Links between (NH)-dynamics and physics

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NH equations in IFS

The NH equations were developped into the IFS/Arpege dynamical core and validated with classical adiabatic cases.

The NH core+ ECMWF current physics is stable and gives the same results than the hydrostatic model at the current ECMWF resolution.

But questions remain for the scale of resolved convection...

Coupling between Physics and Dynamics

- Study (and try to improve...) the properties of the semi-Lagrangian scheme in the context of resolved convective motions.
- Re-visit the NH *multiphasic* equations. Modify the physics/dynamics interface in IFS to be coherent with these equations and validate.
  - Clean the dynamics with respect to multiphasic equations (R, c_p)
  - Projection of diabatism and latent heat release on T *and* p

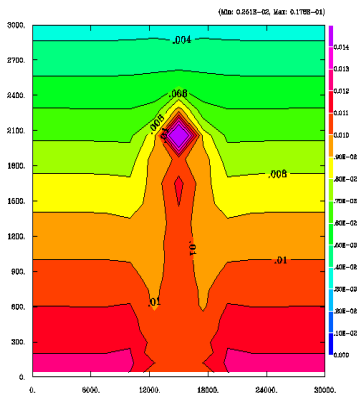
Main tools

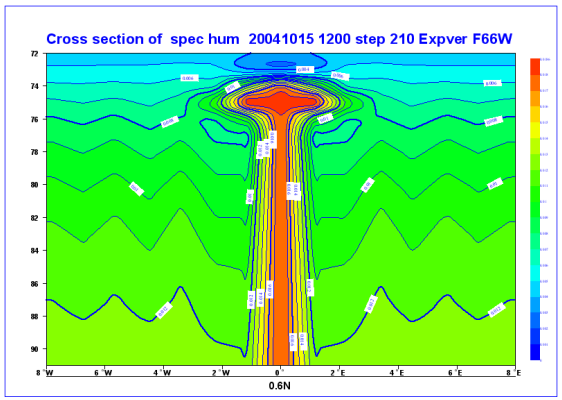
Academic experiments only

- Small Planet Testbed in the IFS (Wedi and Smolarkiewicz, 2009)
  - r=a/100 ($\simeq$ 63 km) , T159 $\Longrightarrow$ $\Delta x \simeq 1.3$ km
  - $\Delta t = 10$ s
  - NH and dynamics setup from IFS
- Comparison with Meso-NH and Eulag
- Basic 1D advection model

KW78 "bubble" (MNH versus IFS) : Vertical cross-sections of q_v after 25 min

IFS (and AROME) behave as if there would be an infinite source of moisture from the surface (300 mm of precip in Arome againt 5 mm in Meso-MH).

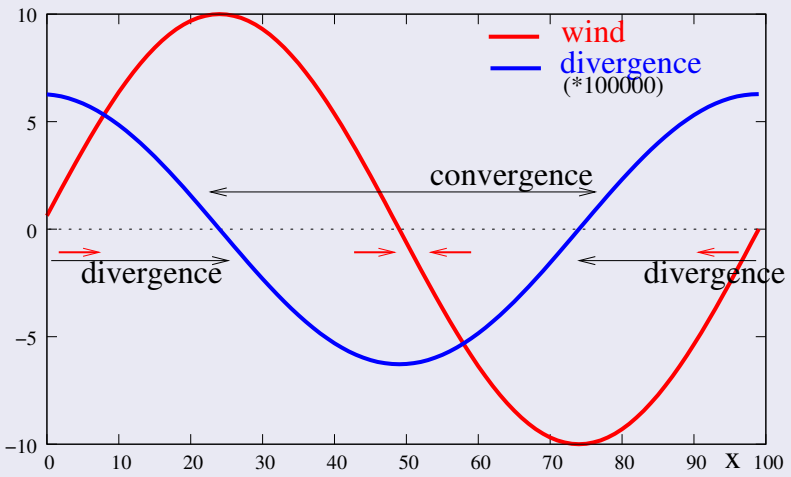




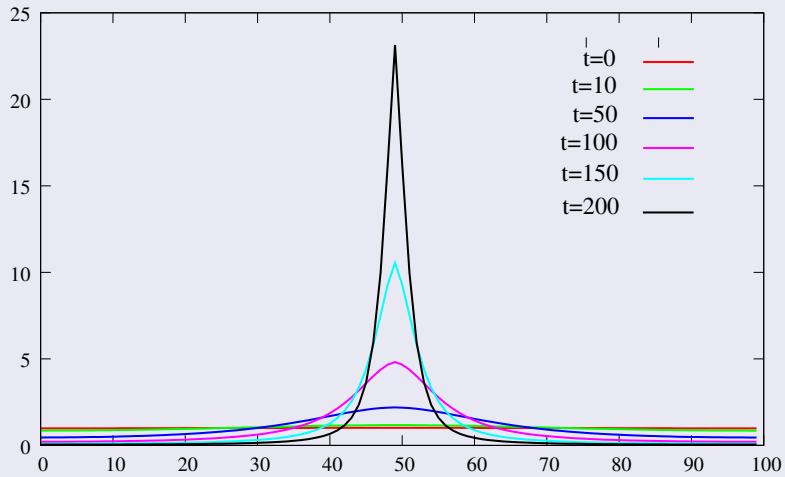
Boundary condition or a more general problem?

