(Very) Last updates of the Liu-Penner parametrization in Hirlam. (and of the KF scheme)

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In this presentation:

- Short description (repetition) of Liu-Penner parametrization of cloud ice.
- 'Liu-Penner' changes of the radiation scheme.
- Reduction of Kain Fritsch (KF) convection activity for high horizontal resolution.
- Test results with 7.3
- Discussion and conclusions
Short description of the Liu-Penner parametrization

- Makes the parametrization of condensation and radiation for cloud ice processes more realistic.
- More suitable for 2-way coupling of chemistry modeling.
- The RK-scheme is used for water phase only, instead of for both water and ice. The ice crystal growth equation below is used for conversion between ice and vapor instead of between ice and water.

\[
\frac{dq_i}{dt} = 0.878k_s q_i^{\frac{1}{3}} N_i^{\frac{2}{3}} f(T, P)(RHi - 1)
\]

- \(q_i\) = cloud ice content, \(k_s\) = temperature and relative humidity dependent crystal shape factor, \(N_i\) = ice crystal number concentration, \(f(T, P)\) = function dependent on temperature and pressure and \(RHi\) = relative humidity (ice).
- Time-scale of cloud ice to reach some equilibrium with the environment is normally much larger (~ minutes to hours) for ice phase than for water. (~ seconds)
- The cloud fraction is a sum of one pure cloud-ice part based on relative humidity with respect to ice and cloud ice content and a cloud water part based on relative humidity with respect to water and the cloud liquid water content. (The present cloud cover calculation is based on a mixed ice-water relative humidity, dependent on the cloud ice+water content)
- Cloud scheme called only one time. (New, simpler → Alaro physics)
To the left is the Hirlam 7.3 parametrization and to the right is the new parametrization. RH\(_i\) is relative humidity with respect to ice, RH\(_w\) is with respect to water and RH\(_{\text{MIX}}\) is a mixture of those two. RH\(_{\text{MIX}}\) and the size of the subgrid scale parts with water and ice depend on the fraction of the cloud condensate that is ice and of temperature. A ’*’ means cloud ice and a ’.’ means cloud water.

\[ A_{\text{mix}} = \max(0, 1 - \sqrt{1 - \frac{\text{RH}_{\text{MIX}} - \text{RHLIM}}{1 - \text{RHLIM}}}) \]  
\[ A_w = \max(0, 1 - \sqrt{1 - \frac{\text{RH}_w - \text{RHLIM}_w}{1 - \text{RHLIM}_w}}) \]  
\[ A_i = \min(1, 0.5(1 - e_{si}/e_{sw})/(1 - \text{RHLIM}_w)), A_w > 0 \]  
\[ A_i = \min(1, 0.5\max(0, \text{RH}_i - \text{RHLIM}_i)/(1 - \text{RHLIM}_i)), A_w = 0 \]  
\[ \text{RHLIM}_i = 1 + e_{sw}/e_{si}(\text{RHLIM}_w - 1). \]
'Smoother' mixed-phase or ice clouds with LP-parametrization (Left: pseudo sat. picture without LP-param. Middle: with. Right: Sat. picture 20080621+036h. Note that this satellite picture underestimates cloudiness, but the pseudo satellite pictures overestimates it)
'Liu-Penner' changes of the radiation scheme.

- The effective radius of ice crystals is a function of ice crystal concentration (which is dependent on the IN concentration and temperature) and the cloud ice content ($q_i$).
- Only a function of temperature in the present scheme

$$R^3 = k \ r^3$$

$$k = \exp (a + b(T-240) + c \ln(q_i))$$

- Ice crystals have a more or less infinity variation of shapes. Here, the volume mean radius, $R$, and the effective one, $r$, are assumed to be related to each other by $k$. The value of $k$ has been determined by a linear regression expression.
Reduction of Kain Fritsch (KF) convection activity for high horizontal resolution.

- Code in 7.3 but not activated. (Lisa Bengtssons param.)
- Method: Use longer timescale for convection for higher horizontal resolution if the ratio cloud height to updraft speed is high.
- Introduced below 0.15 degrees resolution.
Results of reducing KF activity for high horizontal resolution

- **Test:** 5.5km resolution 60 levels. May 2010 SMHI E-area and 11km July 2007 SMHI C area
- **Red:** no reduction
- **Green:** reduction
Model domains Big: C area, small: E-area, smallest: G-area
2010-05 (two weeks) 5.5km E-area
No reduction (left), reduction (right) 5.5 km
Kupiers skill score for Precipitation (mm/12h)
Selection: ALL 1228 stations
Period: 20100510-20100525 At [00,12] + 18-06 30-18

Y28

Y22

KSS

mn/12h

0
0.1
0.2
0.3
0.4
0.5
0.6

0
1
10
100
Similar, but somewhat smaller changes for 11km resolution
E-area 5.5 km 60 levels

• Important that changes fit together. Here, test Liu-Penner changes together with reduction of KF activity (convective time scale) vs ref 7.3.

• Red : ref 7.3

• Green : 7.3 with Liu-Penner changes for radiation, condensation + KF.

• Top : Summer, bottom : winter
Discussion and conclusions

- KF activity reduction for high horizontal resolution gives a little better temperatures at 700 Hpa in summer and a little lower RMSE of mslp pressure. Little lower wind speed near ground in summer.
- Liu-Penner parametrization for cloud ice microphysics lower RMS-error of cloudiness. Somewhat better diurnal cycle of cloudiness in summer. A little lower temperature over whole troposphere, except very near ground in winter. Other effect mainly small.
- Liu-Penner parametrization for radiation properties of cloud ice gives a little warmer temperatures over whole troposphere.
- Together, those temperature changes are counteracting each other.
- All three changes seems so far fit well together, at least for around 5 km resolution, 60 levels, so worth testing for 7.4. (65 levels)
- LP parametrization could have some potential to improve Alaro's ice microphysics, perhaps also the ICE3.
References

• Lohmann U. 2004: Can anthropogenic aerosols decrease the snowfall rate? J A S Vol 61 p 2457-2468
• Rotstaysn et al 2000: A Scheme for calculation of the liquid fraction in mixed-phase stratiform clouds in large scale models. Mon. wea. rev. 128 1070-1088
• Zhang et al 2003: A modified formulation of fractional stratiform condensation rate in the NCAR Community atmospheric model. J. Geophys. Res. 108(D1) ACL 10 1-11
Extra slides follows ...
Other updates (for condensation dependence of CCN, IN)

Collection of cloud water by snow, original:

Bulk formula:

\[ P_{sacw} = C_{sac} E_{sw} q_w \]  

(1)

Here, \( C_{sac} \) = constant dependent on microphysics (Lin et al) \( q_w \) = cloud-water content, \( E_{sw} \) = collision efficiency, 0.1

New (From Lohmann, 2004):

\[ E_{sw} = 0.939 St^{2.657} \]  

(2)

Here, \( St = \frac{2(V_t-v_t)v_t}{Dg} \) is the stokes number, \( V_t \) = fall speed of snow (currently just 0.9 m/s), \( v_t \) = fall speed of cloud droplets (here comes CCN concentration in), \( D \)

Collection of cloud water by rain, original bulk formula:

\[ P_{racw} = C_{racw} q_w \]  

(3)

New (Rogers and Yau, 1989)

\[ P_{racw} = 2C_{racw} E_{rw} q_w \]  

(4)

Here, \( C_{racw} \) = constant dependent on microphysics, etc \( E_{rw} \) = collision efficiency, function of drop radius:

\[ E_{rw} = \frac{e^{Ar} - 1}{e^{Ar} + 1} \]  

(5)

\( A = 2.5 \times 10^5 \), \( r \) = mean cloud droplet radius, m
RK reduction 11 km
Kupiers skill score for Precipitation (mm/12h)
Selection: ALL 2042 stations
Period: 20070701-20070731 At {00,12} + 18-06 30-18 42-30
Liu-Penner tests C area 22km area 40 lev

- Red : Reference 7.3
- Green : 7.3, Liu-Penner. Both condensation and radiation
- Blue : 7.3, Liu-Penner condensation. 7.3ref for ice-crystal effects on radiation
- Top : Summer, bottom : winter