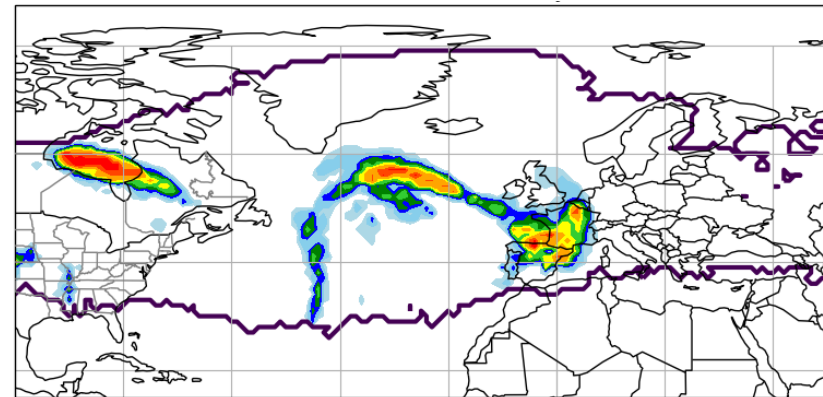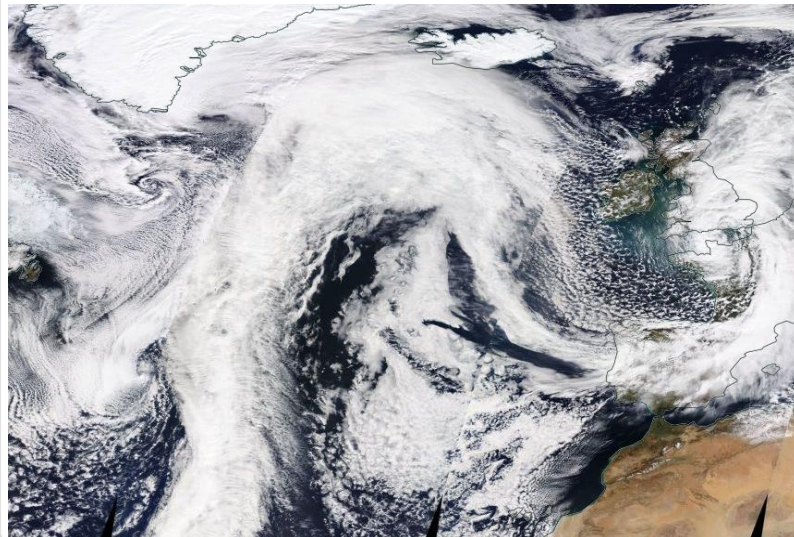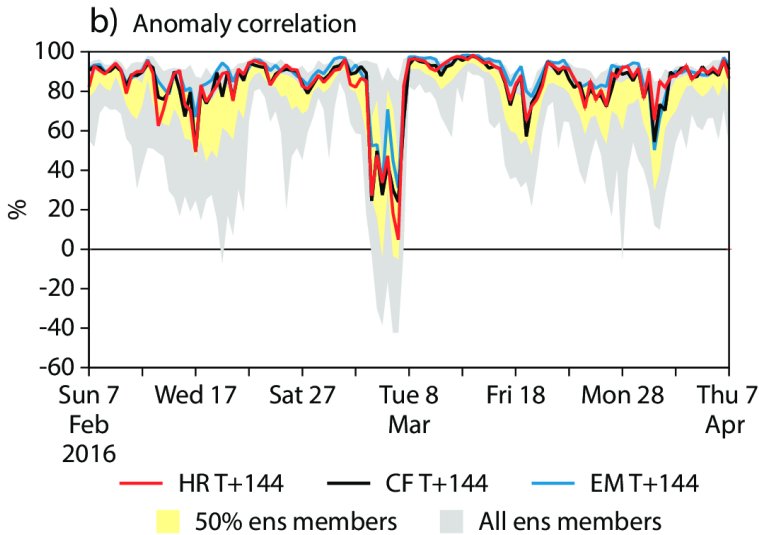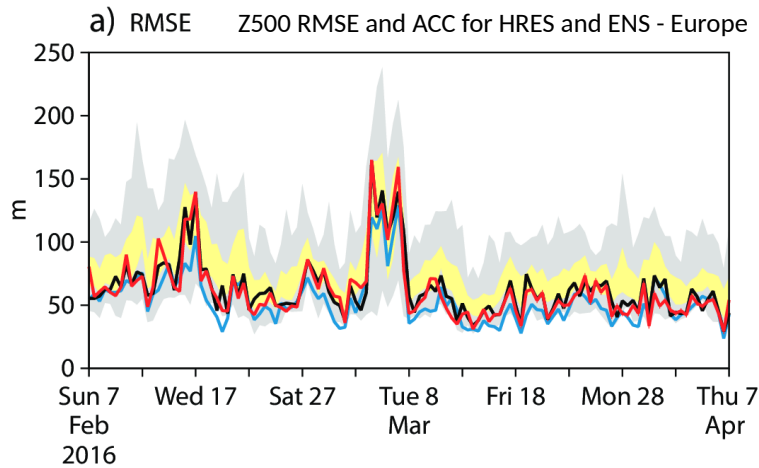# Verification of warm conveyor belts in ECMWF IFS subseasonal reforecasts

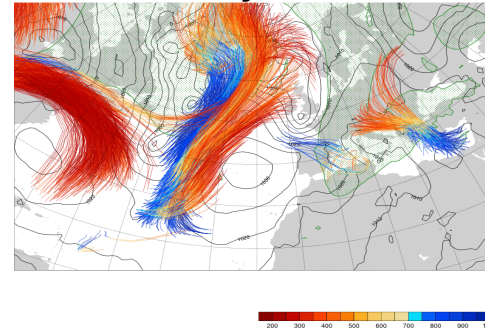**Jan Wandel, Julian F. Quinting, Christian M. Grams**

Institute of Meteorology and Climate Research

Motivation: Forecast bust cases and the link to WCB forecast
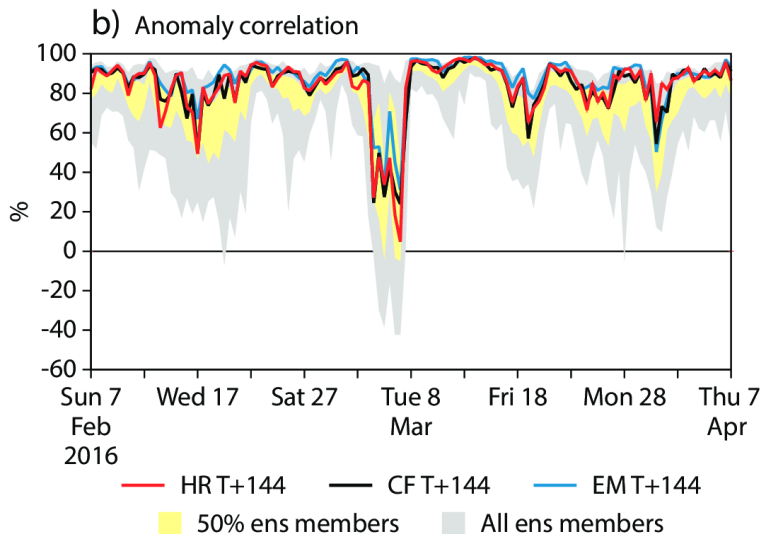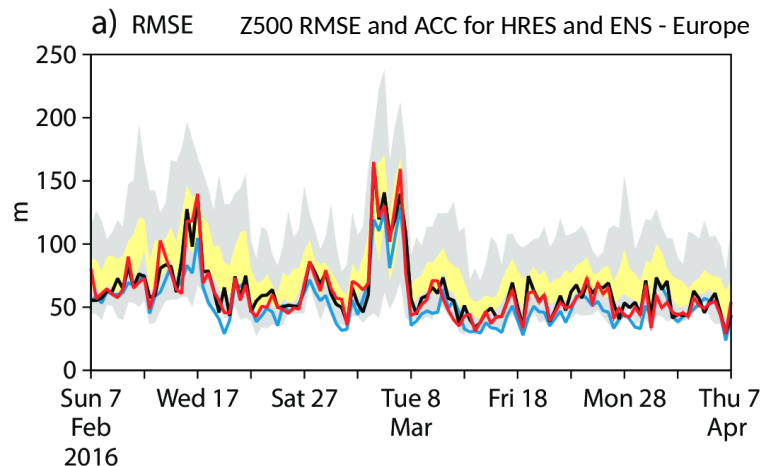
Wcb trajectories

