# Rasch-Kristjanson CCM3 condensation in ALARO-0

Lisa Bengtsson-Sedlar
Radmila Brožková
Jean-Francois Geleyn
Doina Banciu
Karl-Ivar Ivarsson

2010-02, ALARO workweek, Budapest

# Background

- Adjustment: Condensation rate based on grid-scale saturation -> update qv and T correspondingly.
- Cloud fraction diagnosed separately from the condensation rate.

# Background

- RK98: condensation rate used to update also cloud water and ice, but changes in cloud cover is not directly linked to changes in cloud water/ice.
- Zhang et al 03: Start from in-cloud condensate equation -> total cloud water/ice variation is expressed in terms of changes of cloud fraction and in-cloud condensate.
- Also with the possibility to update cloud-fraction after condensation rate is determined.

# Background/Motivation

- Goal to have “one” cloud fraction which is the same for radiation, microphysics and adjustment.
- In RK there are advection terms in the computation of Condensation-Evaporation, which introduces a “memory” also in the computation of large scale condensation.

# Status/Progress

Implemented all 'adjustment' code from RK (HIRLAM version by Karl-Ivar) including computations of:

- Critical humidity
- Cloud fraction
- Condensation-Evaporation as fluxes for ice and liquid

into cycle 36

# Cloud fraction

- Sundqvist formulation

  (Shallow Cu) + Deep Cu + Stratiform

  Resolved clouds

- Cloud fraction $1-\sqrt{\left(\frac{1-RH}{1-PHCRICS}\right)}$

- PHCRICS is a function of height, and depends on changes in RH over a gridbox, in x, y and z direction

# Cloud condensation tendency (C-E)

- Rasch, P.J, Kristjansson, J.E 1998
- Zhang, M., W. Lin, C.S. Bretheron, J.J. Hack and P.J. Rasch, 2002
- + CAM3 and HIRLAM specific changes by Karl-Ivar Ivarsson

Compute the grid-averaged net stratiform condensation of cloud water/ice (condensation-evaporation), based on following governing equations:

$$\frac{\partial q}{\partial t} = A_q - Q + E_r$$

$$\frac{\partial T}{\partial t} = A_T + \frac{L}{C_p}(Q - E_r)$$

$$\frac{\partial c}{\partial t} = A_c + Q - R_c$$

# Cloud condensation tendency (C-E)

$$\frac{\partial q}{\partial t} = A_q - Q + E_r$$

$$\frac{\partial T}{\partial t} = A_T + \frac{L}{C_p}(Q - E_r)$$

$$\frac{\partial c}{\partial t} = A_c + Q - R_c$$

- A-terms = Tendencies of q, T and c from processes other than stratiform condensation and evaporation of cloud water/ice and rain water.
- Q = grid averaged net stratiform condensation of cloud water/ice (condensation-evaporation)
- Er = grid averaged evaporation rate of rain/snow water.
- Rc = conversion rate of cloud water/ice to rain/snow.

# Relative humidity

$$\frac{\partial RH}{\partial t} = \alpha A_q - \beta A_T - \gamma(Q - E_r)$$

$$\alpha = \frac{1}{q_s}, \beta = \frac{q\partial q_s}{q_s^2\partial T}, \gamma = \alpha + \frac{L}{Cp}\beta$$

All equations so far are applicable on both grid, and sub-grid scales as long as Q, Er and Rc are defined correspondingly.

1. Whole grid saturation (if RH = 1)

$$\hat{Q} = \frac{\alpha \hat{A}_q - \hat{\beta} \hat{A}_T}{\hat{\gamma}}$$

2. Fractional saturation (if 1 >RH > PHCRICS)

$$Q = c_q A_q - c_t A_t - c_l A_c + c_r E_r + a \hat{E}_r \sigma F_a^{-1}$$

3. When RH < PHCRICS (but c > 0), evaporate existing cloud water/ice

$$Q = -c$$

4. No condensation nor evaporation (if RH < PHCRICS and c =0)

$$Q = 0$$

# Implementation in 3MT

- Input: T, q, p, At, Aq, Ac, cloud-fraction, ql, qi, Fa.
- Er could be diagnosed from above input, will discuss in a few slides.
- Output: Q (to update T,q,ql,qi and potentially cloud-fraction)
- No “micro-physics” from the RK scheme is included to describe conversion rates, Rc, between cloud water, cloud ice to rain/snow water.

