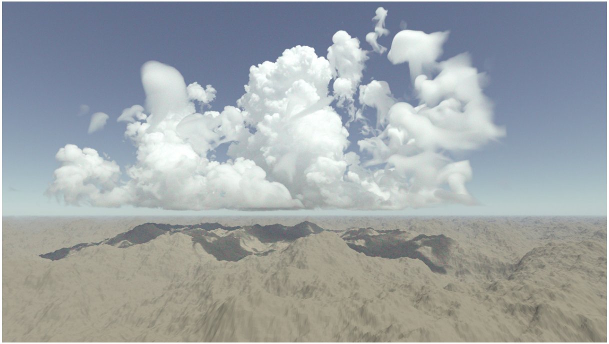
Diagnostics

Meso-NH Tutorial Class 1-4 December 2025



Outline

Online diagnostics

- Passive pollutants
- Lagrangian trajectories
- Temporal series
- LES
- Conditionnal sampling
- Ballons & Aircrafts
- Stations & Profilers
- Budgets

Offline diagnostics

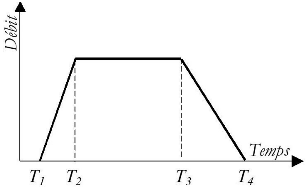
- DIAG program
  - Radar & Lidar simulators
  - Satellite images
- SPECTRE program

Passiv pollutants

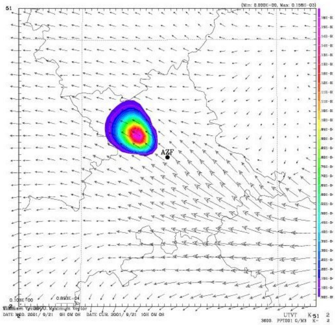
You can initialize passive pollutants, they will be advected and transported (by the turbulence scheme and convection (optional) during the simulation)
Ponctual release at the ground or in altitude of a pollutant mass with 3 stages for the emission rate. There are no deposition nor scavenging.

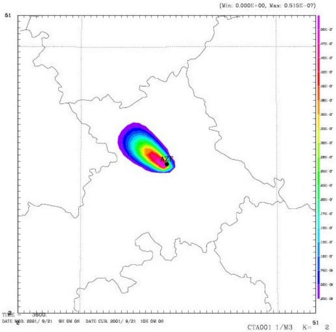
&NAM_PASPOL

```
LPASPOL = T ,
NRELEASE = 1 ,
CPPINIT(1) = "1PT" ,
XPPLAT(1) = 43.567 ,
XPPLON(1) = 1.439 ,
XPPBOT(1) = 10.0 ,
XPPTOP(1) = 500.0 ,
XPPMASS(1) = 10000000. ,
CPPT1(1) = "20010921090000",
CPPT2(1) = "20010921090000",
CPPT3(1) = "20010921091500",
CPPT4(1) = "20010921091500" /
```



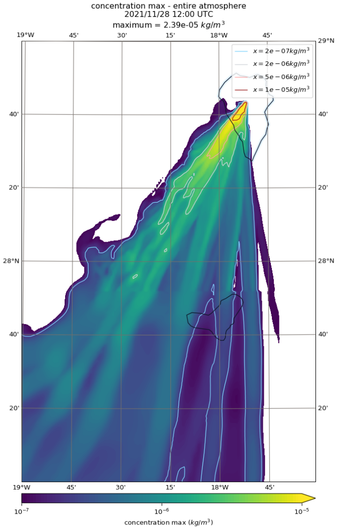
Ex : AZF on 21/09/2001 : 10 tons released from 9h to 9h15 on 500m



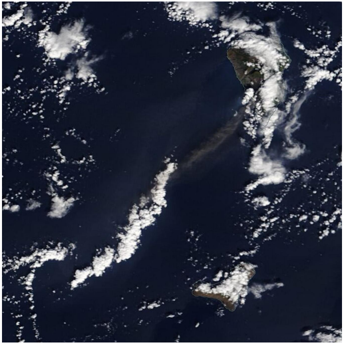


Concentration (g/m3) at 10h

Atmospheric coefficient transfer at 10h : integral and normalized concentration



Vertical maximum concentration at 12h UTC



La Palma volcanic eruption 28/10/2021 12h UTC (Terra)

Lagrangian trajectory

They are 3 special passive scalars because they are initialized with the spatial coordinates at the initial time. They are advected and transported during the simulation. They allow to plot fields on an iso-"initial altitude", trajectories ('parcel plumes') and back-trajectories, WITHOUT specifying the positions of the particules at the beginning of the simulation.

Documentation

`http://mesonh.aero.obs-mip.fr/`
section "`Books and Guides`",
Lagrangian Analyses' Documentation (Gheusi et Stein, mai 2005).

Lagrangian trajectory

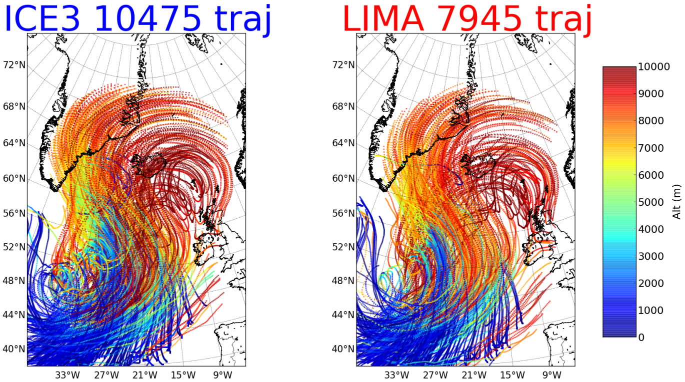
Namelists

- **EXSEG1.nam** in `&NAM_CONF`
  - **LLG=T** : to select the tracers
  - `LINIT_LG =T` : to reinit the valued at the beginning of each segment
  - `LNOMIXLG=T` : to desactivate the turbulent transport
- **EXSEGn.nam**
  - `&NAM_PARAM_KAFRn` : `LCHTRANS=T` to activate the convective transport.