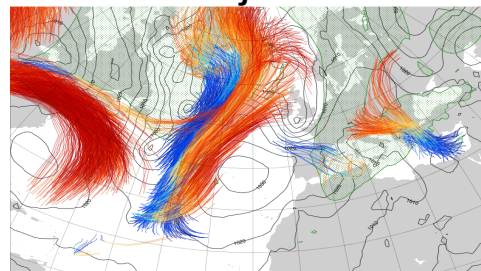a) RMSE   Z500 RMSE and ACC for HRES and ENS - Europe

b) Anomaly correlation

— HR T+144   — CF T+144   — EM T+144

50% ens members   All ens members

Plots by Linus Magnusson (ECMWF)

Motivation: Forecast bust cases and the link to WCB forecast

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Plots by Linus Magnusson (ECMWF)

Wcb trajectories

- Forecast bust case can be linked to a misrepresentation of WCB in forecast model (f.e. Grams et al., 2018)

- Upper-level diabatic outflow can affect large-scale flow regimes (Grams and Archambault, 2016)

- Studies on WCB verification have been limited to single cases or winter seasons

Motivation: Forecast bust cases and the link to WCB forecast

a) RMSE — Z500 RMSE and ACC for HRES and ENS - Europe

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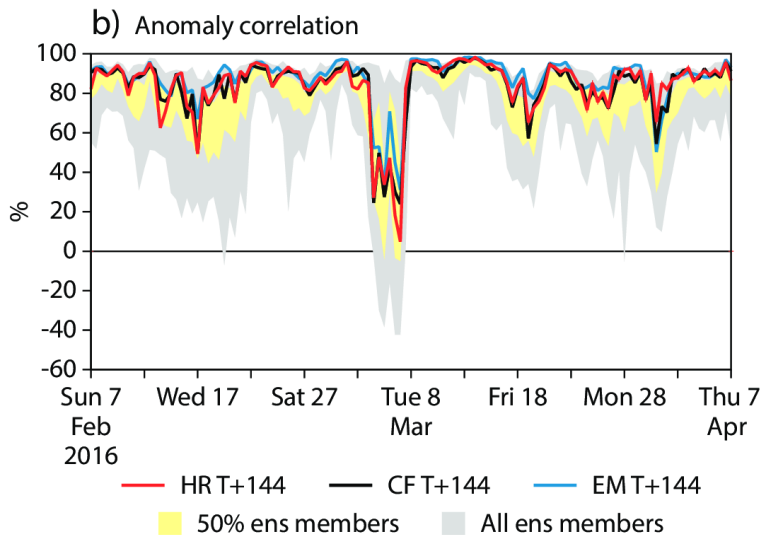Legend: HR T+144, CF T+144, EM T+144, 50% ens members, All ens members
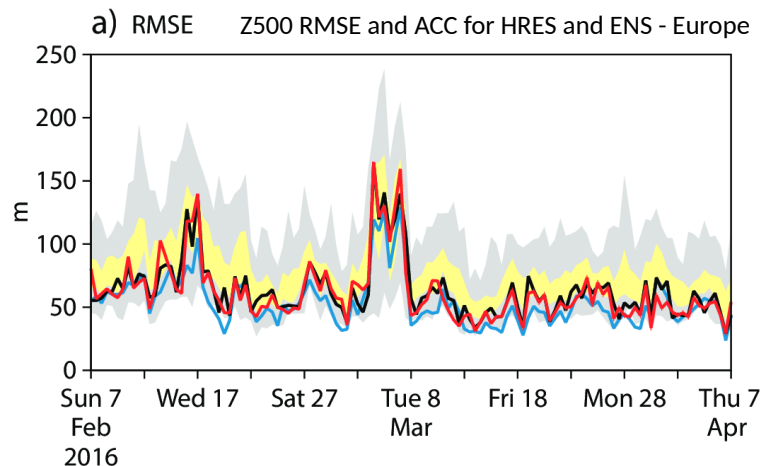
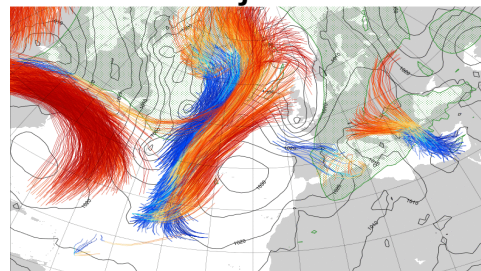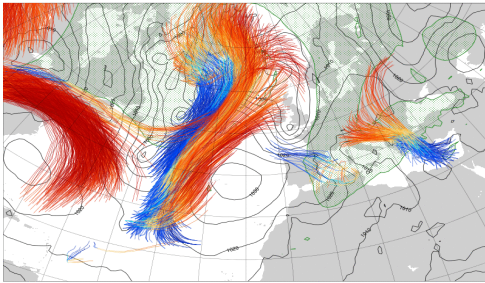Plots by Linus Magnusson (ECMWF)

Wcb trajectories

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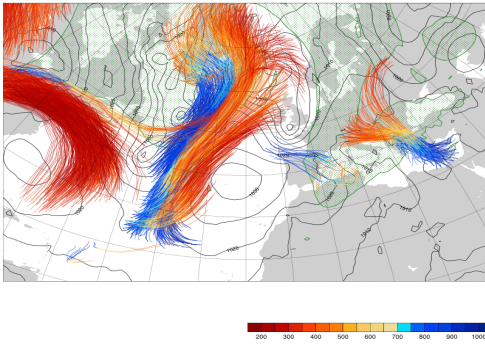- Studies on WCB verification have been limited to single cases or winter seasons

→ **systematic verification of WCB forecast**
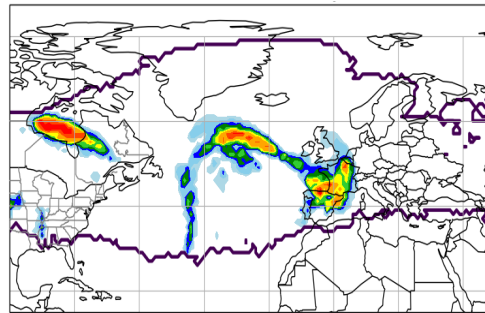
Systematic investigation of WCB Forecast

Lagrangian definition
hinders systematic
verification of WCB forecast

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts

IMK – TRO

Systematic investigation of WCB Forecast

Lagrangian definition
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Statistical model can be
used as a appropriate
representation of inflow,
ascent and outflow phase
of WCB
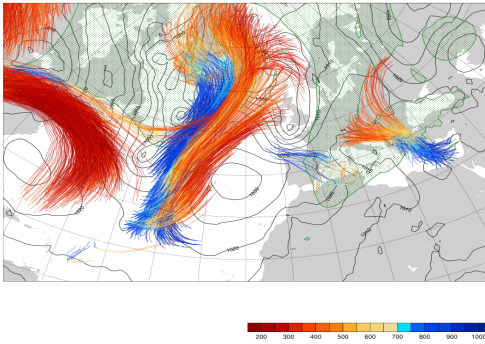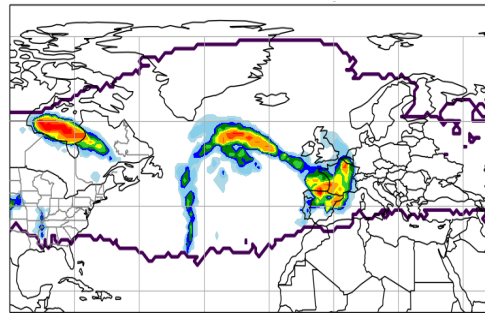
Systematic investigation of WCB Forecast