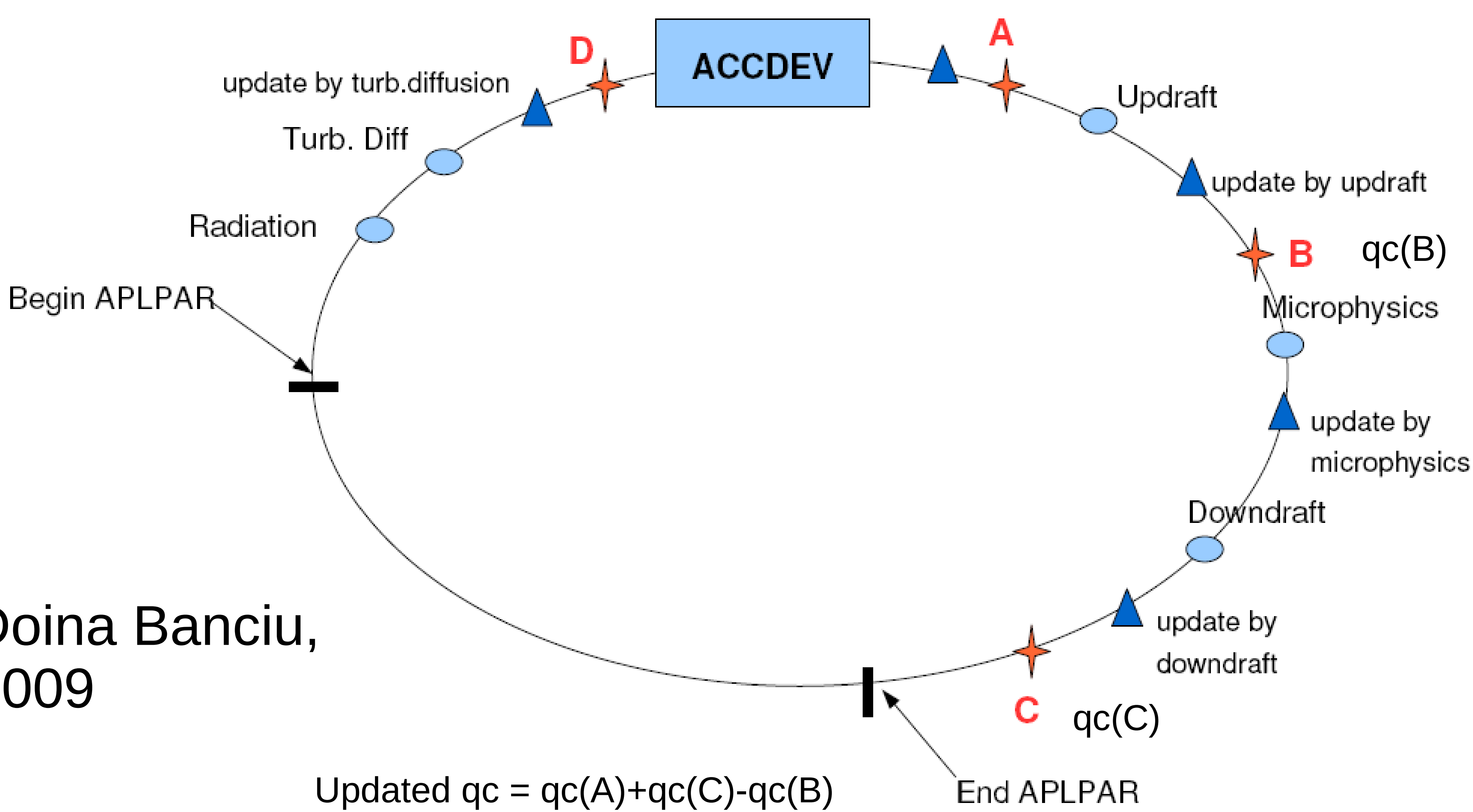
# A-terms

- Aq, AT and Ac are advective, radiative, and turbulent diffusion tendencies of water vapour, temperature, and cloud water + cloud ice.
- Moist advection (positive Aq), cold air advection (negative AT), evaporation of rain/snow water (positive Er), and import of cloud water/ice (positive Ac) all lead to an increase of cloud amount.

# Plan of attack for cascade

(ACCDEV).

Ac=qc(D)-updated qc




Doina Banciu,
2009

Updated qc = qc(A)+qc(C)-qc(B)

# Remaining terms for fractional saturation

$$Q = c_q A_q - c_t A_t - c_l A_c + c_r E_r + a\hat{E}_r \sigma F_a^{-1}$$

- 5th term on RHS comes from Karl-Ivar Ivarsson's implementation of also considering snow deposition
- $$F_a = \frac{a^* - a}{RH^* - RH}$$ , obtained by calling

ACNEBCOND twice with small perturbation of RH

# Remaining terms for fractional saturation

$$Q = c_q A_q - c_t A_t - c_l A_c + c_r E_r + a\hat{E}_r \sigma F_a^{-1}$$

- In HIRLAM Er is evaporation rate of stratiform rain/ snow water. (computed from stratiform precipitation fluxes)
- In ALARO-0 the precipiation fluxes are stratiform + convective.
- Protection of re-evaporation of convective precipitation -> putting the exact contribution from evaporation in to the A-terms.
- What to do with Er?

# Back to early discussions in the M-T framework

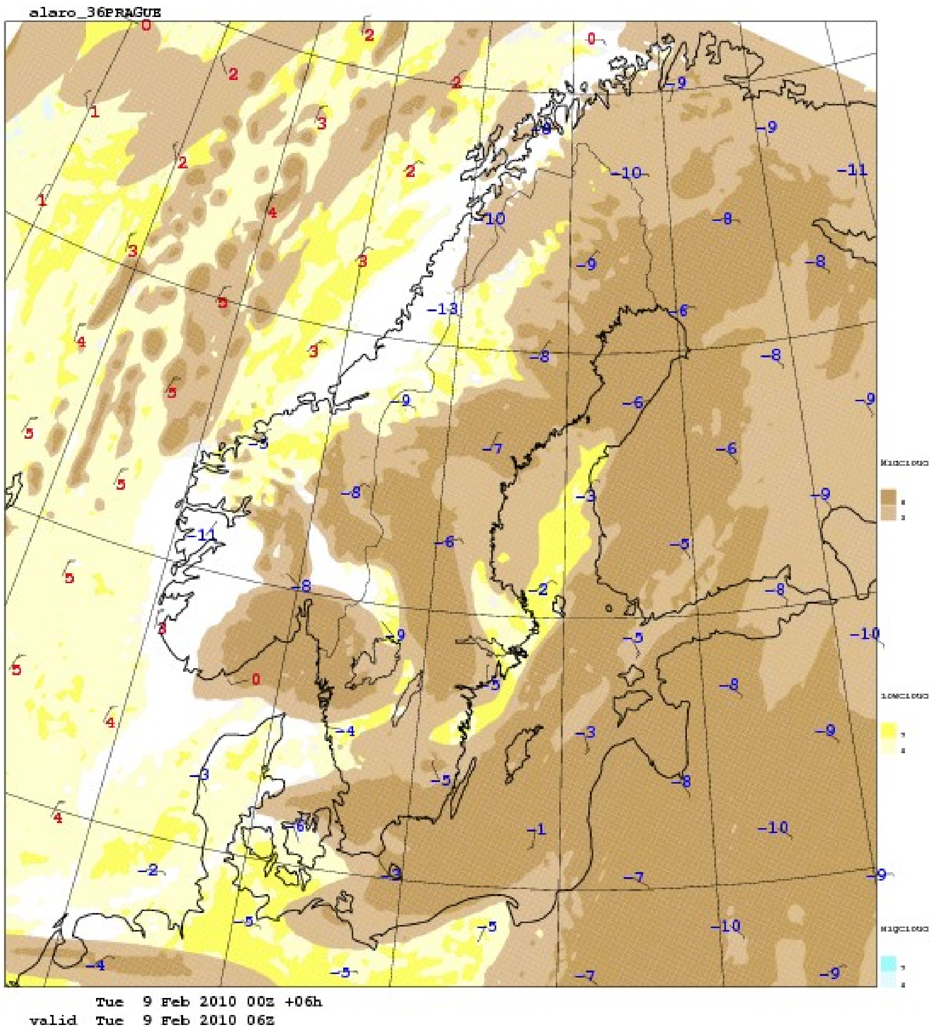
- A-terms are tendencies of thermodynamic variables from processes other than strat. + convective cond. and evap. of cloud water and rain. Such as advective, radiative, turbulent and convective-transport tendencies.
- If detrainment of convective cloud water is considered in Ac and convection also impacts At and Aq, and if the convective detrained portion is made available to the microphysics for possible evaporation (and precipitation) then could Er be considered from stratiform+convective rain/snow fluxes?

