COST Action Meeting
20-22 March 2012

Diagnosis of convective parameterisation schemes in extratropical cyclones

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DIAMET project

DIAbatic influences on Mesoscale structures in ExTratropical storms

- Consortium constituted by four UK universities (Manchester, Leeds, Reading and East Anglia) and the Met Office
- Three Work Packages
  - WP A. Structure of mesoscale anomalies and their wide-scale consequences
  - **WP B. Physical processes and their parameterisation**
  - WP C. Predictability

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  - WP A. Structure of mesoscale anomalies and their wide-scale consequences
  - **WP B. Physical processes and their parameterisation**
    1. **Improving convective parameterisation**
    2. Air-sea fluxes and their influence on storm development
    3. Microphysical processes
  - WP C. Predictability

Budget diagnostics

- Tracers (affected by advection) for potential temperature (θ), specific humidity (q), cloud liquid water (q_{cl}) and cloud ice content (q_{cf})
- The variables of interest (θ, q, q_{cl} and q_{cf}) are decomposed in the following way:

$$\varphi = \varphi_0 + \Delta\varphi \tag{1}$$

- In turn the total increment to the variable is decomposed as follows:

$$\Delta\varphi(x,t) = \sum_{i=\mathrm{proc}} \Delta\varphi_i(x,t) \tag{2}$$

proc = {parameterised processes}

- These processes depend on the variable under consideration. For example,
  - For potential temperature:
    - Microphysics, mixing in BL, latent heating in BL, convection, radiation
  - For specific humidity:
    - Microphysics, boundary layer, convection

Budget diagnostics

- For each tracer there is an evolution equation of the form

$$\frac{D\varphi_0}{Dt} = \frac{\partial\ \varphi_0}{\partial t} + \mathbf{v}\cdot\nabla\varphi_0 = 0 \qquad (3)$$

- The initial field (φ_0) satisfies the following equation

$$\frac{D\Delta\varphi_i}{Dt} = \frac{\partial\ \Delta\varphi_i}{\partial t} + \mathbf{v}\cdot\nabla\Delta\varphi_i = S_{\varphi_i} \qquad (4)$$

- Rewriting equation (3) and (4) as

$$\frac{\partial\ \varphi_0}{\partial t} = -\mathbf{v}\cdot\nabla\varphi_0 \qquad (5)$$

$$\frac{\partial\ \Delta\varphi_i}{\partial t} = -\mathbf{v}\cdot\nabla\Delta\varphi_i + S_{\varphi_i} \qquad (6)$$

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- Rewriting equation (3) and (4) as

$$\frac{\partial\ \varphi_0}{\partial t} = -\mathbf{v}\cdot\nabla\varphi_0 \tag{5}$$

Only affected by advection

$$\frac{\partial\ \Delta\varphi_i}{\partial t} = -\mathbf{v}\cdot\nabla\Delta\varphi_i + S_{\varphi_i} \tag{6}$$

Affected by sources/sinks of the relevant variable

Budget diagnostics

- The evolution equation for the relevant variables can then be written as

$$\frac{\partial \varphi}{\partial t} = \frac{\partial \varphi_0}{\partial t} + \frac{\partial \Delta\varphi_i}{\partial t} = -\mathbf{v}\cdot\nabla\varphi_0 - \mathbf{v}\cdot\nabla \sum_{i = \text{proc}} \Delta\varphi_i + \sum_{i = \text{proc}} S_{\varphi_i} \tag{7}$$

Budget diagnostics

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Redistribution of conserved component

Advection of conserved component

Budget diagnostics

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Redistribution of conserved component

Evolution of non-conserved components

Advection of conserved component

Advection of non-conserved components

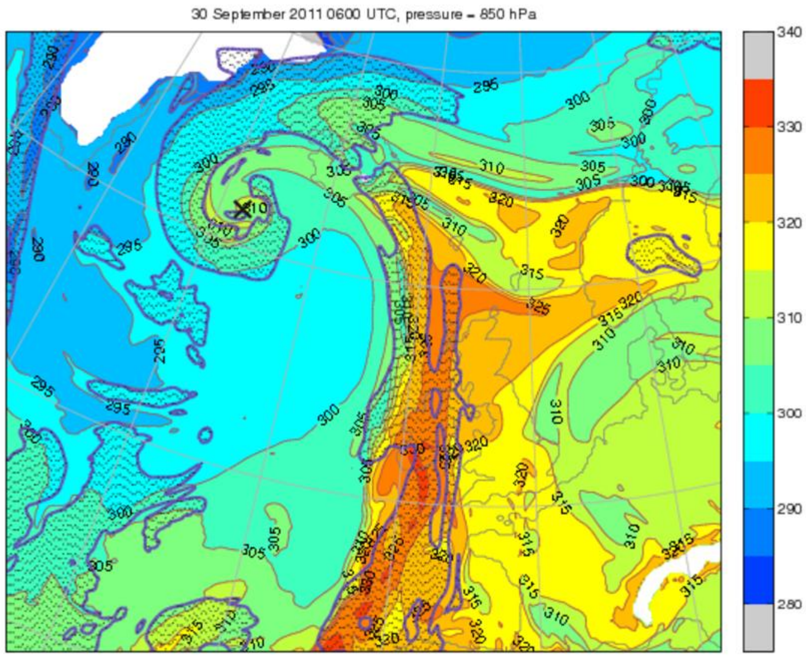
Creation/destruction of non-conserved components

Data and model

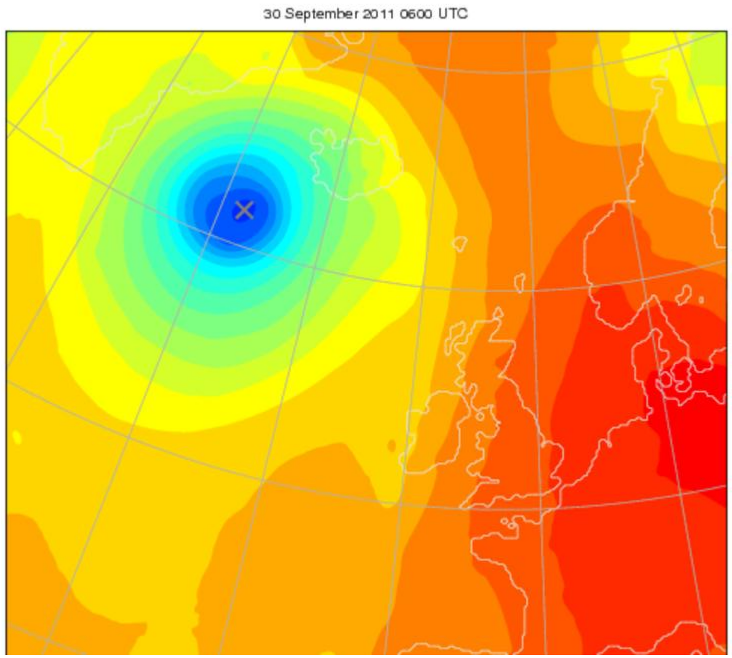
- Case from DIAMET first field campaign:
  - 30 September 2011
  - Low-pressure system centred to the south-west of Iceland
  - Long trailing active cold front
- Model:
  - Met Office Unified Model (MetUM) version 7.3
  - North-Atlantic—Europe (NAE) domain
  - Grid spacing 0.11^{o} (~12 km)
  - 38 vertical levels (lid ~40 km)
  - (MetUM Modified) Gregory—Rowntree convection scheme

DIAMET field campaign
0600 UTC 30 September 2011

University of Reading



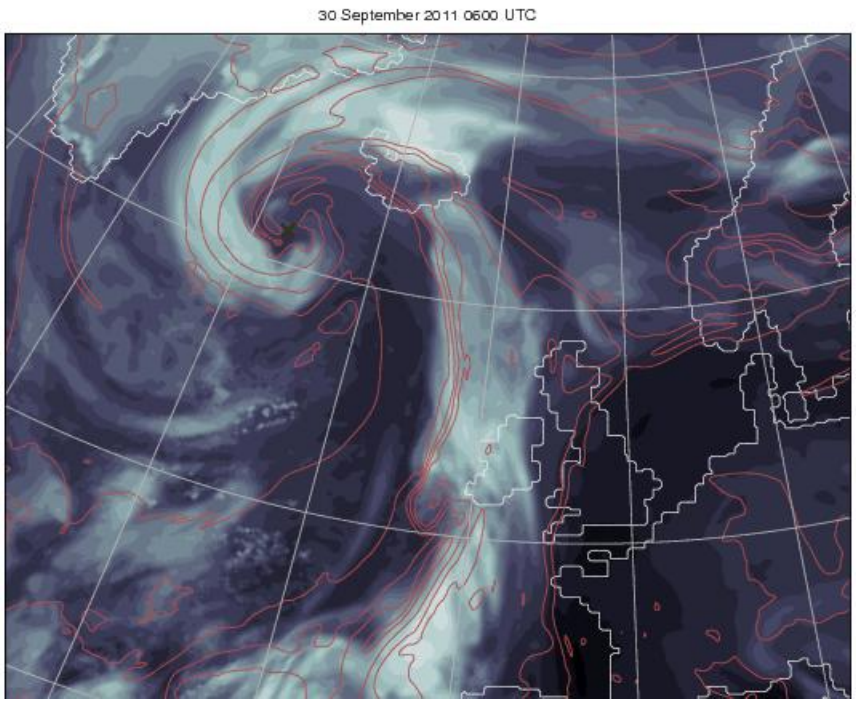
850-hPa equivalent potential temperature