Output fields

`LGXT,LGYT,LGZT(x,y,z) = position in meters of the point compared to the previous output`
in synchronous files CEXP.n.CSEG.00**n** (n>0)

Lagrangian trajectory : back-trajectory



Back-trajectories of the extratropical cyclone Stalactite (a warm conveyor belt) the 01-04 oct. 2016). Trajectories of parcels that were lifted by 600hPa over 48 hours are computed and plotted.

Python script example on the website

Temporal series

You can store prognostic variables during the simulation.

Three types of series :

- **(t)** : horizontally and vertically averaged values (in a box to be specified by its indexes Imin,Imax,Jmin,Jmax,Kmin,Kmax),
- **(z,t)** : horizontally averaged values (in an area to be specified by its indexes I,J)
- **(x,t)** : values at a given level K (or averaged between 2 levels) horizontallly added along y (in a slice to be specified by Jmin,Jmax).

Note :

You can code other types of storage by modifying the routines themselves (`ini_seriesn.f90`, `seriesn.f90`, `write_seriesn.f90`)

Temporal series

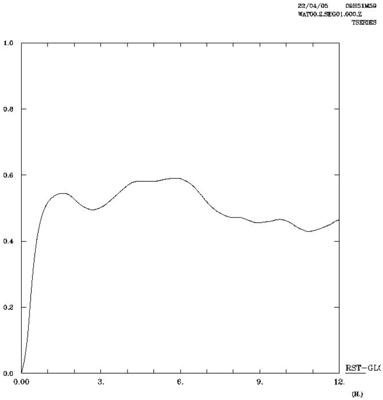
To do it :

- EXSEG1.nam : select the series with `LSERIES=T` in `&NAM_SERIES`
- EXSEGn.nam : specify the averaging areas, the slices, the levels and the storage frequency in `&NAM_SERIESn`.

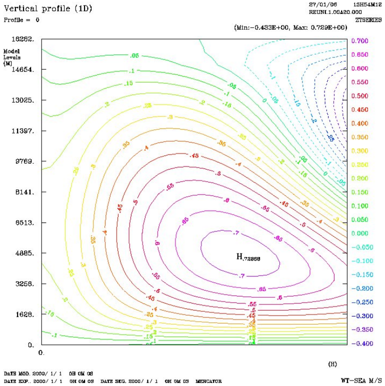
Outputs

Data are in the **TSERIES, ZTSERIES, XTSERIESnn** fields of the diachronic file CEXP.n.CSEG.**000**

Temporal series



snow mixing ratio (t)



vertical velocity (z,t)
averaged above sea mask

LES Diagnostics

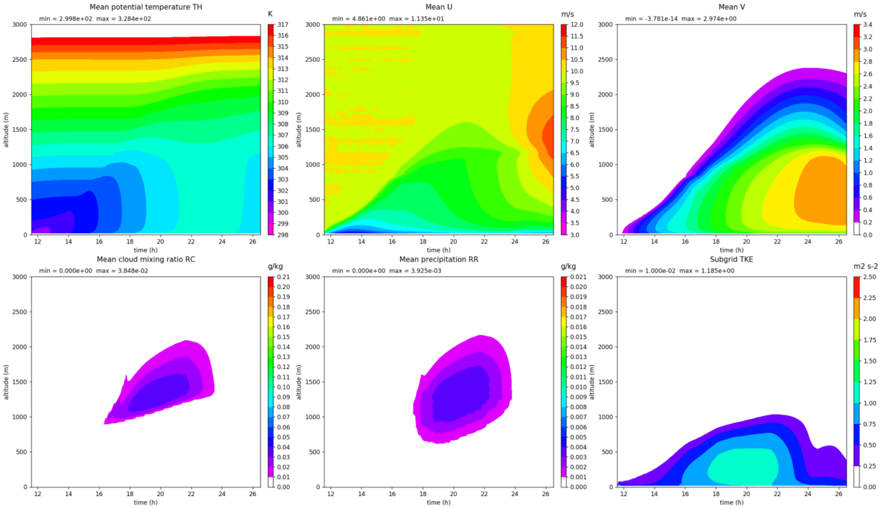
Writing of turbulent diagnostics (mainly used by Large Eddy Simulations) :

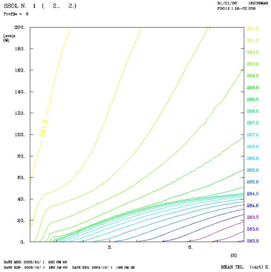
- temporal evolution of vertical profiles,
- temporal average and/or normalisation of vertical profiles.

To do it :

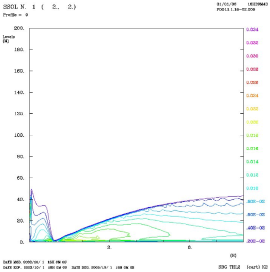
In file `EXSEG1.nam`, define the characteristics of the budgets in the namelist **&NAM_LES**

Data are in the diachronic file CEXP.n.CSEG.**000**

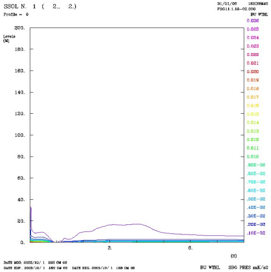

Mean potential temperature TH
min = 2.998e+02 max = 3.284e+02
K
Mean U
min = 4.861e+00 max = 1.135e+01
m/s
Mean V
min = -3.781e-14 max = 2.974e+00
m/s
Mean cloud mixing ratio RC
min = 0.000e+00 max = 3.848e-02
g/kg
Mean precipitation RR
min = 0.000e+00 max = 3.925e-03
g/kg
Subgrid TKE
min = 1.000e-02 max = 1.185e+00
m2 s-2
altitude (m)
time (h)



