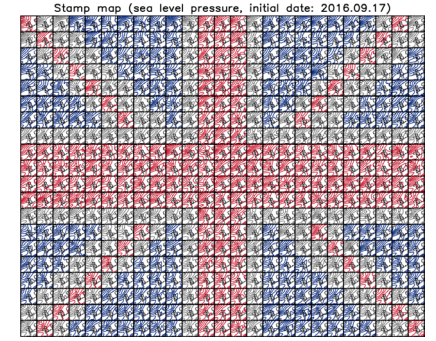
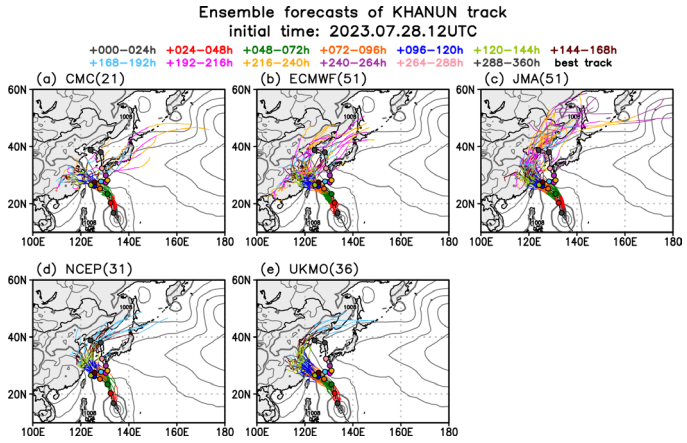
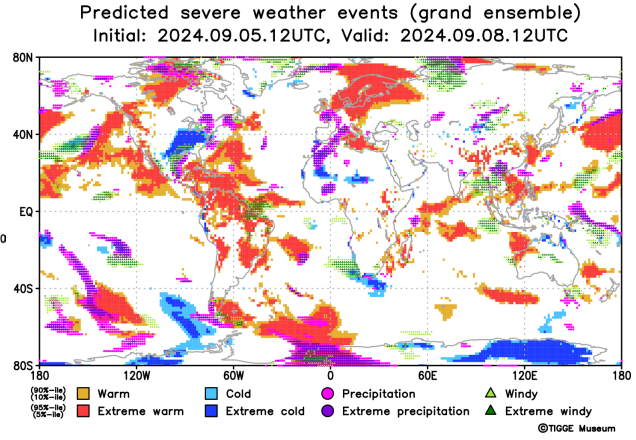
The Ensemble Museums

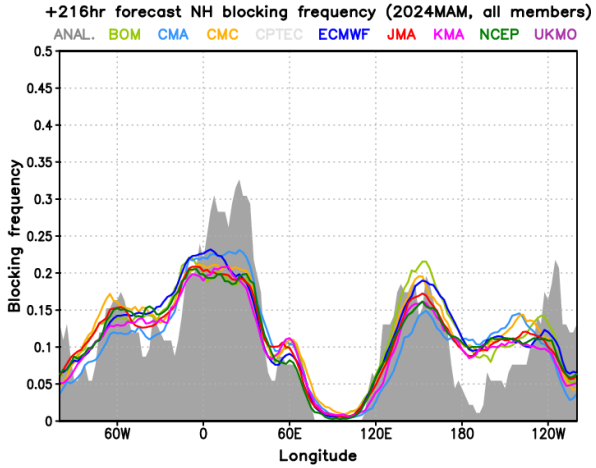
– a diagnostic tool of weather forecasting –

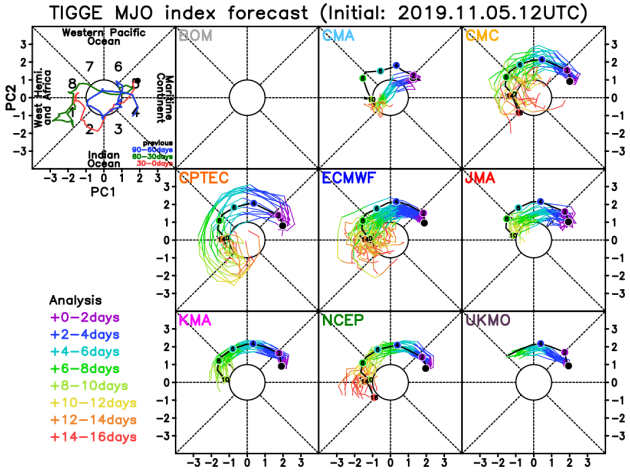
Mio Matsueda (Univ. of the Ryukyus, Japan)

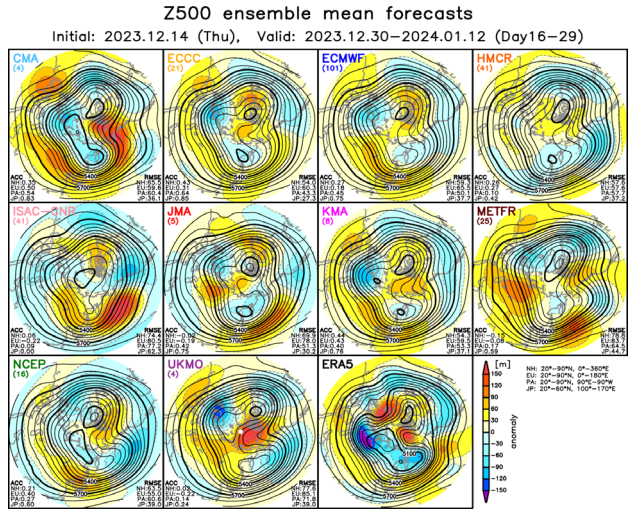


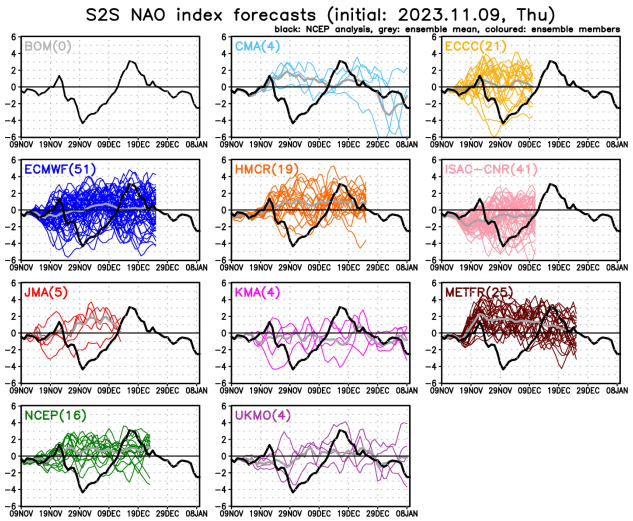


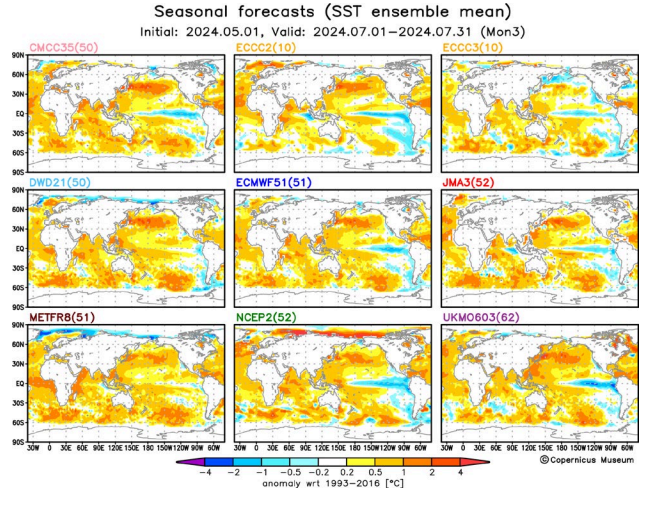


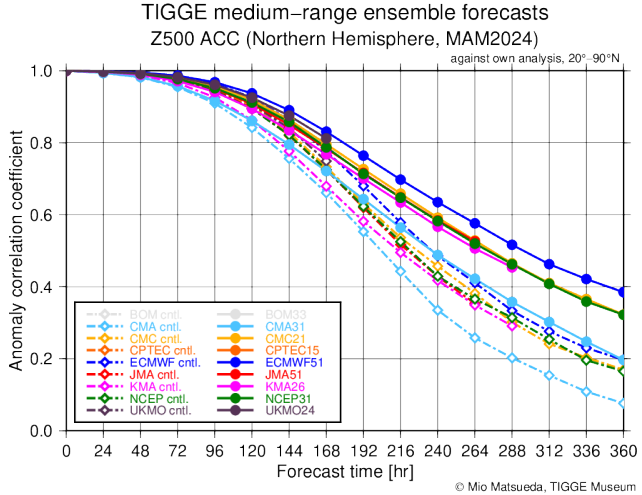












Outline of my talk

- Overview of three ensemble datasets
- TIGGE Museum (since 2010)
- TIGGE article survey
- S2S Museum (since 2016?)
- C3S Museum (since 2021)
- Summary

TIGGE: The Interactive Grand Global Ensemble

S2S: subseasonal to seasonal

C3S: Copernicus Climate Change Service

Routine work at the Museums:

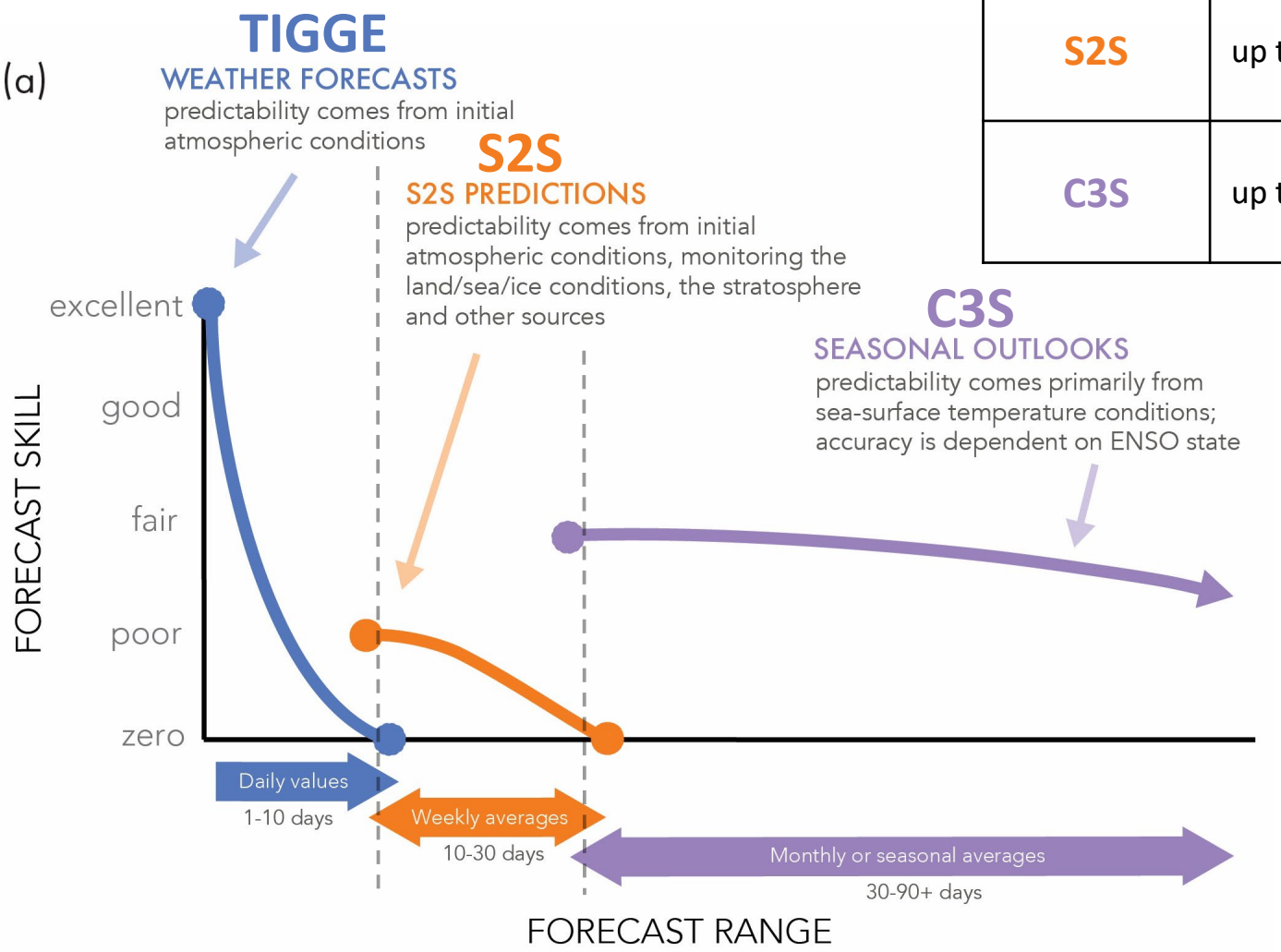
1. retrieve ensemble forecast data (GRIB2 format) from data portals
2. compute additional variables (e.g., stream function), indices, statistics or scores
3. generate graphical forecast products with analysis (if available) and verification products

Ensemble datasets

ensemble dataset	forecast length	number of models	data availability (forecast)	reforecast (hindcast)*	data portal
TIGGE	up to 2 wks	13 (mostly atm-only models)	since Oct. 2006 (2-day delay)	No	ECMWF, CMA
S2S	up to 2 mns	13 (mostly coupled models)	since Jan. 2015 (21-day delay)	Yes (1995-)	ECMWF, CMA & IRI
C3S	up to 6 mns	9 (coupled models)	since Jan. 2017 (10-day delay)	Yes (1993-2016)	Copernicus

* model error is too large to be ignored at longer-range timescales

(a)



White et al. 2017(BAMS)

My predictability research using TIGGE, S2S and C3S ensemble data

- TIGGE project summary: Swinbank et al. (2016) * citations: 245 (google scholar)
- NH Blocking: Matsueda (2009)
- Madden-Julian Oscillation (MJO): Matsueda & Endo (2011)
- Arctic cyclone: Yamagami et al., (2018a,b, 2019)
- weather regimes: Matsueda & Kyouda (2016), Matsueda & Palmer (2018)
- early warning product for severe weather events: Matsueda & Nakazawa (2015), available in TIGGE Museum
- Russian heatwave in 2010: Matsueda (2011) * citations: 300 (google scholar)
- Japanese heavy rainfall in 2018: Matsunobu & Matsueda (2019)
- summertime sea ice forecast: Nakanowatari et al. (2018, 2022)
- forecast verification in the Polar region: Jung & Matsueda (2016)
- forecast bust in the Polar region: Yamagami & Matsueda (2021)
- forecast bust of surface solar radiation: Uno et al. (2018)
- verification of grand ensemble: Matsueda & Tanaka (2008)
- teleconnection: Yamagami & Matsueda (2020)
- initial state-dependent predictability: Inatsu et al. (2023)
- cherry blossom: Yamaki et al. (2024)
- The TIGGE/S2S/C3S Museums (websites)

QR codes to Museums

TIGGE S2S C3S

Ongoing research project | 2006 - 2028

TIGGE was established as a key component of the WWRP THORPEX program (2005-2014) to accelerate the improvements in the accuracy of 1-day to 2-week high-impact weather forecasts for the benefit of society, the economy, and the environment. The name **TIGGE** originally stood for "**T**HORPEX **I**nteractive **G**rand **G**lobal **E**nsemble".

Although the 10-year THORPEX program ended at the end of 2014, TIGGE has continued and the next 5-year phase of the archive (2024–2028) is currently underway. The name **TIGGE** was officially changed to "**T**he **I**nternational **G**rand **G**lobal **E**nsemble", but it is recommended to simply refer to "TIGGE". As of September 2024, TIGGE provides **medium-range ensemble forecasts from 13 NWP centres**: BoM, CMA, ECCC, CPTEC, DWD, ECMWF, IMD, JMA, KMA, Météo France, NCEP, NCMRWF, and UKMO.

Before TIGGE started…

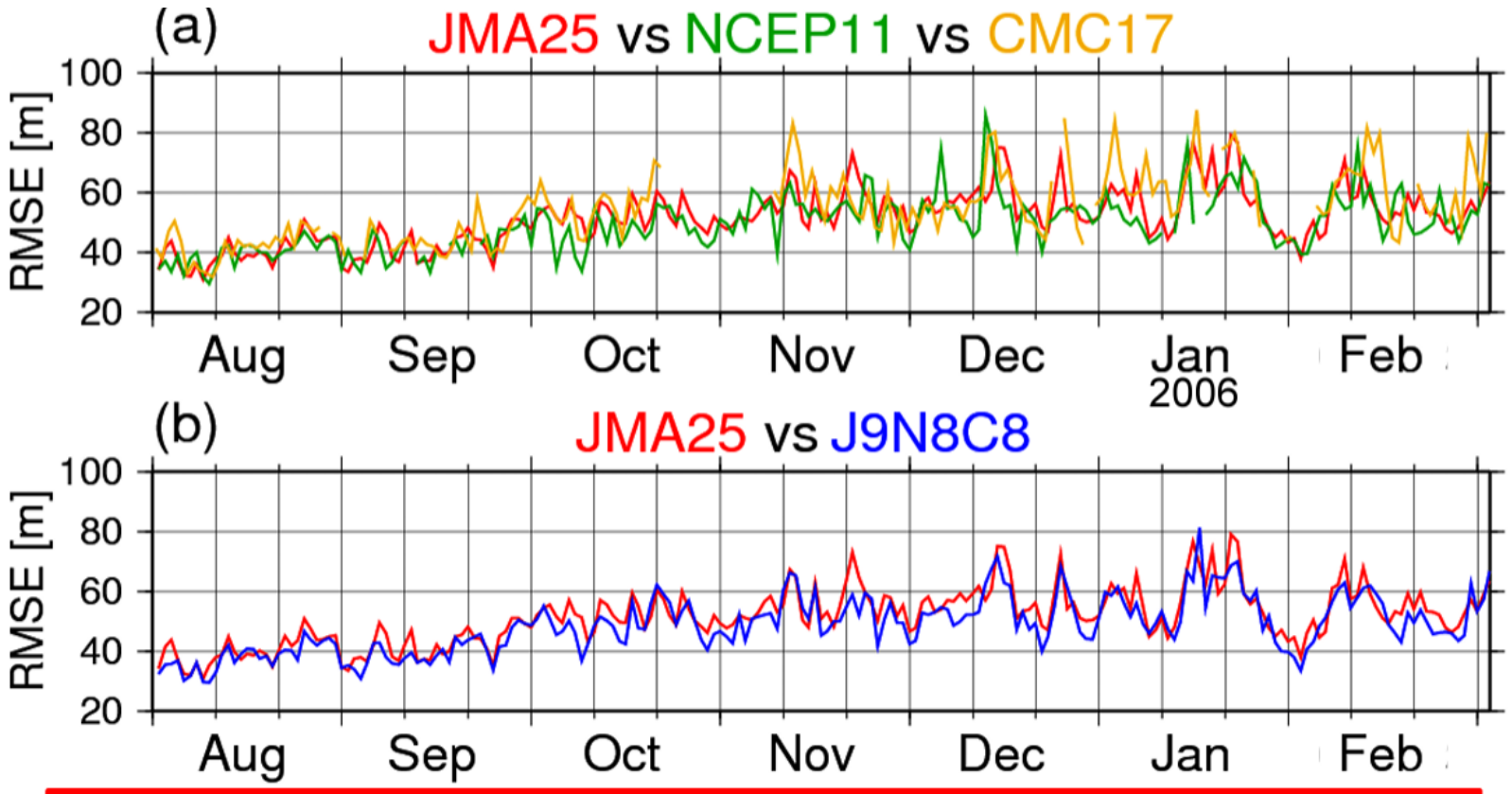
A pilot project between JMA and Univ. of Tsukuba

Daily RMSE
for August 2005
- February 2006

Result from **MIGGE** using JMA, NCEP & CMC ensembles

Mio **I**nteractive **G**rand **G**lobal **E**nsemble

NH Z500 120hr forecast skill (Aug. 2005 – Feb. 2006)



Grand ensemble is more skillful than single-center ensembles.