A 1D advective model

Wind and divergence profils

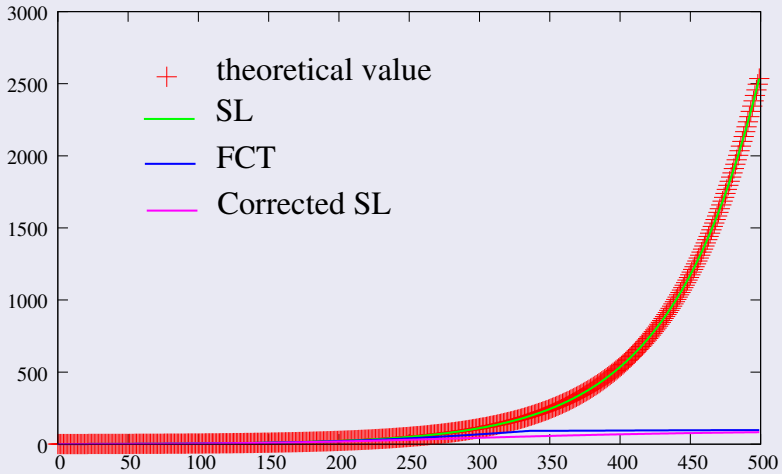


Evolution of the "linear" density

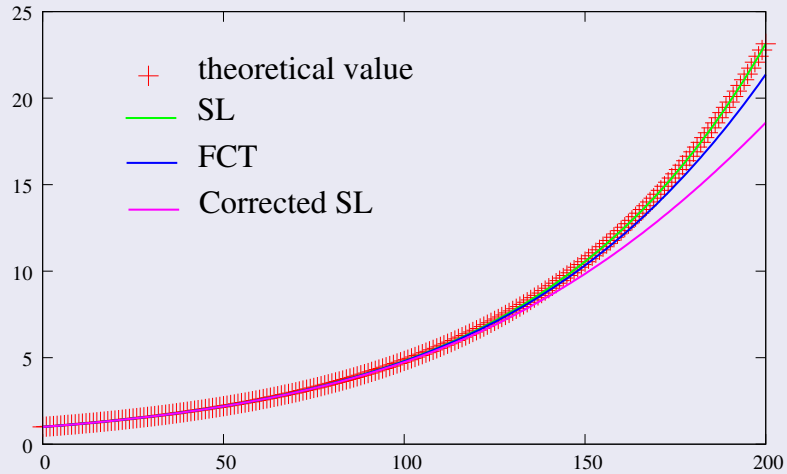


Total mass at the grid point in the center of the convergence zone

"Linear" density evolution



Zoom for the first 200 steps



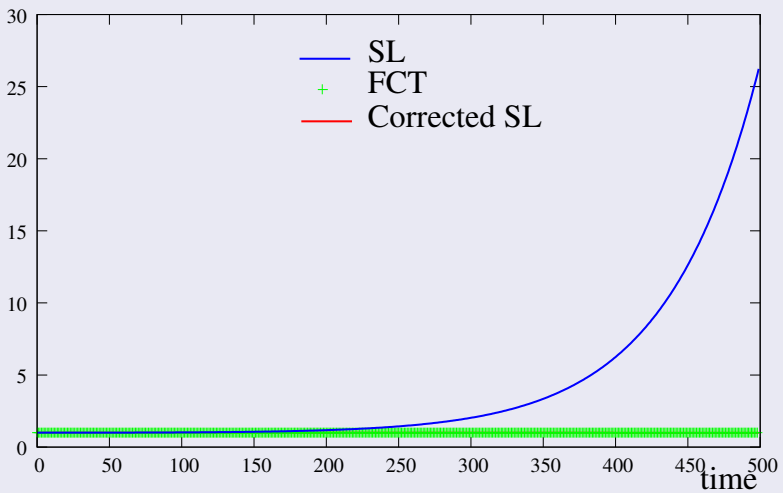
The SL is very precise but the grid point value is a "pinpoint" value which is not representative of the grid box value (in the center of the convergence zone, it becomes a "subgrid" information). In the FCT scheme, the grid box value represents the mean in the grid box.

