HIRLAM
Physics time step organization
(and some other stuff)

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Thanks: Mariano Hortal, Anton Beljaars, Per Unden, Isabel Martinez

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  - Parallel versus sequential time splitting
  - Order of processes
  - Explicit parts
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- Example: waves in wind speed
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Time stepping

- Parallel splitting: processes are calculated independent of each other, tendencies added after all calculations: used in HIRLAM
- Sequential splitting (time splitting, fractional stepping): tendencies from previous fractional step are used in next small step, option in HIRLAM

Time step organization

- Order of processes
  - Quick, slower, quick, slow
  - First quick, then slower ones
  - Before the slower ones, the dynamic tendencies are added to the prognostic parameters
  - Physical processes are used to stabilize the effects that the dynamics has on the model state (Beljaars)
  - All extensively written up in proceedings of ECMWF yearly seminar, September 2004, Beljaars et al.

Time step organization

- Order of processes:
  - Radiation (explicit, quick)
    - Addition of dynamic tendencies (option)
  - Surface (explicit, implicit in ALADIN/ECMWF, slow)
  - (MSO/SSO)
  - Turbulence (explicit, TKE & momentum boundary condition semi-implicit, quick)
  - Convection (explicit, slower)
  - Condensation (explicit, slow)

Time step organization

- Time steps in HIRLAM relatively short for column physics
- 11km resolution, 240 seconds time step
- Not much effort put in implicit calculations
- ECMWF: time steps much larger, 40 km resolution 900 seconds time step, EPS 80 km 2700 seconds, implicit schemes necessary

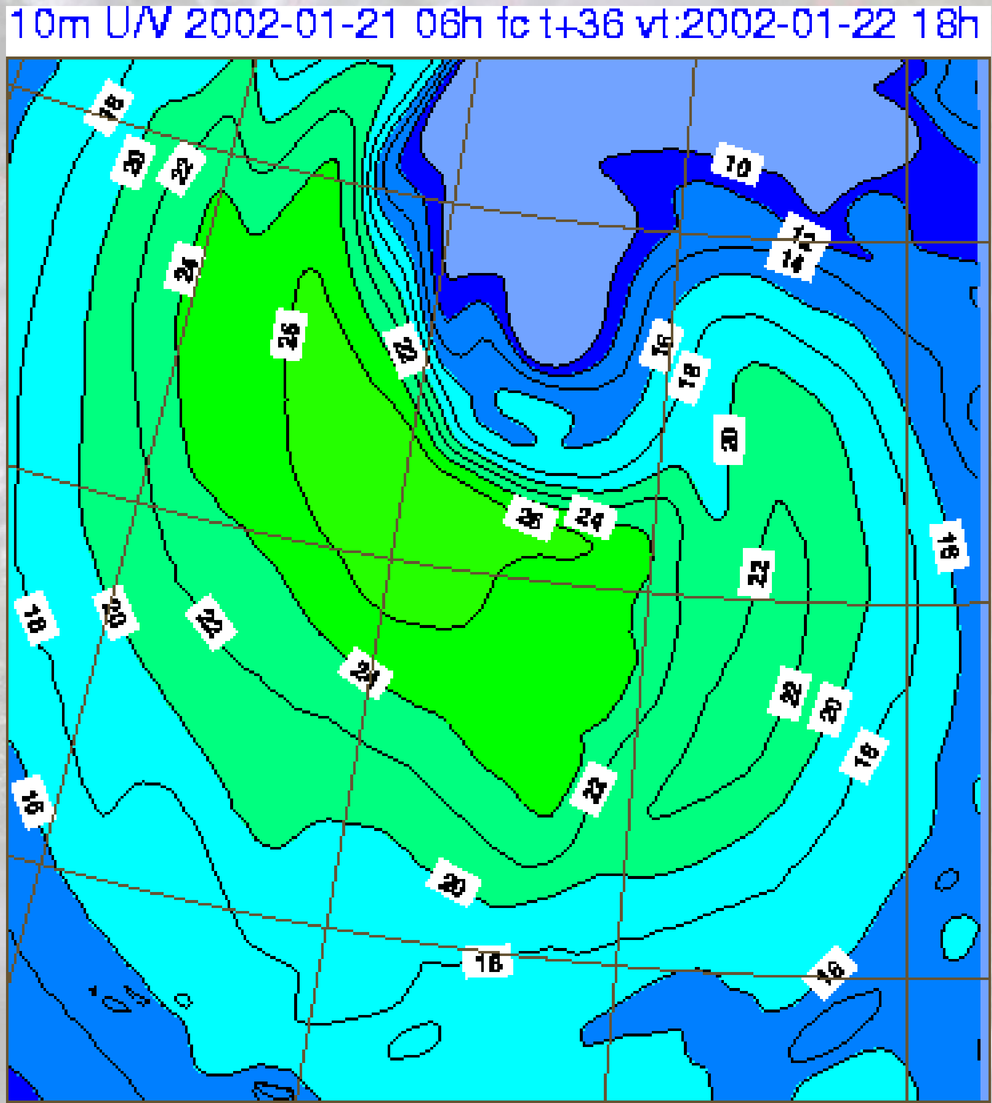
Waves in wind speed

- In HIRLAM possibility update model state with dynamical tendencies before physics calls to turbulence, convection and condensation
- What happens when dynamical tendencies are not added to atmosphere?

