Supplements for

Aircraft measurements of black carbon in the boundary layer over the North China Plain

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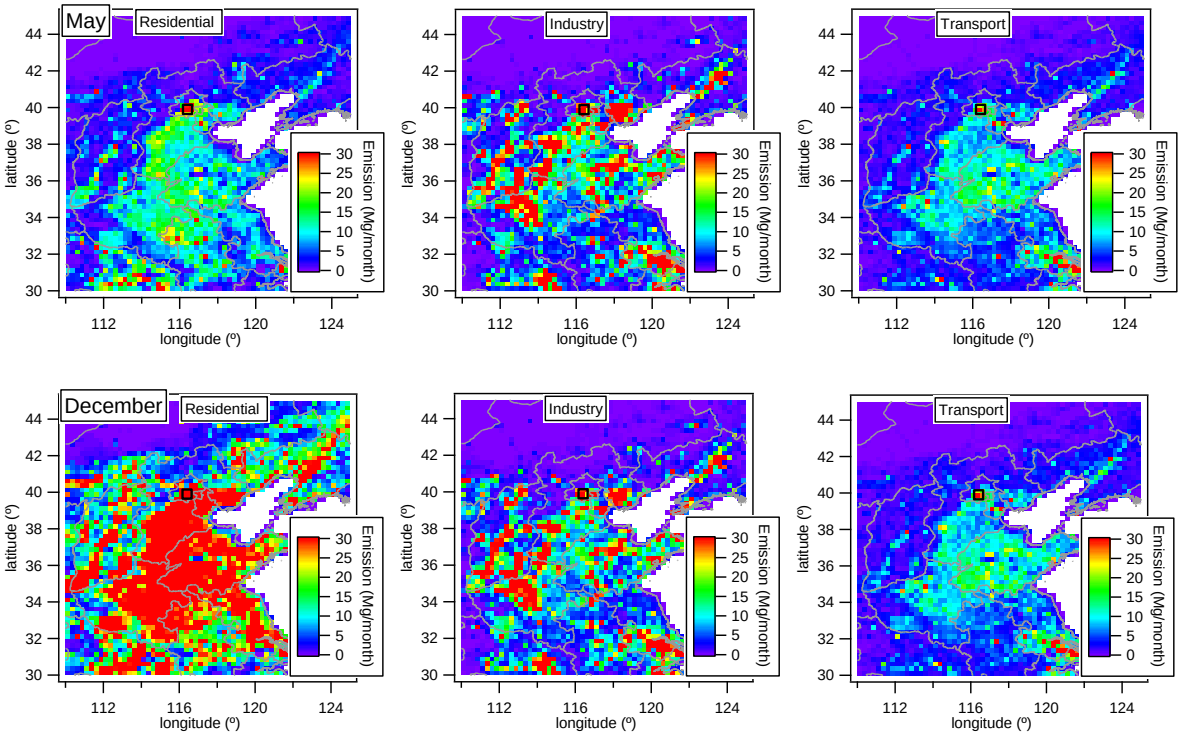

Fig. S1. The 2010 0.5°×0.5° BC emission inventories for residential, industry and transportation sectors for May and December. The open square marks the location of central Beijing.

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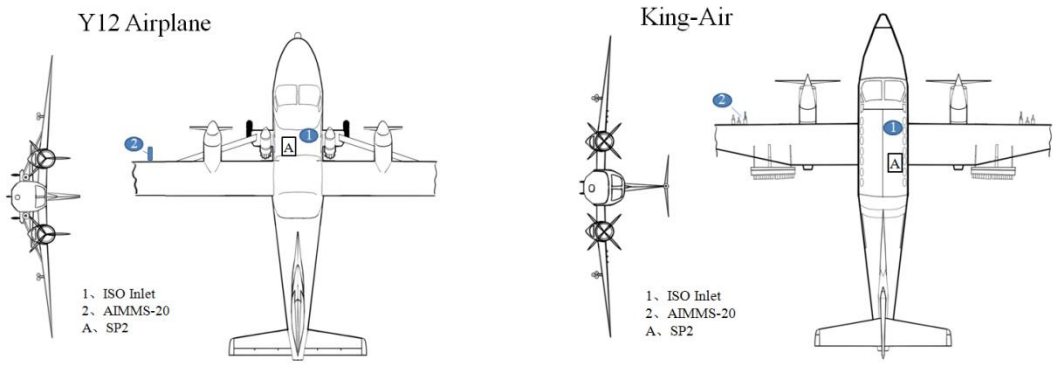


Fig. S2. The side and top sketch of Y12 and King-air aircraft, showing the position of ISO inlet and the SP2.

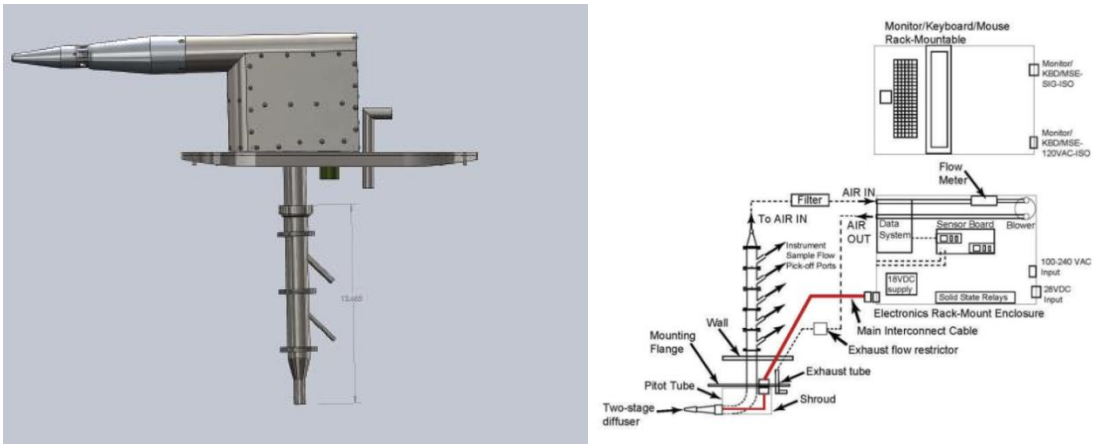


Fig. S3. The picture of the ISO inlet; the schematic of the ISO inlet and the associated flow system in the cabin.

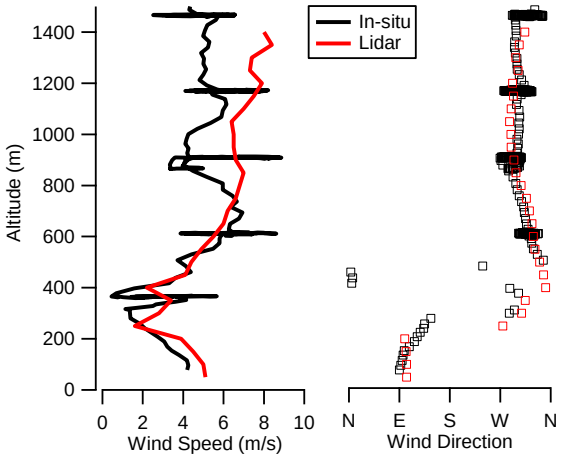


Fig. S4. Comparison between the in-situ and radar measured wind vertical profile for the return flight 20161219.

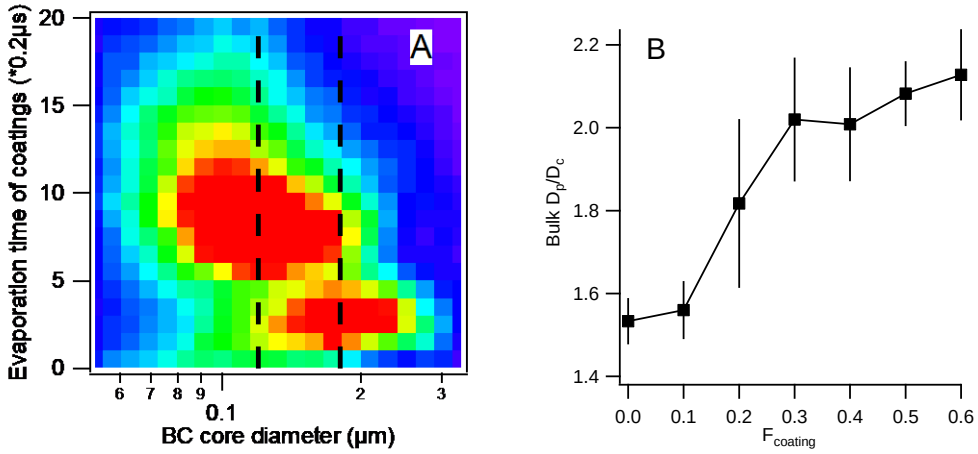


Fig. S5. An example of the methods in determining the BC mixing state for flight 20120417. A) The coating evaporation time as a function of BC core size, colored by the particle number density; B) Comparison between the coating evaporation time and optical sizing methods in determining the BC mixing state from the SP2 measurement.

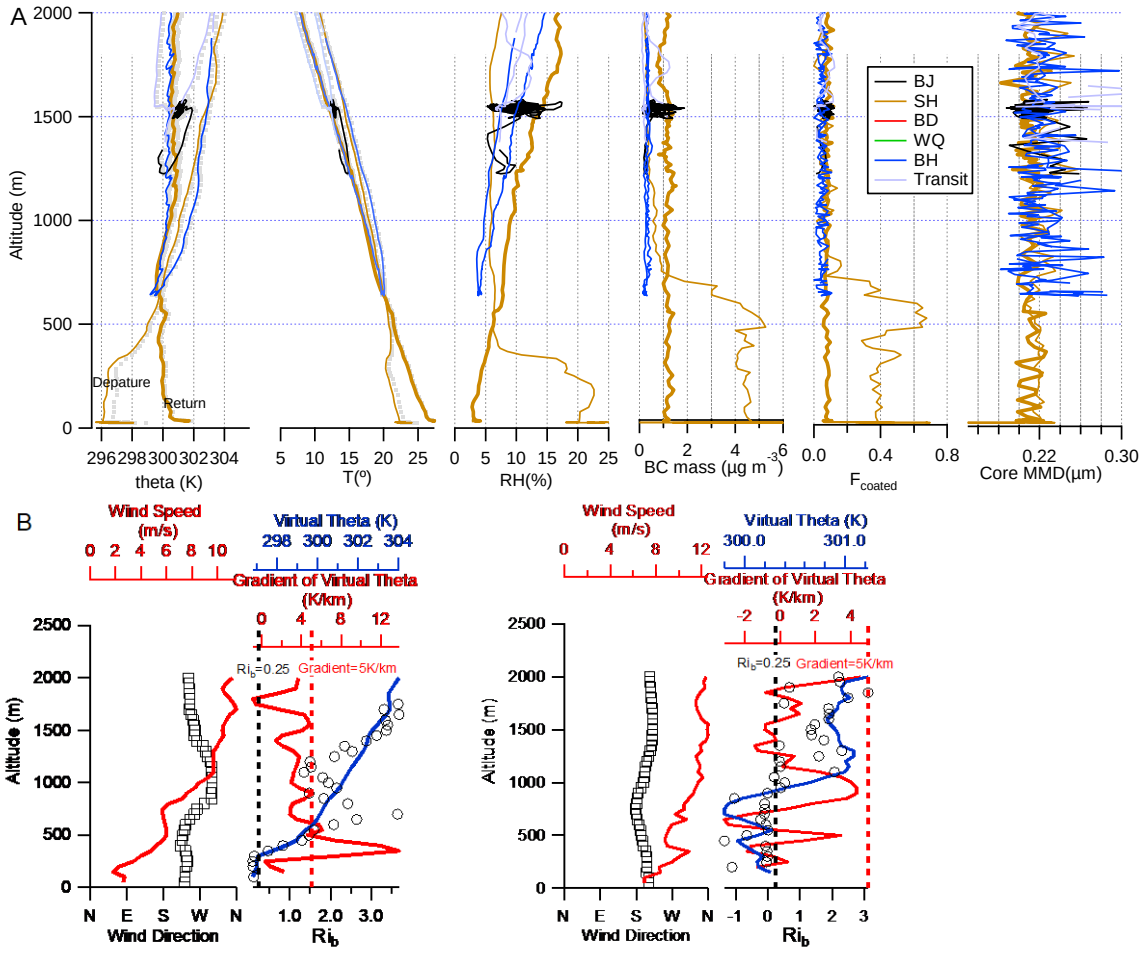
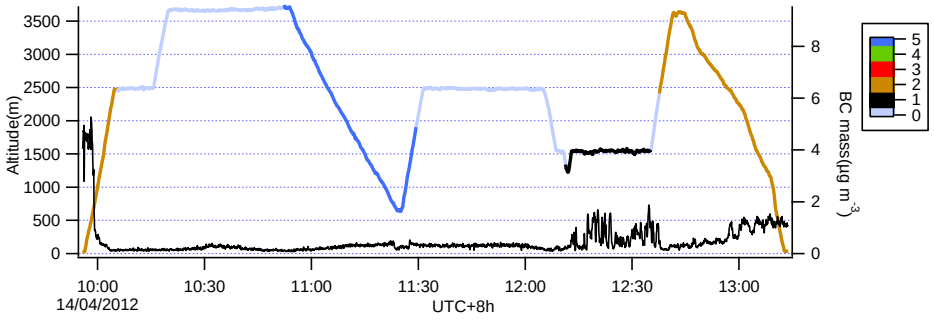
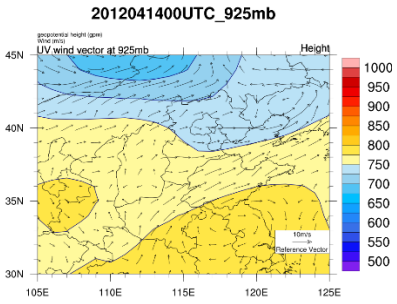


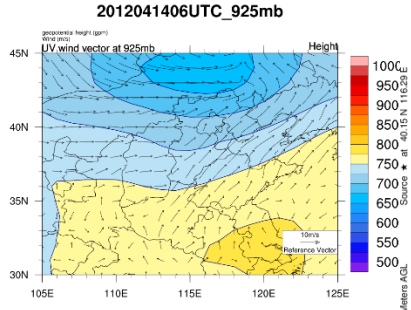
Fig. S6. A) The vertical profiles of meteorological parameters and BC properties for flight 20120414, colored by the locations of aircraft over different regions (marked in Fig .1B). The thicker lines show the return leg. The flight departure was in the morning and returned in the early afternoon. B) The determination of PBLH for the departure and return legs.

