Improving the ECMWF model's representation of supercooled layers in Arctic mixed-phase clouds

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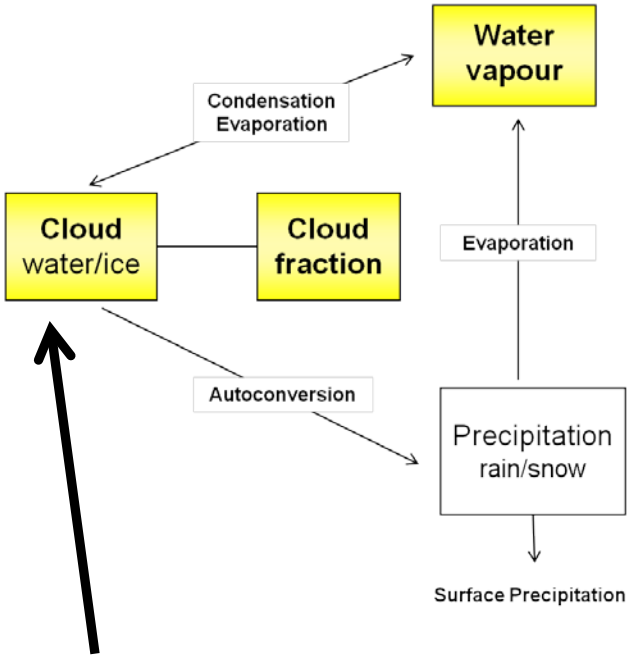
ECMWF

The model's cloud scheme

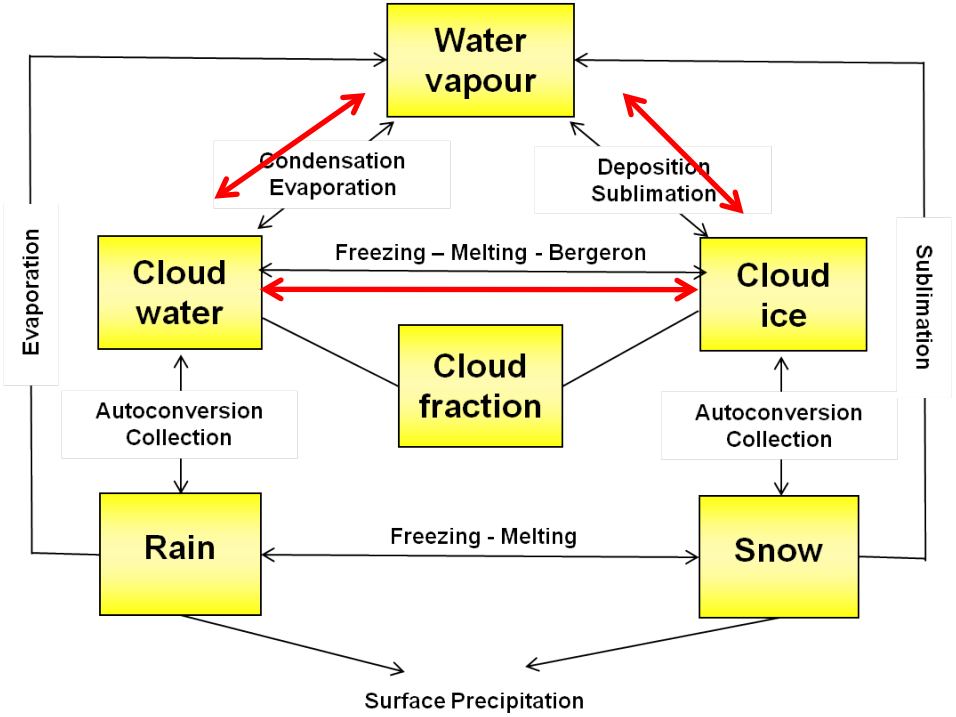
OLD cloud scheme
(Tiedtke scheme operational 1995-2010)