Waves in wind speed

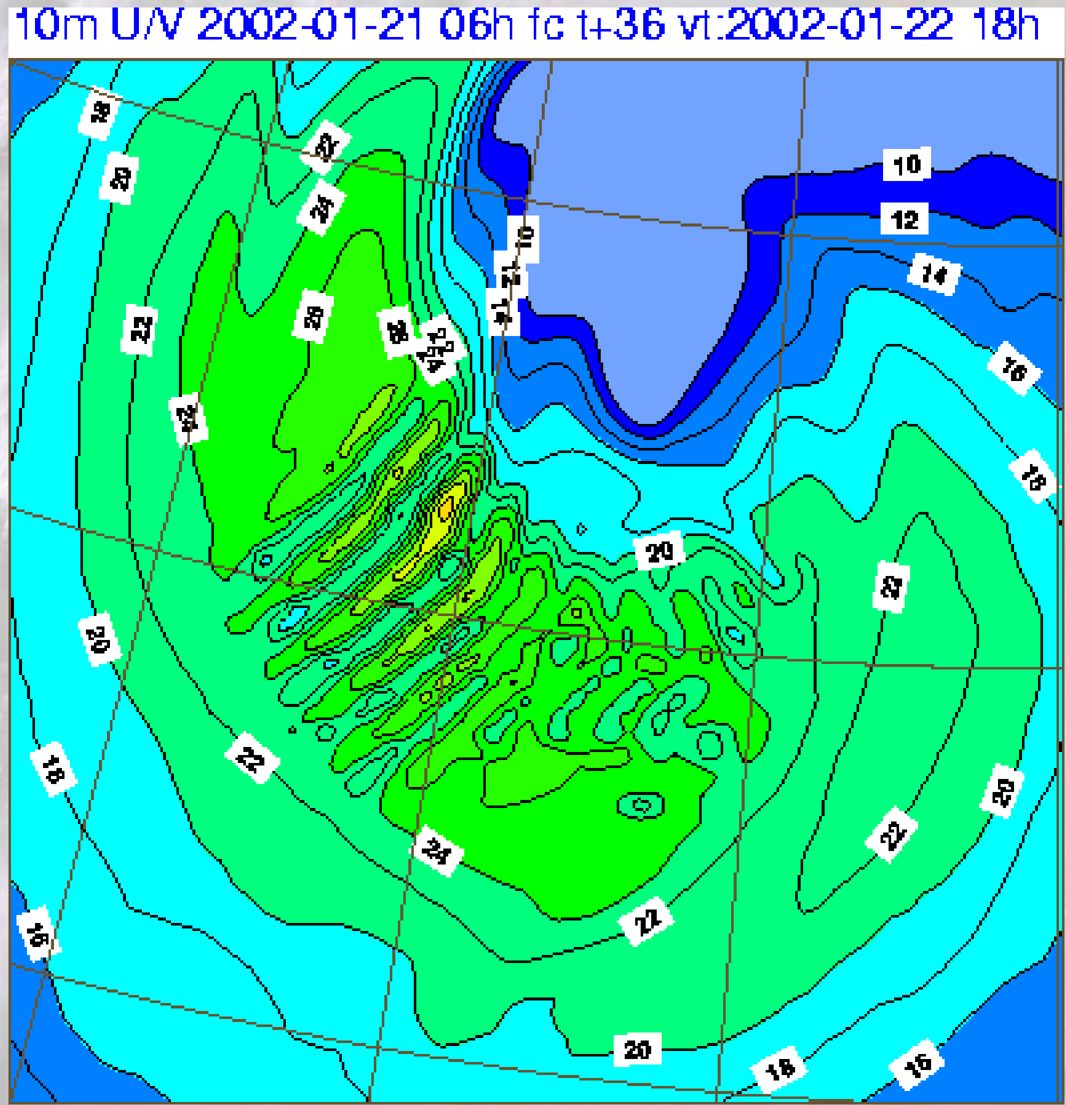
- When going from a 55 km to a 22 km version of HIRLAM (2002) tests showed that waves could develop in wind field
- In conditions with cold air over a warm ocean and very strong winds (>30 m/s) first waves in TKE develop, then in wind speed