SL versus FCT for the total mass

Total mass conservation

$$M_{tot}(t) = \sum_{i=1}^{i=NX} \rho(i,t)\Delta x$$

Total mass/initial mass



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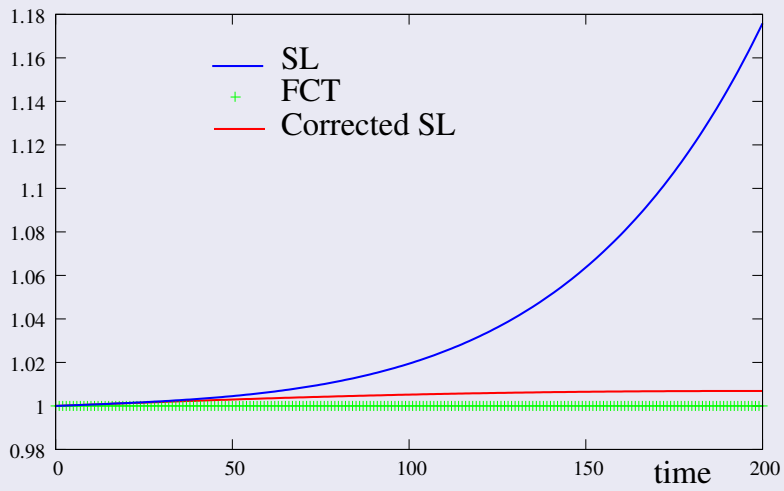
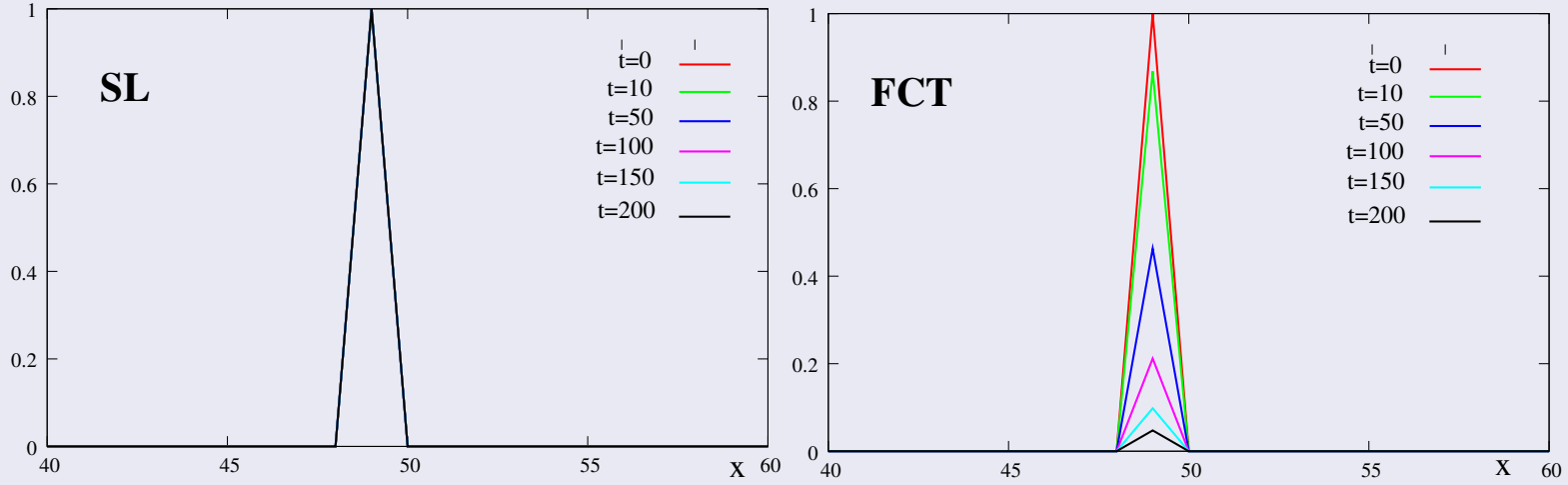


