

First aircraft based observations of a North Atlantic tropopause polar vortex and its representation in the ECMWF analysis and ensemble forecasts

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Synoptic overview IOP8 TPV

Representation in ECMWF (ensemble) FCST and analysis

- ENS vs analysis
- 12h FCST – analysis

HALO RF7 dropsondes vs. ECMWF operational FCST

Synoptic overview

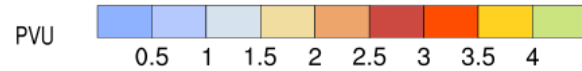
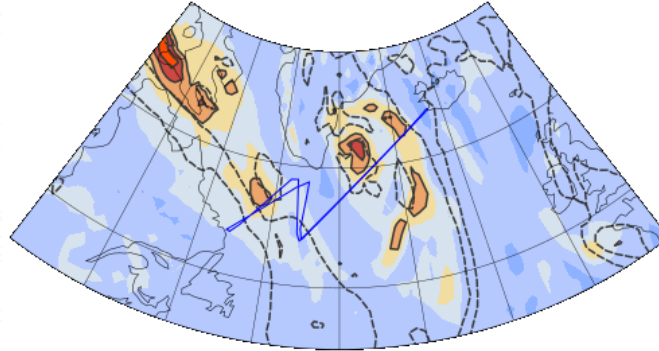
5 October – 7 October 2016

Synoptic overview: 20161005_12

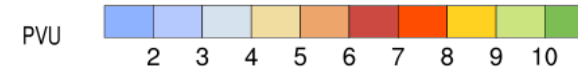
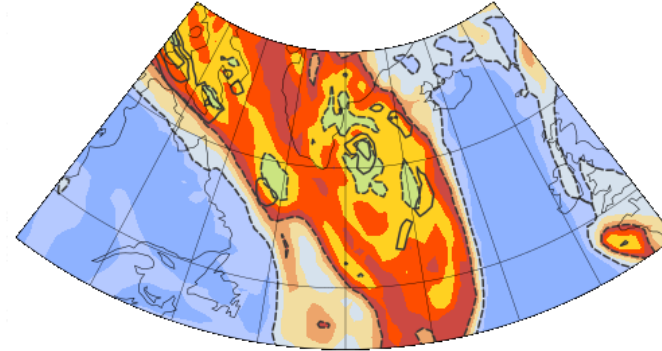
Data source: analysis

VAPV 285-310K

20161005_12: VAPV 285K-310K



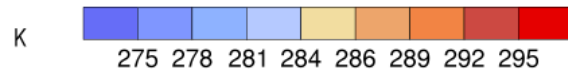
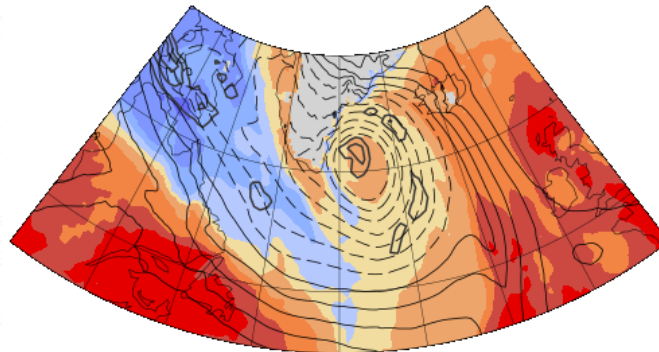
VAPV 320K-345K



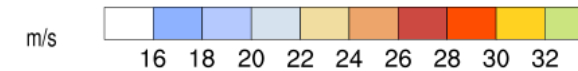
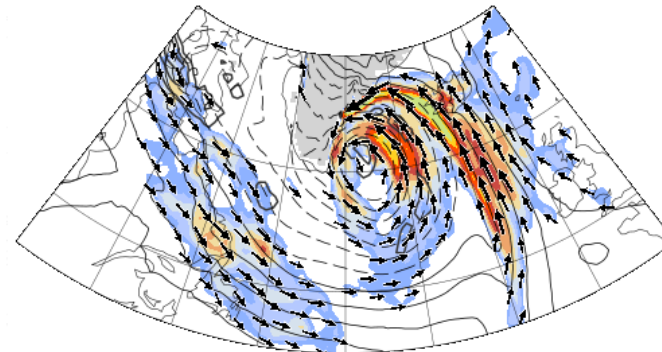
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



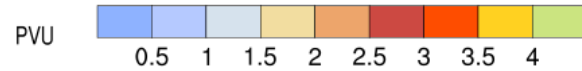
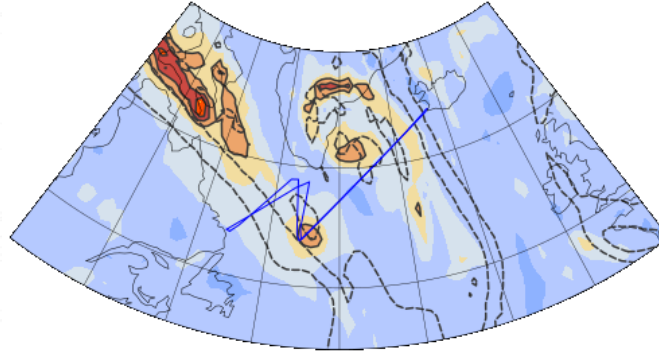
VEL@850hPa

Synoptic overview: 20161005_18

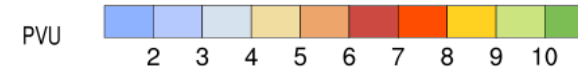
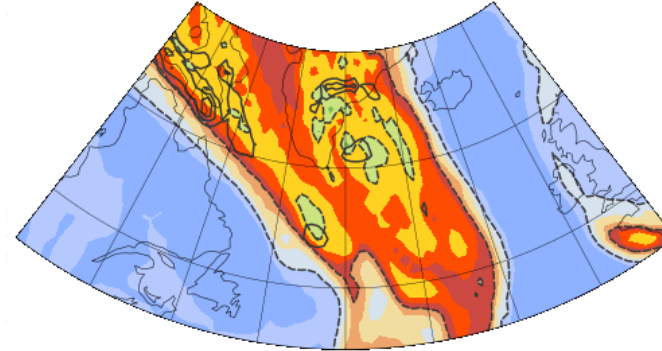
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VAPV 285-310K

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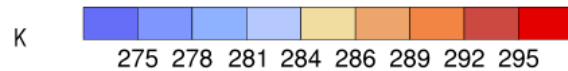
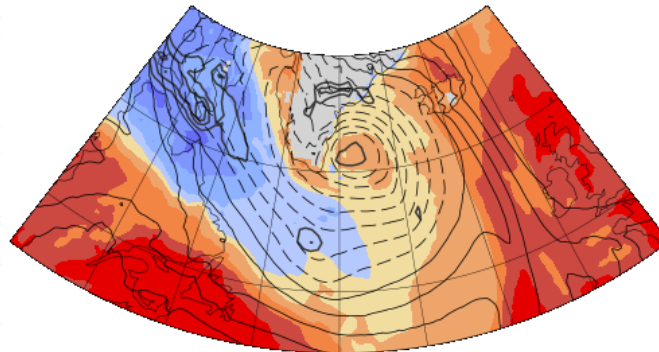
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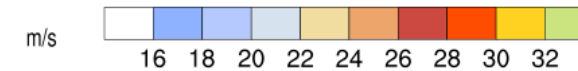
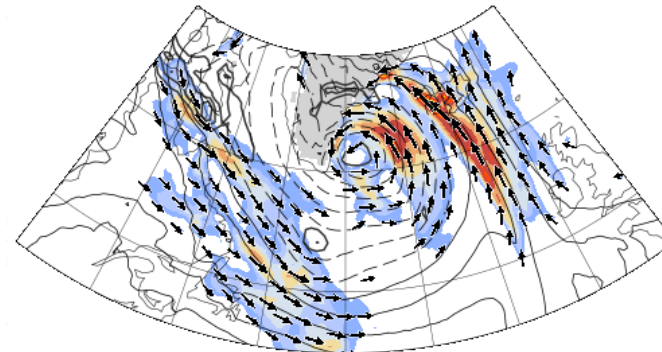
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



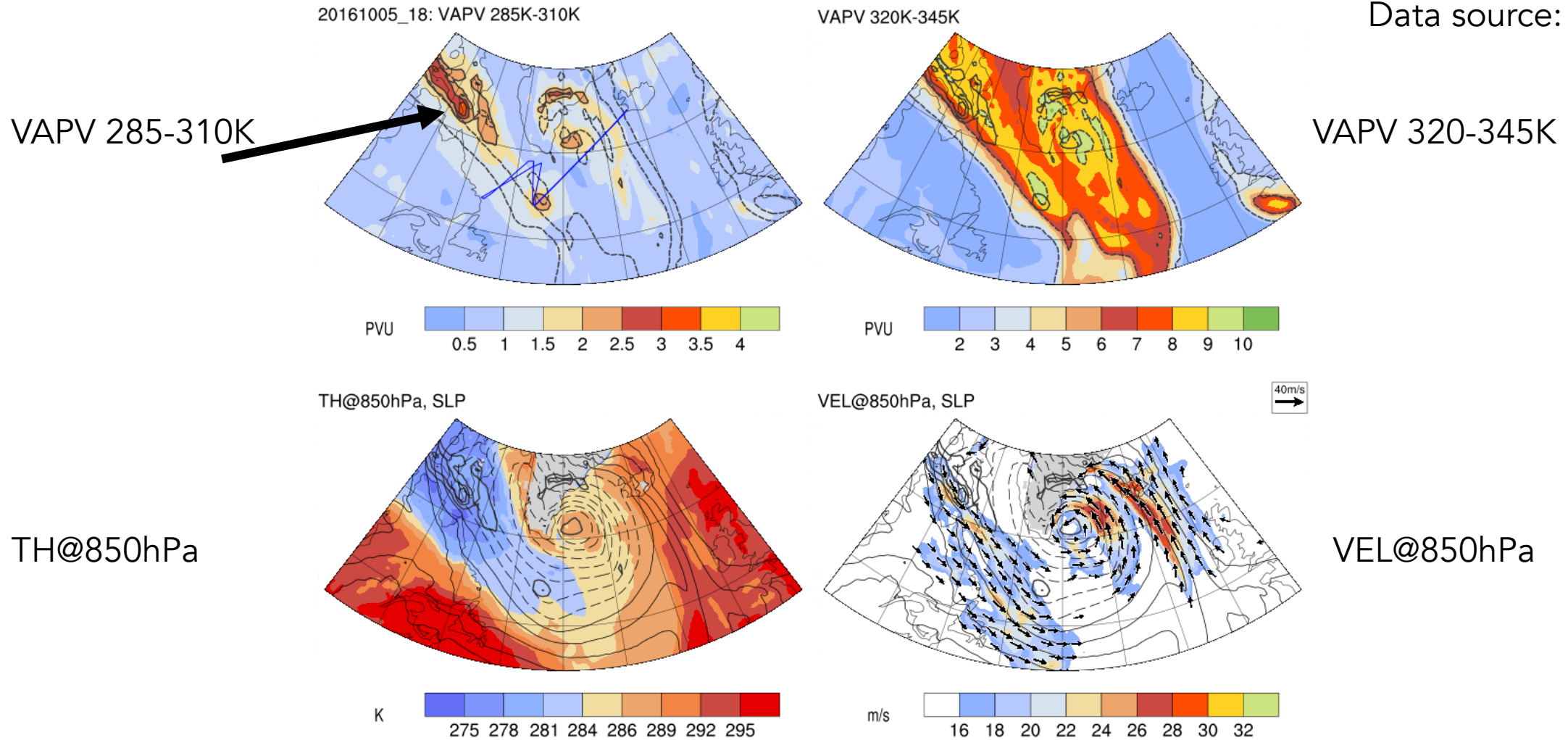
VEL@850hPa, SLP



VEL@850hPa

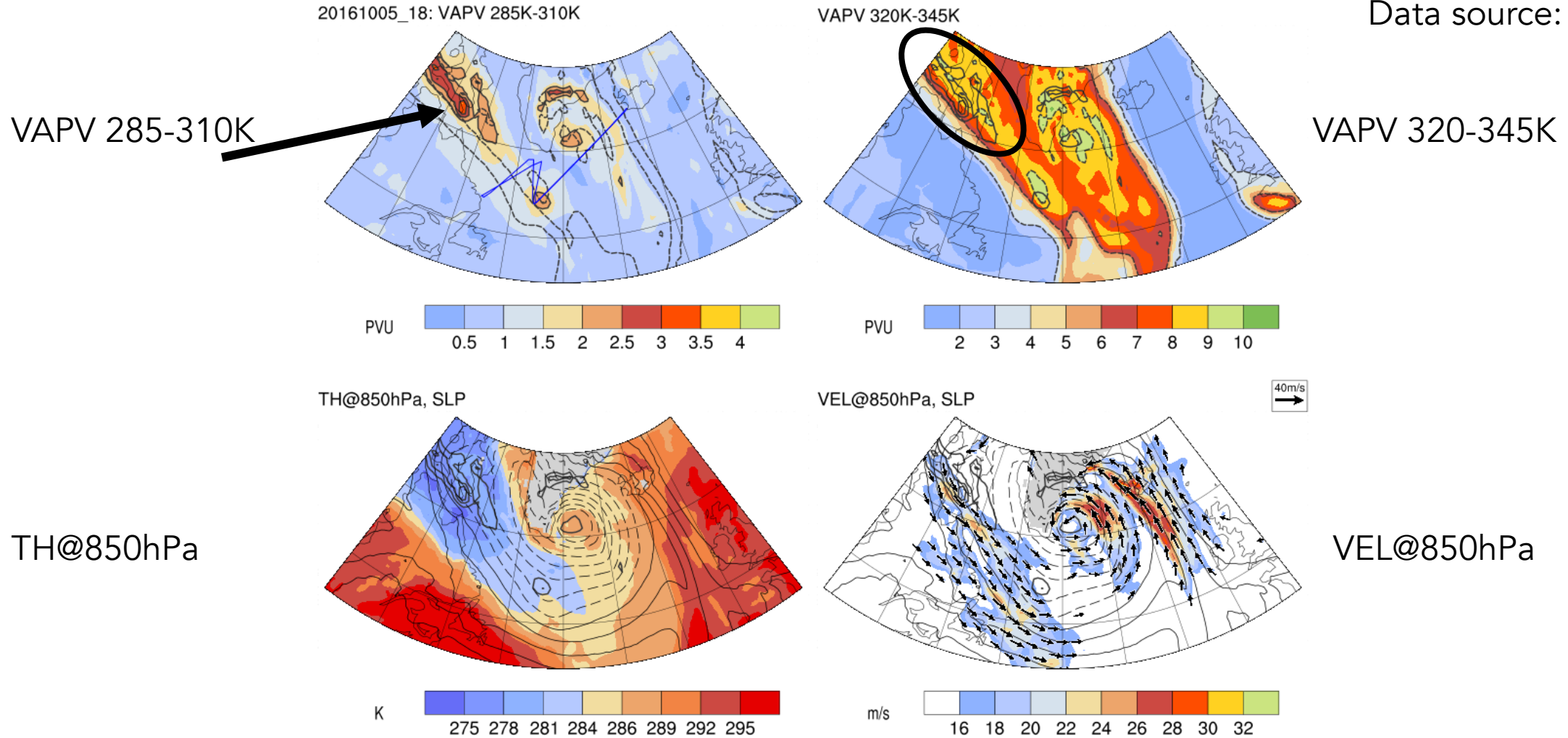
Synoptic overview: 20161005_18

Data source: analysis



Synoptic overview: 20161005_18

Data source: analysis

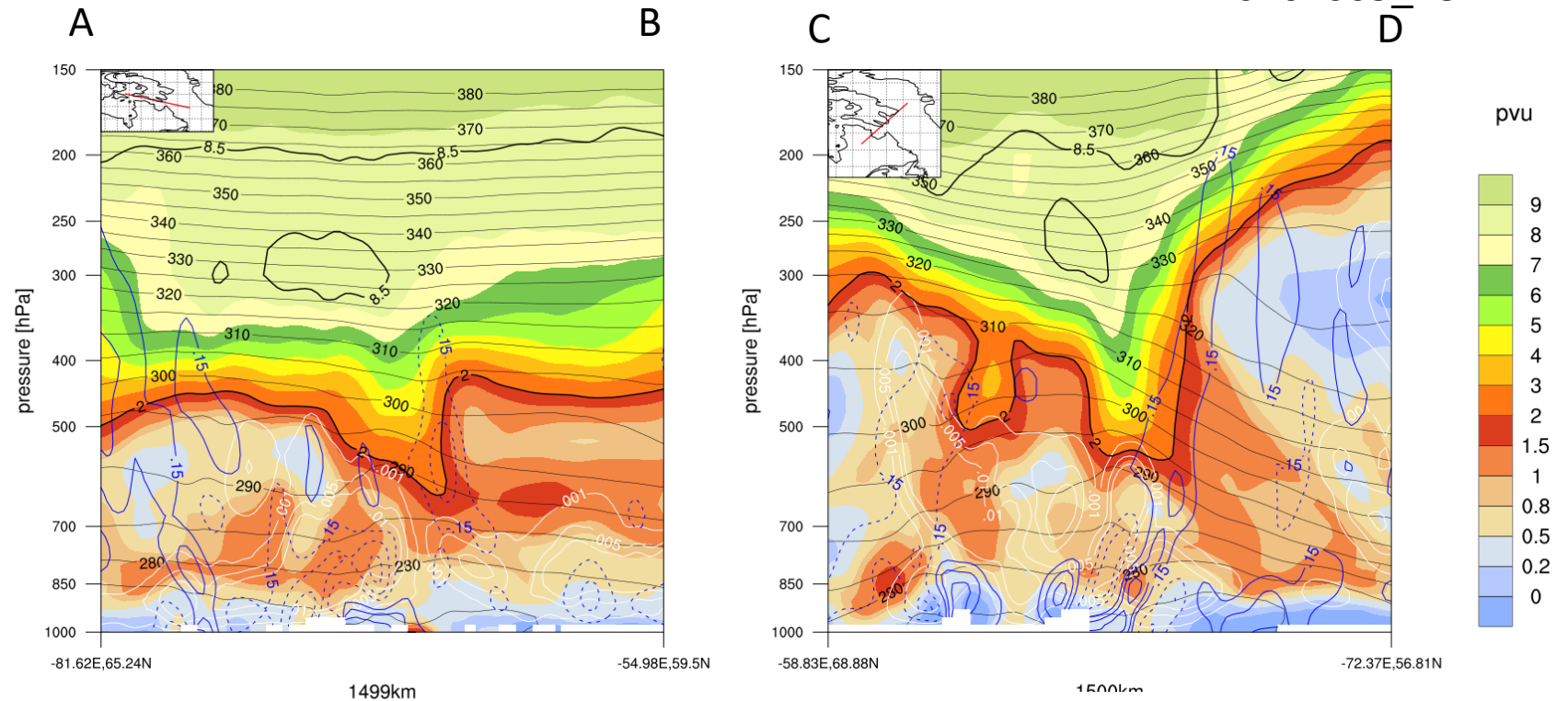
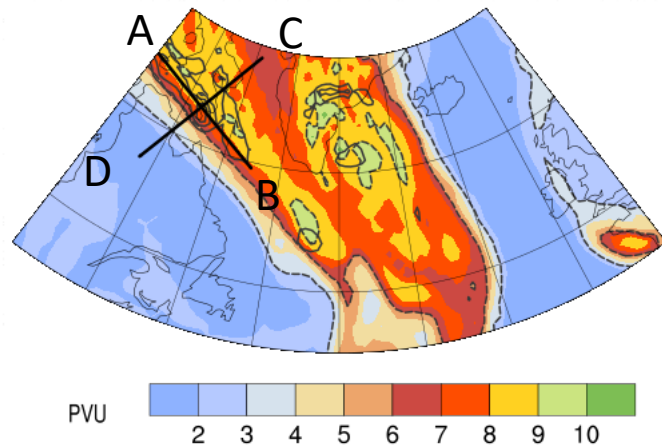


Synoptic overview

Blue solid (dashed) positive (negative) Omega
White: Ice clouds

VT: 20161005_18
D

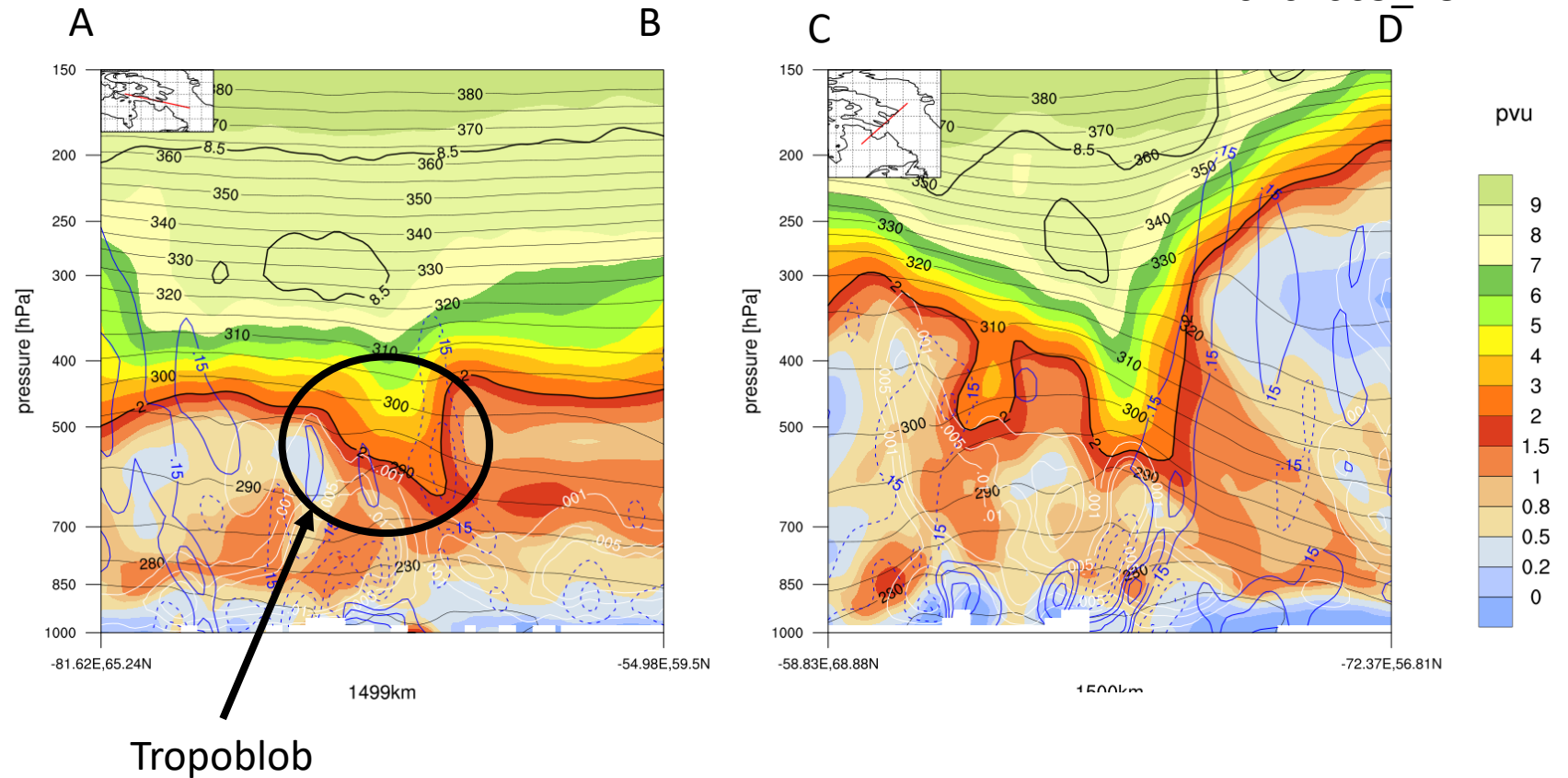
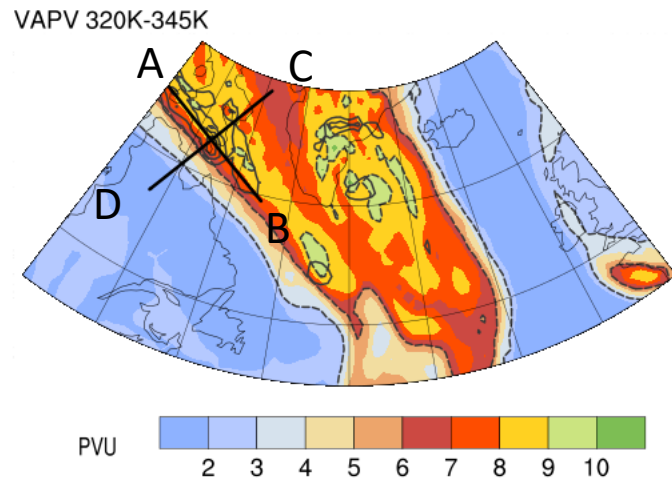
VAPV 320K-345K



Synoptic overview

Blue solid (dashed) positive (negative) Omega
White: Ice clouds

VT: 20161005_18
D

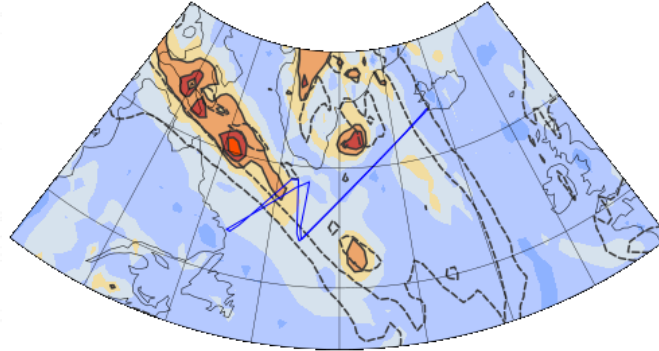


Synoptic overview: 20161006_00

Data source: analysis

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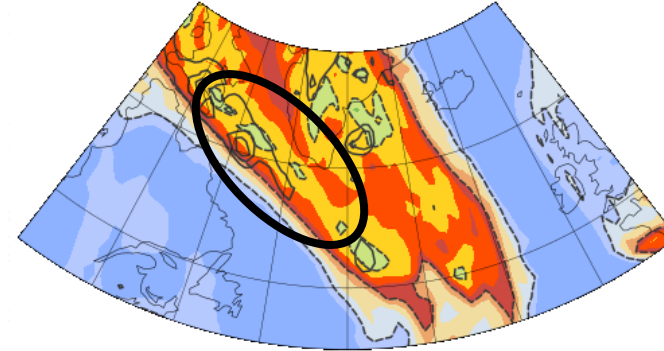
20161006_00: VAPV 285K-310K



PVU

0.5 1 1.5 2 2.5 3 3.5 4

VAPV 320K-345K



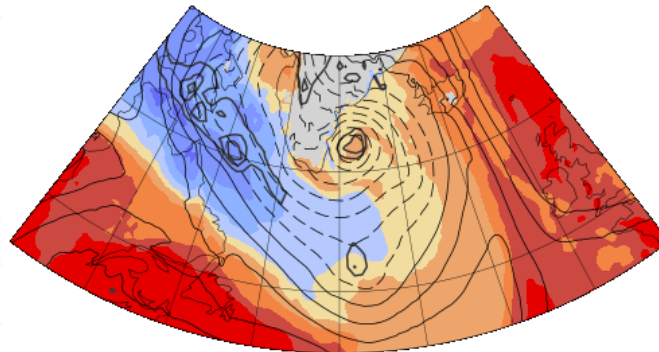
PVU

2 3 4 5 6 7 8 9 10

VAPV 320-345K

TH@850hPa

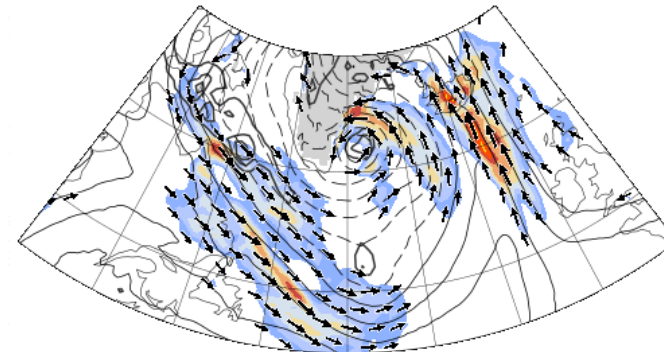
TH@850hPa, SLP



K

275 278 281 284 286 289 292 295

VEL@850hPa, SLP



m/s

16 18 20 22 24 26 28 30 32

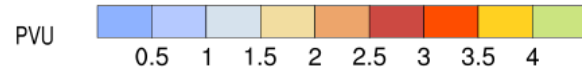
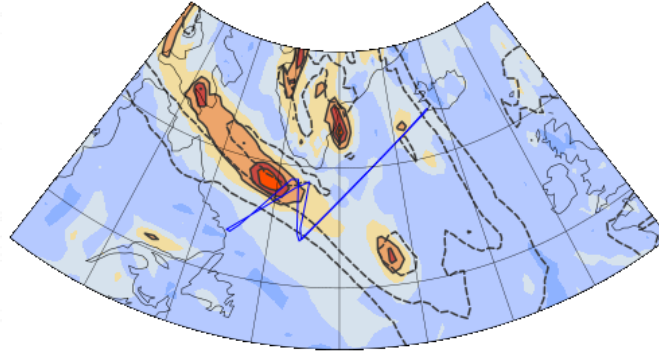
VEL@850hPa

Synoptic overview: 20161006_06

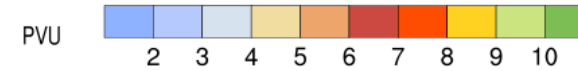
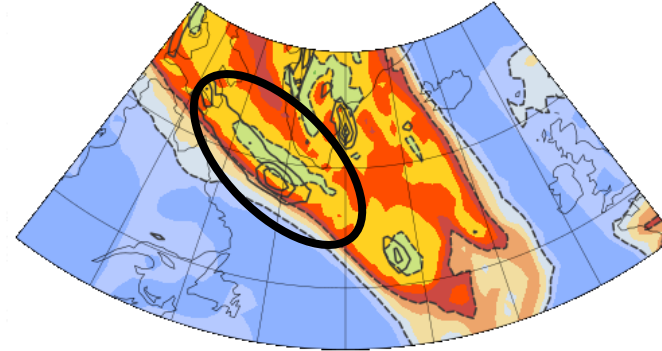
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VAPV 285-310K

20161006_06: VAPV 285K-310K



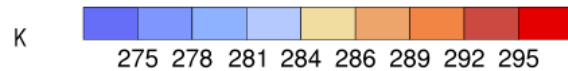
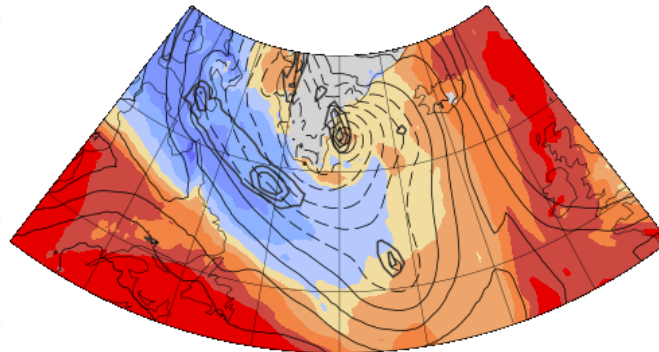
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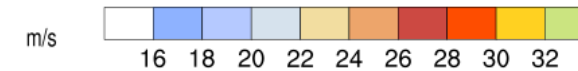
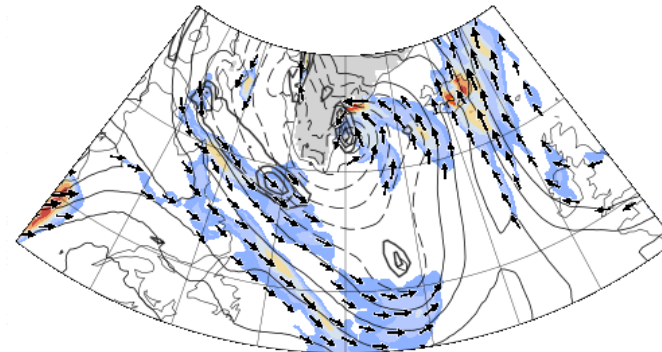
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



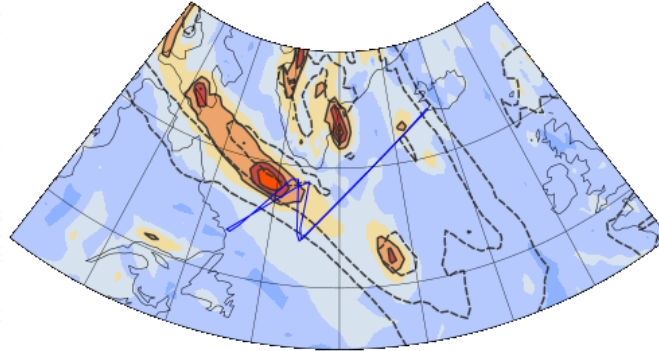
VEL@850hPa

Synoptic overview: 20161006_06

Data source: analysis

VAPV 285-310K

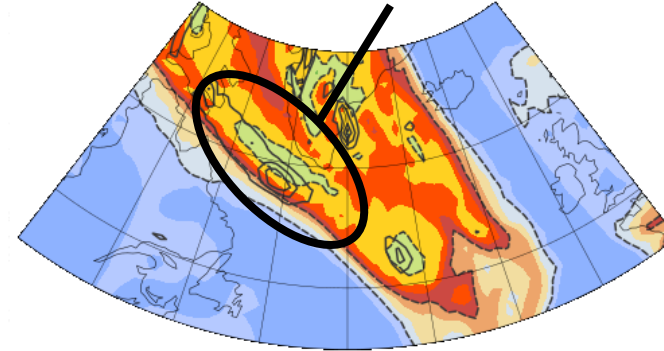
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PVU

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VAPV 320K-345K



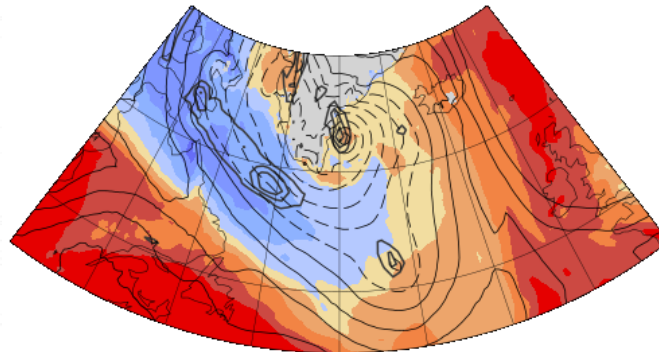
PVU

2 3 4 5 6 7 8 9 10

VAPV 320-345K

TH@850hPa

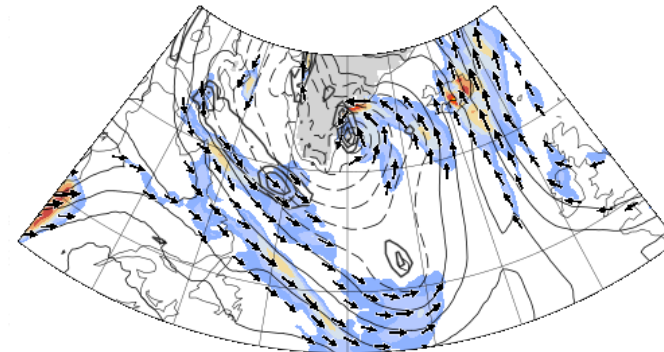
TH@850hPa, SLP



K

275 278 281 284 286 289 292 295

VEL@850hPa, SLP



m/s

16 18 20 22 24 26 28 30 32

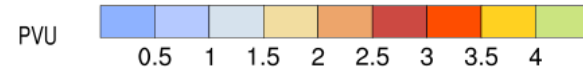
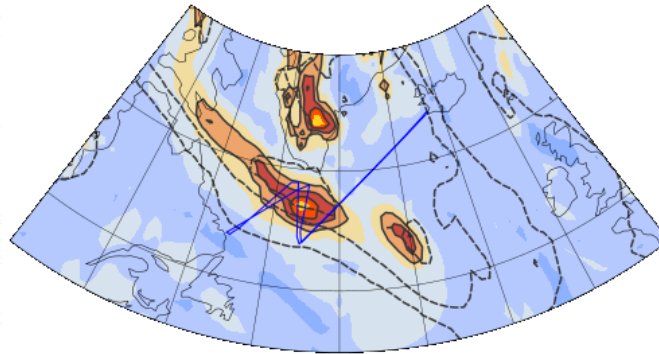
VEL@850hPa

Synoptic overview: 20161006_12

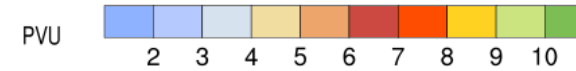
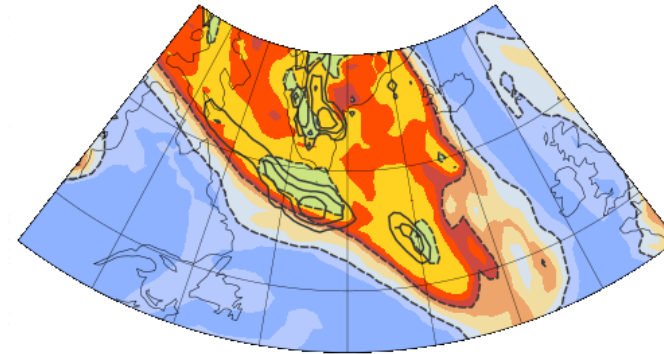
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VAPV 285-310K

20161006_12: VAPV 285K-310K



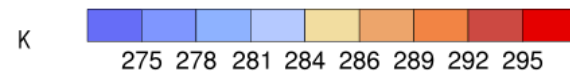
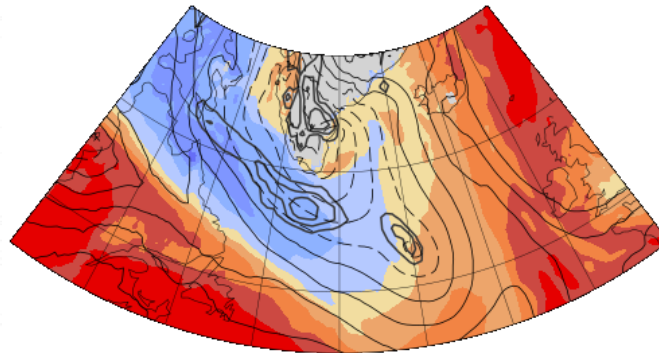
VAPV 320K-345K



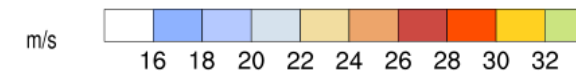
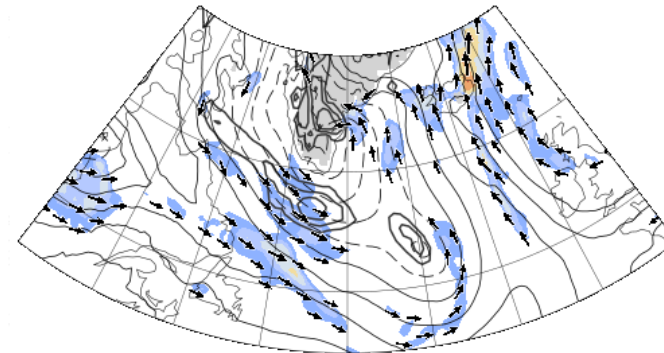
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



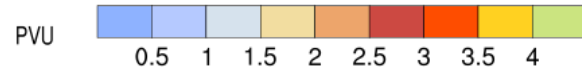
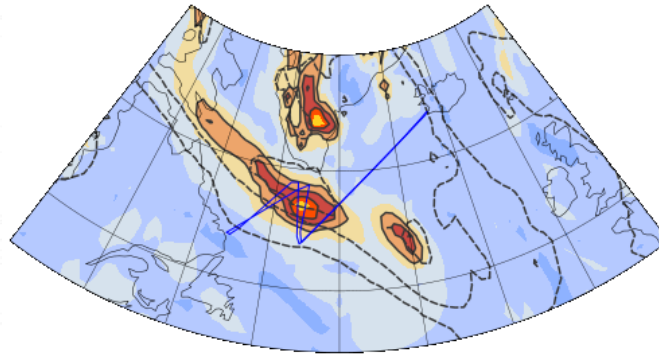
VEL@850hPa

Synoptic overview: 20161006_12

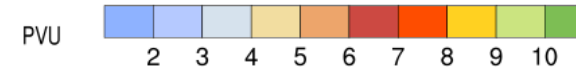
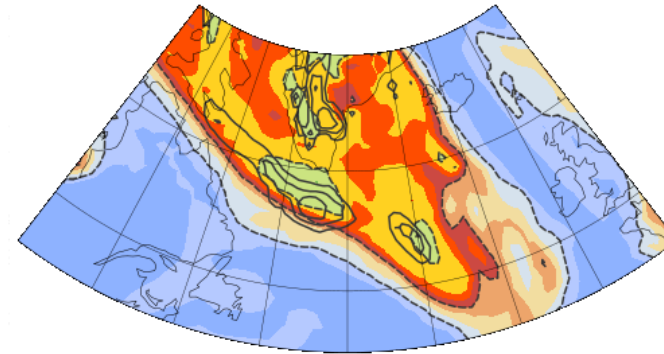
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VAPV 285-310K

20161006_12: VAPV 285K-310K



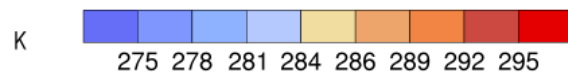
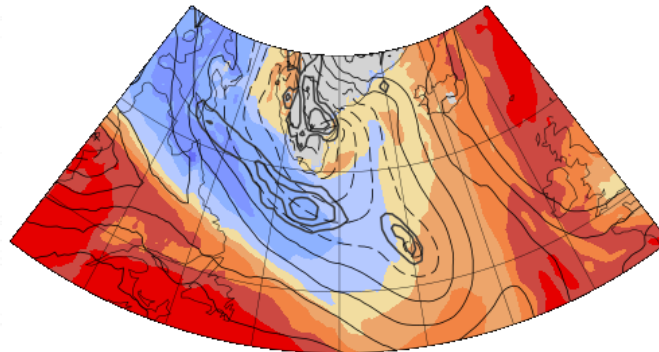
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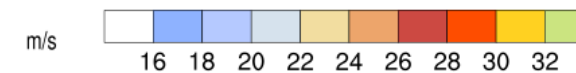
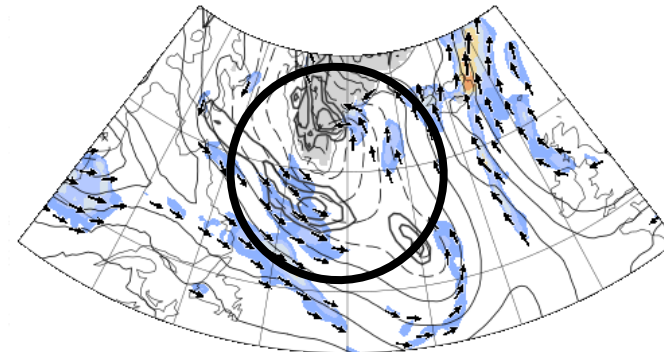
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



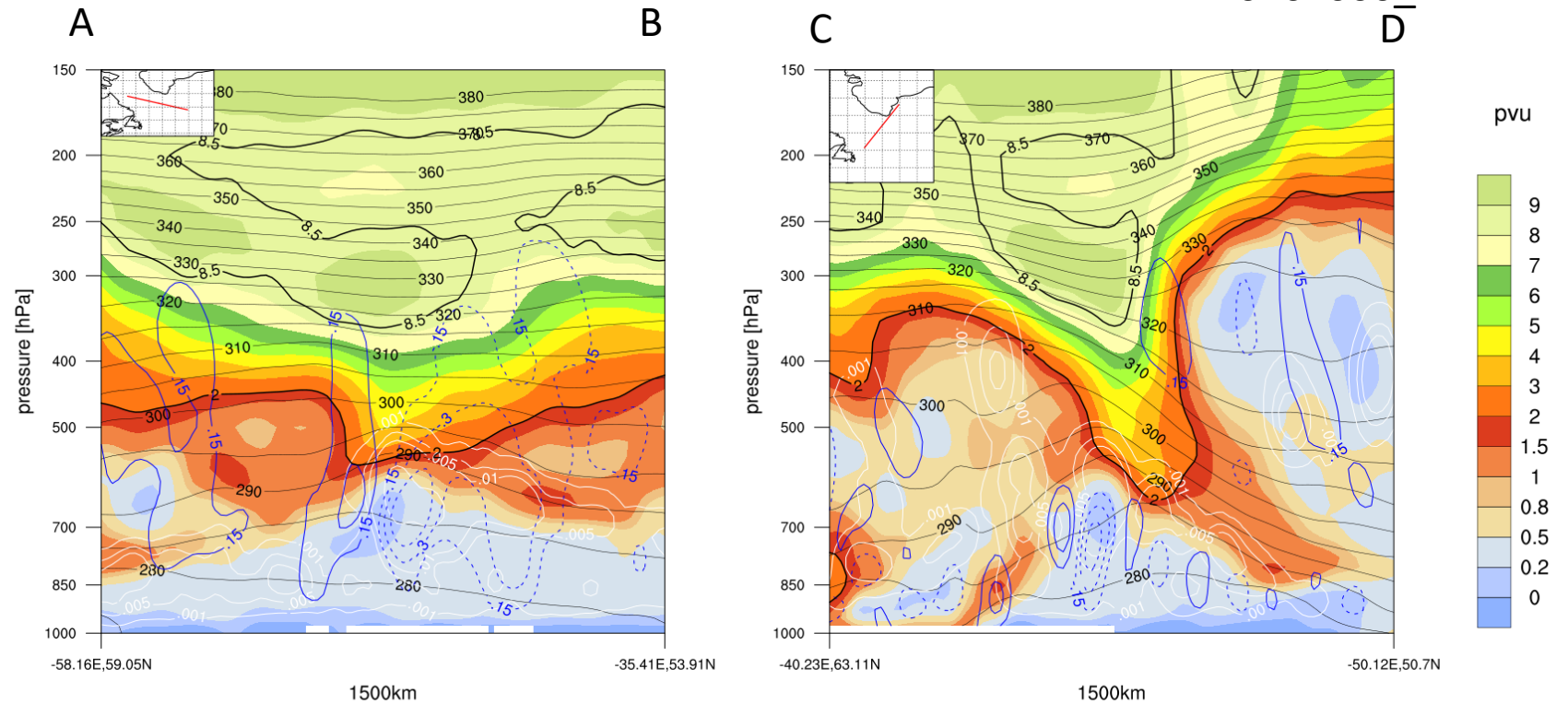
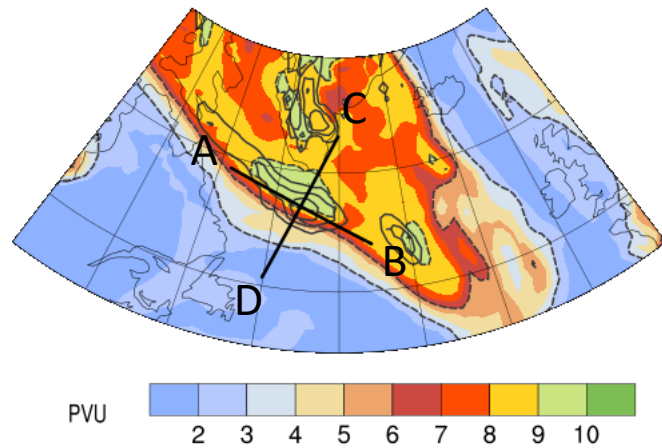
VEL@850hPa

Synoptic overview

Blue solid (dashed) positive (negative) Omega
White: Ice clouds

VT: 20161006_12
D

VAPV 320K-345K

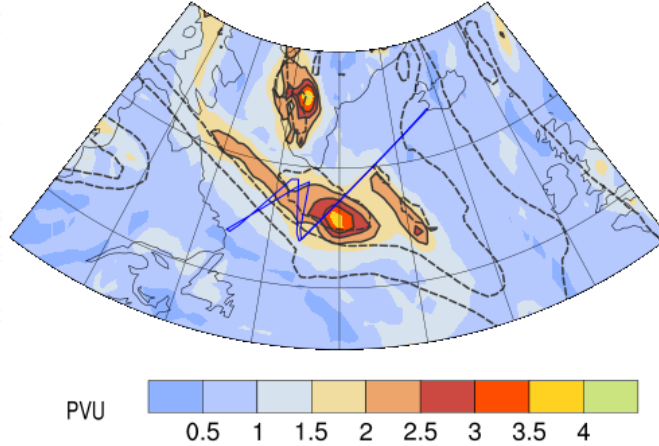


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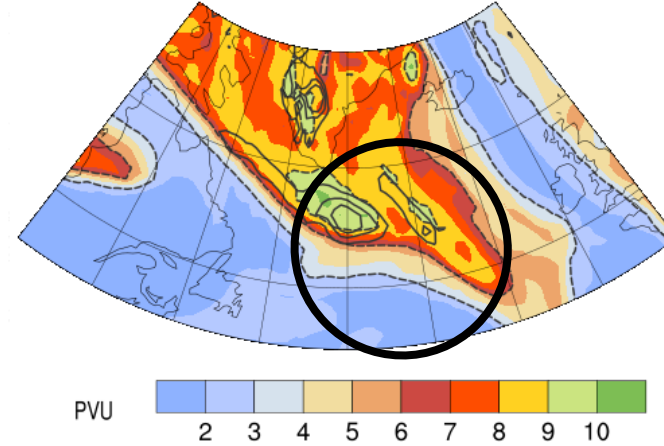
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VAPV 285-310K

20161006_18: VAPV 285K-310K



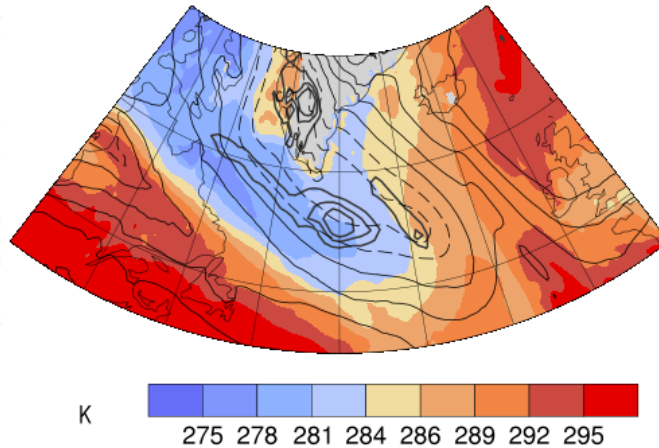
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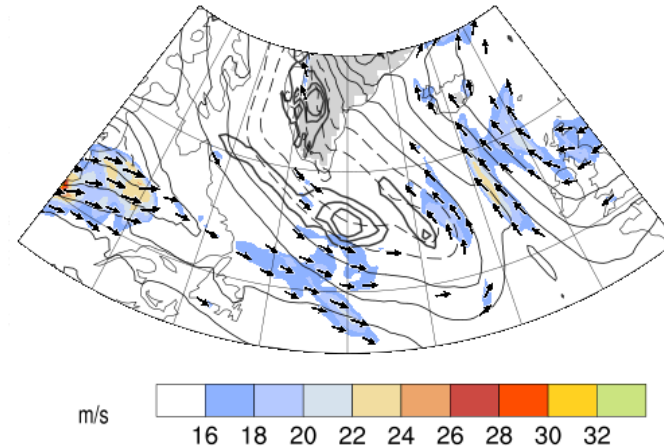
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



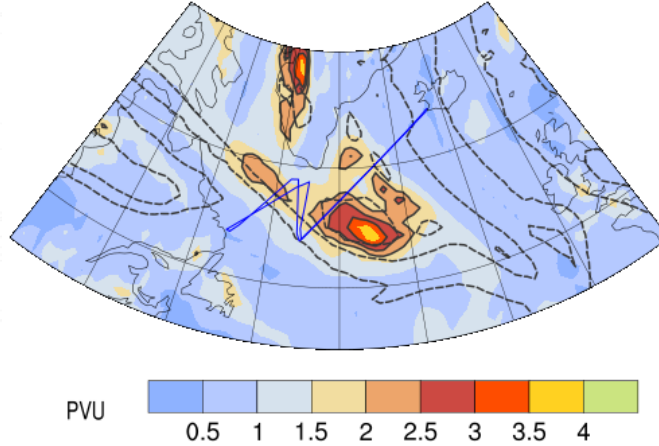
VEL@850hPa

Synoptic overview: 20161007_00

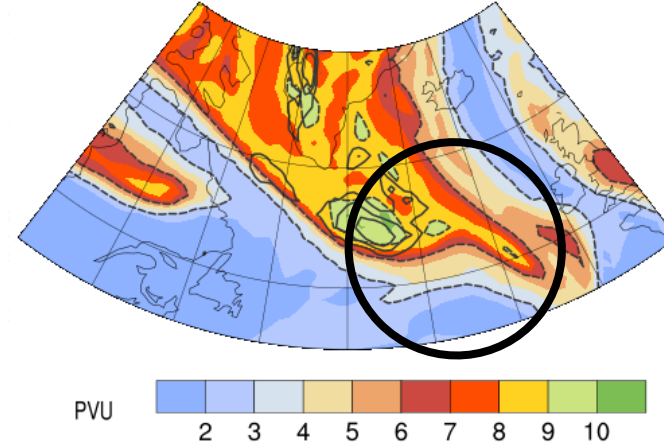
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VAPV 285-310K

20161007_00: VAPV 285K-310K



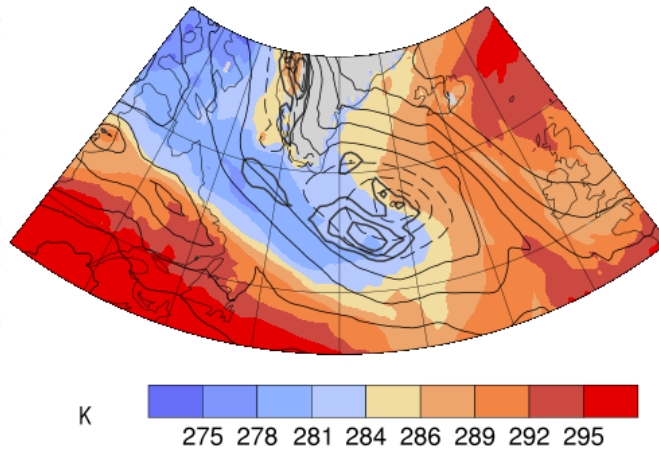
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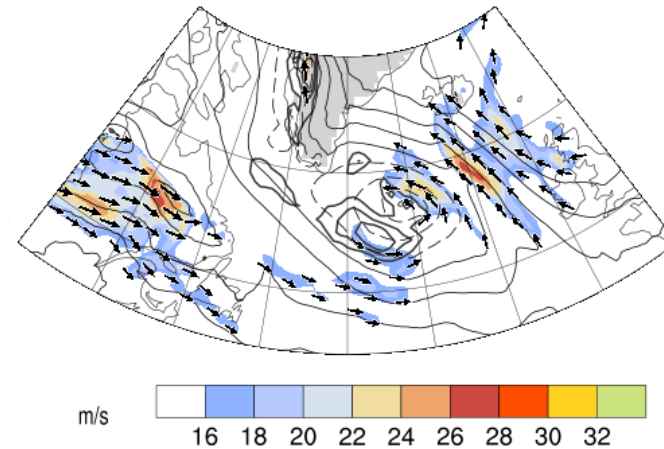
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