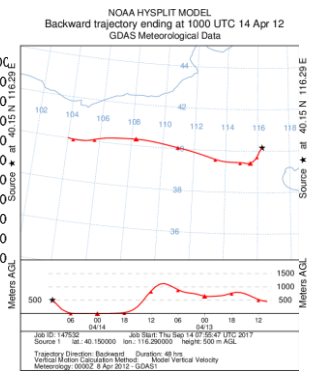
Summer flights

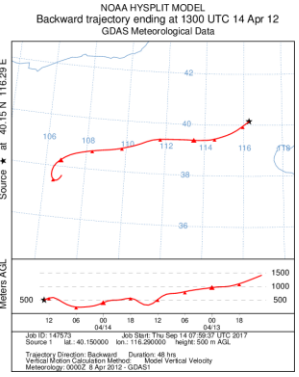
20120414

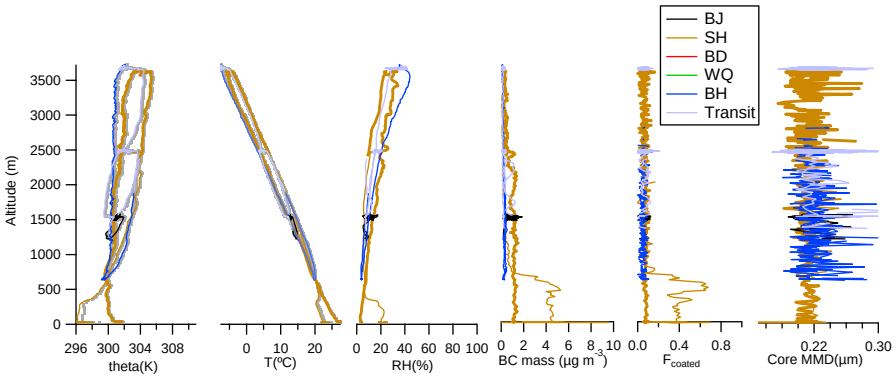












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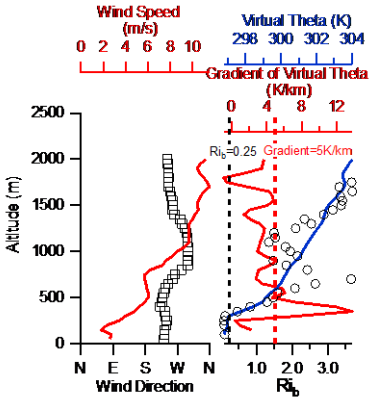
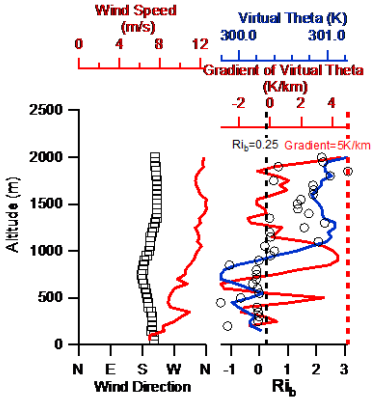
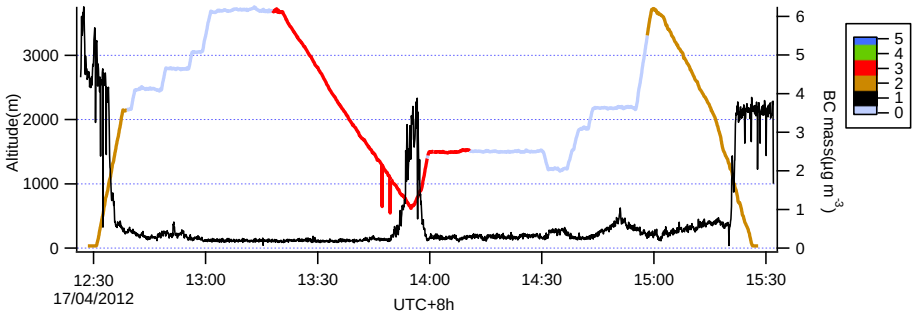




20120417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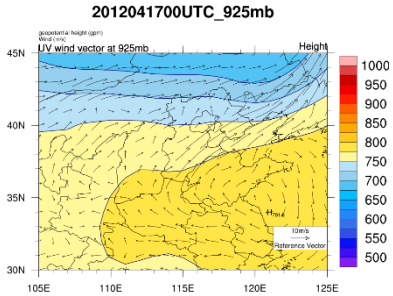
BC mass(μg m-3)
12:30
17/04/2012
13:00
13:30
14:00
UTC+8h
14:30
15:00
15:30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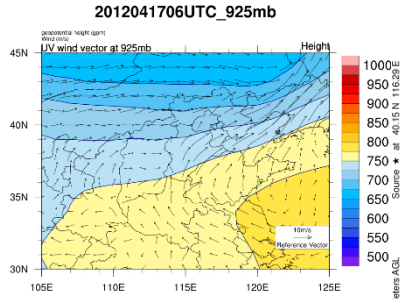
UV wind vector at 925mb
Height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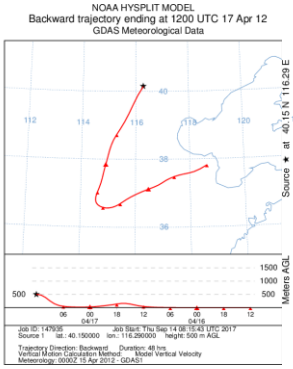
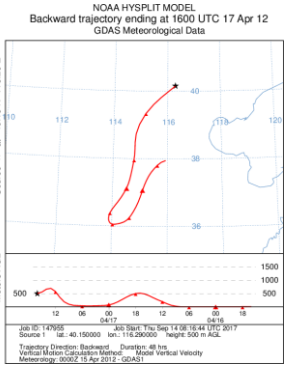
Height


NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 17 Apr 12
GDAS Meteorological Data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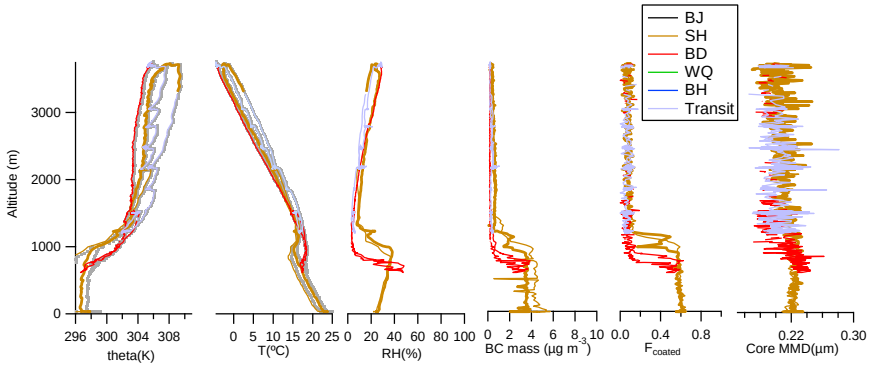
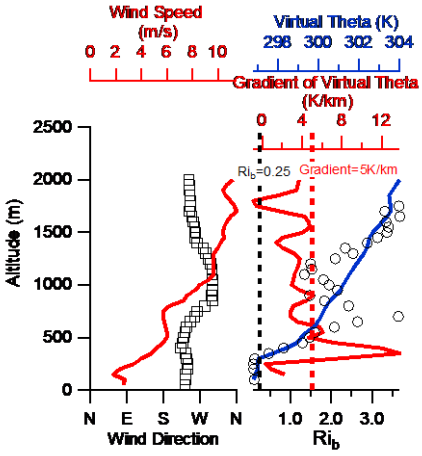
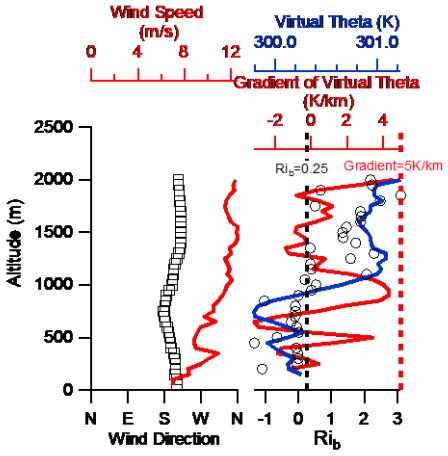
Backward trajectory ending at 1600 UTC 17 Apr 12
GDAS Meteorological Data

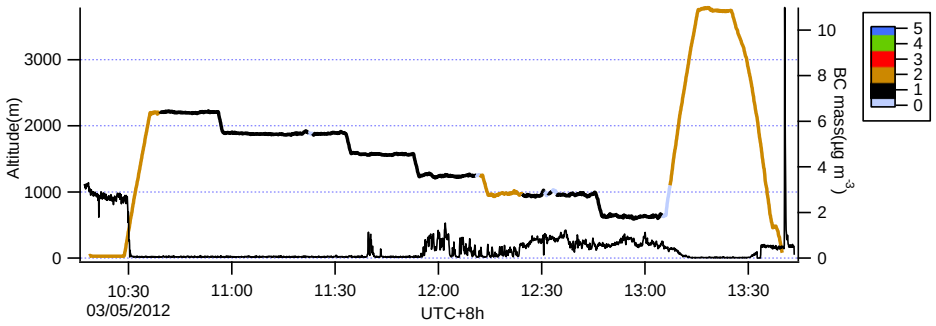

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)


Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b


Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

5

20120503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BC mass(μg m-3)
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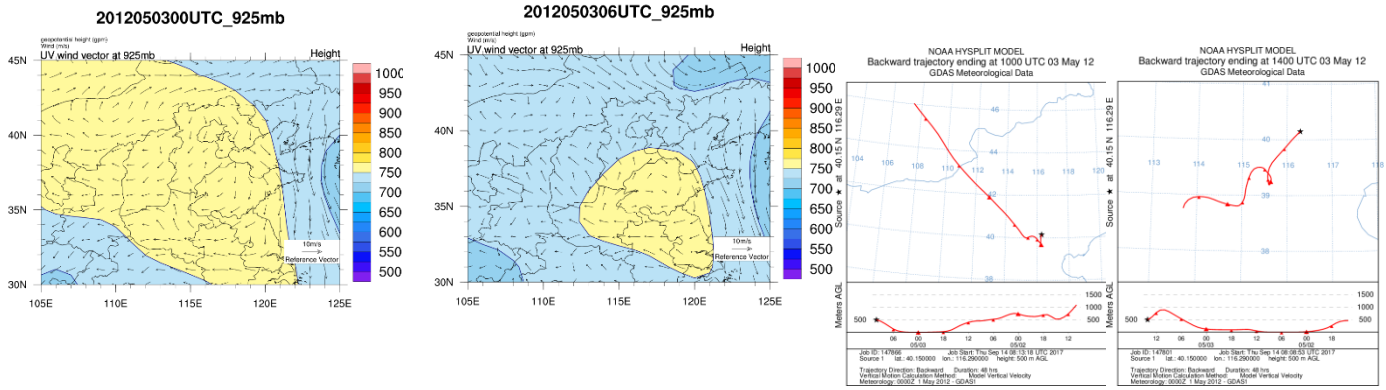
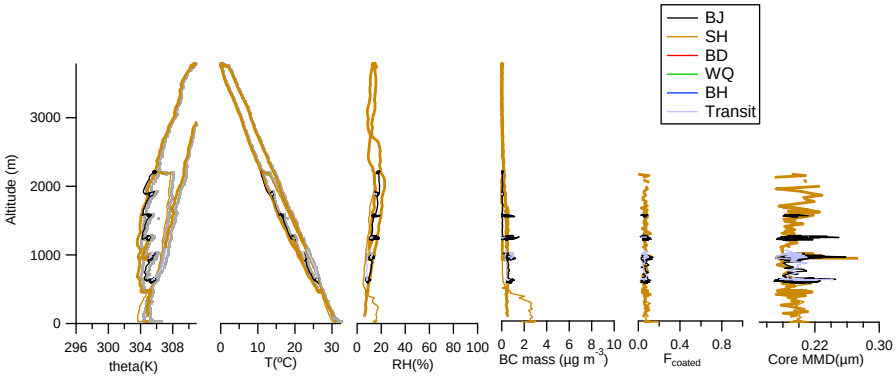
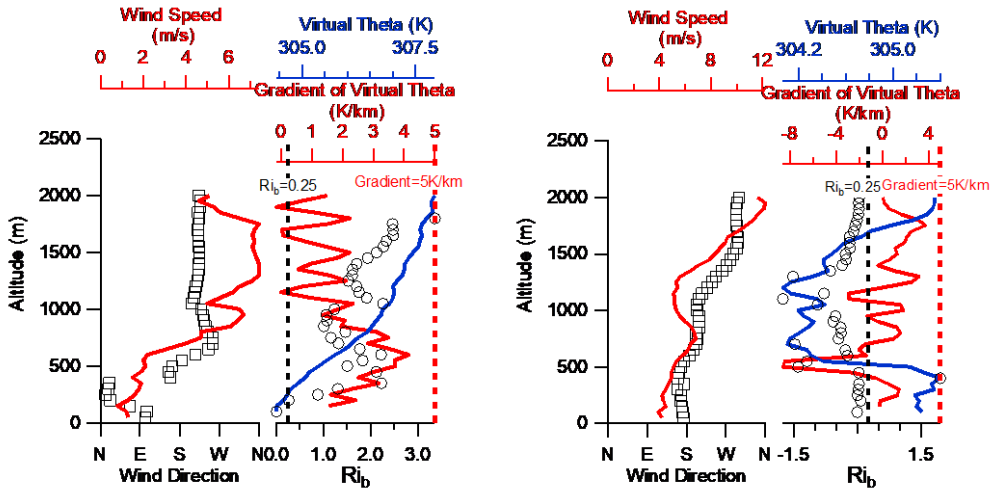
03/05/2012
11:00
11:30
12:00
UTC+8h
12:30
13:00
13:30

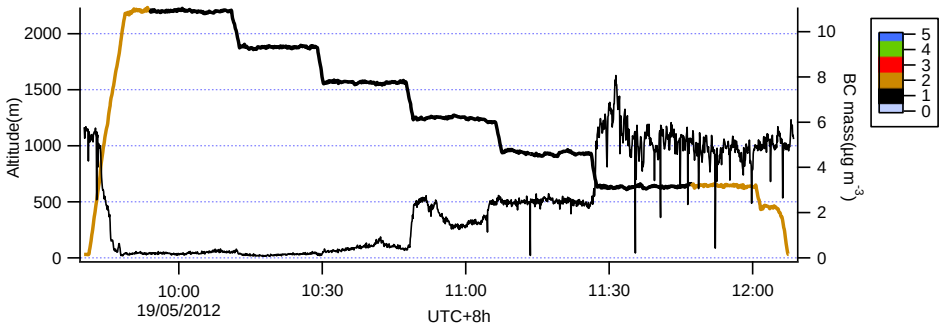

2012050300UTC_925mb
2012050306UTC_925mb
UV wind vector at 925mb
Height
NOAA HYSPLIT MODEL
Backward trajectory ending at 1000 UTC 03 May 12
GDAS Meteorological Data
NOAA HYSPLIT MODEL
Backward trajectory ending at 1400 UTC 03 May 12
GDAS Meteorological Data


BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)


Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

5

20120519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BC mass(μg m-3)
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10:30
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UTC+8h
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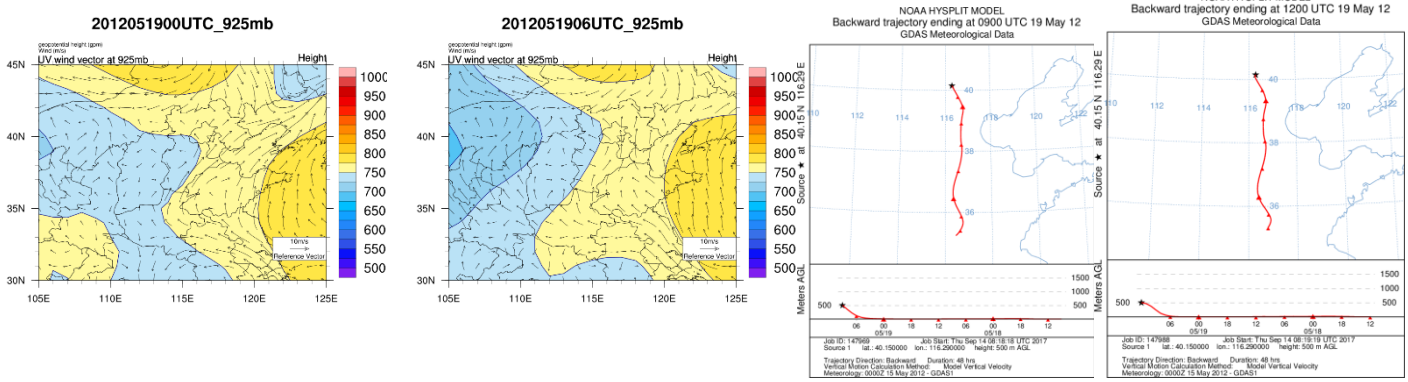
12:00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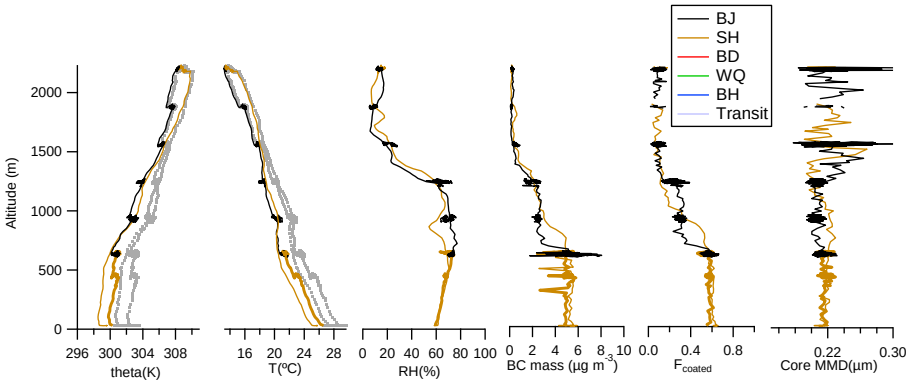
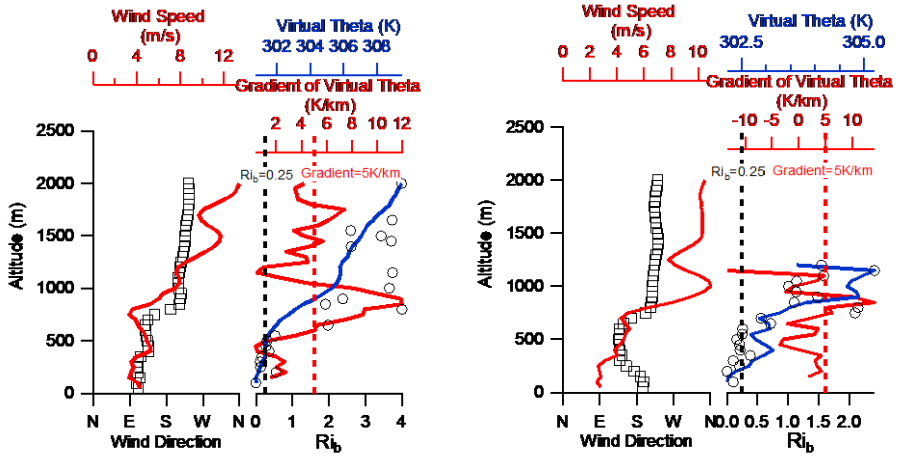
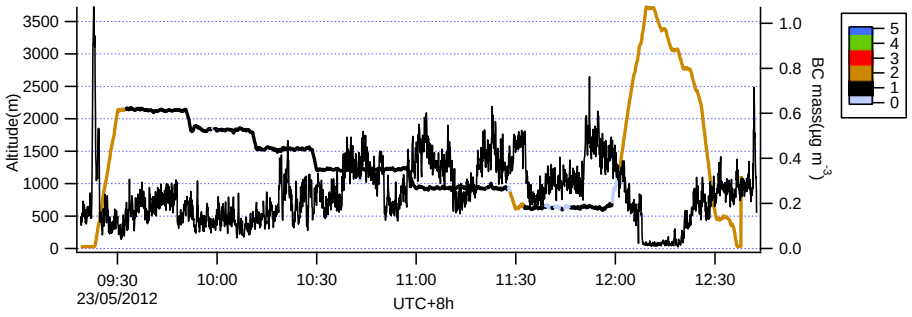
2012051906UTC_925mb
UV wind vector at 925mb
Height
NOAA HYSPLIT MODEL
Backward trajectory ending at 0900 UTC 19 May 12
Backward trajectory ending at 1200 UTC 19 May 12
GDAS Meteorological Data


BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)


Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25 Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

5

20120523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BC mass(μg m-3)
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23/05/2012
10:00
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11:00
11:30
12:00
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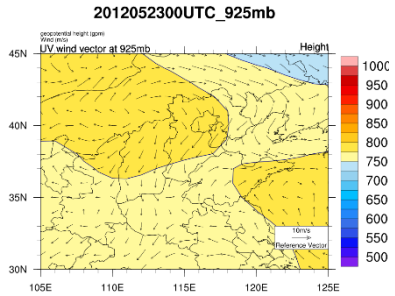
UTC+8h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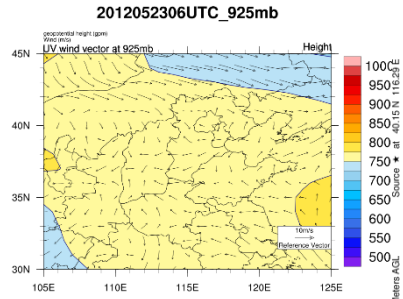
UV wind vector at 925mb
Height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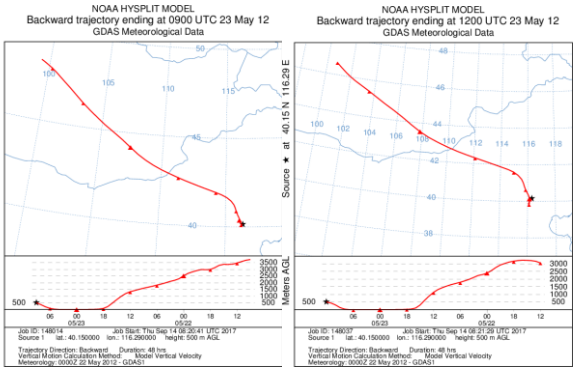
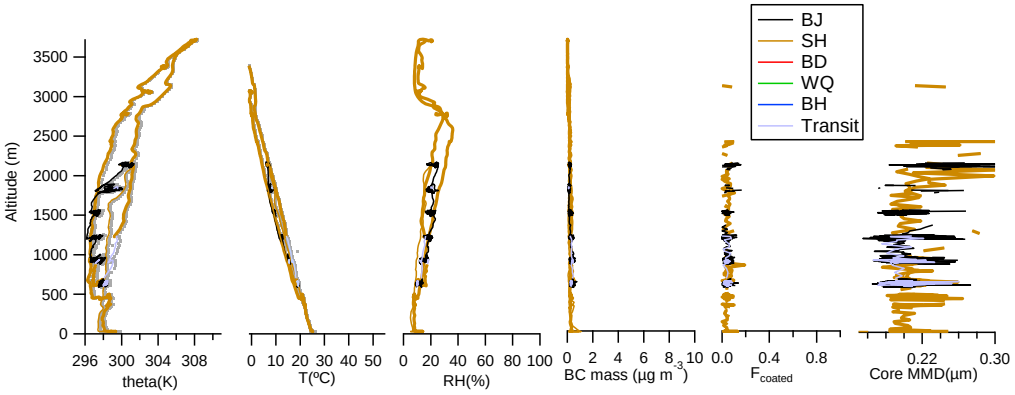
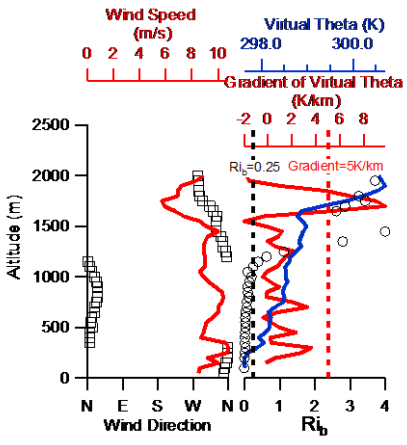
UV wind vector at 925mb
Height

