ECMWF Workshop on "Parametrization of clouds and precipitation across model resolutions”

Themes:

1. Parametrization of microphysics
2. Representing sub-grid cloud variability
3. Constraining cloud and precipitation parametrization with observations

…across model resolutions

…with an emphasis on NWP

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Representing cloud and precipitation in the ECMWF global model

Richard Forbes

(European Centre for Medium-range Weather Forecasts)

Thanks to Maike Ahlgrimm, Adrian Tompkins, Hanna Joos

Talk Outline:

1. Parametrization of cloud and precipitation in the ECMWF model
2. Understanding impacts
3. Some issues to consider…

…from a global NWP perspective

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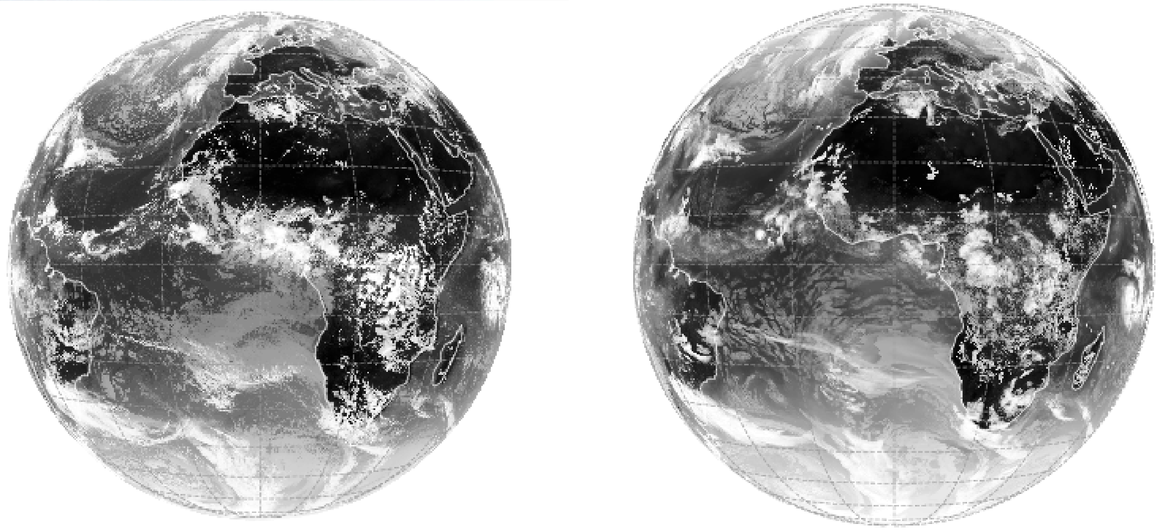
1. Parametrization of cloud and precipitation in the ECMWF model

The ECMWF Global Model (IFS) - resolutions



Model Resolutions in use at ECMWF:

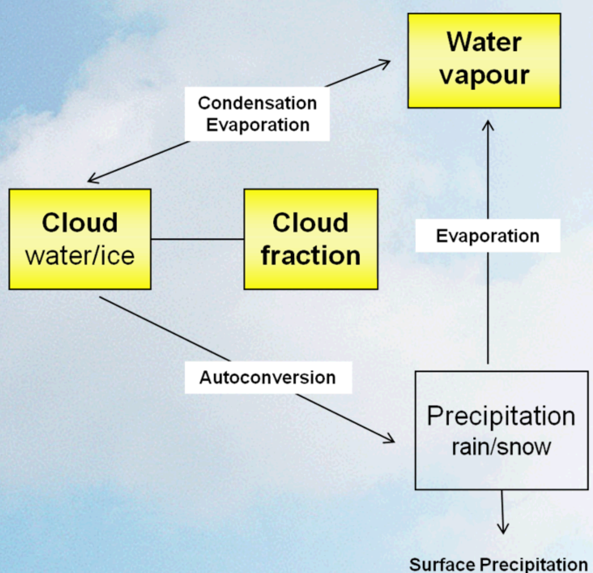
- T159 (125 km)
- T255 (80 km) – Seasonal forecasts
- T319 (62 km) – Monthly forecasts
- T511 (40 km)
- T639 (31 km) – Current operational 51 member ensemble
- T799 (25 km)
- T1279 (16 km) – Current operational high resolution “deterministic”
- T2000 (10 km) and higher – Future…

ECMWF Global NWP model (IFS)

Recent changes to the microphysics scheme

Previous Cloud Scheme

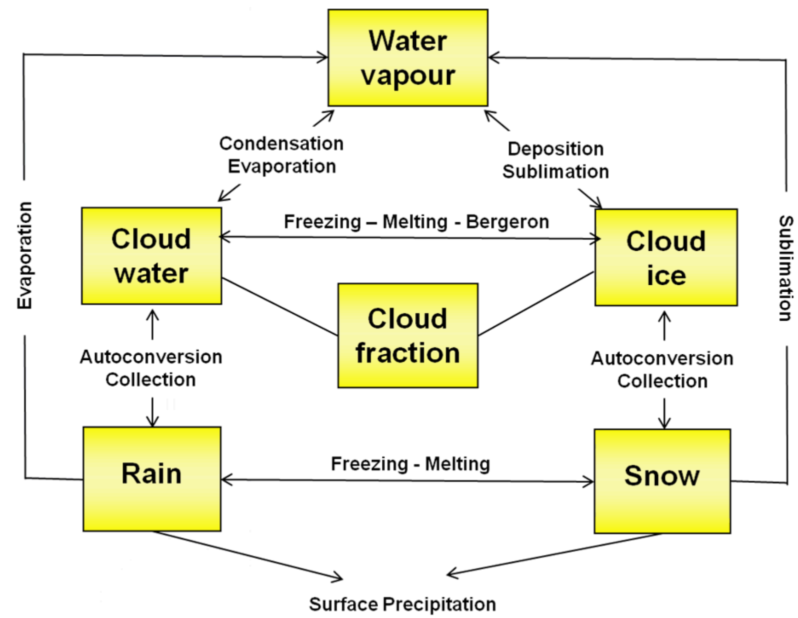
(Tiedtke scheme operational 1995-2010)



- Prognostic condensate, fraction + w.v.
- Parametrized sources and sinks
- Includes convective detrainment
- Ice/water a diagnostic fn(temperature)
- Diagnostic precipitation + fraction
- Tiedtke (1993)

Current Cloud Scheme

(operational from 9th Nov 2010, Cy36r4 onwards)



- Prognostic liquid, ice, rain, snow, humidity
- Single moment hydrometeors
- Retains prognostic cloud fraction
- Retains Tiedtke approach to sources and sinks
- Diagnostic precipitation fraction

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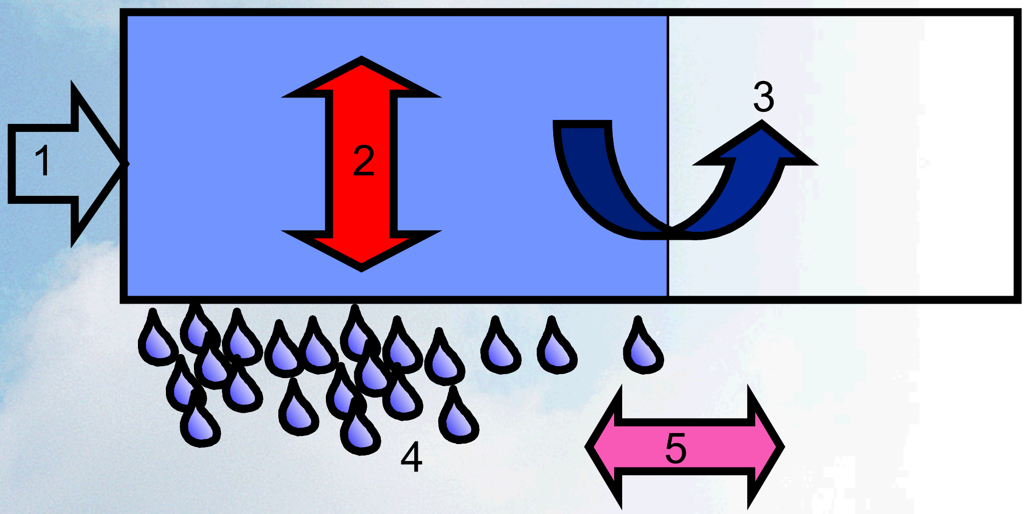
The ECMWF model sub-grid cloud scheme