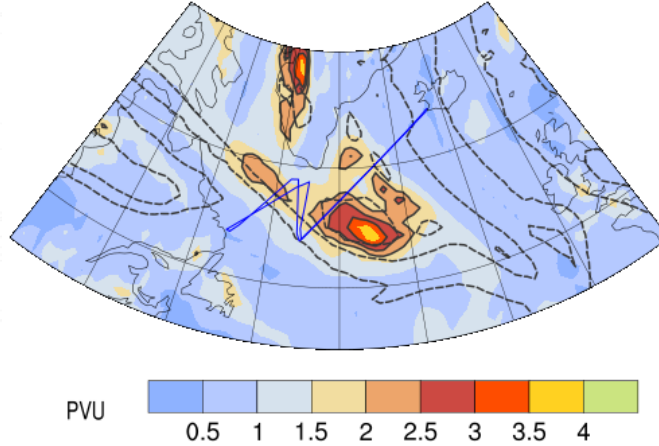
VEL@850hPa

Synoptic overview: 20161007_00

Data source: analysis

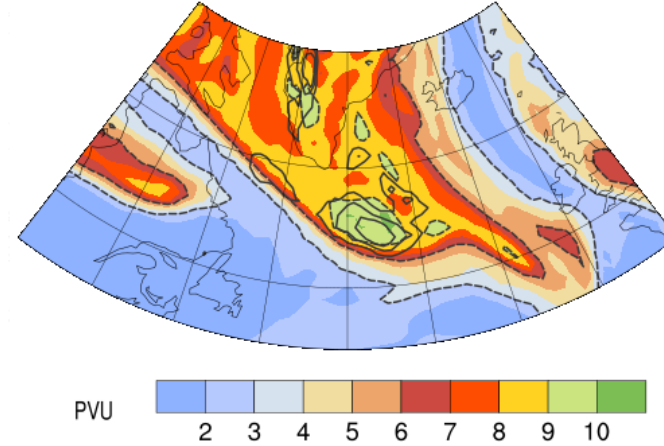
VAPV 285-310K

20161007_00: VAPV 285K-310K



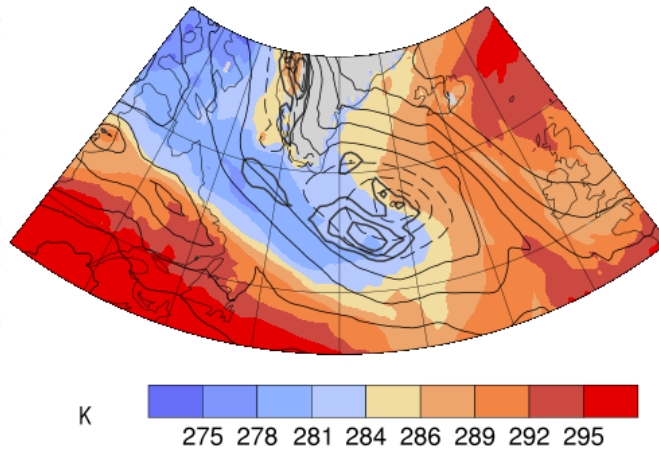
VAPV 320K-345K

VAPV 320-345K

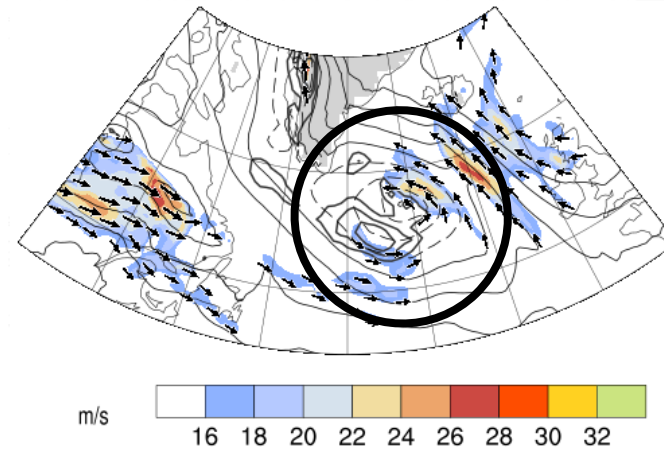


TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



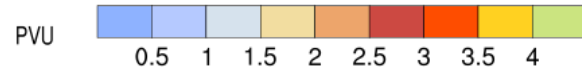
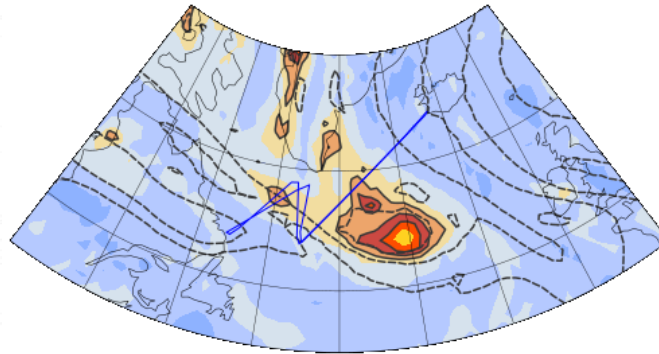
VEL@850hPa

Synoptic overview: 20161007_06

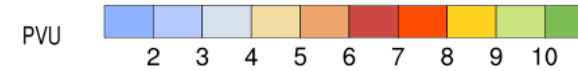
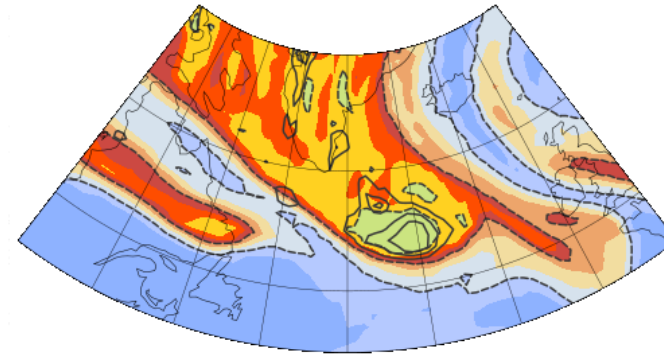
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VAPV 285-310K

20161007_06: VAPV 285K-310K



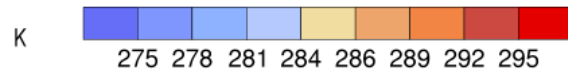
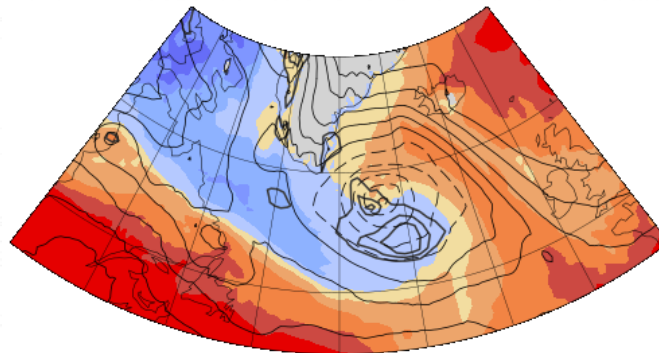
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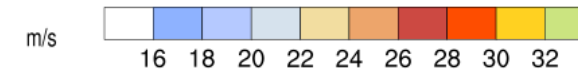
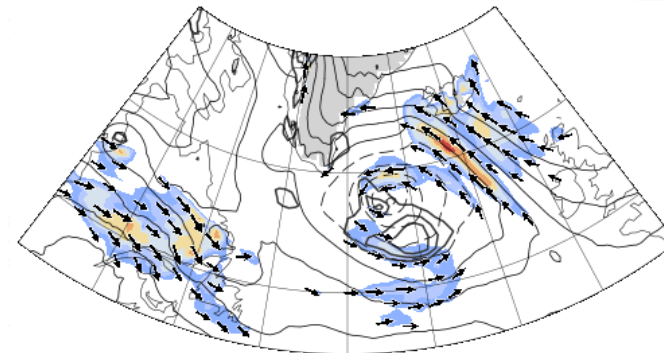
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



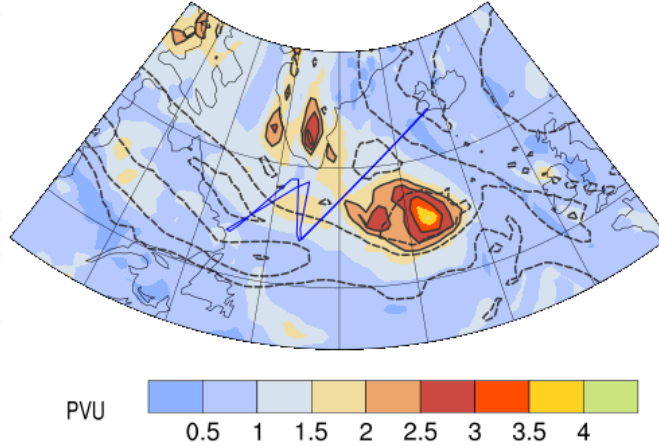
VEL@850hPa

Synoptic overview: 20161007_12

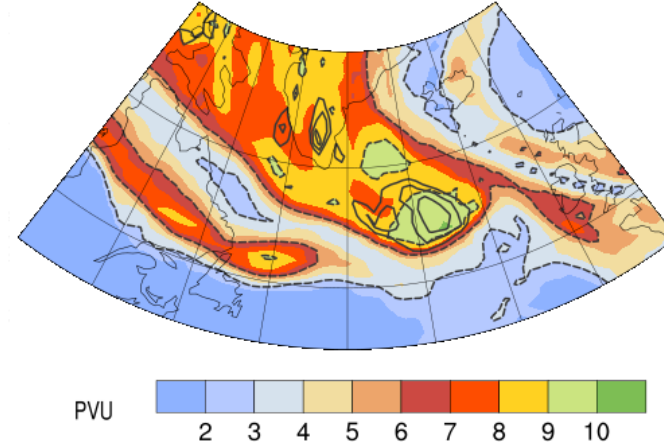
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VAPV 285-310K

20161007_12: VAPV 285K-310K



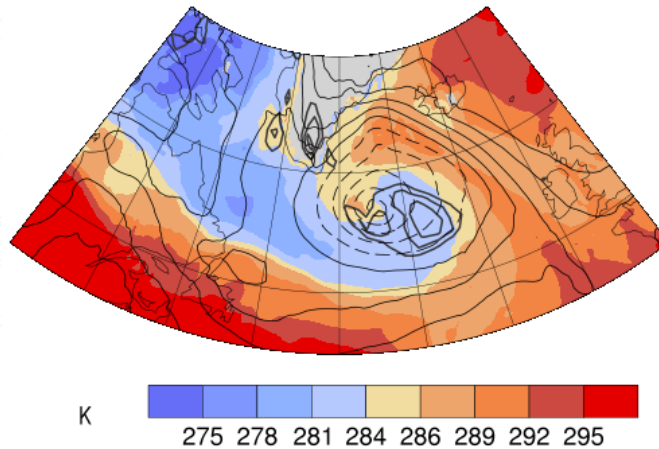
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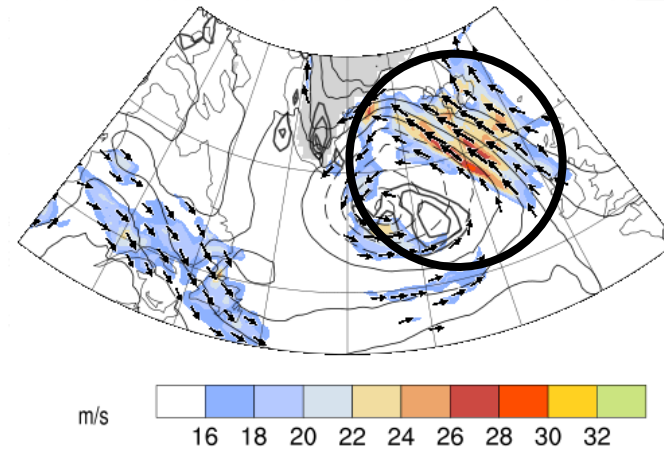
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



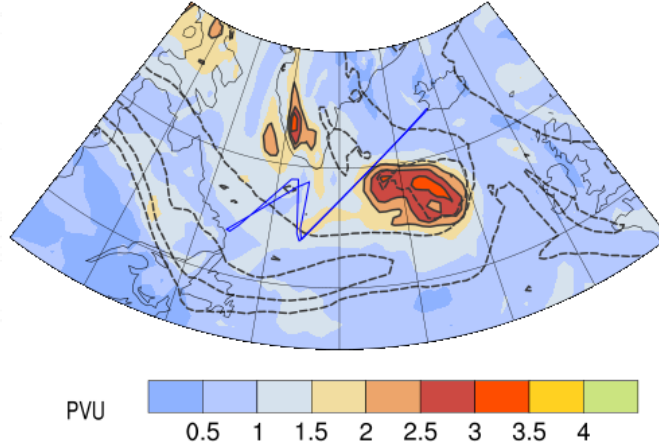
VEL@850hPa

Synoptic overview: 20161007_18

Data source: analysis

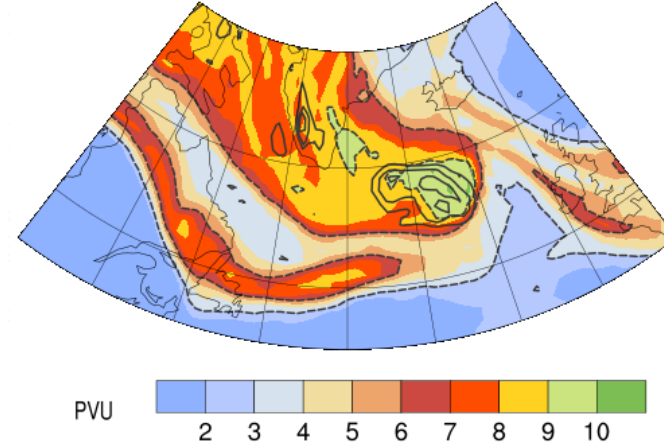
VAPV 285-310K

20161007_18: VAPV 285K-310K



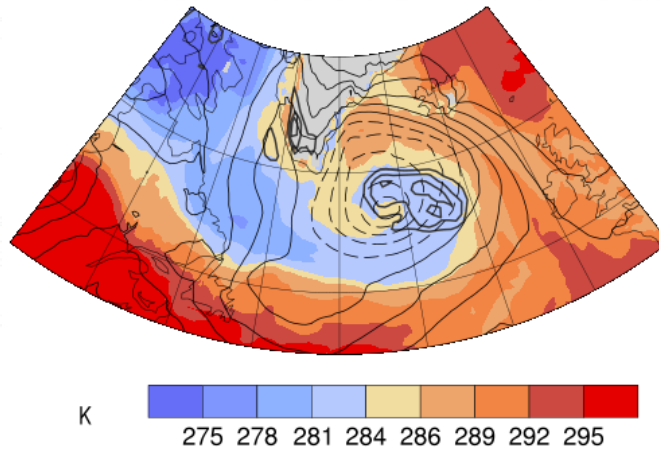
VAPV 320K-345K

VAPV 320-345K



TH@850hPa

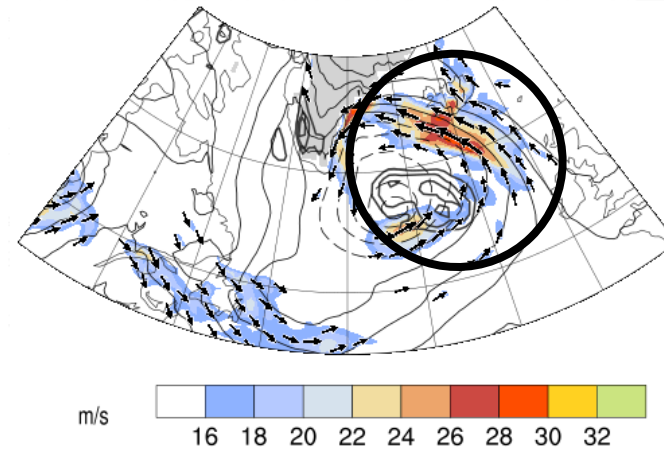
TH@850hPa, SLP



VEL@850hPa, SLP

40m/s
→

VEL@850hPa

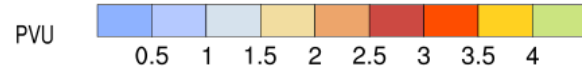
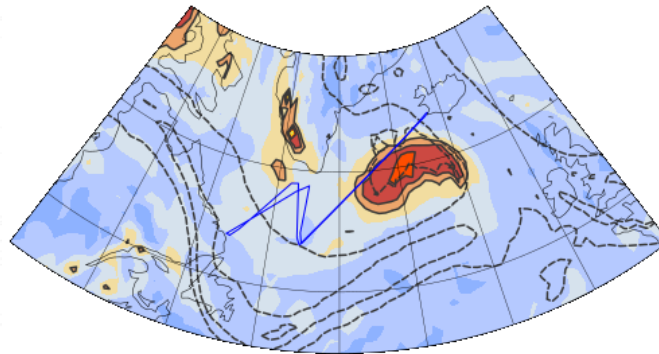


Synoptic overview: 20161008_00

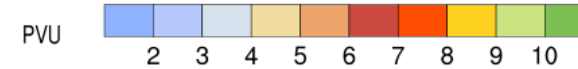
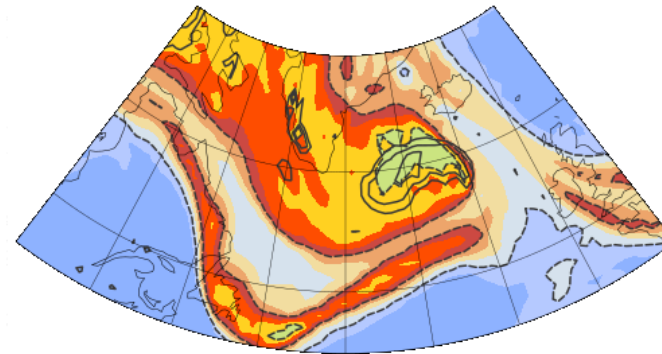
Data source: analysis

VAPV 285-310K

20161008_00: VAPV 285K-310K



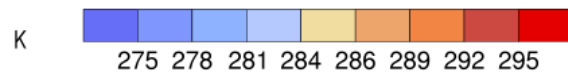
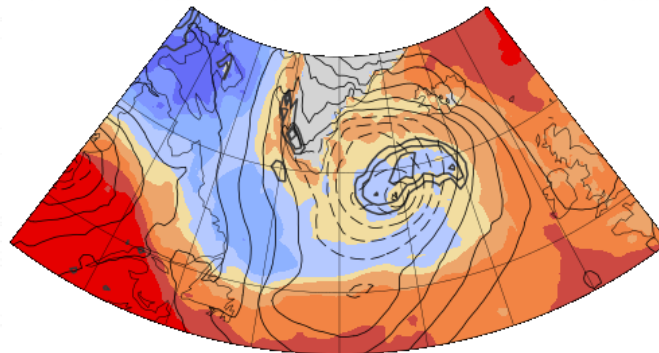
VAPV 320K-345K



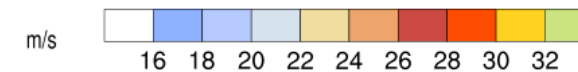
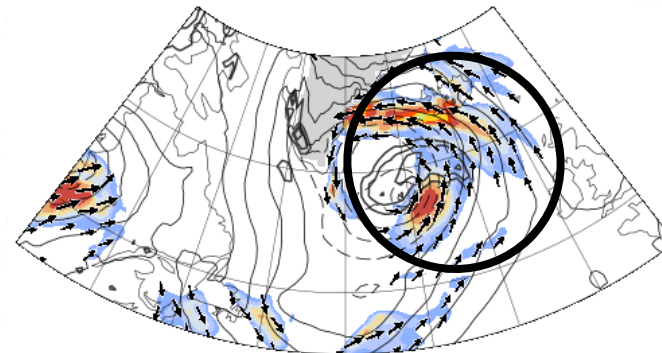
VAPV 320-345K

TH@850hPa

TH@850hPa, SLP



VEL@850hPa, SLP



VEL@850hPa

Synoptic overview

Two features, on the tropopause (Tropoblob) and in the lower stratosphere (Kewblob)

Strengthening of Kewblob during HALO RF7

Interaction with straight jet, ridge building downstream of the TPV

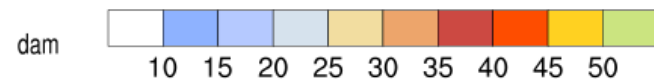
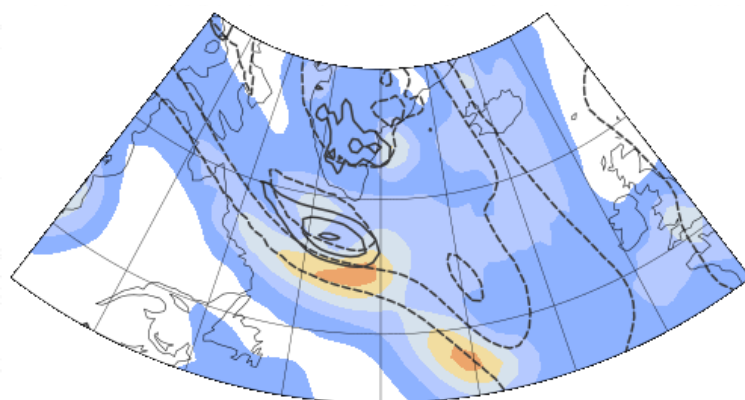
Surface cyclogenesis, 850hPa winds $> 30\text{ms}^{-1}$ after HALO RF7

Ensemble spread

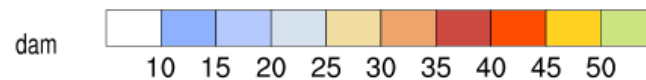
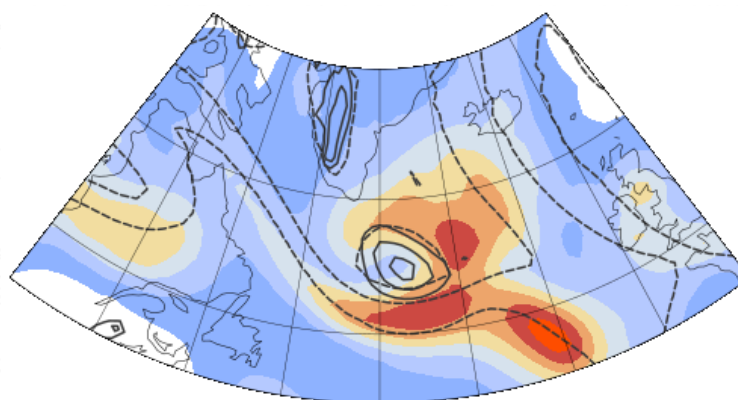
Z500 ensemble spread

INIT: 20161004_12

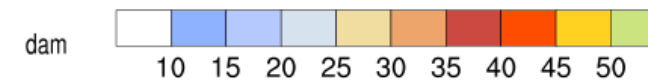
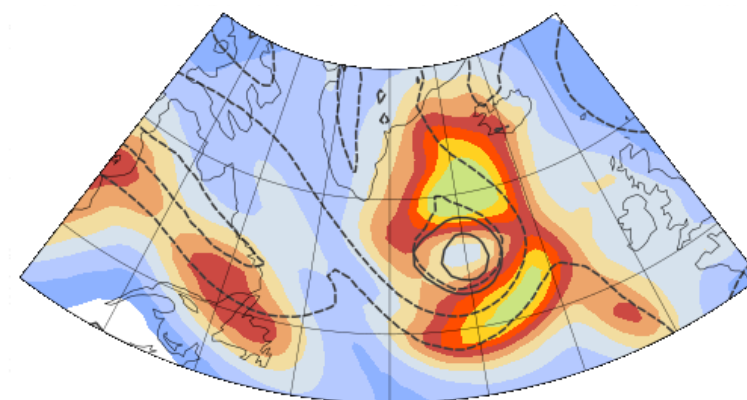
VT: 20161006_12



VT: 20161007_00



VT: 20161007_12

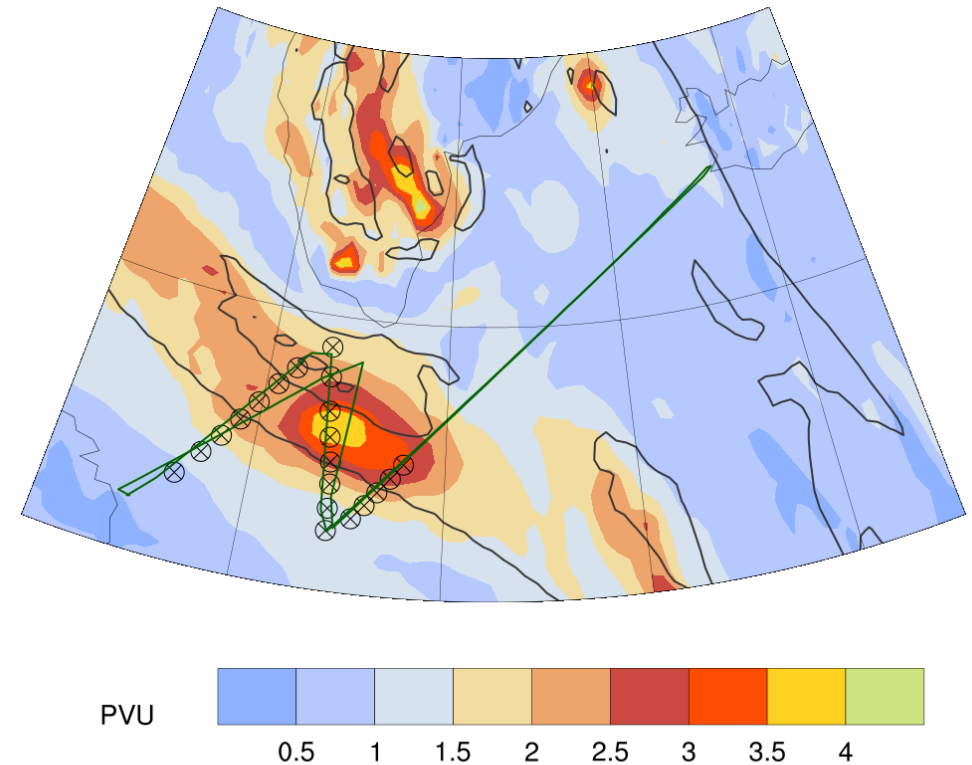


HALO RF7 flight plan

Take off: 07.03 UTC
Landing: 16.13 UTC
Total Time: 09.10h

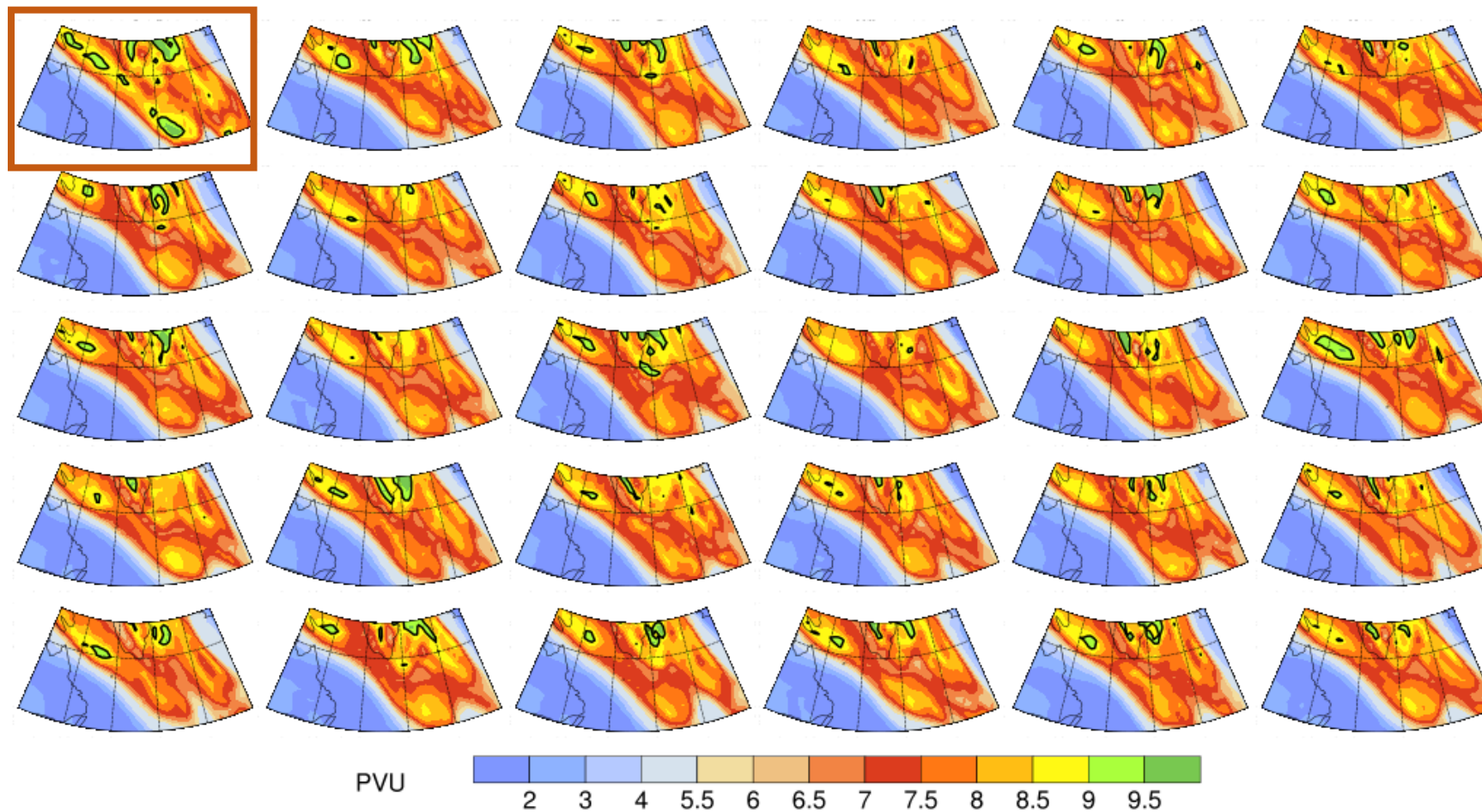
20 dropsondes released

20161006_12: VAPV 285K-310K



Representation in ECMWF (ensemble) FCST and analysis

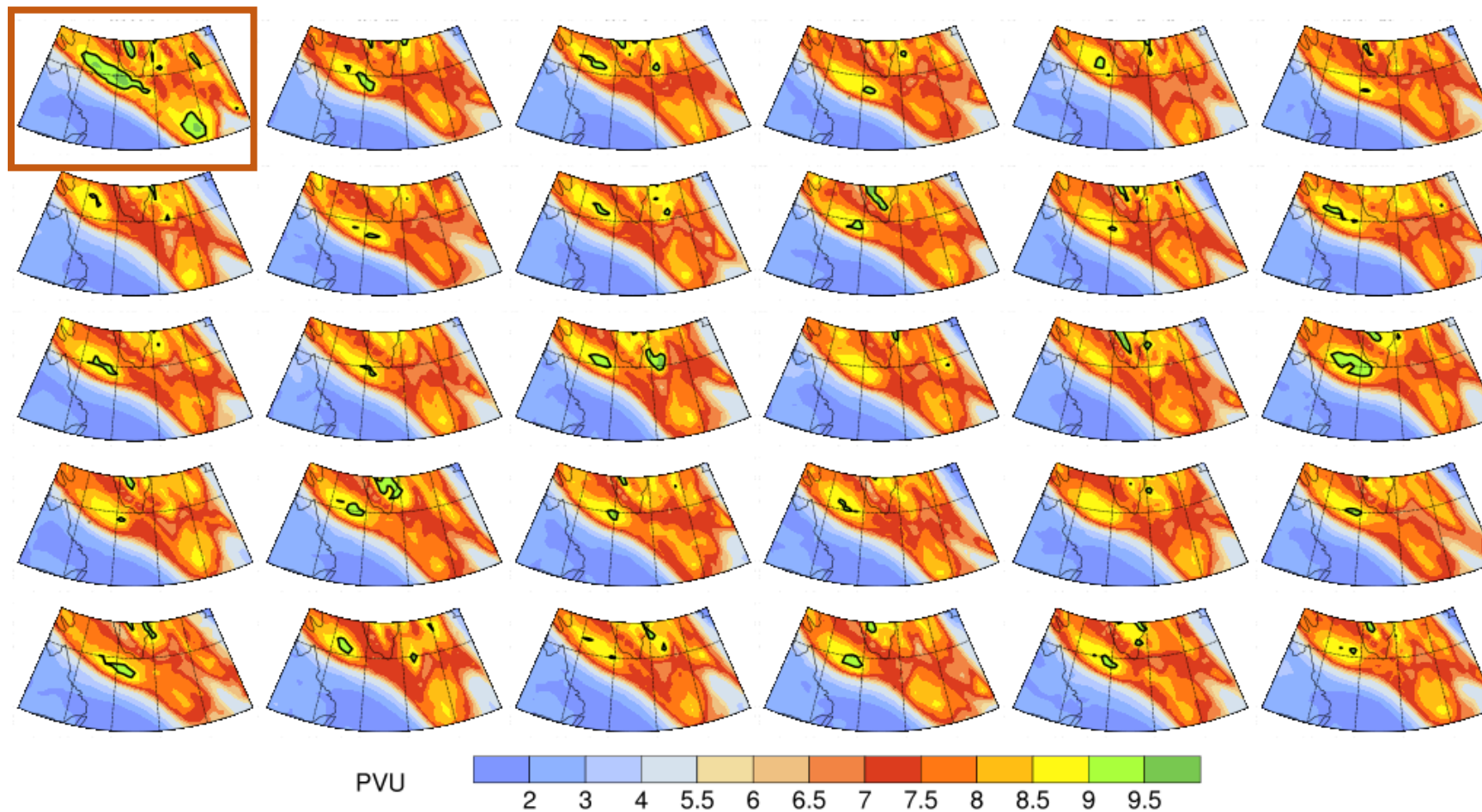
Ensemble vs. analysis: Kewblob



VAPV 320-345K

VT: 20161006_00
INIT: 20161004_12

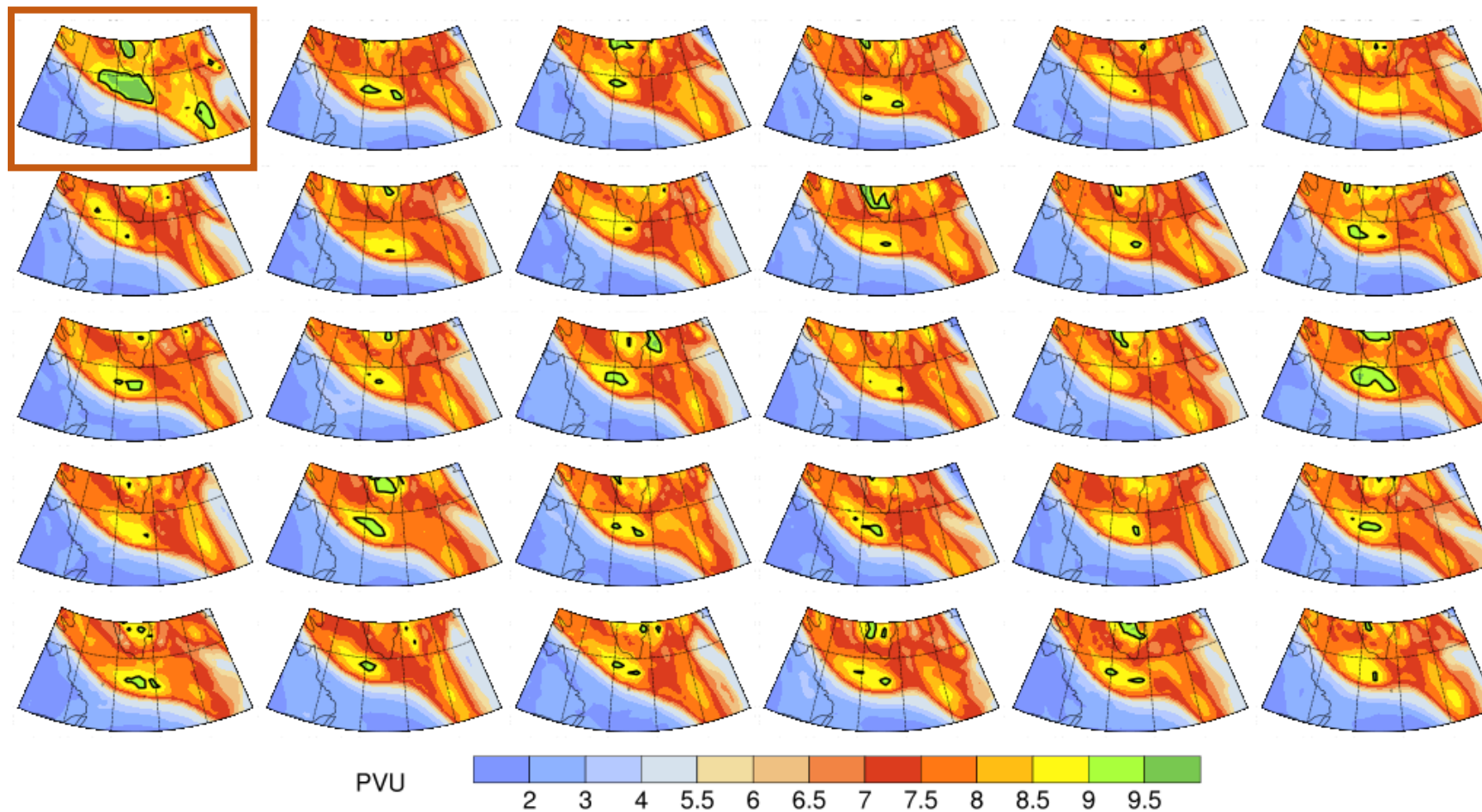
Ensemble vs. analysis: Kewblob



VAPV 320-345K

VT: 20161006_06
INIT: 20161004_12

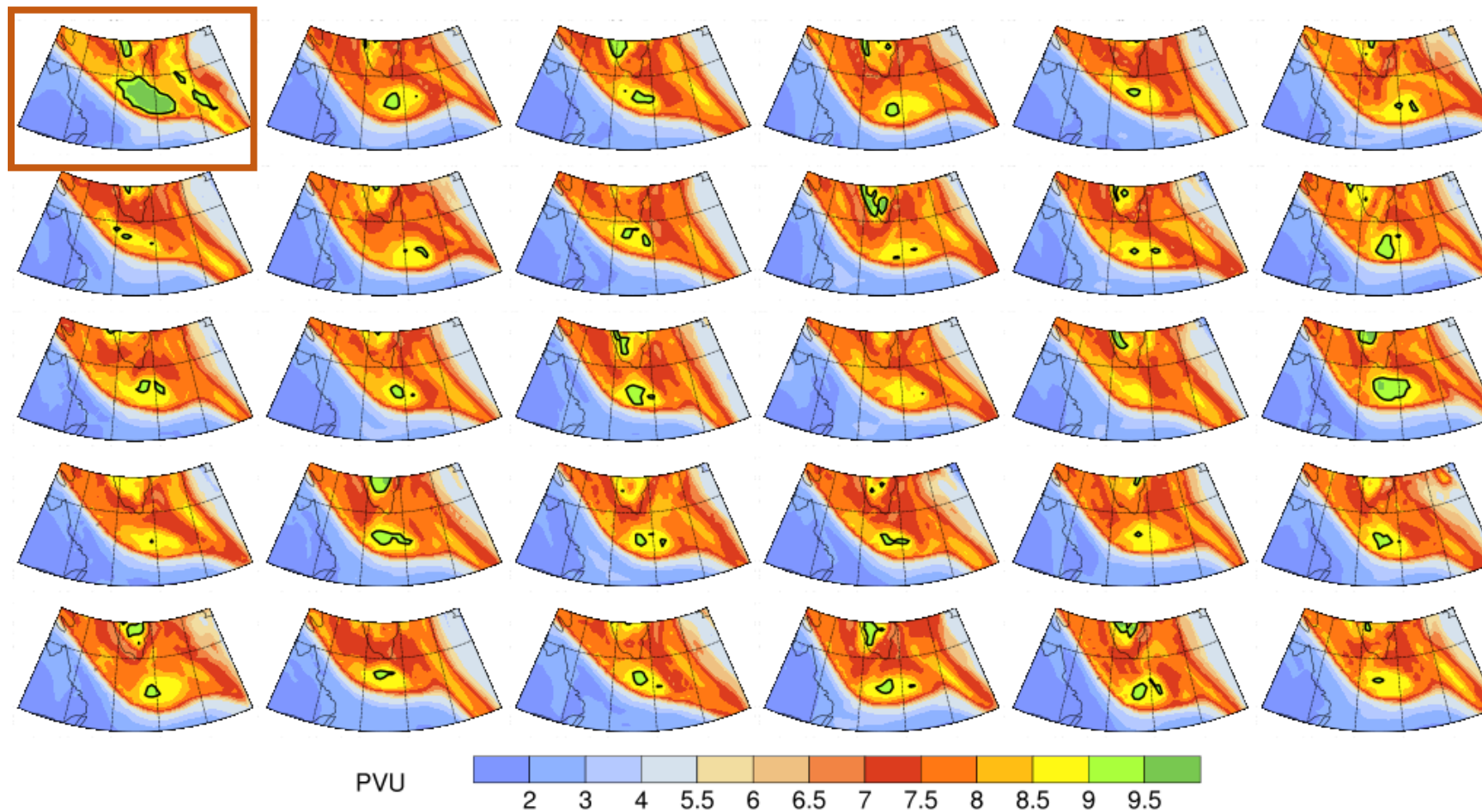
Ensemble vs. analysis: Kewblob



VAPV 320-345K

VT: 20161006_12
INIT: 20161004_12

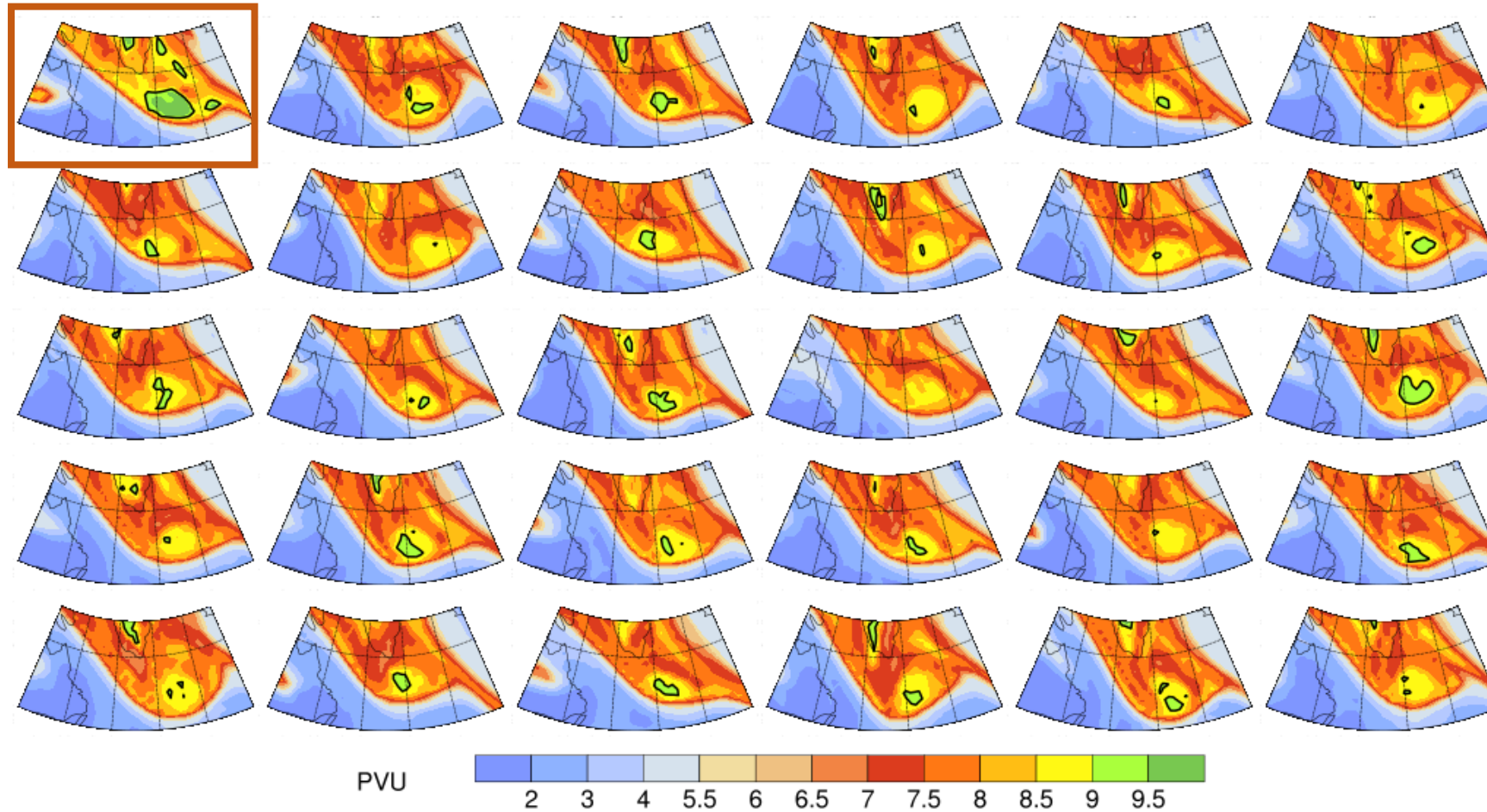
Ensemble vs. analysis: Kewblob



VAPV 320-345K

VT: 20161006_18
INIT: 20161004_12

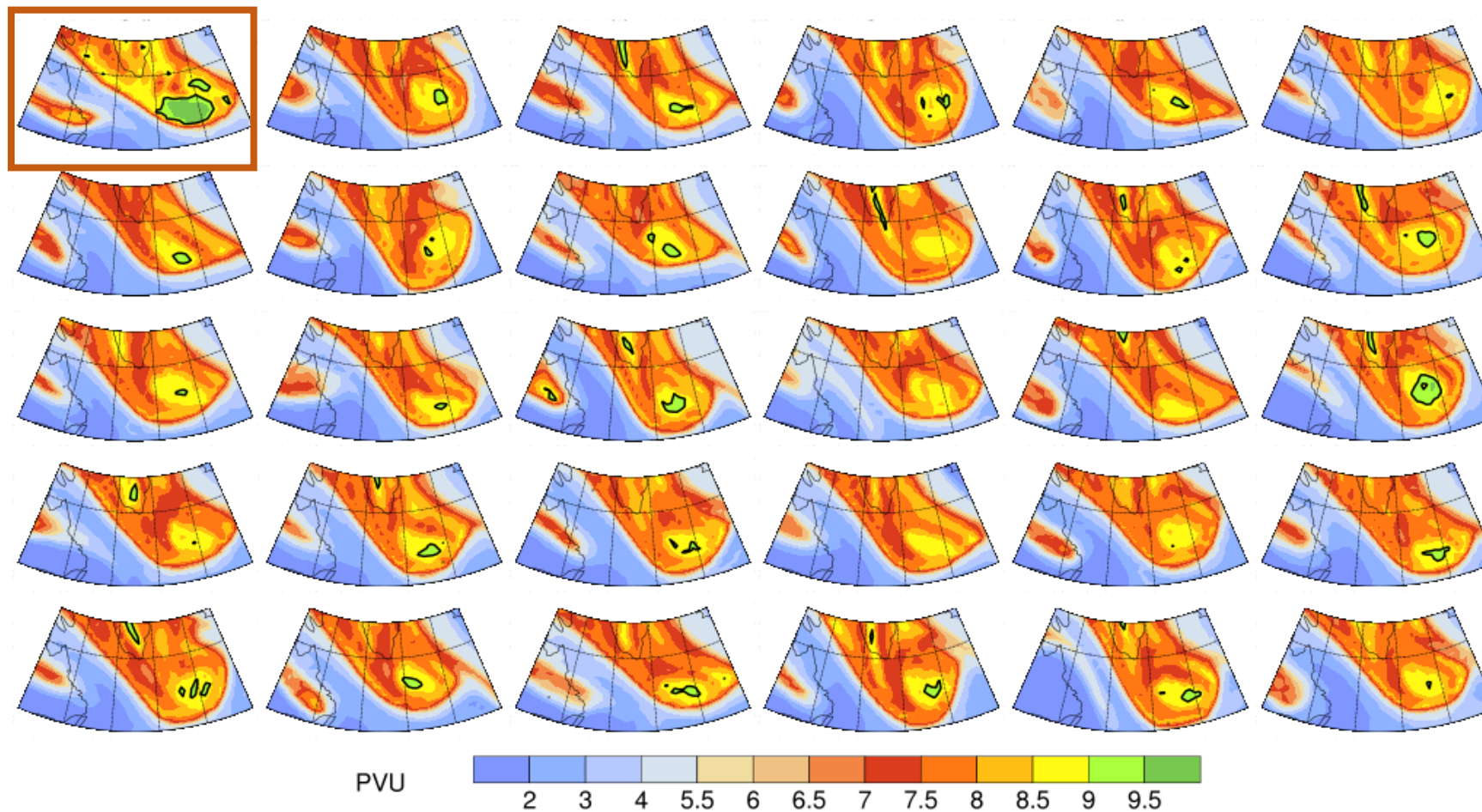
Ensemble vs. analysis: Kewblob



VAPV 320-345K

VT: 20161007_00
INIT: 20161004_12

Ensemble vs. analysis: Kewblob

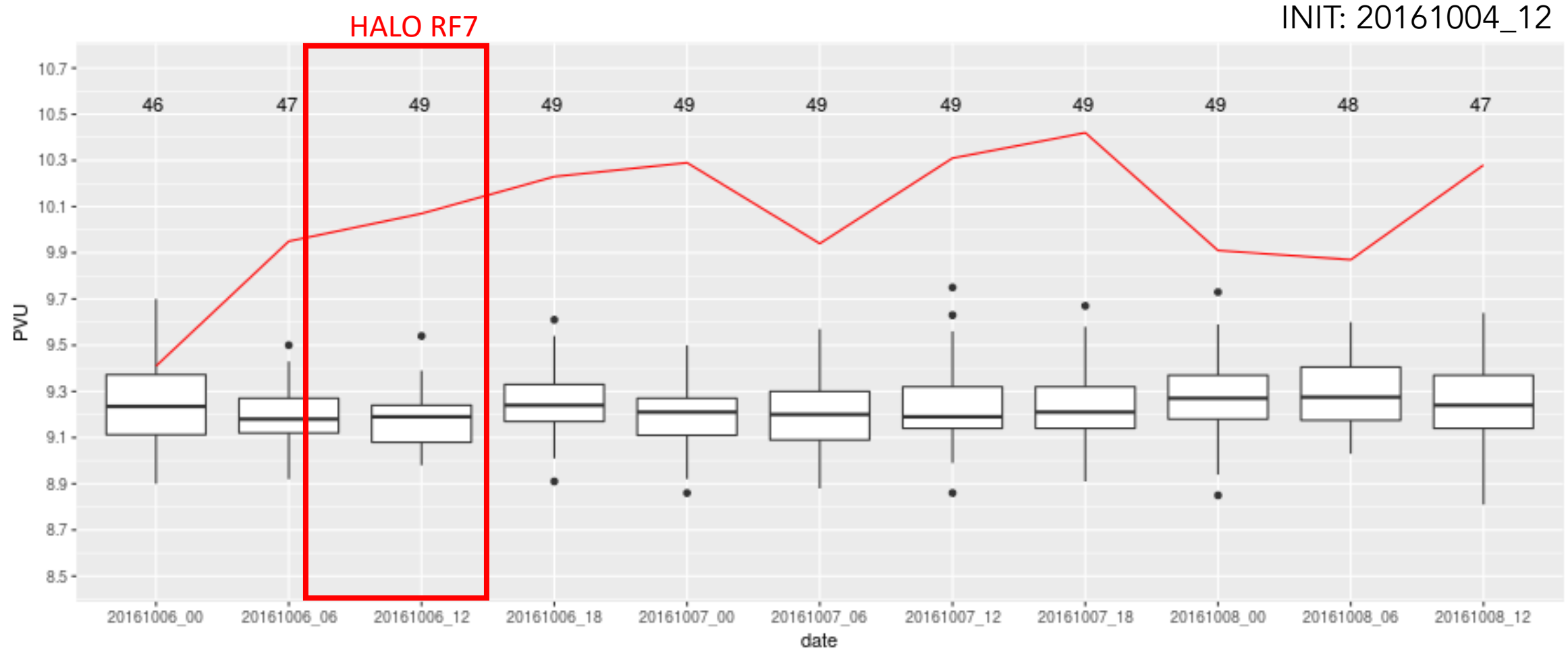


VAPV 320-345K

VT: 20161007_06
INIT: 20161004_12

Ensemble vs. analysis: Kewblob

Maximum VAPV in Kewblob



Role of measurements in Kewblob strengthening

Kewblob strengthening just during HALO RF7 **only in the analysis**.

If the Kewblob strengthening does not occur in the FCSTs, is conceivably results from the assimilation of relevant data gathered around the time of HALO RF7.

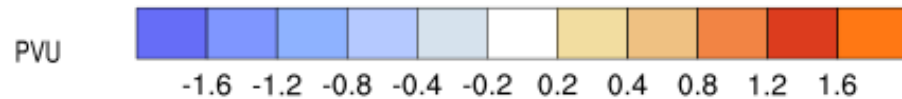
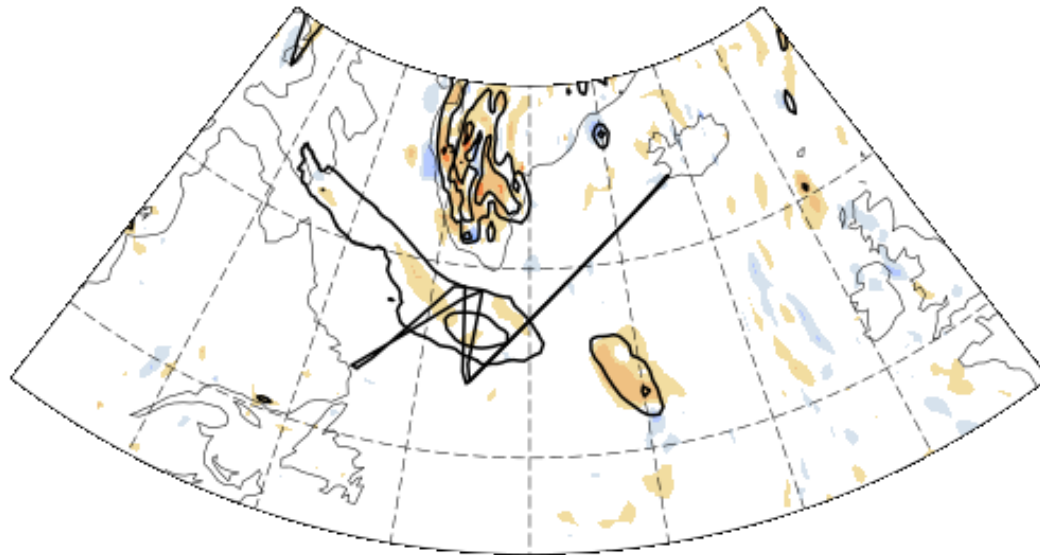
Is it possible that HALO RF7 dropsonde data were responsible for the Kewblob strengthening in the analysis?