Matsueda et al. (2007, SOLA)

https://confluence.ecmwf.int/display/TIGGE/Models

TIGGE Models

13 models

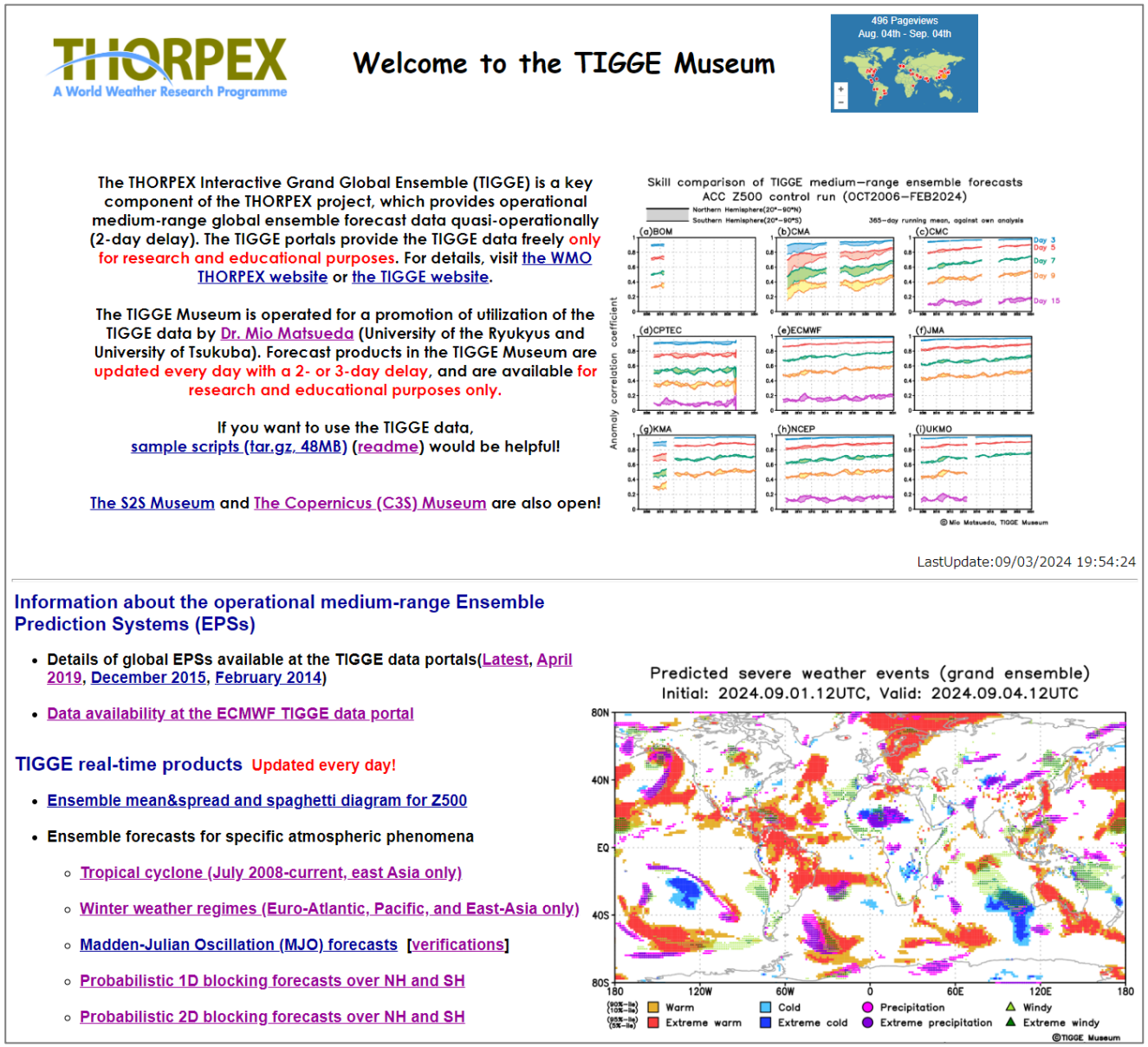
Model's outputs are archived on their original grid or the coarser regular lat-lon grid.

	Status on 2021-04-27	Time range [Days/Hours]	Resolution (original)	Resolution (original) [km]	Resolution (archived) [°]	Ens. Size	High-res.? ***	Runs [UTC]	Daily data volume (all runs) [GB]
1	BoM (ammc)	d 0-10			0,45 x 0.3 (800 x 600)	17		0/6/12/18	23.5
2	CMA (babj)	d 0-15	0.5° x 0.5°	50	as original	30		0/12	83
3	CPTEC (sbsj)	d 0-15	0.9375° x 0.9375° (384 x 192, GG)	104	as original	15		0/12	7
4	DWD (edzw)	h 0-180	R3B06 L120 km	26.5	0.5 x 0.5 (720 x 361)	40	yes	0/12	78
5	ECCC (cwao)	d 0-16	Yin-Yang grid	39	0.25 x 0.25 (1440 x 721)	21	yes	0/12	153
6	ECMWF (ecmf)	d 0-15	O1280 L137	~9	O640 (ORGG)	51	yes	0/12	1100
7	IMD (vabb)	d 0-10	T1534 L64 (3072 x 1536 RGG)	12	0.12 x 0.12 (3000 x 1501)	21	cf	0/12	467
8	JMA (rjtd)	d 0-11	1.25° x 1.25° (288 x 145, TL479 L100)	139	as original	51		0/12	15
9	KMA (rksl)	d 0-12	cubed spherical grid	32	0.5 x 0.5 (720 x 360)	26	yes	0/12	60
10	Meteo-France (lfpw)	h 0-48/0-90/0-48/0-102	TL1198 c2.2 (stretched coefficient)	7.5-37**	0.5 x 0.5 (720 x 361)	35	cf	0/6/12/18	46 (7.8/ 14/ 7.8/ 16.6)
11	NCEP (kwbc)	d 0-16	C384 L64	25	0.5 x 0.5 (720 x 361)	31		0/6/12/18	102
12	NCMRWF (dems)	d 0-10	0.117° x 0.175° (ACG, N1024)	13	0.18 x 0.12 (2000 x 1501)	12	cf	0/12	398
13	UKMO (egrr)	h 0-174	0.187° x 0.28125° (1280 x 960, ACG, N640)	21	as original	18		0/6/12/18	225

The TIGGE Museum – website of medium-range forecast products –

Google **"TIGGE Museum"** or use QR code below

http://gpvjma.ccs.hpcc.jp/TIGGE/

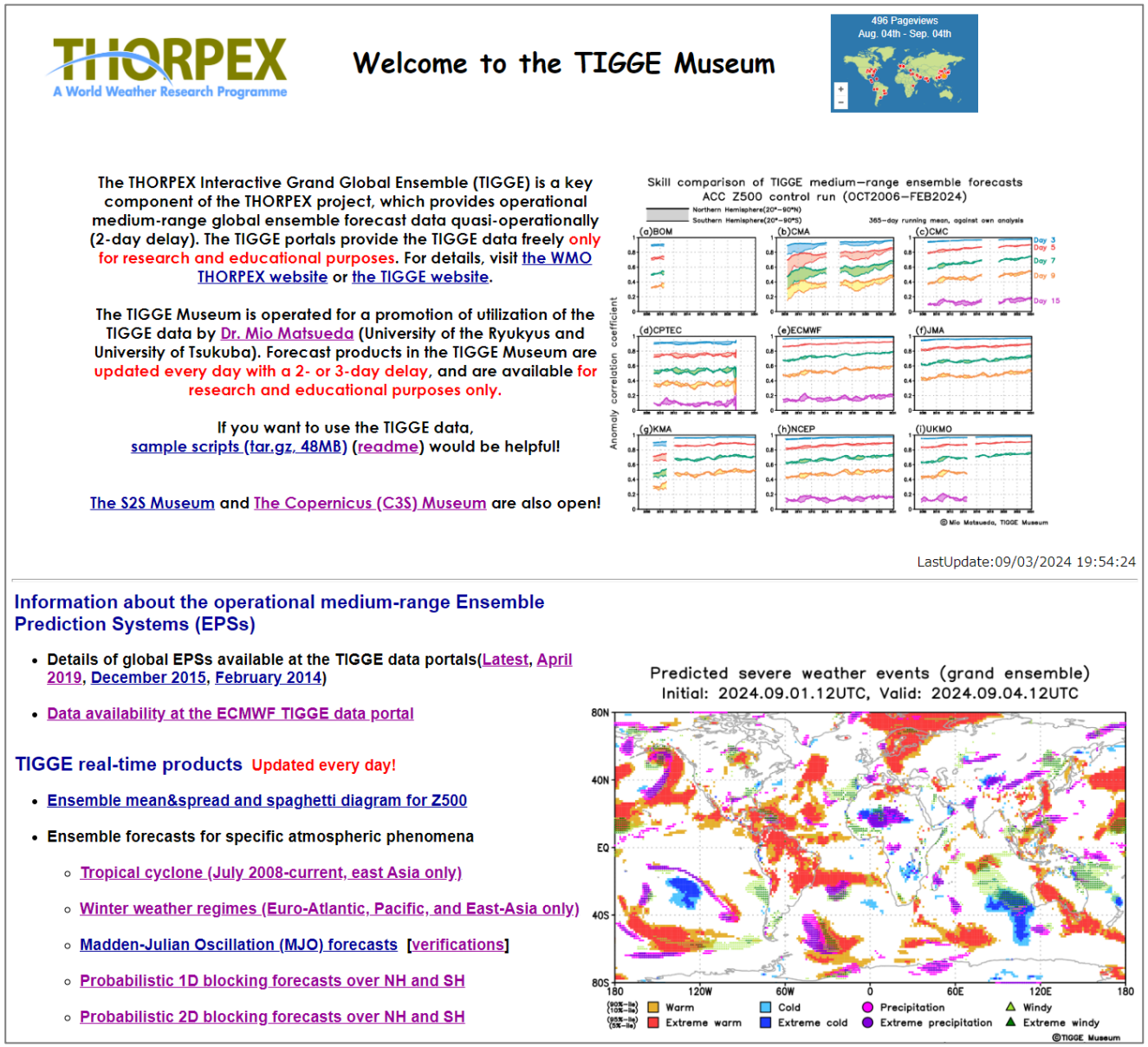


- ❑ opened in 2010
- ❑ products are updated everyday with a 3-day delay
- ❑ 10 models (DWD, IMD, and NCMRWF to be added)
- ❑ 16 forecast products from Oct. 2006 to the present (7.8TB):
  - ➢ Z500 spaghetti & stamp maps
  - ➢ tropical cyclone (only East Asia)
  - ➢ winter weather regimes
  - ➢ MJO (Madden-Julian Oscillation)
  - ➢ atmospheric blocking
  - ➢ teleconnection indices: EA, PNA, WP & EU
  - ➢ probabilistic forecast of severe weather events: high/low temperature, heavy rainfall, strong winds
  - ➢ forecast verifications & model biases: daily and seasonal scores, MJO & blocking)

The TIGGE Museum – website of medium-range forecast products –

Google **"TIGGE Museum"** or use QR code below

http://gpvjma.ccs.hpcc.jp/TIGGE/



The Museum originally started on a small hard drive and was later opened to the public to encourage the use of TIGGE data. In the early stages, when I searched 'TIGGE Museum' on Google, it suggested "Did you mean: FIGGE art Museum?" I have been spending much time operating the Museum...

The TIGGE Museum – tropical cyclone track forecasts (only East Asia) –

forecasts after 2008 are available

track data is available at the NCAR website (TC cxml data)

TIGGE tropical cyclone forecasts

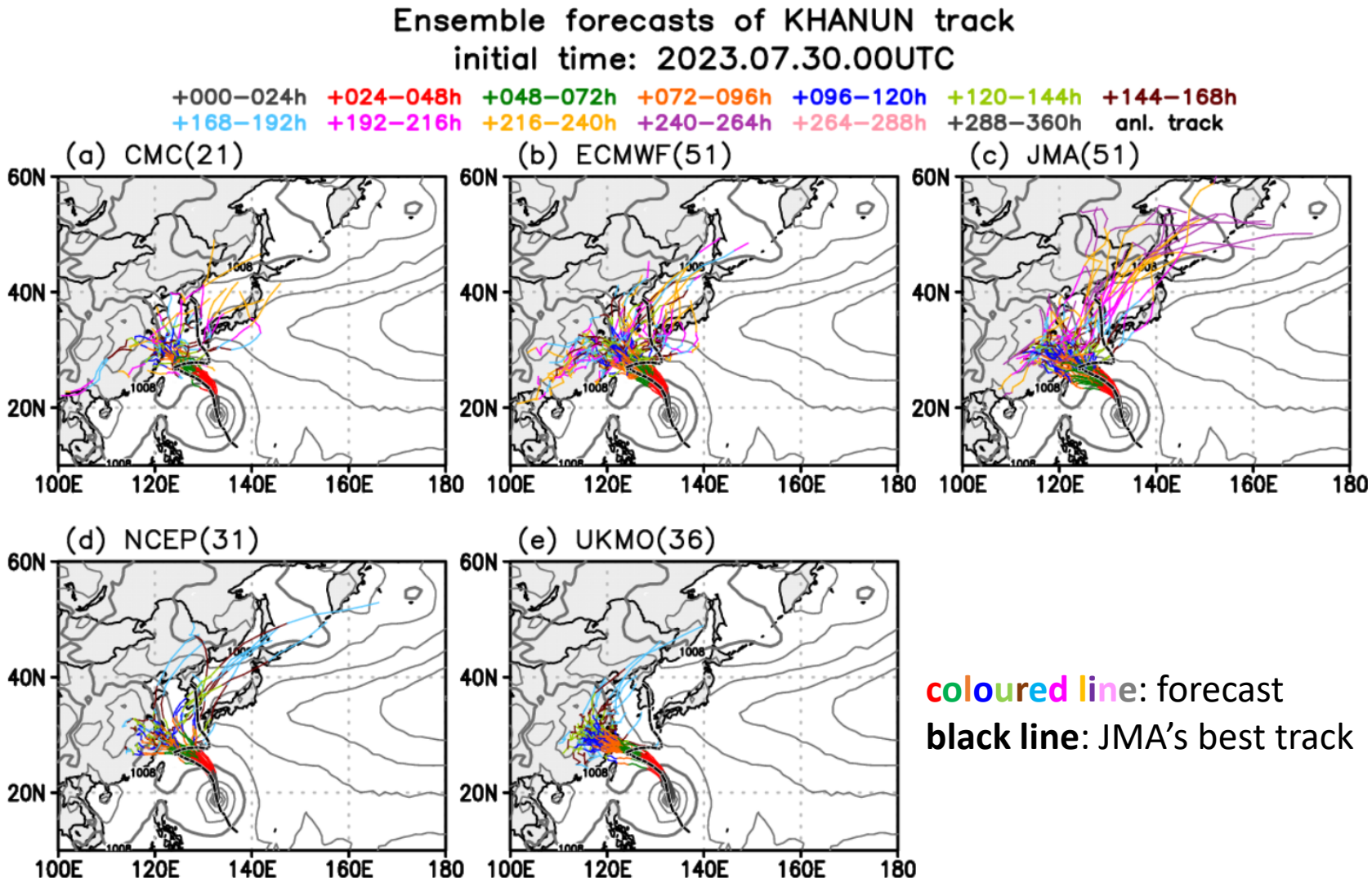
Please refresh the page before browing!
Windows: Ctrl + Shift + R
Mac: Command + Shift + R

Year: 2023

Tropical cyclone name: KHANUN

Initial time of forecast: (YYYYMMDDHH) 2023073000 UTC
Use arrow keys to change time.