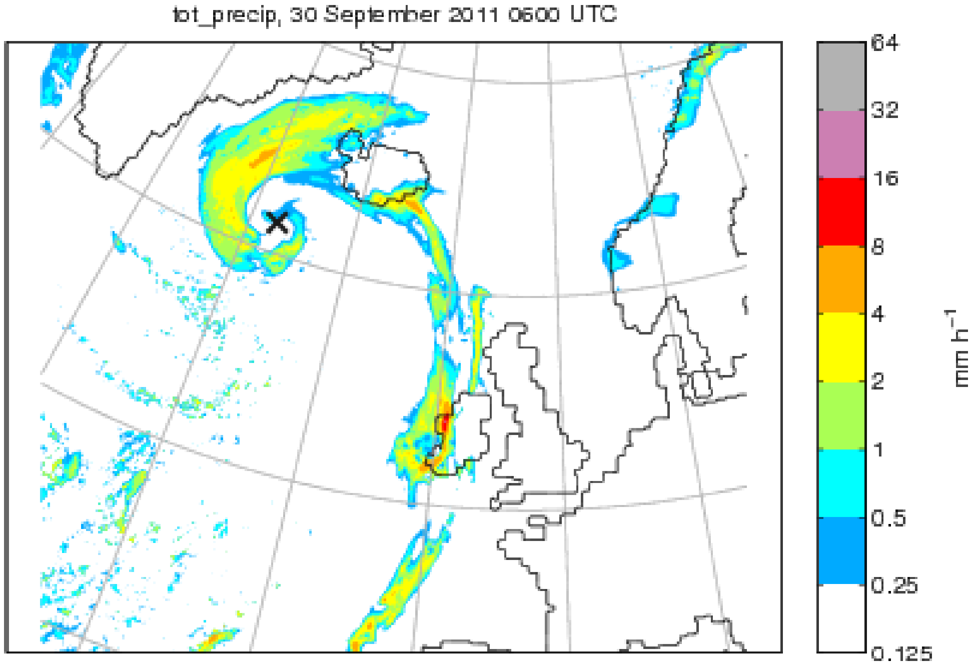
Mean sea-level pressure

DIAMET field campaign
0600 UTC 30 September 2011

Model-derived OLR



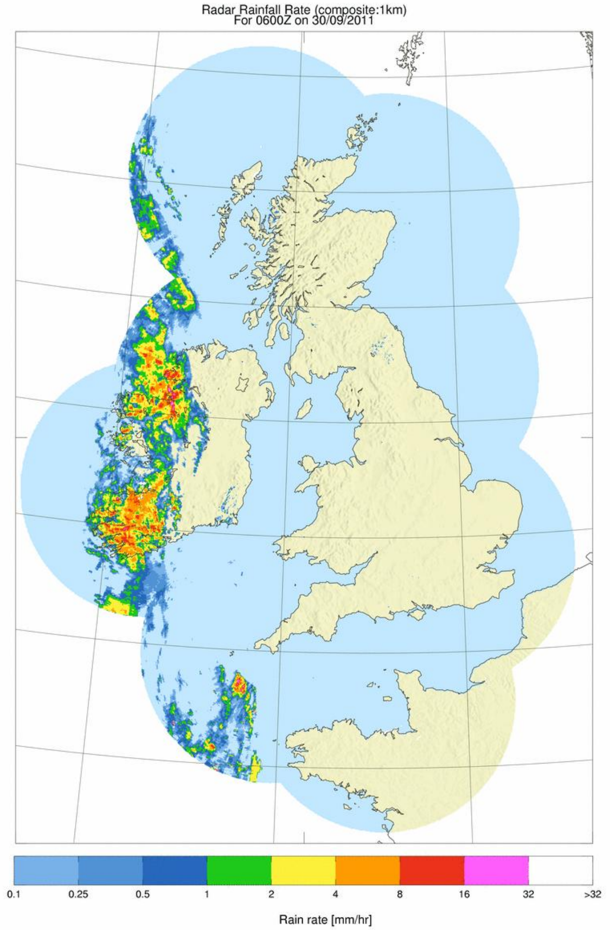
Model derived Total precipitation



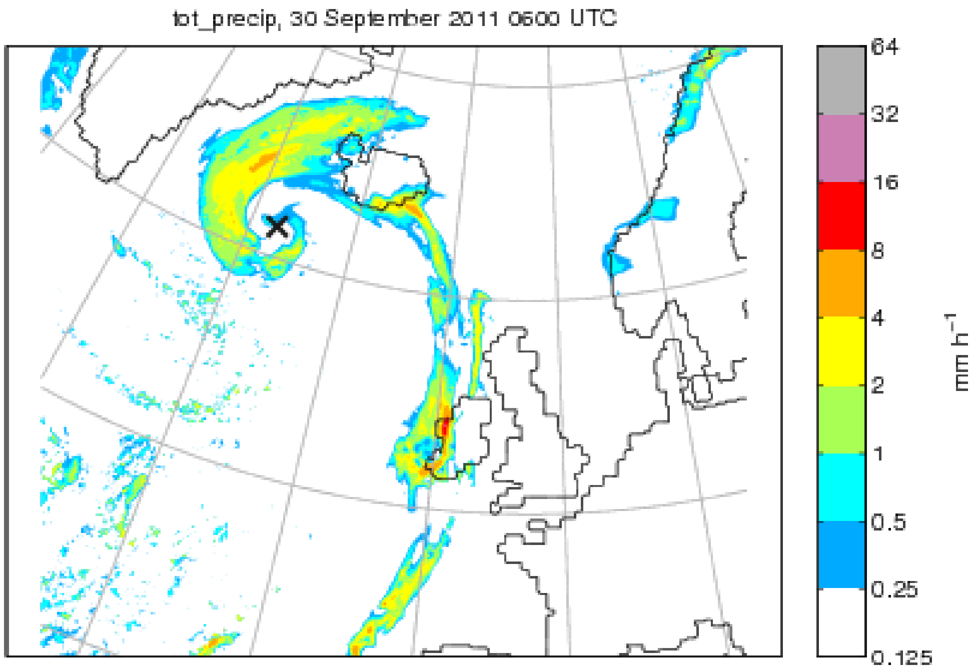
850-hPa equivalent potential temperature