Sources and sinks



Sub-grid cloud assumptions:
Prognostic cloud water, cloud ice
Prognostic cloud fraction
Uniform in-cloud condensate
Clear sky humidity variability
Ice supersaturation (Tompkins 2007)

Sub-grid precip assumptions:
Prognostic rain, snow
Diagnostic precipitation fraction
(reduces with evaporation)

1. *Convective Detrainment (deep and shallow)*
2. *(A)diabatic warming (radiation/dynamics)*
3. *Subgrid turbulent mixing (cloud top, horiz eddies)*
4. *Precipitation generation*
5. *Precipitation evaporation/melting*
6. *Advection/sedimentation*

Some (not all) of these are derived from a pdf approach

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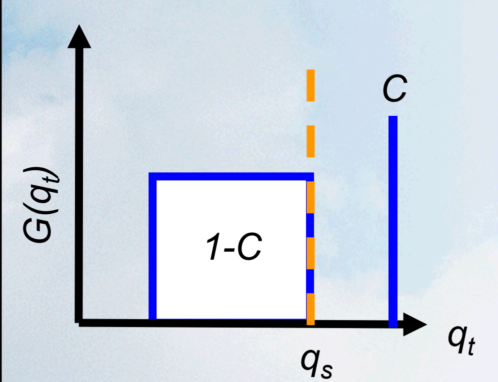
The ECMWF model sub-grid cloud scheme

Comparison of Tiedtke and continuous PDF scheme (e.g. Tompkins)

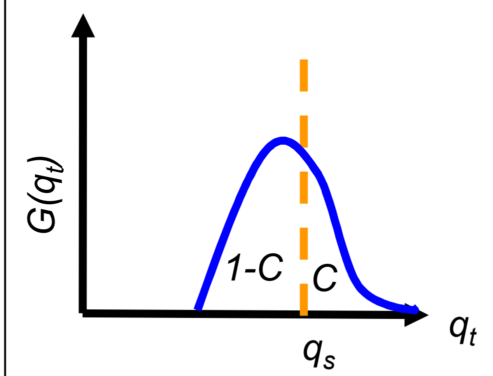
Tiedtke(1993) in ECMWF IFS



A mixed 'uniform-delta' total water distribution is assumed for the condensation process.
3 prognostic variables:

- Humidity, q_v
- Cloud condensate, q_c
- Cloud fraction, C

Tompkins (2002)



A bounded beta function with positive skewness.

Effectively 3 prognostic variables:

- Mean q_t
- Variance of PDF
- Skewness of PDF

Same degrees of freedom ?

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Microphysics Parametrization Development for NWP/climate
Drivers for Change….

1. Improving the large-scale dynamics
   - latent/radiative heating
2. Improving forecasts of weather parameters
   - hydrological (cloud, rain, snow, fog), but also radiative (T2m)
3. A desire to improve the physical basis of the parametrization
   - new observations, trust in model, right answer for the right reasons, internal consistency
4. Increasing model resolution
   - towards convective resolving
5. Representing aerosol-cloud-radiative interactions
   - improving feedbacks, climate
6. Assimilation of cloud/precipitation affected data.
   - to extract the maximum info from observations

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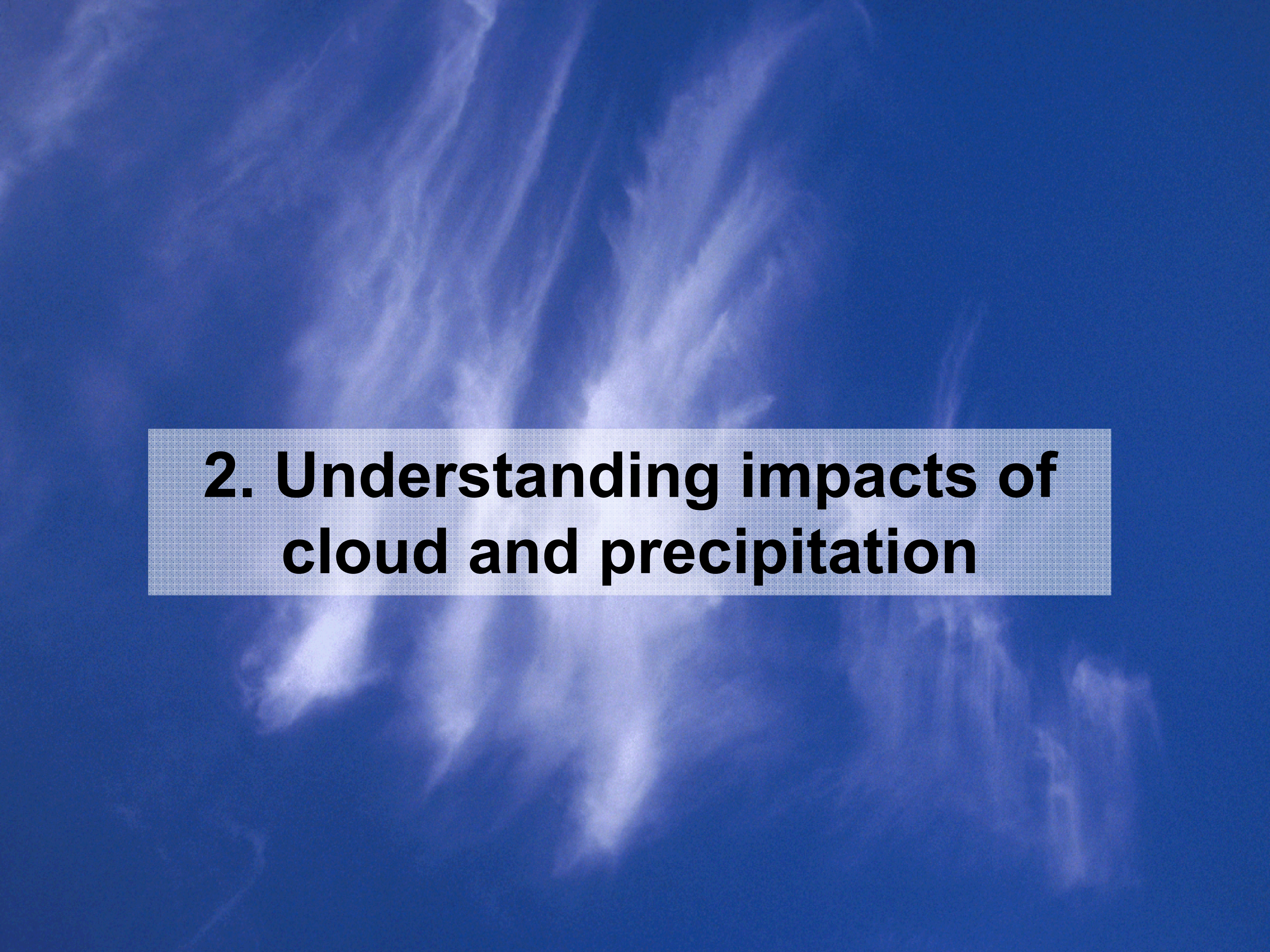