SL versus FCT for the "colored" mass initially in the central grid box

Specific ratio of "colored" mass



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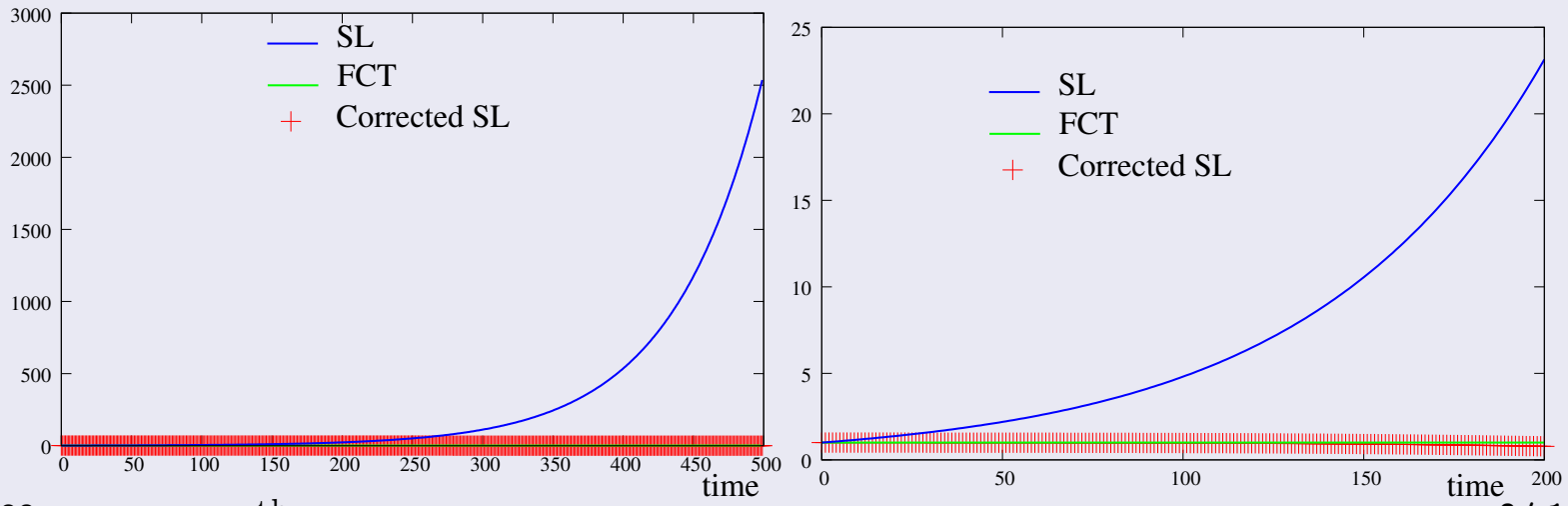
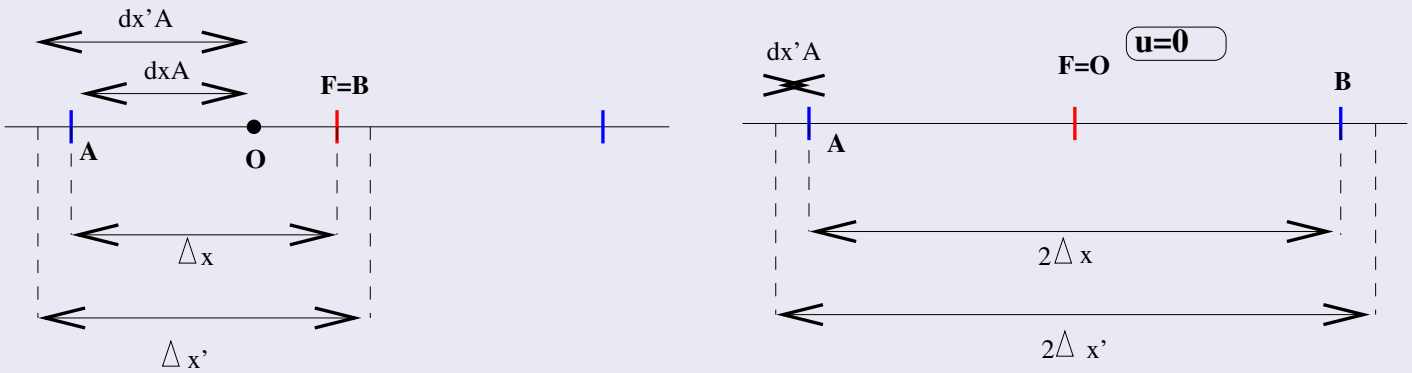