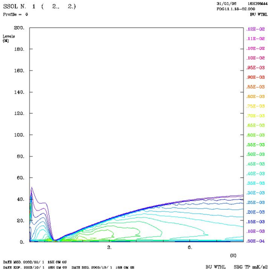
moyenne : $<\theta_l>$



covariance : $<\overline{\theta_l'^2}>$



bilan : $\left(\dfrac{\partial<\overline{w'\theta_l'}>}{\partial t}\right)_{pres}$



bilan : $\left(\dfrac{\partial<\overline{w'\theta_l'}>}{\partial t}\right)_{therm.prod.}$

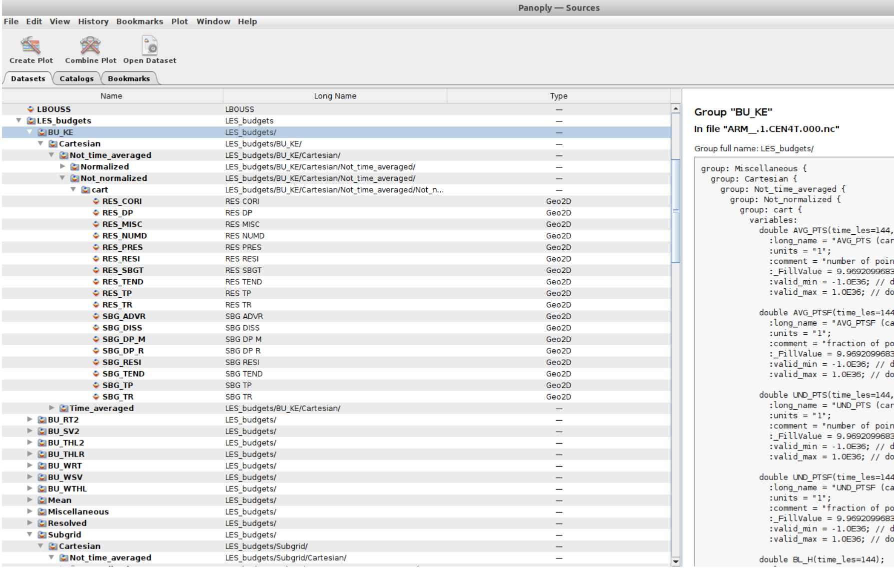
LES Diagnostics

All available variables are in appendix C of the user's guide

C.3 LES averaged fields (LLES_MEAN=TRUE)

field	notation in the diachronic file	dim.	if	comments
$< u >$	MEAN_U	z,t,p		dimension 'p' is equal to the number of masks when this dimension is not present, the computation is made only on the cartesian mask.
$< v >$	MEAN_V	z,t,p		
$< w >$	MEAN_W	z,t,p		
$< p >$	MEAN_PRE	z,t,p		
$< \rho >$	MEAN_RHO	z,t,p		
$< \theta >$	MEAN_TH	z,t,p		
$< \theta_l >$	MEAN_THL	z,t,p	r_c	
$< \theta_v >$	MEAN_THV	z,t,p	r_v	
$< r_v >$	MEAN_RV	z,t,p	r_v	
$< r_c >$	MEAN_RC	z,t,p	r_c	
$< r_r >$	MEAN_RR	z,t,p	r_r	
$< r_i >$	MEAN_RI	z,t,p	r_i	
$< r_s >$	MEAN_RS	z,t,p	r_s	
$< r_g >$	MEAN_RG	z,t,p	r_g	
$< r_h >$	MEAN_RH	z,t,p	r_h	
$< s_v >$	MEAN_SV	z,t,p,n	s_v	
$< \sqrt{\overline{u}^2 + \overline{v}^2} >$	MEAN_WIND	z,t,p		different from $\sqrt{< \overline{u} >^2 + < \overline{v} >^2}$!
$< \overline{\rho} \max(\overline{w}, < w >) >$	MEAN_MSFX	z,t,p		mean upward mass flux

LES Diagnostics in panoply



Conditionnal Sampling

Tracer emission with radioactive decay (Couvreux et al. 2010)

S' > m σ_s

3 tracers emission from

- The surface of the ground
- The cloud base
- The cloud top

Parameters in &NAM_CONDSAMP

- The period of radioative decay
- The scaling factor m
- The depth and offset of emissions
- The method for identifying the altitude of the cloud top

Object-oriented sampling

- *Definition of coherent structures* :

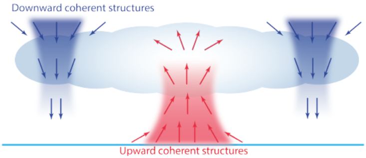
1. Ensemble of grid boxes satisfying the **conditional sampling CS =** $\{s'(x,y,z) > m^* \sigma_s(z)\}$ based on *Couvreux et. al (10)* (with s'(x,y,z) anomalies of tracer concentrations)
2. *Object* = Contiguous cells of positive CS (sharing face, edge, corner)
3. *Selected object* = Object with volume larger than V_{min}

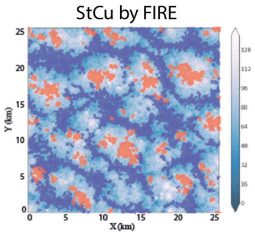
Collaborative project:
https://gitlab.com/tropics/objects

- *Advantages:*
  - **3D geometrical coherence**
  - Individual object characterisation
  - No **a priori** assumptions of flow characteristics (ω, q_l)

- *Main results for StCu*:
  - Objects cover **20%** of the volume, but contribute to **~80%** of moisture and temperature resolved fluxes
  - **Coherent downdrafts** matter !