Waves in wind speed



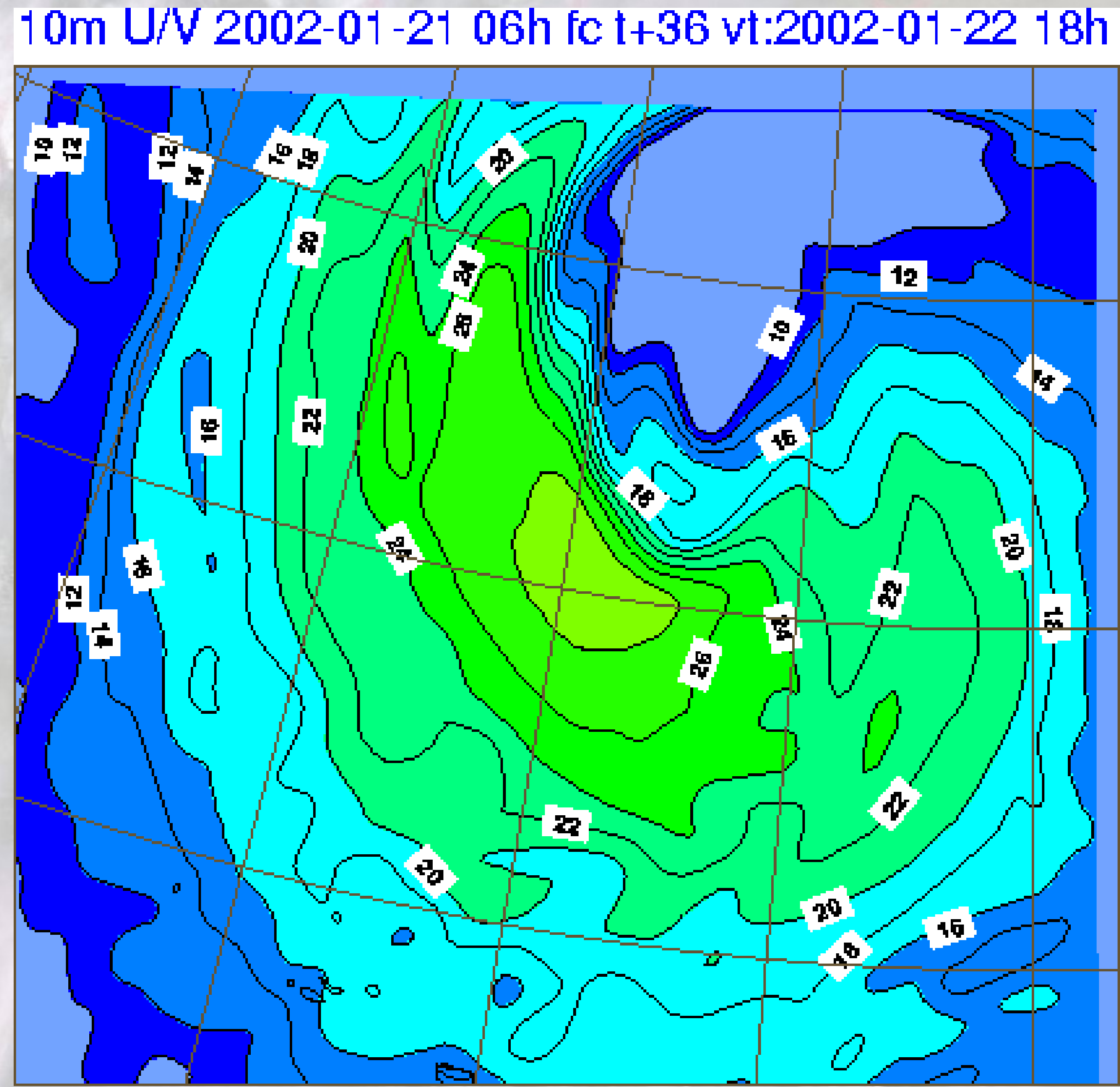
Old vertical diffusion scheme

Waves in wind speed



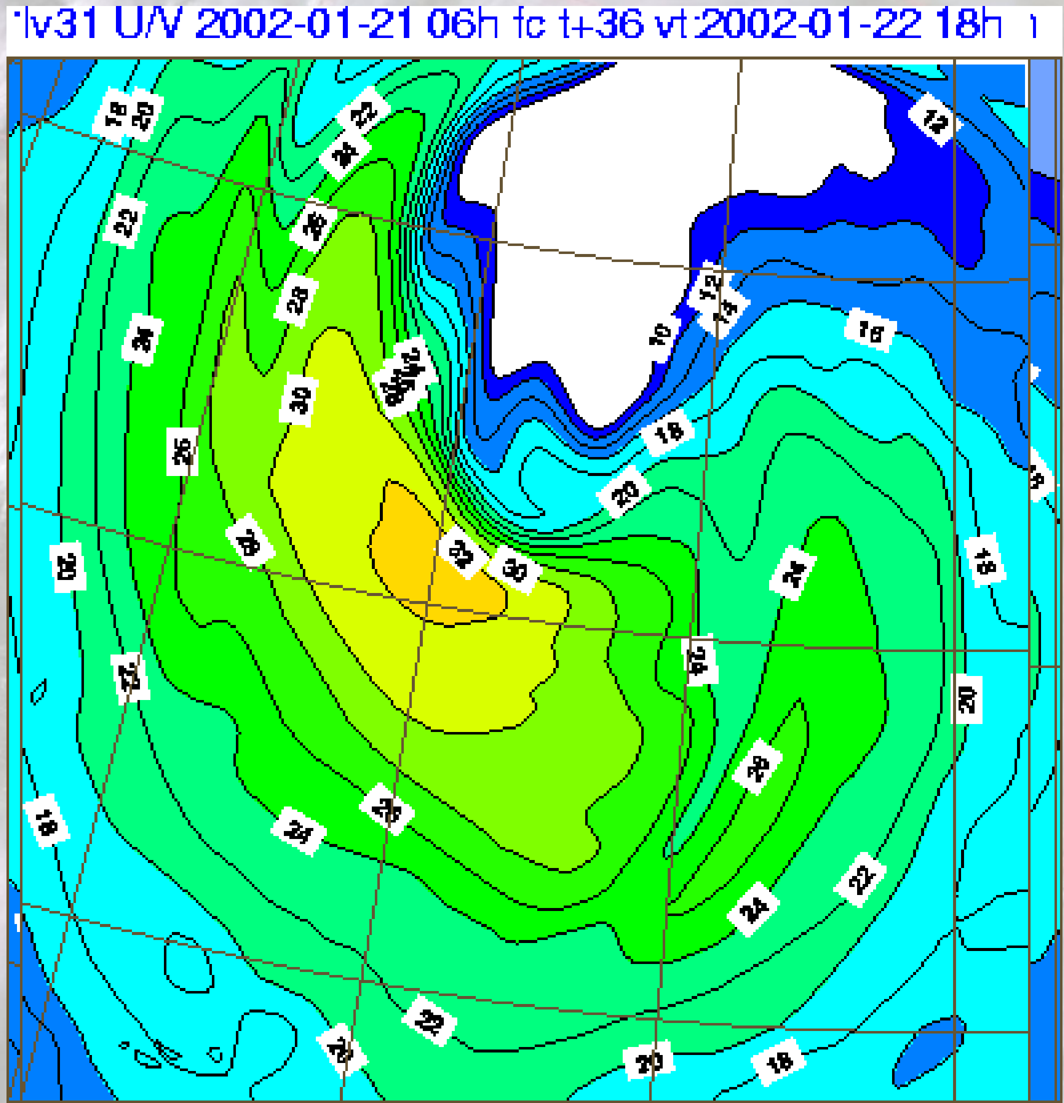
New vertical diffusion scheme

Waves in wind speed



New vertical diffusion Scheme, DT/2

Waves in wind speed

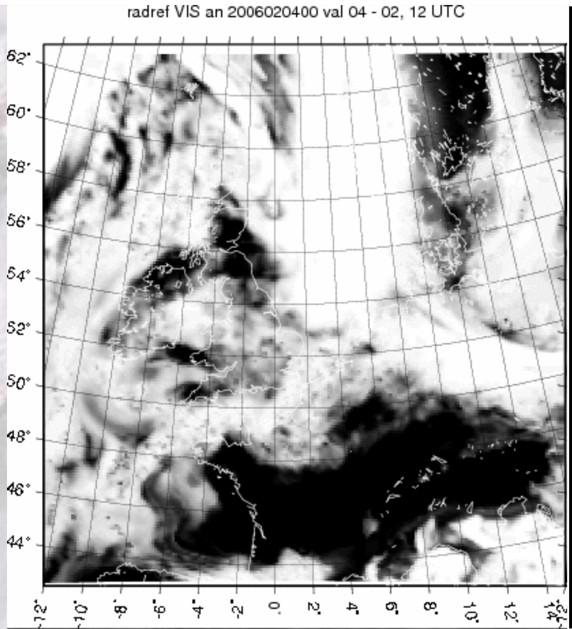


Additional

- Averaging of physical tendencies along semi-lagrangian trajectory
- Increases accuracy
- Physical tendencies averaged between departure point (previous time step) and