One condensate variable with diagnostic split

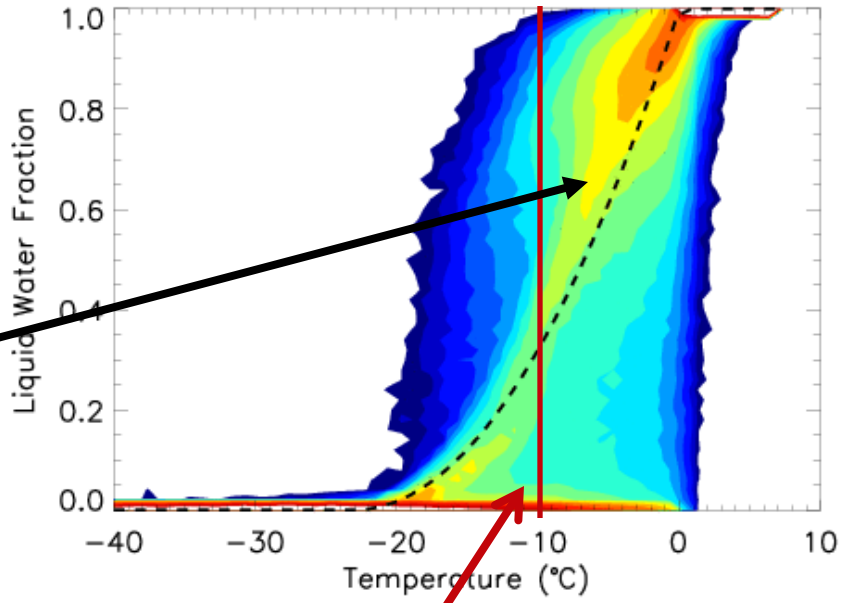
NEW Cloud Scheme
(operational from 9th Nov 2010, Cy36r4 onwards)

More prognostic variables – physical processes for conversion between water species individually parameterized



The old cloud scheme: Diagnostic split between cloud ice and liquid

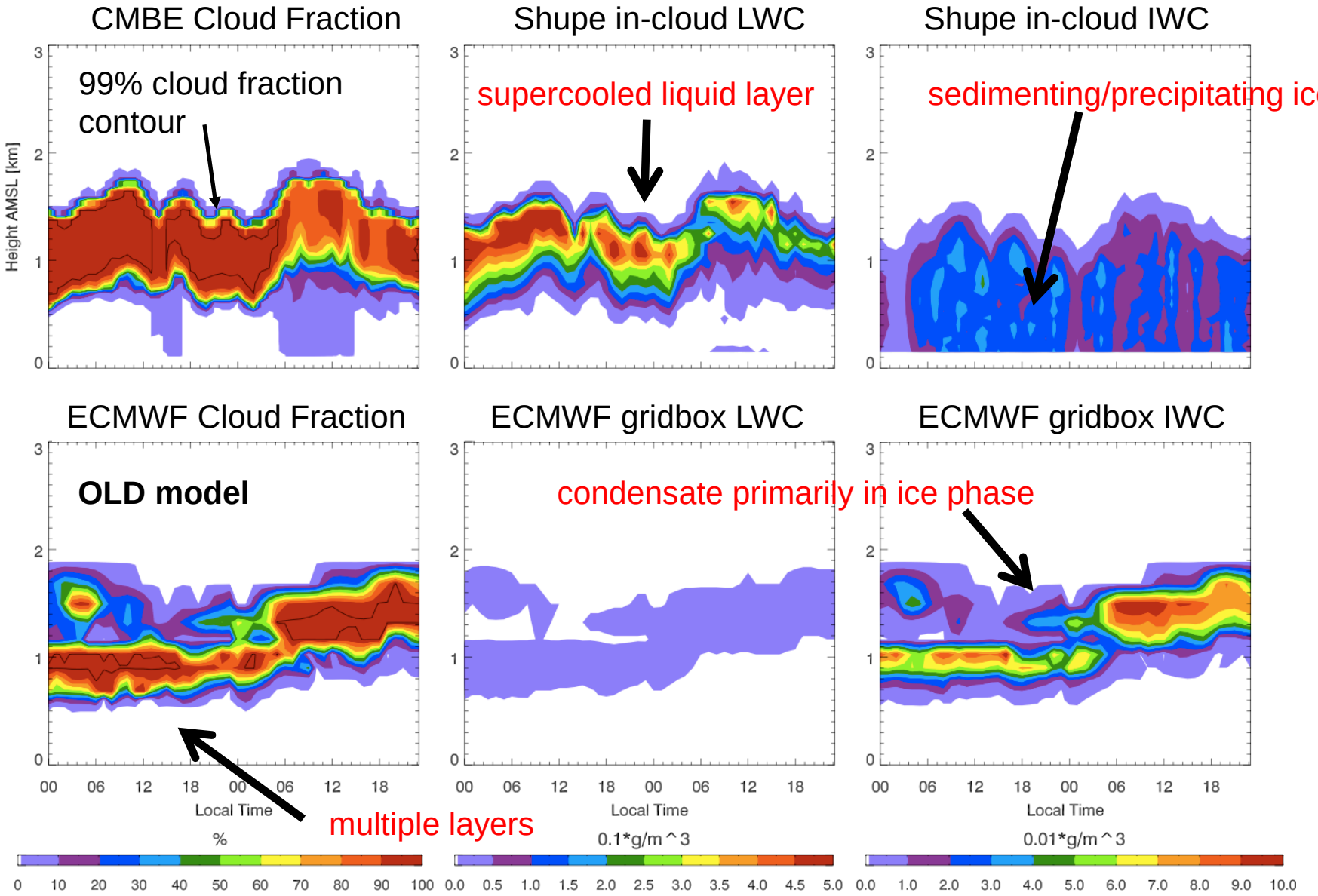
- One prognostic variable for condensate
- Liquid/ice split is temperature dependent
- Not well-suited to represent mixed-phase Arctic clouds



