



Combined and Calibrated ECMWF Forecasts

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Acknowledgment: Michael Denhard, ECMWF & SafeWind project

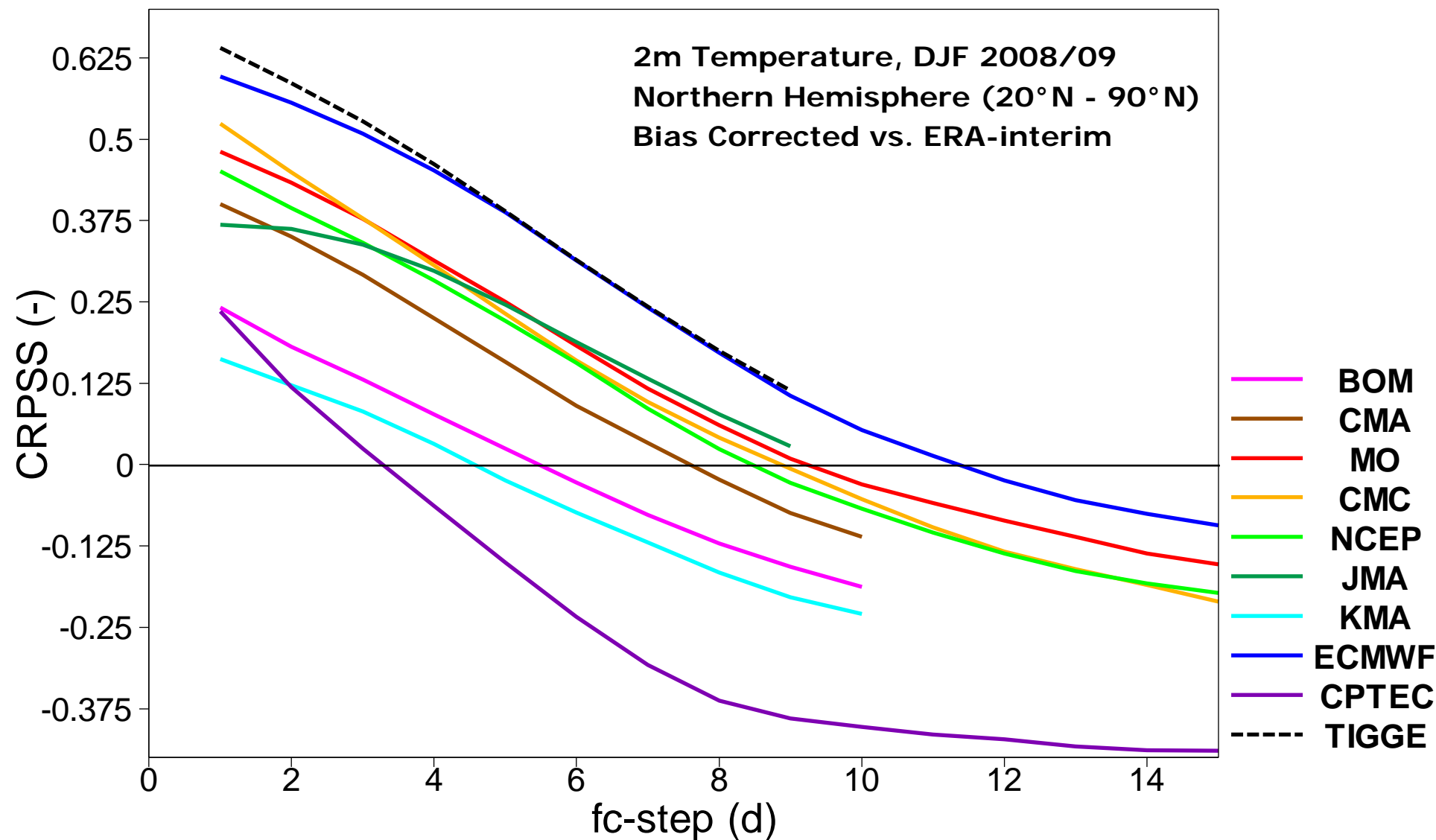


Motivation

- Traditionally, ECMWF provides forecasts from Direct Model Output (DMO) and Member States are responsible for any post-processing
- The new reforecast dataset for the EPS enables using new calibration methods
- Recent studies showed that combining the High-Resolution Deterministic and EPS forecasts can lead to further improvements
- Questions:
 - What are the benefits of using the reforecasts to calibrate the EPS?
 - What are the benefits of combining the High-Res and the EPS?
 - Should ECMWF provide post-processed products?

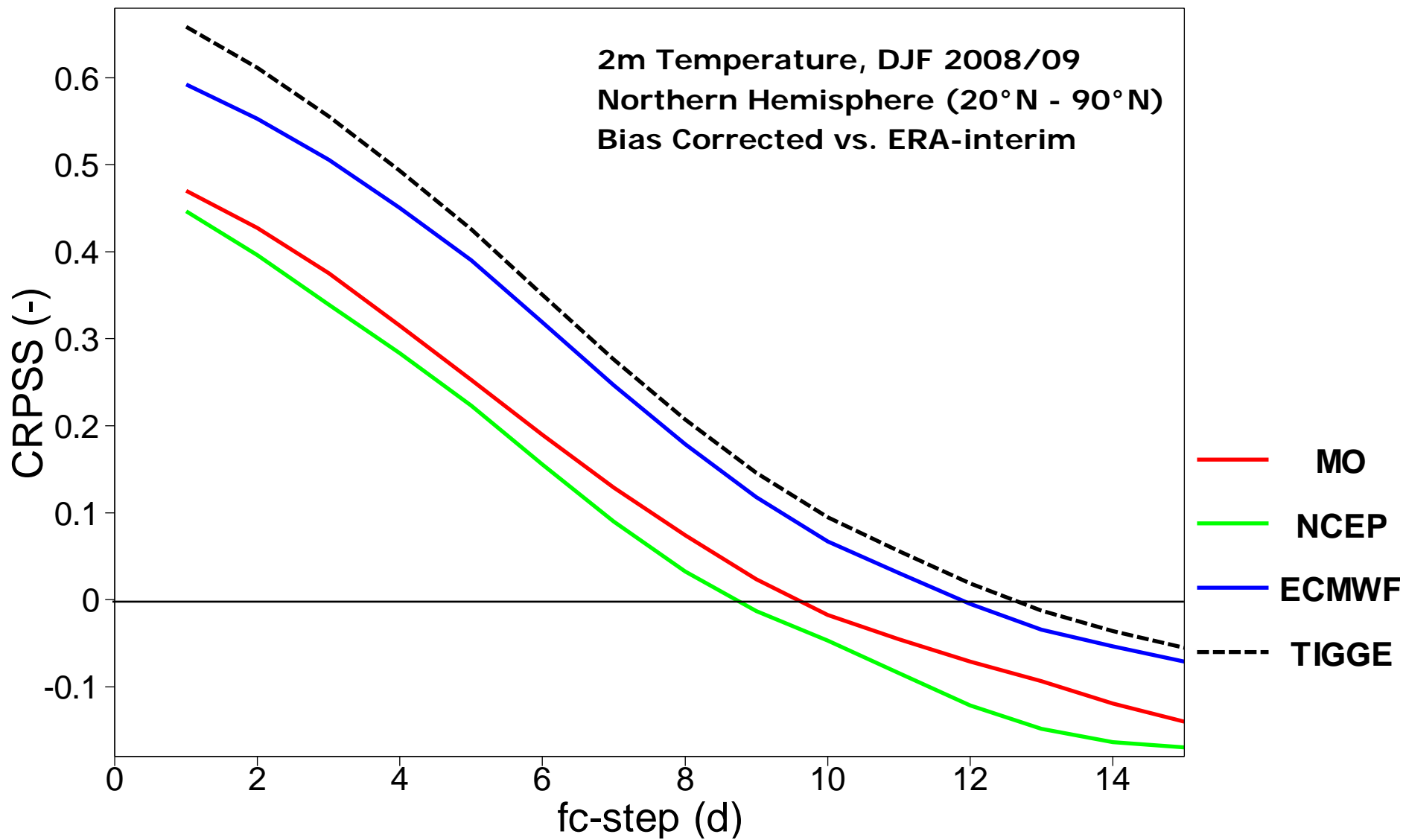


Comparing 9 TIGGE models & the MM





Comparing 3 TIGGE models & the MM





Calibration using reforecasts

- All calibration methods need a training dataset, containing a number of forecast-observation pairs from the past



The reforecast dataset

	2008																															2009						
	Nov		Dec																													Jan						
	29	30	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	01	02			
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The reforecast dataset

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Calibration using reforecasts

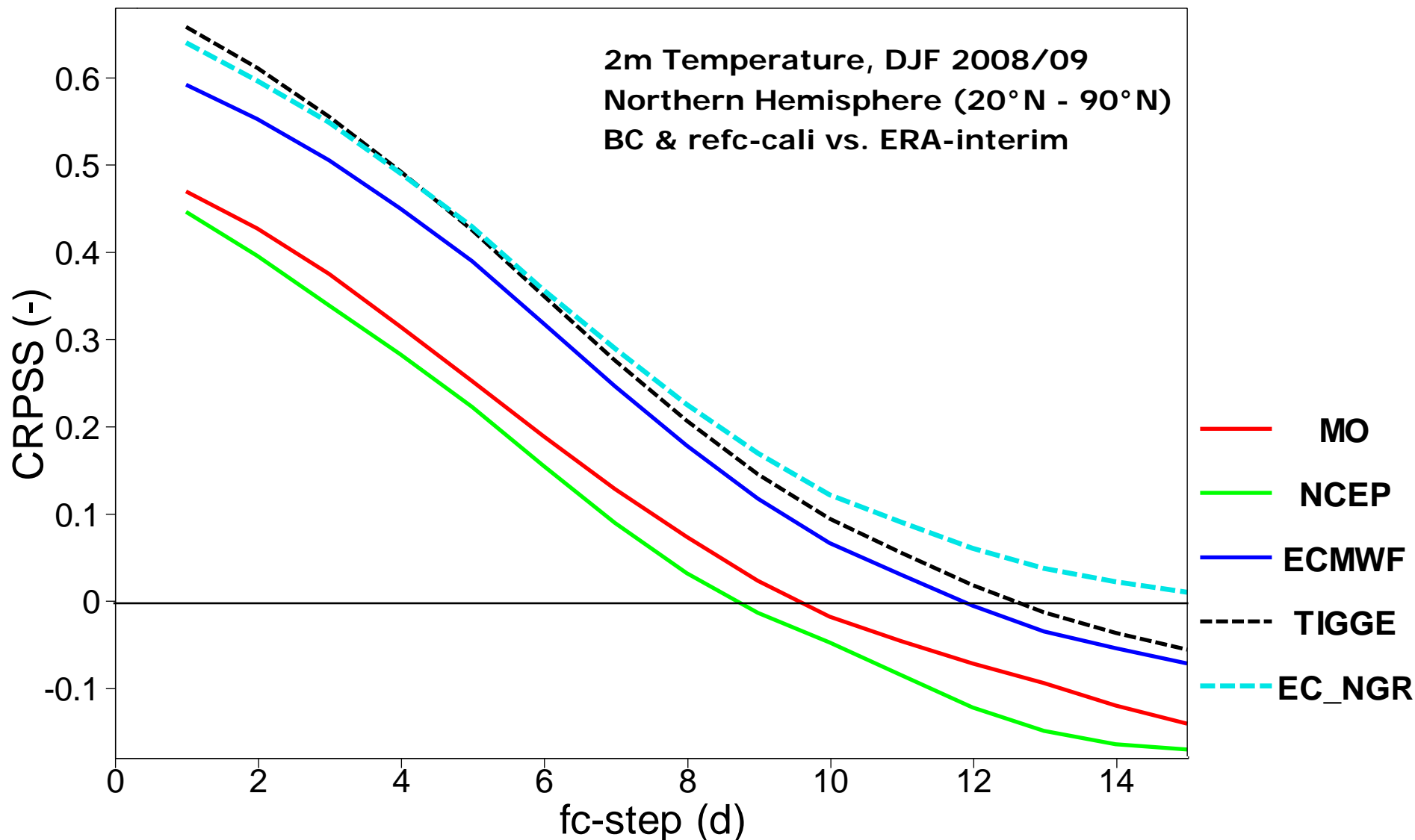
- All calibration methods need a training dataset, containing a number of forecast-observation pairs from the past
- Non-homogeneous Gaussian Regression (NGR) provides a Gaussian PDF based on the ensemble mean and variance of the raw forecast distribution

$$P(v \leq q) = \Phi \left[\frac{q - (a + b\bar{x}_{ens})}{\sqrt{c + ds_{ens}^2}} \right] \quad \text{with: } \Phi = \text{CDF of standard Gaussian distribution}$$

- Calibration process:
 - Determine optimal **calibration coefficients** by minimizing CRPS for training dataset
 - Apply calibration coefficients to determine calibrated PDF from ensemble mean and variance of actual forecast to be calibrated
 - Create calibrated NGR-ensemble with 51 *synthetic* members
 - Combine NGR-ensemble with '30-day bias corrected' forecast ensemble

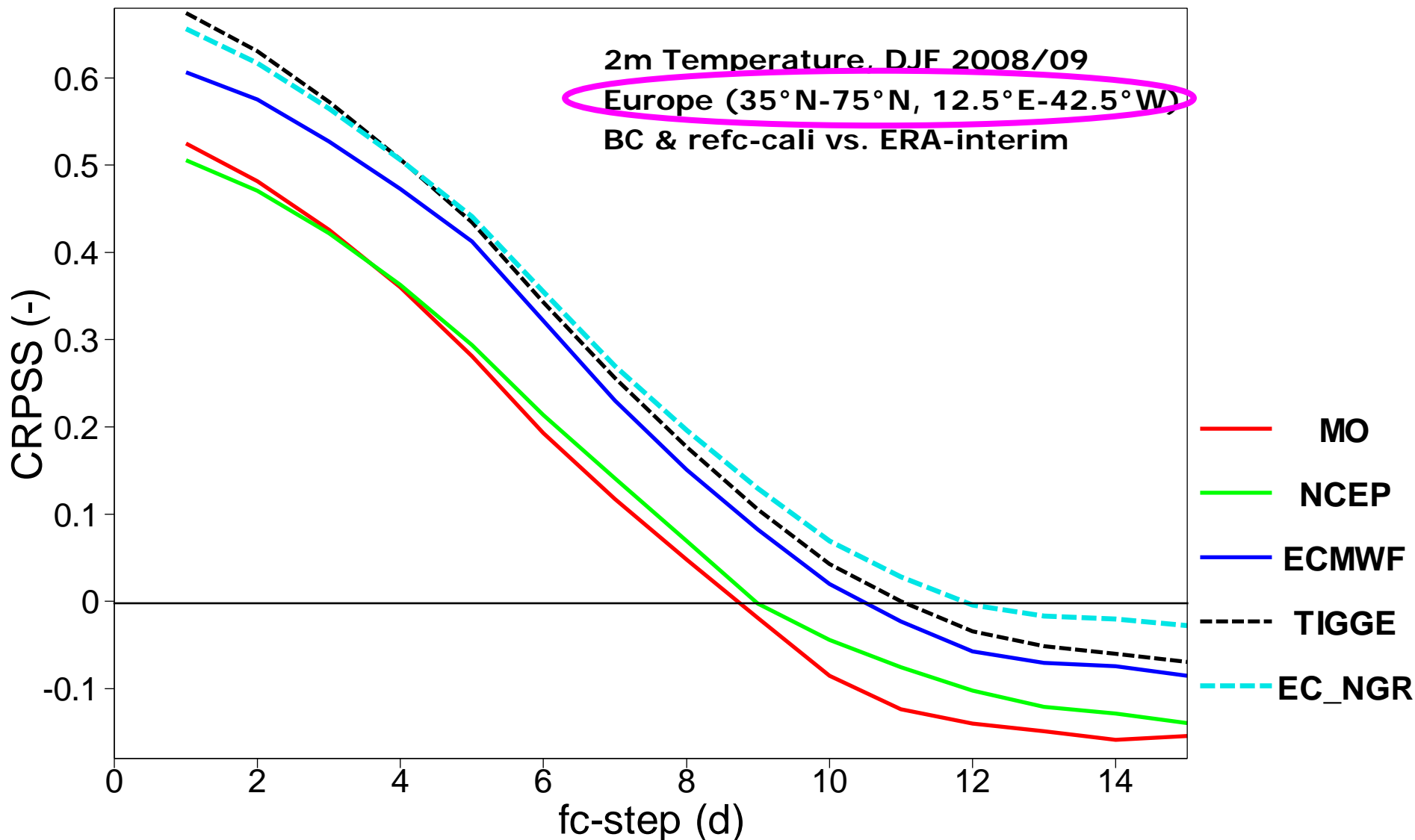


Comparing 3 TIGGE models, MM, EC_NGR



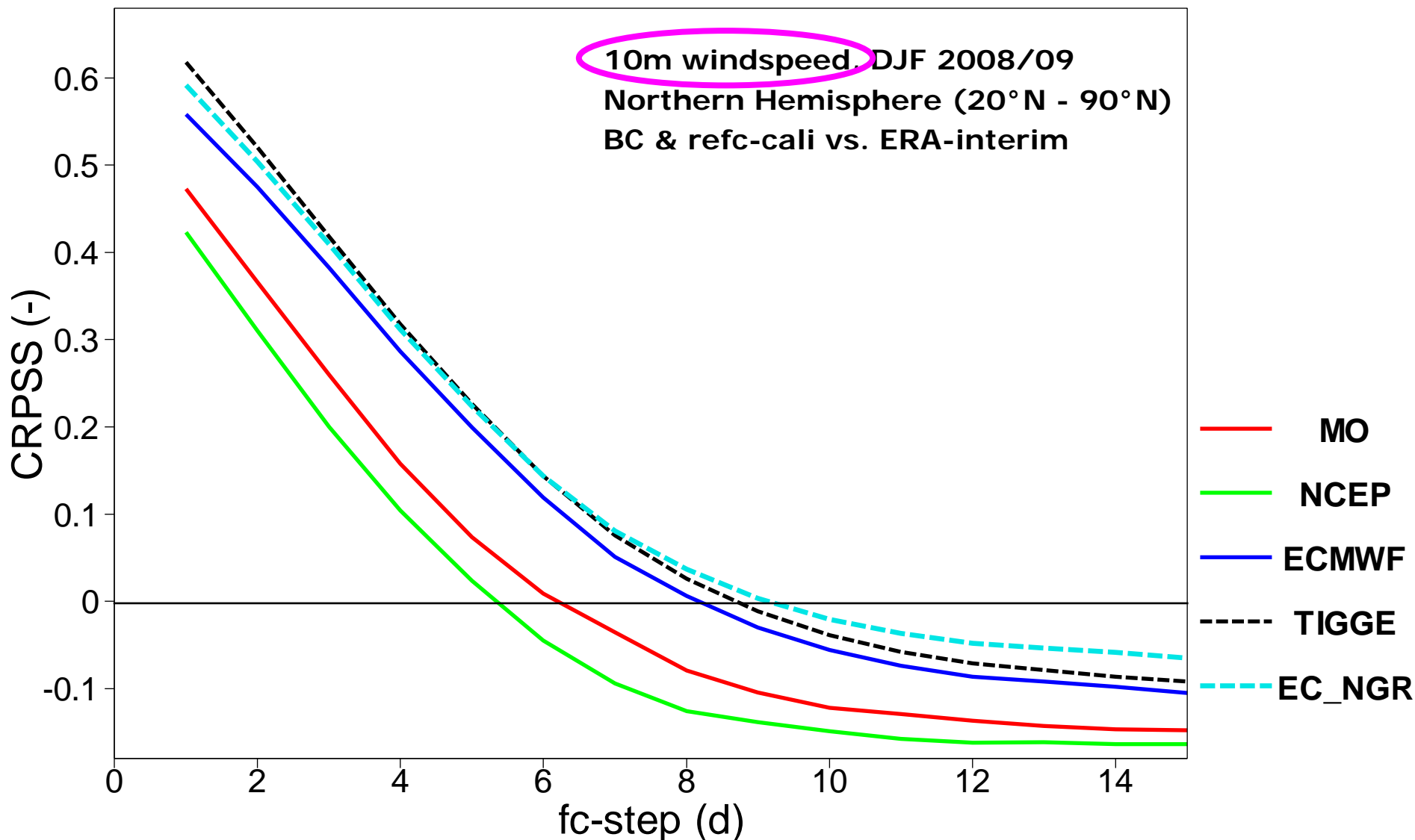


Comparing 3 TIGGE models, MM, EC_NGR



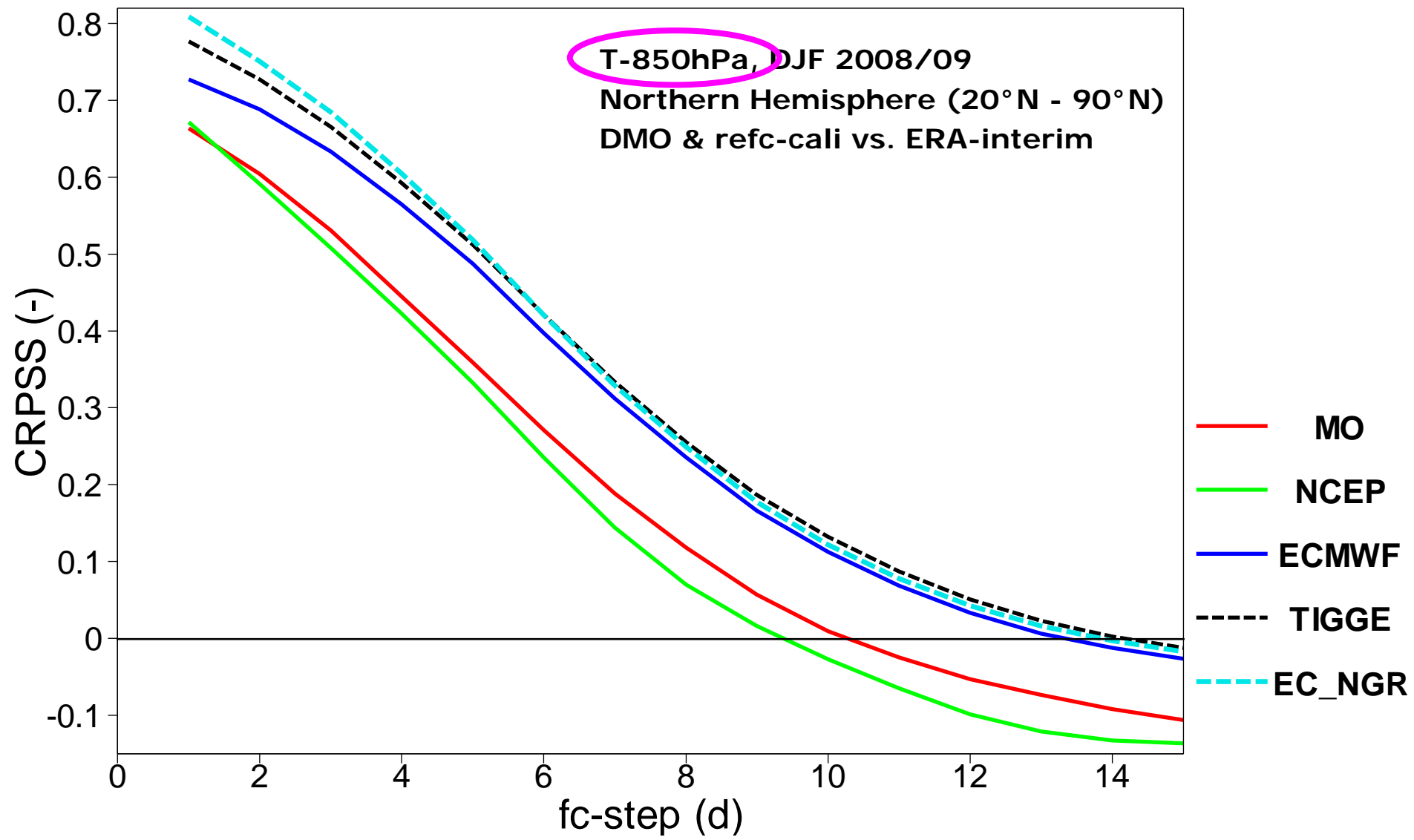


Comparing 3 TIGGE models, MM, EC_NGR



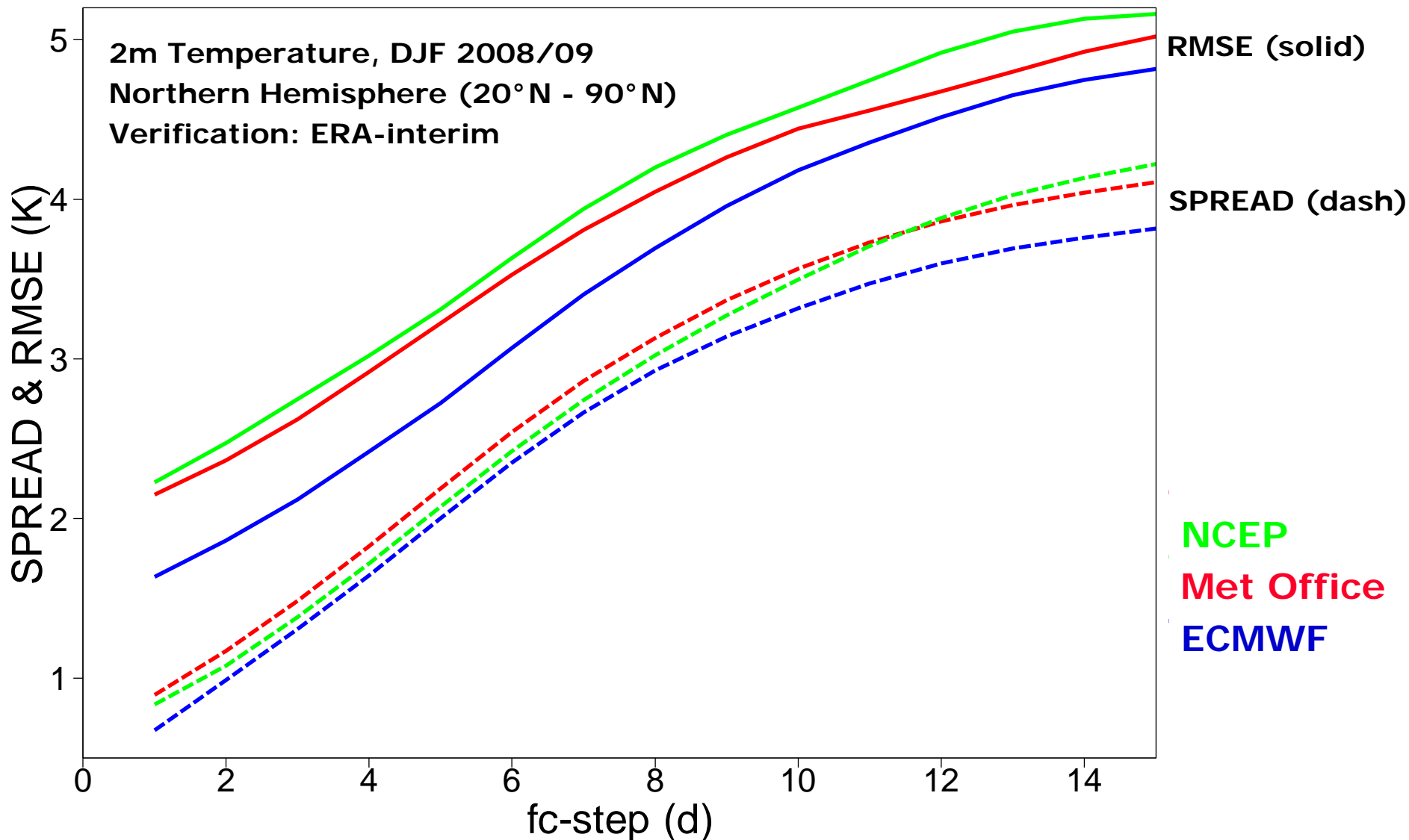


Comparing 3 TIGGE models, MM, EC_NGR



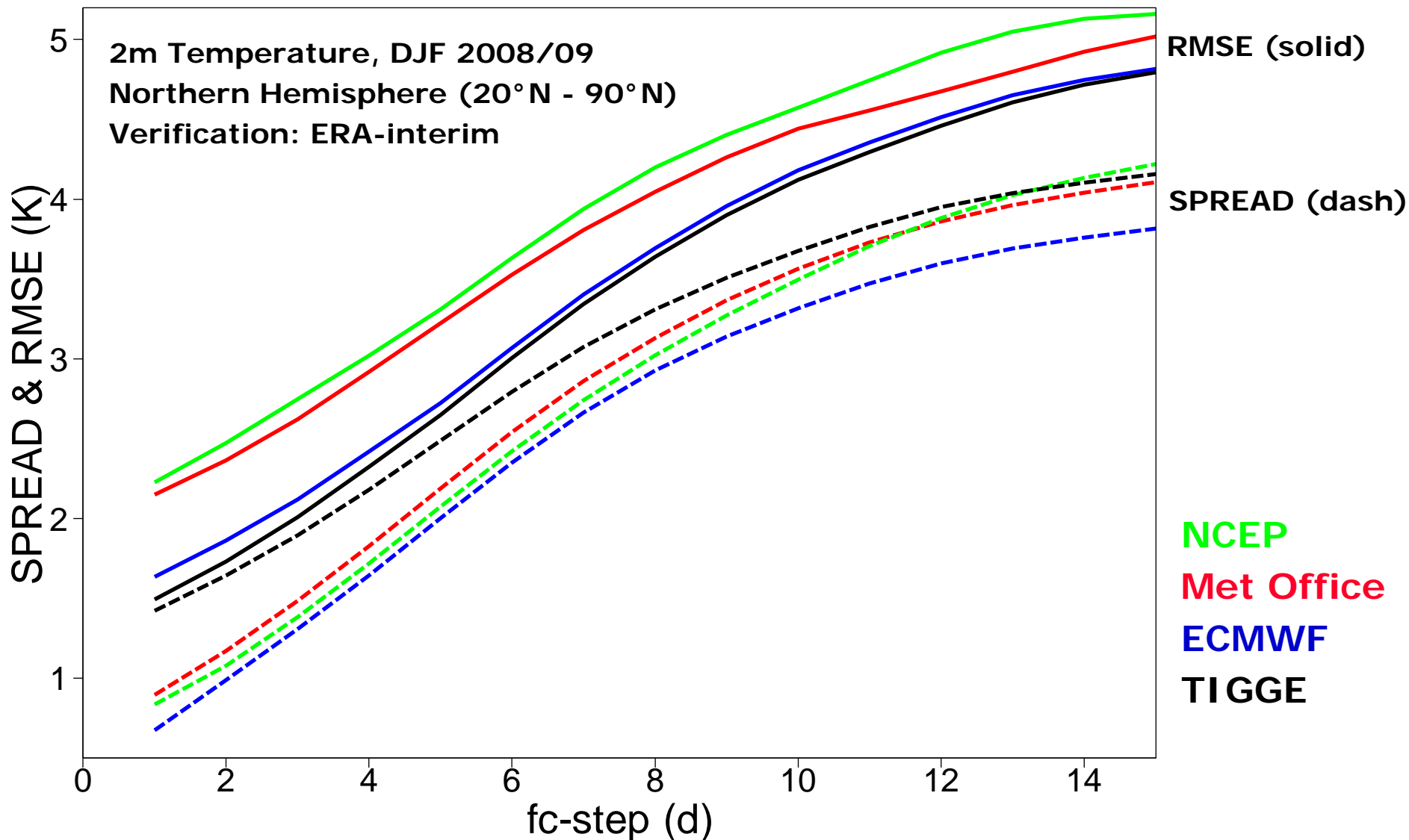


Mechanism behind improvements



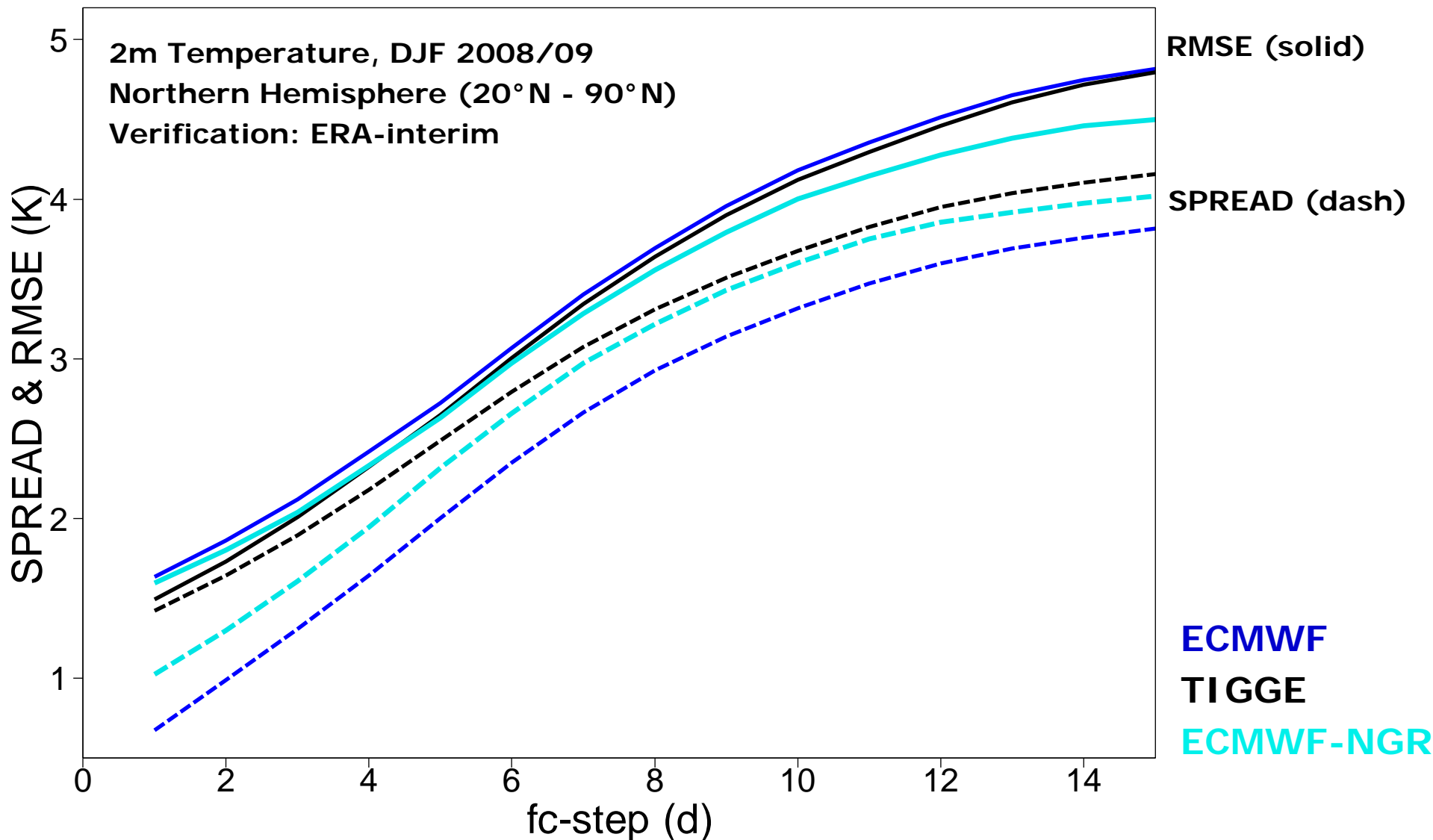


Mechanism behind improvements