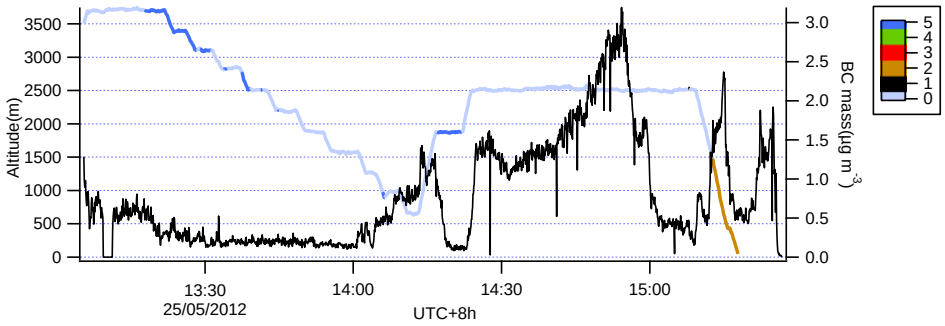

NOAA HYSPLIT MODEL
Backward trajectory ending at 0900 UTC 23 May 12
GDAS Meteorological Data
NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 23 May 12
GDAS Meteorological Data

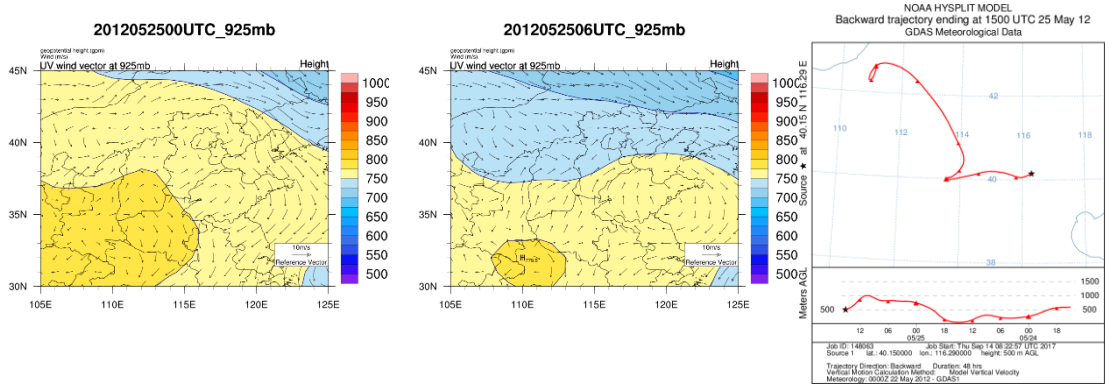

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)

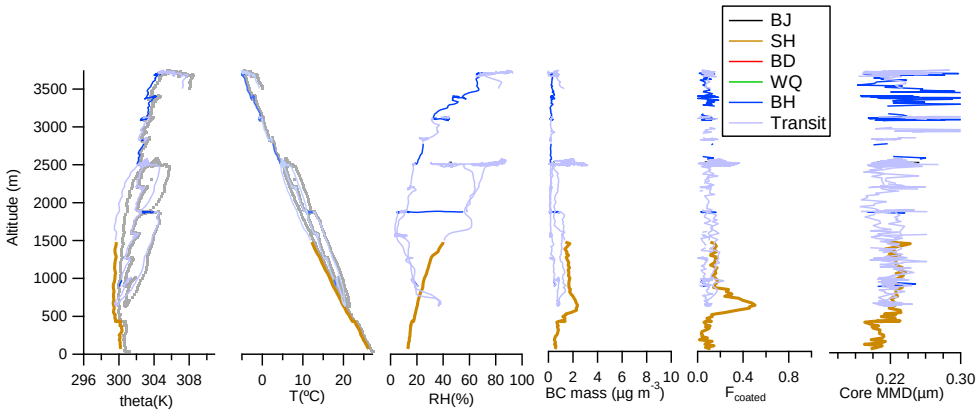

Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri=0.25 Gradient=5K/km
Altitude (m)
Wind Direction
Rib

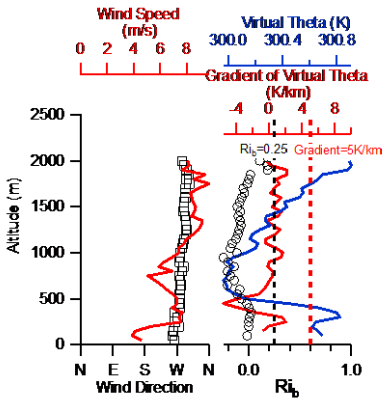
5

20120525


Altitude(m)
BC mass(μg m-3)
13:30
25/05/2012
14:00
14:30
15:00
UTC+8h

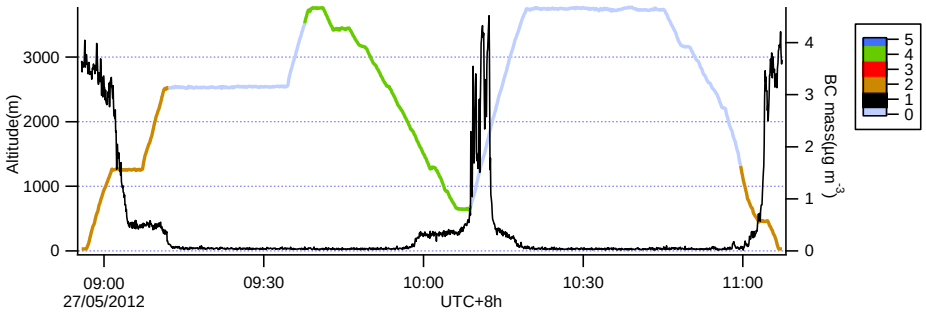

2012052500UTC_925mb
2012052506UTC_925mb
UV wind vector at 925mb
Height
NOAA HYSPLIT MODEL
Backward trajectory ending at 1500 UTC 25 May 12
GDAS Meteorological Data


BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(°C)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)


Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri=0.25 Gradient=5K/km
Altitude (m)
Wind Direction
Rib

5

20120527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BC mass(μg m-3)
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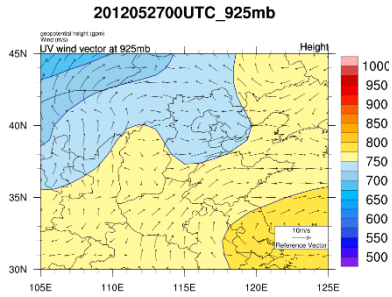
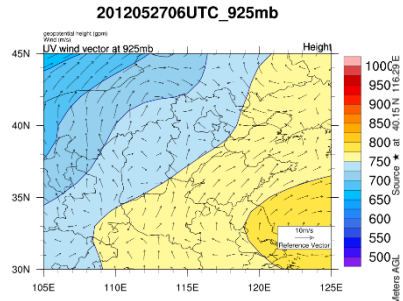
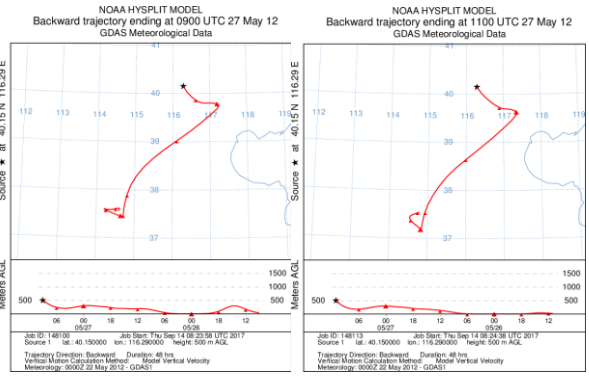
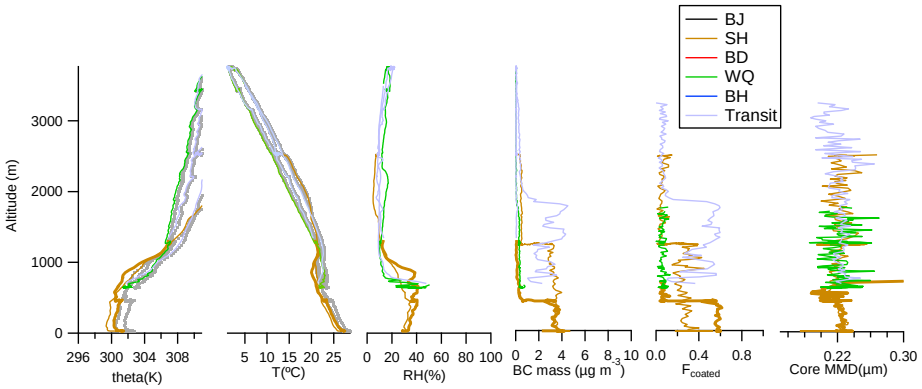
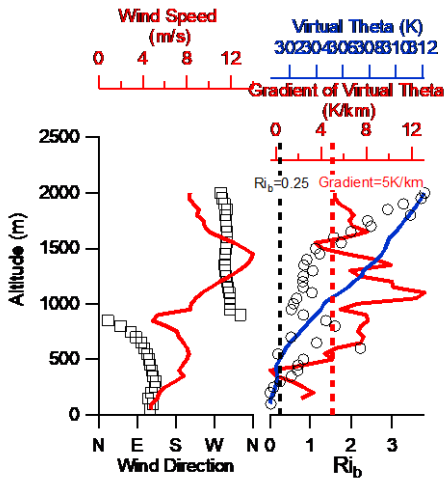
27/05/2012
09:30
10:00
UTC+8h
10:30
11:00

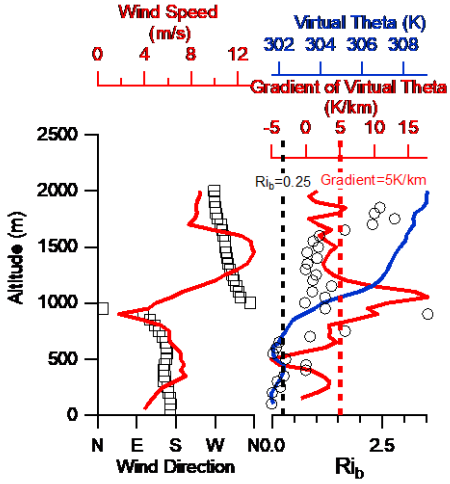

2012052700UTC_925mb
UV wind vector at 925mb
Height


2012052706UTC_925mb
UV wind vector at 925mb
Height


NOAA HYSPLIT MODEL
Backward trajectory ending at 0900 UTC 27 May 12
GDAS Meteorological Data
NOAA HYSPLIT MODEL
Backward trajectory ending at 1100 UTC 27 May 12
GDAS Meteorological Data

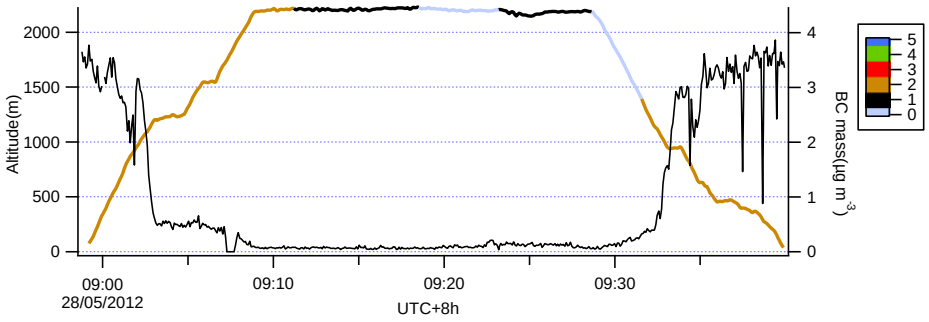

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)