2. Understanding impacts of cloud and precipitation

Impacts of clouds

- Hydrological
- Radiative
- Diabatic

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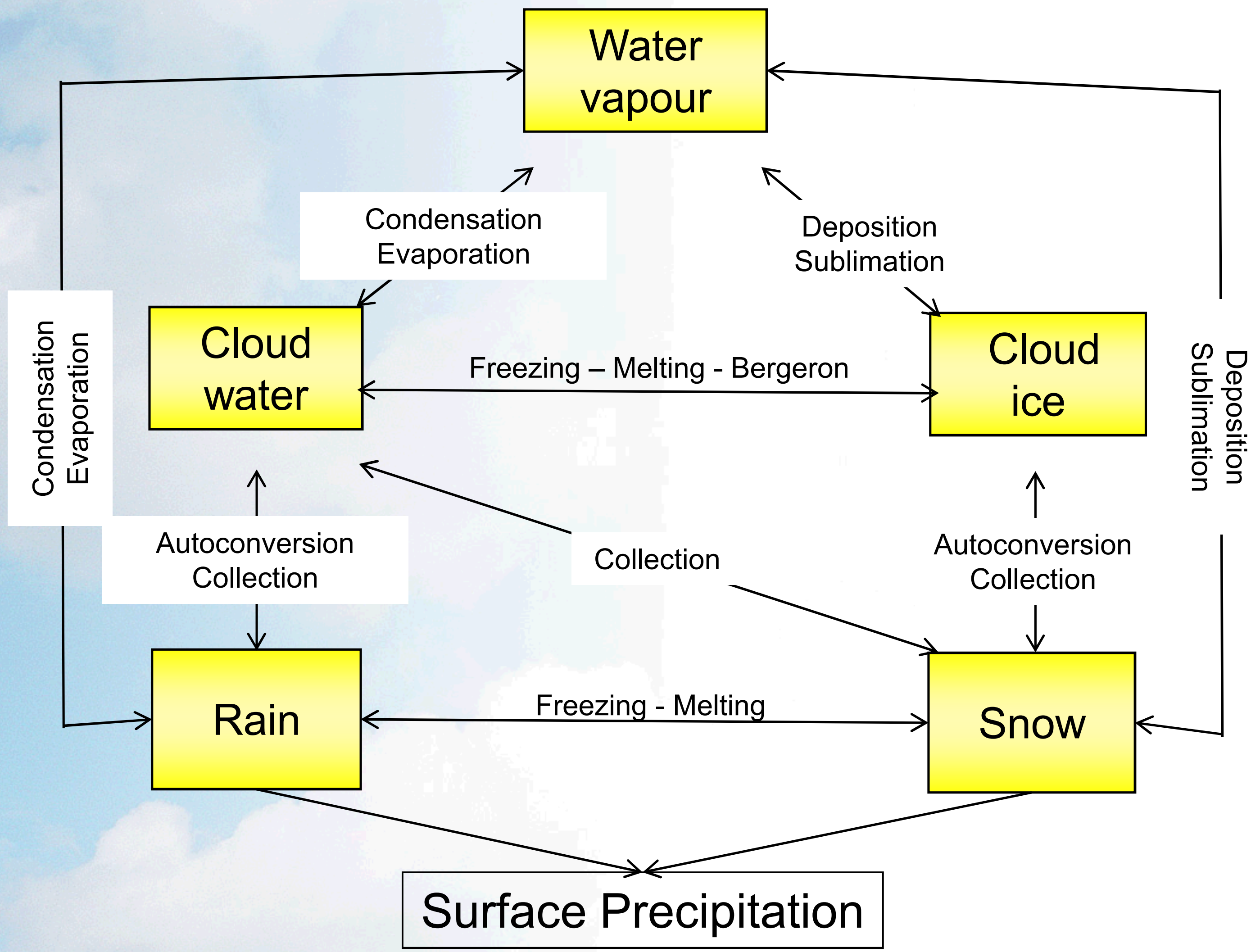
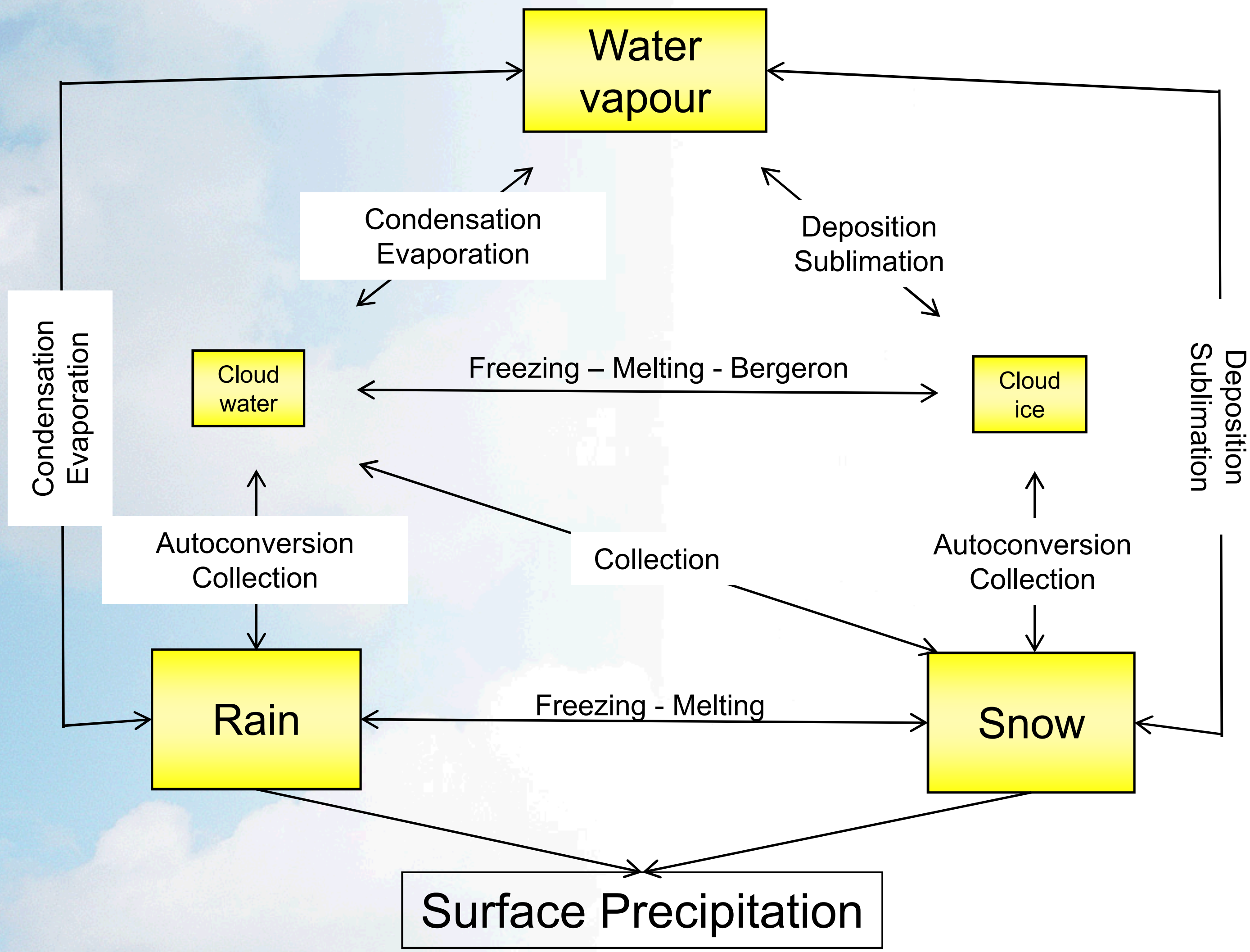
Microphysics Parametrization:
The "category" view



