# Influence of weather data on a fireball's dark flight

Felix* & Dušan Bettonvil**, Tammo Jan Dijkema, Kees Habraken, Jacob Kuiper**, Gert-Jan Netjes**, Sebastiaan de Vet***

*Leiden University / NOVA Optical Infrared Instrumentation Group / KNVWS Meteor Section; ** KNVWS Meteor Section; *** TU Delft / KNVWS Meteor Section

Introduction

- *PyDAF*: a Python coded ablation & dark flight calculator
  - Presented at IMC2021
  - For fireballs
- For the dark flight atmospheric data is needed. And quickly.
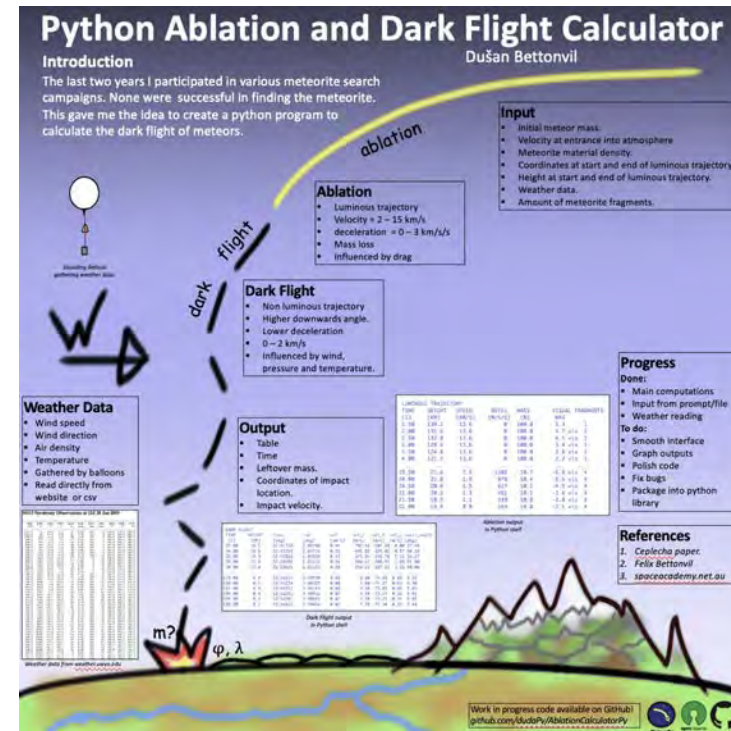
D. Bettonvil

Dark flight: *Equation of motion*

$$(dv_l/dh) = (-\Gamma S \varrho v (V_1 + v_1) - 2\omega(v_x \sin \varphi +$$
$$+ v_h \cos \varphi \sin a_R))/v_h$$

$$(dv_h/dh) = (-\Gamma S \varrho v v_h - g + 2\omega \cos \varphi \, .$$
$$. \, (v_l \sin a_R + v_x \cos a_R))/v_h$$

$$(dv_x/dh) = (\Gamma S \varrho v (V_x + v_x) +$$
$$+ 2\omega(v_l \sin \varphi - v_h \cos \varphi \cos a_R))/v_h \, ,$$

$$\varrho = (3 \cdot 483676 P/T) \times 10^{-4} \, \text{g cm}^{-3}$$

Atmospheric data: options

- Weather balloons (sounding balloons)

- Weather models

- Aeolus (-2)

- Doppler weather radars

Atmospheric data: details

- Balloons
  - They give *T, p, v* as function of altitude (e.g. *weather.uwyo.edu*)
  - Usually good altitude resolution
  - Con: time & location of the measurement are usually not identical to time/location of the fireball.