SL weight correction

$$\Delta x'(t-\Delta t) = \frac{\Delta x(t+\Delta t)}{(1+D\Delta t)}$$

Embryo of a more conservative SL scheme

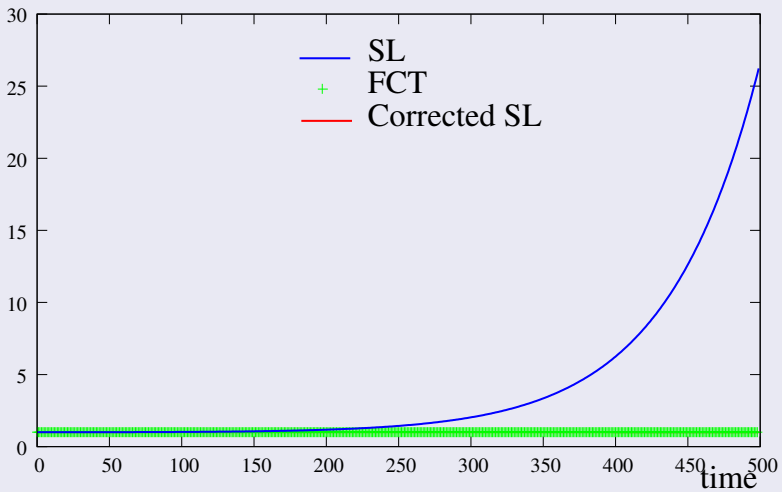


$$\alpha_A = \frac{dx_B + 0.5(\Delta x' - \Delta x)}{\Delta x'}$$

$$\alpha_B = \frac{dx_A + 0.5(\Delta x' - \Delta x)}{\Delta x'}$$

Corrected SL versus SL and FCT for the total mass

Total mass/initial mass



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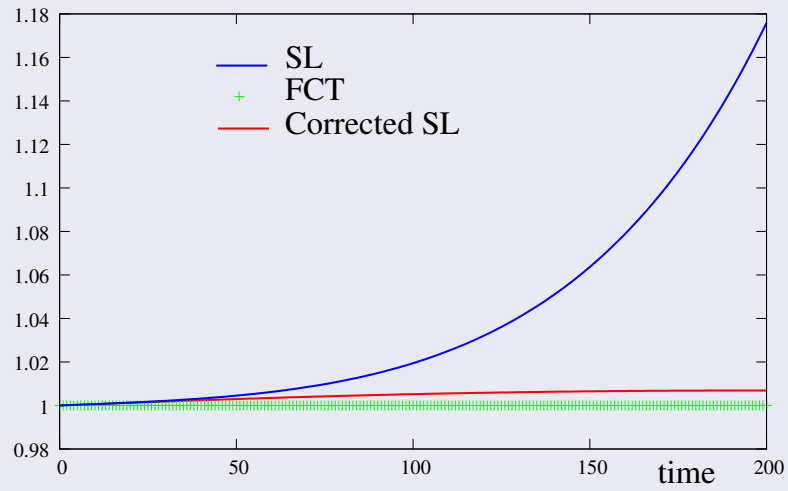

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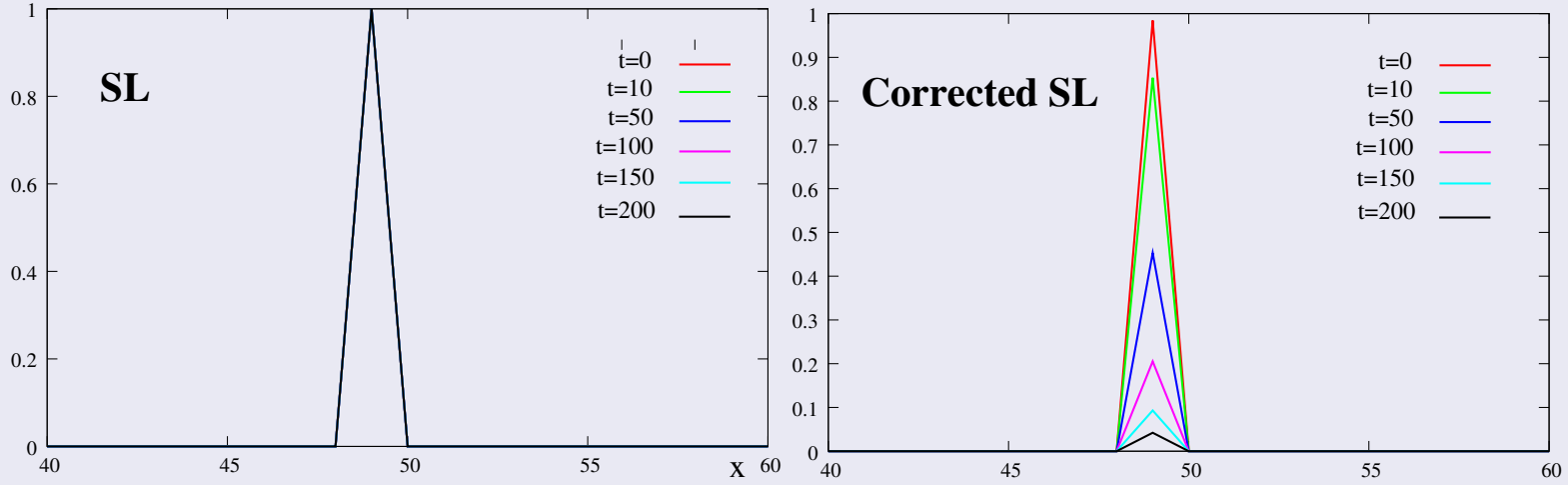

