# AVHRR Polar Winds Derivation at EUMETSAT: Current Status and Future Developments

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## Background

- METOP-A polar orbiting satellite launched October 2006
- Operated by EUMETSAT
- Joint European-US satellite system agreement foresees that both NOAA and EUMETSAT derive and provide polar wind data to users
- NOAA generate polar winds data from METOP AVHRR IR channel

## Overview of EUMETSAT Implementation

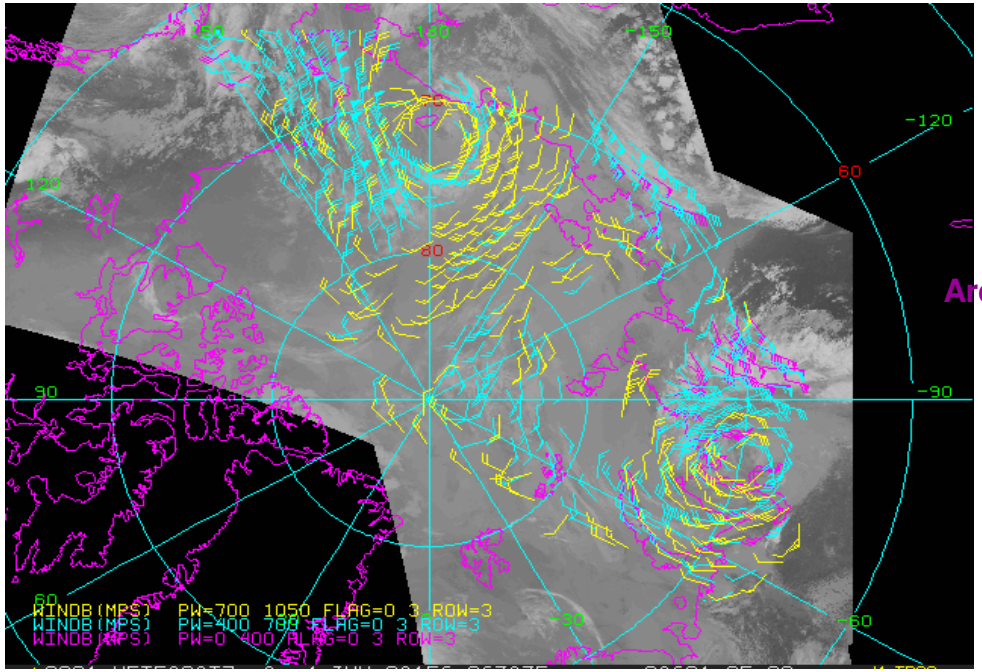
- Prototype Development based on CIMSS Polar Winds Code
- Operational Development
- Validation of operational version using prototype, ECMWF re-analysis, radiosonde data
- Pre-operational availability of products
- Assimilation experiments at ECMWF
- Routine Operations

## Prototype

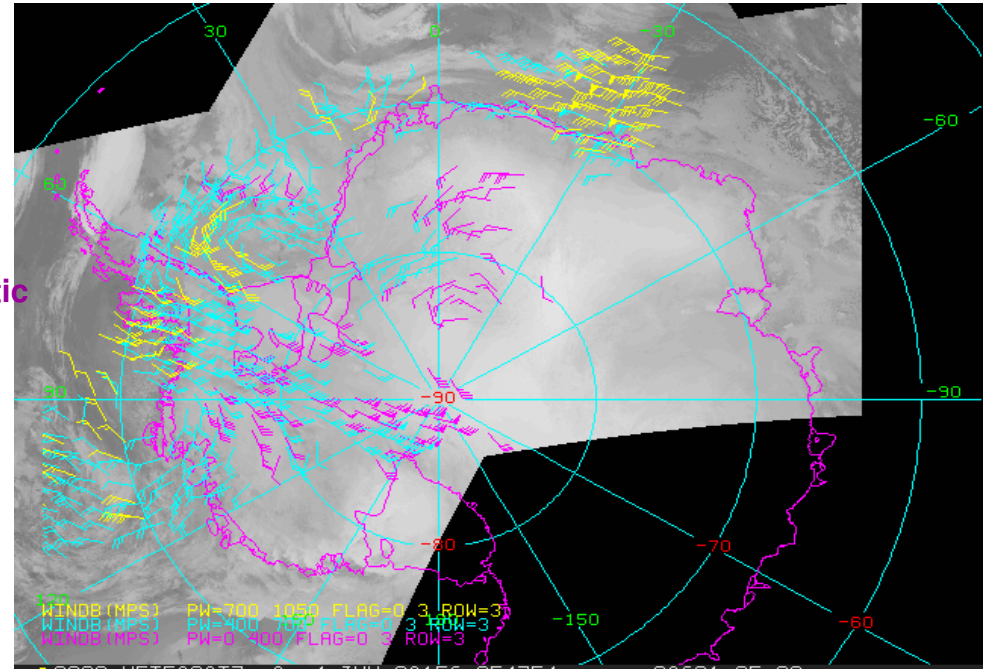
- Off-line post-processing tool - adapted CIMSS Polar Winds Code
- Mapping onto a polar stereographic grid
  - winds output twice per orbit (North, South Pole regions)
- Generates winds using triplets, ie sequences of 3 overlapping orbits
- Uses forecast data to provide a first guess of tracked target position
- IR window height assignment and RFF to adjust heights

# Prototype Example

## AVHRR polar cap wind fields




Arctic

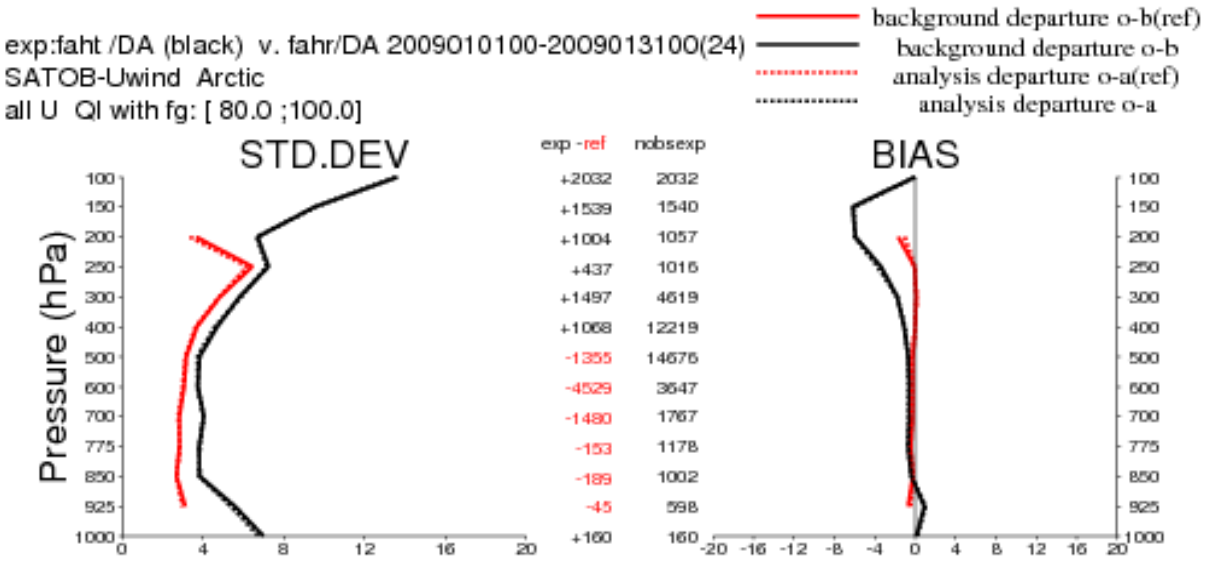


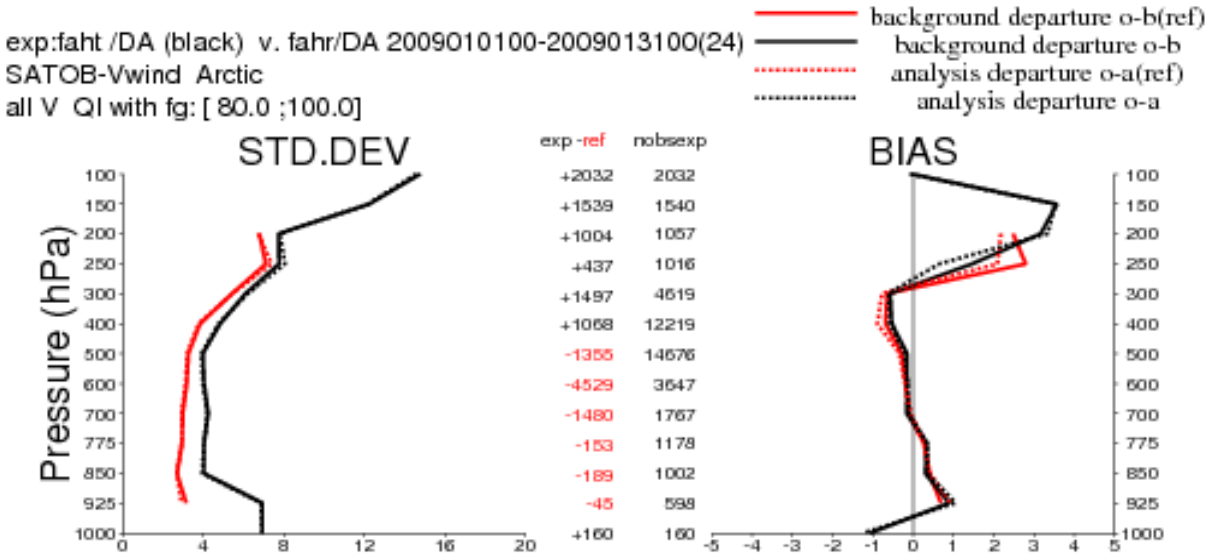

**Arctic** **Antarctic**

## Prototype Production Data Sets

- January 2009 AVHRR winds data set
- Co-locations with METOP-A IASI instrument derived cloud top information ($CO_2$ slicing method – potentially better for thin clouds)
- Data sets
  - winds co-located with IASI heights (prototype heights)
  - winds co-located with IASI heights (IASI heights)

# Prototype Data Sets ECMWF Observation Departures



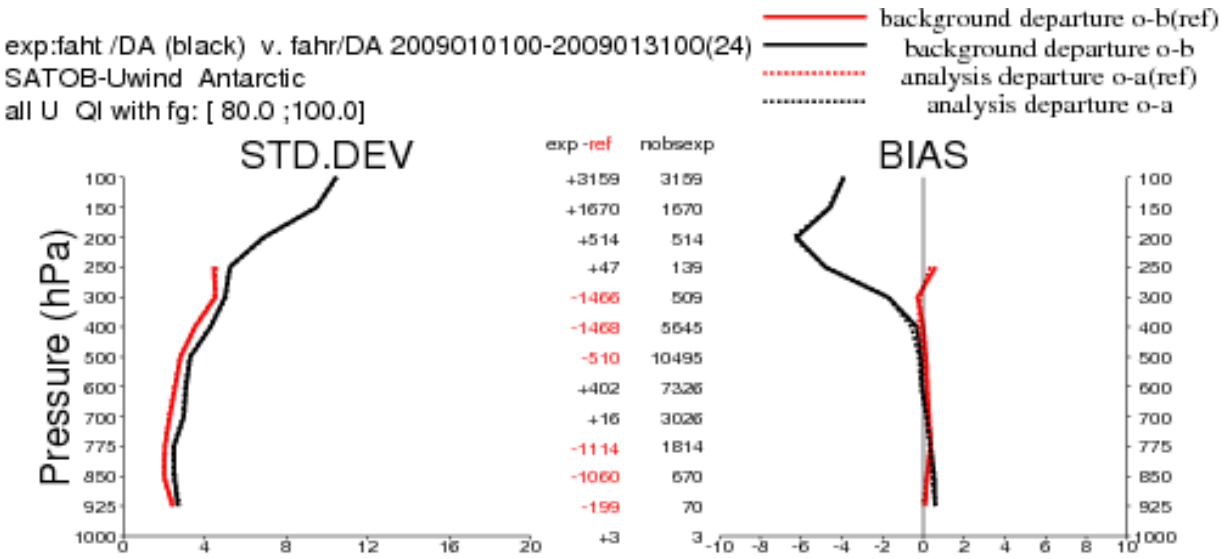

North Pole

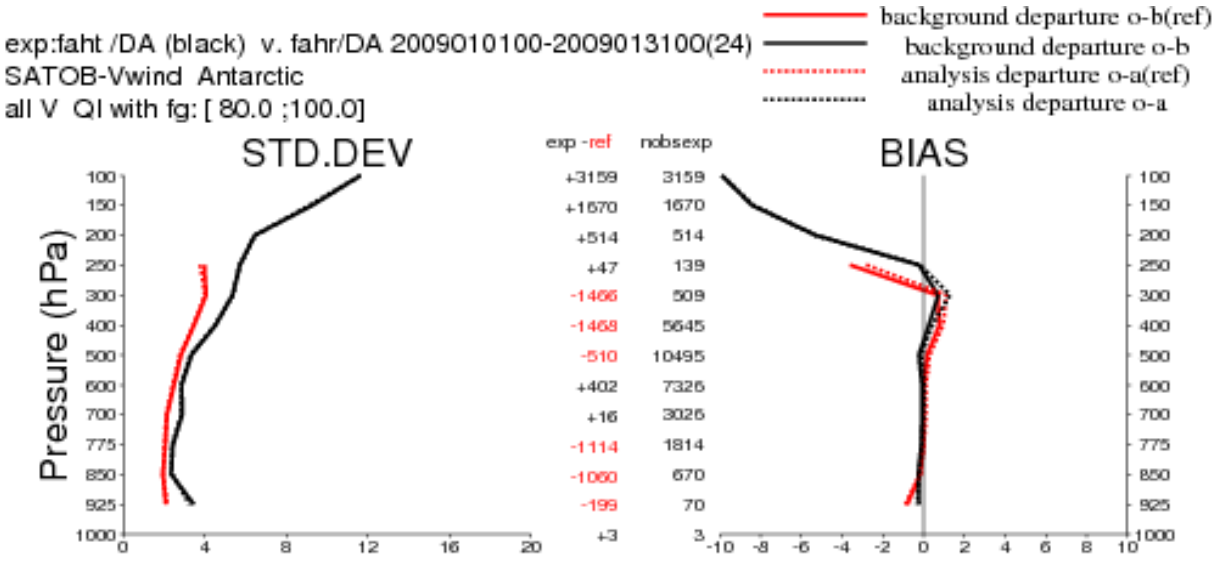
All AMVs, QI≥80

Prototype Heights – red

IASI Heights - black

# Prototype Data Sets ECMWF Observation Departures



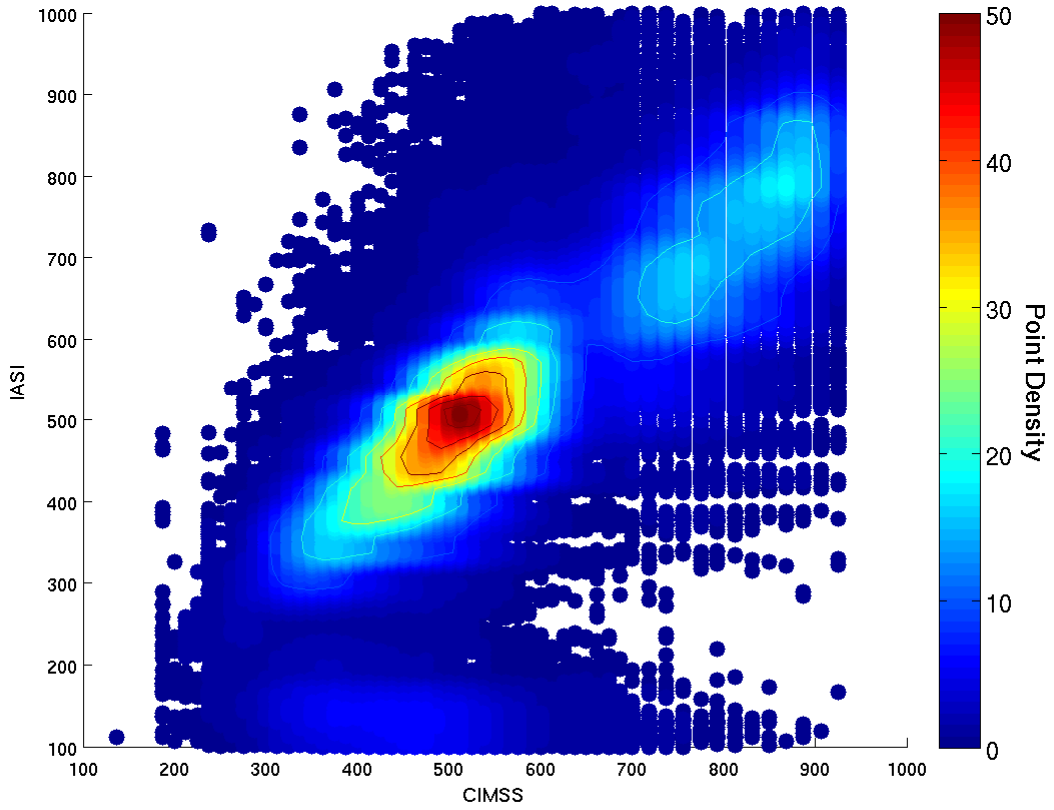

South Pole

All AMVs, QI≥80

Prototype Heights – red

IASI Heights - black

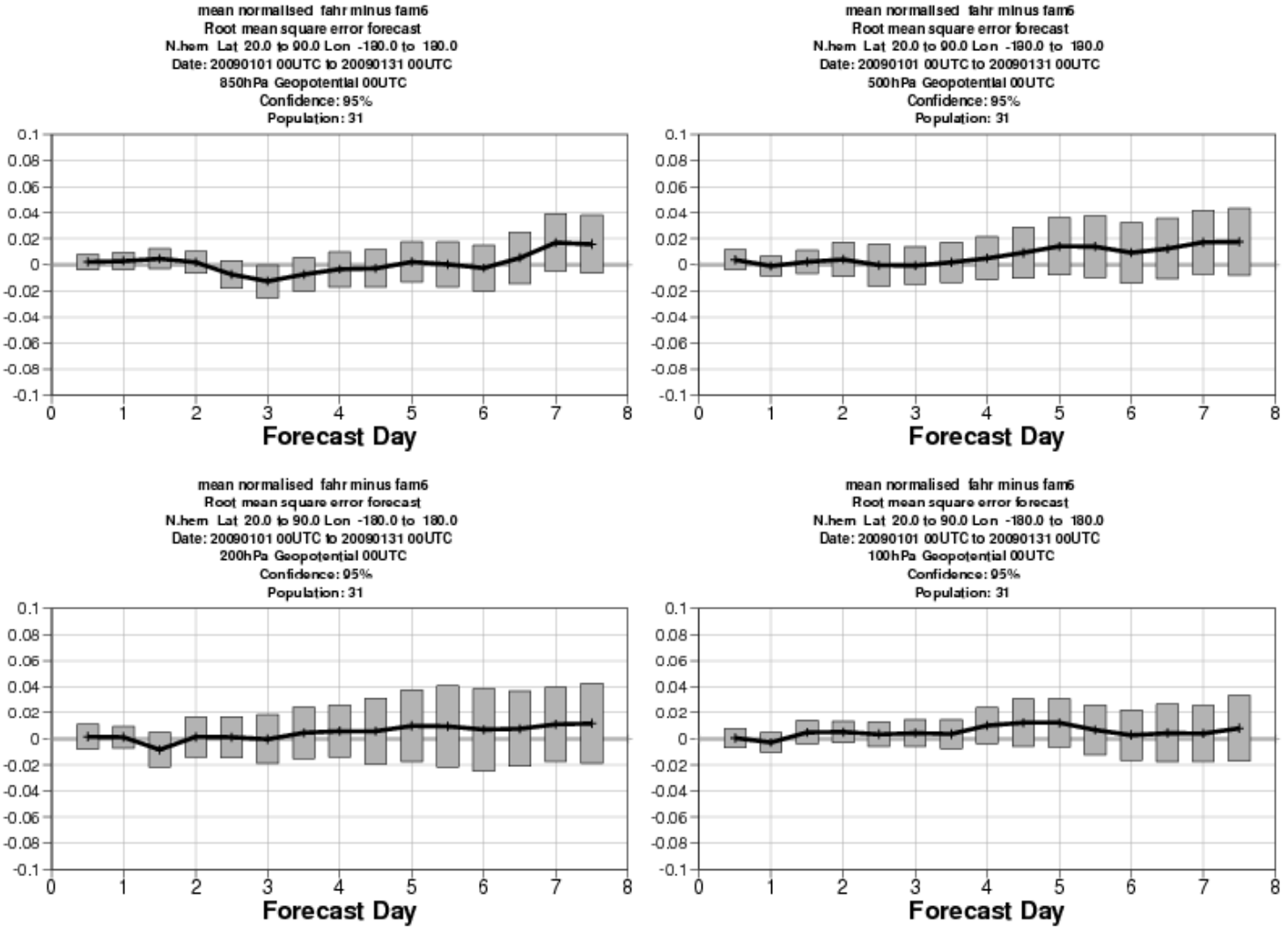
# Prototype Data Sets Height Coverage



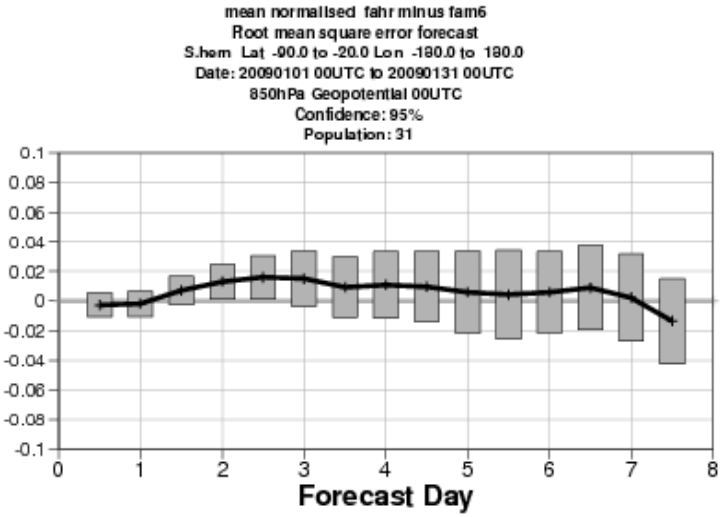

IASI version > 27 January 2009 – heights adjusted downwards

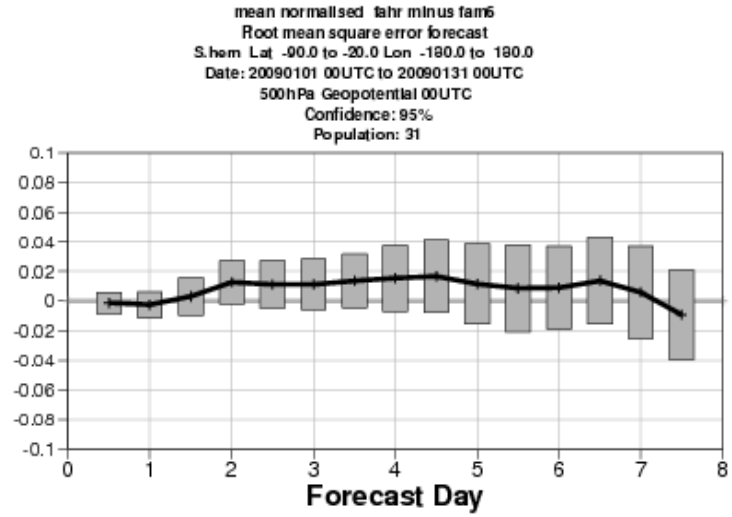
IASI Height Assignment Implementation further upgrades in pipeline

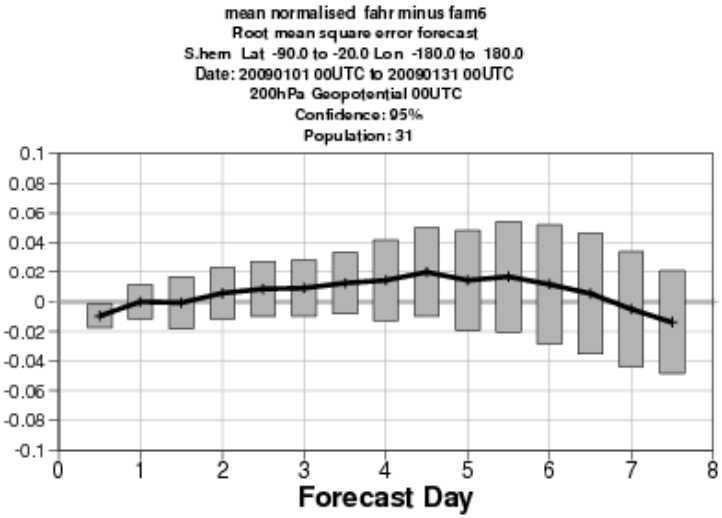
# Z norm diff of the RMS of FC Error as a function of forecast range – NH positive diff -> positive impact

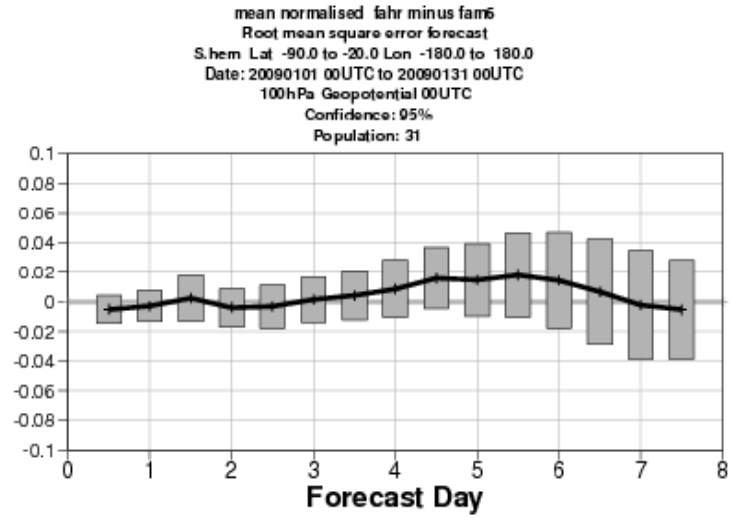


# Z norm diff of the RMS of FC Error as a function of forecast range – SH
# positive diff -> positive impact

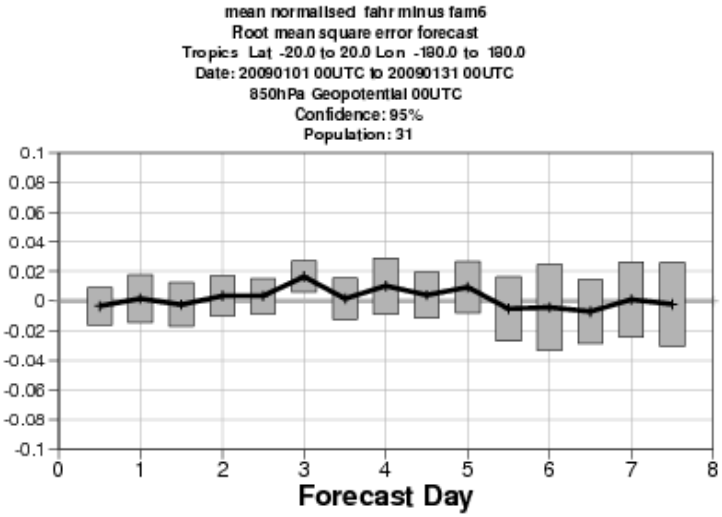


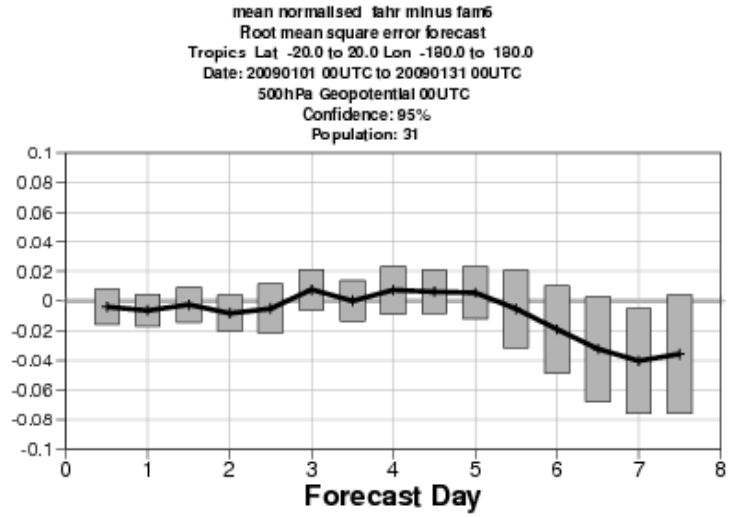



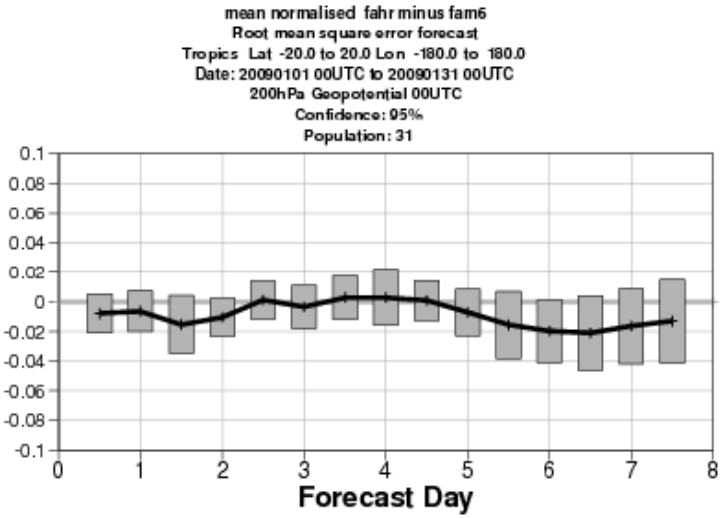



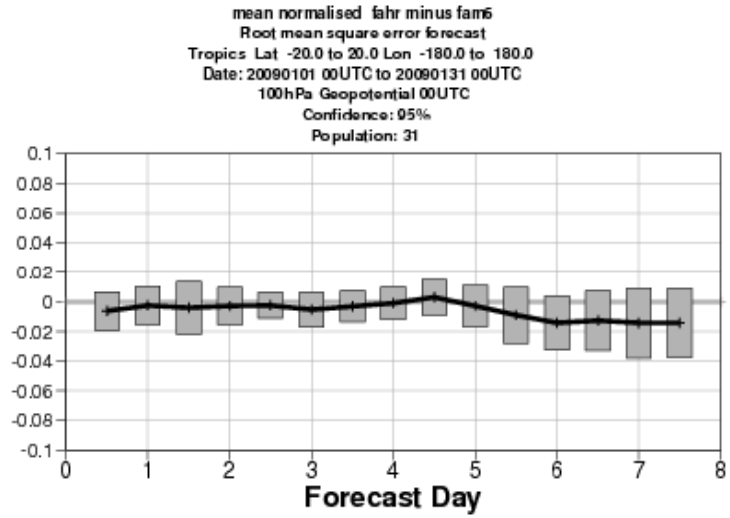



# Z norm diff of the RMS of FC Error as a function of forecast range –TR positive diff -> positive impact



## Prototype Data Sets ECMWF Impact Conclusions

- EUM Prototype (CIMSS height assignment) Polar Winds data set for January 2009 has a neutral impact on forecast
- Local 'positive' and 'negative' forecast impact regions are alternating and they don't show any trends
- IASI height assignment produces worse departure statistics
  - improvements expected
- ECMWF ideally require longer than one month worth of data

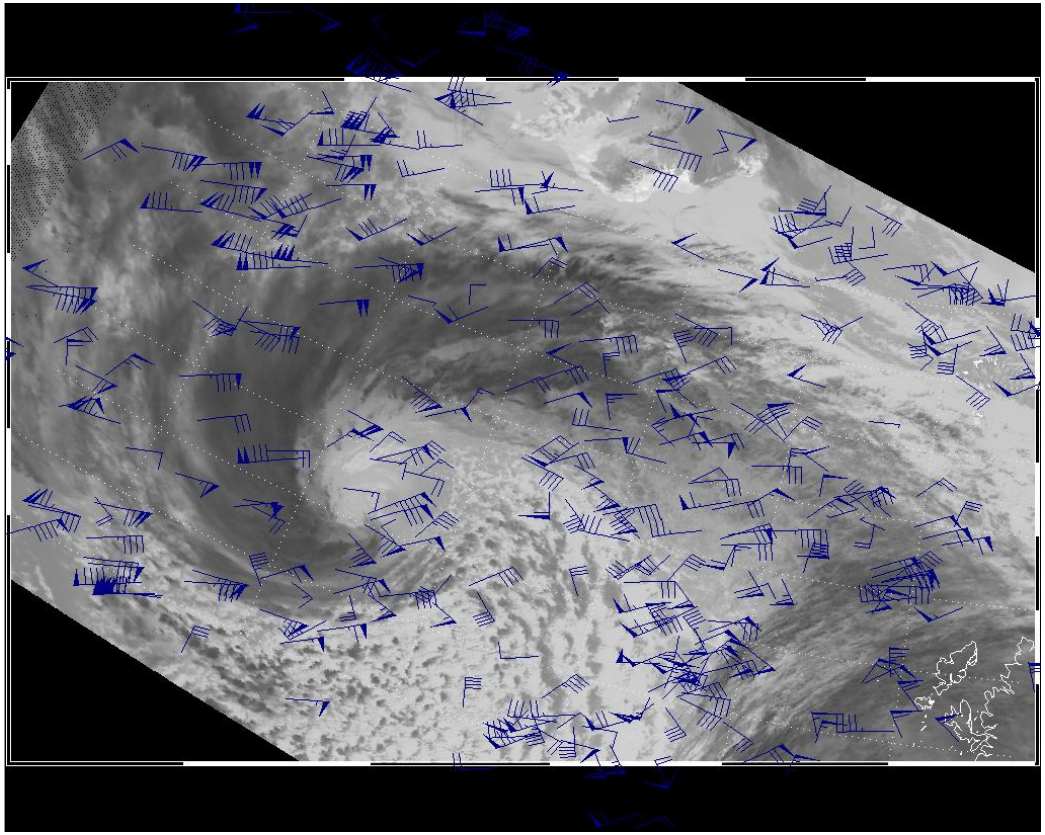
## EUMETSAT Operational Version Winds Derivation

- All Level 2 wind products processed in NRT using 3 minute (PDU) image data at a time, nominal processing time 3 minutes
- Only use 2 orbits to produce the winds for each PDU
- For each target PDU – map the 3 search PDUs in the previous orbit which overlap onto the target PDU co-ordinate system
- Tracking between pairs of images (current and previous orbit)
- Disseminated between 90 and 110 minutes after sensing time

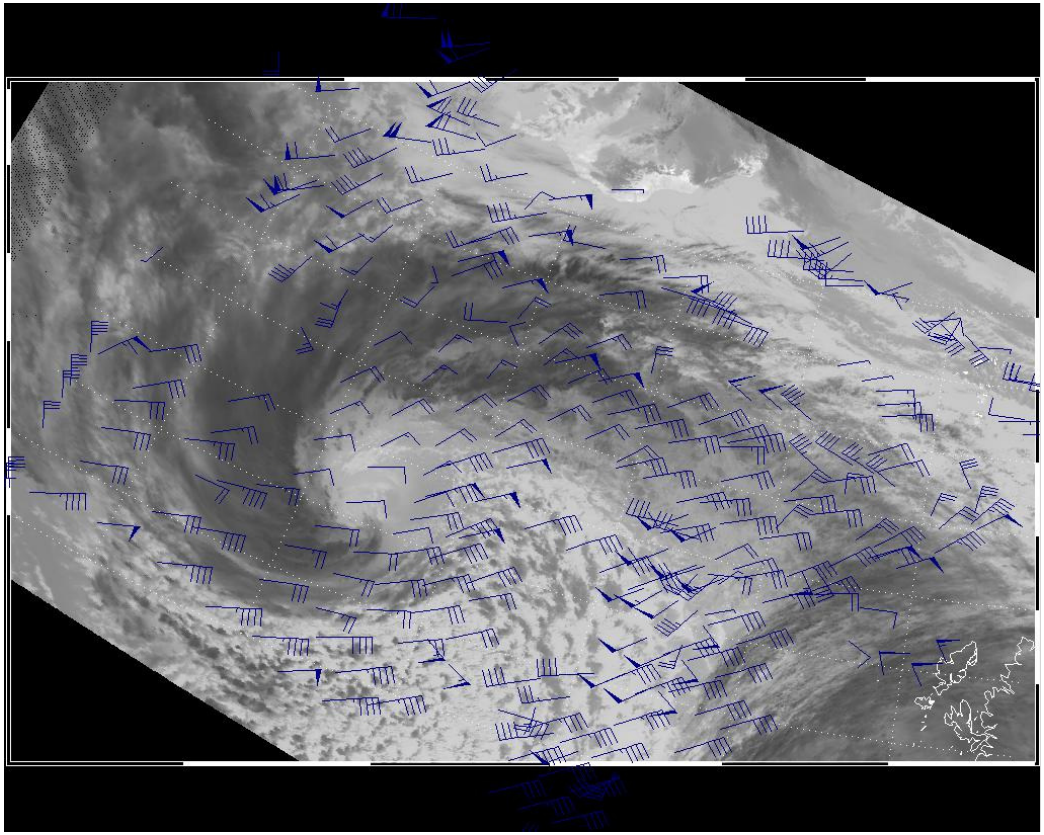
## Tracking Issues

- Use/non-use of forecast first guess information
- Tracking methods
  - cross-correlation, euclidean distance, centre of mass
- Pixel size - normal , super 3x3, super 9x9
- Target size - 28 x 28, 152 x 152
- Pyramid approach: large target and search area -> 1st estimate
  - small target and search area centred on 1st estimate

# Tracking Methodology – no forecast, large search area



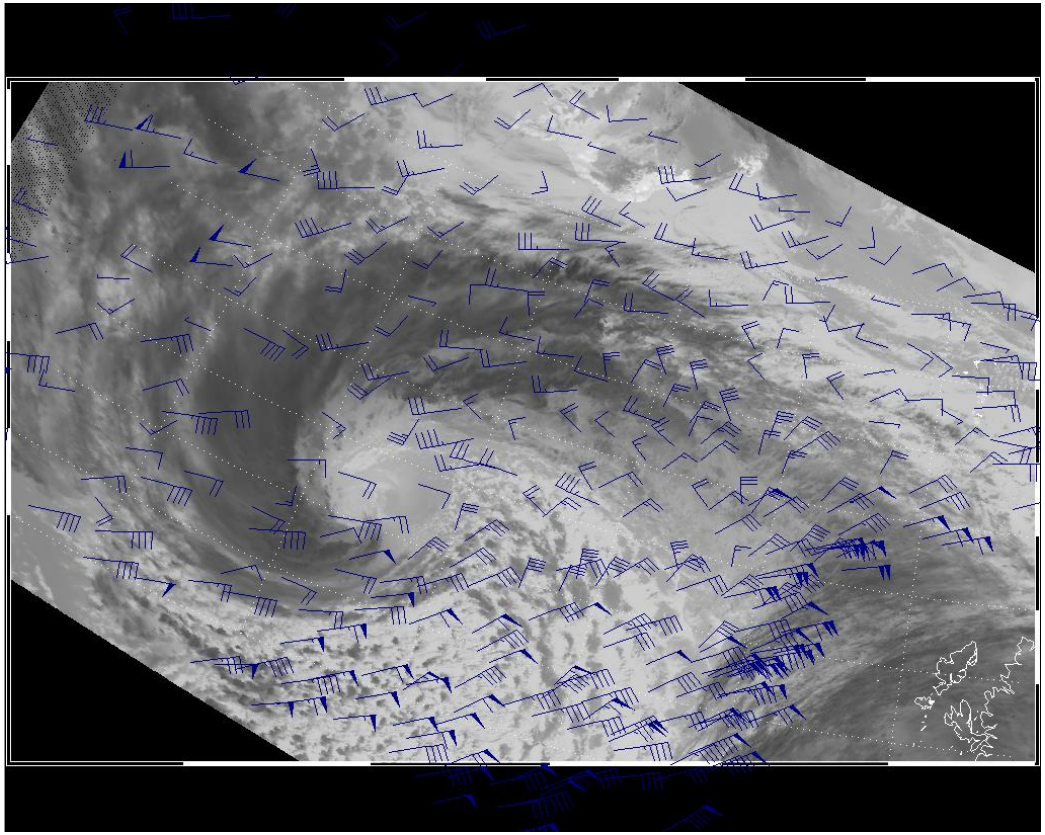
Target Size 28x28



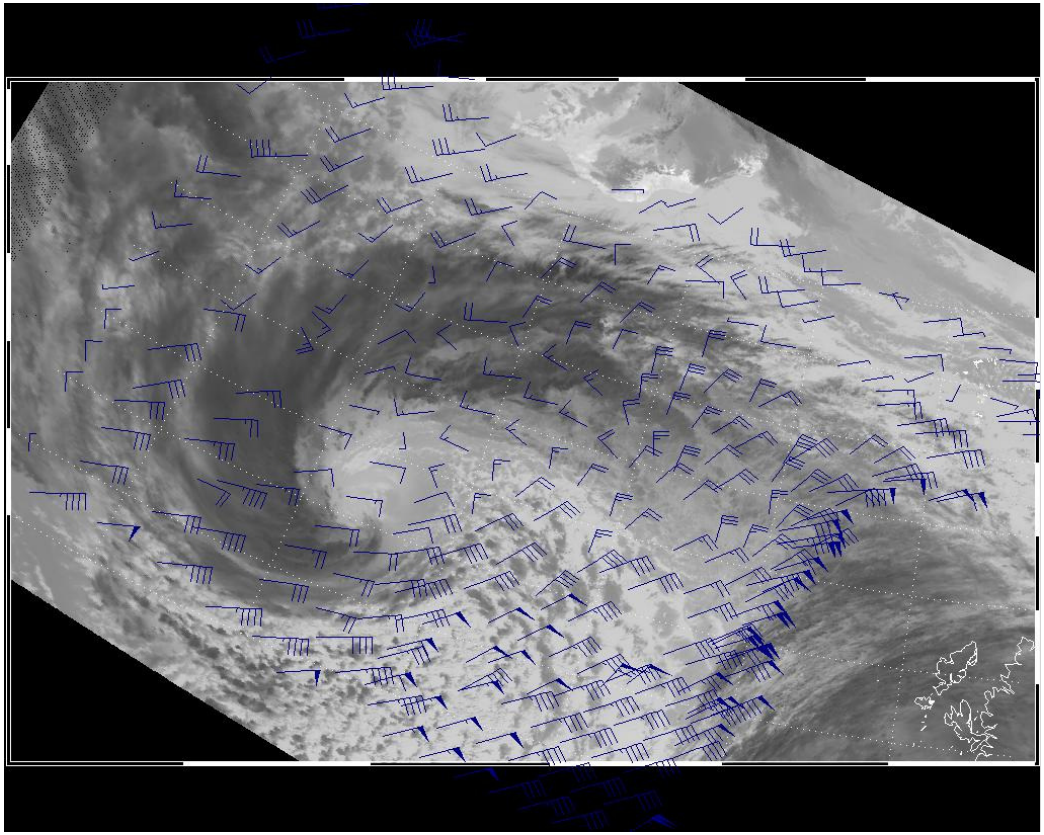
Target Size 152 x 152

Option without first guess – need large target size

# Tracking Methodology – forecast first guess, small search area



Target Size 28x28



Target Size 152 x 152

Option with first guess – can use small target size

# QI Issues

- Spatial and Forecast Consistency

- **Tracking Consistency**
  - track target from current to previous orbit
  - track target from previous orbit back again to current orbit
  - use vector, speed, direction differences as an indication of tracking consistency

- **Temporal Height Consistency**
  - separate height assignments for target in both orbits
  - use height differences as an indication of consistency

## Preliminary Validation Overview

- Prototype
- Pre-Operational – forecast guided (small target size 28 x 28)
- Pre-Operational – no forecast guide (large target size 152 x 152)

- Validation against ECMWF re-analysis

QI filtering

- prototype QI > 60
- pre-operational (forecast) QI > 50
- pre-operational (non-forecast guided) QI > 50
- removes about 50 % of winds

# AVHRR Winds vs Re-Analysis Sample One Day

## Arctic (Red)

| | PROTOTYPE | FORECAST FIRST GUESS (GS2) | NO FORECAST (GS3) |
|---|---|---|---|
| Speed Bias (m/s) | -1.21 | 0.87 | -1.45 |
| Speed RMS (m/s) | 2.67 | 4.50 | 8.21 |
| Direction Bias (deg) | 1.00 | 0.45 | 5.05 |
| Direction RMS (deg) | 8.60 | 15.65 | 59.40 |
| Mean Speed AMV | 19.47 | 21.52 | 16.90 |
| Mean Speed Analysis | 20.69 | 20.65 | 18.35 |
| Sample size | 3988 | 970 | 1035 |

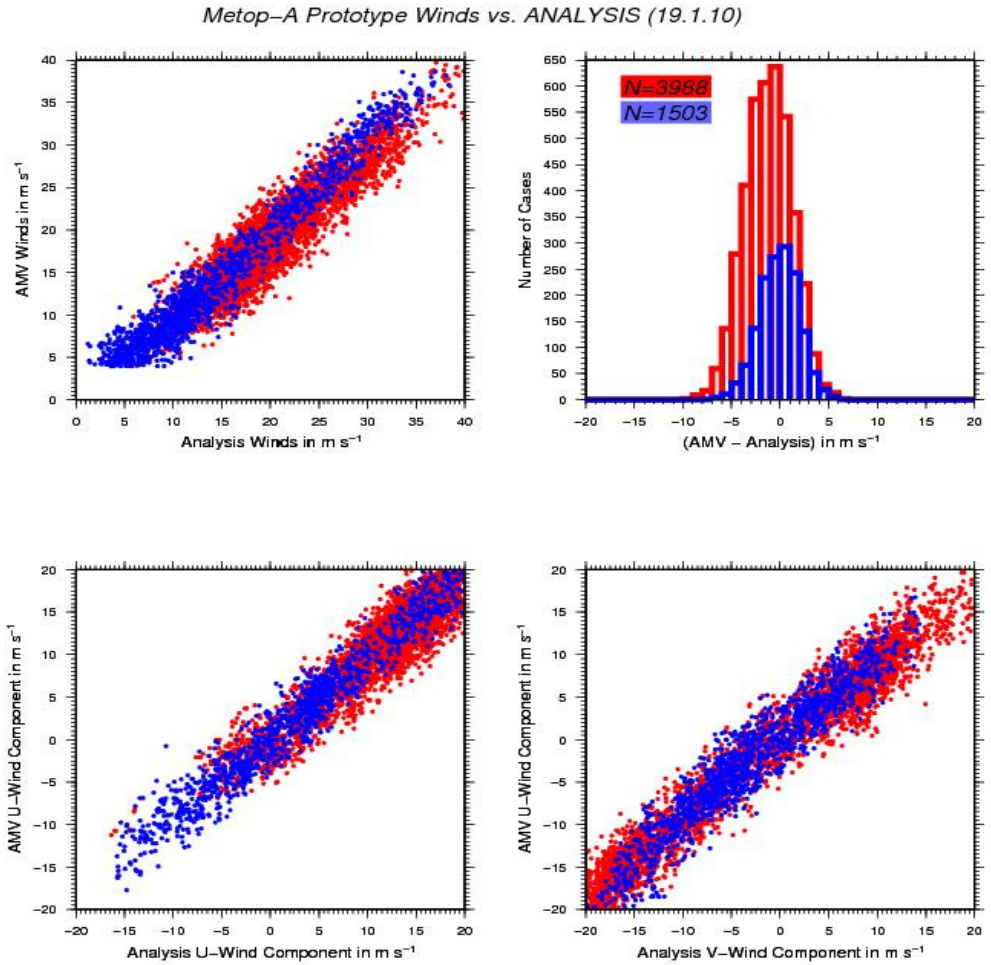
| | | | |
|---|---|---|---|
| % AMV low level | 24 | 16 | 11 |
| % AMV mid level | 71 | 80 | 84 |
| % AMV high level | 5 | 4 | 5 |

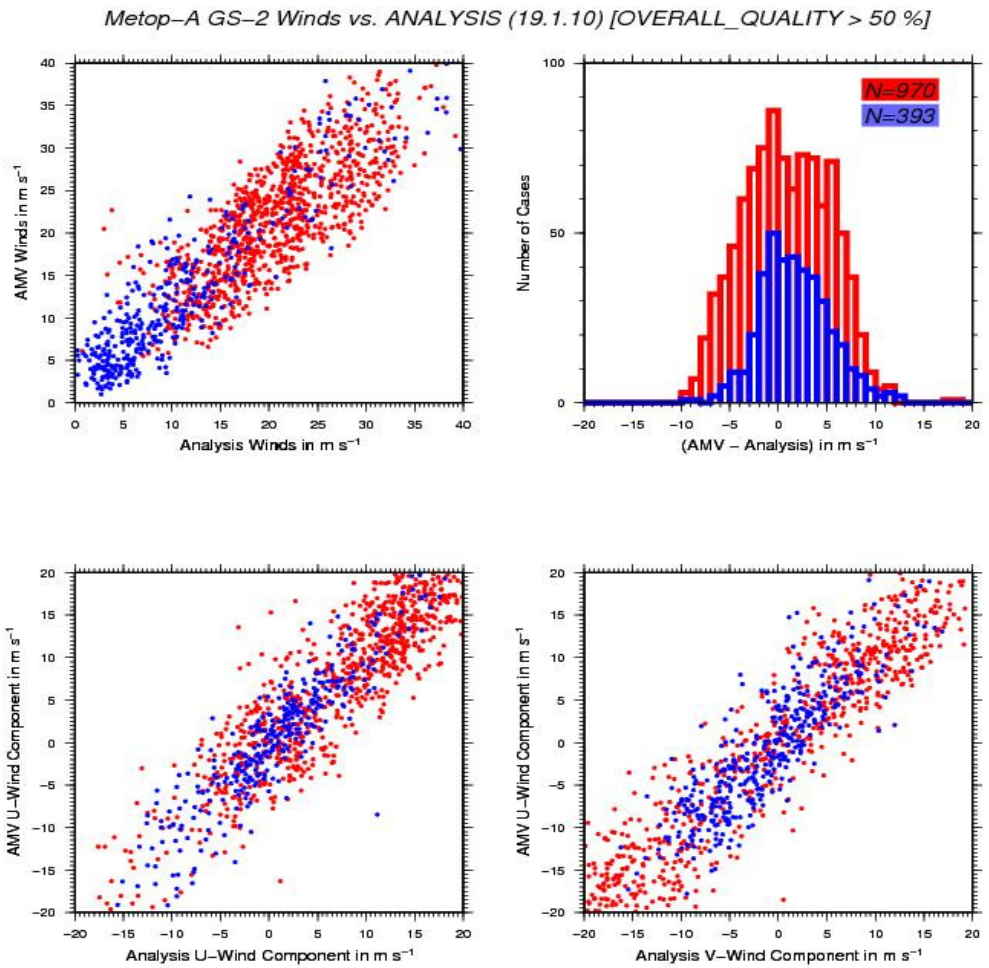
## Antarctic (Blue)

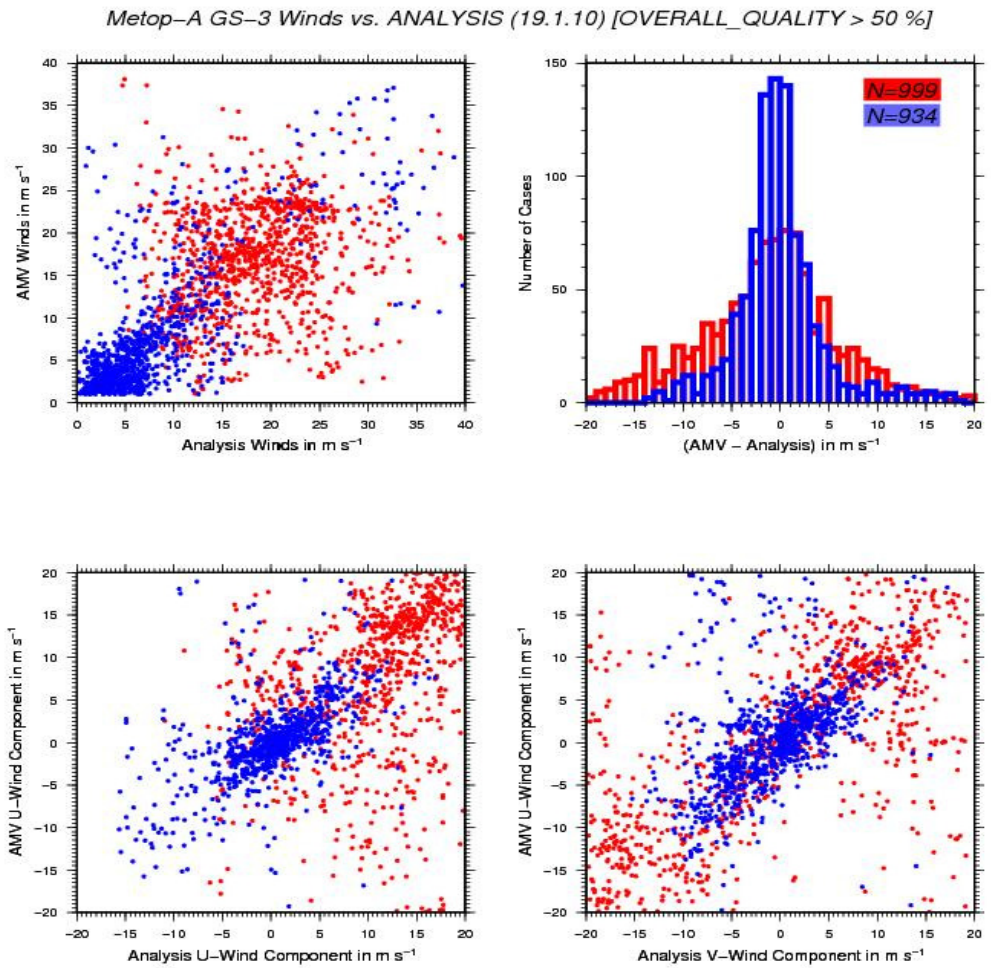
| | PROTOTYPE | FORECAST FIRST GUESS (GS2) | NO FORECAST (GS3) |
|---|---|---|---|
| Speed Bias (m/s) | -0.10 | 1.72 | -0.02 |
| Speed RMS (m/s) | 2.01 | 3.97 | 5.30 |
| Direction Bias (deg) | 0.54 | 2.25 | 11.39 |
| Direction RMS (deg) | 13.33 | 38.45 | 66.91 |
| Mean Speed AMV | 14.69 | 12.83 | 7.65 |
| Mean Speed Analysis | 14.79 | 11.11 | 7.66 |
| Sample size | 1503 | 393 | 947 |

| | | | |
|---|---|---|---|
| % AMV low level | 25 | 32 | 20 |
| % AMV mid level | 73 | 64 | 78 |
| % AMV high level | 2 | 4 | 2 |

- Prototype departure statistics better
- Forecast guided winds better departure statistics
- Height distribution predominantly medium level (400 – 700 hPa)


Metop–A Prototype Winds vs. ANALYSIS (19.1.10)
AMV Winds in m s⁻¹
Analysis Winds in m s⁻¹
Number of Cases
N=3988
N=1503
(AMV – Analysis) in m s⁻¹
AMV U–Wind Component in m s⁻¹
Analysis U–Wind Component in m s⁻¹
AMV U–Wind Component in m s⁻¹
Analysis V–Wind Component in m s⁻¹


Metop–A GS–2 Winds vs. ANALYSIS (19.1.10) [OVERALL_QUALITY > 50 %]
AMV Winds in m s⁻¹
Analysis Winds in m s⁻¹
Number of Cases
N=970
N=393
(AMV – Analysis) in m s⁻¹
AMV U–Wind Component in m s⁻¹
Analysis U–Wind Component in m s⁻¹
AMV U–Wind Component in m s⁻¹
Analysis V–Wind Component in m s⁻¹


Metop–A GS–3 Winds vs. ANALYSIS (19.1.10) [OVERALL_QUALITY > 50 %]
AMV Winds in m s⁻¹
Analysis Winds in m s⁻¹
Number of Cases
N=999
N=934
(AMV – Analysis) in m s⁻¹
AMV U–Wind Component in m s⁻¹
Analysis U–Wind Component in m s⁻¹
AMV U–Wind Component in m s⁻¹
Analysis V–Wind Component in m s⁻¹

## Validation Activities Leading Up To Operations

- More statistics over longer time periods, inc. radiosonde

- Isolate and filter out areas in which quality is lower
- Fine tuning of processing parameters eg QI weights
- Comparison of forecast and non-forecast guided winds

- Pre-operational availability (test products available for ECMWF test dissemination) est > May 2010

# Error Sources

- Tracking
  - feature changes significantly in 100 minutes
  - feature tracked representative of flow ?
  - parallax (more at extreme viewing geometry)
  - correlation surface peak analysis
  - if using forecast as first guess, impacted by errors in height assign

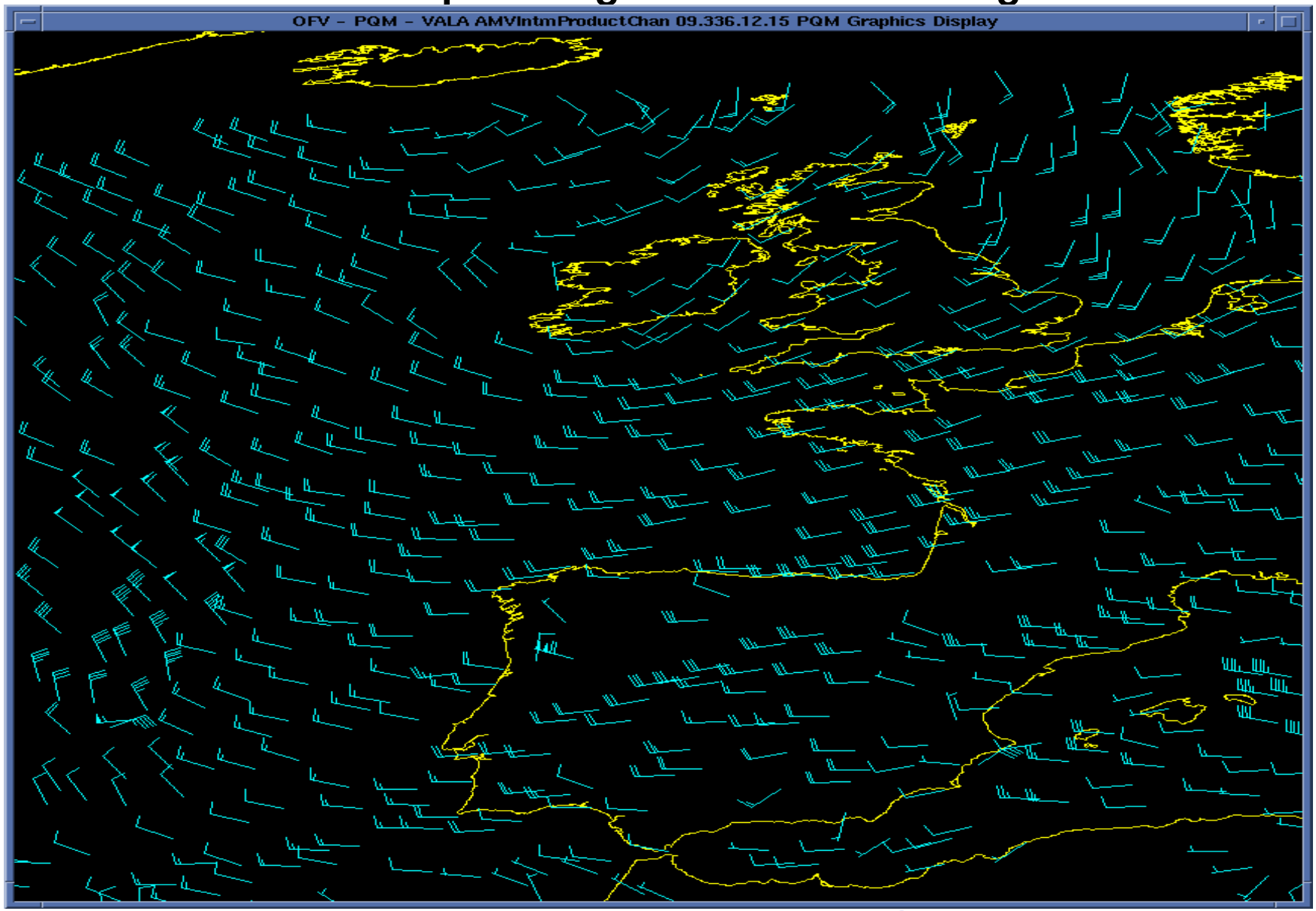
- Height Assignment
  - IR Window for thin clouds
  - IASI height assignment
  - temperature inversions

## Degradation in Tracking Quality

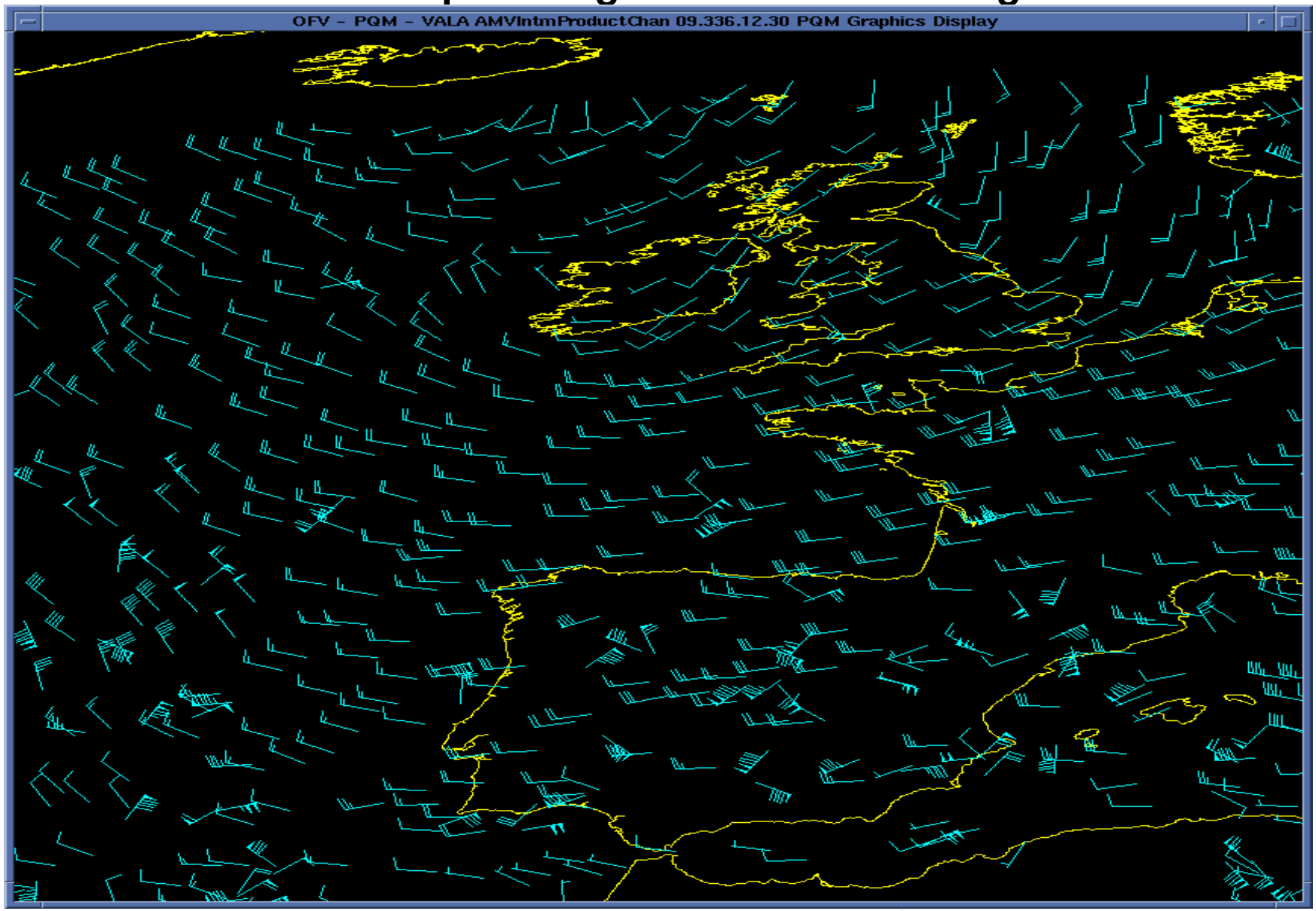
- Illustration of deterioration in tracking quality as time interval between successive images increases and the feature correspondingly changes

- Examples using Meteosat Second Generation Images
  - tracking intervals 15, 30, 45, 60, 75, 90, 105 minutes
  - search area increasingly expanded with time about target centre to contain the feature movement
  - IR channel 24x24 target sizes
  - HRVIS 32x32, 48x48, 96x96 target sizes

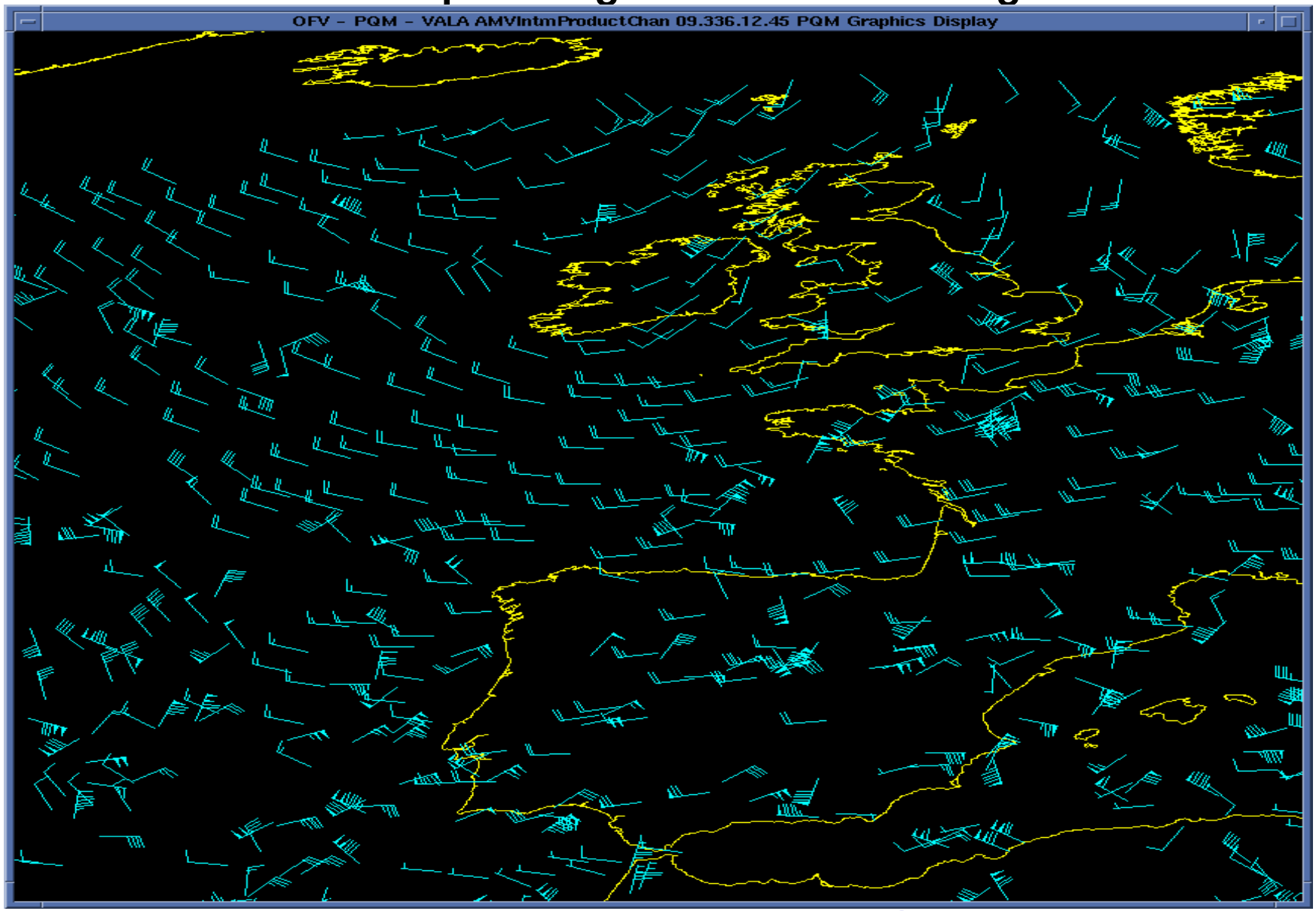
# MSG IR – 24x24 pixel target 15 minute tracking interval



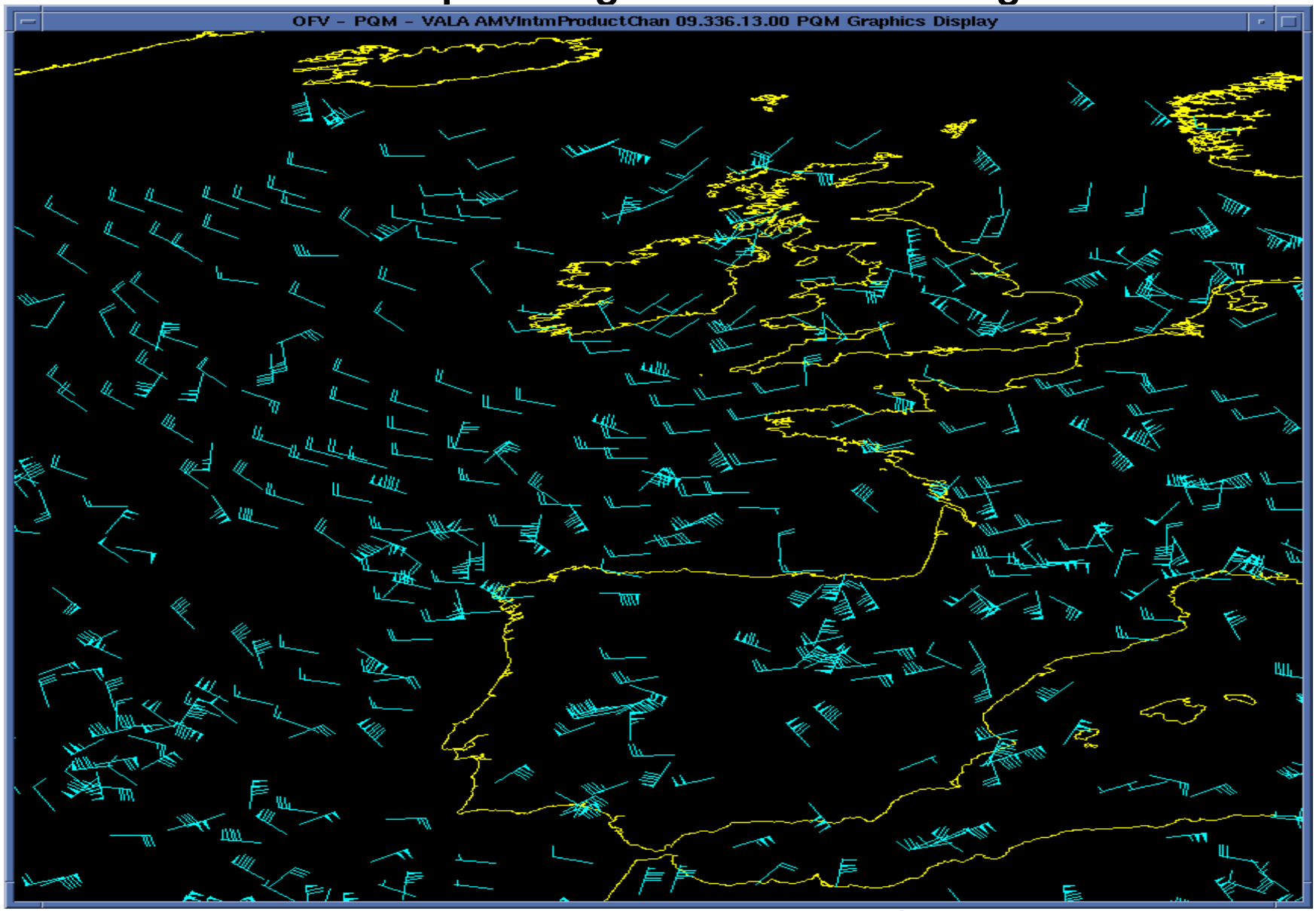
# MSG IR – 24x24 pixel target 30 minute tracking interval



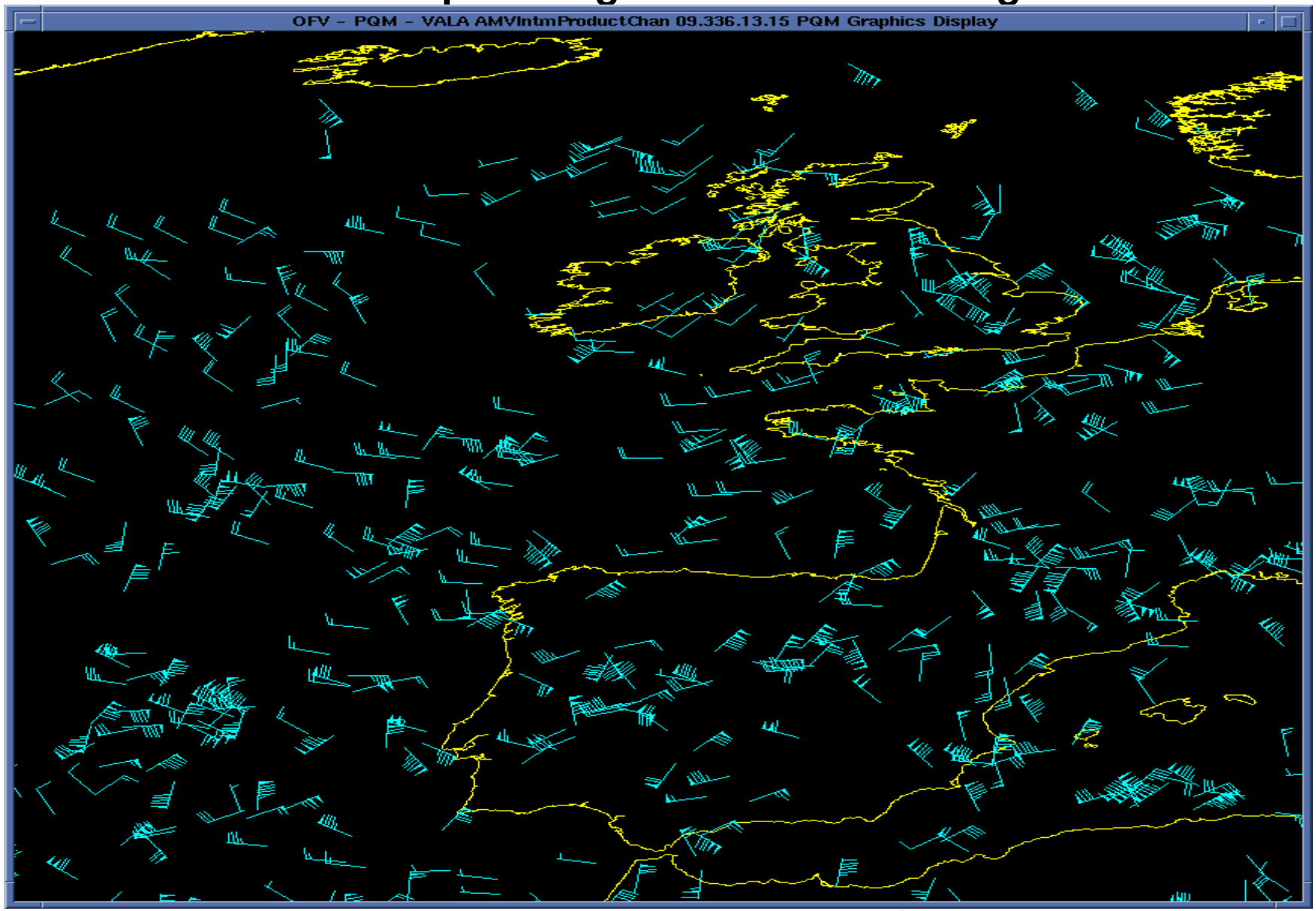
# MSG IR – 24x24 pixel target 45 minute tracking interval



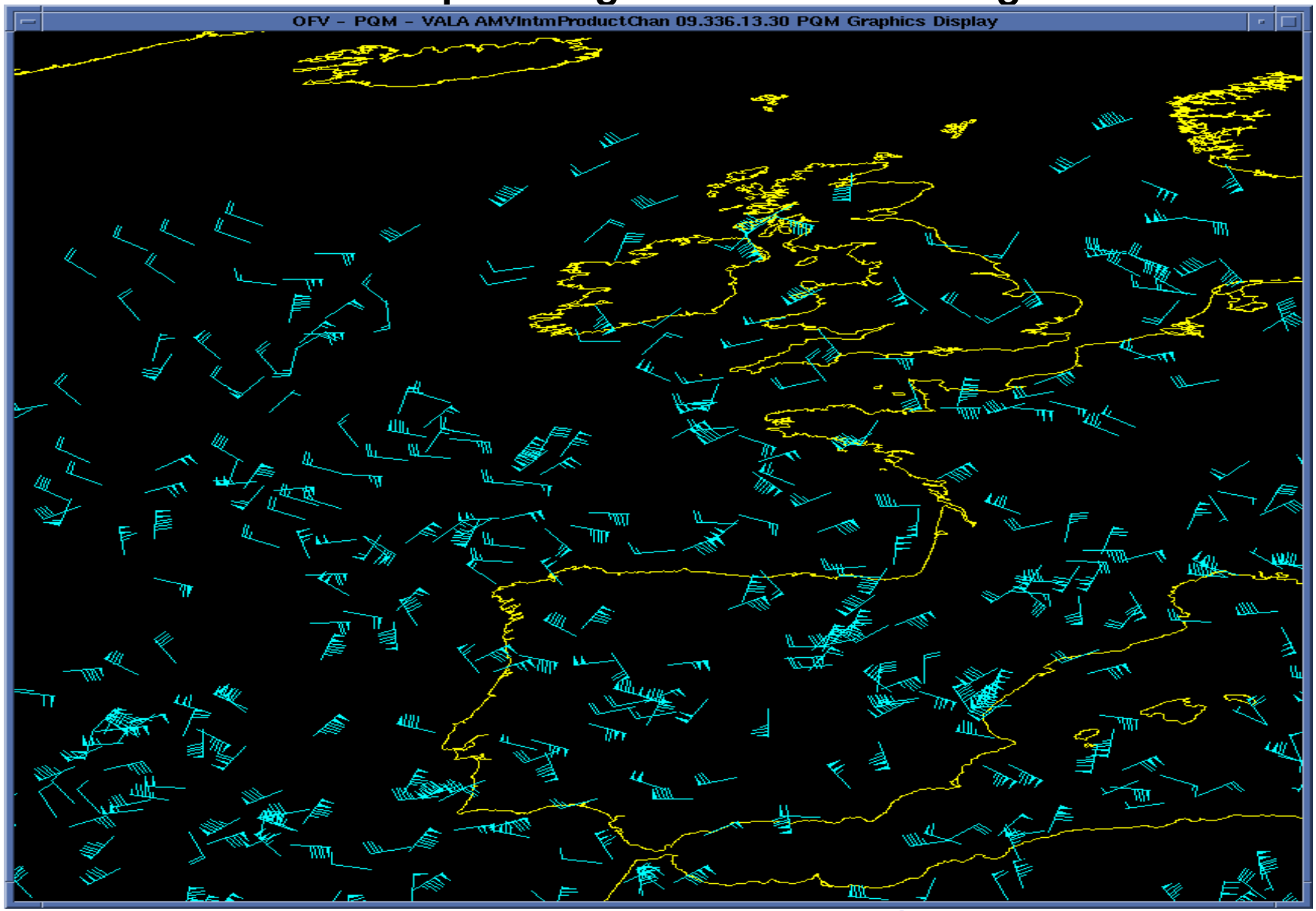
# MSG IR – 24x24 pixel target 60 minute tracking interval



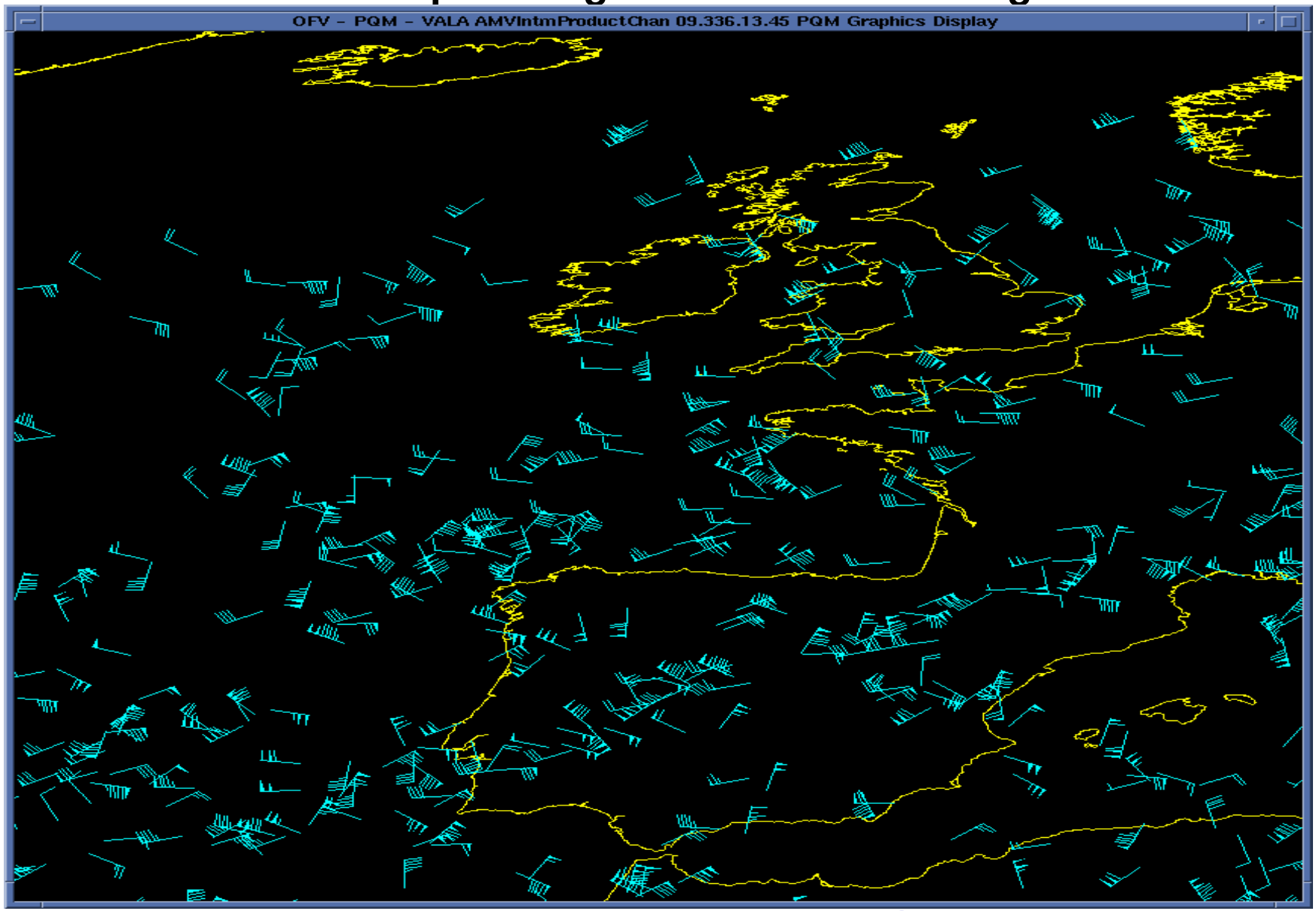
# MSG IR – 24x24 pixel target 75 minute tracking interval



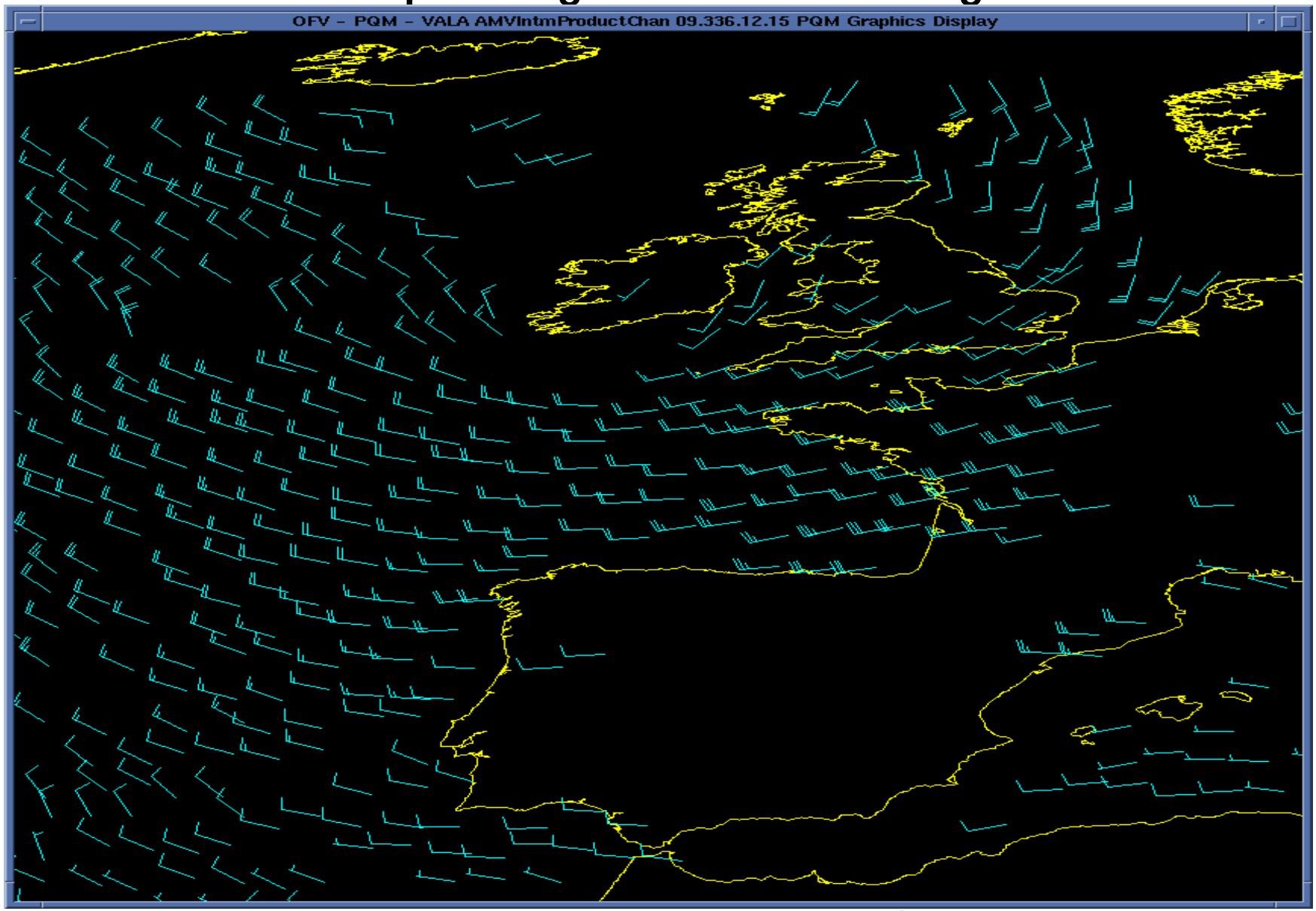
# MSG IR – 24x24 pixel target 90 minute tracking interval



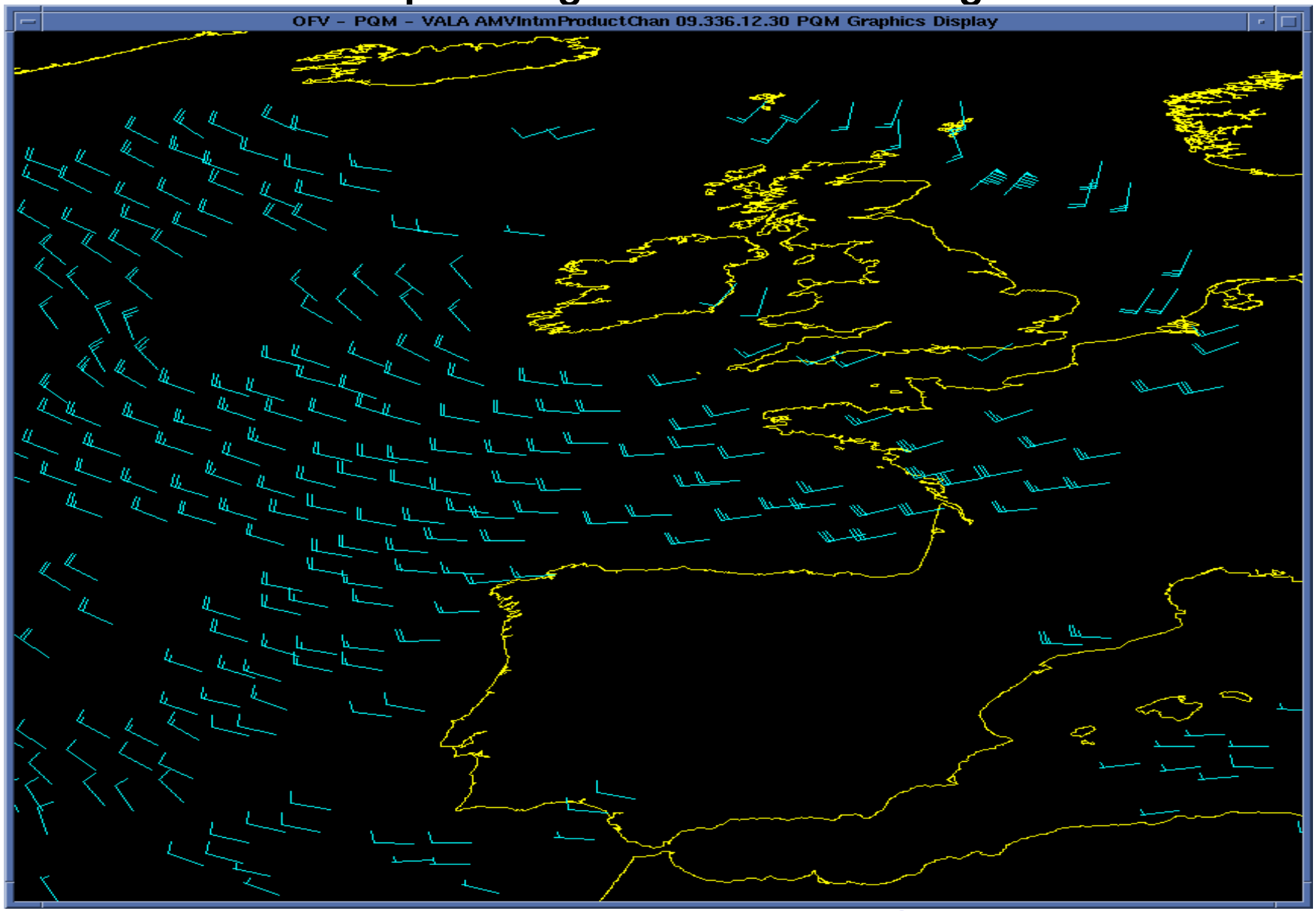
# MSG IR – 24x24 pixel target 105 minute tracking interval



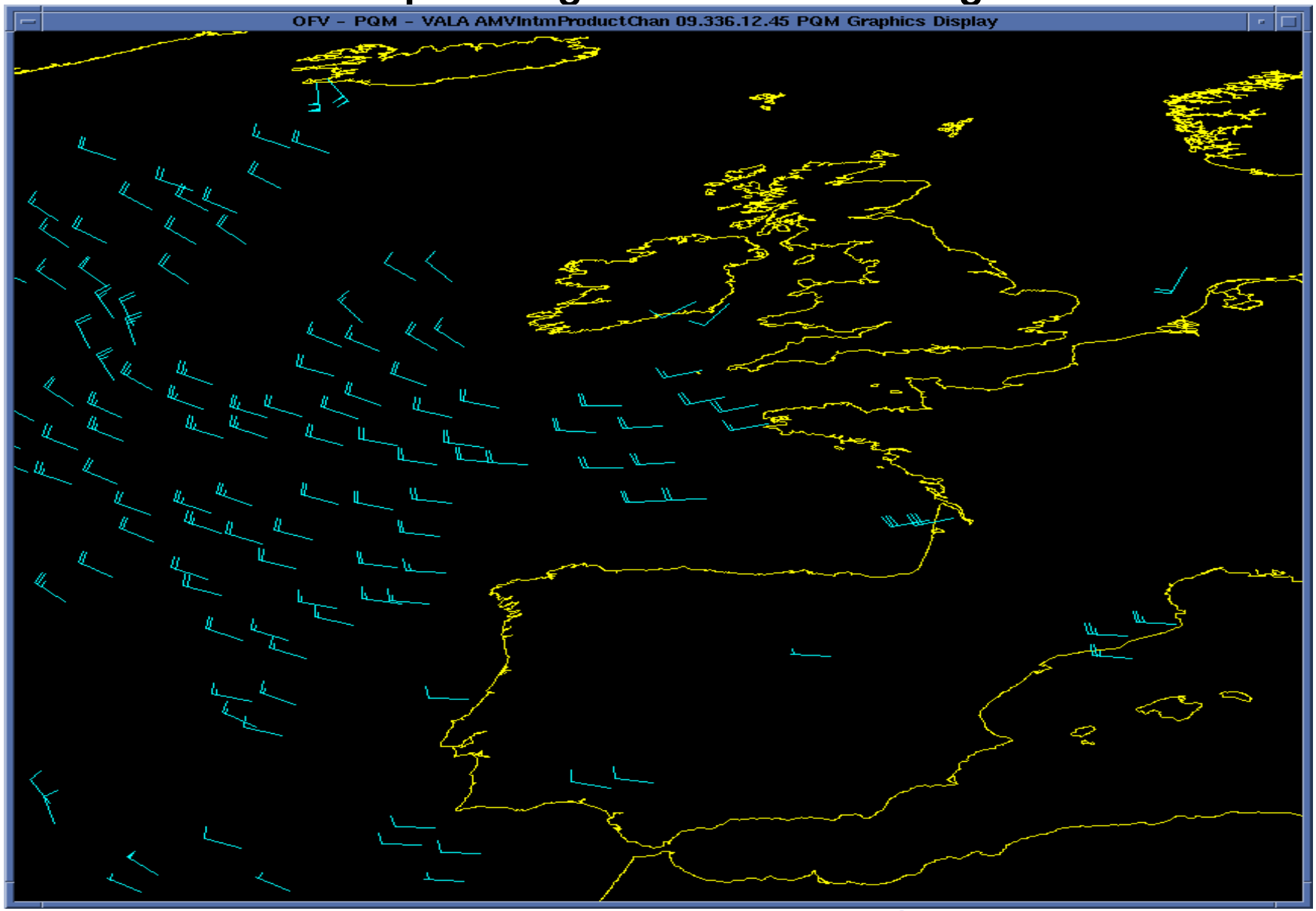
# MSG HRVIS – 32x32 pixel target 15 minute tracking interval: QI > 80



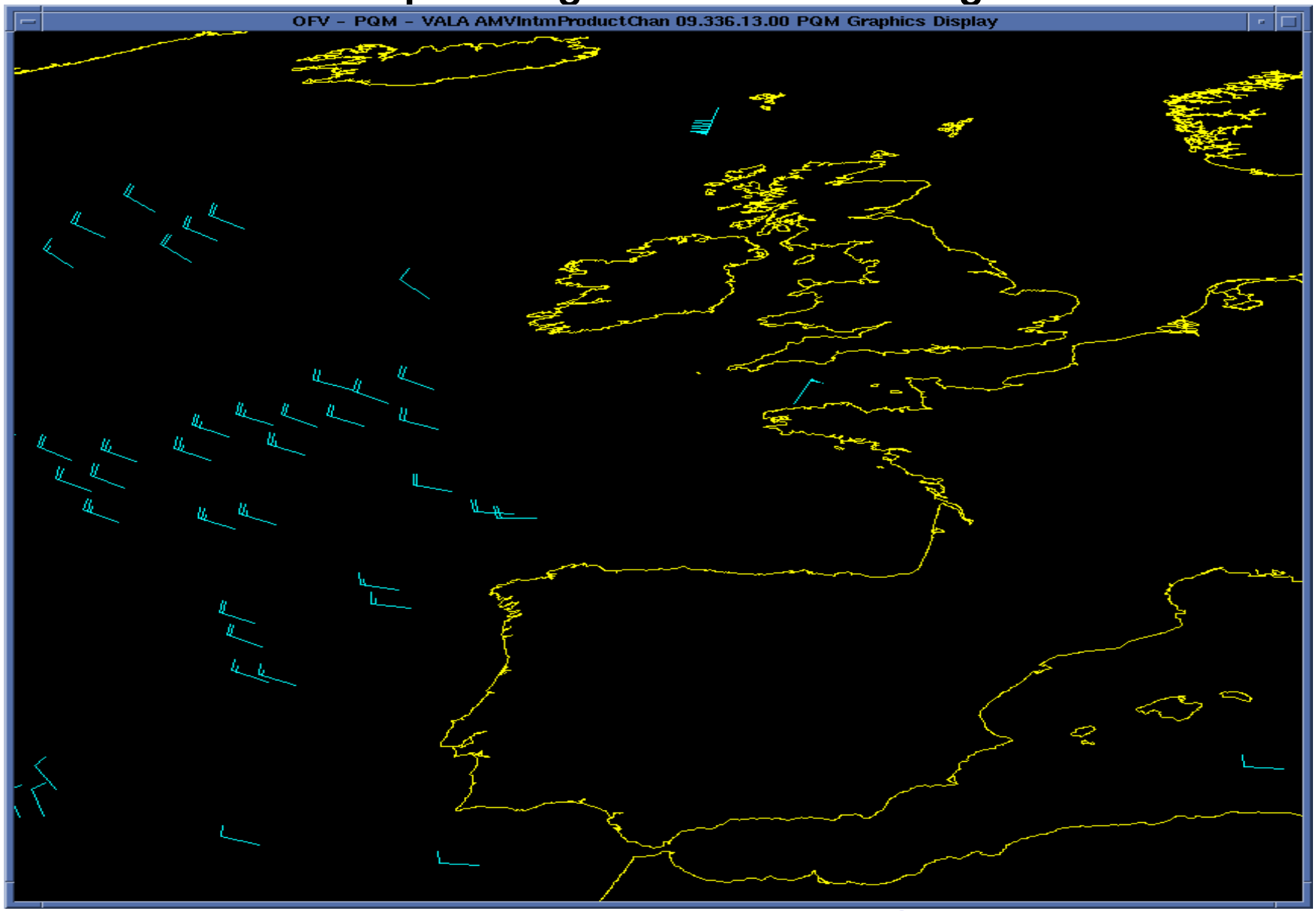
# MSG HRVIS – 32x32 pixel target 30 minute tracking interval: QI > 80



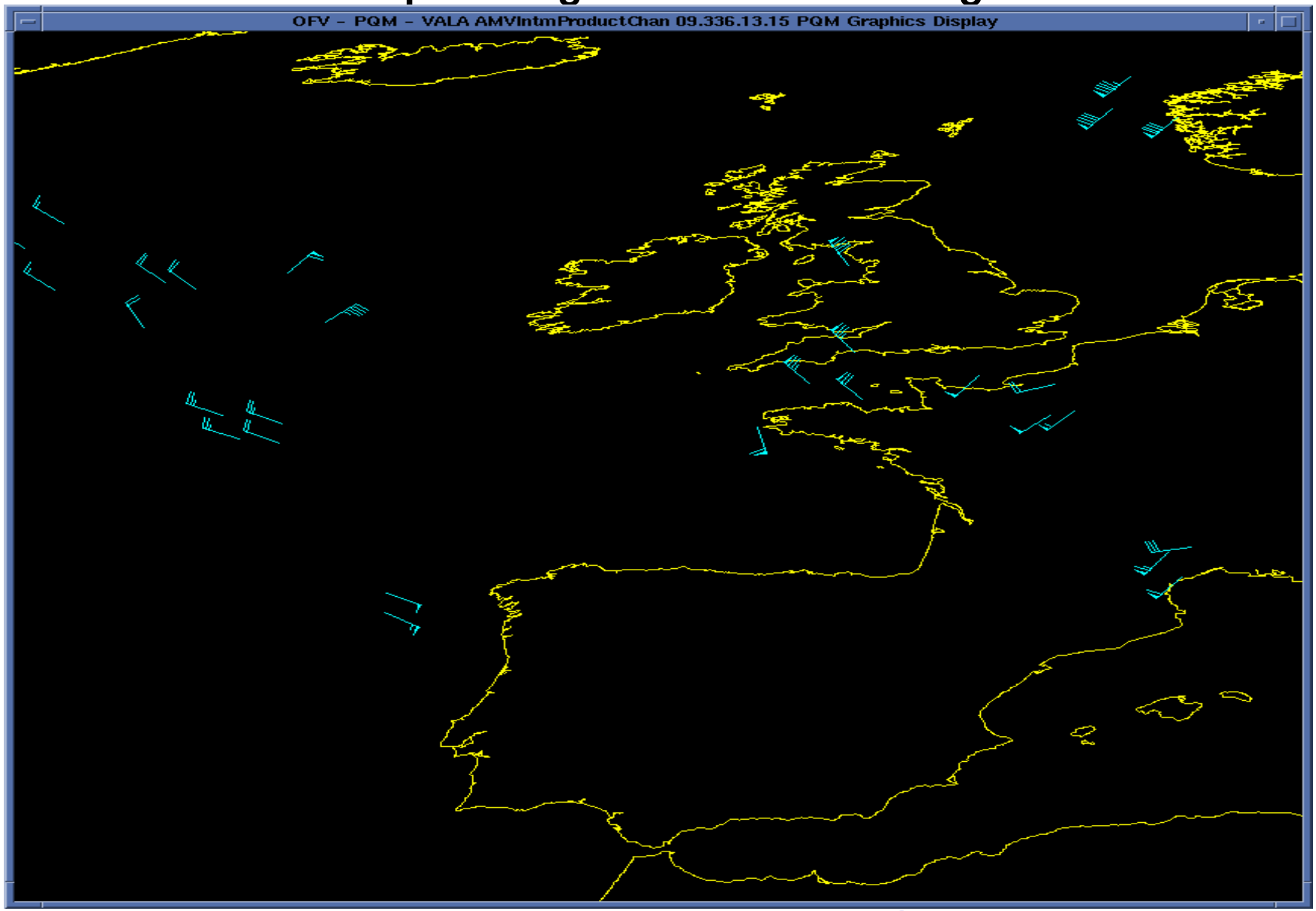
# MSG HRVIS – 32x32 pixel target 45 minute tracking interval: QI > 80



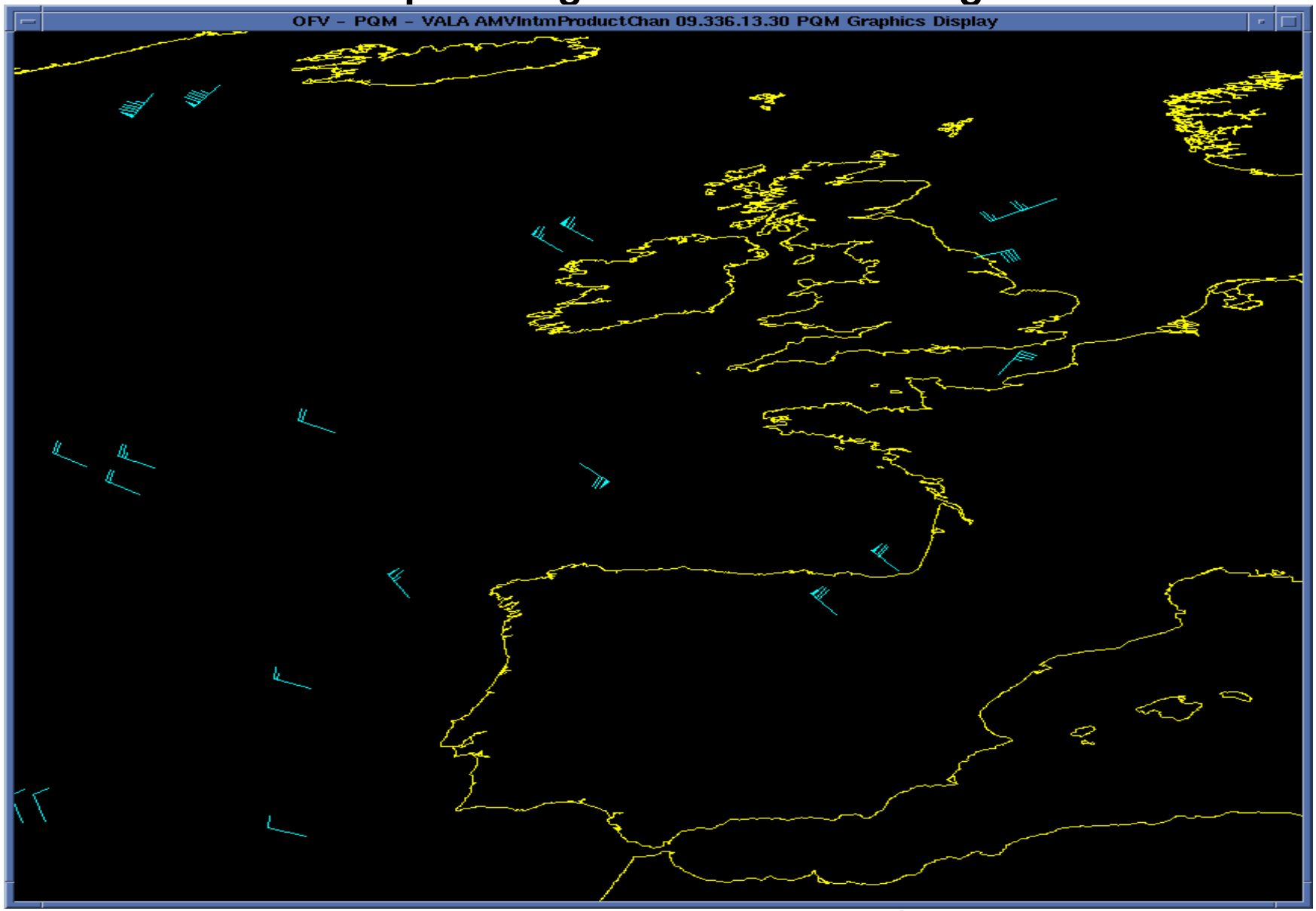
# MSG HRVIS – 32x32 pixel target 60 minute tracking interval: QI > 80



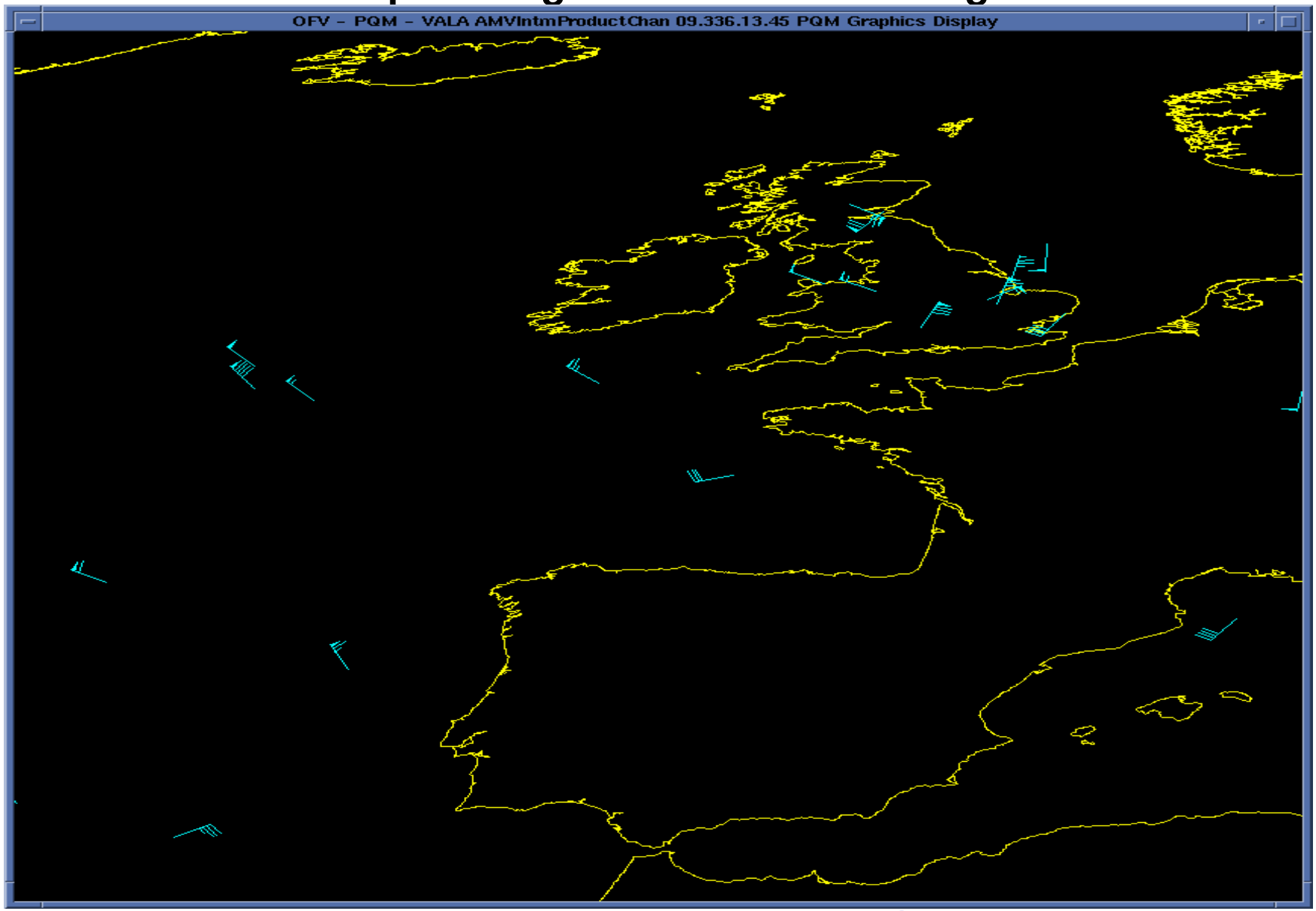
# MSG HRVIS – 32x32 pixel target 75 minute tracking interval: QI > 80

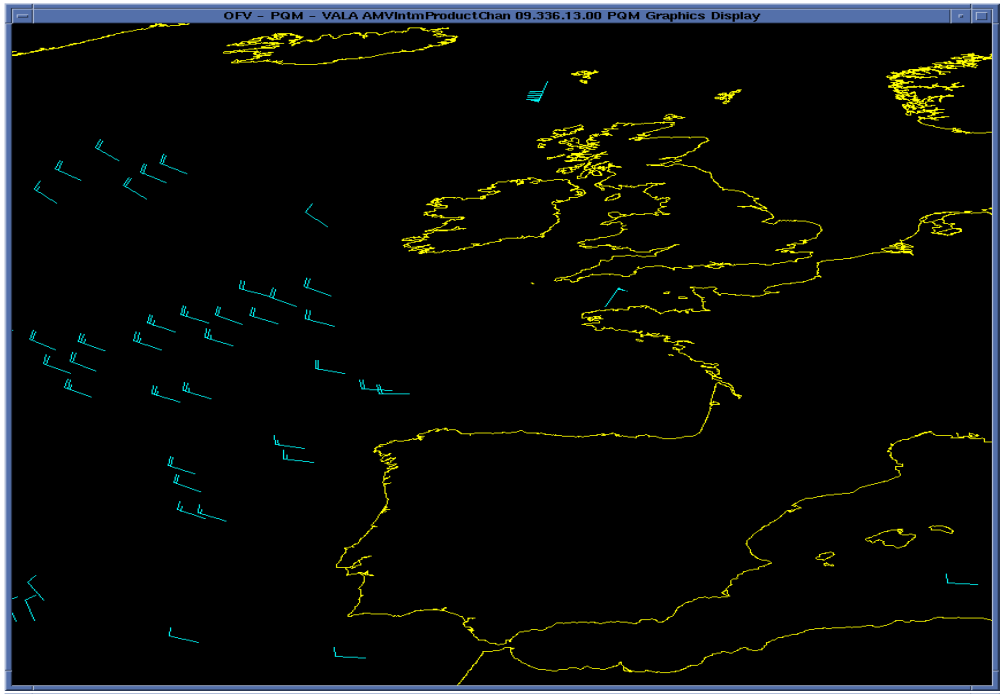


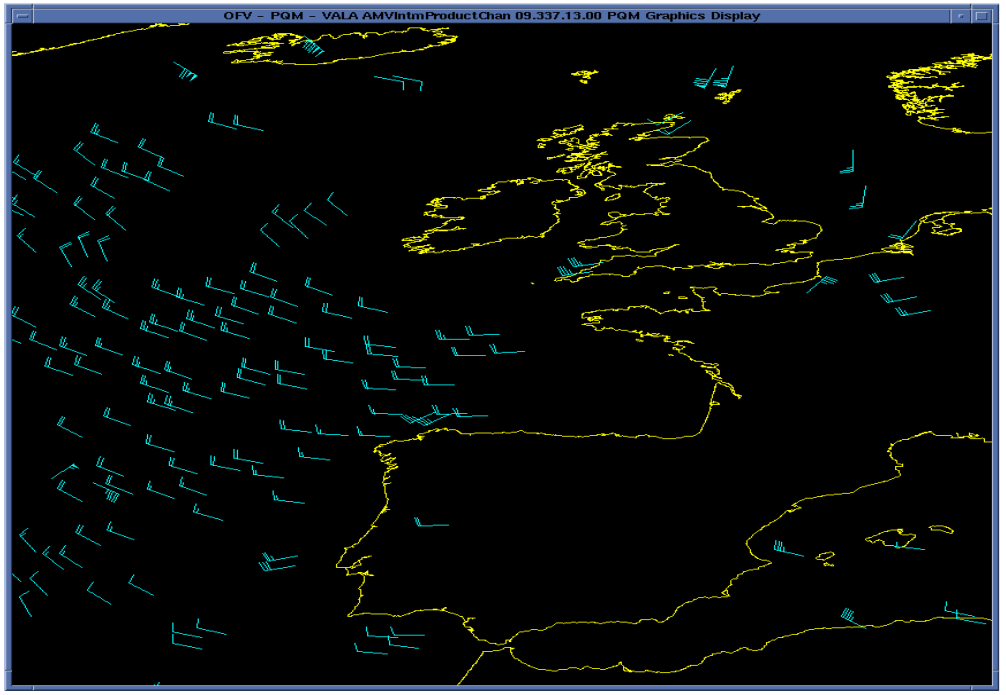
# MSG HRVIS – 32x32 pixel target 90 minute tracking interval: QI > 80

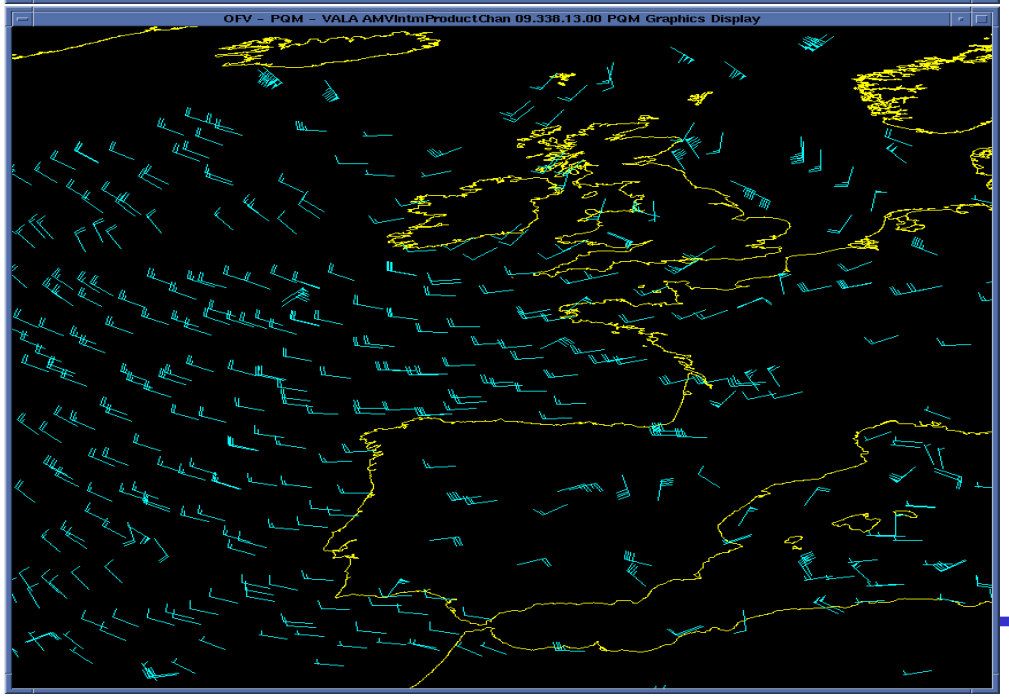


# MSG HRVIS– 32x32 pixel target 105 minute tracking interval: QI > 80






60 MINUTE INTERVAL : QI > 80

IMPACT OF TARGET SIZE

32 x 32 (Top Left)

48 x 48 (Top Right)

96 x 96 (Bottom)

EUMETSAT

## Degradation in Tracking Quality Conclusions

- Tracking severely degraded for time intervals above 60 minutes
  - even if the feature is contained in the expanded search area
  - even if forecast estimate good
- Degradation can be reduced by increasing the target size
- METOP-B to be launched April 2012
- Recommendation to investigate combining METOP-A and METOP-B images (separation of 50 minutes)

## Future Plans

- Monitor differences between forecast/non-forecast guided winds
- Incorporation of IASI height assignment information
- Height assignment improvements eg low-level clouds
- Use of 2 satellites – expected to significantly improve tracking quality
  - Metop B scheduled for launch Apr 2012
- Parallax consideration
- Consideration of triplets
  - feature tracked for 200 minutes
  - delay winds availability by 100 mins : availability 190 to 210 mins
- Additional receiver station in Antarctic – improve timeliness
- Improvements to quality filtering