Lagrangian definition
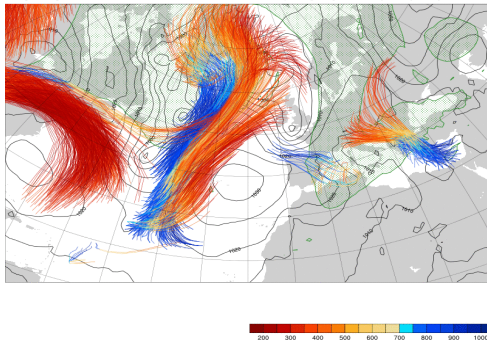hinders systematic
verification of WCB forecast

Statistical model can be
used as a appropriate
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ascent and outflow phase
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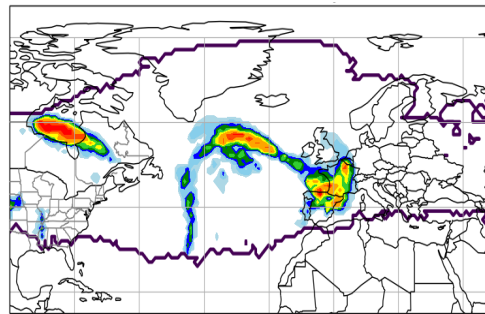| Status on 2020-01-16	Time range	Resolution	Ens. Size	Frequency	Re-forecasts	Rfc length	Rfc frequency	Rfc size	Remarks
BoM (ammc)	d 0-62	T47L17	3*11	2/week	fix	1981-2013	6/month	3*11	
CMA (babj)	d 0-60	T266L56	4	2/week	fix *	2004-2018	2/week	4	
CNR-ISAC (isac)	d 0-32	0.75x0.56 L54	41	weekly	fix	1981-2010	every 5 days	5	
CNRM (lfpw)	d 0-32	T255L91	51	weekly	fix	1993-2014	4/month	15	
ECCC (cwao)	d 0-32	0.45x0.45 L40	21	weekly	on the fly	1998-2017	weekly	4	control forecast
ECMWF (ecmf)	d 0-46	Tco639/319 L91	51	2/week	on the fly	past 20 years	2/week	11	
HMCR (rums)	d 0-61	1.1x1.4 L28	20	weekly	on the fly	1985-2010	weekly	10	
JMA (rjtd)	d 0-33	TI479/TI319L100	50	weekly	fix	1981-2010	3/month	5	
KMA (rksl)	d 0-60	N216L85	4	daily	on the fly	1991-2010	4/month	3	
NCEP (kwbc)	d 0-44	T126L64	16	daily	fix	1999-2010	daily	4	
UKMO (egrr)	d 0-60	N216L85	4	daily	on the fly	1993-2016	4/month	7	

(*) CMA reforecasts are provided "on-the-fly" together with the real-time forecasts since 11.11.2019 (the whole fixed re-forecast period will be completed that way by the 9th Nov 2020)

**Subseasonal-to-Seasonal
database (S2S database)**
contains compact and thorough
data set

Systematic investigation of WCB Forecast

Lagrangian definition hinders systematic verification of WCB forecast

Statistical model can be used as a appropriate representation of inflow, ascent and outflow phase of WCB

ECMWF IFS reforecasts from **1997-2017** with **11 ensemble members** can be used to investigate WCB forecast with the statistical model

Status on 2020-01-16	Time range	Resolution	Ens. Size	Frequency	Re-forecasts	Rfc length	Rfc frequency	Rfc size	Remarks
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Subseasonal-to-Seasonal database (S2S database) contains compact and thorough data set

Variables used in statistical model

Inflow

Thickness advection 700 hPa
Meridional moisture transport 850 hPa
Moisture flux convergence 1000 hPa
Moist PV 500 hPa

Ascent

Relative vorticity 850 hPa
Realtive humidity 700 hPa
Thickness advection 300 hPa
Meridional moisture transport 500 hPa

Outflow

Relative humidity 300 hPa
Divergent wind 300 hPa
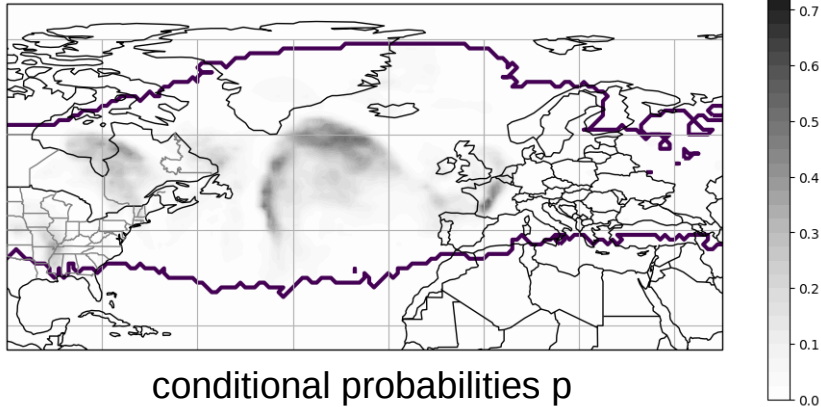Static stability 500 hPa
Relative Vorticity 300 hPa

Calculation of conditional probabilities p:

$$g = \beta_0 + \beta_1 * var1 + \beta_2 * var2 + \beta_3 * var3 + \beta_4 * var4$$

$$p = \frac{1}{1 + e^{-1*g}}$$

Calculation in ERA Interim and ECMWF IFS reforecasts – outflow phase

ERA-Interim   20160309_00

conditional probabilities p

Calculation in ERA Interim and ECMWF IFS reforecasts – outflow phase

ERA-Interim   20160309_00
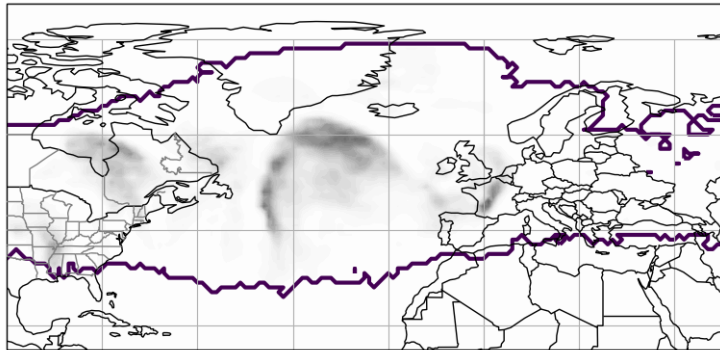
conditional probabilities p

Applying a threshold criteria

Calculation in ERA Interim and ECMWF IFS reforecasts – outflow phase

ERA-Interim   20160309_00
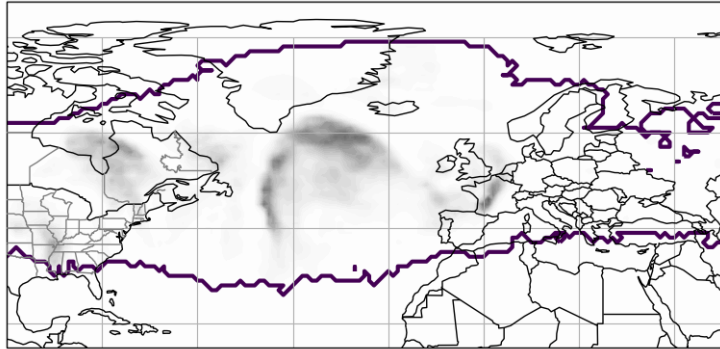
conditional probabilities p
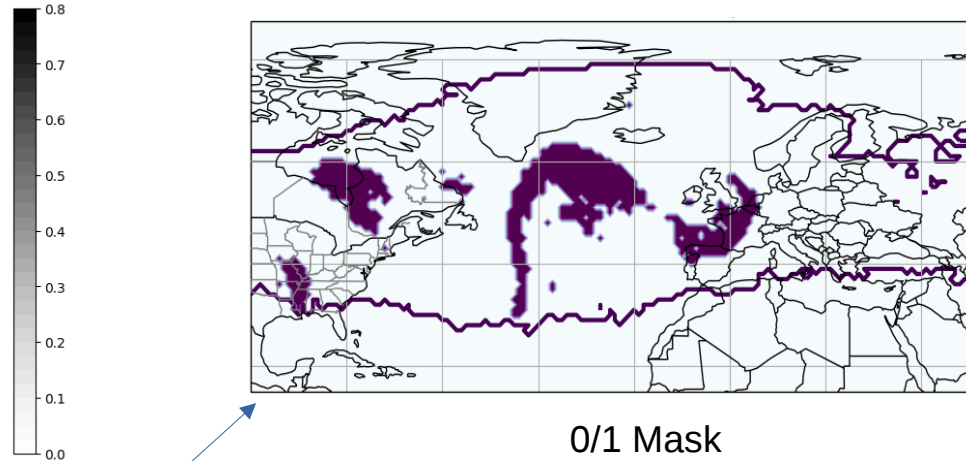
0/1 Mask