Brient et. al, 19 (GRL)





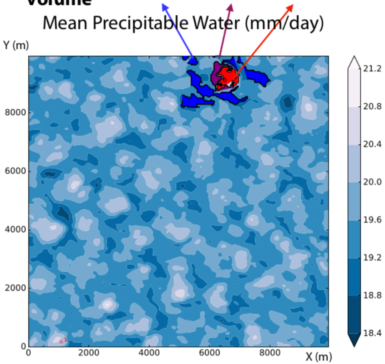
Characteristics of boundary layers

All Structures
Updraft
Entrained downdraft
Returning shells

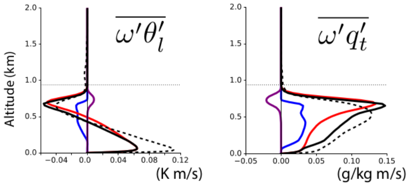
Convective Clear Sky (IHOP)

Domain-mean volume 11% 1% 13%

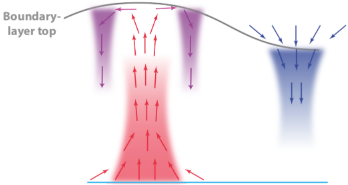
Mean Precipitable Water (mm/day)



Domain-mean resolved fluxes -----



- **Objects** contribute to **74/86%** of total heat/moisture fluxes (for **25%** of volume)



Balloons, aircrafts

You can store the prognostic fields along virtual aircraft (30 max.) and balloon trajectories (9 max.) during the simulation.

since MNH-V5.6.0

&NAM_FLYERS NAIRCRAFTS=1, NBALLONS=2 /

before MNH-V5.6.0

The ini_balloon.f90 routine allows to define the initial position of the balloons (iso-density type, constant volume or radio-sounding) which will be advected.
The ini_aircraft.f90 routine allows to define the aircraft trajectory.

Note :

Compute trajectories from the synchronous file with stationnary fields (`LAIRCRAFT_BALLOON` in `&NAM_DIAG` of DIAG1.nam).

Aircrafts

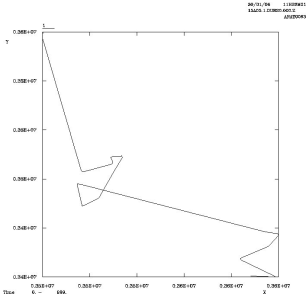
Definition of the stations positions in namelist **or** csv file.

&NAM_AIRCRAFTS

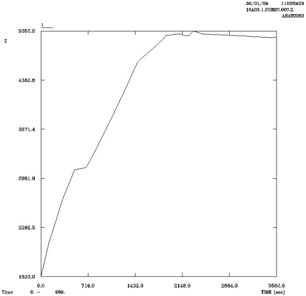
- number of aircrafts
- sampled domain for the flight (fixed or the finest grid)
- data storage frequency
- csv file name
- instant of take off

CSV file

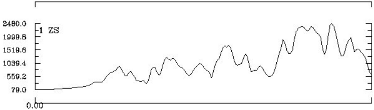
Time	Lat	Lon	Alt(p)
0.	45.	-4.	1003.6
150.	47.5	-.5	990.8
300.	50.	2.	988.1



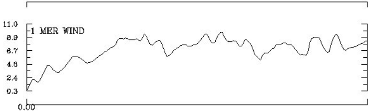
aircraft trajectory (x,y)



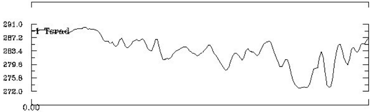
aircraft altitude (t)



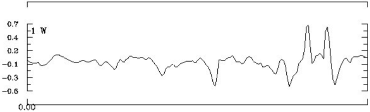
topography (t)



meridional wind (t)



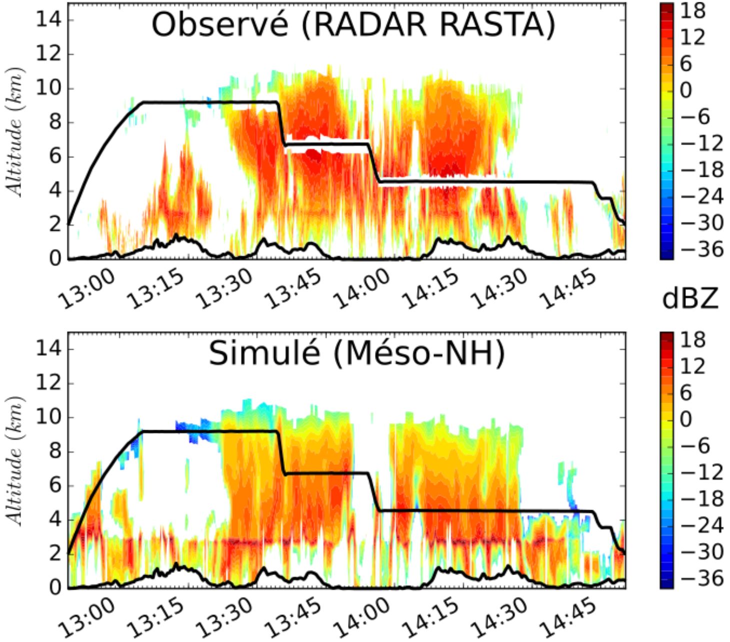
radiative surface temperature (t)



vertical velocity (t)

Data are in the diachronic file CEXP.n.CSEG.**000**

Aircraft



Observé (RADAR RASTA)
Simulé (Méso-NH)
Altitude (km)
14
12
10
8
6
4
2
0
13:00
13:15
13:30
13:45
14:00
14:15
14:30
14:45
dBZ
18
12
6
0
−6
−12
−18
−24
−30
−36

Balloons

Same options than aircrafts with the following additionnal options :

&NAM_BALLOONS

- type of balloon (iso-volume, iso-density or classic radiosounding)
- if iso-volume : diameter, volume or mass of balloon
- aerodynamic drag
- ascentional vertical speed for radiosounding (in calm air)

Stations, profilers

You can store prognostic fields and surface diagnostics at the profilers or stations locations during the simulation.