Microphysics Parametrization:
The hydrological perspective



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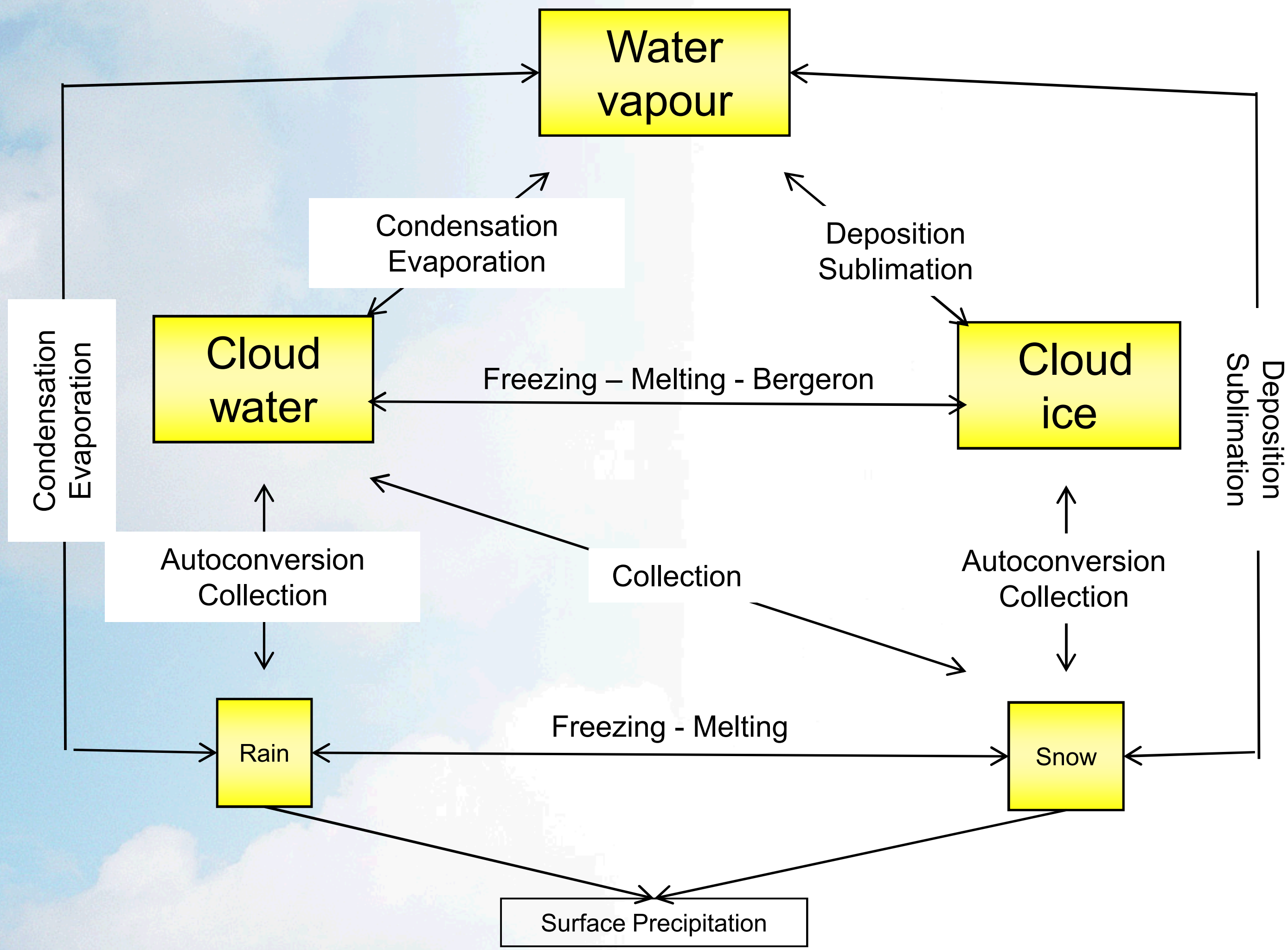
Microphysics Parametrization:
The radiative perspective



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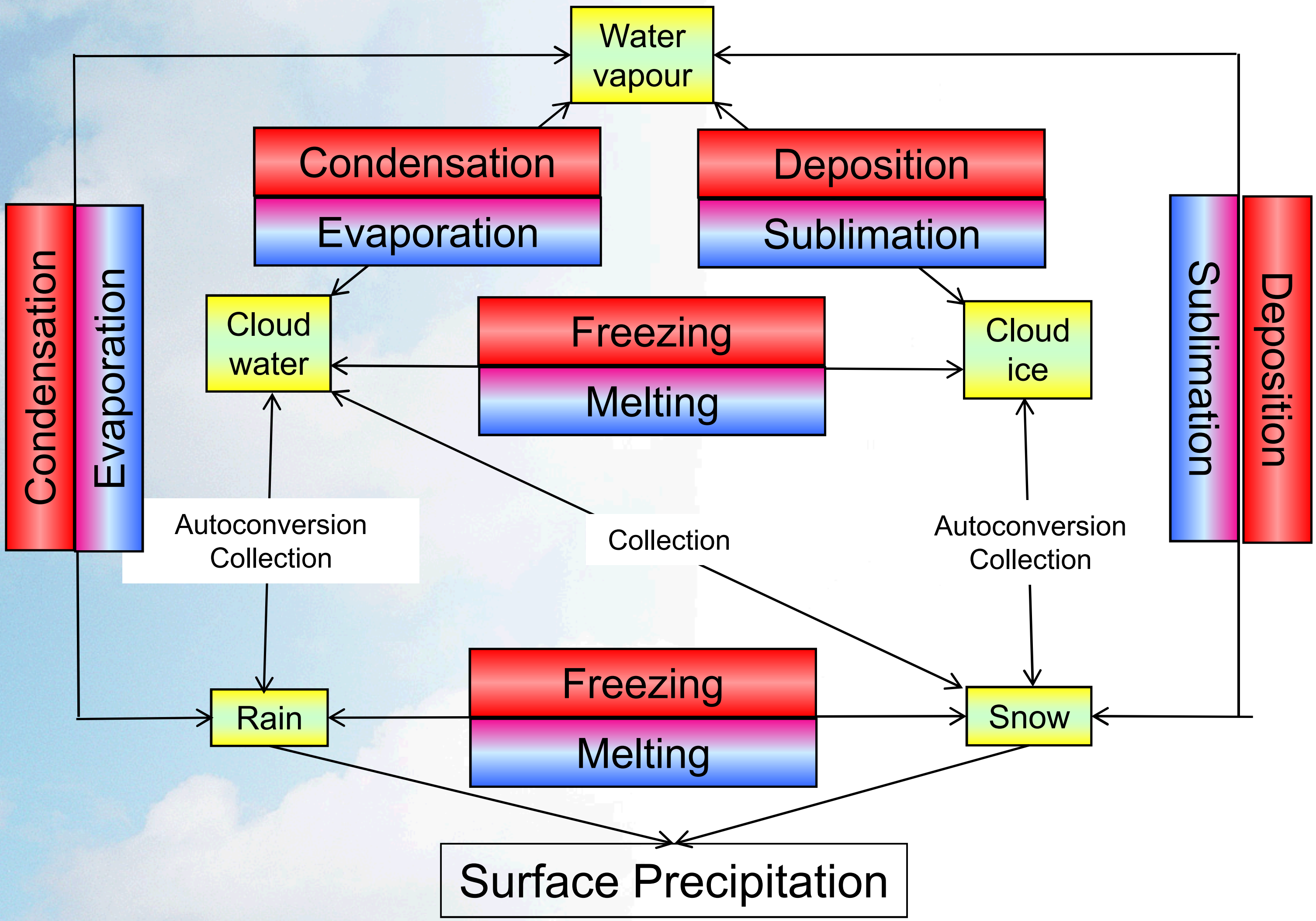
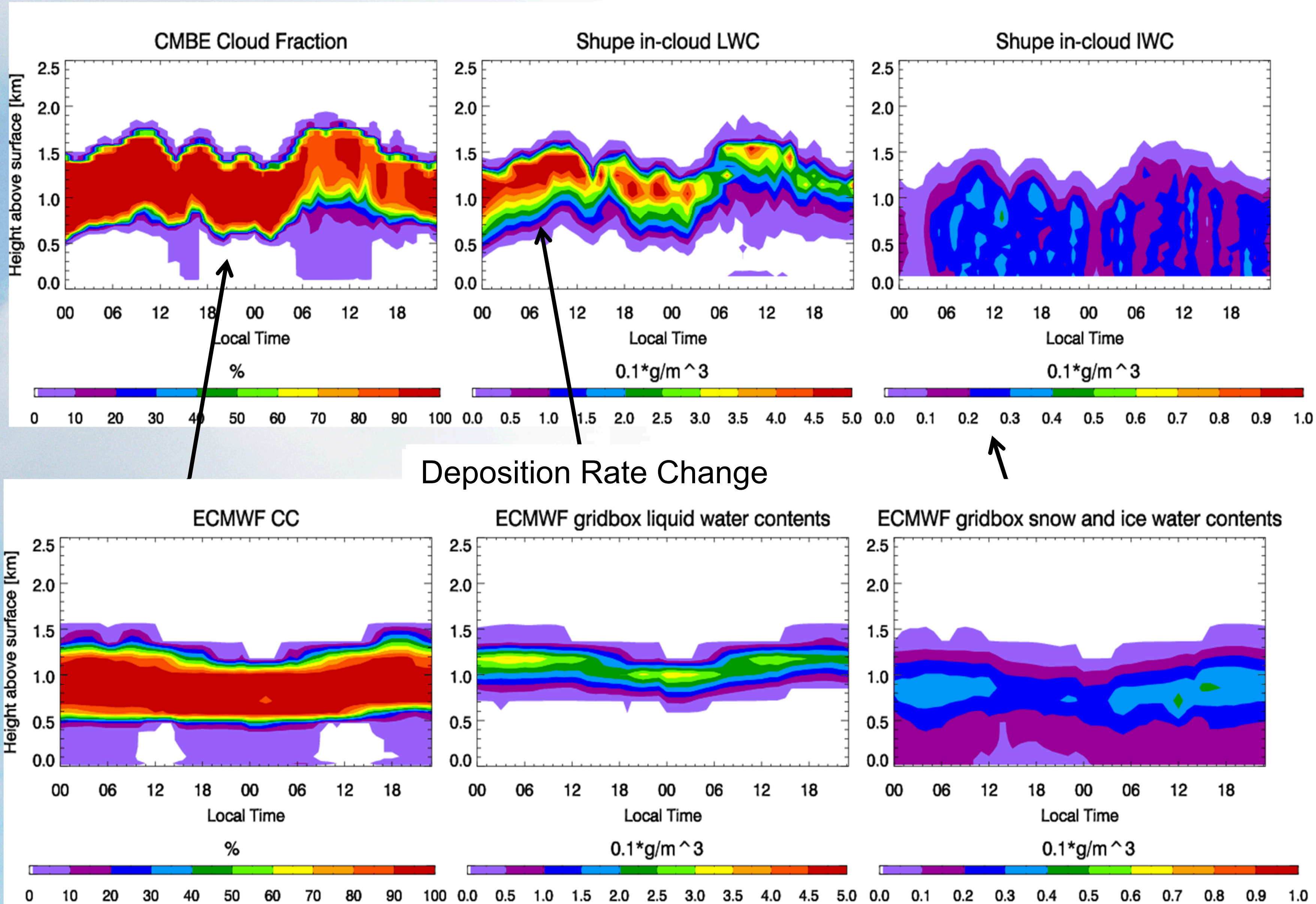
Microphysics Parametrization:
The "diabatic process" perspective