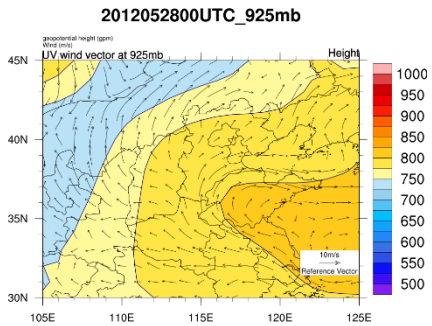

Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

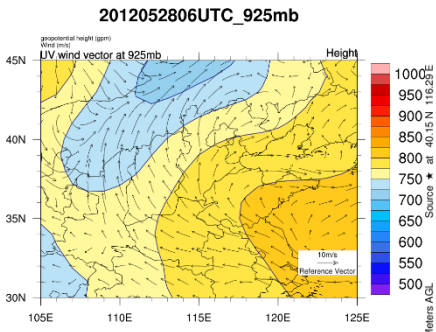

Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

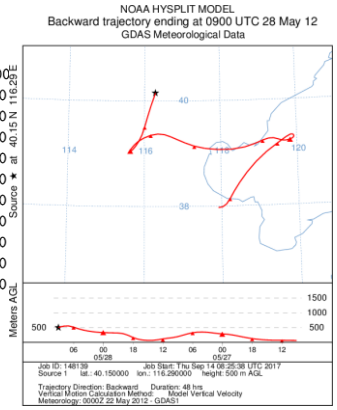
5

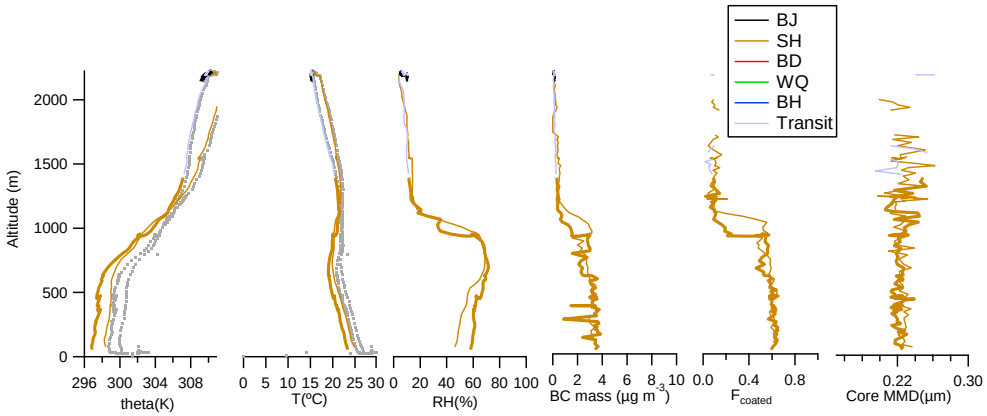
20120528

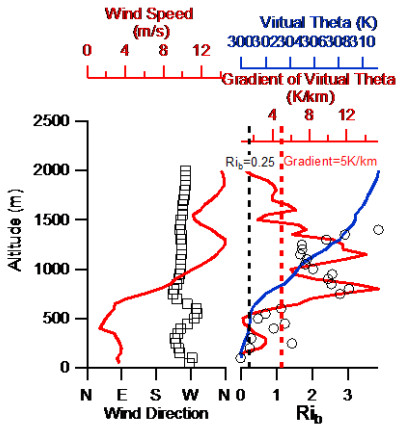

Altitude(m)
BC mass(μg m-3)
09:00
28/05/2012
09:10
09:20
09:30
UTC+8h

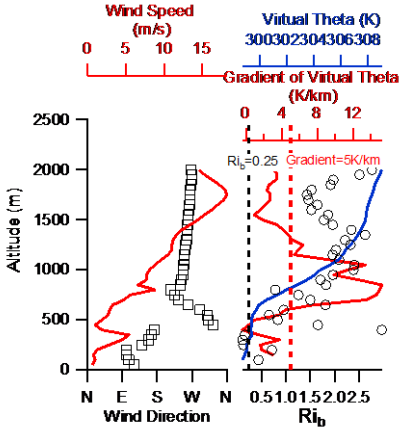

2012052800UTC_925mb
UV wind vector at 925mb
Height


2012052806UTC_925mb
UV wind vector at 925mb
Height

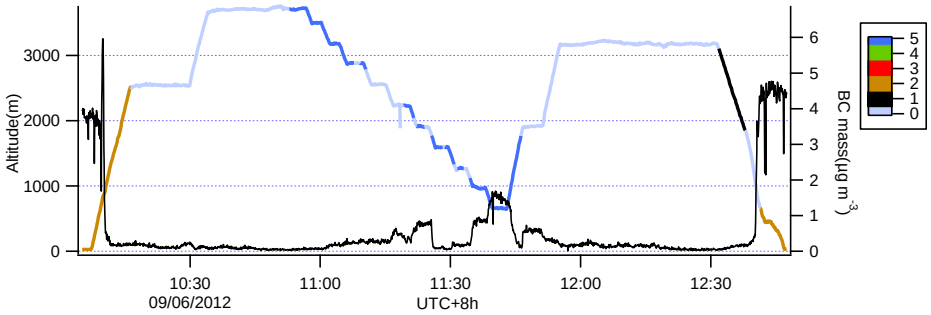

NOAA HYSPLIT MODEL
Backward trajectory ending at 0900 UTC 28 May 12
GDAS Meteorological Data

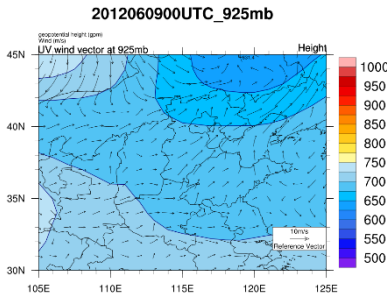

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)

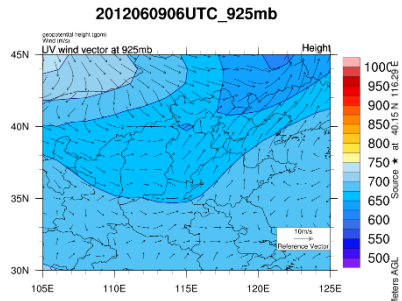

Wind Speed (m/s)
Virtual Theta (K)
300302304306308310
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
N E S W N
Wind Direction
Ri_b

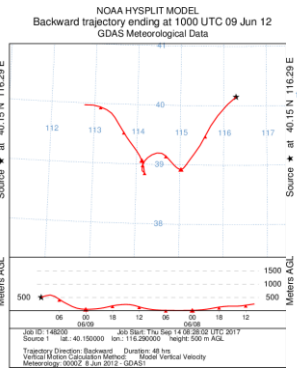

Wind Speed (m/s)
Virtual Theta (K)
300302304306308
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
N E S W N
Wind Direction
Ri_b

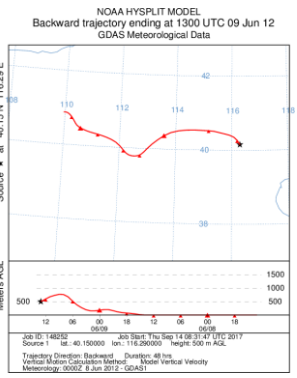
20120609

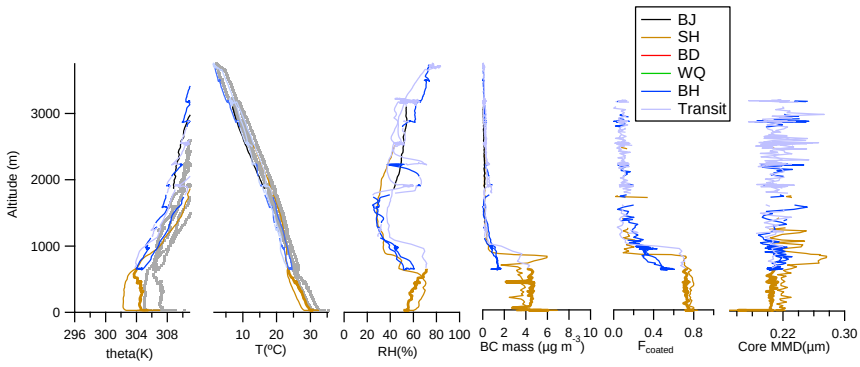

Altitude(m)
BC mass(μg m-3)
10:30
09/06/2012
11:00
11:30
UTC+8h
12:00
12:30


2012060900UTC_925mb
UV wind vector at 925mb
Height

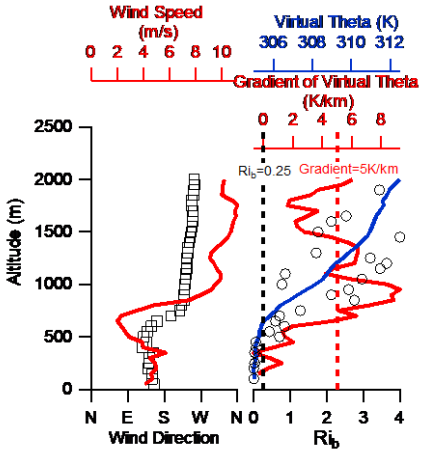

2012060906UTC_925mb
UV wind vector at 925mb
Height

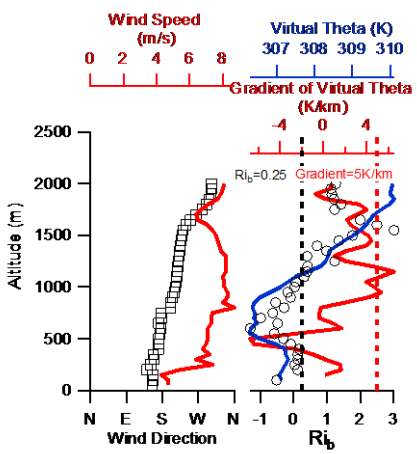

NOAA HYSPLIT MODEL
Backward trajectory ending at 1000 UTC 09 Jun 12
GDAS Meteorological Data


NOAA HYSPLIT MODEL
Backward trajectory ending at 1300 UTC 09 Jun 12
GDAS Meteorological Data

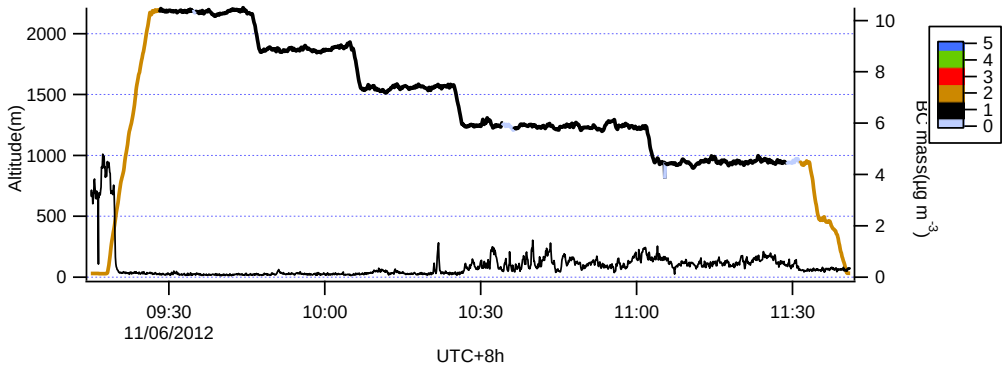

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)