0600 UTC 30 September 2011
Comparison with observations

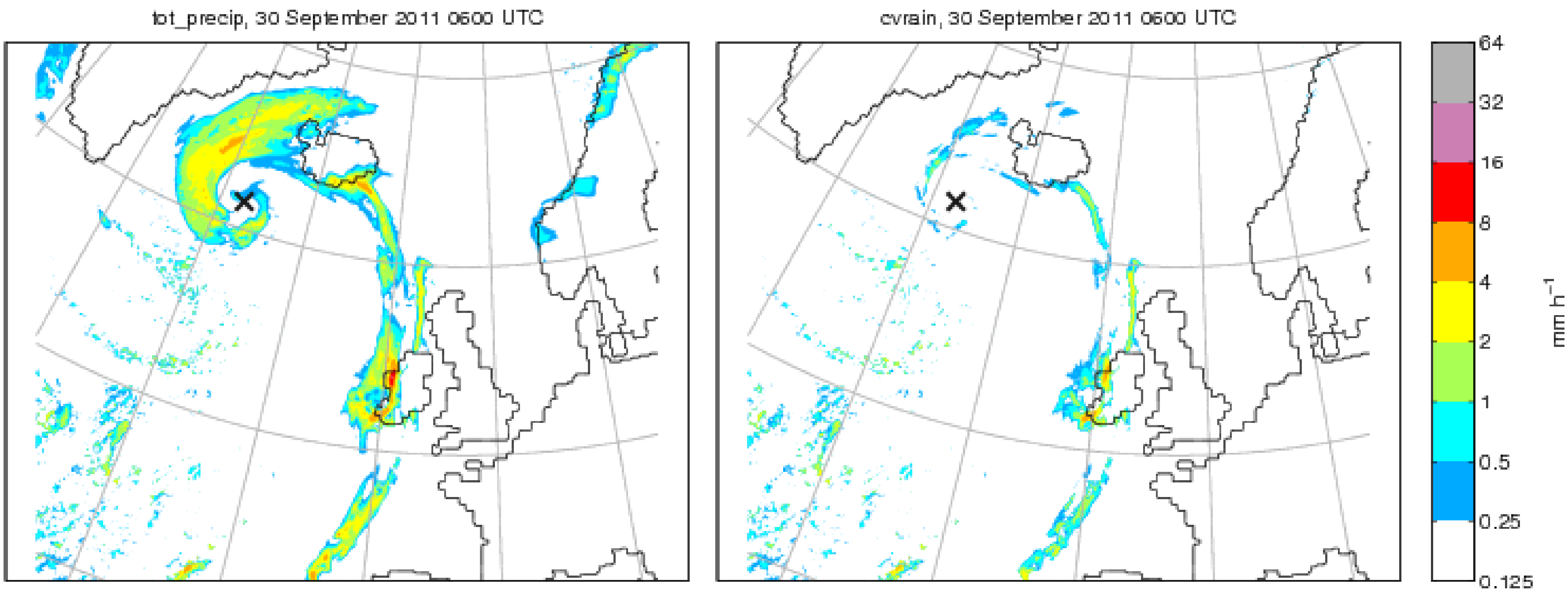
Radar image



Model derived Total precipitation



0600 UTC 30 September 2011
Convective – Large-scale rain split



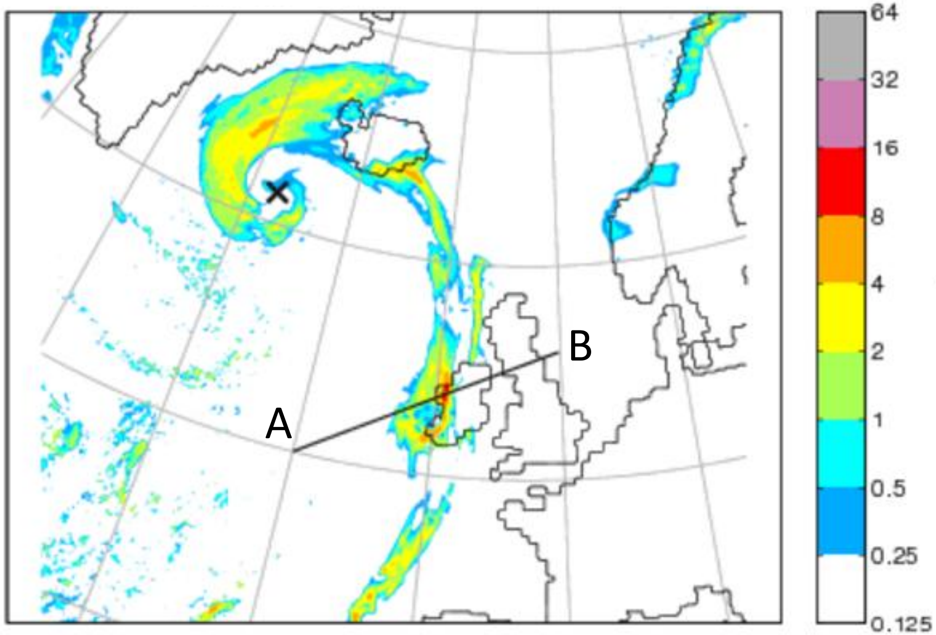
Total precipitation

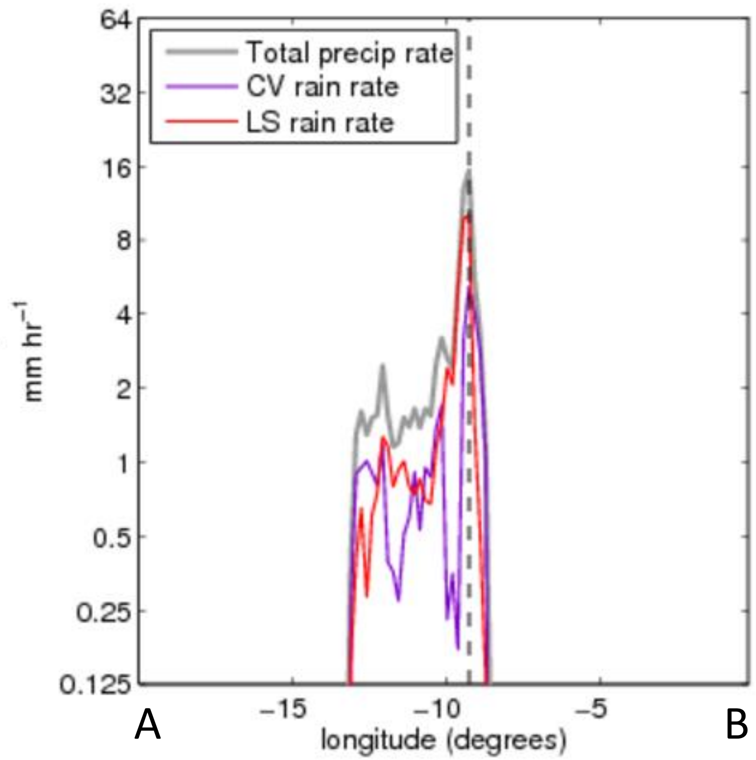
Convective rain

0600 UTC 30 September 2011
Convective – Large-scale rain split

University of Reading

Total precipitation

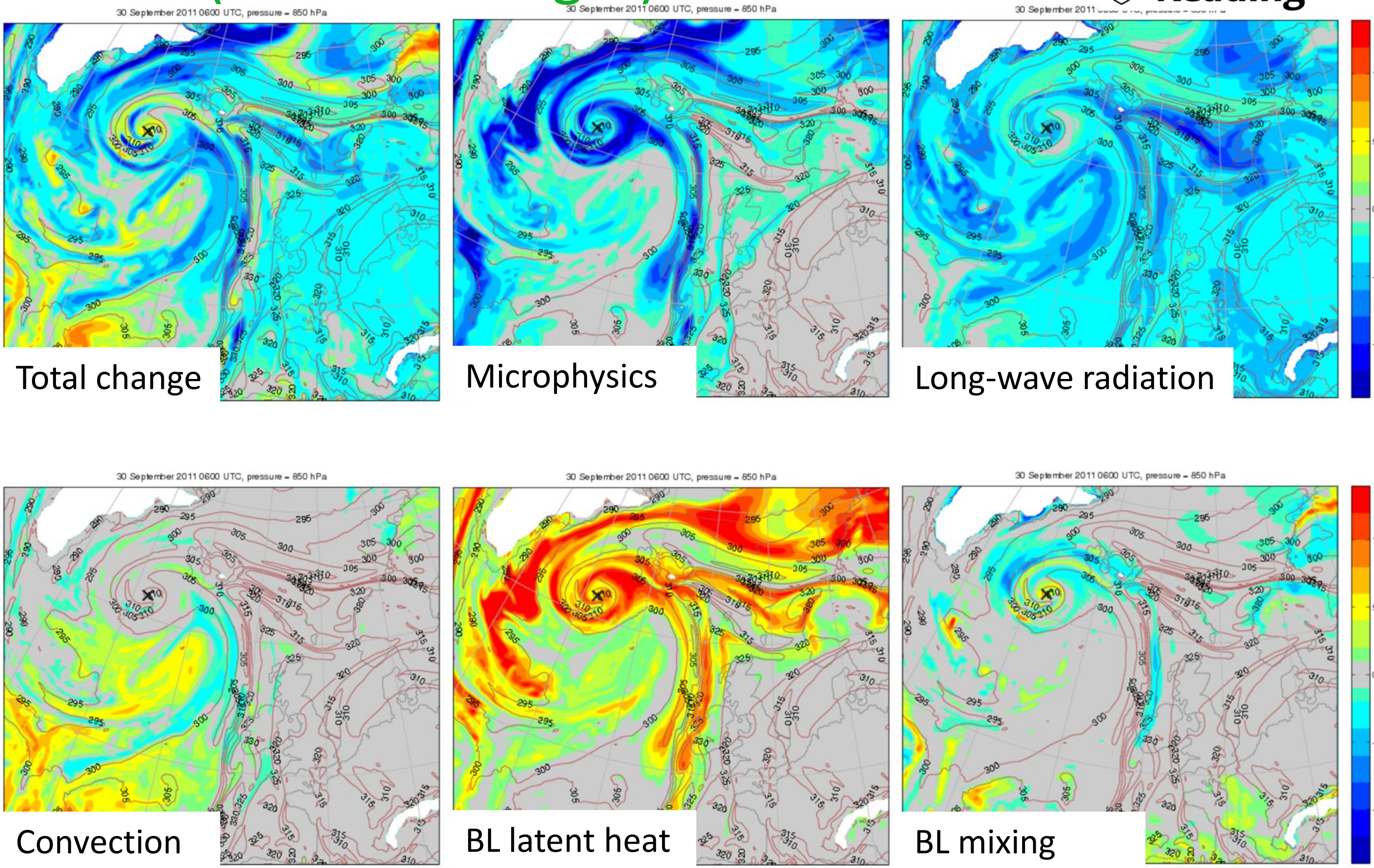




Preliminary results

- Integration starting on 1200 UTC 28 September 2011
- The following slides show cumulative increments on 0600 UTC 30 September 2011 (T+42)

Sources/sinks of potential temperature
850 hPa (~1300 m height)