# Experiment setup

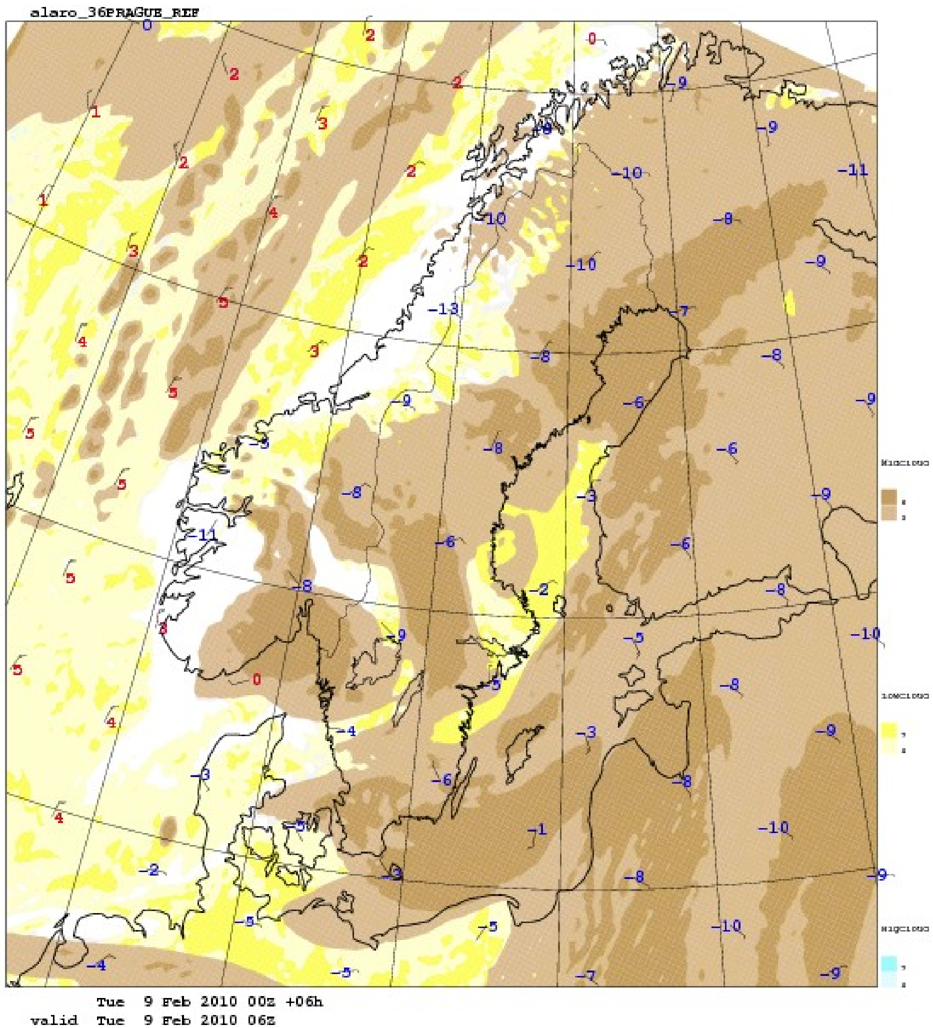
- For now Er = 0
- Cycle 36
- Cold start, ECMWF bc and ic
- Cy36 Prague namelist
- LXRCDEV vs LRKCDEV