Before MNH-V5-6-0

The **ini_stationn.f90** routine allows to set the position of the stations (latitude, longitude and altitude)
The **ini_profilern.f90** routine allows to set the position of the profilers (latitude, longitude).

Data are stored in the diachronic file CEXP.n.CSEG.**000**

Stations, profilers (>MNH-V5-6-0)

Definition of the positions in namelist **or** csv file.

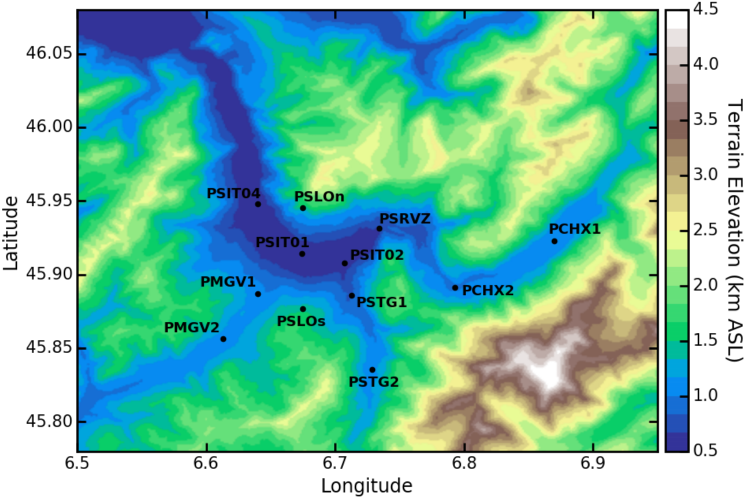
&NAM_STATIONn / &NAM_PROFILERSn

- number of stations/profilers
- time between two sampling written in the diachronic file
- X/Y (lat/lon) position of each station/profiler in the cartesian (conformal) coordinates
- altitude (in meters) of each station
- names of each station/profilers

CSV file

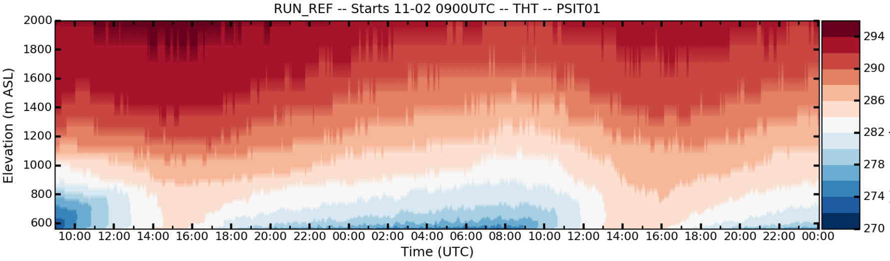
```
Name, X[m]/Lat[deg], Y[m]/Lon[deg], Z[m]
probe1, 50.0,  50.0, 10.0
probe2, 50.0,   1.0, 11.25
probe3, 350.0, 50.0, 10.0
```

Stations, profilers



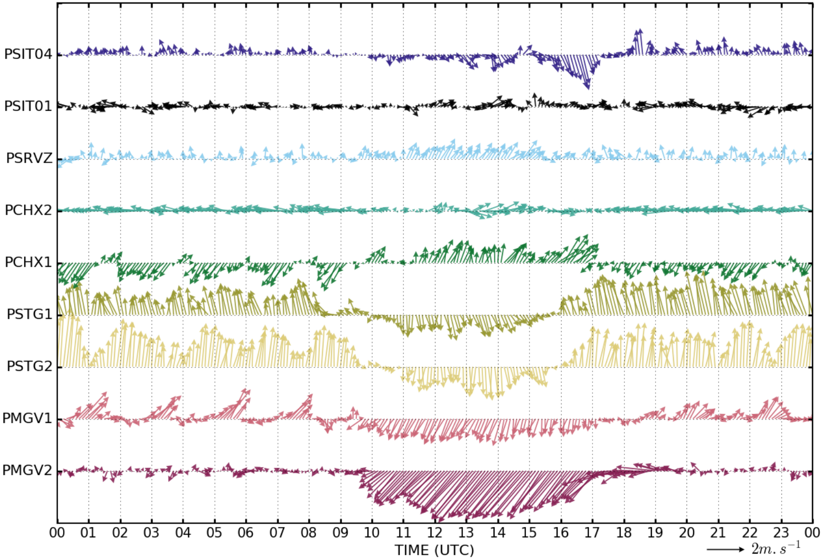
The Arve valley (Alpes, France)

Stations, profilers



Potential Temperature (z,t) at profileur PSIT01

Stations, profilers



Evolution of the wind at all stations

Budgets

You can store during the simulation the different source terms of the equation of every prognostic variable (u,v,w,θ,mixing ratio,TKE) :

- on a part of the simulation domain defined by
  - a box (Imin,Imax,Jmin,Jmax,Kmin,Kmax) : `CBUTYPE='CART'`
  - some areas selected according a criteria (ex : `WHERE XUM >0.`) evaluated at each timestep : `CBUTYPE='MASK'`
- optional spatial average to the 3 directions,
- optional temporal average to a specified duration.