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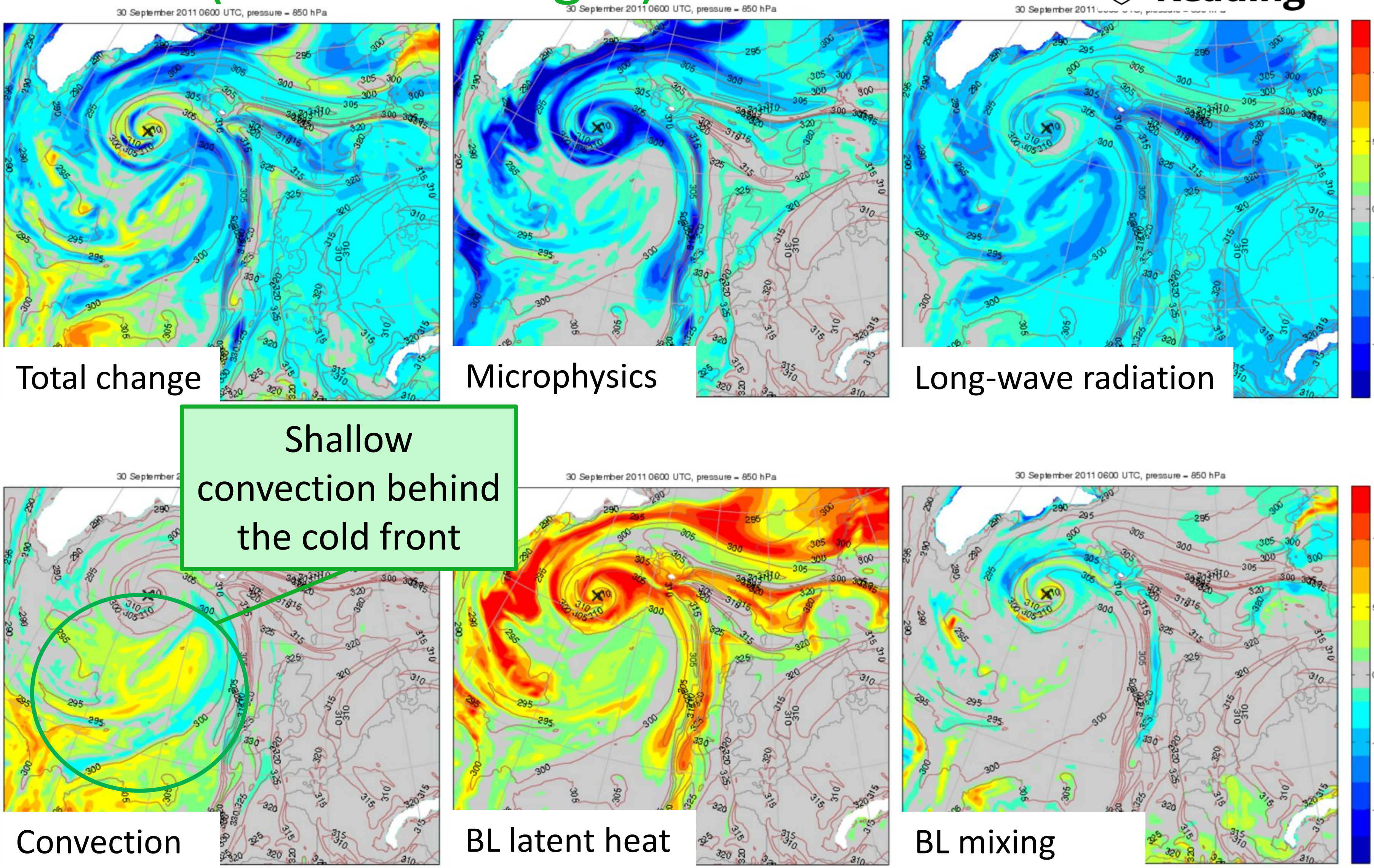
University of Reading



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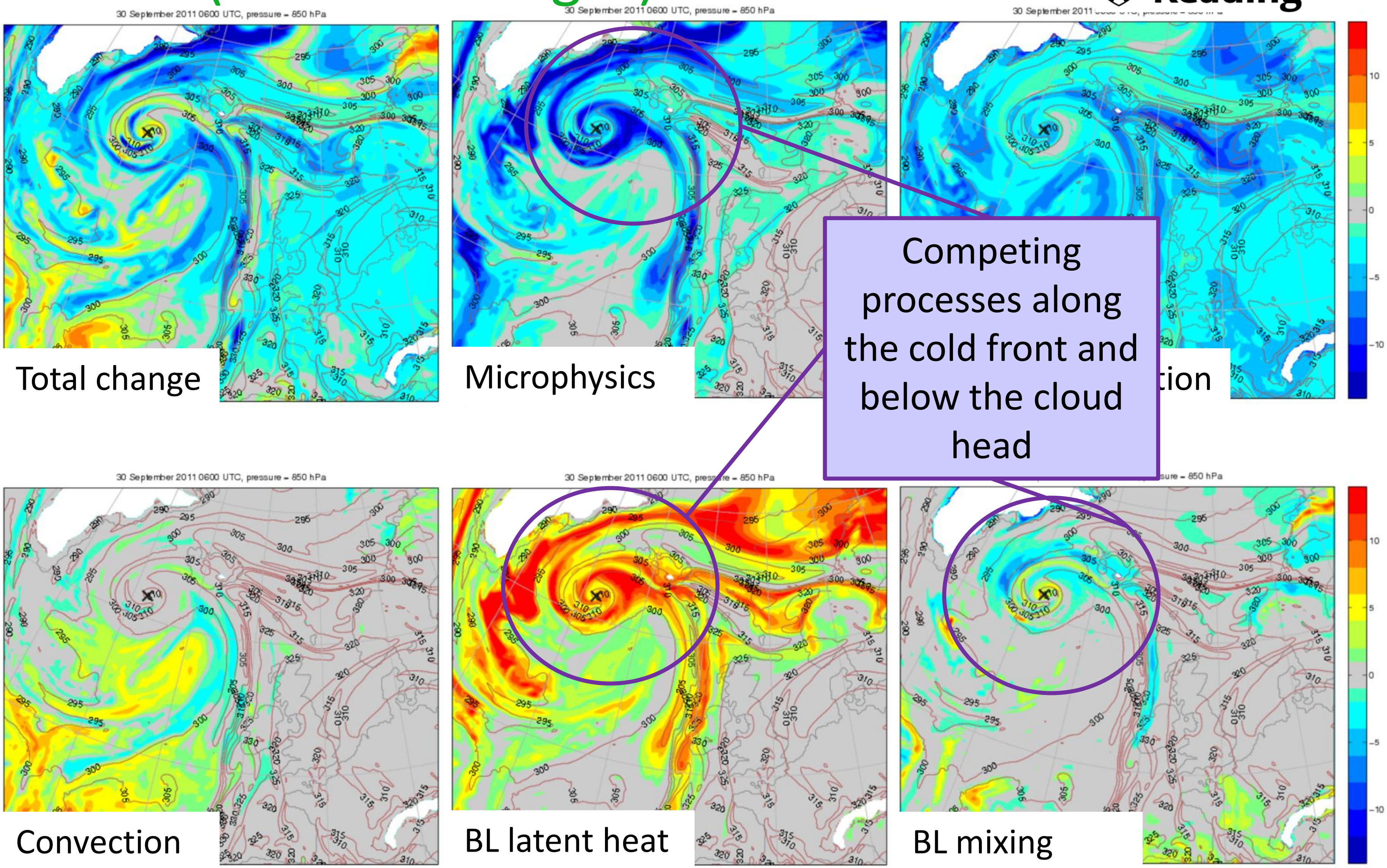
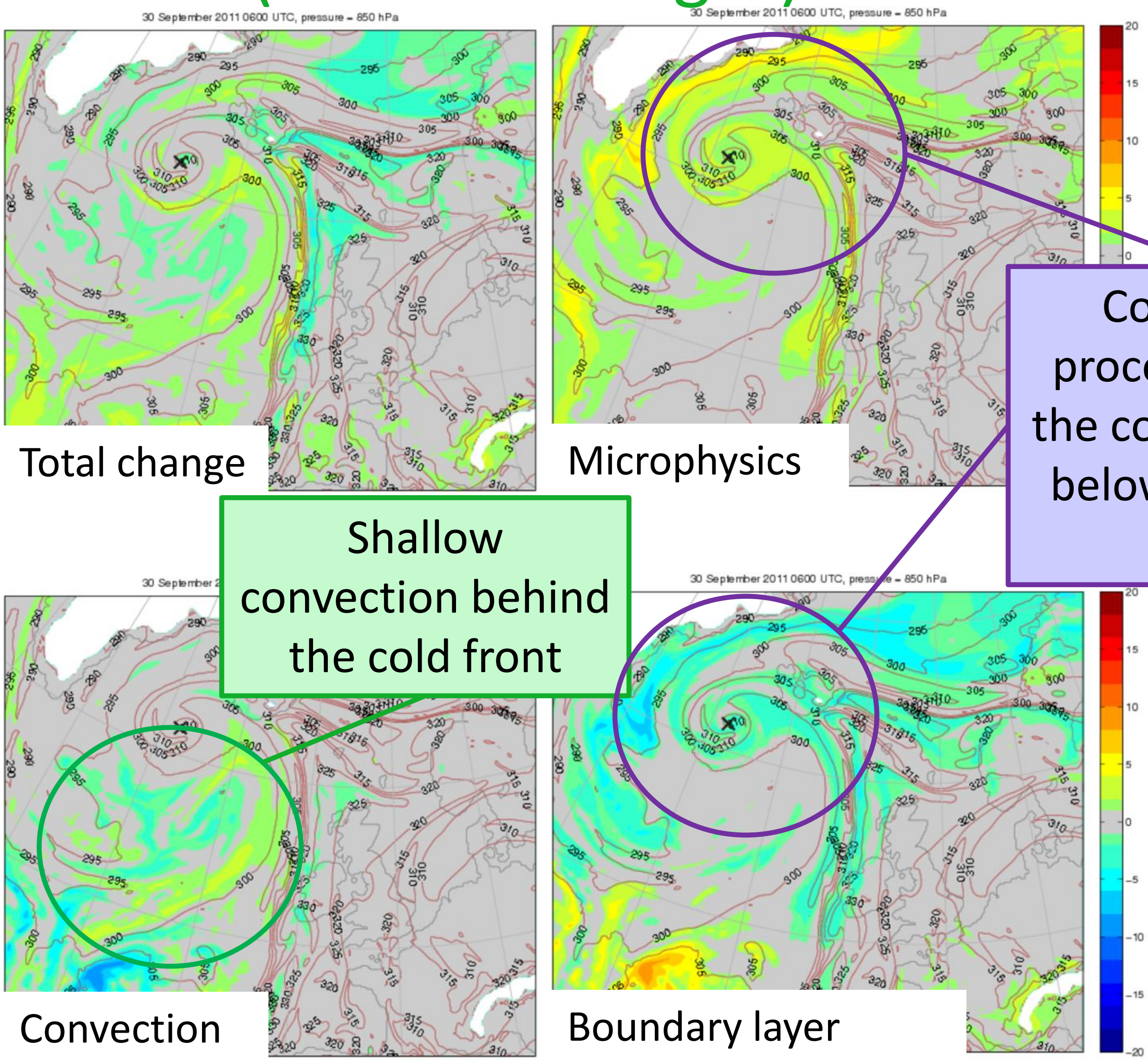


