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Supplement of

The LAGRANTO Lagrangian analysis tool – version 2.0

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SUPPLEMENT

This supplement contains all detailed LAGRANTO calls discussed in the article. Furthermore some screen dumps show the output of LAGRANTO commands.

```
# ----------------------------------------------------------------------
# Example 1: Identification of a warm-conveyor belt (section 2)
# ----------------------------------------------------------------------

# ------ List of all input files  ------------------------------------
> ls -1
P20090129_12
P20090129_18
P20090130_00
P20090130_06
P20090130_12
P20090130_18
P20090131_00
P20090131_06
P20090131_12

# ----- Create start positions ---------------------------------------

# Define region 1 (60 W to 20 E, 30 N to 80 N)
> echo \"1 -60 20 30 80\" >! regionf

# Run LAGRANTO command startf
> startf 20090129_12 startf.2 'region.eqd(1,80)@profile(790,1030,8)@hPa'

# List the trajectory file (format .2 is ASCII)
> more startf.2
Reference date 20090129_0600 / Time range       0 min

  time      lon     lat     p     level
---------------------------------------

   0.00   -59.72   30.36   790   790.000
   0.00   -58.89   30.36   790   790.000
   0.00   -58.05   30.36   790   790.000
   0.00   -57.22   30.36   790   790.000
   0.00   -56.38   30.36   790   790.000
   0.00   -55.55   30.36   790   790.000
   0.00   -54.71   30.36   790   790.000
   0.00   -53.87   30.36   790   790.000
   0.00   -53.04   30.36   790   790.000
...

# ----- Run forward trajectories -------------------------------------

# Calculate forward trajectories
> caltra 20090129_12 20090131_12 startf.2 traj.4 -j

# Show trajectories (format .4 is binary, trainfo is used for listing)
> trainfo traj.4 list
Reference date 20090129_1200 / Time range    2880 min
```

```
  time      lon     lat     p
------------------------------

   0.00   -59.72   30.36   790
   6.00   -58.22   30.58   795
  12.00   -56.87   30.76   797
  18.00   -55.76   31.08   807
  24.00   -54.56   31.70   827
  30.00   -52.71   32.64   839
  36.00   -50.37   33.41   847
  42.00   -47.96   33.89   854
  48.00   -45.64   34.34   869

   0.00   -58.89   30.36   790
   6.00   -57.39   30.81   794
...


# ----- Select WCB trajectories ----------------------------------------

# Select ascending trajectories
> select traj.4 wcb.1 'GT:p(DIFF):600:0,48'

# Get the number of selected trajectories
> trainfo wcb.1 ntra
76

# ----- Trace additional fields along trajectories --------------------

# Trace potential temperature (TH) along trajectory
> trace wcb.1 wcb.1 -f TH 1

# Look at the final trajectories
> more wcb.1
Reference date 20090129_1200 / Time range    2880 min

  time      lon     lat     p        TH
---------------------------------------

   0.00   -22.72   33.96   859   294.151
   6.00   -18.04   35.58   734   298.055
  12.00   -14.25   39.49   555   306.311
  18.00   -11.23   45.85   406   312.269
  24.00    -9.46   53.83   370   311.663
  30.00    -7.87   62.48   313   312.610
  36.00     2.76   71.83   299   311.725
  42.00    32.38   71.24   269   311.074
  48.00    32.20   62.84   259   310.461

   0.00   -18.39   38.29   859   293.320
   6.00   -14.46   41.44   692   299.575
...


# ---------------------------------------------------------------------
# Example 1: Refined analysis of WCB (section 4.1)
# ---------------------------------------------------------------------

# ----- GT:p(CHANGE):600:FIRST,LAST  ----------------------------------
```

```
# Select trajectories
select traj.4 refinement_01 'GT:p(CHANGE):600:FIRST,LAST'


# ----- GT:TH(DIFF):10:48,0 -------------------------------------------

# Select trajectories
> select wcb.1 refinement_04 'GT:TH(DIFF):10:48,0'

# ----- GT:IWC:0:1(LABEL) ---------------------------------------------

# Trace ice water contents along trajectories
> trace wcb.1 wcb.1 -f IWC 1000

# Apply label criterion
> select wcb.1 refinement_05 'GT:IWC:0:1(LABEL)' -label

# Show trajectory file with label
> more refinement_05
Reference date 20090129_0600 / Time range    2880 min

  time      lon     lat     p        TH       IWC     LABEL
-------------------------------------------------------------

   0.00   -65.42   42.61   859   293.010     0.000     0.000
   6.00   -58.64   47.48   713   296.745     0.208     1.000
  12.00   -56.04   51.31   463   302.152     0.060     1.000
  18.00   -57.41   52.11   433   302.394     0.003     1.000
  24.00   -57.32   51.44   442   301.877     0.000     0.000
  30.00   -56.25   51.42   424   300.992     0.011     1.000
  36.00   -55.61   52.41   389   300.583     0.013     1.000
  42.00   -55.53   54.24   364   300.416     0.011     1.000
  48.00   -55.61   56.92   346   300.161     0.004     1.000

   0.00   -64.44   42.61   859   294.493     0.000     0.000
   6.00   -58.34   47.69   708   296.658     0.226     1.000
...

