

CASE1: orographic flow case study simulated by MésoNH

by

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<<http://www.aero.obs-mip.fr/mesonh>>

Some useful features of **MésoNH** for the simulation of Case1: microphysics and transport schemes

MésoNH is a flexible anelastic NH model with grid-nesting.
MésoNH simulates 1D/2D/3D idealized or real flows for
many applicative purposes in a wide range of scales.
The code is vect. & parallelized (PC, cluster, SX8, BGene)

- **Dynamics:** resolved and turbulent flow
- **Microphysics:** mixed-phase processes
- **Surface processes:** soil+vegetation, emis./dep.
- **Chemistry:** gas reactivity and solubility, pH
- **Electricity:** lightning flash and NO_x production
- **Aerosols:** chemical composition, etc.

A recent update of 3D transport schemes in Méso-NH

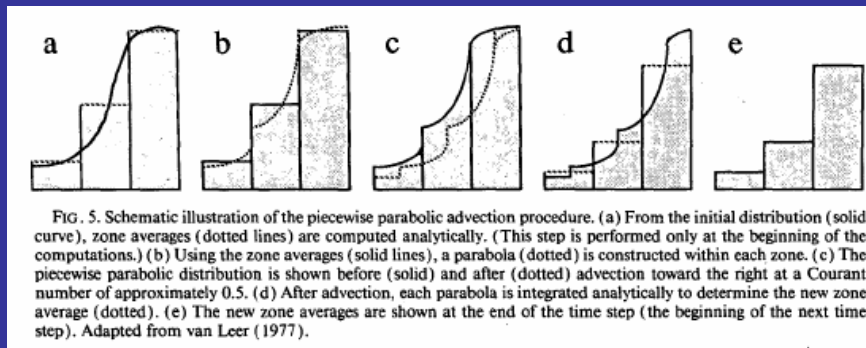
(T. Maric, J.-P. Pinty, C. Lac and J. Escobar, LA & MF)

- **Momentum:**

- 4th ~~2nd~~ order time-centered advection scheme
- needs 4th order numerical diffusion to damp short waves

- **Scalar fields:**

- **PPM** (piecewise parabolic) scheme (~~FCT~~, ~~MPDATA~~)
- highly accurate, monotonic, positive definite scheme



Short review of the microphysical schemes in MésoNH

1-moment: J.-P. Pinty, E. Richard, J.-P. Chaboureau, @ LA

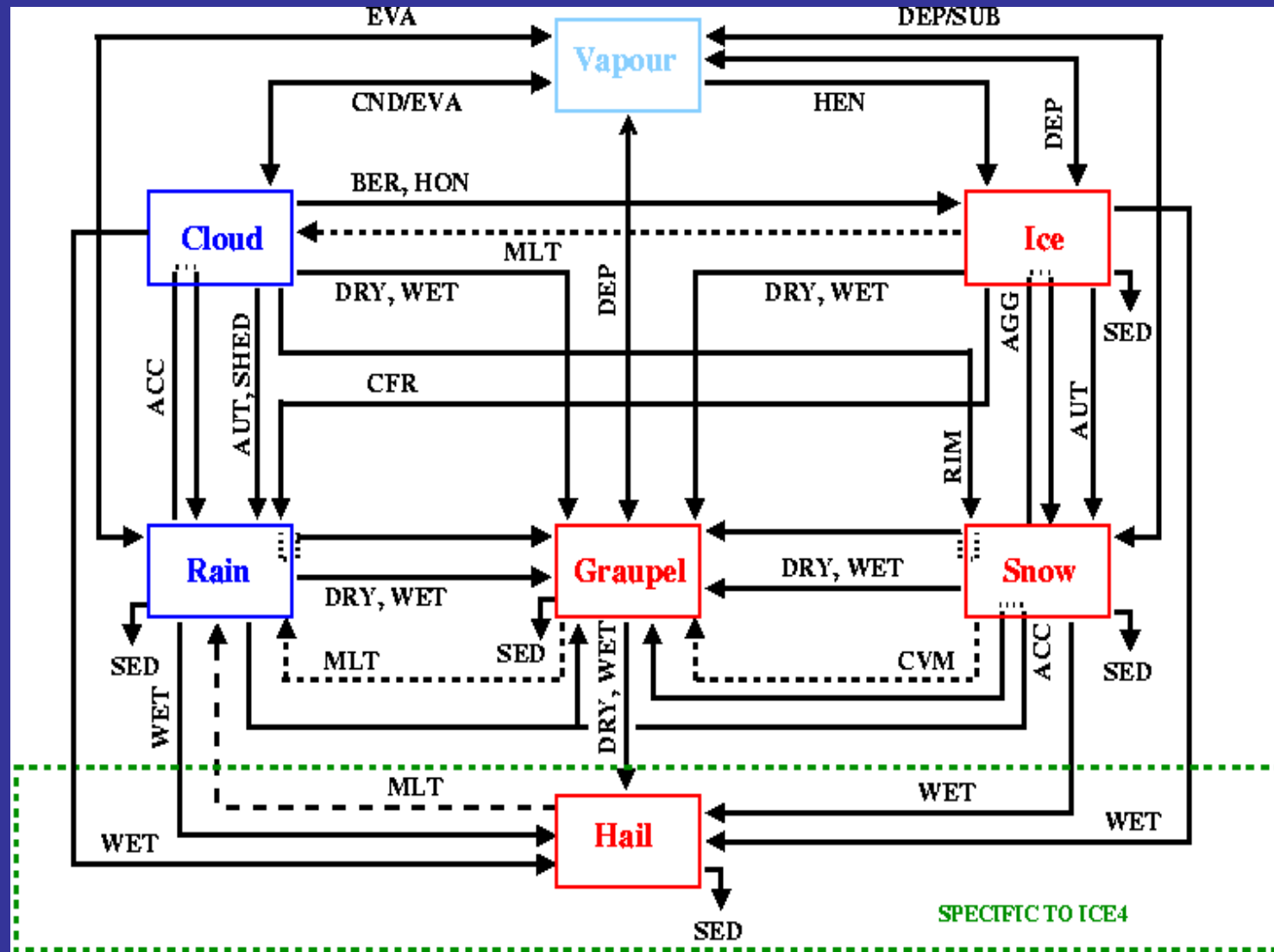
- **Content of the scheme:**

- mixing ratios: 2 liq. (Kessler) + 3 or 4 (hail) ice species
- particle size distribution: generalized gamma law
- ana./num. integration of collection processes using geom. gravitational kernels
- upstream fract. timestep (sedimentation)
- process-by-process integration (exact conservation)
- adjustment to saturation (barycentric $r_v^{\text{sat}}(T)$, last process)
- most recent reference: *Lascaux et al., QJRMS, 2006.*

- **Other applications of the scheme:**

- cloud electricity, radiative transfer, aqueous chemistry
- used in Arome, the new NWP model @ Météo-France

Sketch of the 1-moment scheme



Short review of the microphysical schemes in MésoNH

2-moment: J.-P. Pinty, J.-M. Cohard, S. Berthet, @ LA

- « **Warm** » **part of the scheme** (Cohard & Pinty, QJRMS, 2000)
 - cloud $\{r_c, N_c\}$, rain $\{r_r, N_r\}$ and generalized gamma law (dsd)
 - original CCN activation scheme based on the analytical integration of Twomey's equation (Cohard et al. JAS, 1997)
 - autoconversion (Berry and Reinhardt), collection (Long kernels \rightarrow analytical integration)
- **Extension to the mixed-phase** (unpublished, conf. paper, 2002)
 - cloud (pristine) ice $\{r_i, N_i\}$, snow $\{r_s\}$, graupel $\{r_g\}$
 - IFN nucleation (deposition and contact: Meyers et al. JAM, 1982), homogeneous nucleation and aerosol freezing (Kärcher)
 - cloud ice \rightarrow snow particles as in Harrington et al. JAS, 1995

Short review of the microphysical schemes in MésoNH

2-moment: J.-P. Pinty, J.-M. Cohard, S. Berthet, @ LA

- **Extention to the mixed-phase (cont'd)**
 - no supersaturation over water
 - explicit computation DEP/SUB rates of cloud ice (N_i is prognostic variable) → possible SSi in glaciated clouds
 - other processes are similar to the 1-moment scheme
- **... on-going developments:**
 - activation of a multimodal population of CCN: each CCN mode is a 3D prognostic variable
 - nucleation of ice on multiple IFN types (*Phillips et al., JAS, 2008*)
 - scavenging of CCN and IFN by rain (*Berthet et al., poster ICCP_2008*)

Set up of CASE 1 « orographic flows » in MésoNH

(Top damping layer, slip free, open LBC, turbulence)

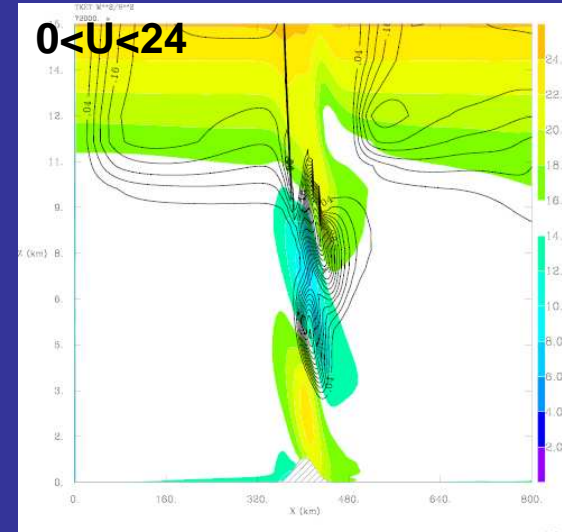
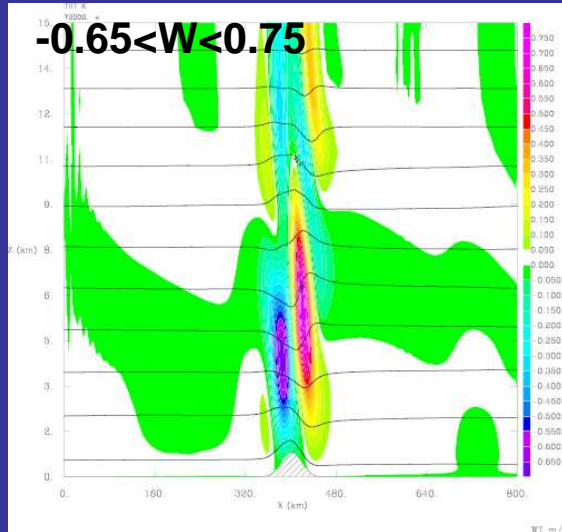
- **Moderate mountain height case with $H=800$ m \rightarrow non-linear hydrostatic flow:**
 - $NH/U \sim 0.6$; $Ua/N \sim 15 \rightarrow Dt = 10$ s ($Dx = 2$ km)
 - 20 hour dry run to build-up the solution and
 - additional 10 hour run \rightarrow wet solution with either 1- or 2-moment microphysics
- **High mountain case with $H=3000$ m \rightarrow highly non-linear blocked flow with hydraulic jump moving in the lee**
 - $NH/U \sim 2.2 \rightarrow Dt = 1$ s.
 - 22 hour dry run to move the jump outward the domain boundary and additional 10 hour run \rightarrow wet solution with 1-moment microphysics