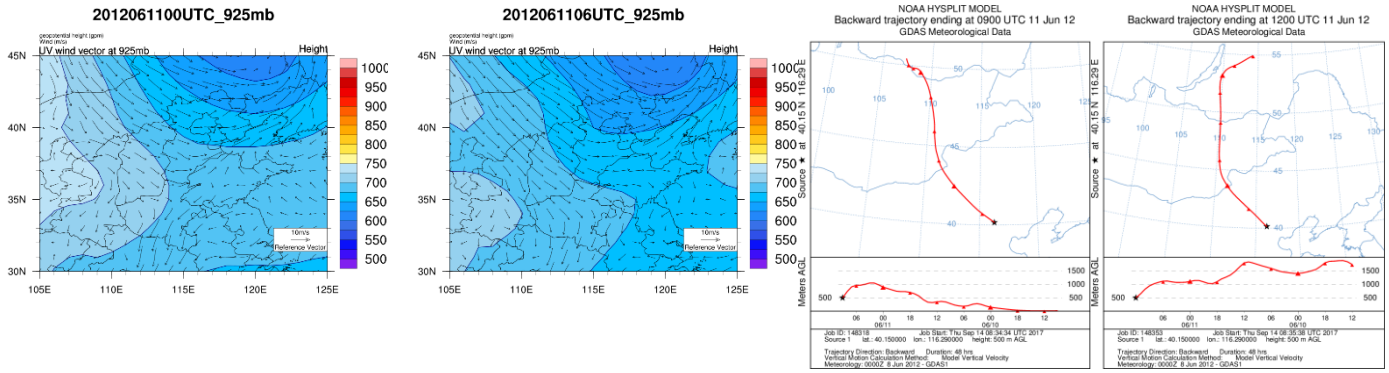
5

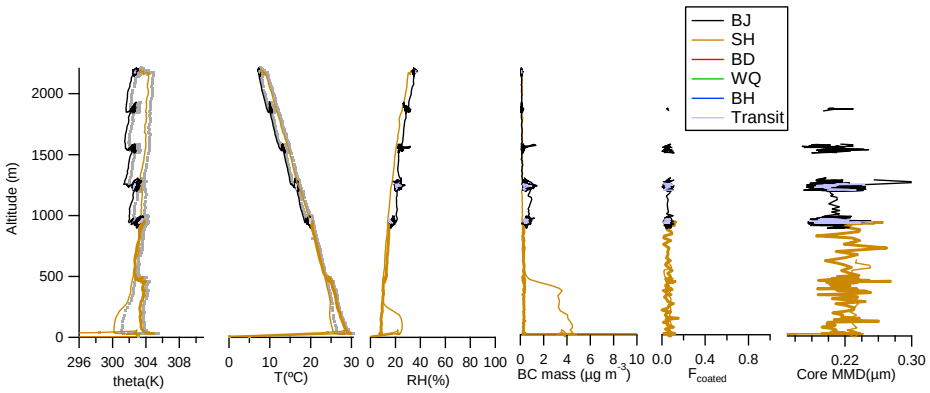

Wind Speed (m/s)
Virtual Theta (K)
306 308 310 312
Gradient of Virtual Theta (K/km)
Ri_b=0.25 Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

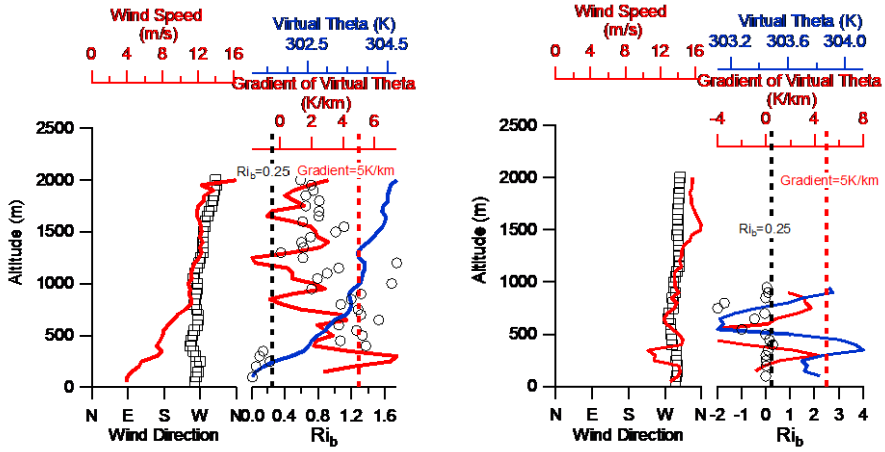

Wind Speed (m/s)
Virtual Theta (K)
307 308 309 310
Gradient of Virtual Theta (K/km)
Ri_b=0.25 Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

20120611


Altitude(m)
2000
1500
1000
500
0
10
8
6
4
2
0
09:30
11/06/2012
10:00
10:30
11:00
11:30
UTC+8h
BC mass(ug m-3)
5
4
3
2
1
0

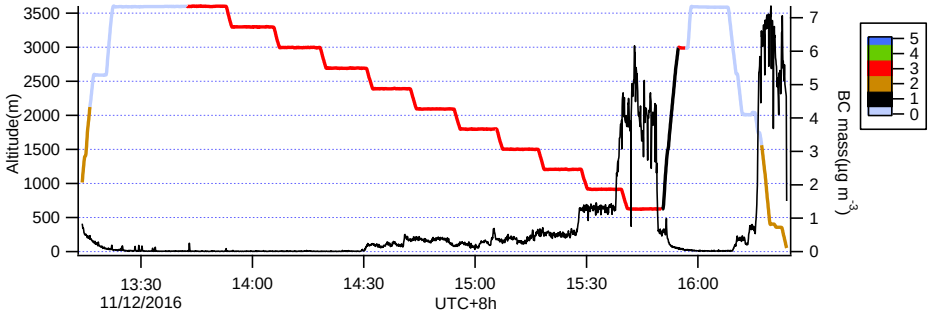

2012061100UTC_925mb
2012061106UTC_925mb
UV wind vector at 925mb
Height
45N
40N
35N
30N
105E
110E
115E
120E
125E
NOAA HYSPLIT MODEL
Backward trajectory ending at 0900 UTC 11 Jun 12
GDAS Meteorological Data
NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 11 Jun 12
GDAS Meteorological Data

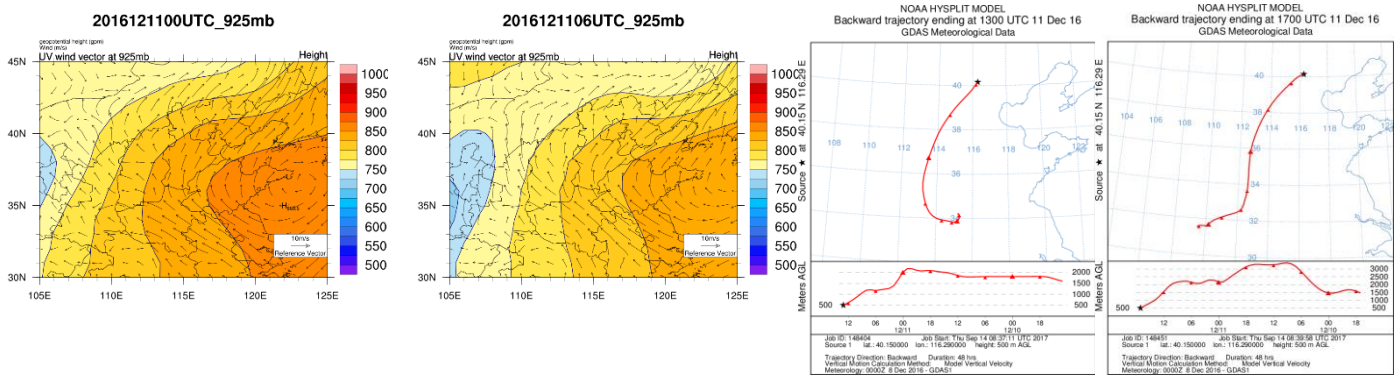

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(°C)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)

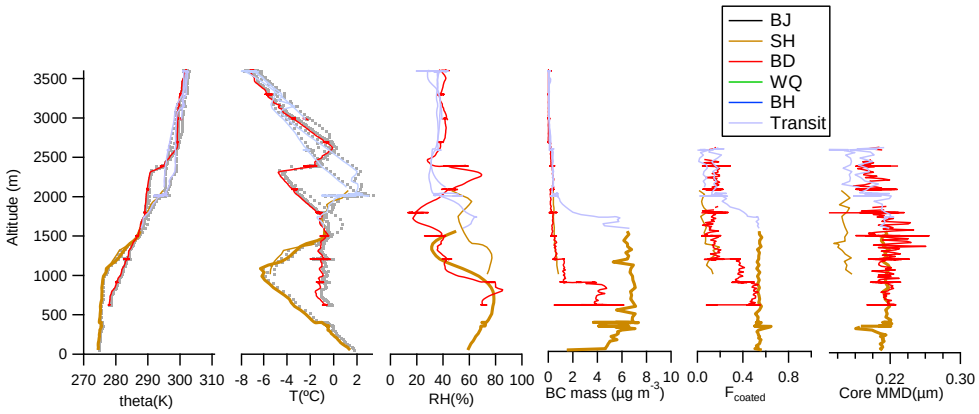

Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
N E S W N
Wind Direction
Ri_b