Applying a threshold criteria

Calculation in ERA Interim and ECMWF IFS reforecasts – outflow phase

ERA-Interim 20160309_00
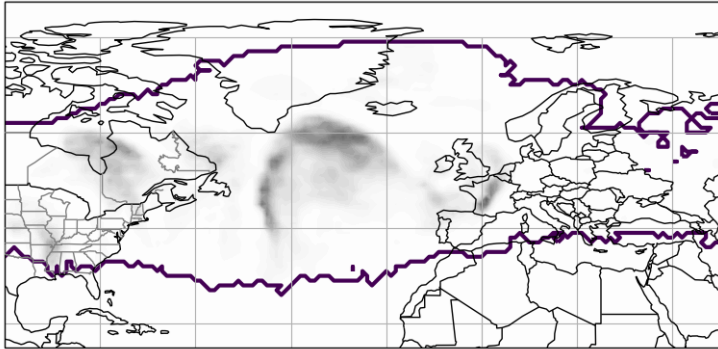
conditional probabilities p
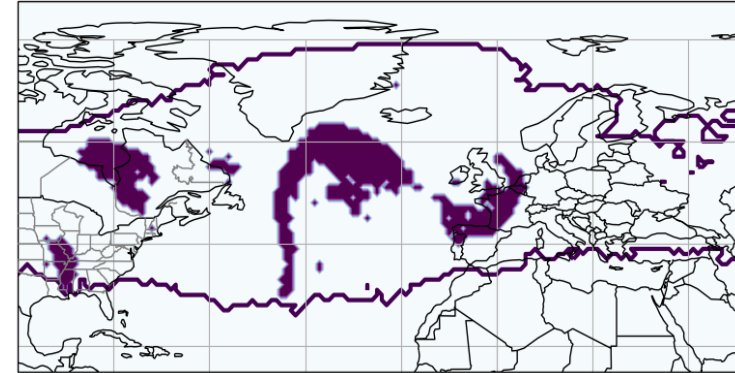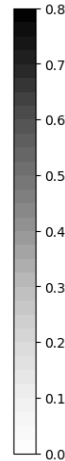
0/1 Mask

ECMWF IFS reforecasts

3 day forecast
Initial time: 20160306_00
1 Ensemblemember
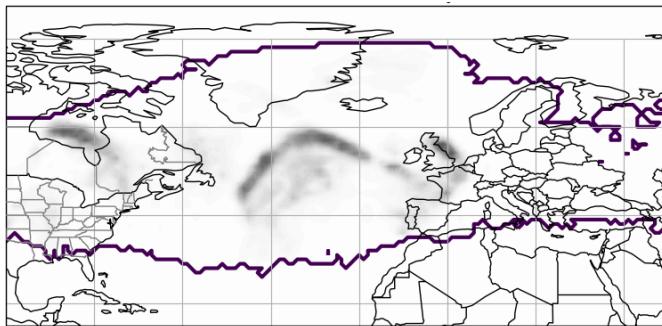
conditional probabilities p
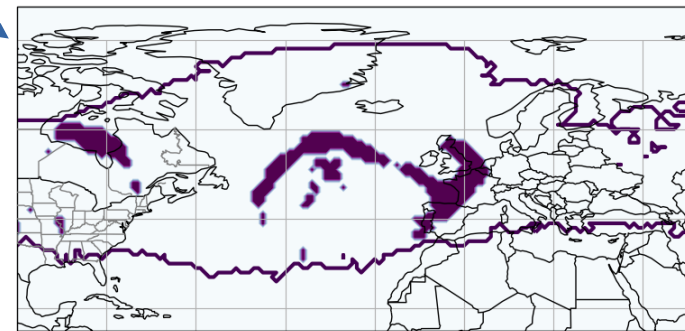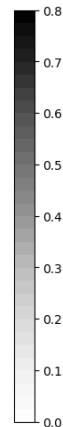
Applying a threshold criteria

0/1 Mask

Construction of ensemble probabilities in ECMWF IFS reforecasts – outflow phase

3 day forecast
Initial time: 20160306_00
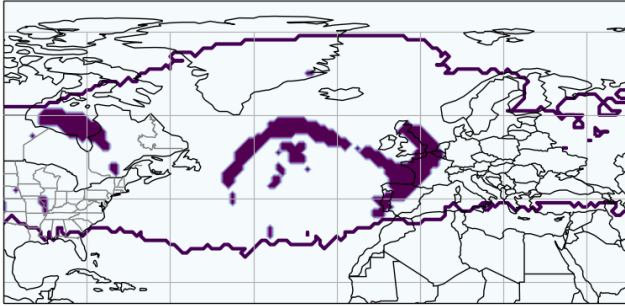
0/1 Mask

Construction of ensemble probabilities in ECMWF IFS reforecasts – outflow phase
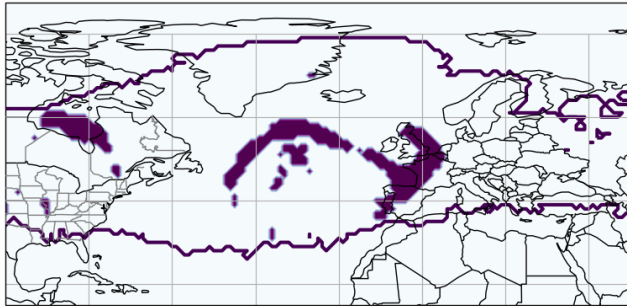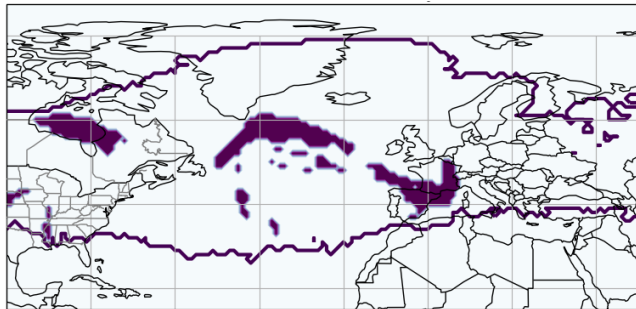
3 day forecast
Initial time: 20160306_00
2 ensemble members

0/1 Mask

Construction of ensemble probabilities in ECMWF IFS reforecasts – outflow phase
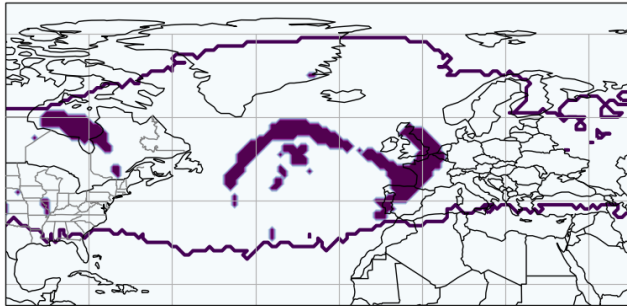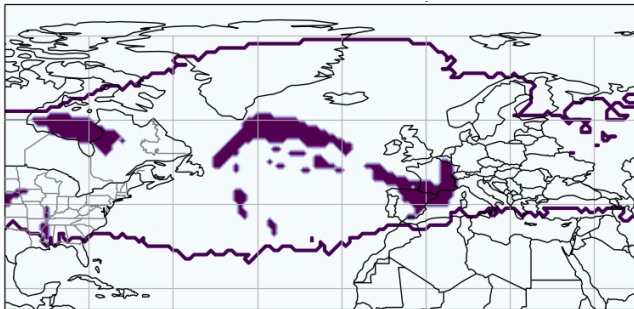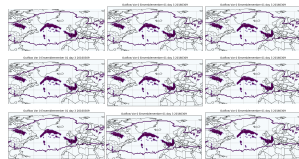
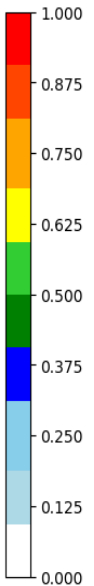3 day forecast
Initial time: 20160306_00
2 ensemble members