\rightarrow Dry runs to get a pseudo-stationary flow

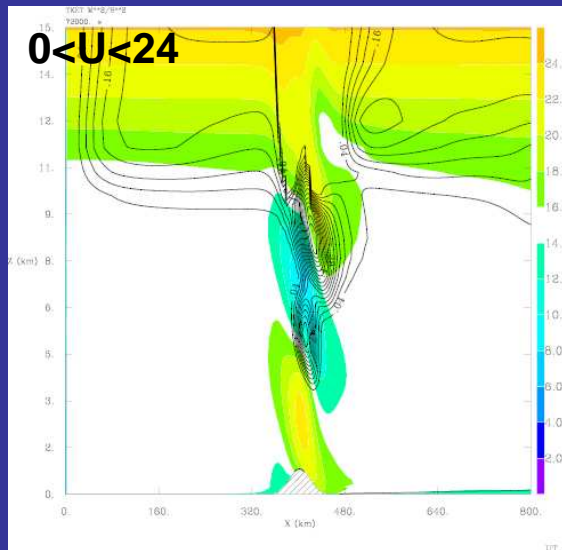
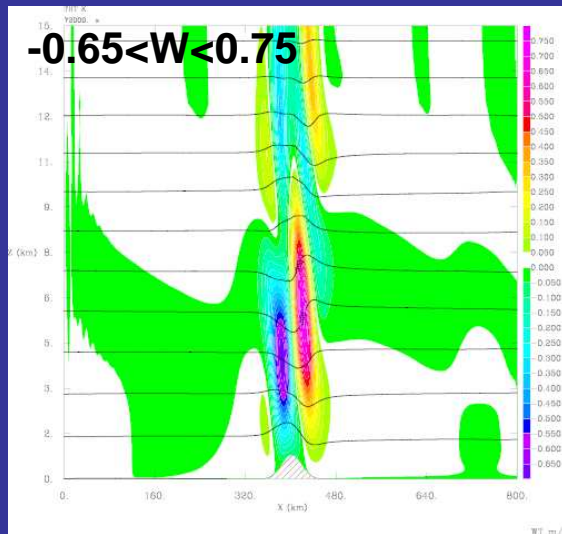
CASE1: end of dry runs

Mountain height : $H=800$ m

$T=273\text{K}$
after 20h



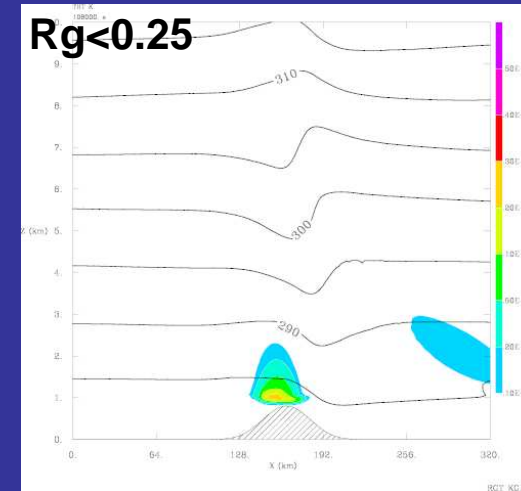
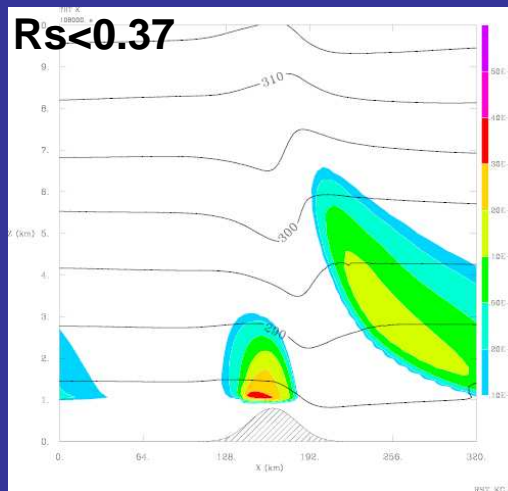
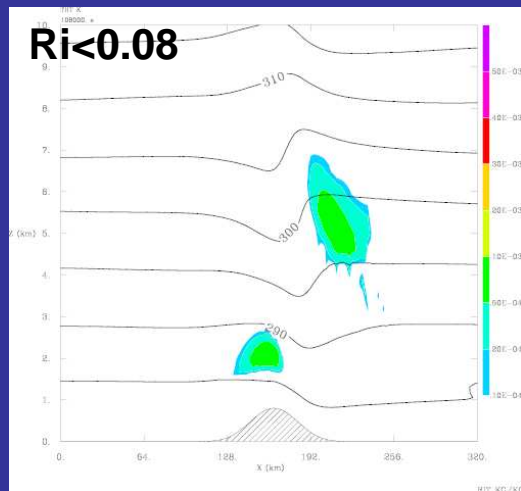
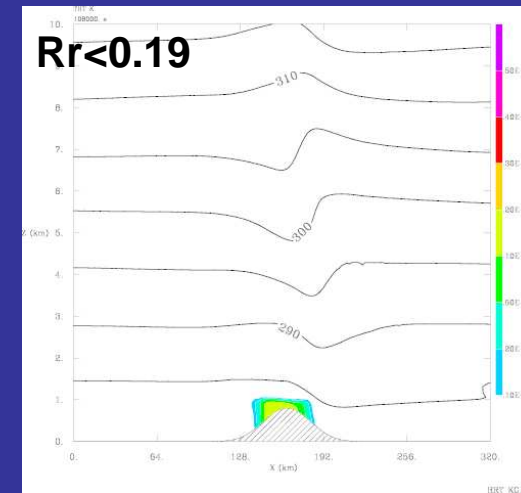
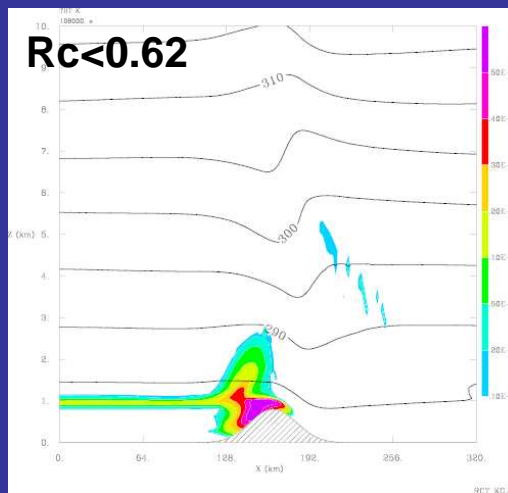
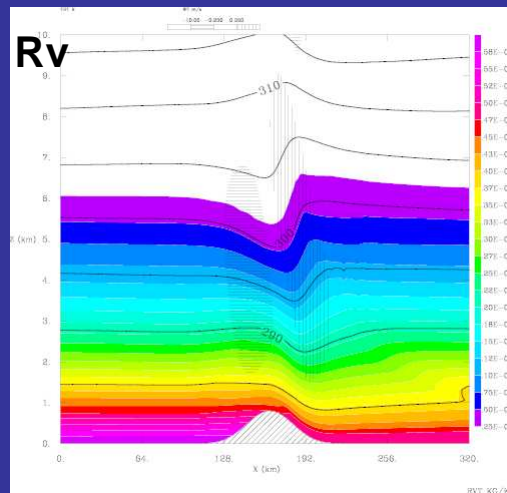
$T=280\text{K}$
after 20h