Budgets

Activation

In file `EXSEG1.nam`, define the characteristics of the budgets in the namelist **&NAM_BUDGET**

In files `EXSEGn.nam`, choose the terms to be stored in the namelists

`&NAM_BU_RU LBU_RU=T, CBULIST_RU(1)='ADV', CBULIST_RU(2)='HTURB+VTURB' /` u

`&NAM_BU_RV /` v

`&NAM_BU_RW /` w

`&NAM_BU_RTH LBU_RTH=T, CBULIST_RTH(1)='ALL' /` θ

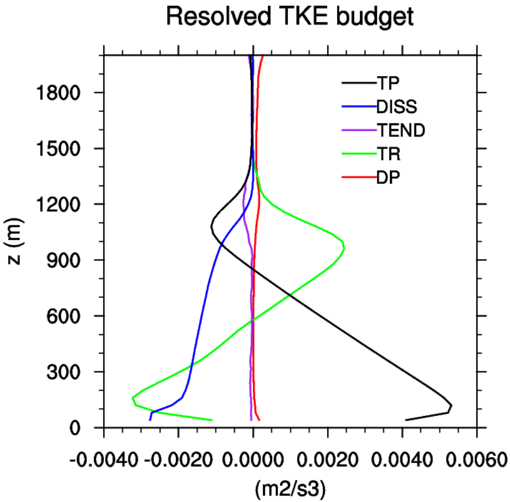
`&NAM_BU_RRV /` r_v

`&NAM_BU_RRR /` r_r`, etc`

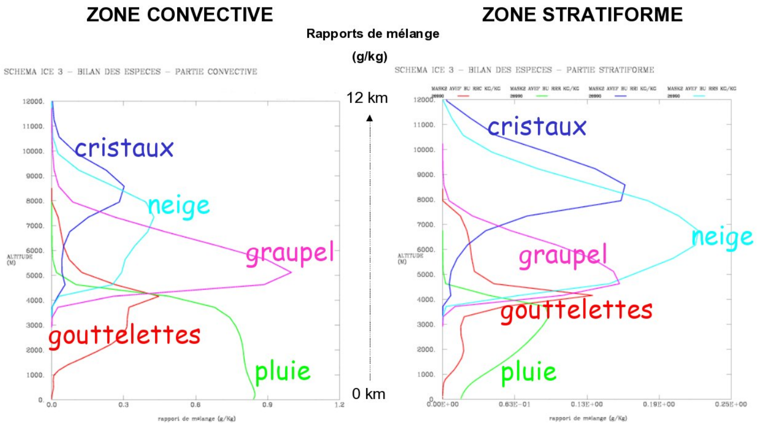
Data are in the diachronic file CEXP.n.CSEG.**000**

Budgets

$$\frac{DTKE}{Dt} = TP + TR + DISS + DP$$



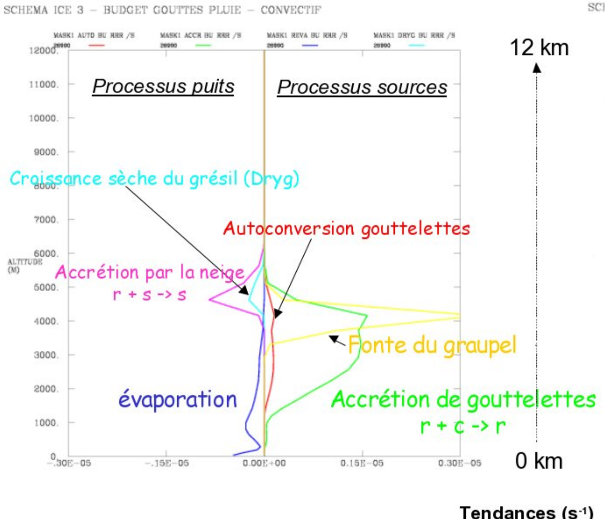
Budgets



ZONE CONVECTIVE
ZONE STRATIFORME
Rapports de mélange
(g/kg)
SCHEMA ICE 3 – BILAN DES ESPECES – PARTIE CONVECTIVE
SCHEMA ICE 3 – BILAN DES ESPECES – PARTIE STRATIFORME
12 km
0 km
cristaux
neige
graupel
gouttelettes
pluie
ALTITUDE (M)
rapport de mélange (g/Kg)

Budgets

$$\frac{Dr_r}{Dt} = DRYG + ACC\_SNOW + ACC\_DROP + EVAP + MELT + CONV$$



Program DIAG

To compute a large number of quantitites from a synchronous file :

- variables derived from prognostic ones (vorticities, 'moist' temperatures, integrated mixing ratios),
- to compare to radar, lidar, satellites data,
- diagnostics from physical parametrisations : convection, radiation and turbulence schemes,
- diagnostics of the externalized surface scheme,
- derived chemical, aerosols, dust and sea salt variables,
- interpolation on altitude, isobaric and isentropic levels of prognostic variables,
- Lagrangian trajectories with several start points,

See the whole list of diagnostic at chapter 10 of "the Meso–NH user's guide" (book3).

Program DIAG

Example of DIAG1.nam :

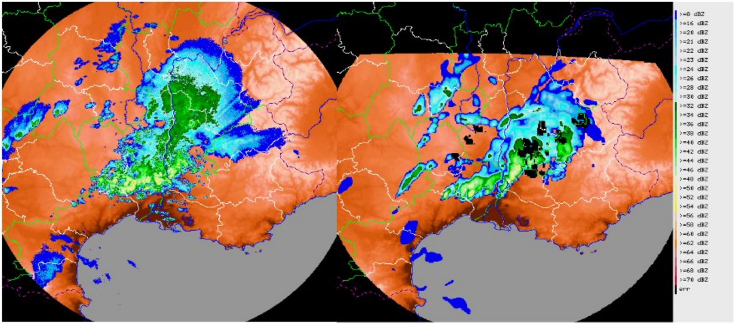
```
 &NAM_DIAG
CISO='TKPREV',
LVAR_RS=T,
LVAR_MRW=T,
NCONV_KF=1, NCAPE=1,
LTPZH=F,
LMOIST_V=F,
LMOIST_E=T,
LMSLP=T,
LTHW=T,
LCLD_COV=T,
LRADAR=F,
LDIAG(:)=.FALSE. /
```

```
 &NAM_DIAG_FILE
YINIFILE(1)= "16JT0.1.09A12.001" ,
YINIFILEPGD(1)= "FILE_PGD" ,
YSUFFIX = "dg" /

&NAM_KAFR_PARAMn /
&NAM_RAD_PARAMn /
&NAM_DIAG_SURFn
N2M=2 LSURF_BUDGET=T /
&NAM_DIAG_ISBAn
LPGD=F LSURF_EVAP_BUDGET=T /
```