0/1 Mask

+ 9 other

ensemble members

3 day forecast
Initial time: 20160306_00
2 ensemble members
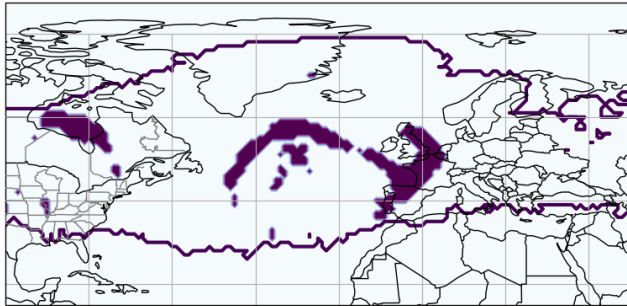
0/1 Mask
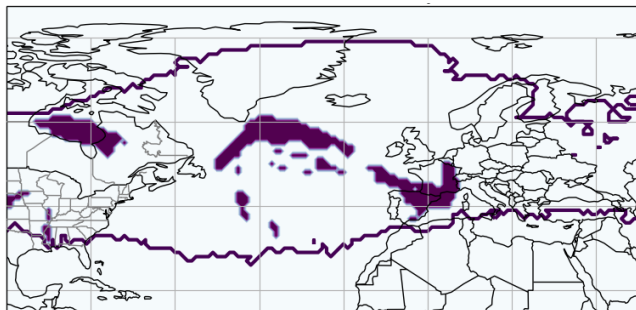
+ 9 other
ensemble members

ensemble probabilities

Overview
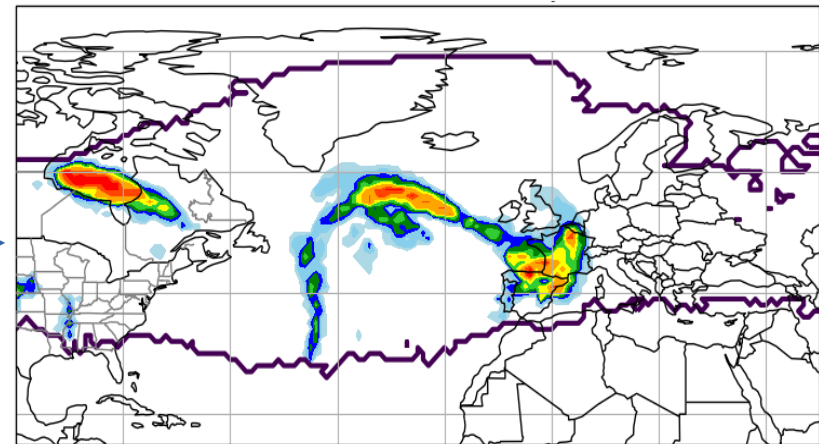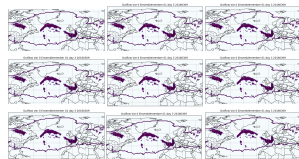
- Bias

  → Bias of **conditional probabilities** for outflow phase

  → **Frequency bias** of outflow masks

- Verification (ensemble probabilities)

  → **Forecast skill** of ensemble probabilities for outflow

  → Forecast skill on day 3 for **inflow, ascent, outflow**
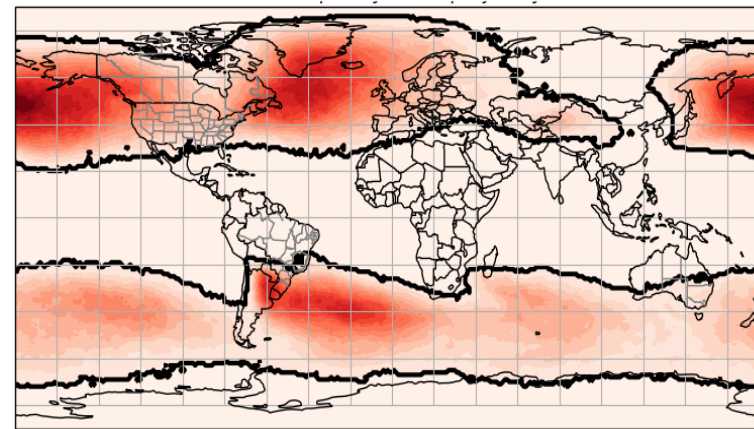
  → Verification of **weekly outflow probabilities**

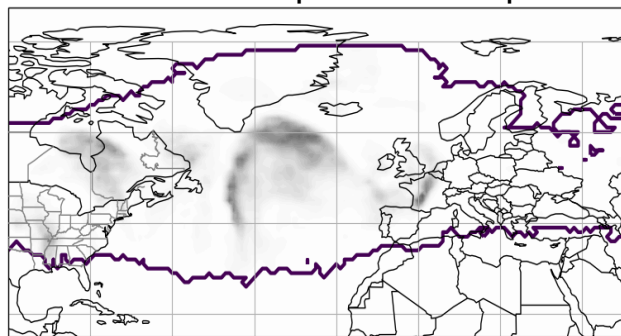# Bias conditional probabilities - outflow - DJF
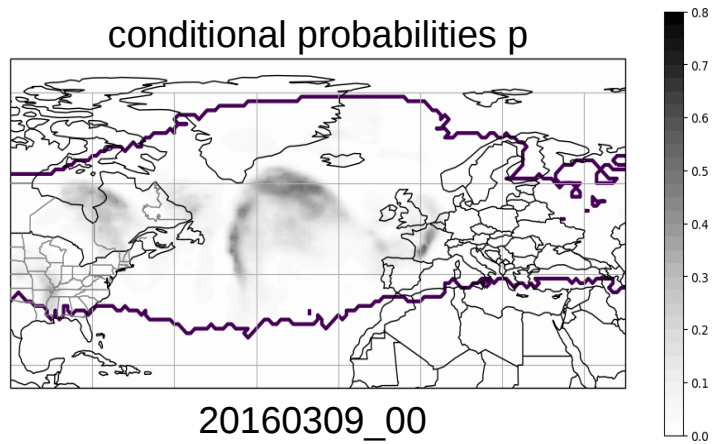
conditional probabilities p