# Select all trajectories with at least 2 label entries
> select refinement_05 refinement_05 'GT:LABEL:2:ALL'

# ----- TRUE:INPOLYGON:ireland:1(LABEL) -----------------------------

# Label all times over Ireland
select traj.4 ireland.1 'TRUE:INPOLYGON:ireland:1(LABEL)

# Check for the change in specific humidity
select ireland.1 ireland.1 'GT:Q(CHANGE):1.5:LABEL'

# ---------------------------------------------------------------------
# Example 2: Stratosphere-Troposphere Exchange (section 4.2)
# ---------------------------------------------------------------------

# List of all input files
> ls -1
P20090118_00
P20090118_06
P20090118_12
```

```
P20090118_18
P20090119_00
P20090119_06
P20090119_12
P20090119_18
P20090120_00
P20090120_06
P20090120_12
P20090120_18
P20090121_00
P20090121_06
P20090121_12
P20090121_18
P20090122_00

# Create starting positions
> startf 20090118_00 startf.2 'box.eqd(-80,20,40,80,50) @
profile(250,600,20) @ hPa'

# Show the geographical distribution of the starting points
> density startf.2 startf.cdf

# Add PV to the starting file
> trace startf.2 startf.2 -f PV 1.

# Select all trajectories with PV > 2 PVU at start
> select startf.2 startf.2 'GT:PV:2:FIRST'

# Calculate forward trajectories
> caltra 20090118_00 20090122_00 startf.2 traj.1

# Select descending trajectories
> select traj.1 intrusion.1 'GT:p(RANGE):300:ALL & ...
                                     ... LT:p(DIFF):0:FIRST,LAST'

# Let's have a look at the trajectory file
> more intrusion.1
Reference date 20090118_0000 / Time range    5760 min

  time      lon     lat     p         PS
-----------------------------------------

   0.00     2.32   40.00   250  1019.747
   6.00     3.60   38.61   253  1022.652
  12.00     3.17   36.64   269   984.330
  18.00    -0.33   33.36   342   892.395
  24.00    -5.38   27.39   416   968.710
  30.00    -5.03   19.91   494   984.722
  36.00    -0.09   23.97   428   976.625
  42.00     0.45   29.65   392   966.377
  48.00    -0.08   28.94   401   974.737
  54.00     1.24   25.21   489   971.265
  60.00     6.58   23.72   607   858.164
  66.00    12.21   25.86   606   928.157
  72.00    17.70   29.10   590   976.789
  78.00    21.42   32.53   564   987.006
  84.00    23.97   35.97   553  1005.462
  90.00    26.86   39.07   534   994.472
  96.00    29.17   40.86   512  1001.104
```

```
   0.00     2.28   40.45   250  1020.201
   6.00     3.48   38.74   253  1022.073
...

# Select all trajectories that come close to Jungfraujoch site
> select intrusion.1 jfj.1 'TRUE:INCIRCLE:7.985,46.5474,100:ALL(ANY)'

 ---------------------------------------------------------------------
# Example 3: Orographic blocking (section 4.3)
# ---------------------------------------------------------------------

# List of all input files
> ls
LMCONSTANTS   P20100128_12  P20100128_13  P20100128_14  P20100128_15
P20100128_16  P20100128_17  P20100128_18  P20100128_19  P20100128_20
P20100128_21  P20100128_22  P20100128_23  P20100129_00  P20100129_01
...

# Create starting positions along a line north of the Alps
> create_startf 20100128_09 startf_3000m.2 ...
                            ... 'line(0,16,49,52,100) @ level(3000) @ m'
> create_startf 20100128_09 startf_2250m.2 ...
                            ... 'line(0,16,49,52,100) @ level(2250) @ m'
> create_startf 20100128_09 startf_1500m.2 ...
                            ... 'line(0,16,49,52,100) @ level(1500) @ m'
> create_startf 20100128_09 startf_0750m.2 ...
