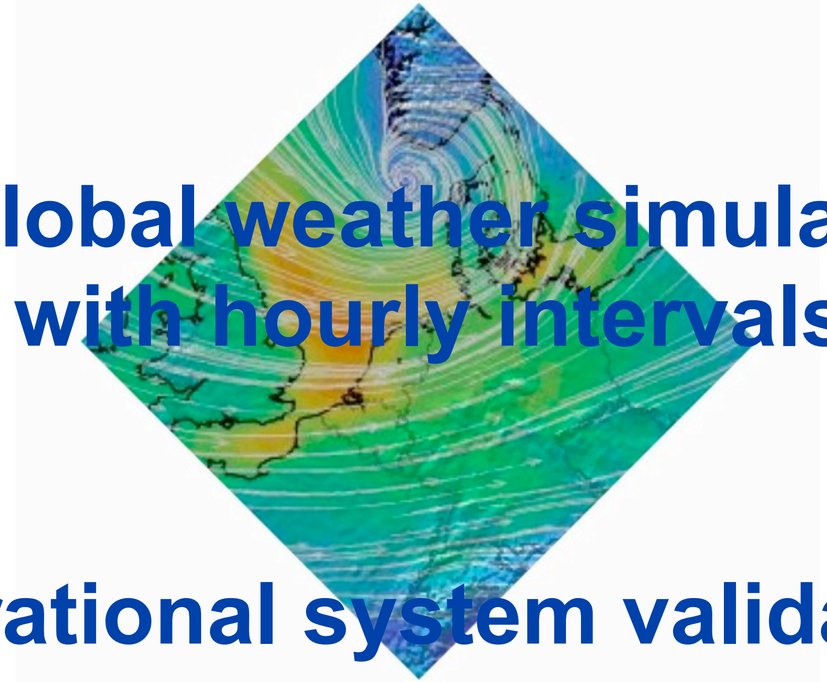
meteoblue
weather ☼ close to you

Global weather simulation with hourly intervals



operational system validation

meteoblue®

Dr. Karl G. Gutbrod, Dr. Mathias Müller
meteoblue AG, Basel, Switzerland

Meteorological World Expo, Brussels, 16 October 2013

Global weather simulation with hourly intervals

NEMS (NOAA Environmental Modeling System)

- Further development of NMM-Framework
- Developed at the NCEP / NOAA
- Replaces NMM (Numerical MesoScale Model), WRF Frameworks
- Operational at NOAA (North America, Hurricane Model) .
- Testing by University of Basel since 2011
- Testing versions on meteoblue clusters since 2012
- Operational at meteoblue since May 2013

NEMS - Main features

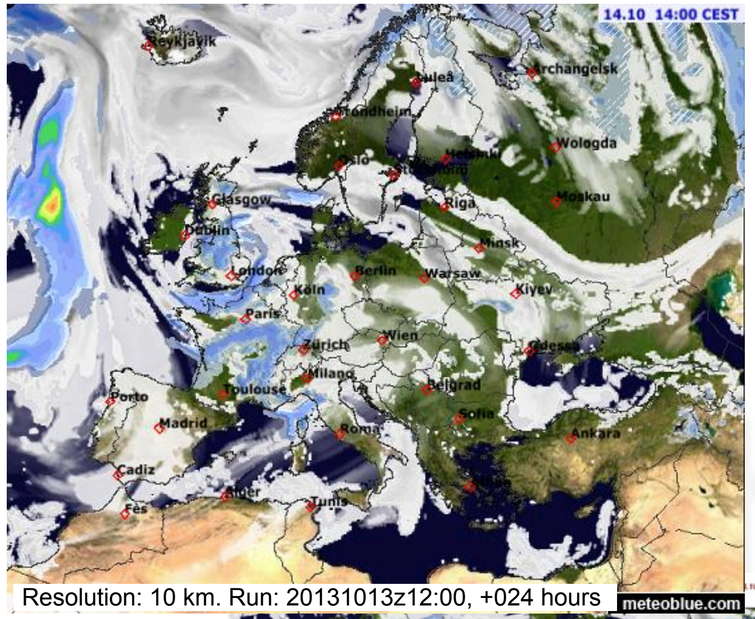
- Framework allows Modelling from Global to Mesoscale
- Seamless nesting for regional domains
- Improved cloud and precipitation schemes
- Option to add improved schemes (radiation, soil moisture, etc.)
- Option for initialization with different sources
- Hourly data extractions

Global weather simulation with hourly intervals

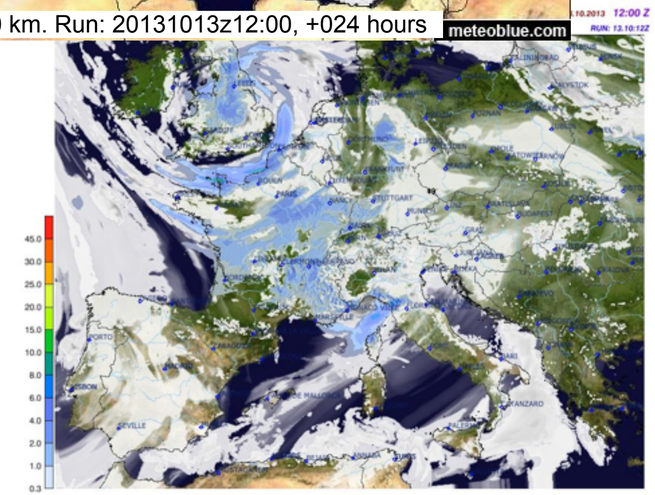
NEMS at meteoblue: 2010-2013

- improvements in precipitation physics for high resolution (grid-scale and convection)
- assimilation cycling of soil parameters (moisture, humidity, snow)
- improvements in pre and post-processing
- adaptations of turbulence for sloping surfaces
- major tuning in land-surface processes to reduce biases and systematic errors of 2m properties
- interfacing with meteoblue high performance data mining
- discovery and solution for several bugs within the modeling system

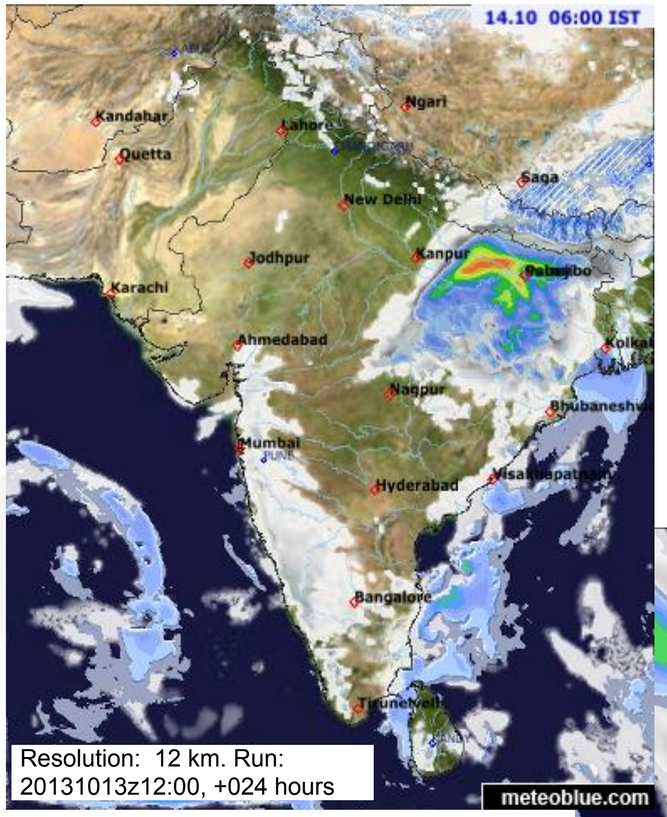
meteoblue NEMS: domains



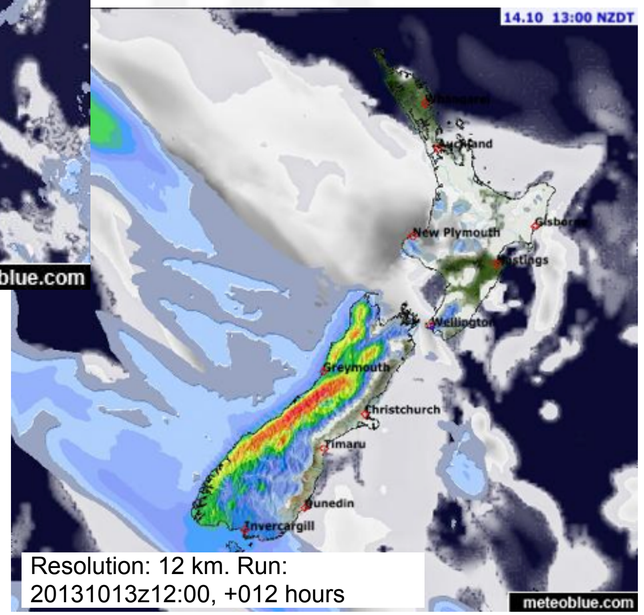
Resolution: 10 km. Run: 20131013z12:00, +024 hours



Resolution: 3 km. Run: 20131013z12:00, +024 hours



Resolution: 12 km. Run: 20131013z12:00, +024 hours



Resolution: 12 km. Run: 20131013z12:00, +012 hours

Operational experience:

- ➡ 5 domains
- ➡ 3 continents
- ➡ Resolution 3-30 km

NEMS at meteoblue: 2010-2013

- Testing versions on highperformance cluster since 2012
  - Europe 12 and 3 km resolution
  - Global 30 km resolution
  - India 10 km, New Zealand 12 km
- Recalculations of years 2010-2013
  - 01.01.2010 - 31.12.2012
  - Hourly intervals, 0 - 36 hours , 0-23 hours for validation
  - Forecast range: 168 hours
- Post-Processing with MOS (temperature, wind).

Global weather simulation with hourly intervals

The NEMS Model

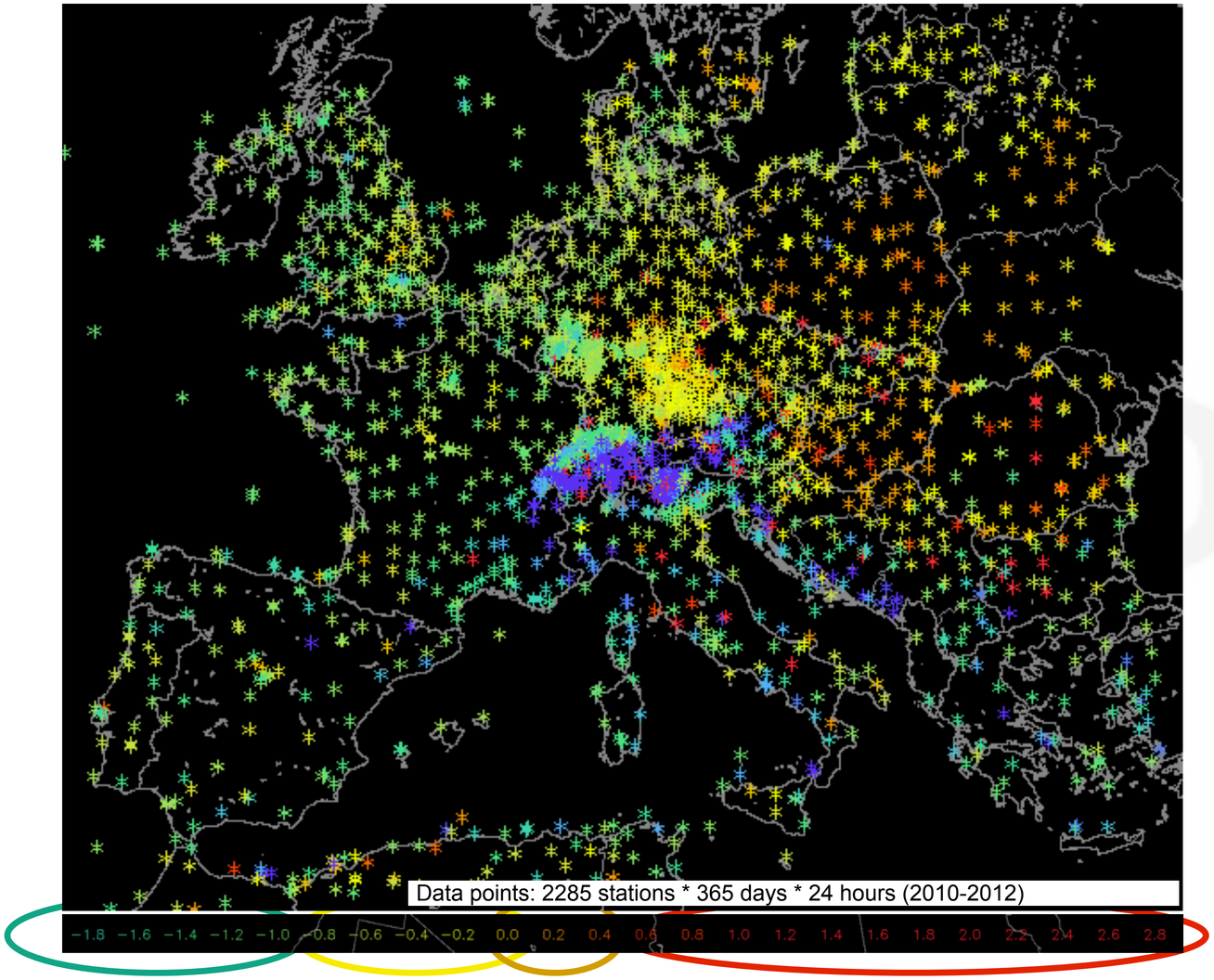
NEMS simulation at meteoblue

NEMS Europe: verification

NEMS Global: verification for temperature and wind

Conclusions

NEMS Europe 03-km: verification of temperature



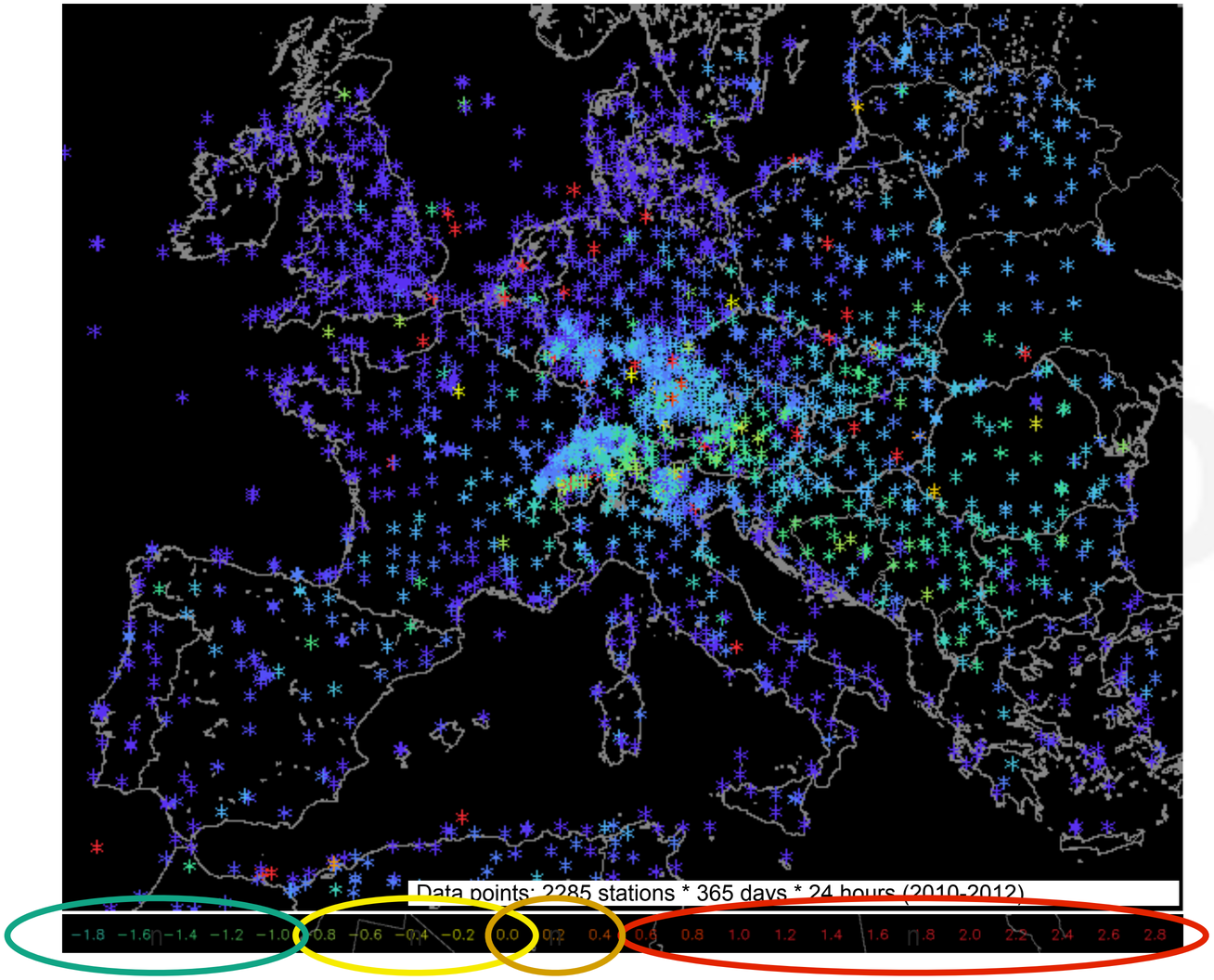
Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 2285 Stations
- **RAW forecast (model)**

➡ Absolute error 2.0°C
➡ Largest errors in
  ➡ Alpes
  ➡ continental areas.
  ➡ Specific locations

Temperature Forecast accuracy:
➡ Higher in maritime climate
➡ Mountains and continental more difficult
➡ Mediterrannean inhomogenous

NEMS Europe 03-km: verification of temperature



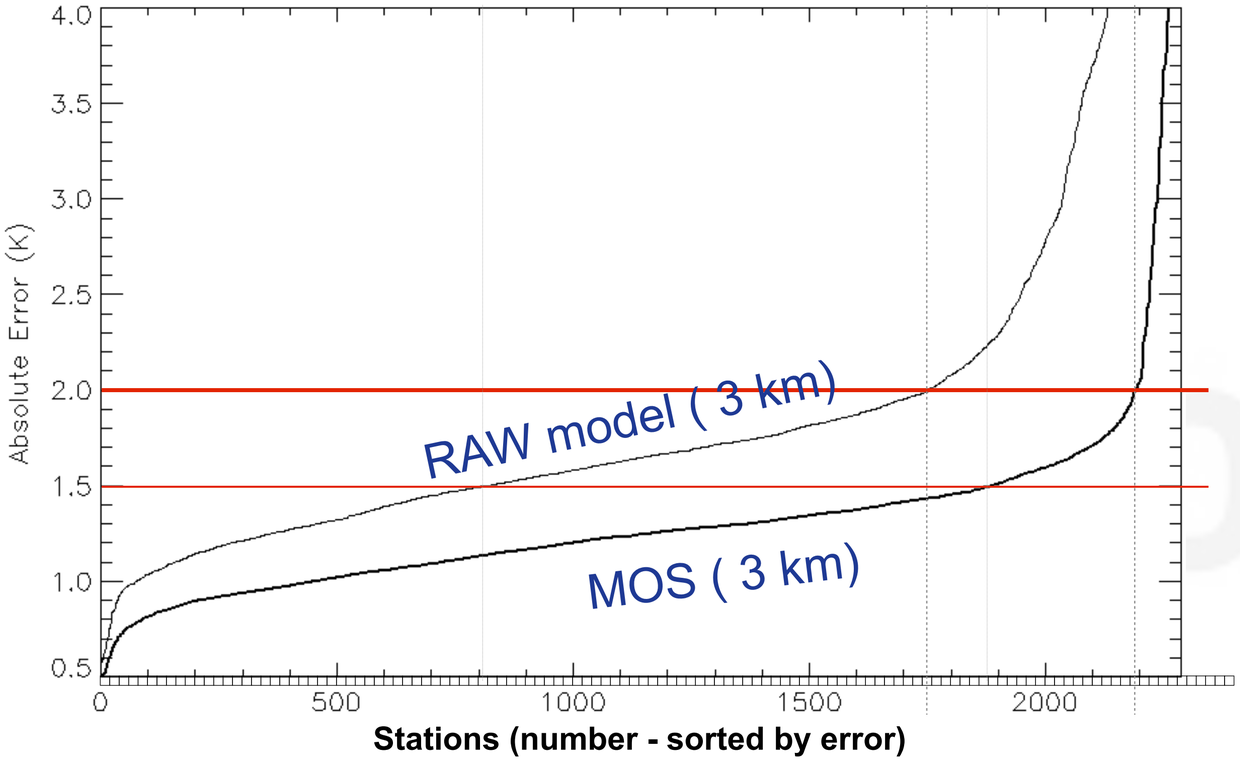
Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 2285 Stations
- **MOS forecast**

➡Absolute error 1.3°C
➡Largest errors in
  ➡Mountains & Hills
  ➡Specific locations

Temperature Forecast with MOS:
➡corrects most errors
➡mountains remain difficult

NEMS Europe 03-km: verification of temperature



Data points: 2285 stations * 365 days * 24 hours (2010-2012)

MAE = Mean Absolute error of hourly measurements (hourly, 3 years)

Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 2285 Stations
- RAW and MOS forecast
- Stations sorted by MAE (3 years)

Absolute error

➡RAW = 77% < 2.0°C MAE

➡MOS = 96% < 2.0°C MAE

Temperature Forecast with MOS:

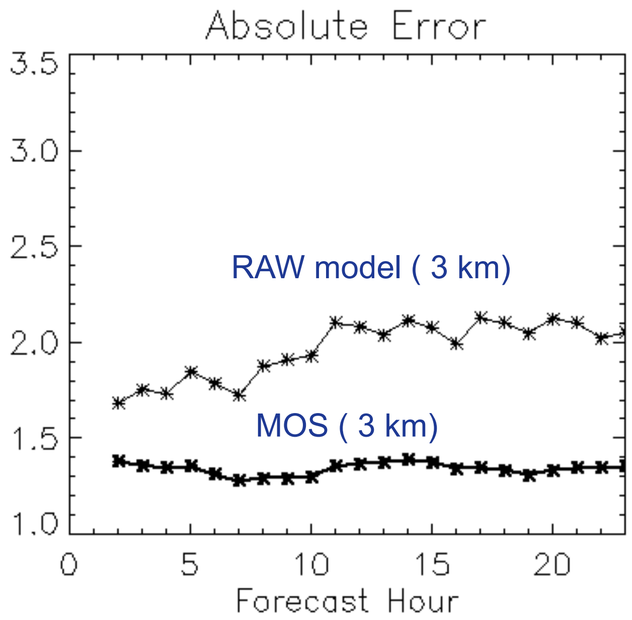
➡corrects most errors

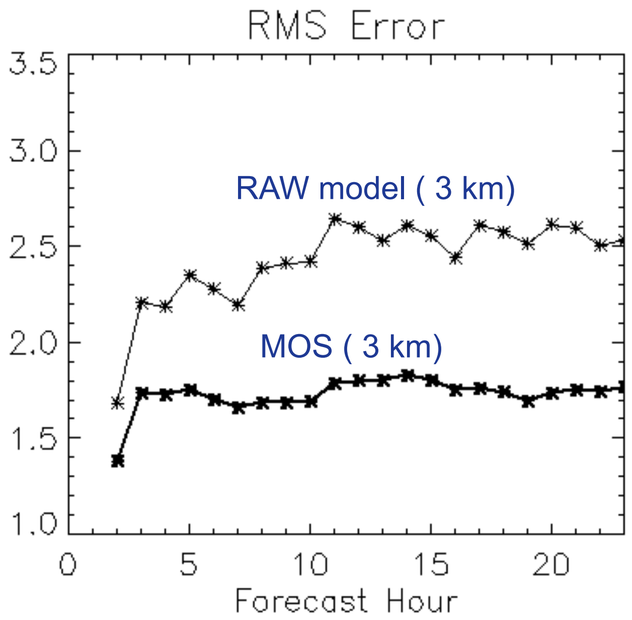
➡4% of stations with MAE > 2.0°C

➡Improvement vs. RAW = 0.7°C

➡Few stations are “difficult”

NEMS EU-03: Temperature forecast improvement





NEMS EU-03
Temperature forecast:

- 0-23 hours
- 2010-2012
- 2285 Stations
- Total = 26280 hours

Absolute error

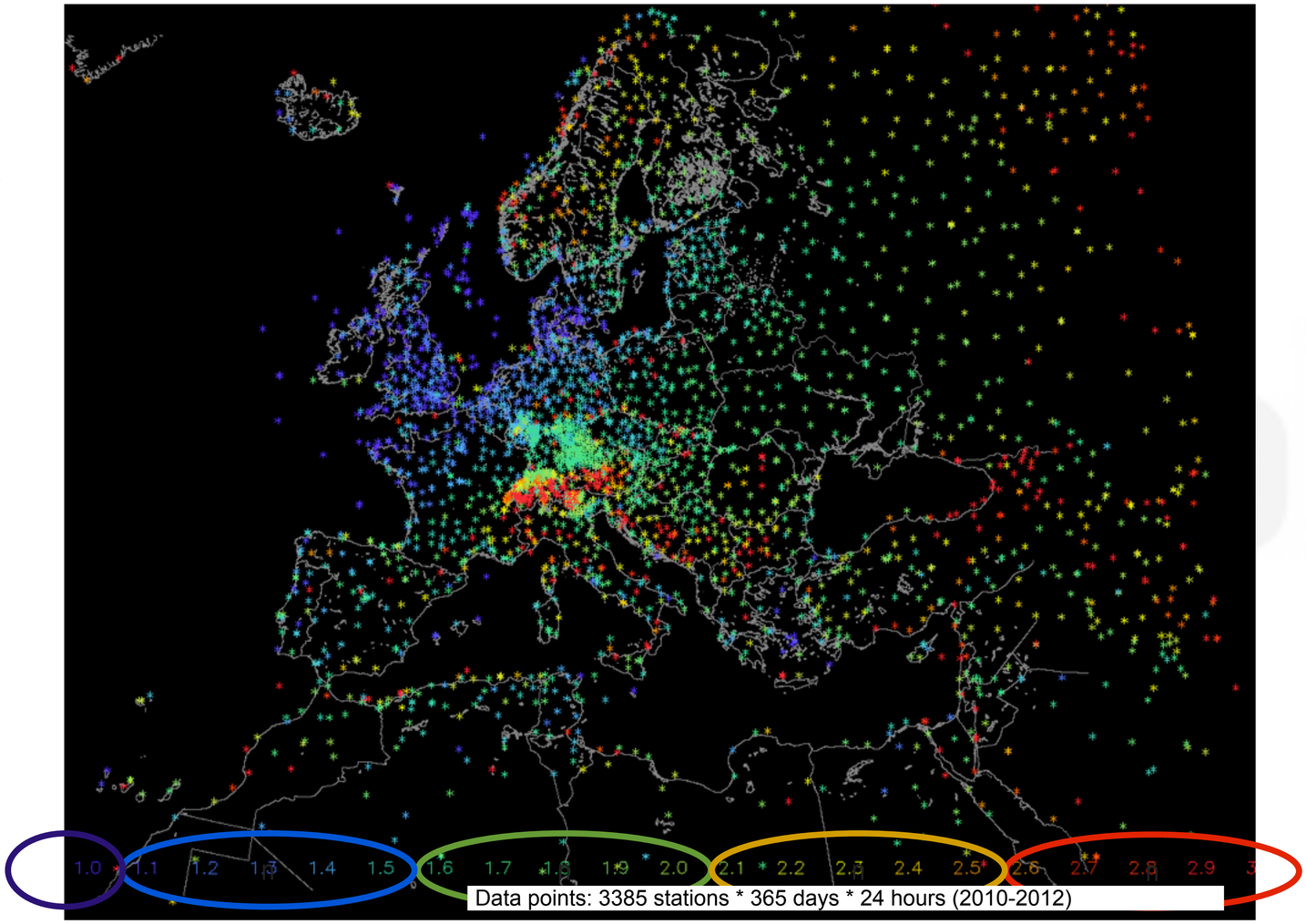
➡ RAW = 2.0°C

➡ MOS = 1.3°C

➡ Constant accuracy 0-23 hours with MOS

MAE of 2.0°C with model ☼ MAE of 1.3°C with MOS

NEMS Europe 12-km: verification of temperature



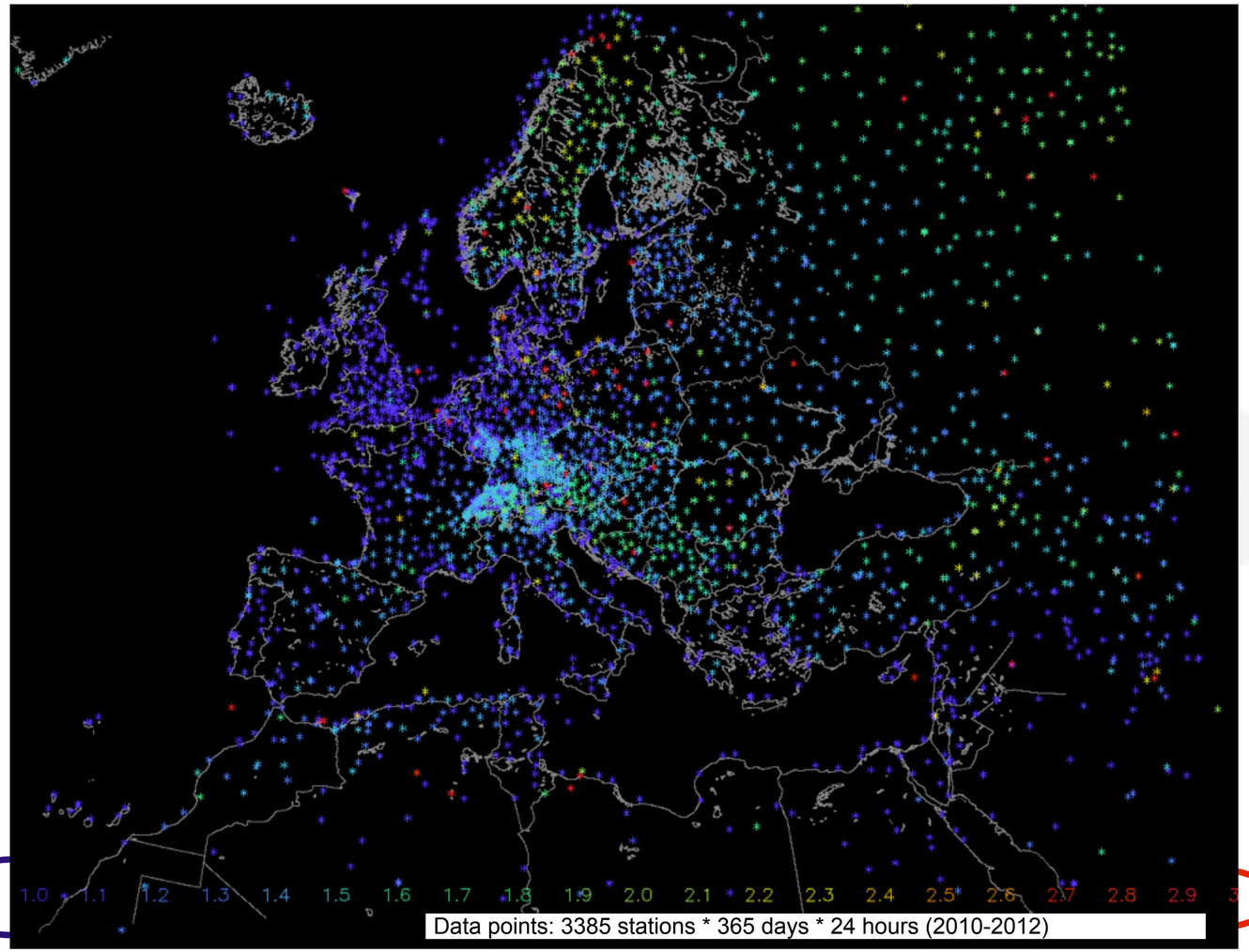
Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 3385 Stations
- **Raw forecast (model)**

➡ Absolute error 2.2°C
➡ Largest errors in
  ➡ Alpes
  ➡ continental areas.
  ➡ Specific locations

Temperature Forecast accuracy:
➡ Higher in maritime climate
➡ Mountains and continental more difficult
➡ Mediterranean inhomogenous

NEMS Europe 12-km: verification of temperature



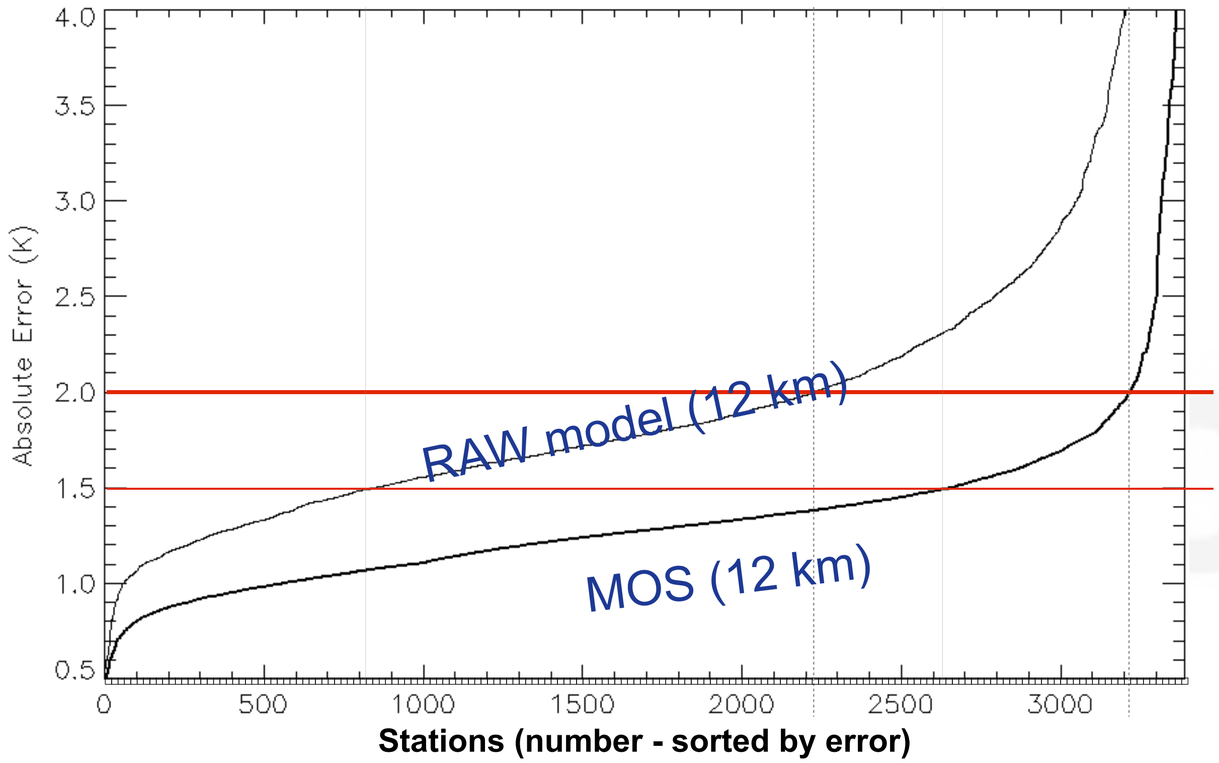
Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 3385 Stations
- **MOS forecast**

➡Absolute error 1.4°C
➡Largest errors in
  ➡Mountains & Hills
  ➡Specific locations

Temperature Forecast with MOS:
➡corrects most errors
➡less accurate:
  ➡mountains
  ➡continental areas
➡Specific stations "escape"

NEMS Europe 12-km: verification of temperature



Data points: 3385 stations * 365 days * 24 hours (2010-2012)

MAE = Mean Absolute error of hourly measurements (hourly, 3 years)

Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 3385 Stations
- RAW and MOS forecast
- Stations sorted by MAE (3 years)

Absolute error

➡RAW = 66% < 2.0°C MAE

➡MOS = 95% < 2.0°C MAE

Temperature Forecast with MOS:

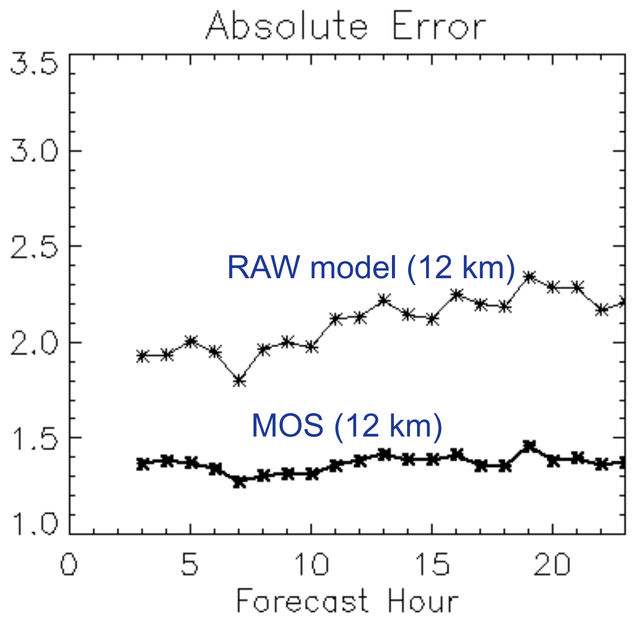
➡corrects most errors

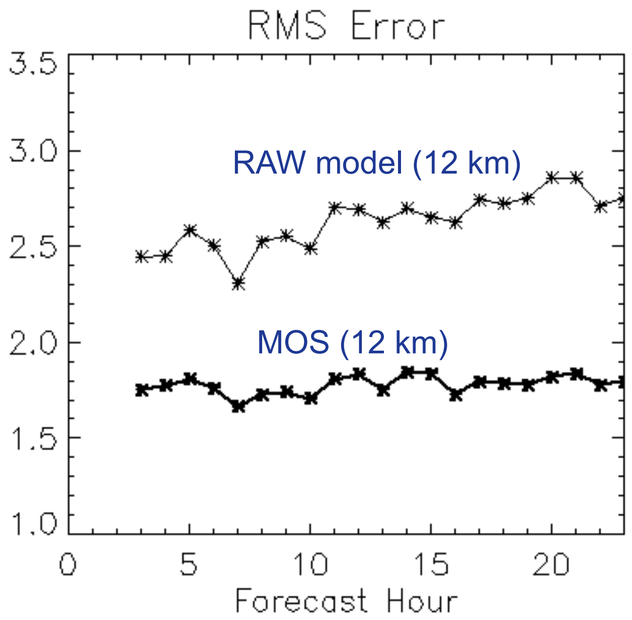
➡5% of stations with MAE > 2.0°C

➡Improvement vs. RAW = 0.8°C

➡Few stations are “difficult”

NEMS EU-12: Temperature forecast improvement





NEMS EU-12
Temperature forecast:

- 0-23 hours
- 3385 Stations
- 2010-2012
- Total = 26280 hours

Absolute error

➡ RAW = 2.2°C
➡ MOS = 1.4°C
➡ Constant accuracy 0-23 hours with MOS

MAE of 2.2°C with model ☼ MAE of 1.4°C with MOS

Global weather simulation with hourly intervals

The NEMS Model

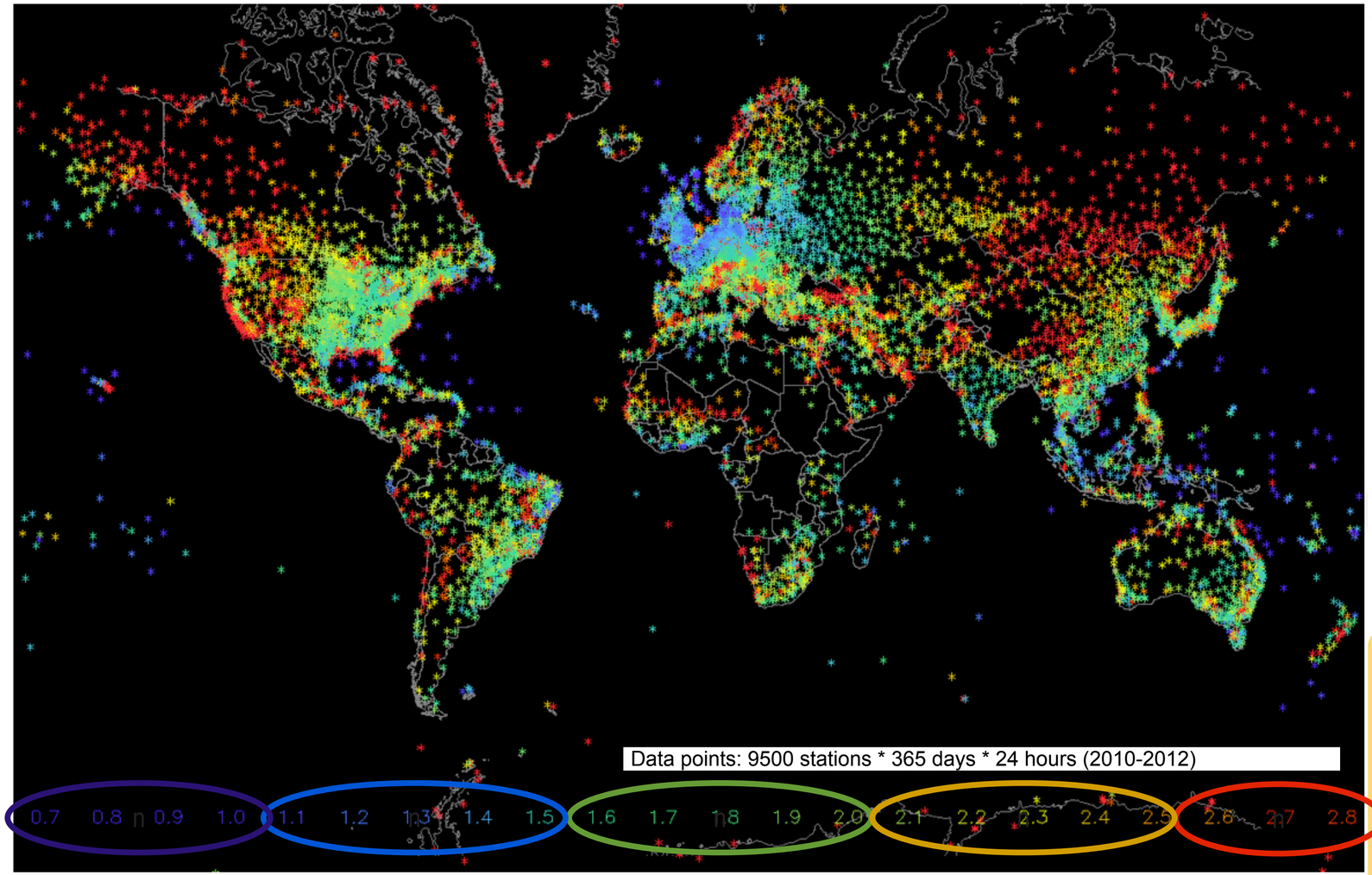
NEMS simulation at meteoblue

NEMS Europe: verification

NEMS Global: verification for temperature and wind

Conclusions

NEMS Global 25-km: verification of temperature



Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 9500 Stations
- **RAW forecast (model)**

➡ Absolute error 2.5°C

➡ Largest errors in

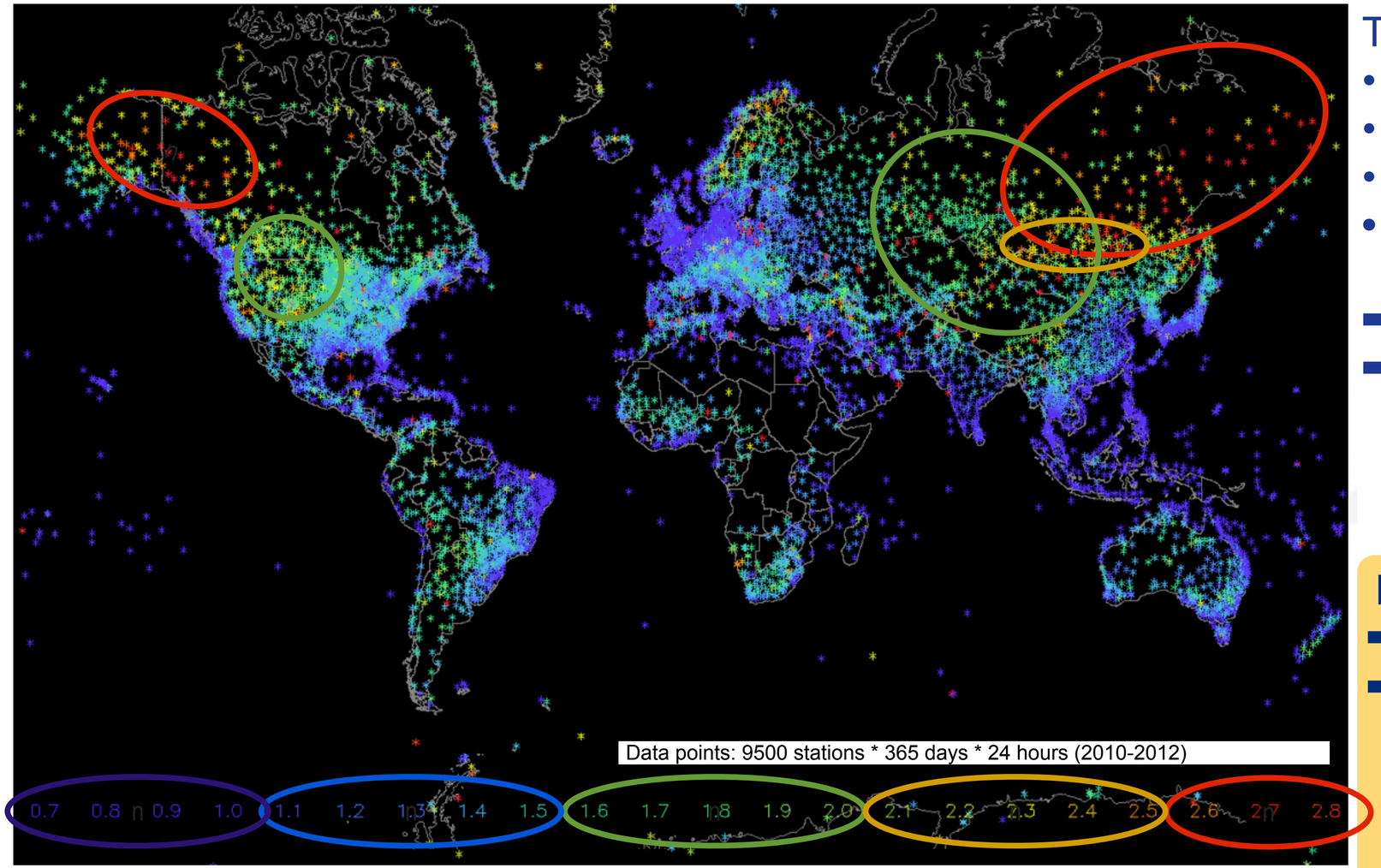
- ➡ Mountains
- ➡ Continental areas.
- ➡ Coast lines
- ➡ Specific locations

Forecast accuracy:

➡ High in temperate climate

➡ Large regional differences

NEMS Global 25-km: verification of temperature



Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 9500 Stations
- **MOS forecast**

➡Absolute error 1.8°C

➡Largest errors in

➡Mountains & Hills

➡Specific locations

MOS Forecast:

➡Coast "easiest"

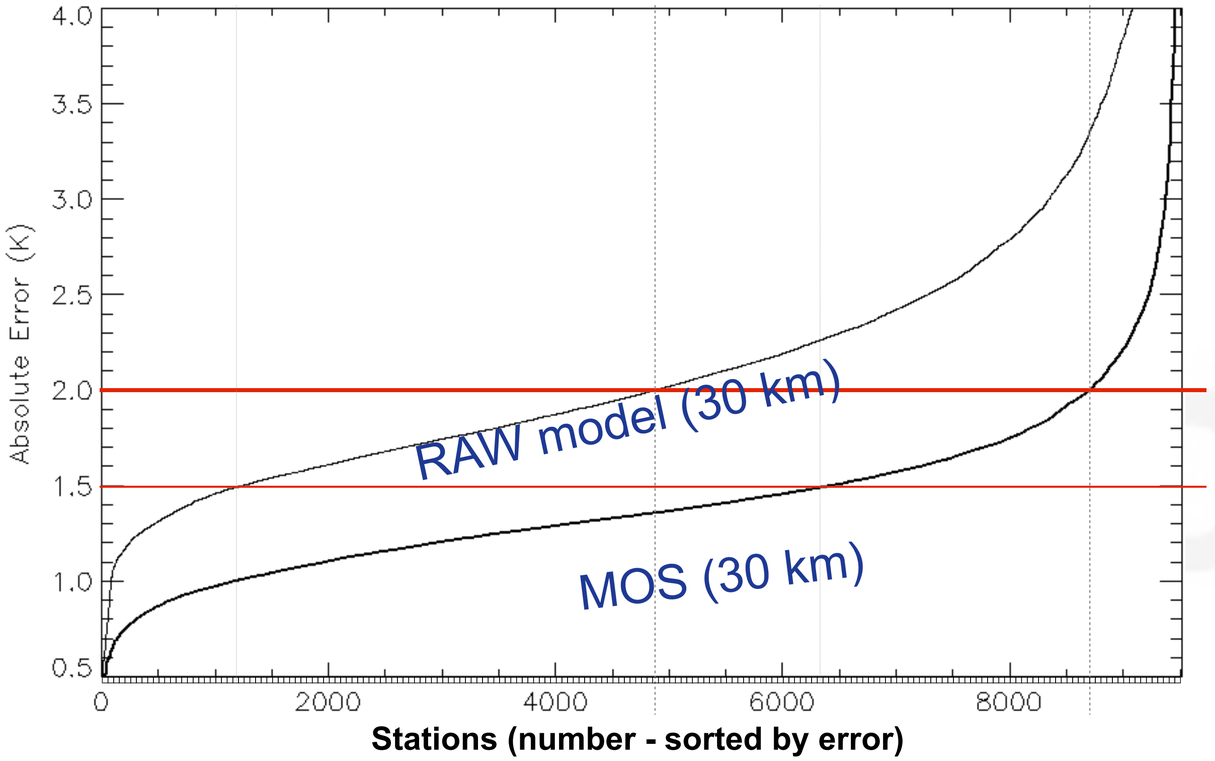
➡less accurate:

➡Mountains

➡Continental areas

➡Northern forest areas

NEMS Global 25-km: verification of temperature



Data points: 9500 stations * 365 days * 24 hours (2010-2012)

MAE = Mean Absolute error of hourly measurements (hourly, 3 years)

Temperature model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 9500 Stations
- RAW and MOS forecast
- Stations sorted by MAE (3 years)

Absolute error

➡RAW = 51% < 2.0°C MAE

➡MOS = 92% < 2.0°C MAE

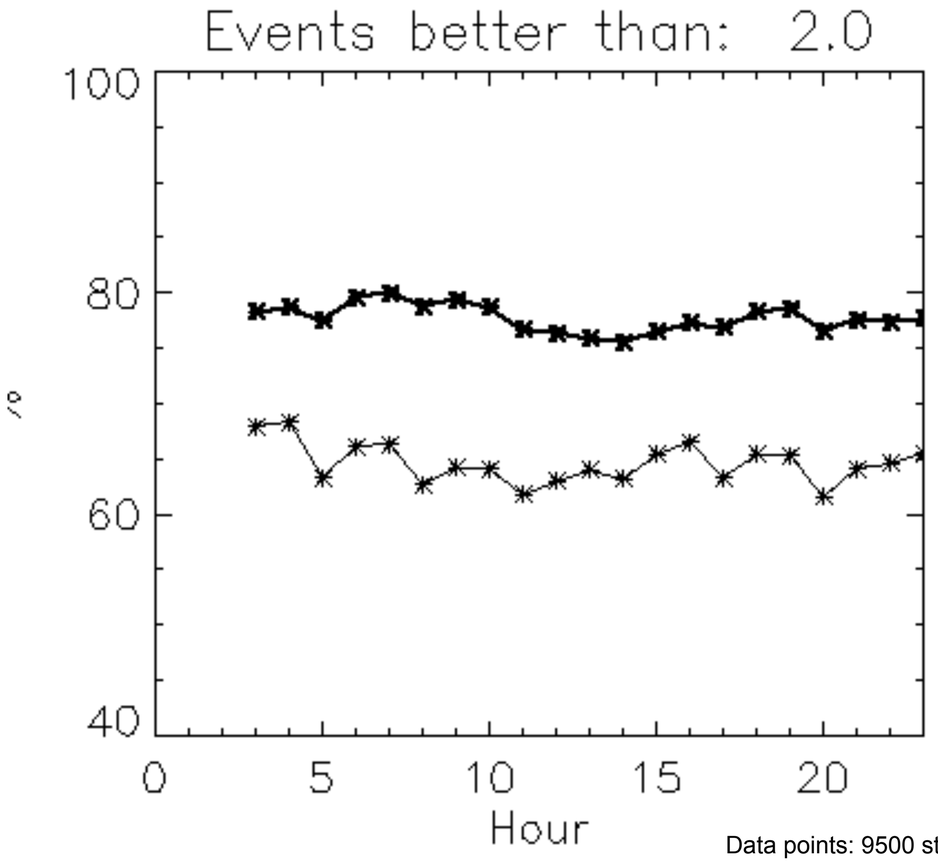
Temperature Forecast with MOS:

➡corrects most errors

➡8% of stations with MAE > 2.0°C

➡Improvement vs. RAW = 0.8°C

NEMS Global 25-km: Temperature forecast



Data points: 9500 stations * 365 days * 24 hours (2010-2012)

NEMS EU-12
Temperature forecast:

- 0-23 hours
- 9500 Stations
- 2010-2012
- Total = 26280 hours

Absolute error

➡ RAW = 2.5°C
➡ MOS = 1.8°C
➡ Constant accuracy
0-23 hours with MOS

MOS ☼ less than 2.0°C MAE with 75-80% of stations

NEMS at meteoblue: Temperature accuracy

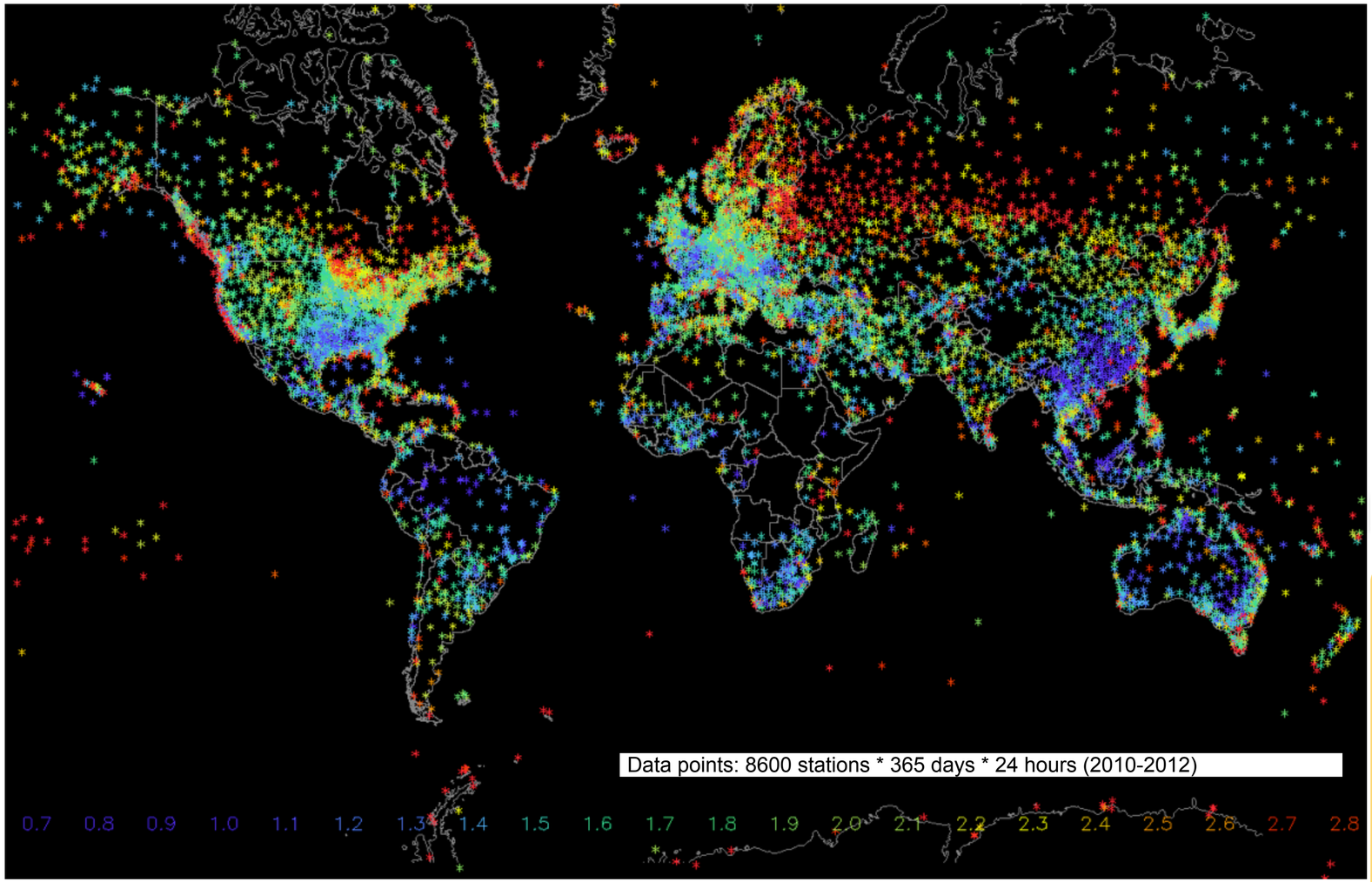
Mean absolute error (hourly measurements) : 2010-2012

Resolution	Region	Stations	RAW <1.5°C	**MOS <1.5°C**	RAW <2.0°C	**MOS <2.0°C**
30 km	Global	9'500	12%	**66%**	51%	**92%**
12 km	EU	3'385	24%	**78%**	66%	**95%**
3 km	CEU	2'285	35%	**82%**	76%	**96%**

Resolution from 25 to 3 km ☼ Stations with MAE <2.0°C from 51 to 76%

MOS increases Stations with MAE <2.0°C to 92 - 96%

NEMS Global 25-km: verification of wind



Wind model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 8600 Stations
- **RAW forecast (model)**

➡ Absolute error 2.0 m/s

➡ Largest errors in

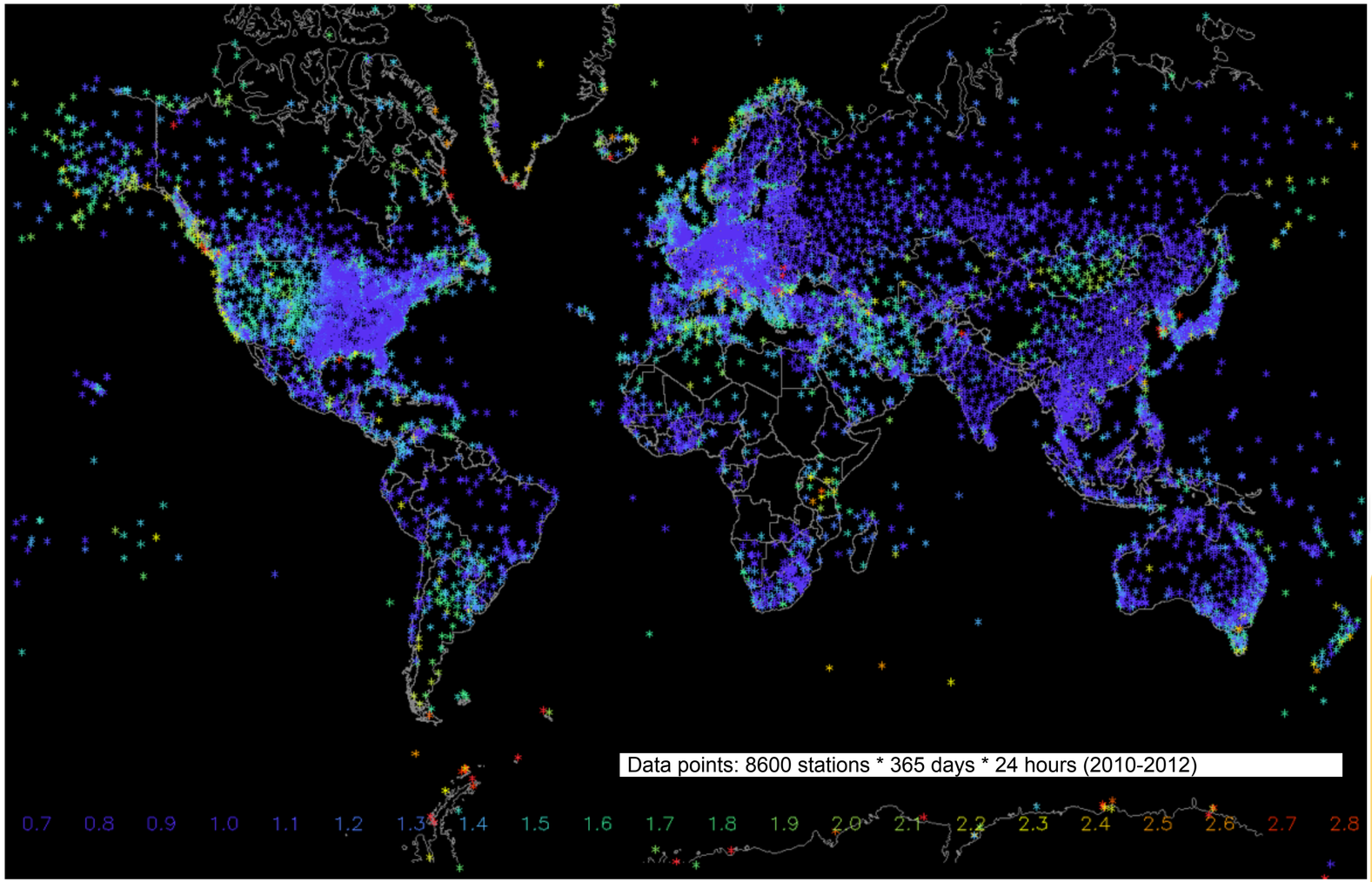
- ➡ Alpes
- ➡ continental areas.
- ➡ Specific locations

Forecast accuracy:

➡ **Higher in maritime climate**

➡ **Mountains and continental more difficult**

NEMS Global 25-km: verification of wind



Wind model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 8600 Stations
- **MOS forecast**

➡Absolute error 1.3 m/s

➡Largest errors in

➡Mountains & Hills

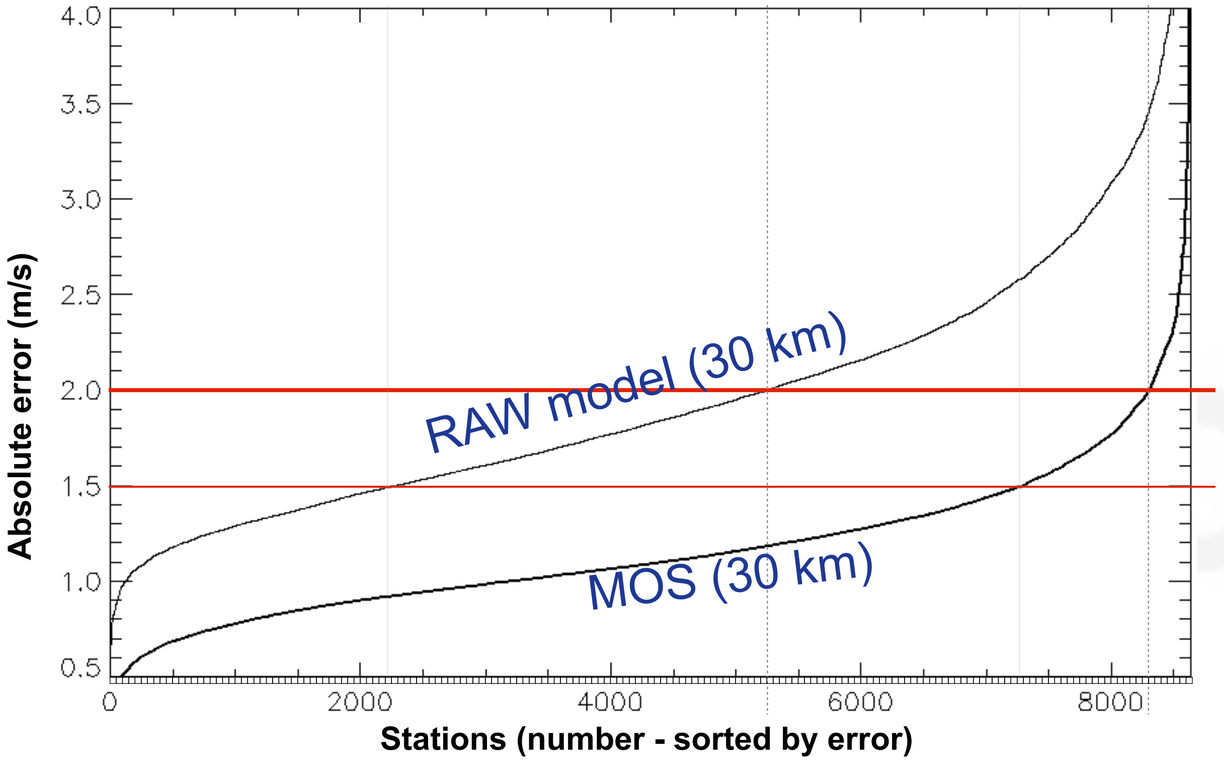
➡Specific locations

Wind Forecast with MOS:

➡corrects most errors

➡mountains remain difficult

NEMS Global 25-km: verification of wind



Data points: 8600 stations * 365 days * 24 hours (2010-2012)

MAE = Mean Absolute error of hourly measurements (hourly, 3 years)

WIND model forecast:

- 0-23 hours
- 2010-2012 (26280 hours)
- 8600 Stations
- RAW and MOS forecast
- Stations sorted by MAE (3 years)

Absolute error

➡RAW = 61% < 2.0 m/s MAE

➡MOS = 96% < 2.0 m/s MAE

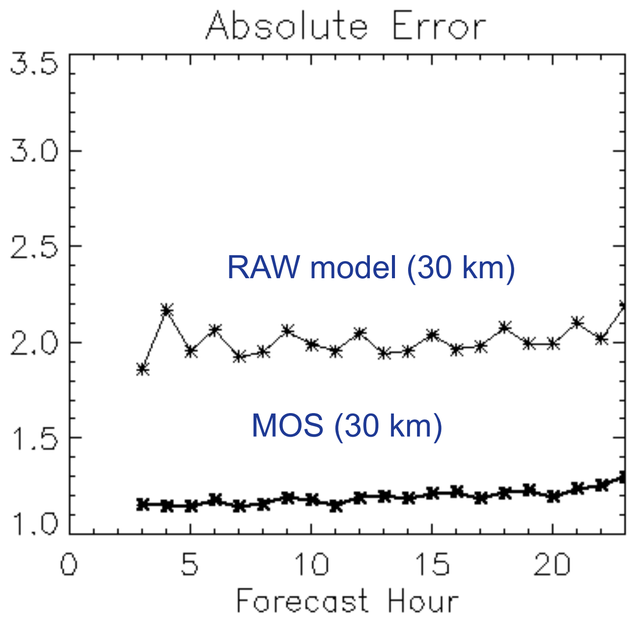
Wind Forecast with MOS:

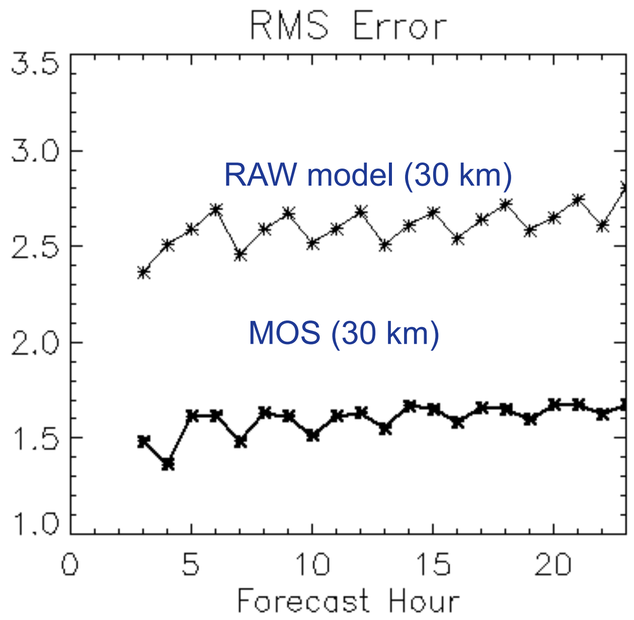
➡reduces MAE by 40%

➡4% stations with MAE > 2.0 m/s

➡Improvement vs. RAW = 0.9 m/s

NEMS Global 25-km: Wind forecast





NEMS EU-12
Temperature forecast:

- 0-23 hours
- 8600 Stations
- 2010-2012
- Total = 26280 hours

Absolute error

➡ RAW = 2.1 m/s
➡ MOS = 1.2 m/s
➡ Constant accuracy 0-23 hours with MOS

Data points: 9500 stations * 365 days * 24 hours (2010-2012)

High level precision ☼ improved with stations

Global weather simulation with hourly intervals

The NEMS Model

NEMS simulation at meteoblue

NEMS Europe: verification

NEMS Global: verification for temperature and wind

Applications

Conclusions

NEMS at meteoblue: Conclusion of Validation

Consistency through all scales global to local (30 to 3 km resolution): same physics and dynamics.

Temperature forecast: > 75% events with <2°C error, extrapolated to area by gridded MOS.

Wind forecast: 80-90% events with <2 m/s error with global model.

Regional quality zoning possible: EU North Sea (GB, NL) easiest to predict

MOS fixes most areas: coast, tropical regions, great plains.

Some “tough” regions remain: Siberia, High Mountains ranges, misplaces stations.

NEMS at meteoblue: Outlook

- Datafeeds: Hourly data for all parameters worldwide -
  - Make global datafeeds accessible for commercial users
- Domains: Continue operating EU-12, EU-03, India-10, NZ-10
  - Add more regional domains: LATAM, East Asia,
  - Multinesting (continental and regional) were needed
- Build global and regional multilayer archives.
- Post-processing: Apply MOS (Temperature, Wind) to services
  - Develop MOS for more parameters (radiation, precipitation)

NEMS at meteoblue: Summary

- NEMS Hourly 6-day forecast globally, EU-12, EU-3, India-10, NZ-12
- Temperature forecast: > 75% hourly events with less than 2°C error.
- Wind forecast: 80-90% hourly events with <2 m/s error (global model).
- Build global and regional multilayer archives.
- Add more regional domains (LATAM, East Asia, etc.)
- Develop MOS for more parameters (radiation, precipitation)
- Test other initialisations

Global simulation h☼ur by h☼ur

Meteo-Expo: Stand 1010

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