Exploring the impact of ice phase microphysical processes on mesoscale structures in mid-latitude cyclones using WRF

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Motivation

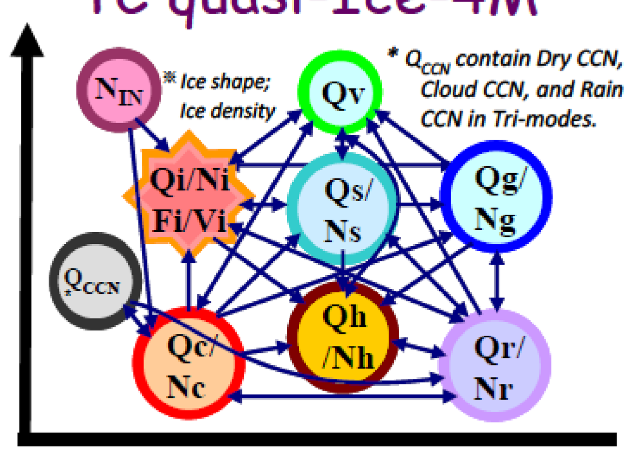
- The latest microphysics observations of mid-latitude cyclones indicate the prevalence of secondary ice columns produced via the Hallett-Mossop process, and significant variations in ice crystal habit (see poster #65).
- Local rates of diabatic heating and cooling associated with deposition growth and sublimation, as calculated from the in-situ measurements, show sensitivity to variations in the observed crystal habit (Dearden et al 2014, MWR; poster #213). Yet historically bulk microphysics schemes assume either spherical ice or a fixed mass-size relationship.
- Thus there is a need to explore the impact of habit evolution on meoscale structures in extratropical storms. **We aim to do this using a new bulk microphysics scheme with an adaptive habit parameterization, implemented within the Weather Research and Forecasting model (WRF).**

Introducing the Tsai and Chen bulk microphysics scheme

Microphysics NTU-TC (Tsai and Chen) scheme

- aerosol activation and time-splitting technique adopted from *Cheng et al. (2007; 2010).*
- liquid-phase processes via *Chen and Liu (2004).*
- mixed-phase and solid-phase processes referred to *Milbrandt and Yau (2005a,b), Morrison et al. (2005), Resiner et al. (1998) and others.*
- hailstone dry/wet growth modes based on Chen and Lamb (1994b)
- ice deposition-nucleation mechanisms referred to Chen et al. (2008) and Hoose et al. (2010)

TC quasi-Ice-4M



18 Variables

Hydrometeor		Moments	Shape	Density (kg/m^3)	α value	m-D	V-D
C	Cloud	Q, N	Spherical	997	Fixed		
R	Rain	Q, N					
I	Pristine Ice	Q, N, F, V	Non-spherical	100 ~ 910	Optional	Variable	
S	Aggregate	Q, N	Spherical	100 ~ 910	Fixed		
G	Graupel	Q, N		400			
H	Hail	Q, N		900			

- Bulk parameterization of adaptive growth (inherent growth ratio varies as a function of temperature, based on the method of Chen and Lamb, 1994);
- Ice crystal shape is influenced by deposition and riming processes;
- Aggregation of pristine ice is modified from a simple collection kernel of Cotton et al. (1986). Removes the need for an arbitrary threshold size for autoconversion, and also permits pristine ice to grow to larger sizes (~1mm) as seen in the observations;
- The effect of pristine ice shape (plates or columns) on the fall speed is included based on Mitchell and Heymsfield (2005). NB - The effects of shape on the ventilation of pristine ice is not yet included.