                            ... 'line(0,16,49,52,100) @ level(750)  @ m'

# Calculate forward trajectories
> caltra 20100128_09 20100130_09 startf_3000m.2 traj_3000m.1 -j
> caltra 20100128_09 20100130_09 startf_2250m.2 traj_2250m.1 -j
> caltra 20100128_09 20100130_09 startf_1500m.2 traj_1500m.1 -j
> caltra 20100128_09 20100130_09 startf_0750m.2 traj_0750m.1 -j

# Show the forward trajectories (colored by time [in hours])
> quickview -v time traj_3000m.1
> quickview -v time traj_2250m.1
> quickview -v time traj_1500m.1
> quickview -v time traj_0750m.1

# Find trajectories passing over Gotthard pass
> select traj_3000m.1 gotthard.1
'TRUE:INCIRCLE:8.5608,46.5726,18:ALL(ANY)'

# Increase the time resolution by linear interpolation
> timerews gotthard.1 gotthard.1 - min 15

# Calculate a pseudo profile along the Gotthard trajectory
> echo "V  1. 0 P" >! tracevars
> echo "T  1. 0 P" >> tracevars
> echo "QV 1. 0 P" >> tracevars
> echo "W  1. 0 P" >> tracevars
> profile gotthard.1 profile.nc

# Online calculation of potential temperature and relative humidity
> echo "TH 1. 1 P" >! tracevars
> echo "RH 1. 1 P" >> tracevars
> trace traj_1500m.1 diabatic.1
> more diabatic.1
```

```
Reference date 20100128_0900 / Time range    2880 min

   time       lon      lat     z        TH        RH
-------------------------------------------------------

   0.00     0.000   49.000  1500   281.285    74.914
   1.00     0.134   48.699  1380   281.050    70.088
   2.00     0.243   48.392  1271   280.905    66.284
   3.00     0.339   48.080  1278   280.978    62.950
   4.00     0.429   47.748  1297   281.169    62.354
   5.00     0.491   47.405  1318   281.215    64.467
   6.00     0.506   47.081  1271   281.520    64.882
   7.00     0.496   46.809  1250   281.313    67.519
   8.00     0.506   46.578  1257   281.155    67.624
   9.00     0.538   46.352  1306   280.745    73.874
...

# Find trajectories which experience a lot of diabatic heating or cooling
> select traj_1500.1 gotth.1 'GT:TH(RANGE):10:ALL(ANY)'

# Define a region of 300 km around the Alps (distance from 1500m height
contour)
> more alps_300km.txt
 8.568 46.572
18.711 47.648
18.667 47.898
18.592 48.133
18.479 48.374
...

# Find all trajectories reaching RH>90% within 300 km around Alps
> select traj_1500m.1 within.1 'TRUE:INPOLYGON:alps_300km.txt:1(LABEL)'
-label
> trace within.1 within.1 -f RH 1.
> select within.1 within.1 'GT:RH:90:2(LABEL)' -label
> select within.1 within.1 'ALL:LABEL:1,2:ALL(ANY)'

 ------------------------------------------------------------------------
# Example 4: Origin of air masses at observational site (section 4.4)
# ------------------------------------------------------------------------

# List of all input files
> ls -1
P20071026_00
P20071026_06
P20071026_12
P20071026_18
P20071027_00
P20071027_06
P20071027_12
P20071027_18
P20071028_00
P20071028_06
P20071028_12
P20071028_18
P20071029_00
P20071029_06
P20071029_12
P20071029_18
```

```
P20071030_00
P20071030_06
P20071030_12
P20071030_18
P20071031_00
P20071031_06
P20071031_12
P20071031_18

# Create the starting positions
> startf 20071031_18 startf.2 'circle.eqd(86.80,27.95,100,10) @ list(500)
@ hPa'

# Let's have a quick view at the starting positions
> density startf.2 density.nc -latlon 81 81 66.90 7.95 0.5 0.5

# Calculate the backward trajectories
> caltra 20071031_18 20071026_00 startf.2 traj.1 -j

# Use the Python quickview tool to have a look at the trajectories
> quickview -v p traj.1

# Trace potential vorticity, potential temperature and velocity along
backward trajectories
> trace traj.1 traj.1 -f VEL 1.

# Select trajectories which  experienced long-range transport
> select traj.1 long.1 'GT:DIST0:1000:LAST'
> quickview -v p long.1

# Select the trajectories which descend more than 250 hPa (method 1)
> select long.1 descend.1 'GT:p(DIFF):250:FIRST,LAST'

# Select the trajectories which descend more than 250 hPa (method 2)
> select long.1 descend.1 'GT:VERT0:250:ALL(ANY)'
```