← Coloured field is TKE
← TKE

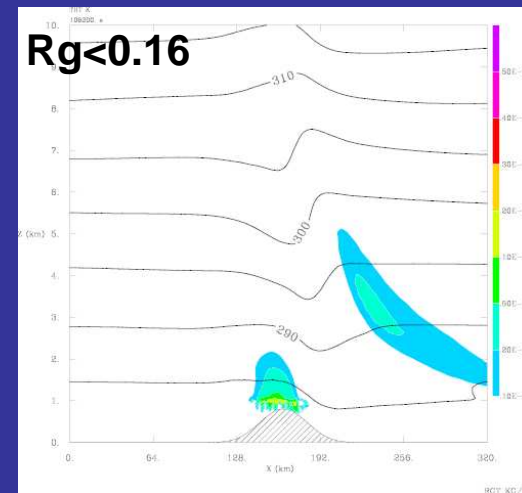
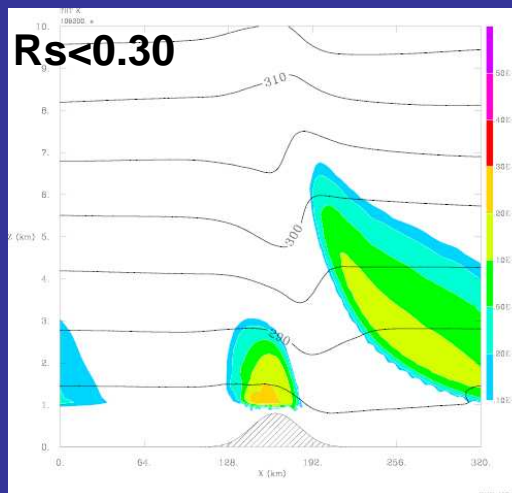
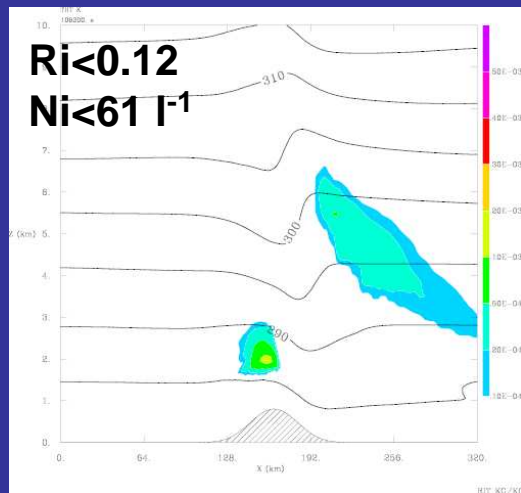
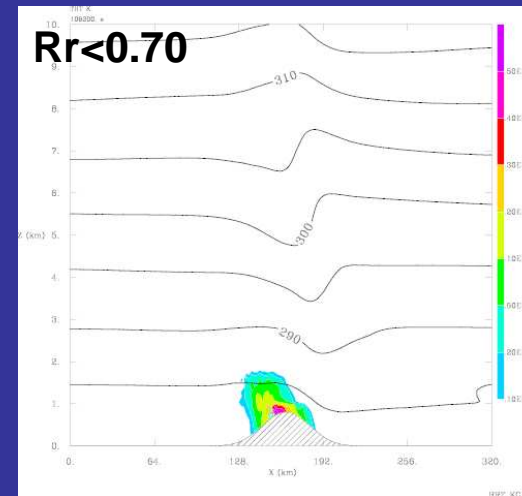
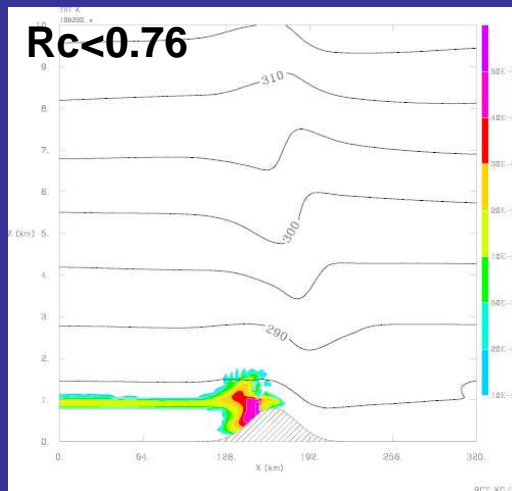
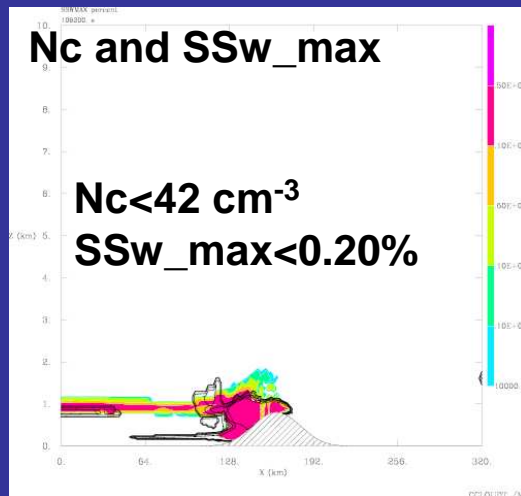
CASE1: wet run starting from dry run

T=280K Mountain height : H=800 m and 1-moment scheme
after 10 h



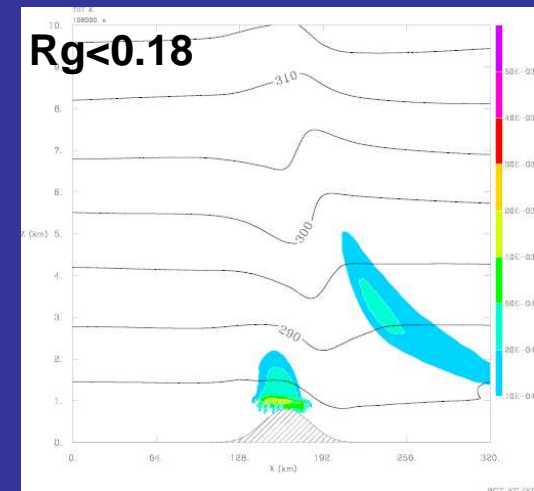
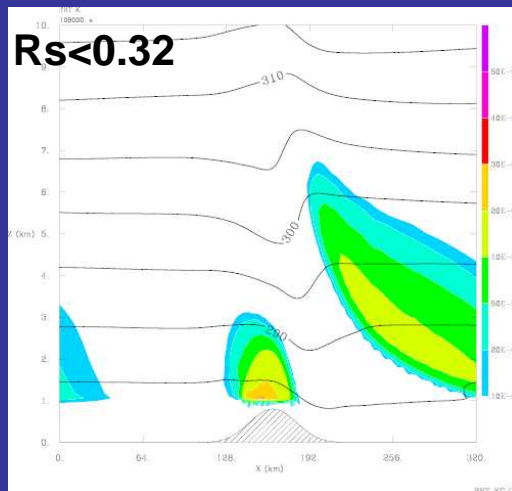
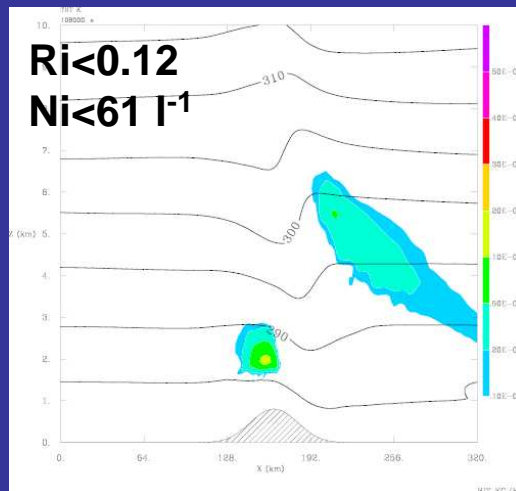
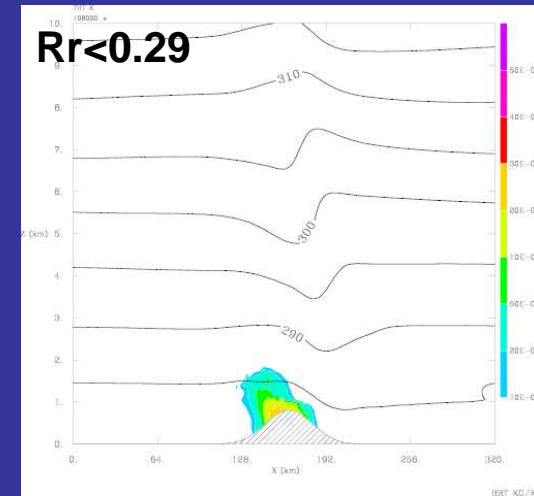
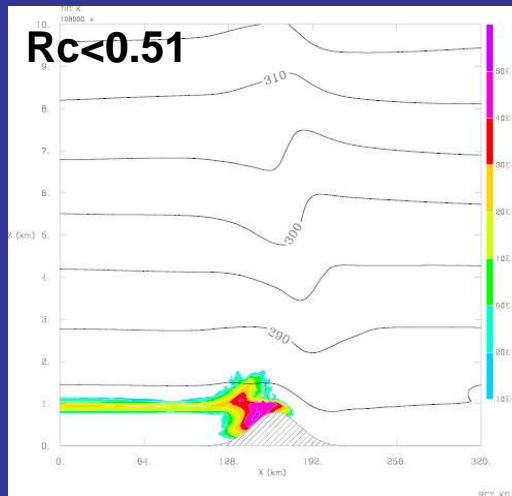
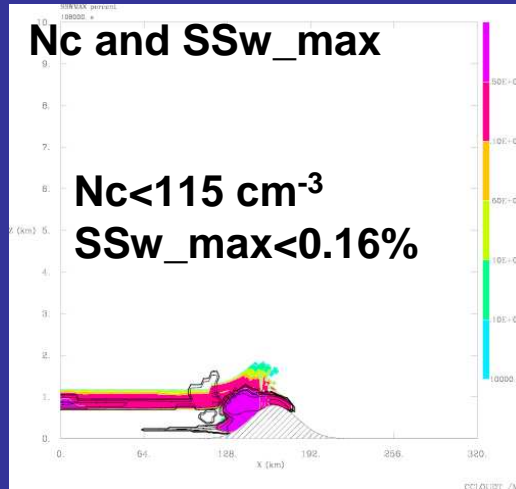
CASE1: wet run starting from dry run

T=289K with 2-moment scheme ($N_{ccn}=100 \text{ cm}^{-3}$, $N_{in}=100 \times N_{Meyers}$)
after 10 h