20160309_00

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts

IMK – TRO

Bias conditional probabilities - outflow - DJF

conditional probabilities p
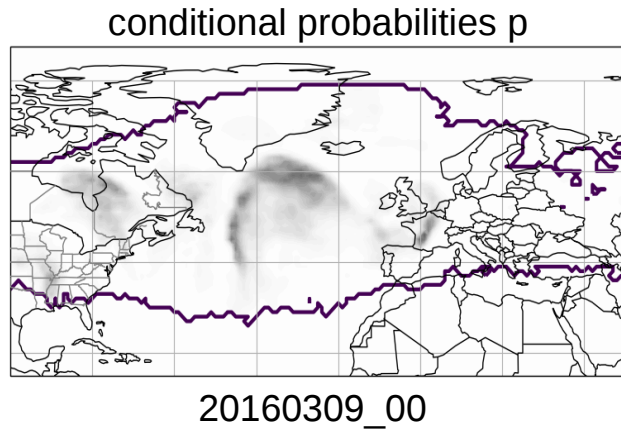
20160309_00

Mean conditional probabilities in ERA Interim

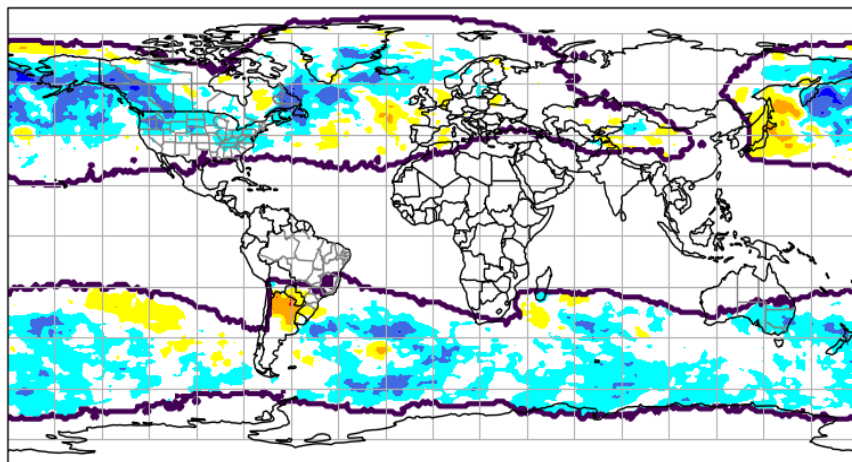# Bias conditional probabilities - outflow - DJF
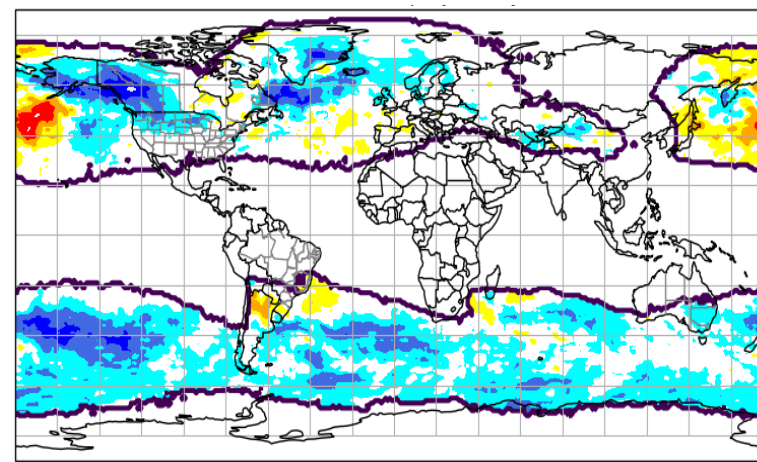
conditional probabilities p

20160309_00

Mean conditional probabilities in ERA Interim
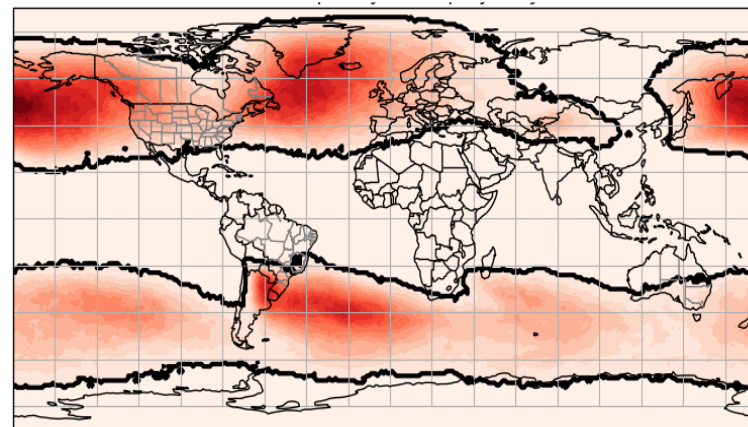
Bias conditional probabilities in ECMWF IFS reforecasts (1997 - 2017)
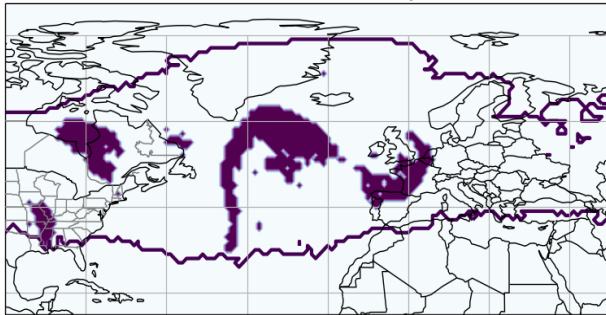

Day 5

Day 15

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts   IMK – TRO
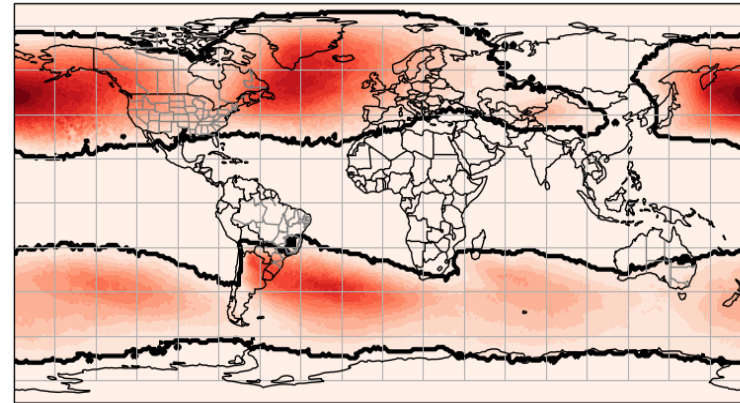
Outflow frequency bias in ECMWF IFS reforecasts - DJF

0/1 Mask

20160309_00
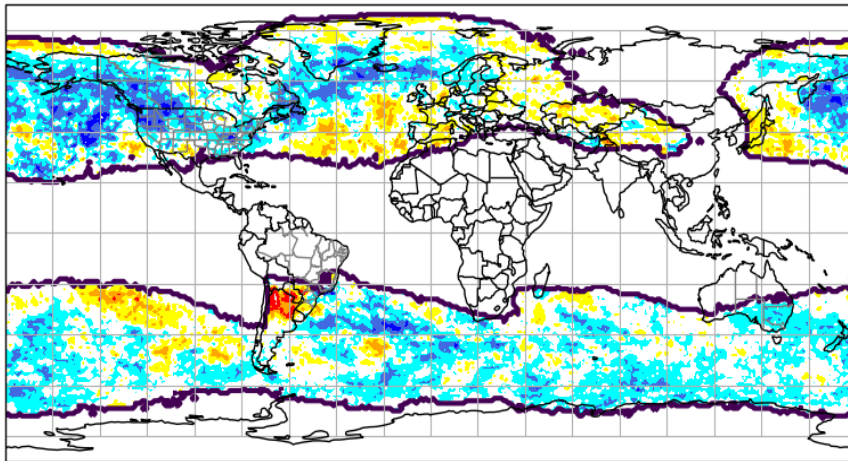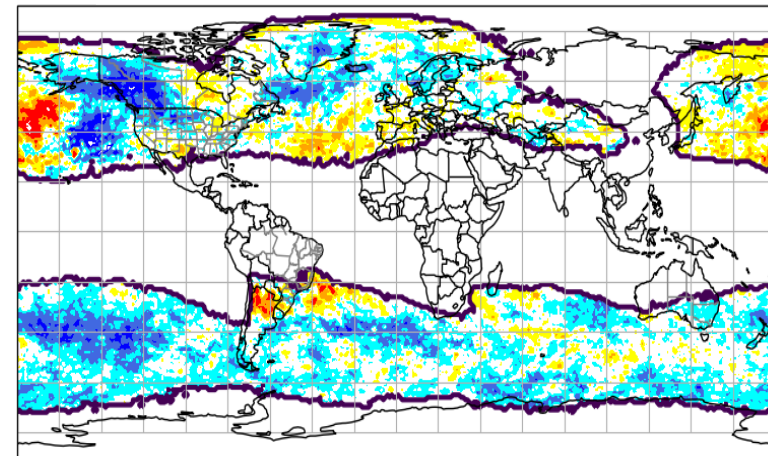
Mean outflow frequency in ERA Interim

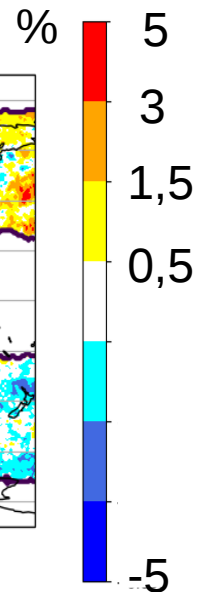16 %

8 %

0 %

Frequency Bias in ECMWF IFS reforecasts (1997 - 2017)