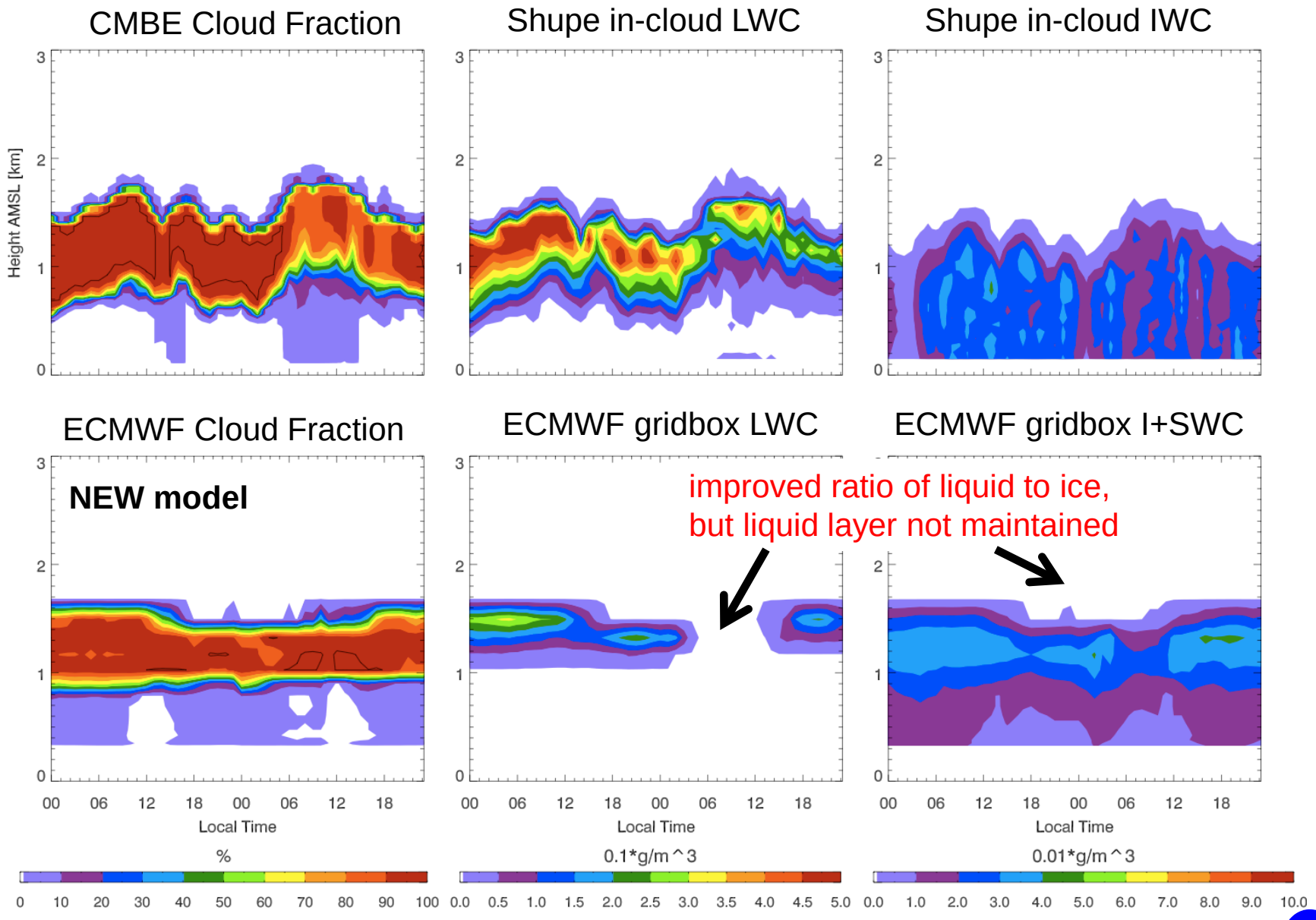
Example: -10°C
OLD: 35% liquid, 65% ice
NEW: any liquid-to-ice ratio possible