# Cloud-cover 2010-02-09_00 + 06

RK

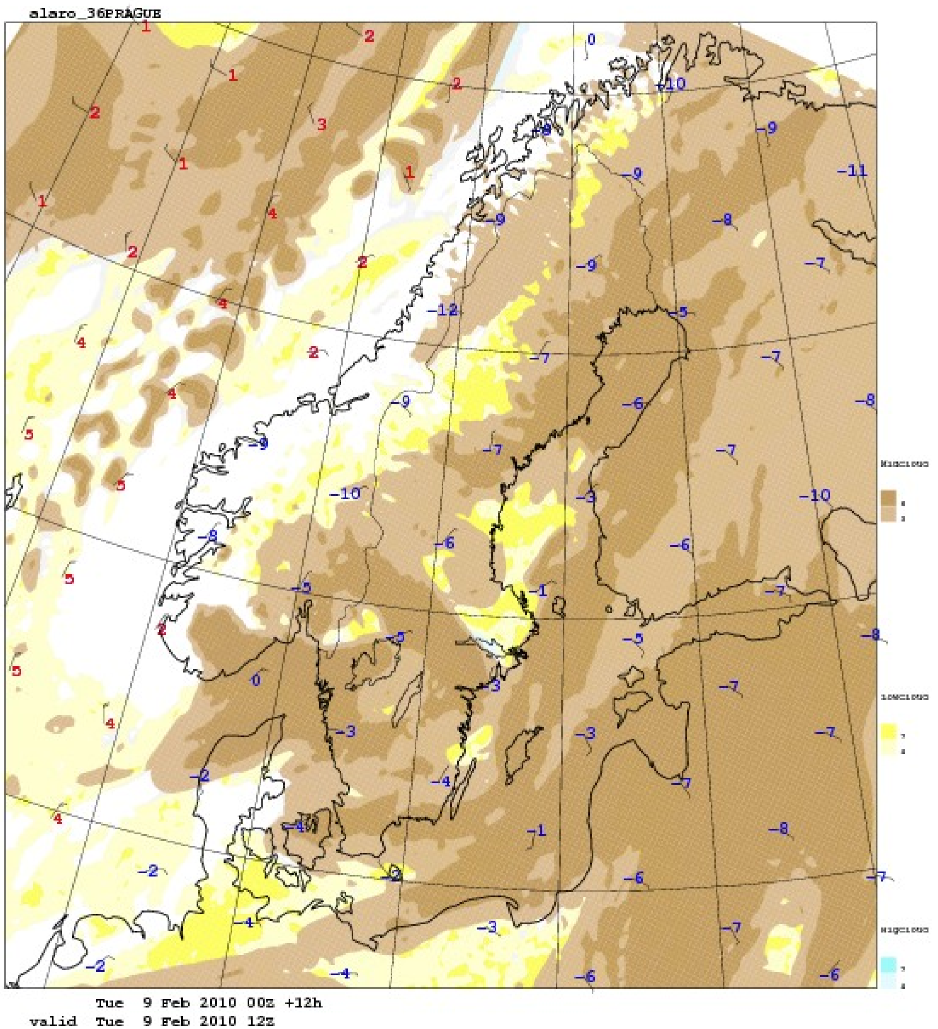



XR

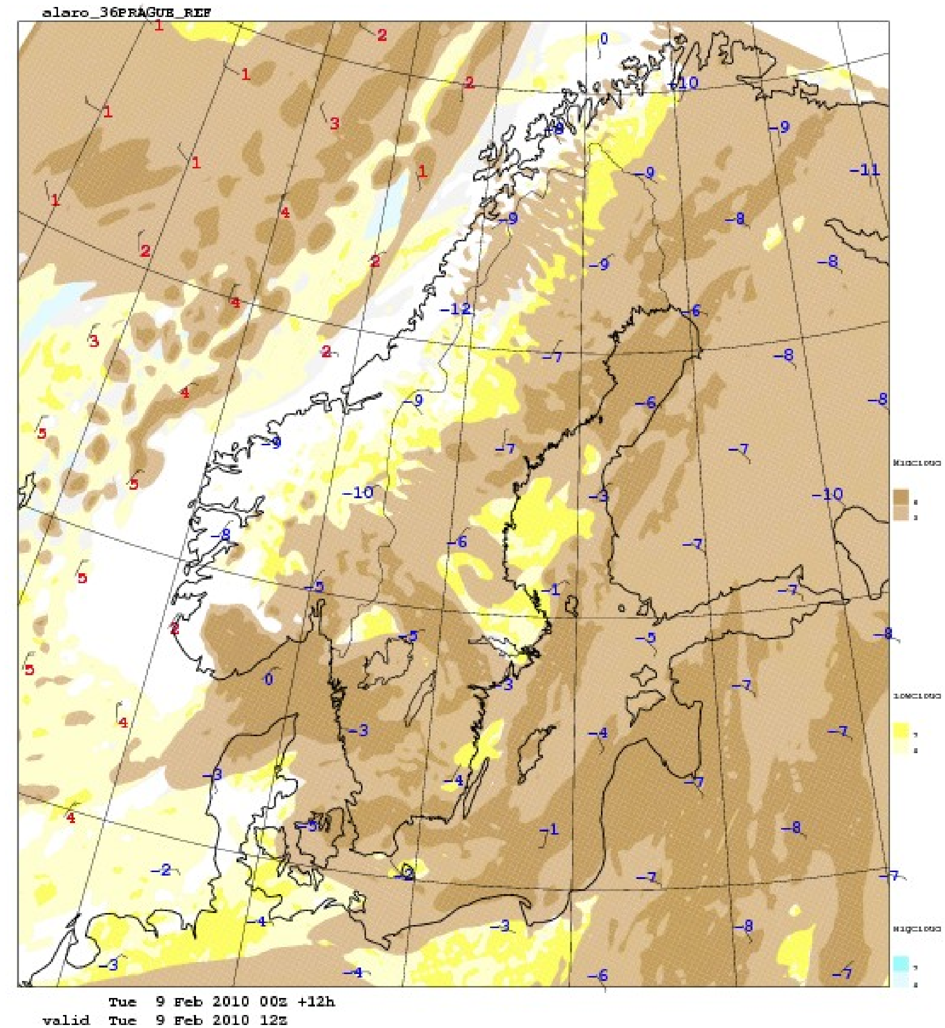


# Cloud-cover 2010-02-09 00 + 12

RK

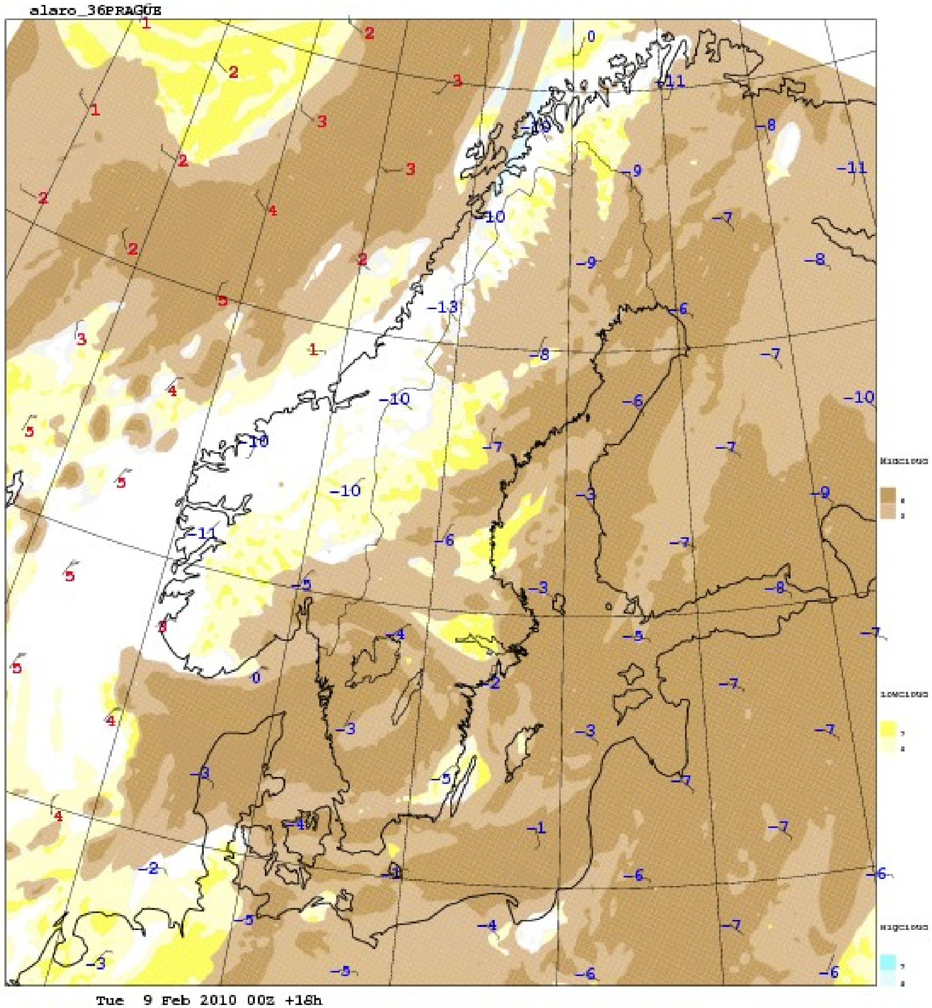



XR

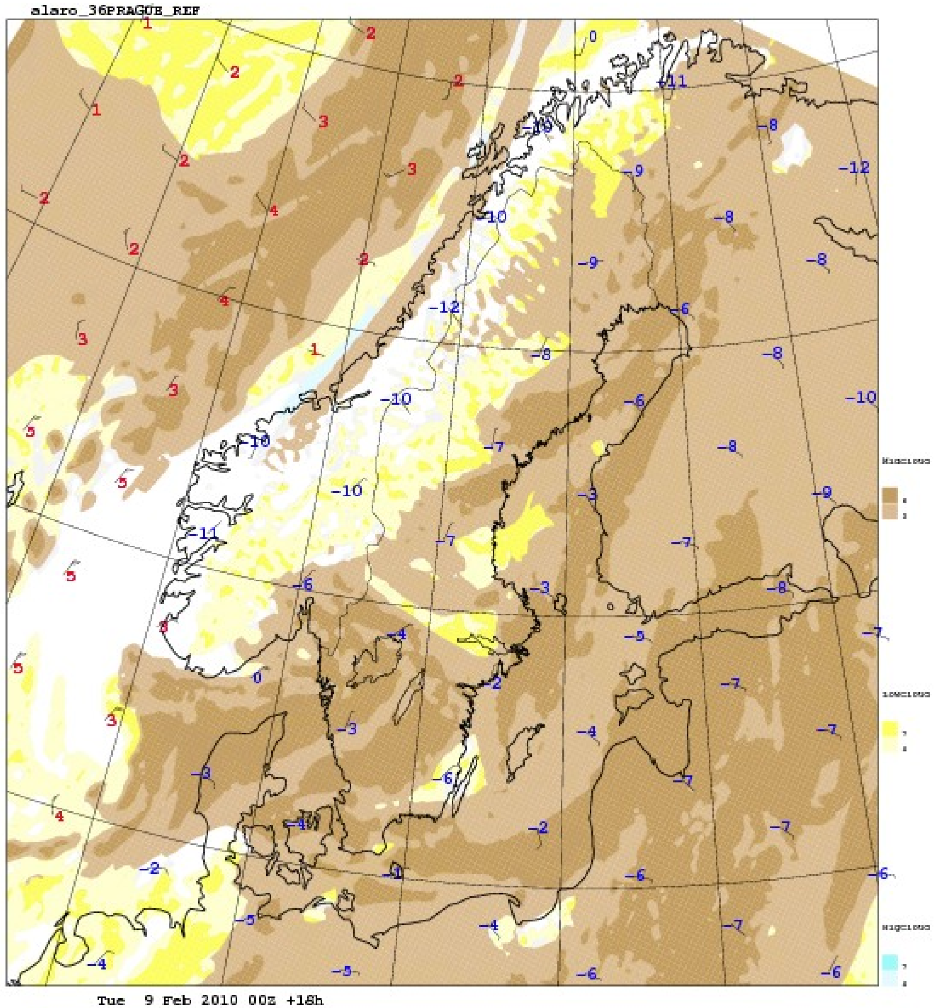