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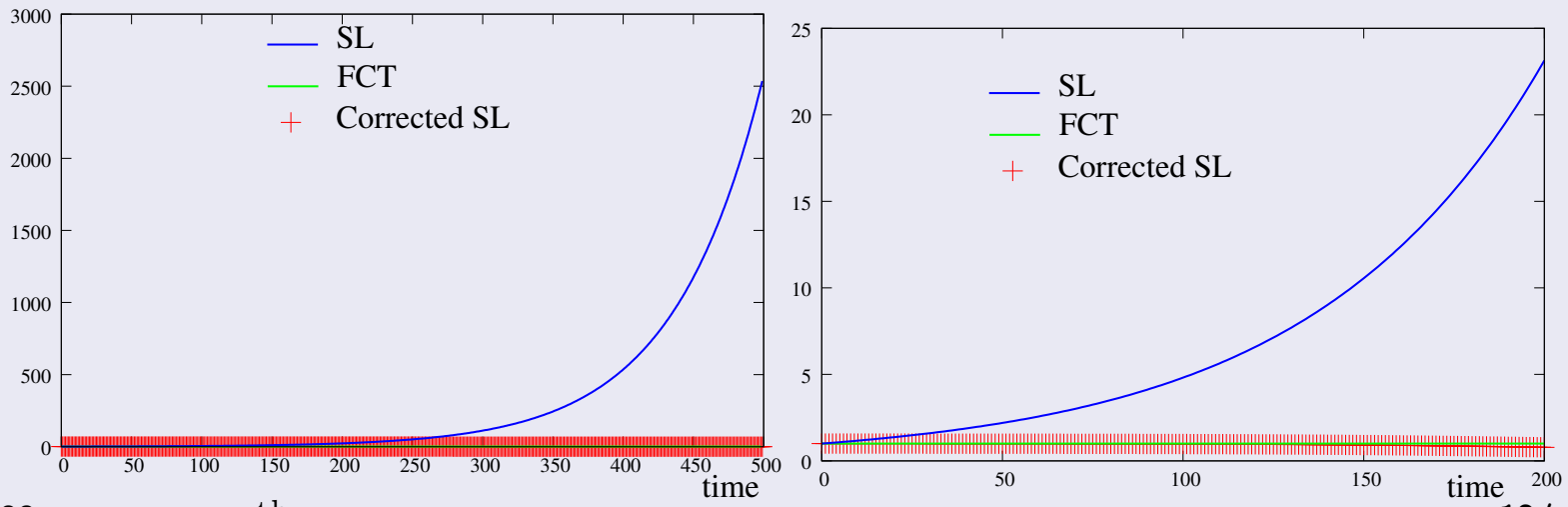

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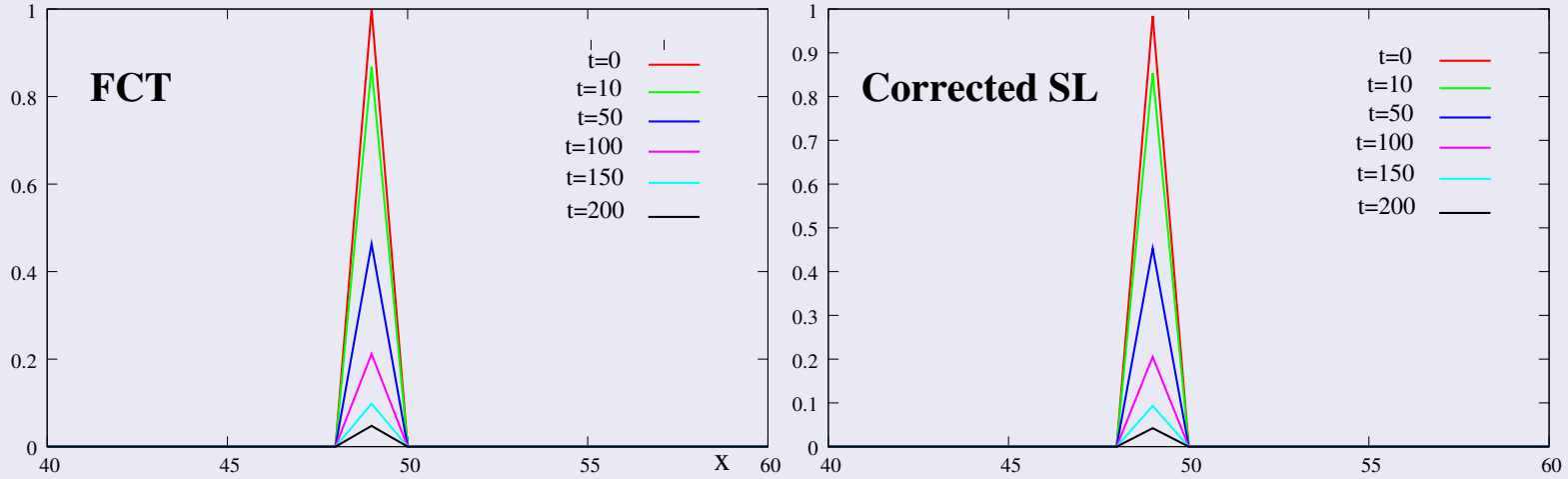