Sources/sinks of specific humidity 850 hPa (~1300 m height)

University of Reading



Total change

Microphysics

Convection

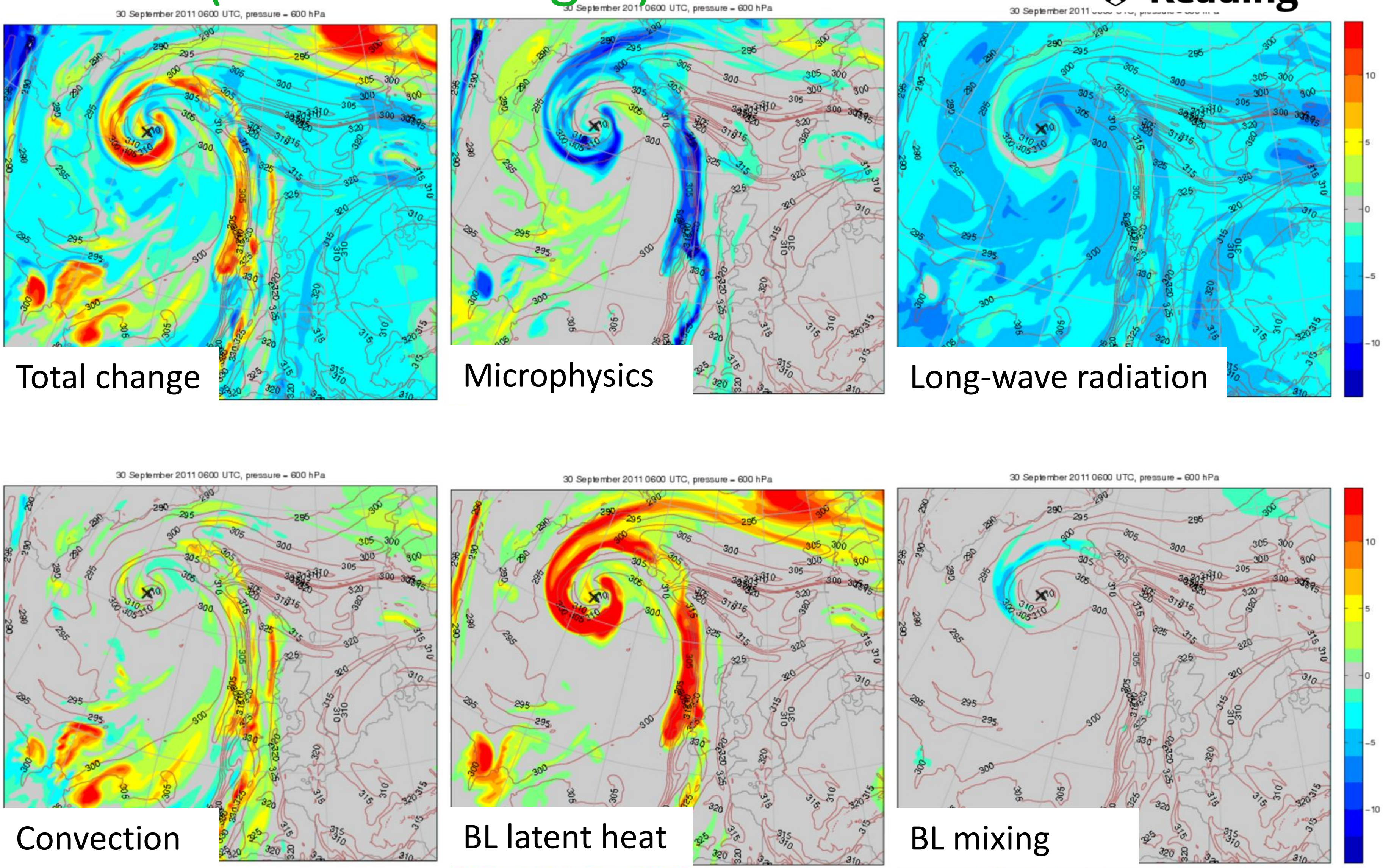
Boundary layer

Shallow convection behind the cold front

Competing processes along the cold front and below the cloud head

Sources/sinks of potential temperature
600 hPa (~4000 m height)

University of Reading



Sources/sinks of potential temperature
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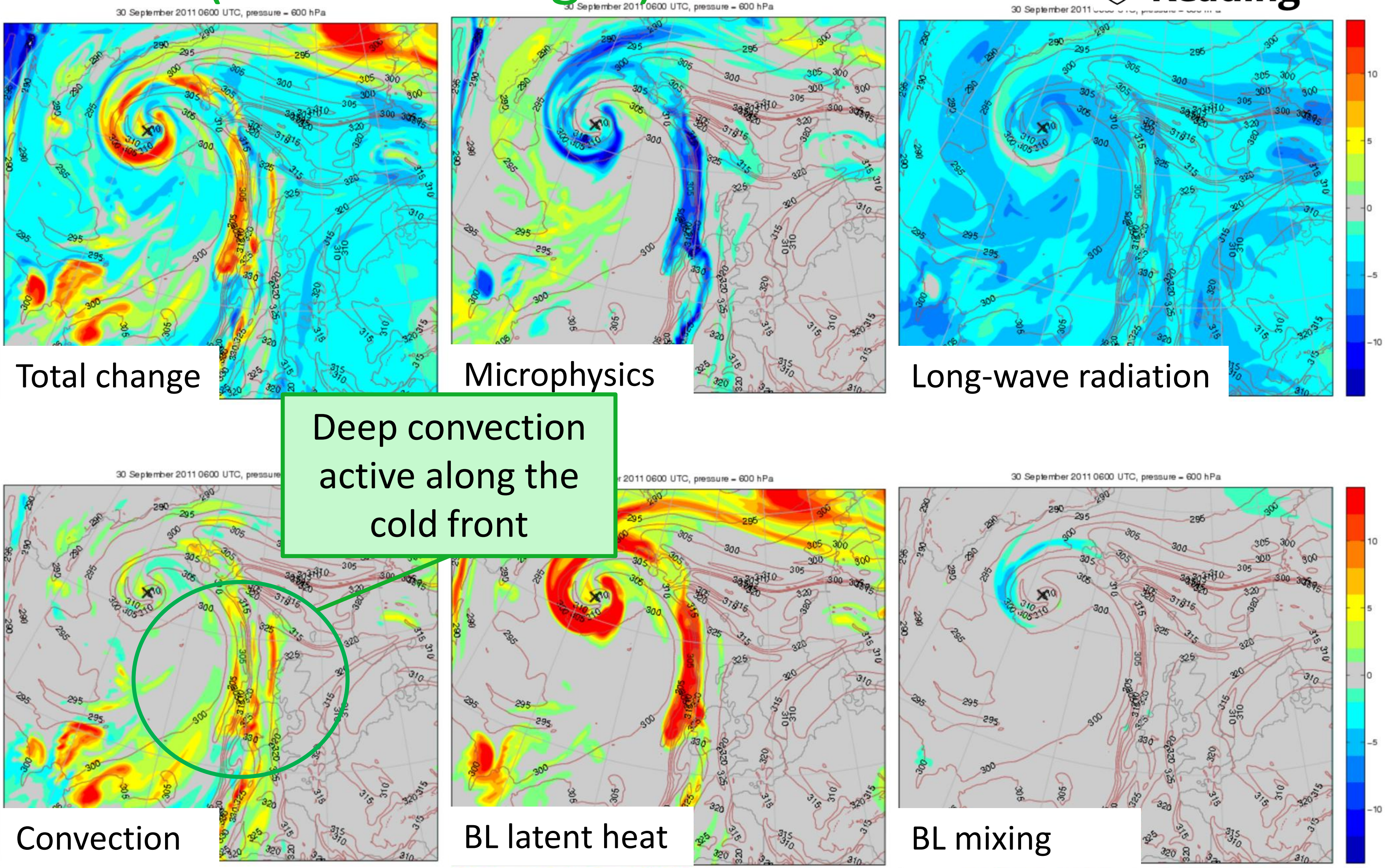
University of Reading