arrival point (current time step) for the slower processes (convection, condensation)

Low cloud and fog problems

- HIRLAM has tendency to underestimate low clouds and fog and dissolve them during the day
- Especially in Winter in Central and Western Europe
- Usually during cold conditions, temperatures around or just below 0° C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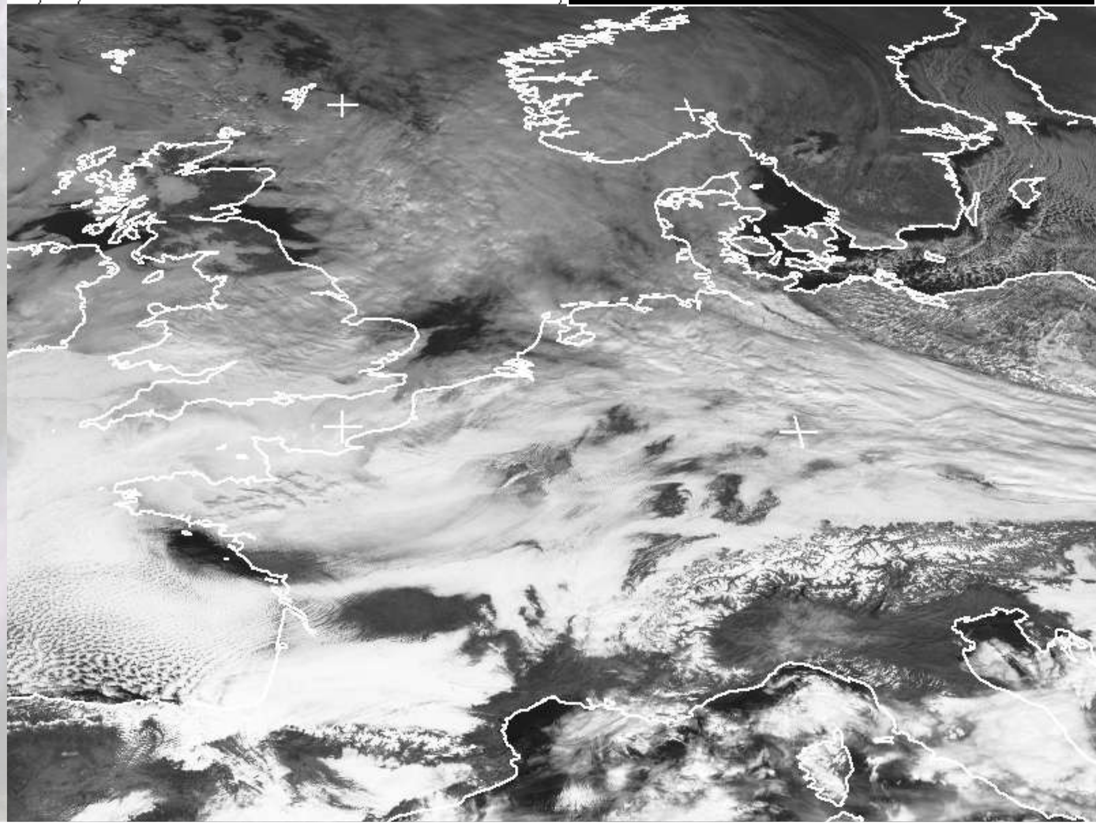
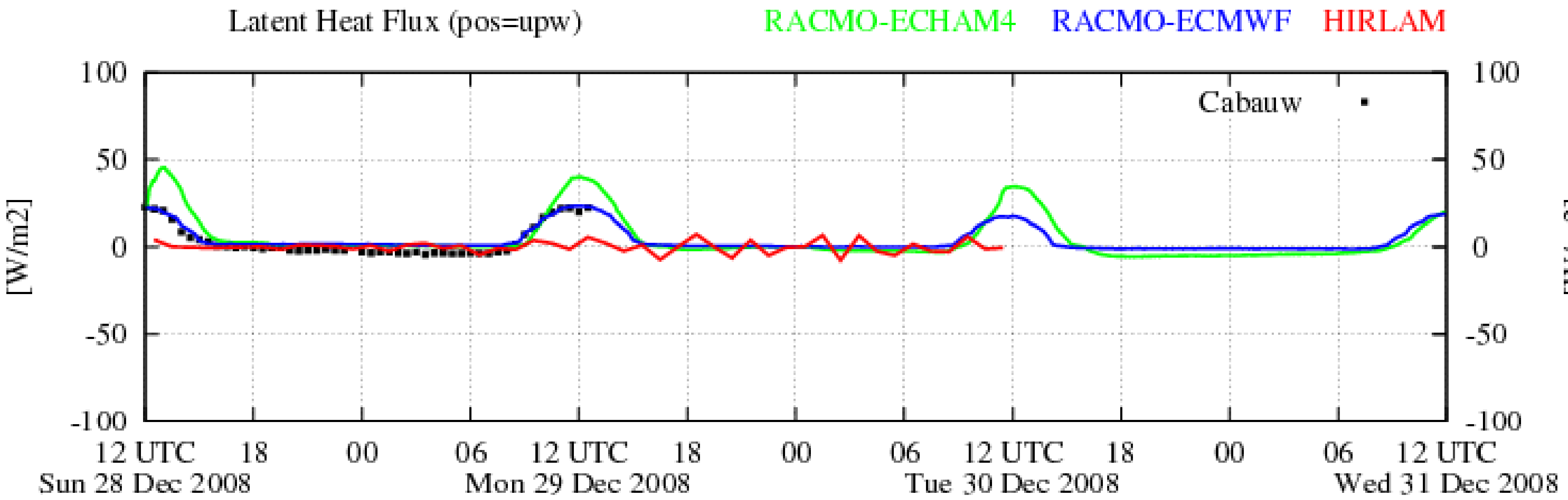
6°
8°
10°
12°
14°