Analysis – 12h FCST at 00Z and 12Z

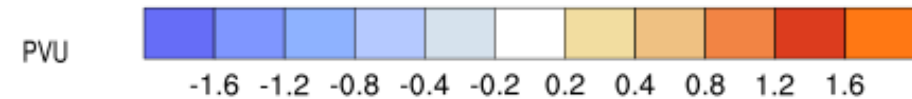
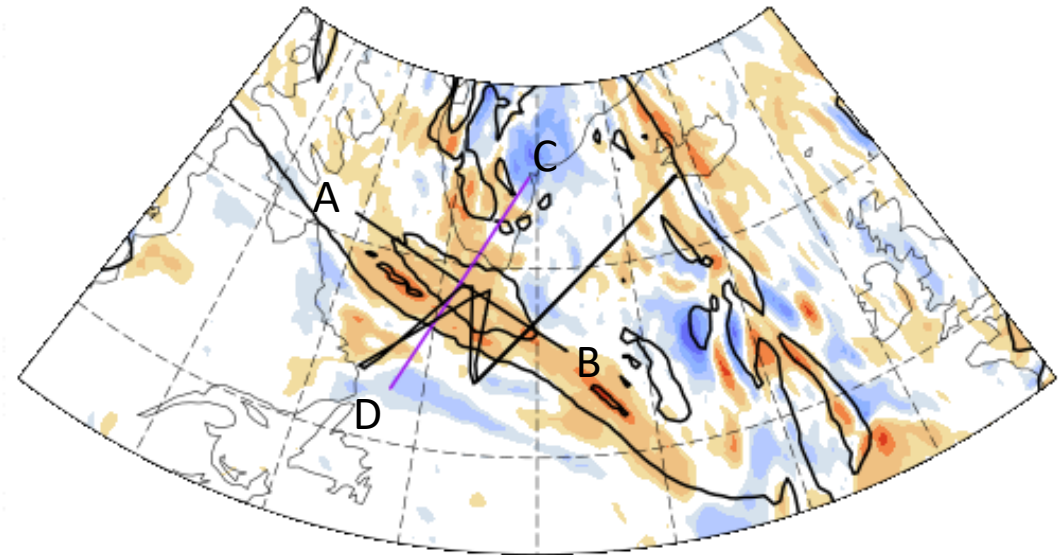
Analysis – 12h FCST (first guess)

VT: 20161006_12

ANA - 12h FCST VAPV_285K_310K

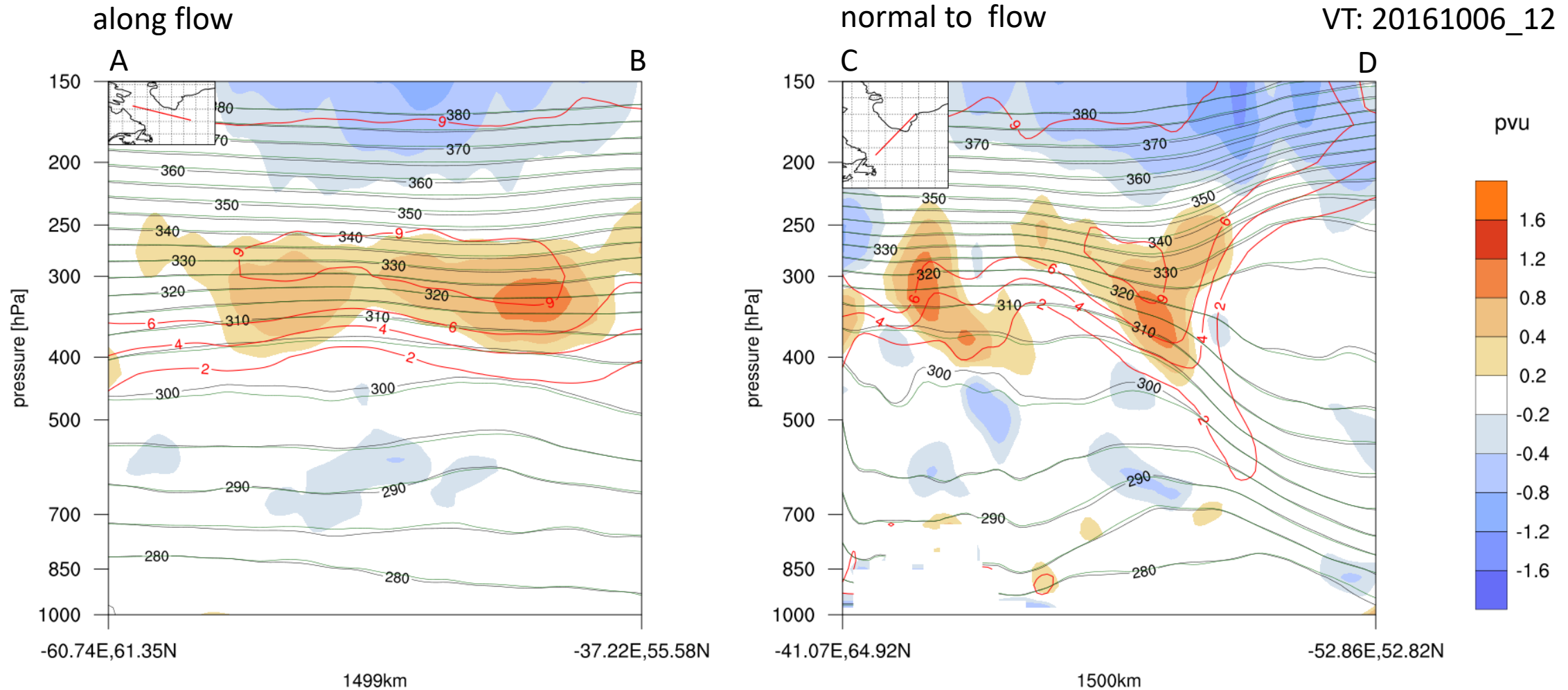


ANA - 12h FCST VAPV_320K_345K

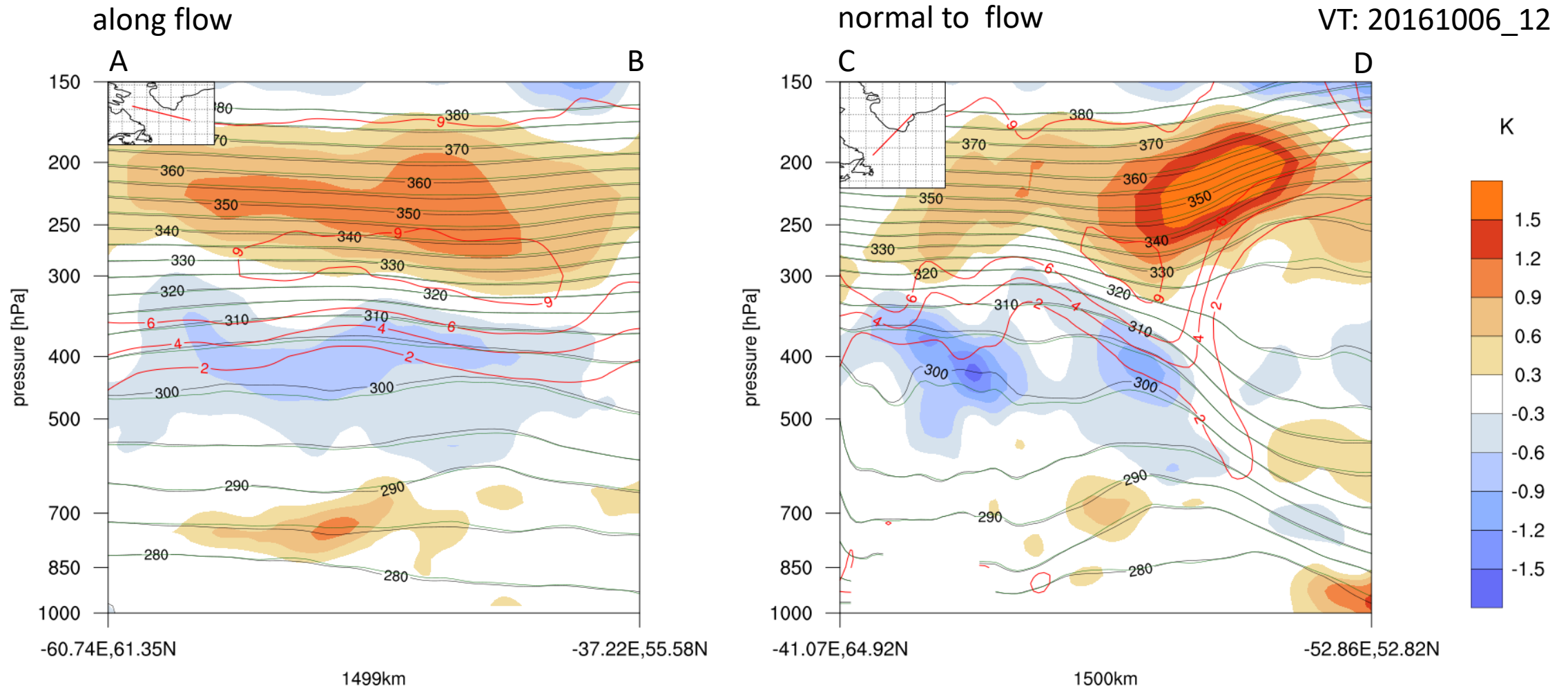


Analysis – 12h FCST (first guess) PV increment

VT: 20161006_12



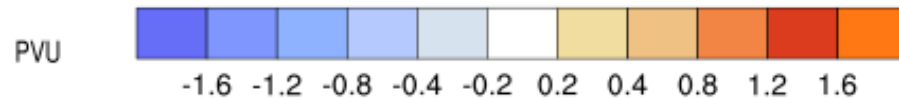
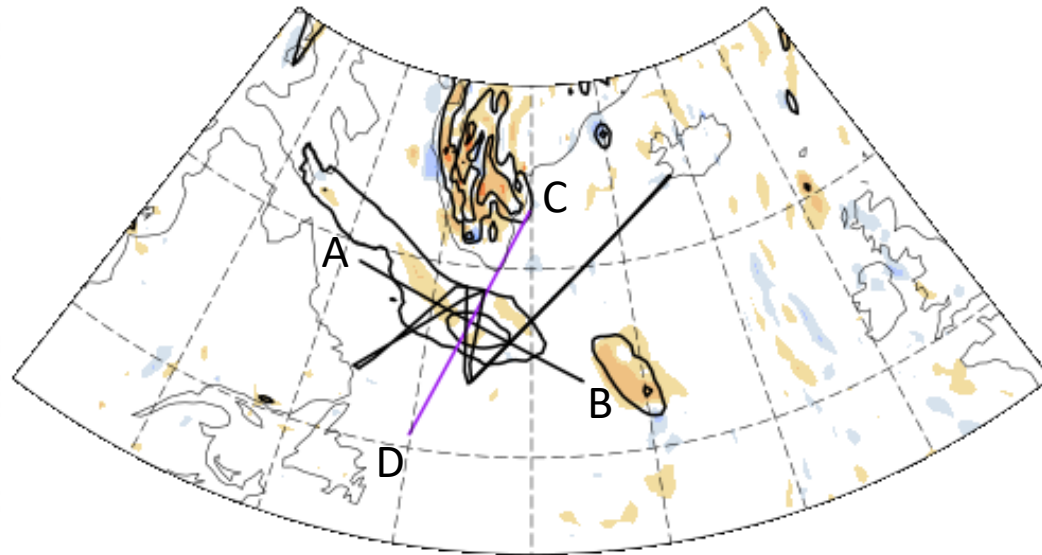
Analysis – 12h FCST (first guess) TH increment



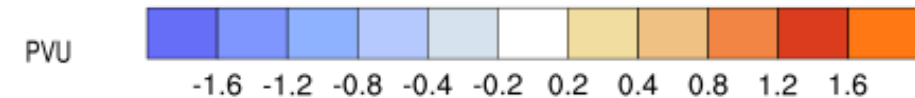
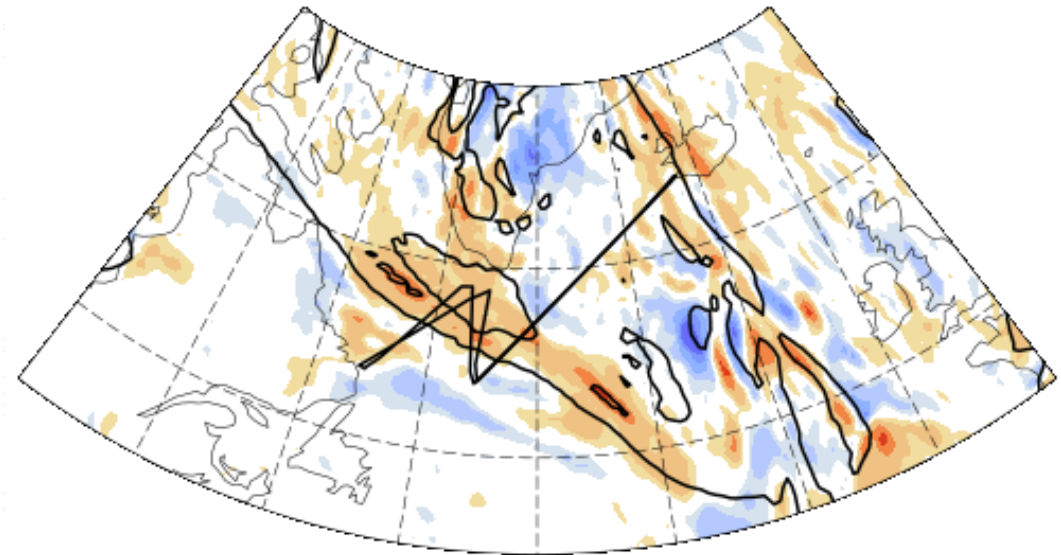
Analysis – 12h FCST (first guess)

VT: 20161006_12

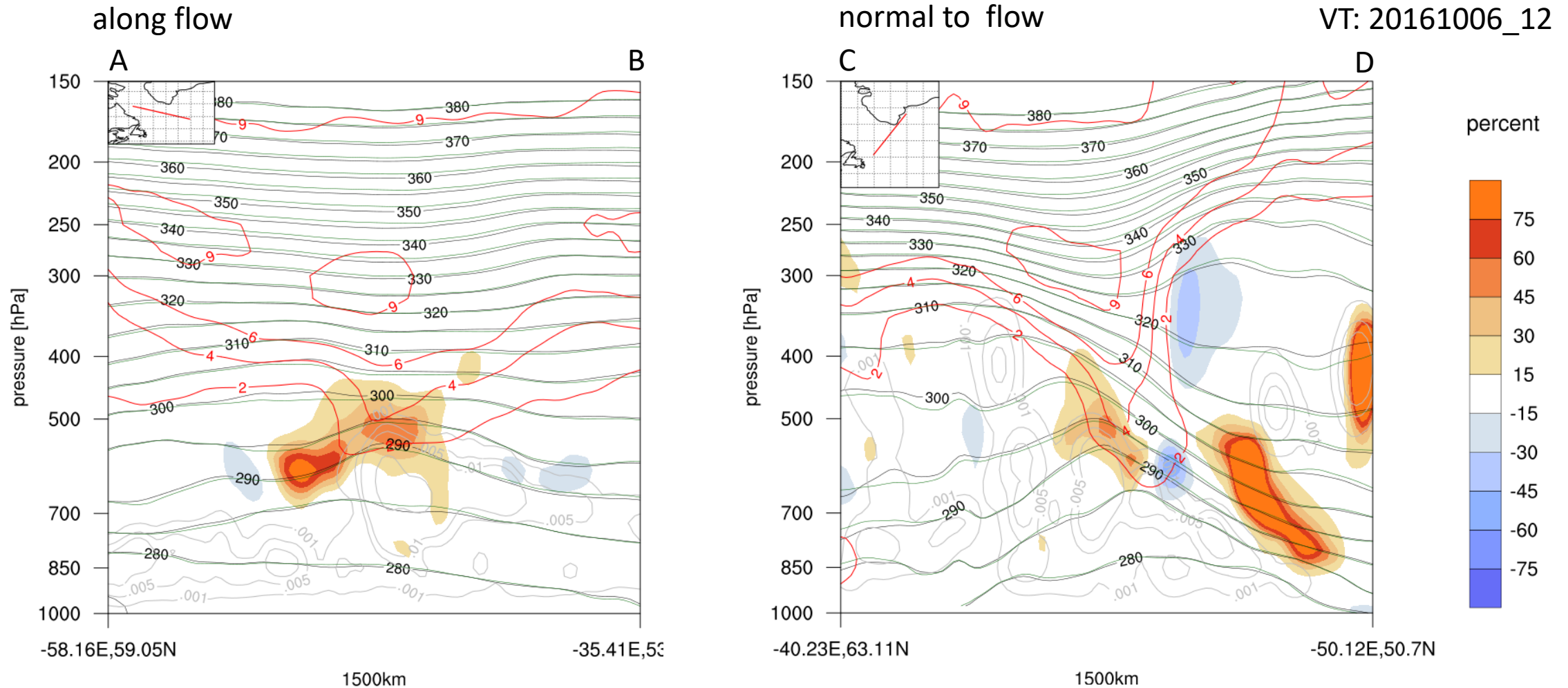
ANA - 12h FCST VAPV_285K_310K



ANA - 12h FCST VAPV_320K_345K



Analysis – 12h FCST (first guess) q increment (expressed as relative change)



Analysis – 12h FCST fields suggest that indeed the assimilation of new measurements was responsible for the strengthening of the Kewblob in the analysis, i.e., not a physical process.

It appears possible that the HALO RF7 dropsonde measurements were partly responsible for the Kewblob strengthening in the analysis.

Vertical moisture gradients underneath the Tropoblob were strengthened by assimilation of measurements.

HALO RF7 dropsondes

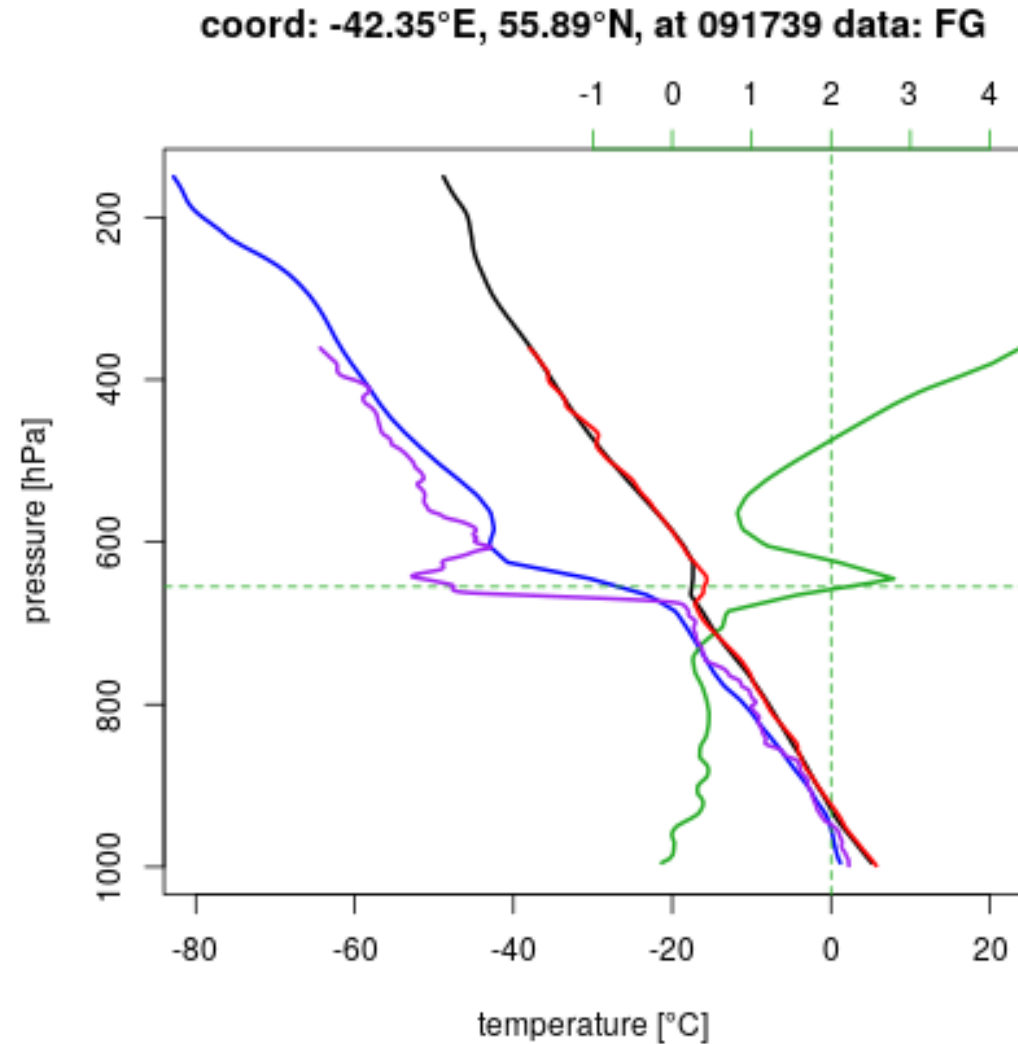
Dropsondes vs first guess (INIT:20161006_00)

Vertical interpolation of ECMWF data to the pressure levels of dropsonde data

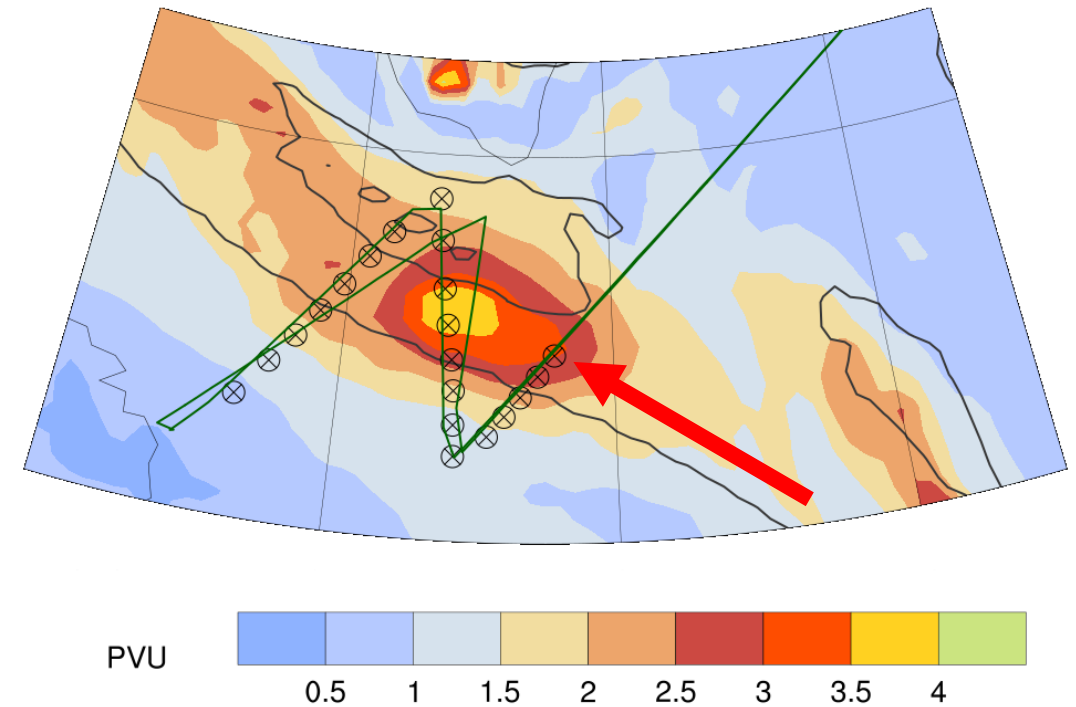
Bilinear interpolation in space

Linear interpolation in time

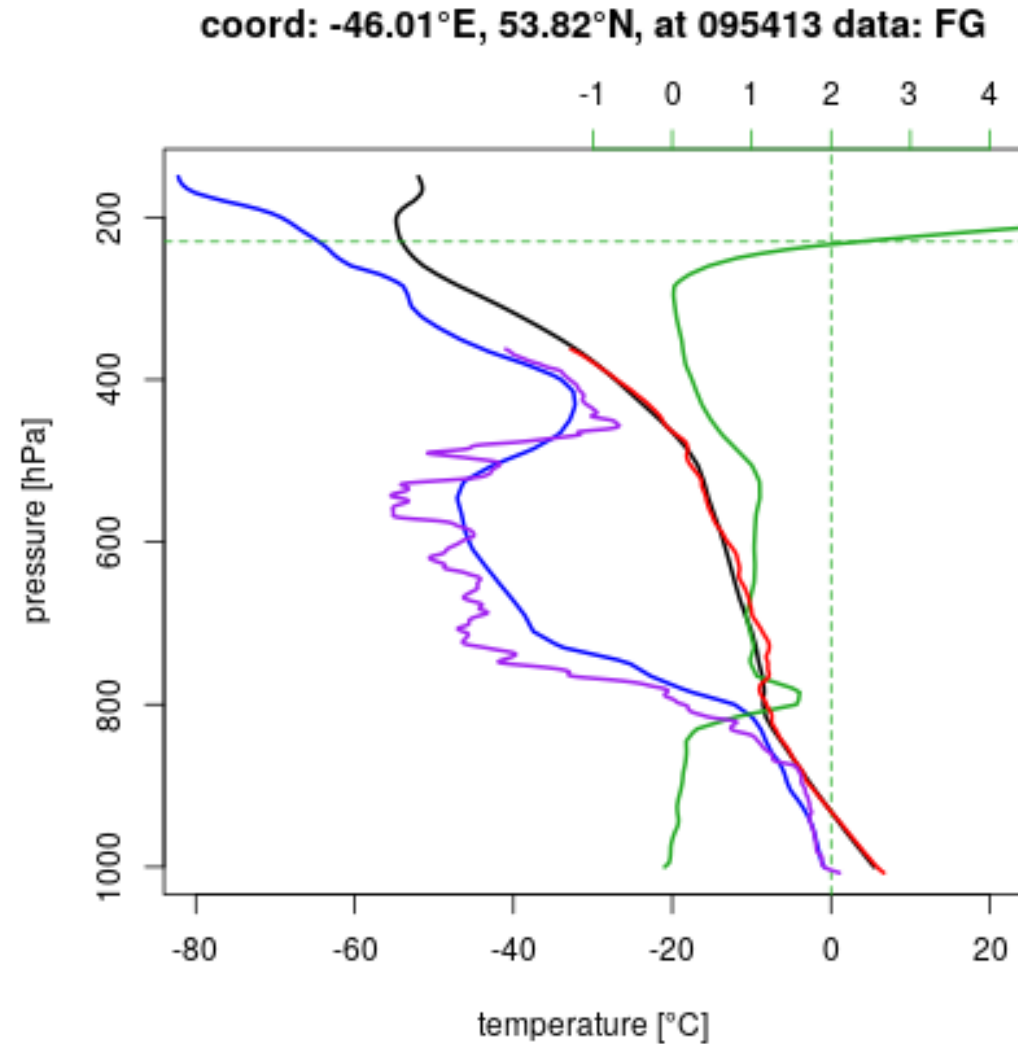
Dropsondes vs first guess (INIT:20161006_00)



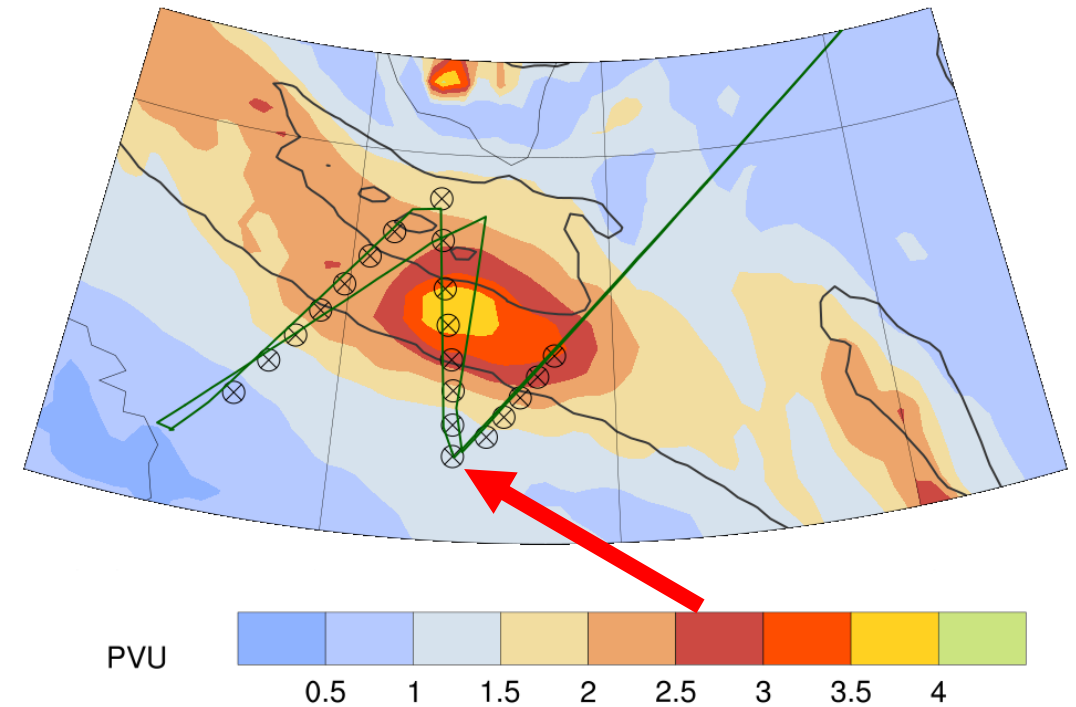
20161006_12: VAPV 285K-310K



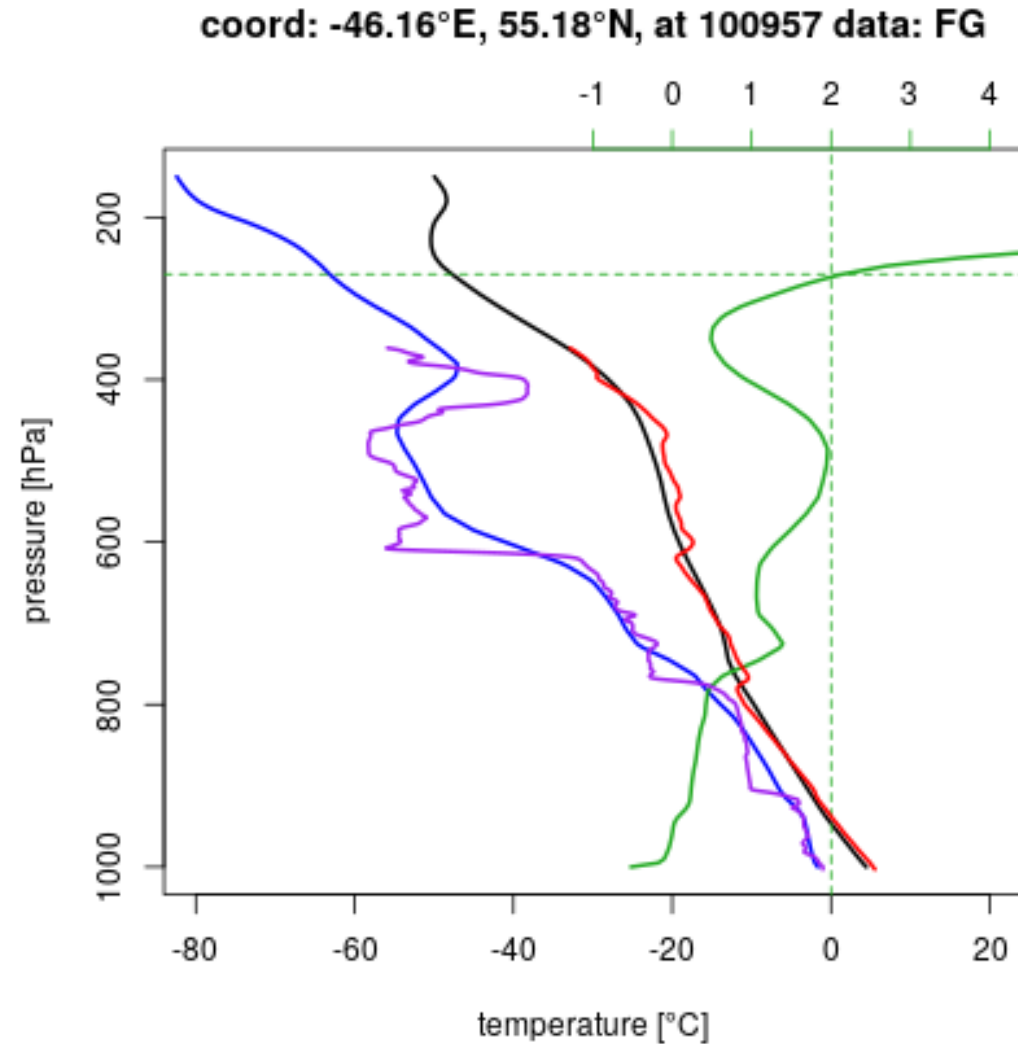
Dropsondes vs first guess (INIT:20161006_00)



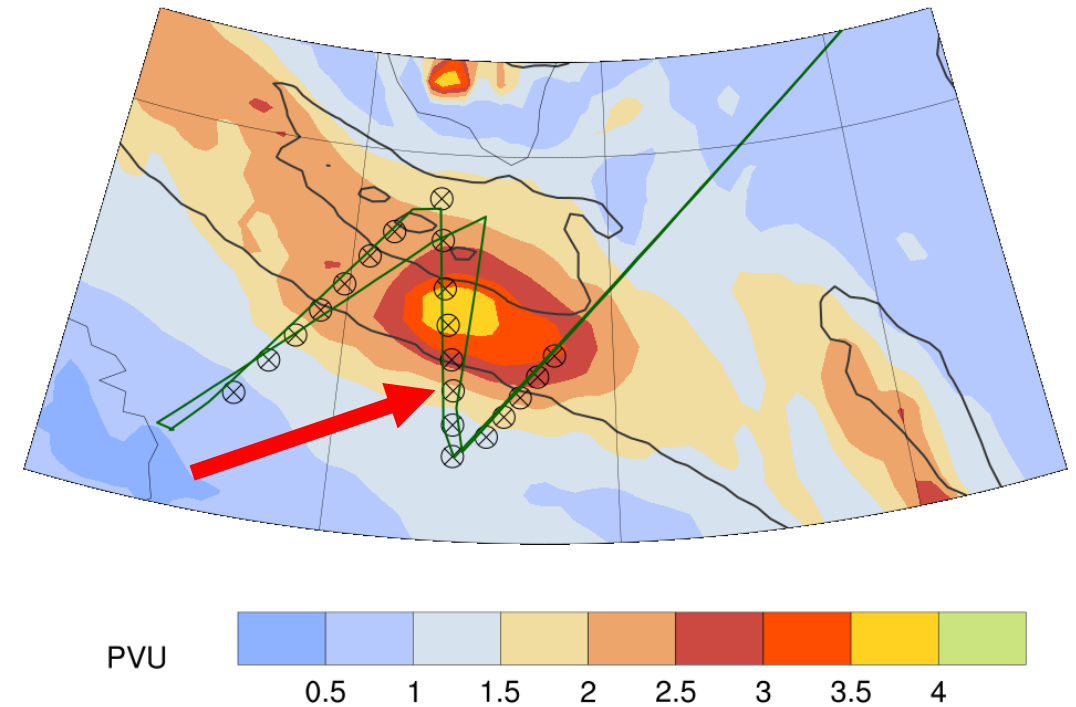
20161006_12: VAPV 285K-310K



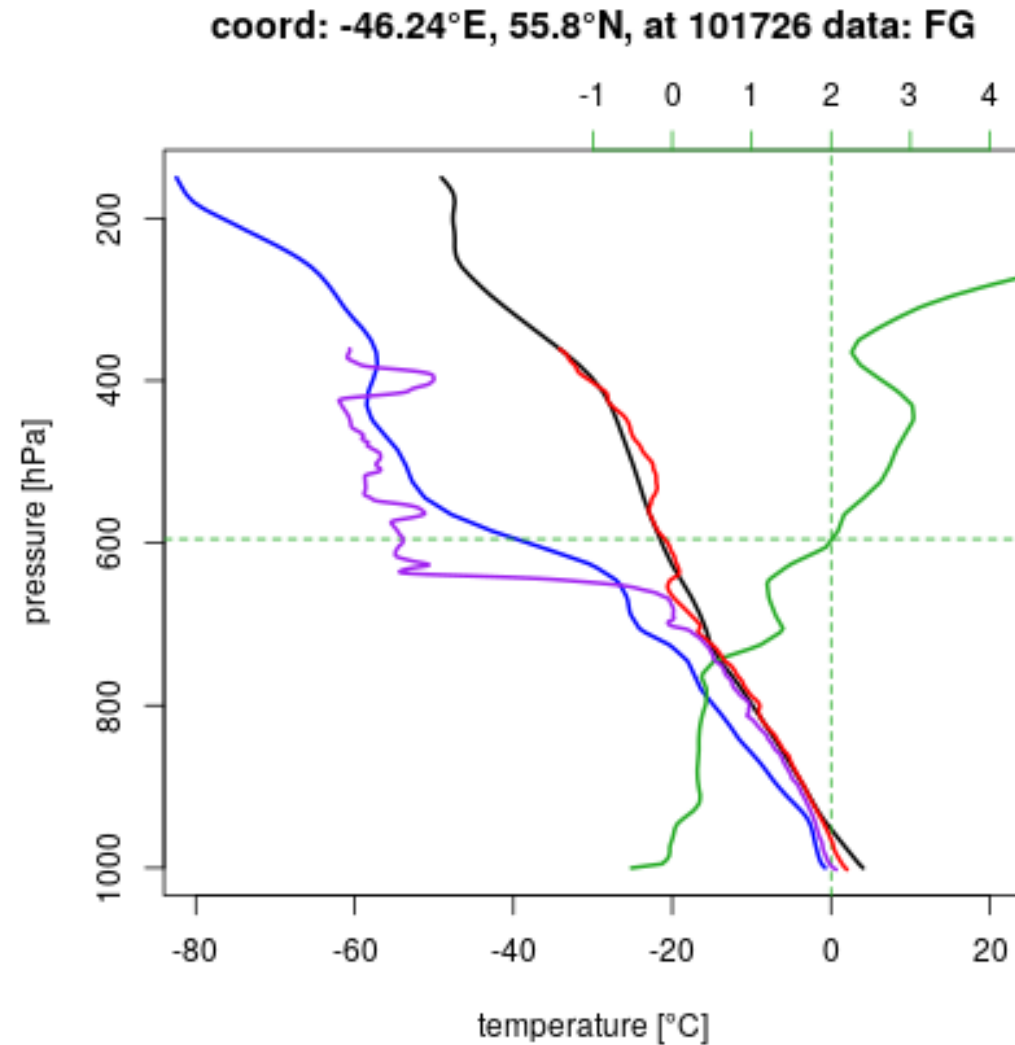
Dropsondes vs first guess (INIT:20161006_00)



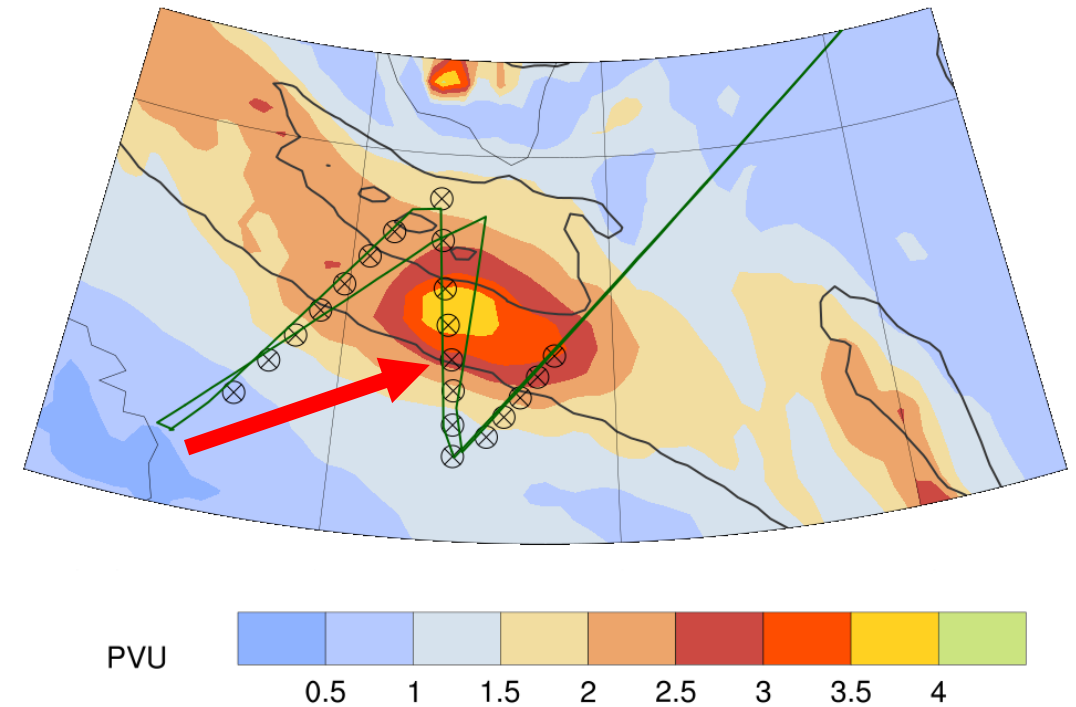
20161006_12: VAPV 285K-310K



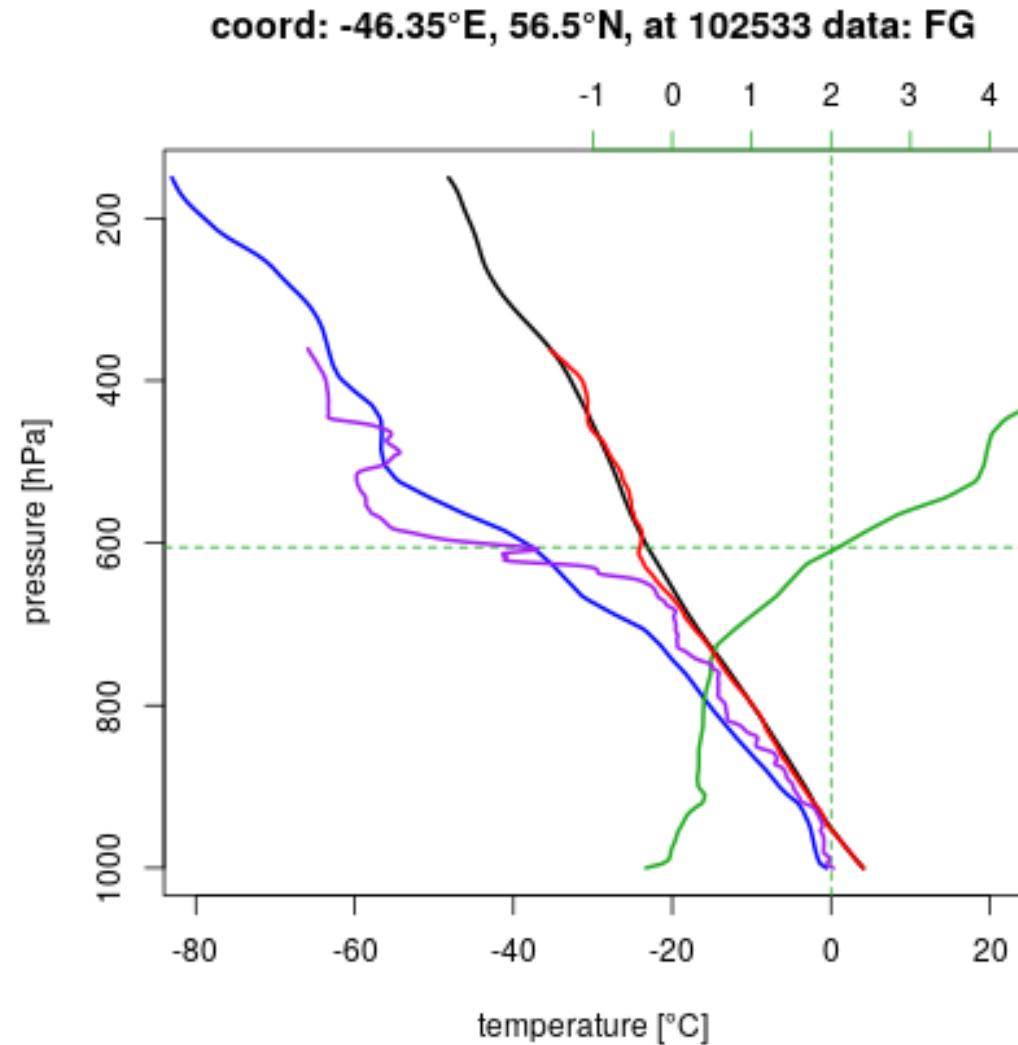
Dropsondes vs first guess (INIT:20161006_00)



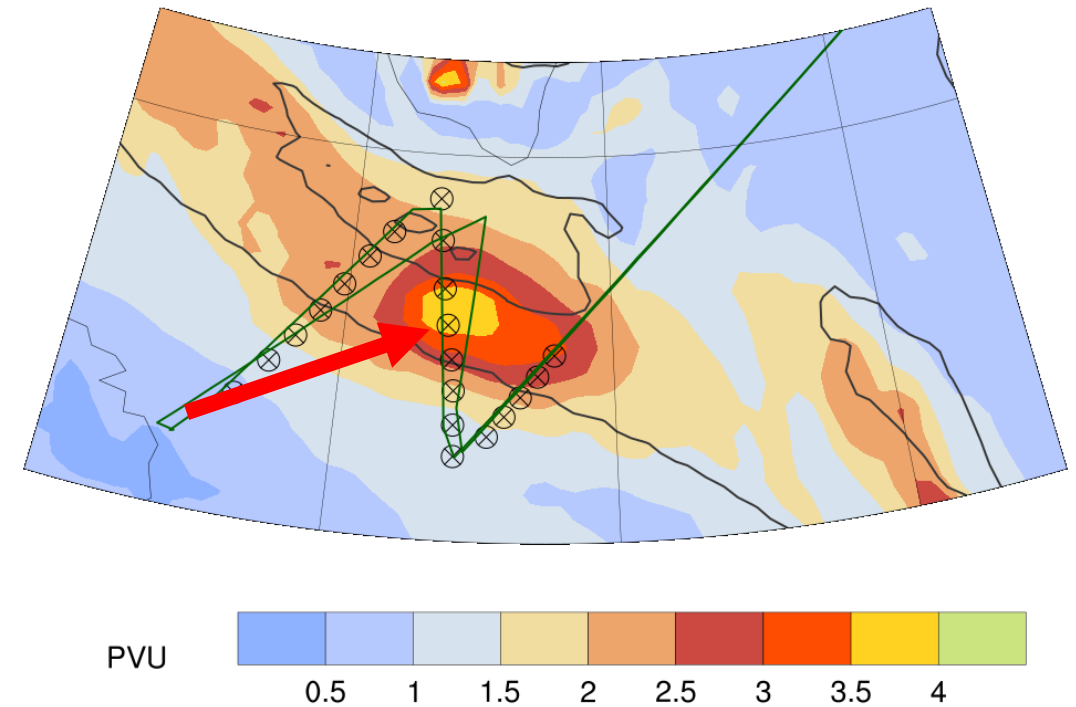
20161006_12: VAPV 285K-310K



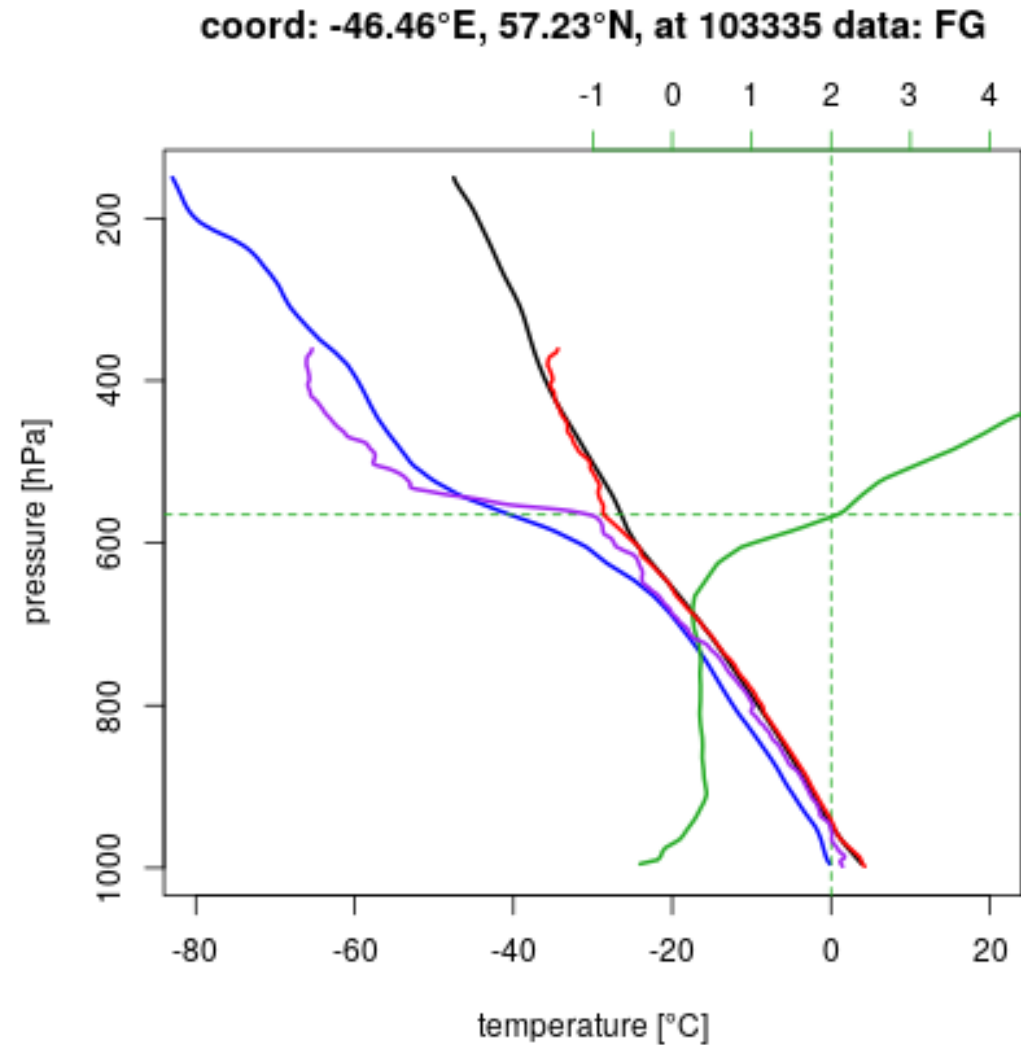
Dropsondes vs first guess (INIT:20161006_00)



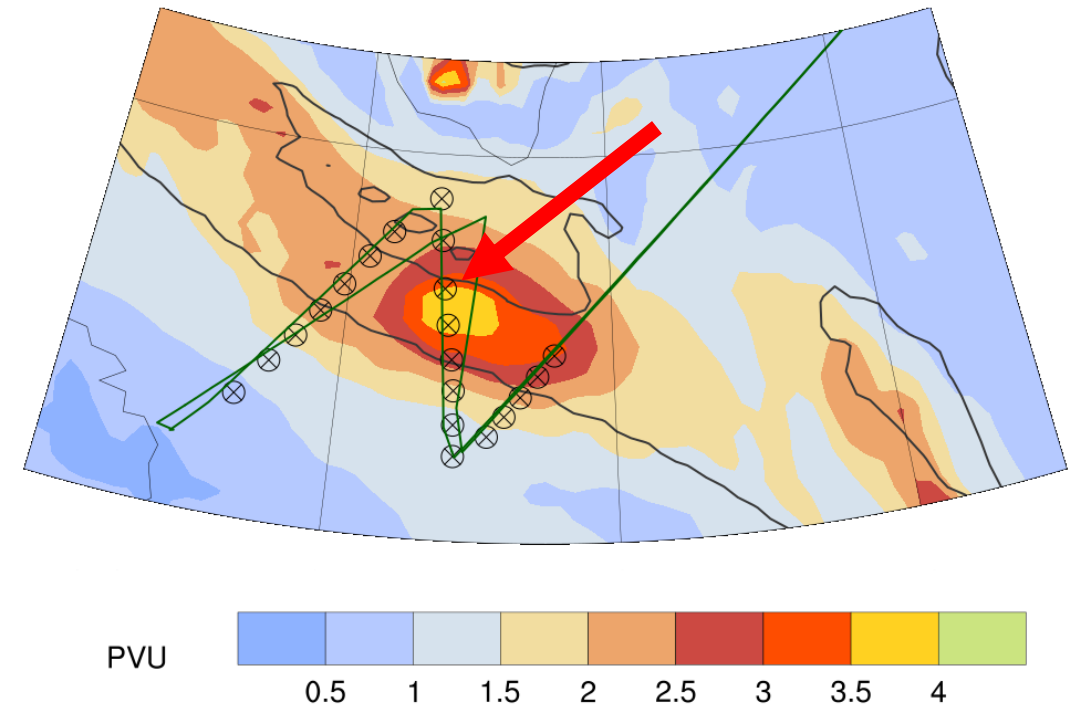
20161006_12: VAPV 285K-310K



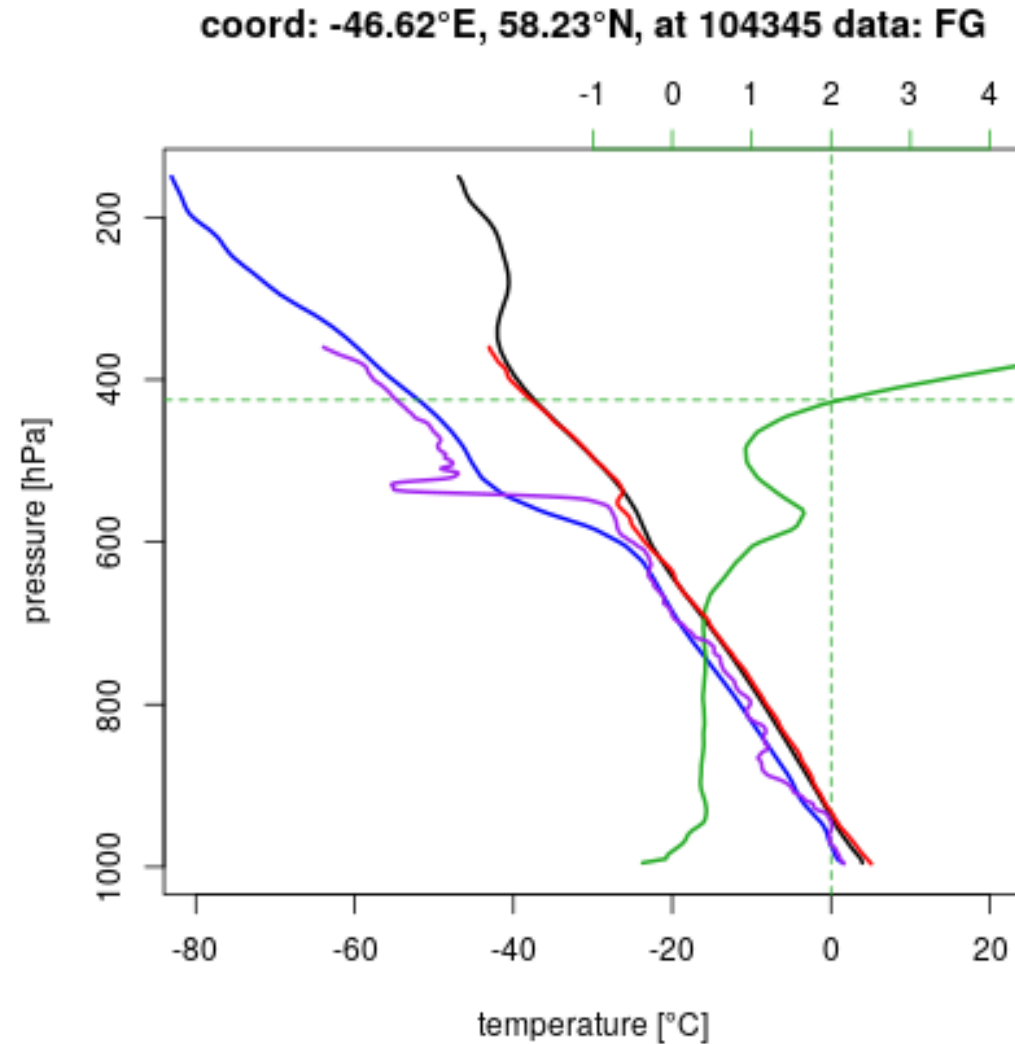
Dropsondes vs first guess (INIT:20161006_00)



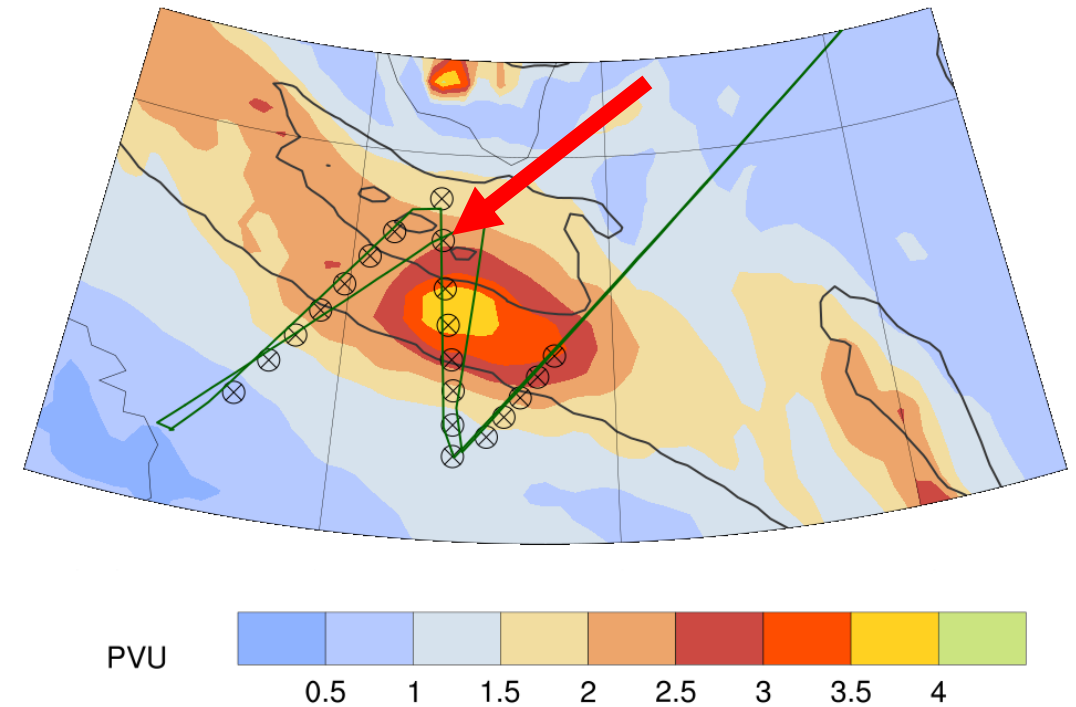
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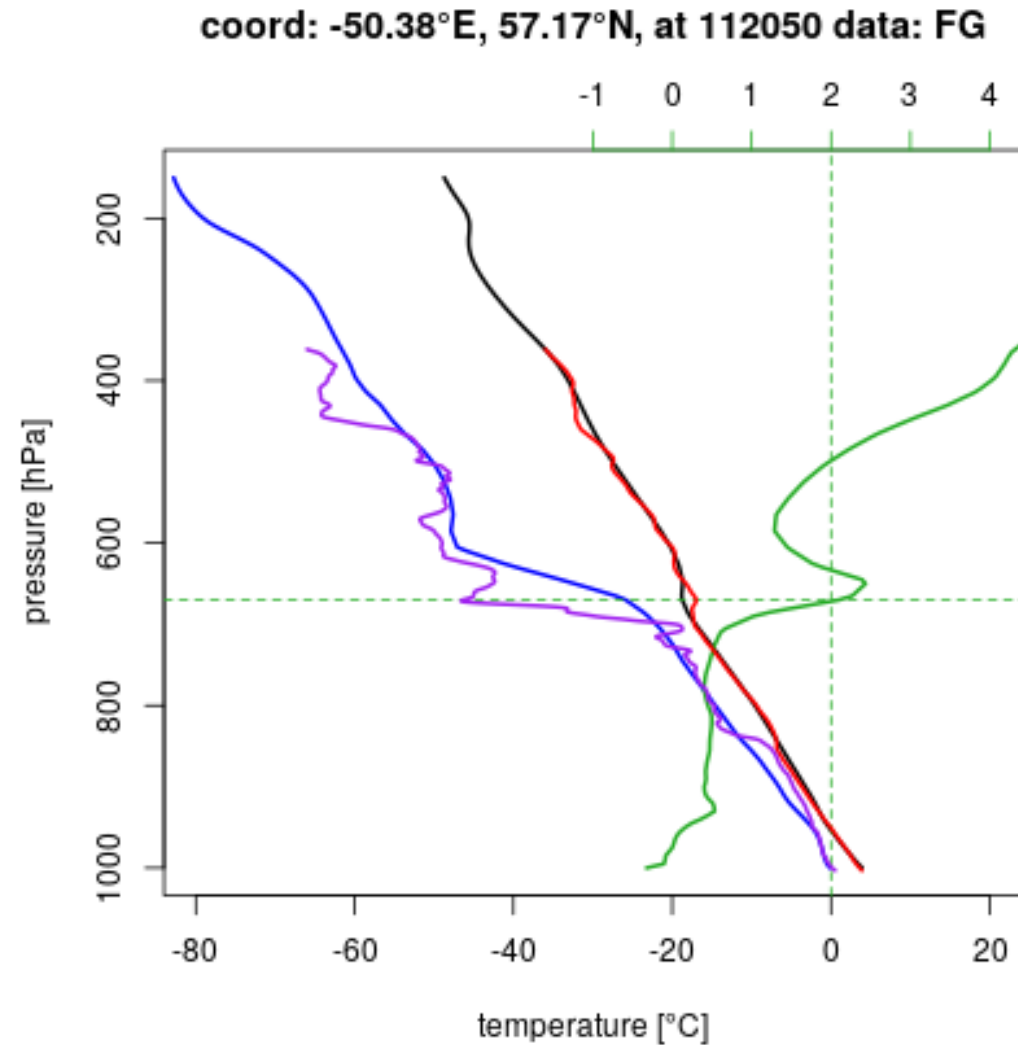
Dropsondes vs first guess (INIT:20161006_00)



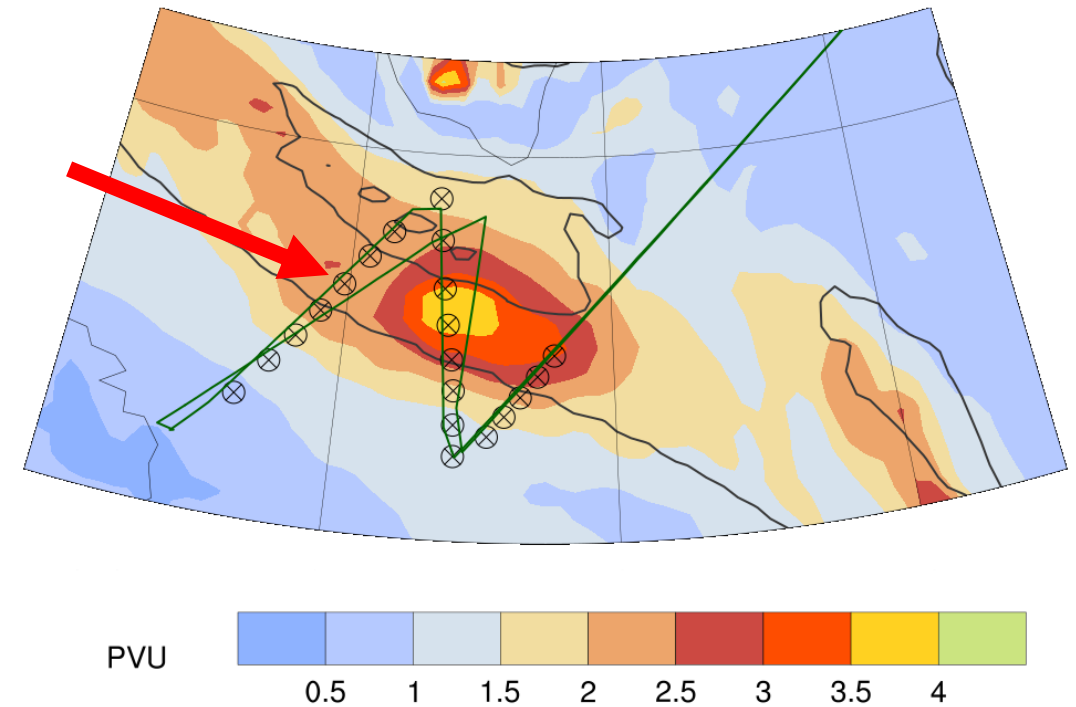
20161006_12: VAPV 285K-310K



Dropsondes vs first guess (INIT:20161006_00)



20161006_12: VAPV 285K-310K



HALO RF7 dropsondes

Comparison of dropsonde measurements with analysis/forecasts is challenging because of interpolation issues.