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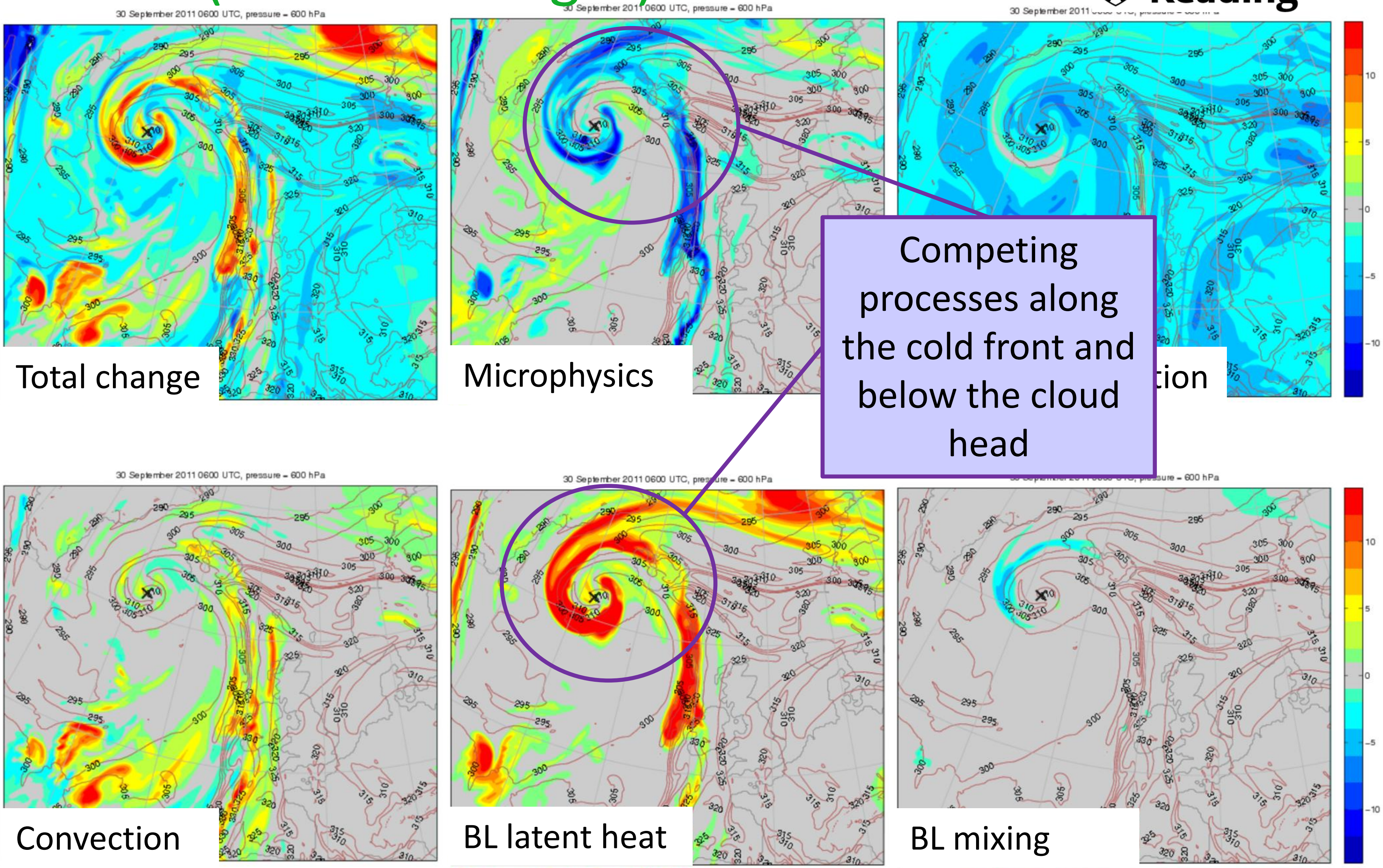
University of Reading



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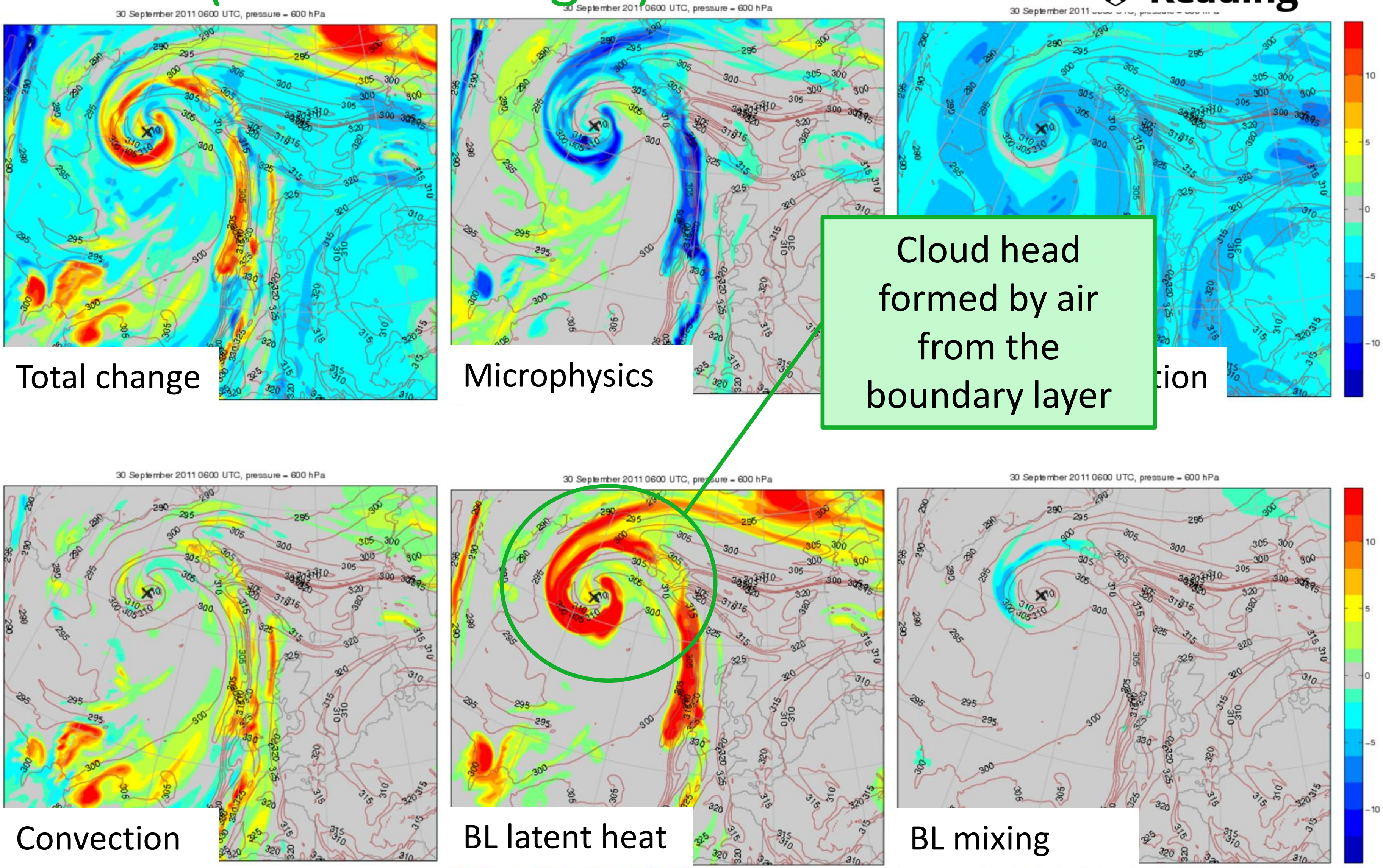
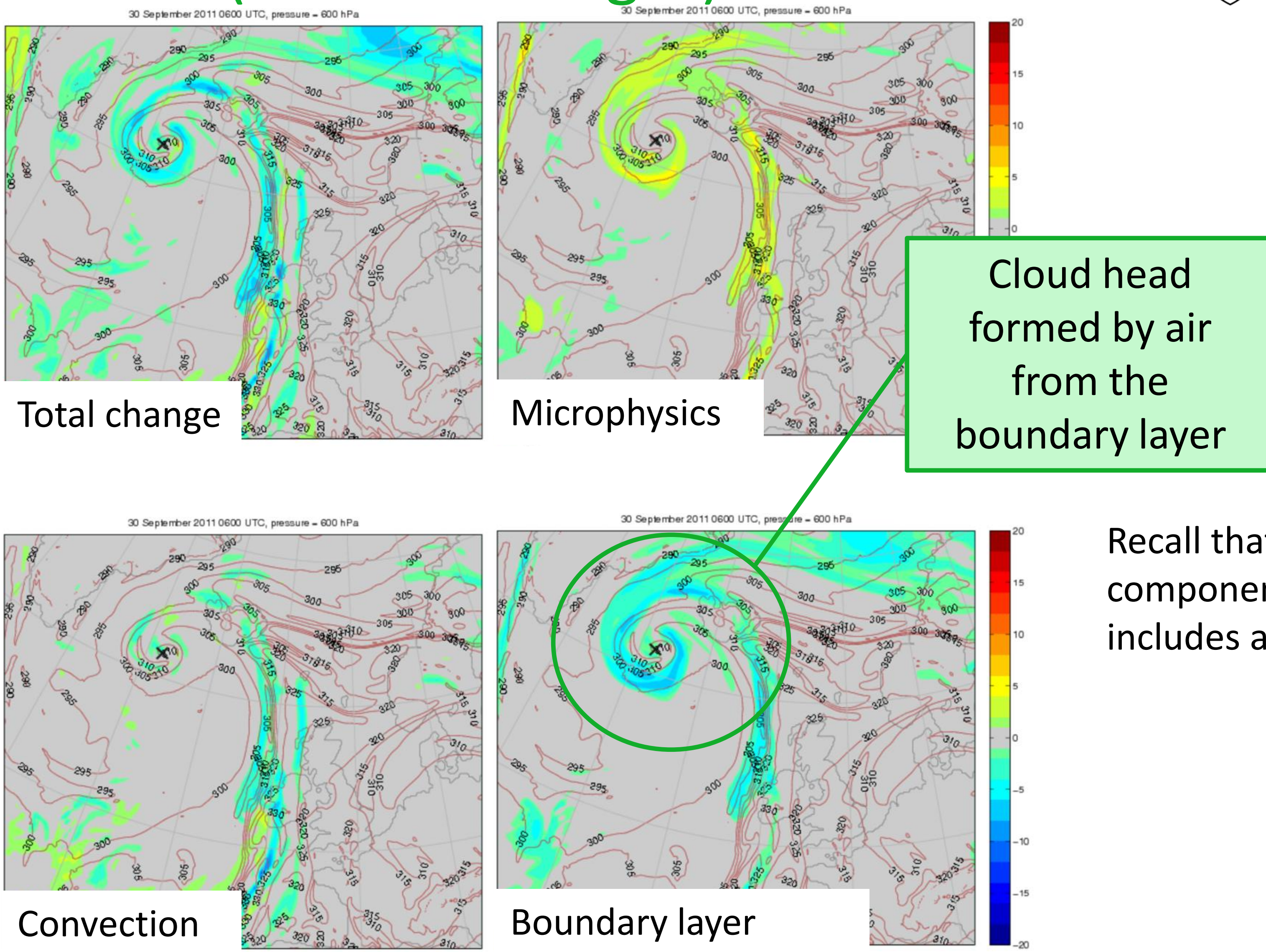