See the whole list of diagnostic at chapter 10 of "the Meso–NH user's guide" (book3).

Radar simulator

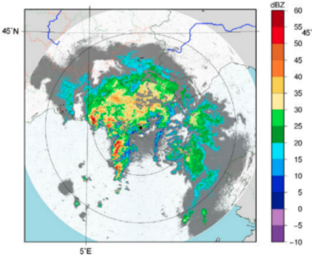


Réflectivités observées *Réflectivités simulées avec Méso-NH*

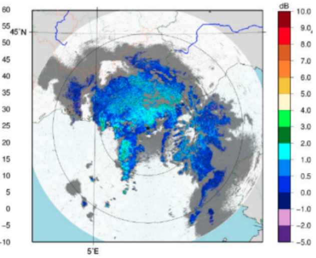
(radar de Bollène le 8 sep. 2002 à 21 UTC, élévation=1,2°)

- LRADAR=T
- you have to specify the version : NVERSION_RAD= 1 or 2

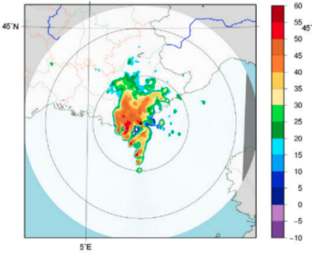
Polarimetric radar simulator, elevation = 1.4°



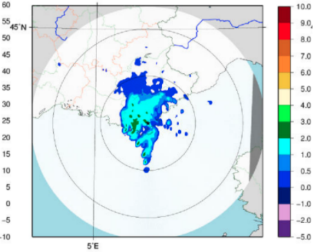
Zhh radar (dBZ)



Zdr radar (dB)

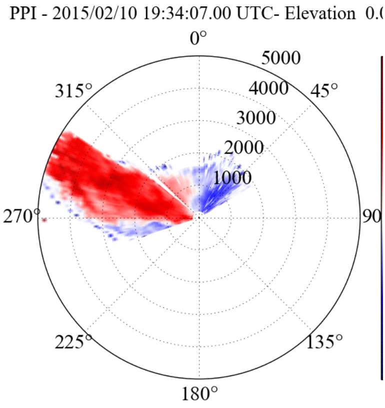


Zhh modèle (dBZ)

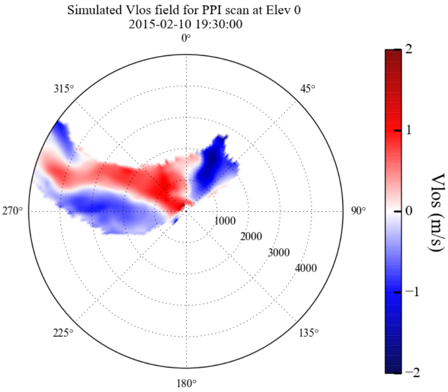


Zdr modèle (dB)

Radar simulator

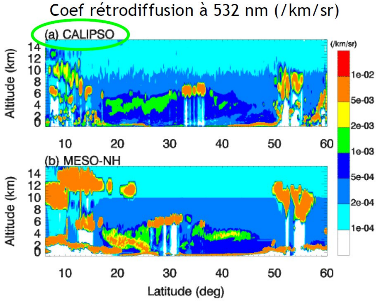


Observed radial velocity



Simulated radial velocity

Lidar simulator

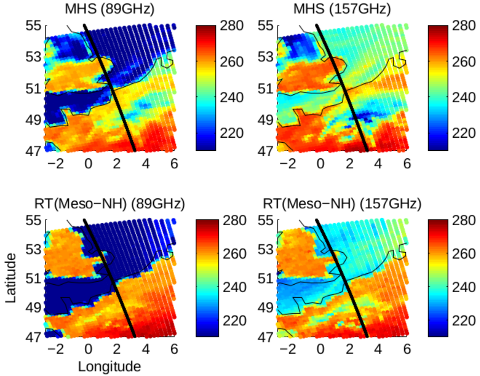


Chaboureau et al , QJRMS 2011

In &NAM_DIAG / :

- LLIDAR=T
- CVIEW_LIDAR= : lidar point of vew 'NADIR' or 'ZENIT'
- XALT_LIDAR=0 : altitude of lidar in meters
- XWVL_LIDAR=0.532E-6 : wavelength of lidar in meters

Satellite images simulator (brightness temperature)



In &NAM_DIAG :

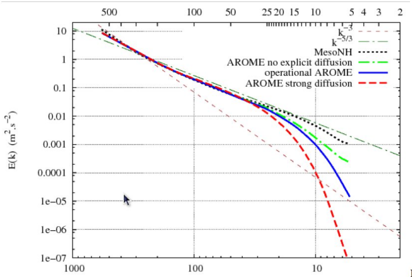
- CRAD_SAT= type of satellite
- Water vapor or IR channel
- with/without subgrid condensation scheme taken into account
- Highly recommended to use RTTOV (see the doc)