Example 1: Radiative Impacts: Arctic mixed-phase low cloud



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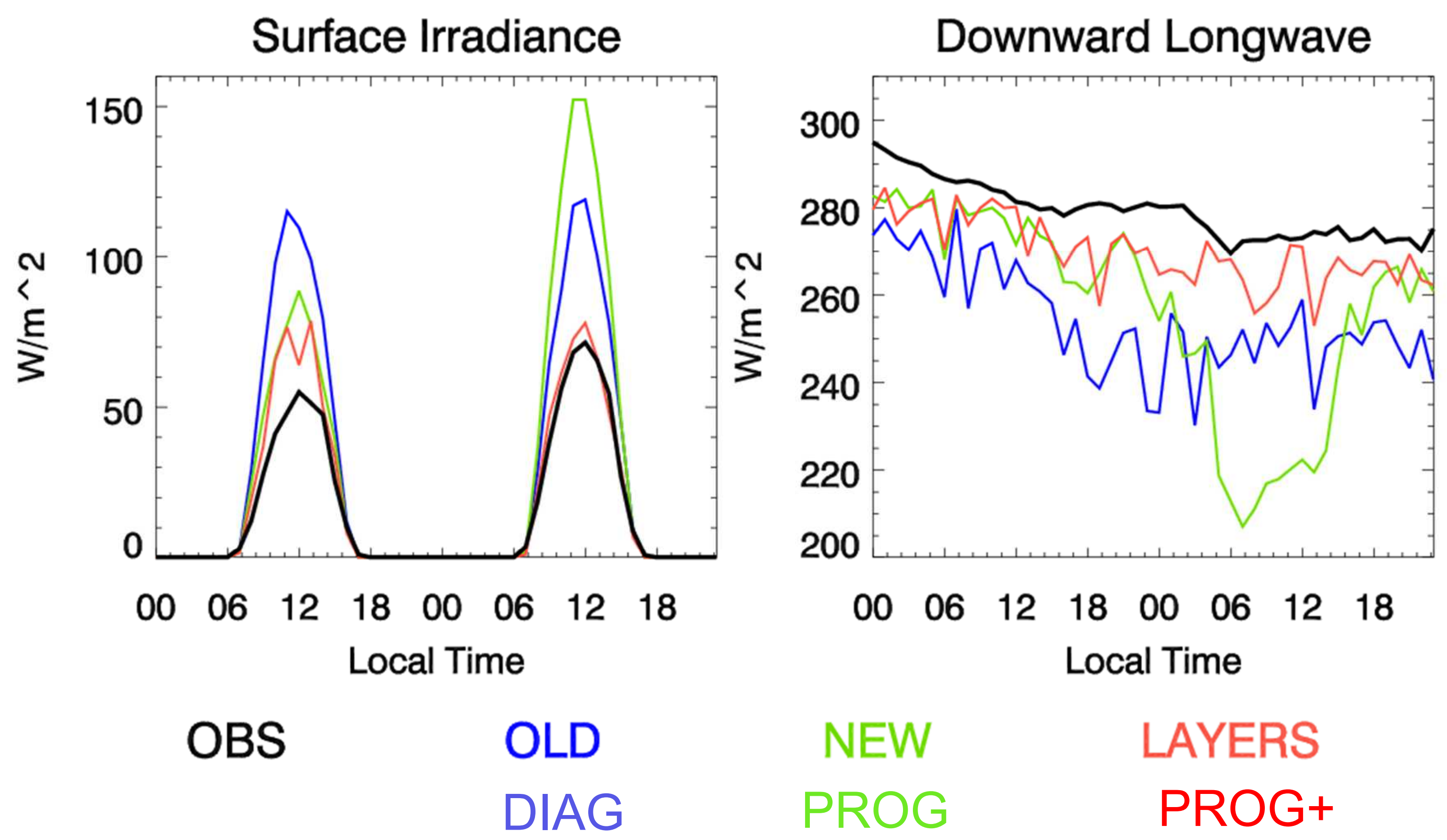
Example 1: Radiative Impacts Arctic mixed-phase low cloud
Impact of supercooled liquid water representation on surface radiation