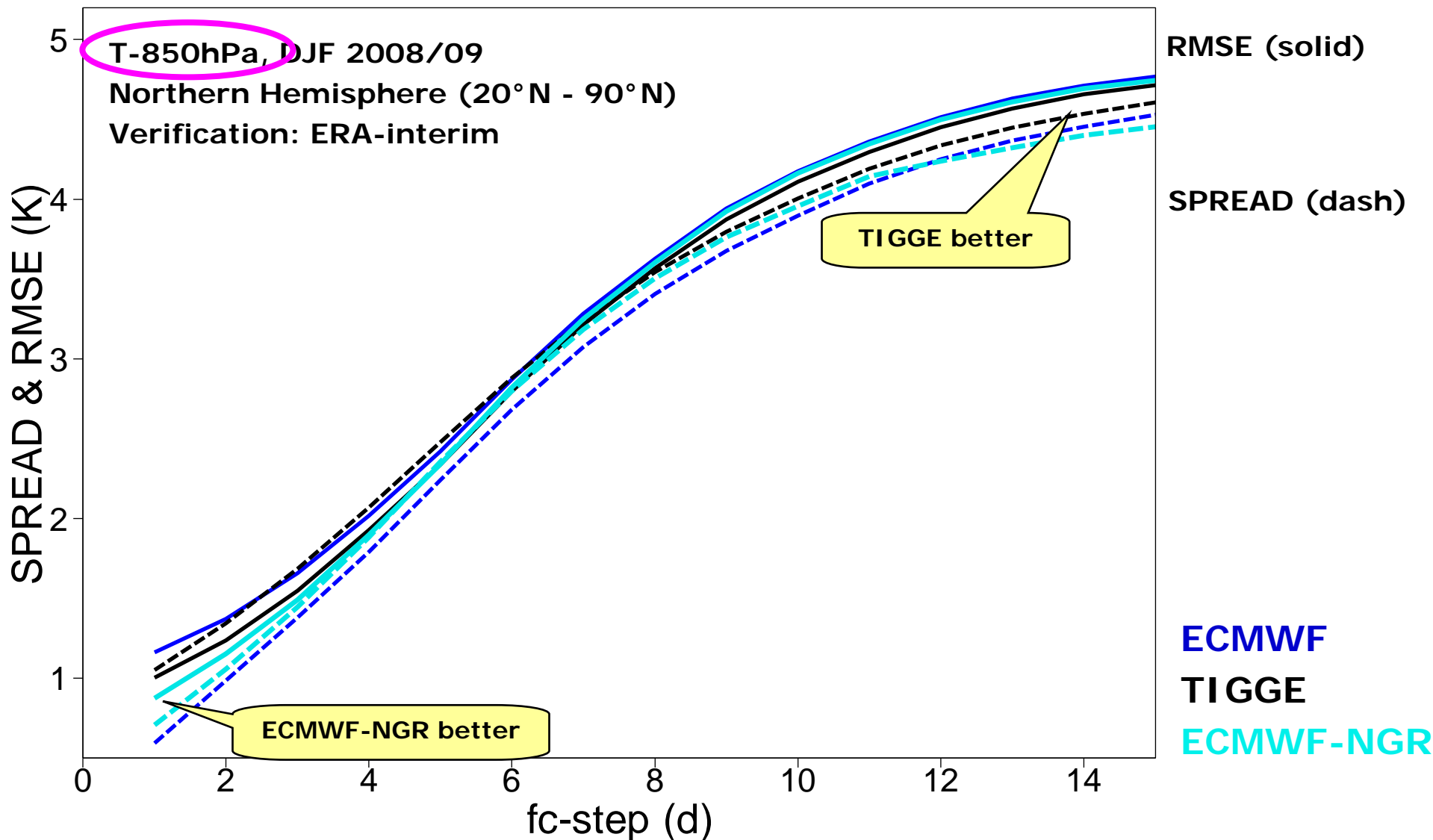


Mechanism behind improvements



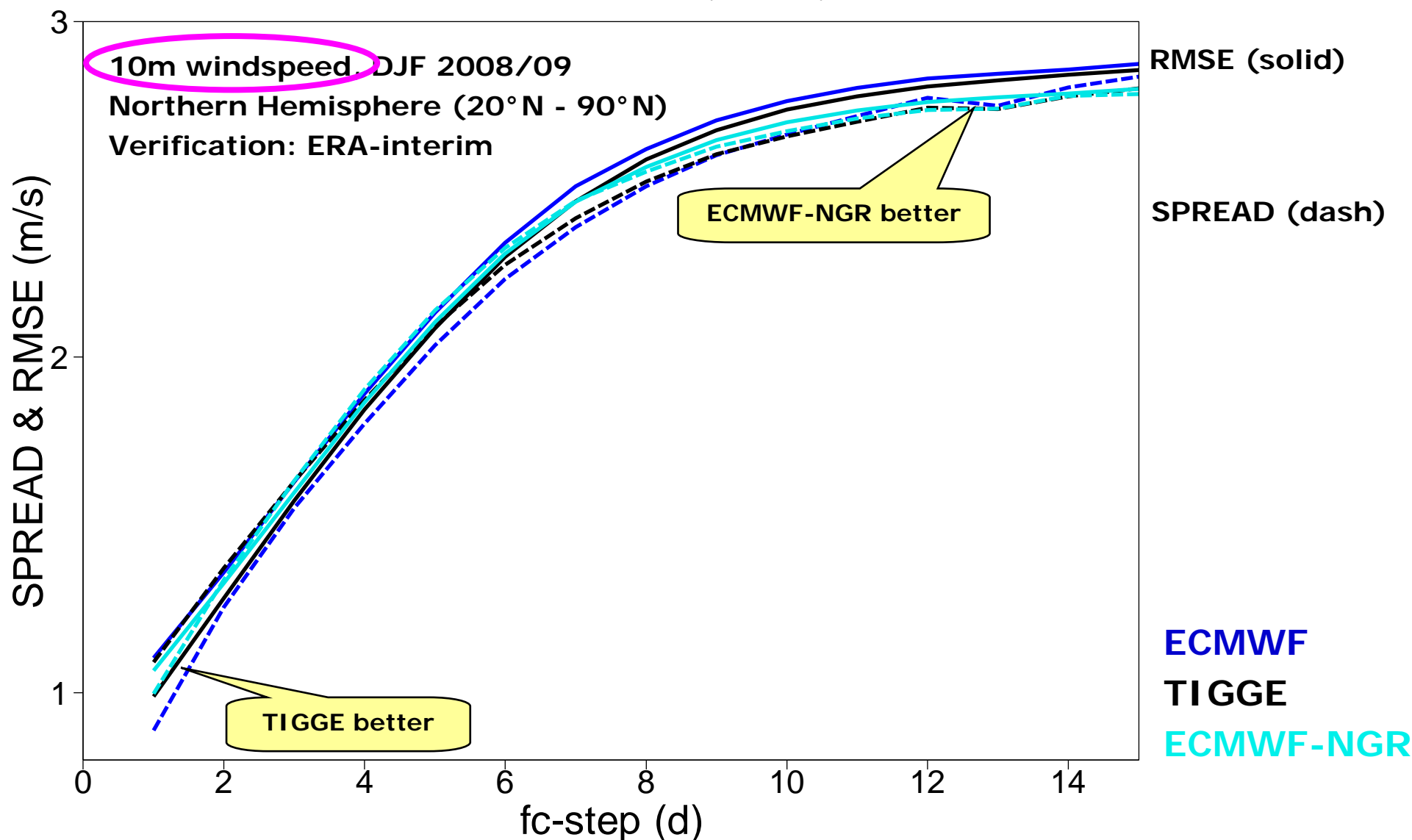


Mechanism behind improvements



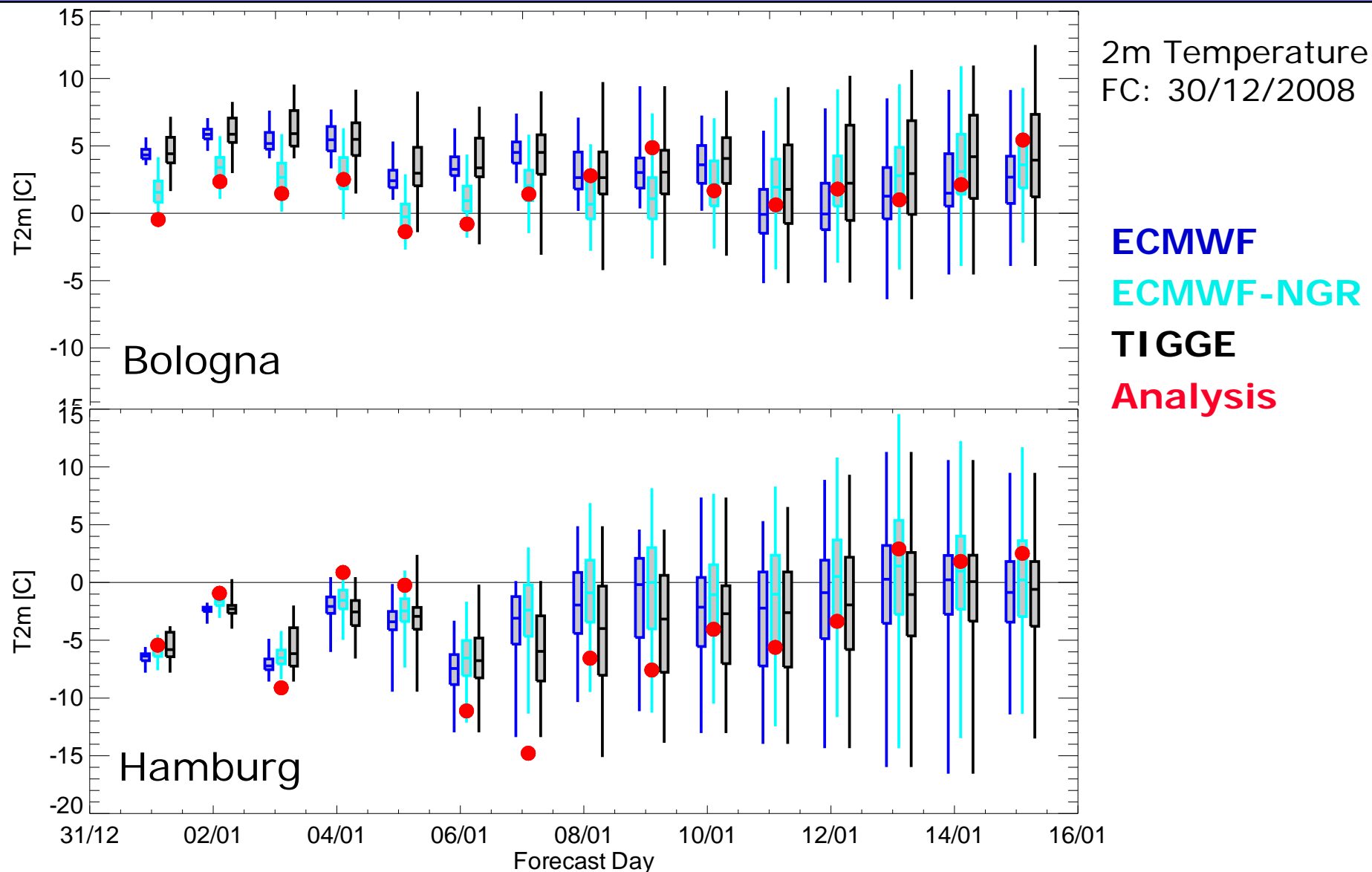


Mechanism behind improvements





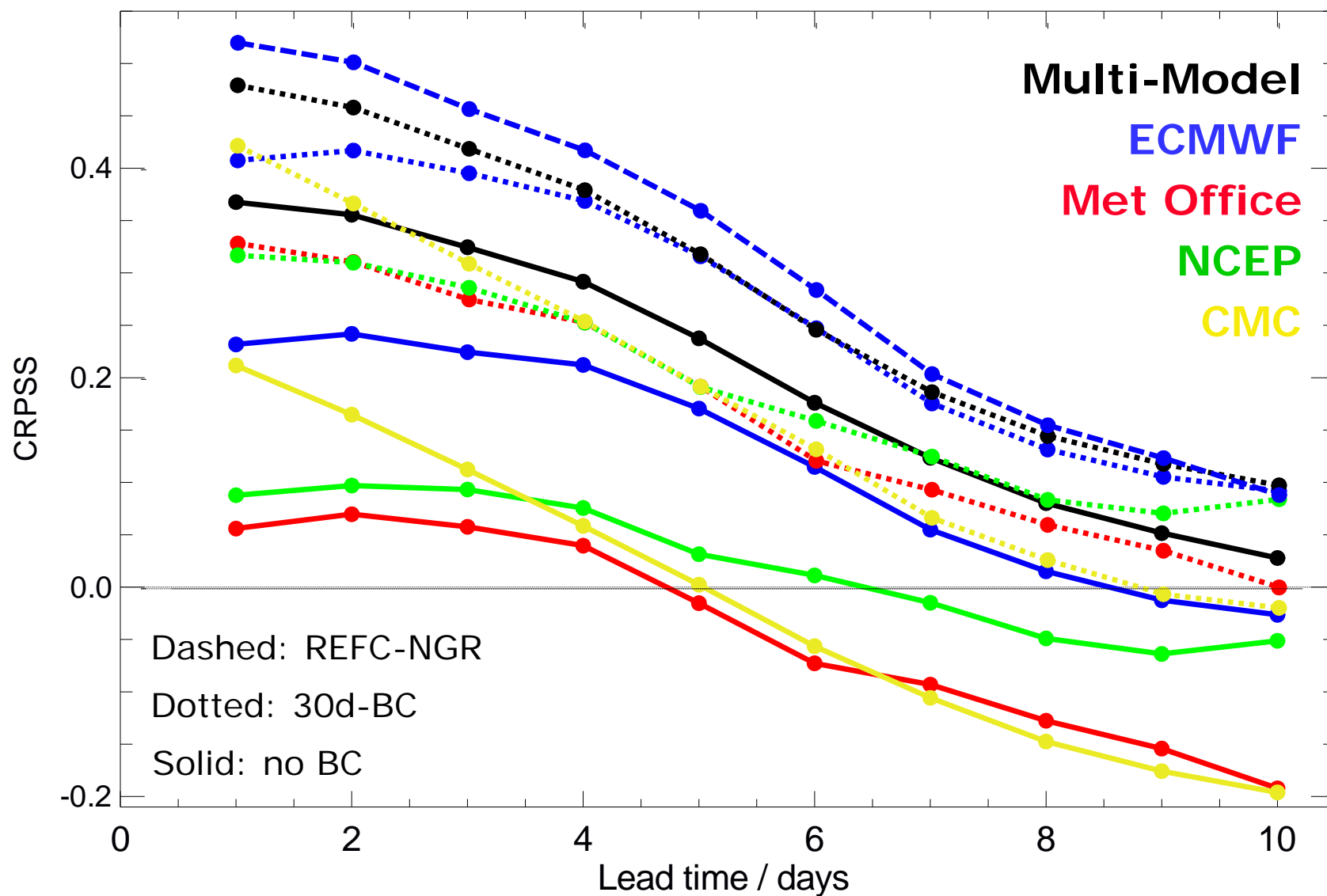
Impact of calibration & MM in EPSgrams





What about station data?

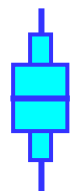
T-2m, 250 European stations
DJF 2008/09



Dashed: REFC-NGR
Dotted: 30d-BC
Solid: no BC



Motivation to combine High-Res and EPS



EPS

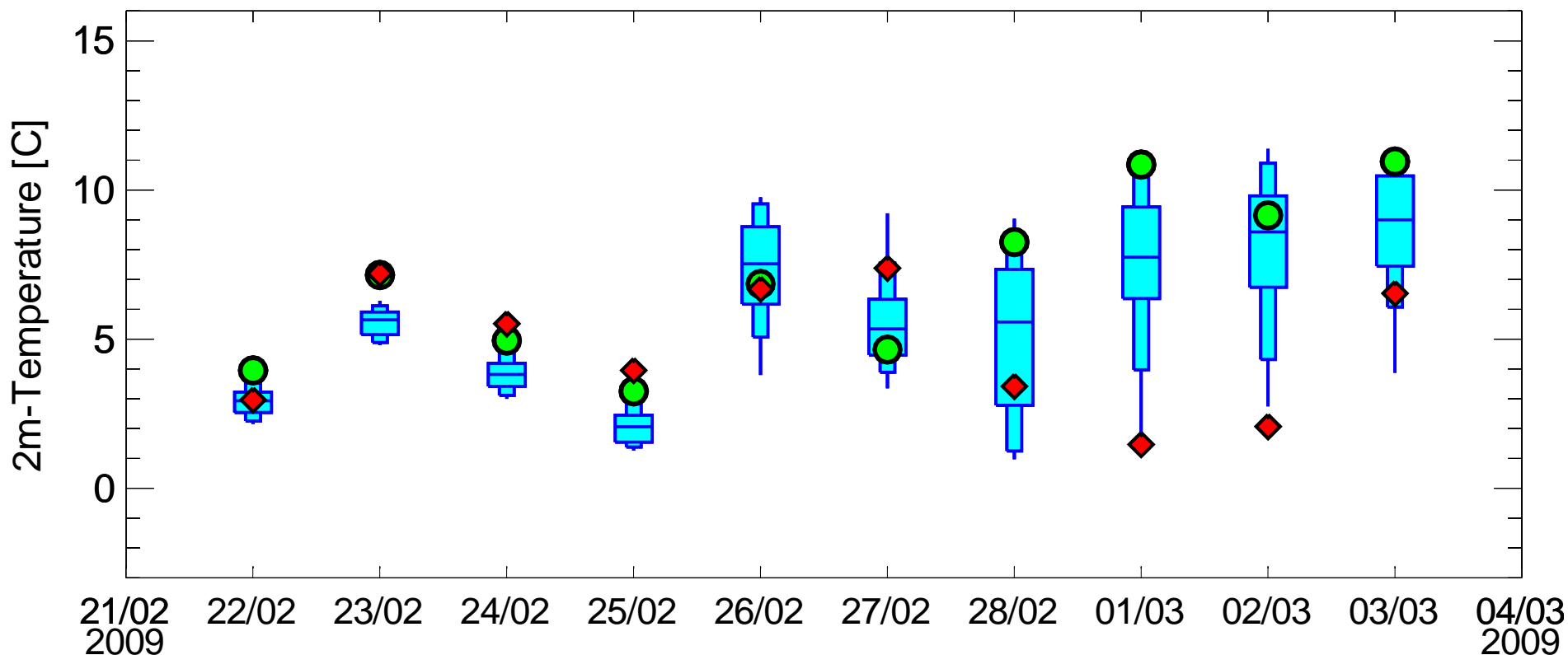


Observation



High-Resolution

2m-Temperature: Rome, FC-start: 21/02/2009 00:00





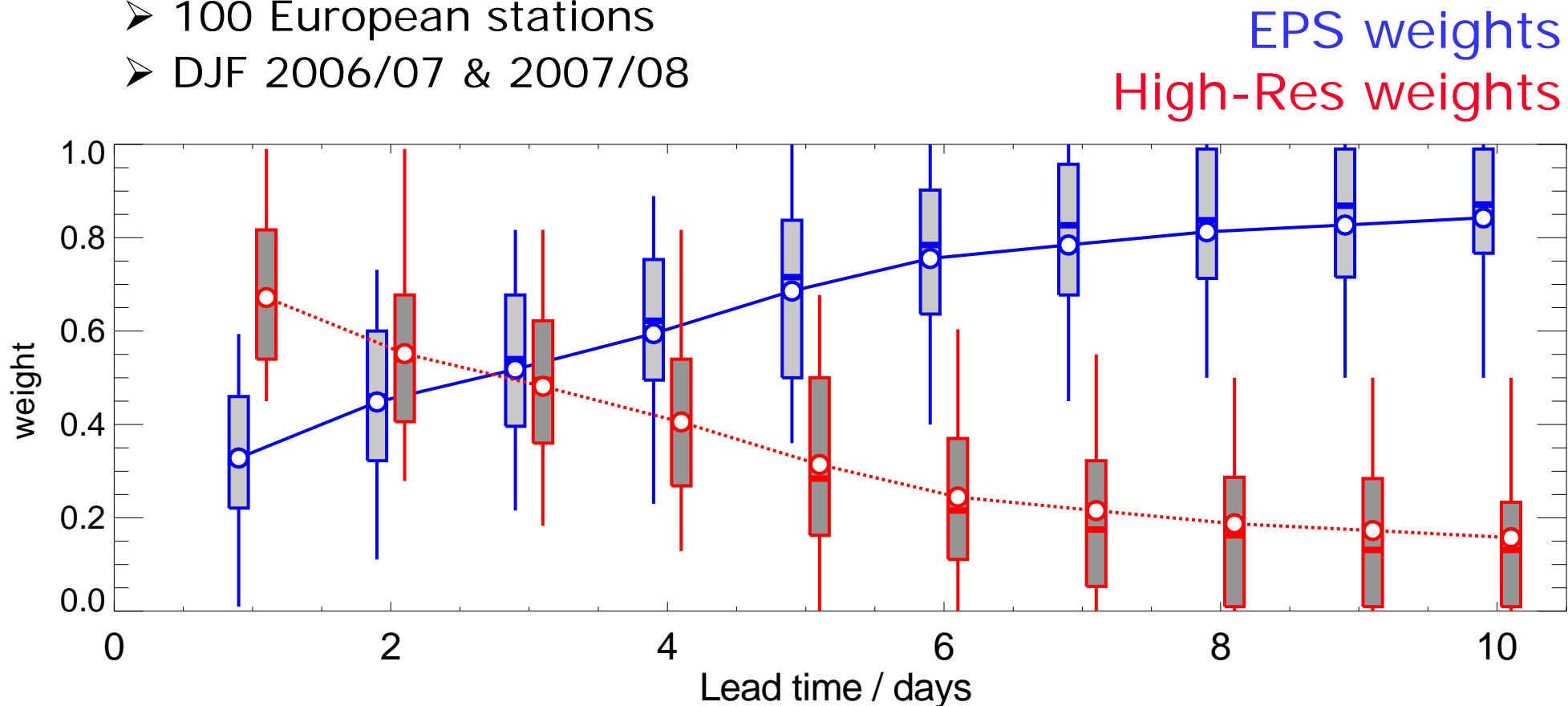
Method to combine High-Res and EPS

- Training dataset: DJF 2006/07 & DJF 2007/08
- Use the dressed High-Resolution and raw EPS forecasts as components of the Combined Prediction System (CPS)
- Calculate weights for HR and EPS by minimizing the Ignorance Score in the training dataset
- Apply weights to independent test dataset: DJF 2008/09
- Score CPS forecasts and compare with EPS forecasts (for 100 stations in Europe, 2m-Temperature)

Distribution of CPS weights

Training Data:

- 2m-Temperature
- 100 European stations
- DJF 2006/07 & 2007/08

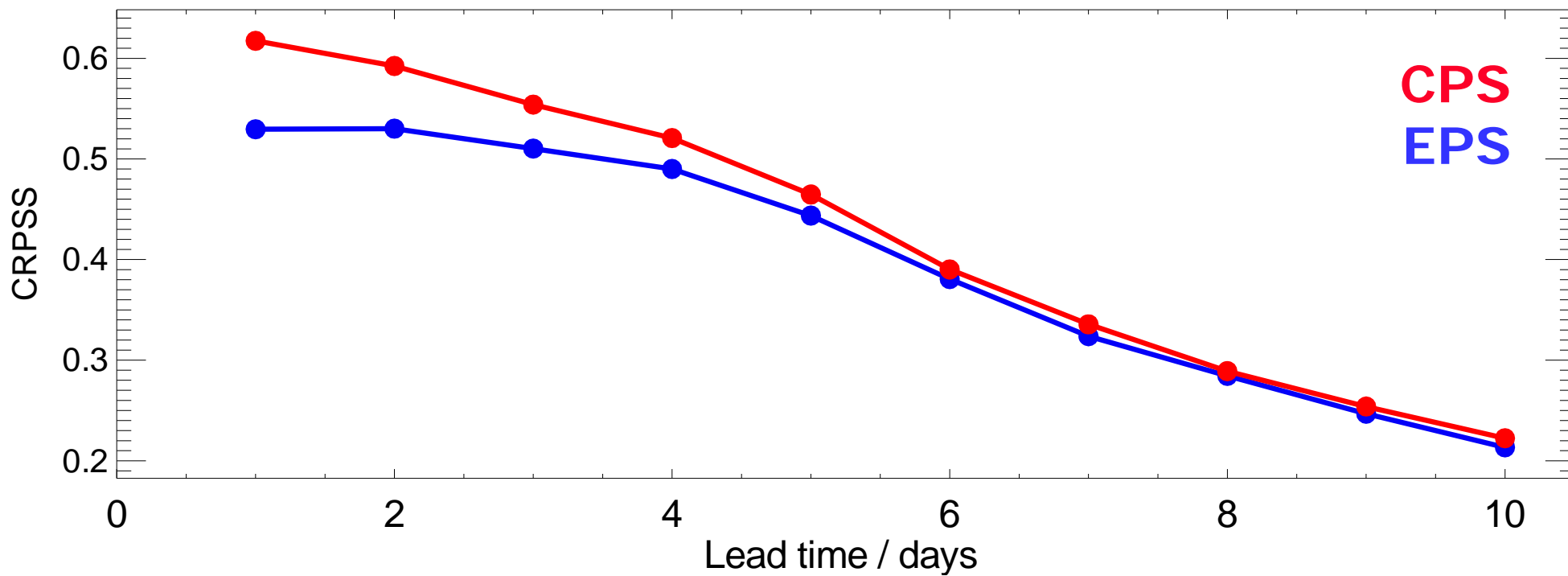




CRPSS: EPS versus CPS

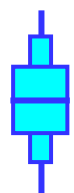
Test Data:

- 2m-Temperature
- 100 European stations
- DJF 2008/09





EPSgram versus CPSgram for Rome



EPS



Observation

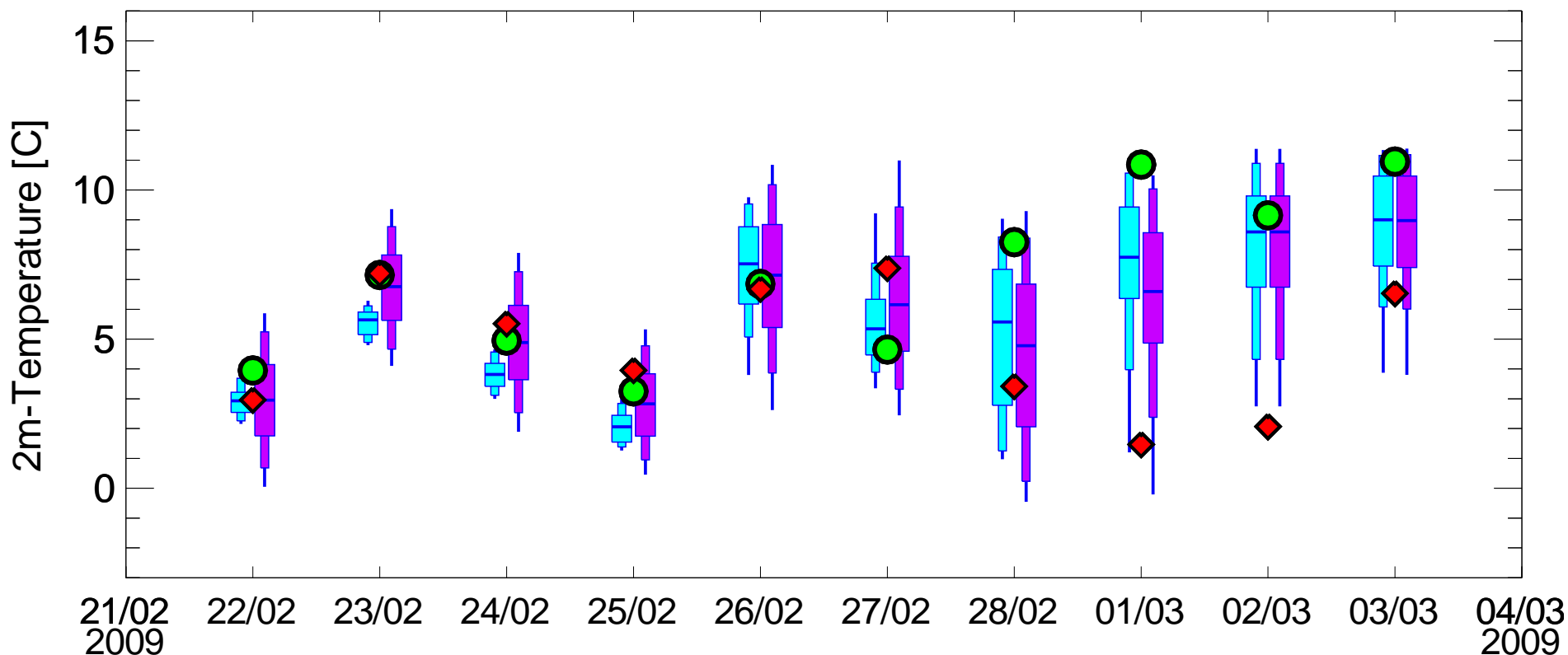


High-Resolution



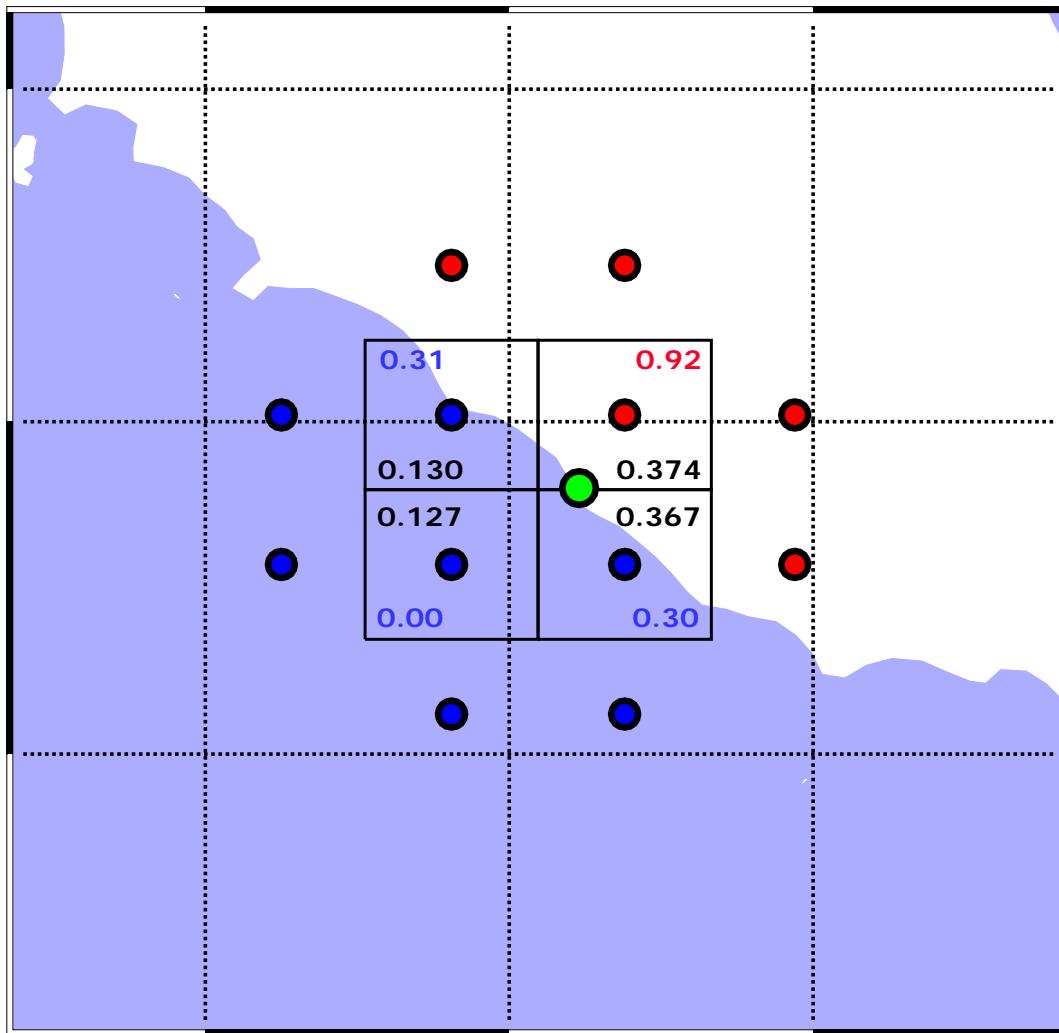
CPS

2m-Temperature: Rome, FC-start: 21/02/2009 00:00

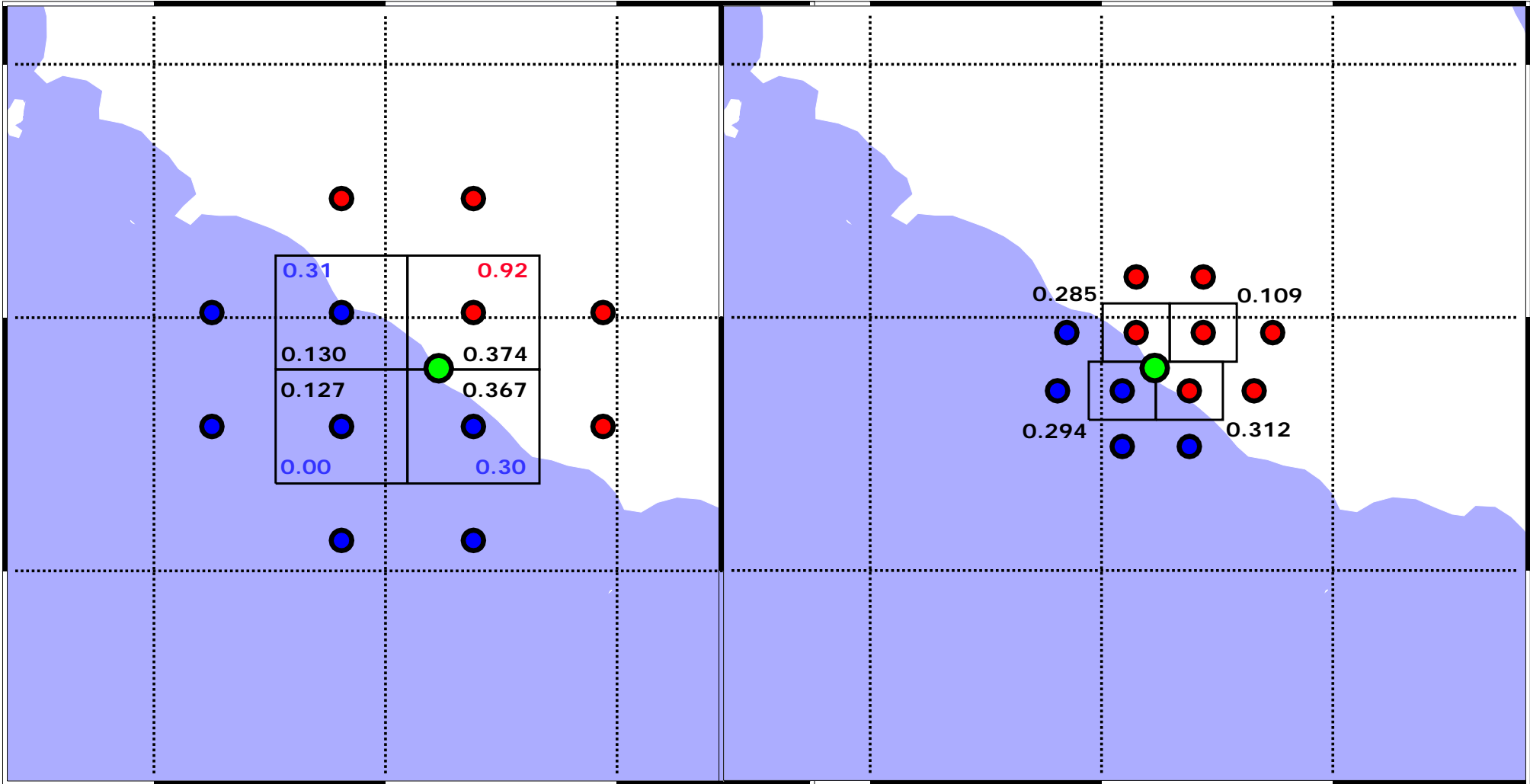




EPS-grid around Rome



EPS Grid vs. High-Res Grid

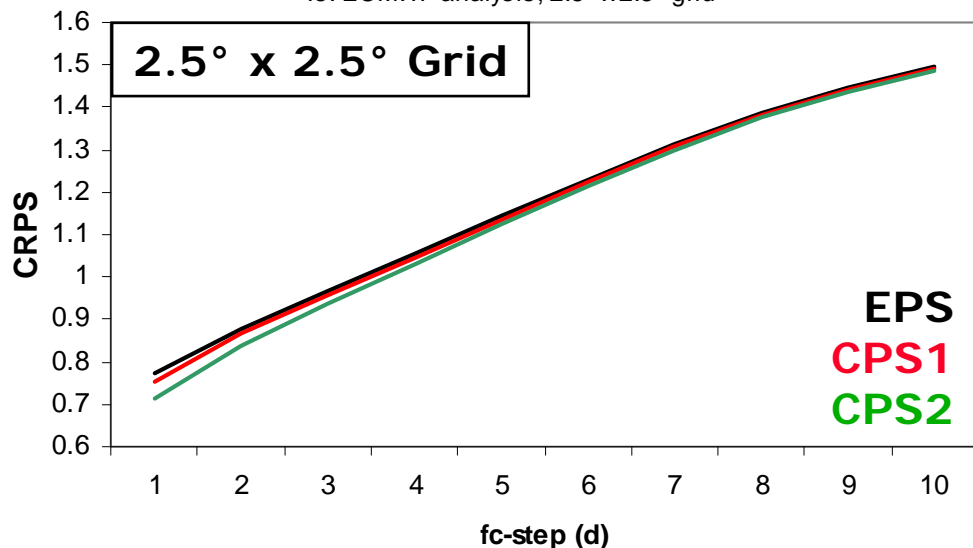




What about global CPS products?

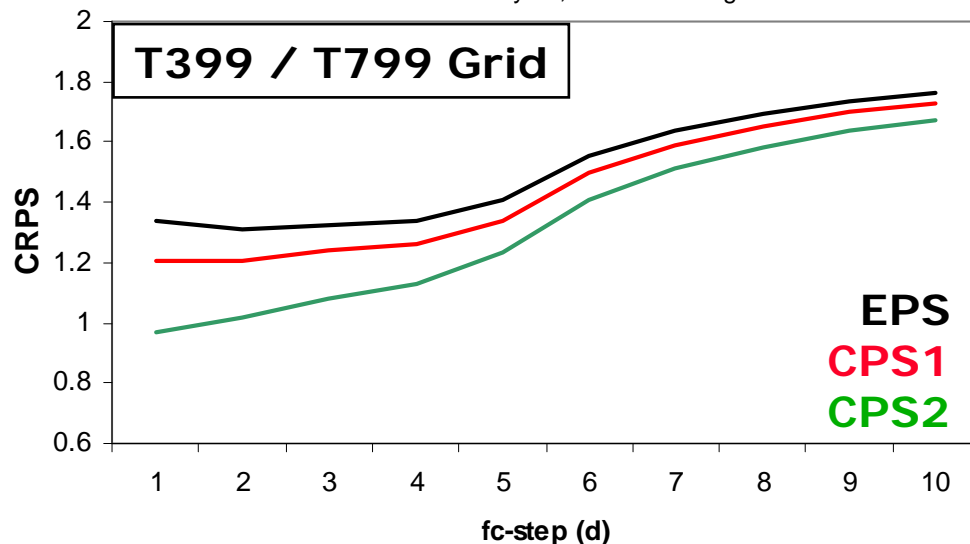
2m Temperature, global

ContinuousRankedProbabilityScore, 20081201-20090228
vs. ECMWF analysis, 2.5° x 2.5° grid



2m Temperature, Europe

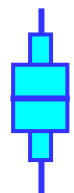
ContinuousRankedProbabilityScore, 20090101-20090131
vs. ECMWF analysis, 0.25° x 0.25° grid



- Evaluation of global CPS products on 2.5 x 2.5 grid –currently- shows only a slight improvement to EPS only forecasts
- CPS methodology shows more impact on original model grid
- We are in the process of testing and refining different optimization routines and plan to evaluate the CPS methodology for other fields



Cold air outbreak Germany 6-7 Jan 2009



EPS



Observation



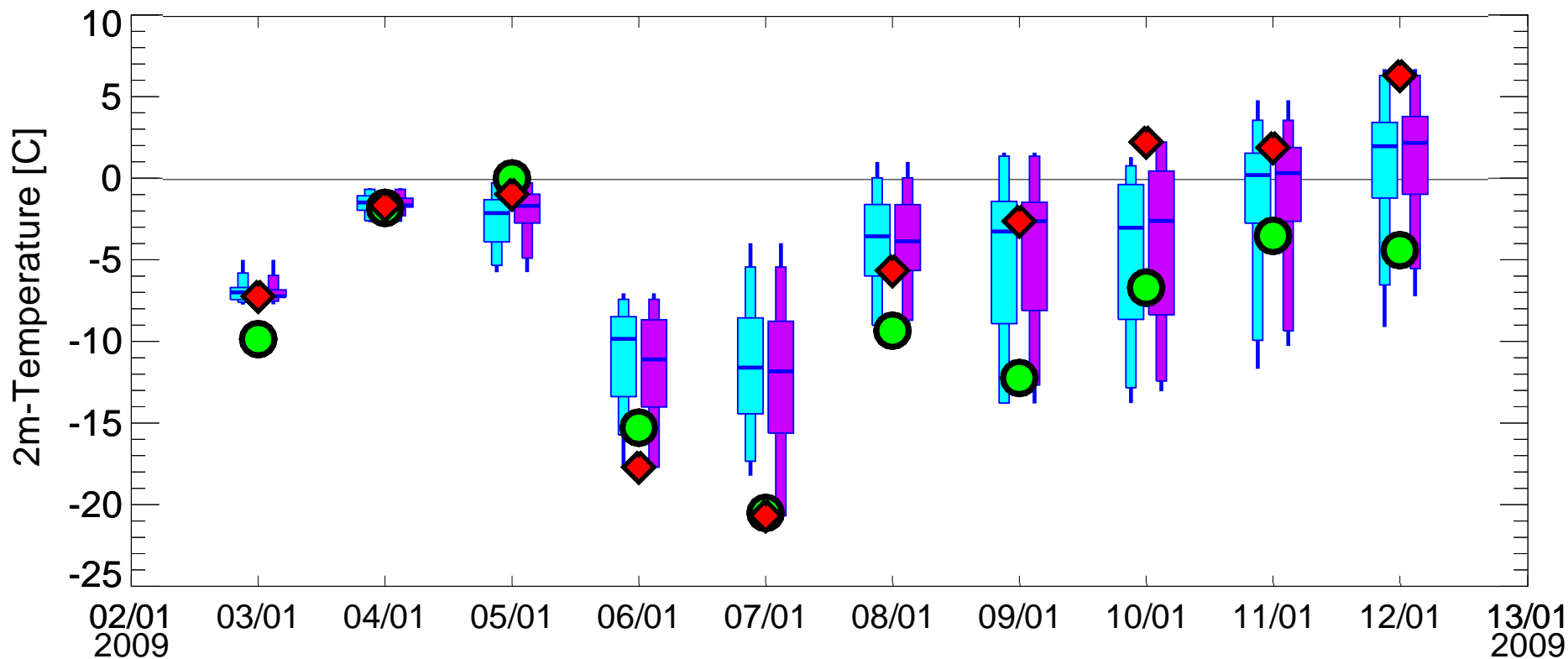
High-Resolution



CPS

on model grid

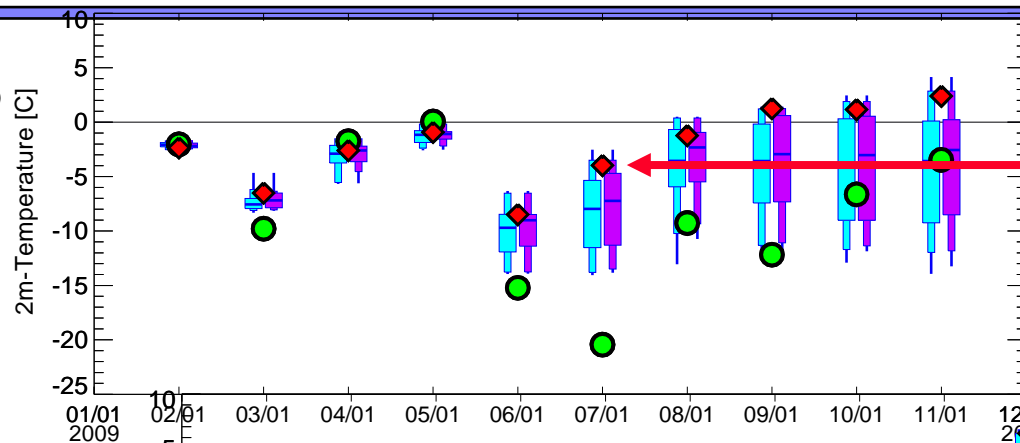
2m-Temperature: Oschatz, FC-start: 02/01/2009 00:00





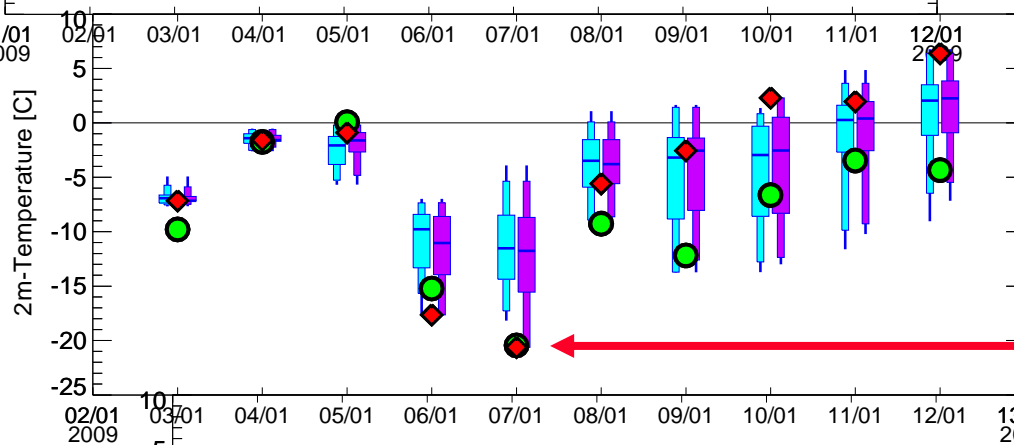
Cold air outbreak Germany 6-7 Jan 2009

FC-start: 01/01/2009



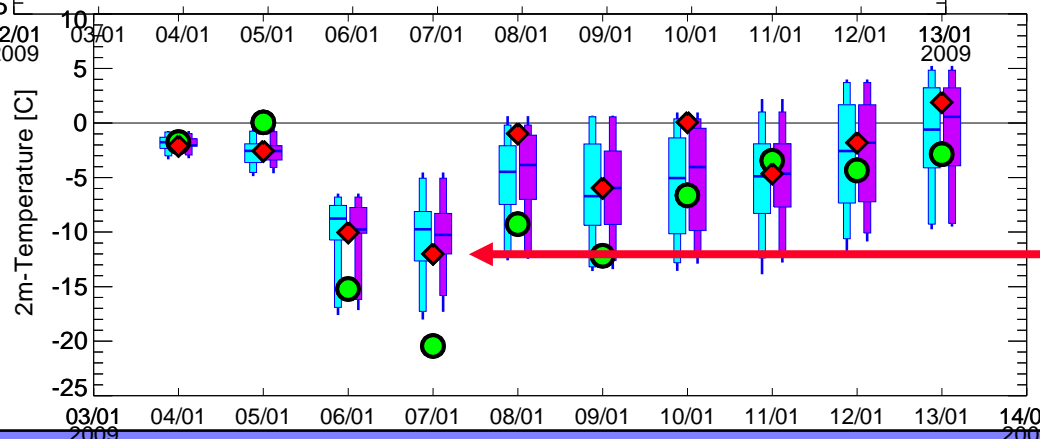
High-Res
6-Day FC

FC-start: 02/01/2009



High-Res
5-Day FC

FC-start: 03/01/2009



High-Res
4-Day FC



Summary

- What are the benefits of using the reforecasts to calibrate the EPS?
 - Reforecasts enable detection & correction of systematic errors in forecast system (bias and/or spread deficiencies)
 - Calibrated ECMWF forecasts are as good as or even better than TIGGE multi-model forecasts
 - Both global upper air fields and surface variables can be improved
- What are the benefits of combining the High-Res and the EPS?
 - Improved forecasts, in particular for shorter lead times
 - Improvements mainly for CPS forecasts at station location or original model grid
- Should ECMWF provide post-processed products?
 - Up to you... (yes, if you use DMO; no, if you apply your own MOS)