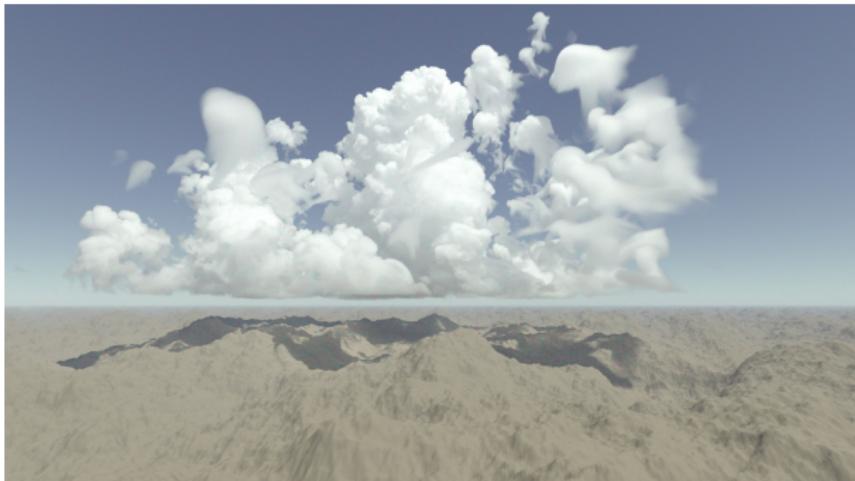


# Diagnostics

Meso-NH Tutorial Class 12-15 November 2024



# 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

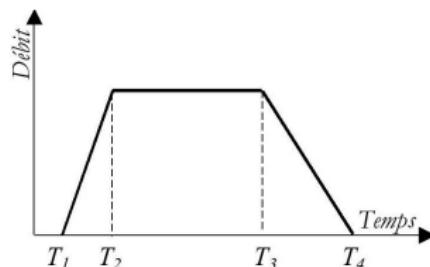
## Passiv pollutants

You can initialize passive pollutants, they will be advected and transported (by the turbulence scheme and convection (optional) during the simulation)

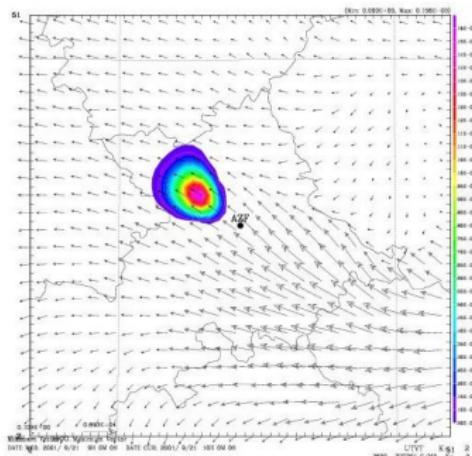
Ponctual release at the ground or in altitude of a pollutant mass with 3 stages for the emission rate. There are no deposition nor scavenging.

&NAM\_PASPOL

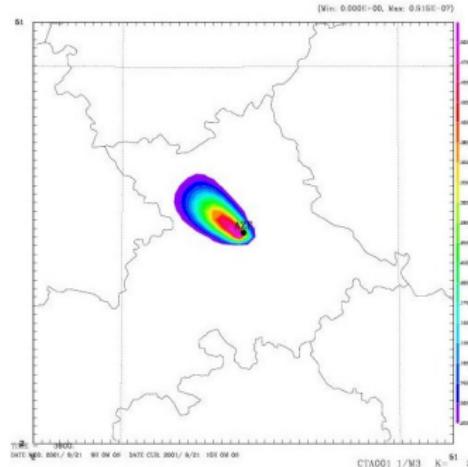
```
LPASPOL = T,  
NRELEASE = 1,  
CPPINIT(1) = "1PT" ,  
XPPLAT(1) = 43.567 ,  
XPPLON(1) = 1.439 ,  
XPPBOT(1) = 10.0 ,  
XPPTOP(1) = 500.0 ,  
XPPMASS(1) = 10000000. ,  
CPPT1(1) = "20010921090000" ,  
CPPT2(1) = "20010921090000" ,  
CPPT3(1) = "20010921091500" ,  
CPPT4(1) = "20010921091500" /
```



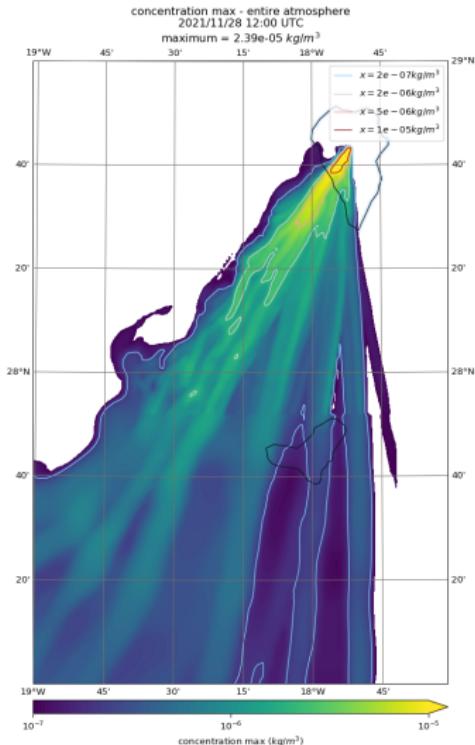
Ex : AZF on 21/09/2001 : 10 tons released from 9h to 9h15 on 500m



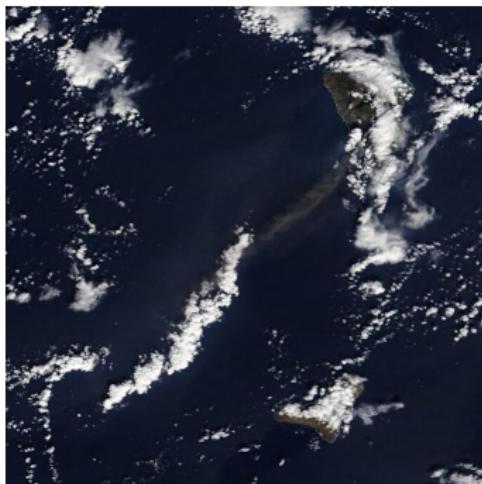
Concentration ( $\text{g}/\text{m}^3$ ) at 10h



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 particles 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

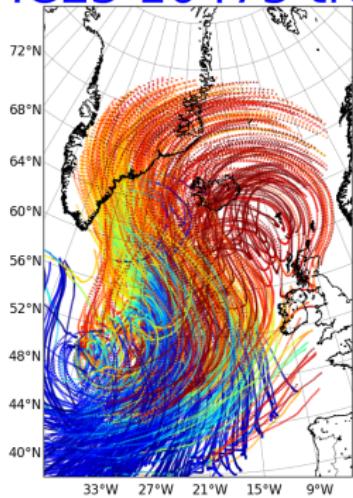
- ▶ EXSEG1.nam in &NAM\_CONF
  - ▶ LLG=T : to select the tracers
  - ▶ LINIT\_LG =T : to reinit the valued at the beginning of each segment
  - ▶ LNOMIXLG=T : to desactivate the turbulent transport
- ▶ EXSEGn.nam
  - ▶ &NAM\_PARAM\_KAFRn : LCHTRANS=T to activate the convective transport.