%

5

3

1,5

0,5

-5

Day 5

Day 15

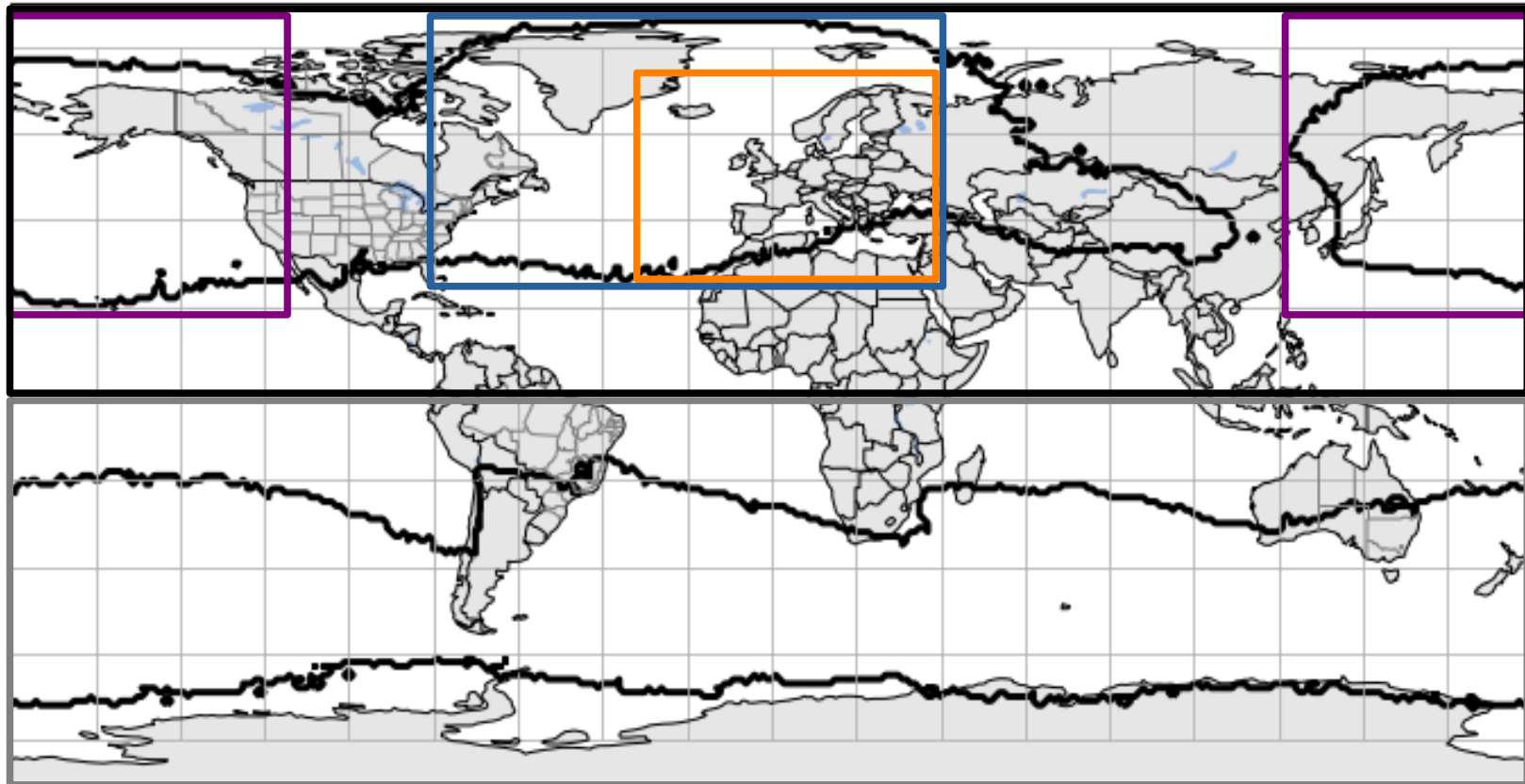Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts

Verification of WCB ensemble probabilities in ECMWF IFS reforecasts
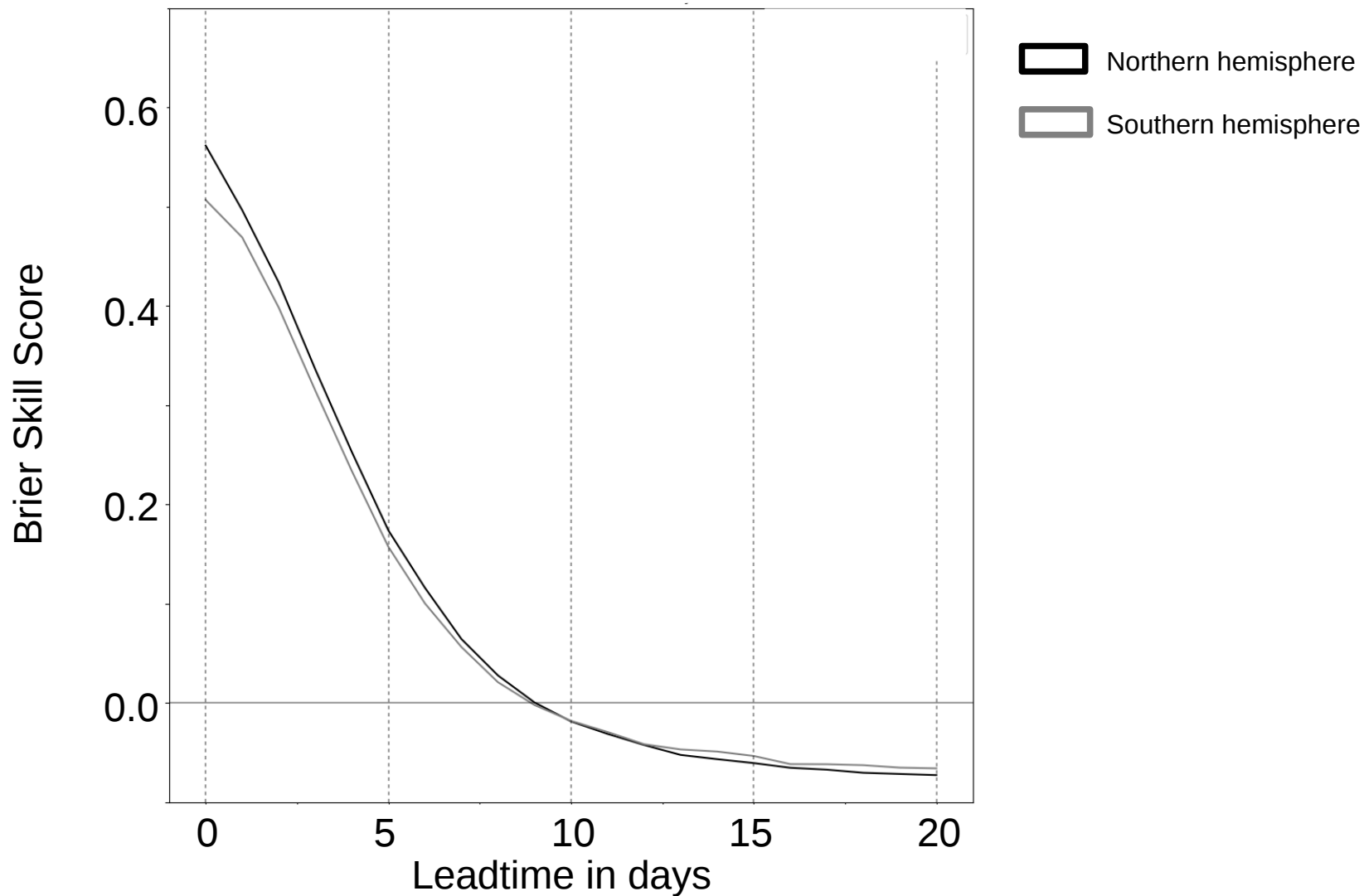