Low cloud and fog problems

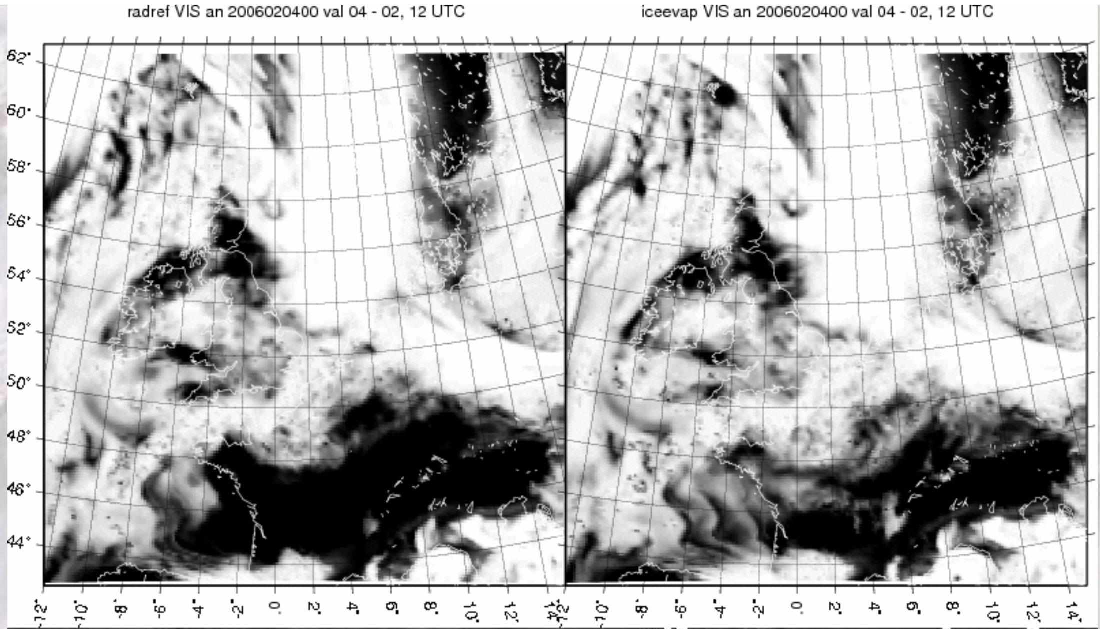


Low cloud and fog problem

- Too little evaporation, cold conditions so vegetation not active
- Underestimation evaporation gives overestimation of sensible heat flux
- Both cause too little low clouds and fog and too quick dissolving