## Output fields

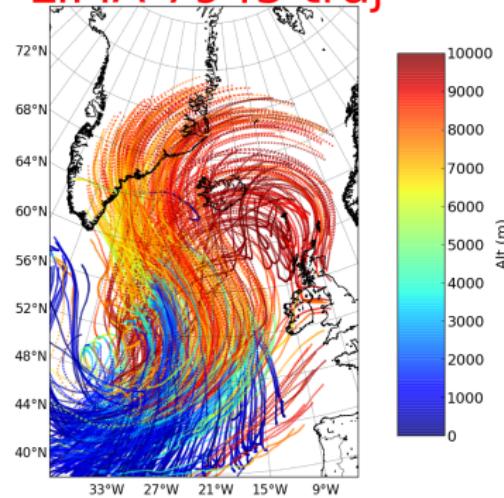
LGXT, LGYT, LGZT(x,y,z) = position in meters of the point compared to the previous output in synchronous files CEXP.n.CSEG.00n (n>0)

# Lagrangian trajectory : back-trajectory

ICE3 10475 traj



LIMA 7945 traj



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) horizontally 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

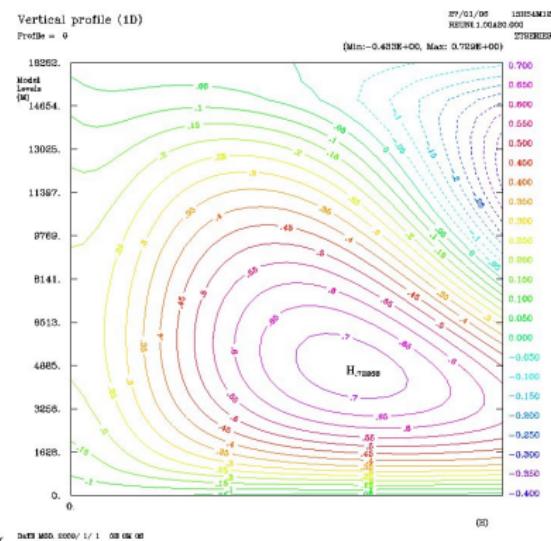
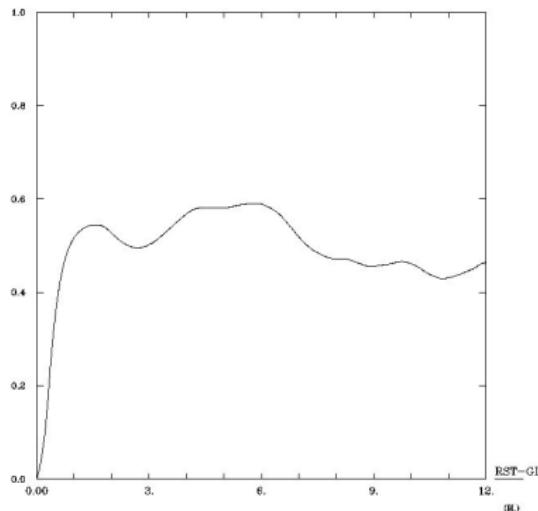
To do it :

- ▶ 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



vertical velocity ( $z, t$ )  
averaged above sea mask

## LES Diagnostics

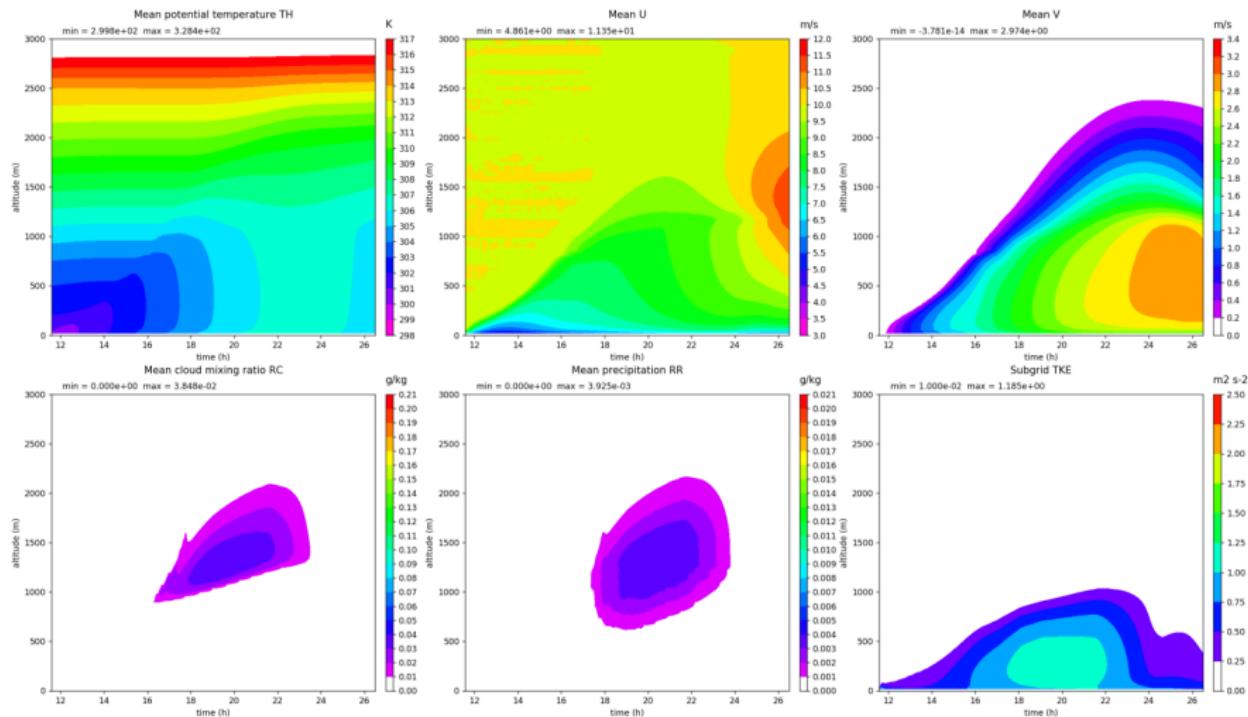
Writing of turbulent diagnostics (mainly used by Large Eddy Simulations) :

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

To do it :

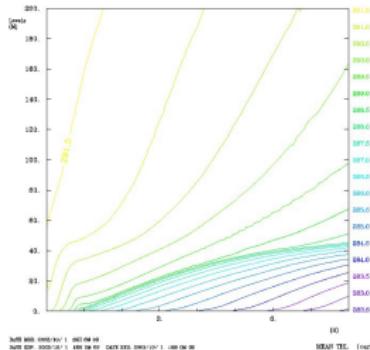
In file EXSEG1.nam, define the characteristics of the budgets in the namelist **&NAM\_LES**

