

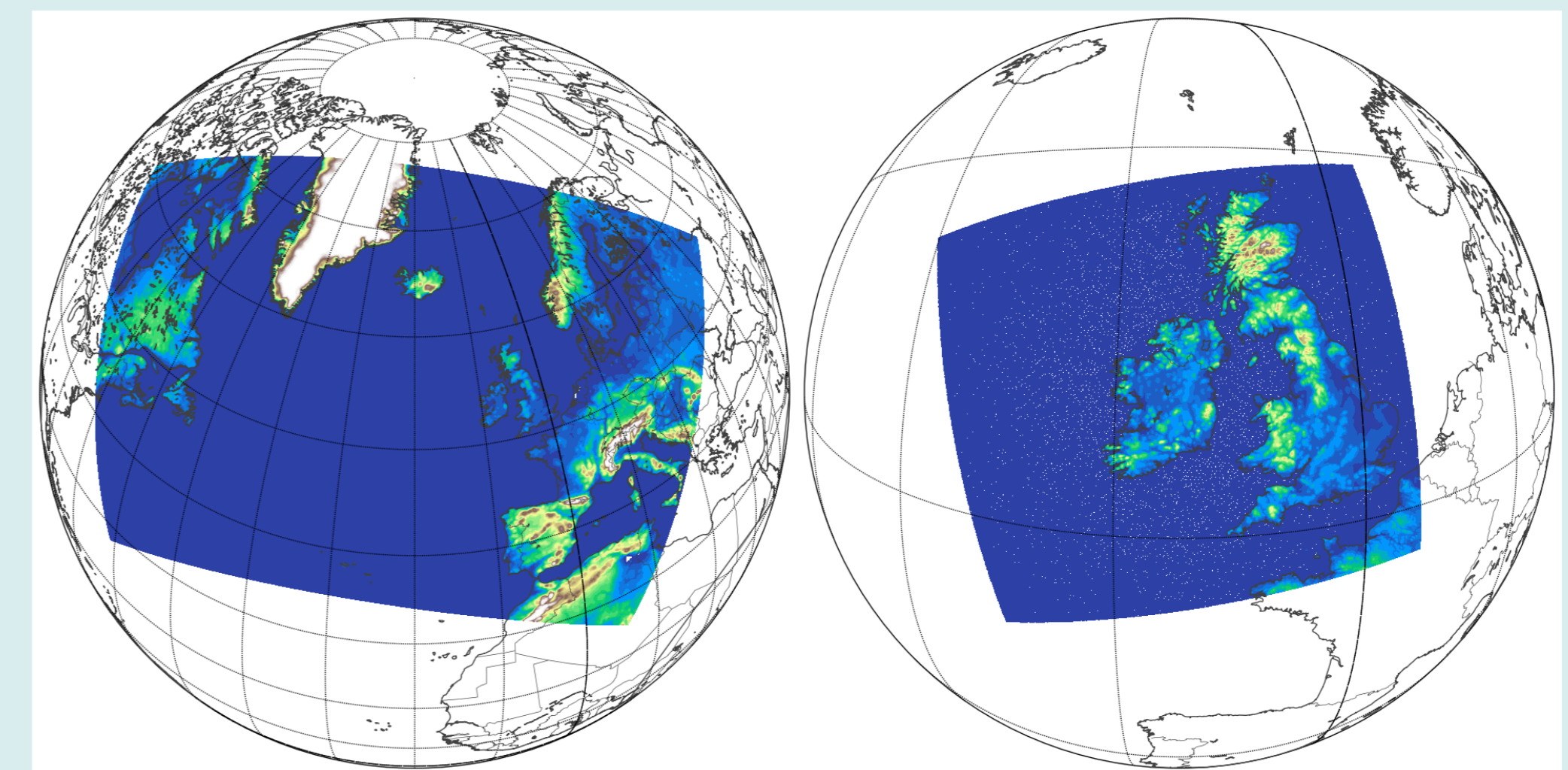
## Introduction

Met Éireann, Ireland's National Meteorological Service, is the leading provider of weather information and related services in Ireland and is a member of the HIRLAM consortium [1]. The limited area NWP models in operational use are the hydrostatic HIRLAM model, run in two configurations (see details below), and the nonhydrostatic, mesoscale HARMONIE-AROME configuration of the shared ALADIN-HIRLAM system [2], hereafter referred to as HARMONIE. Operational NWP has been running at the Irish Centre for High-End Computing (ICHEC) since 2007. Met Éireann has recently ported the operational suite to ECMWF. HARMONIE was first made operational by Met Éireann on the 11th of July 2011. Cycle 37h1.1 was introduced on the 31st of January 2013 and is currently run at a 2.5 km resolution every six hours. An upgrade to cycle 40 is underway.

### Model Details

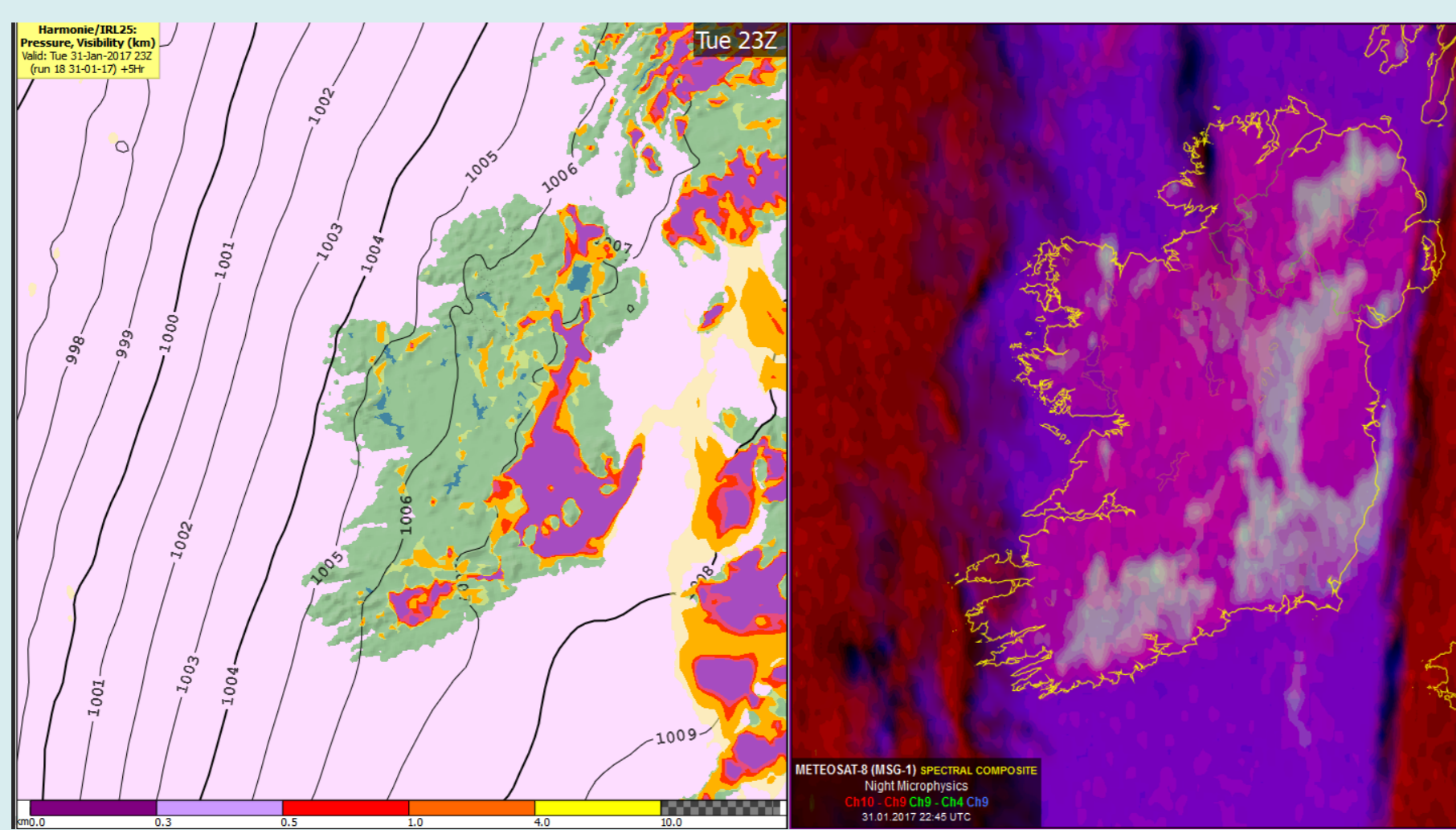
	HARMONIE	HIRLAM I10	HIRLAM HH7
<b>Domain</b>	540×500×65	654×424×60	366×344×60
<b>Grid spacing</b>	2.5 km	0.1°	0.07°
<b>Model top</b>	10 hPa	10 hPa	10 hPa
<b>Timestep</b>	60 s	240 s	150 s
<b>Observations</b>	Conventional only	Conventional only	Conventional only
<b>Cut-off</b>	45 mins	2 hrs	20 mins
<b>Data assimilation</b>	Surface analysis only with blending (6 hr cycle)	4DVAR with large-scale mixing	3DVAR with large-scale mixing
<b>Forecast</b>	54 hour forecasts at 00Z, 06Z, 12Z, & 18Z	54 hour forecasts at 00Z, 06Z, 12Z, & 18Z	9 hour forecasts every hour
<b>Boundaries</b>	IFS	IFS	HIRLAM I10