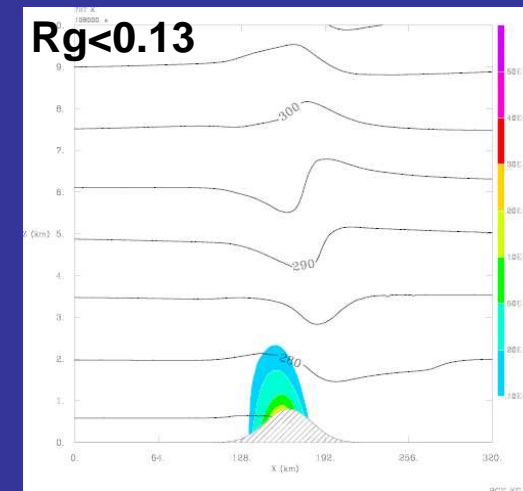
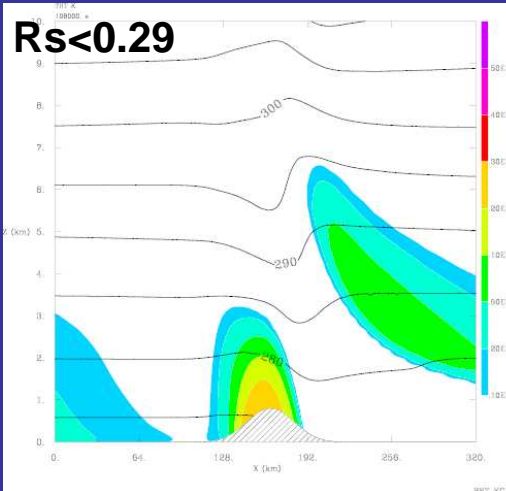
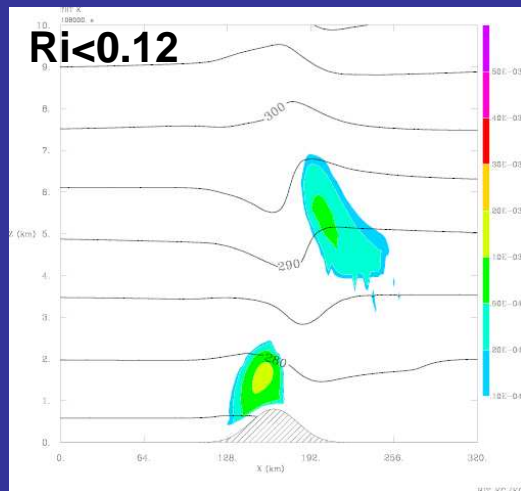
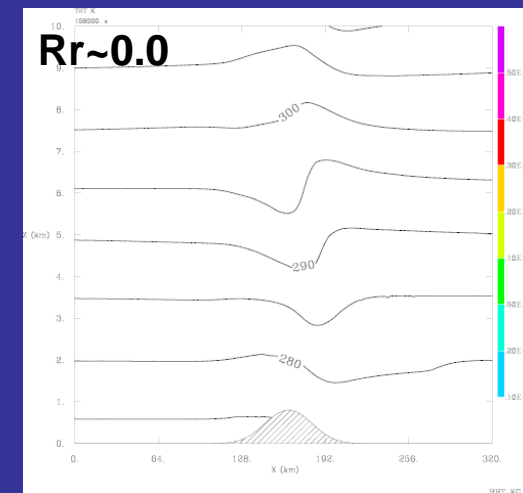
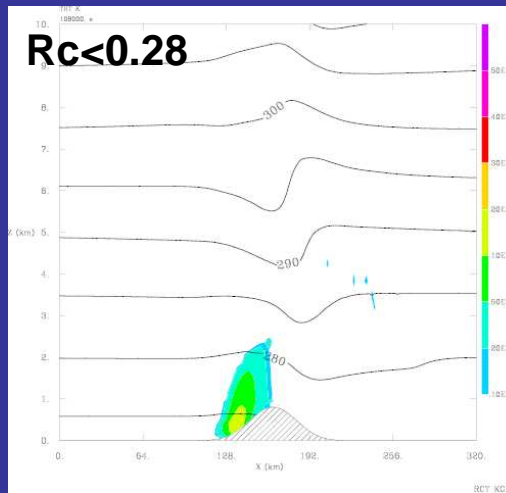
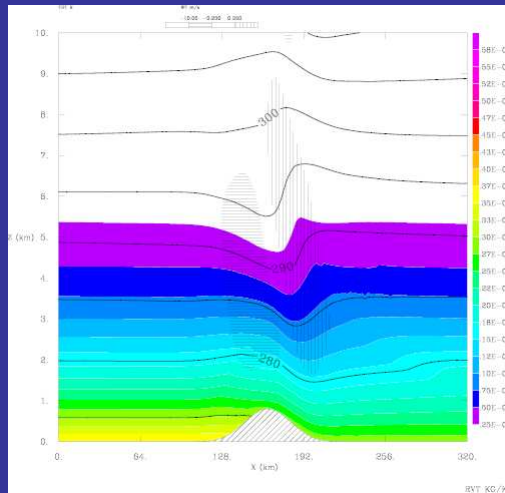
CASE1: wet run starting from dry run

T=280K with 2-moment scheme ($N_{ccn}=400 \text{ cm}^{-3}$, $N_{in}=100 \times N_{Meyers}$)
after 10 h



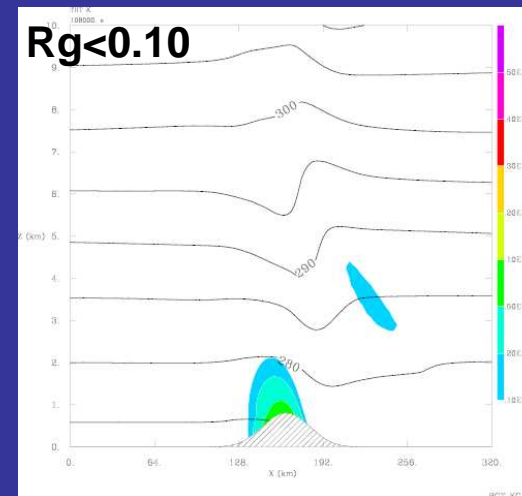
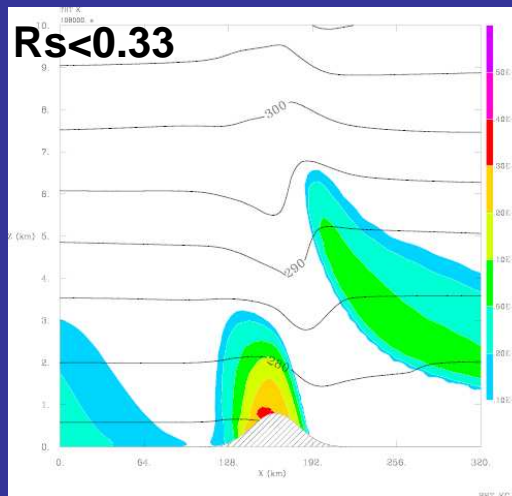
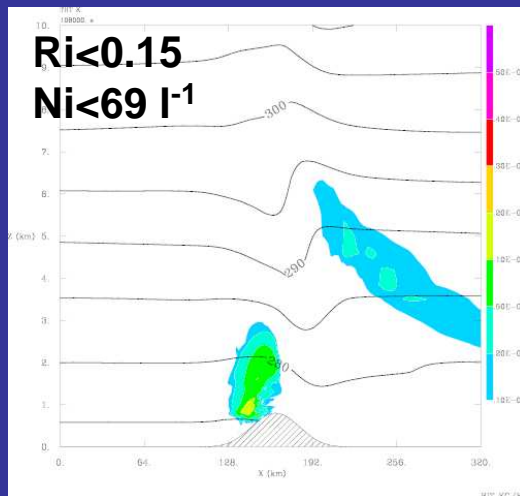
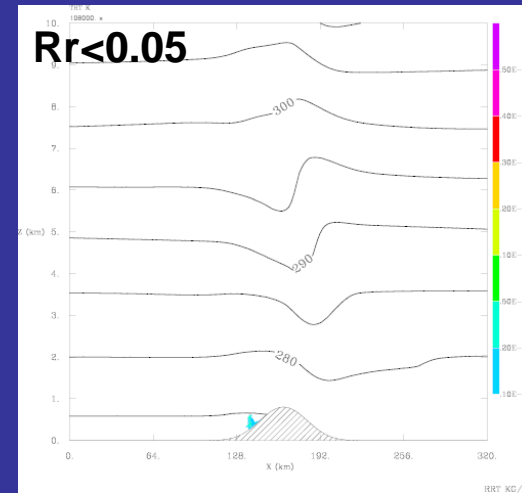
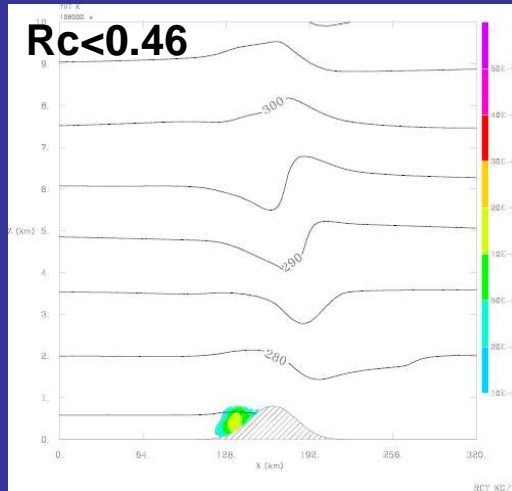
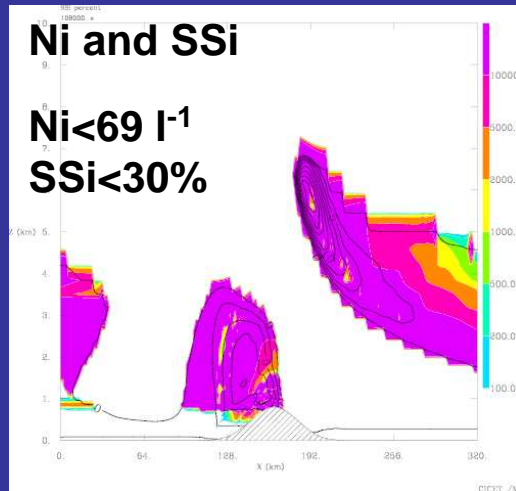
CASE1: wet run starting from dry run