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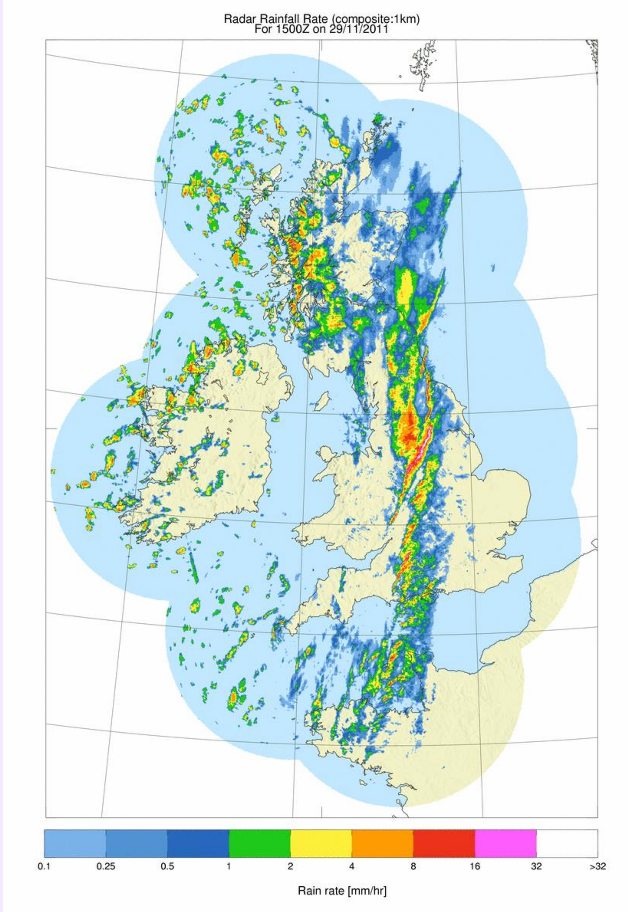
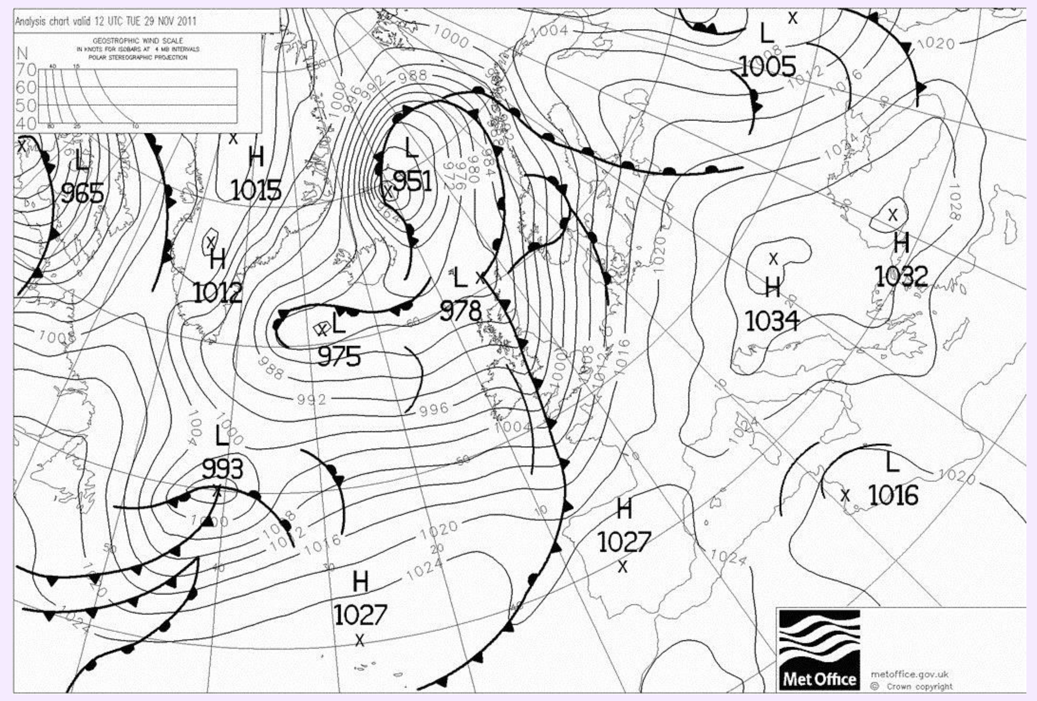
Case study details and initial WRF simulations

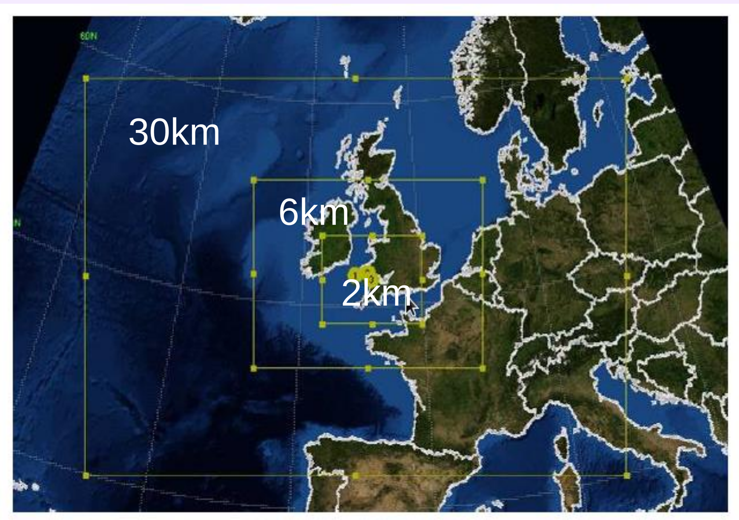
Case studies are taken from the DIAMET field campaign (DIAbatic influences on Mesoscale structures in ExtraTropial storms) which took place in the UK between September 2011 and August 2012.