Winter flights

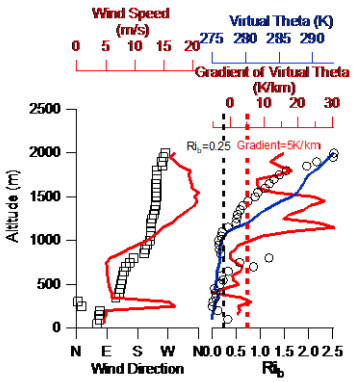
20161211



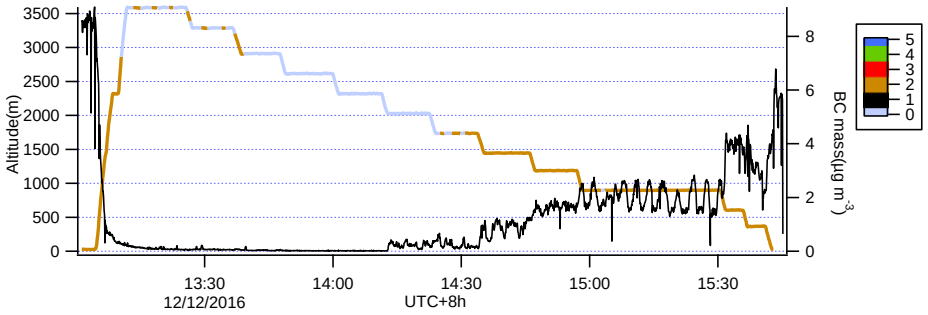


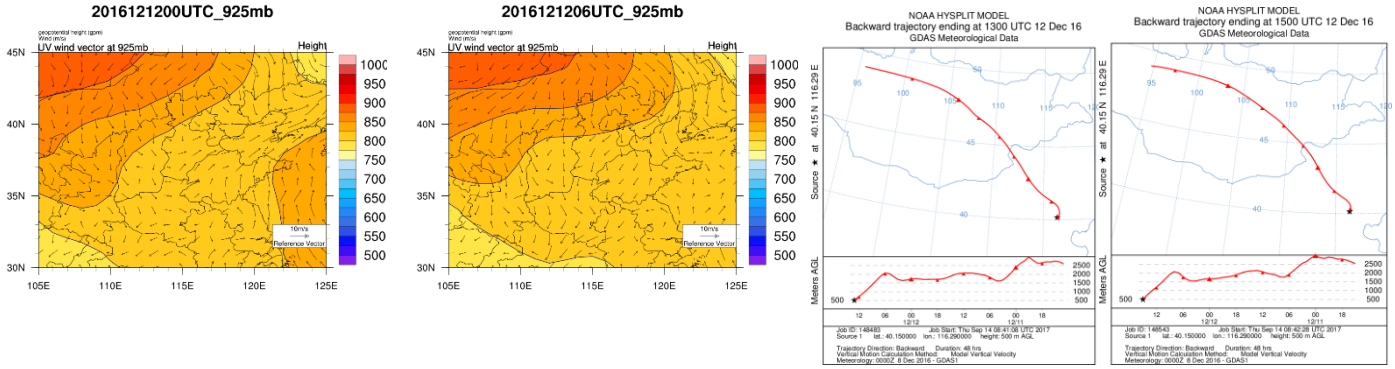


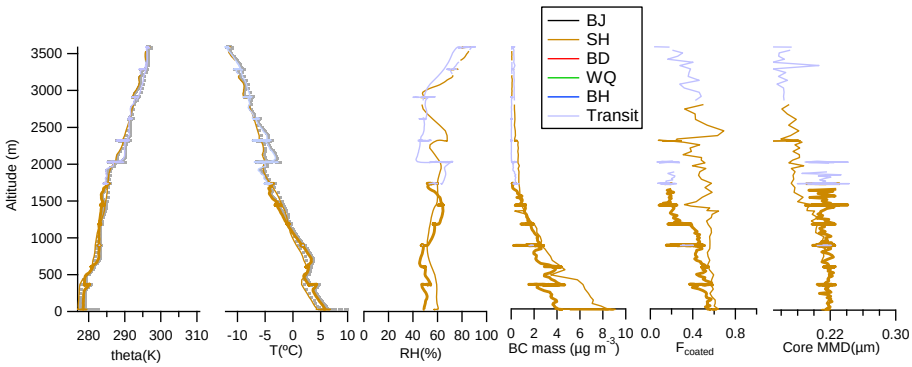
5

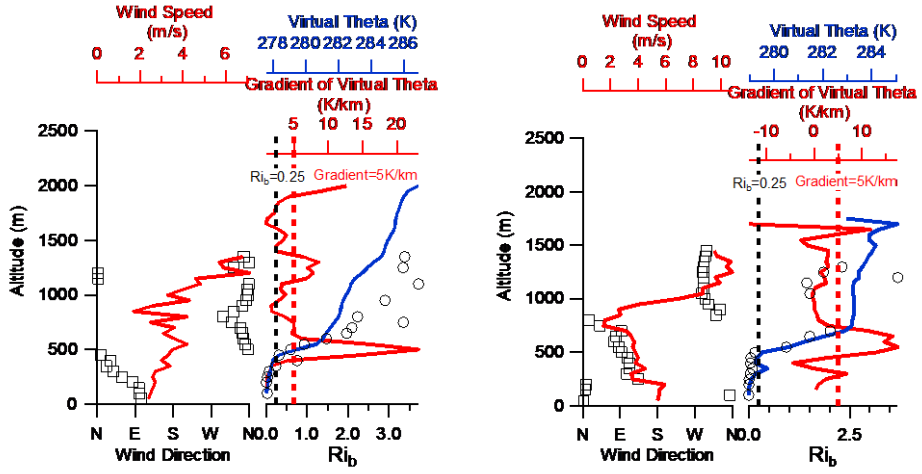


20161212


Altitude(m)
BC mass(μg m-3)
13:30
12/12/2016
14:00
14:30
UTC+8h
15:00
15:30

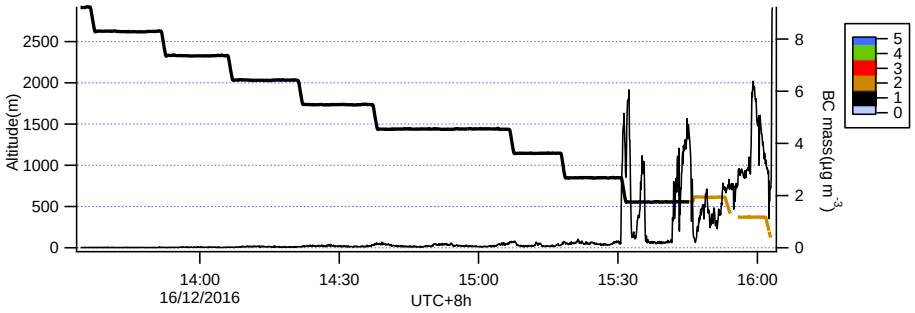

2016121200UTC_925mb
2016121206UTC_925mb
UV wind vector at 925mb
Height
NOAA HYSPLIT MODEL
Backward trajectory ending at 1300 UTC 12 Dec 16
Backward trajectory ending at 1500 UTC 12 Dec 16
GDAS Meteorological Data

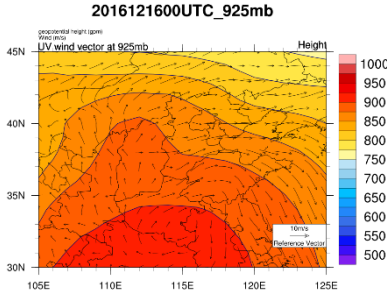

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)

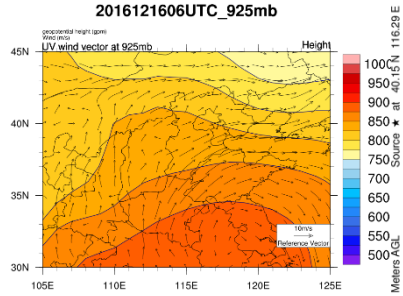

Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25 Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

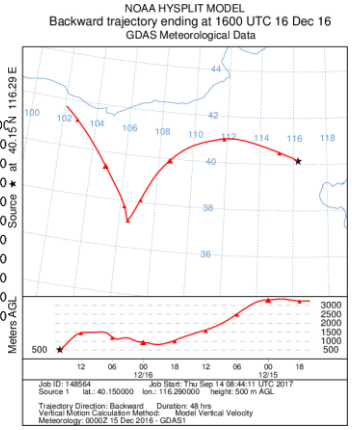
5

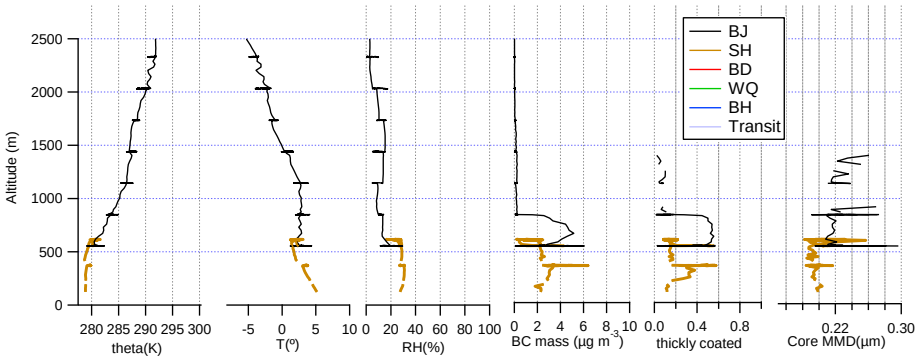
20121216

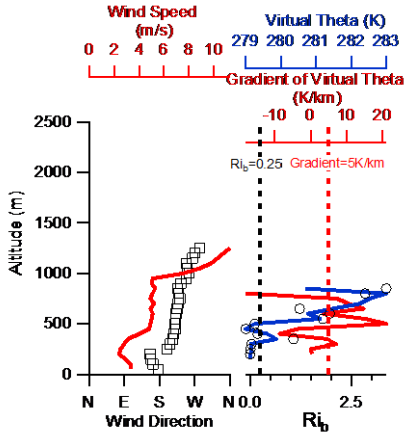

Altitude(m)
BC mass(μg m-3)
14:00
16/12/2016
14:30
15:00
15:30
16:00
UTC+8h


2016121600UTC_925mb
UV wind vector at 925mb
Height


2016121606UTC_925mb
UV wind vector at 925mb
Height

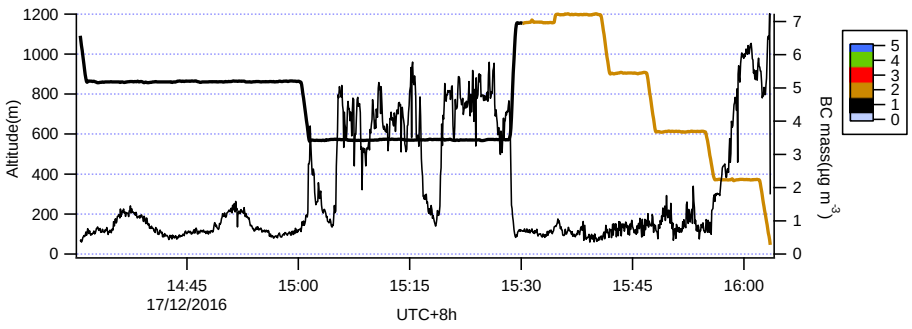

NOAA HYSPLIT MODEL
Backward trajectory ending at 1600 UTC 16 Dec 16
GDAS Meteorological Data
Meters AGL

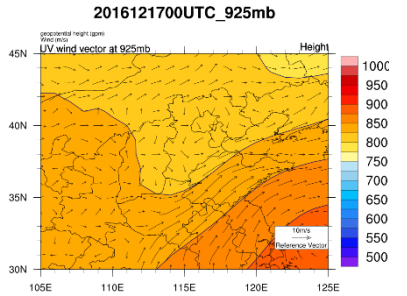

Altitude (m)
theta(K)
T(°)
RH(%)
BC mass (μg m-3)
thickly coated
Core MMD(μm)
BJ
SH
BD
WQ
BH
Transit

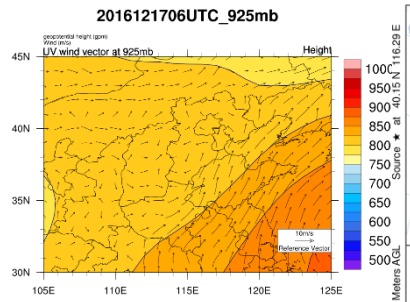

Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Rib=0.25
Gradient=5K/km
Altitude (m)
Wind Direction
Rib

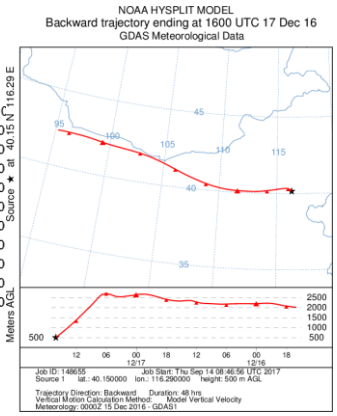
5

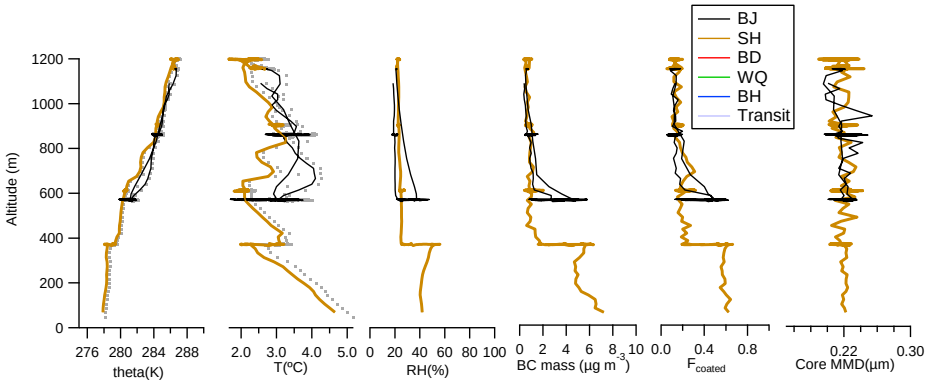
20161217

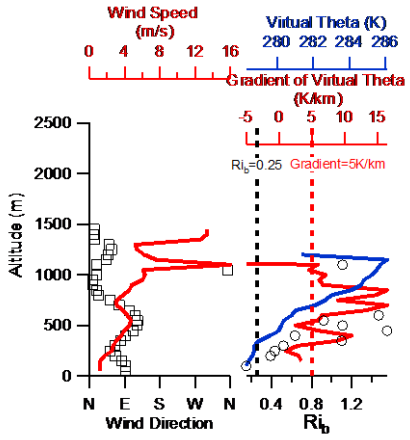

Altitude(m)
BC mass(μg m-3)
14:45
17/12/2016
15:00
15:15
15:30
15:45
16:00
UTC+8h


2016121700UTC_925mb
UV wind vector at 925mb
Height


2016121706UTC_925mb
UV wind vector at 925mb
Height

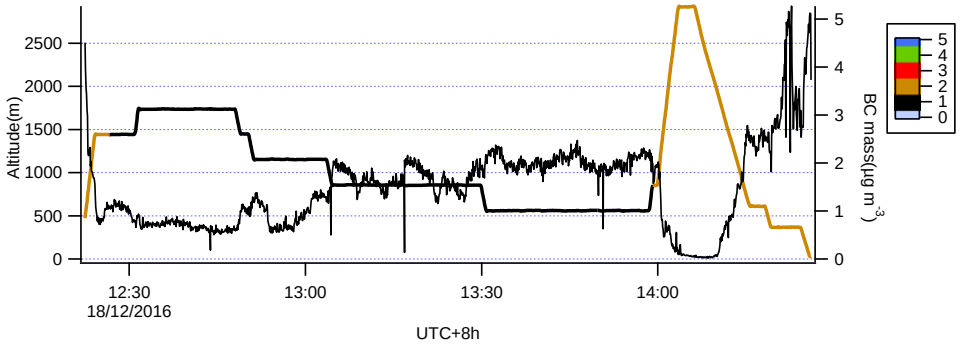

NOAA HYSPLIT MODEL
Backward trajectory ending at 1600 UTC 17 Dec 16
GDAS Meteorological Data
Meters AGL

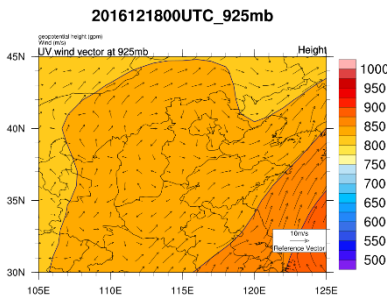

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)