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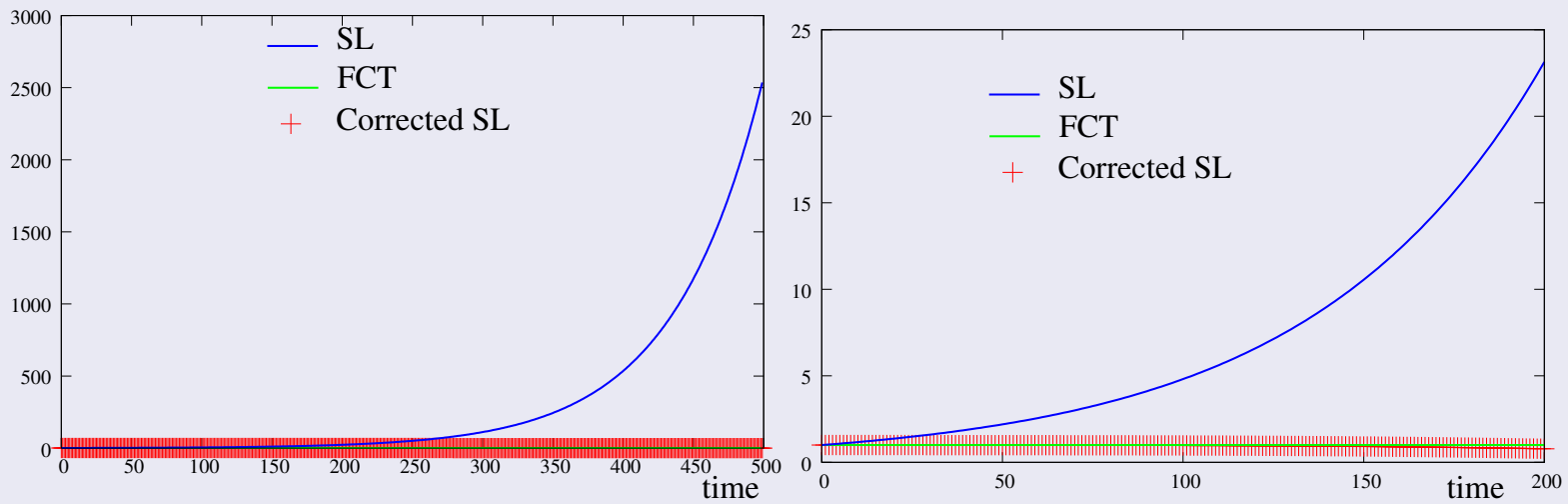


Heat, work and (T, p, τ)

The hydrostatic case : Equation for the enthalpy

$$\frac{DT}{Dt} = \boxed{\underbrace{\frac{RT}{pc_p}\frac{Dp}{Dt}}_{conversion\ \ term}} + \frac{Q}{c_p}$$

The NH case : Equation for the internal energy

$$\frac{DT}{Dt} = \boxed{\underbrace{-\frac{RT}{c_v}D_3}_{conversion\ \ term}} + \frac{Q}{c_v}$$

$$\frac{Dp}{Dt} = \boxed{-p\frac{c_p}{c_v}D_3} + \frac{pQ}{c_v T}$$

Heat, work and (T, p, τ)

If no change in the physics :

$$\frac{DT}{Dt} = \boxed{-\frac{RT}{c_v} D_3} + \frac{Q}{c_p}$$

$$\frac{Dp}{Dt} = \boxed{-p\frac{c_p}{c_v} D_3}$$

instead of

$$\frac{DT}{Dt} = \boxed{-\frac{RT}{c_v} D_3} + \frac{Q}{c_v}$$

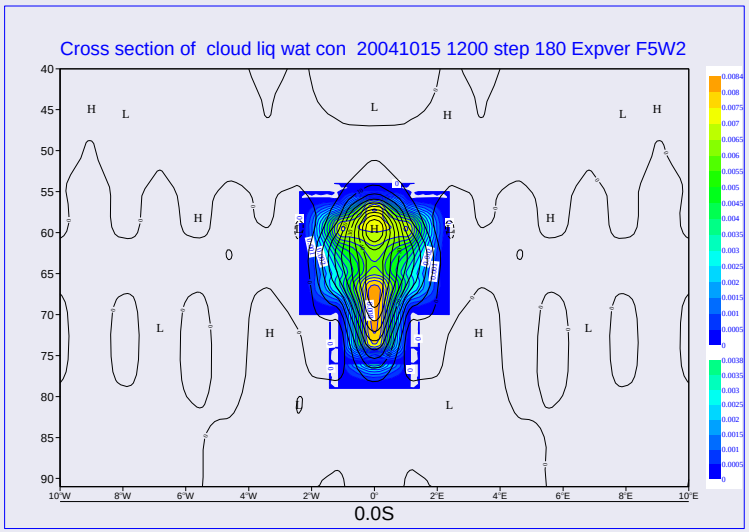
$$\frac{Dp}{Dt} = \boxed{-p\frac{c_p}{c_v} D_3} + \frac{pQ}{c_v T}$$