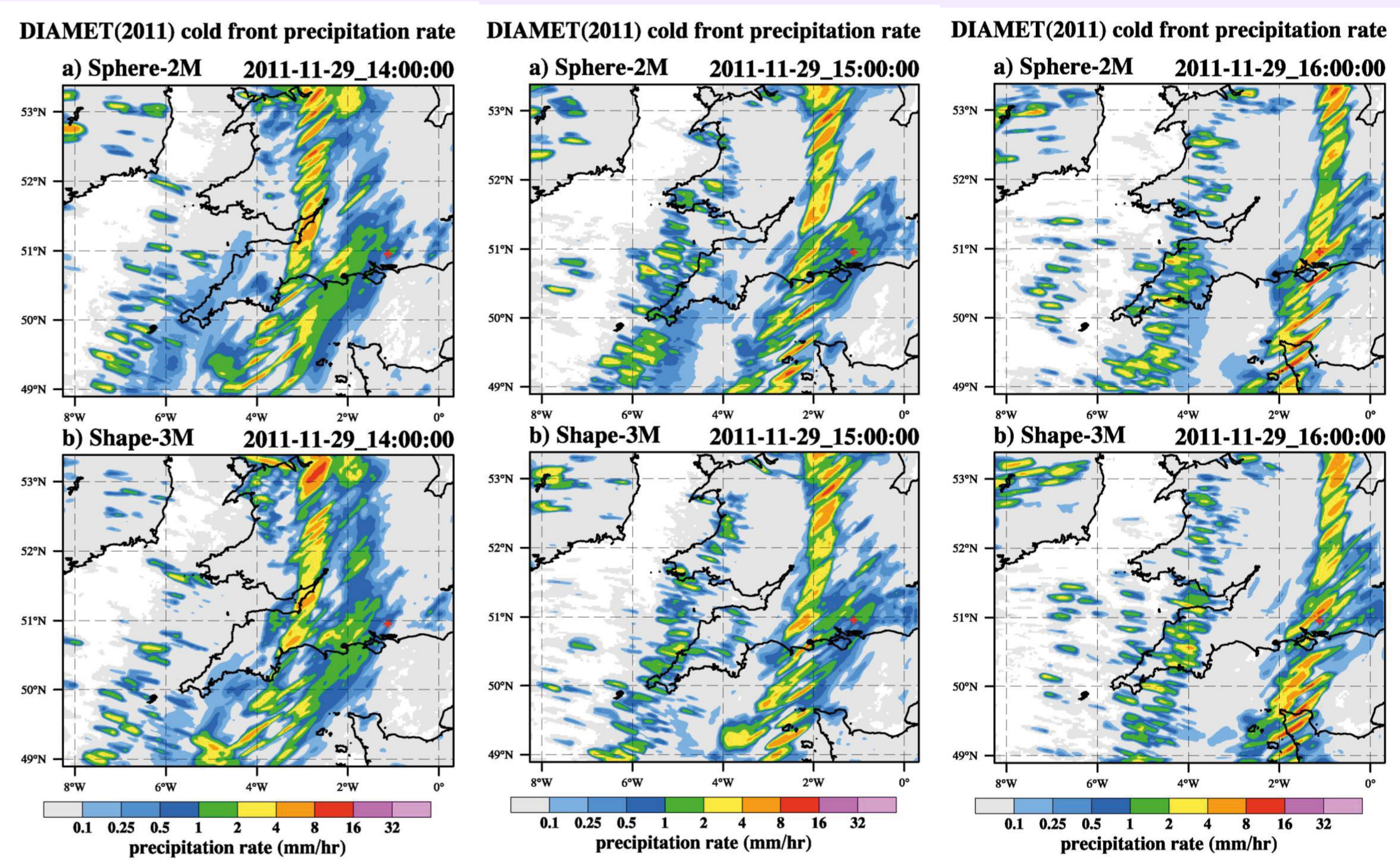
Case study #1: 29th November 2011. Narrow cold frontal rainband associated with the passage of a kata cold front over the UK