T=273K Mountain height : H=800 m and 1-moment scheme
after 10 h



CASE1: wet run starting from dry run

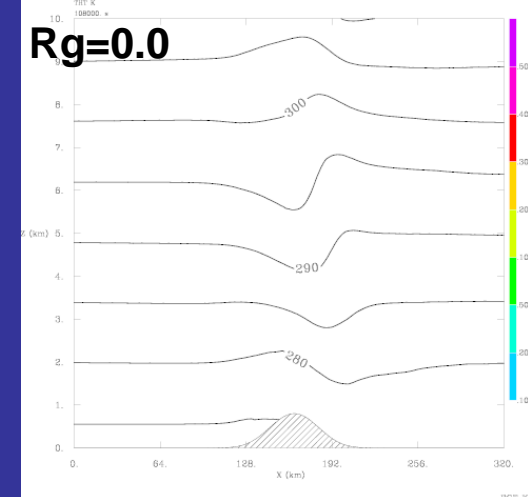
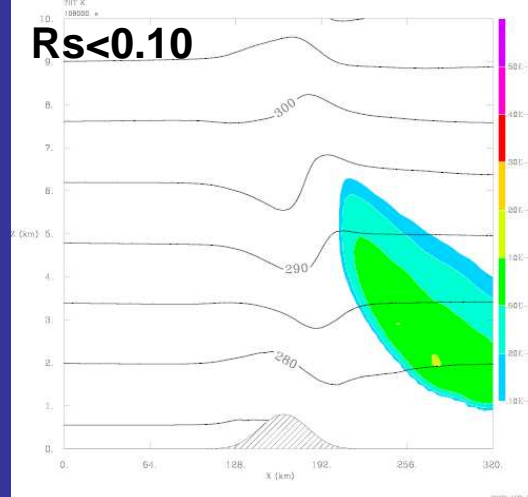
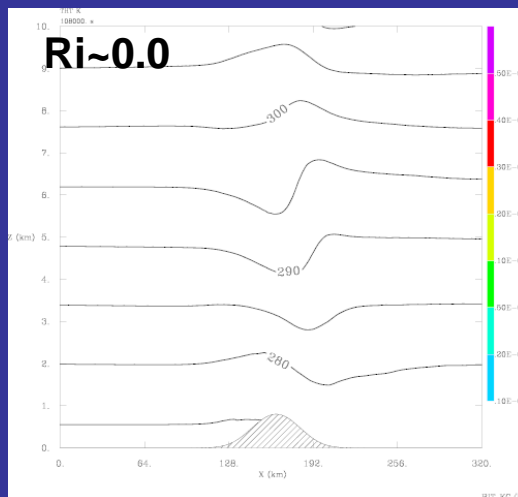
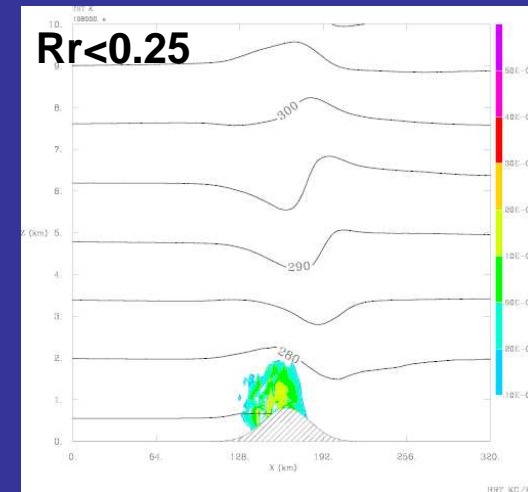
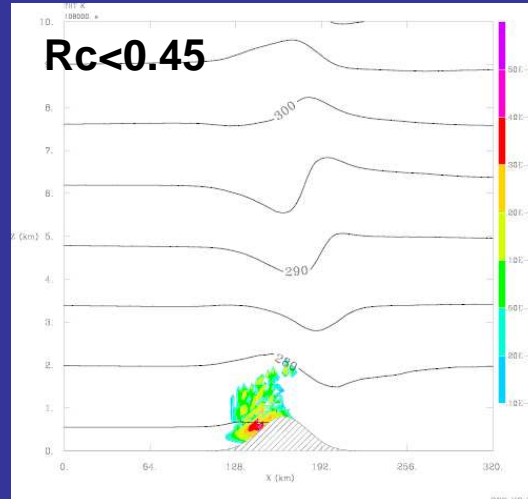
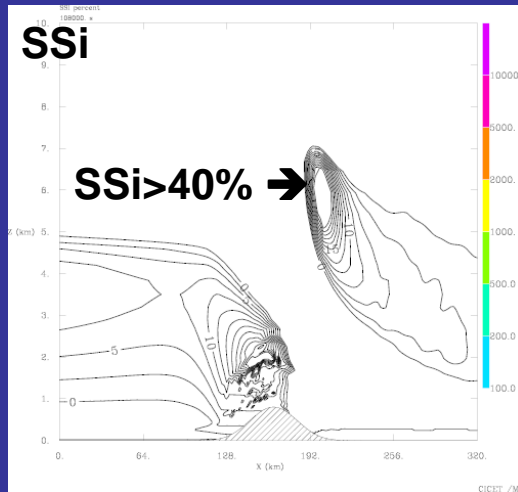
$T=273\text{K}$ with 2-moment scheme ($N_{\text{ccn}}=100\text{ cm}^{-3}$, $N_{\text{in}}=100\times N_{\text{Meyers}}$)
after 10 h



CASE1: wet run starting from dry run

T=273K
after 10 h

with 2-moment scheme ($N_{ccn}=100 \text{ cm}^{-3}$, $N_{in}=0$)

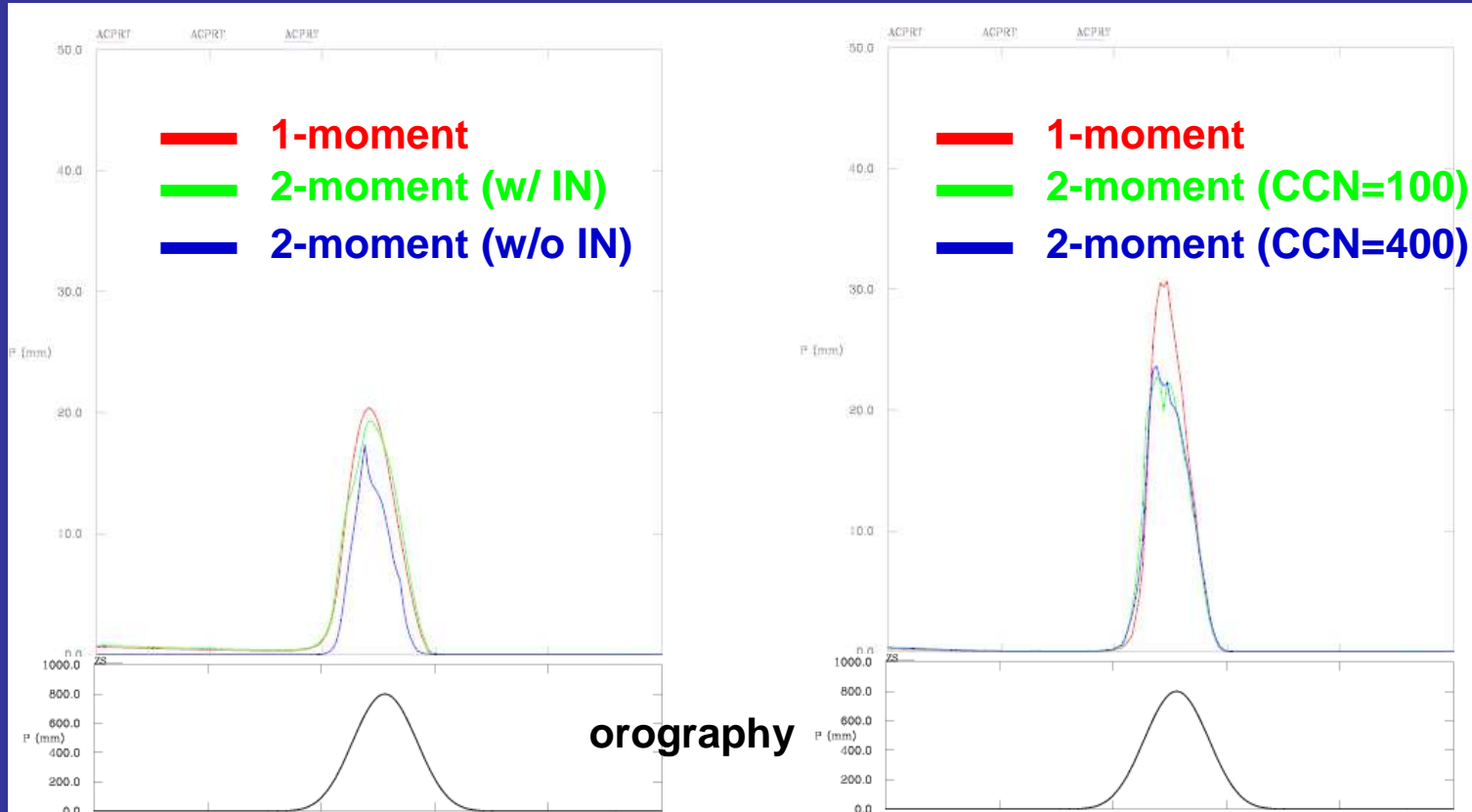


CASE1: wet run for H = 800 m

Summary of the total accumulated precipitation

T=273K
after 10 h

T=280K
after 10 h

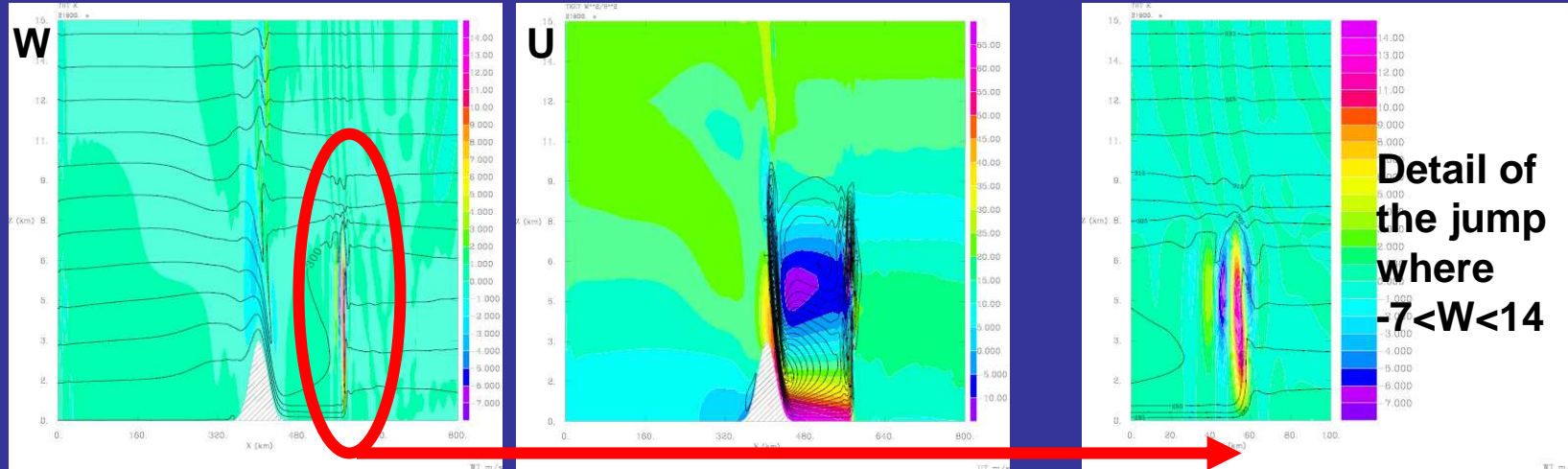


Precipitation peak is shifted upstream (effect of the dynamics)
Precipitation pattern is insensitive to CCN conc. (T=280K case)