Interpolated (first guess) dropsondes do not show strong enough vertical dew point gradients across the tropopause.

Dropsonde measurements were taken below the Kewblob. It is thus questionable, to what extent and how the (assimilated) HALO RF7 dropsondes were responsible for the Kewblob strengthening in the Analysis during/after HALO RF7.

- Synoptic overview: Tropoblob, Kewblob, surface cyclogenesis after HALO RF7, strong winds in Iceland on 7-8 October.
- FCST uncertainty: increased ENS spread of various variables related to TPV-jet interaction and subsequent cyclogenesis.
- Kewblob too weak in ENS FCST.
- 12h FCST – analysis fields reveal that assimilation of new data around HALO RF7 was responsible for Kewblob strengthening.
- 12h FCST – analysis fields and dropsonde vs first guess comparisons thus raise the question to what extent HALO RF7 dropsondes might have played a role in the Kewblob strengthening in the analysis.
- Next steps: ECMWF feedback files, WALES LIDAR and RADAR measurements

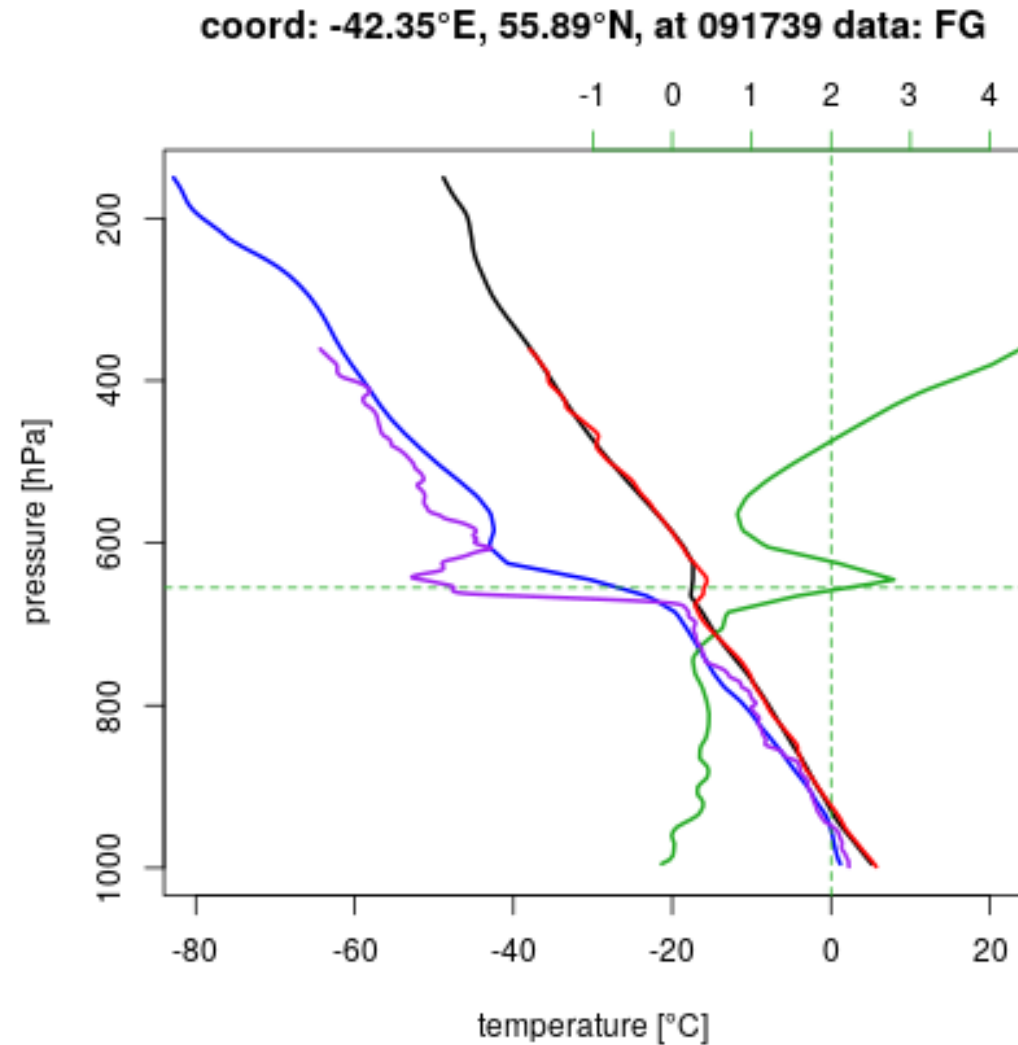
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Many thanks for your attention!

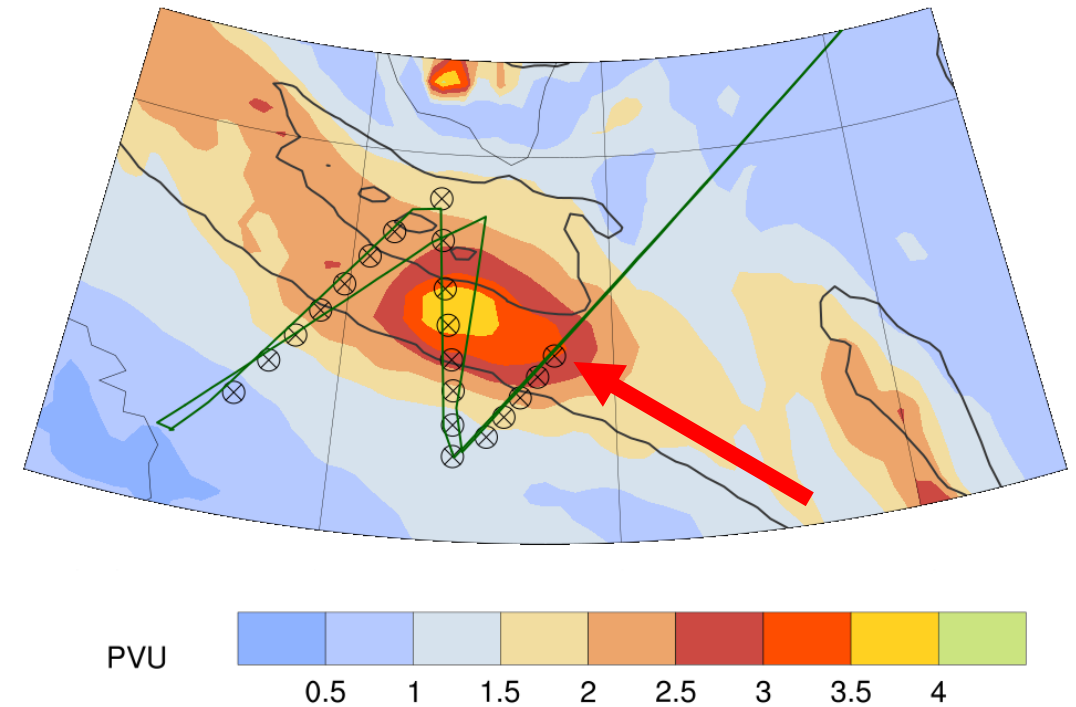
Supplementary slides

CF dropsondes, fg

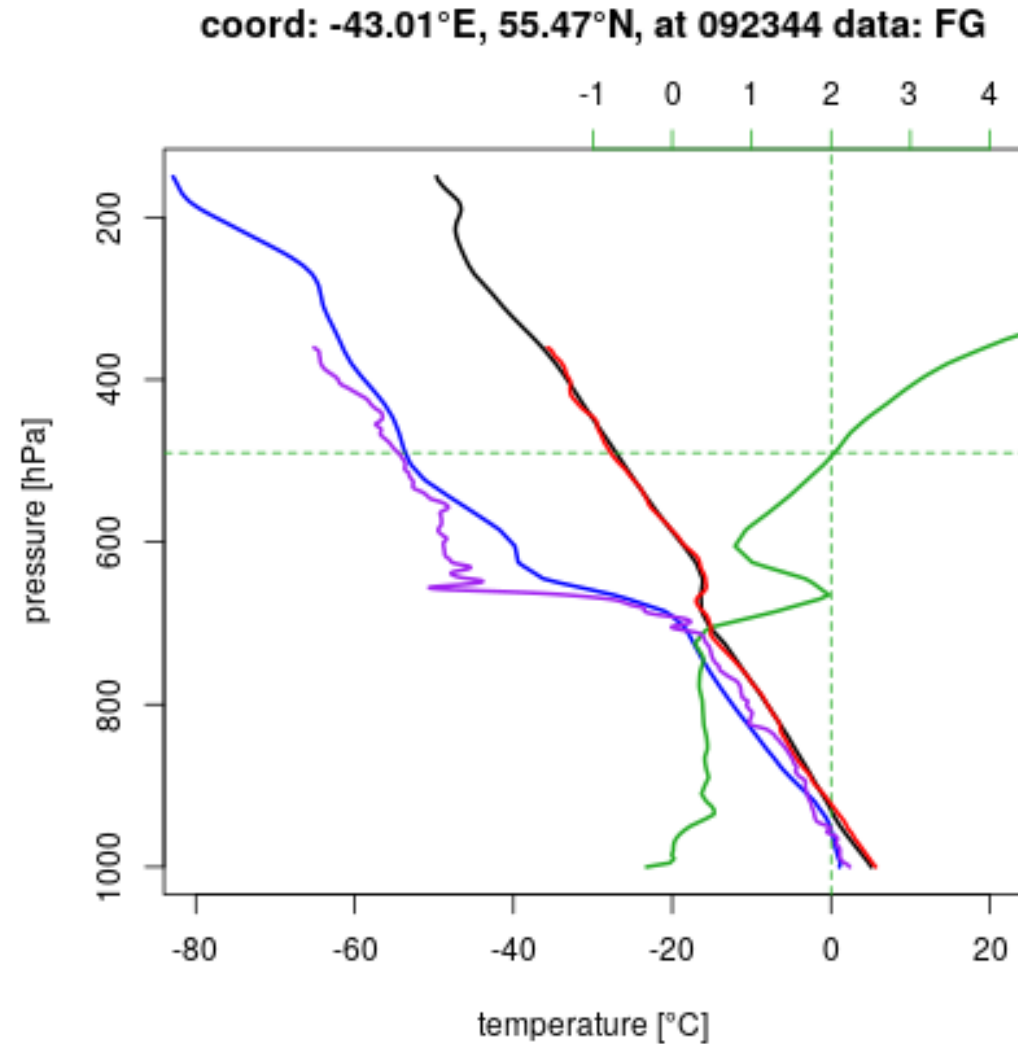
Dropsondes vs first guess (INIT:20161006_00)



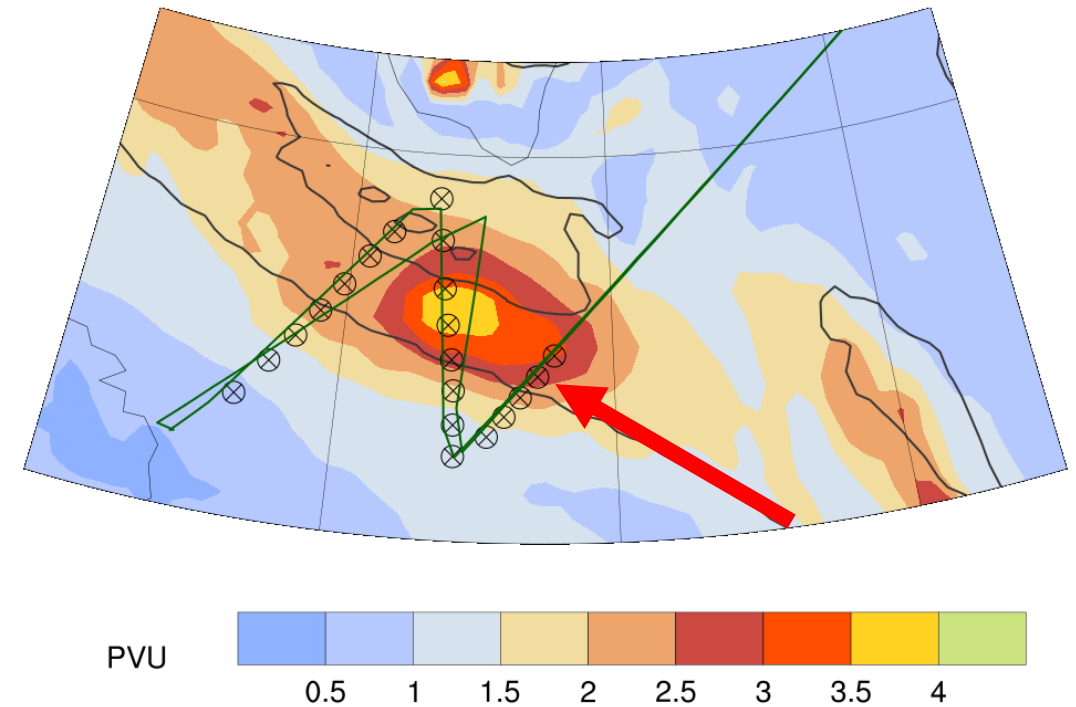
20161006_12: VAPV 285K-310K



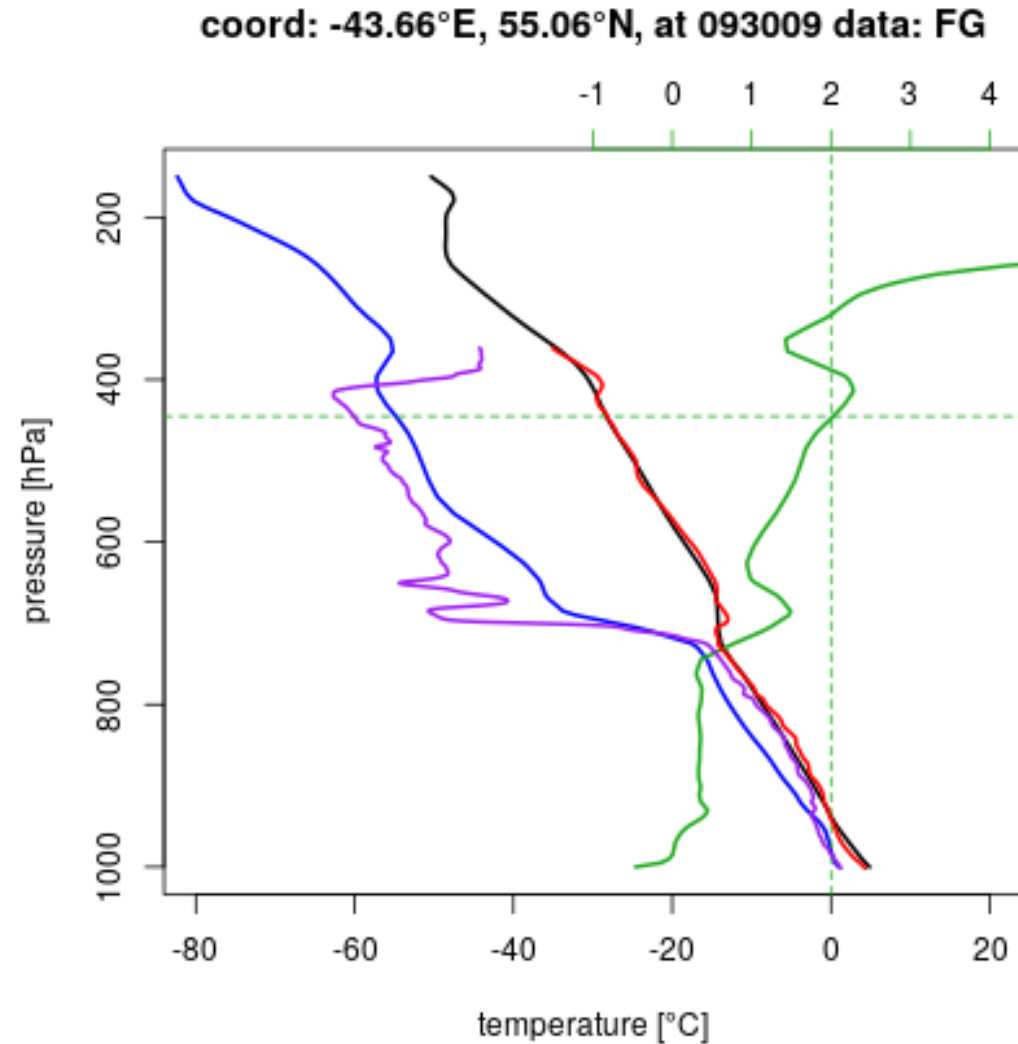
Dropsondes vs first guess (INIT:20161006_00)



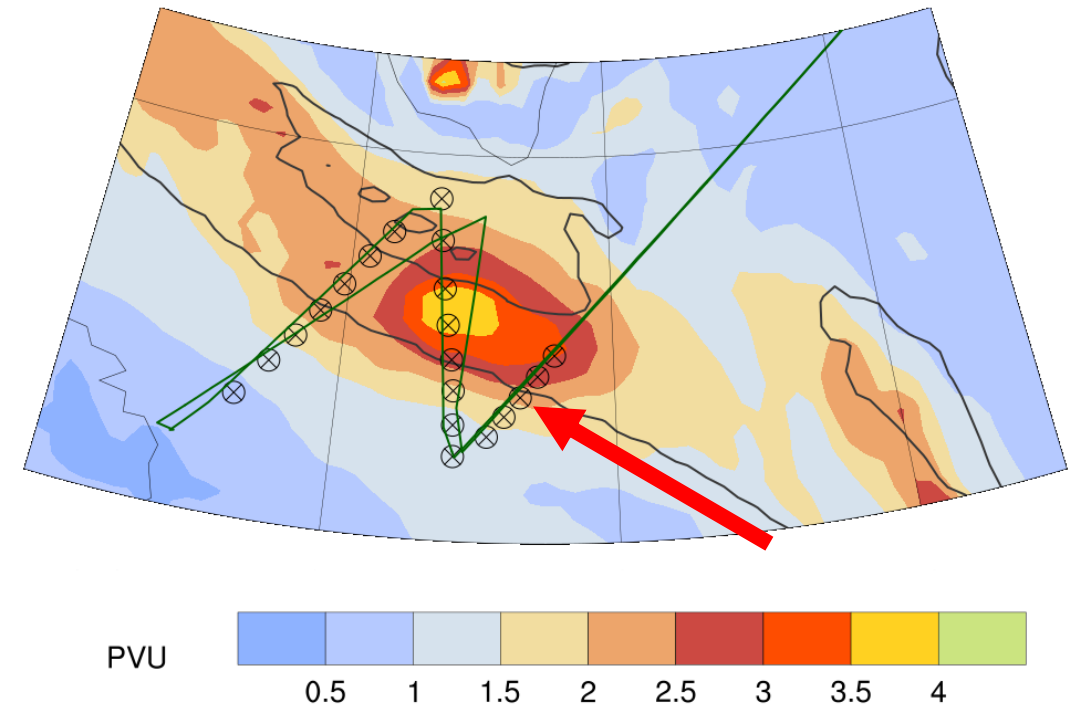
20161006_12: VAPV 285K-310K



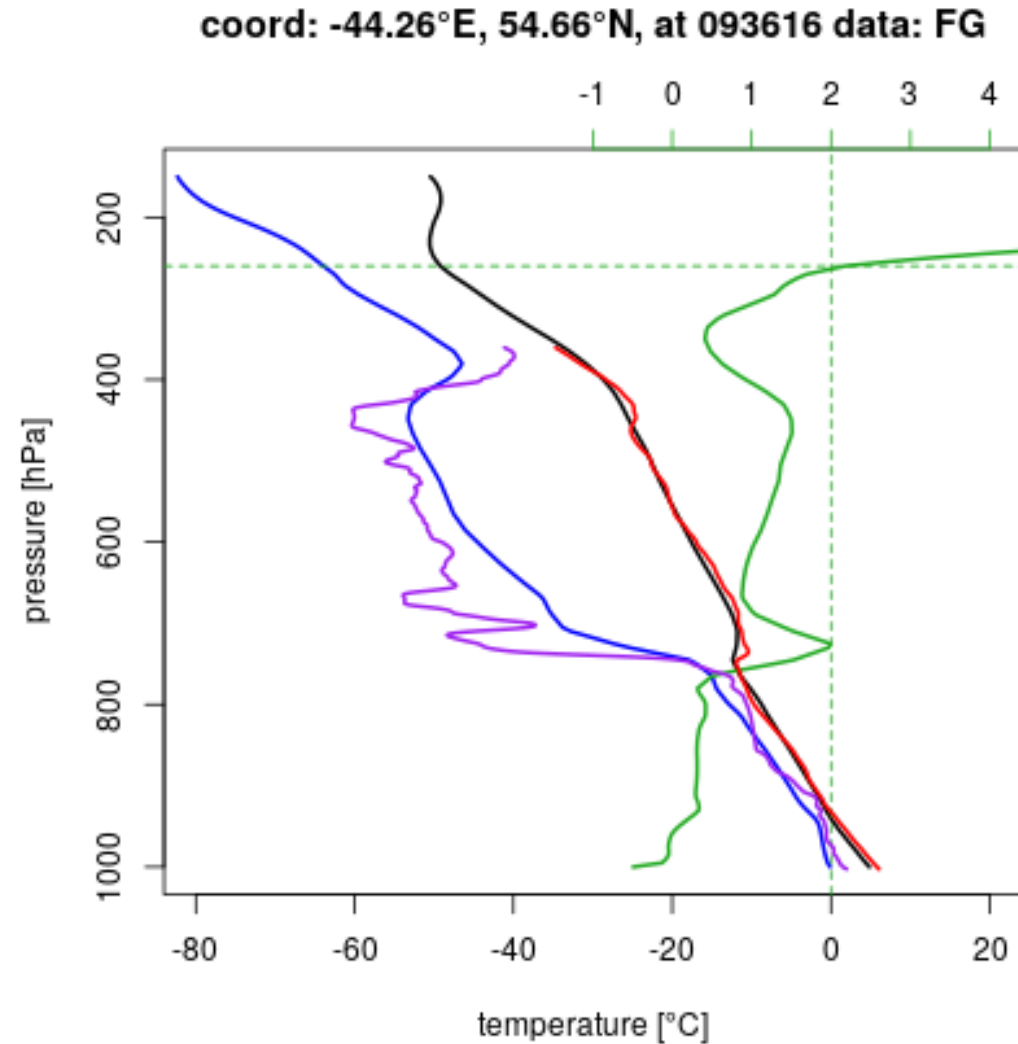
Dropsondes vs first guess (INIT:20161006_00)



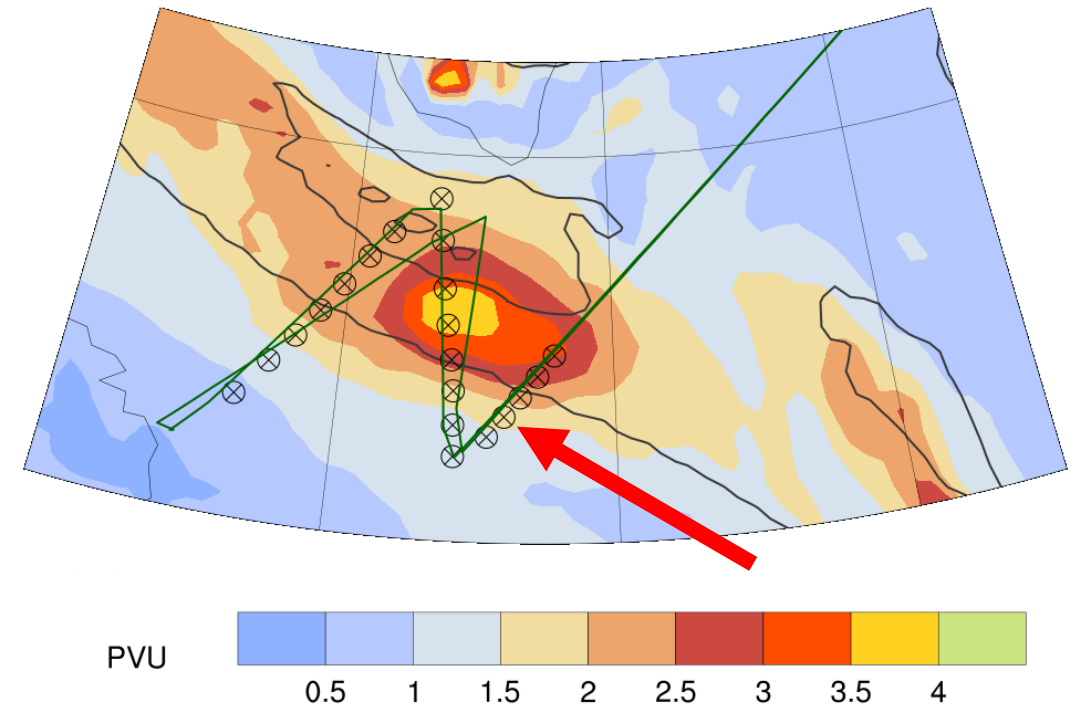
20161006_12: VAPV 285K-310K



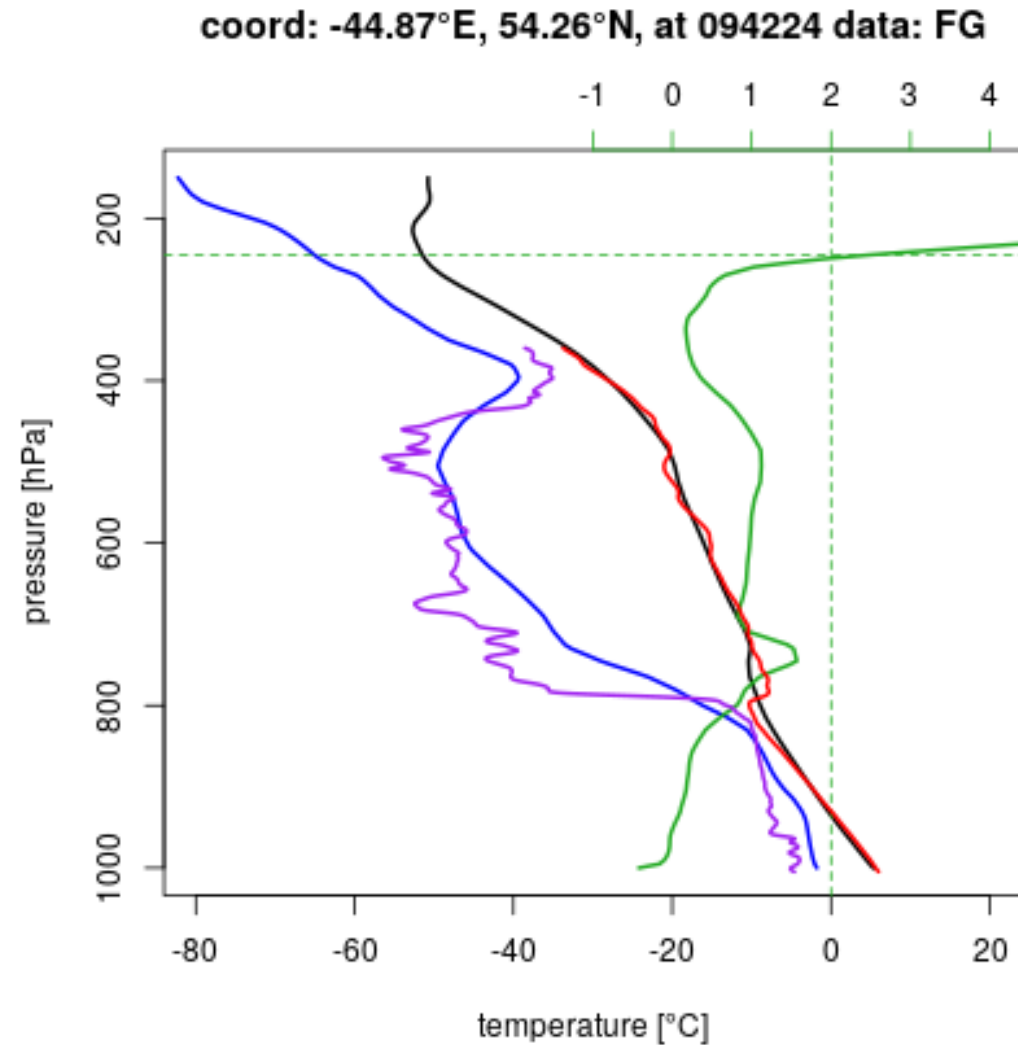
Dropsondes vs first guess (INIT:20161006_00)



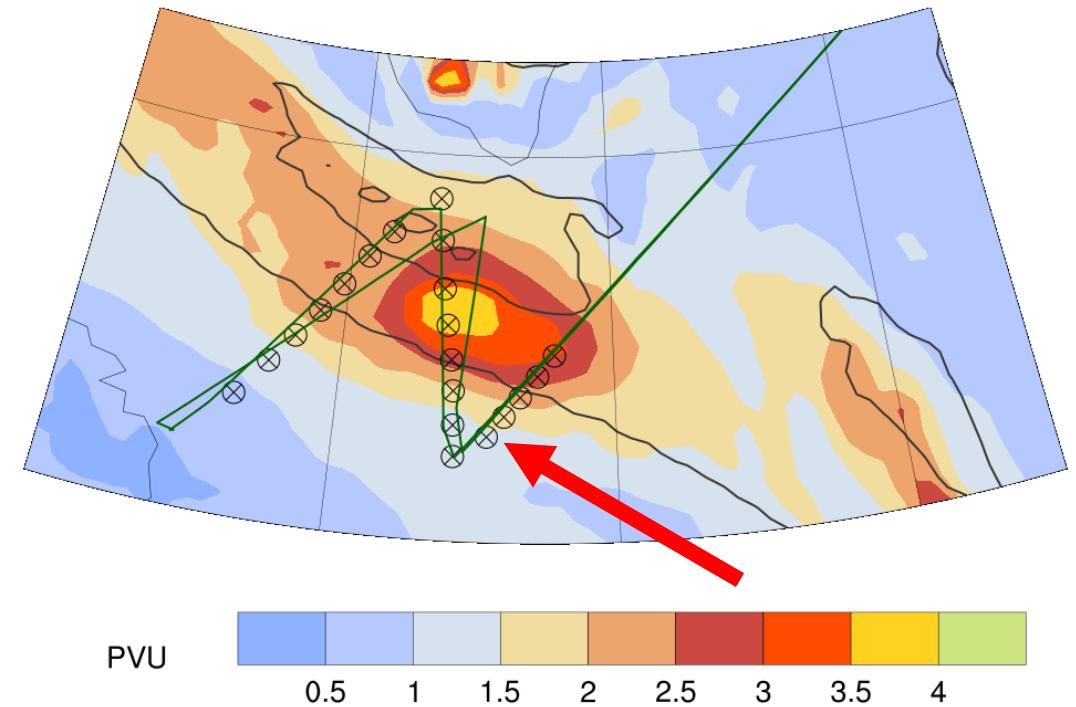
20161006_12: VAPV 285K-310K



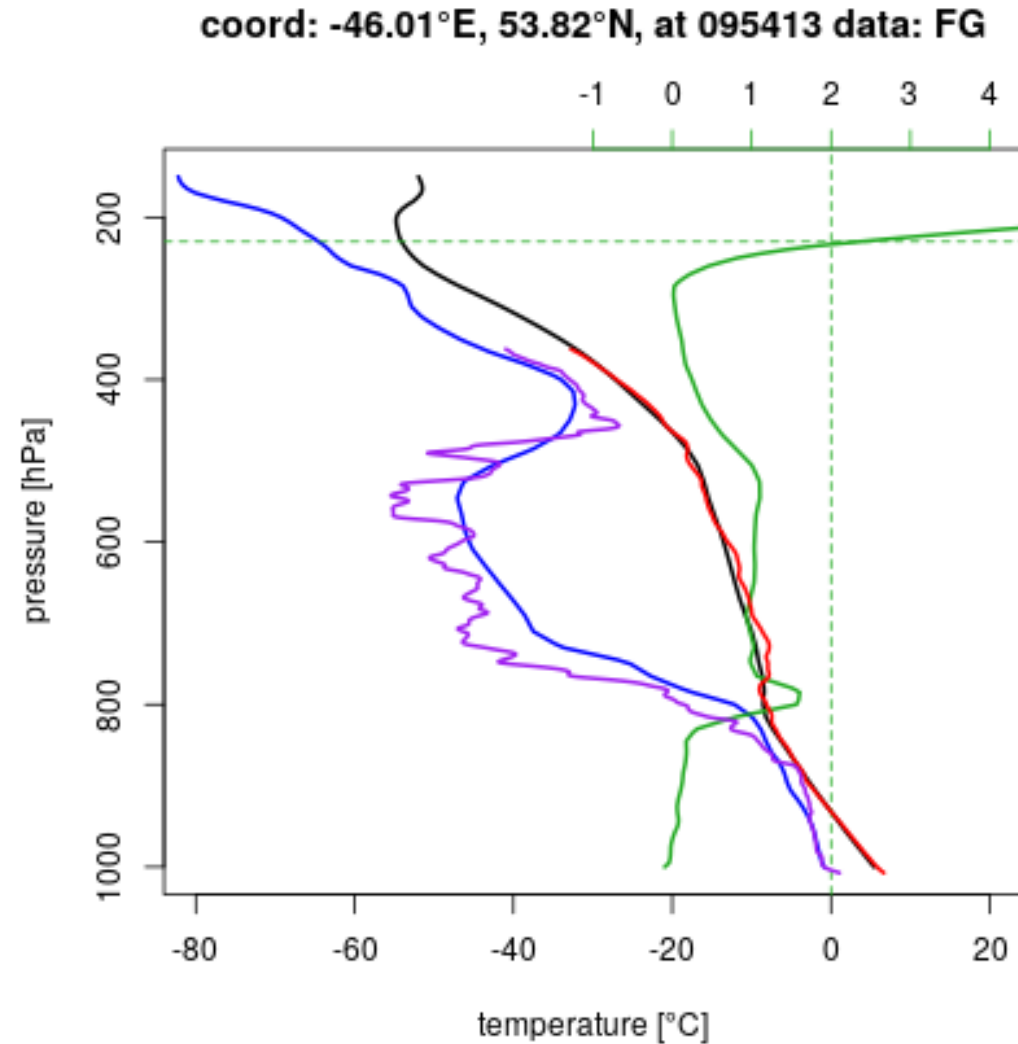
Dropsondes vs first guess (INIT:20161006_00)



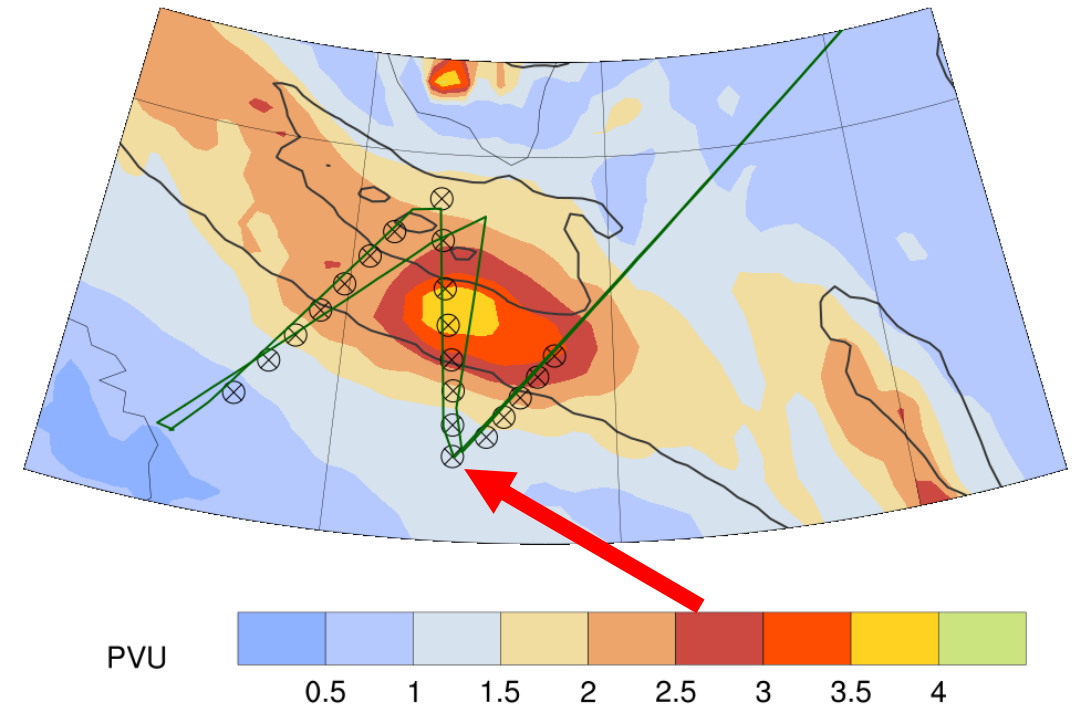
20161006_12: VAPV 285K-310K



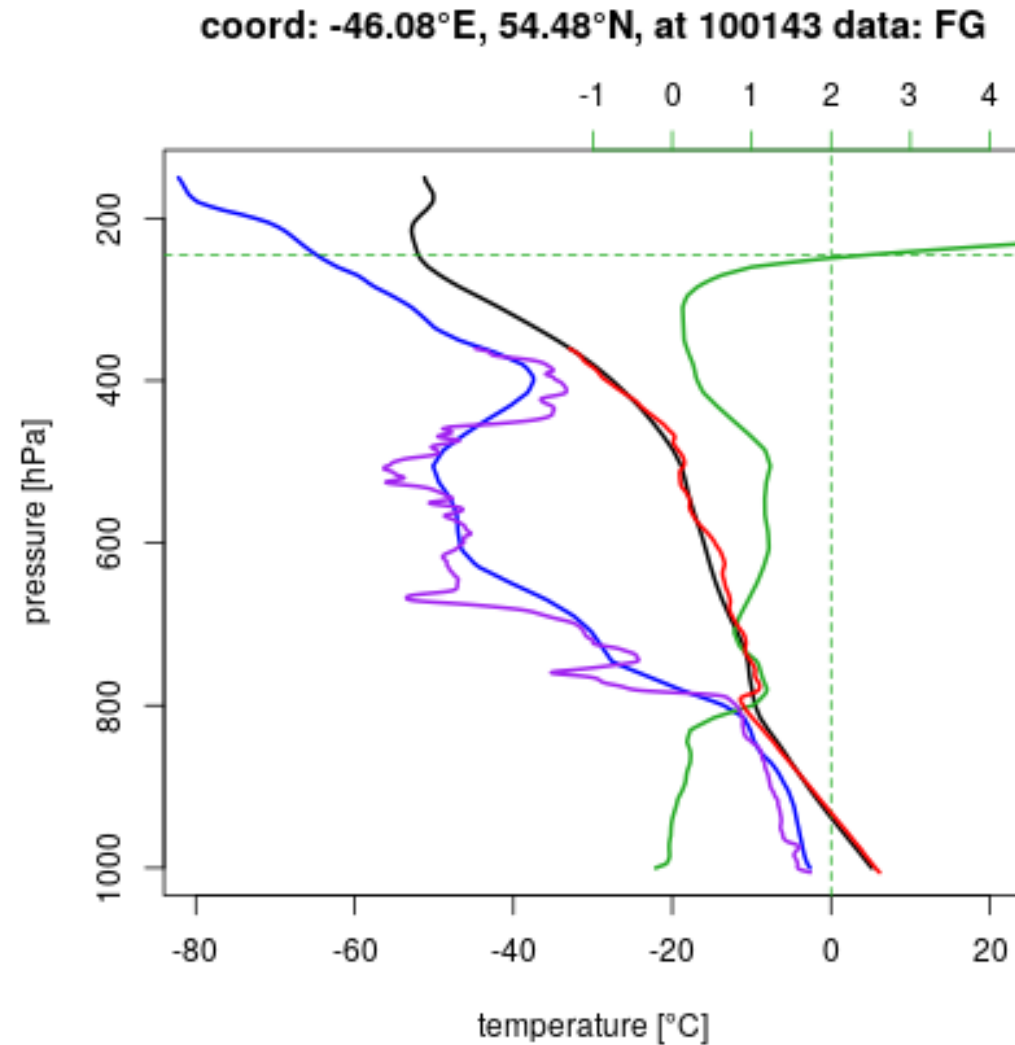
Dropsondes vs first guess (INIT:20161006_00)



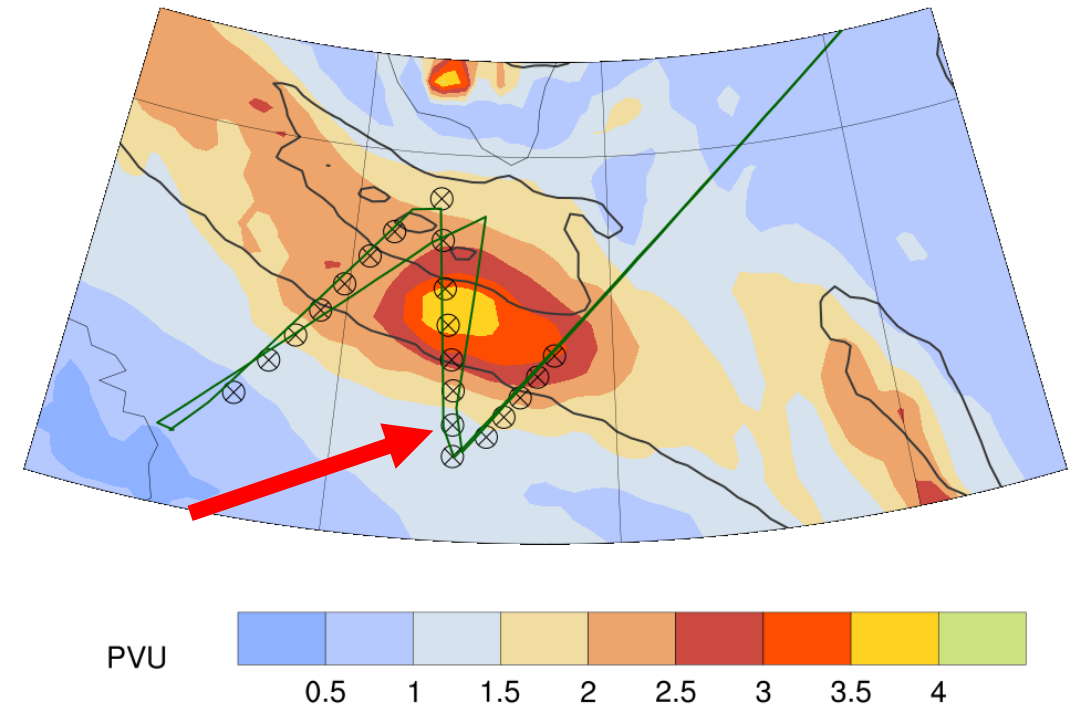
20161006_12: VAPV 285K-310K



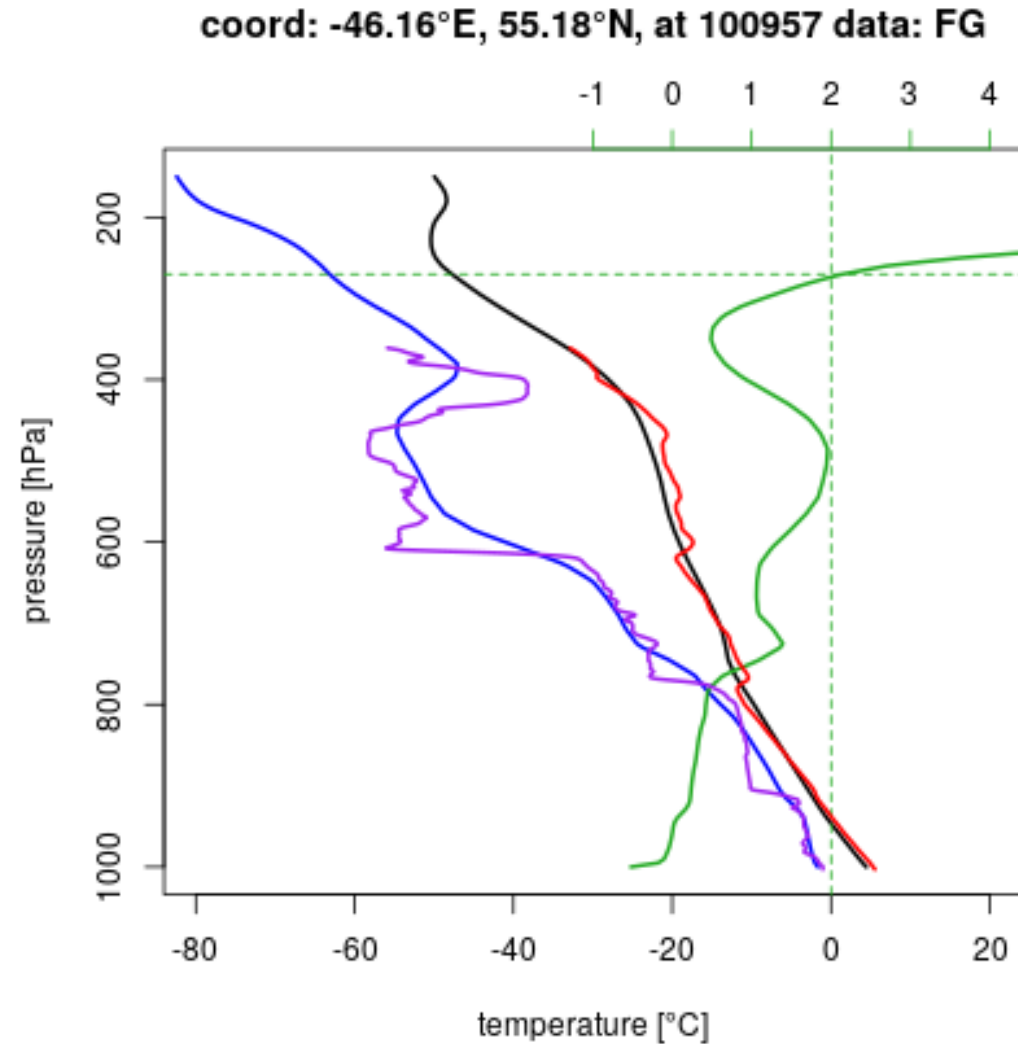
Dropsondes vs first guess (INIT:20161006_00)



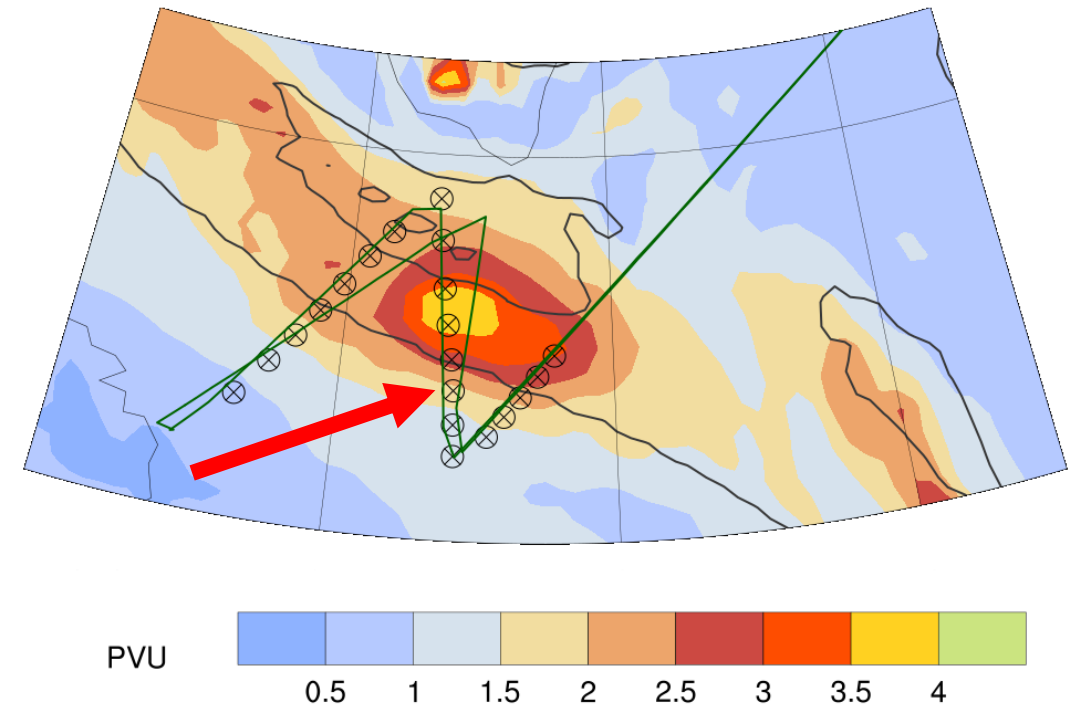
20161006_12: VAPV 285K-310K



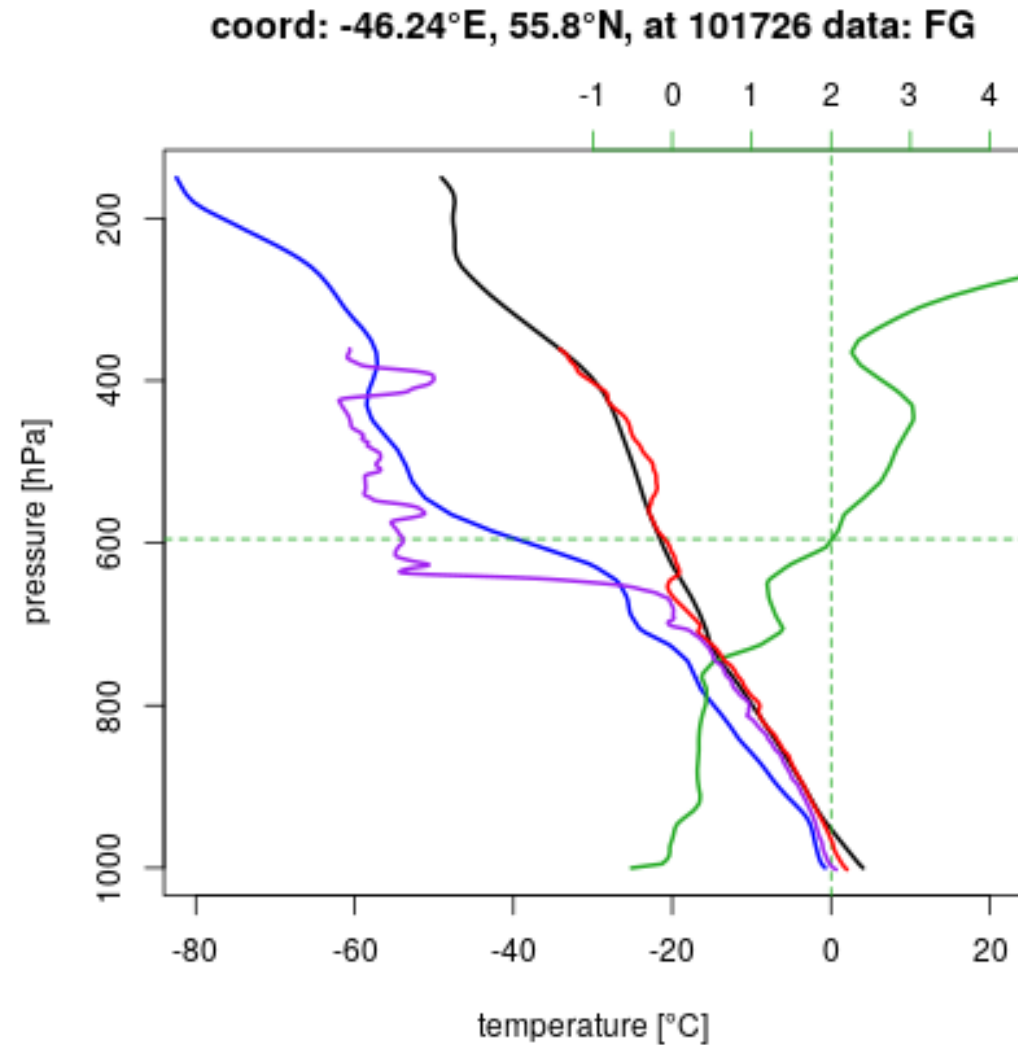
Dropsondes vs first guess (INIT:20161006_00)