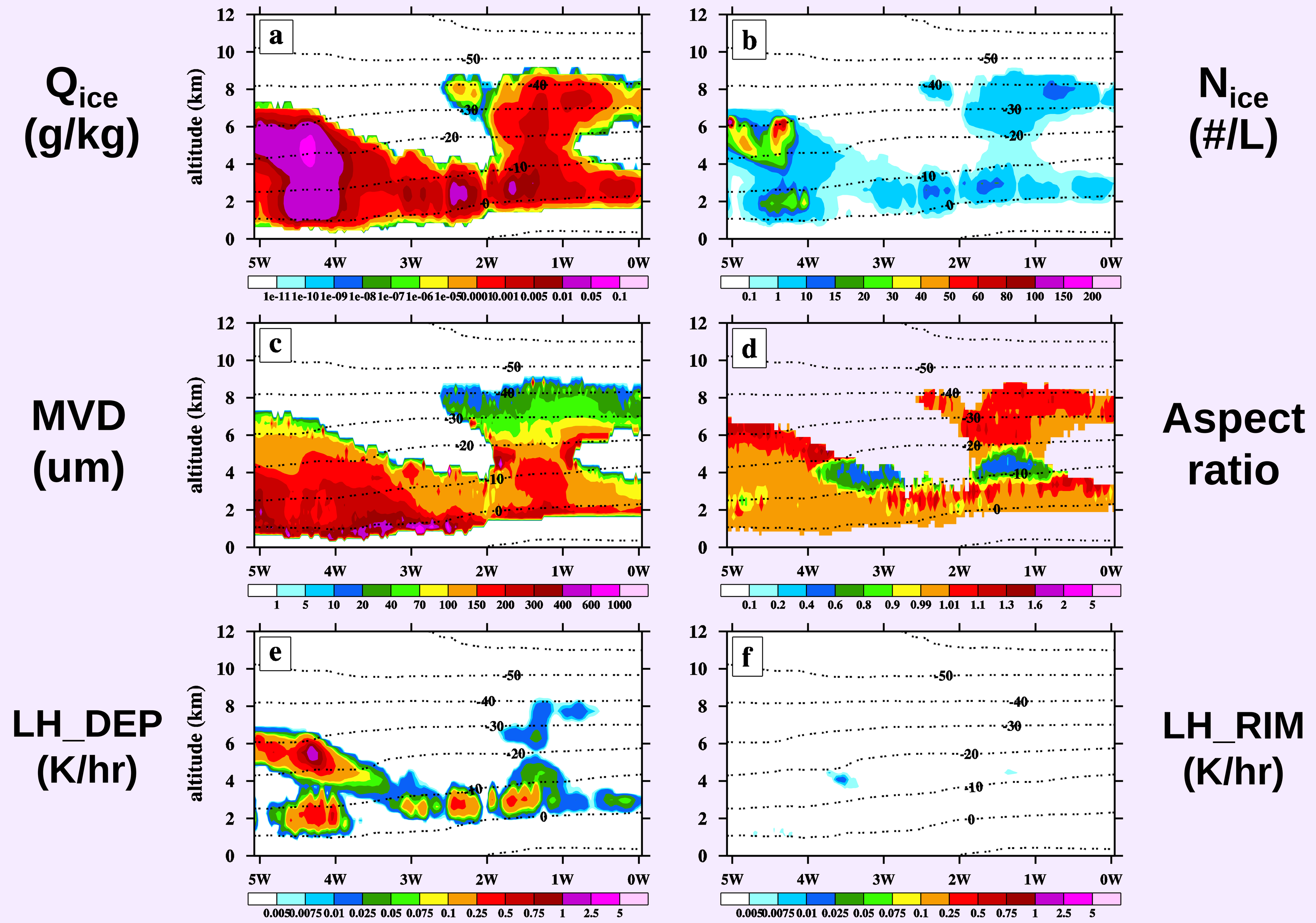
Simulations of this case were performed with a beta version of the TC scheme implemented into WRFv3.4.1, with 3 domains as illustrated below (50 vertical levels). 18 hour simulations were initialised at 00 UTC 29th November 2011 using ECMWF analysis data at 0.25deg resolution, with boundary conditions updated every 6 hours.