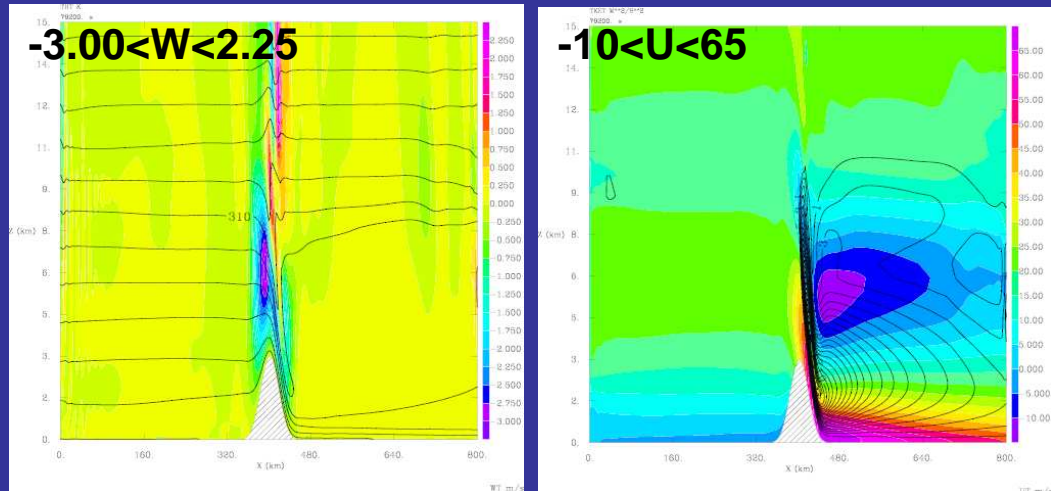
CASE1: dry run flow

Mountain height : $H=3000$ m

$T=273K$
after 6 h



after 22 h



isocontours
of TKE are
superimposed

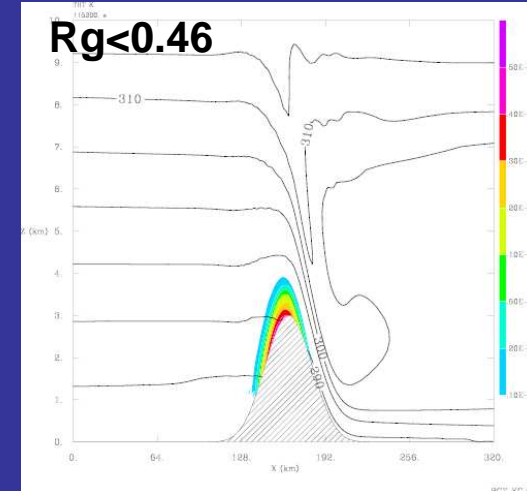
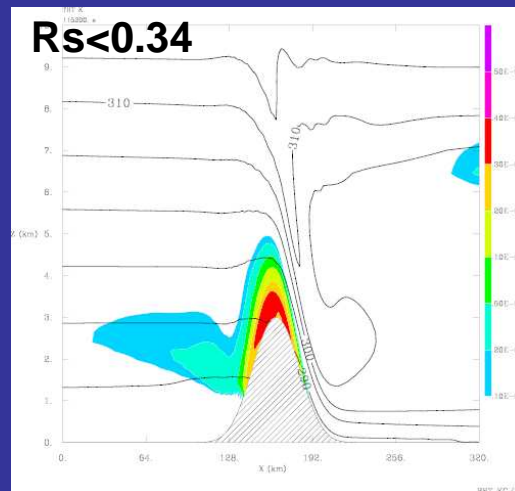
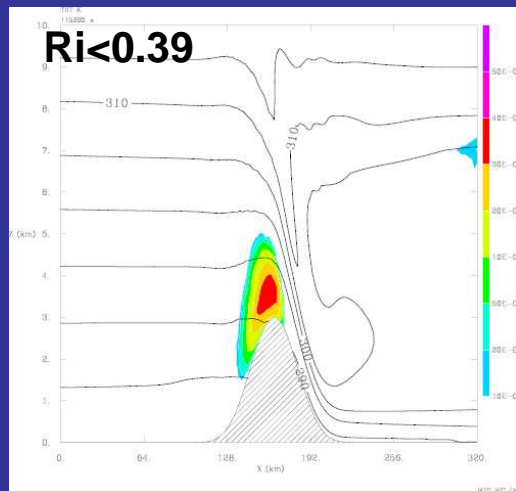
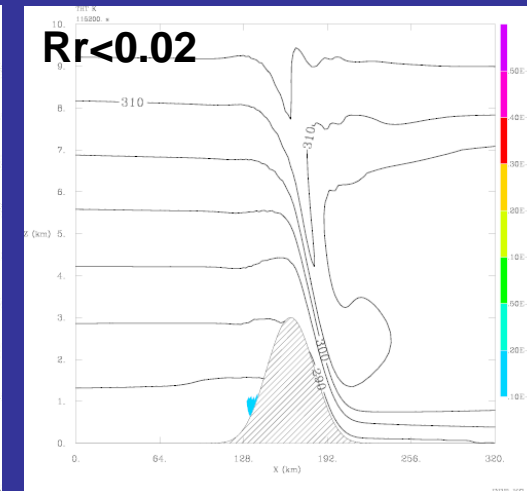
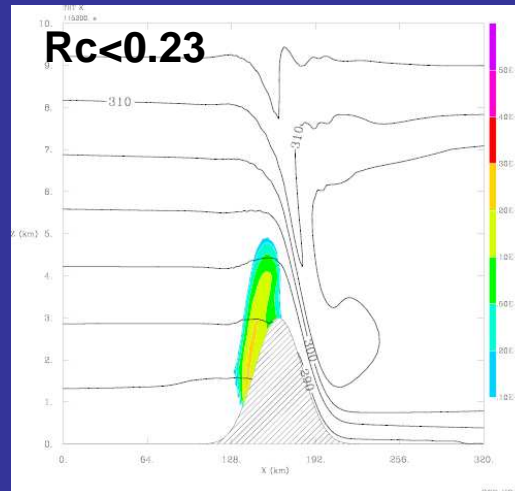
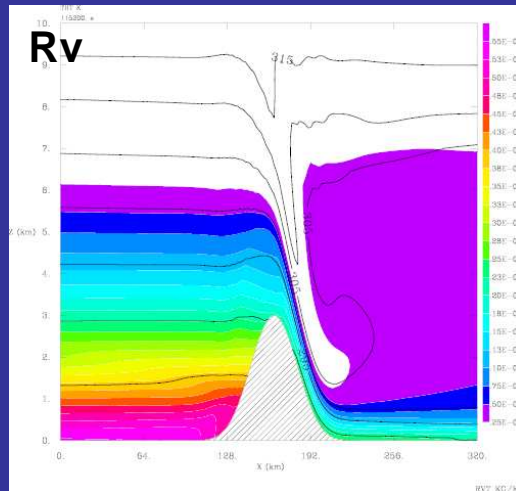