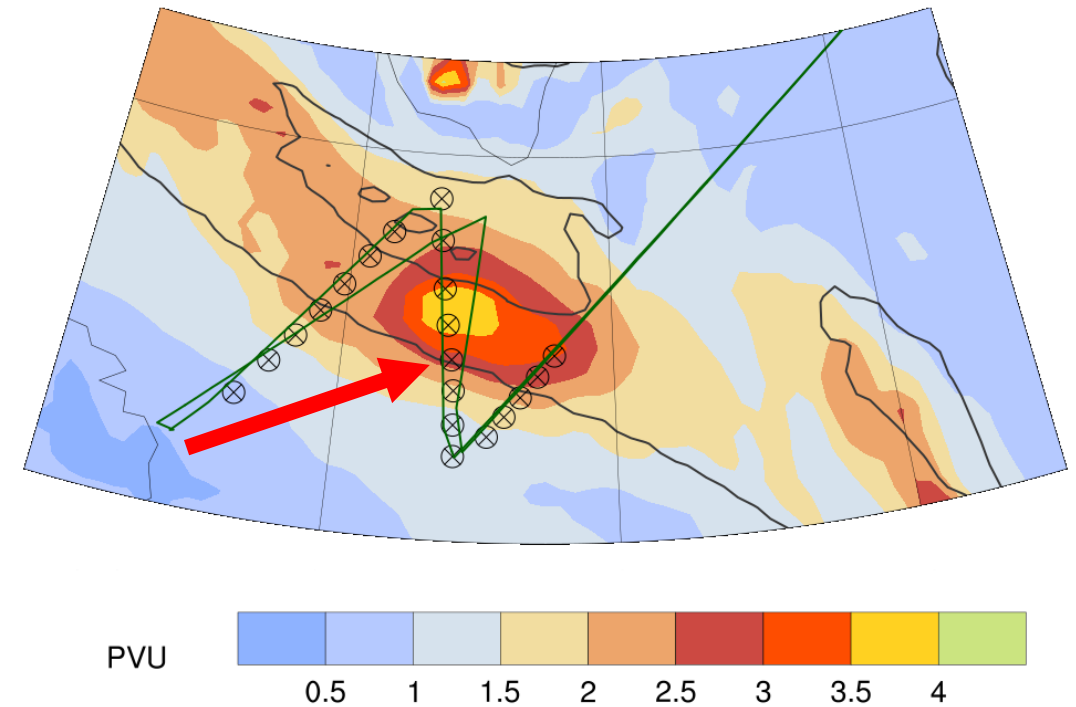
20161006_12: VAPV 285K-310K



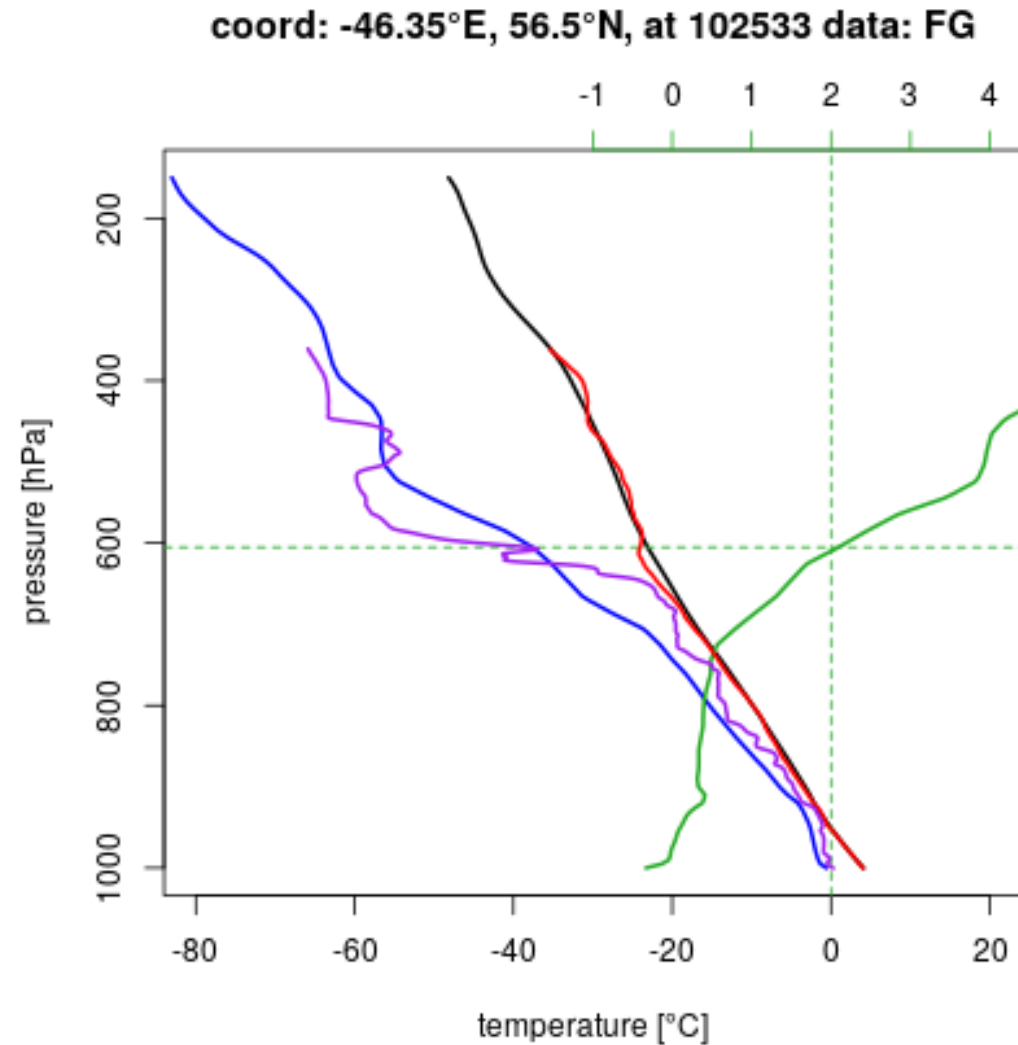
Dropsondes vs first guess (INIT:20161006_00)



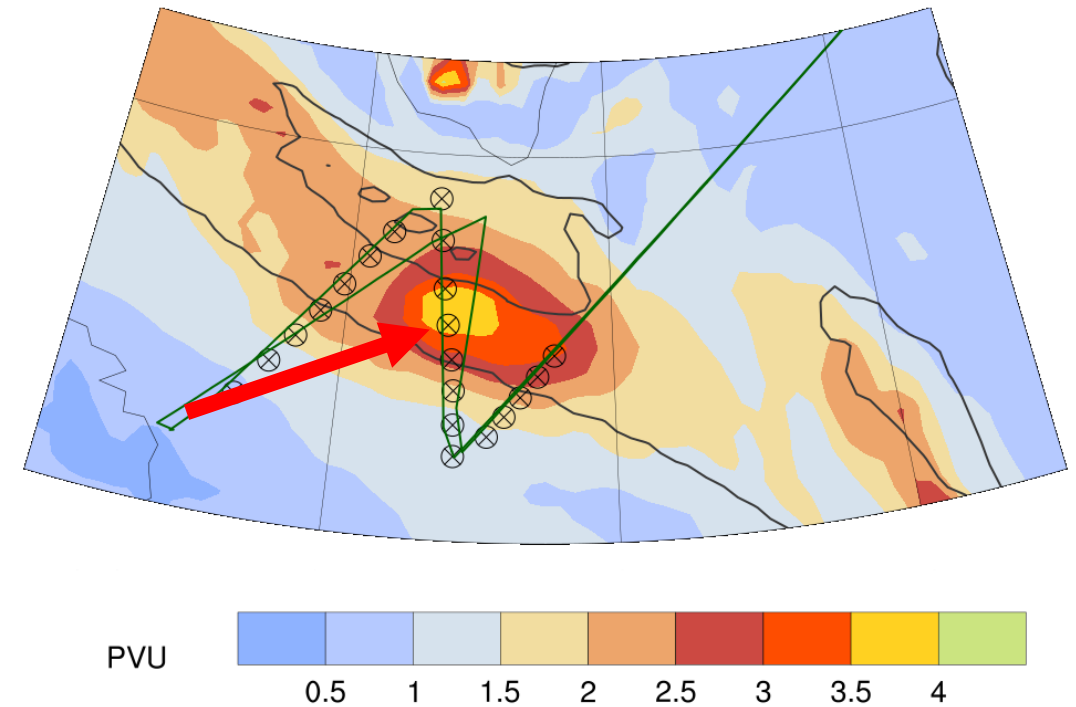
20161006_12: VAPV 285K-310K



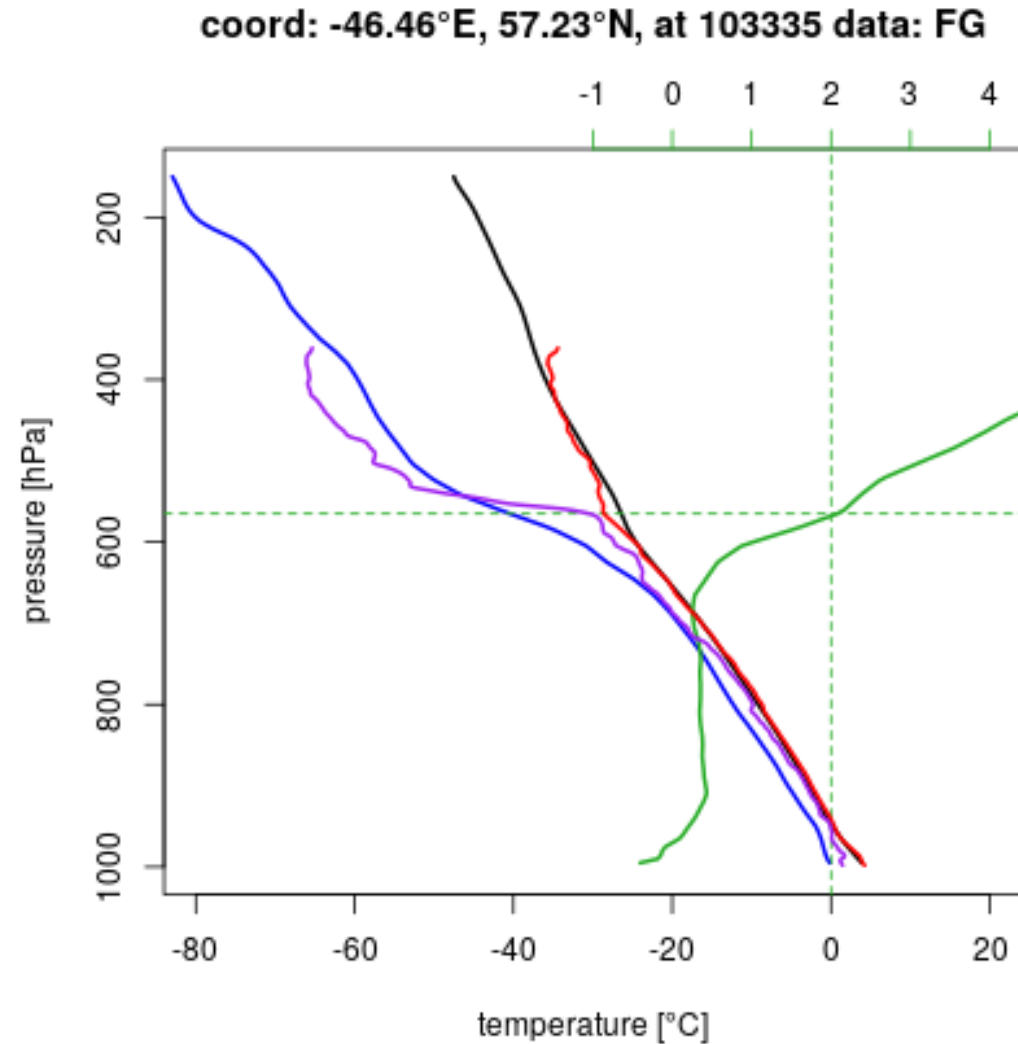
Dropsondes vs first guess (INIT:20161006_00)



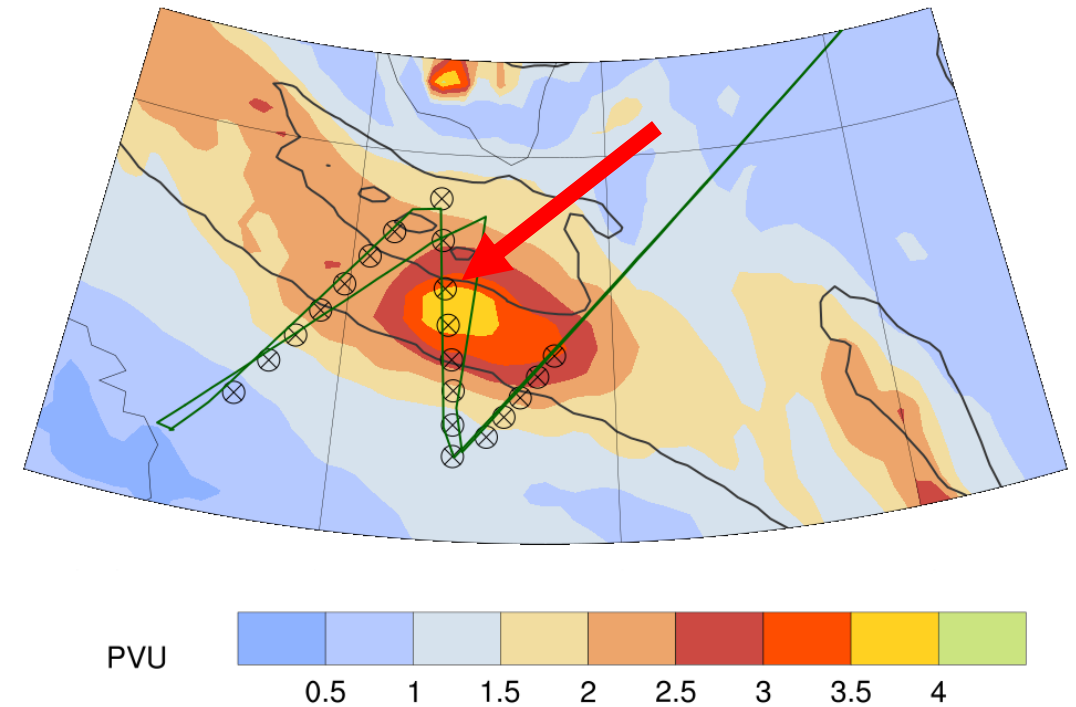
20161006_12: VAPV 285K-310K



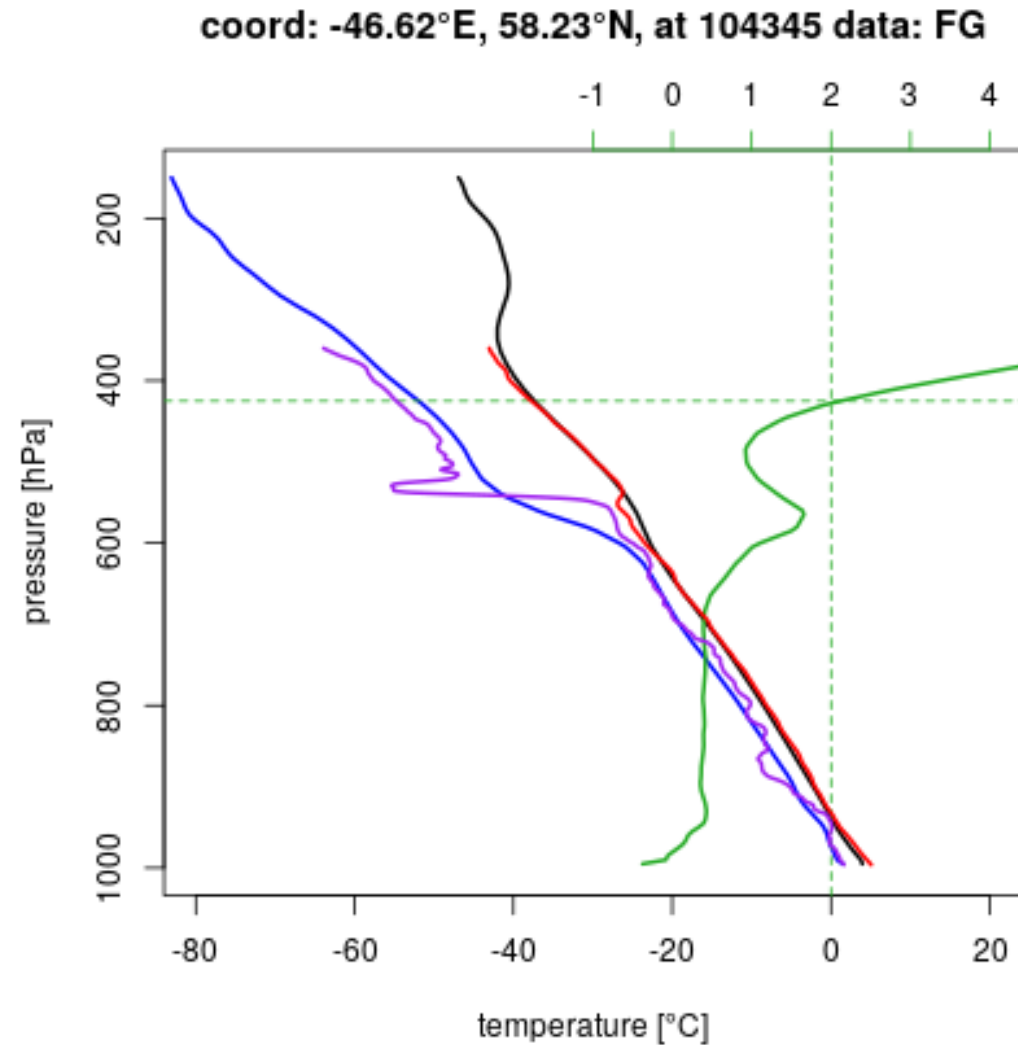
Dropsondes vs first guess (INIT:20161006_00)



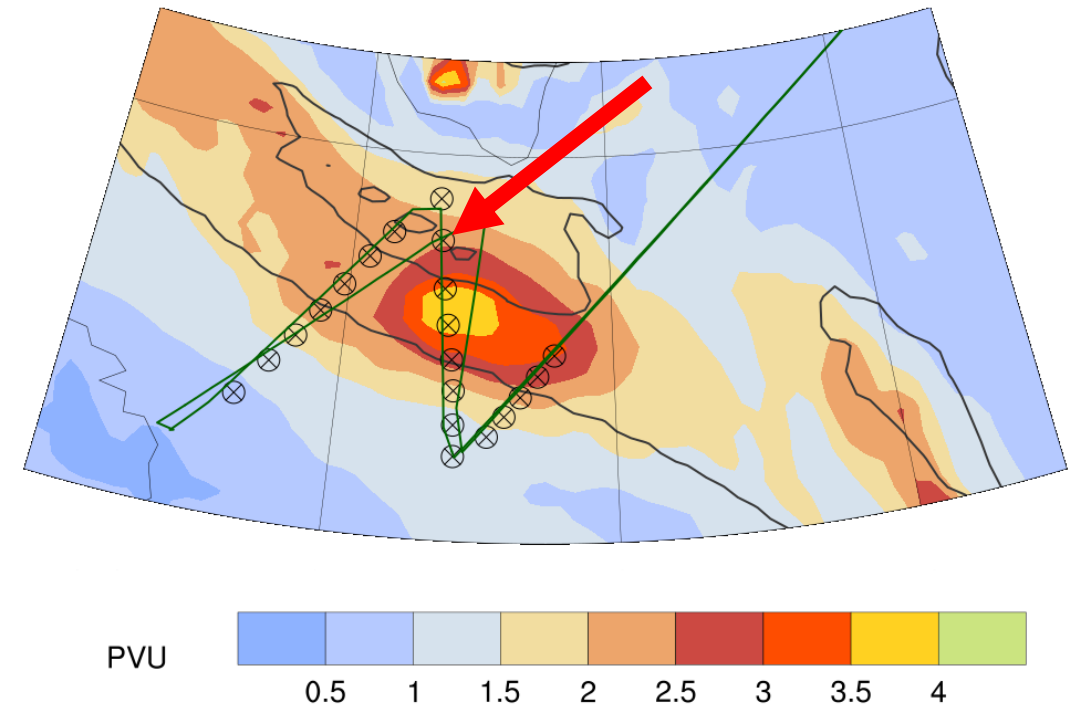
20161006_12: VAPV 285K-310K



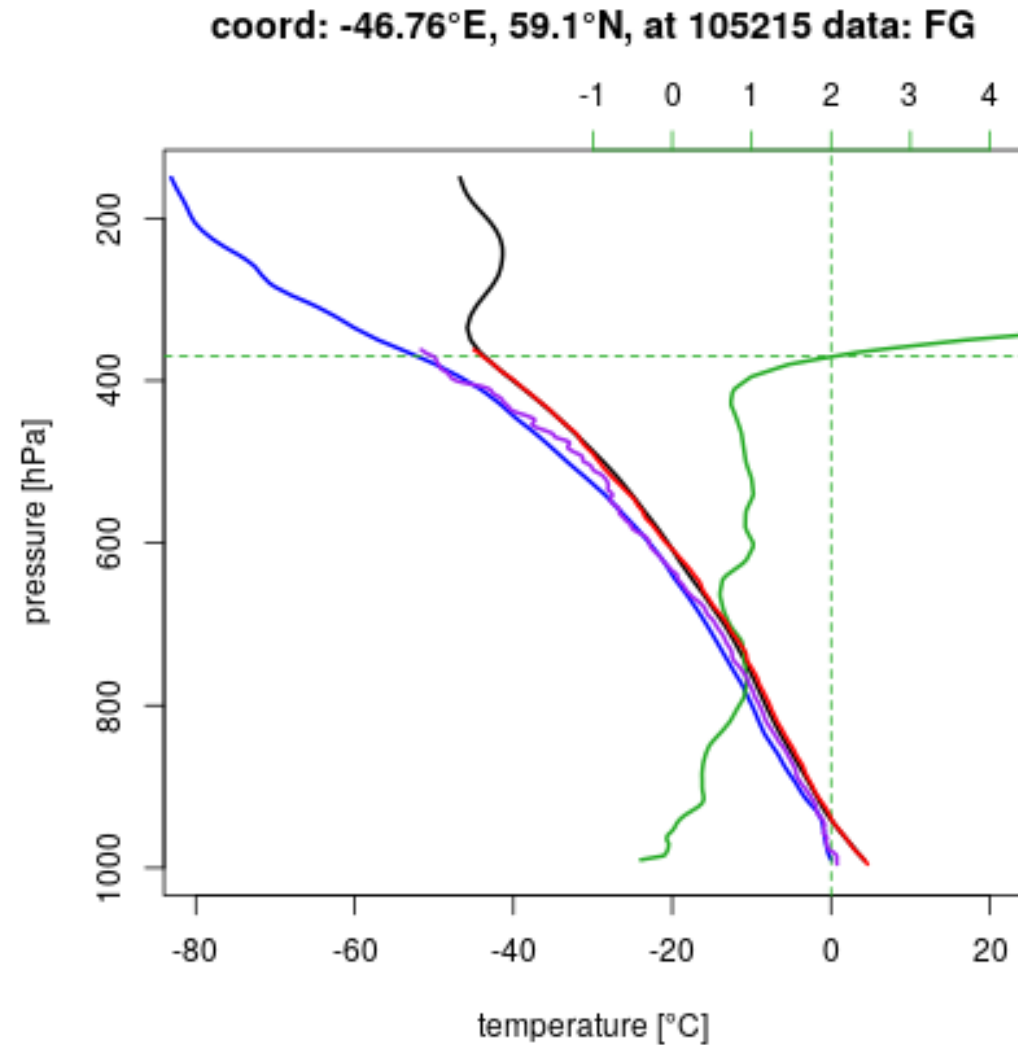
Dropsondes vs first guess (INIT:20161006_00)



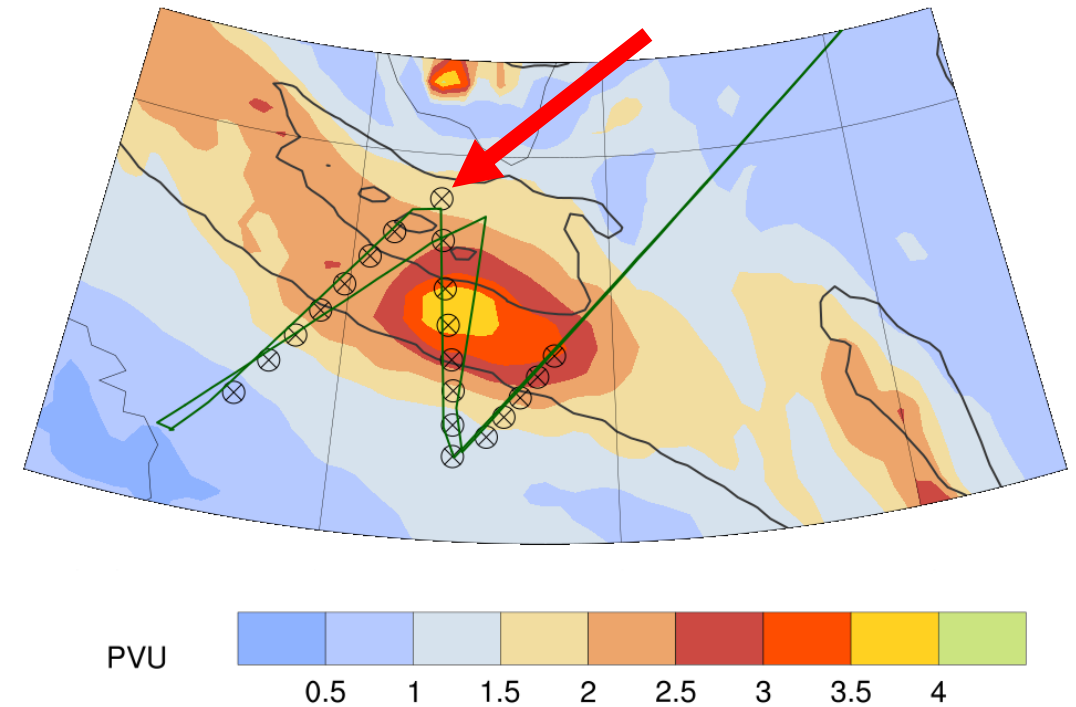
20161006_12: VAPV 285K-310K



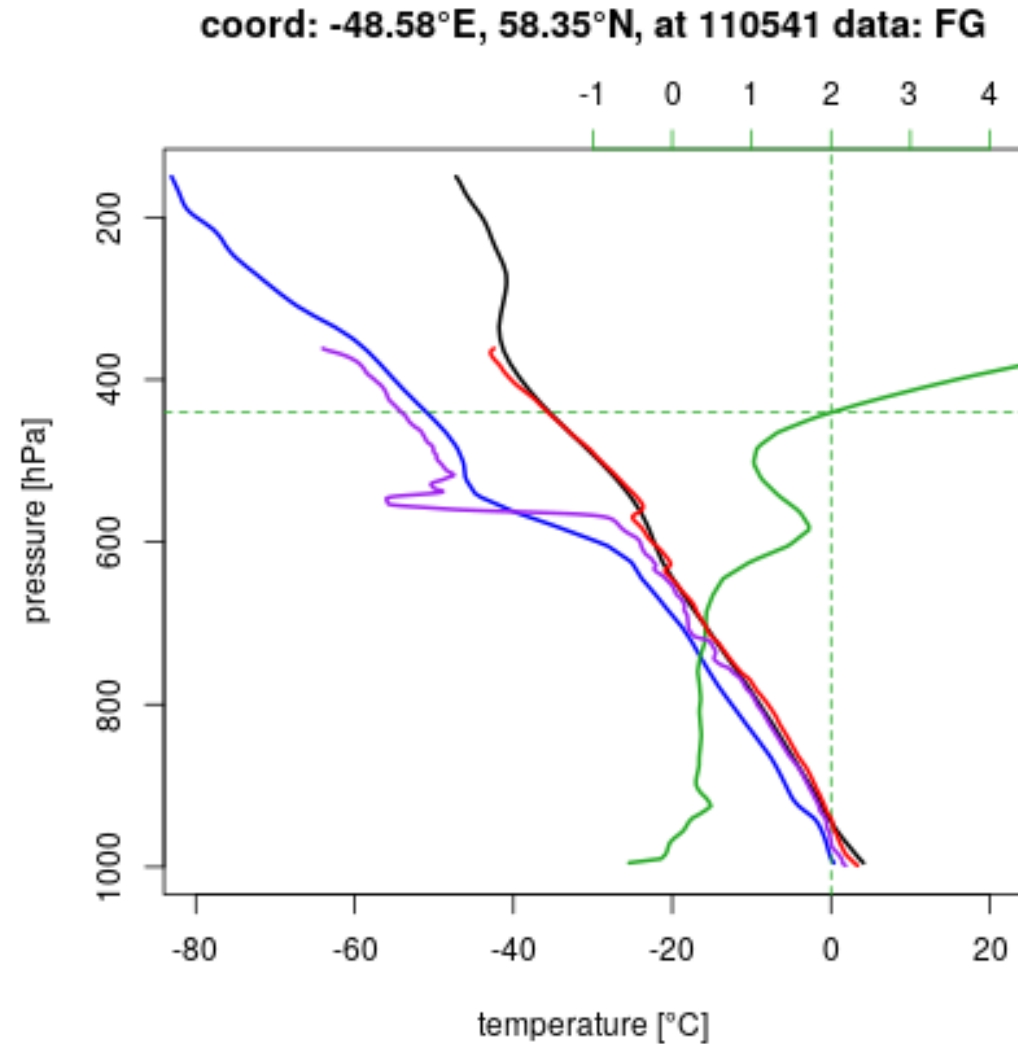
Dropsondes vs first guess (INIT:20161006_00)



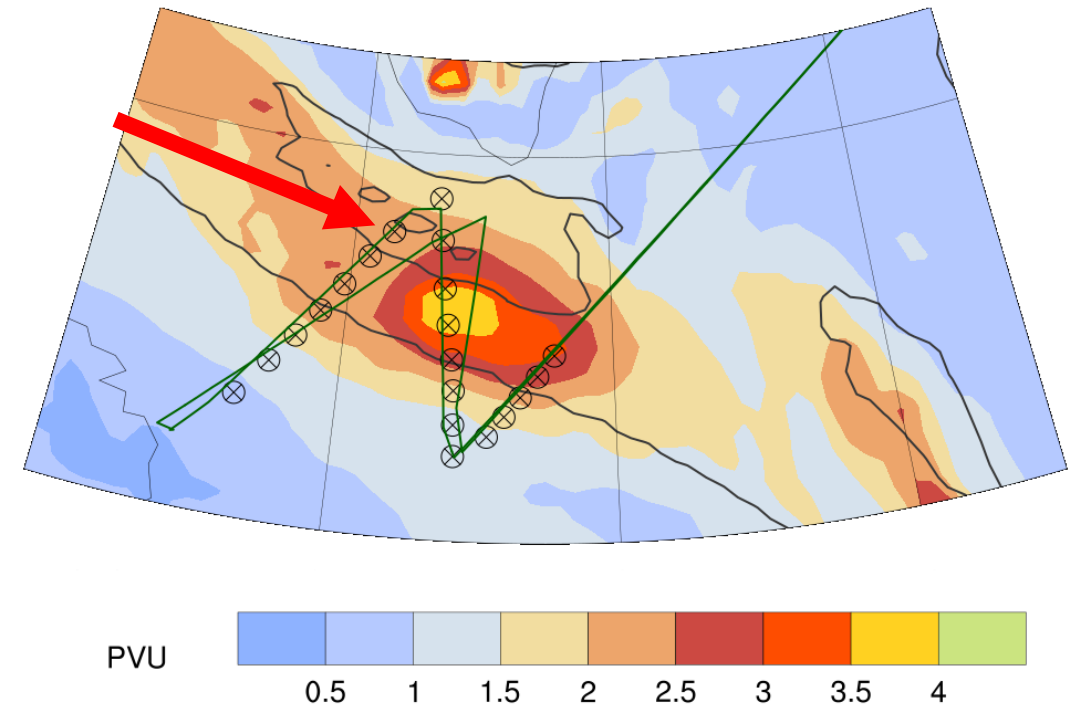
20161006_12: VAPV 285K-310K



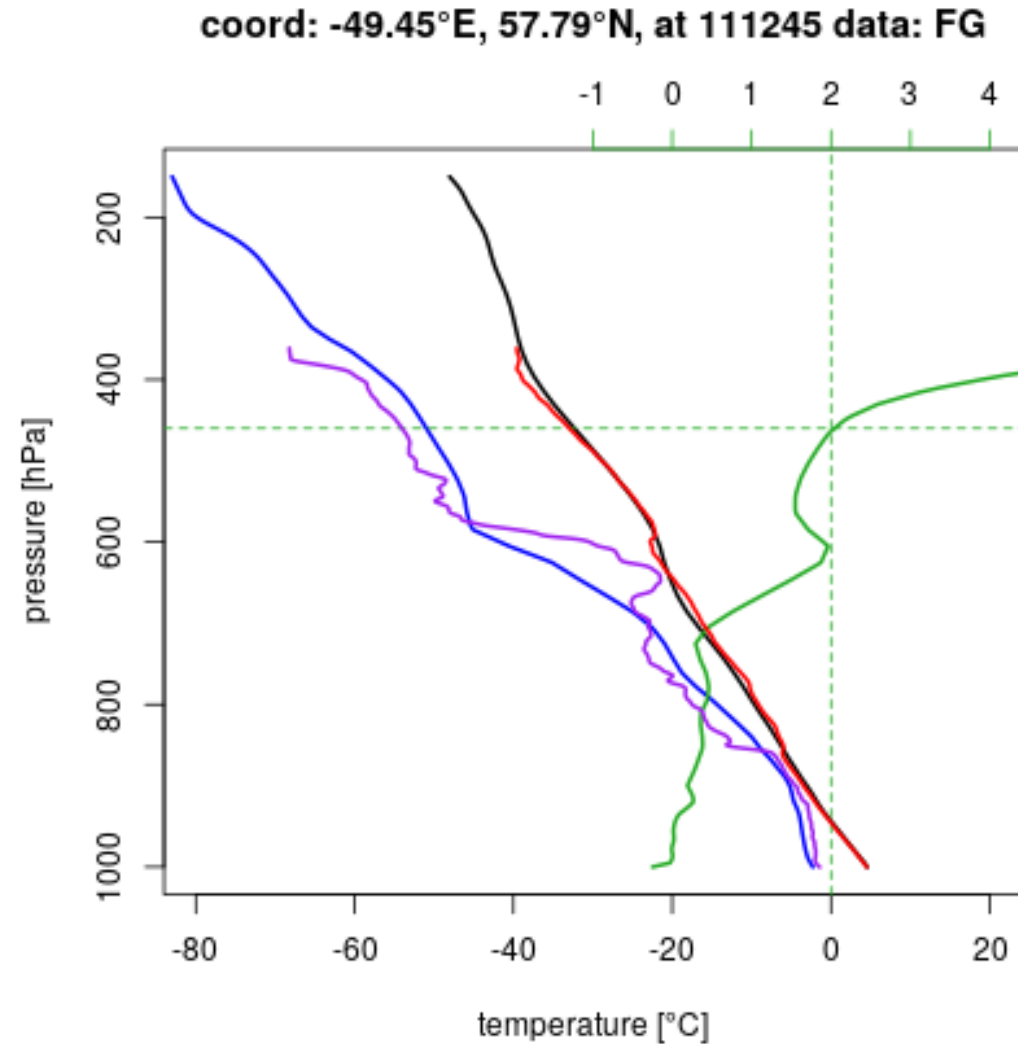
Dropsondes vs first guess (INIT:20161006_00)



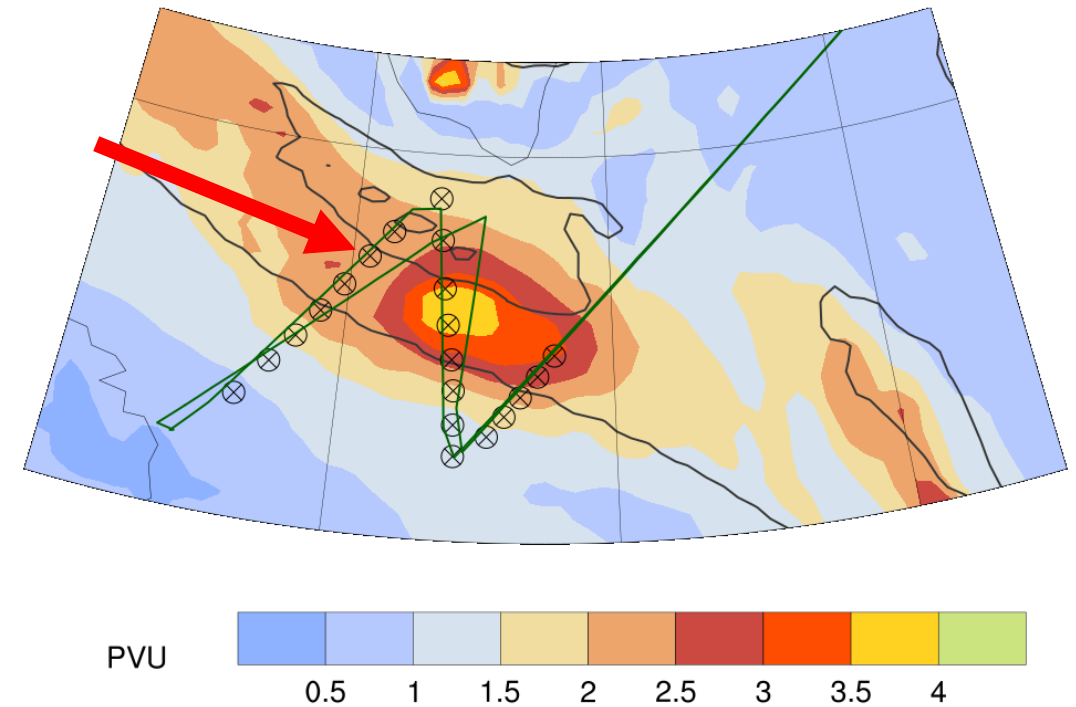
20161006_12: VAPV 285K-310K



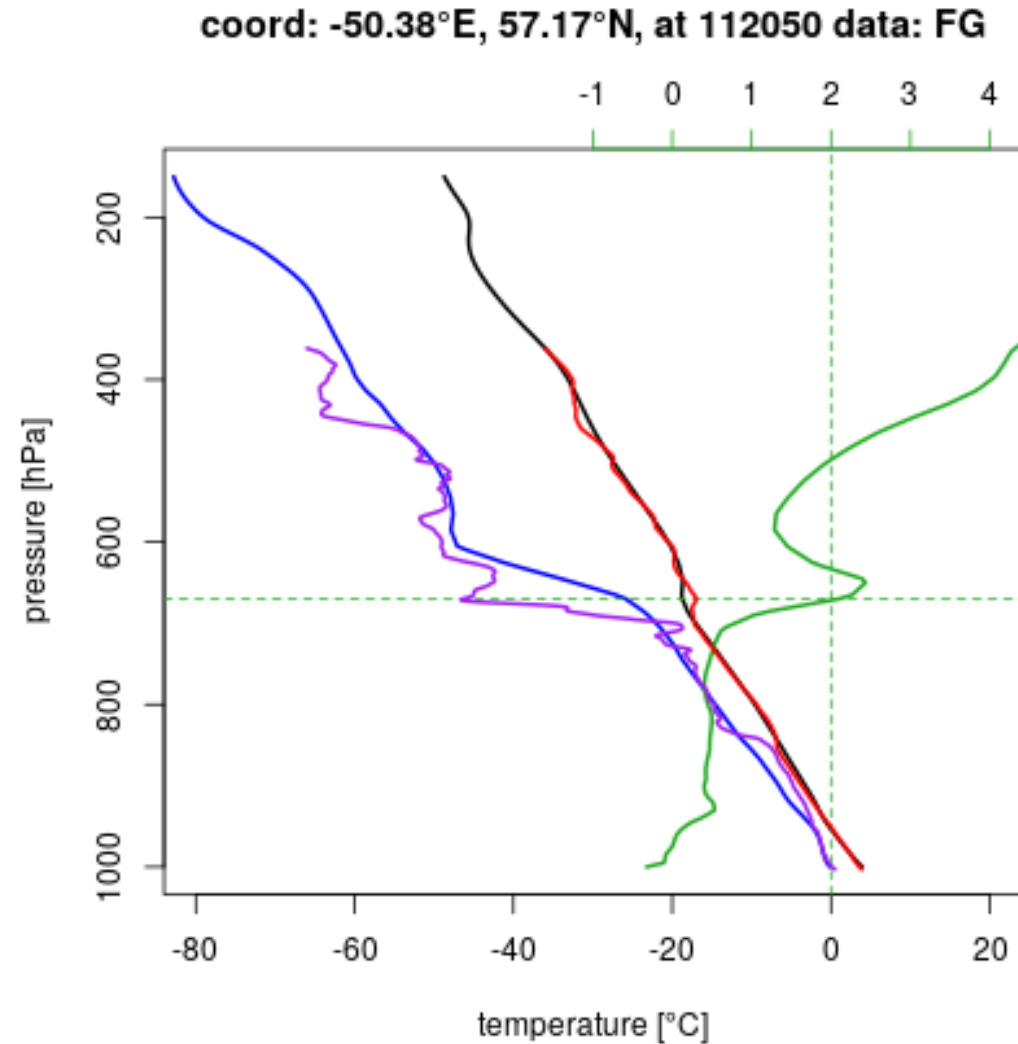
Dropsondes vs first guess (INIT:20161006_00)



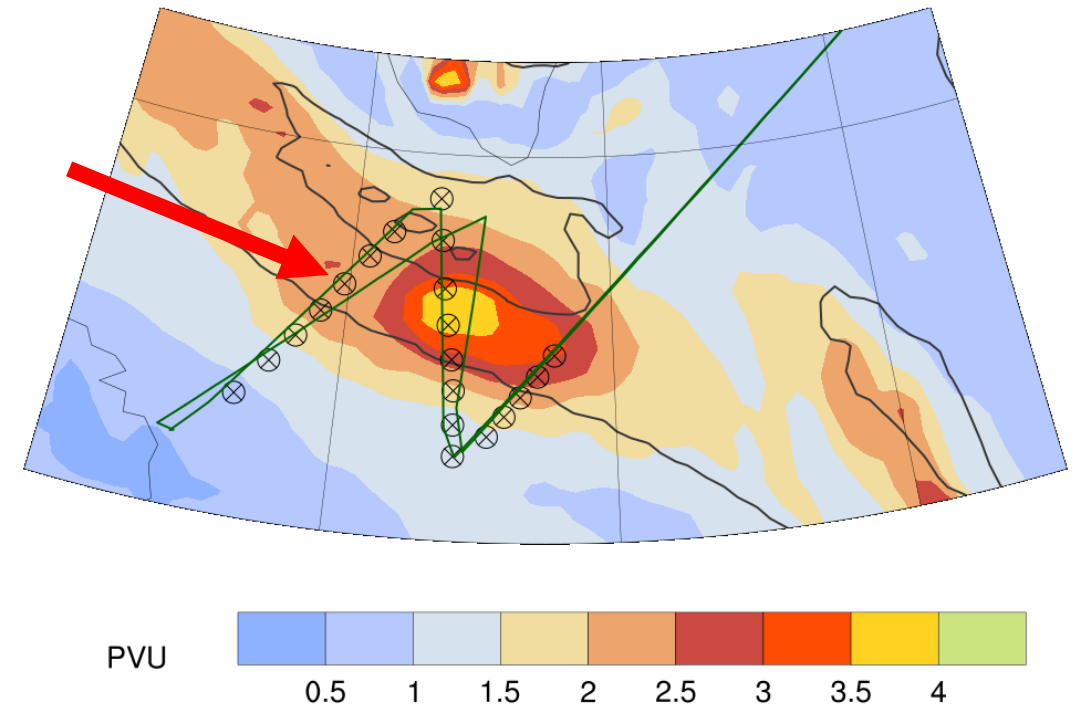
20161006_12: VAPV 285K-310K



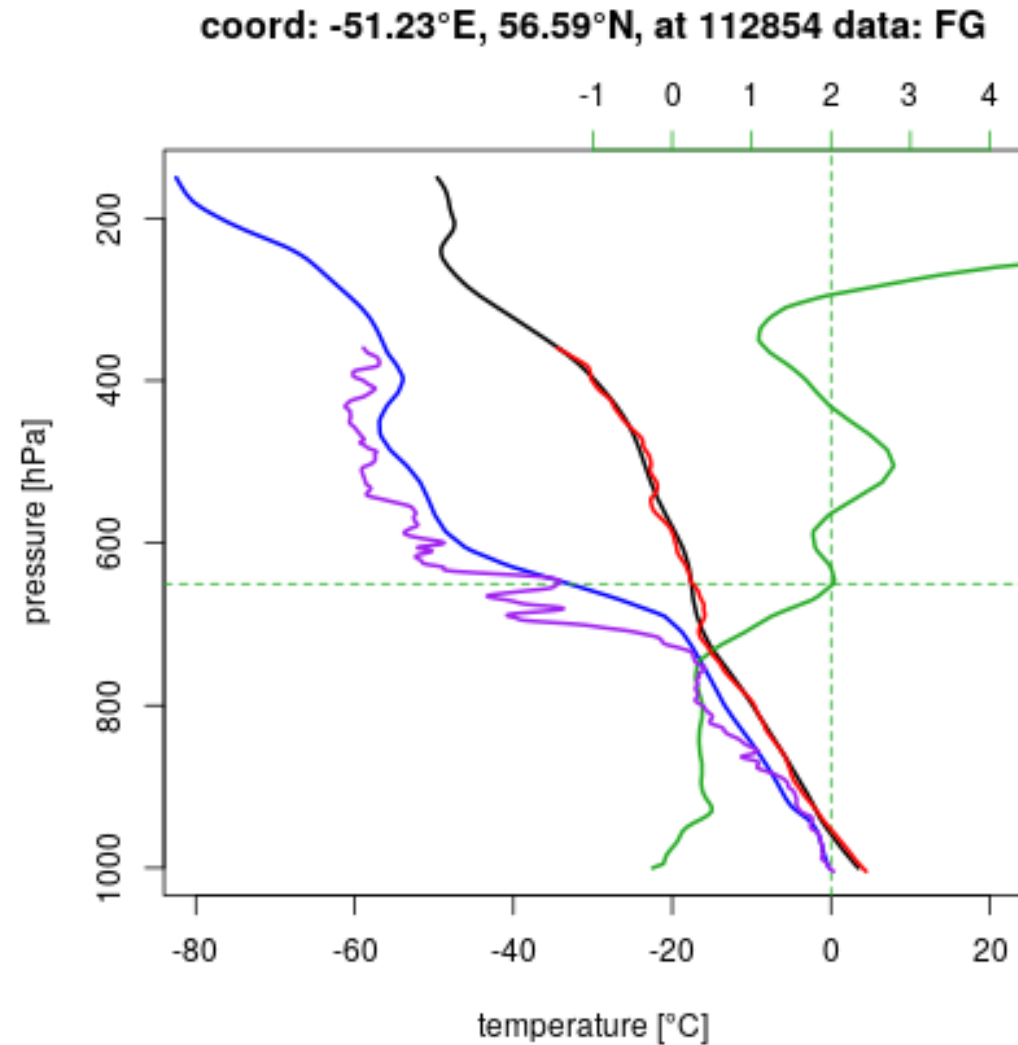
Dropsondes vs first guess (INIT:20161006_00)



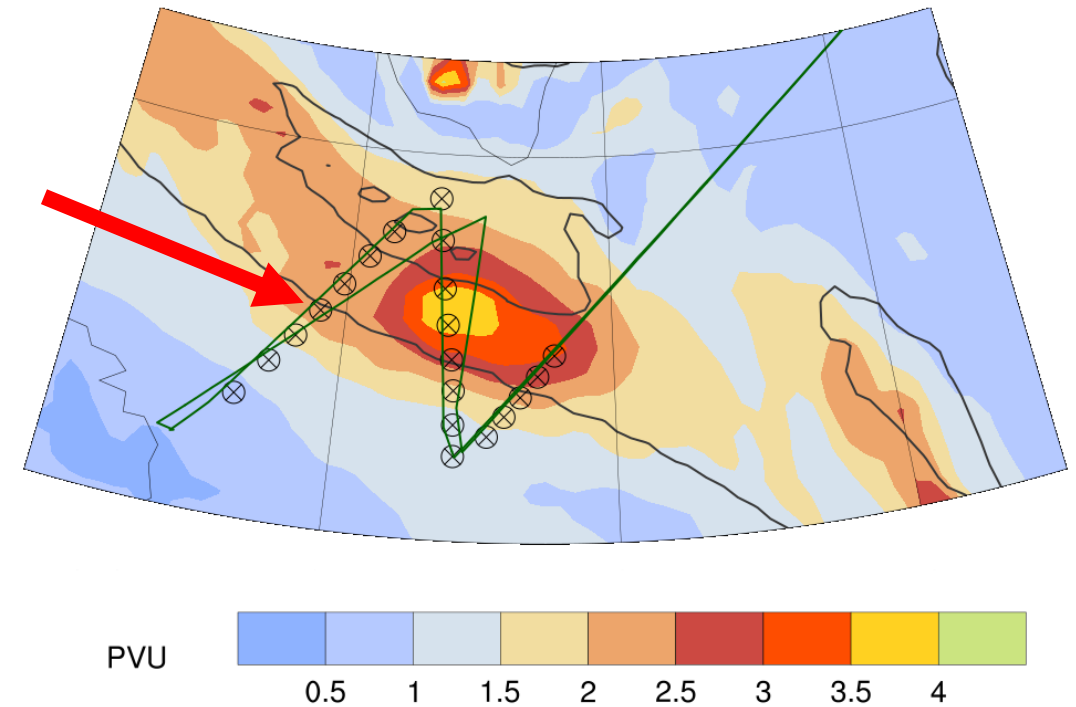
20161006_12: VAPV 285K-310K



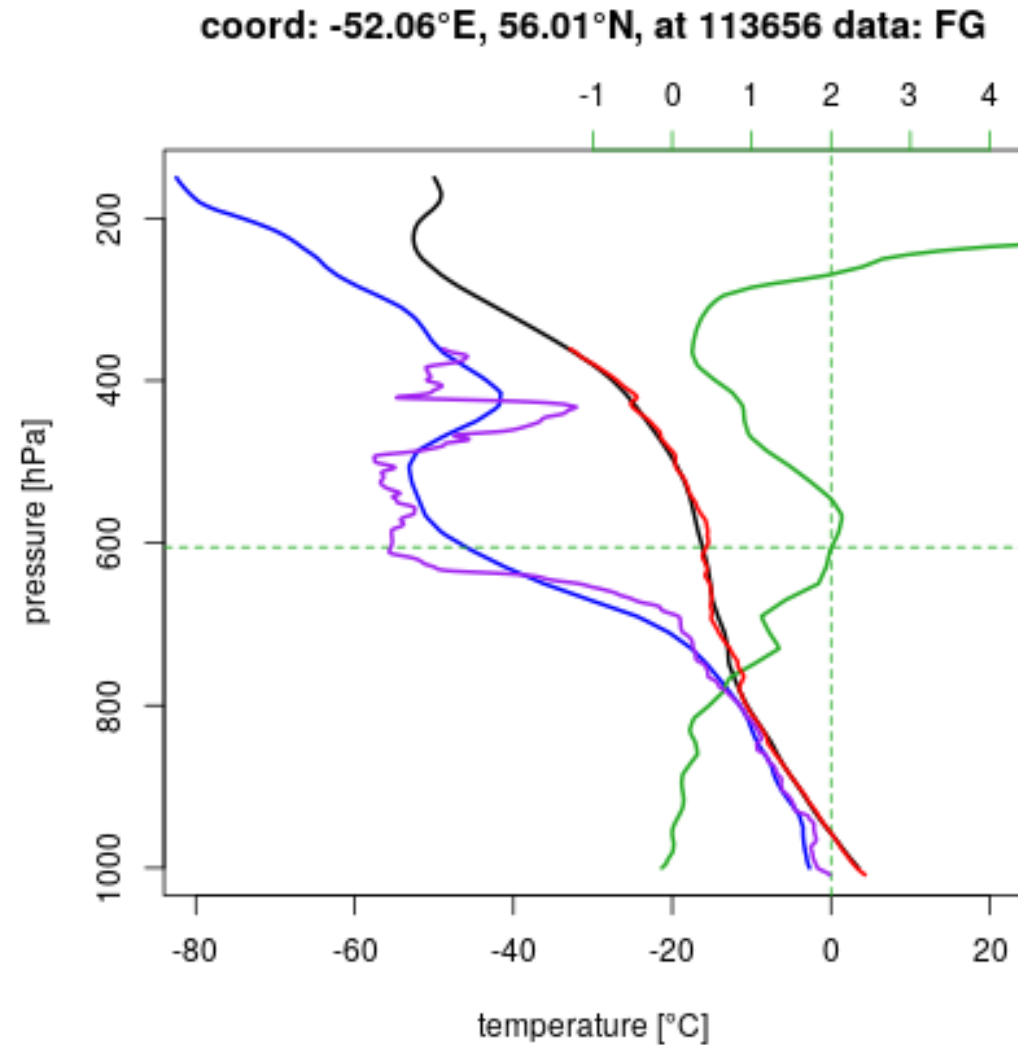
Dropsondes vs first guess (INIT:20161006_00)