The initial sensitivity experiments explore the impact of the adaptive habit parameterization ('Shape-3M') on the intensity and distribution of surface precipitation, relative to the more simple assumption of spherical cloud ice crystals ('Sphere-2M')

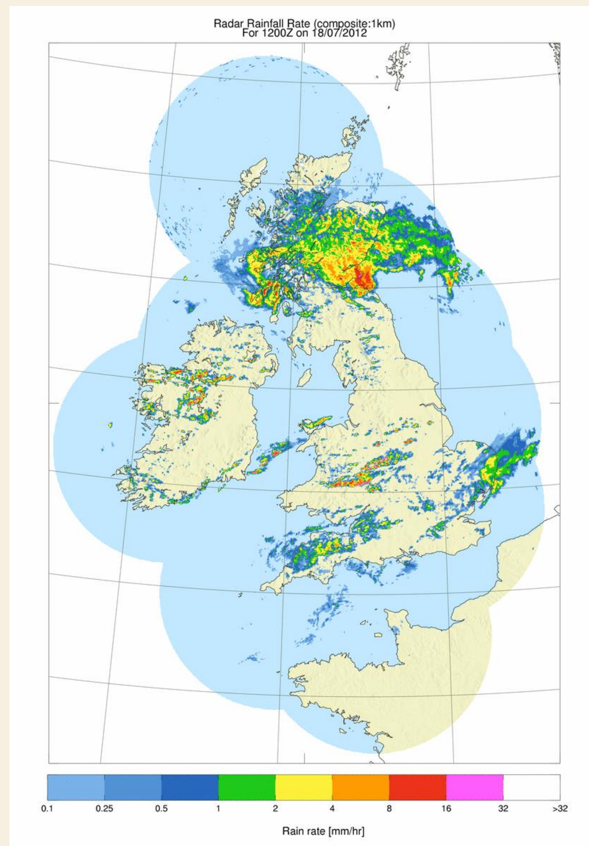


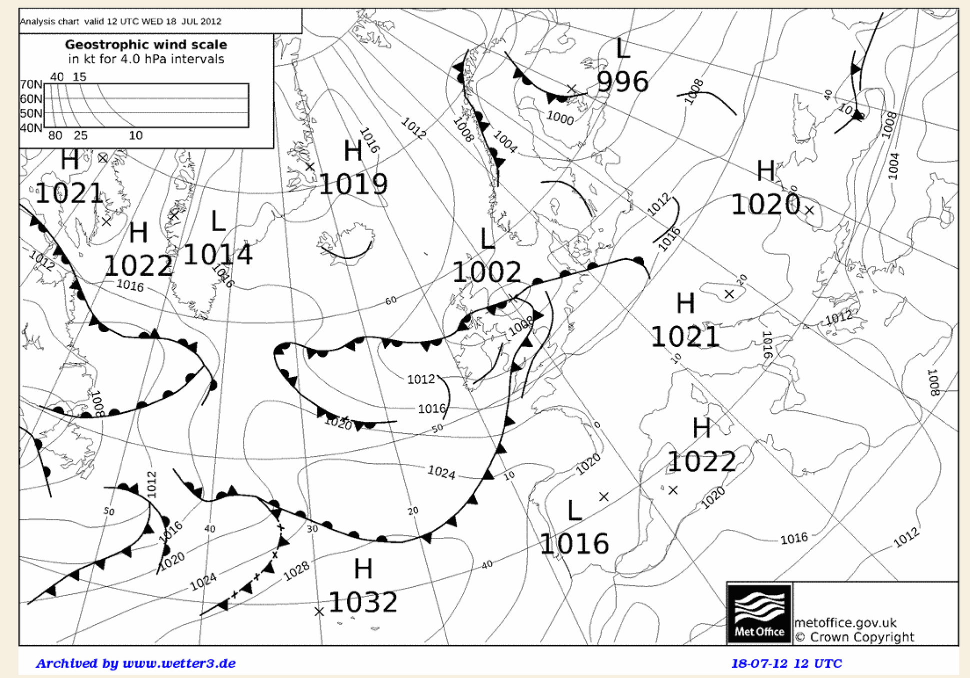
Vertical cross-sections (averaged from 50.5N - 51.5N, inner domain) at 1530 UTC, with 3-M ice



Preliminary findings and future work

- Initial results suggest that the subtleties of ice phase microphysical processes in wintertime kata cold frontal rainbands are overshadowed by the strong dynamical forcing of such systems (further work is required to confirm this)
- The role of diabatic heating and cooling may be more significant in other cases, e.g. in summer when the baroclinicity is generally weaker and there is more condensible water vapour available due to the Clausius-Clapeyron relationship. E.g. case study #2: 18th July 2012 (bent-back front over Scotland, bringing flooding to the Edinburgh/Fife area).





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