- Models
  - ECWMF and several others compute every 6 hrs a prediction. E.g. *Windy.com*
  - WRF (Weather Research and Forecast model simulation tool) give options to run models yourself. E.g. *Wetterzentrale.de*, DFN (Devillepoix).
  - Con: the open data is generally not very detailed. Also, it does not mostly go beyond 15km altitude (exception: *rucsounding.noaa.gov* (GFS)).
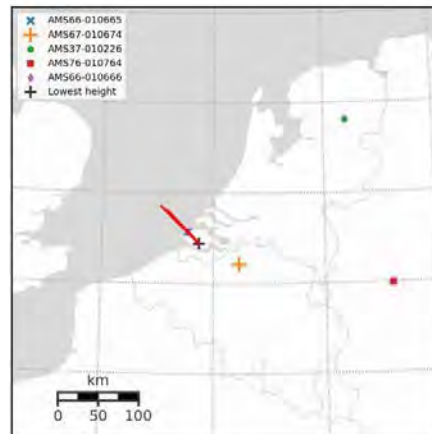
Case study

- Fireball June 04, 2023, Zeeland, Netherlands
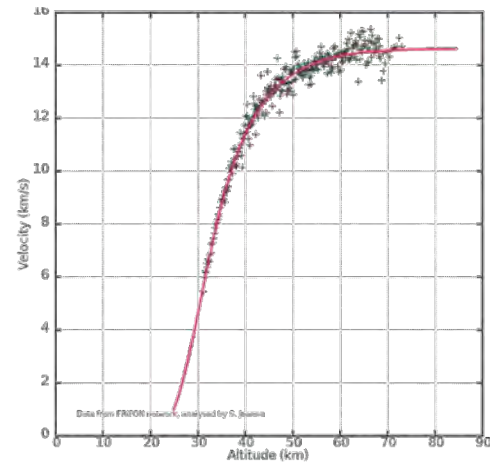 - Captured by FRIPON, Allsky7, GMN, DMS, WGM
  - Meteorite dropper?

WGM capture
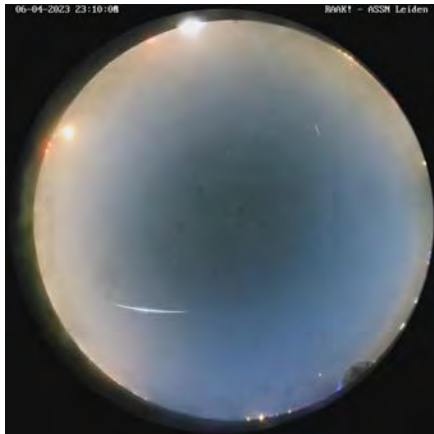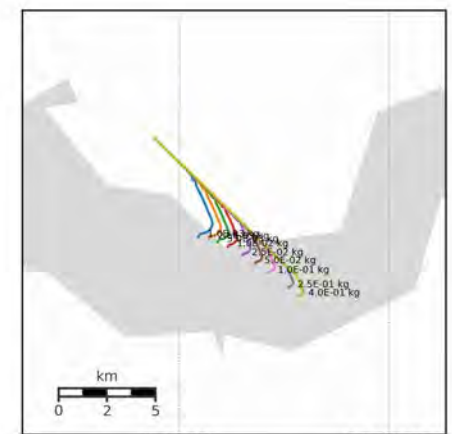
Allsky7 trajectory

FRIPON velocity
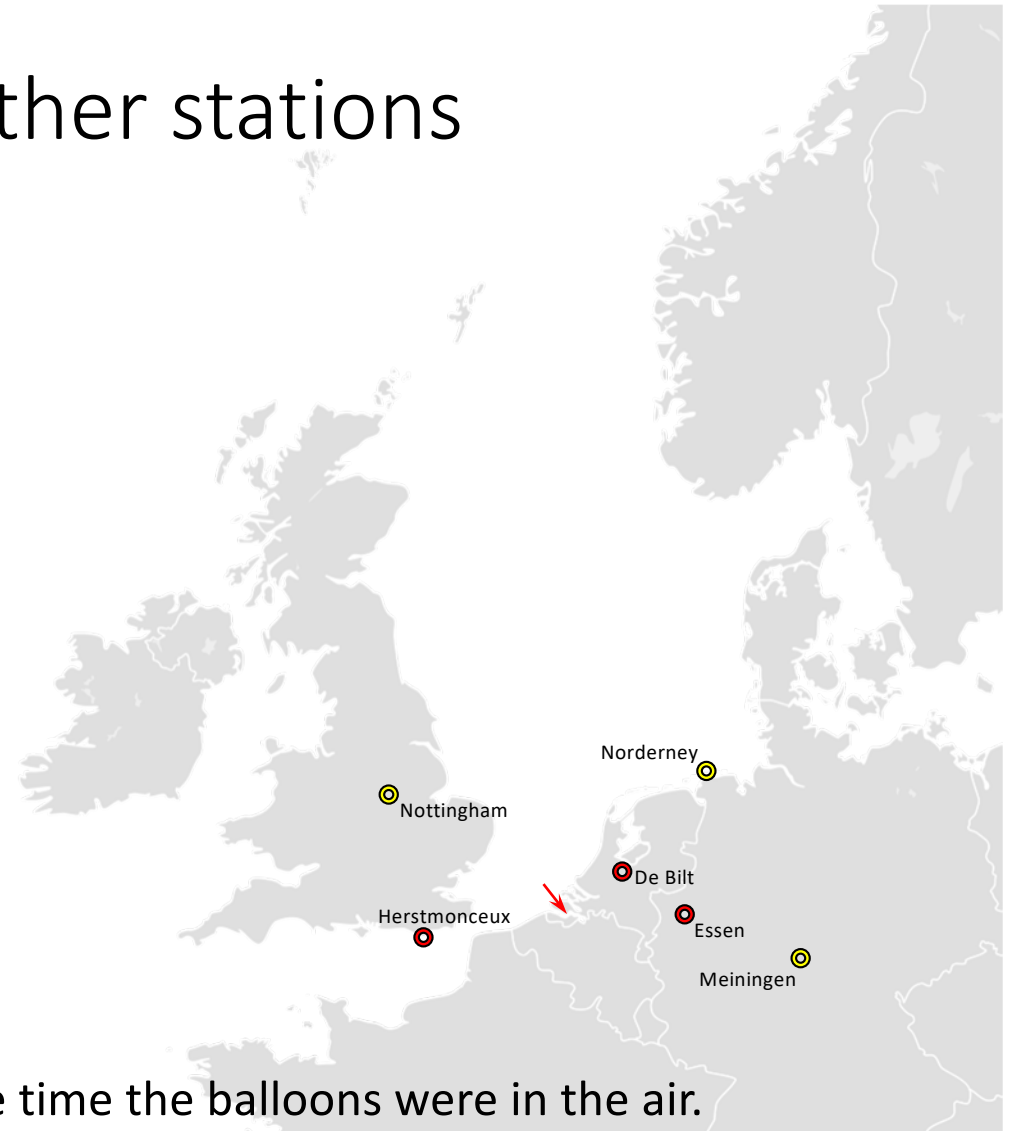
GMN dark flight

F. Bettonvil et al   -   IMC 2023, Redu, Belgium, August 31 – September 03
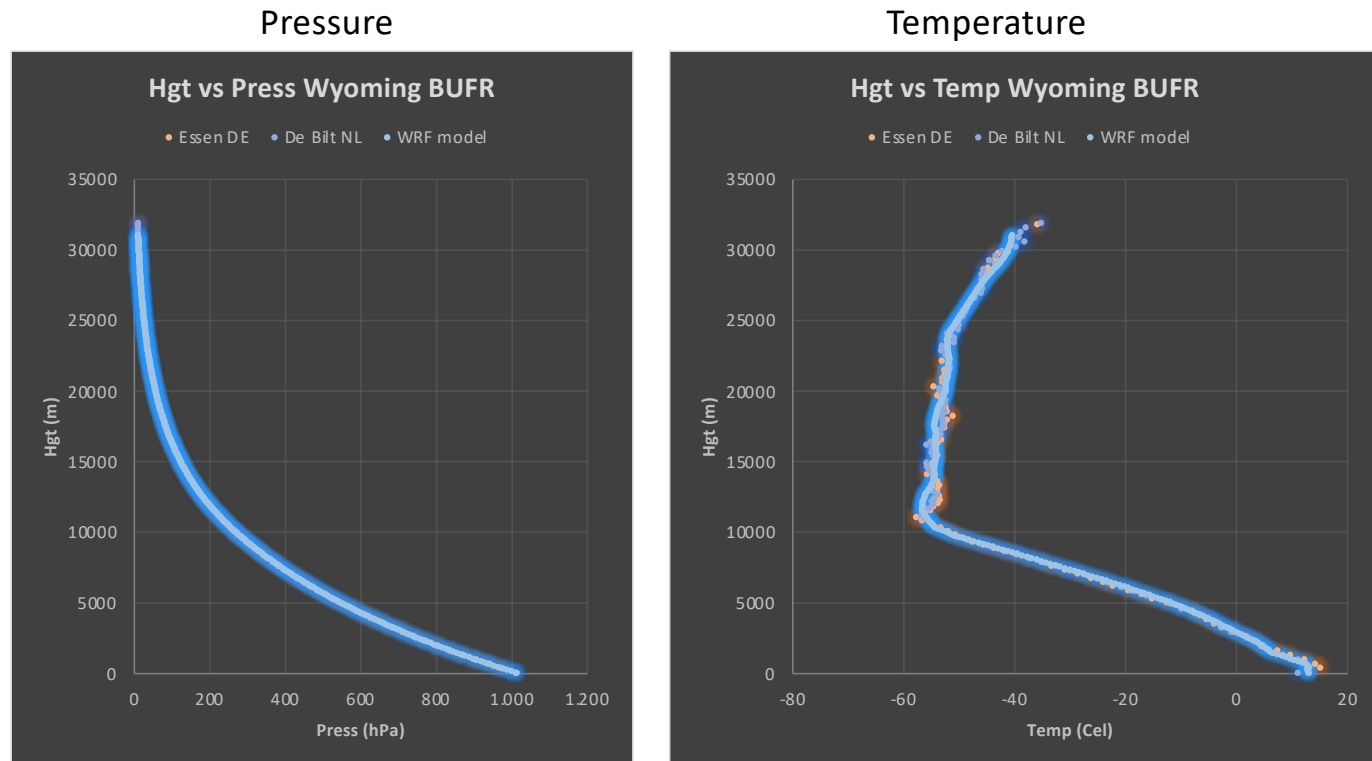
Nearby 'sounding' weather stations

- De Bilt
- Essen
- Herstmonceux
- Meiningen
- Nottingham
- Norderney

- Curious fact: the fireball appeared at the time the balloons were in the air.

Atmospheric data: pressure and temperature
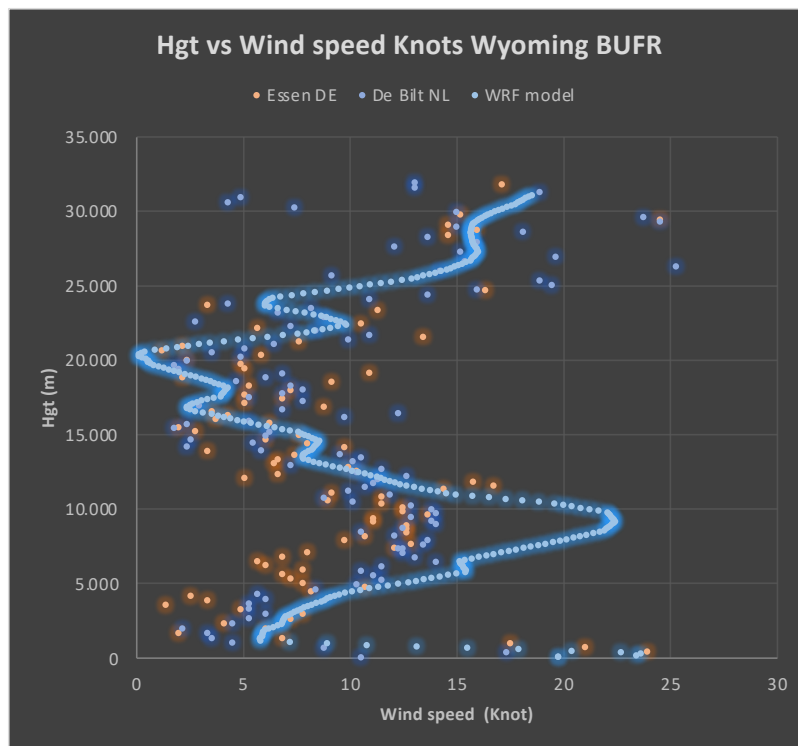
Pressure

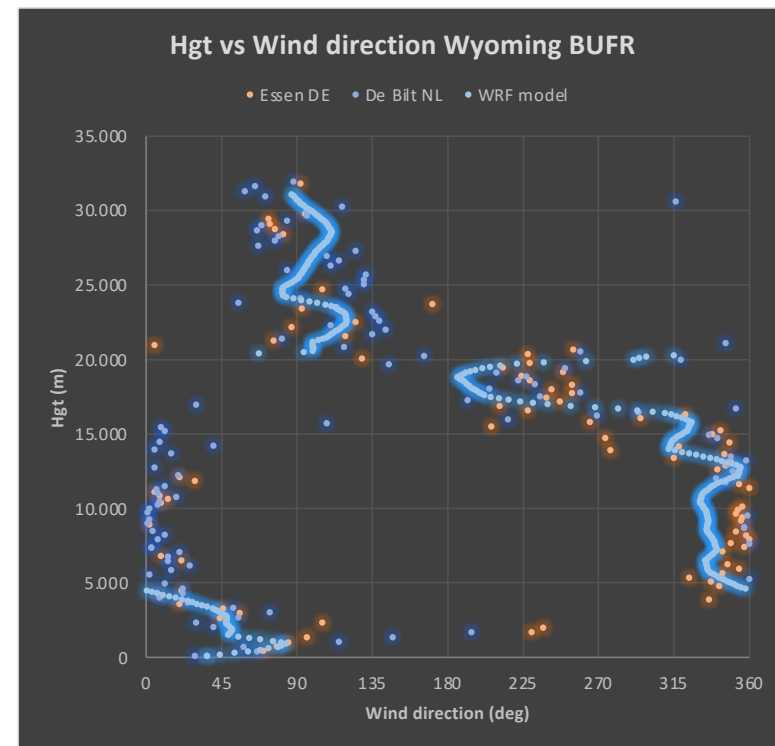Temperature

K. Habraken

- Conclusion: for different stations *p*, *T* is quite similar
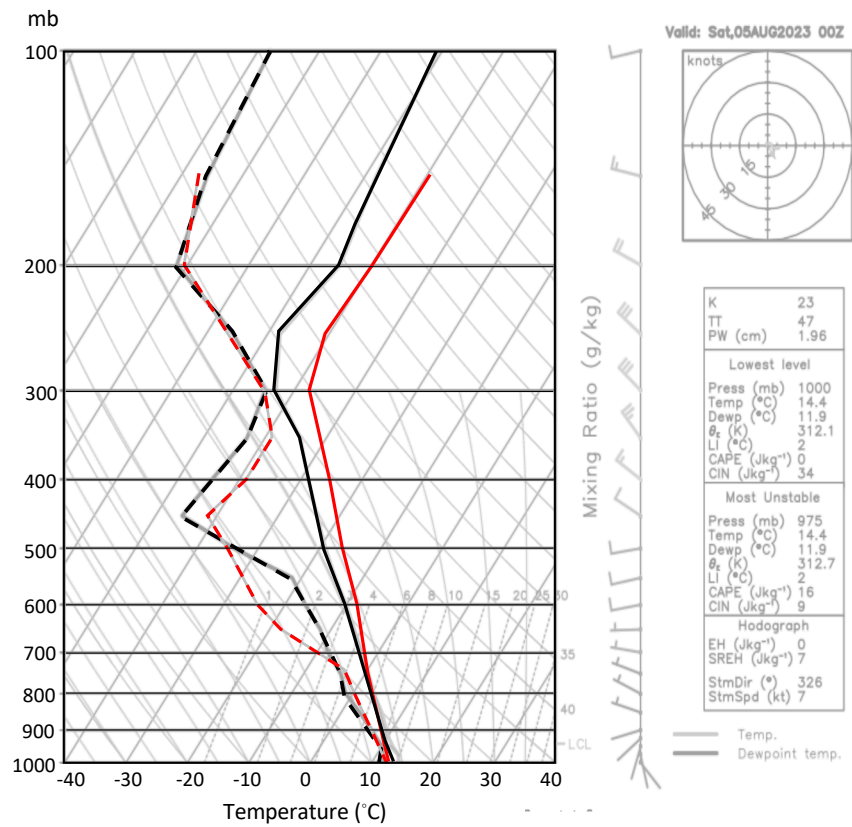
Atmospheric data: wind speed and -direction

Wind speed

Wind direction

K. Habraken

- Conclusion: Wind speed and – direction do vary.

Valid: Sat,05AUG2023 00Z

knots

K	23
TT	47
PW (cm)	1.96

Lowest level

Press (mb)	1000
Temp (°C)	14.4
Dewp (°C)	11.9
θ_E (K)	312.1
LI (°C)	2
CAPE (Jkg⁻¹)	0
CIN (Jkg⁻¹)	34

Most Unstable

Press (mb)	975
Temp (°C)	14.4
Dewp (°C)	11.9
θ_E (K)	312.7
LI (°C)	2
CAPE (Jkg⁻¹)	16
CIN (Jkg⁻¹)	9

Hodograph

EH (Jkg⁻¹)	0
SREH (Jkg⁻¹)	7
StmDir (°)	326
StmSpd (kt)	7

—— Temp.
—— Dewpoint temp.

Wetterzentrale.de

Modellzentrale.de

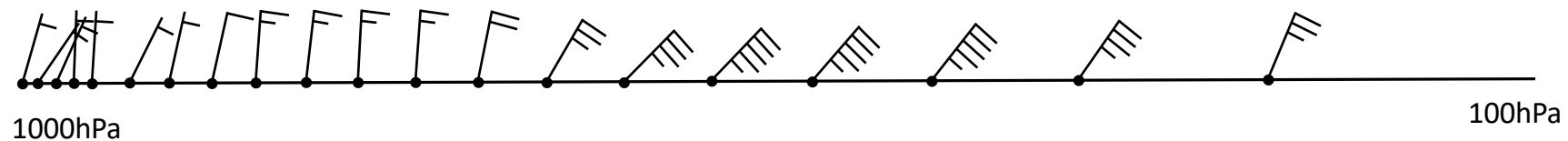1000hPa   100hPa
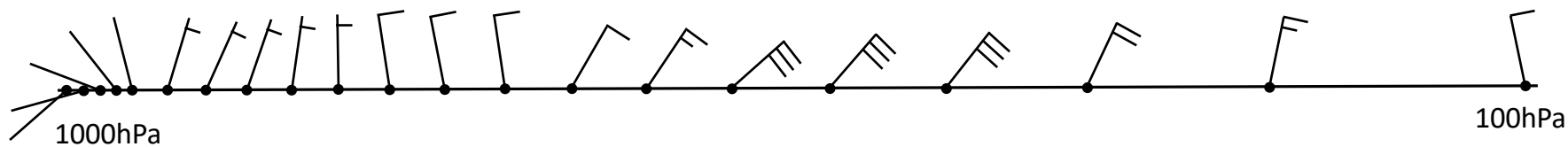
Wetterzentrale.de (WRF)

1000hPa   100hPa

Modellzentrale.de (WRF)

1000hPa   100hPa

Windy.com (ECWMF)

1000hPa
100hPa

Windy.com (ECWMF)

1000hPa
100hPa
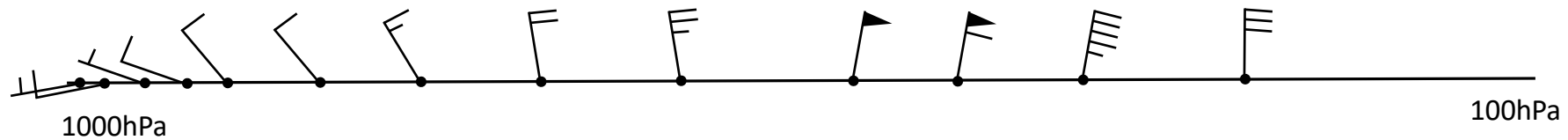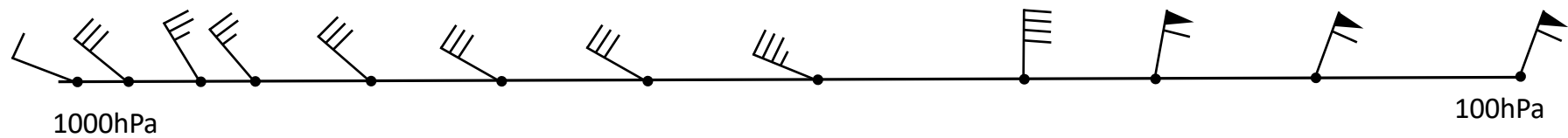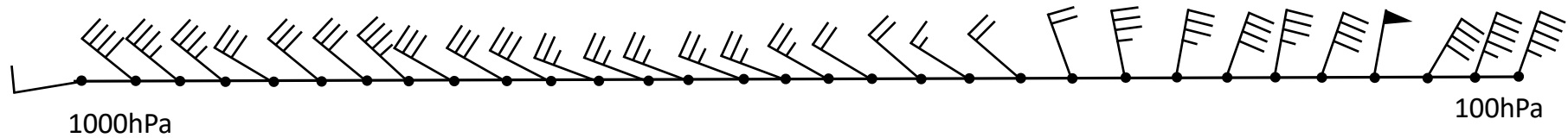
Windy.com (sounding De Bilt)

What data to take?

- Let's do a comparison: compute the dark flight of a single fragment for each different weather data set.

- We take again the fireball of June 04:
    - we use the Allsky7 trajectory
    - a 3 gr and 16 gr fragment