### Operational Domains



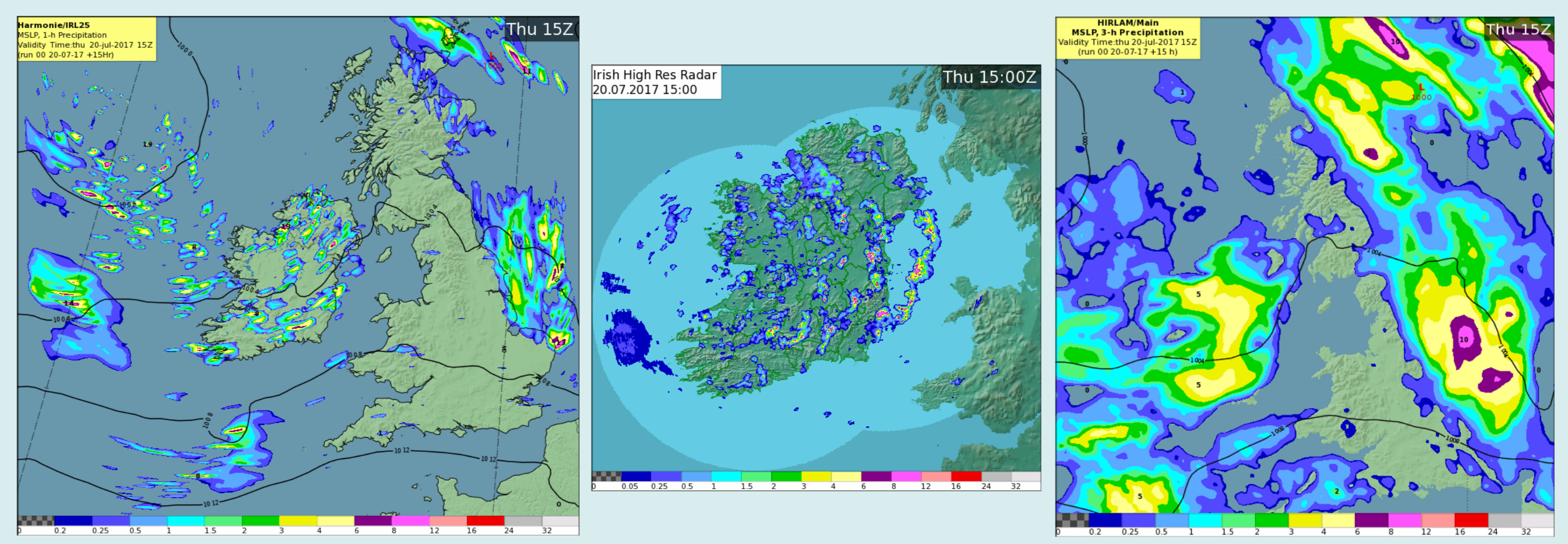
HIRLAM I10 (left) and HARMONIE (right)

### Sample Forecasts: Visibility, 31st of January 2017



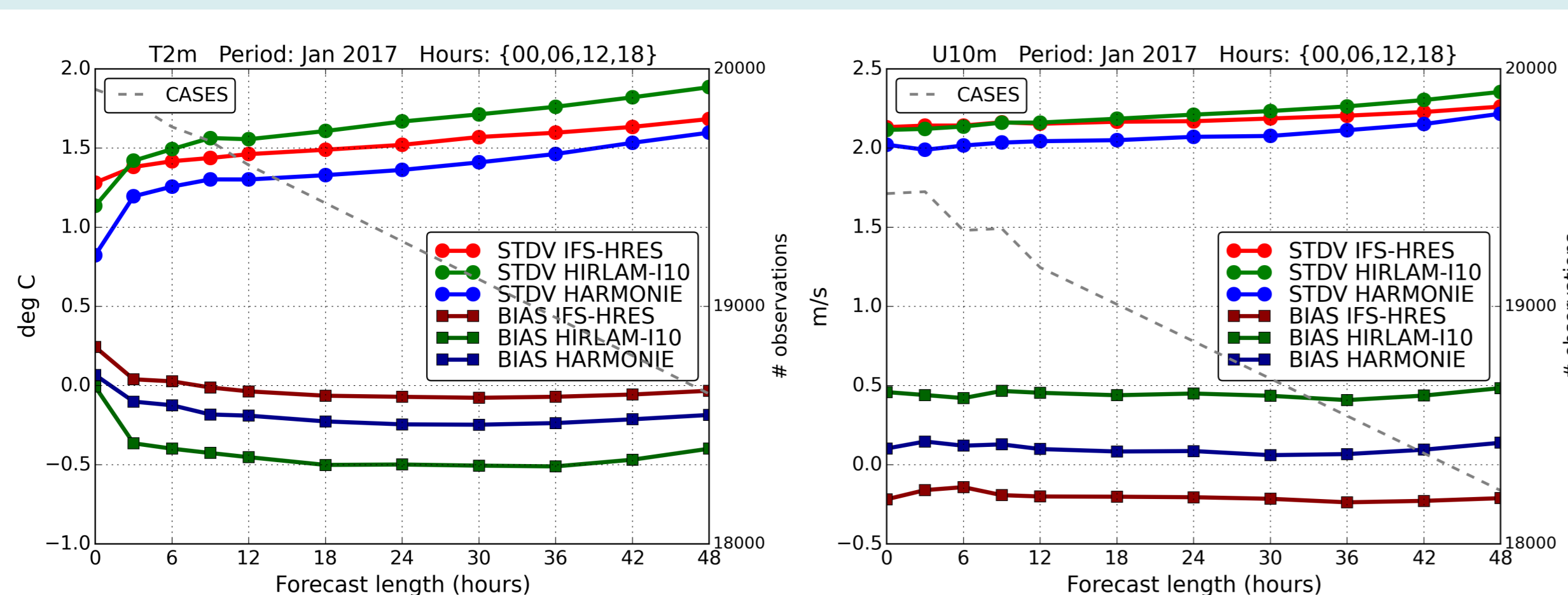
Example of an accurate prediction of visibility over Ireland by HARMONIE (left), with the satellite image (right)

### Sample Forecasts: Rainfall, 20th of July 2017



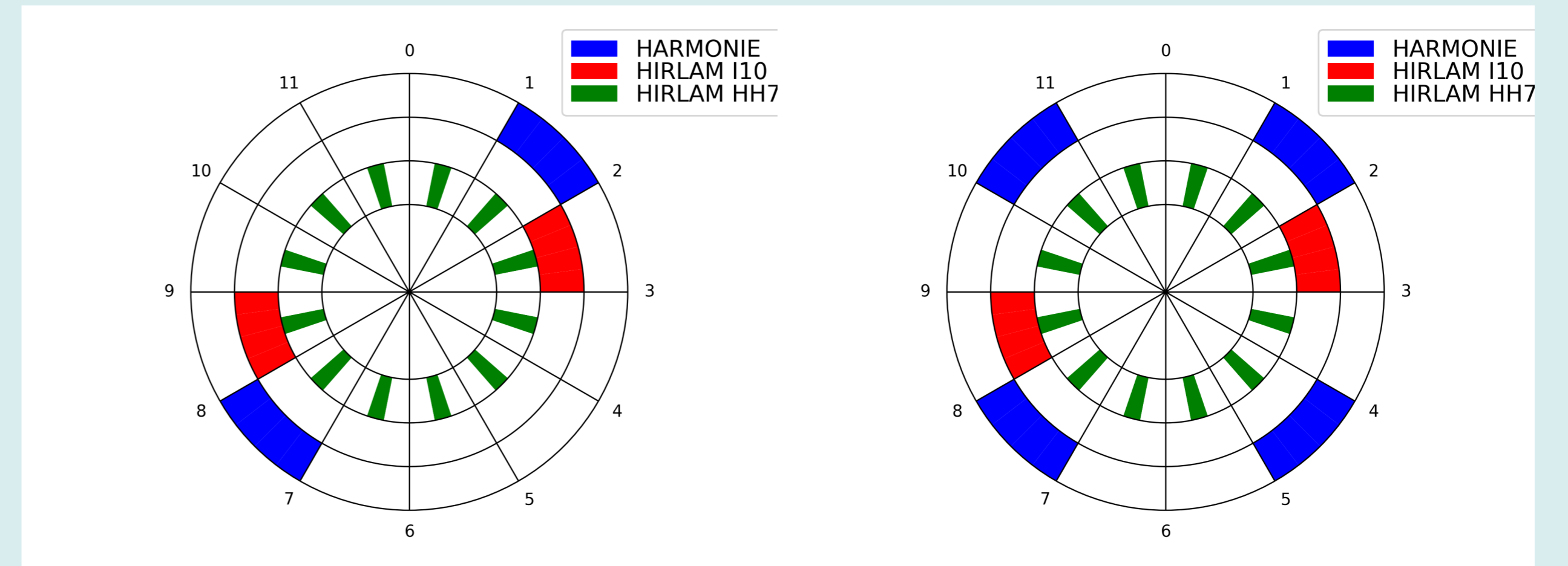
Rainfall on the 20th of July 2017: forecasts from HARMONIE (left) and HIRLAM I10 (right), along with the verifying radar (middle).

### Verification: January 2017



HARMONIE 37h1.1 continues to perform well operationally. Point verification against observations of 2 m temperature (left) and 10 m wind-speed (U10m, right) are shown for January 2017 comparing HARMONIE (blue), HIRLAM I10 (green), and IFS (red).

### Operational Timeline at ECMWF



Operational schedules at ECMWF: current suite (left) and proposed (right) with forecasts every three hours. A HARMONIE forecast takes approximately 1 hour, a HIRLAM I10 forecast takes approximately 1.25 hours, and a HIRLAM HH7 forecast takes approximately 15 minutes.

## Cycle 40 Upgrade

Met Éireann is planning to upgrade its operational HARMONIE model from cycle 37 to cycle 40 in the near future. Tests and verification are currently ongoing. Technical changes being considered include an increased cycle frequency, with a forecast every three hours instead of six, as well as an expansion of the domain. Two possibilities are shown (right), of size 800×800 and 1000×900 gridpoints. There are a number of scientific changes, included in the new cycle, being explored:

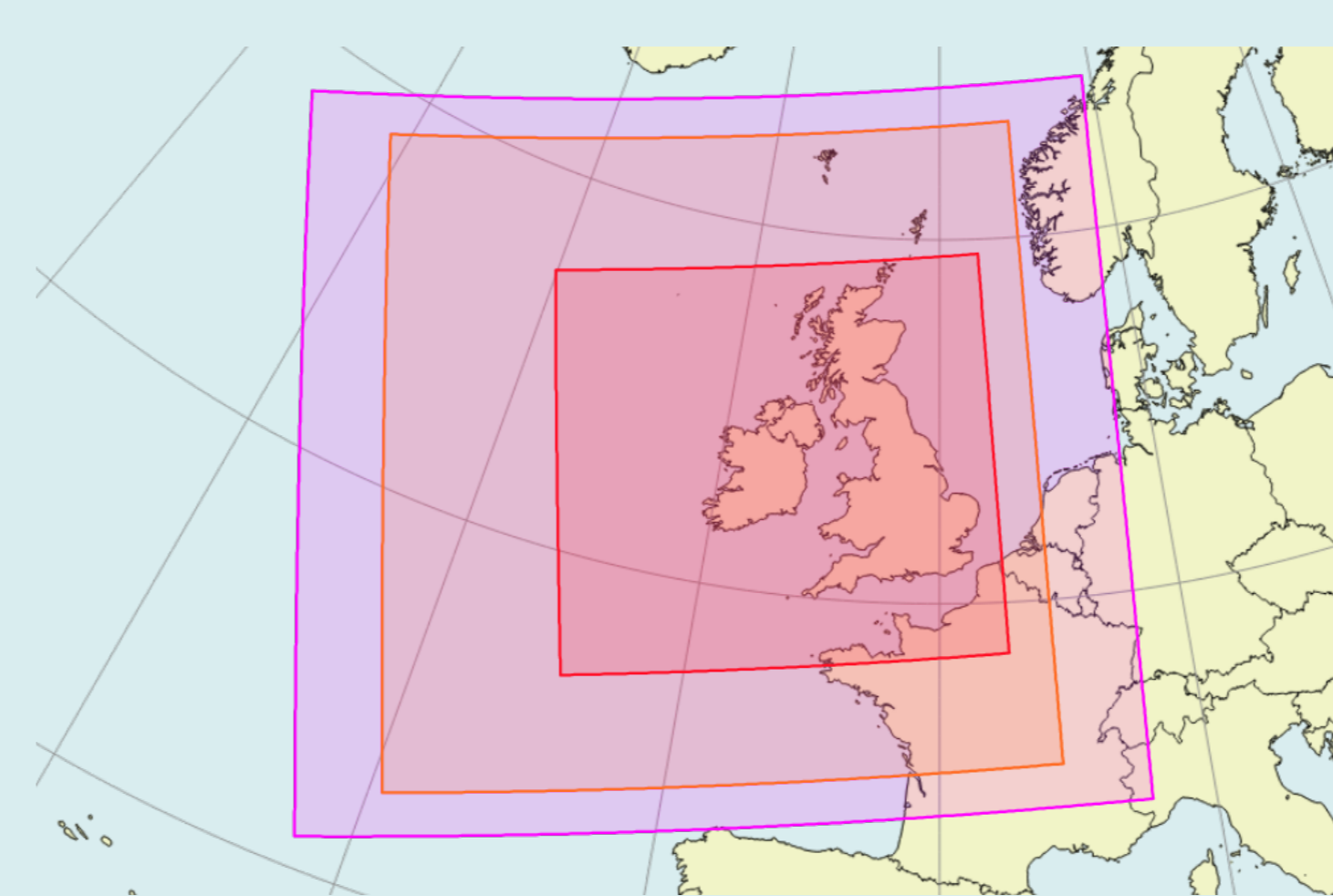
- **Data Assimilation:** Conventional observations will be assimilated using 3D-Var. The assimilation of radiances (AMSU-A, AMSU-B, MHS) and aircraft derived (Mode-S EHS) observations will be tested and implemented once cycle 40 is made operational.
- **Dynamics:** For a spectral truncation  $N$ , we denote the following:
  - ▶ linear spectral grid →  $2N + 1$  physical gridpoints
  - ▶ quadratic spectral grid →  $3N + 1$  physical gridpoints
  - ▶ cubic spectral grid →  $4N + 1$  physical gridpoints

With a fixed number of gridpoints, the quadratic and cubic grids have a reduced spectral truncation. Efficiency gains (~20% for cubic) must be evaluated against loss of accuracy.

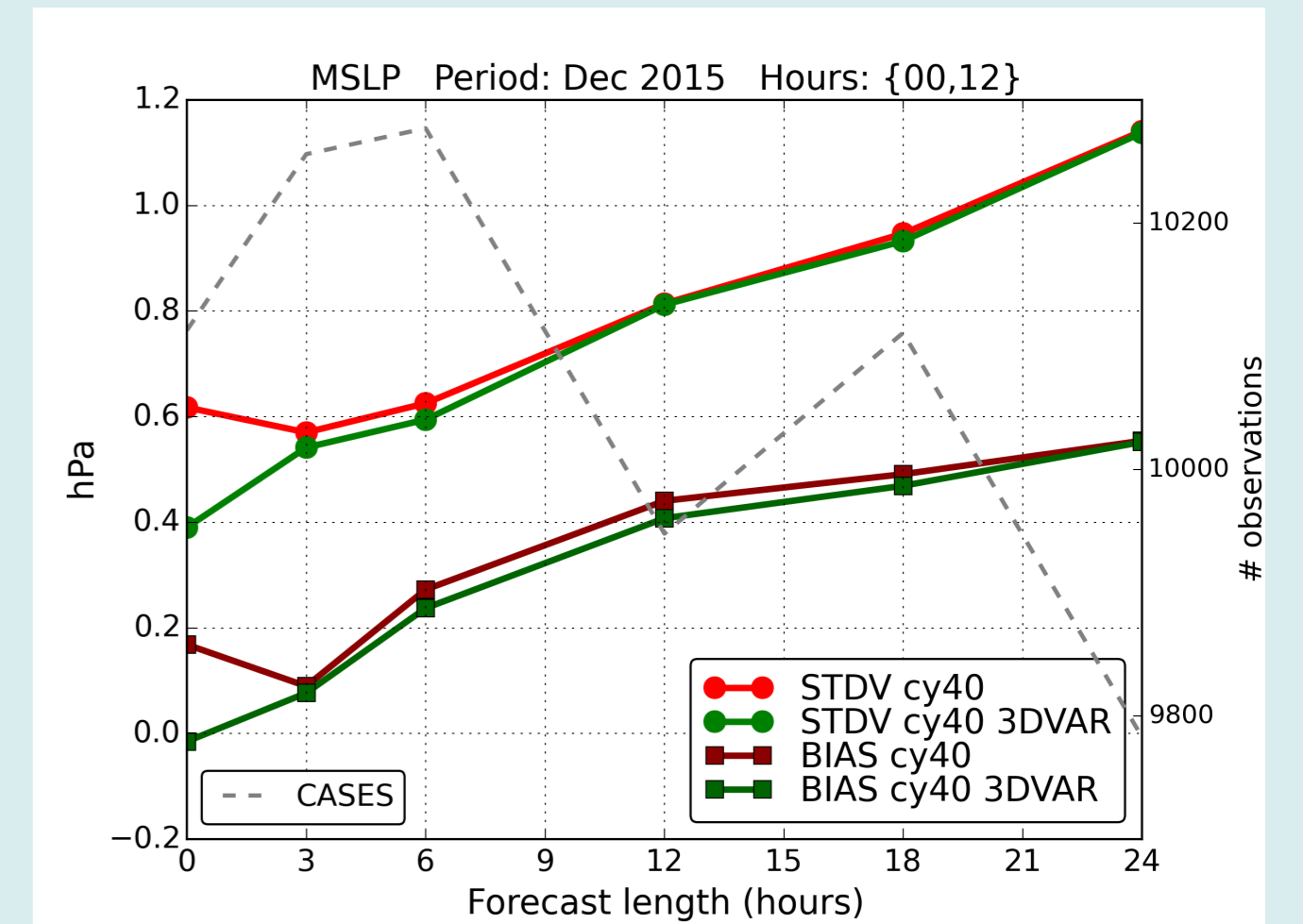
- **Physics:** Some of the changes in cycle 40:

- ▶ Improved cloud liquid optical property scheme [3, 4] and due to increased model grid resolution, clouds are now assumed to be homogeneous where present in a cell.
- ▶ Improvements to the ICE3 micro-physical parametrization [5], including separation between fast liquid and slower ice water process, reduction of the deposition rate of the ice-phase water species, correction to lower optical thickness of ice clouds compared with water clouds and a reduction of the ice nucleolus concentration in temperatures between 0°C and -25°C.
- ▶ Adjustments to the diffuse and direct shortwave albedo representation.

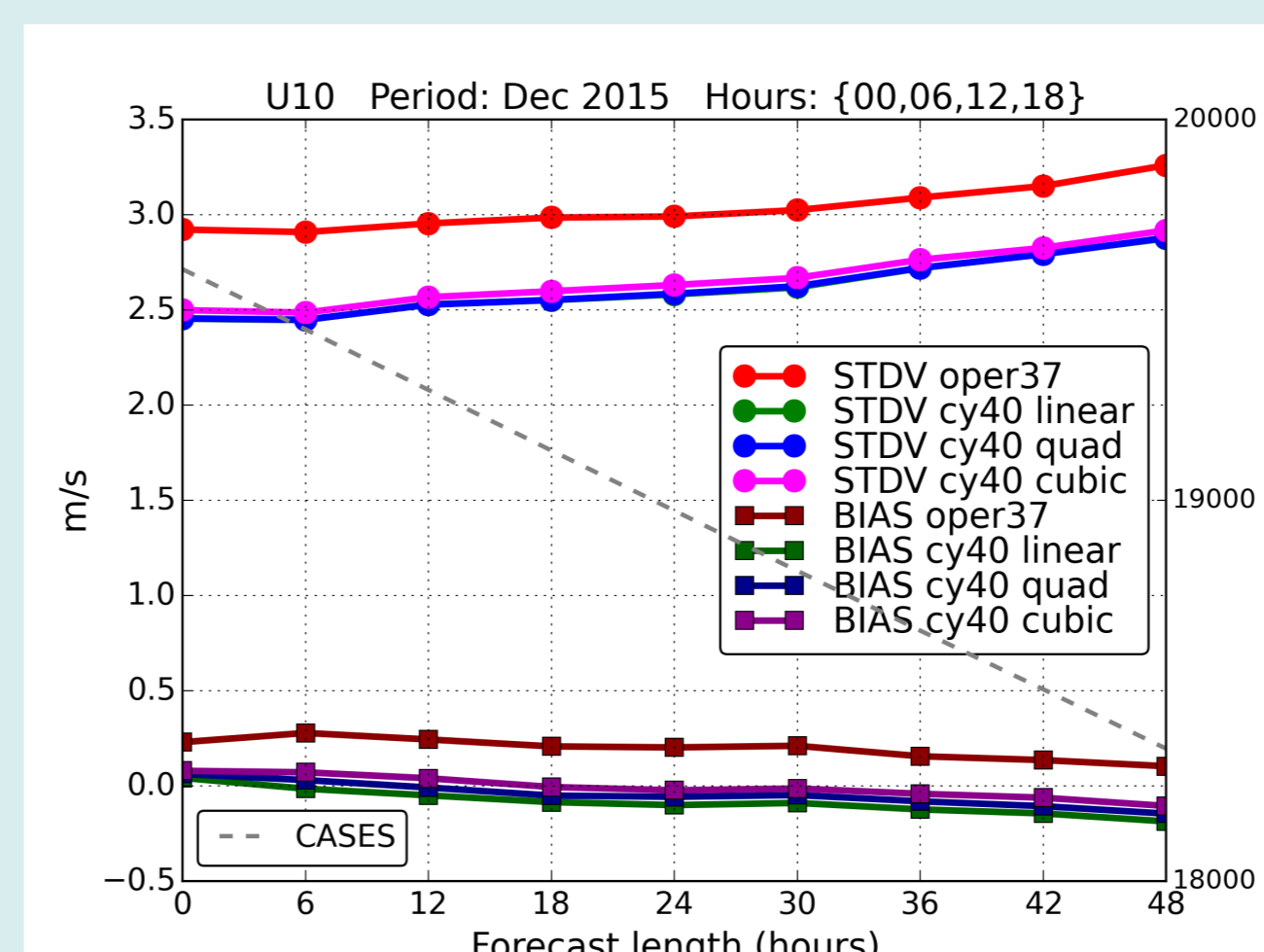
In addition, tuning of the vegetation heat capacity (see right) is being carried out to investigate the effect on 2 m temperature forecasts.