Program SPECTRE

Example SPEC1.nam :

```
&NAM_SPECTRE
LSPECTRE_U=.TRUE.,
LSPECTRE_V=.TRUE.,
LSPECTRE_W=.TRUE.,
LSPECTRE_TH=.TRUE.,
LSPECTRE_RV=.TRUE.,
LSPECTRE_LSU=.FALSE.,
LSPECTRE_LSV=.FALSE.,
LSPECTRE_LSW=.FALSE.,
LSPECTRE_LSTH=.FALSE.,
LSPECTRE_LSRV=.FALSE.,
LSMOOTH=.TRUE./
&NAM_ZOOM_SPECTRE
LZOOM=.FALSE.,
NXDEB=10,
NYDEB=20,
NITOT=20,
NJTOT=30/
&NAM_DOMAIN_AROME /

&NAM_SPECTRE_FILE
       YINIFILE(1) = "16JAN.1.12B18.001",
       CTYPEFILE='MESONH'/
```



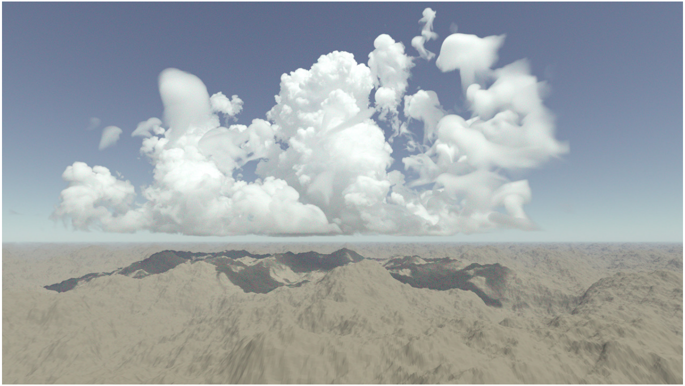
Spectres EC AROME et MesoNH, Δz=3-9 km, 11/042007 13-17UTC

Δx=2.5km

Ricard, D., C.Lac and S.Riette, *Soumis QJRMS*

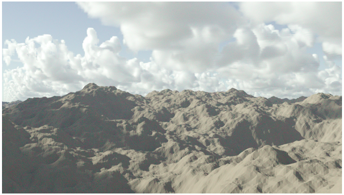
HTRDR : High-Tune RenDeRer

Monte-Carlo radiative transfer simulator + Méso-NH LES

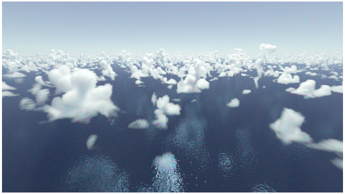


https ://www.meso-star.com
http ://www.umr-cnrm.fr/high-tune
https ://gitlab.com/meso-star/htrdr

Clouds renderer HTRDR

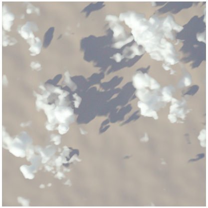


ARM continental cumulus



BOMEX oceanic cumulus

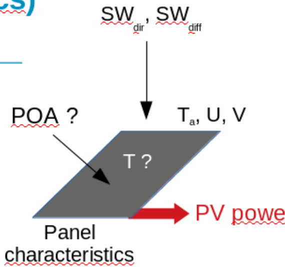
FIRE stratocumulus

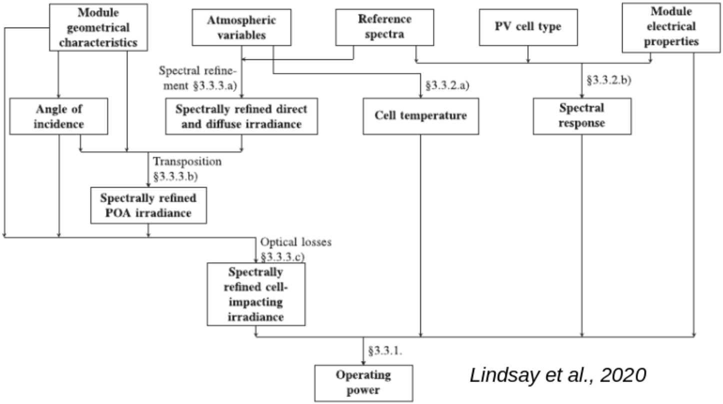


top view of continental cumulus

WO2PV (Weather outputs to PhotoVoltaics)

- A code to convert atmospheric variables into PV production
- Based on **physical principles** (no free parameter)
- Available through GitHub (https://github.com/liboisq/WO2PV)
- Practical use :
  → model output (e.g. Meso-NH)
  → in situ observations

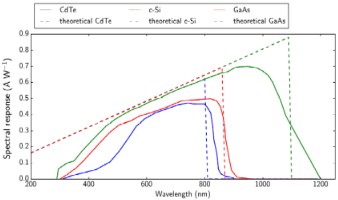




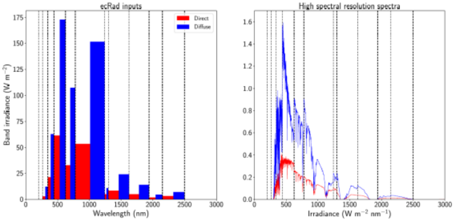
Lindsay et al., 2020

WO2PV (Weather outputs to PhotoVoltaics)

- Many models just use Global Horizontal Irradiance from forecasts (GHI) $= SW_{dir} + SW_{diff}$
- Then machine learning or very basic physical models to reconstruct the dir/diff components
  → overall **loss of information from atmospheric radiative code**
- Specificity of the code = treatment of detailed spectral information



Spectral responses of various solar cells



Spectral enhancement of band outputs

The efficiency of a panel depends on the nature of the incident spectrum
(cf broadband albedo of a surface)

METEO FRANCE