Sources/sinks of specific humidity 600 hPa (~4000 m height)

University of Reading



Recall that the component evolution includes advection

Sources/sinks of potential temperature 250 hPa (~10000 m height)

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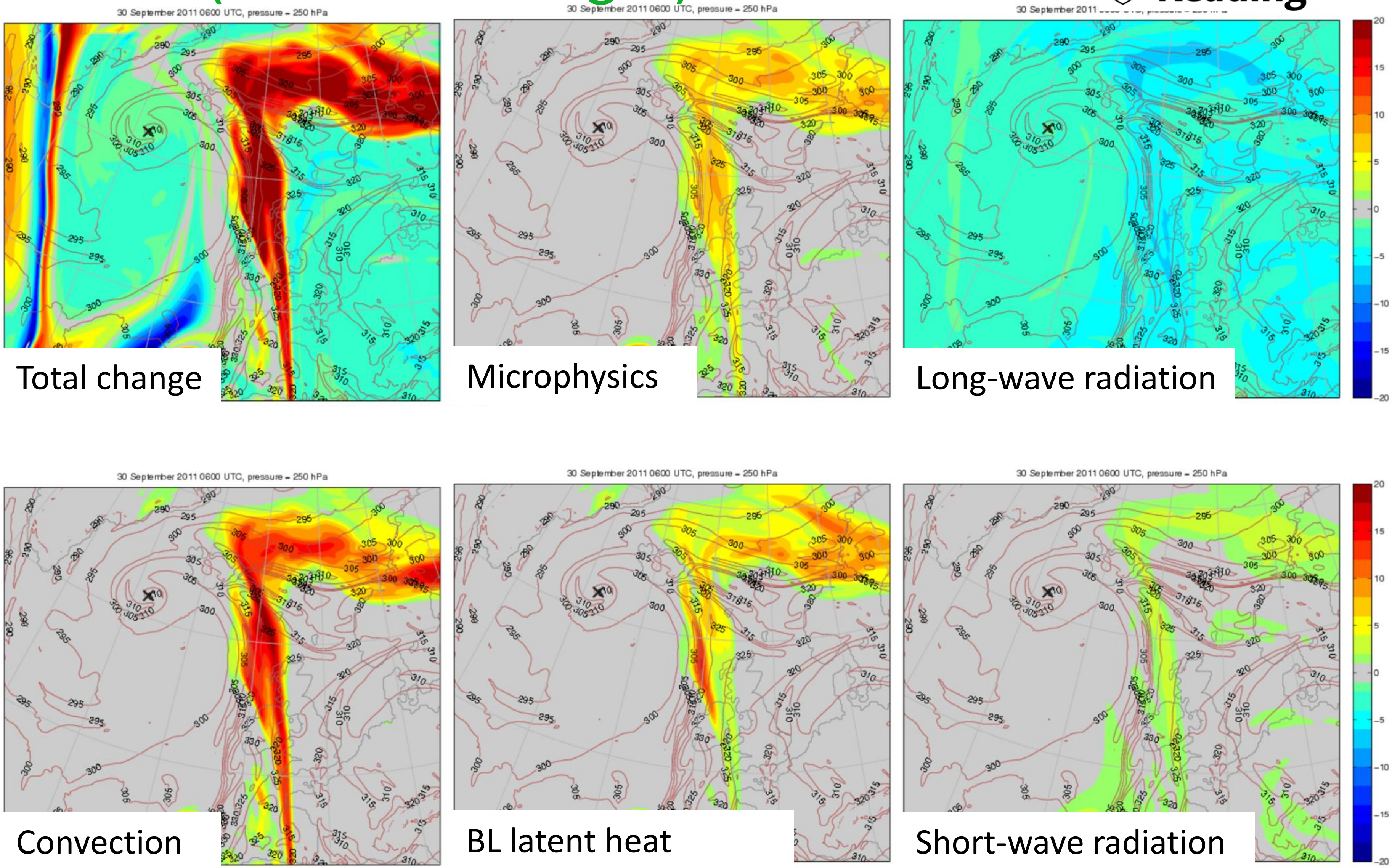
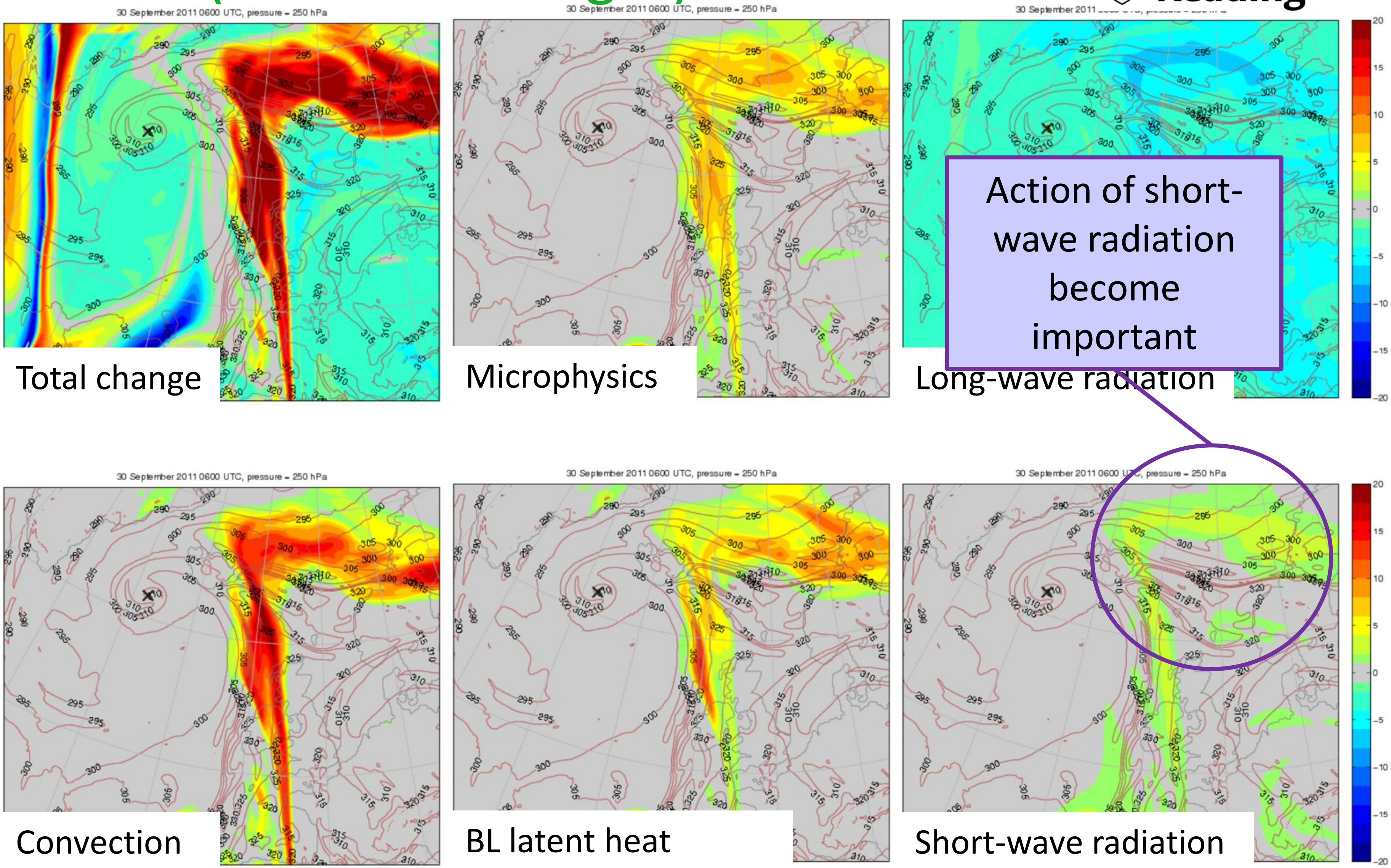
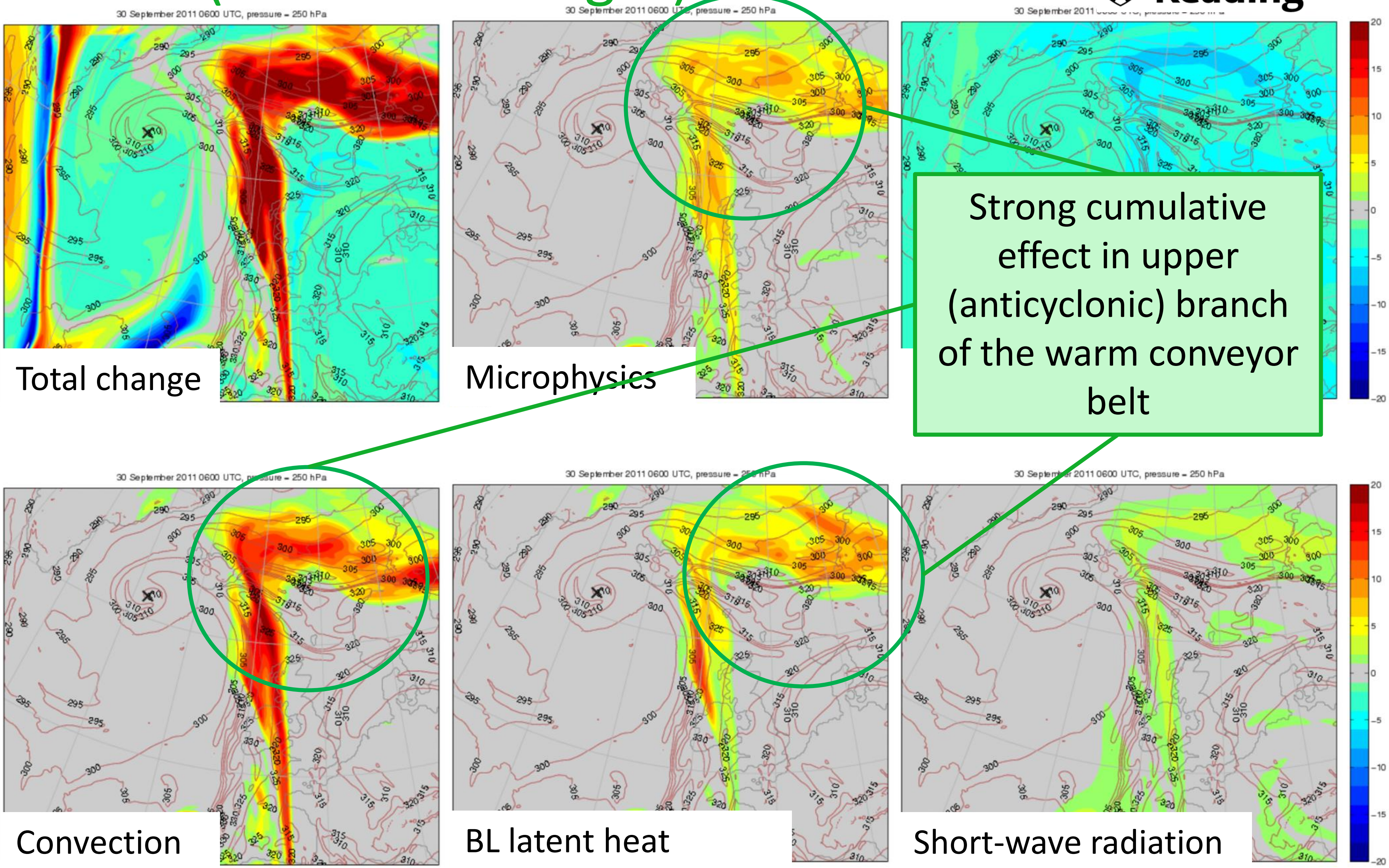