M-PACE single layer cloud

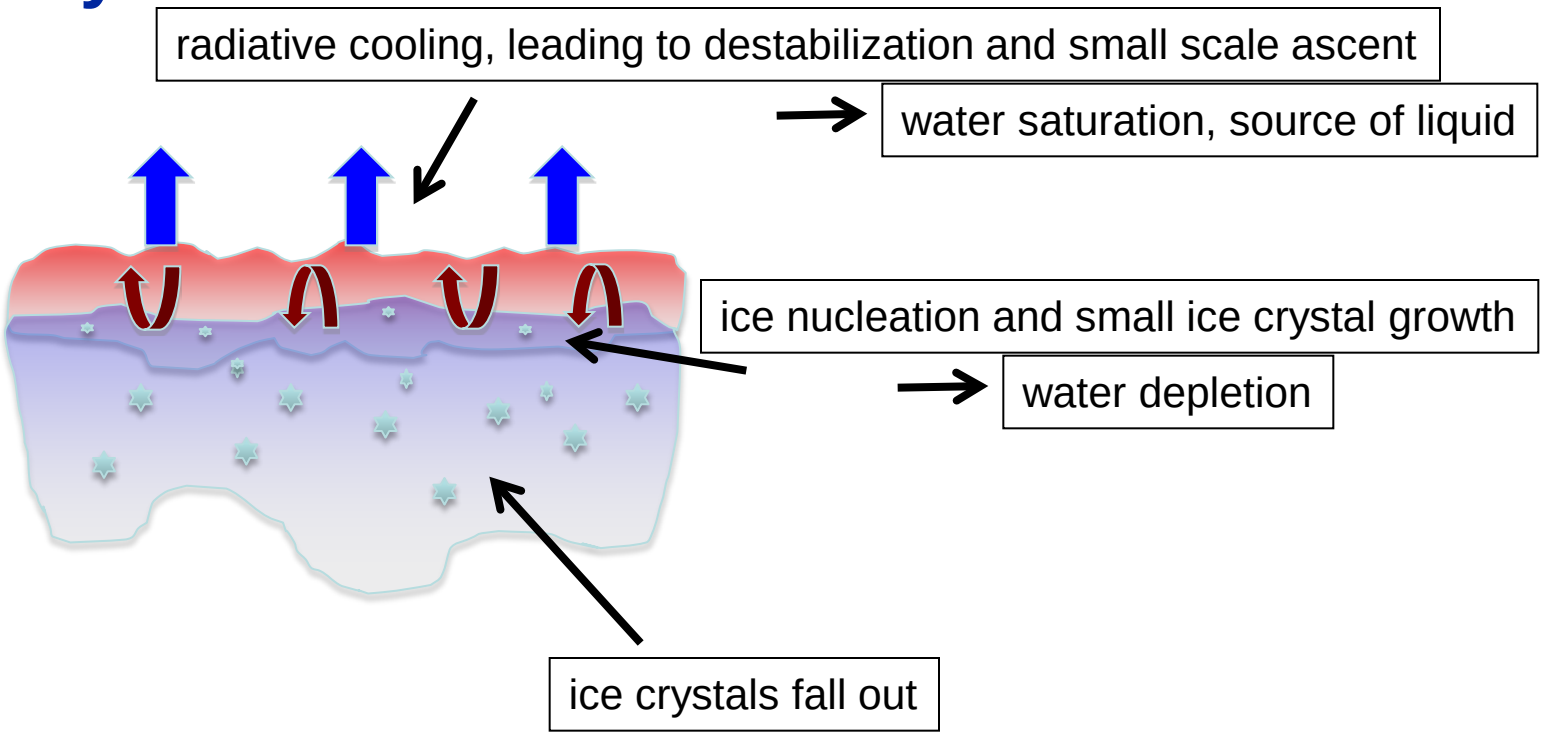
Oct 8/9 2004



Prognostic liquid and ice variables

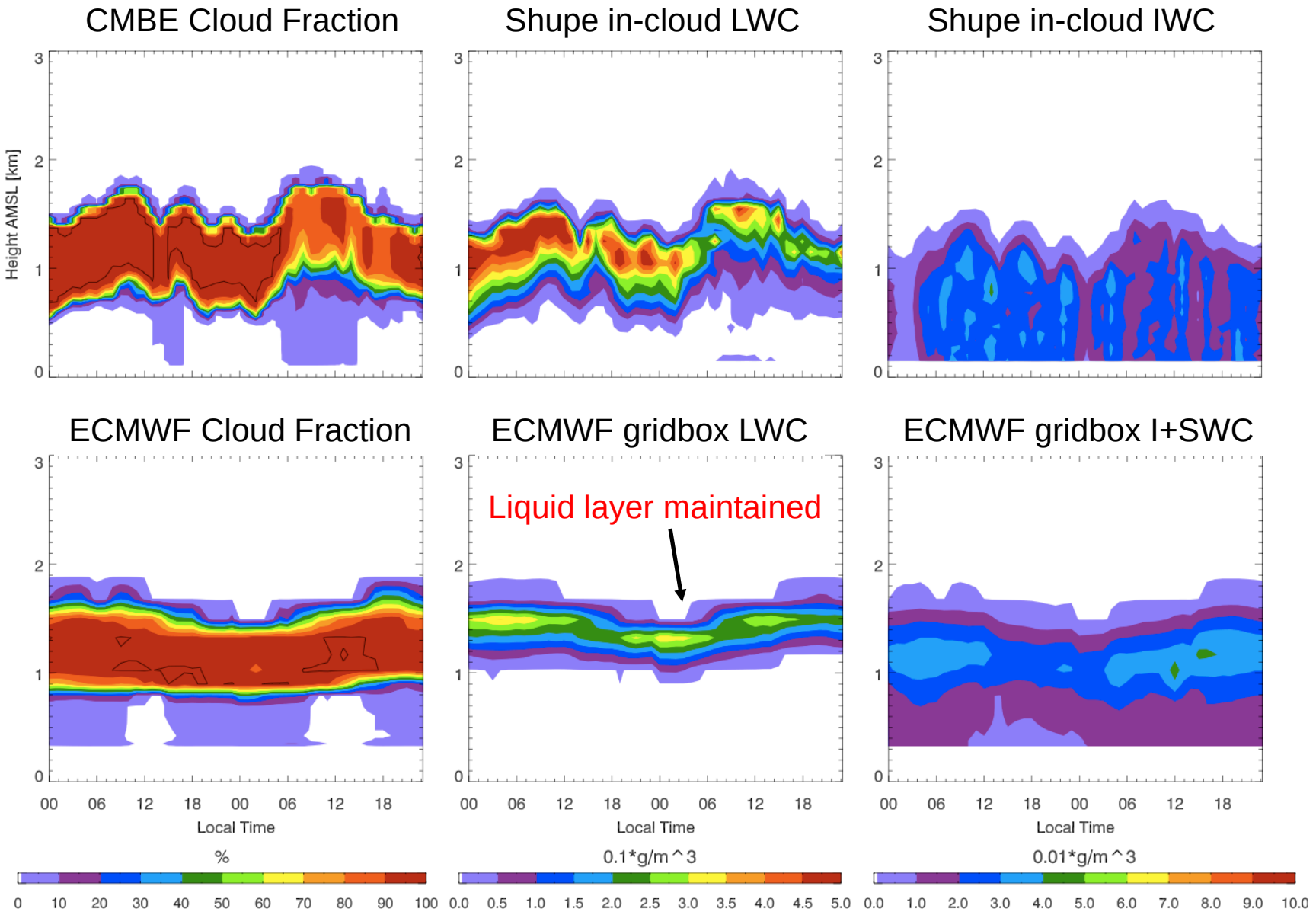


Processes involved in maintaining supercooled liquid layer



Model doesn't represent the small-scale mixed-phase cloud top processes of water production from convective overturning, ice nuclei activation and depletion, and fall-out of growing ice crystals separating ice and liquid *in a shallow layer.*