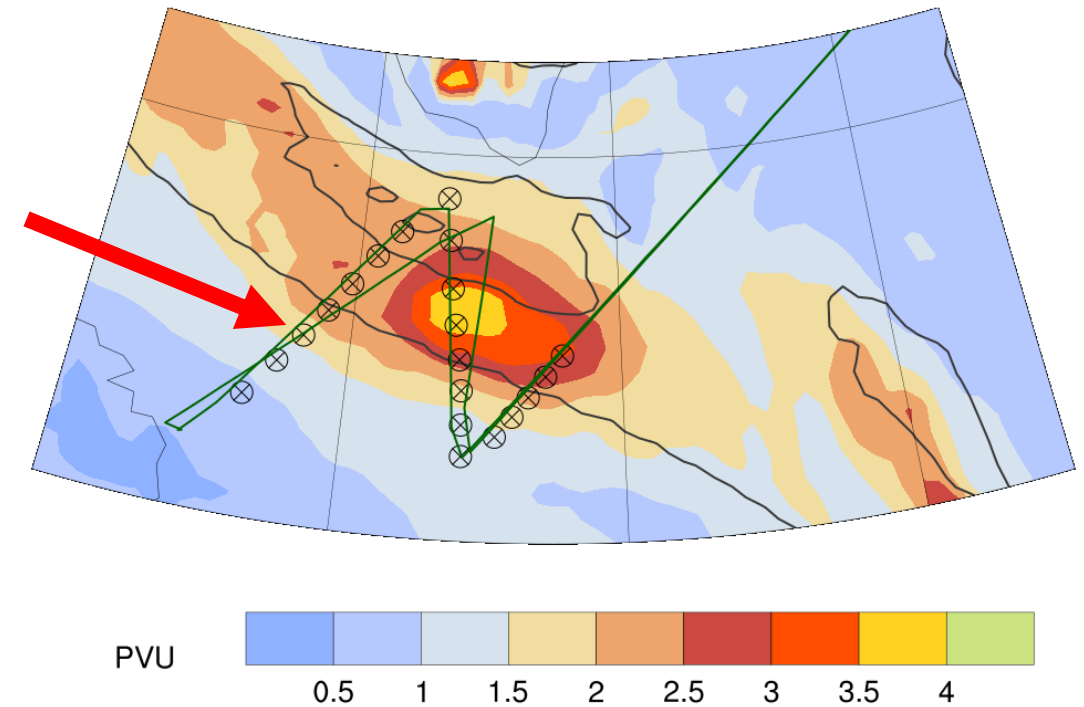
20161006_12: VAPV 285K-310K



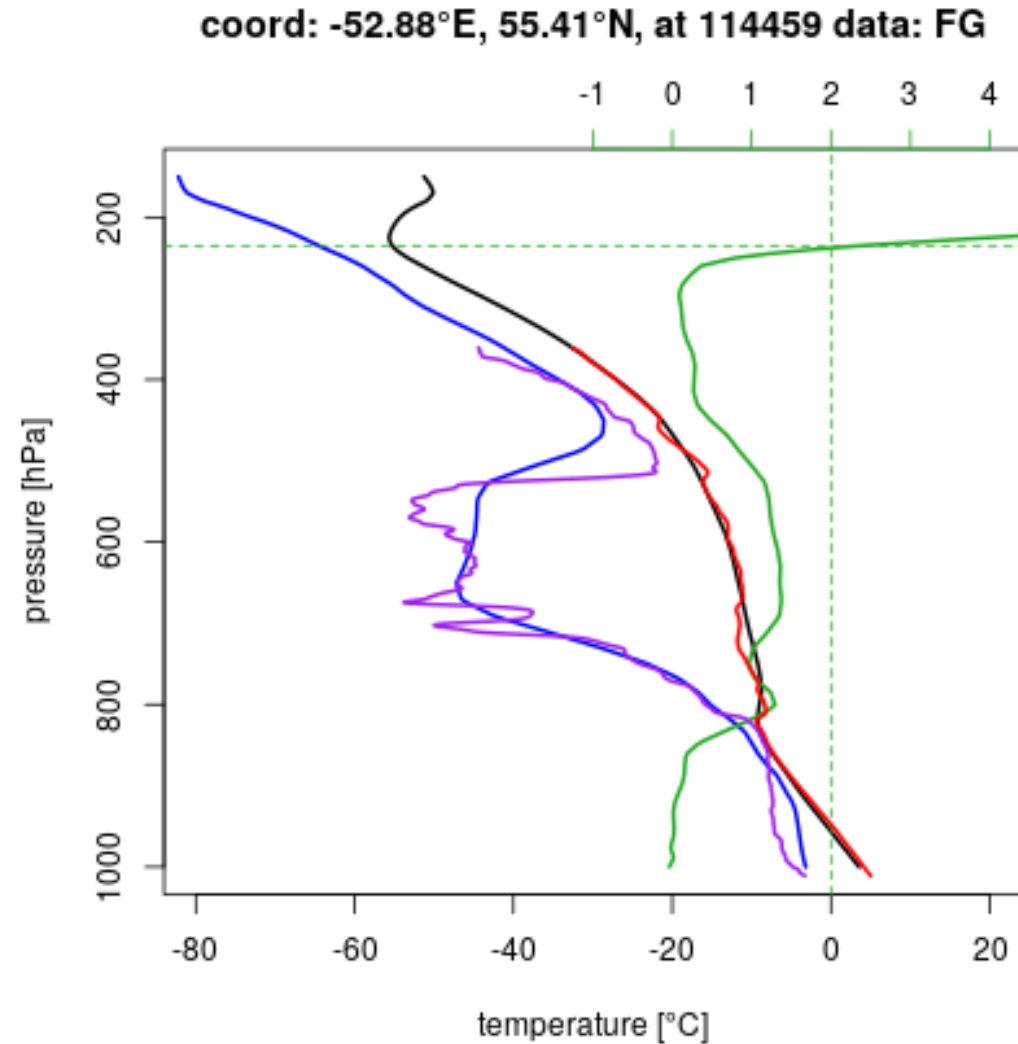
Dropsondes vs first guess (INIT:20161006_00)



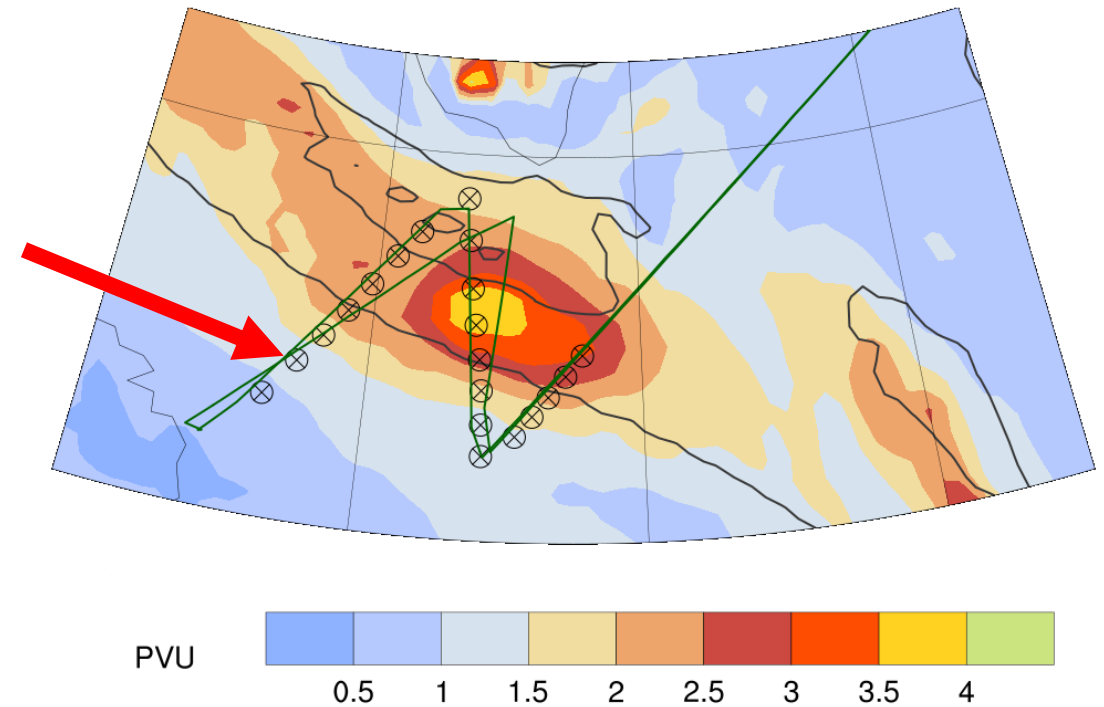
20161006_12: VAPV 285K-310K



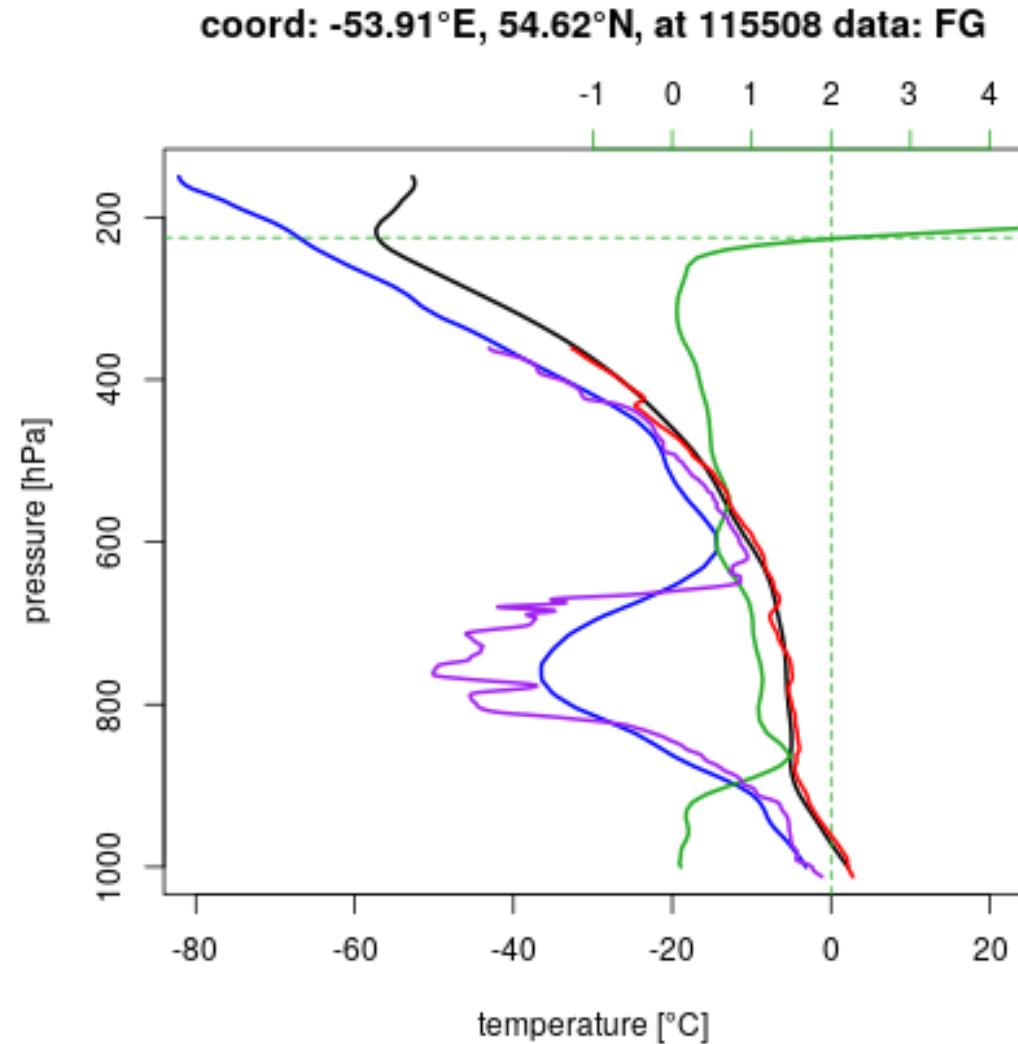
Dropsondes vs first guess (INIT:20161006_00)



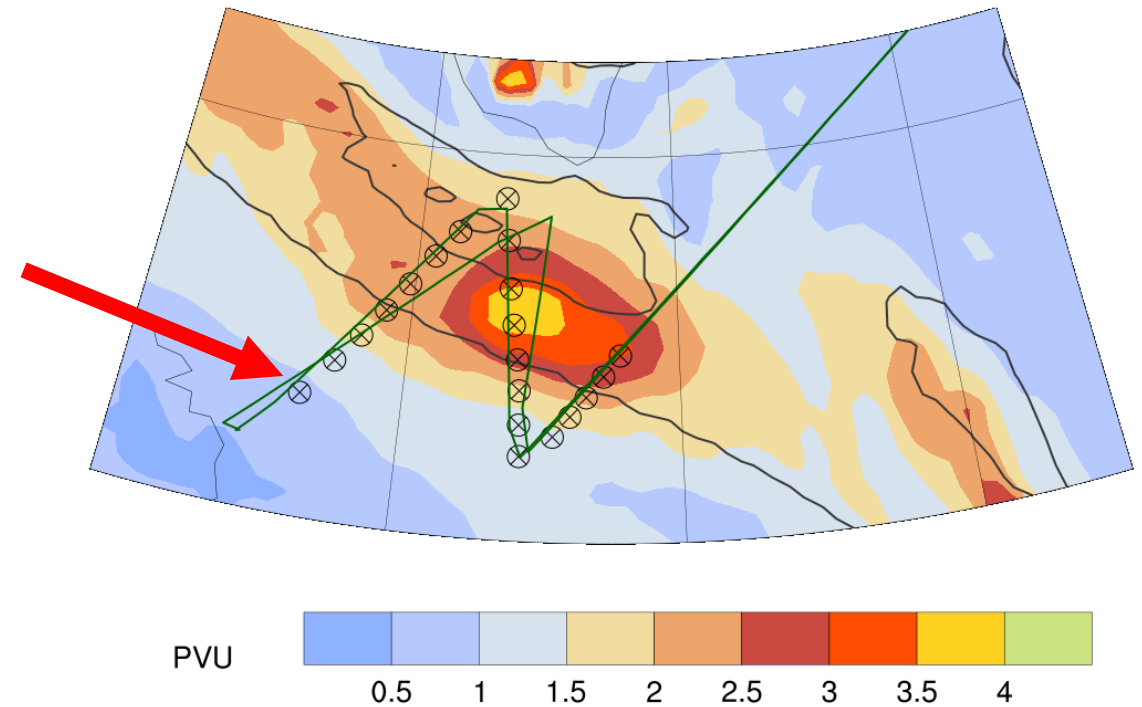
20161006_12: VAPV 285K-310K



Dropsondes vs first guess (INIT:20161006_00)

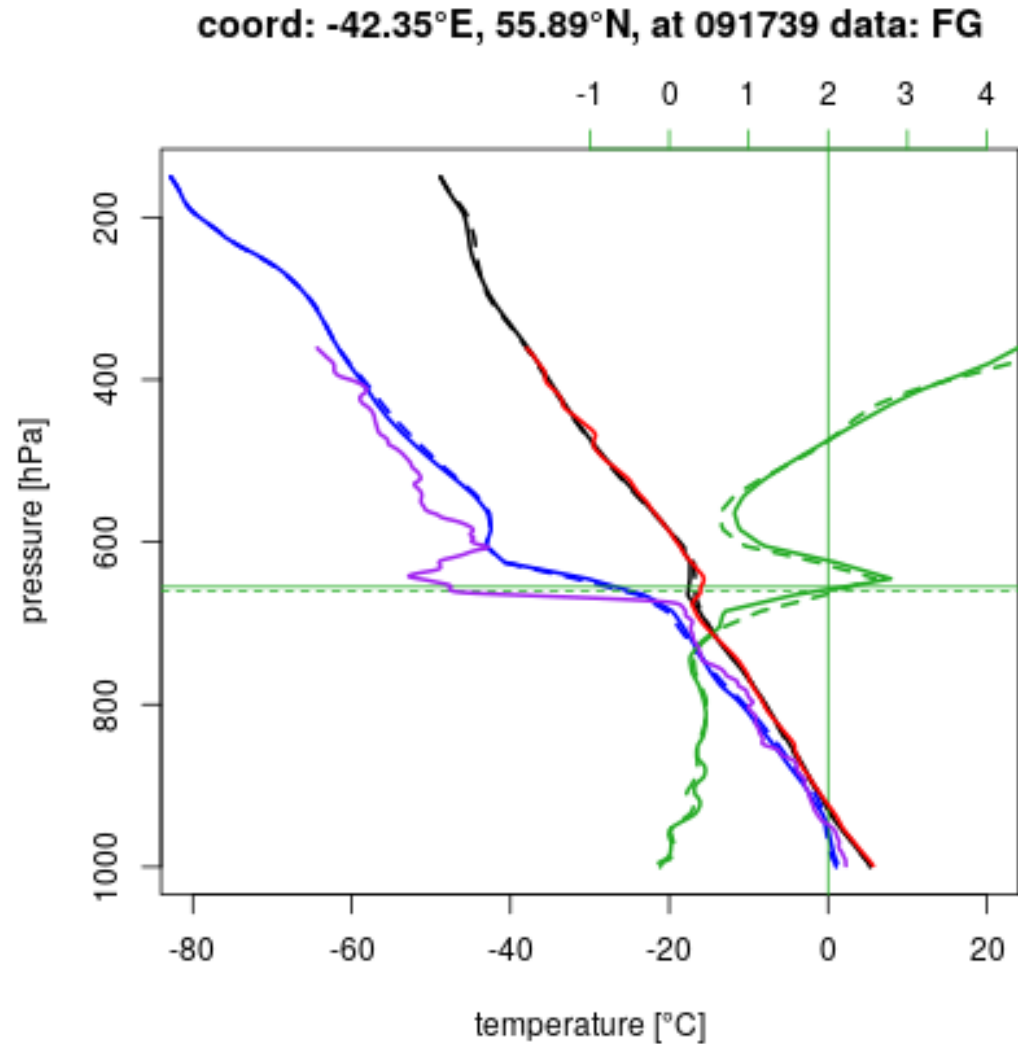


20161006_12: VAPV 285K-310K

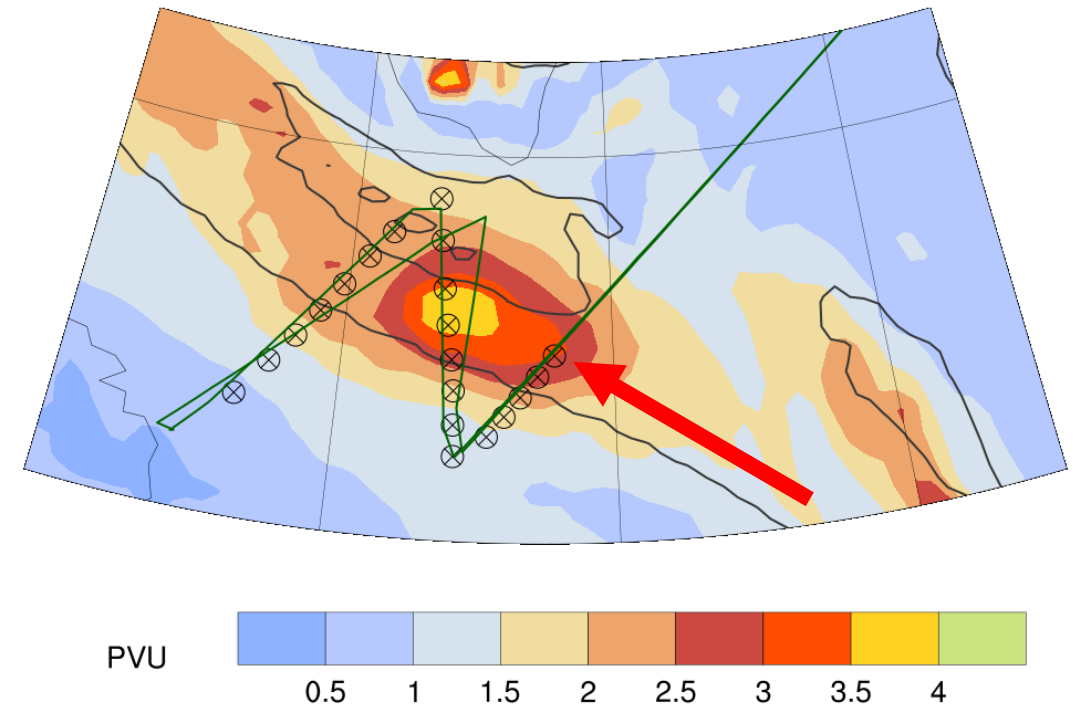


CF dropsondes, fg, ana

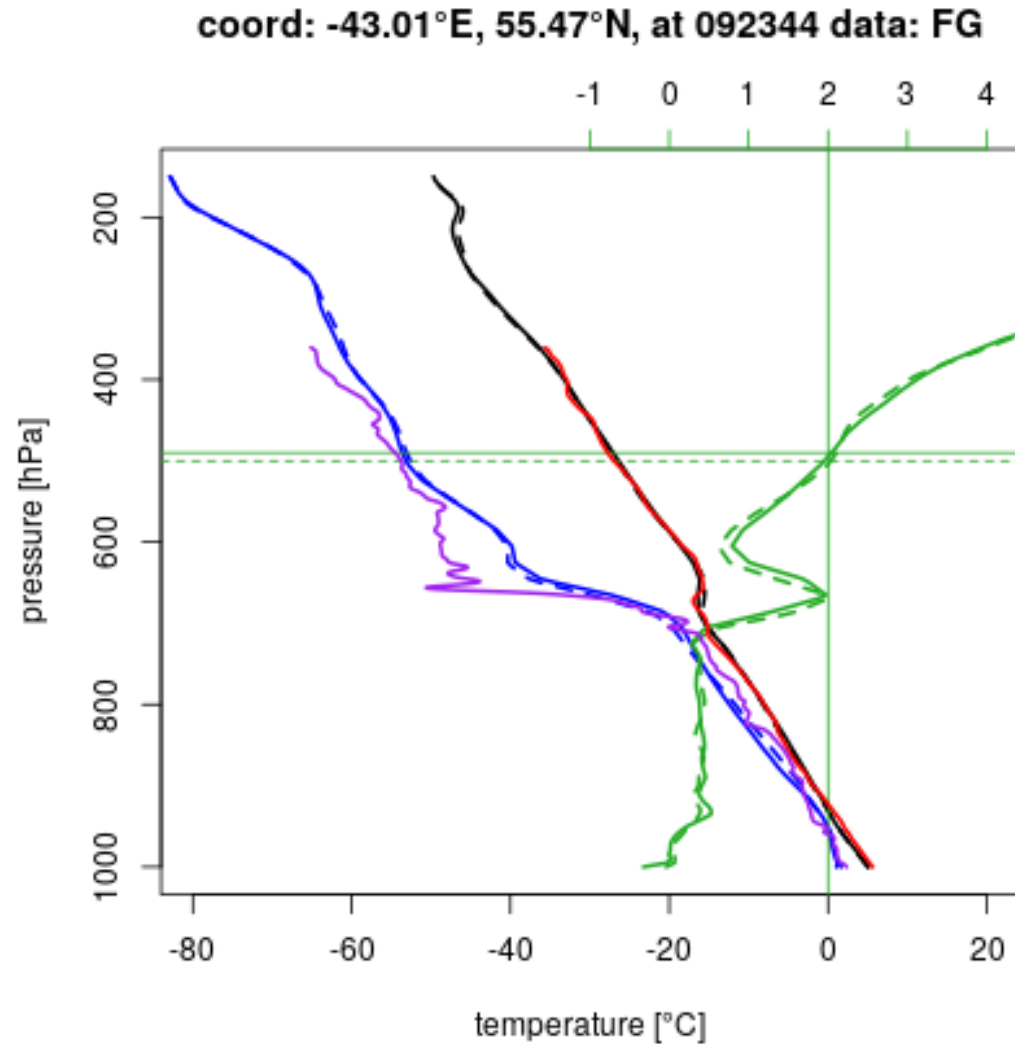
Dropsondes vs first guess and analysis (INIT:20161006_00)



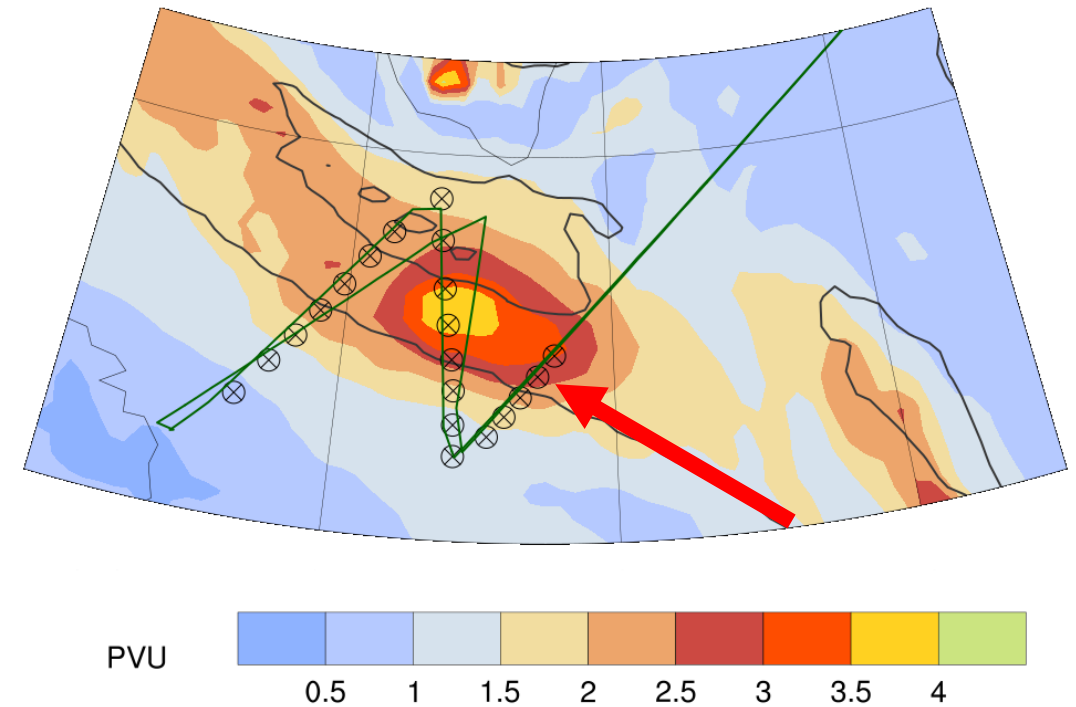
20161006_12: VAPV 285K-310K



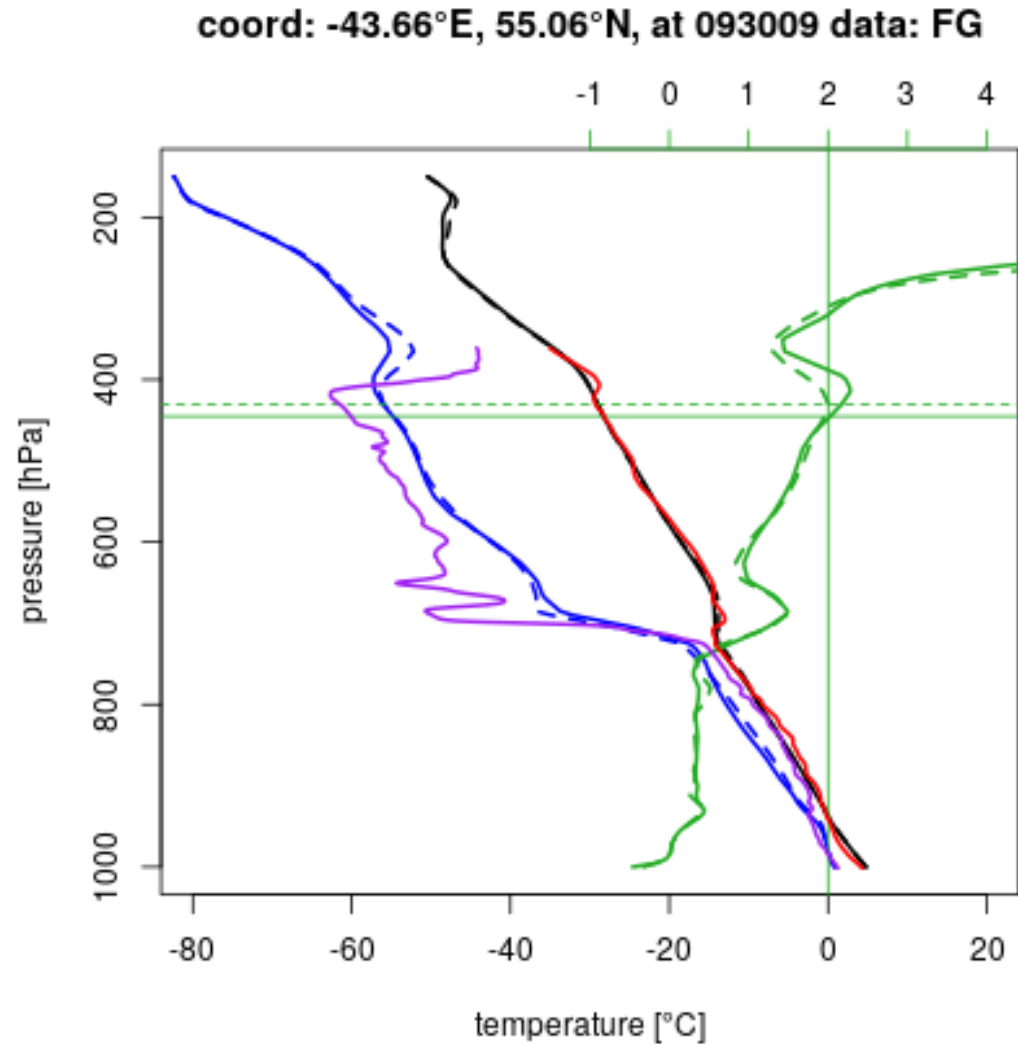
Dropsondes vs first guess and analysis (INIT:20161006_00)



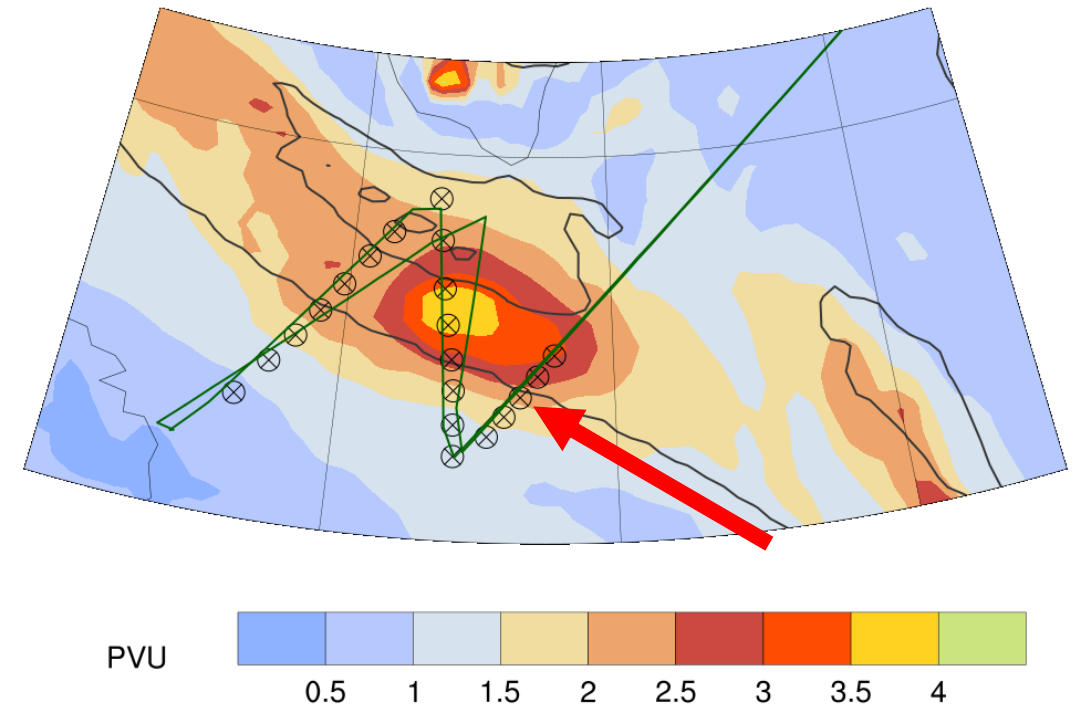
20161006_12: VAPV 285K-310K



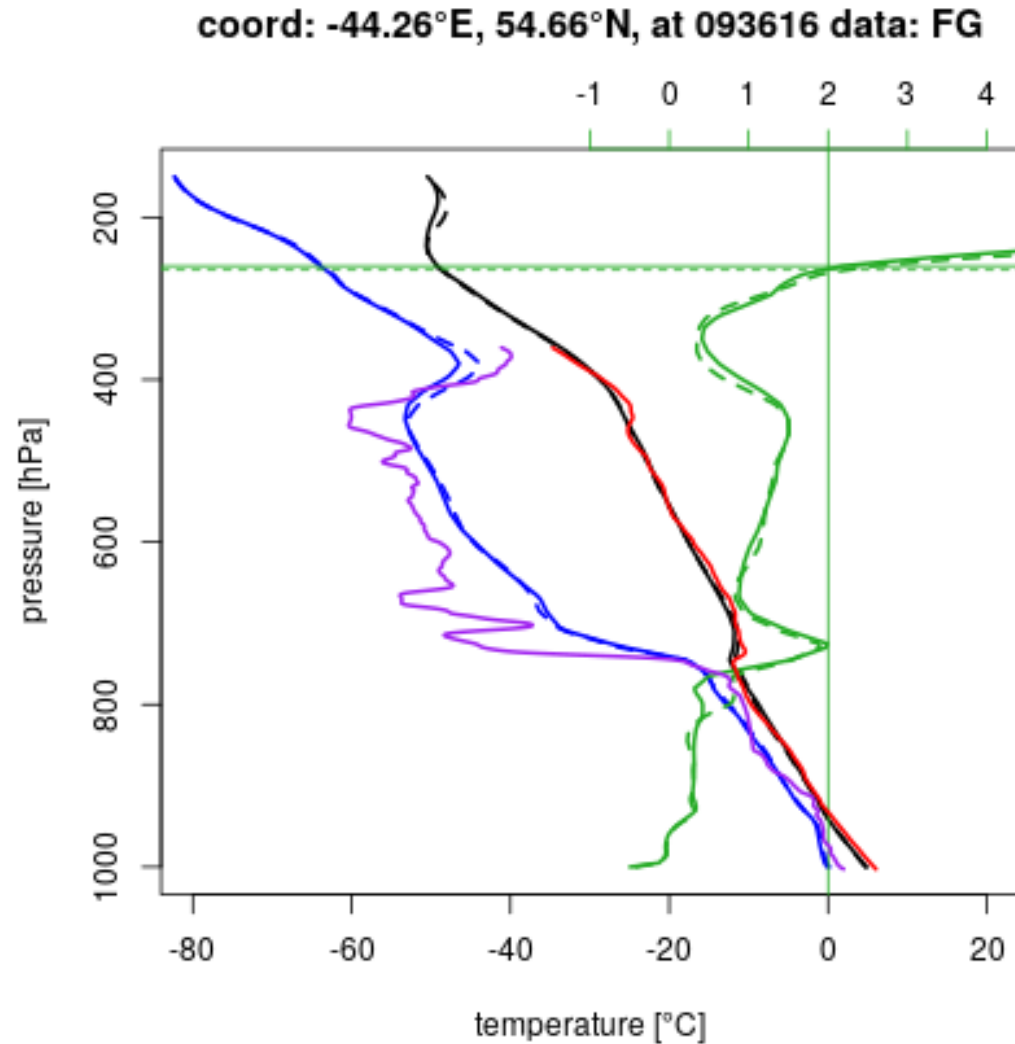
Dropsondes vs first guess and analysis (INIT:20161006_00)



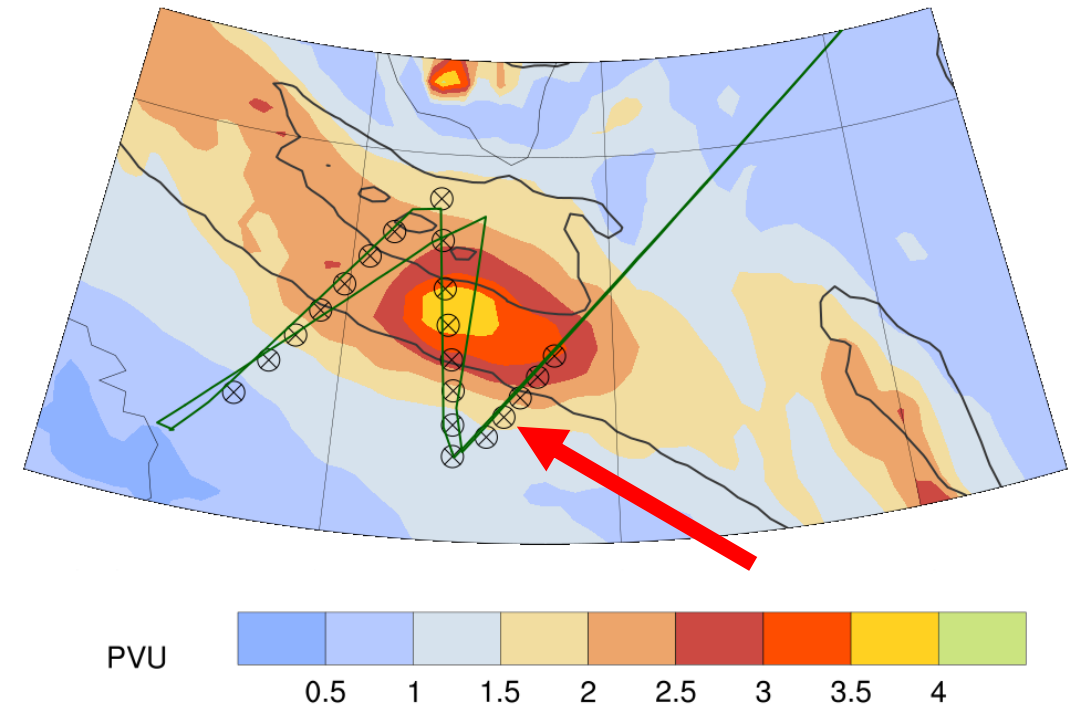
20161006_12: VAPV 285K-310K



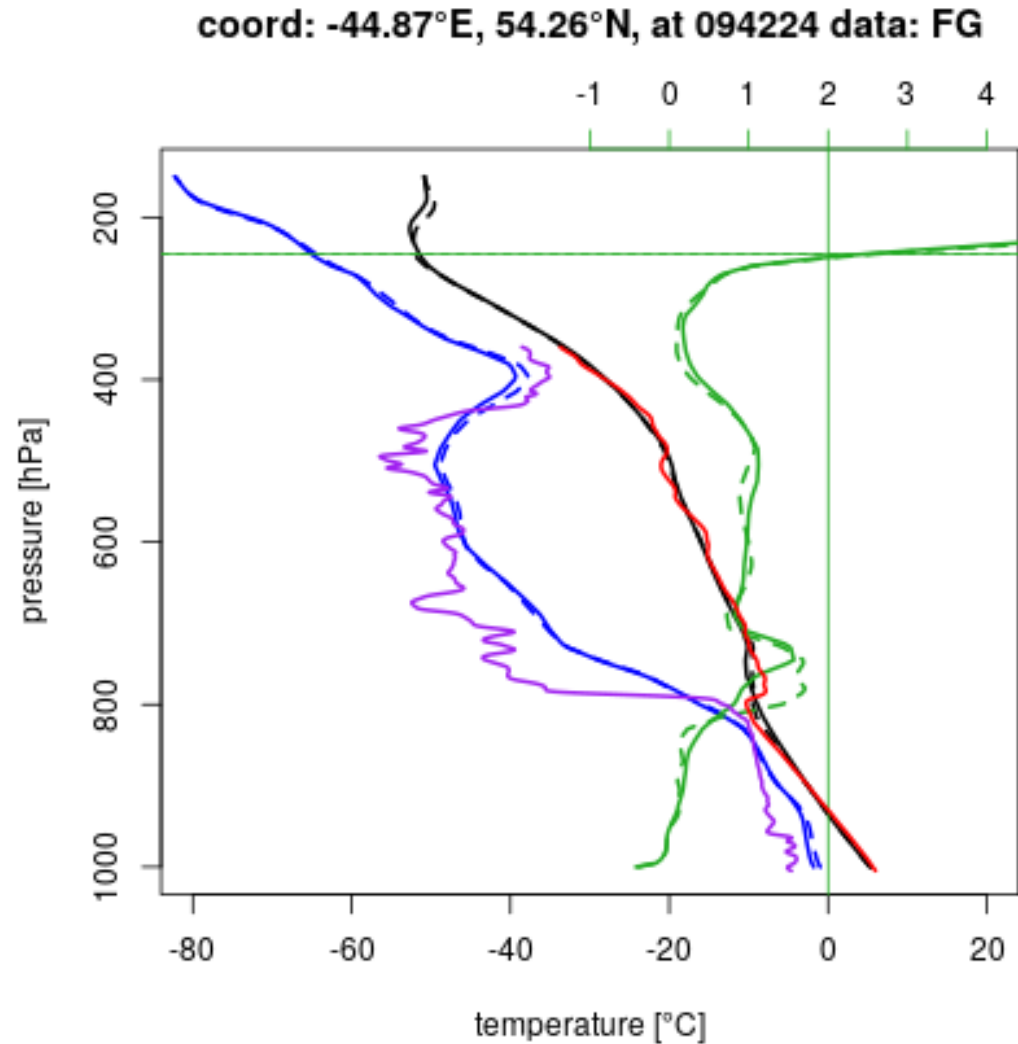
Dropsondes vs first guess and analysis (INIT:20161006_00)



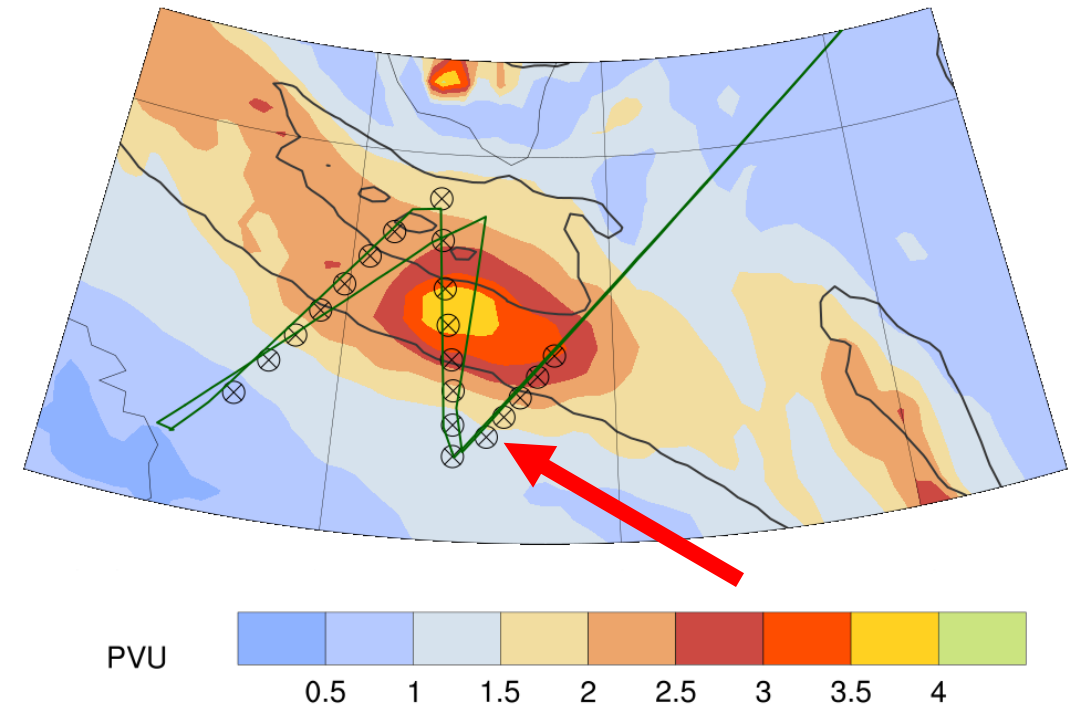
20161006_12: VAPV 285K-310K



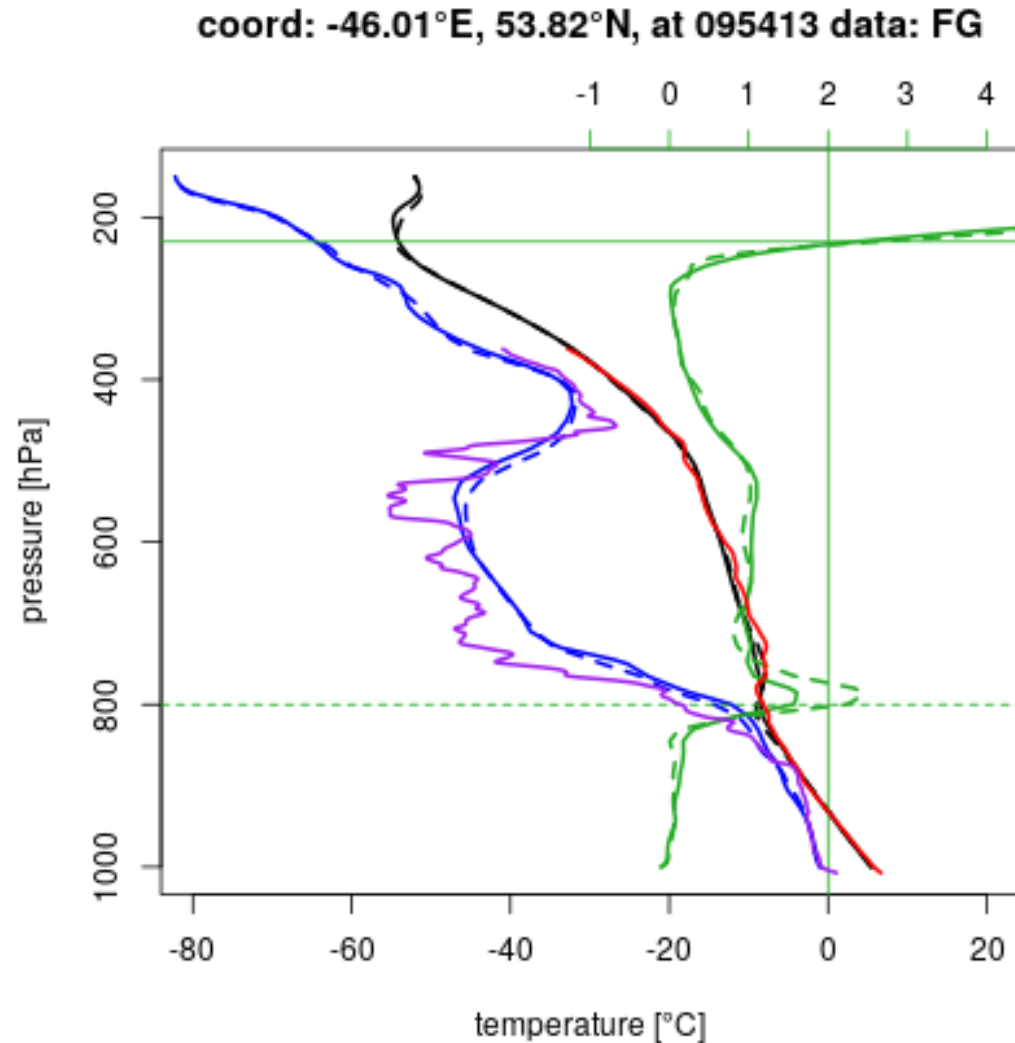
Dropsondes vs first guess and analysis (INIT:20161006_00)



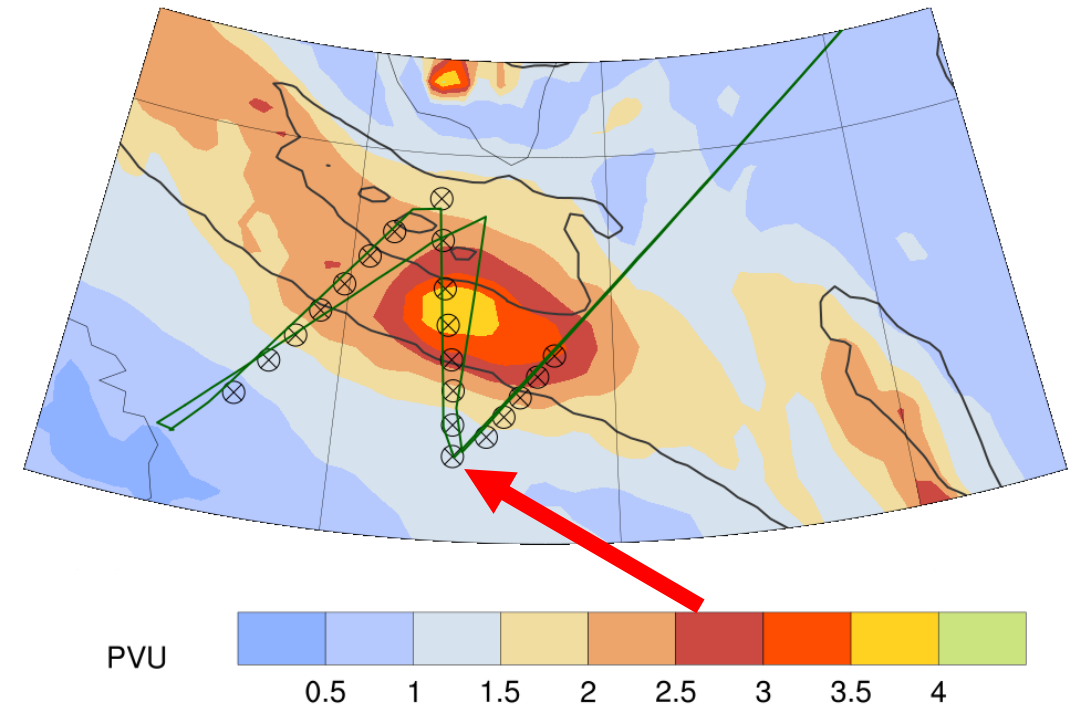
20161006_12: VAPV 285K-310K



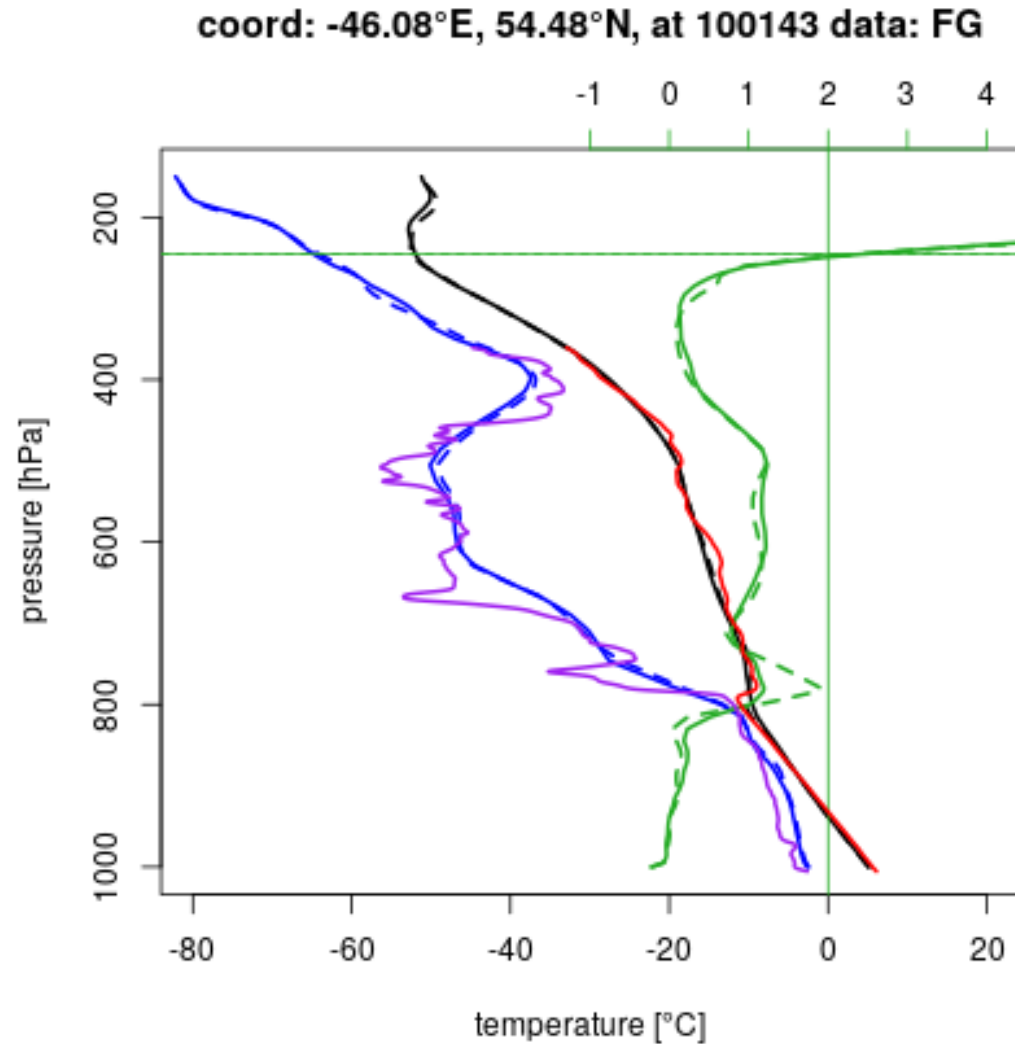
Dropsondes vs first guess and analysis (INIT:20161006_00)



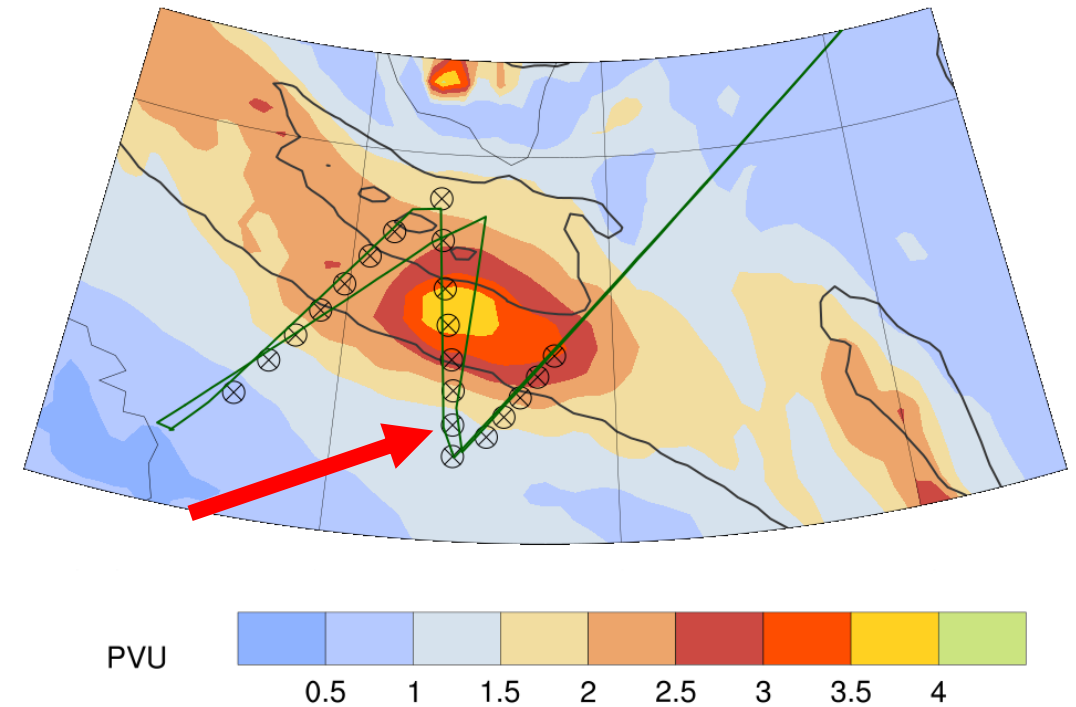
20161006_12: VAPV 285K-310K



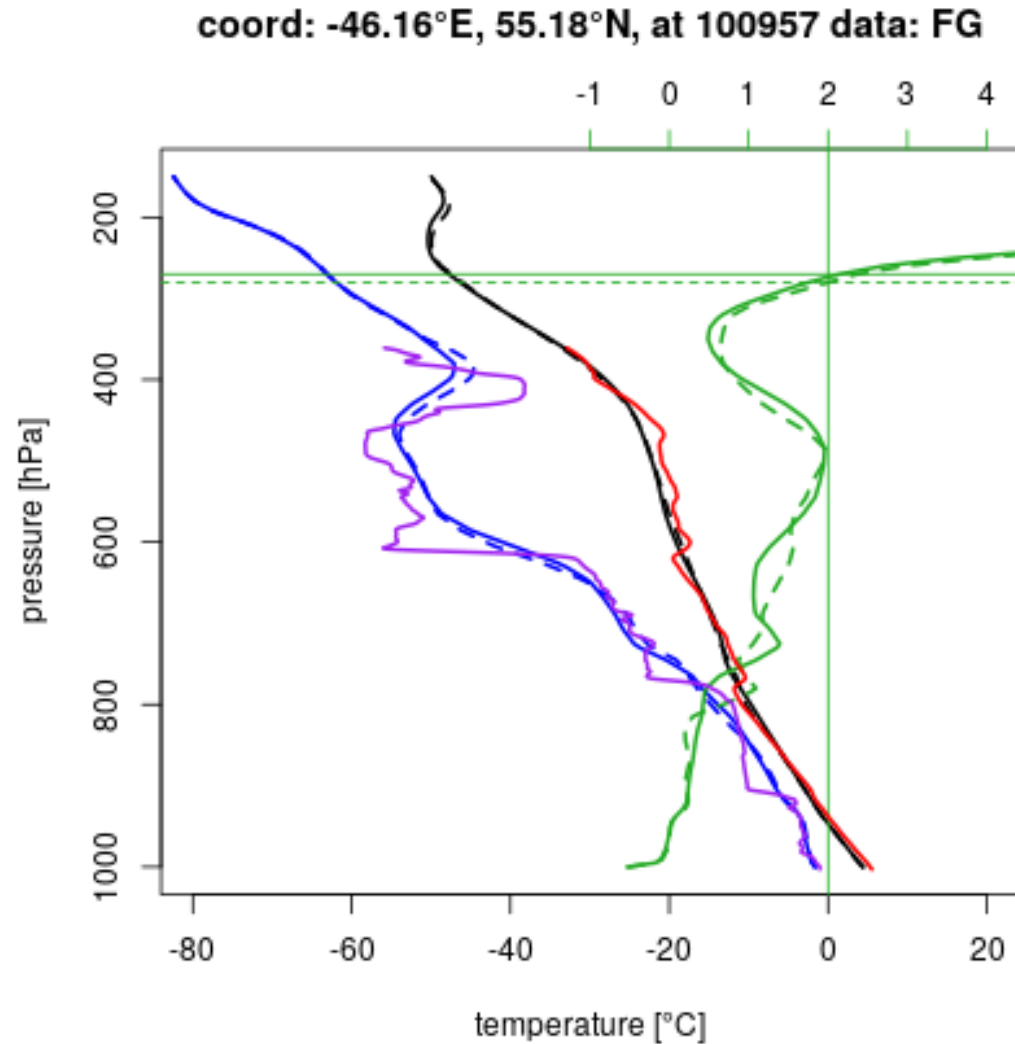
Dropsondes vs first guess and analysis (INIT:20161006_00)



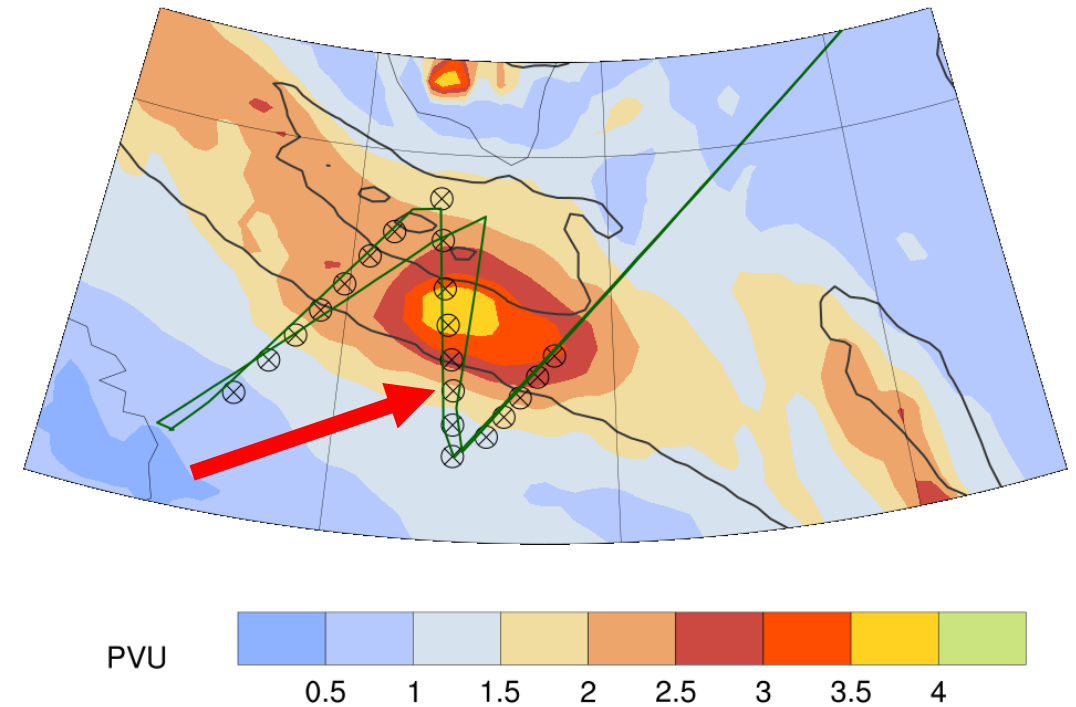
20161006_12: VAPV 285K-310K



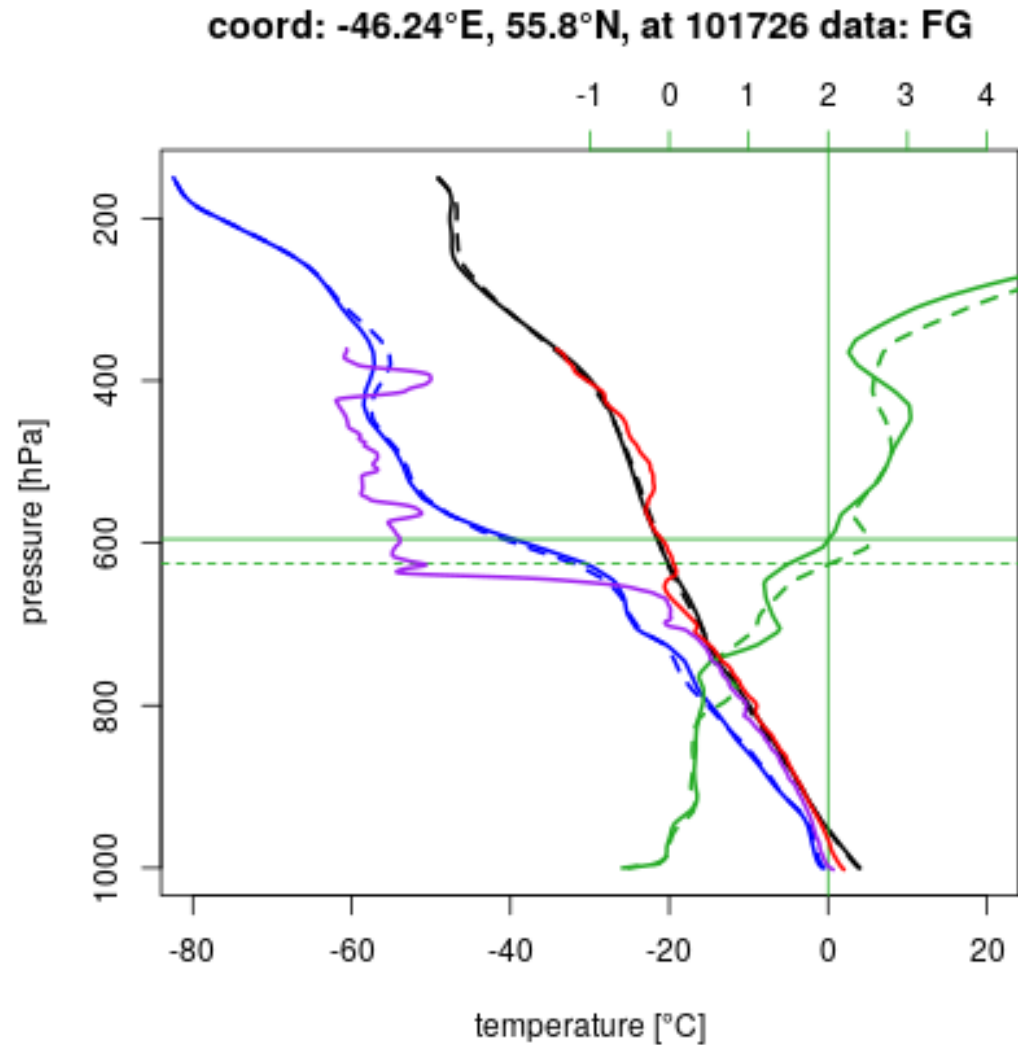
Dropsondes vs first guess and analysis (INIT:20161006_00)



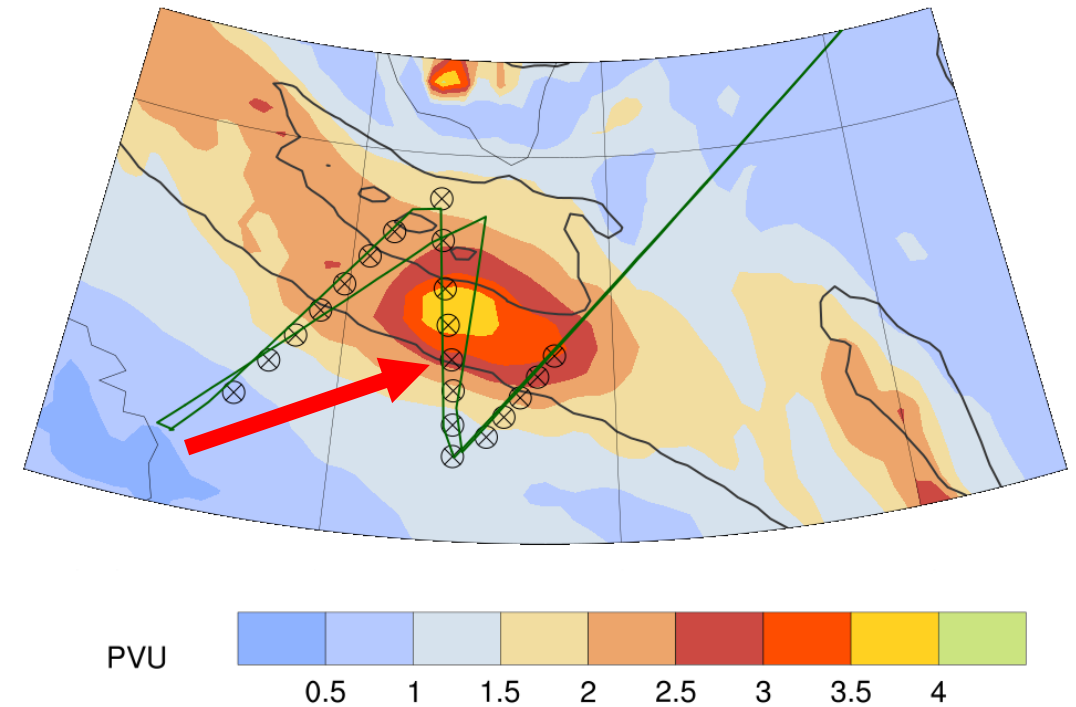
20161006_12: VAPV 285K-310K



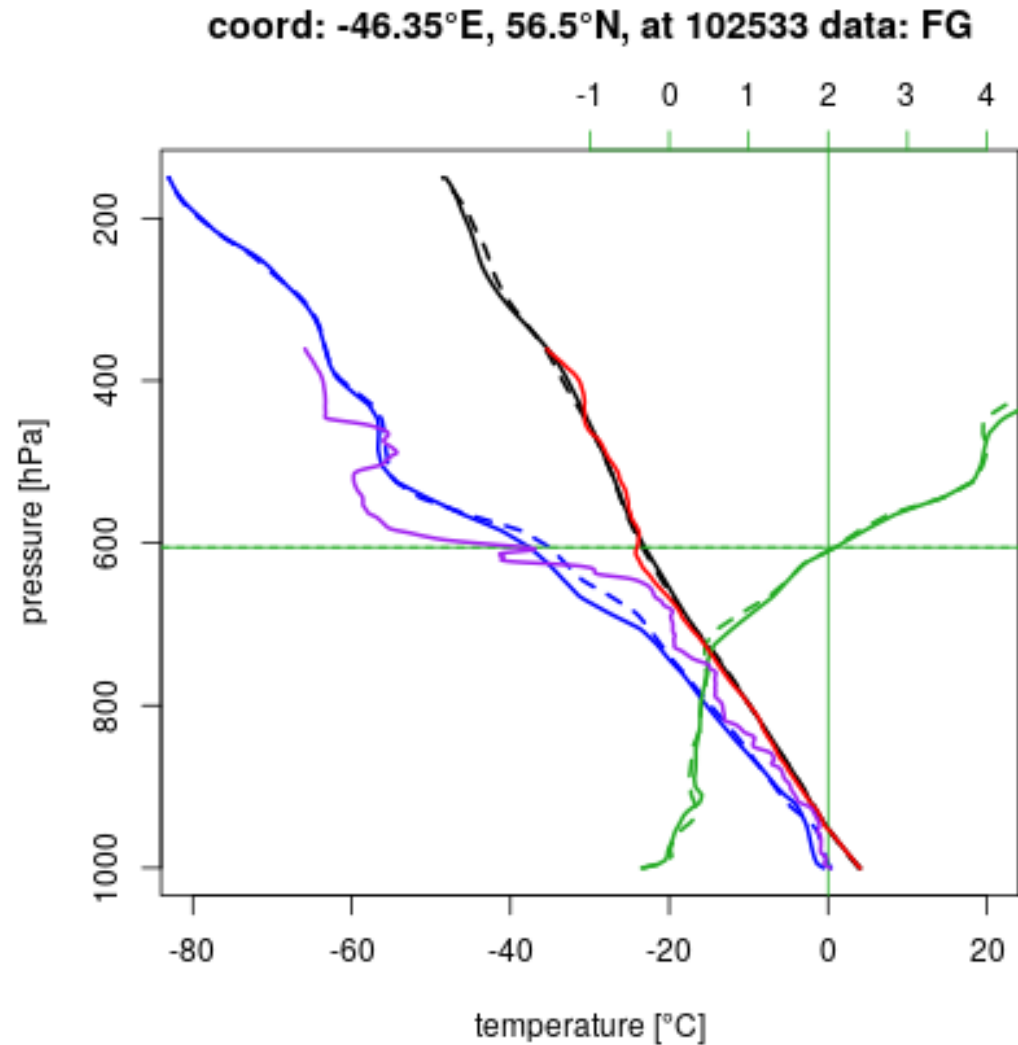
Dropsondes vs first guess and analysis (INIT:20161006_00)



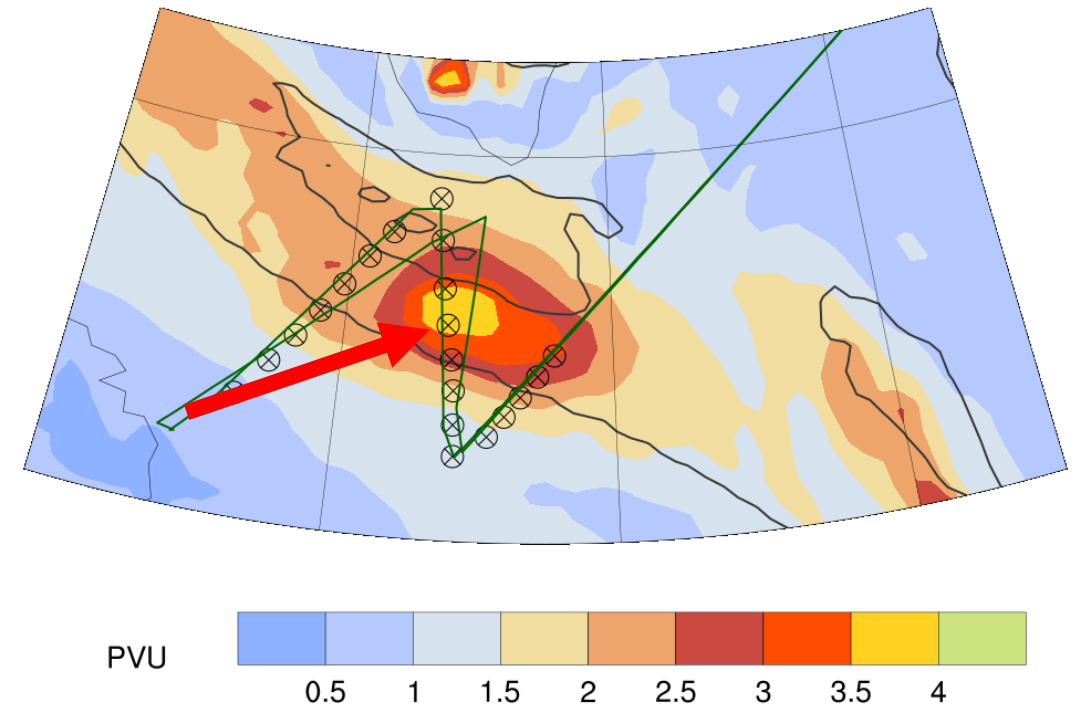
20161006_12: VAPV 285K-310K



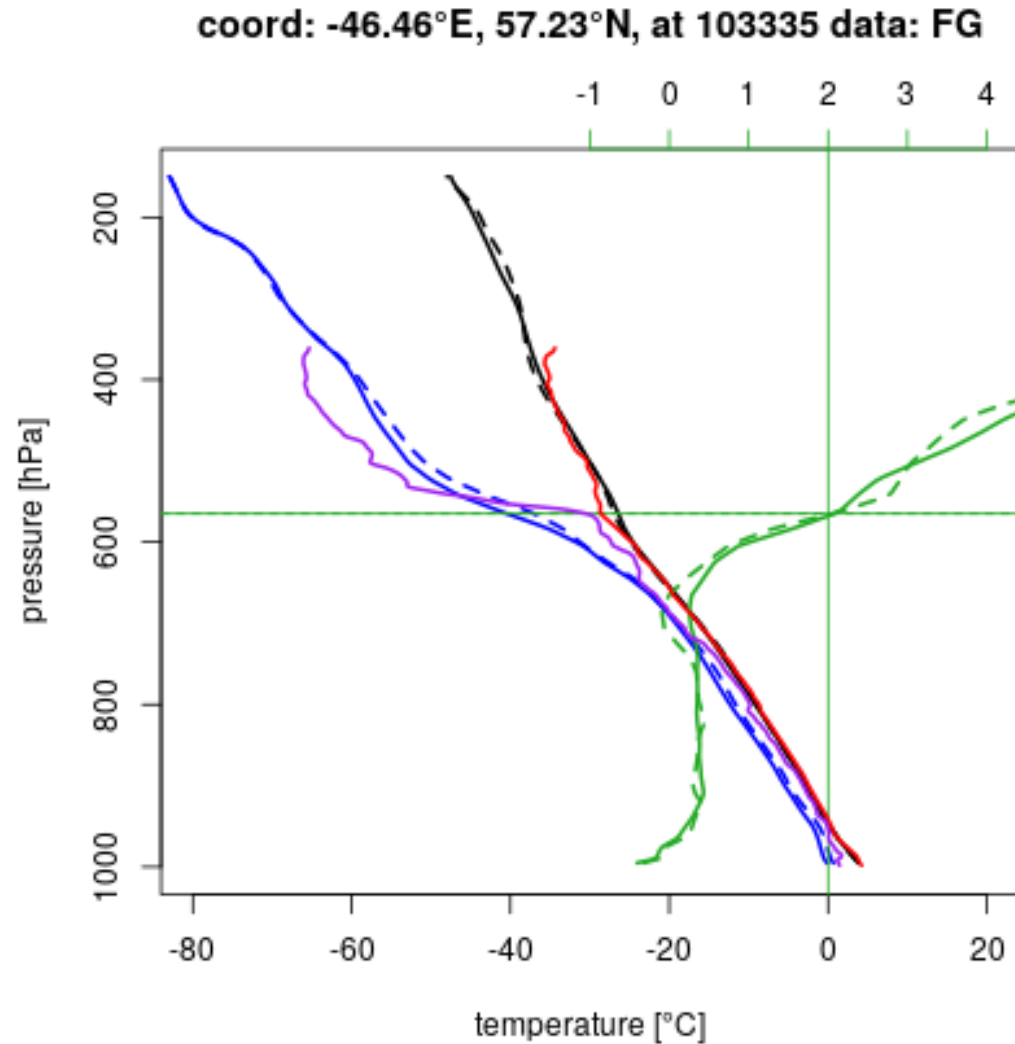
Dropsondes vs first guess and analysis (INIT:20161006_00)



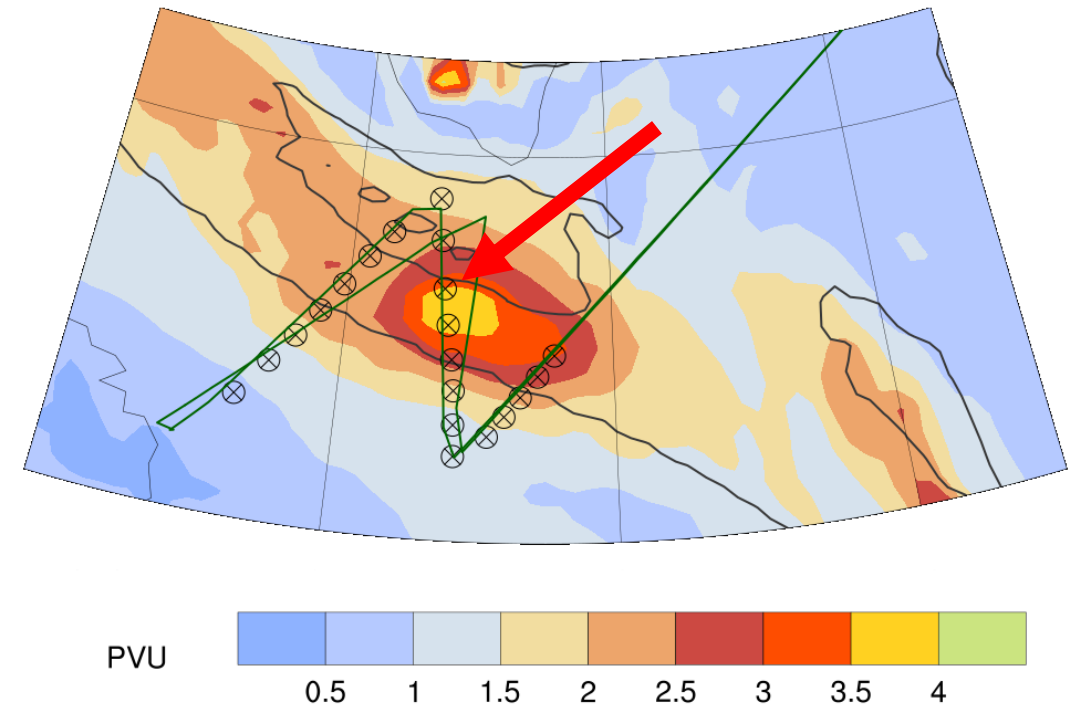
20161006_12: VAPV 285K-310K



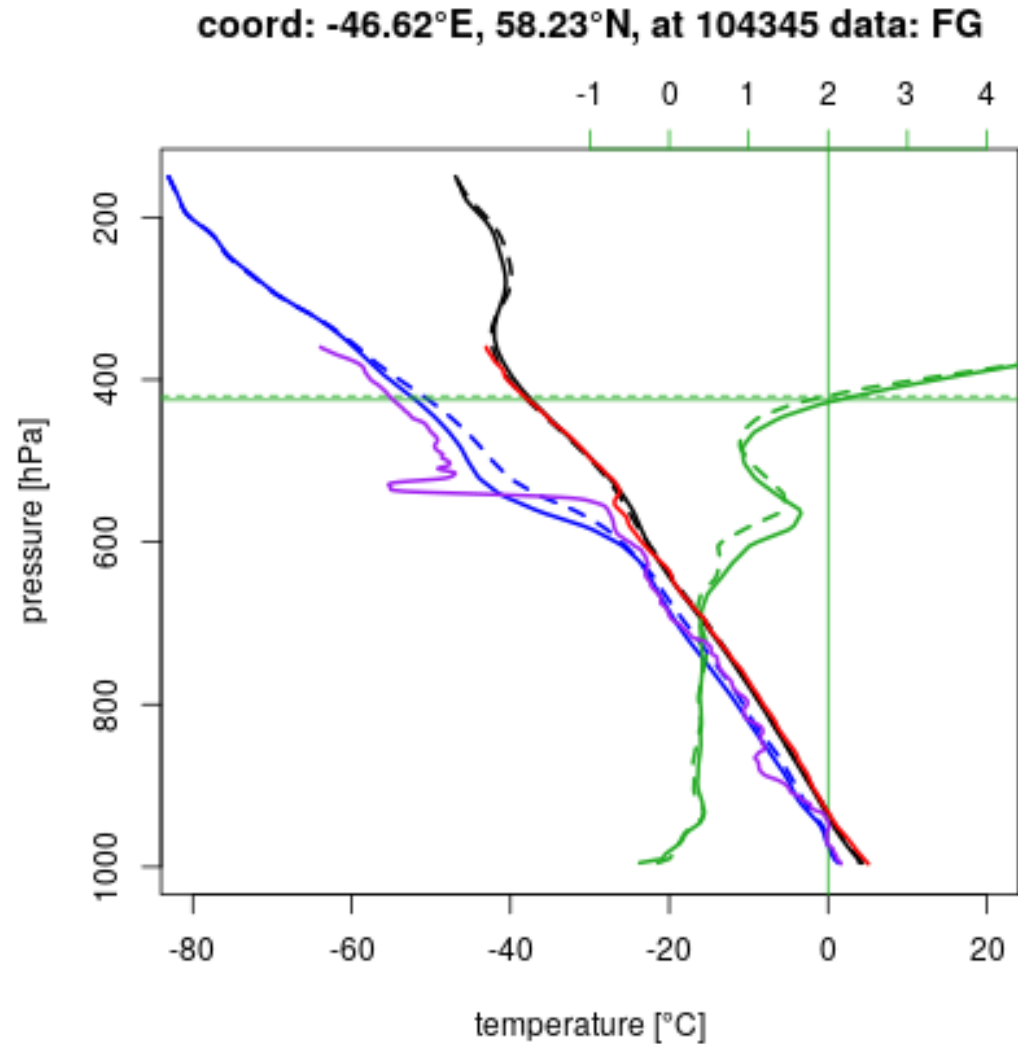
Dropsondes vs first guess and analysis (INIT:20161006_00)



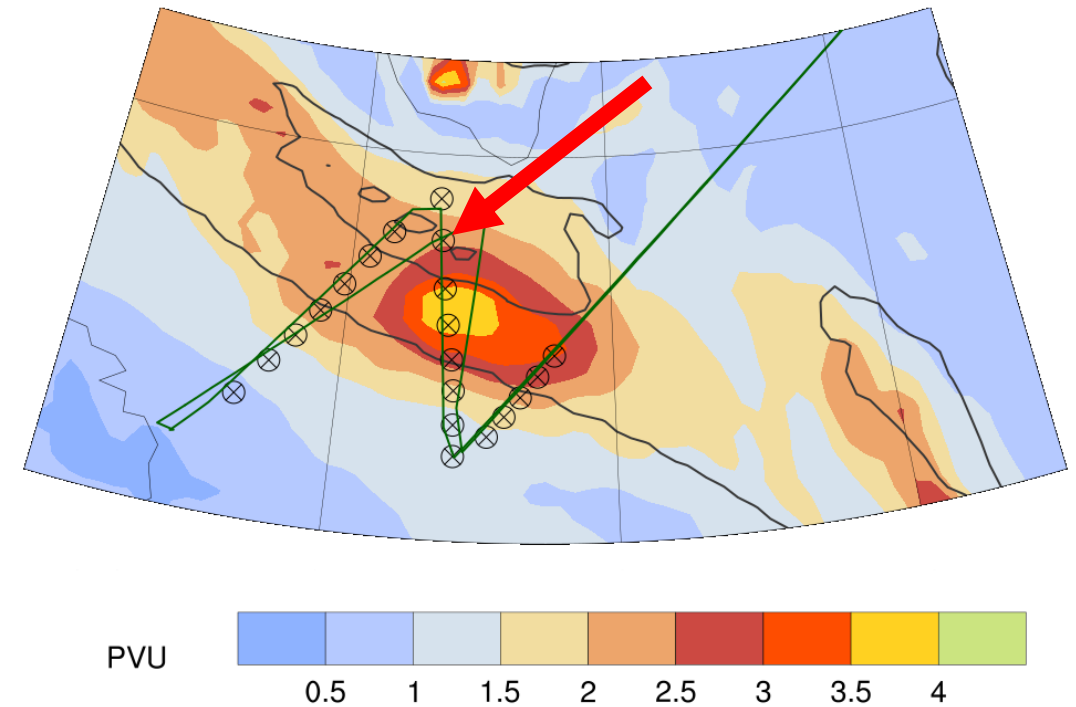
20161006_12: VAPV 285K-310K



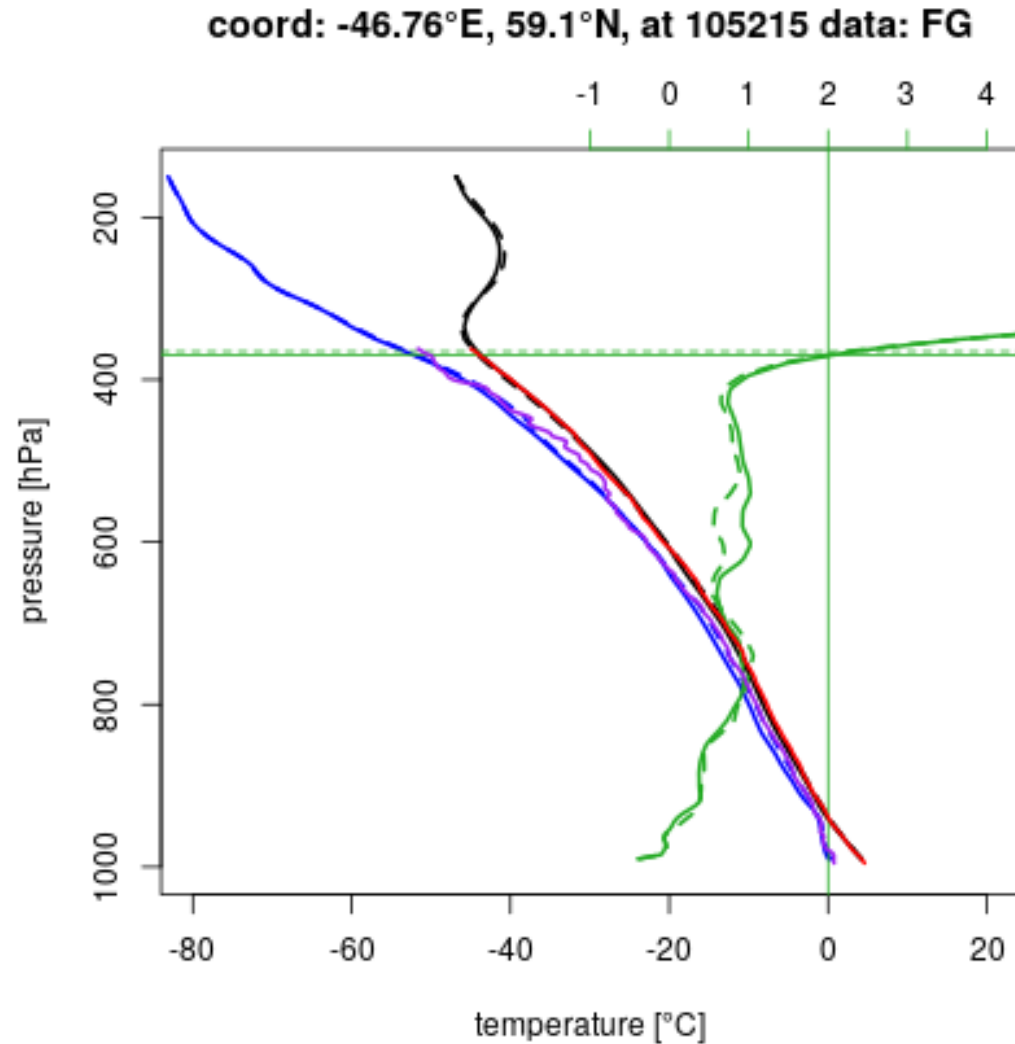
Dropsondes vs first guess and analysis (INIT:20161006_00)



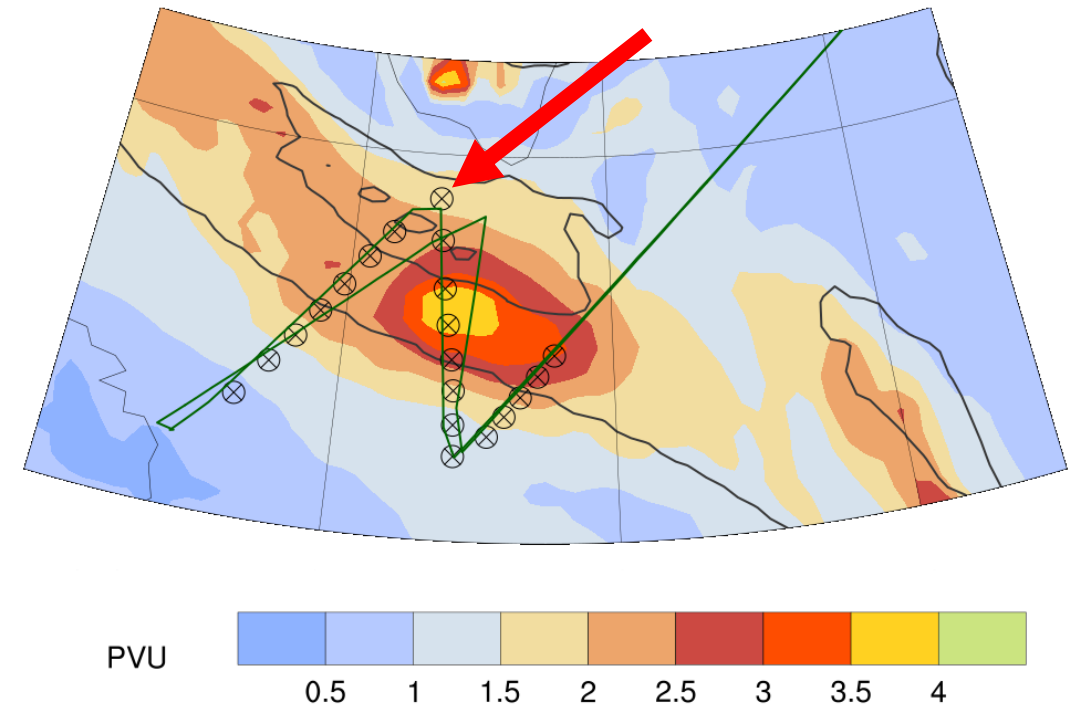
20161006_12: VAPV 285K-310K



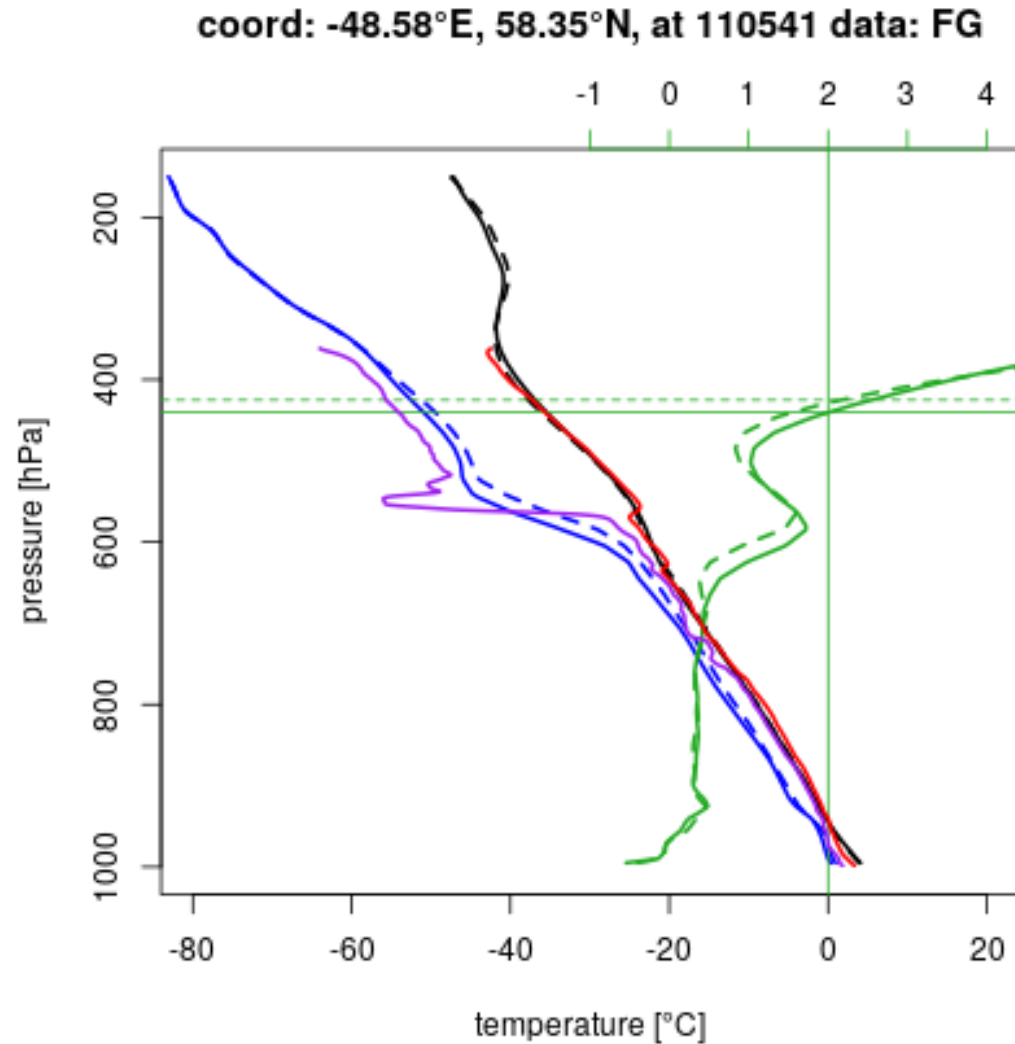
Dropsondes vs first guess and analysis (INIT:20161006_00)



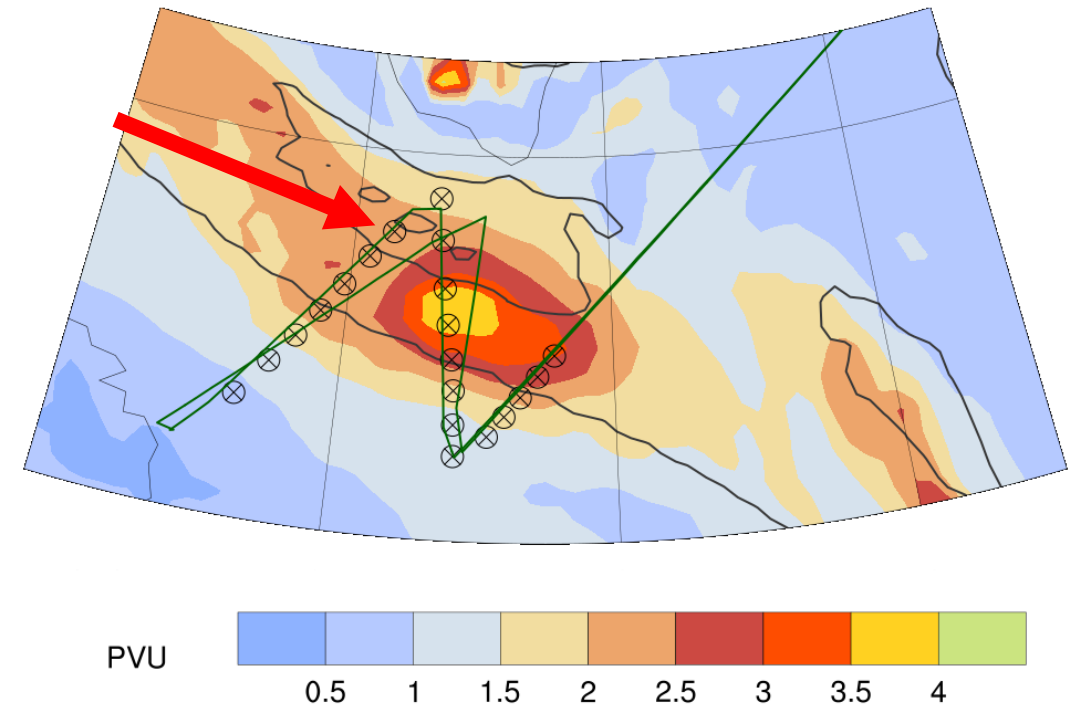
20161006_12: VAPV 285K-310K



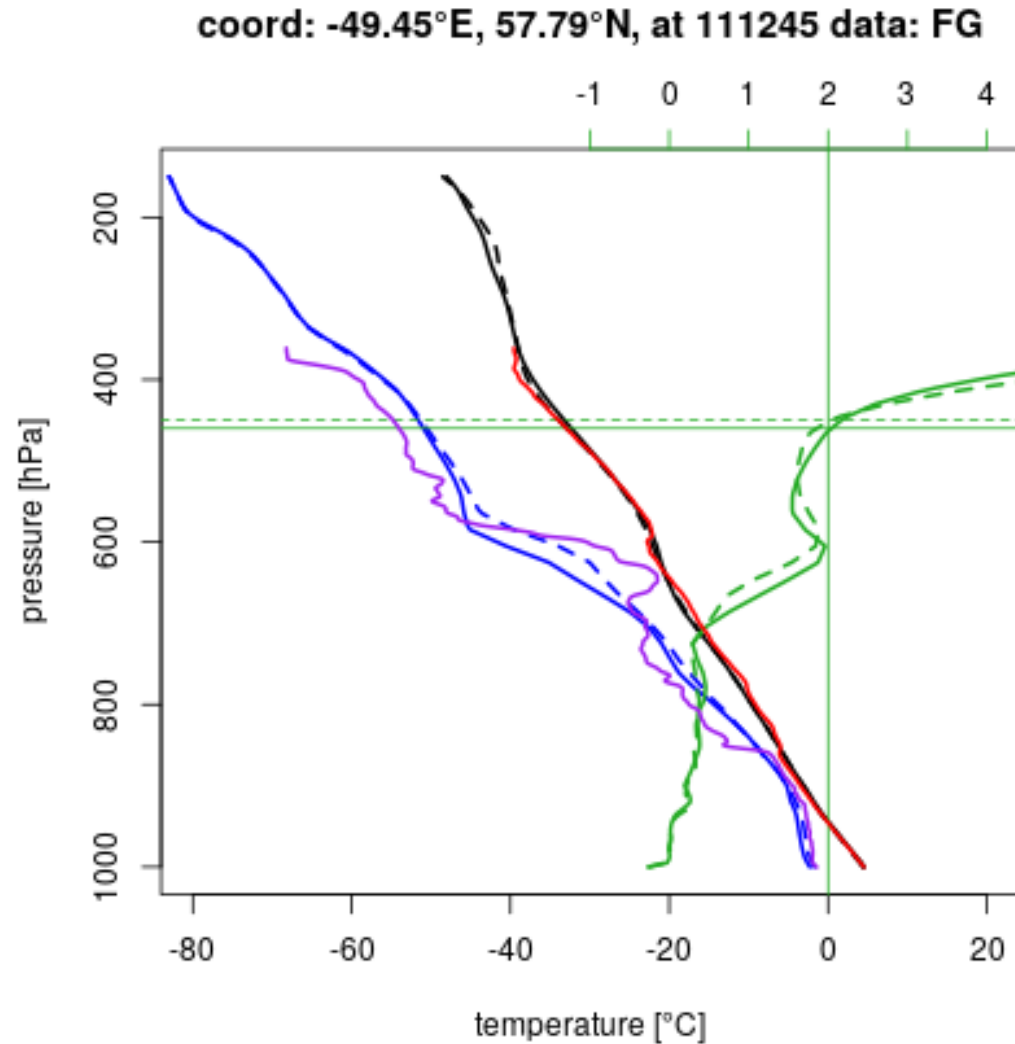
Dropsondes vs first guess and analysis (INIT:20161006_00)



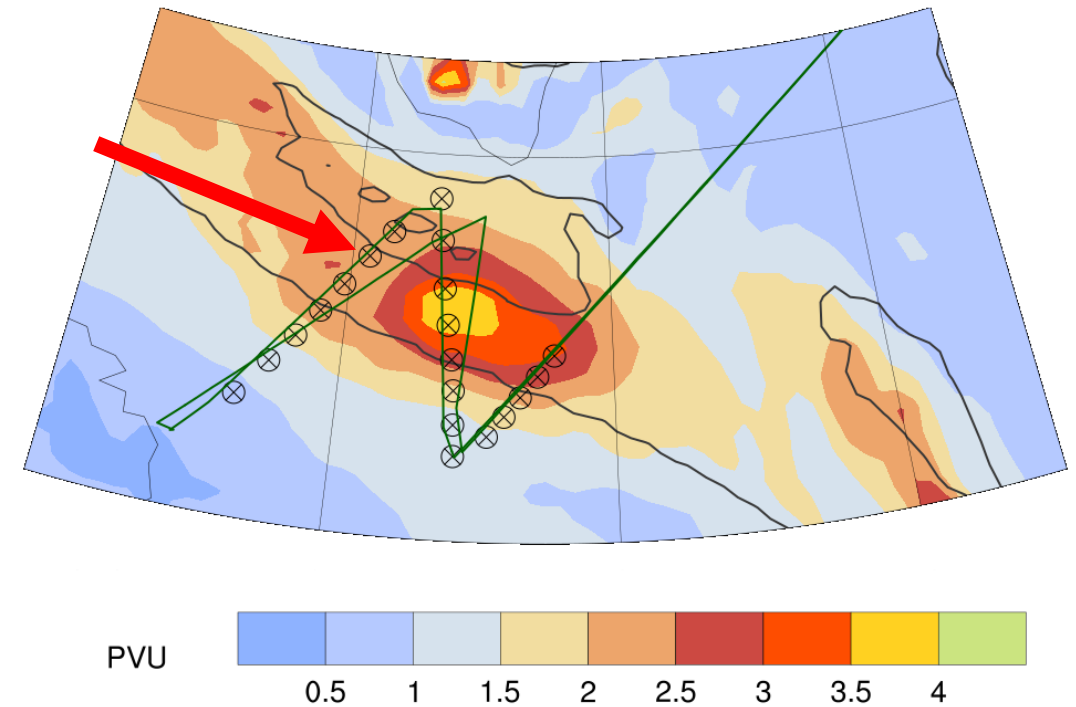
20161006_12: VAPV 285K-310K



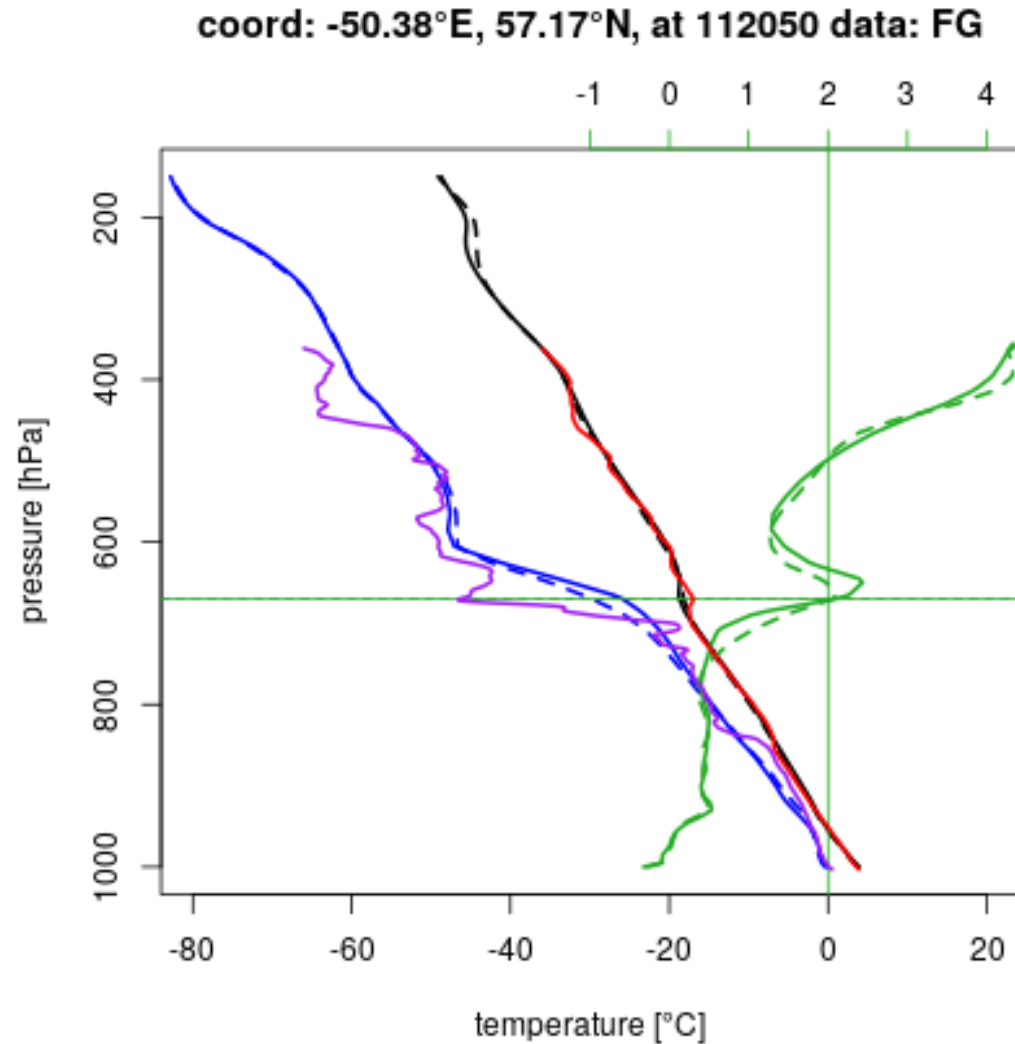
Dropsondes vs first guess and analysis (INIT:20161006_00)



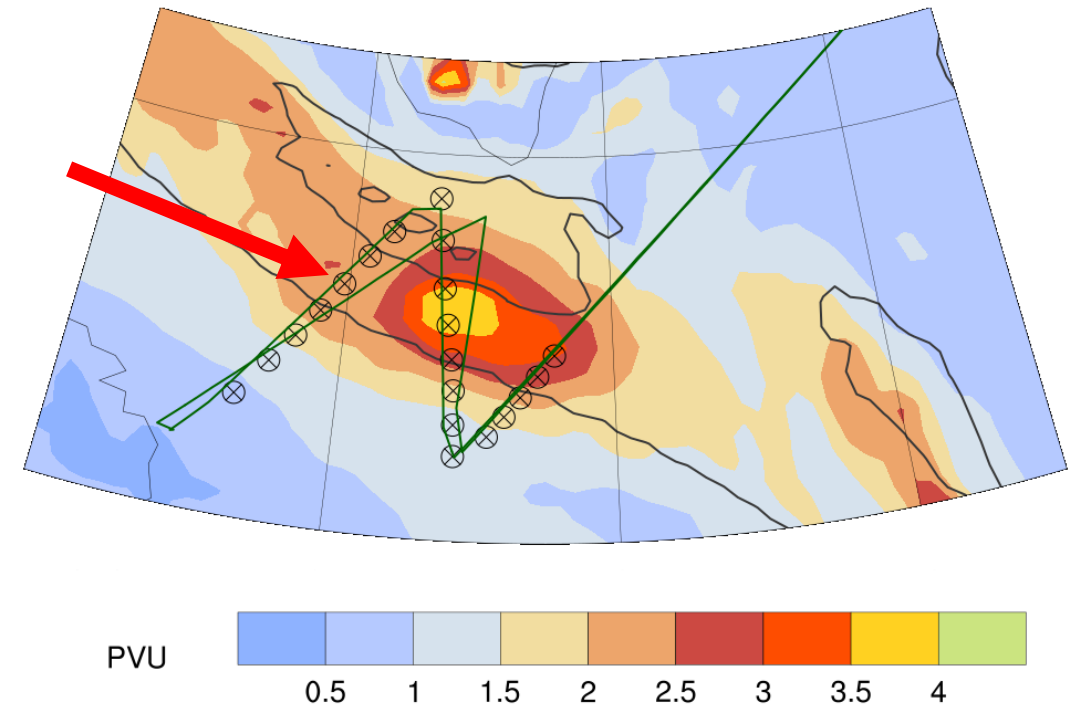
20161006_12: VAPV 285K-310K



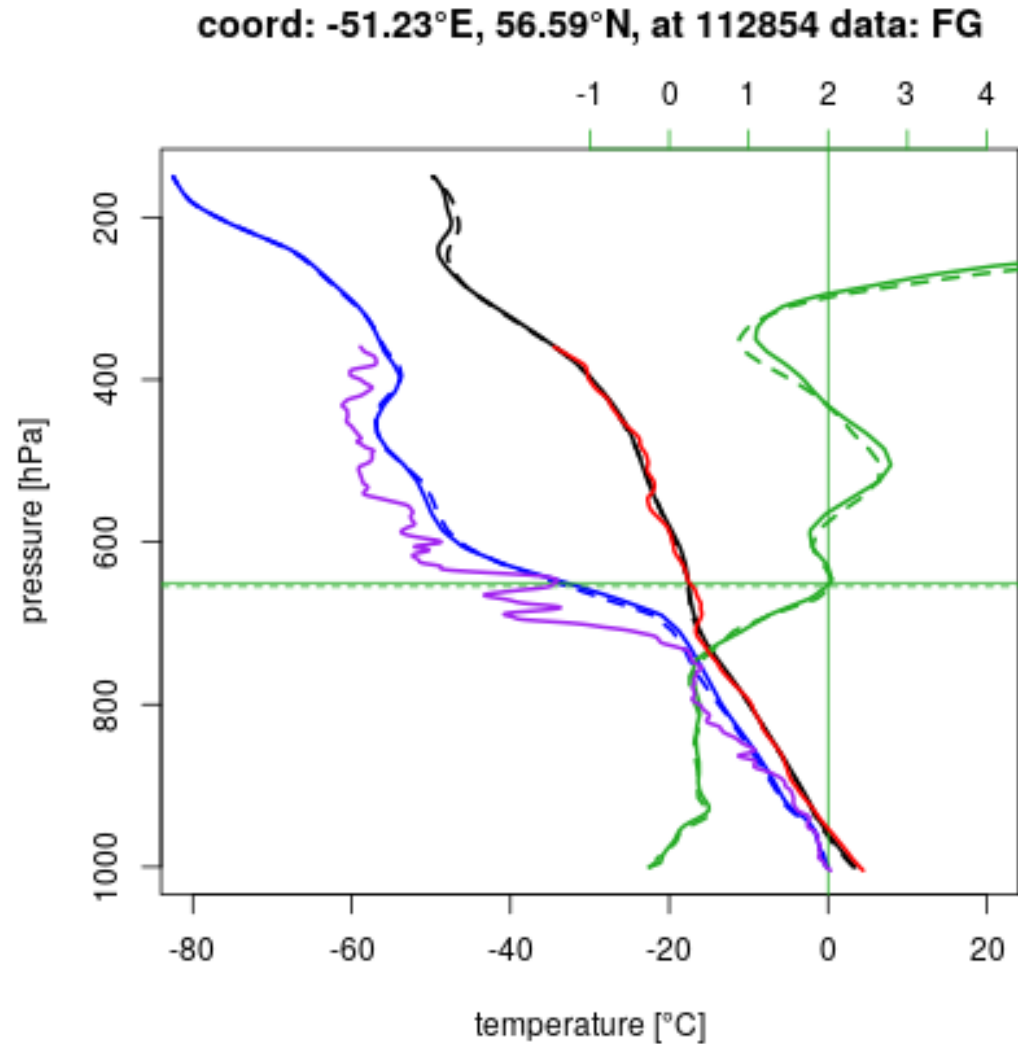
Dropsondes vs first guess and analysis (INIT:20161006_00)