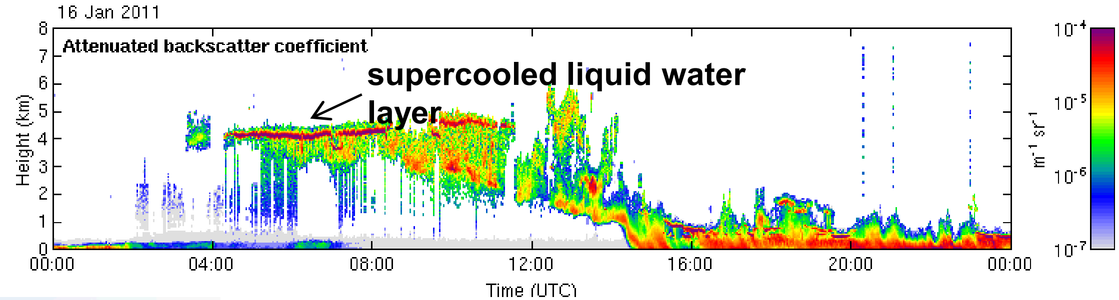
Maike Ahlgrimm

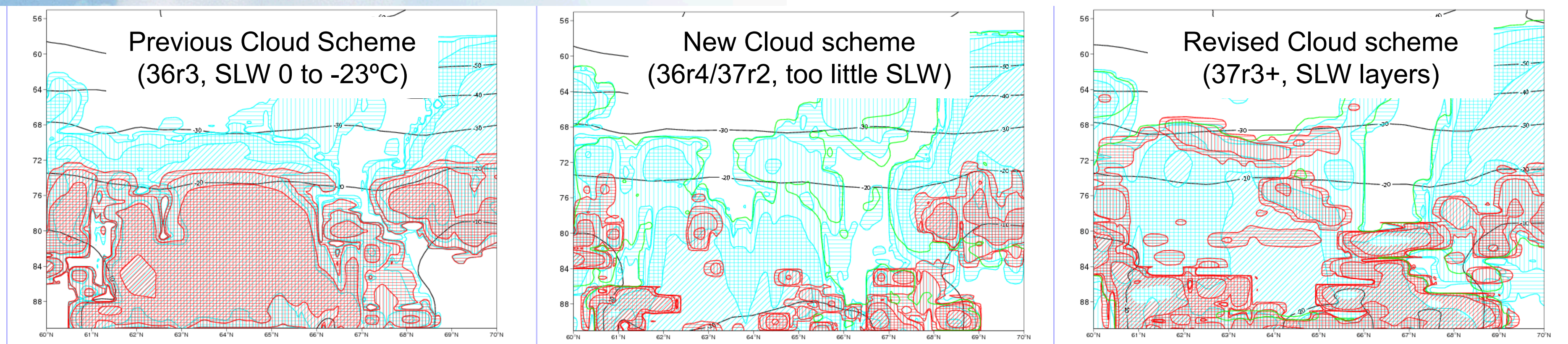
ECMWF

Example 1: Radiative Impacts: Boundary layer clouds over Finland
Revised cloud top ice deposition in IFS 37r3 improved temperatures

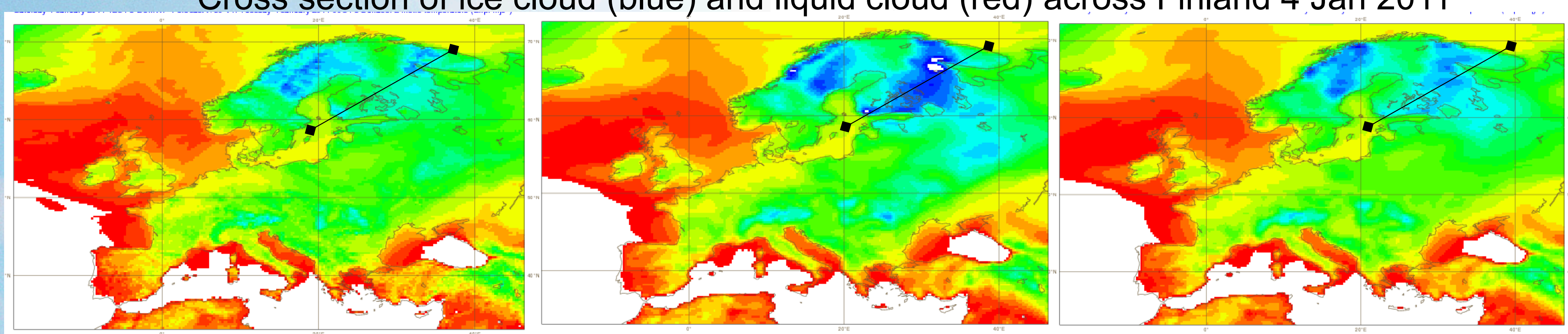
Ceilometer obs show SLW layers, e.g. case study Sodankyla,Finland

Inspired new cloud top parametrization for Cy37r3





Cross section of ice cloud (blue) and liquid cloud (red) across Finland 4 Jan 2011



Temperature for case study 4 January 2011

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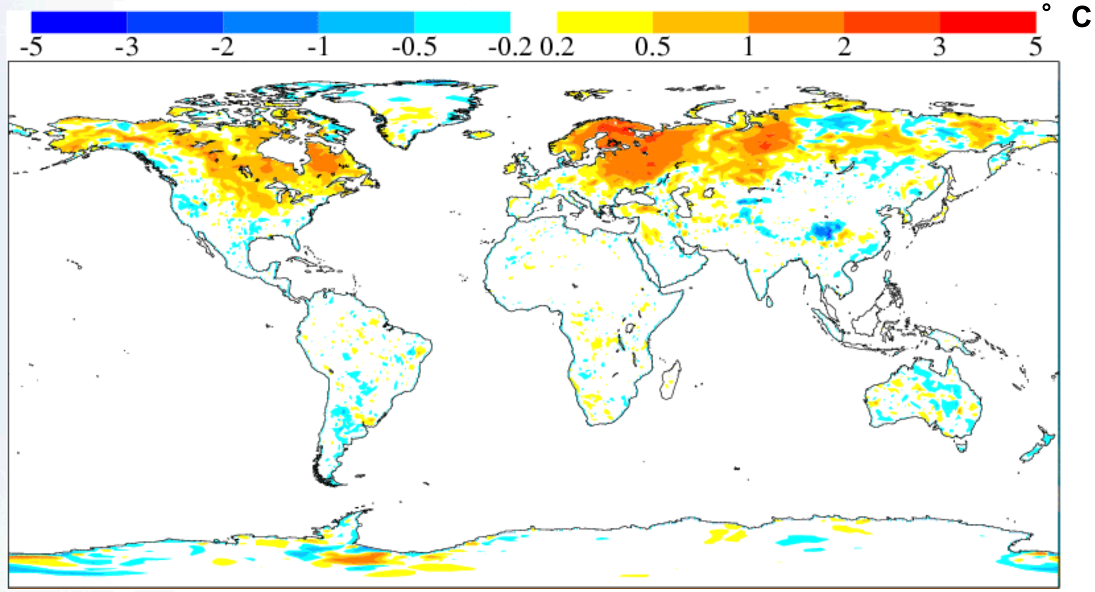
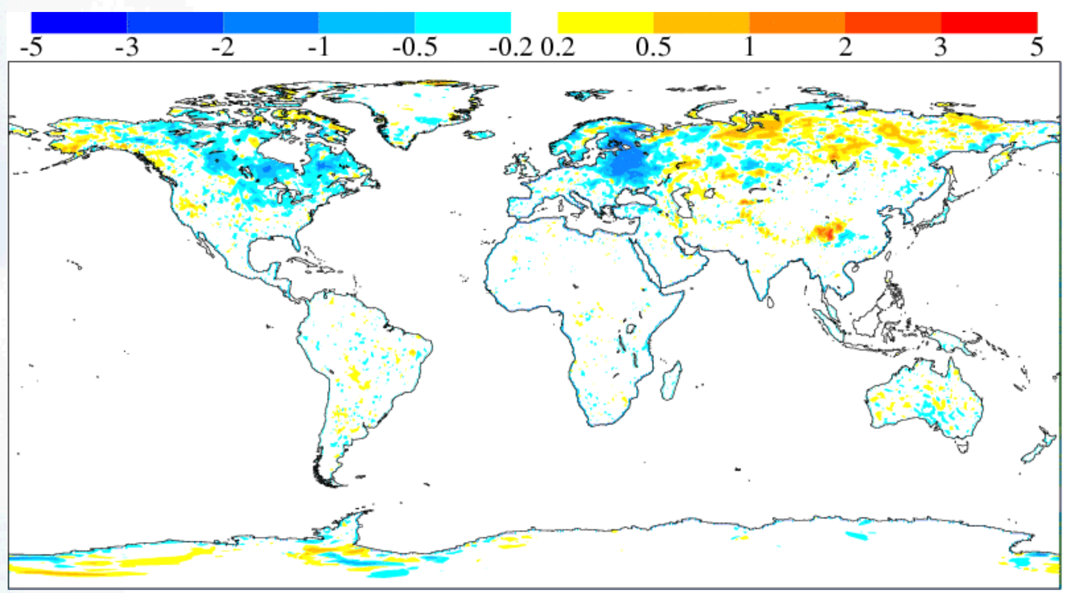
Example 1: Radiative Impacts: NWP global 2m temperature

