation
- Div: divergence

Decoupling can decrease for increased precipitation



Tendency due to shortwave and longwave radiation



Sensitivity experiments: precipitation

Generally good agreement between models, but not for all variables: