Studying the relationship between synthetic NWP-derived AMVs and model winds

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Met Office

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

EUMETSAT

University of Reading

Background

- Atmospheric Motion Vectors are observations of cloud motions, **not** direct wind measurements.

- What do AMVs represent?
  - wind at a single height?
  - layer average wind?

Assumption of most observation operators

- Difficulties validating AMVs:
  - sparse sonde observations provide few co-located observations.

Motivation: Latest high resolution NWP models provide very realistic representation of cloud features and their movements.

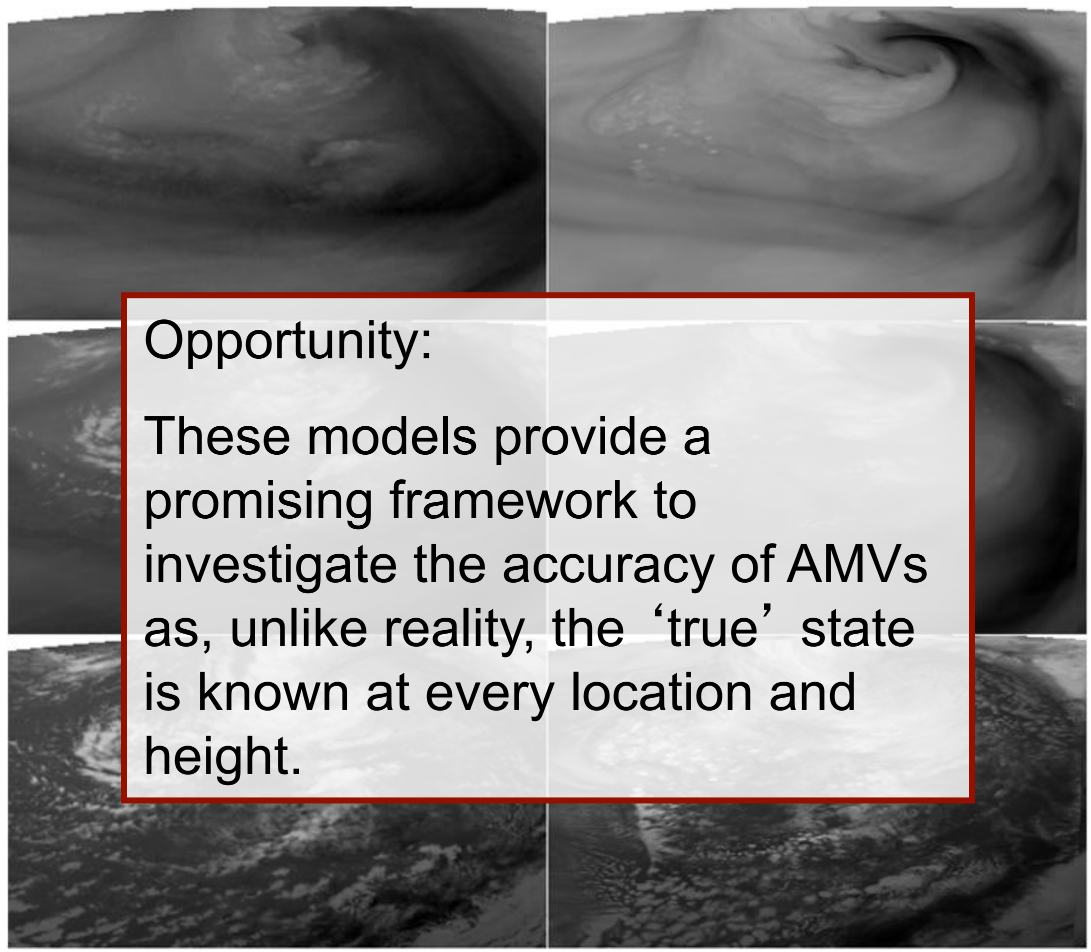
Met Office

MSG SEVIRI Q. which is real?

6.2μm

7.3μm

8.7μm



Opportunity:

These models provide a promising framework to investigate the accuracy of AMVs as, unlike reality, the 'true' state is known at every location and height.

Robert Tubbs

Perfect model framework

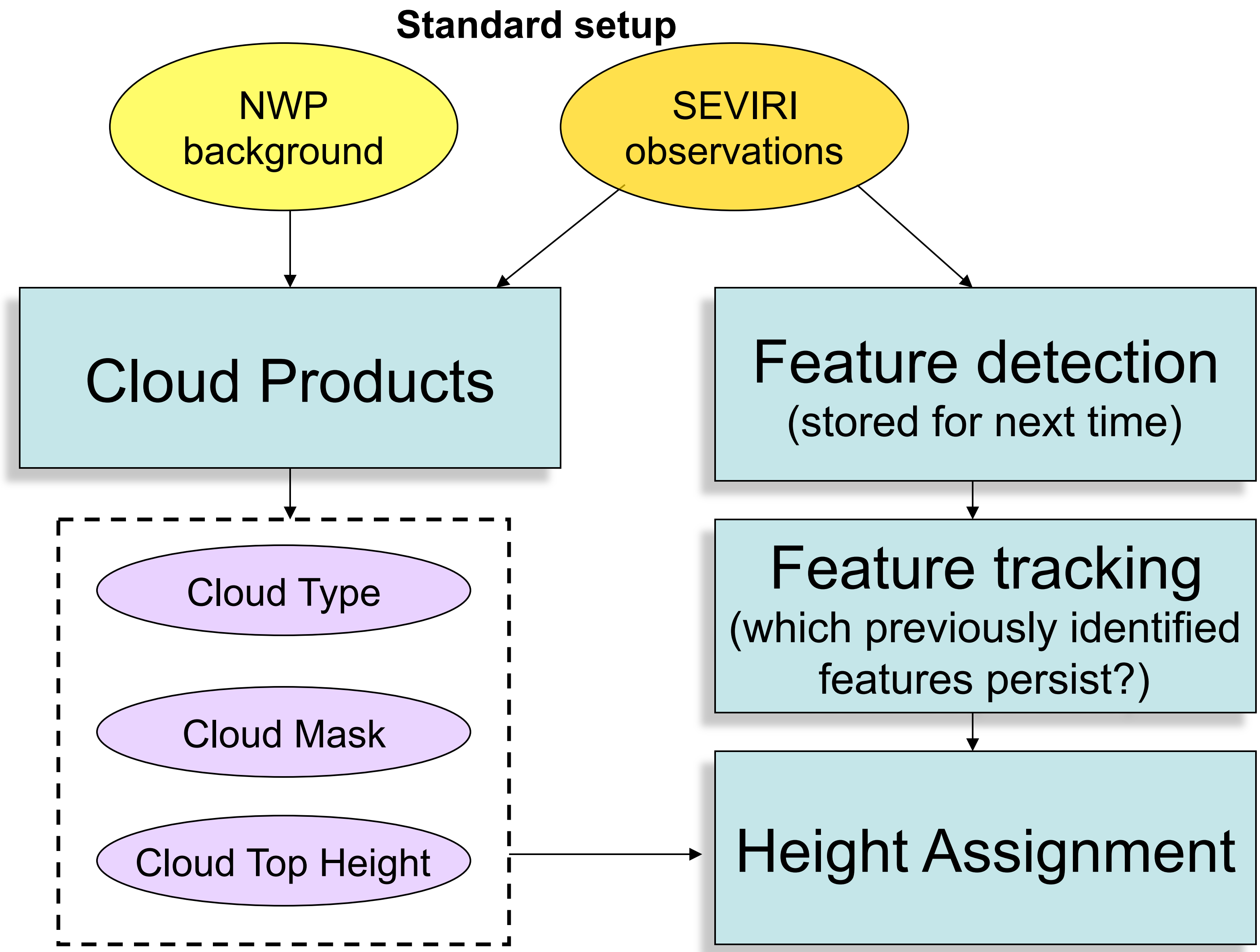
- ‘Synthetic’ AMVs generated from simulated model radiances.
- ‘Truth’ wind profile and cloud structure known at every location.
- Allows us to study the relationship between AMVs and the model winds.
- Quantify random and systematic AMV errors as function of cloud type.
- Design an improved observation operator using relationships found in synthetic AMV study.

Improved assimilation of high resolution AMVs into high resolution mesoscale models.

Part 1:

NWCSAF
high resolution AMV product

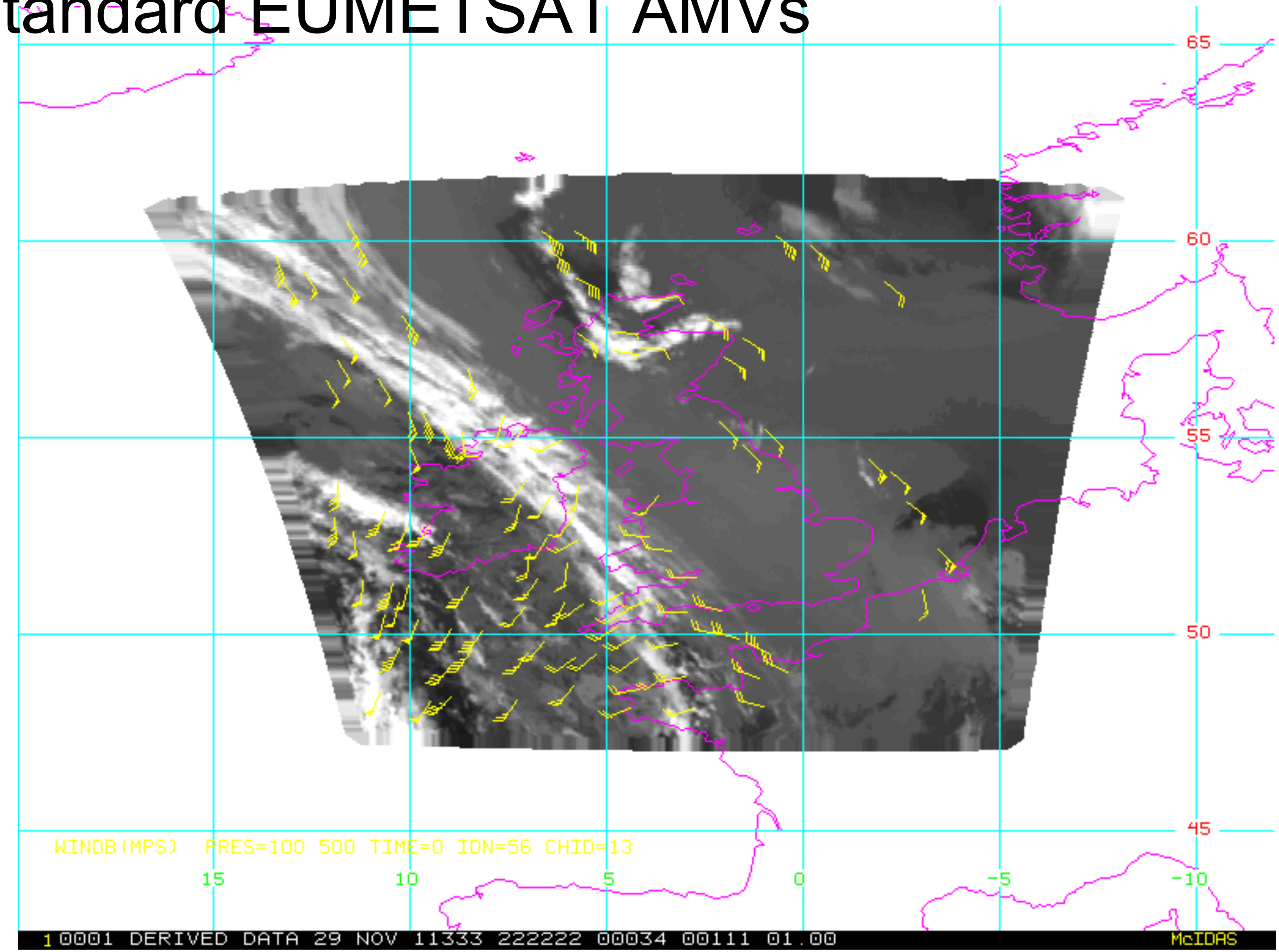
NWCSAF package workflow



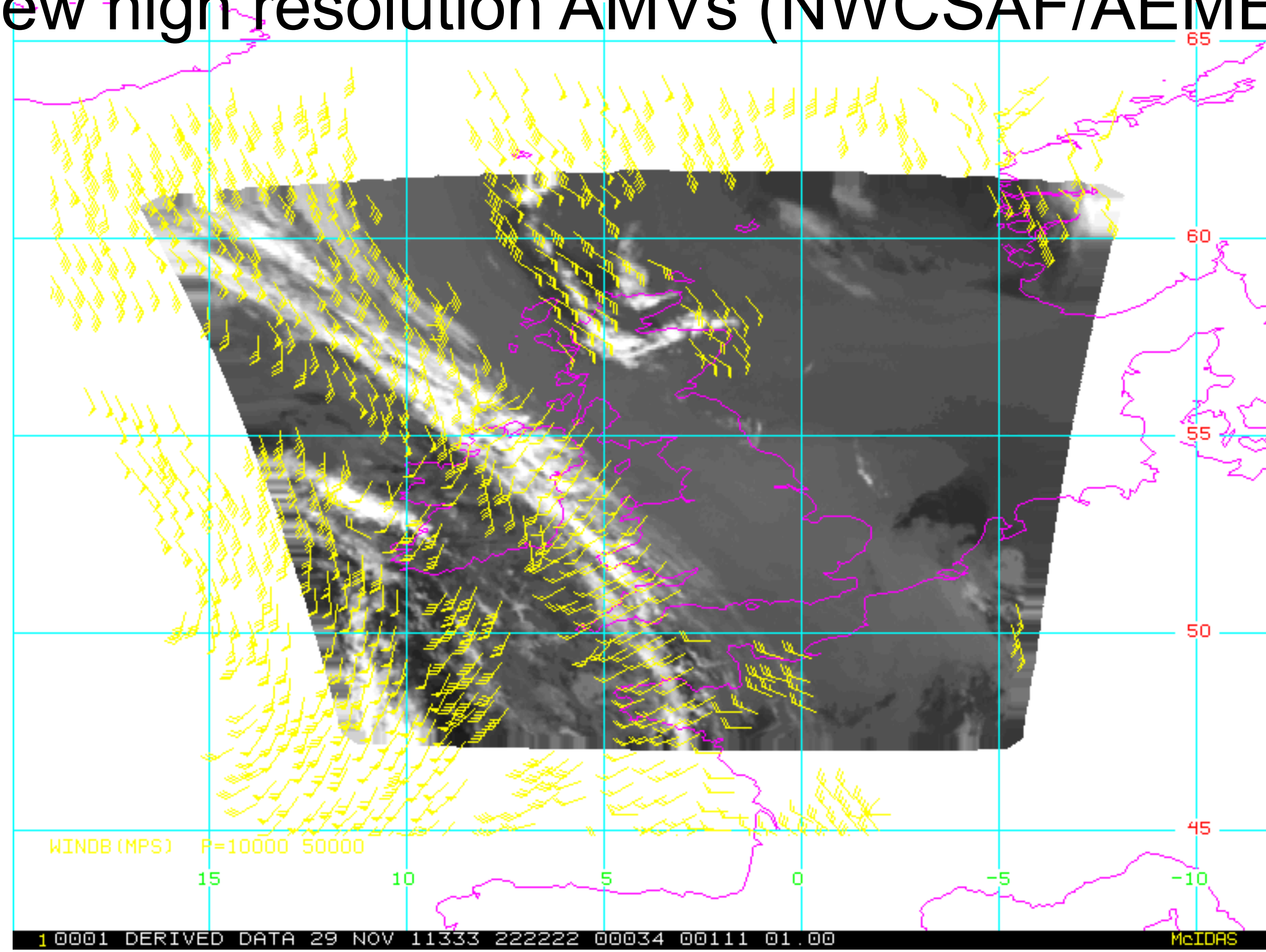
AMV configuration

- 24x24 tracking box (no ‘detailed’ winds)
- 15 minute time interval between frames
- ‘CCC’ method for height assignment
- 10.8µm channel winds only
- 2011 v3.1 NWCSAF code

Standard EUMETSAT AMVs



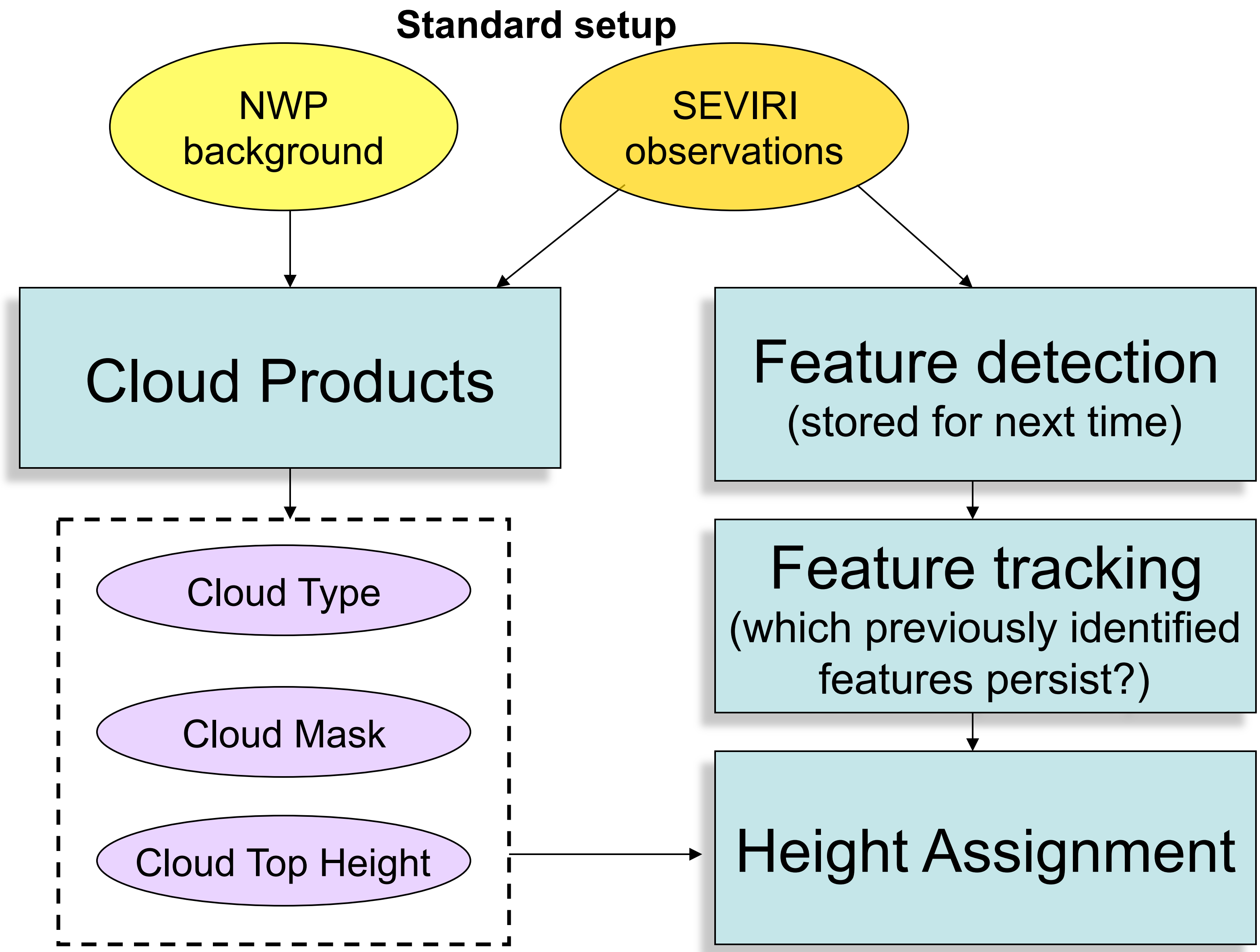
New high resolution AMVs (NWCSAF/AEMET)



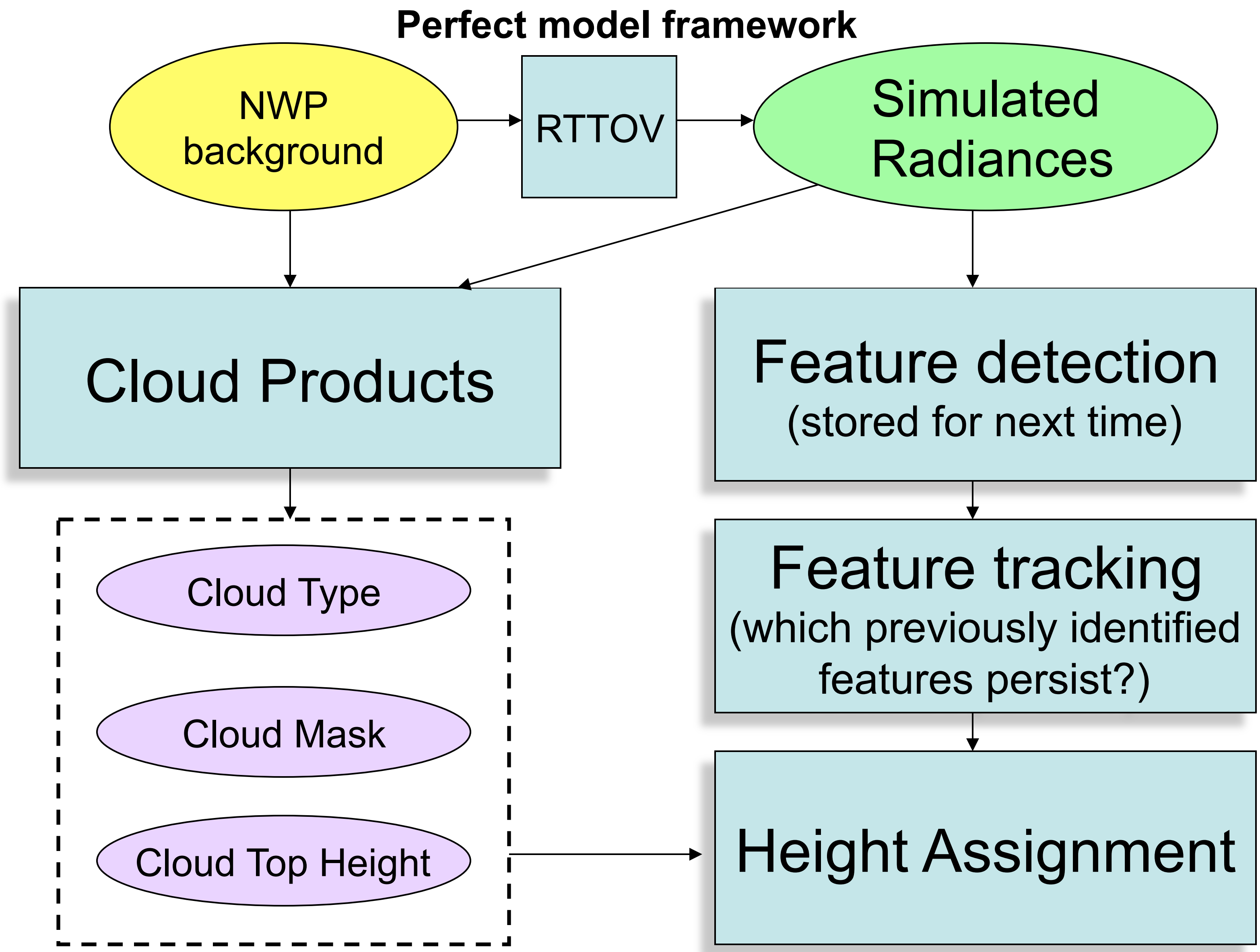
Part 2:

Producing synthetic model-derived AMVs –a case study

NWCSAF package workflow

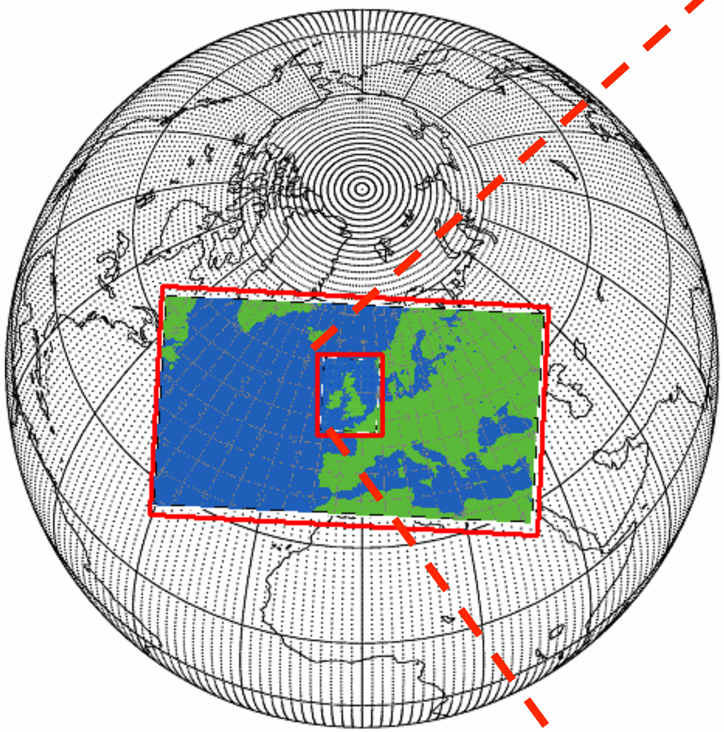


NWCSAF package workflow



Met Office operational NWP models

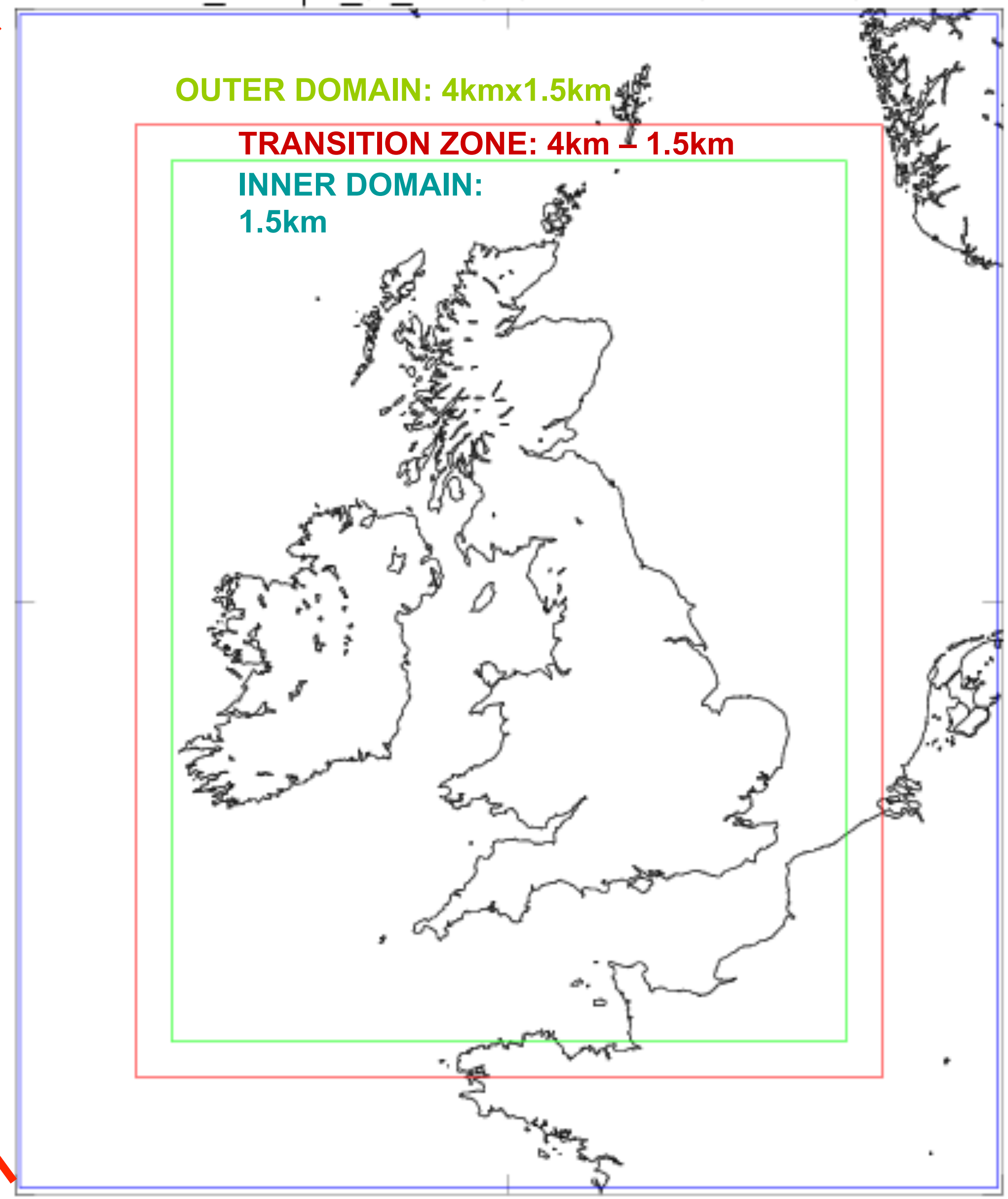
Global: 25km grid, L70 80km lid



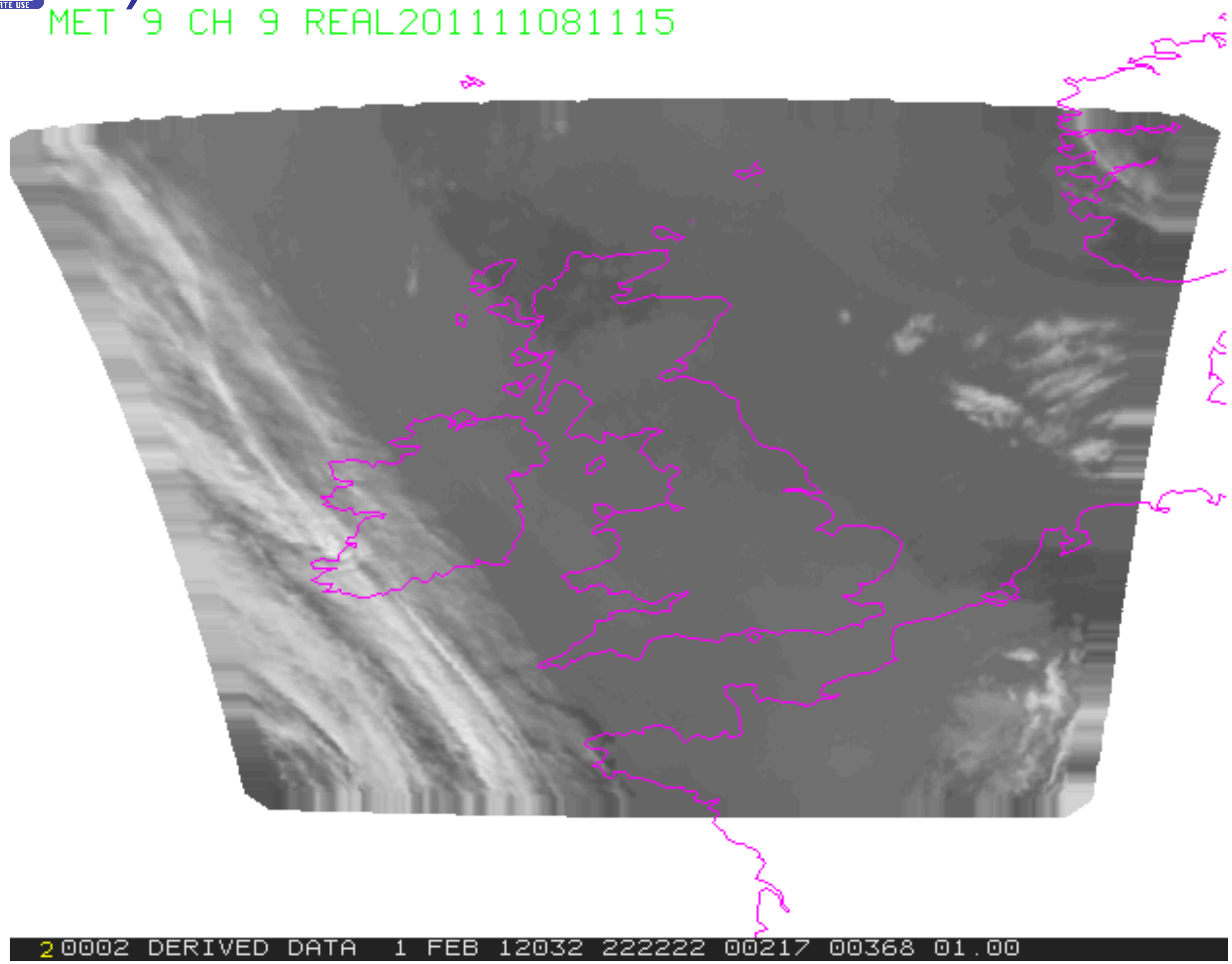
N.Atlantic: 12km grid, L70 80km lid

UK: 1.5km grid, L70 40km lid

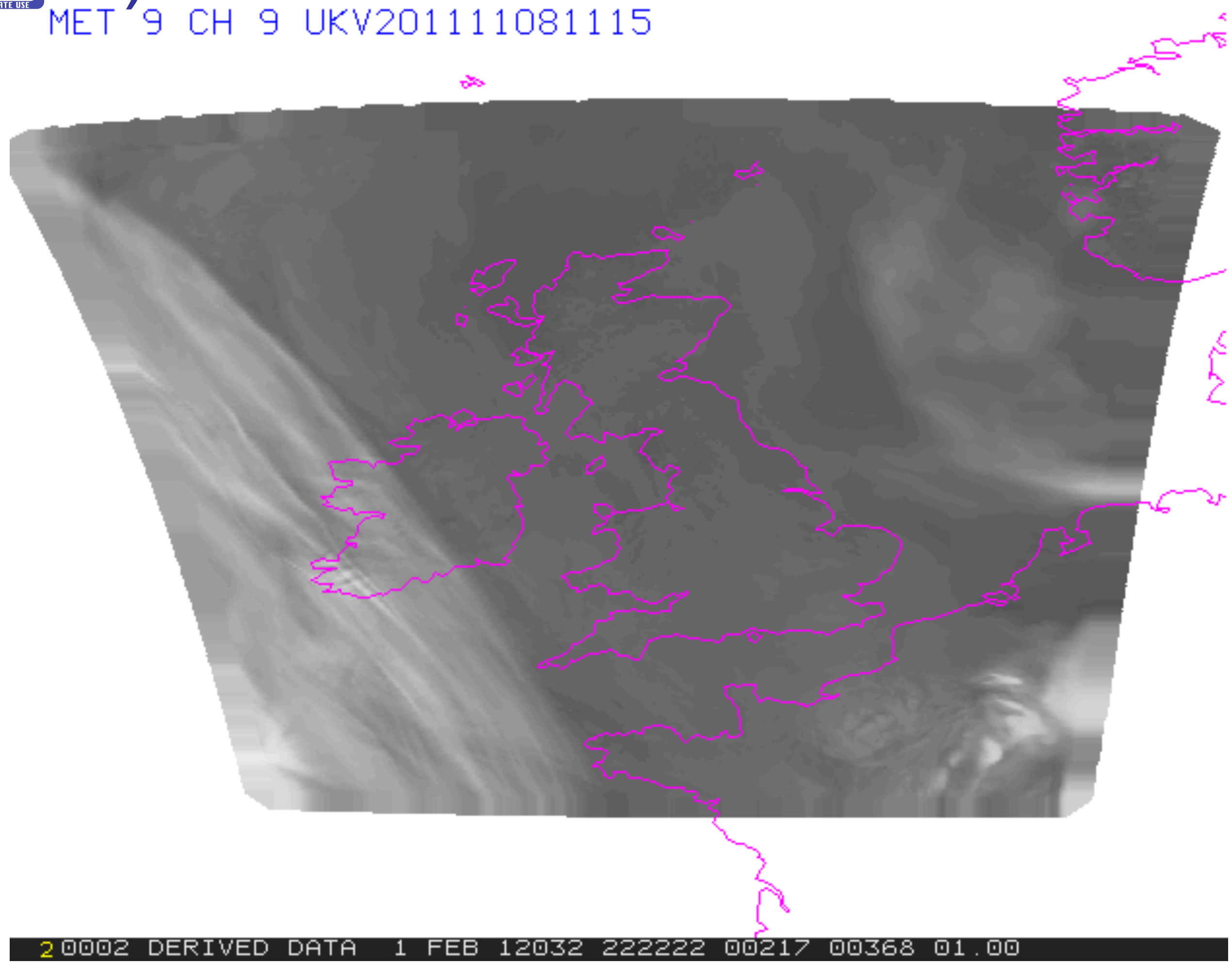
UKV_D5 1p5_to_4 Variable Resolution Domain



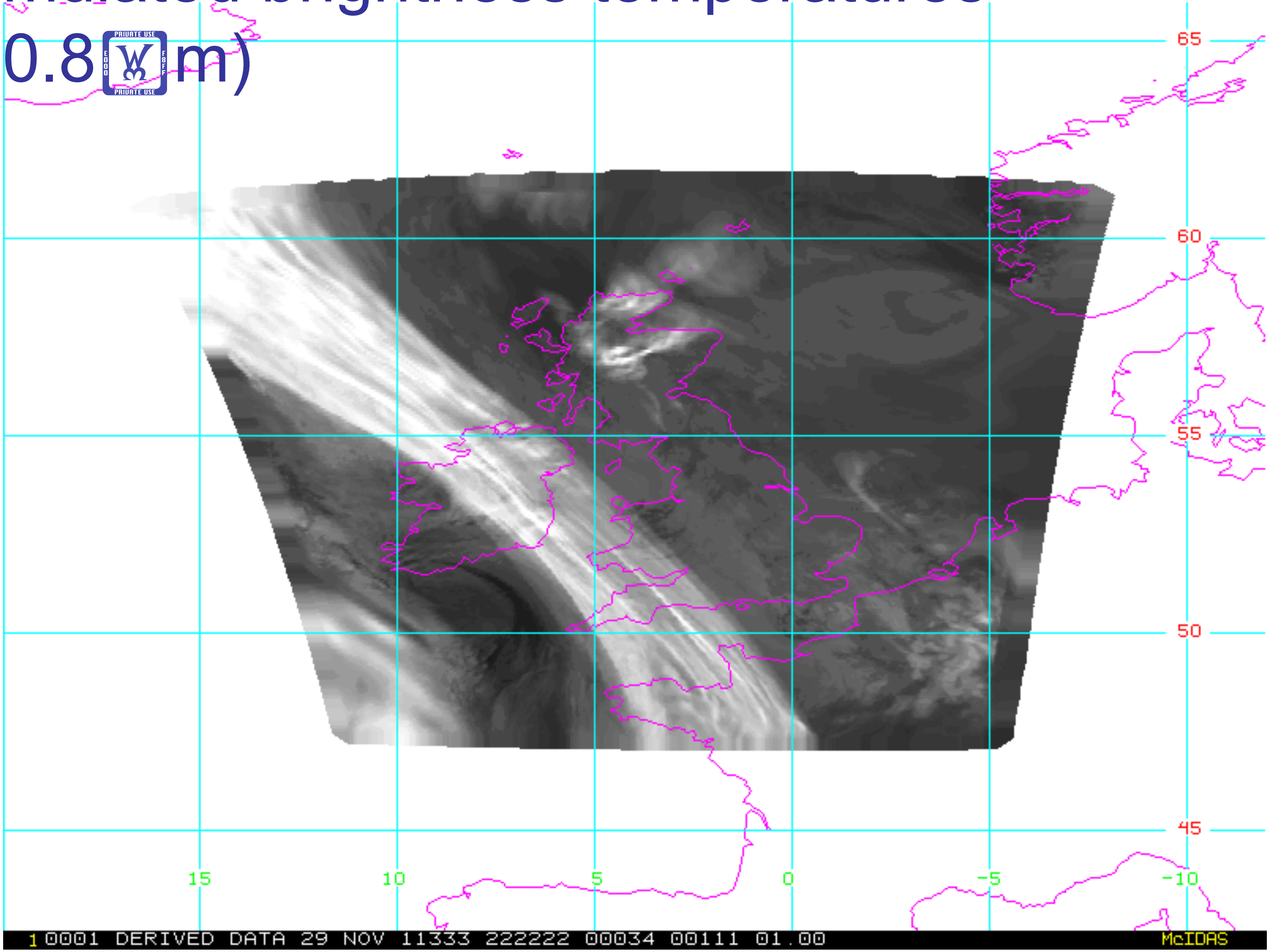
Observed brightness temperatures (10.8μm)



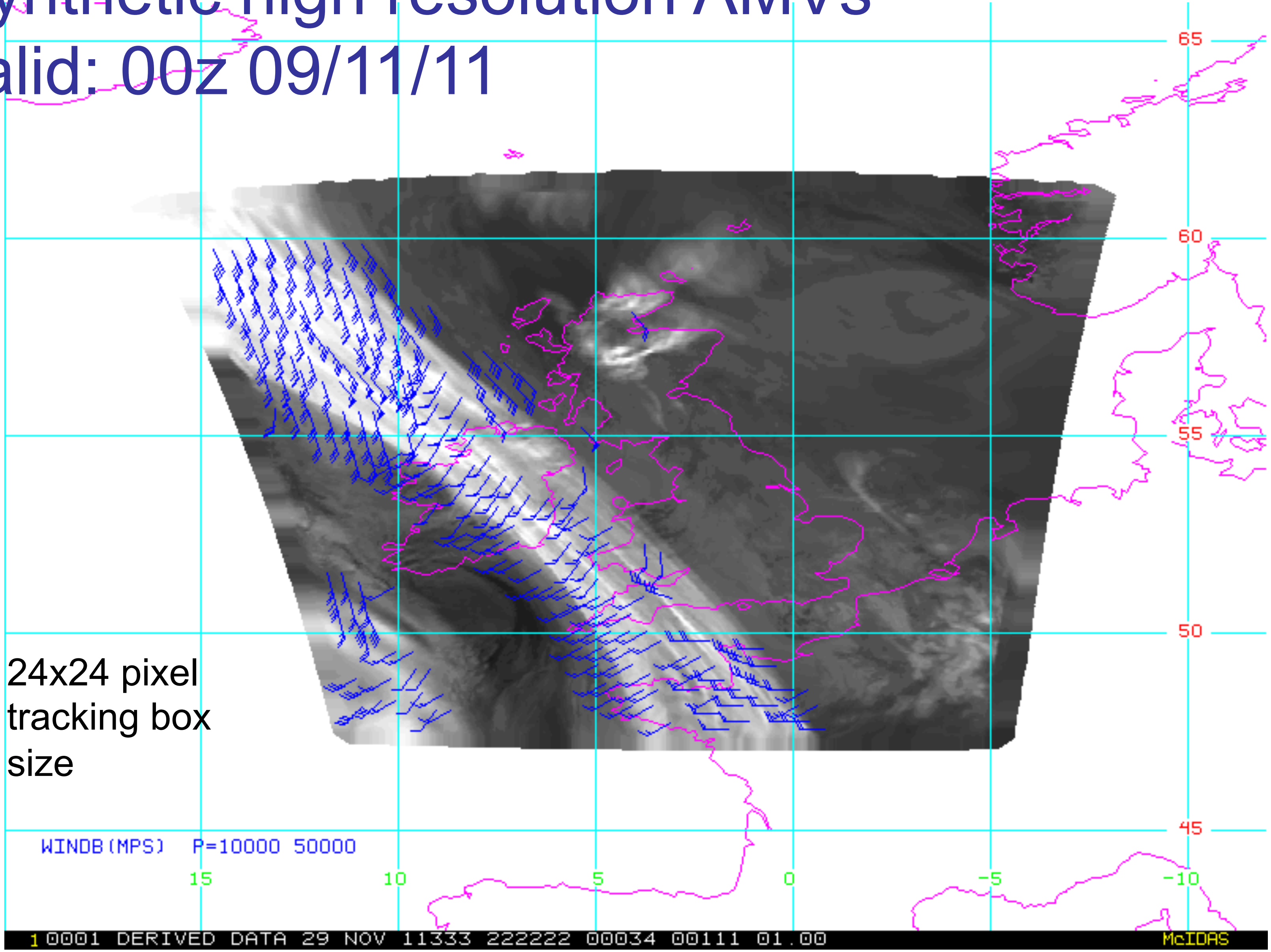
Simulated brightness temperatures (10.8μm)



Simulated brightness temperatures (10.8μm)

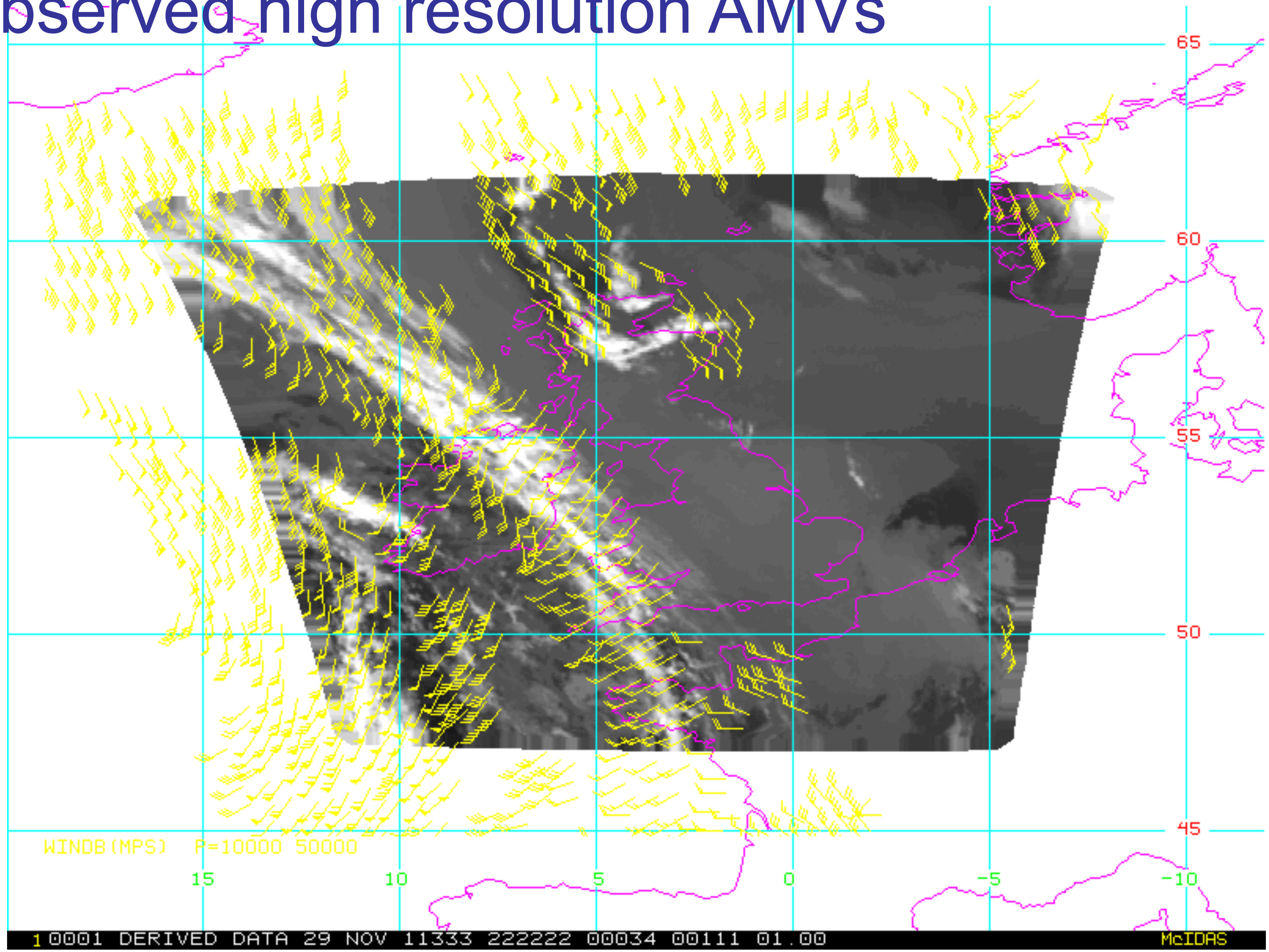


Synthetic high resolution AMVs valid: 00z 09/11/11



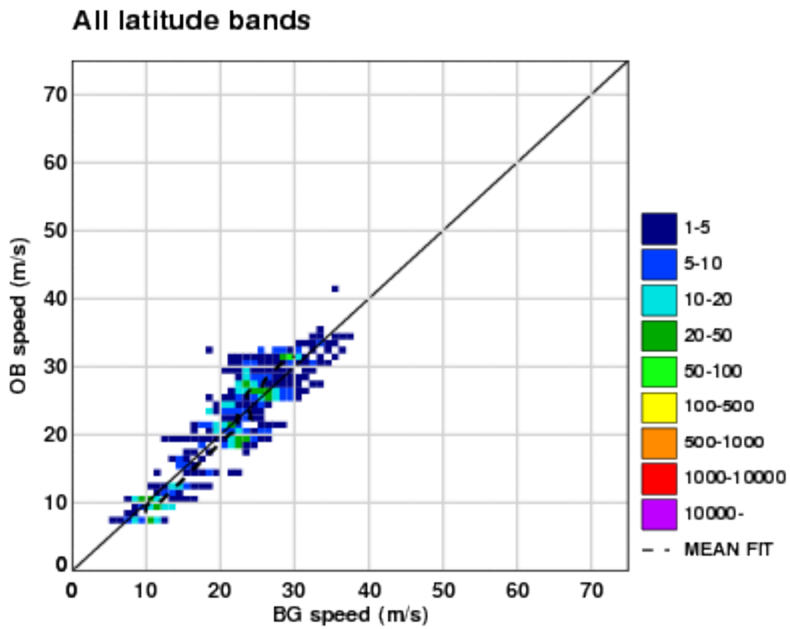
24x24 pixel tracking box size

Observed high resolution AMVs



Speed:
synthetic AMV v model truth
at assigned height

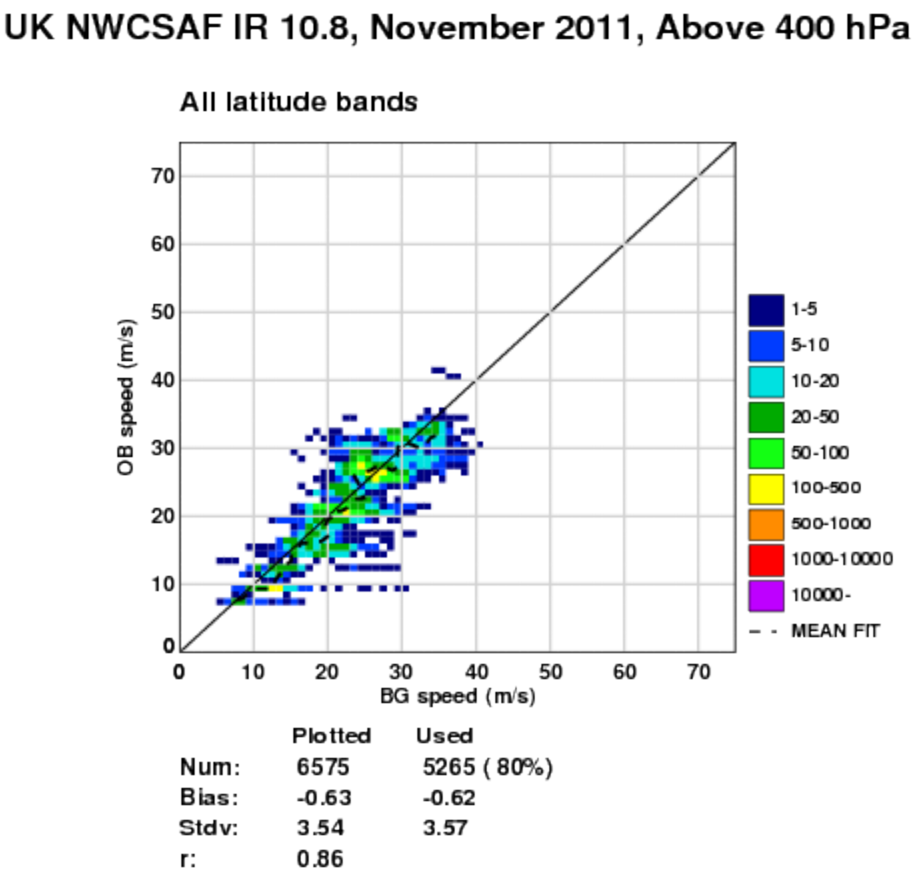
UK NWCSAF IR 10.8, November 2011, Above 400 hPa



	Plotted	Used
Num:	1406	1129 (80%)
Bias:	0.27	0.26
Stdv:	2.99	3.04
r:	0.92	

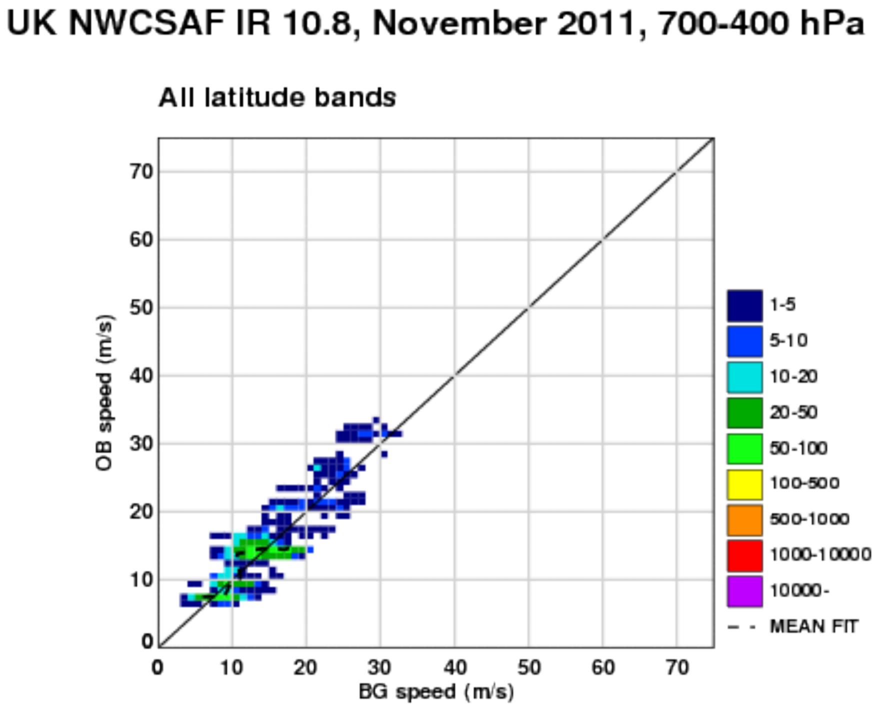
High Clouds Only

Speed:
real AMV v ECMWF background at assigned height



High Clouds Only

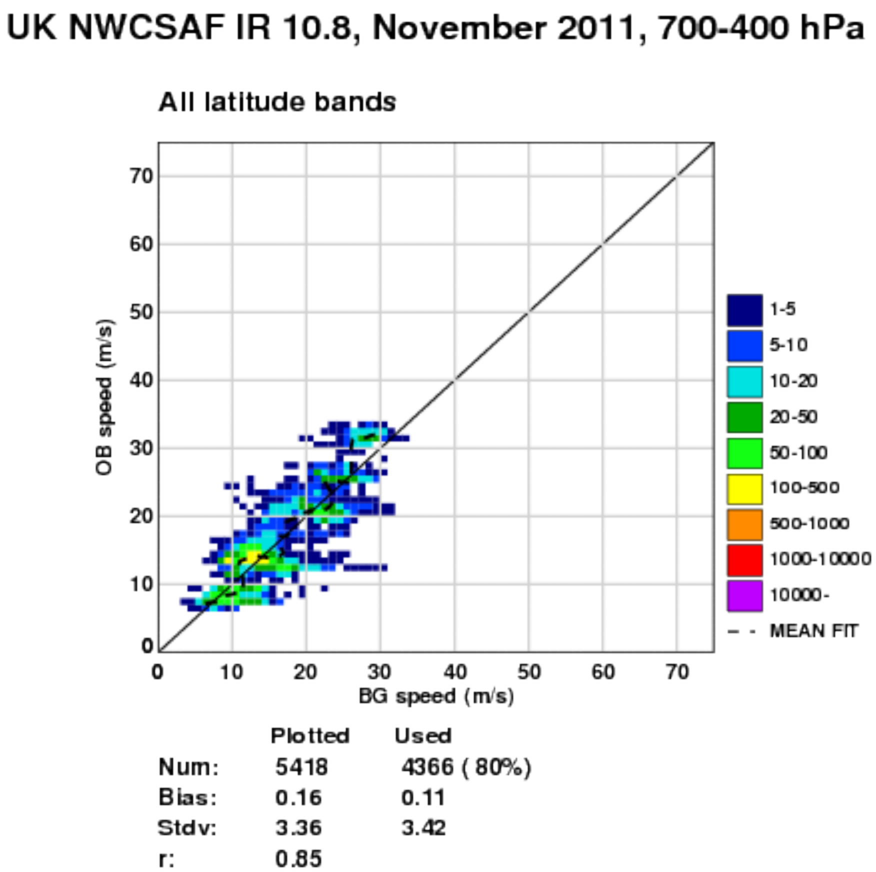
Speed:
synthetic AMV v model truth
at assigned height



	Plotted	Used
Num:	2157	1793 (83%)
Bias:	0.15	0.14
Stdv:	2.66	2.69
r:	0.87	

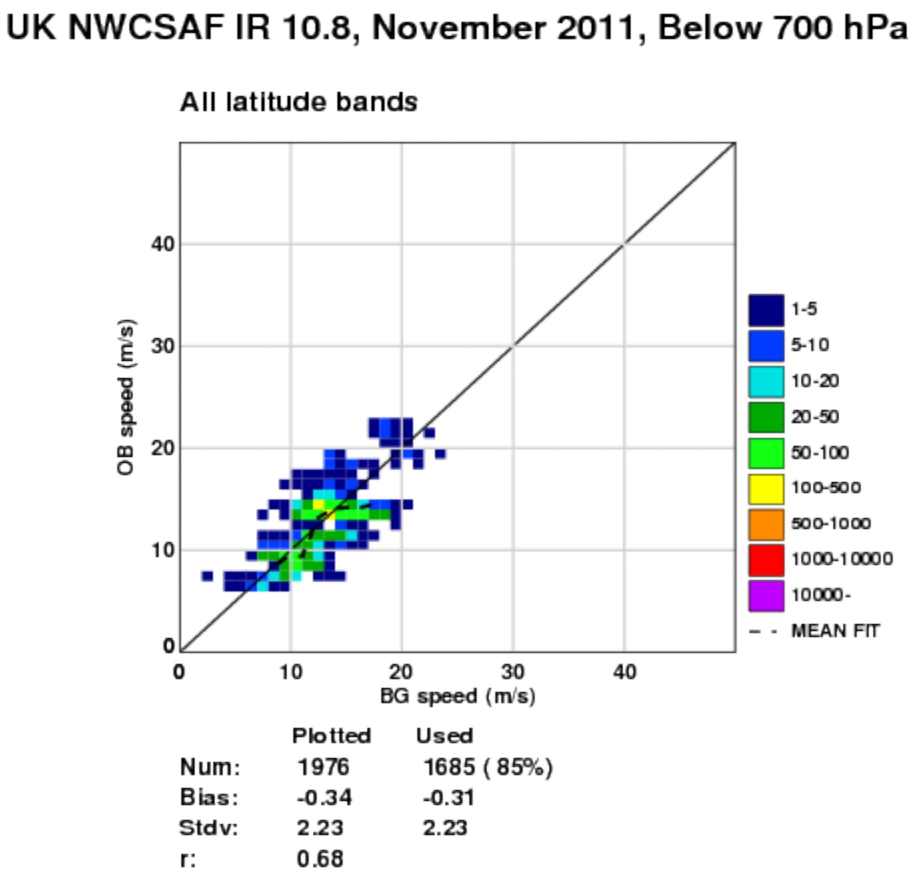
Medium Clouds Only

Speed: real AMV v ECMWF background at assigned height



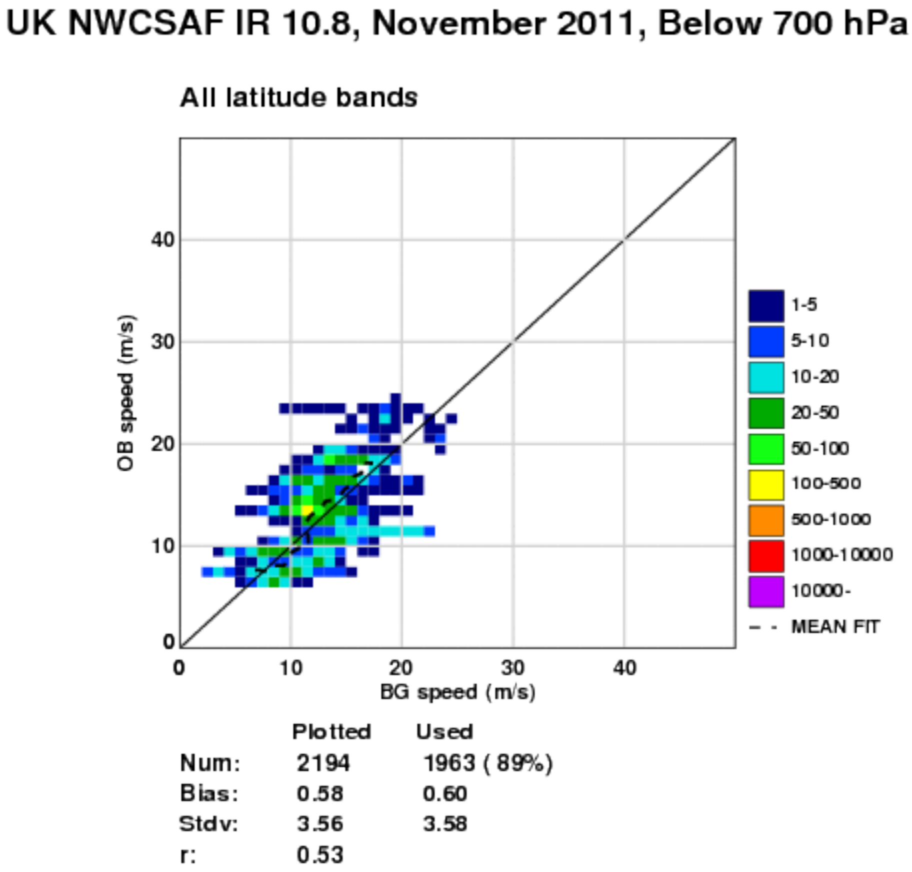
Medium Clouds Only

Speed:
synthetic AMV v model truth at assigned height



Low Clouds Only

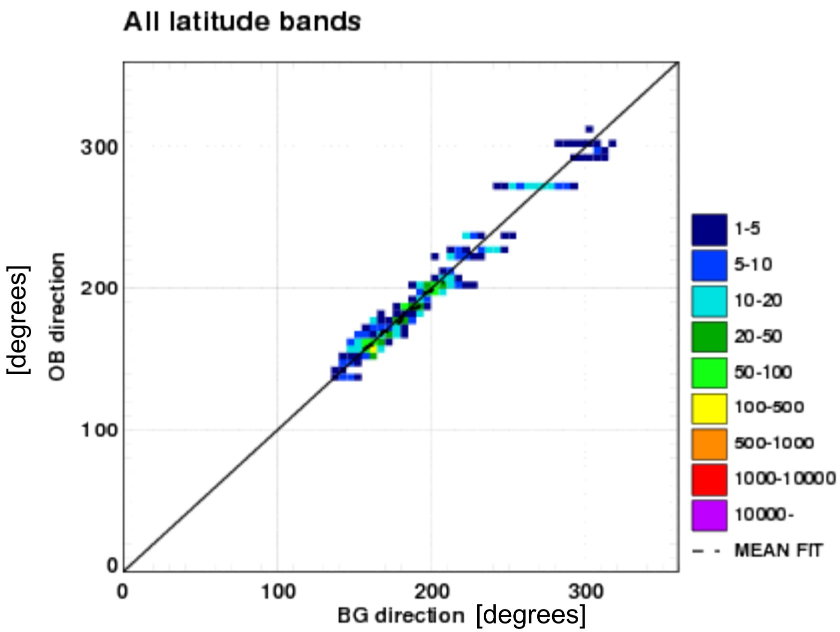
Speed: real AMV v ECMWF background at assigned height



Low Clouds Only

Direction:
synthetic AMV v model truth
at assigned height

UK NWCSAF IR 10.8, November 2011, Above 400 hPa

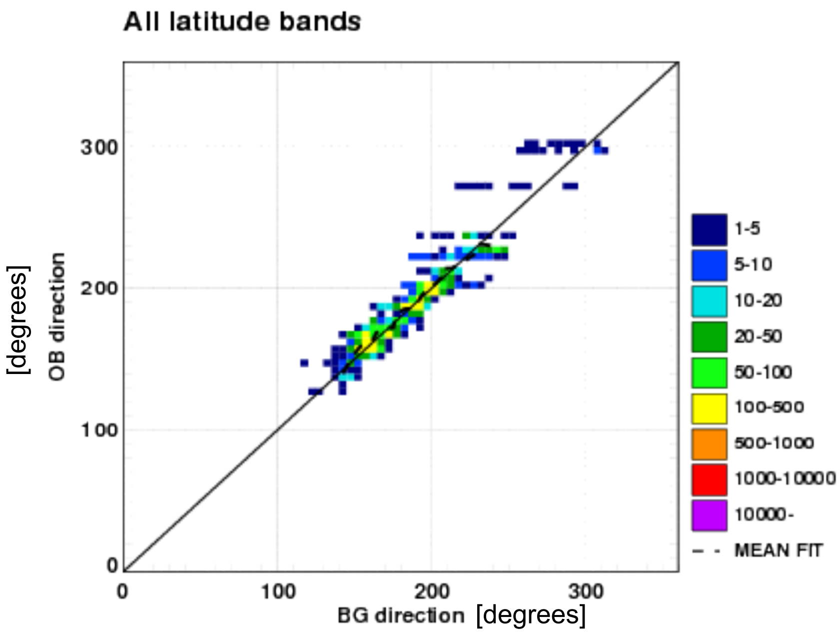


	Plotted	Used
Num:	1406	1129 (80%)
Bias:	-0.79	-0.56
Stdv:	6.85	6.91
r:	0.98	

High Clouds Only

Direction: real AMV v ECMWF background at assigned height

UK NWCSAF IR 10.8, November 2011, Above 400 hPa

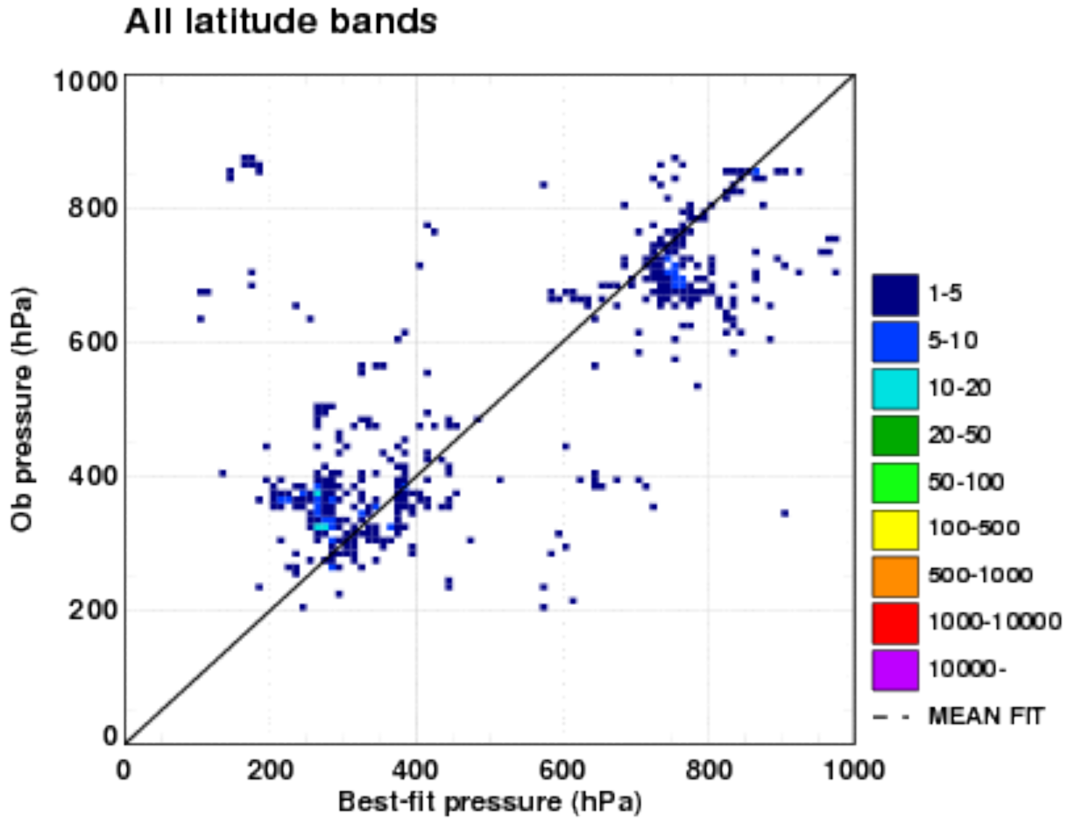


	Plotted	Used
Num:	4601	3691 (80%)
Bias:	1.28	1.48
Stdv:	7.62	7.67
r:	0.95	

High Clouds Only

Best fit pressure level: synthetic AMVs

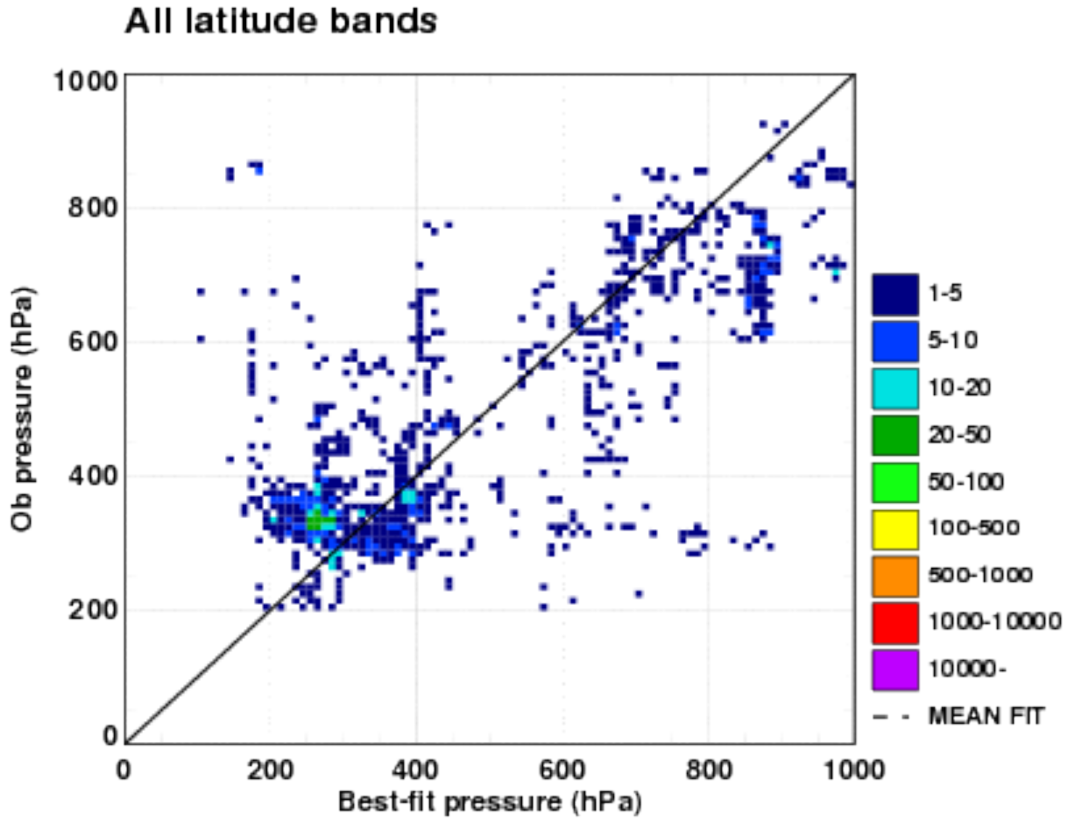
UK NWCSAF IR 10.8, November 2011, All levels



	Plotted	Used
Num:	725	600 (82%)
Bias:	23.62	23.65
Stdv:	149.46	157.77
r:	0.78	

Best fit pressure level: real AMVs

UK NWCSAF IR 10.8, November 2011, All levels



	Plotted	Used
Num:	1996	1642 (82%)
Bias:	0.63	-0.89
Stdv:	147.01	150.27
r:	0.80	

Plans

- Categorize results by cloud type:
  - Are error characteristics the same for all cloud types?
  - Does AMV representivity change according to cloud type?
    - e.g. should height assignment be the same for thin cirrus as for a deep convective storm?

- Observation error correlation:
  - Model 'truth' known at every AMV location.
  - Use "Hollingsworth-Lonnberg" method to quantify error correlations.
  - Use results to inform thinning length scales used in assimilation.

- Sensitivity to tracking box size:
  - Larger tracking boxes track large scale flow
  - What size tracking box has best relationship with model grid-scale winds?

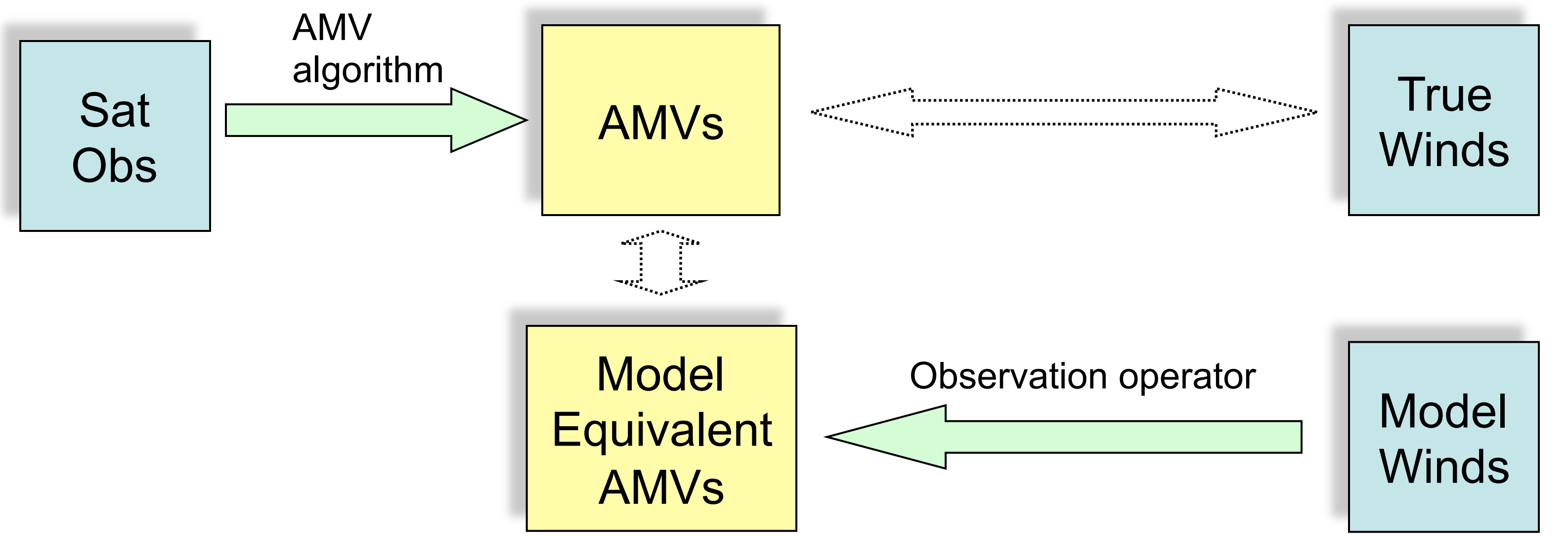
- Design and test an improved observation operator.

Validating wind estimates:

$$\varepsilon_{\text{AMV\_wind\_estimate}} = \varepsilon_{\text{tracking}} + \varepsilon_{\text{height assignment}} + \varepsilon_{\text{representivity}}$$

$$\varepsilon_{\text{height assignment}} = \varepsilon_{\text{CTH product}} + \varepsilon_{\text{pixel selection}}$$

$$\varepsilon_{\text{CTH product}} = \varepsilon_{\text{radiative transfer}} + \varepsilon_{\text{model background}} + \varepsilon_{\text{observation (bt)}}$$



In observation space:

$\underline{\mathbf{v}}$ = atmospheric motion vector (**not** wind vector)

$$\delta\underline{\mathbf{v}}_{\text{O-B}} = \delta\underline{\mathbf{v}}_{\text{forecast error}} + \delta\underline{\mathbf{v}}_{\text{observation operator error}}$$

Error sources

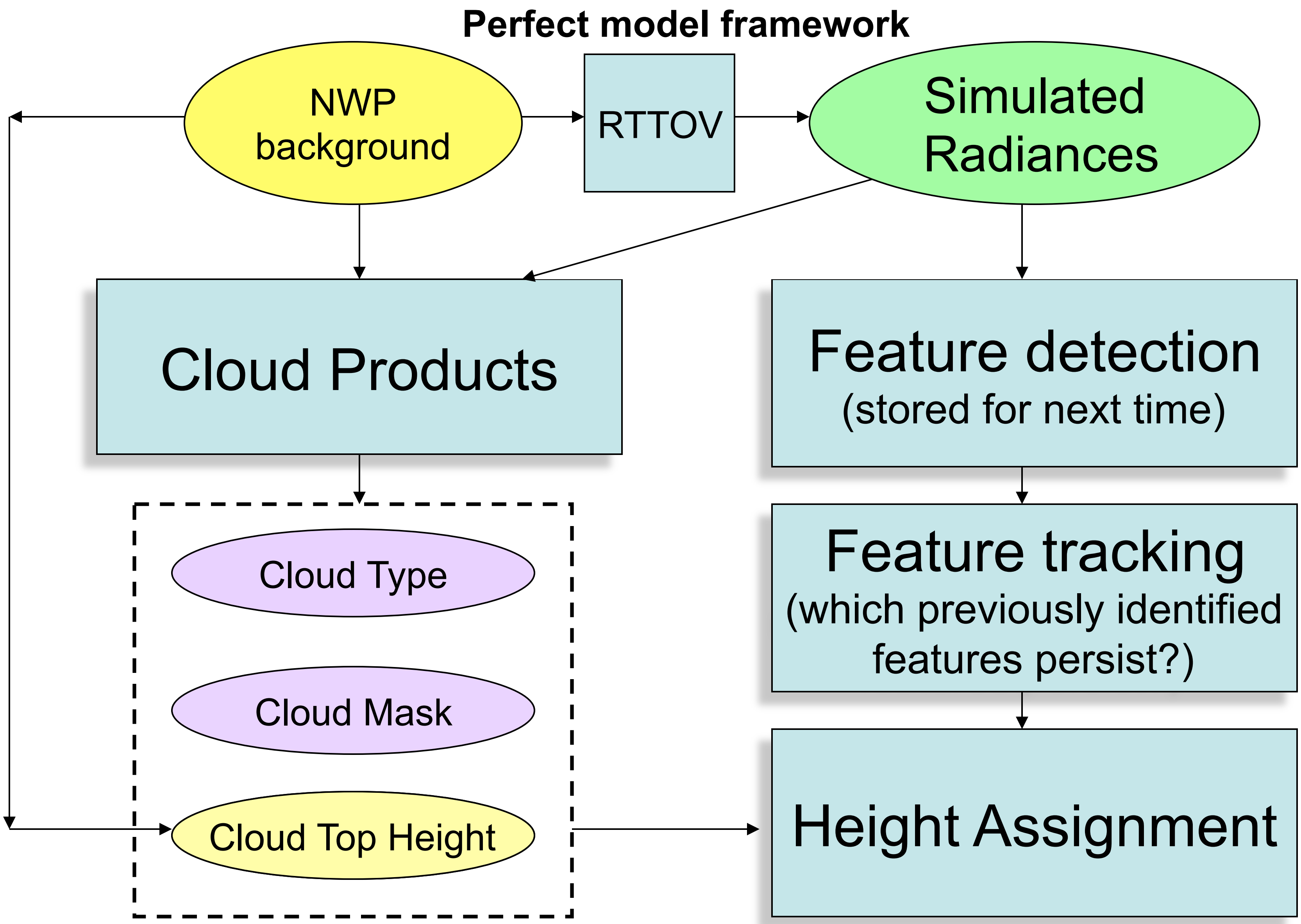
In model space

$$\varepsilon_{\text{AMV\_wind\_estimate}} = \varepsilon_{\text{tracking}} + \varepsilon_{\text{height assignment}} + \varepsilon_{\text{representivity}}$$

$$\varepsilon_{\text{height assignment}} = \varepsilon_{\text{CTH product}} + \varepsilon_{\text{pixel selection}}$$

$$\varepsilon_{\substack{\text{CTH product} \\ \text{(bt)}}} = \varepsilon_{\text{radiative transfer}} + \varepsilon_{\text{model background}} + \varepsilon_{\text{observation}}$$

NWCSAF package workflow



Summary

- A new perfect model framework has been set up to study the relationship between AMVs and the true wind vectors.
  - Technical challenges now complete.
  - Starting work on interesting science.

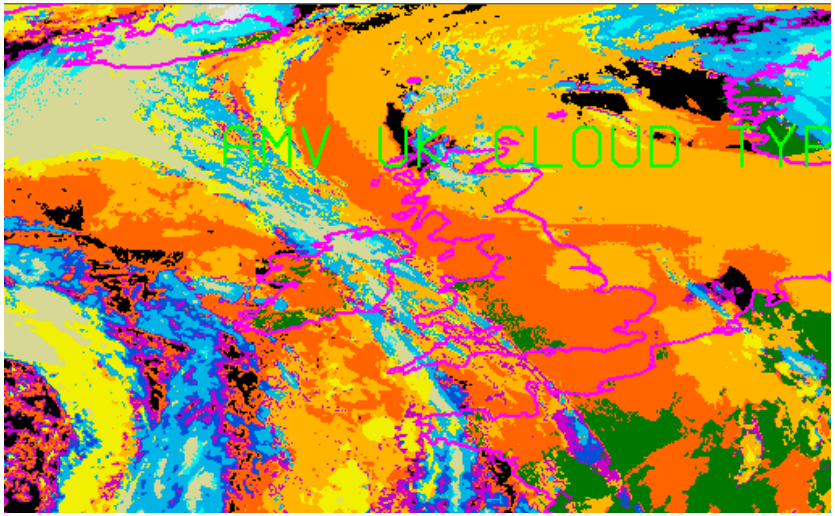
- Preliminary results presented from a case study.

- System has great potential:
  - Allows different contributions to total AMV error to be isolated and quantified.
  - Results will be used to inform the design of an improved AMV observation operator for mesoscale models.

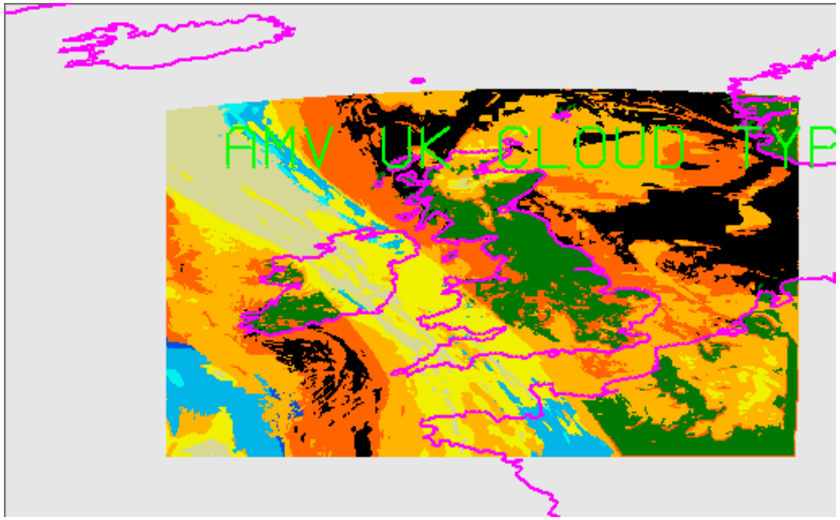
- **Suggestions for further uses of this system would be very welcome.**

Thanks for listening

Cloud Type Product



Obs

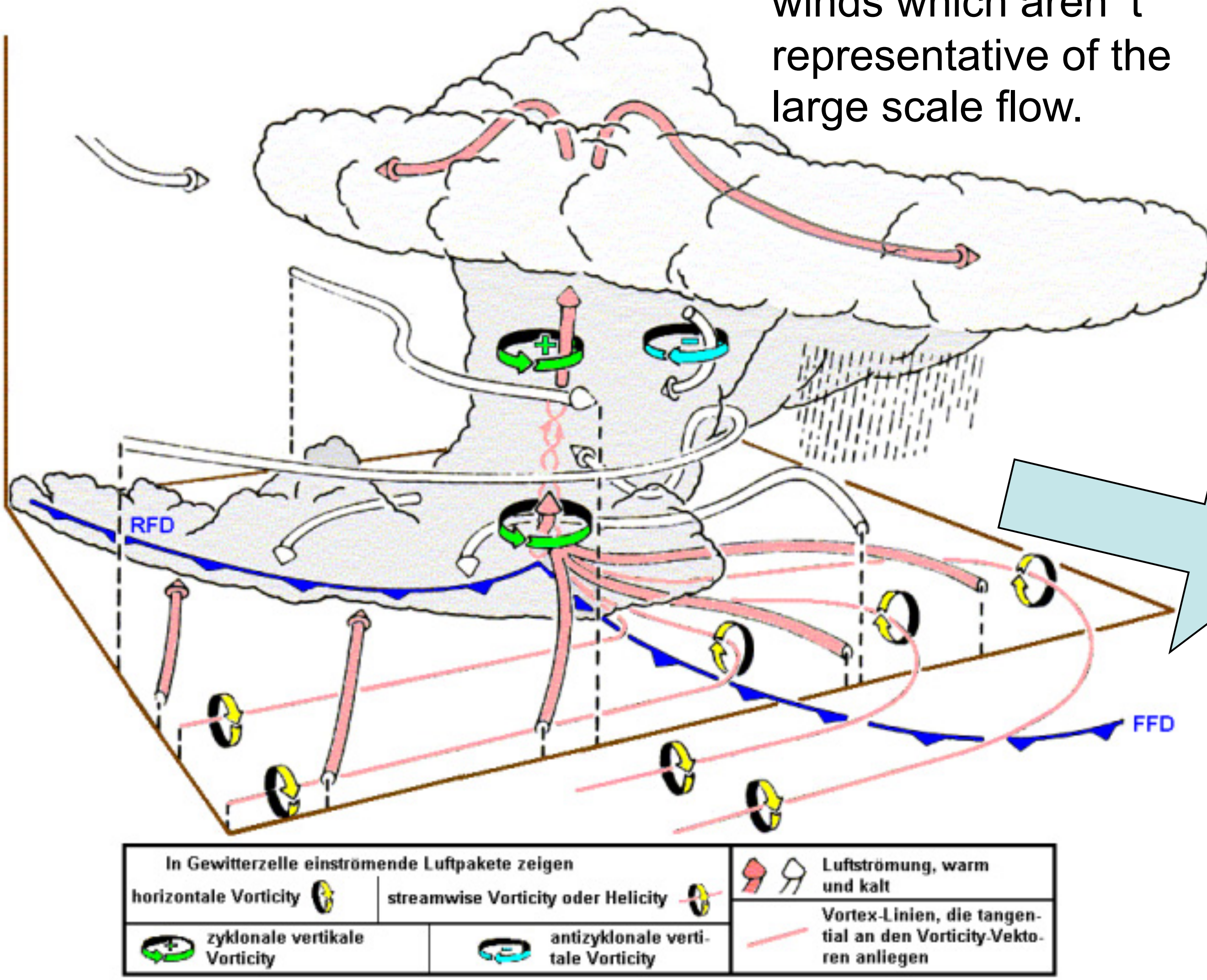


Model

What do we need an AMV to represent?

- Storm creates local winds which aren’t representative of the large scale flow.

- A global model with 30km grid boxes can’t resolve the storm or its local winds, so high res AMVs may make analysis worse.



- A high resolution mesoscale model can resolve the storm so may benefit from high res AMVs.

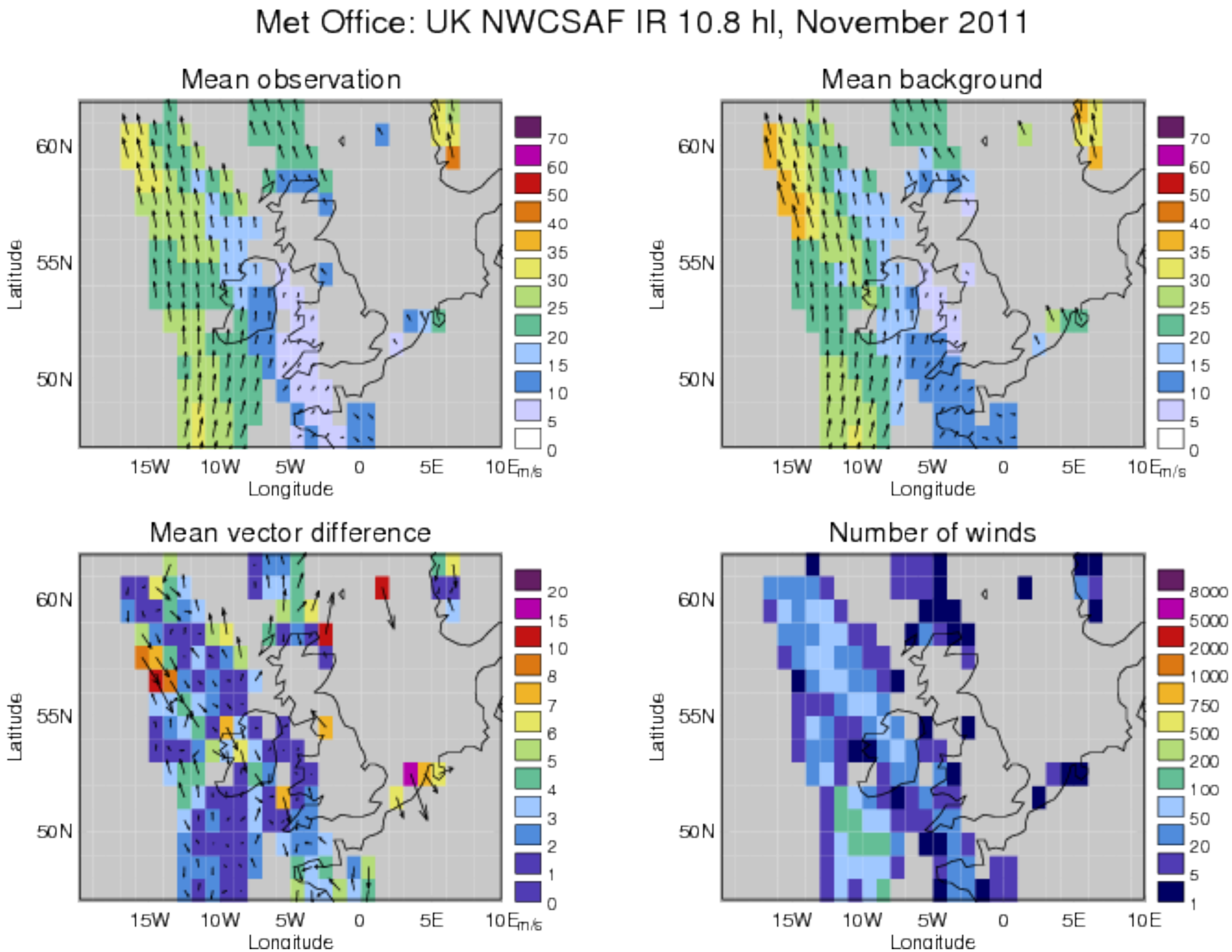
Image courtesy of ZAMG

What do we need AMVs to represent?

Spatial Scale	Time Scale	Features tracked
1000's km	~days	Movement of synoptic systems
100's km	~hours	Movement of fronts / troughs
10's km	30-60 mins	Movement of convective storms
1km	minutes	Local winds within convective storm systems

Vector Difference

High Clouds Only



Error sources

<u>In observation space</u>

$\underline{\mathbf{V}}$ = atmospheric motion vector (**not** wind vector)

$$\delta\underline{\mathbf{v}}_{\text{O-B}} = \cancel{\delta\underline{\mathbf{v}}_{\text{forecast error}}} + \delta\underline{\mathbf{v}}_{\text{observation operator error}}$$

Perfect model framework