Impact of cloud top SLW enhancement on 72 hour IFS T2m forecasts over land for January 2011



Change in 2m temperature:
Warmer across North America and Europe



Change in absolute mean error of 2m temperature:
Blue = reduced errors

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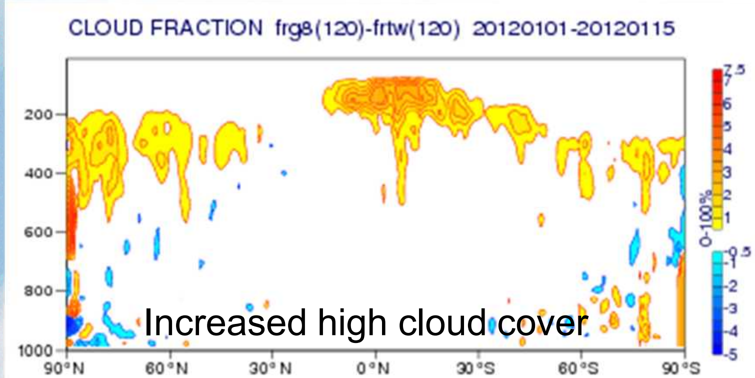
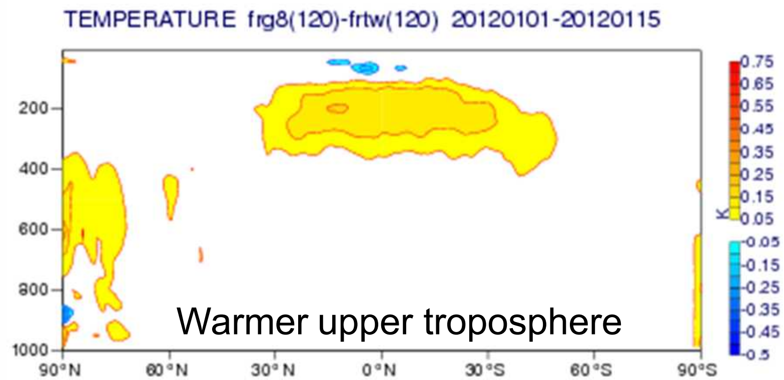
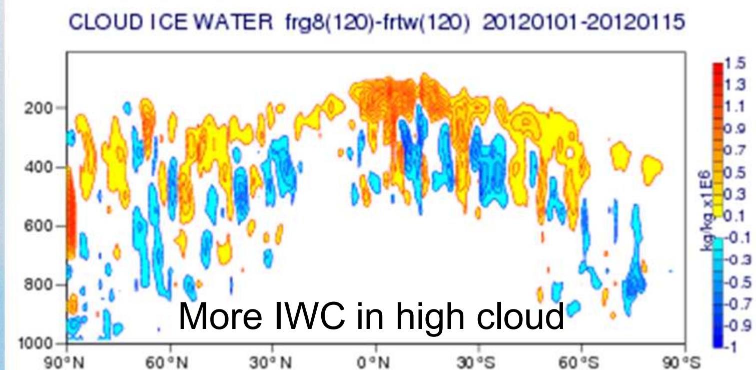
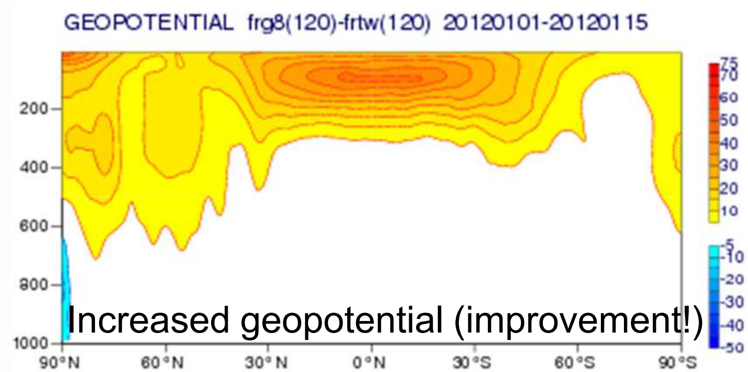
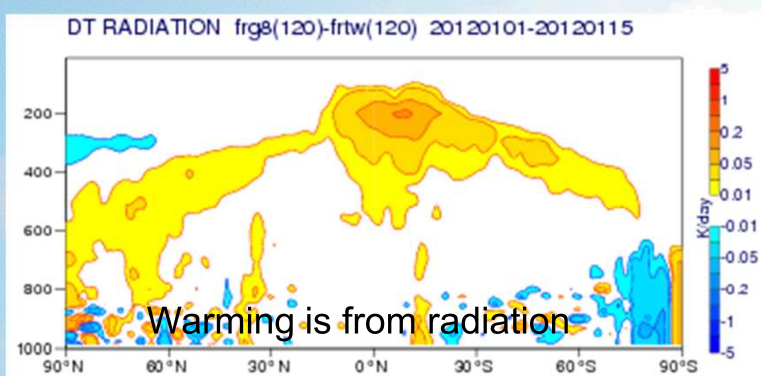
Example 2: Radiative Impacts: Reduced ice fall speed and upper-tropospheric heating (IFS Cycle 38R1)