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



SSOL N. 1 ( -2.. -2.)  
Profle = 4

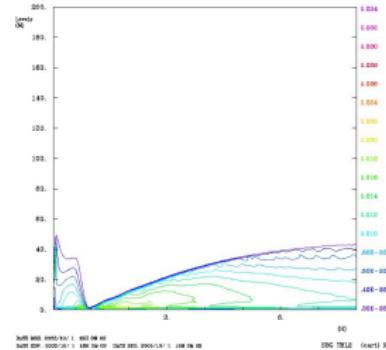
06/01/95 00020844  
PS011.118--02.00



$$\text{moyenne : } \langle \theta_l \rangle$$

SSOL N. 1 ( -2.. -2.)  
Profle = 4

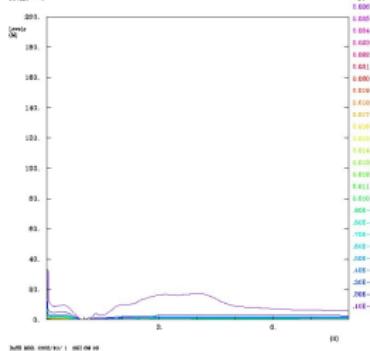
06/01/95 00020844  
PS011.118--02.00



$$\text{covariance : } \langle \overline{\theta_l'^2} \rangle$$

SSOL N. 1 ( -2.. -2.)  
Profle = 4

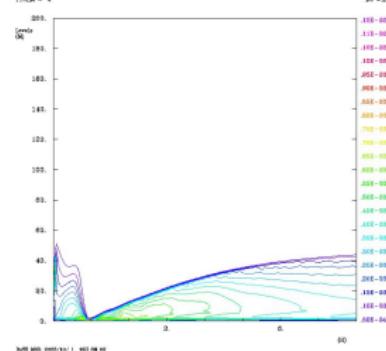
06/01/95 00020844  
PS011.118--02.00  
DO WIND



$$\text{bilan : } \left( \frac{\partial \langle \overline{w' \theta'_l} \rangle}{\partial t} \right)_{\text{pres}}$$

SSOL N. 1 ( -2.. -2.)  
Profle = 4

06/01/95 00020844  
PS011.118--02.00  
DO WIND



$$\text{bilan : } \left( \frac{\partial \langle \overline{w' \theta'_l} \rangle}{\partial t} \right)_{\text{therm.prod.}}$$

# 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
$\langle u \rangle$	MEAN_U	z,t,p		
$\langle v \rangle$	MEAN_V	z,t,p		
$\langle w \rangle$	MEAN_W	z,t,p		
$\langle p \rangle$	MEAN_PRE	z,t,p		
$\langle \rho \rangle$	MEAN_RHO	z,t,p		
$\langle \theta \rangle$	MEAN_TH	z,t,p		
$\langle \theta_l \rangle$	MEAN_THL	z,t,p	$r_c$	
$\langle \theta_v \rangle$	MEAN_THV	z,t,p	$r_v$	
$\langle r_v \rangle$	MEAN_RV	z,t,p	$r_v$	
$\langle r_c \rangle$	MEAN_RC	z,t,p	$r_c$	
$\langle r_r \rangle$	MEAN_RR	z,t,p	$r_r$	
$\langle r_i \rangle$	MEAN_RI	z,t,p	$r_i$	
$\langle r_s \rangle$	MEAN_RS	z,t,p	$r_s$	
$\langle r_g \rangle$	MEAN_RG	z,t,p	$r_g$	
$\langle r_h \rangle$	MEAN_RH	z,t,p	$r_h$	
$\langle s_v \rangle$	MEAN_SV	z,t,p,n	$s_v$	
$\langle \sqrt{u^2 + v^2} \rangle$	MEAN_WIND	z,t,p		different from $\sqrt{\langle u \rangle^2 + \langle v \rangle^2}$ !
$\langle \bar{\rho} \max(\bar{w}, \langle w \rangle) \rangle$	MEAN_MSFX	z,t,p		mean upward mass flux

# LES Diagnostics in panoply

Panoply — Sources

File Edit View History Bookmarks Plot Window Help

Create Plot Combine Plot Open Dataset

Datasets Catalogs Bookmarks

Name	Long Name	Type
LBOUSS	LBOUSS	--
LES_budgets	LES_budgets	--
BU_KE	LES_budgets/BU_KE/	--
Cartesian	LES_budgets/BU_KE/Cartesian/	--
Not_time_averaged	LES_budgets/BU_KE/Cartesian/Not_time_averaged/	--
Normalized	LES_budgets/BU_KE/Cartesian/Not_time_averaged/Normalized	--
Not_normalized	LES_budgets/BU_KE/Cartesian/Not_time_averaged/Not_normalized/	--
cart	LES_budgets/BU_KE/Cartesian/Not_time_averaged/Not_normalized/cart	--
RES_CORI	RES CORI	Geo2D
RES_DP	RES DP	Geo2D
RES_MISC	RES MISC	Geo2D
RES_NUMD	RES NUMD	Geo2D
RES_PRES	RES PRES	Geo2D
RES_RESI	RES RESI	Geo2D
RES_SGBT	RES SGBT	Geo2D
RES_TEND	RES TEND	Geo2D
RES_TP	RES TP	Geo2D
RES_TR	RES TR	Geo2D
SBG_ADVVR	SBG ADVVR	Geo2D
SBG_DISS	SBG DISS	Geo2D
SBG_DP_M	SBG DP M	Geo2D
SBG_DP_R	SBG DP R	Geo2D
SBG_RESI	SBG RESI	Geo2D
SBG_TEND	SBG TEND	Geo2D
SBG_TP	SBG TP	Geo2D
SBG_TR	SBG TR	Geo2D
Time_averaged	LES_budgets/BU_KE/Cartesian/Time_averaged/	--
BU_RT2	LES_budgets/BU_RT2	--
BU_SW2	LES_budgets/BU_SW2	--
BU_THL2	LES_budgets/BU_THL2	--
BU_THLR	LES_budgets/BU_THLR	--
BU_WRT	LES_budgets/BU_WRT	--
BU_WSV	LES_budgets/BU_WSV	--
BU_WTHL	LES_budgets/BU_WTHL	--
Mean	LES_budgets/Mean	--
Miscellaneous	LES_budgets/Miscellaneous	--
Resolved	LES_budgets/Resolved	--
Subgrid	LES_budgets/Subgrid/	--
Cartesian	LES_budgets/Subgrid/Cartesian/	--
Not_time_averaged	LES_budgets/Subgrid/Not_time_averaged/	--

**Group "BU\_KE"**  
In file "ARM\_.1.CEN4T.0000.nc"

Group full name: LES\_budgets/BU\_KE

```

group: Miscellaneous {
  group: Cartesian {
    group: Not_time_averaged {
      group: Not_normalized {
        group: cart {
          variables:
            double AVG PTS(time_le=144):long_name = "AVG PTS (car";
            :units = "1";
            :comment = "number of points";
            :FillValue = 9.9692099683;
            :valid_min = -1.0E36; // do not use
            :valid_max = 1.0E36; // do not use
        }
      }
      double AVG PTSF(time_le=144):long_name = "AVG PTSF (car";
      :units = "1";
      :comment = "fraction of points";
      :FillValue = 9.9692099683;
      :valid_min = -1.0E36; // do not use
      :valid_max = 1.0E36; // do not use
    }
    double UND PTS(time_le=144):long_name = "UND PTS (car";
    :units = "1";
    :comment = "number of points";
    :FillValue = 9.9692099683;
    :valid_min = -1.0E36; // do not use
    :valid_max = 1.0E36; // do not use
  }
  double UND PTSF(time_le=144):long_name = "UND PTSF (car";
  :units = "1";
  :comment = "fraction of points";
  :FillValue = 9.9692099683;
  :valid_min = -1.0E36; // do not use
  :valid_max = 1.0E36; // do not use
}
double BL H(time_le=144);

```

# Conditionnal Sampling

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

$$S' > m \sigma_s$$

3 tracers emission from

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

Parameters in &NAM\_CONDSAMP

- ▶ The period of radioactive 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>

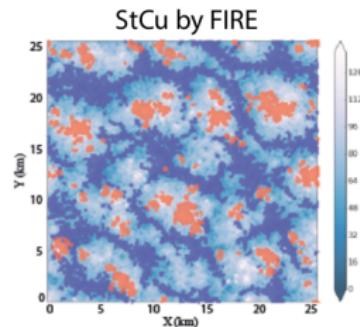
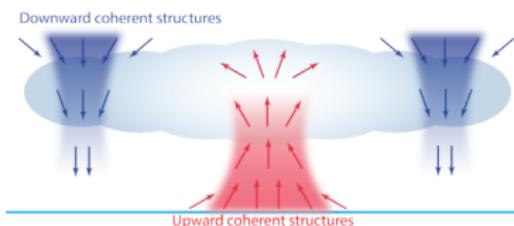
- Advantages:

- **3D geometrical coherence**
- Individual object characterisation
- No **a priori** assumptions  
of flow characteristics ( $\omega, q$ )

- 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

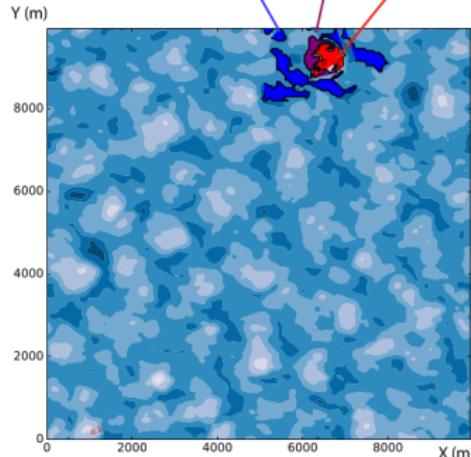
Entrained downdraft

## Convective Clear Sky (IHOP)

Domain-mean  
volume

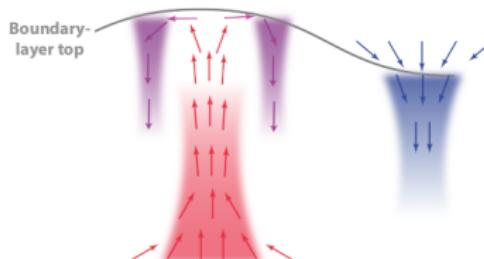
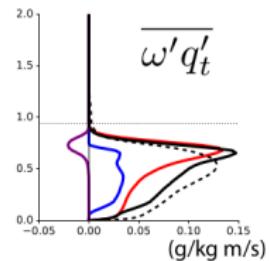
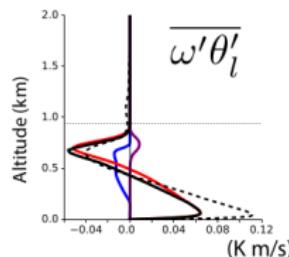
11%  
1%  
13%

Mean Precipitable Water (mm/day)



Returning shells

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

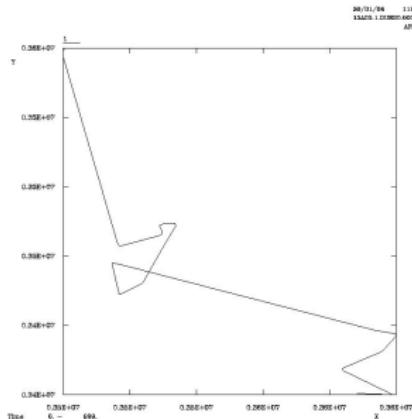
Definition of the stations positions in namelist **or** csv file.

## &NAM\_AIRCRAFTS

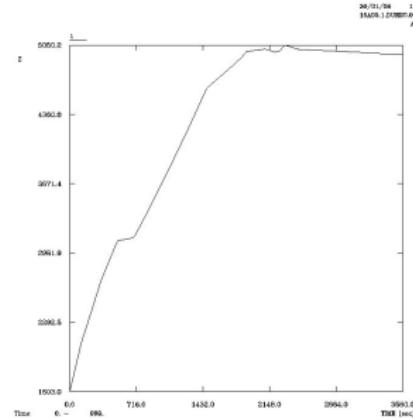
- ▶ number of aircrafts
- ▶ sampled domain for the flight (fixed or the finest grid)
- ▶ data storage frequency
- ▶ csv file name
- ▶ instant of take off

## CSV file

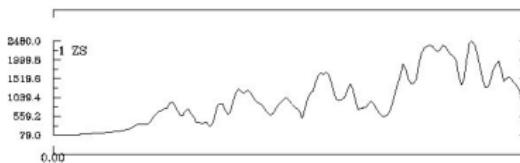
Time	Lat	Lon	Alt (p)
0.	45.	-4.	1003.6
150.	47.5	-.5	990.8
300.	50.	2.	988.1



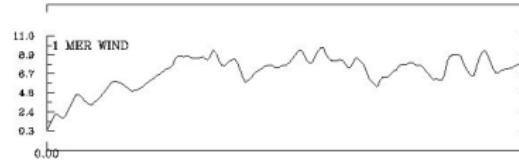
aircraft trajectory (x,y)



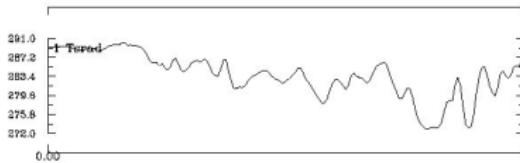
aircraft altitude (t)



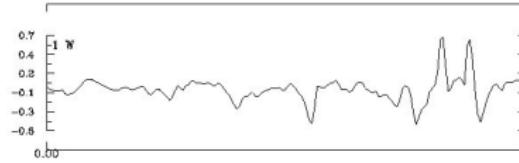
topography (t)



meridional wind (t)