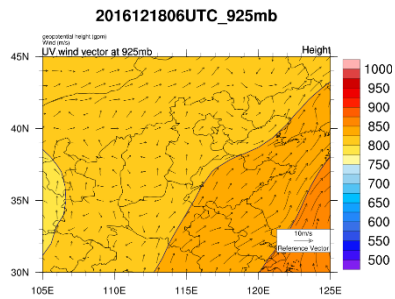

Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

5

20161218


Altitude(m)
BC mass(μg m-3)
12:30
18/12/2016
13:00
13:30
14:00
UTC+8h


2016121800UTC_925mb
UV wind vector at 925mb
Height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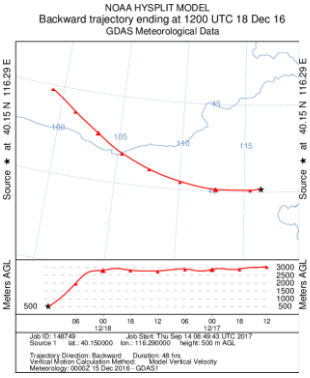
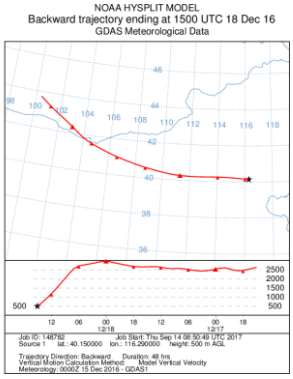
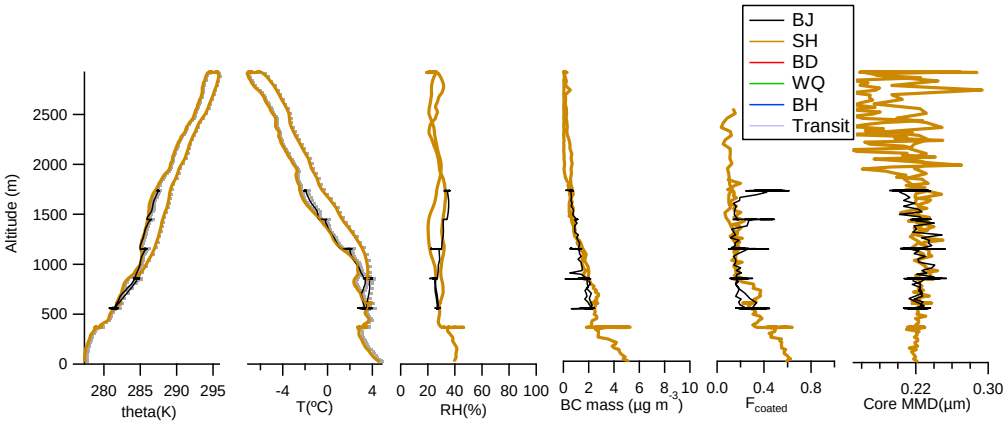
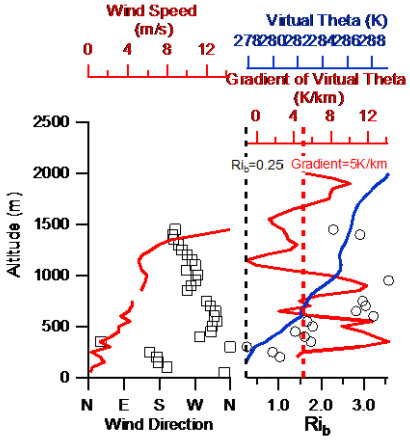
UV wind vector at 925mb
Height


NOAA HYSPLIT MODEL
Backward trajectory ending at 1200 UTC 18 Dec 16
GDAS Meteorological Data

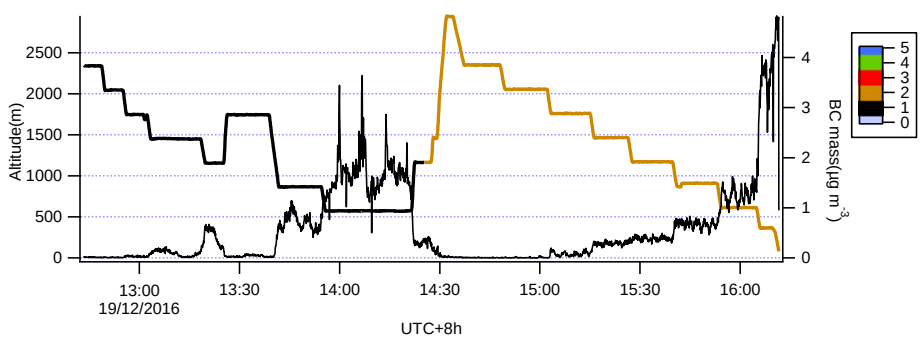

NOAA HYSPLIT MODEL
Backward trajectory ending at 1500 UTC 18 Dec 16
GDAS Meteorological Data

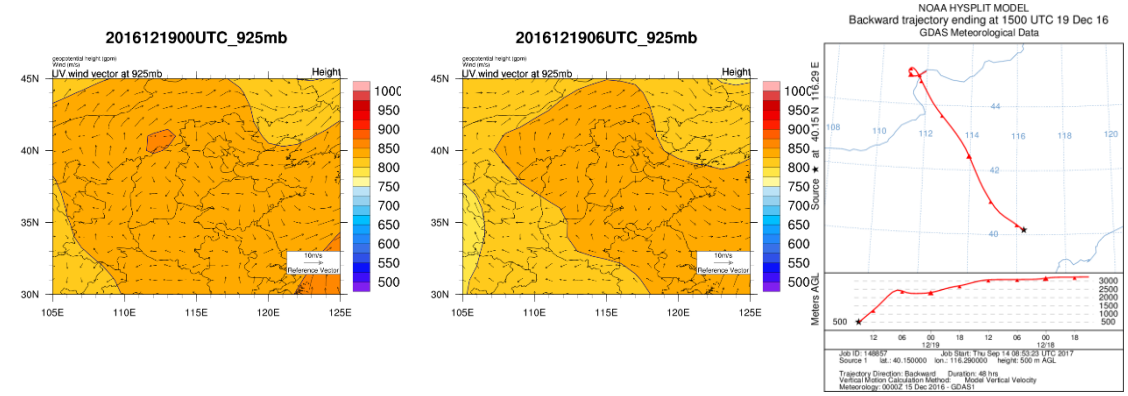

BJ
SH
BD
WQ
BH
Transit
Altitude (m)
theta(K)
T(ºC)
RH(%)
BC mass (μg m-3)
Fcoated
Core MMD(μm)

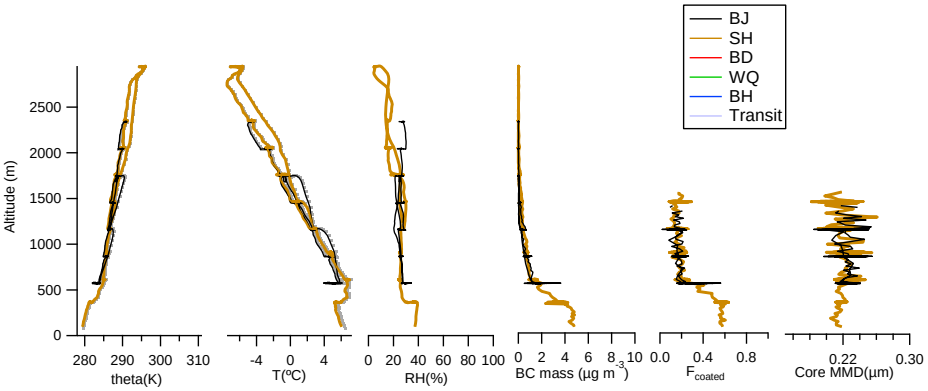

Wind Speed (m/s)
Virtual Theta (K)
Gradient of Virtual Theta (K/km)
Ri_b=0.25
Gradient=5K/km
Altitude (m)
Wind Direction
Ri_b

5

20161219







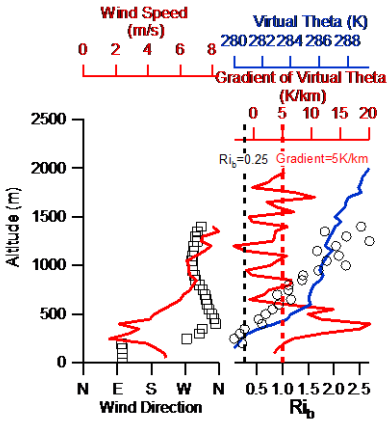


Fig. S7. The identical plots for each flight, from top to bottom: flight track colored by aircraft locations; the synoptic wind field and pressure charts at geopotential pressure 925mbar for flight departure and return respectively; the HYSPLIT

backtrajectories over the last 48 hours initialized at the location of Shahe, 500m a.s.l. for departure and return respectively; the vertical profiles of potential temperature (the dash line is virtual potential temperature), the ambient temperature (the dash line is virtual temperature), RH, BC mass loading, BC thickly coated fraction, BC core mass median diameter (MMD), with the thicker lines indicating the return flight and the thinner ones are departure; the in-situ measured wind direction and wind speed, the right panel shows the criteria to determine the height of the planetary boundary layer, with dash lines showing the vertical gradient $d\theta_v/dz$=5K/km and critical bulk Richardson number ($Ri_{b,c}$=0.25).

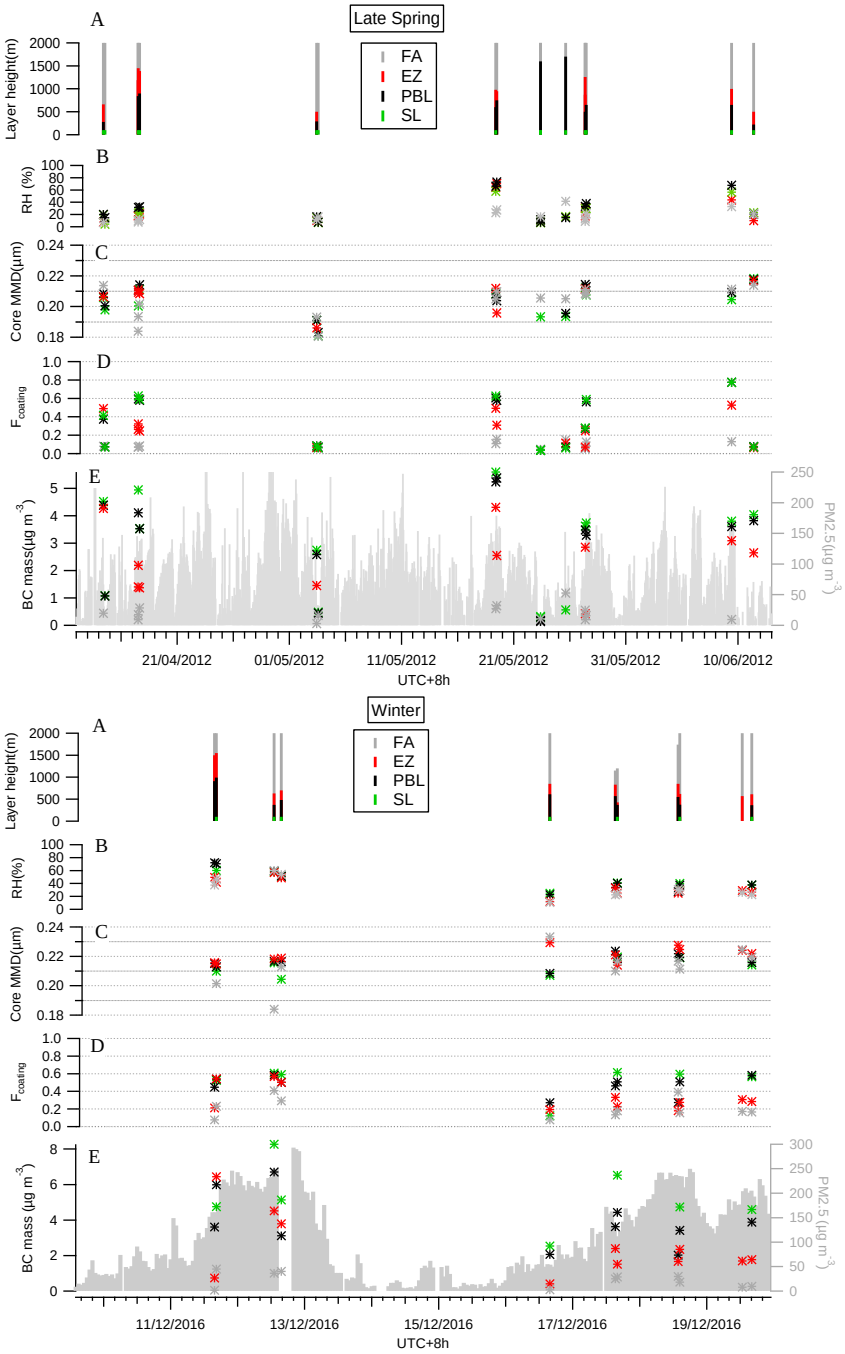


Fig. S8. A) the height of defined layers; B) averaged RH; C) mean BC core MMD; D) $F_{coating}$; E) BC mass loadings at different layers, with right axis showing the surface PM2.5. The top and bottom panel is for late spring and winter flights respectively.