Influence weather data on 3 & 16 gr fragment

Meiningen 3g

Norderney 3g · Essen 3g · De Bilt 3g

1gr

Herstmonceux 3g

Meiningen 16g

WRF 3g

2.5gr · 5gr

Nottingham 3g

10gr

Norderney 16g · Essen 16g

De Bilt 16g · 25gr

Herstmonceux 16g · WRF 16g · 50gr

1 km

Nottingham 16g

100gr

250gr

Nearby 'sounding' weather stations

- De Bilt
- Essen
- Herstmonceux
- Meiningen
- Nottingham
- Norderney
- Beauvechain
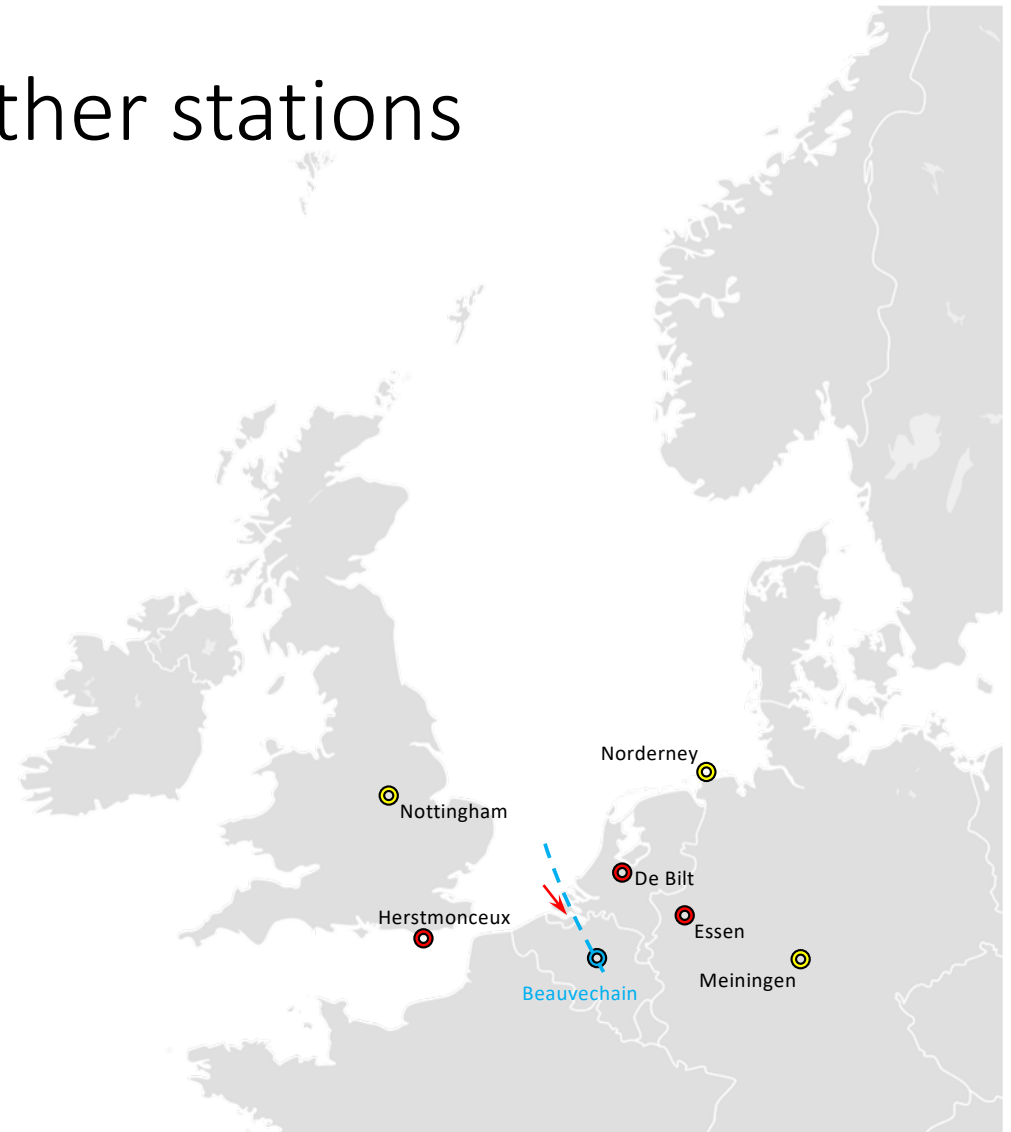
Discussion & conclusions

- There are many sources for atmospheric data.

- It matters which sounding station to take: **wind speed and wind direction usually vary from station to station**.

- **Models do vary too**. Publicily available models are generally less detailed (particularly at higher altitudes) and often the maximum altitude is limited.

- Our case study (with favourable weather conditions) showed a **spread in dropping area of ~ 1km**, which is not negligible. Sounding and model data give differences.

- Choice what to use is not trivial. Based on this study, we tend to prefer model data over sounding data. But best check also sounding data (e.g. weighted average both over time and geographic location).

- Expert input is always welcome, as well as their data. (Recalculated model data).