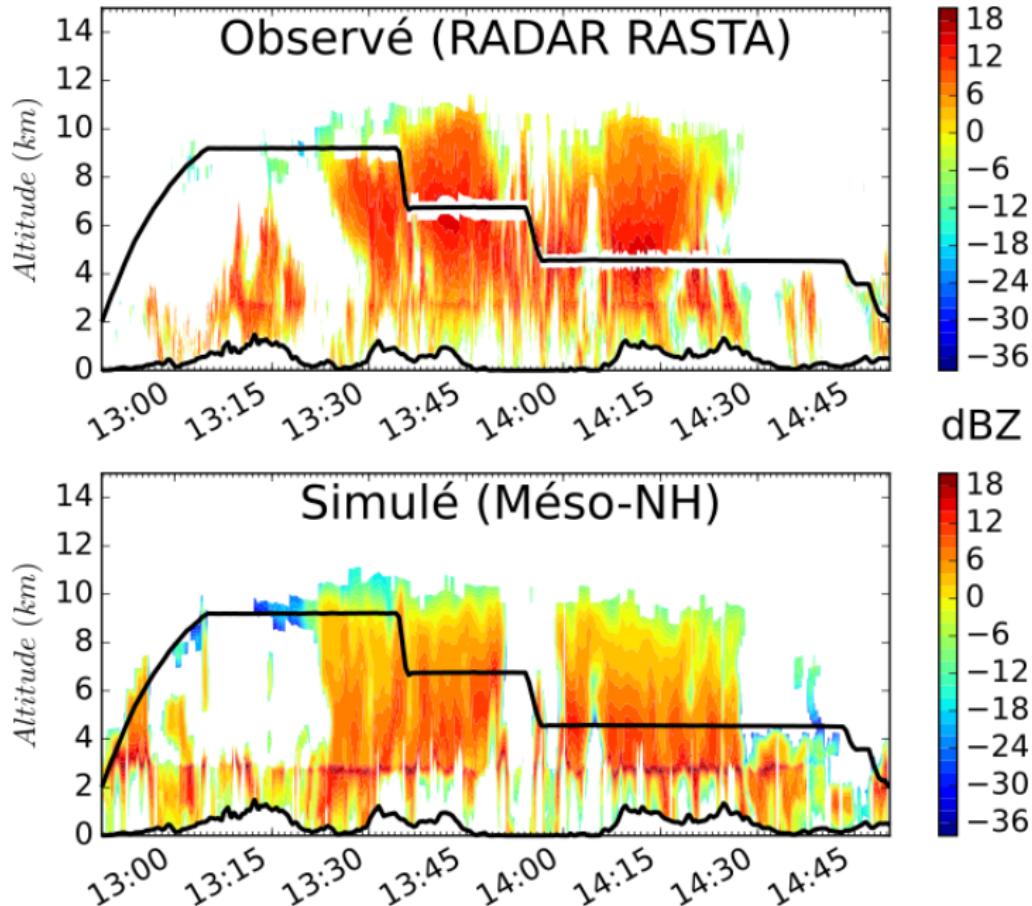
radiative surface temperature ( $t$ )



vertical velocity (t)

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

# Aircraft



# 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.

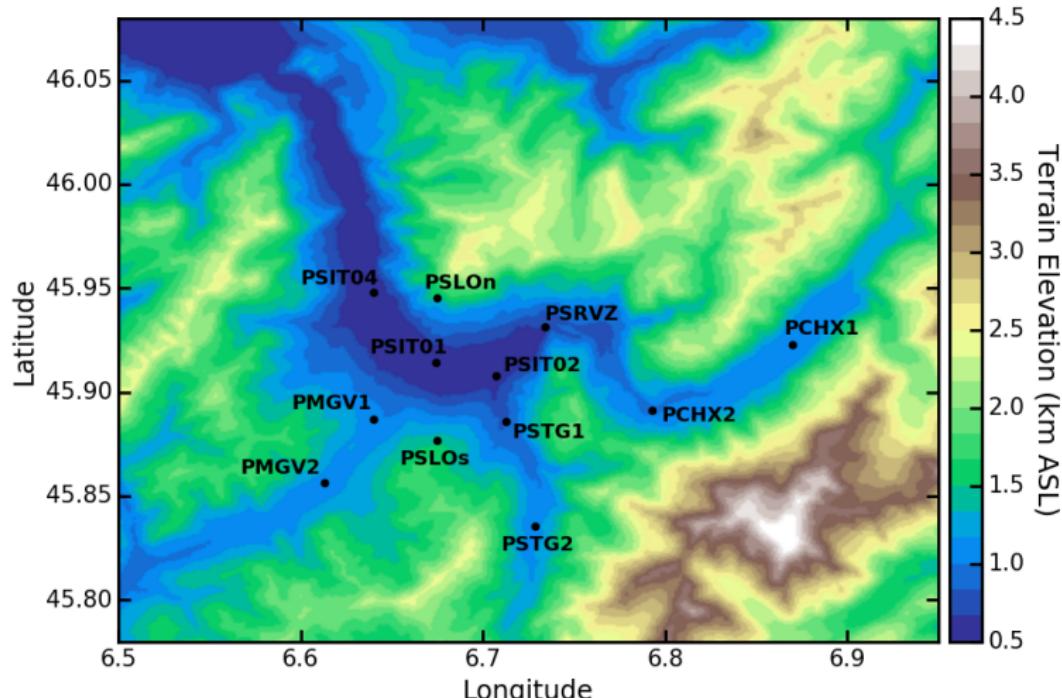
### &NAM\_STATIONn / &NAM\_PROFILERSn

- ▶ 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

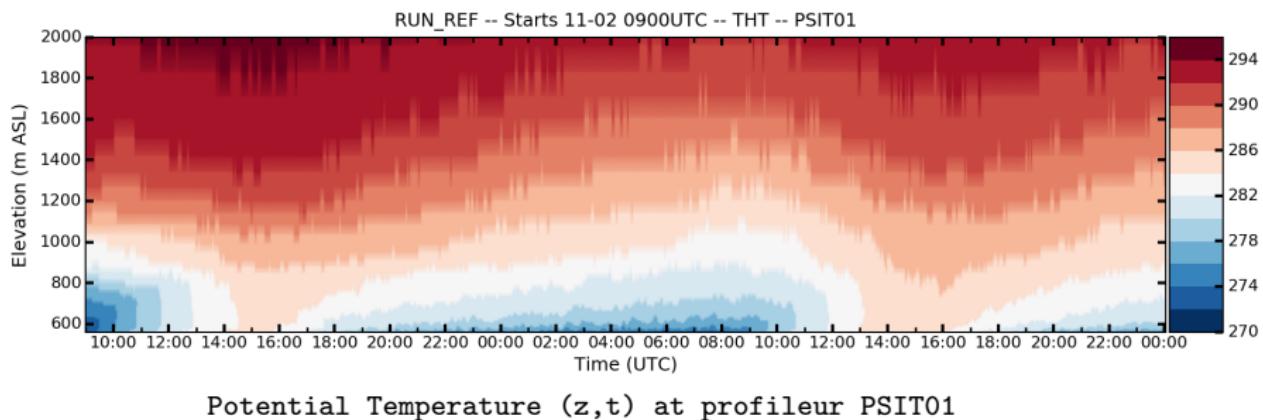
Name, X[m]/Lat[deg], Y[m]/Lon[deg], Z[m]
probe1, 50.0, 50.0, 10.0
probe2, 50.0, 1.0, 11.25
probe3, 350.0, 50.0, 10.0