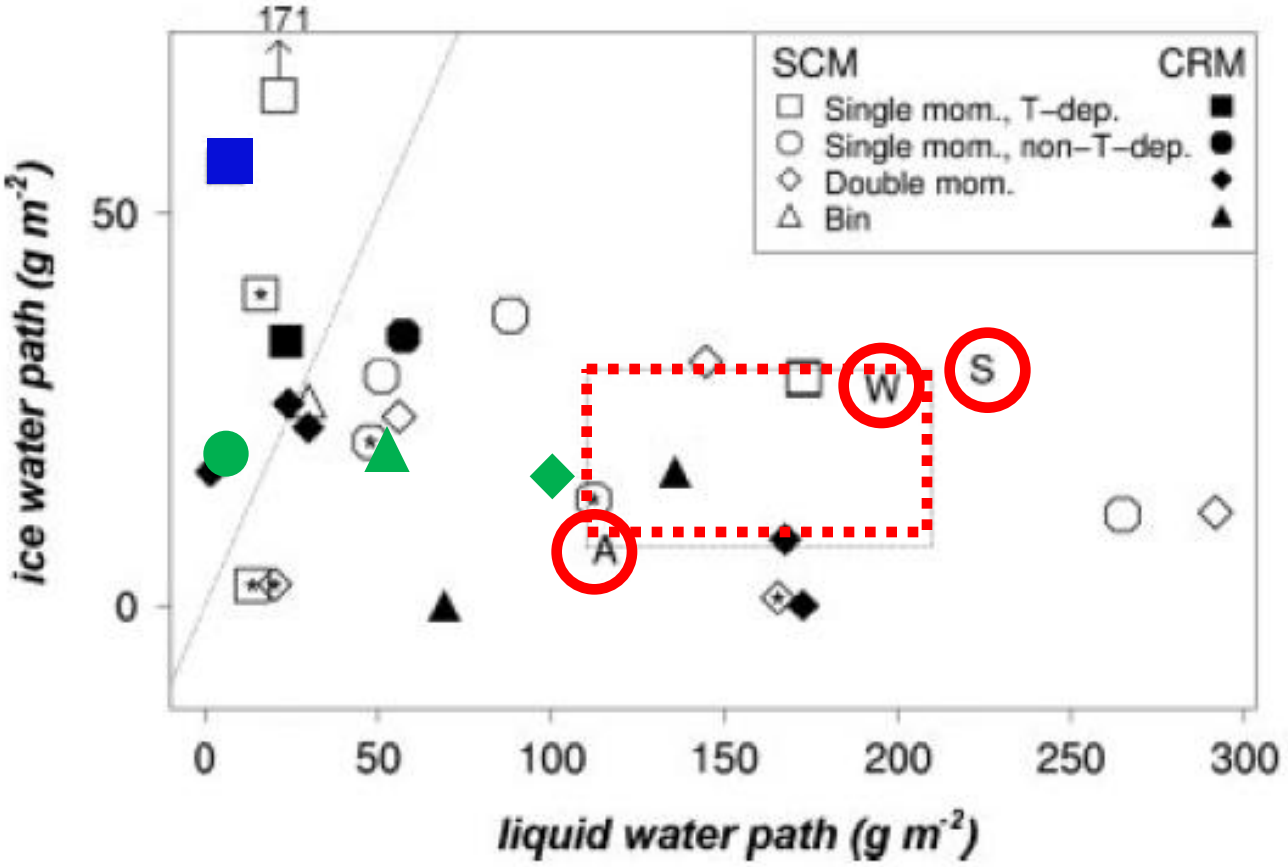
Reduce deposition rate near cloud top



M-PACE single layer cloud LWP/IWP

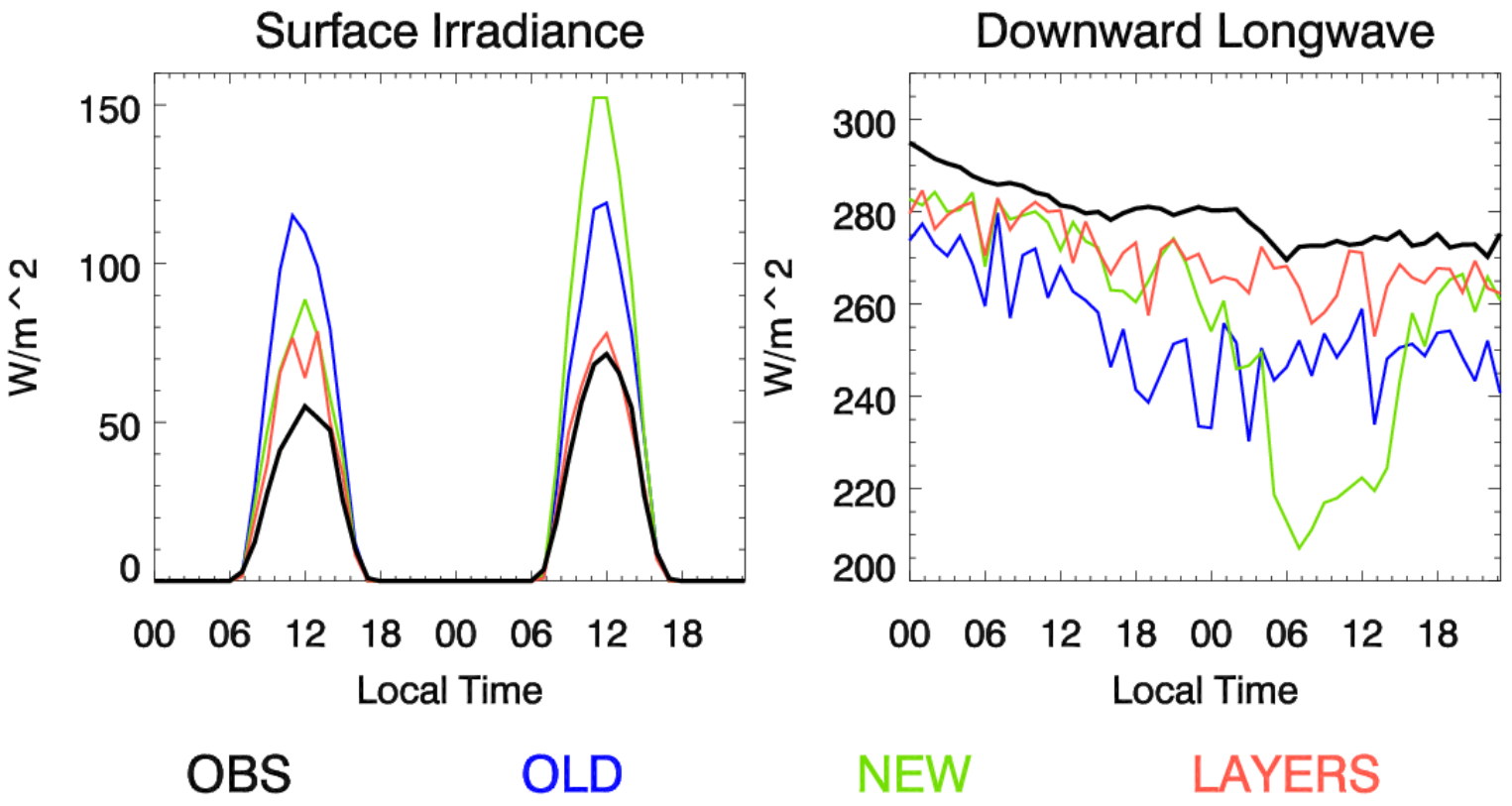
Observations: **A** aircraft, **W** Wang retrieval, **S** Shupe

- SCM 2007
- CY36R1 diagnostic split for condensate
- CY36R4 prognostic ice/liquid
- CY37R3 enhanced liquid layers