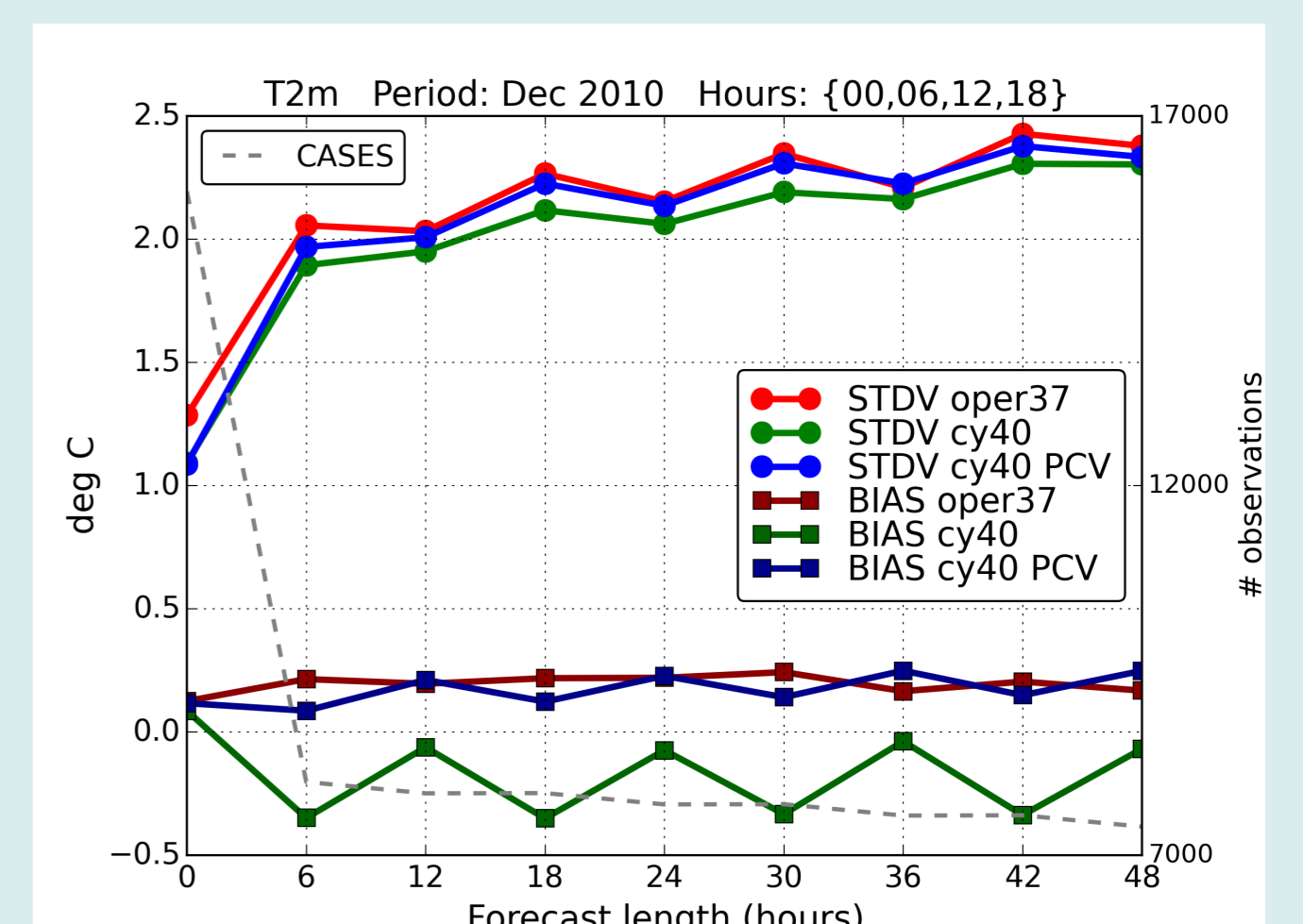
Proposed domains for HARMONIE-40; current domain in red.



Point verification of MSLP for cycle 40, with and without 3D-Var.



Point verification of U10m for cycle 40 against current operational cycle 37 with different spectral grids.



Point verification of T2m for cycle 37 against cycle 40 with default and lower ("cy40 PCV") values of the vegetation heat capacity.