# Stations, profilers

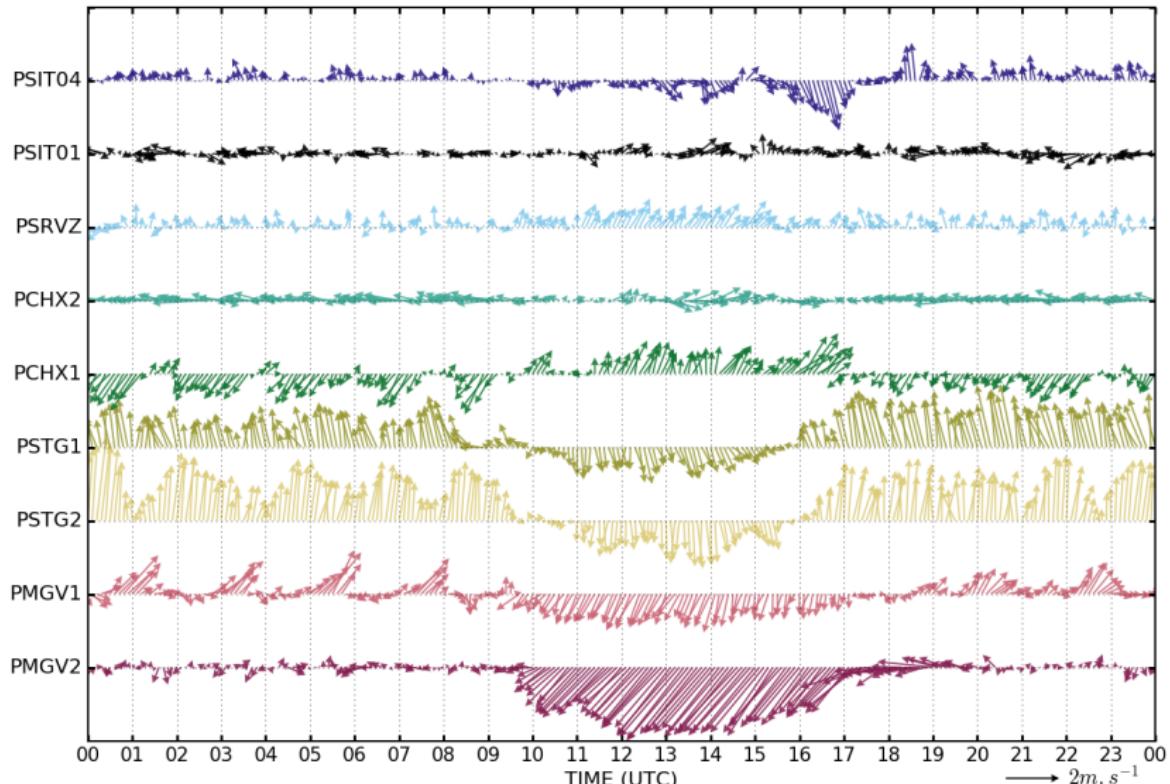


The Arve valley (Alpes, France)

# Stations, profilers



## 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 ( $u, v, w, \theta, \text{mixing ratio}, \text{TKE}$ ) :

- ▶ on a part of the simulation domain defined by
  - ▶ a box ( $I_{\min}, I_{\max}, J_{\min}, J_{\max}, K_{\min}, K_{\max}$ ) : 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<sub>v</sub>*

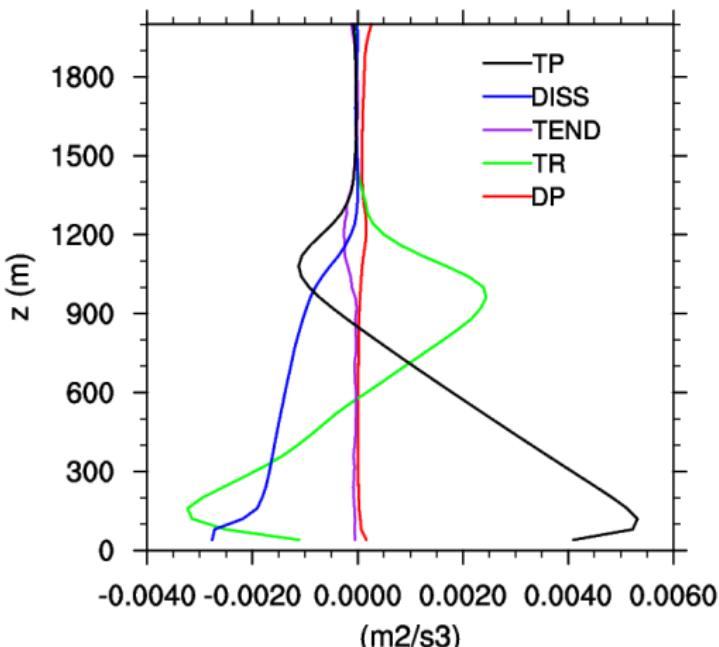
**&NAM\_BU\_RRR** / *r<sub>r</sub>*, etc