Main tools

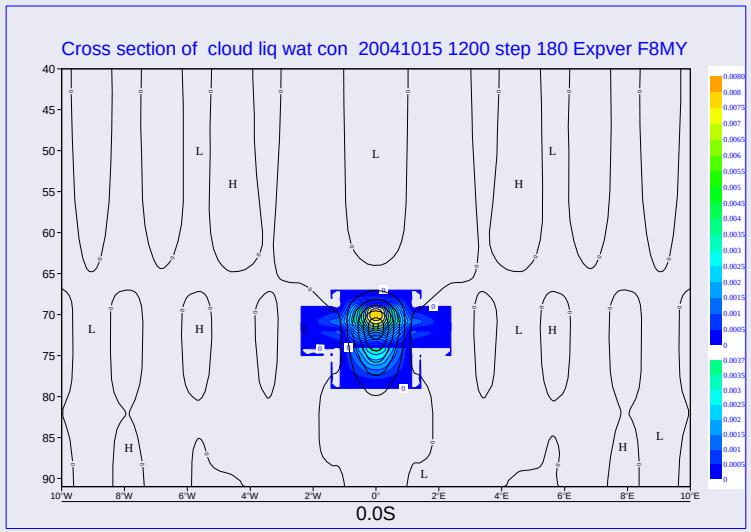
- Small Planet Testbed in the IFS (Wedi and Smolarkiewicz, 2009)
- Klemp and Wilhelmson (1978) vertical thermodynamical profils (no initial wind)
- "All or Nothing" condensation scheme instead of ECMWF physics

KW78 Cumulonimbus

"Exact" coupling



"Hydrostatic" coupling

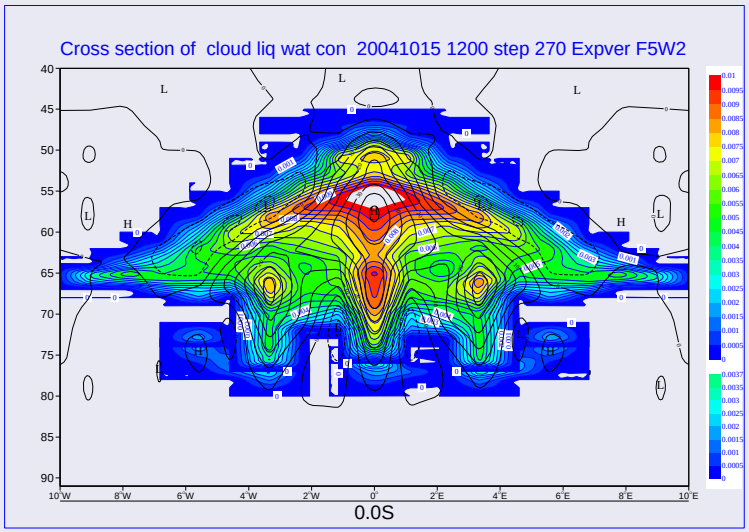


q_l,q_i (shading, kg/kg), w (black isolines, m/s)

30 min simulations

KW78 Cumulonimbus

"Exact" coupling



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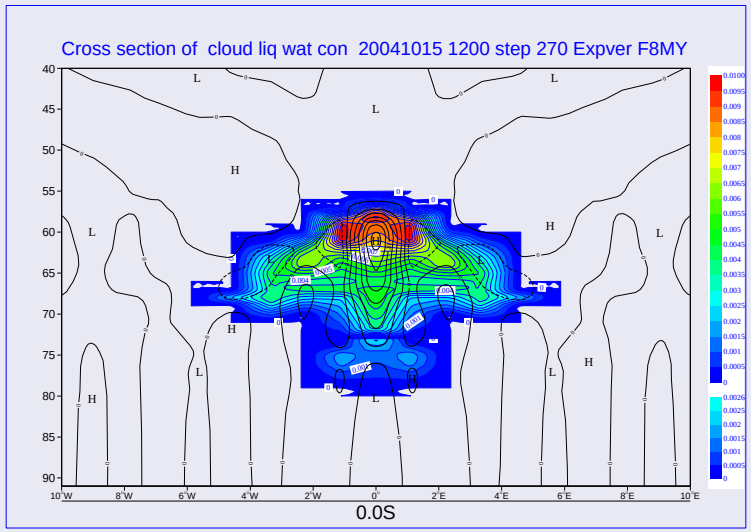

q_l,q_i (shading, kg/kg), w (black isolines, m/s)

45 min simulations

Futur plan

- Implement and try the "corrected" SL scheme in IFS
- Analyse further the phys/dyn coupling problem.