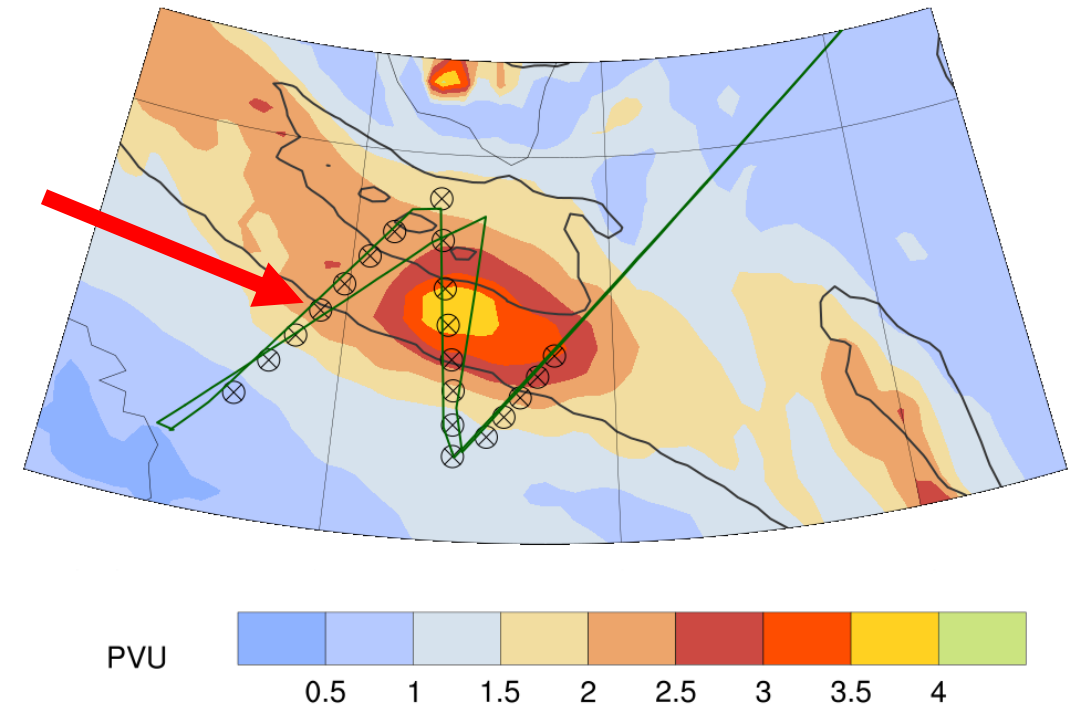
20161006_12: VAPV 285K-310K



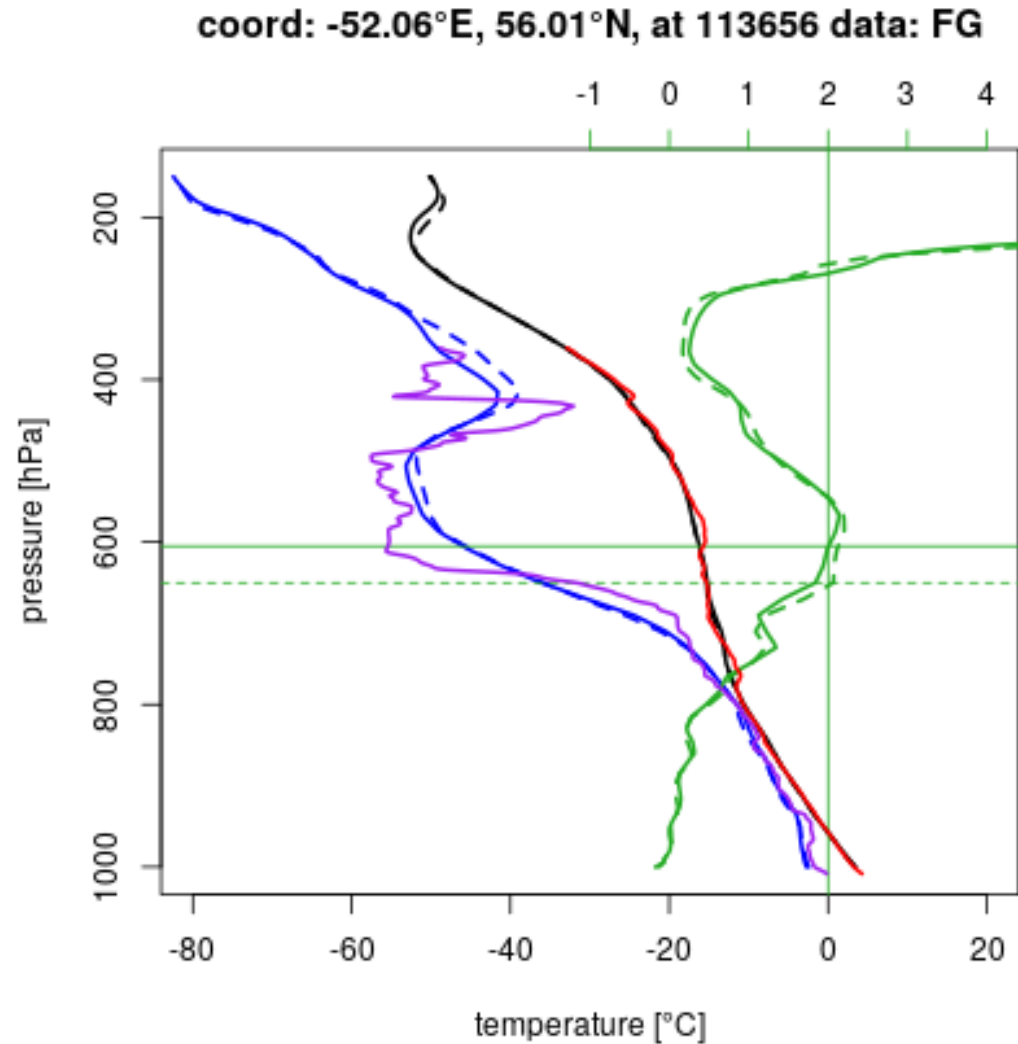
Dropsondes vs first guess and analysis (INIT:20161006_00)



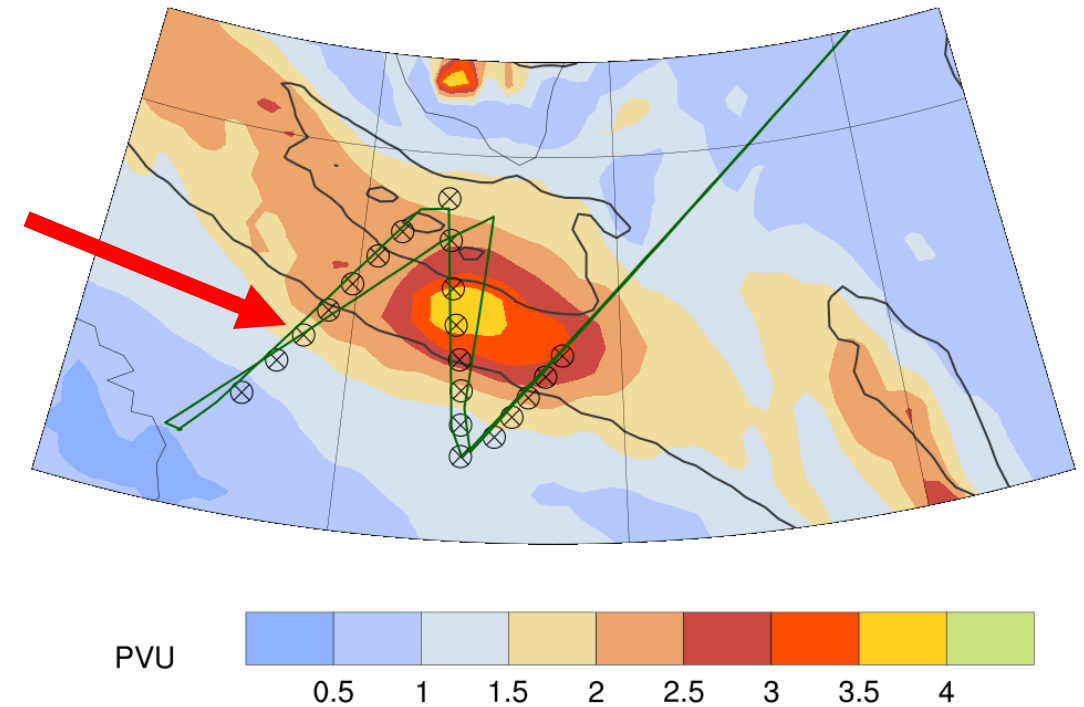
20161006_12: VAPV 285K-310K



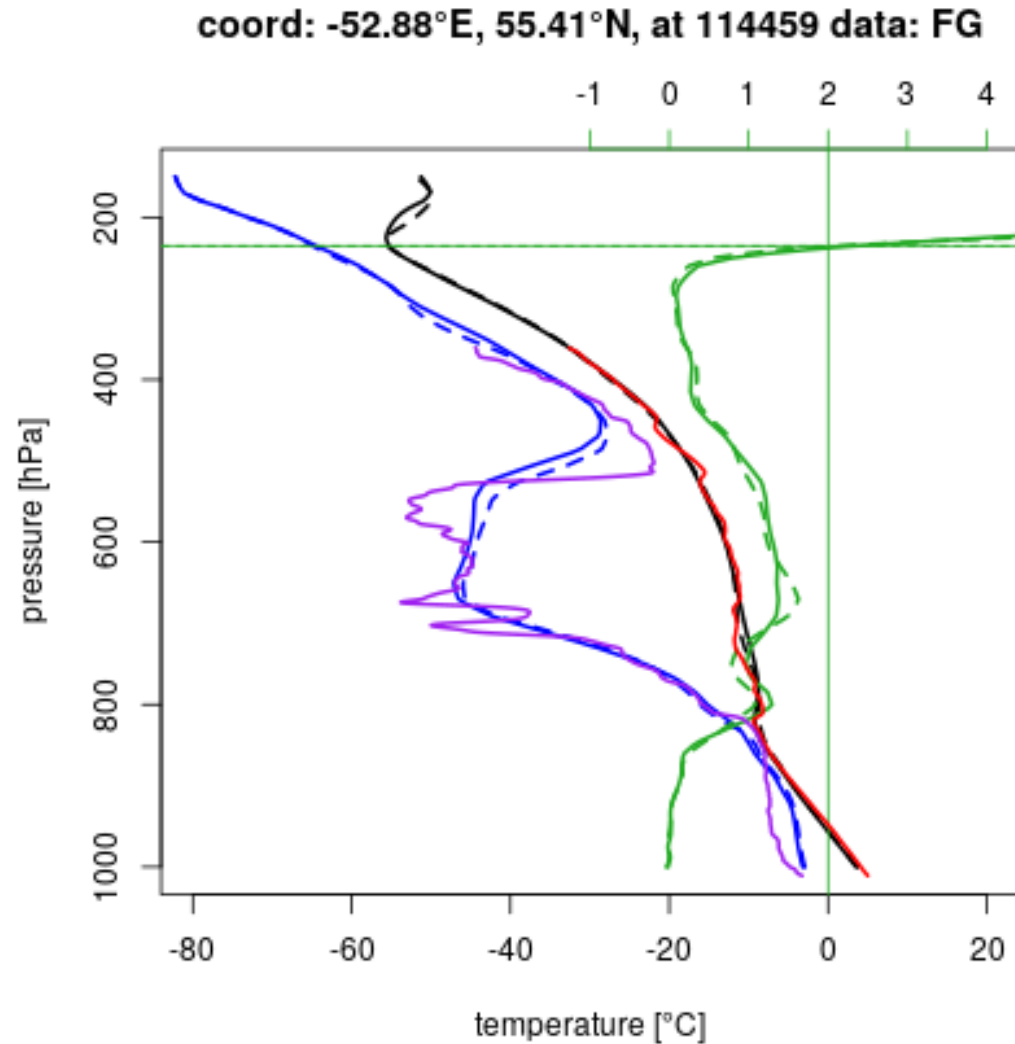
Dropsondes vs first guess and analysis (INIT:20161006_00)



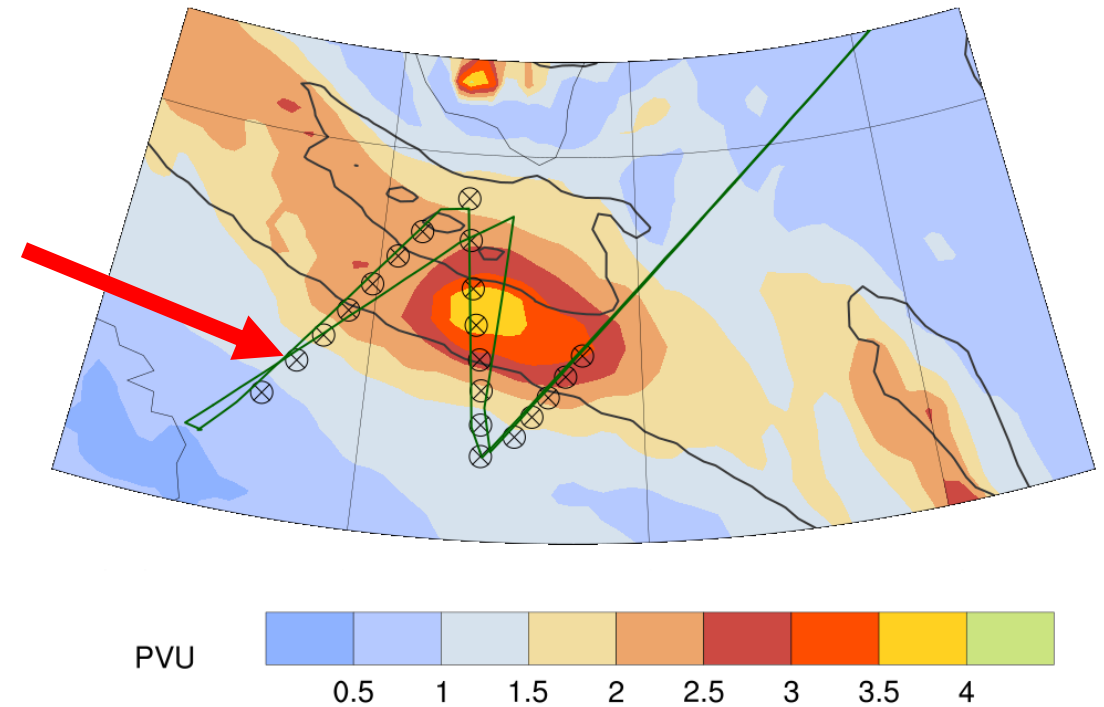
20161006_12: VAPV 285K-310K



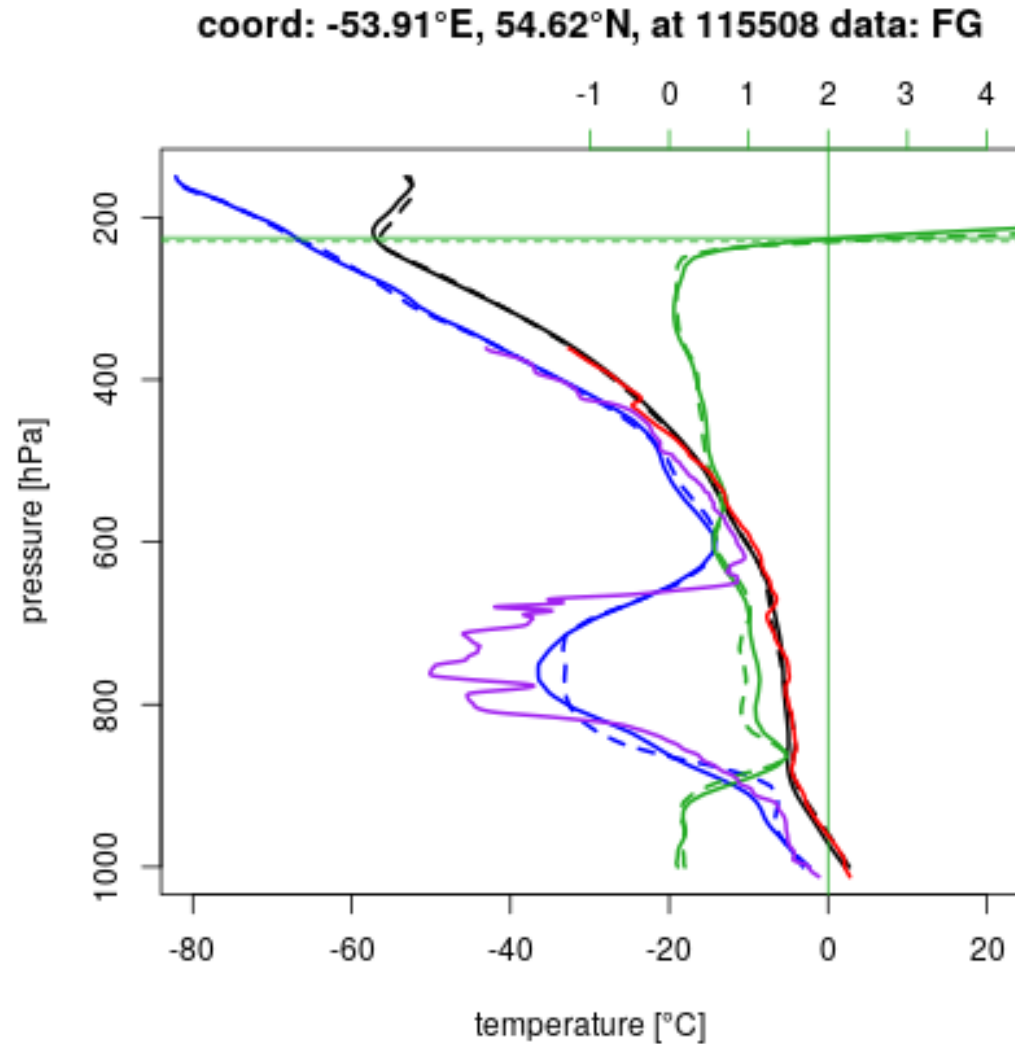
Dropsondes vs first guess and analysis (INIT:20161006_00)



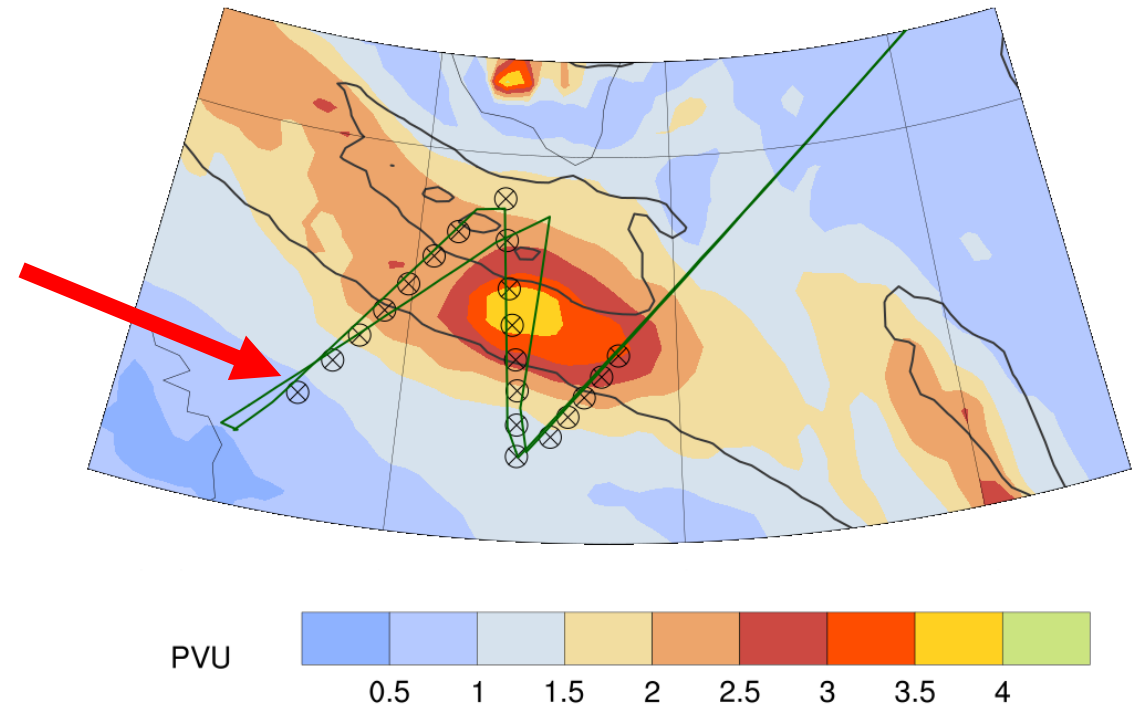
20161006_12: VAPV 285K-310K



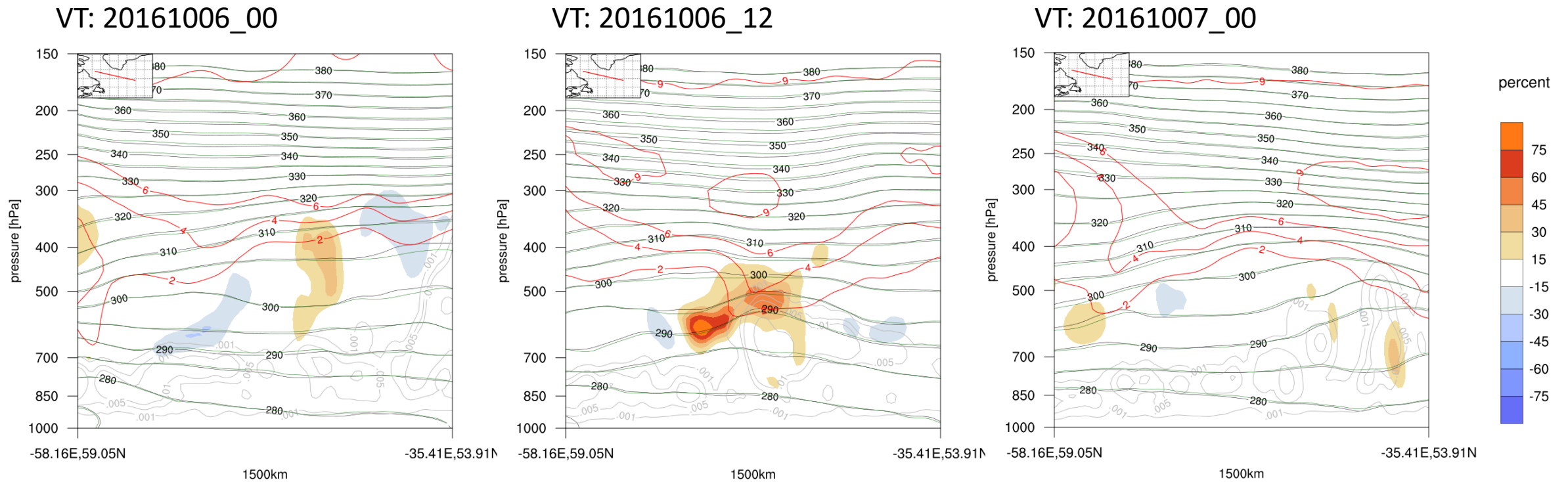
Dropsondes vs first guess and analysis (INIT:20161006_00)



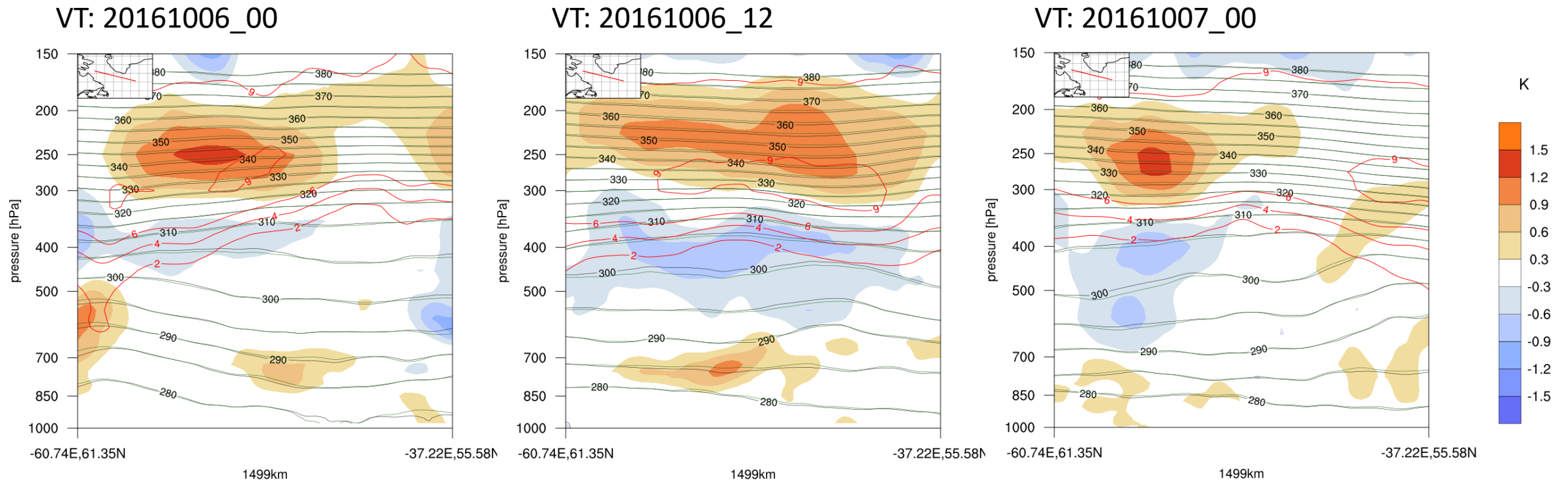
20161006_12: VAPV 285K-310K



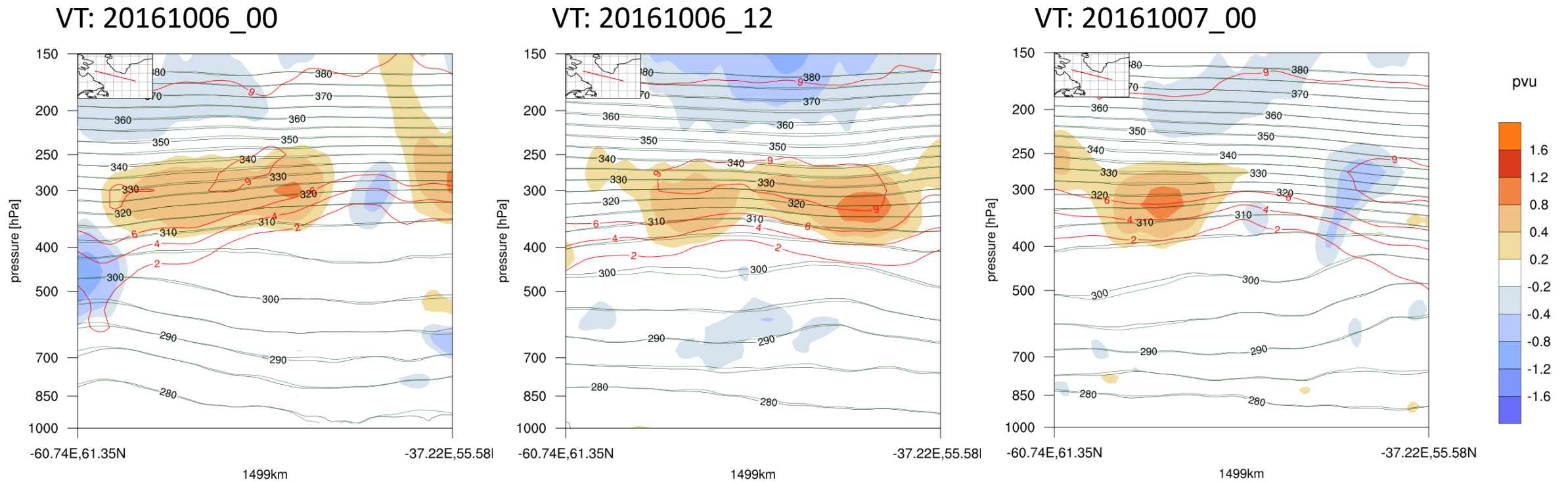
Analysis – 12h FCST q increment (expressed as relative change)



Analysis – 12h FCST Theta increment



Analysis – 12h FCST (first guess) PV increment



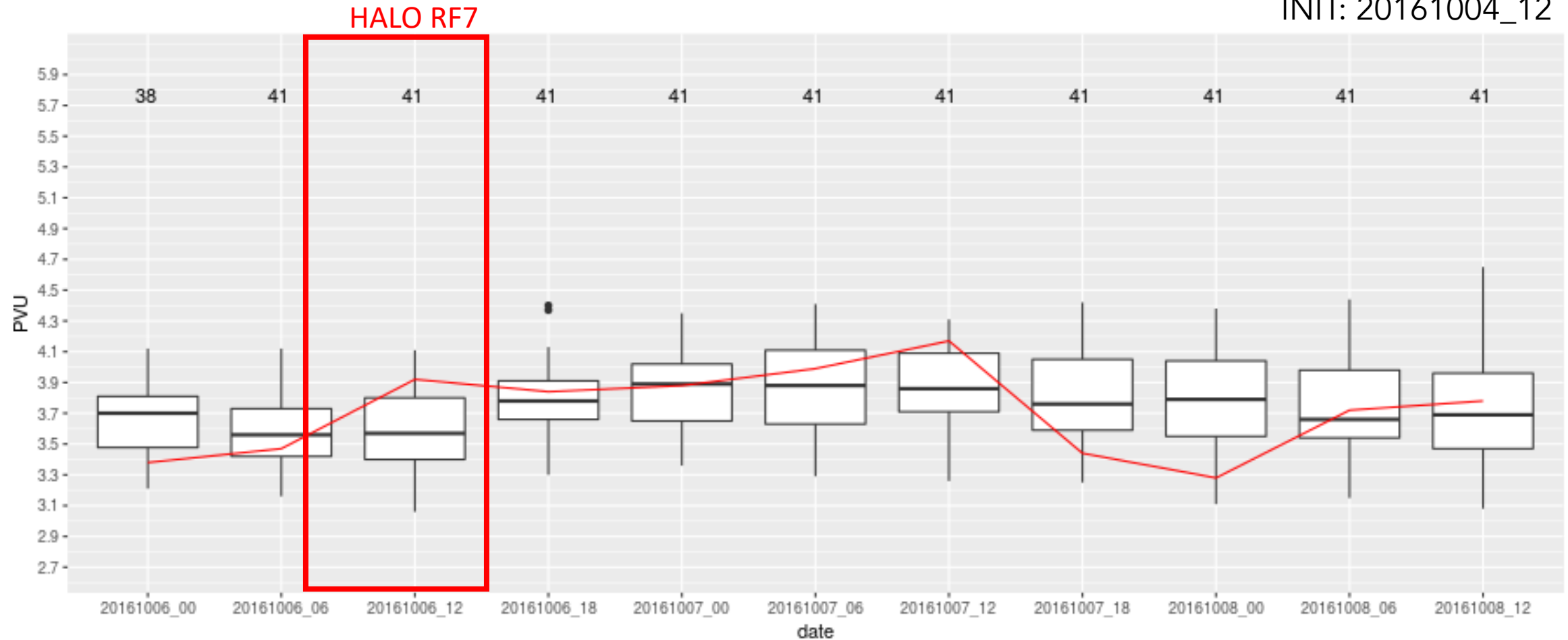
Ensemble vs. analysis

Tracking of blobs in ECMWF ens with init=20161004_12/20161005_12:

- VAPV 320K–345K > 8.5 PVU [Kewblob]
- VAPV 285K–310K > 2.0 PVU [Tropoblob]
- spatial overlap of at least one grid point between time steps
- At 12Z 6 October tracks need to pass through 8°lat by 10°lon box centred on analysis blob position at 12Z 6 October.

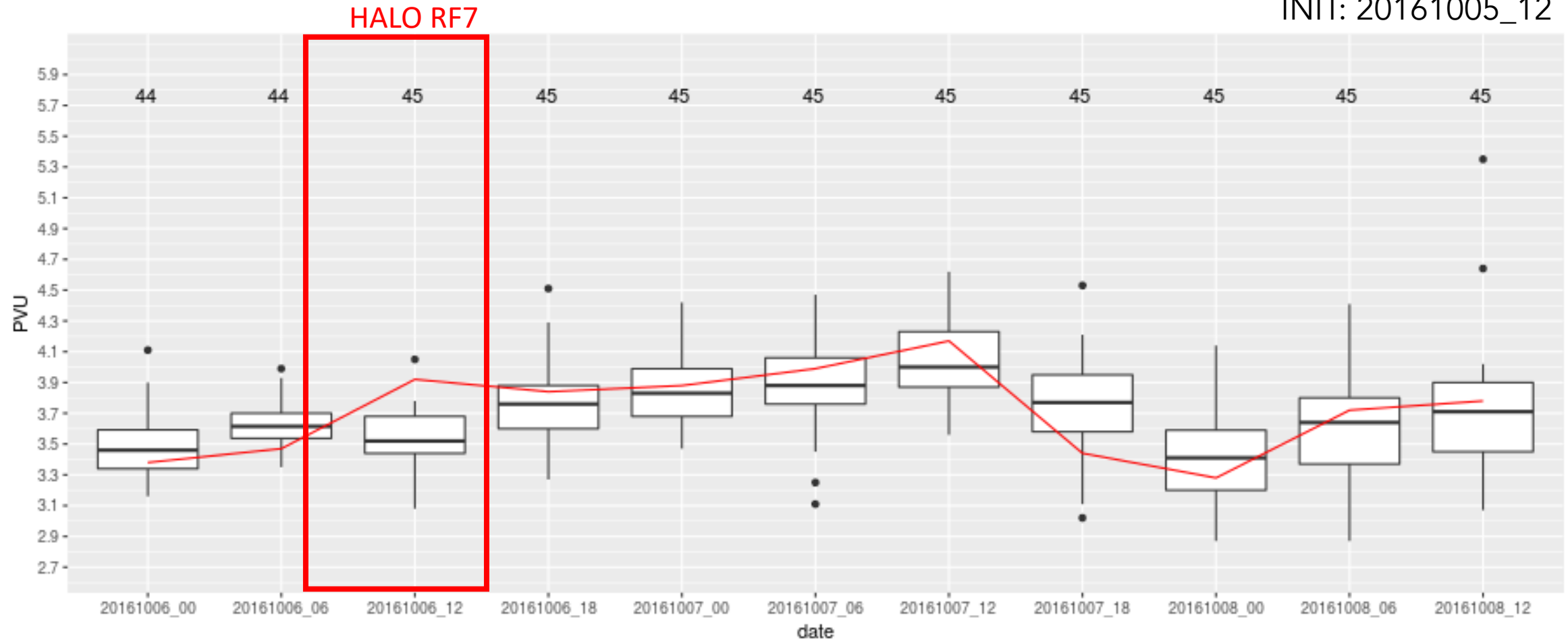
Ensemble vs. analysis: Tropoblob Maximum VAPV in Tropoblob

INIT: 20161004_12



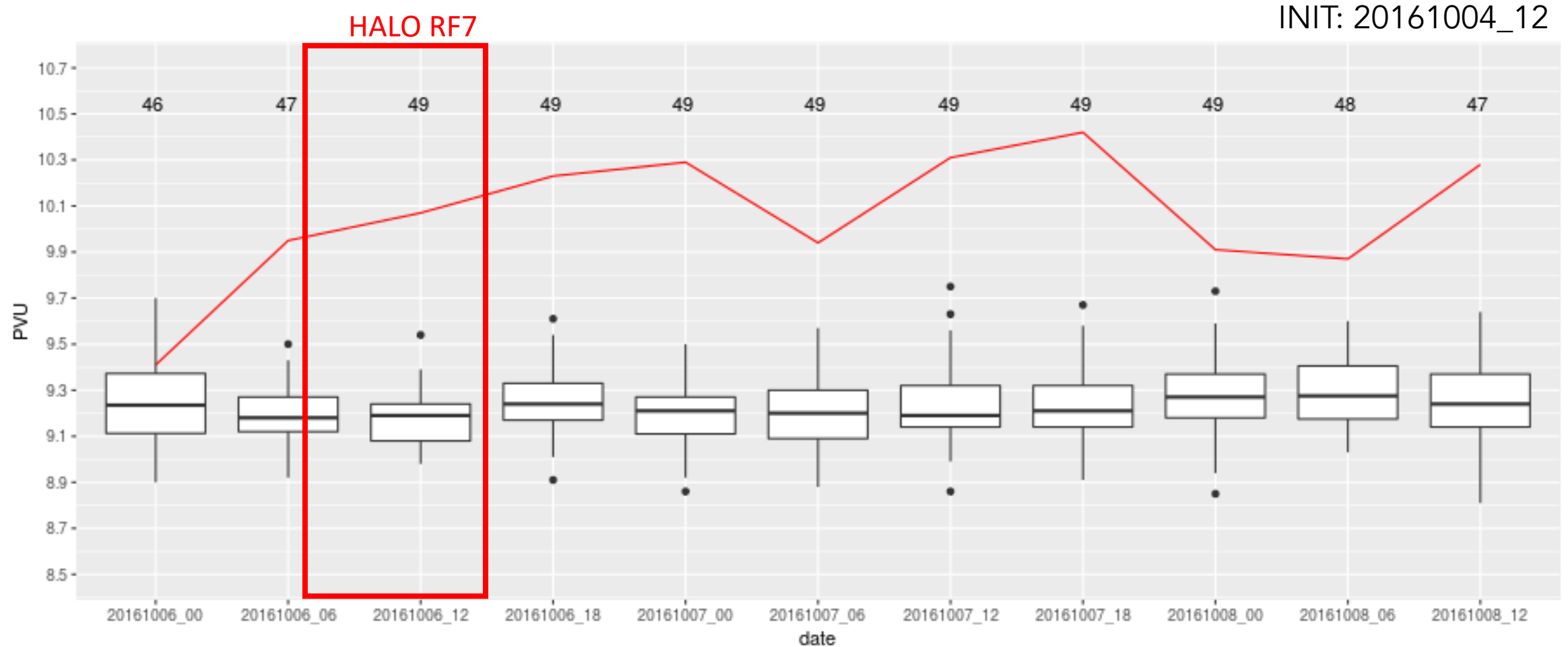
Ensemble vs. analysis: Tropoblob Maximum VAPV in Tropoblob

INIT: 20161005_12



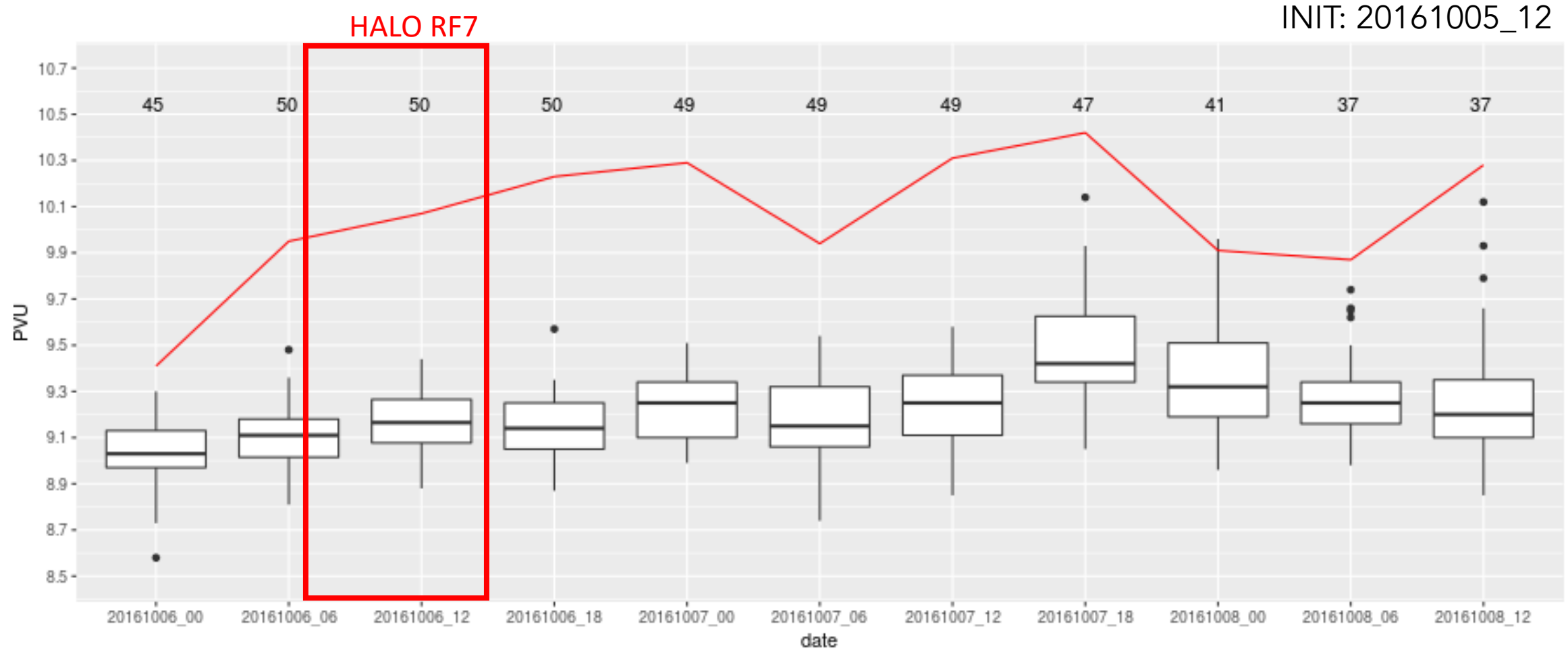
Ensemble vs. analysis: Kewblob

Maximum VAPV in Kewblob



Ensemble vs. analysis: Kewblob

Maximum VAPV in Kewblob



ECMWF second early delivery configuration

(Haseler 2004, ECMWF technical memorandum 454)

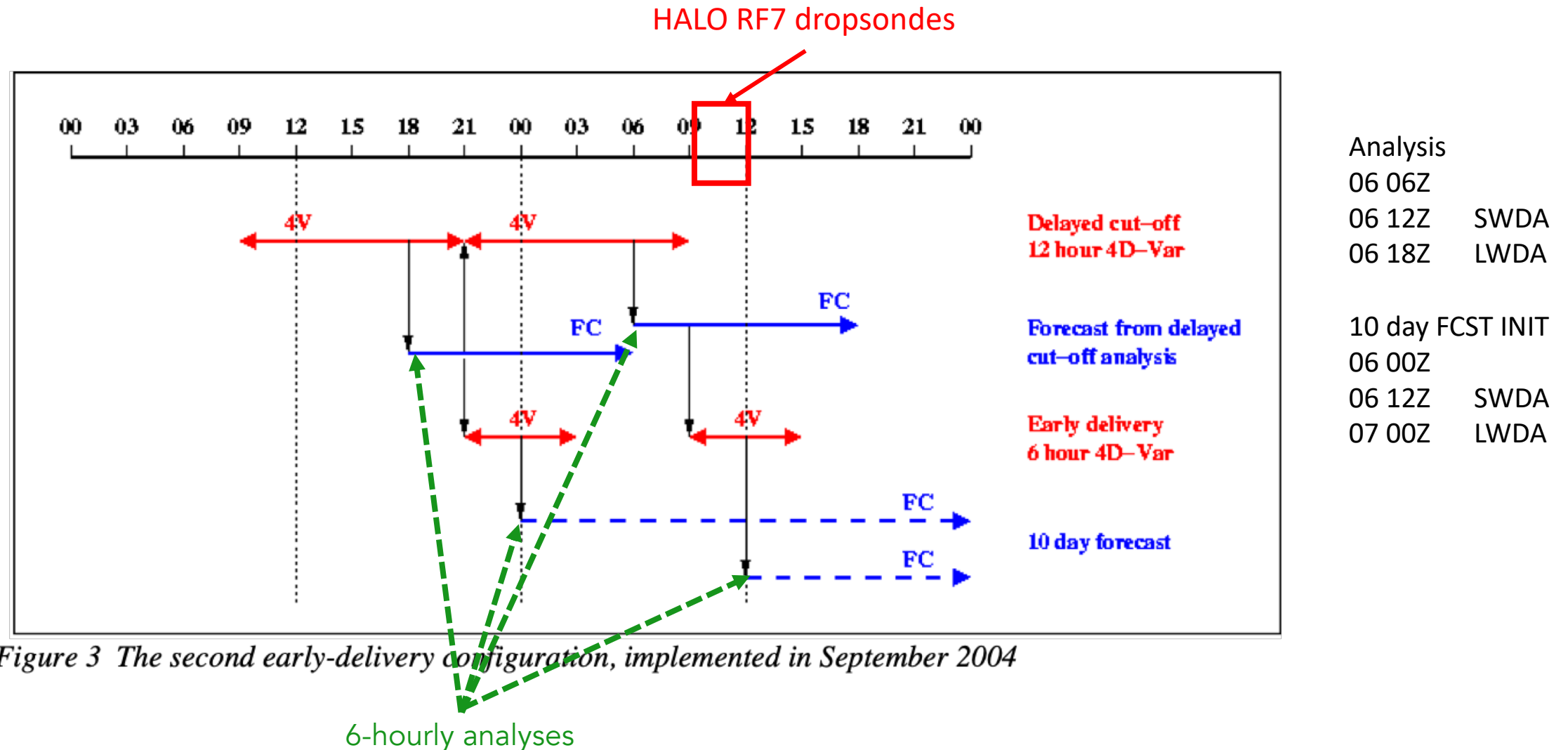
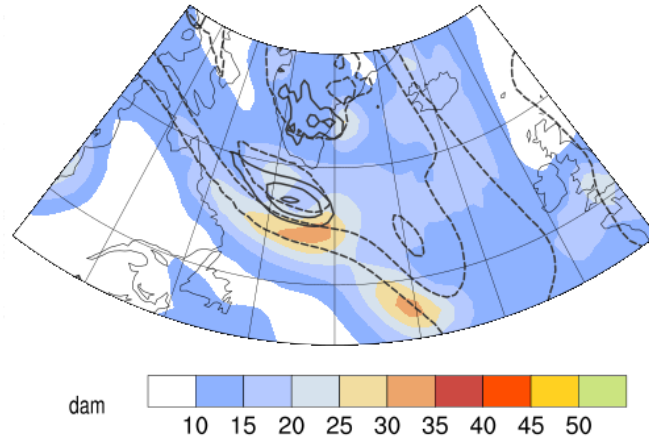


Figure 3 The second early-delivery configuration, implemented in September 2004

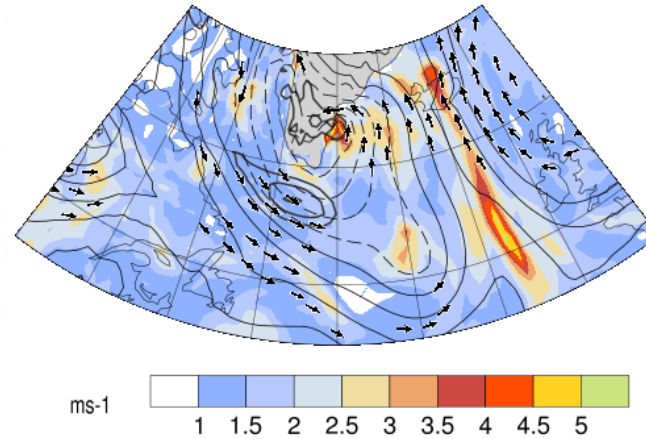
Ensemble spread

Z500

ENS STD Z500, VAPV 285K-310K & 320K-345K



ENS STD VEL850, VAPV 285K-310K

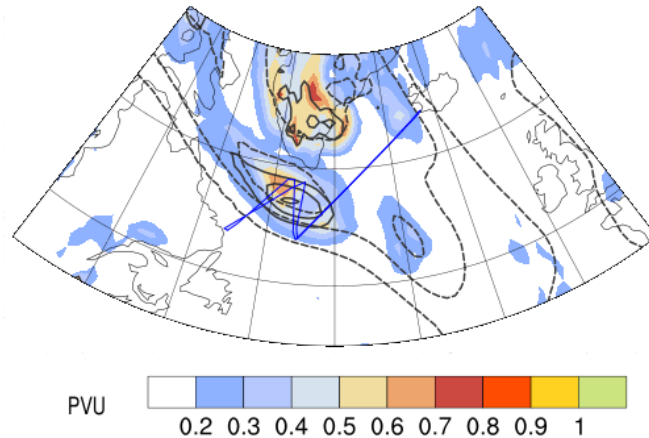


VEL850

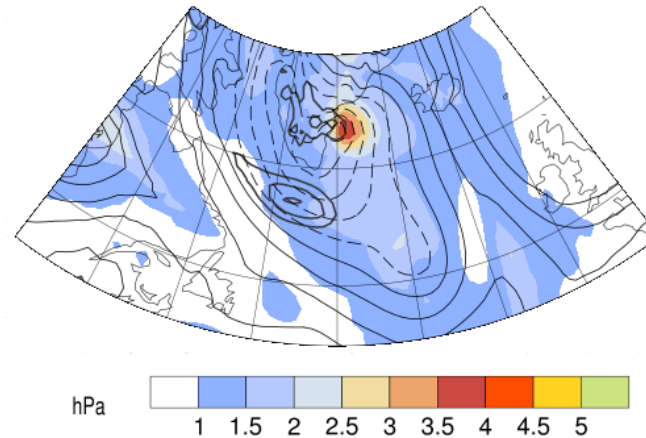
INIT: 20161004_12
VT: 20161006_12

VAPV 285-310K

ENS STD VAPV 285K-310K



ENS STD SLP, SLP

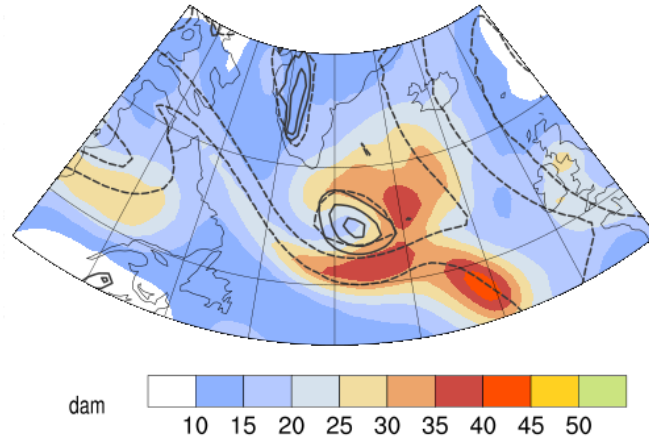


SLP

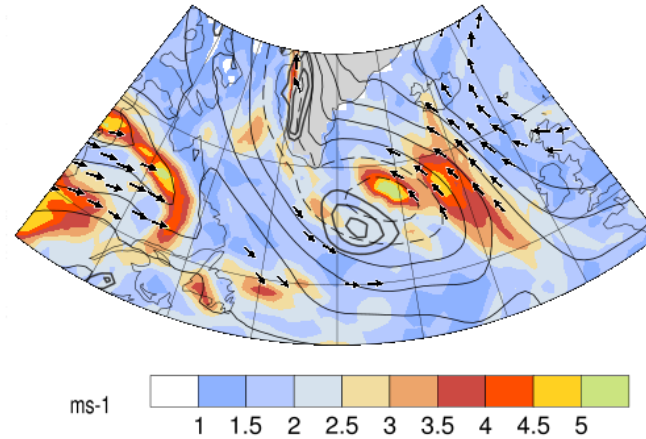
Ensemble spread

Z500

ENS STD Z500, VAPV 285K-310K & 320K-345K



ENS STD VEL850, VAPV 285K-310K

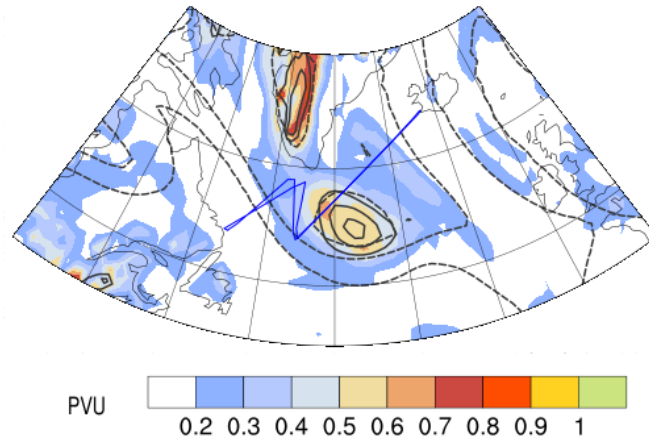


VEL850

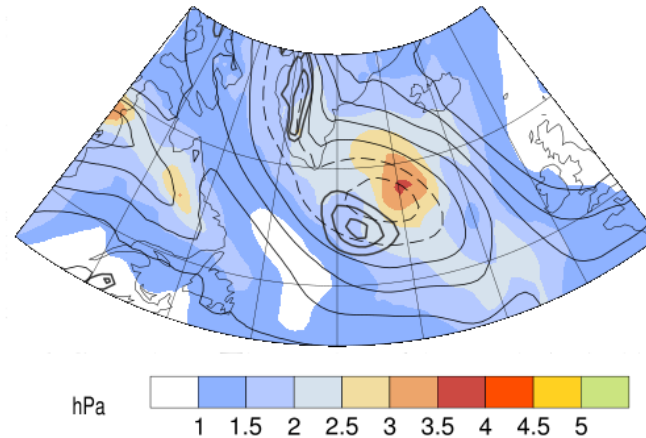
INIT: 20161004_12
VT: 20161007_00

VAPV 285-310K

ENS STD VAPV 285K-310K



ENS STD SLP, SLP

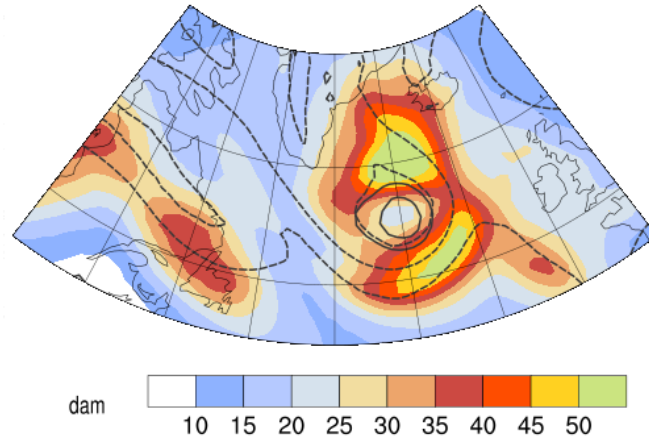


SLP

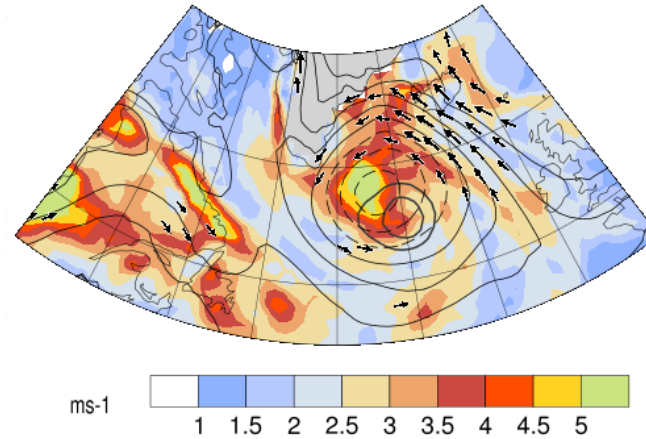
Ensemble spread

Z500

ENS STD Z500, VAPV 285K-310K & 320K-345K



ENS STD VEL850, VAPV 285K-310K

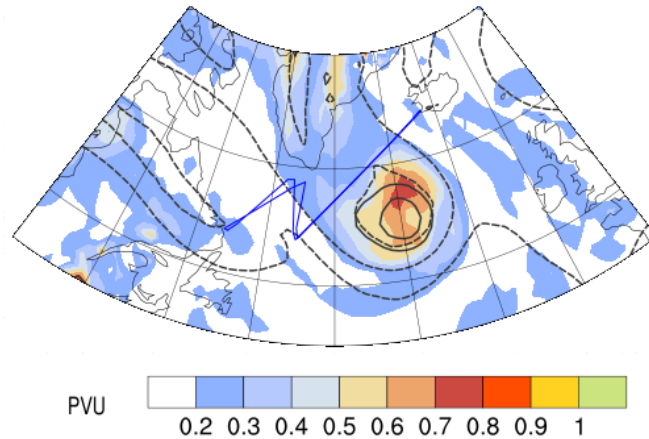


VEL850

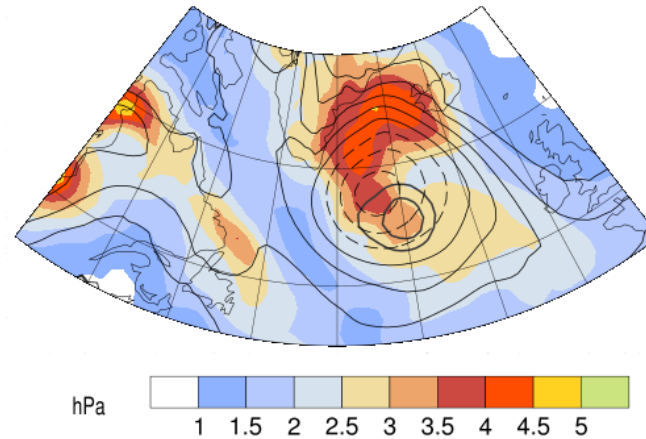
INIT: 20161004_12
VT: 20161007_12

VAPV 285-310K

ENS STD VAPV 285K-310K



ENS STD SLP, SLP



SLP