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

## Budgets

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

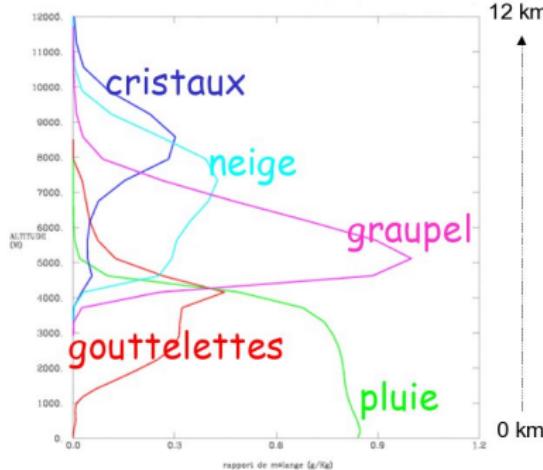
Resolved TKE budget



# Budgets

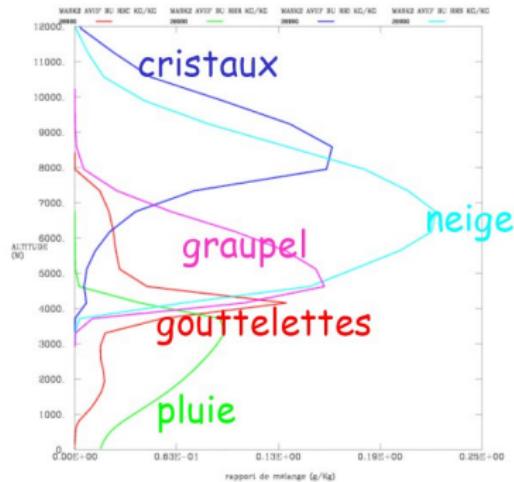
## ZONE CONVECTIVE

SCHEMA ICE 3 – BILAN DES ESPECES – PARTIE CONVECTIVE



## ZONE STRATIFORME

SCHEMA ICE 3 – BILAN DES ESPECES – PARTIE STRATIFORME

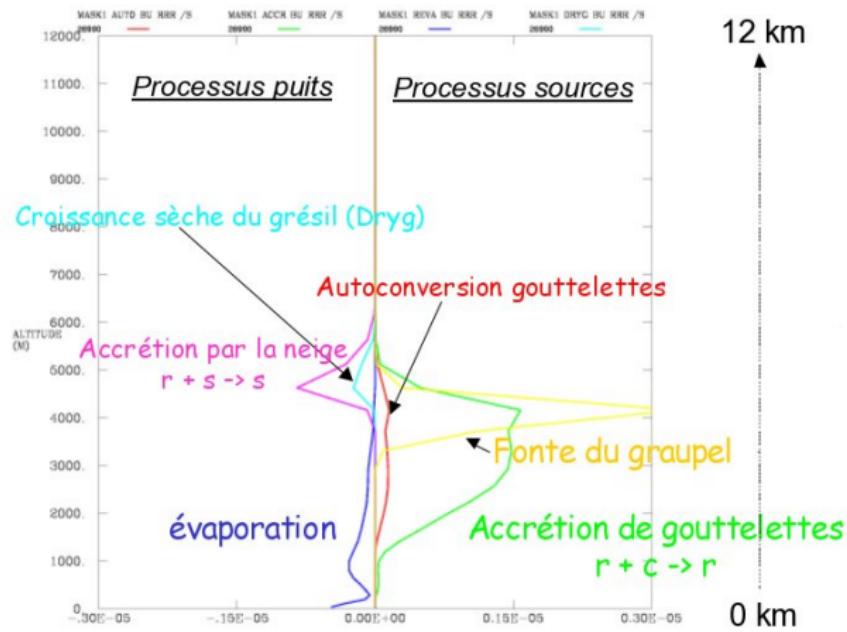


# Budgets

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

SCHEMA ICE 3 – BUDGET GOUTTES PLUIE – CONVECTIF

SCI



## 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

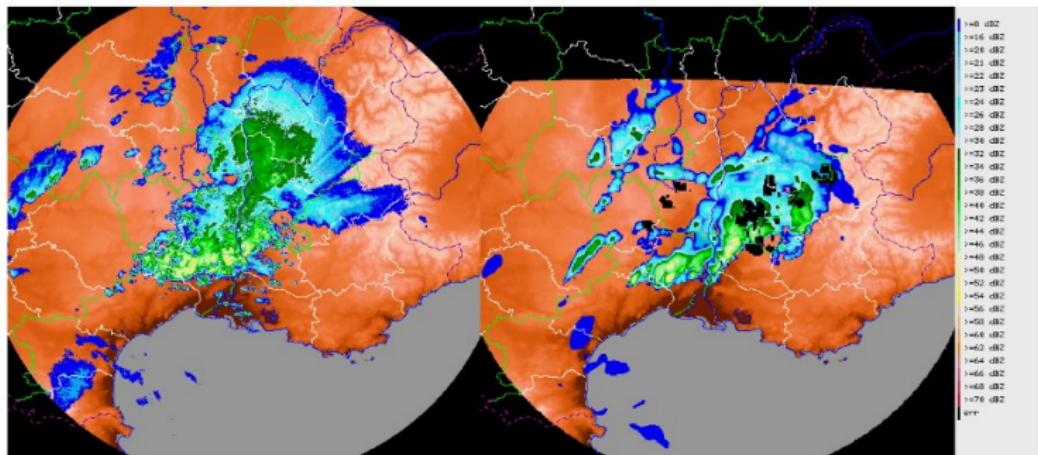
Example of DIAG1.nam :

```
&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



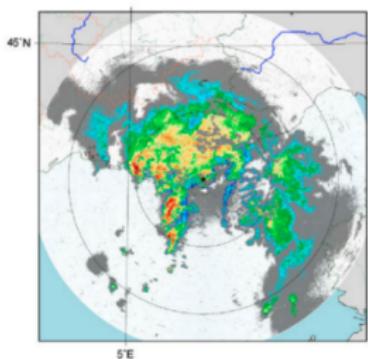
*Réflectivités observées*

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

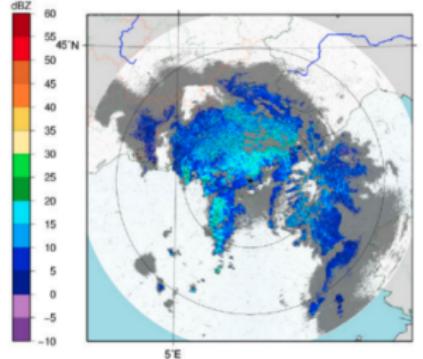
*Réflectivités simulées avec Meso-NH*

- ▶ LRADAR=T
- ▶ you have to specify the version : NVERSION\_RAD= 1 or 2

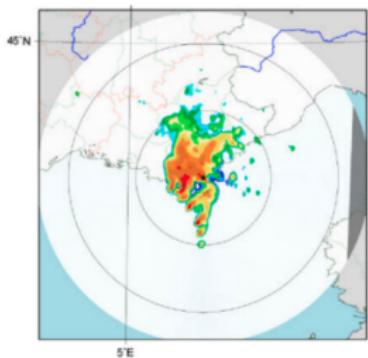
# Polarimetric radar simulator, elevation = 1.4 °



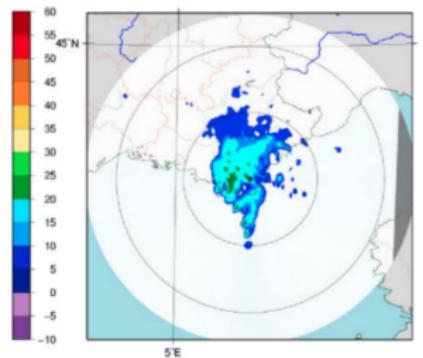
Zhh radar (dBZ)



Zdr radar (dB)



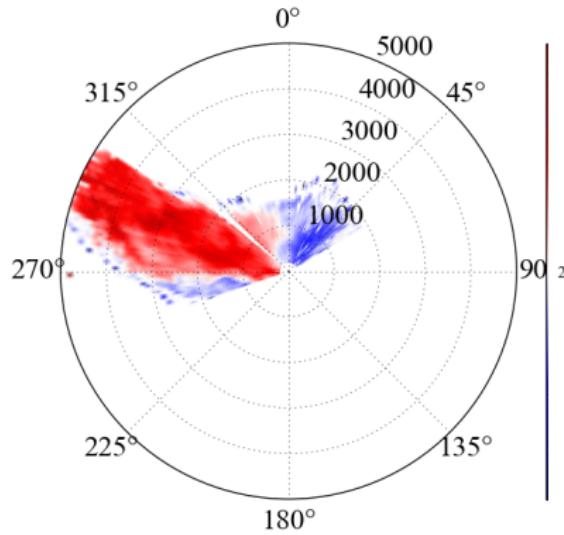
Zhh modèle (dBZ)



Zdr modèle (dB)

# Radar simulator

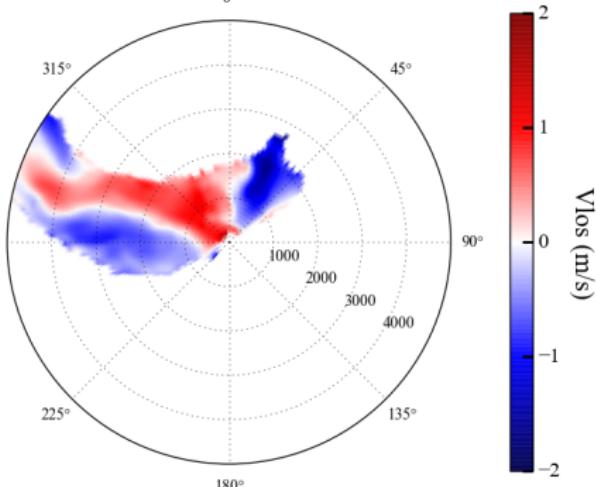
PPI - 2015/02/10 19:34:07.00 UTC- Elevation 0.0



Observed radial velocity

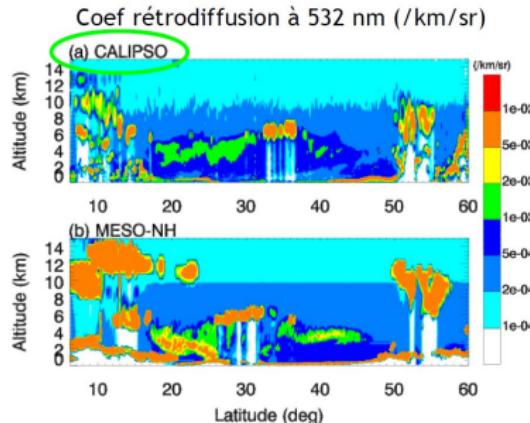
Simulated Vlos field for PPI scan at Elev 0

2015-02-10 19:30:00



Simulated radial velocity

# Lidar simulator

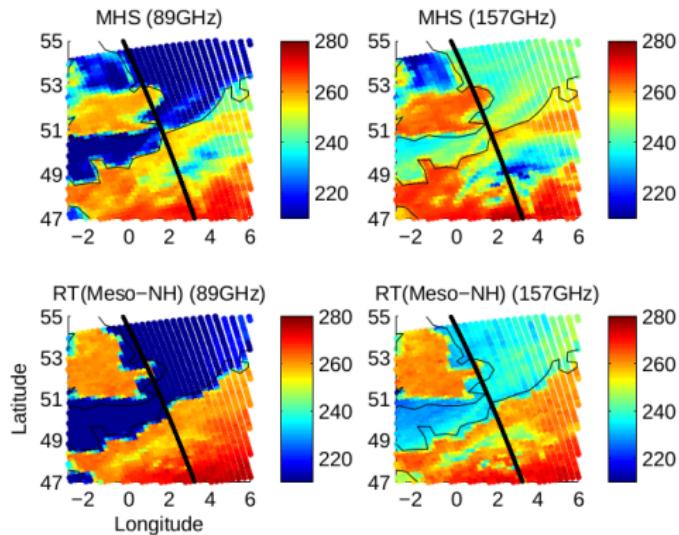


Chaboureau et al , QJRMS 2011

In &NAM\_DIAG / :

- ▶ LLIDAR=T
- ▶ CVIEW\_LIDAR= : lidar point of view '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)



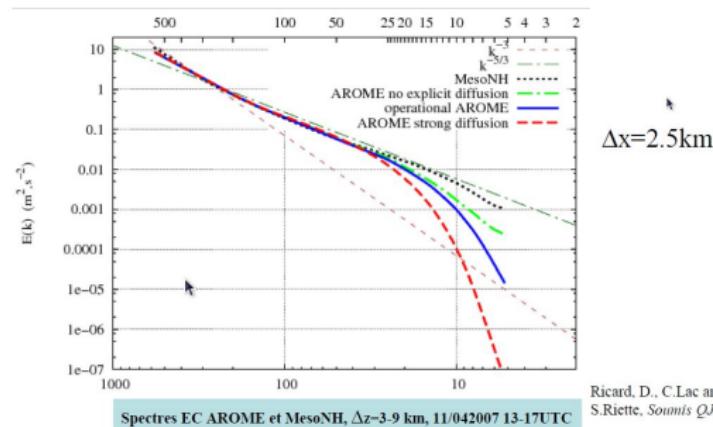
In &NAM\_DIAG :

- ▶ 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'/
```