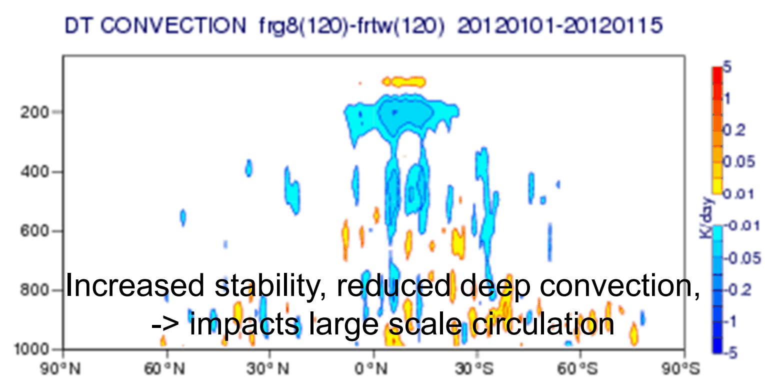












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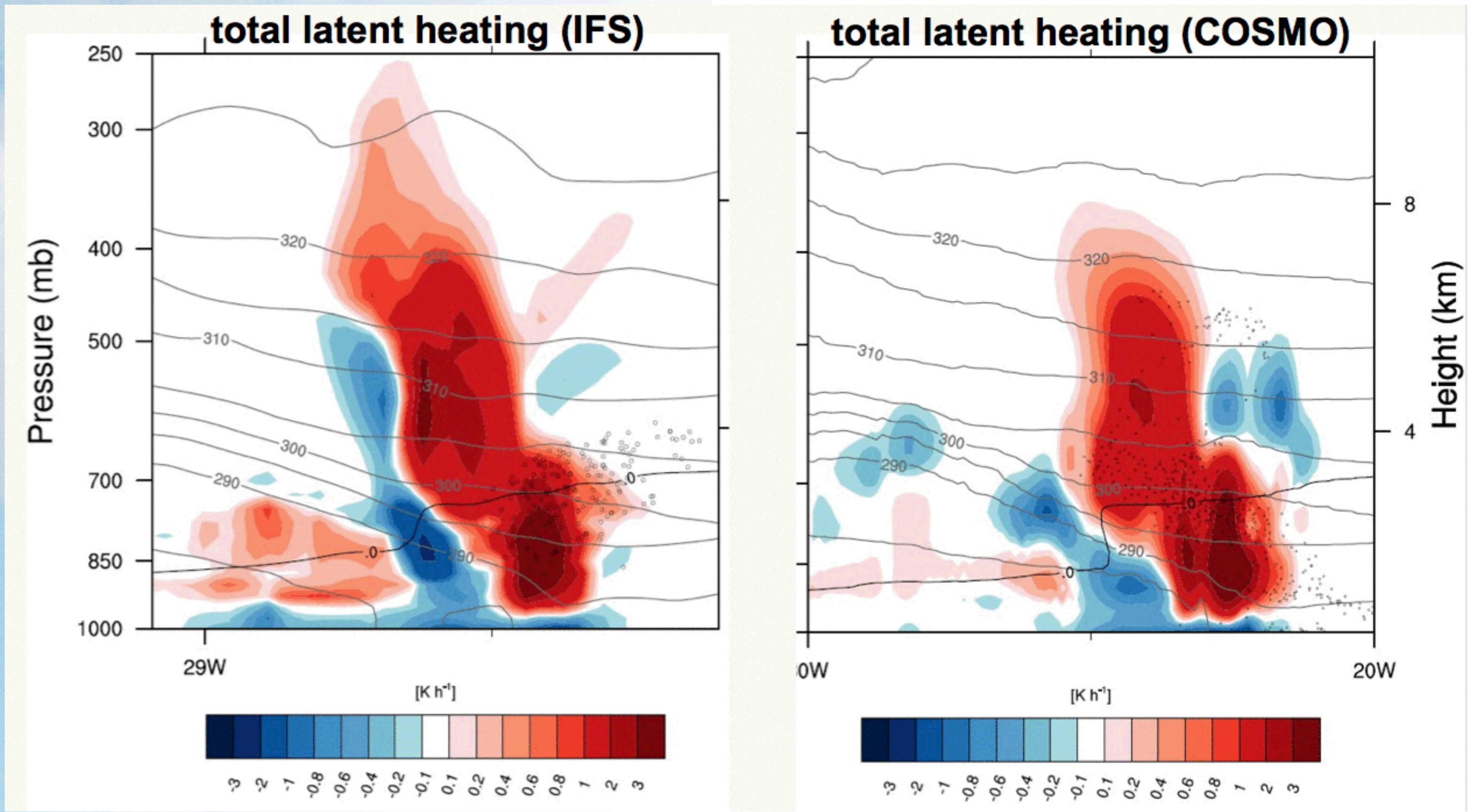
Example 3: Dynamical Impacts:

Latent heating in warm conveyor belt of mid-latitude cyclone (Hanna Joos et al.)



(see Joos et al. poster)

When thinking about representing the formulation and complexity of microphysics, we need to understand the cloud and precipitation parametrization in terms of impacts on the hydrological cycle, radiation and dynamics, and what we can constrain with observations.

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3. Some issues to consider…

Some issues to consider…

- We need parametrizations that are **physically based, constrained by observations** and have the **appropriate degrees of freedom** to represent the **important aspects** of the real world.
- We need to understand our cloud and precipitation parametrization in terms of **impacts on the hydrological cycle, radiation and dynamics**.
- A more complex parametrization provides more degrees of freedom, but does not always lead to a better parametrization in terms of impacts. **Can we constrain the parametrization sufficiently with observations**?
- Are we taking sufficient advantage of current observations and their **synergies** to inform physically based parametrization development. What gaps remain?
- How should we formulate parametrizations of sub-grid variability (humidity, cloud, precip, temp., vert. vel….) for the **warm phase**, **ice phase** and **mixed phase**?
- Can we (should we?) make our cloud microphysics and sub-grid variability assumptions **consistent** across all model parametrizations (convection, radiation)?
- How do we determine the right balance between **complexity**, **accuracy** and **computational efficiency**?
- How can we build parametrizations that **work across scales** (model resolutions)?

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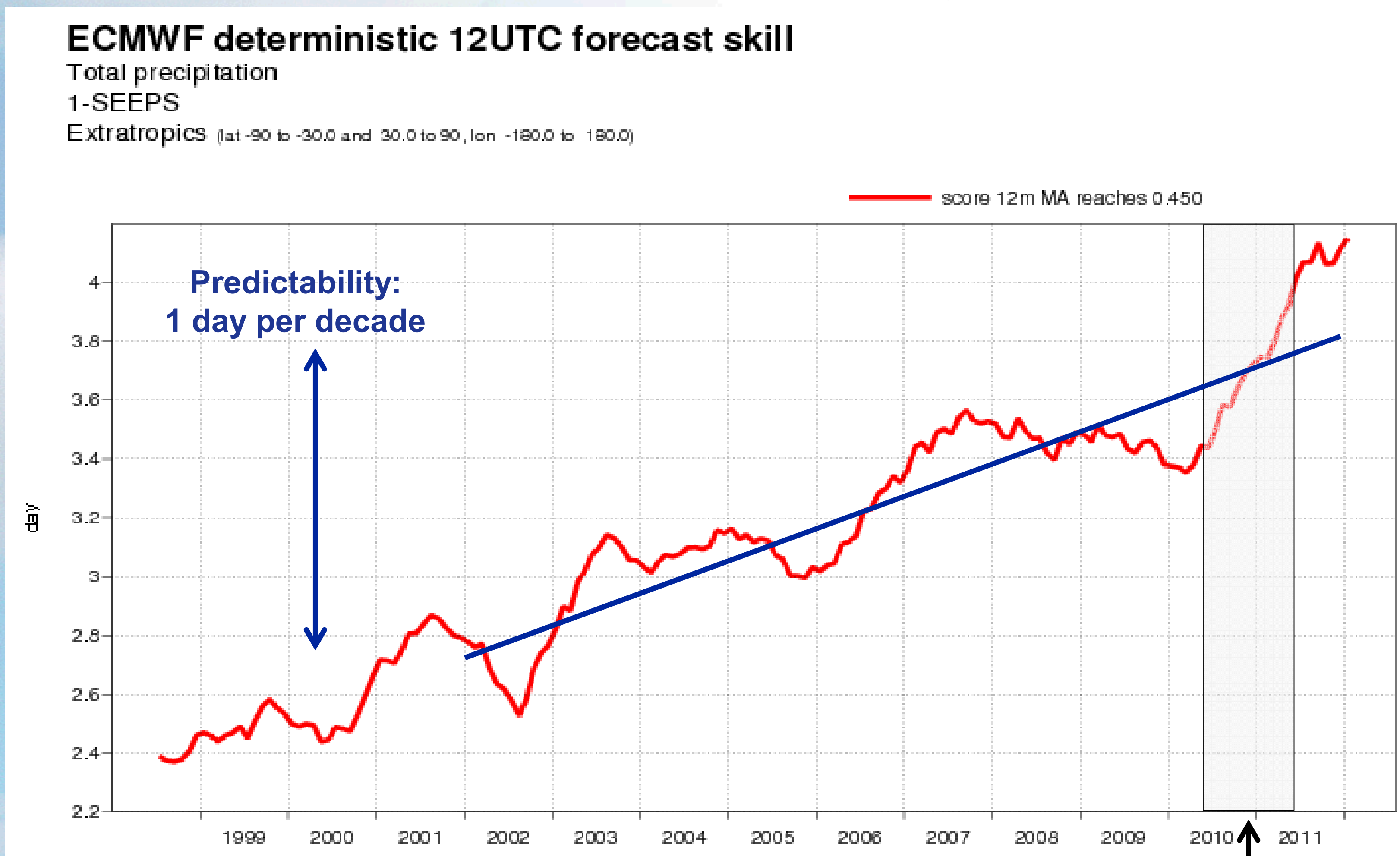
Example: Hydrological Impacts:
Precipitation skill – 1998-2012 (1-SEEPS 12 month running mean)



36r4
Cycle with new 5-species microphysics
with prognostic rain and snow

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