# Cloud-cover 2010-02-09 + 18

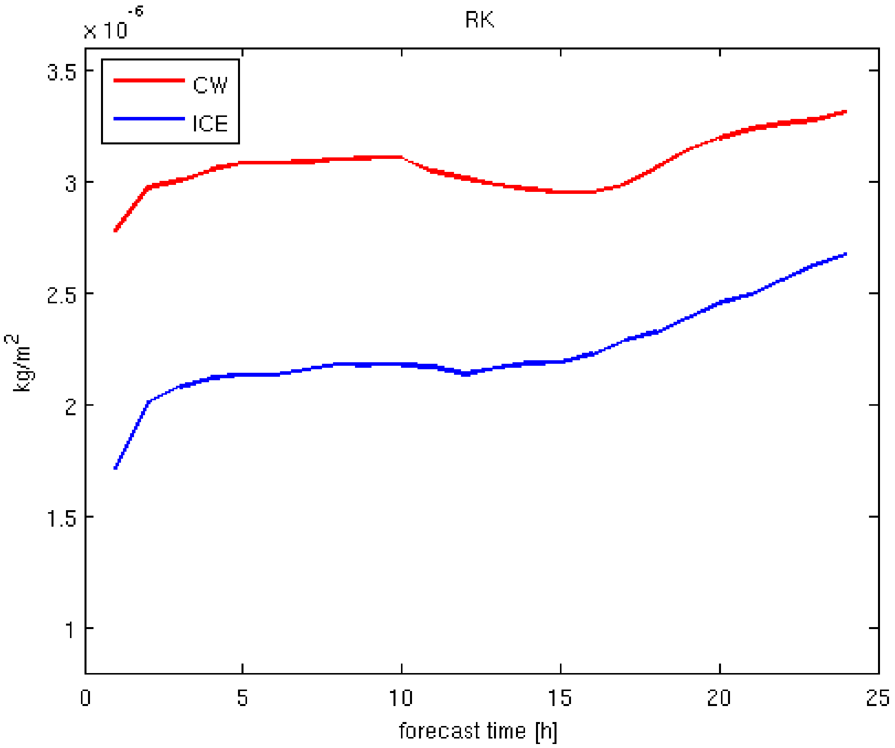
RK

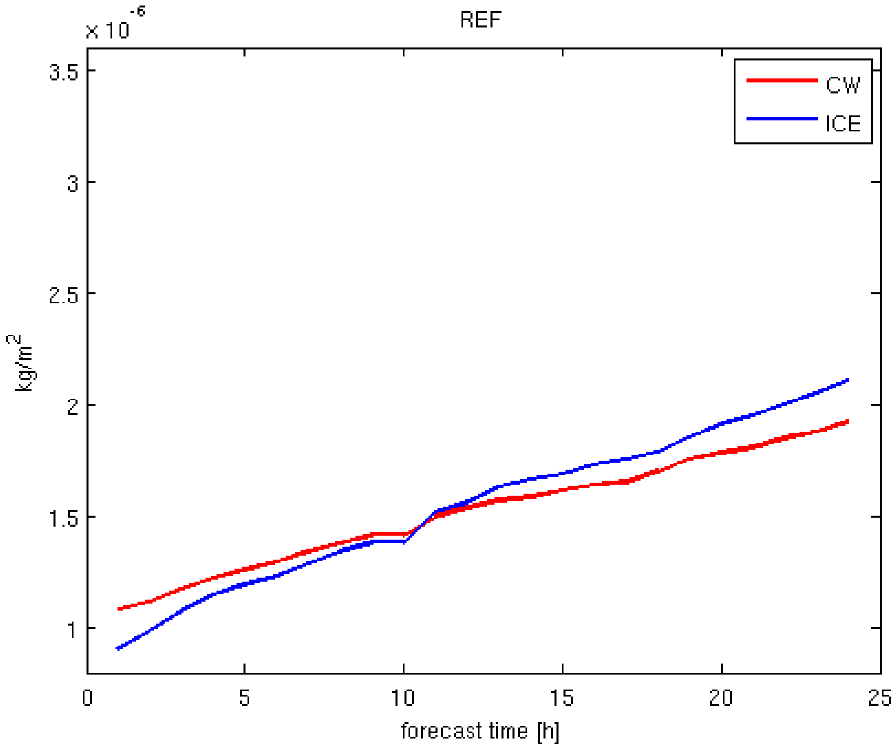



XR

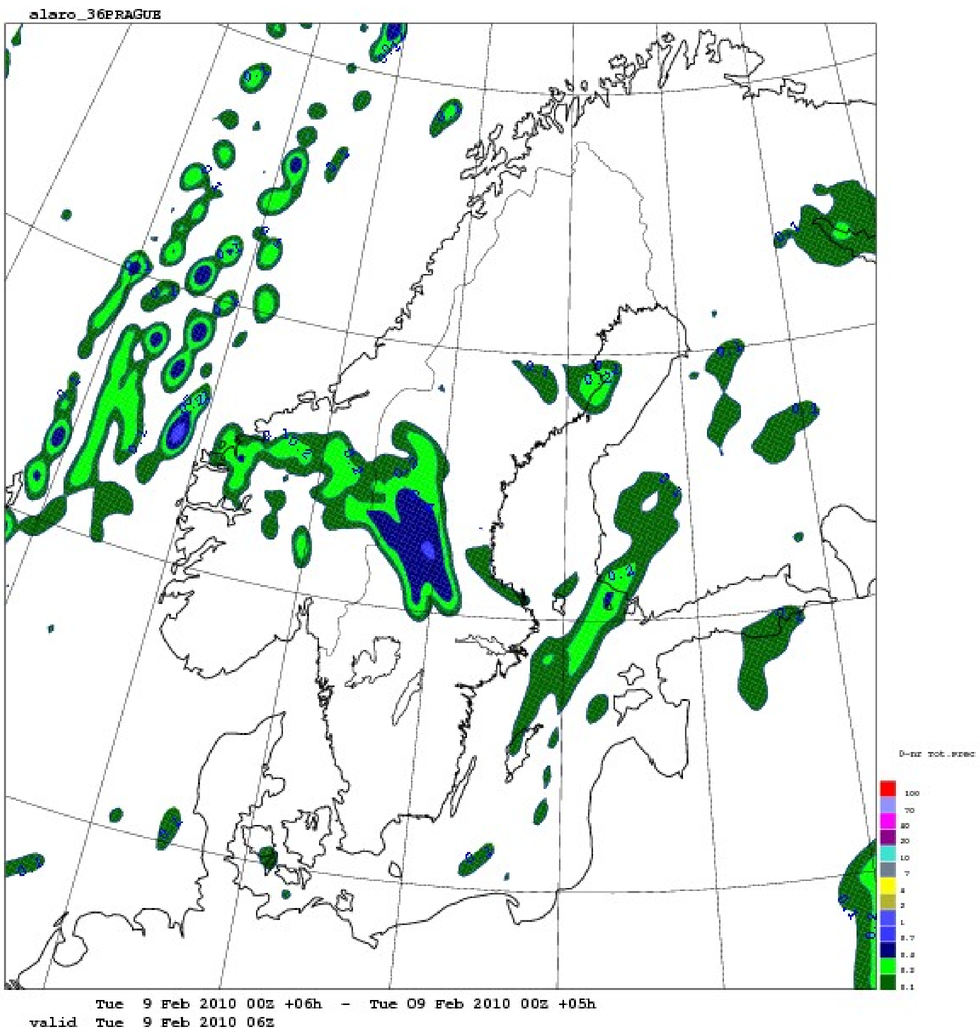


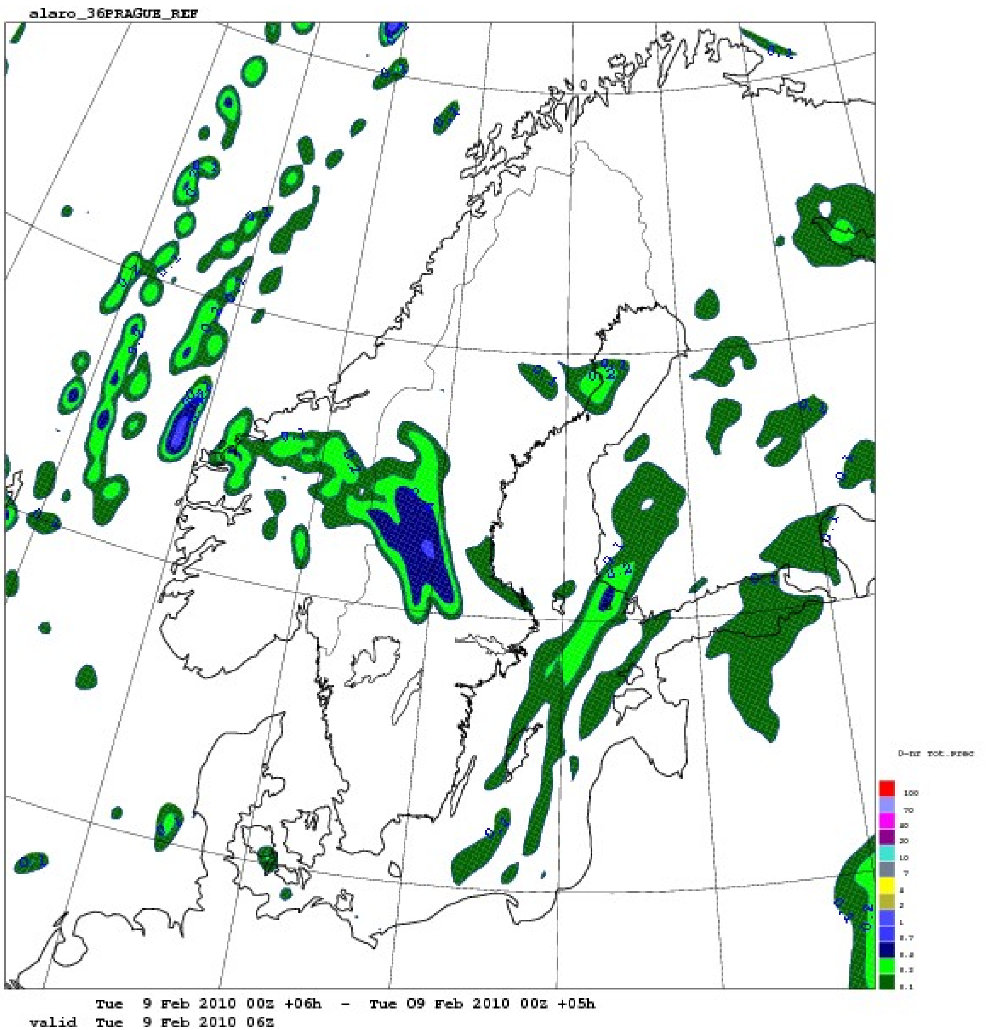
# Cloud water, Cloud ice



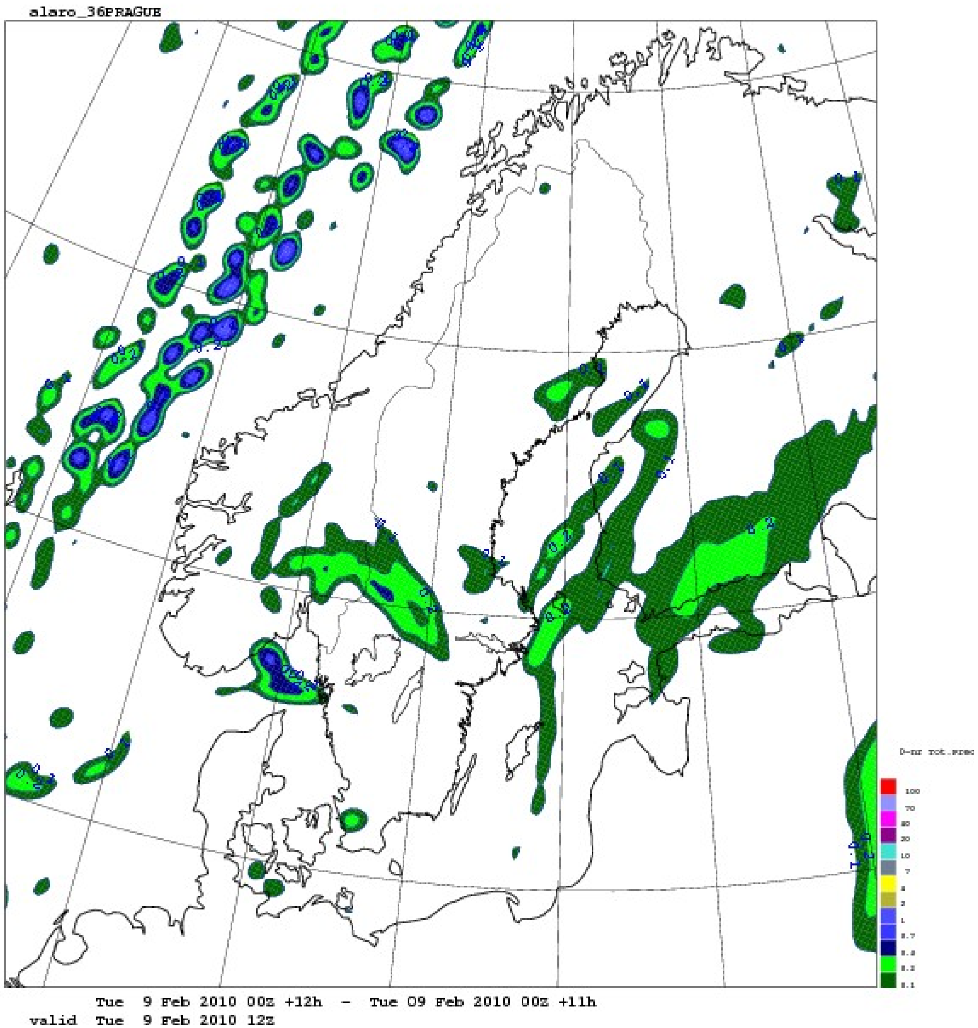