# HTRDR : High-Tune RenDeRer

Monte-Carlo radiative transfer simulator + Meso-NH LES



<https://www.meso-star.com>

<http://www.umr-cnrm.fr/high-tune>

<https://gitlab.com/meso-star/htrdr>

# Clouds renderer HTRDR



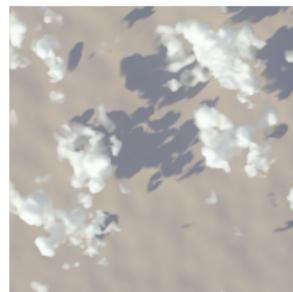
ARM continental cumulus



BOMEX oceanic cumulus



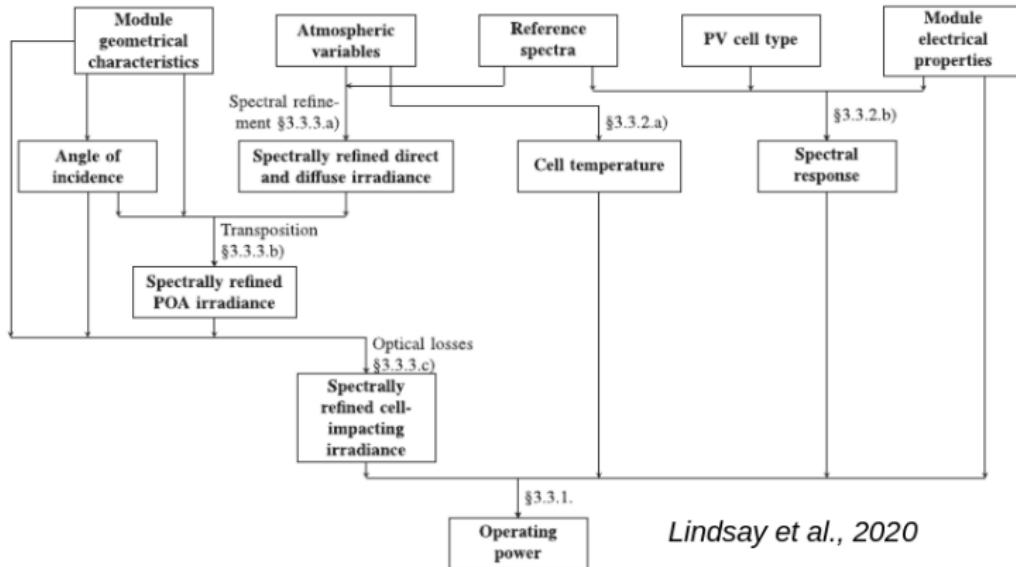
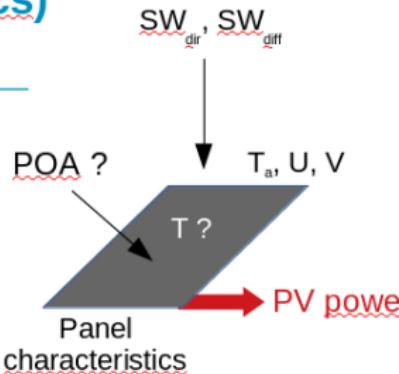
FIRE stratocumulus



top view of continental cumulus

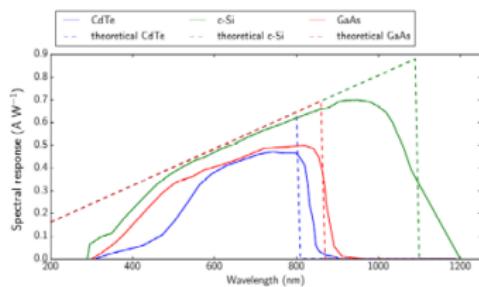
# WO2PV (Weather outputs to PhotoVoltaics)

- 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

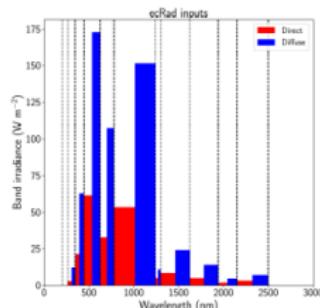


## WO2PV (Weather outputs to PhotoVoltaics)

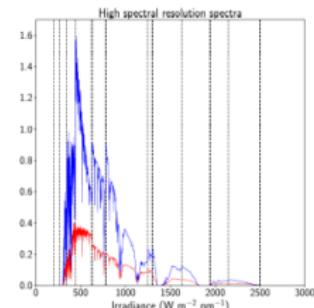
- Many models just use Global Horizontal Irradiance from forecasts (GHI)  
 $= SW_{\text{dir}} + SW_{\text{diff}}$
- Then machine learning or very basic physical models to reconstruct the dir/diff components  
→ overall loss of information from atmospheric radiative code
- Specificity of the code = treatment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