TIGGE Museum (top)



coloured line: forecast
black line: JMA's best track

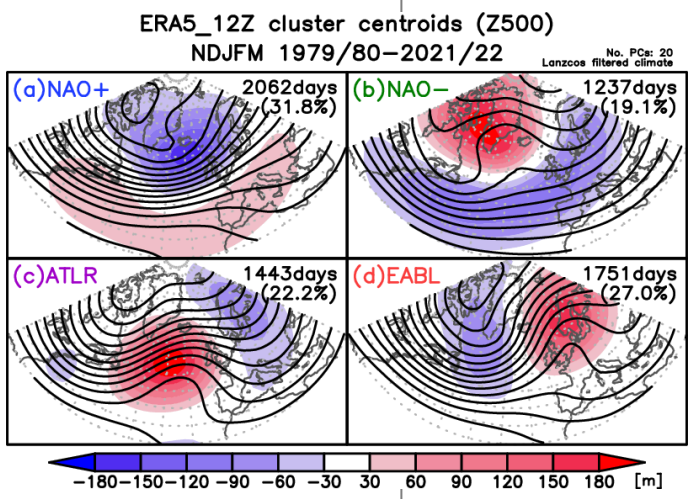
The TIGGE Museum – winter weather regime forecast –

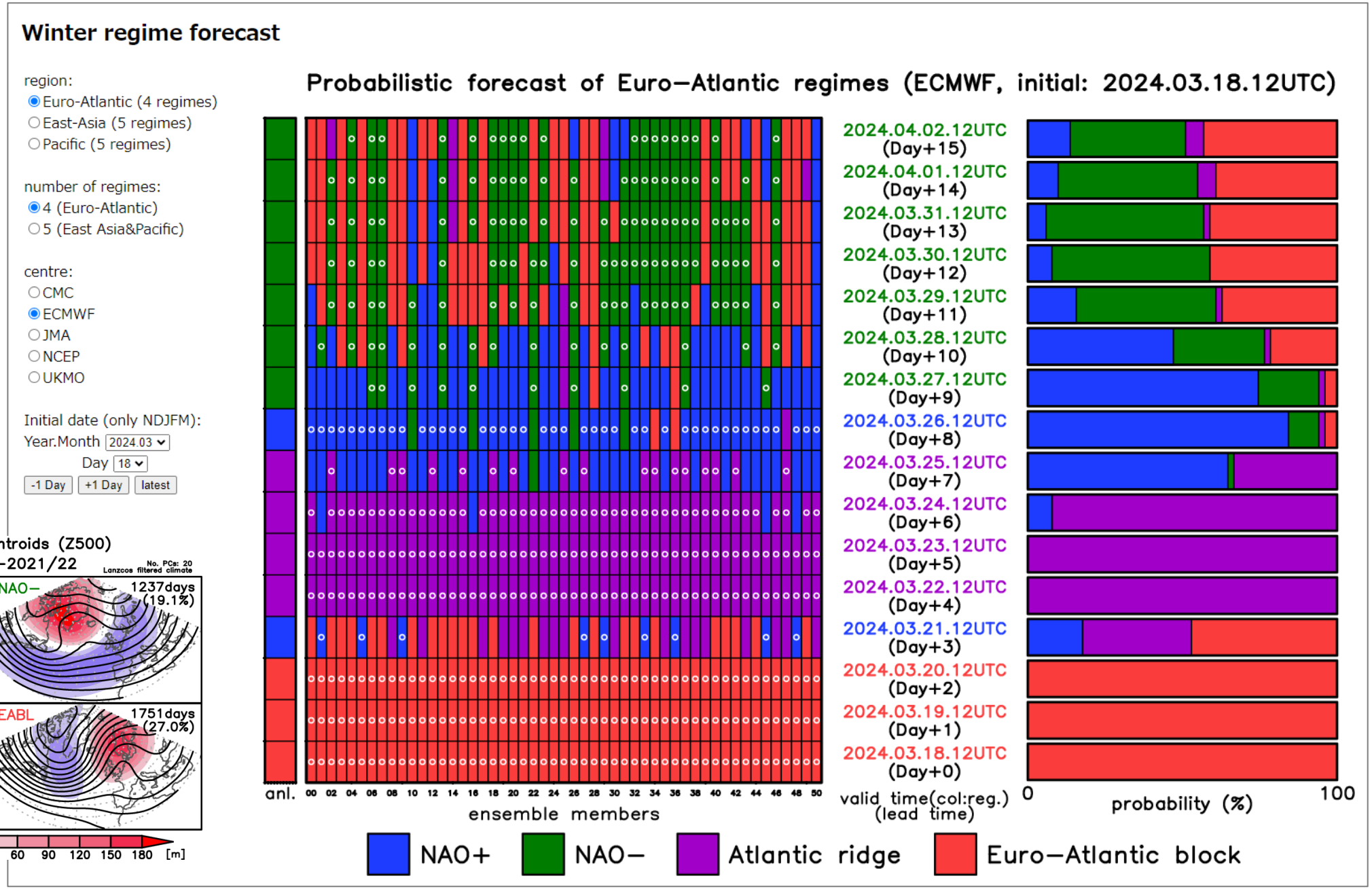
Please also see Matsueda & Palmer (2018) for verifications for regime forecasts

Europe, North Pacific, & East Asia regions

product only for CMC, ECMWF, JMA, NCEP & UKMO

all forecasts in extended winters of 2006-2024 are available





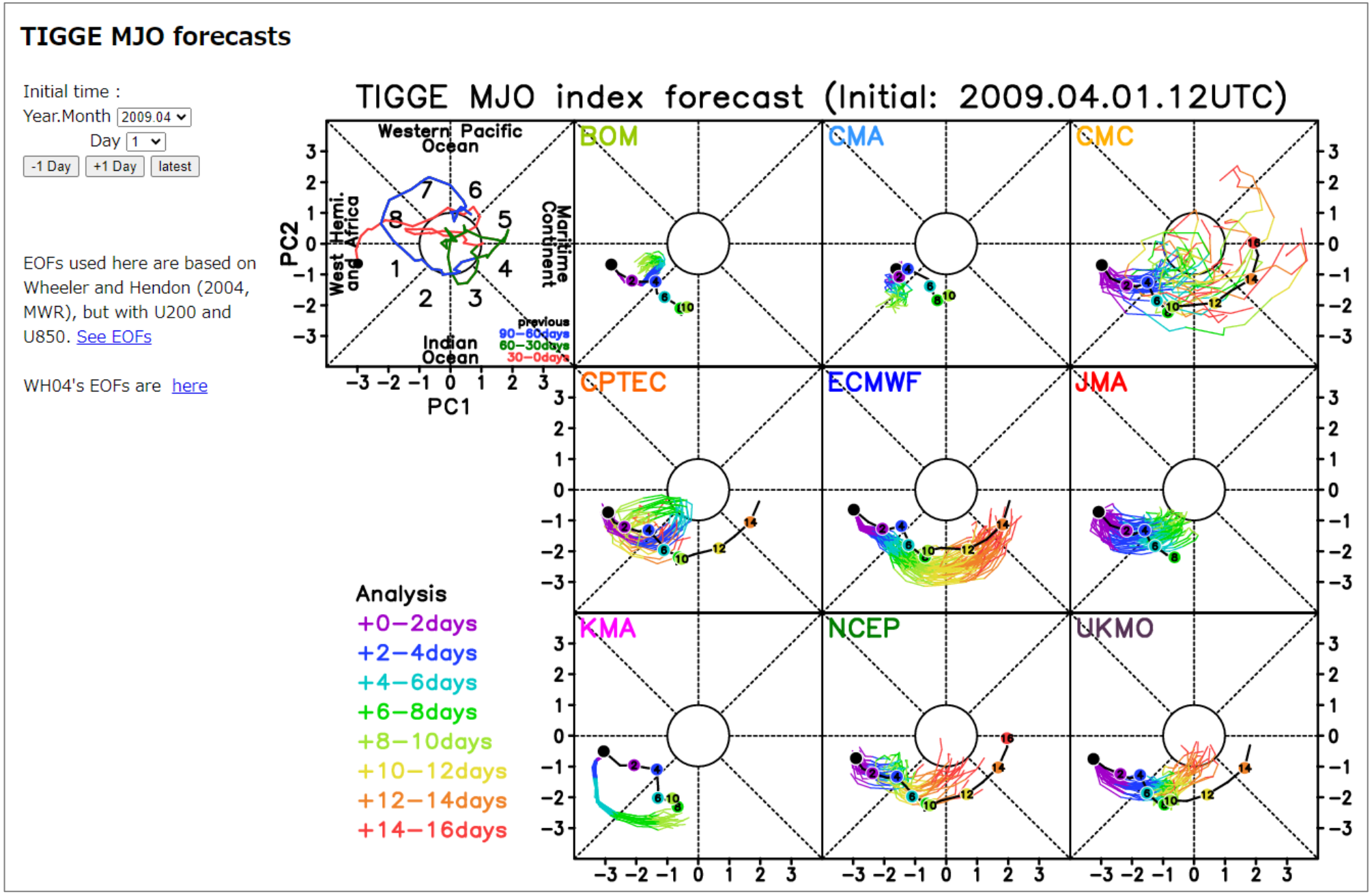
Matsueda and Endo (2011, GRL)

The TIGGE Museum – MJO index forecast –

all forecasts after Oct. 2006 are available

Verification of MJO forecast is also available for 2006-2013 on the TIGGE Museum

The best-performing centre varies with the phase of the MJO (Matsueda & Endo, 2010).



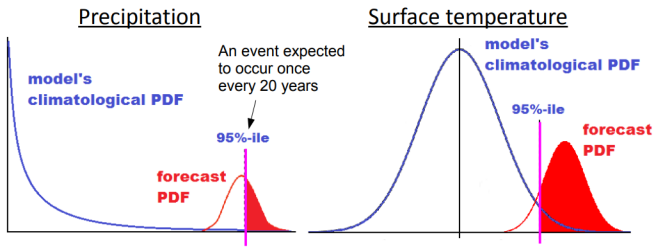
Matsueda & Nakazawa (2015, Met. Appl.)

The TIGGE Museum – probabilistic forecast of severe weather events –

Highlight the risks of heavy rain, strong winds, & high/low temperature in 12 areas

Forecast probability is based on **each model's climatological percentiles**: 1st, 5th, 10th, 90th, 95th, and 99th.

e.g. 95%-ile means that an event expected to occur once every 20 years



all forecasts (up to 15 days) after Oct. 2006 are available

The best-performing ensemble is case-dependent, especially for predicting severe weather events.

Ensemble-based occurrence probability of severe weather events

[A short guide (pdf)]

Extreme events:
- heavy precipitation
- strong wind
- warm
- cold

Climatological percentiles:
- 90th or 10th
- 95th or 5th
- 99th or 1st

Areas: Europe
[Japan&Asia]
[SWFDP regions]

Initial times:
Year.Month 2022.07
Day 12
-1 Day | +1 Day | latest

Forecast days:
- +0-1 days
- +1-2 days
- +2-3 days
- +3-4 days
- +4-5 days
- +5-6 days
- +6-7 days
- +7-8 days
- +8-9 days
- +9-10 days
- +10-11 days
- +11-12 days
- +12-13 days
- +13-14 days
- +14-15 days

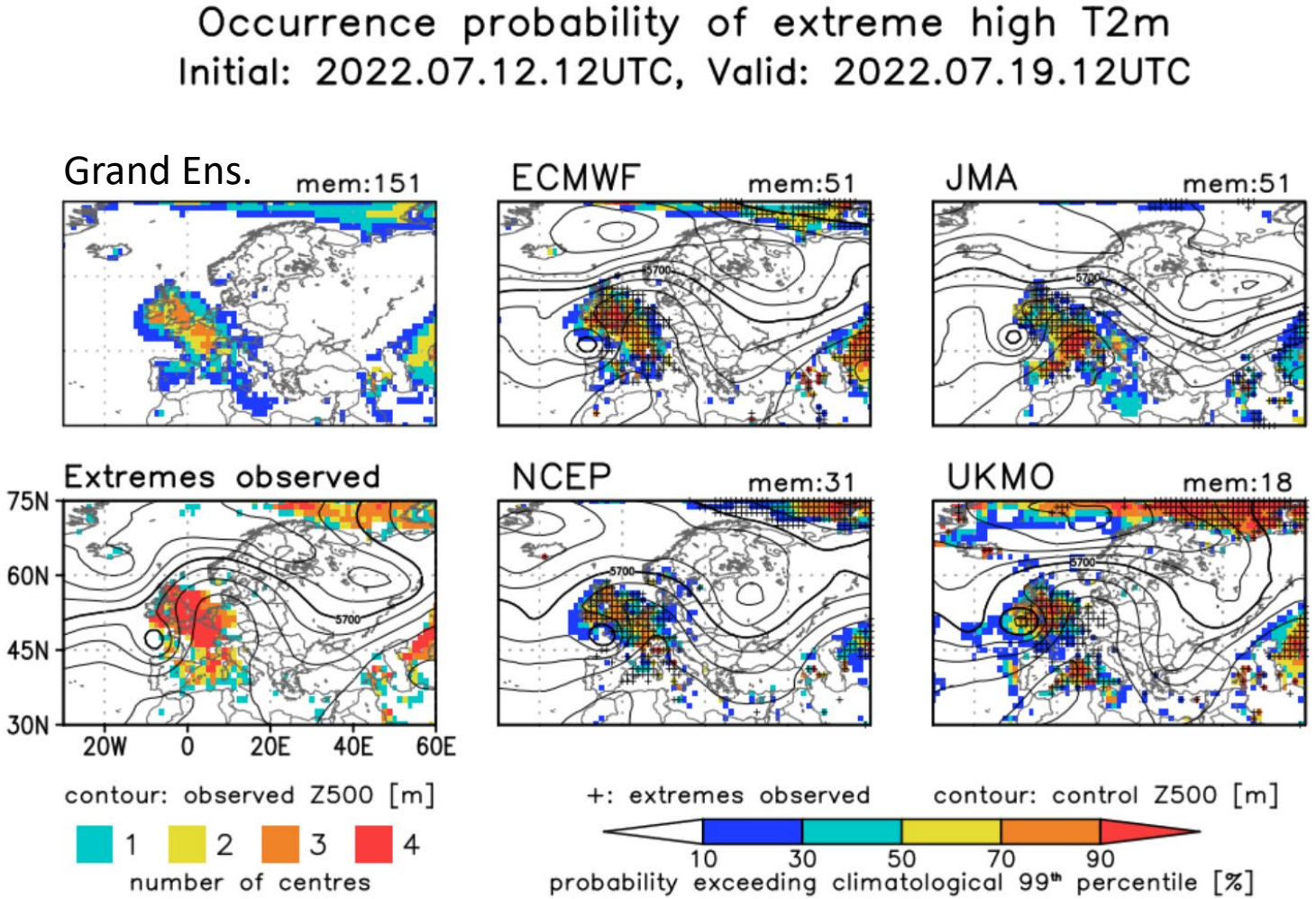


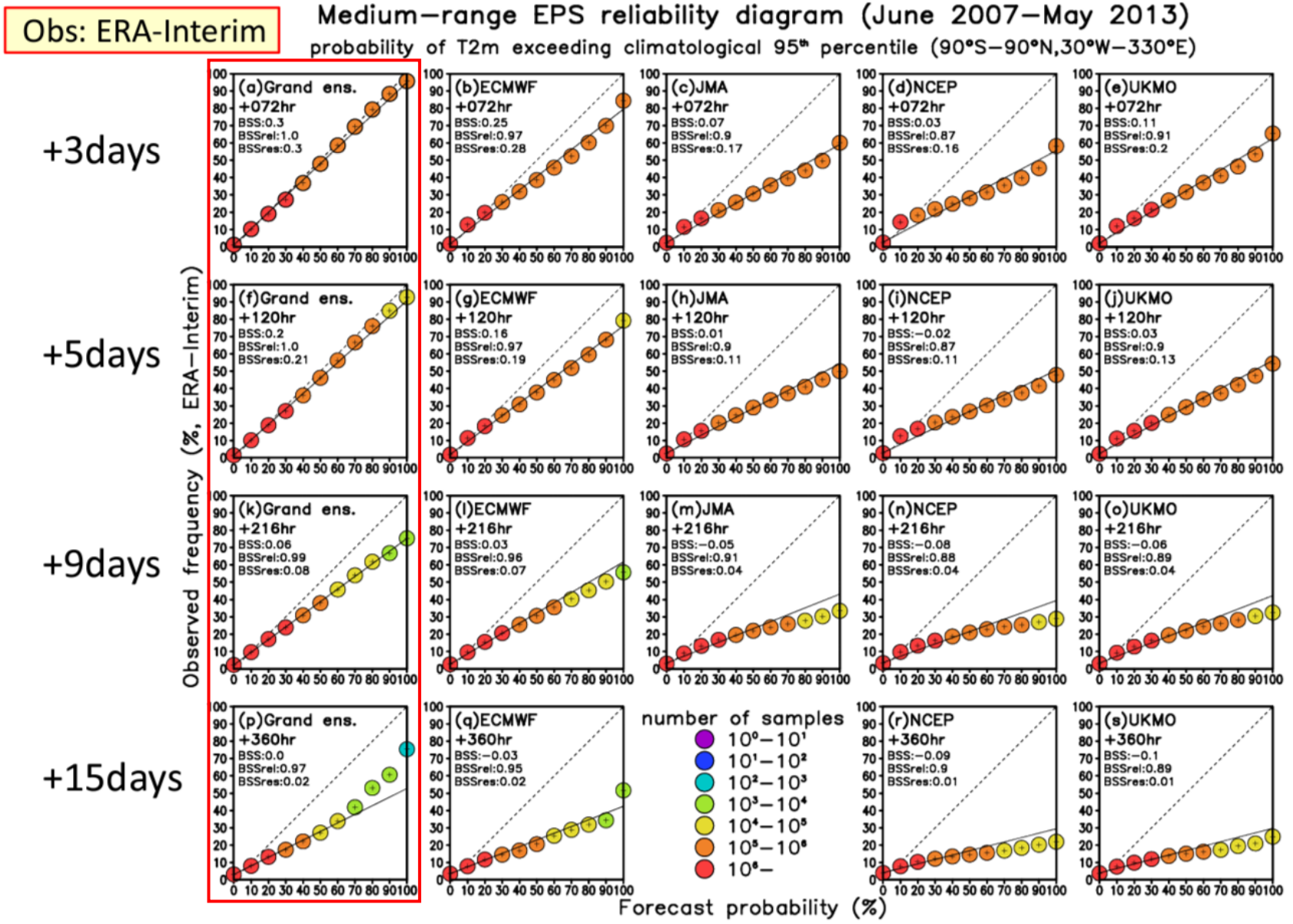
Fig. *Occurrence probabilities (shading) of extreme high temperature for* ***the 2022 European heatwave (40.3degC@Coningsby)****, by the (top left) multi-centre grand ensemble, (top centre) ECMWF, (top right) JMA, (bottom centre) NCEP, (bottom right) UKMO, initialized at 1200UTC* ***12 July 2022****, valid at 1200UTC 19 July 2022, and (bottom left) observed extremes.*

Matsueda & Nakazawa (2015, Met. Appl.)

The TIGGE Museum – probabilistic forecast of severe weather events –

Verification — reliability diagram for extreme high temperature —

The grand ensemble can provide more reliable forecasts than single-centre ensembles. Similar results were obtained for extreme low temperature, rainfall, and strong winds.



The TIGGE Museum – seasonal mean skills –

ACC, RMSE, RPSS and RMSE-spread relation for each season

verified against own analysis and ERA5

8 variables (Z500, PMSL, T850, T2m, UV200, and UV850)

7 major regions

forecasts after DJF 2006/07

Seasonal mean scores

Score:
◉ ACC ○ RMSE
○ RMSE&spread
○ RPSS (choose "ERA5" or "ERA-Interim")

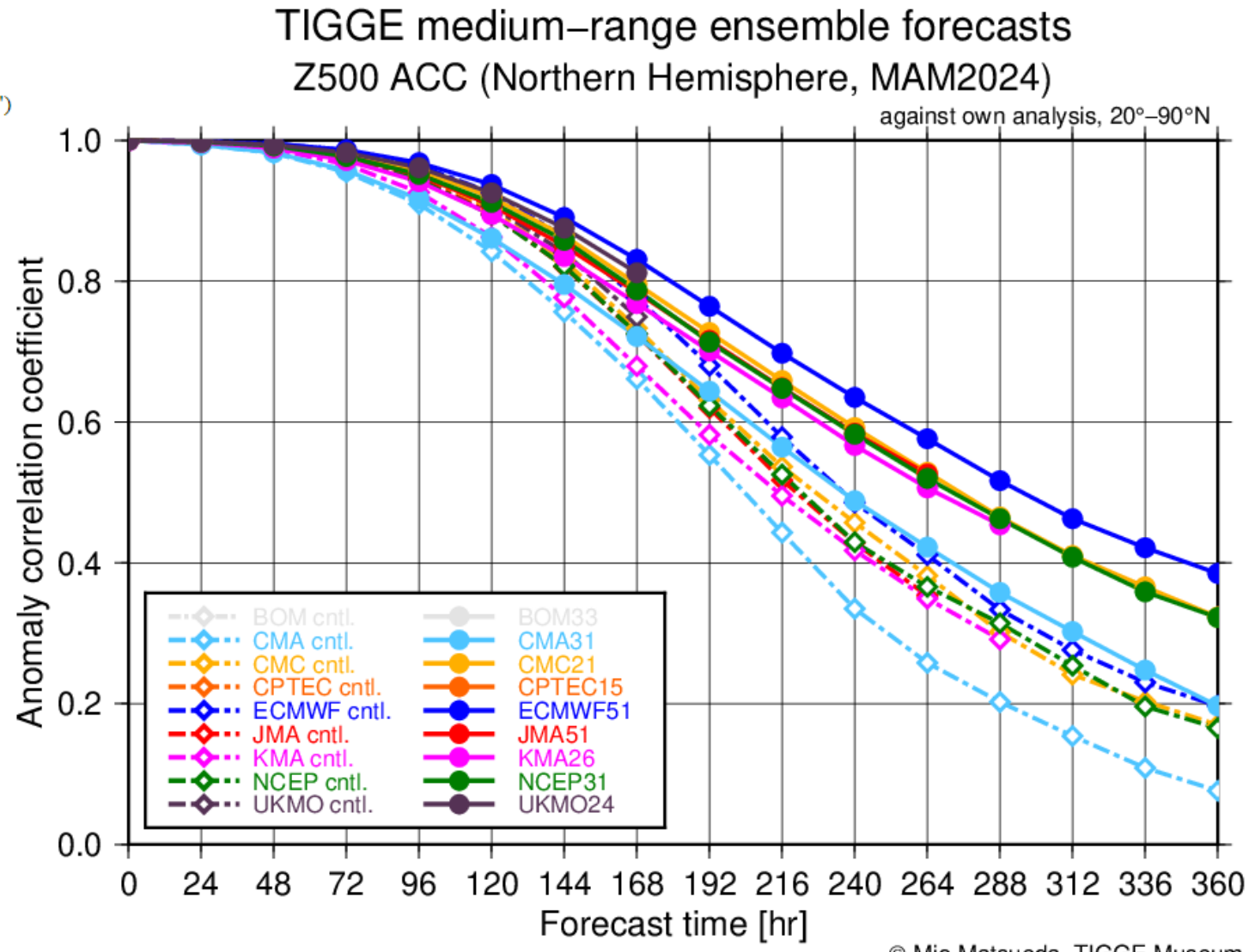
Verified against:
◉ own analysis (latest: MAM2024)
○ ERA5 (latest: MAM2024)
○ ERA-Interim (latest: MAM2019)

Variable:
◉ Z500 ○ PMSL
○ T850 ○ T2m
○ U200 ○ V200
○ U850 ○ V850

Area:
◉ NH (20-90N)
○ SH (20-90S)
○ Tropics (20S-20N)
○ North Pole (65-90N)
○ NH midlatitude (20-60N)
○ South Pole (65-90S)
○ SH midlatitude (20-60S)

Season:
○ DJF ◉ MAM ○ JJA ○ SON

Period:
◉ 2024 ○ 2023 ○ 2022
○ 2021 ○ 2020 ○ 2019
○ 2018 ○ 2017 ○ 2016
○ 2015 ○ 2014 ○ 2013
○ 2012 ○ 2011 ○ 2010
○ 2009 ○ 2008 ○ 2007



ECMWF shows the best, followed by **UKMO**, **CMC**, **NCEP**, & **JMA**.

The TIGGE Museum – daily forecast skills for individual ensemble members –

ACC and RMSE **only for Z500** by individual ensemble members

verified against own analysis and ERA5

12 major areas

2 horizontal axes: initial & valid time

all forecasts (up to 15 days) after Oct. 2006 are available

TIGGE Z500 forecast skill variability

Score:
◉ ACC ○ RMSE

Verified against:
◉ own analysis (OCT2006-APR2024)
○ ERA5 (OCT2006-MAR2024)

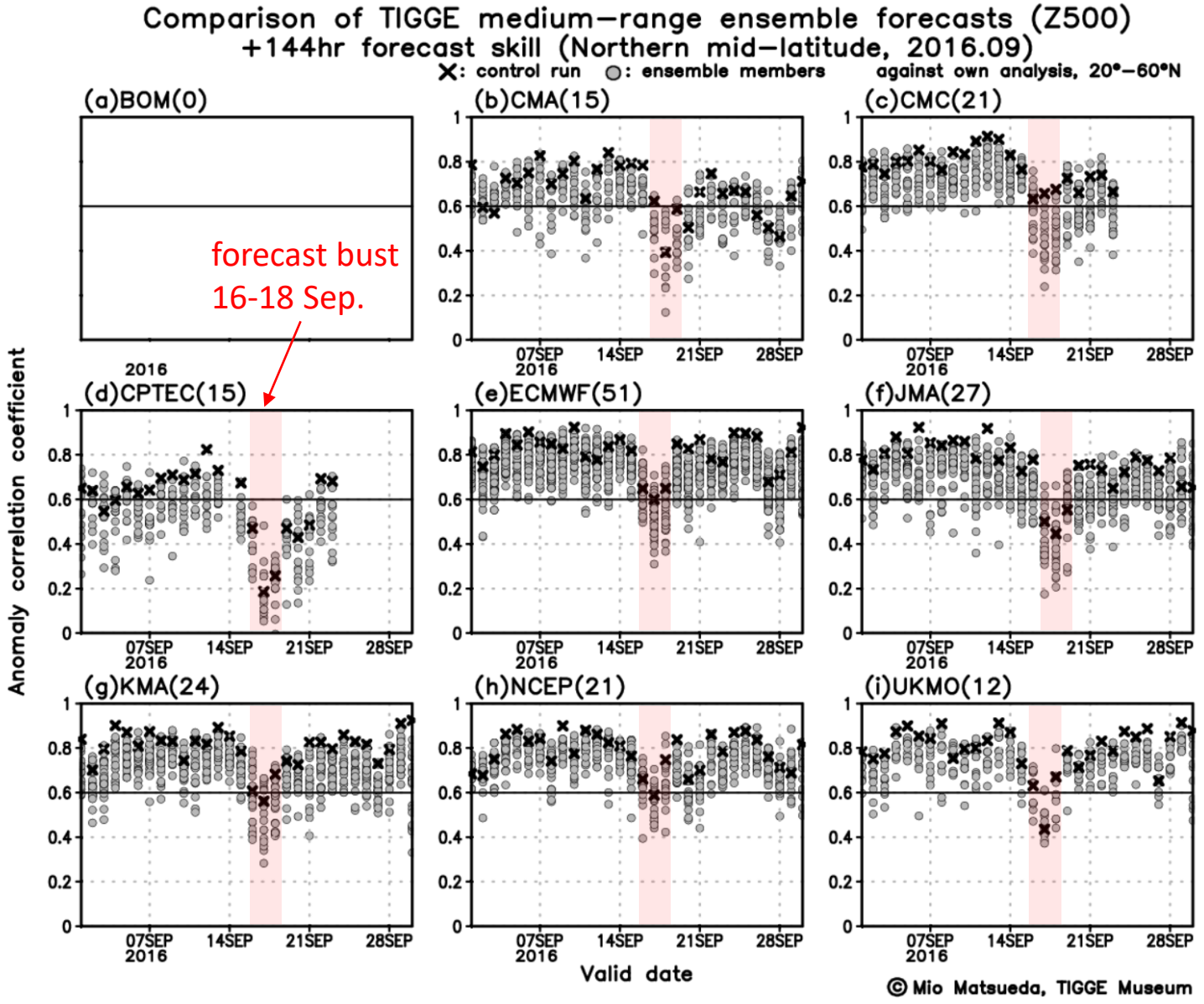
Area:
○ NH (20-90N)
○ SH (20-90S)
○ Tropics (20S-20N)
○ North Pole (65-90N)
◉ NH midlatitude (20-60N)
○ South Pole (65-90S)
○ SH midlatitude (20-60S)
○ Euro-Atl. (30-80N,90W-40E)
○ East Asia (20-60N,100-170E)
○ Pacific (20-80N,120E-60W)
○ Aus-New Zea. (70-10S,60E-160W)
○ South America (85-25S,120-20W)

Horizontal axis:
○ initial time ◉ valid time

Year:
○ 2024 ○ 2023 ○ 2022
○ 2021 ○ 2020 ○ 2019
○ 2018 ○ 2017 ◉ 2016
○ 2015 ○ 2014 ○ 2013
○ 2012 ○ 2011 ○ 2010
○ 2009 ○ 2008 ○ 2007
○ 2006

Month:
○ Jan ○ Feb ○ Mar
○ Apr ○ May ○ Jun
○ Jul ○ Aug ◉ Sep
○ Oct ○ Nov ○ Dec

Forecast hour:
○ +000hr ○ +024hr ○ +048hr
○ +072hr ○ +096hr ○ +120hr
◉ +144hr ○ +168hr ○ +192hr
○ +216hr ○ +240hr ○ +264hr
○ +288hr ○ +312hr ○ +336hr
○ +360hr



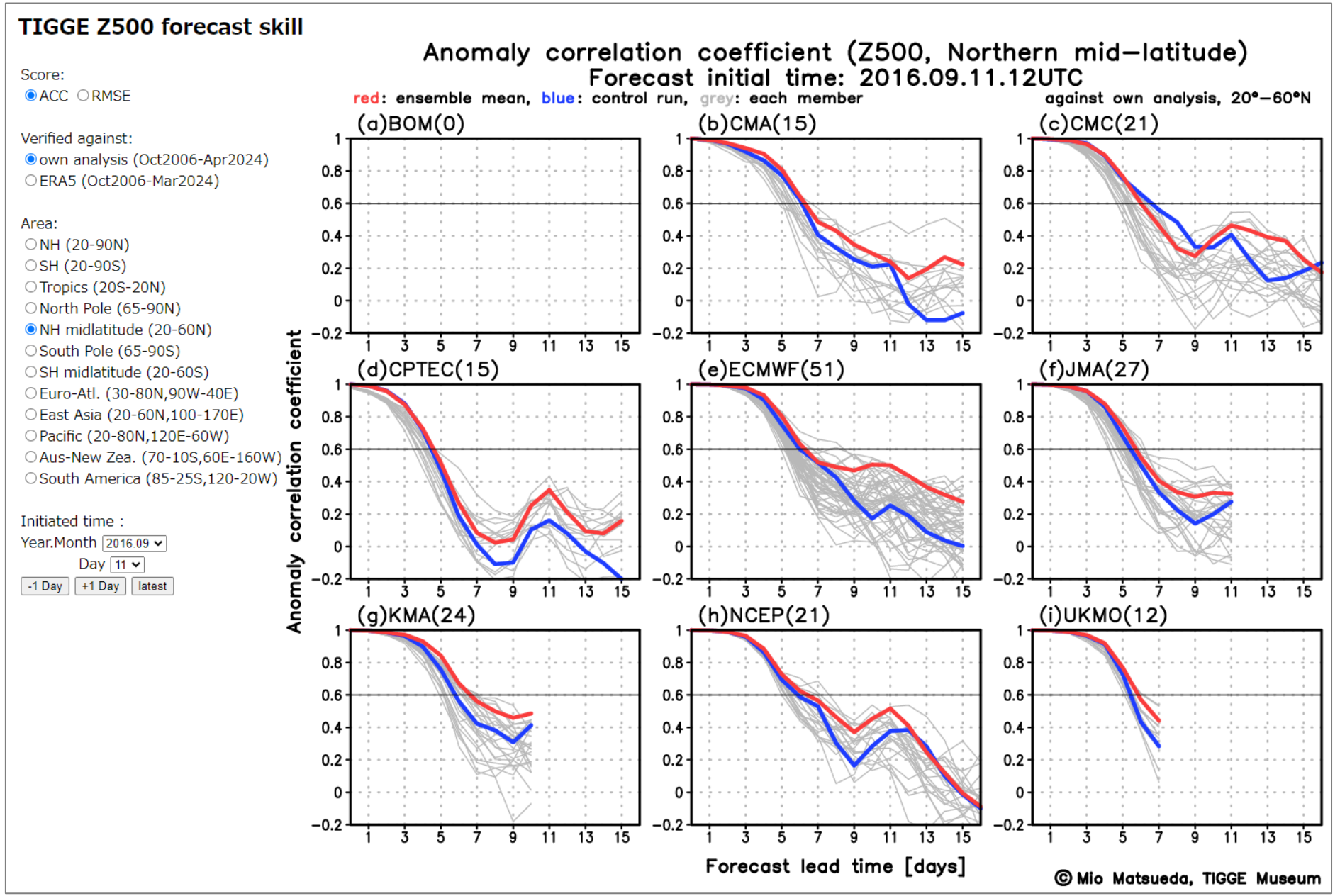
The TIGGE Museum – verification score for each forecast initial time –

ACC and RMSE **only for Z500** by individual ensemble members

verified against own analysis and ERA5

12 major areas

all forecasts (up to 15 days) after Oct. 2006 are available

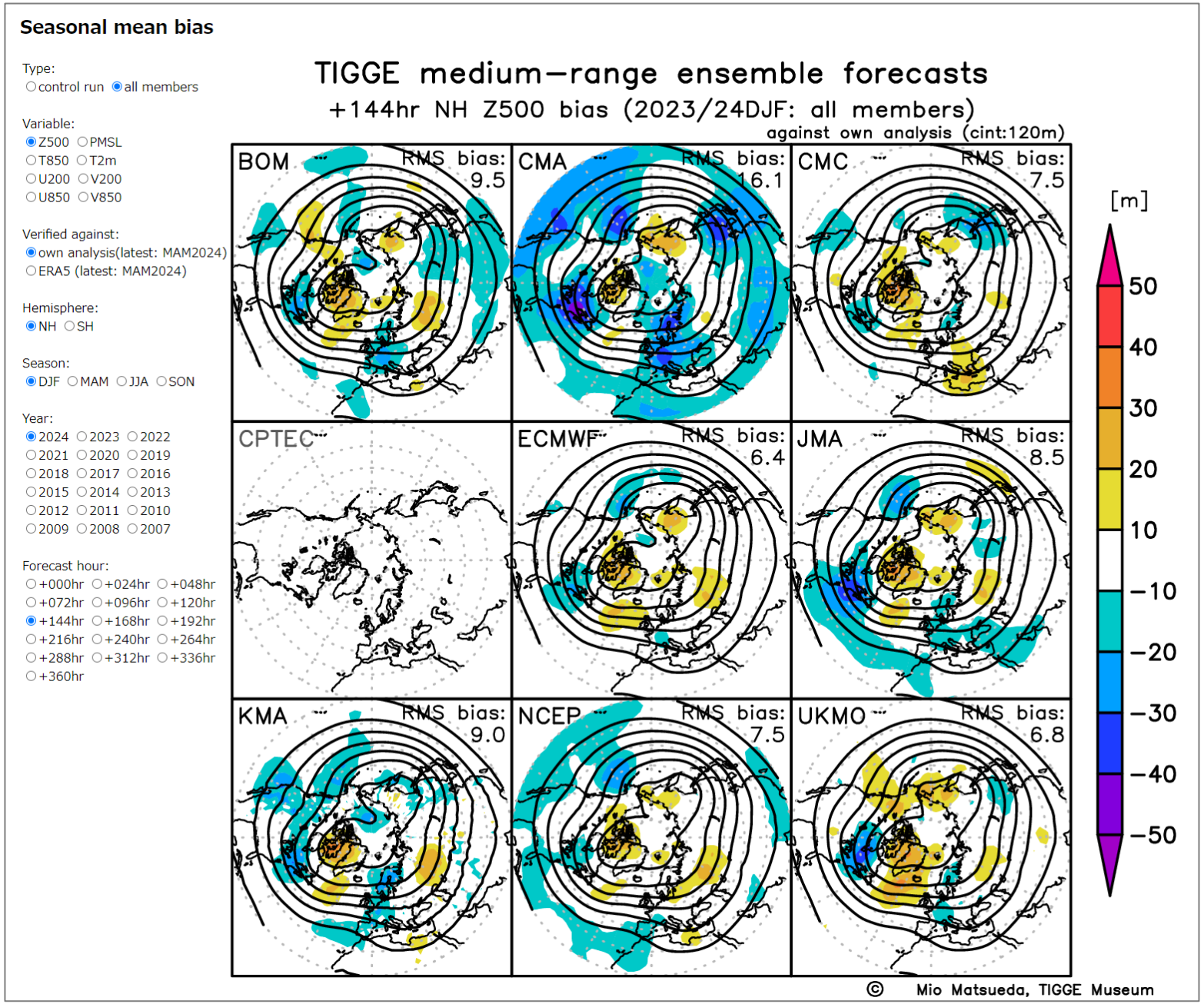


The TIGGE Museum – seasonal mean bias –

Seasonal mean bias of Z500, PMSL, T850, T2m, UV200, and UV850, for control forecast and ensemble mean forecast

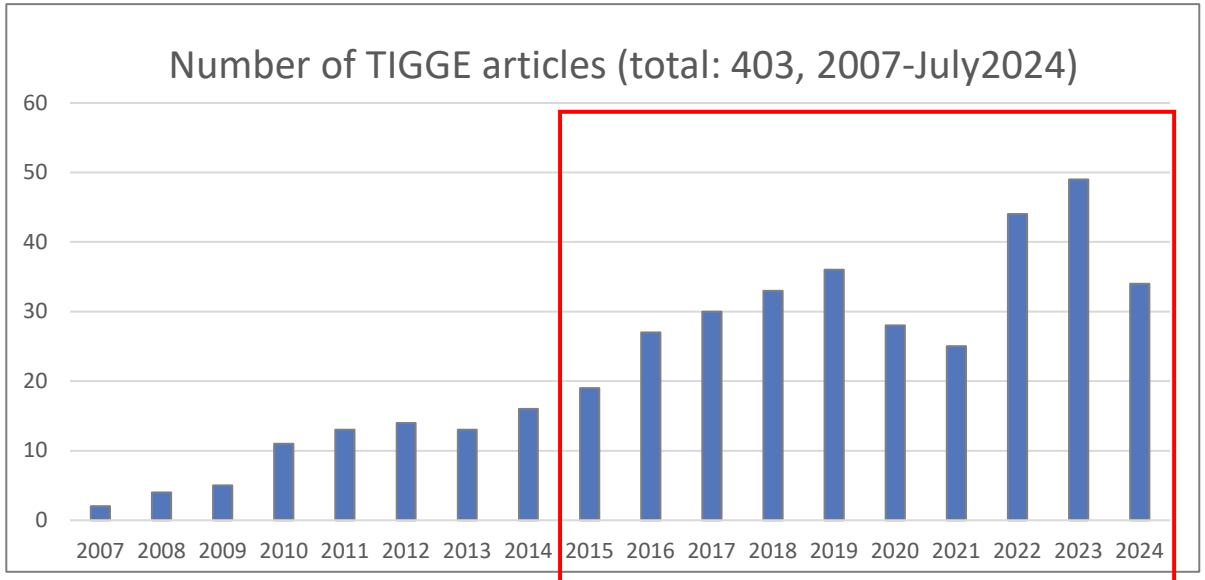
verified against own analysis and ERA5

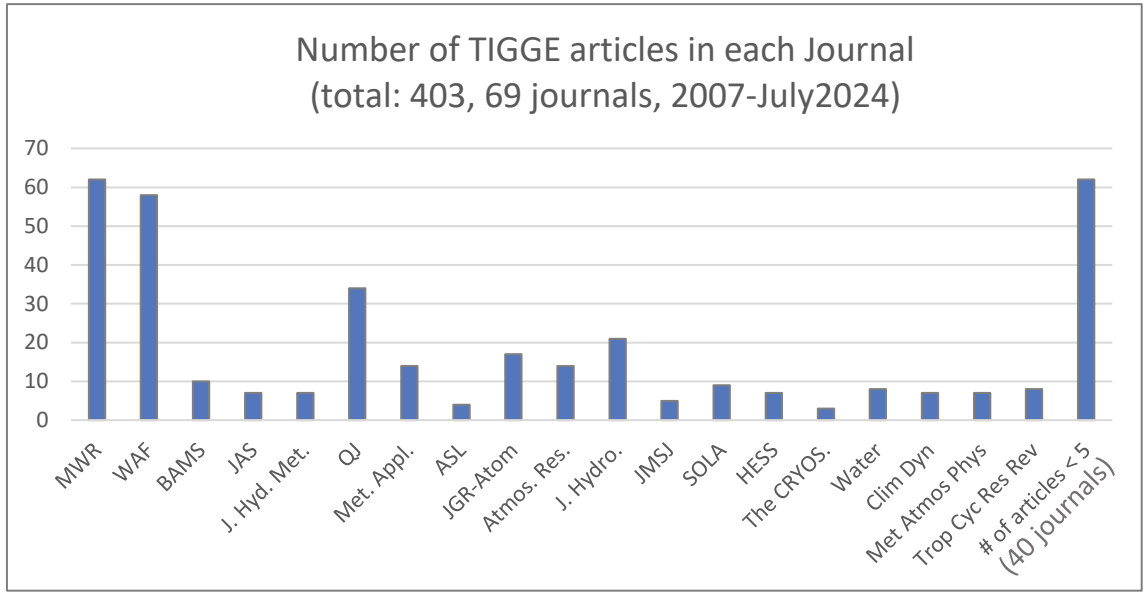
all forecasts (up to 15 days) for each season since winter 2006/07 are available



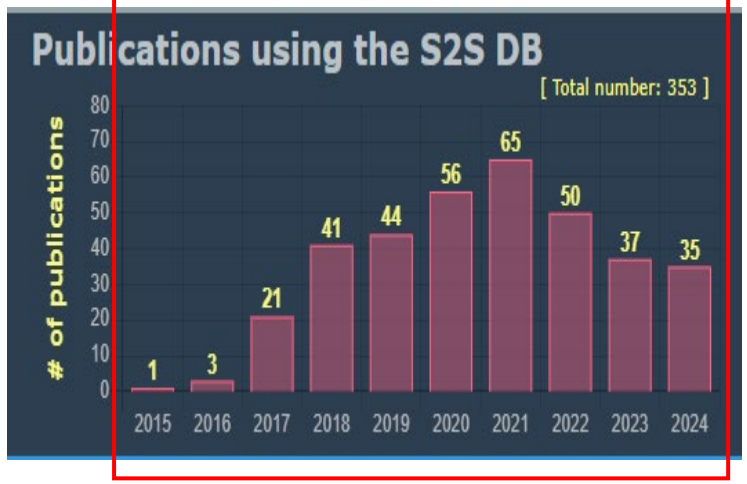
Survey of TIGGE articles (2007-July2024)

my responsibility as a PDEF* WG member
survey done by Munehiko Yamaguchi (MRI) until 2017





Survey of **S2S** articles
(from S2S project website)



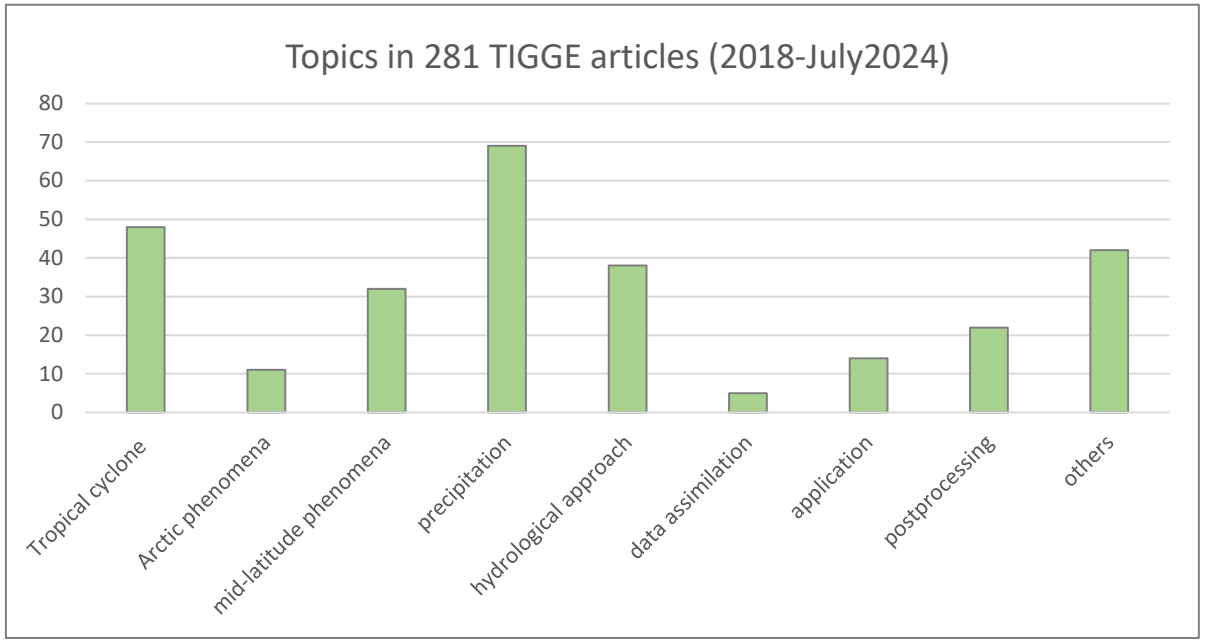
- ❑ 403 TIGGE articles since 2007
- ❑ the number of articles in 2023 was the largest
- ❑ 2024 is expected to surpass 2023 in the number of articles
- ❑ No COVID-19 influence since 2022
- ❑ Published in 69 journals, frequently in MWR, WF, QJ, & J. Hydro (AMS & RMetS Journals less popular recently)

- ❑ 353 S2S articles published since 2015
- ❑ S2S research was active during the COVID-19 pandemic

*PDEF: Predictability, Dynamics and Ensemble Forecasting

Survey of TIGGE articles (2007-July2024)

my responsibility as a PDEF WG member
survey done by Munehiko Yamaguchi (MRI) until 2017



TIGGE Article Survey Result
available in an Excel file

	No	Author(s)	Title	Journal	Year	Research topic	centres used	doi
1	1	Jingnan Wang, Xiaodong Wang, Jiping Guan, Lifeng Zhang, Tao Chang, and Wei Yu	ST-TransNet: A Spatiotemporal Transformer Network for Uncertainty Estimation from a Single Deterministic Precipitation Forecast	Monthly Weather Review	2024	precipitation	CMA	https://doi.org/10.1175/MWR-D-23-0097.1
2	2	David S. Richardson, Hannah L. Cloke, John A. Methven, and Florian Pappenberger	Jumpiness in Ensemble Forecasts of Atlantic Tropical Cyclone Tracks	Weather and Forecasting	2024	Tropical cyclone	ECWMF, NCEP, UKMO	https://doi.org/10.1175/WAF-D-23-0113.1
3	3	Frank P. Colby Jr., Mathew Barlow, and Andrew B. Penny	Steering Flow Sensitivity in Forecast Models for Hurricane Ian (2022)	Weather and Forecasting	2024	Tropical cyclone	ECMWF, NCEP	https://doi.org/10.1175/WAF-D-23-0169.1
4	4	Benjamin M. Kiel and Brian A. Colle	Comparison of Clustering Approaches in a Multimodel Ensemble for U.S. East Coast Cold Season Extratropical Cyclones	Weather and Forecasting	2024	extratropical cyclone	ECCC, ECMWF, NCEP	https://doi.org/10.1175/WAF-D-23-0017.1
5	5	H. A. Titley, H. L. Cloke, E. M. Stephens, F. Pappenberger, and E. Zsoter	Using Ensembles to Analyze Predictability Links in the Tropical Cyclone Flood Forecast Chain	Journal of Hydrometeorology	2024	Flood	ECMWF	https://doi.org/10.1175/JHM-D-23-0022.1
6	6	Pu Liu, Markus Dabernig, Aitor Atencia, Yong Wang, and Yuchu Zhao	Probabilistic Neural Networks for Ensemble Postprocessing	Monthly Weather Review	2024	Probabilistic Precipitation Forecast Postprocessing	ECMWF	https://doi.org/10.1175/MWR-D-23-0220.1
7	7	Jiaying Ke, Mu Mu, and Xianghui Fang	Influence of Physically Constrained Initial Perturbations on the Predictability of Mei-Yu Heavy Precipitation	Monthly Weather Review	2023	use initial perturbations	ECMWF	https://doi.org/10.1175/MWR-D-22-0302.1
8	8	Samantha Ferrett, John Methven, Steven J. Woolnough, Gui-Ying Yang, Christopher E. Holloway, and Gabriel Wolf	Hybrid Dynamical–Statistical Forecasts of the Risk of Rainfall in Southeast Asia Dependent on Equatorial Waves	Monthly Weather Review	2023	precipitation	UKMO	https://doi.org/10.1175/MWR-D-22-0300.1
9	9	Yan Ji, Xiefei Zhi, Luying Ji, and Ting Peng	Conditional Ensemble Model Output Statistics for Postprocessing of Ensemble Precipitation Forecasting	Weather and Forecasting	2023	Precipitation Forecast Postprocessing	ECWMF, NCEP, UKMO	https://doi.org/10.1175/WAF-D-22-0190.1
10	10	Chenkai Cai, Jianqiu Wang, Zhijia Li, Xinyi Shen, Jinhua Wen, Helong Wang, and Xinyan Zhou	Evaluating and Modeling the Reliability of Continuous No-Rain Forecast from TIGGE Based on the First-Passage Problem and Fuzzy Mathematics	Journal of Hydrometeorology	2023	precipitation	CMA, ECMWF, JMA, UKMO	https://doi.org/10.1175/JHM-D-22-0126.1
11	11	William S. Lamberson, Michael J. Bodner, James A. Nelson, and Sara A. Sienkiewicz	The Use of Ensemble Clustering on a Multimodel Ensemble for Medium-Range Forecasting at the Weather Prediction Center	Weather and Forecasting	2023	ensemble clustering	ECCC, ECMWF, NCEP	https://doi.org/10.1175/WAF-D-22-0154.1
12	12	Xiping Zhang, Juan Fang, and Zifeng Yu	The Forecast Skill of Tropical Cyclone Genesis in Two Global Ensembles	Weather and Forecasting	2023	cyclogenesis	ECMWF, UKMO	https://doi.org/10.1175/WAF-D-22-0145.1
13	13	Sivareddy Sankotimi, Sanjue Langodan, Hari Prasad Dasari, Peng Zhan, George Krokos, Yasser O. Abualnaja, Khaled	Making the Case for High-Resolution Regional Ocean Reanalyses: An Example with the Red Sea	Bulletin of the American Meteorological Society	2023	Use as atmospheric forcing	ECMWF	https://doi.org/10.1175/BAMS-D-21-0287.1
14	14	Briana E. Stewart, Jason M. Cordeira, and F. Martin Ralph	Evaluating GFS and ECMWF Ensemble Forecasts of Integrated Water Vapor Transport along the U.S. West Coast	Weather and Forecasting	2022	Atmospheric river	ECMWF, NCEP	https://doi.org/10.1175/WAF-D-21-0114.1
15	15	Patrik Benáček, Aleš Farda, and Petr Štěpánek	Postprocessing of Ensemble Weather Forecast Using Decision Tree–Based Probabilistic Forecasting Methods	Weather and Forecasting	2022	Postprocessing Ensemble Weather Forecasts	ECMWF	https://doi.org/10.1175/WAF-D-22-0006.1
16	16	L. Magnusson, D. Ackerley, J. Bouteloup, J.-H. Chen, J. Doyle, P. Earnshaw, Y. C. Kwon, M. Köhler, S. T. Kusy, Y. J. Lim	Skill of Medium-Range Forecast Models Using the Same Initial Conditions	Bulletin of the American Meteorological Society	2022	Use as verifying analyses	ECCC, ECMWF, JMA, KMA, NCEP, UKMO	https://doi.org/10.1175/BAMS-D-21-0234.1
17	17	Justin G. McLay and Elizabeth Satterfield	Forecast Dropouts in the NAVGEM Model: Characterization with Respect to Other Models, Large-Scale Indices, and Ensemble Forecasts	Weather and Forecasting	2022	Forecast Dropouts	ECCC, NCEP	https://doi.org/10.1175/WAF-D-21-0208.1

- The primary focus is on precipitation, followed by tropical cyclone, hydrological approach & mid-lat. phenomena.
- In recent years, hydrological and ML/DL-related approaches and post-processing researches become more active. This is why articles are published in a variety of Journals.
- Most frequently used ensemble is ECMWF, with 118 out of 281 (42%) articles from 2018 to July 2024 using **ONLY** ECMWF.

Ongoing research project | 2013 - 2028
A WWRP/THORPEX-WCRP joint research project

Aims

- To improve forecast skill and understanding on the sub-seasonal to seasonal timescale with special emphasis on high-impact weather events, including tropical cyclones, droughts, floods, heat waves and monsoon precipitation
- To promote the initiative's uptake by operational centres and exploitation by the application community
- To capitalize on the expertise of the weather and research communities to address issues of importance to the Global Framework for Climate Services

Although the 1st (2013-2018) and the 2nd (2019-2023) phases of project finished, another 5-year period (2024-2028) of the S2S database regular updates is currently underway. As of September 2024, S2S provides **S2S ensemble forecasts from 13 NWP centres**: BoM, CMA, CPTEC, ECCC, ECMWF, HMCR, IAP-CAS, ISAC-CNR, JMA, KMA, Météo France, NCEP, and UKMO.

https://confluence.ecmwf.int/display/S2S/Models

S2S Models

13 models Model's outputs are archived on the common 1.5/1.5 regular lat-lon grid.

	Model version	Implement. date in S2S	Time range	Resolution	Ens. Size *7	Frequency	Re-forecasts	Rfc period	Rfc frequency	Rfc size *7	Ocean resolution	Active Sea Ice
BoM (ammc)	POAMA P24	01/01/2015	d 0-62	T47 L17	32+1	2/week (Thu, Sun)	fixed	1981-2013 (model version date 01/01/2014)	6/month (always on the 1st, 6th, 11th, 16th, 21st and 26th)	32+1	2° x 0.5° L25	no
CMA (babj)	BCC-CPS-S2Sv2	11/11/2019	d 0-60	T266 L56	3+1	2/week (Mon, Thu)	on the fly	past 15 years	2/week (Mon, Thu)	3+1	0.25°	No
CNR-ISAC (isac)	GLOBO	05/09/2024	d 0-35	0.7x0.5 L70	40+1	weekly (Thu)	fixed	2001-2020 (model version date 16/10/2023)	every 5 days (the same days each Rfc year *1)	7+1	N/A	N/A
CNRM (lfpw)	CNRM-CM 6.1	22/10/2020	d 0-47	T359 L91	25	weekly (Thu)	fixed	1993-2017 (model version date 01/07/2019)	every 7 days (starting from 31/12/1992 *2)	10	0.25° L75	yes
CPTEC (sbsj)	BAM-1.2	13/12/2023	d 0-35	TQ126 L42	11	2/week (Wed, Thu)	fixed	1999-2018 (model version date 04/01/2023)	every 7 days (starting from 06/01/1999)	11	N/A	N/A
ECCC (cwao)	GEPS 8	13/06/2024	d 0-39	Yin-Yang grid at 0.25° uniform resolution (~25 km) L85	20+1	2/week (Mon, Thu)	on the fly	2001-2020	2/week (Mon, Thu)	3+1	0.25° L50	yes
ECMWF (ecmf)	CY48R1	27/06/2023	d 0-46	Tco319L137 (about 32 km)	100+1	daily	on the fly	past 20 years	2/week (Mon/Thu)	10+1	1/4 degree	Yes
HMCR (rums)	RUMS	15/09/2022	d 0-46	0.9° x 0.72° L96	40+1	weekly (Thu)	on the fly	1991-2015	weekly (Thu)	10+1	N/A	N/A
IAP- CAS (anso)	CAS-FGOALS-f3	21/08/2024	d 0-65	C96 L32	49	daily	fixed	1999-2018 (model version date 01/01/2019)	daily	4	1° L60	yes
JMA (rjtd)	CPS3	19/02/2023	d 0-34	TI319L100	4+1	daily	fixed	1991-2020 (model version date 30/09/2022)	2/month (always on the 15th and the last day of month *3)	4+1	0.25° L60	yes
KMA (rksl)	GloSea6-GC3.2	01/06/2023	d 0-60	N216 L85 (0.83° x 0.56°, about 60 km in mid latitudes)	8	daily	on the fly	1993-2016	4/month (always on the 1st, 9th, 17th and 25th)	7		yes
NCEP (kwbc)	CFSv2	10/03/2015	d 0-44	T126 L64 (about 100 km)	15+1	daily	fixed	1999-2010 (model version date 01/03/2011)	daily	3+1	0.5° x 0.25° L40 varying resolution (*6)	yes
UKMO (egrr)	GloSea6	02/02/2021	d 0-60	N216 L85	4	daily	on the fly	1993-2016	4/month (always on the 1st, 9th, 17th and 25th)	7	0.25° L75	yes

The S2S Museum – website of sub-seasonal forecast products –

Google **"S2S Museum"** or use QR code below

http://gpvjma.ccs.hpcc.jp/S2S/

Welcome to the S2S Museum

151 Pageviews
Aug. 04th - Sep. 04th

The Subseasonal to Seasonal Prediction (S2S) Project is a proposed WWRP/THORPEX/ WCRP joint research project.

The main goal of the S2S project is to improve forecast skill and understanding on the subseasonal to seasonal timescale, and promote its uptake by operational centres and exploitation by the applications community. Specific attention will be paid to the risk of extreme weather, including tropical cyclones, droughts, floods, heat waves and the waxing and waning of monsoon precipitation.

The S2S data portals provide the S2S data freely with a 3-week delay only for research and education purposes. For details, visit the S2S Project Office website or the ECMWF S2S website. Forecast products in the S2S Museum are updated everyday, with a 3-week delay, and are available for research and educational purposes only.

The S2S Museum is operated for a promotion of utilization of the S2S data by Dr. Mio Matsueda (University of the Ryukyus and University of Tsukuba).

The TIGGE Museum and The Copernicus (C3S) Museum are also open!

LastUpdate:09/03/2024 19:54:09

Information about the operational extended-range Ensemble Prediction Systems (EPSs)

- Details of EPSs available at the S2S portals (Latest, March 2023)
  - BoM (Australia)
  - CMA (China)
  - ECCC (Canada)
  - ECMWF (CY48R1:27/06/2023-,CY47R3:13/10/2021-26/06/2023, CY47R2:11/05/2021-12/10/2021, CY47R1:30/06/2020-10/05/2021, CY46R1:11/06/2019-29/06/2020, CY45R1:06/06/2018-10/06/2019, CY43R3:11/07/2017-05/06/2018, CY43R1:22/11/2016-10/07/2017, CY41R2:08/03/2016-21/11/2016, CY41R1: 14/05/2015-07/03/2016, CY40R1: 21/11/2013-14/05/2015)
  - HMCR (Russia)
  - ISAC-CNR (Italy)
  - JMA (Japan) (CPS3:19/02/2023-, GEPS2203:15/03/2022-15/02/2023, GEPS2103:30/03/2021-09/03/2022, GEPS2003:24/03/2020-24/03/2021, GEPS1701:22/03/2017-18/03/2020, GSM1403C:05/03/2014/-15/03/2017)
  - KMA (Republic of Korea)
  - Meteo France (France)
  - NCEP (US)
  - UKMO (UK)
- Data availability for real-time forecasts at the ECMWF S2S data portal
- Data availability for on-the-fly reforecasts at the ECMWF S2S data portal

S2S products Updated every day with a 21-day delay!

- Ensemble forecasts for specific atmospheric phenomena
  - AO/AAO (Arctic/Antarctic Oscillations) index [definition of AO/AAO (pdf)]

- ❑ opened in 2016?
- ❑ products are updated with a 3-week delay (to be reduced to a 3-day delay)
- ❑ 11 models and ERA5 (if available) (IAP-CAN and CPTEC to be added)
- ❑ 15 forecast products from Jan. 2015 to the present (832GB):
  - ➢AO/AAO/NAO index
  - ➢teleconnection indices: EA, PNA, WA, WP and EU
  - ➢SLP & Z500 anomalies (stamp maps)
  - ➢SSW (Sudden Stratospheric Warming)
  - ➢stream function&velocity potential
  - ➢wave activity flux at 200 hPa
  - ➢MJO (Madden-Julian Oscillation)
  - ➢SST (Sea Surface Temperature)
  - ➢sea-ice cover
  - ➢verification of ensemble mean: SLP, Z500, Z50, U200, & T850

The S2S Museum – verification of ensemble mean forecast –

all forecasts after 2015

analysis (NCEP control run at Day 0) is also included (if available)

S2S NAO index forecasts

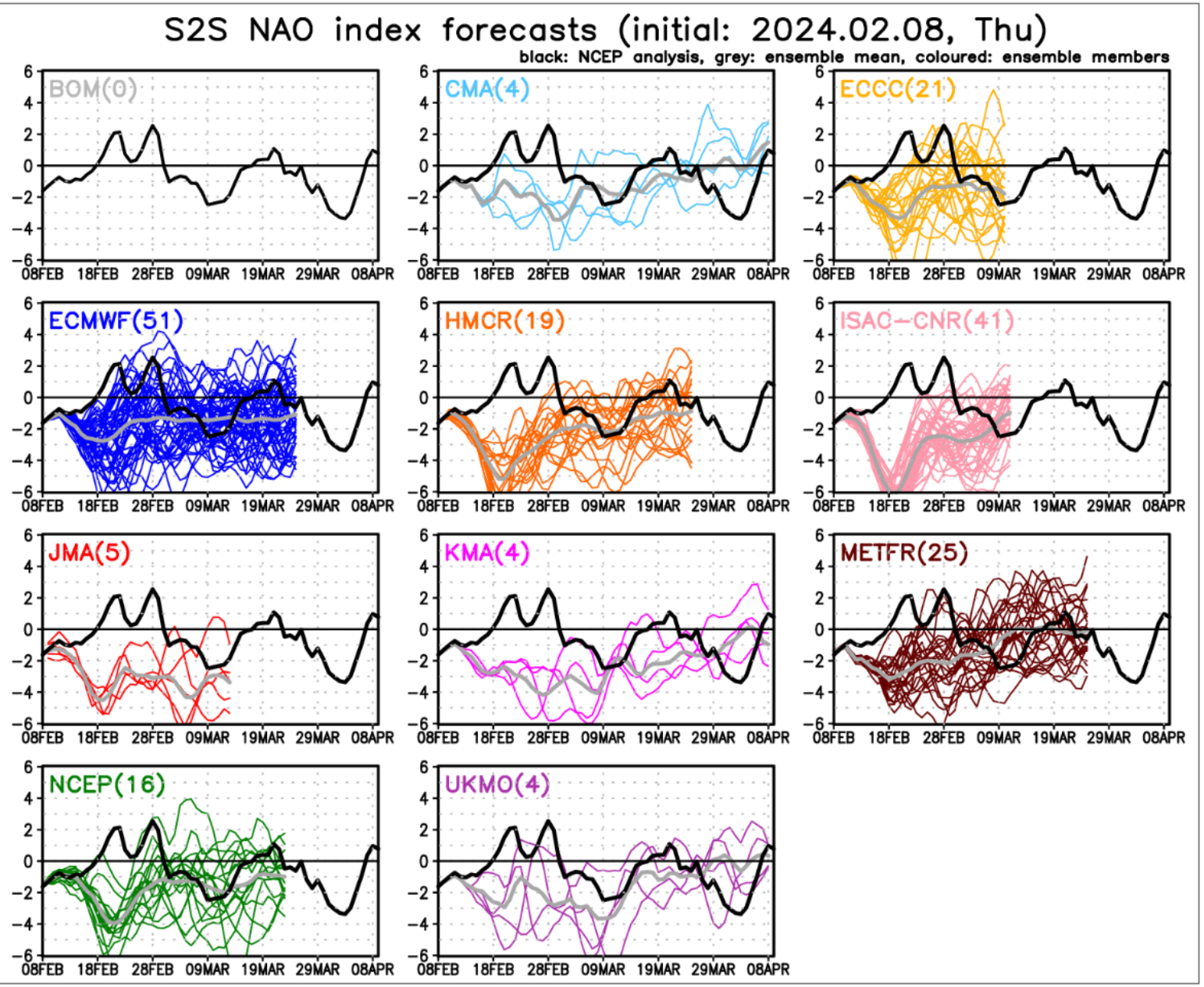
Updated every day with a 21-day delay!
The latest initial date is 20240812.

Initial time :
Year.Month 2024.02
Day 8
-1 Day | +1 Day | latest

Definition of leading mode is here

Initial days of forecasts:

centre	Sun	Mon	Tue	Wed	Thu	Fri	Sat
BoM	■				■		
CMA	■	■	■	■	■	■	■
ECMWF		■			■		
ECCC					■		
HMCR *1				■	■		
ISAC-CNR *2		■			■		
JMA *3	■	■	■	■	■	■	■
KMA	■	■	■	■	■	■	■
METFR *4					■		
NCEP	■	■	■	■	■	■	■
UKMO	■	■	■	■	■	■	■



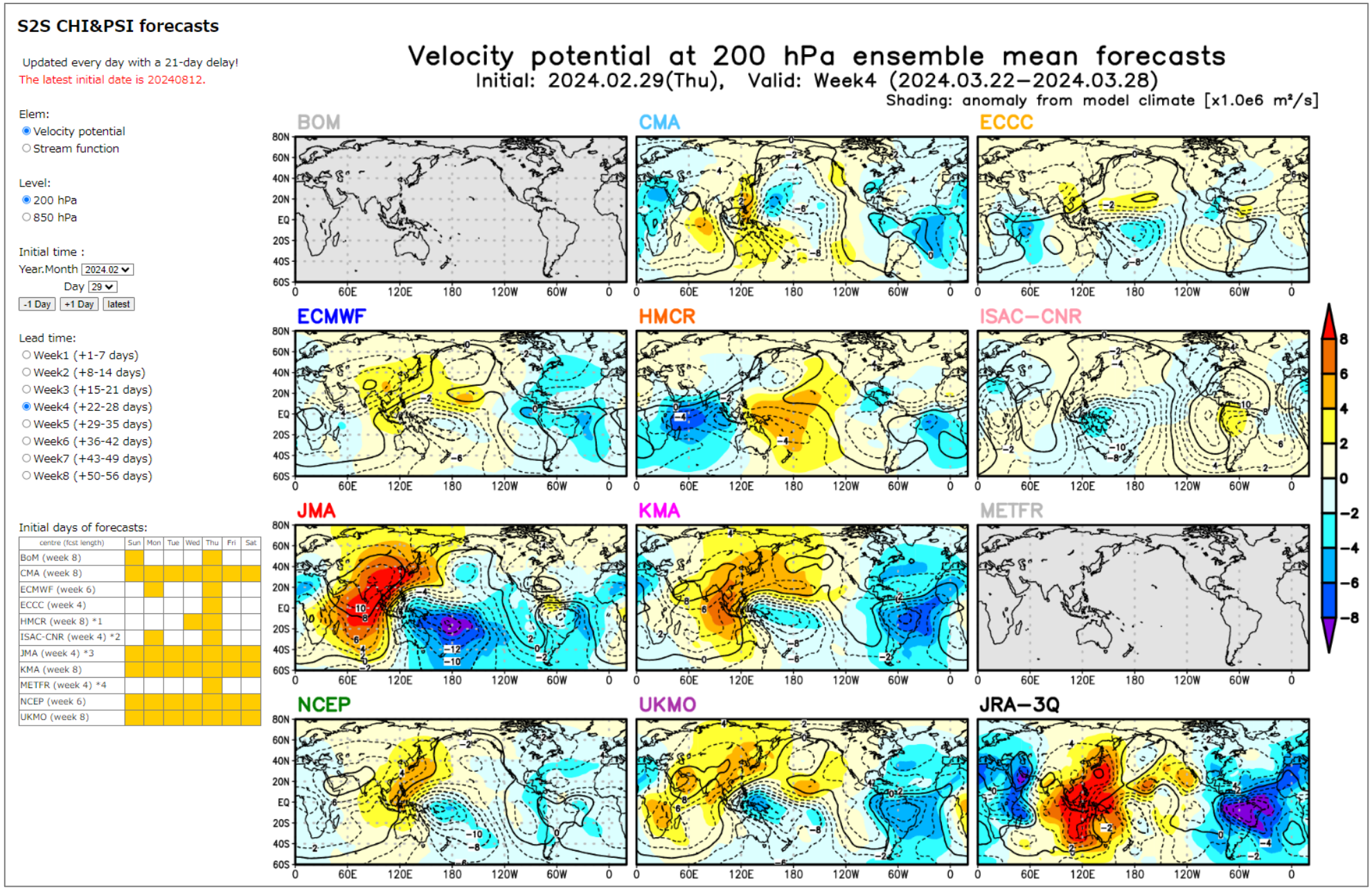
The S2S Museum – weekly mean forecast of velocity potential at 200hPa –

weekly-mean velocity potential/stream function at200/850hPa

all forecasts after 2015

week 1 to 8

JRA3Q also included (if available)



The S2S Museum – sea-ice cover and SST forecast –

weekly-mean sea-ice cover for Arctic/Antarctic, with SST

all forecasts after 2015

week 1 to 8

S2S Sea-ice cover forecasts

Updated every day with a 21-day delay!
The latest initial date is 20240812.

Area:
- (●) The Arctic (inc. SST)
- ( ) The Arctic (ens. spread)
- ( ) The Antarctic (inc. SST)
- ( ) The Antarctic (ens. spread)

Initial time :
Year.Month 2024.08
Day 12
-1 Day | +1 Day | latest

Lead time:
- ( ) Week1 (+1-7 days)
- ( ) Week2 (+8-14 days)
- ( ) Week3 (+15-21 days)
- (●) Week4 (+22-28 days)
- ( ) Week5 (+29-35 days)
- ( ) Week6 (+36-42 days)
- ( ) Week7 (+43-49 days)
- ( ) Week8 (+50-56 days)

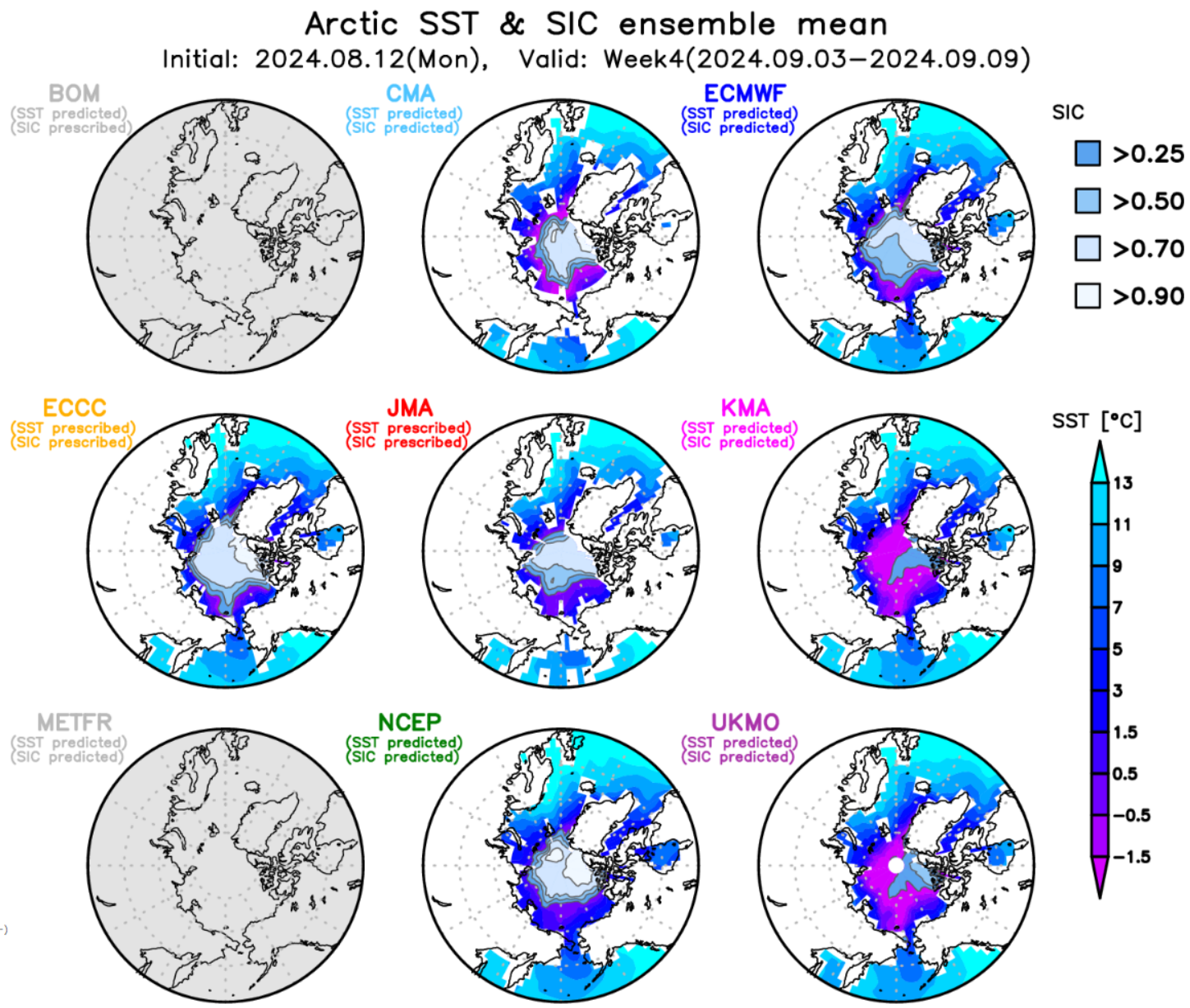
Satellite observation

Initial days of forecasts:

centre (fcst length)	Sun	Mon	Tue	Wed	Thu	Fri	Sat
BoM (week 8)	■				■		
CMA (week 8)	■	■	■	■	■	■	■
ECMWF (week 6)		■			■		
ECCC (week 4)					■		
HMCR (week 8) *1				■	■		
ISAC-CNR (week 4) *2		■			■		
JMA (week 4) *3			■	■			
KMA (week 8)	■	■	■	■	■	■	■
METFR (week 4) *4					■		
NCEP (week 6)	■	■	■	■	■	■	■
UKMO (week 8)							

*1 HMCR: Wed (-31 May 2017); Thu (08 Jun. 2017-)
*2 ISAC-CNR: Mon (-16 Jan. 2017); Thu (19 Jan. 2017-)
*3 JMA: Tue,Wed (-15 Mar. 2017); Wed (22 Mar. 2017-)
*4 METFR: 1st of each month (-Feb 2016), Thu (Mar. 2017-)

Go to the S2S Museum (top)



The S2S Museum – verification of ensemble mean forecast –

all Thursday forecasts after 2015 (10 centres)

5 variables:
- SLP
- Z500
- Z50
- U200
- T850

4 forecast ranges:
- week1 (day2-8)
- week2 (day9-15)
- week3&4 (day16-29)
- week1-4

ERA5 also included (if available)

ACC & RMSE are shown if ERA5 is available

S2S verification of ens. mean forecast

Updated manually!
The latest initial date is 27 June, 2024.

Initial date of forecast (Thu. initial only):
Year.Month.Day 2024.06.27

Variables:
NH(20-90N)
- SLP
- Z500
- Z50
- U200
- T850

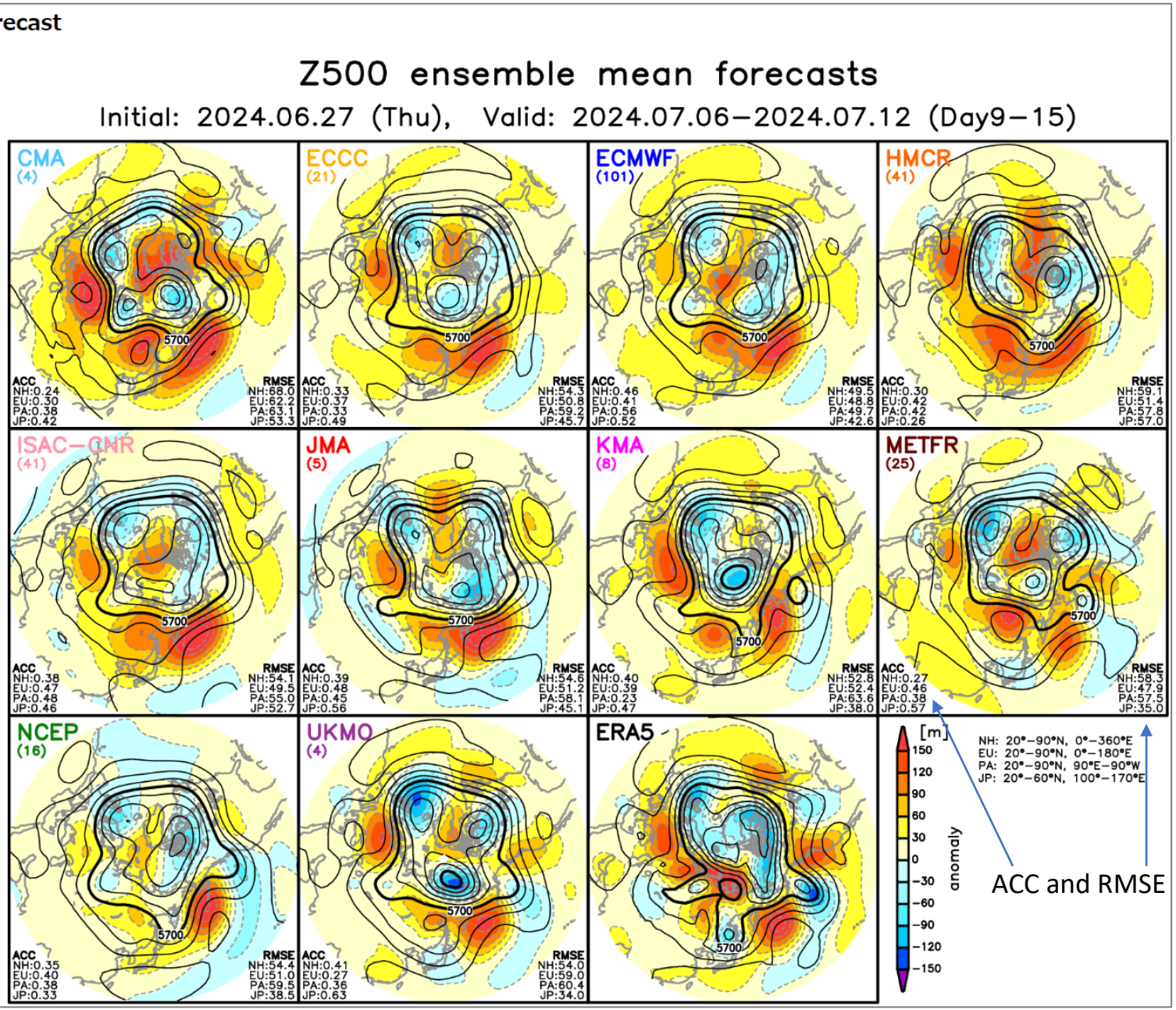
SH(20-90S)
- SLP
- Z500
- Z50
- U200
- T850

Forecast range:
- 1st week (day2-8)
- 2nd week (day9-15)
- 3rd&4th weeks (day16-29)
- 28-day mean

Initial days of forecasts:

centre	country	Sun	Mon	Tue	Wed	Thu	Fri	Sat
BoM	Australia							
CMA	China							
ECMWF	Europe							
ECCC	Canada							
HMCR *1	Russia							
ISAC-CNR *2	Italy							
JMA *3	Japan							
KMA	Korea							
METFR *4	France							
NCEP	US							
UKMO*5	UK							

*1 HMCR: Wed (-31 May 2017); Thu (08 Jun. 2017-)
*2 ISAC-CNR: Mon (-16 Jan. 2017); Thu (19 Jan. 2017-)
*3 JMA: Tue,Wed (-15 Mar. 2017); Wed (22 Mar. 2017-)
*4 METFR: 1st of each month (-Feb 2016), Thu (Mar. 2017-)
*5 UKMO: PMSL is unavailable



Ongoing research project

Mission

The Copernicus Climate Change Service (C3S) mission is to support adaptation and mitigation policies of the European Union by providing consistent and authoritative information about climate change. We offer free and open access to climate data and tools based on the best available science. We listen to our users and endeavour to help them meet their goals in dealing with the impacts of climate change.

C3S has been providing a multi-model seasonal forecasting system, replacing the EUROSIP project since October 2019. As of September 2024, **9 seasonal forecasts from 8 NWP centres** are available.

C3S Seasonal Models

https://confluence.ecmwf.int/display/CKB/Description+of+the+C3S+seasonal+multi-system

9 models

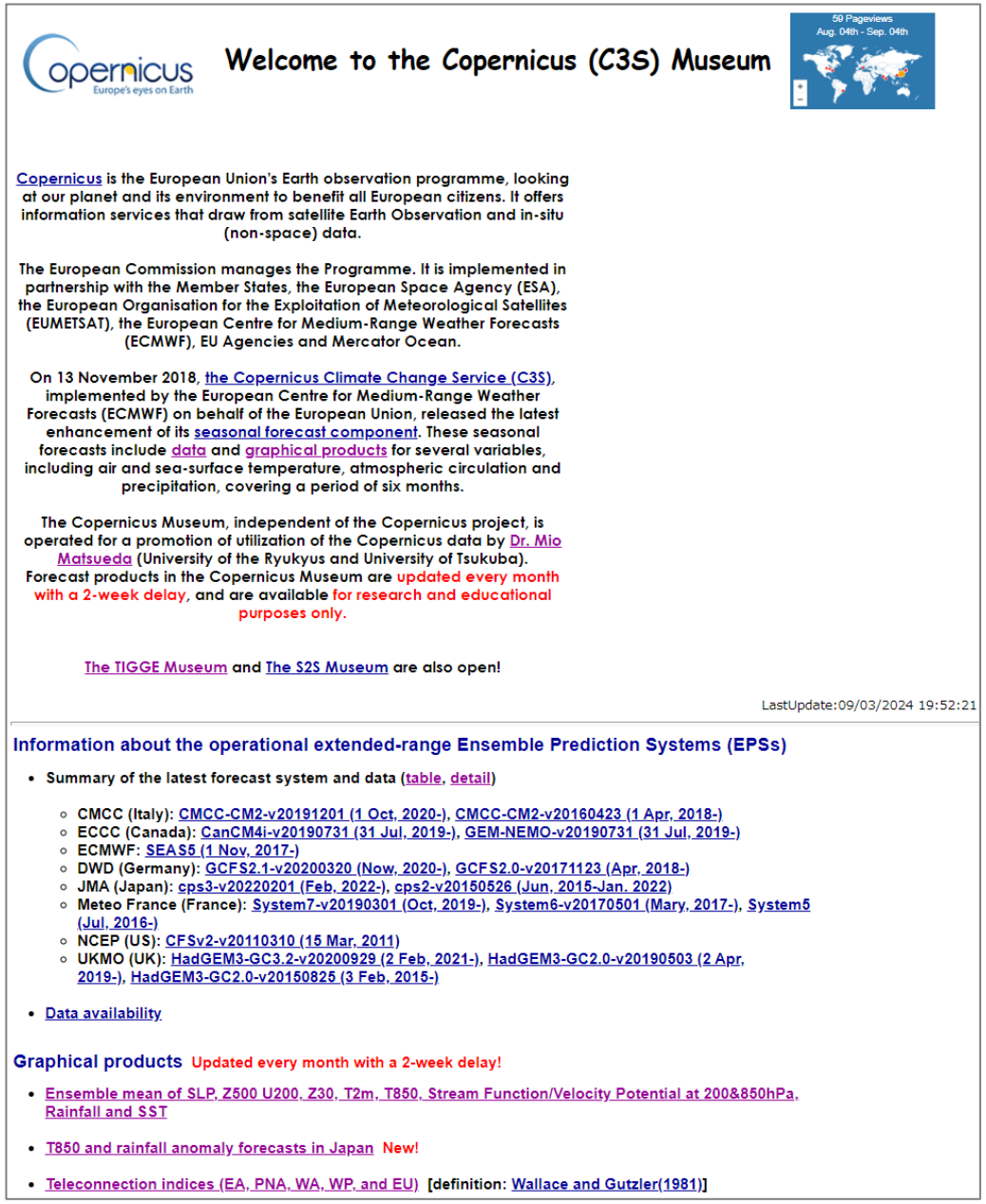
Model's outputs are archived on the common 1.0/1.0 regular lat-lon grid.

Status on 10 Jul 2024	Time range (forecasts and hindcasts)	Forecast initial conditions	Forecast ensemble size	Hindcast initial conditions	Hindcasts ensemble size	Hindcast period	Hindcast production schedule	Resolution of atmospheric model	Resolution of ocean model
ECMWF (ecmf)	215 days	1st of month	51 members	1st of month	25	1981-2016	fixed	T_{CO}319/L91 Dynamics:T_{CO}319 cubic octahedral grid Physics: O320 Gaussian grid (36 km) 91 levels in vertical, to 0.01hPa (80km)	0.25° ORCA grid 75 levels in vertical
UKMO (egrr)	215 days	each day of month	2 members/day[4]	1st, 9th, 17th, 25th of month	7 members/start time	1993-2016	on-the-fly[1]	N216/L85 0.83° x 0.56° (~ 60km in mid-latitudes) 85 levels in vertical, to 85km	0.25° ORCA grid 75 levels in vertical
Météo-France[3] (lfpw)	7 calendar months	last and penultimate Thursday of previous month 1st of month	25 members each 1 member	last and penultimate Thursday of previous month 1st of month	12 members each 1 member	1993-2018	fixed	TL359/L137 (0.5°) 137 levels in vertical, to 0.01hPa	0.25° ORCA grid 75 levels in vertical
DWD (edzw)	6 calendar months	1st of month	50 members	1st of month	30 members	1993-2019	fixed	T127 (~100 km) 95 levels in vertical, to 0.01hPa	0.4° TP04 grid 40 levels in vertical
CMCC (cmcc)	6 calendar months	1st of month	50 members	1st of month	40 members	1993-2016	fixed	approx 0.5° lat-long 46 levels in vertical, to 0.2hPa	0.25° ORCA grid 50 levels in vertical
NCEP (kwbc)	215 days	each day of month members initialised every 6 hours (at 0h, 6h, 12h and 18h UTC)	4 members/day	every 5 days [5] members initialised every 6 hours (at 0h, 6h, 12h and 18h UTC)	4 members/start date	1993-2016	fixed	T128/L64 (~ 1°) 64 levels in vertical, to 0.02hPa	0.25° (equator) to 0.5° 40 levels in vertical
JMA (rjtd)	215 days	every day of month	5 members/day	2 start dates lagged by 15 days [6]	5 members/start date	1993-2016	fixed	TL319 (approx. 55km) 100 levels in vertical, to 0.01hPa	0.25° tripolar grid 60 levels in vertical
ECCC (cwao) [3][7][8] CanESM5.1p1bc (component of CanSIPSv3.0)	214 days	last day of previous month and 5th to last day of previous month	10 members each	last day of previous month and 5th to last day of previous month	10 members each	1980-2023	fixed	T63 (~2.8° lat-long) 49 levels in vertical, to 1hPa	1° ORCA grid 45 levels in vertical
ECCC (cwao) [3][7][8] GEM5.2-NEMO (component of CanSIPSv3.0)	214 days	last day of previous month and 5th to last day of previous month	10 members each	last day of previous month and 5th to last day of previous month	10 members each	1980-2023	fixed	~1.1° lat-long (~110 km) 85 levels in vertical, to 0.1hPa	1° ORCA grid 50 levels in vertical

The C3S Museum – website of seasonal forecast products –

Google **"C3S Museum"**
or use QR code below

http://gpvjma.ccs.hpcc.jp/Copernicus/



- ❑ opened in June 2021
- ❑ products are updated on 10th of each month, with a 9-day delay
- ❑ 9 models and ERA5 (if available)
- ❑ 3 forecast products from Jan. 2017 to the present (18GB):
  - ➢verification of ensemble mean: SLP, Z500 U200, Z30, T2m, T850, stream function/velocity potential at 200&850hPa, rainfall and SST
  - ➢teleconnection indices: EA, PNA, WA, WP and EU
  - ➢T850 and rainfall for Japanese reginal areas

The C3S Museum – verification of ensemble mean forecast –

all forecasts after 2017
(9 models)

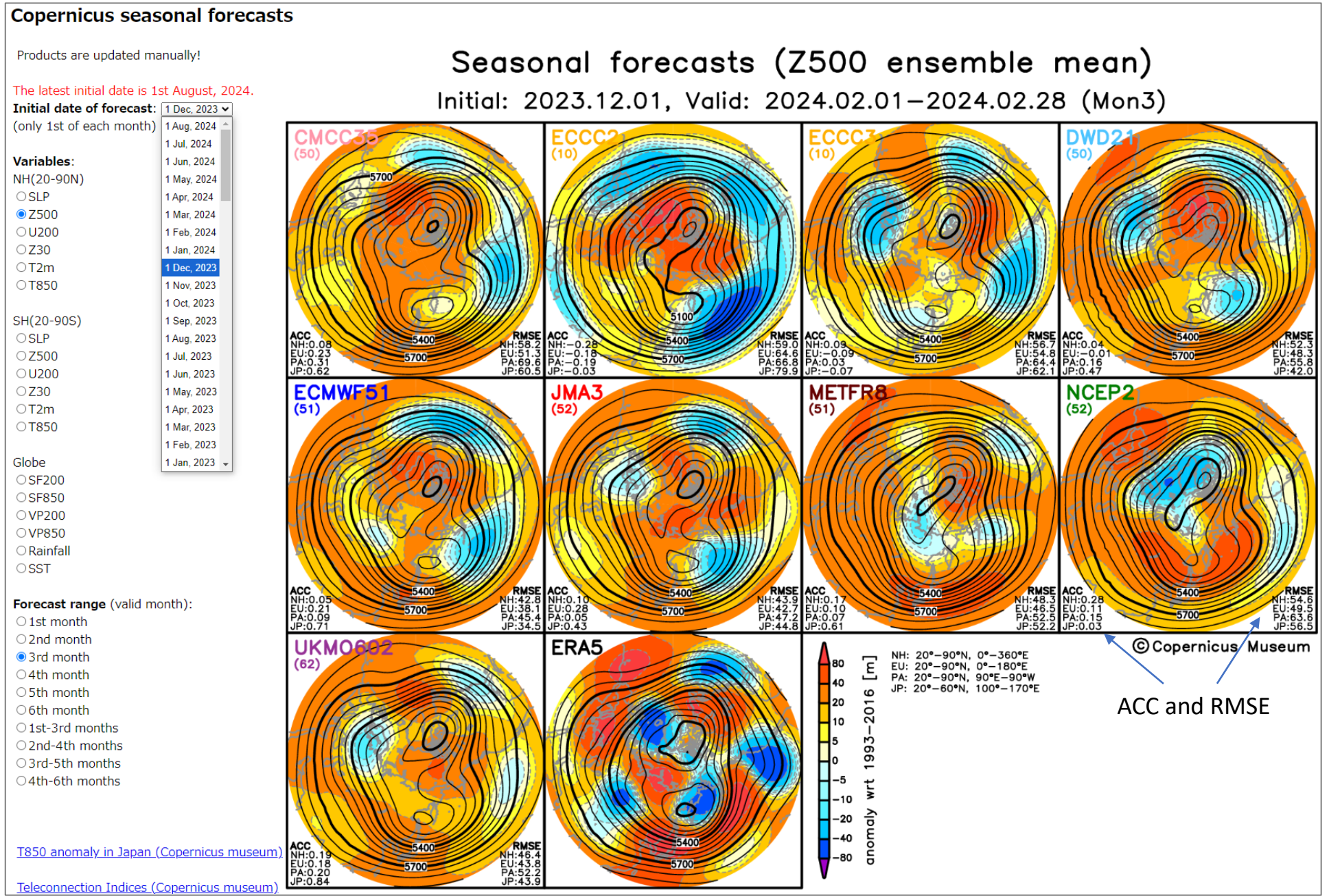
12 variables:

SLP	SF200
Z500	SF850
U200	VP200
Z30	VP850
T2m	rainfall
T850	SST

forecast ranges:
1 month or 3 months mean

ERA5 also included (if available)

ACC & RMSE are shown if ERA5 is available



The C3S Museum – teleconnection indices forecast –

all forecasts after 2017
(9 models)

5 indices:
EA, PNA, WA, WP, & EU

ERA5 also included (if available)

colour: forecast
black: ERA5

Copernicus teleconnection index forecasts

Products are updated manually!
The latest initial date is 1st August, 2024

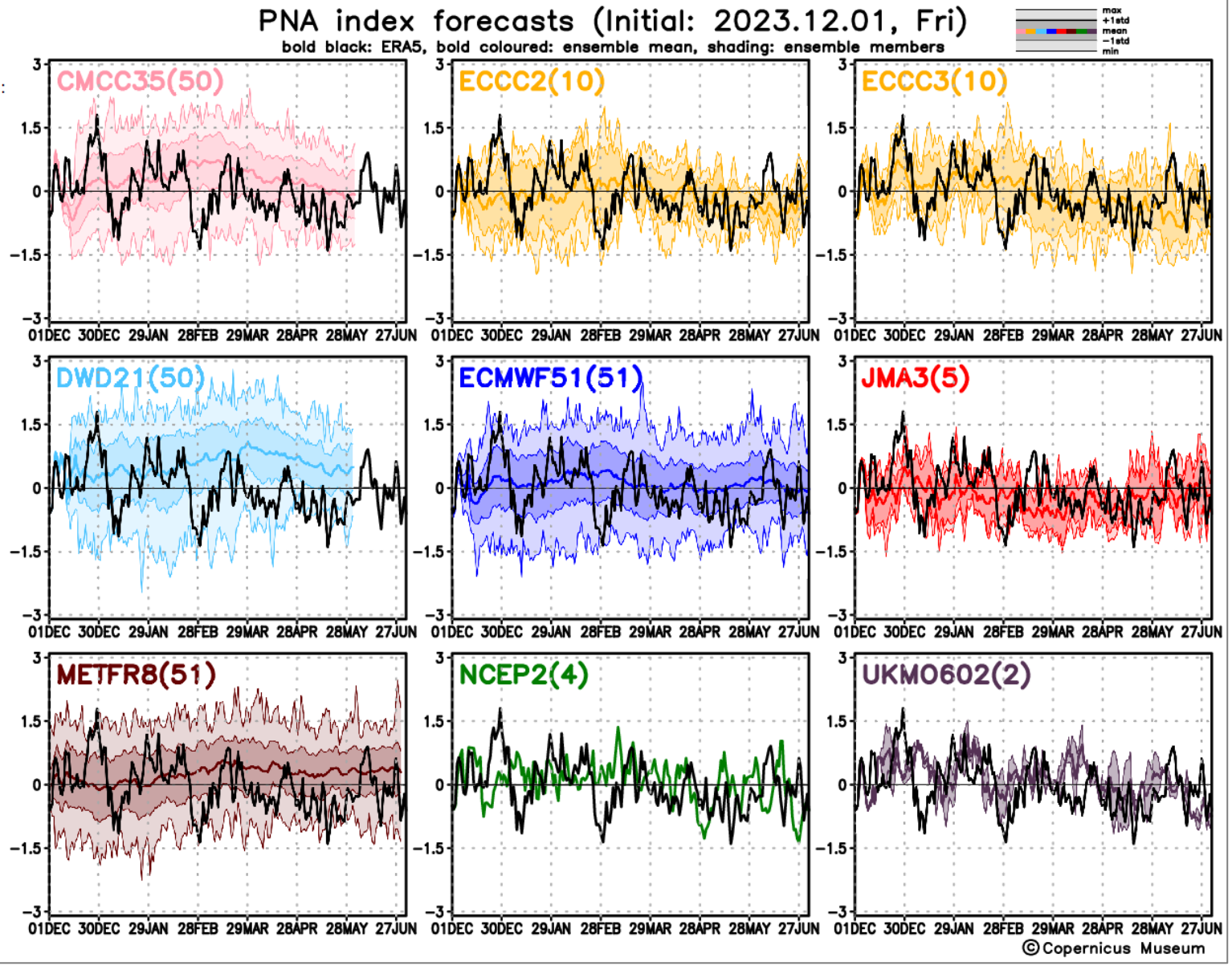
Initial date of forecast (only 1st of each month):
Year.Month 2023.12.01

- EA (Eastern Atlantic)
- PNA (Pacific/North American)
- WA (Western Atlantic)
- WP (Western Pacific)
- EU (Eurasian)

definition: Wallace and Gutzler(1981)

Ens. Mean Verification

Go to the Copernicus Museum (top)



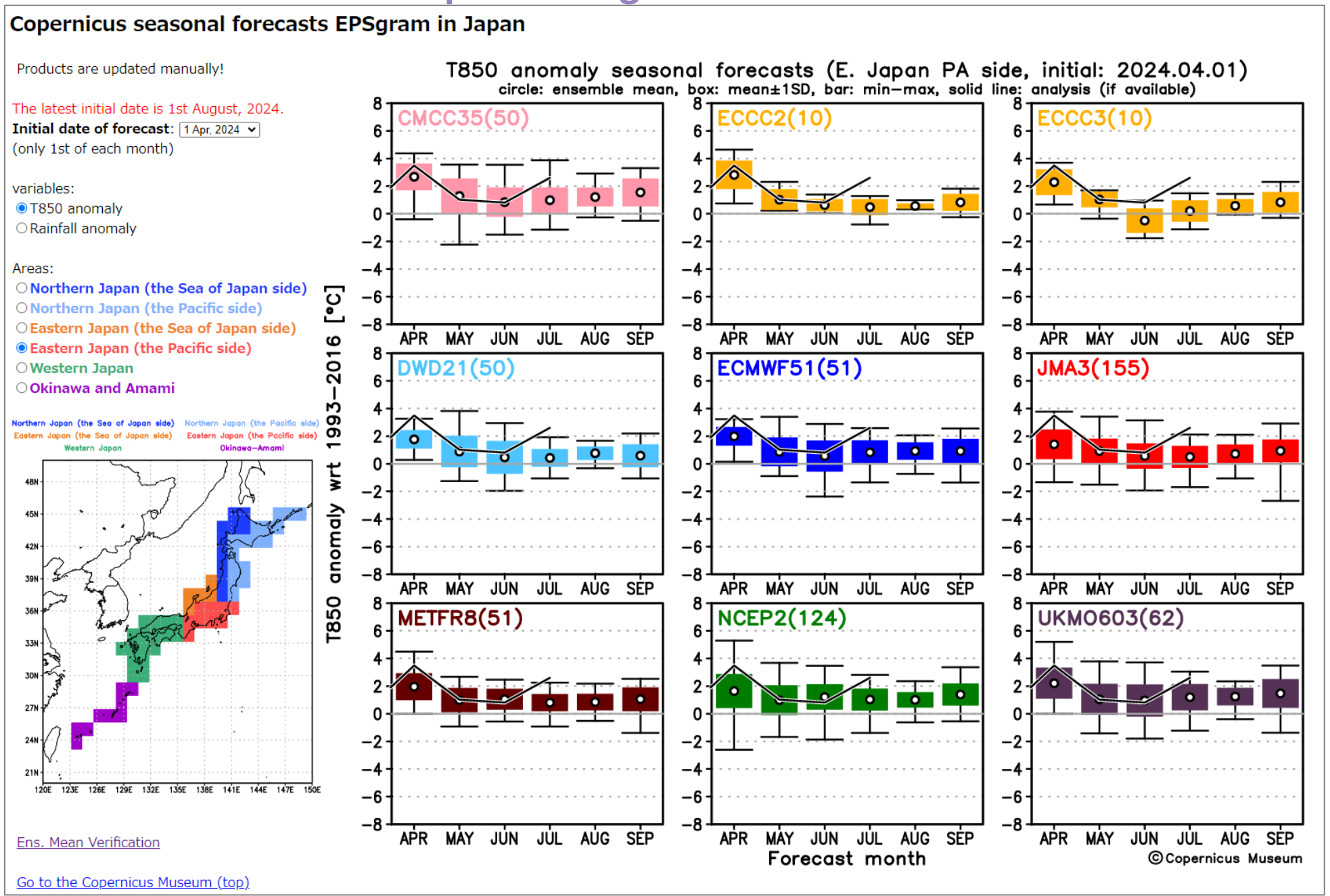
The C3S Museum – T850 forecast for Japanese regional areas –

colour: forecast
black: ERA5

all forecasts after 2017
(9 models)

2 variable:
T850 & rainfall

6 Japanese regions,
used by JMA for
seasonal forecasts



Summary

- The Museums remain a valuable diagnostic tool for weather forecasting and are helpful in finding interesting past forecast cases (please remember to focus on these cases).
- On average, ECMWF shows the best performance, resulting in 42% of TIGGE papers using ONLY ECMWF forecast. But the best-performing centre varies depending on the case, especially in extreme weather events. Other centres should also be focused on.
- Ensemble Museums, ECMWF S2S website, & Copernicus website primarily display archived graphical products. An interactive website that generates and displays graphical products upon user request could also be useful in encouraging the use of ensembles from other centres.

QR codes to Museums

TIGGE S2S C3S

QR codes to TIGGE article survey results (xlsx file)

Graphical forecast products C3S website

Search products...

Parameters

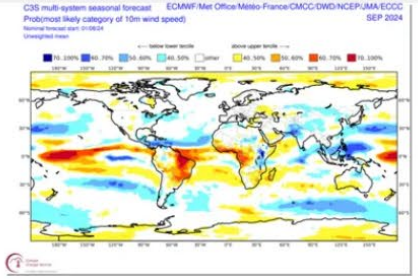
- 10m wind speed
- MSLP
- SST
- T2m
- T850
- geopotential height 500hPa
- precipitation
- zonal wind 10hPa
- sea ice concentration

Plot type

- 1-month maps
- 3-month maps
- Time series

Centres

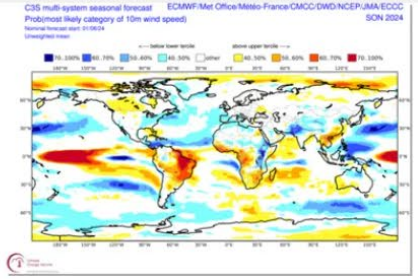
- C3S multi-system



10m wind

C3S multi-system 10m wind speed 1-month

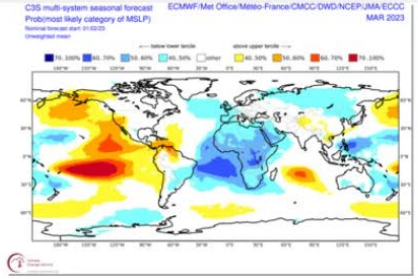
Multi-system combination spatial plots [Ensemble mean anomalies] The charts display the averages of the standardized ensemble mean anomalies. For each component model, ensemble mean anomalies are...



10m wind

C3S multi-system 10m wind speed 3-month

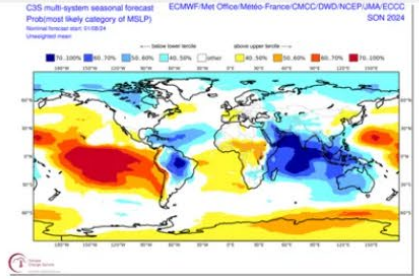
Multi-system combination spatial plots [Ensemble mean anomalies] The charts display the averages of the standardized ensemble mean anomalies. For each component model, ensemble mean anomalies are...



MSLP

C3S multi-system MSLP 1-month

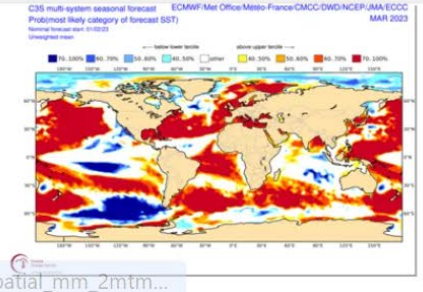
Multi-system combination spatial plots [Ensemble mean anomalies] The charts display the averages of the standardized ensemble mean anomalies. For each component model, ensemble mean anomalies are...

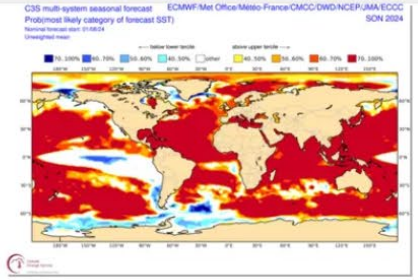


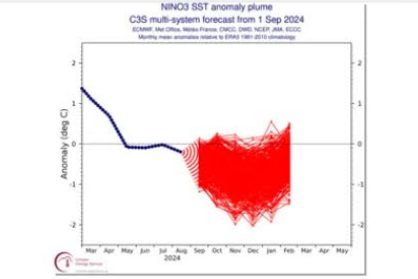
MSLP

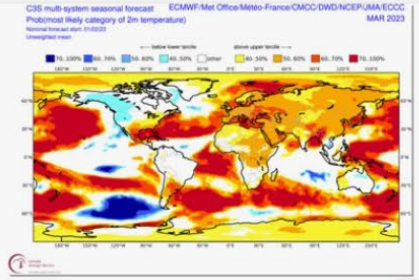
C3S multi-system MSLP 3-month

Multi-system combination spatial plots [Ensemble mean anomalies] The charts display the averages of the standardized ensemble mean anomalies. For each component model, ensemble mean anomalies are...









Matsueda & Nakazawa (2015, Met. Appl.)

The TIGGE Museum – probabilistic forecast of severe weather events –

How climatological PDFs are estimated from the TIGGE data

A climatological PDF (probability density function) from observed data differs from that from forecast data (e.g. 10mm/hr in a model is not equal to 10mm/hr in observation). We have to prepare a climatological PDF in "a model world" for forecasts. However, a climatological PDF is strongly sensitive to model or the model version (e.g. 10mm/hr in a ECMWF model is not equal to 10mm/hr in a JMA model). Also, operational models are frequently upgraded!

The best way to estimate climatological PDFs for each model is to run many forecasts for past cases, using the current versions of each model (often referred to as hindcasts or reforecasts). But reforecast data is not available from all the NWP centres. Instead, we have to estimate climatological PDFs from the TIGGE forecast data.

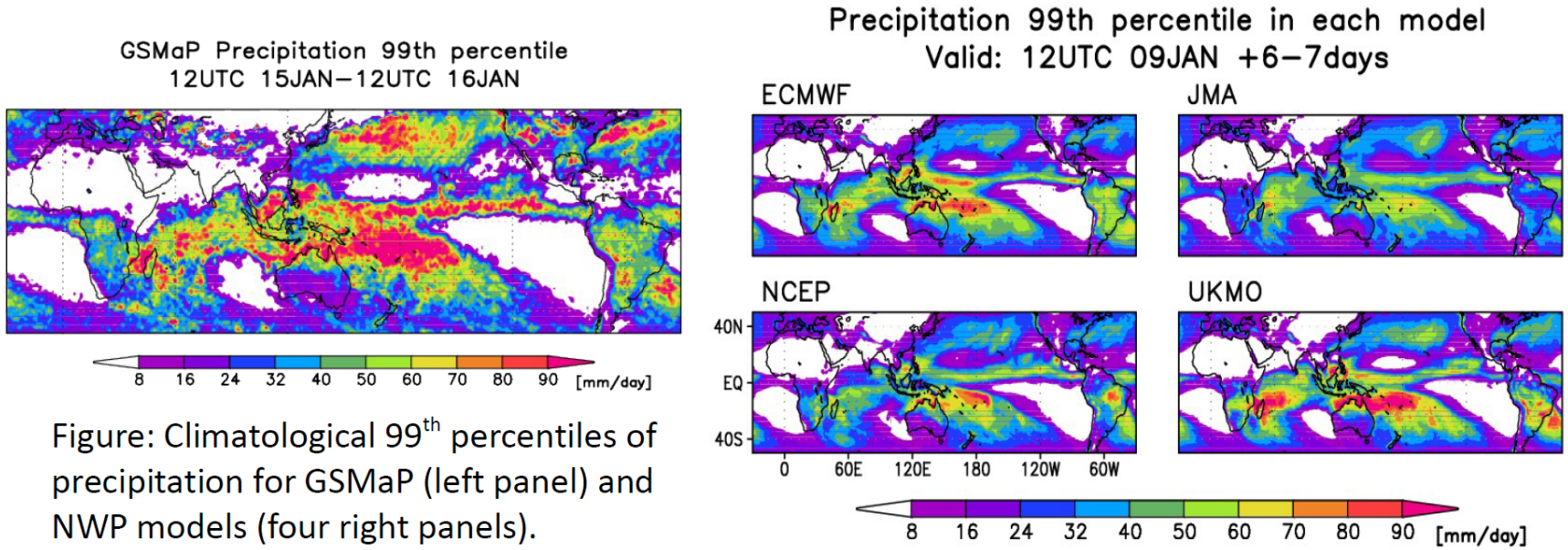


Figure: Climatological 99th percentiles of precipitation for GSMaP (left panel) and NWP models (four right panels).

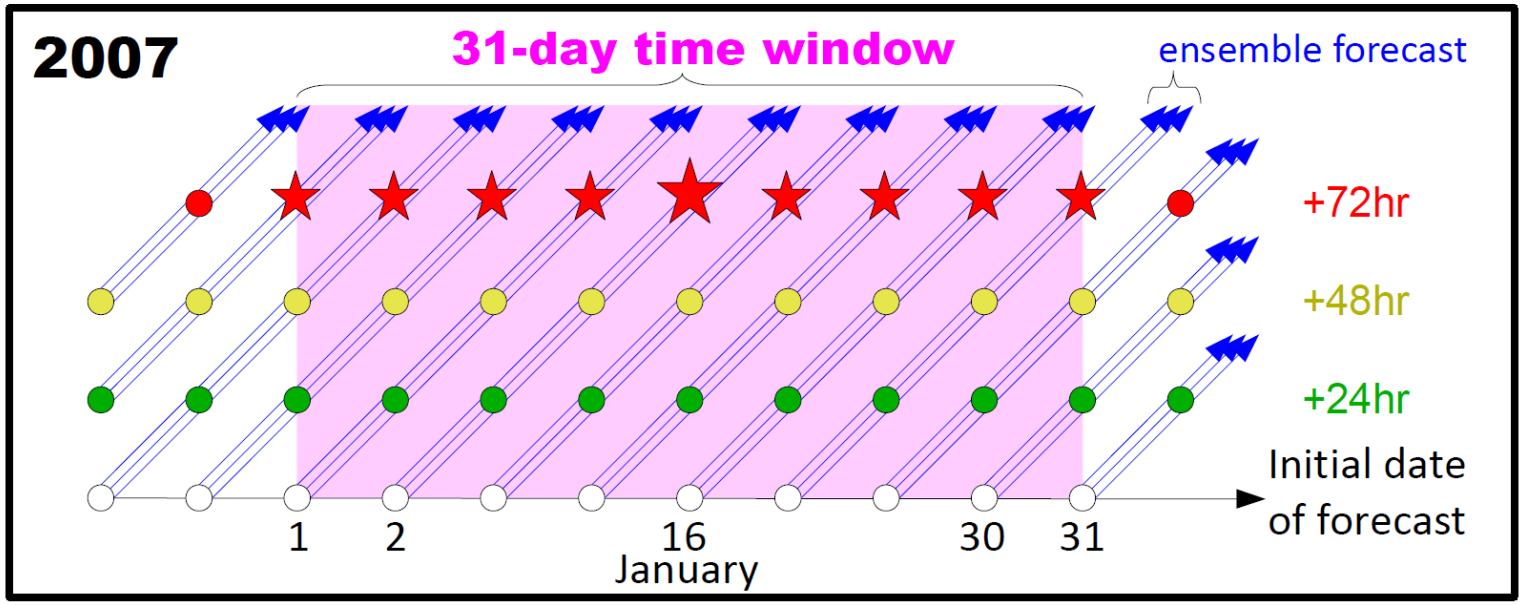
The TIGGE Museum – probabilistic forecast of severe weather events –

How climatological PDFs are estimated from the TIGGE data

A climatological PDF used here is:

- calculated for each EPS using TIGGE data (all members in each EPS) during October 2006 to January 2011
- defined at each grid point for each calender day in each forecast lead time with the 31-day time window.

Example: A climatological pdf for 72-hr ECMWF ensemble forecast verified on 16th January is made from all the 72-hr ECMWF forecasts (members) verified on 1st - 31st January in 2007 to 2011.



No bias correction.

x 5 years

Total number of samples (★) for ECMWF: 31days x 5yrs x 51mems = 7905

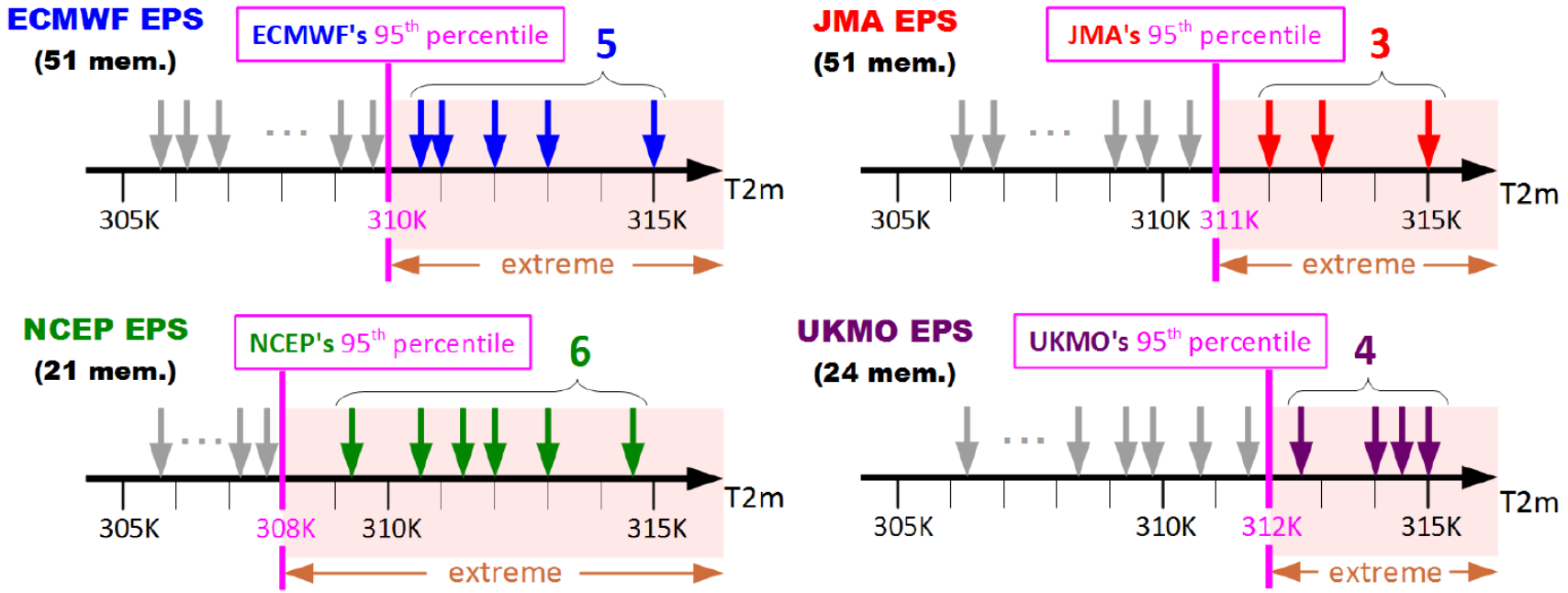
Matsueda & Nakazawa (2015, Met. Appl.)

The TIGGE Museum – probabilistic forecast of severe weather events –

Occurrence probability of an extreme event (grand ensemble)

Climatological percentiles derived from NWP models differ from each other. Each model's climatological percentile value is used for a definition of extreme event.

Example: forecast probability of surface temperature at Oxford



18 (=5+3+6+4) members predict a higher value than each model's climatological 95%-iles (310, 311, 308, and 312K). Then, occurrence probability of extreme high temperature is defined as 12.2% (=18/(51+51+21+24)).