Sources/sinks of potential temperature 250 hPa (~10000 m height)

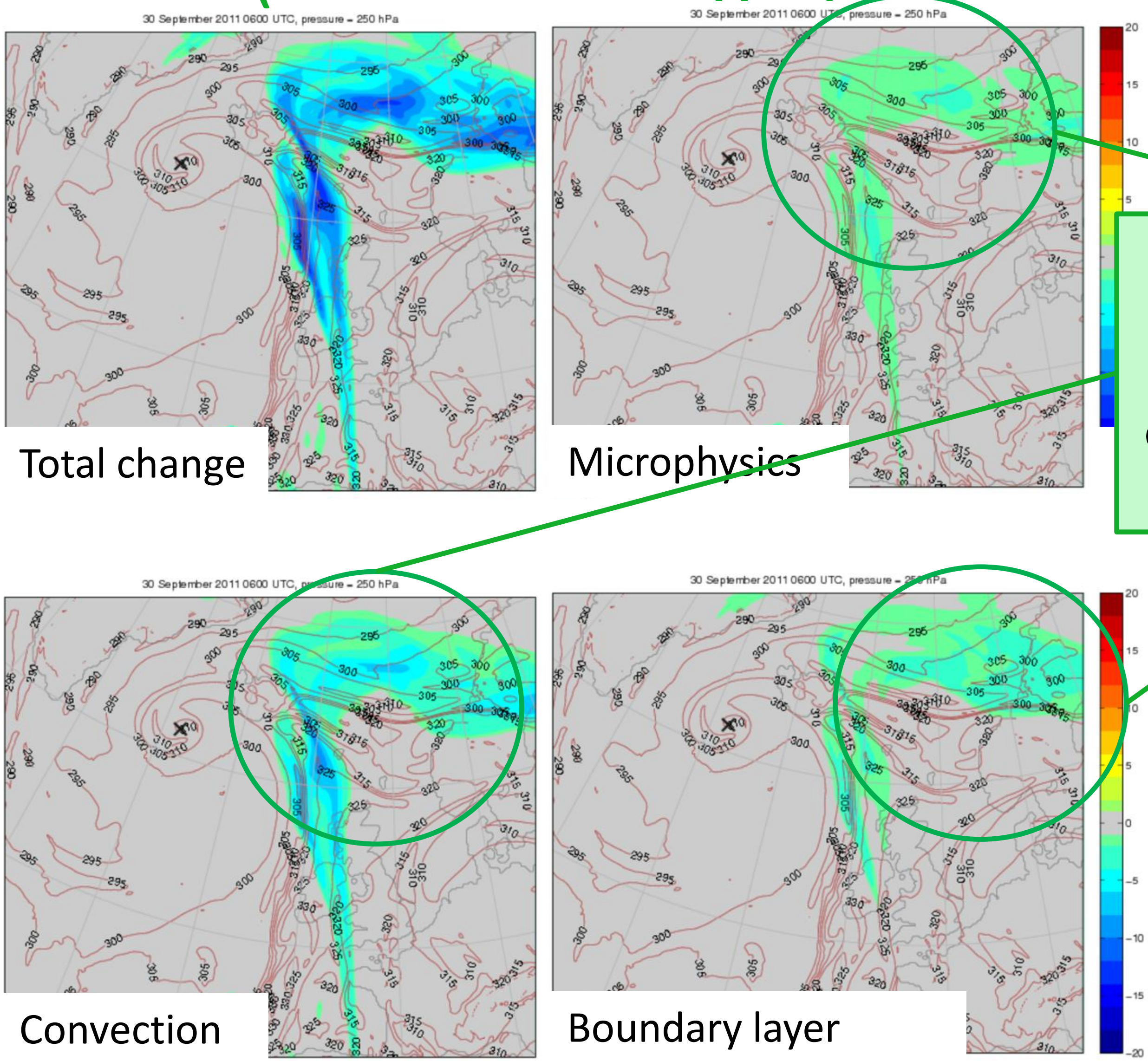


Sources/sinks of potential temperature 250 hPa (~10000 m height)



Sources/sinks of specific humidity 250 hPa (~10000 m height)

University of Reading



Strong cumulative effect in upper (anticyclonic) branch of the warm conveyor belt

Concluding remarks

- One tools for the analysis of convection in large-scale atmospheric models have been presented:

  Budget of energy (heating/cooling) and moisture (drying/moistening)

- It represents an integral view of the processes acting during a simulation (cumulative action/cumulative increments)
  - It is useful not only for the evaluation of convection but for a complete assessment of processes in the model
  - It does not provide instantaneous information about sources and sinks
- It can be coupled with other budget diagnostics such as that for potential vorticity

Concluding remarks

- Instantaneous information about the generation/destruction of the different variables can be obtained
  - By reformulating the approach to output instantaneous increments (perhaps averaged over a predetermined period) or
  - By combining the present approach with trajectories to study the changes due to parameterised processes along trajectories

Concluding remarks

- This method could be useful for
  - The analysis of balance between convective and large-scale achieved by
    - Different spatial model resolutions
    - Different parameterisation schemes (with a focus on convection schemes).
  - The analysis of a broader range of phenomena not restricted to convection parameterisation schemes