Strong turbulent foehn
with return flow
upstream

CASE1: wet run starting from dry run

Mountain height : $H=3000$ m

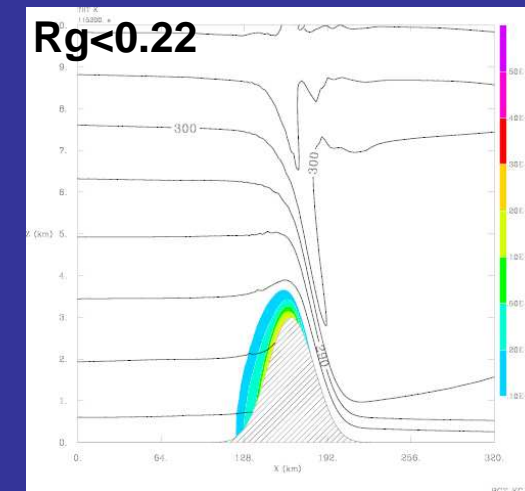
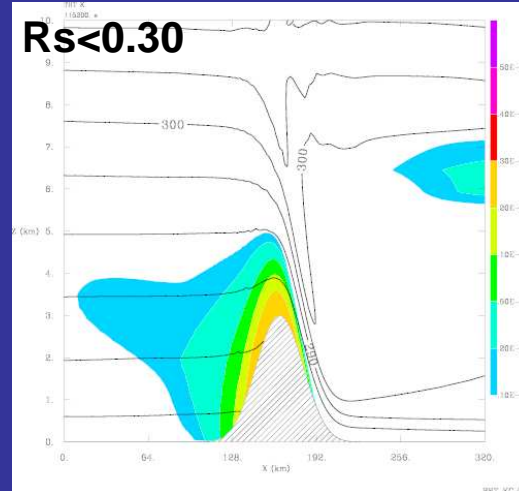
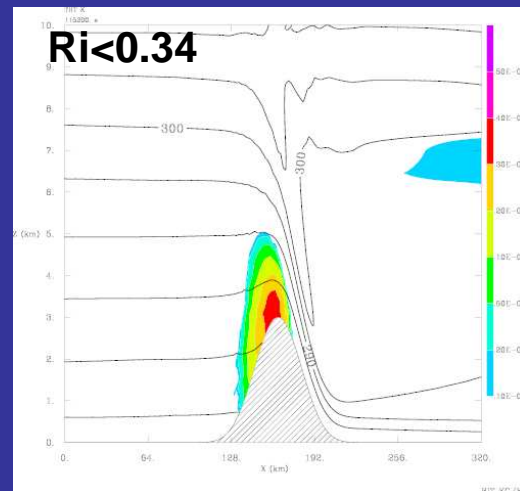
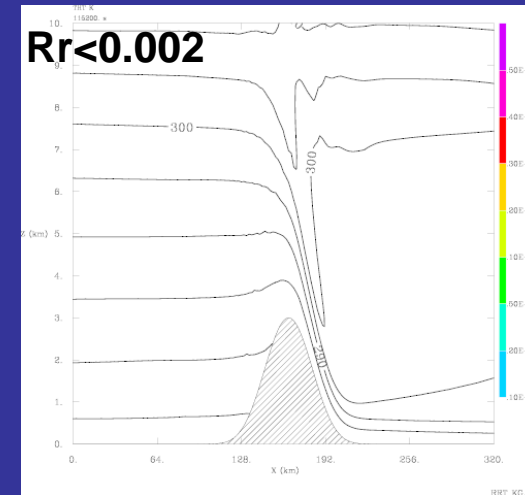
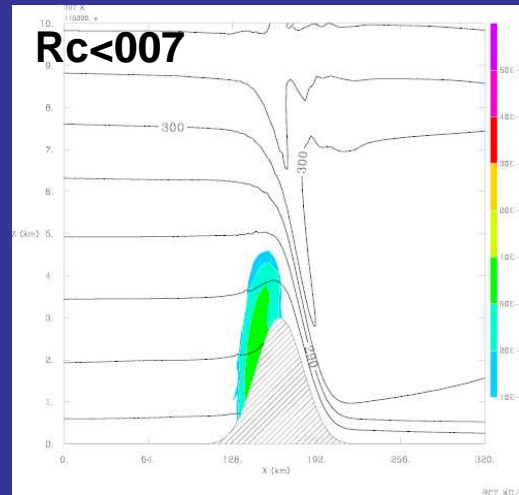
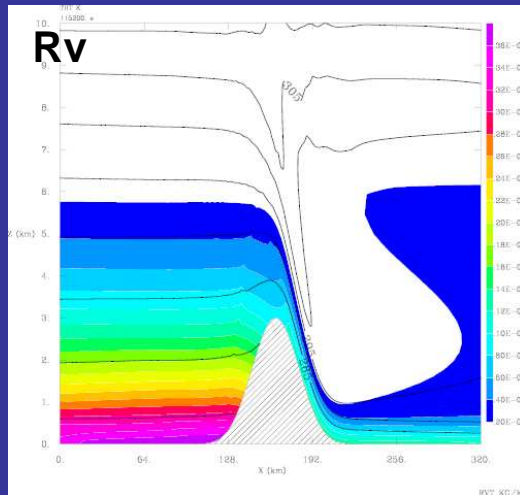
$T=280$ K
after 10 h



CASE1: wet run starting from dry run

Mountain height : $H=3000$ m

$T=273\text{K}$
after 10 h



CASE1: «Jungfrauoch» case

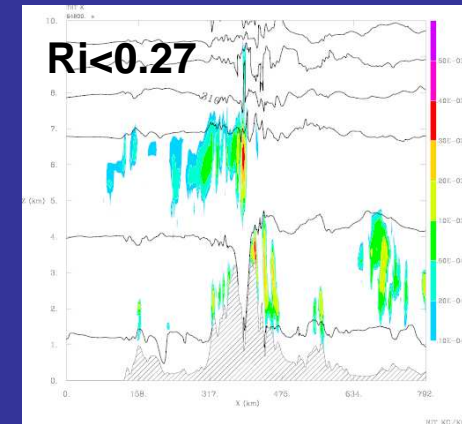
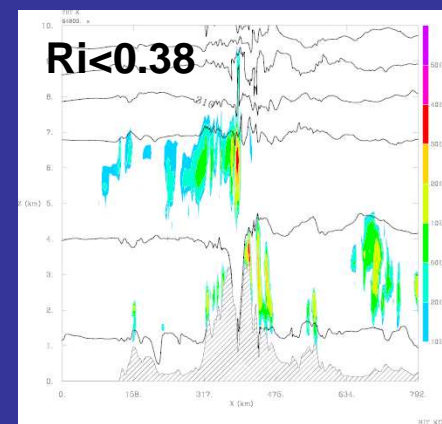
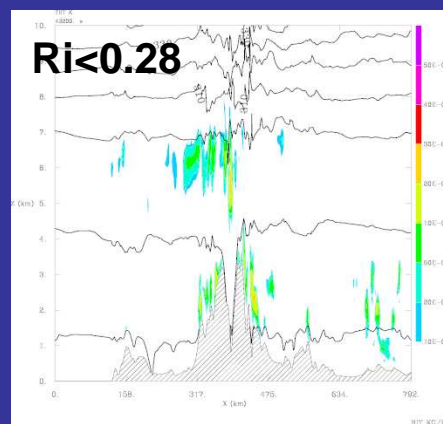
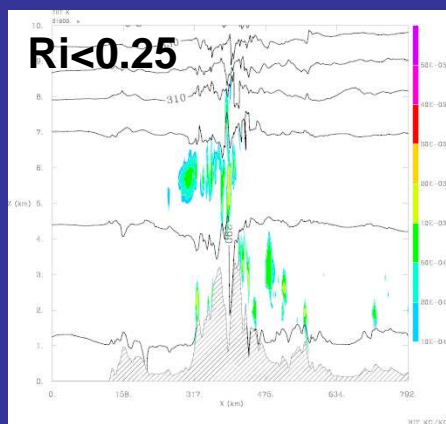
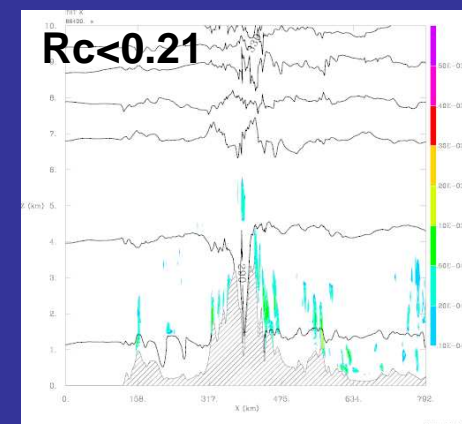
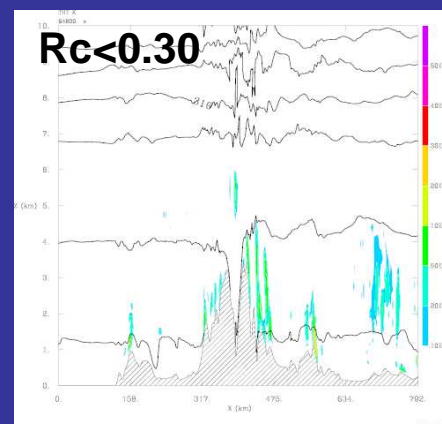
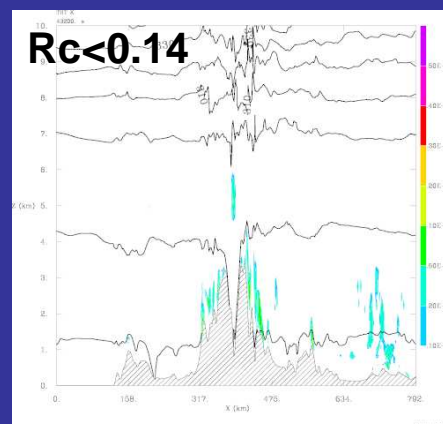
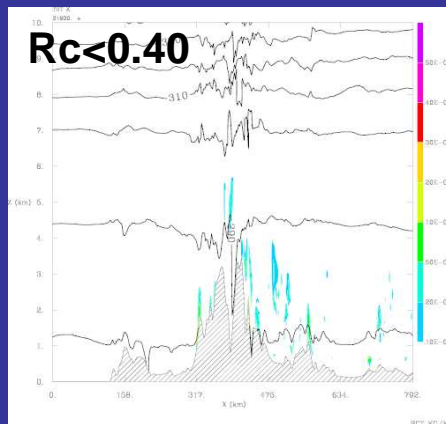
(single R/S, orography transect, $Z_0=0.5$ m, 24 hour wet run, $Dx=2.2$ km, $Dt=1$ s, « H3000 case » setup)