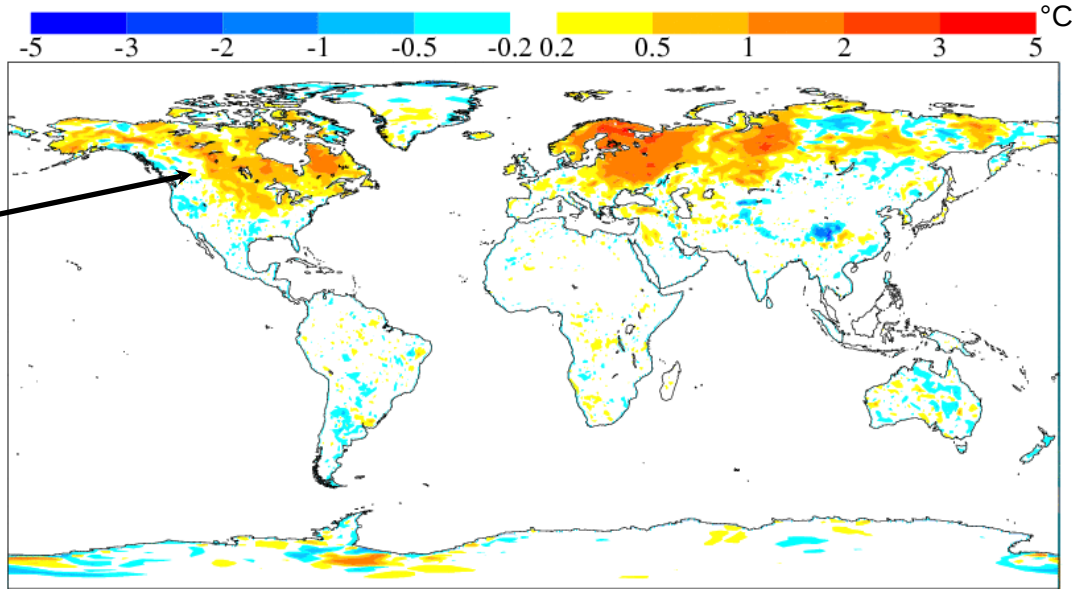
Klein et al. QJRMS 2009

What about radiation?



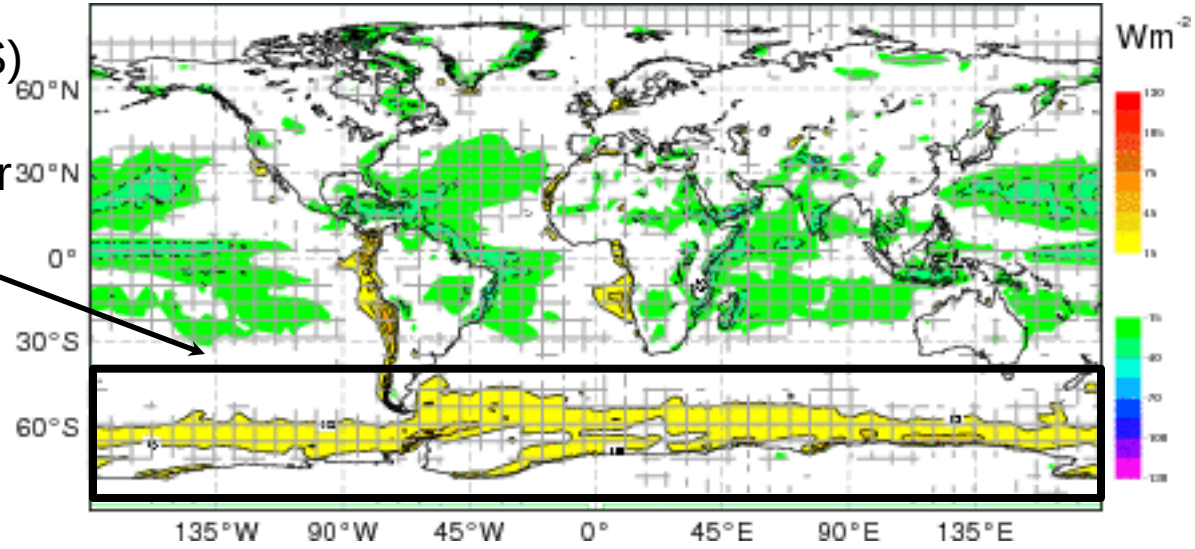
Global results:

Change in 2m Temperature:
warmer across North America
and Europe
Reduced 2m T error,
improved T1000hPa scores



TOA SW bias (ECMWF-CERES)
reduced around Antarctica due
to increased column liquid water

yellow: 15-30W/m^2



Conclusion

- ARM data very useful to guide model development
- Prognostic liquid and ice variables give the model a framework to better represent mixed-phase processes
- Some of these processes remain unresolved, but a simple parameterization improves persistence of liquid layers
- Surface radiation is improved, and so are 2m temperatures over the northern hemispheric continents
- This improvement is reflected in the model scores (T1000hPa)
- Improved TOA net SW bias in the southern hemisphere associated with increased supercooled liquid water in low clouds around Antarctica
- Future: keep working on linking parameterization more directly to physical processes