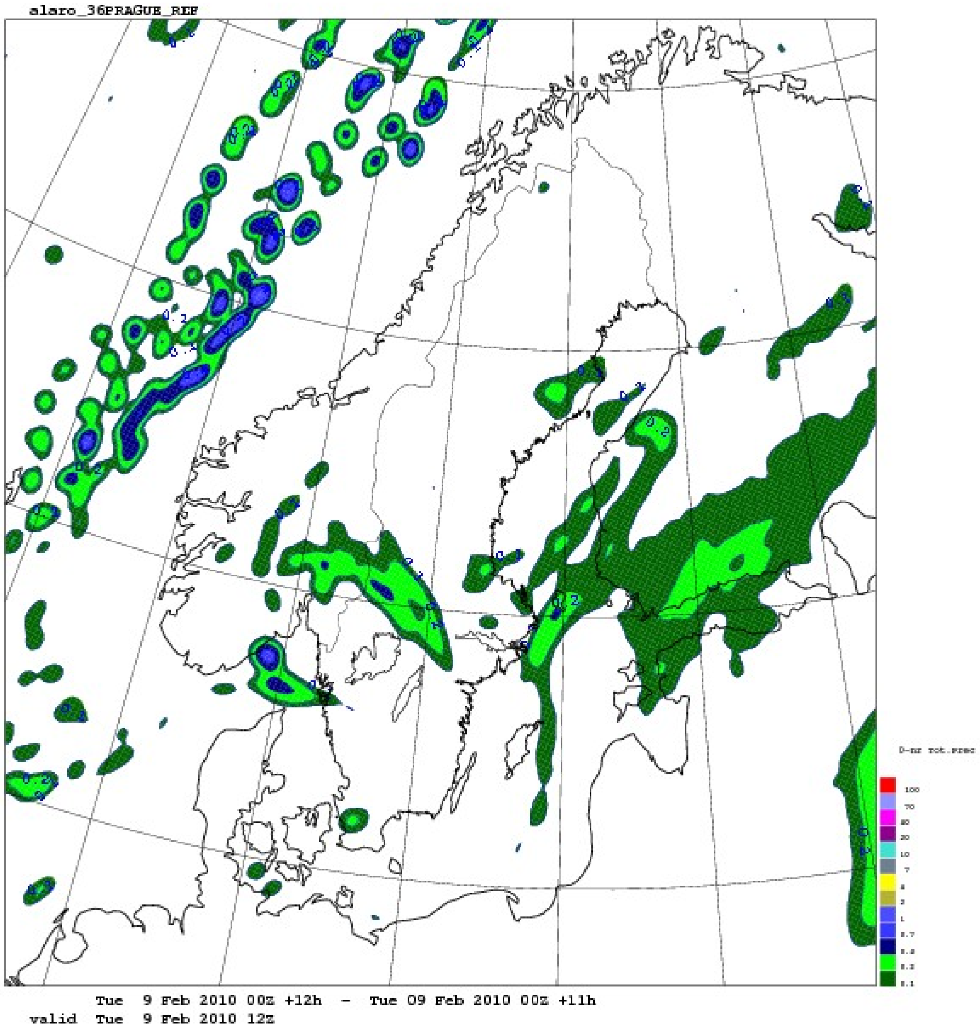
# Precip. 2010-0209 00 + 06



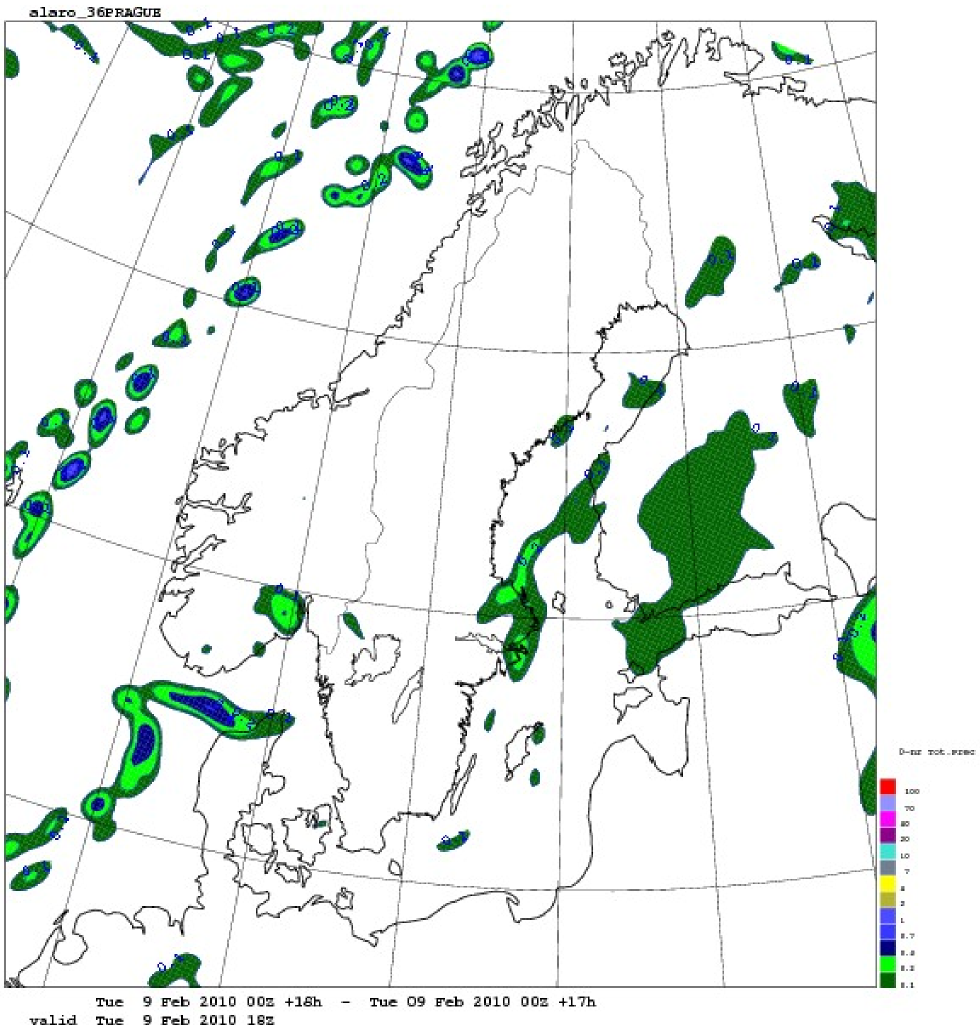



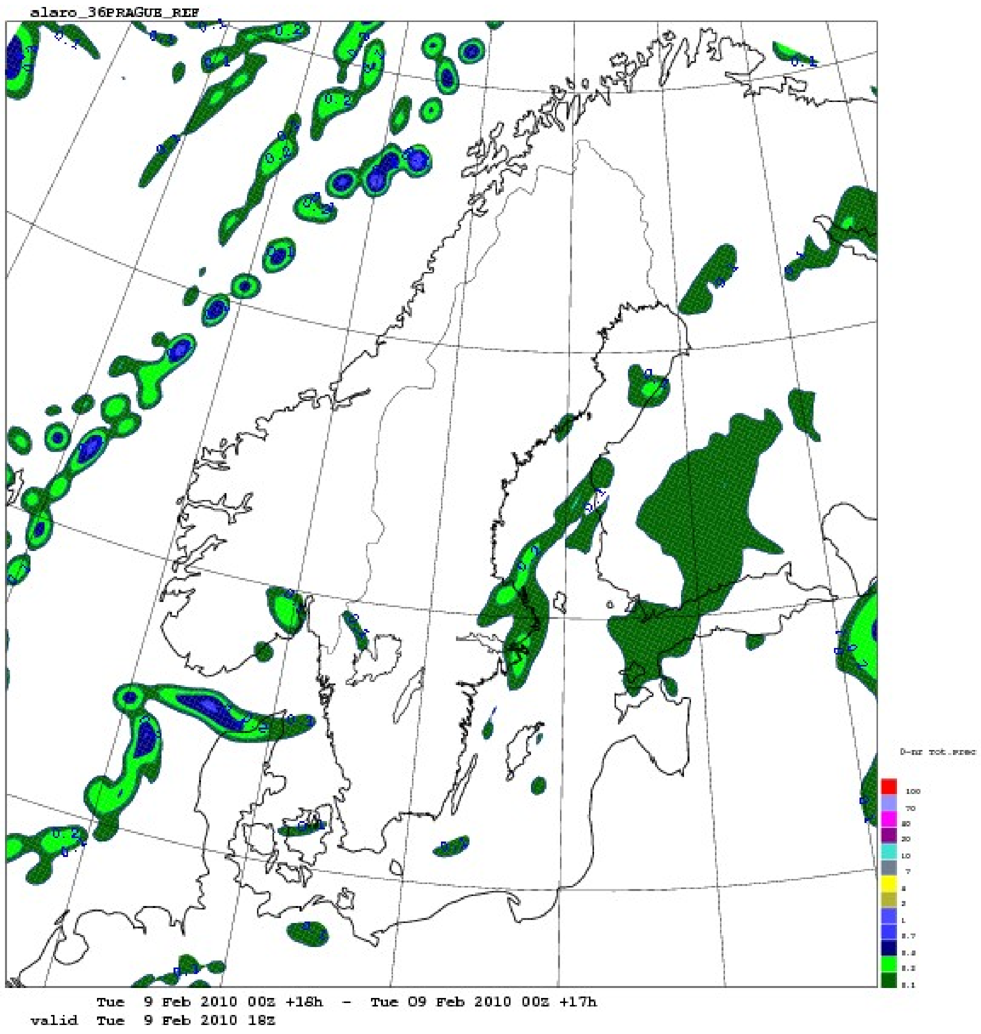
# Precip. 2010-02-09 00 + 12



# Precip. 2010-02-09 00 + 18



# Summary/conclusion/discussion

- Parts of the Rasch-Kristjansson, 1998 condensation scheme has been implemented in ALARO-0
- Confusion (on my part) what to do with Er
- Technical test in cy 36 indicate that there is more cloudiness using RK than XR
- More cloud water and cloud ice and larger difference between the two.
- Larger spin-up of the above using RK
- Small precipitation amounts seem to be reduced

# Possible extentions

- Saturation wrt ice (prognostic ice?)
- Cloudniness as output from accdev.F90