06 h

12 h

18 h

24 h



CASE1: «Jungfrauoch» case

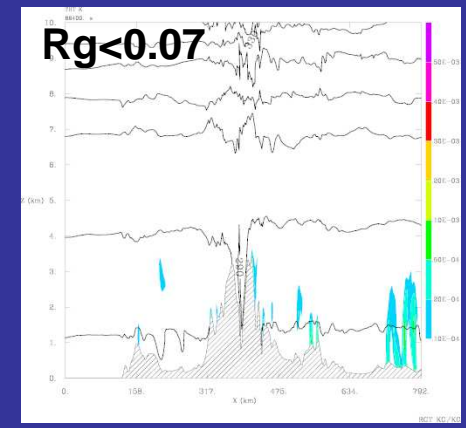
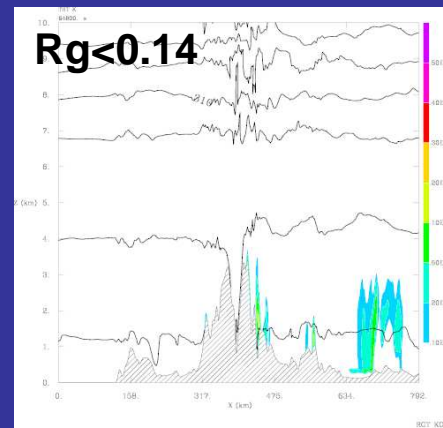
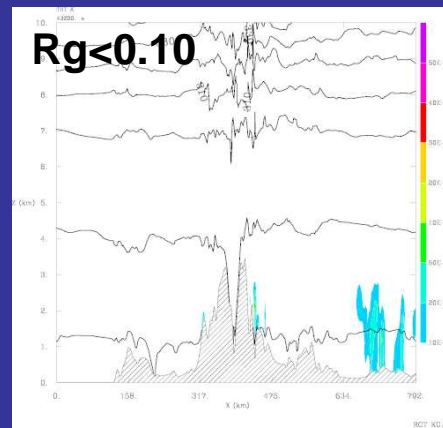
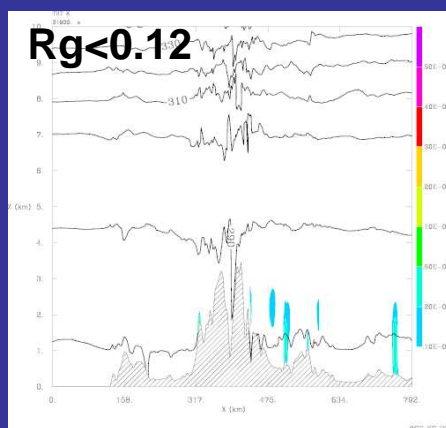
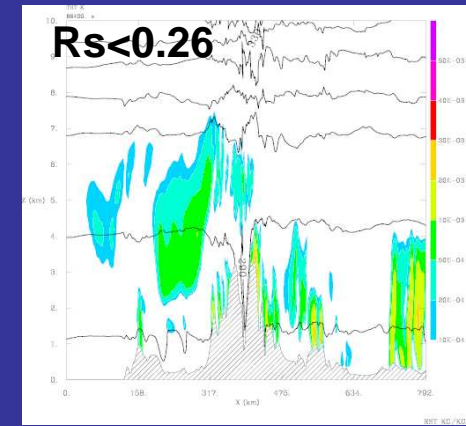
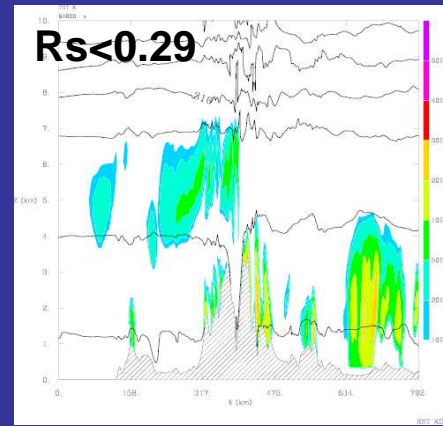
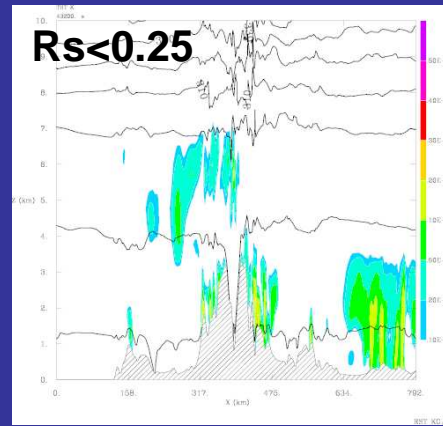
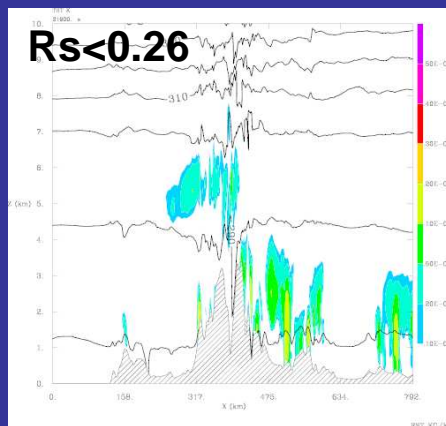
(single R/S, orography transect, $Z_0=0.5$ m, 24 hour wet run, $Dx=2.2$ km, $Dt=1$ s, « H3000 case » setup)

06 h

12 h

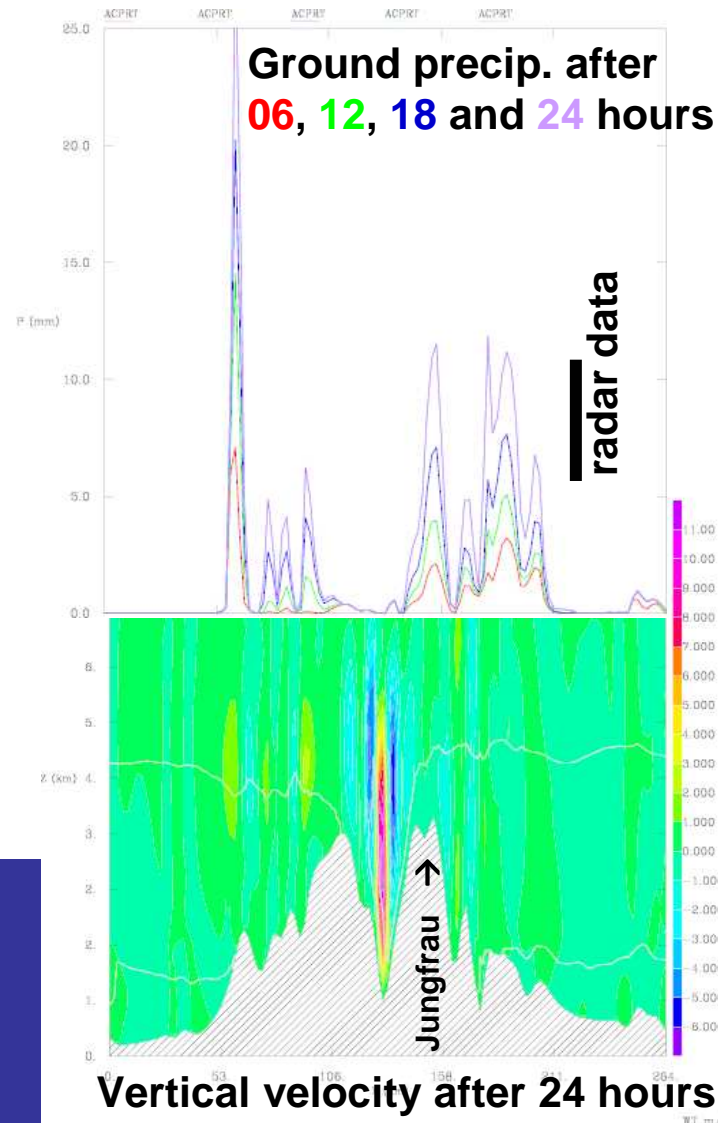
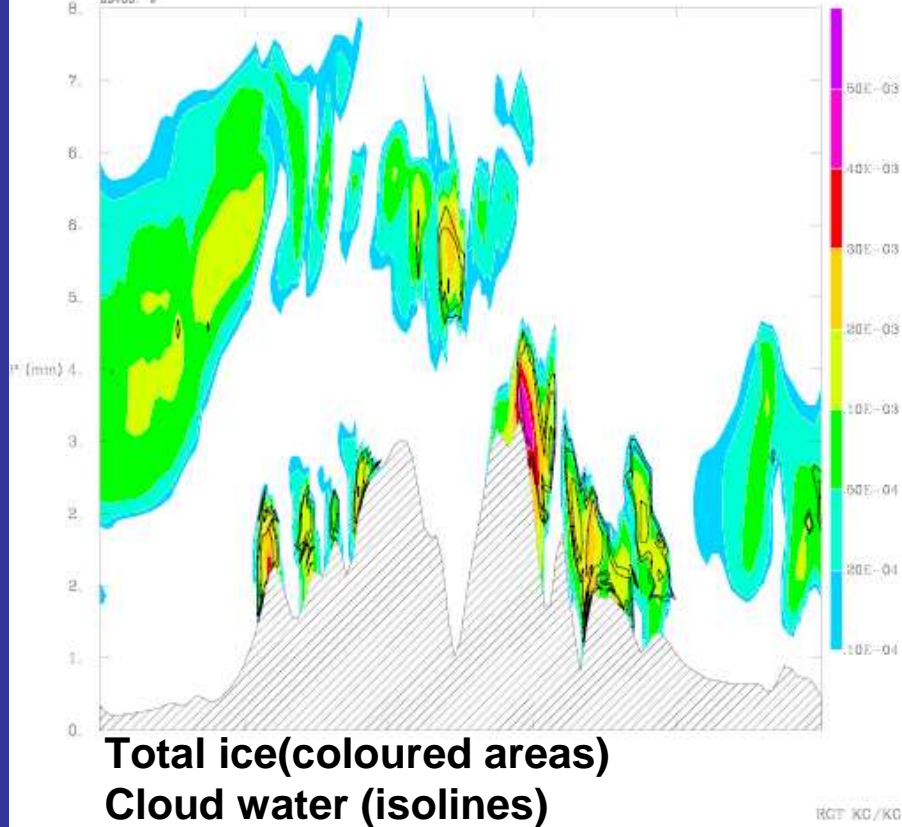
18 h

24 h



CASE1: «Jungfrau» case (precipitation and cloud fields *versus* orography)

After 24 h



Conclusion and Perspectives

- The study of orographic flow is a **good modeling exercise** in several respects:
 - **dynamics** : benchmark numerical schemes (transport & pressure gradient schemes), nearly stationary solution to some flow structure
 - **microphysics** : cloud and precipitation are sensitive to the vertical velocity of the gravity waves
 - **application to hydrology** : several types of precipitation, location of rainfall with respect to orography (=/= watersheds)
- The results shown here are recent and need a careful evaluation although the idealized «Jungfraujoch» transect simulation is **encouraging** when compared to composite radar data
- 2-moment **sensitivity to N_{CCN} and N_{IN}** clearly needs further investigations
- On-going developments will consider **multiple sources of CCN and IN** for the activation and the nucleation processes (S. Berthet's thesis)