Low cloud and fog problem

- Evaporation from bare soil in HIRLAM only from liquid water in soil, ice does not count in RH in soil
- No evaporation from frozen soil
- Experiment where ice is included in RH of bare soil
- Effect included in ALADIN ISBA (sublimation term in evaporation)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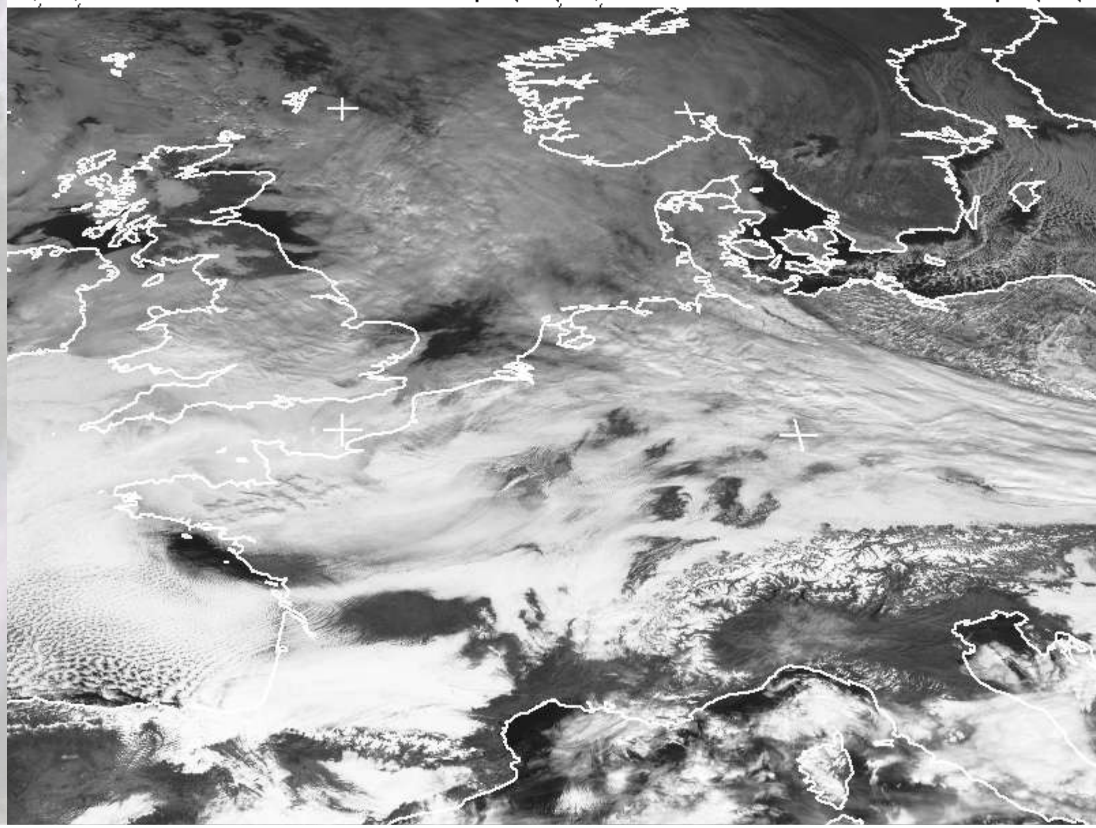
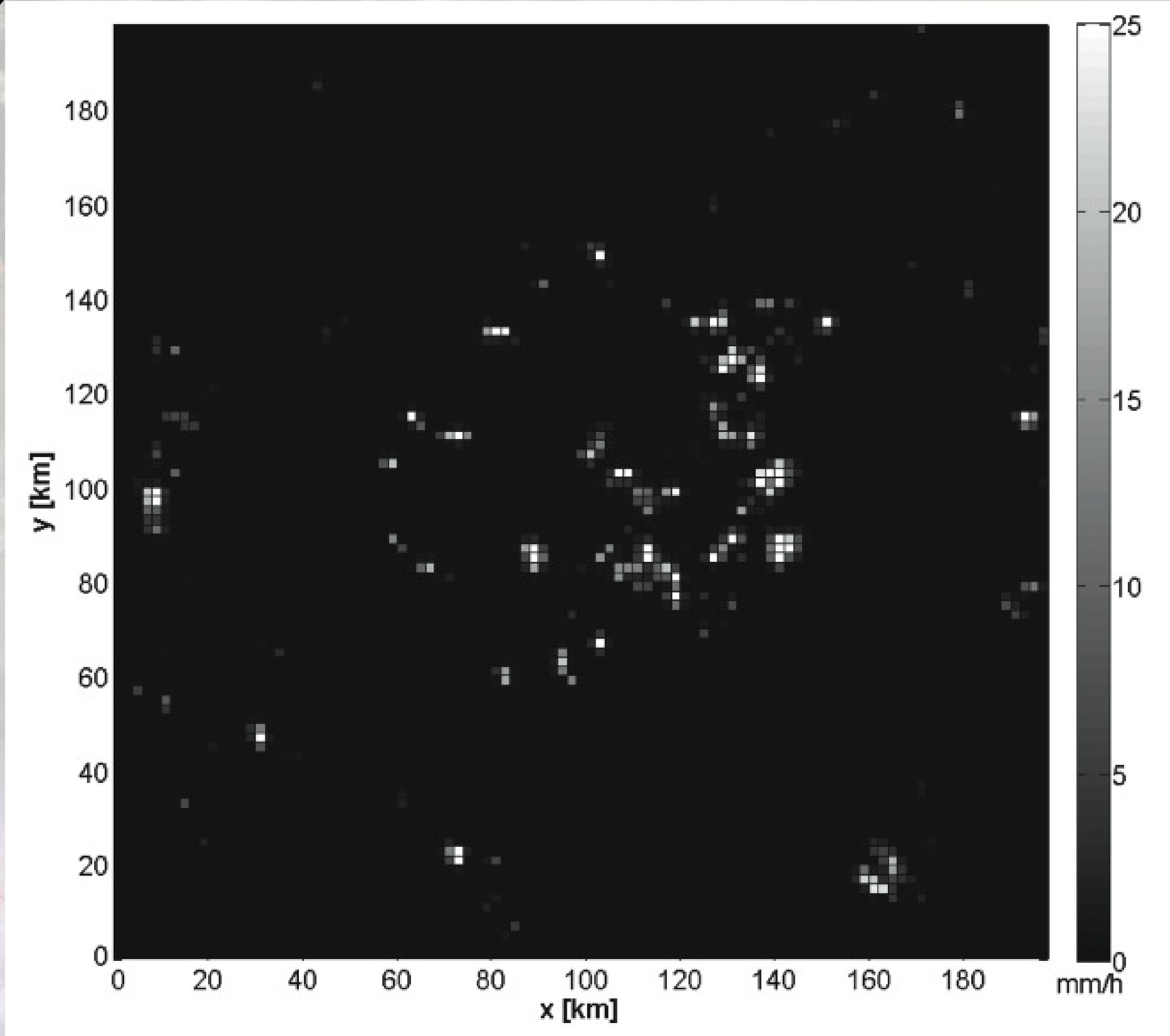


Convection in AROME

- Parodi & Emanuel*, WRF study: Strong impact of terminal velocity rain on convection and convective organization
- AROME convection too spotty, not enough organization
- In AROME impact tested by changing fall speed of rain, snow and graupel

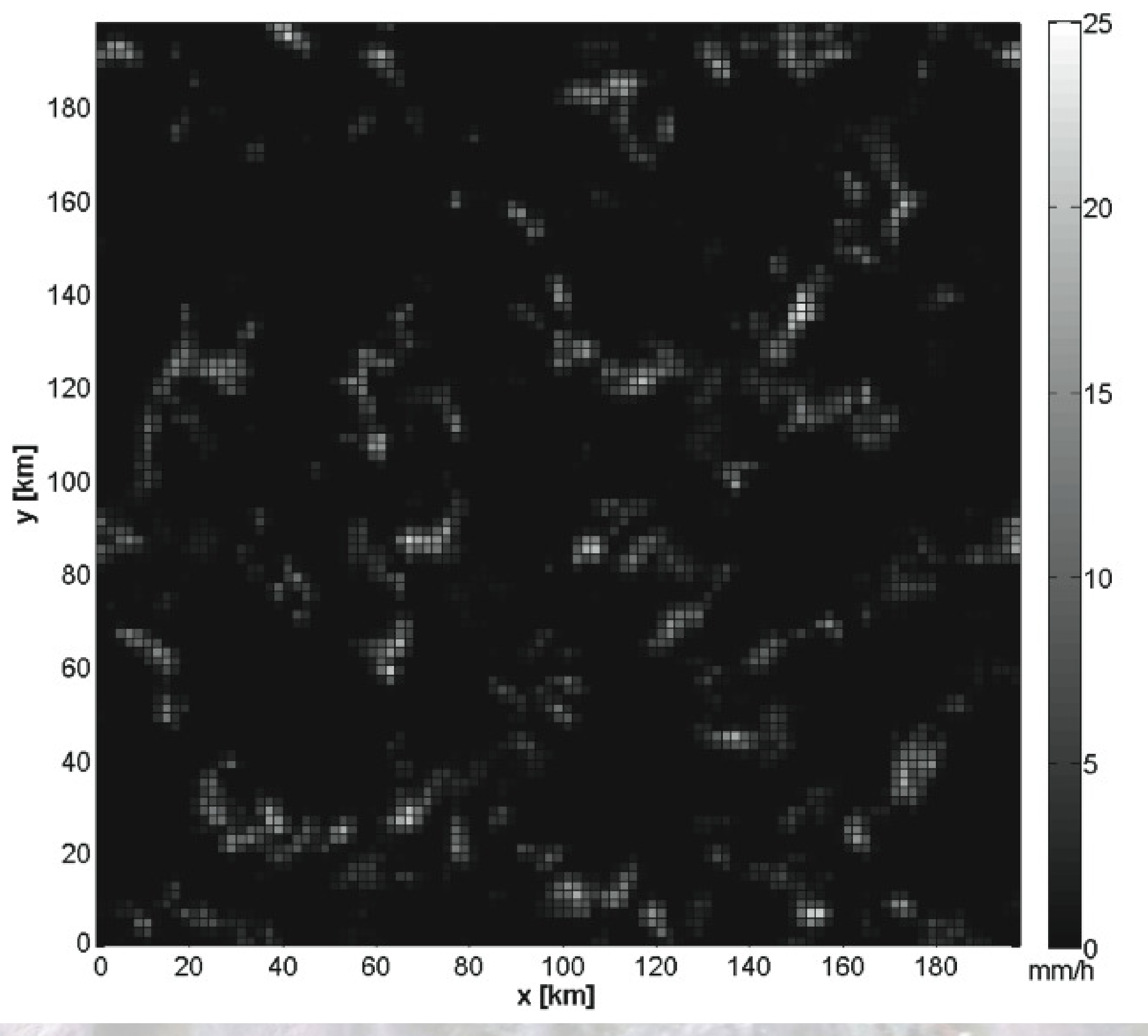
*: JAS, November 2009

Convection in AROME



Terminal Velocity Rain = 10 m/s

Convection in AROME

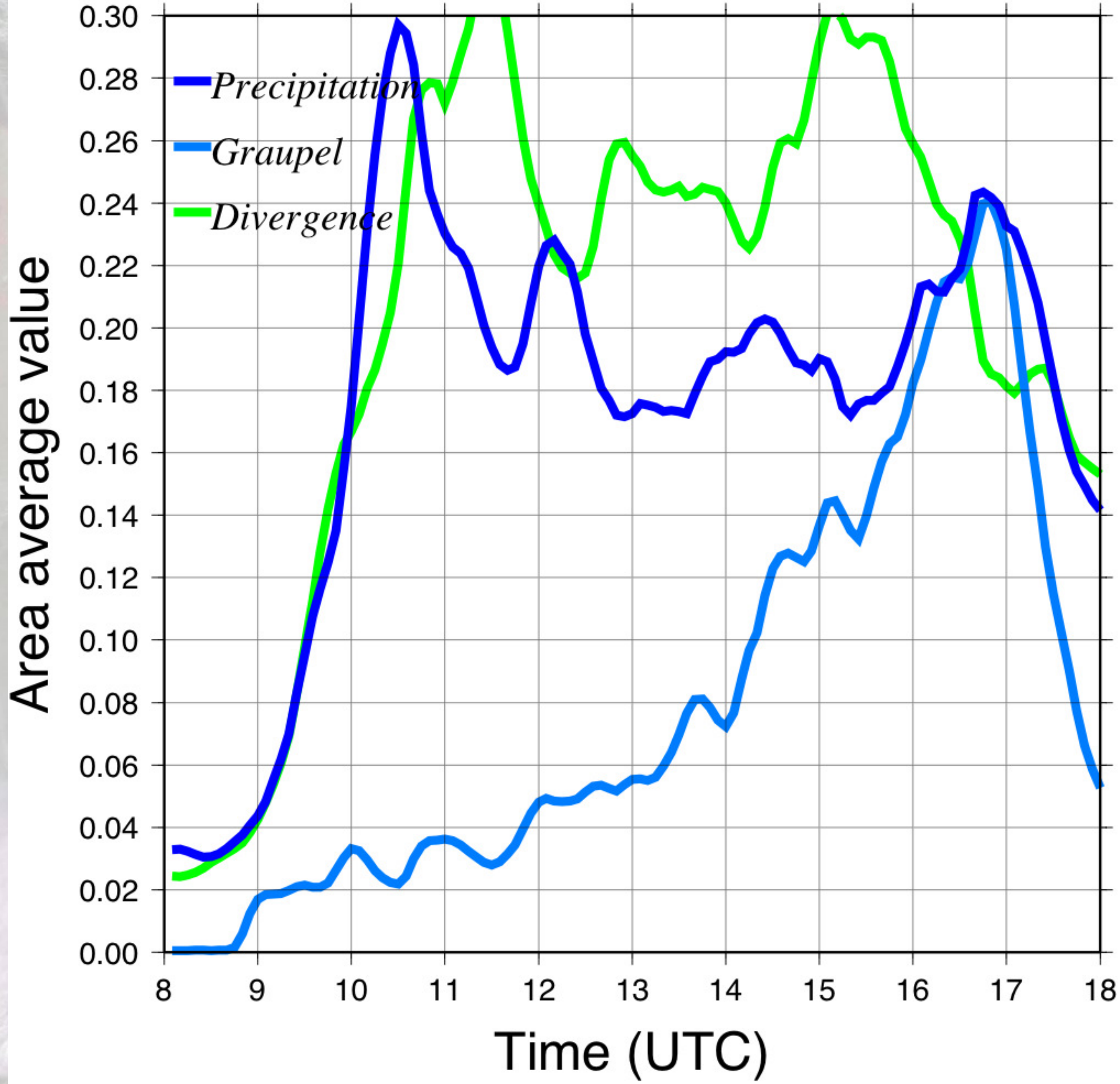


Terminal
Velocity
Rain =
2 m/s

Convection in AROME

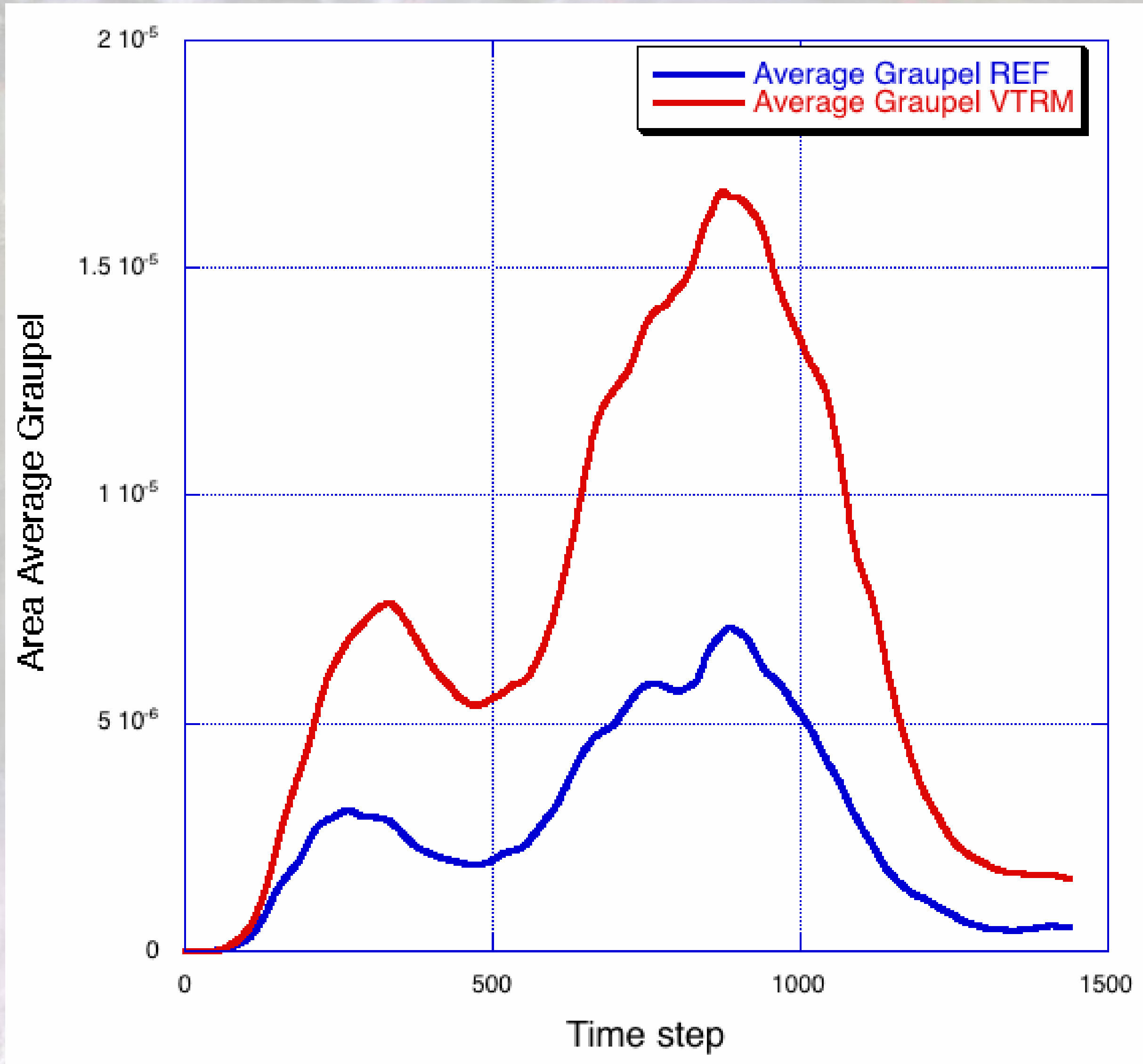
- Decrease in terminal velocity causes higher water loading in parcels, heavier, weaker updraft
- Weaker updraft has impact on characteristics of convection
- Convection less spotty, more coherent structures (in WRF!), spotty convection also seen in AROME/ALARO-deep conv

VTRM

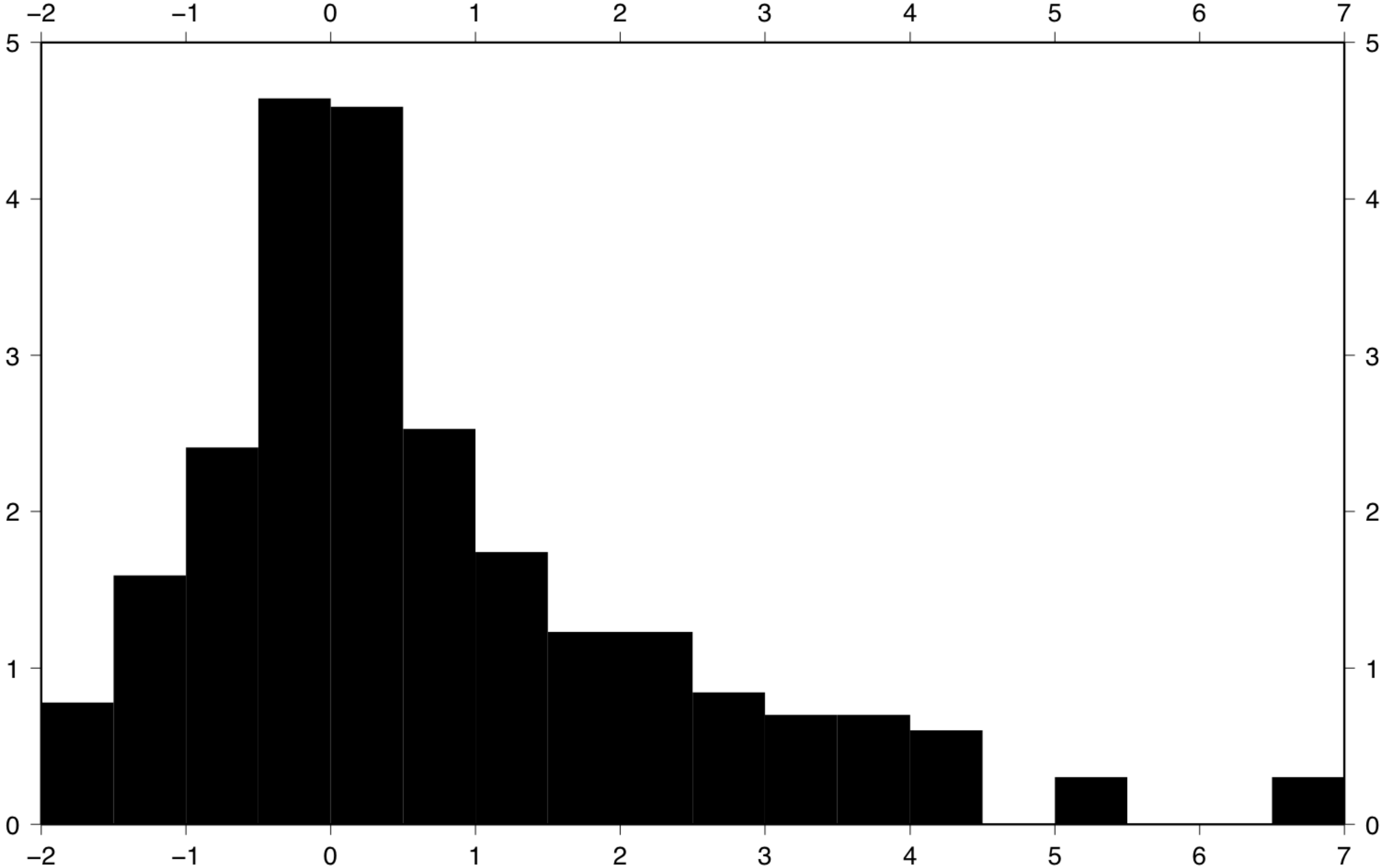


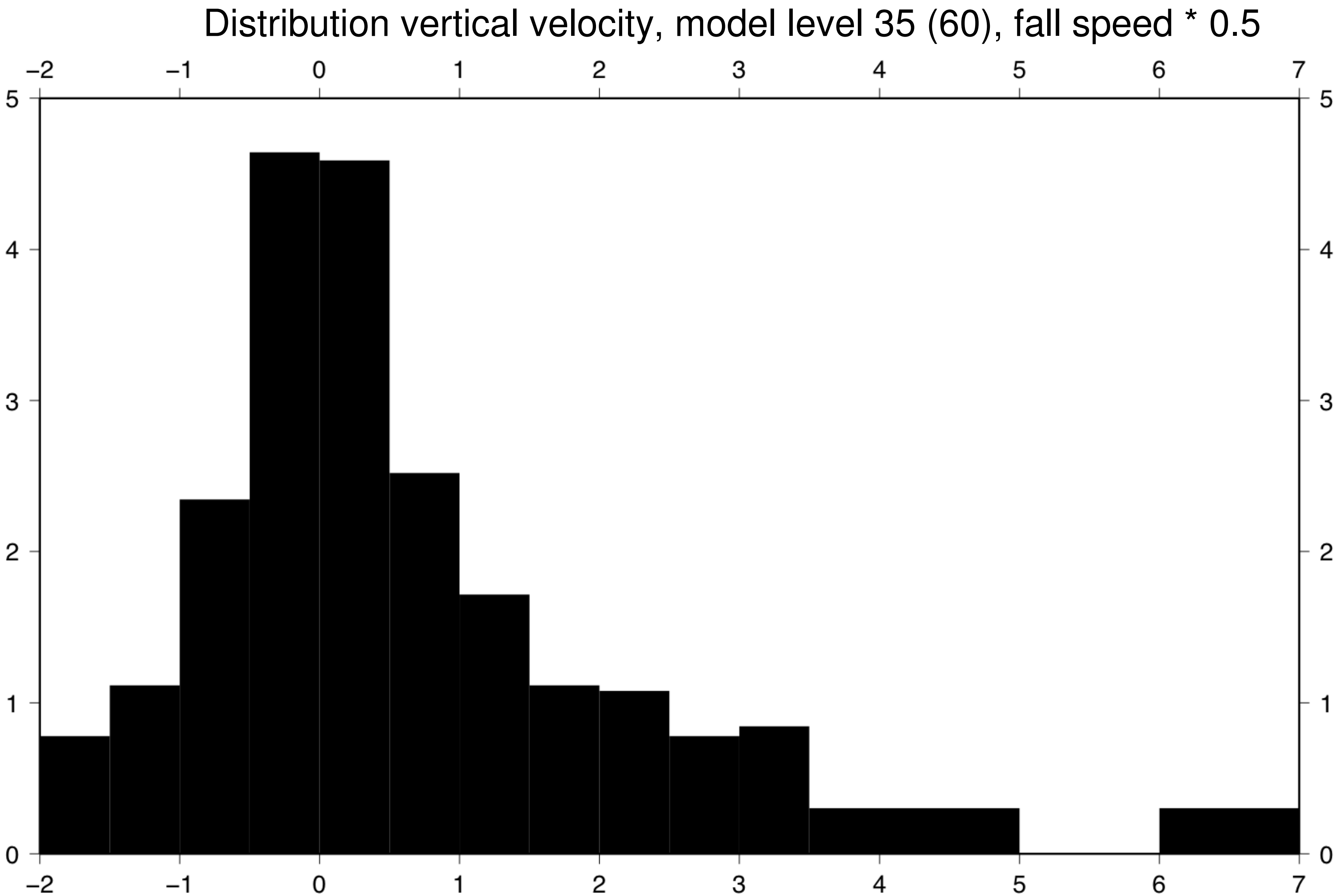
Precipitation
Graupel
Divergence
Area average value
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
8
9
10
11
12
13
14
15
16
17
18
Time (UTC)

Impact fall speed AROME

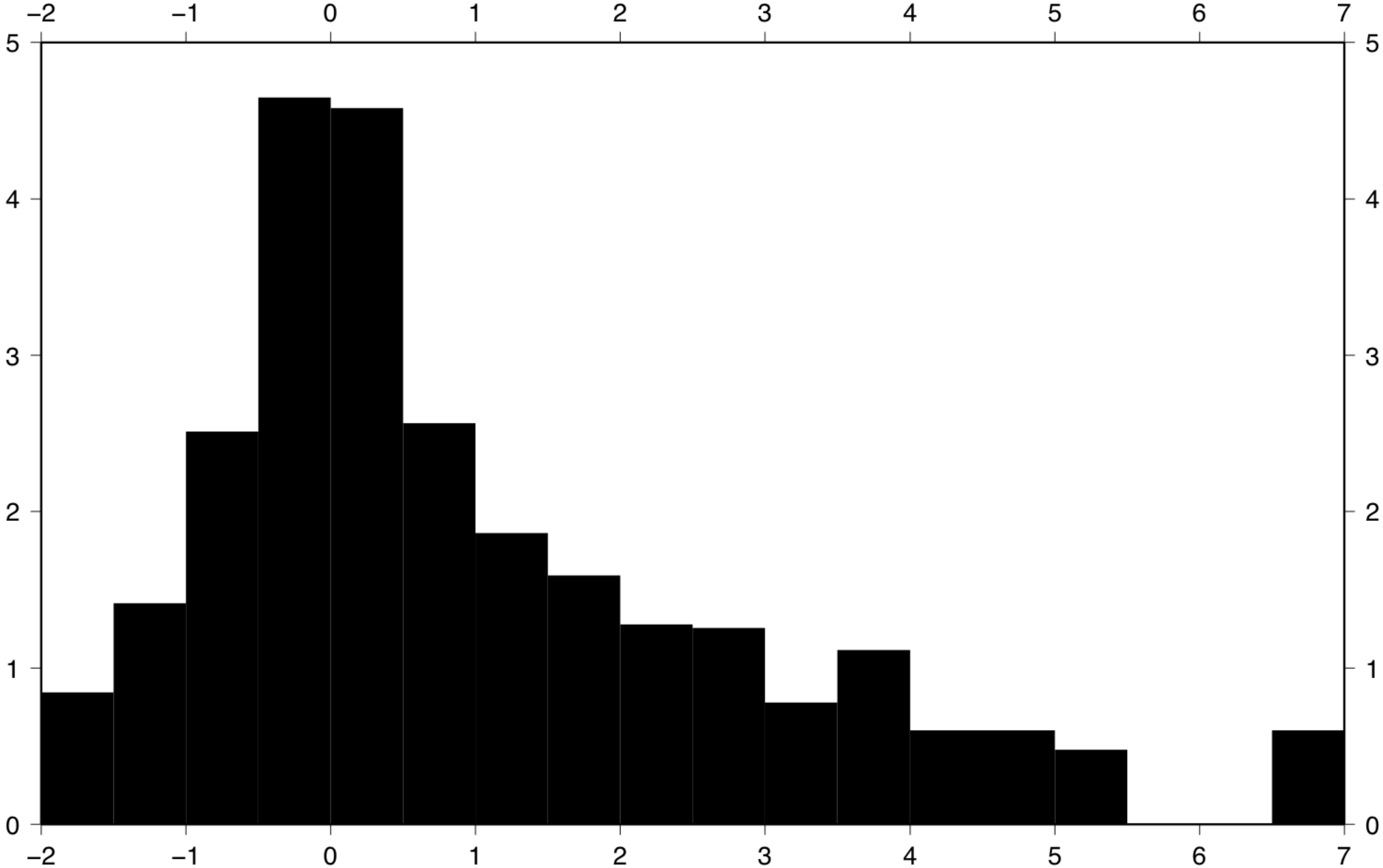


Distribution vertical velocity, model level 35 (60), REF




Distribution vertical velocity, model level 35 (60), fall speed * 0.5
−2
−1
0
1
2
3
4
5
6
7
0
1
2
3
4
5

Distribution vertical velocity, model level 35 (60), fall speed * 2



Impact fall speed

- Impact fall speed not very large
- Halving fall speed doubles water load
- No large impact on precipitation intensity or precipitation pattern
- Effect not as strong as in WRF
- Not enough interaction between neighbouring columns? 3D turbulence?