Northern hemisphere

Southern hemisphere

Pacific

Atlantic/European
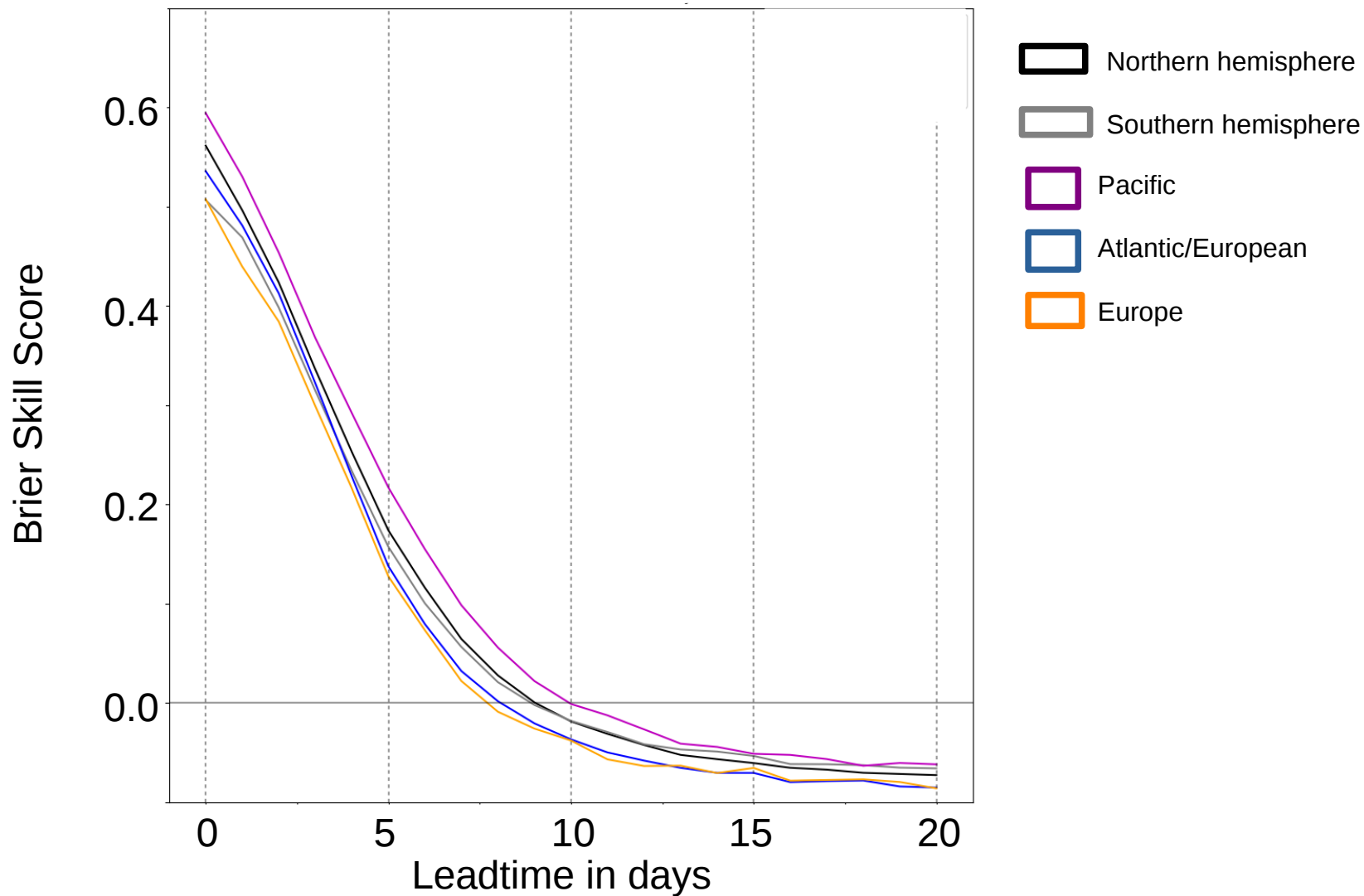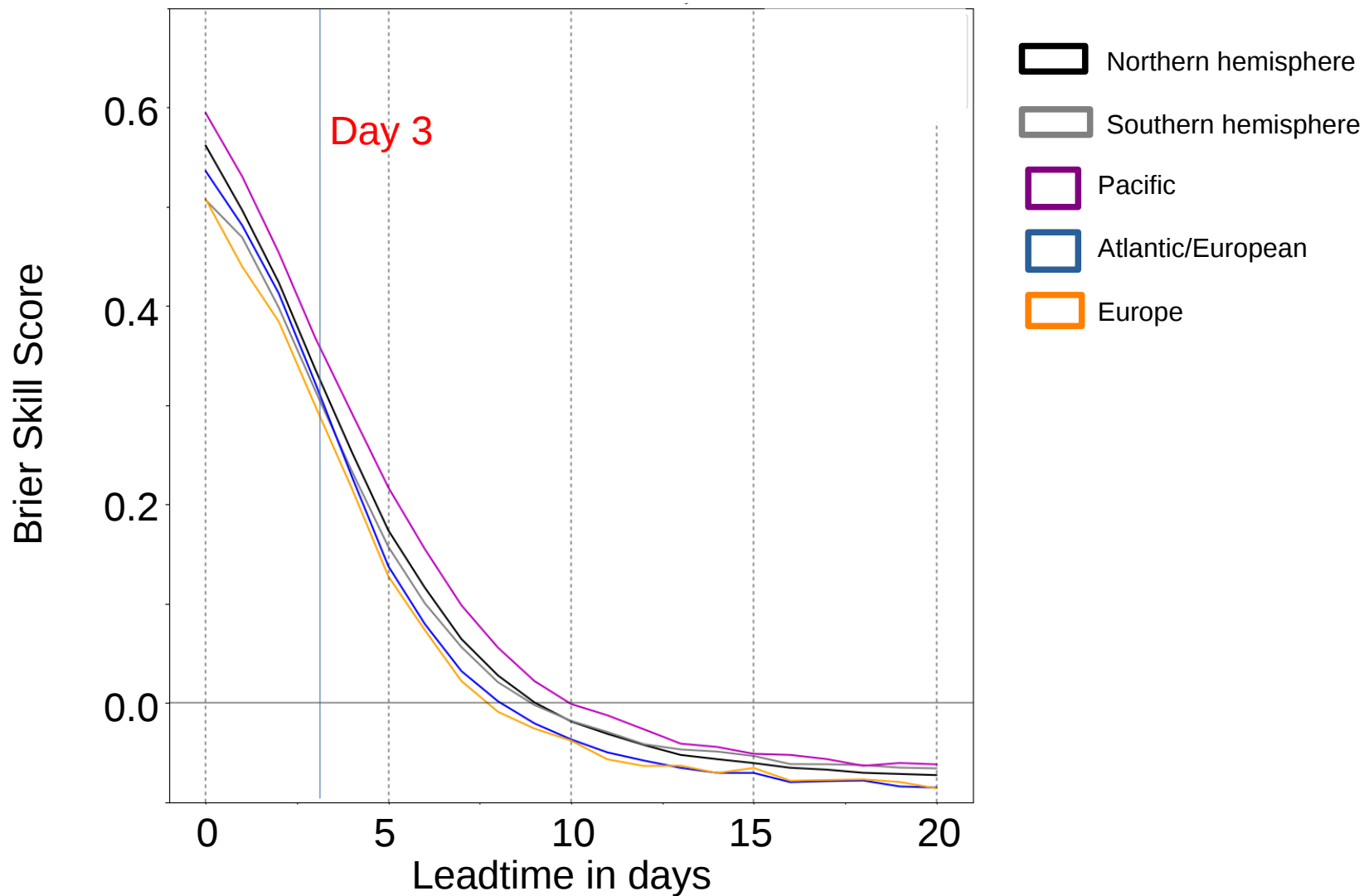
Europe

Outflow forecast skill in ECMWF IFS reforecasts - DJF

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts   IMK – TRO

Outflow forecast skill in ECMWF IFS reforecasts - DJF

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts

IMK – TRO

Outflow forecast skill in ECMWF IFS reforecasts - DJF

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts
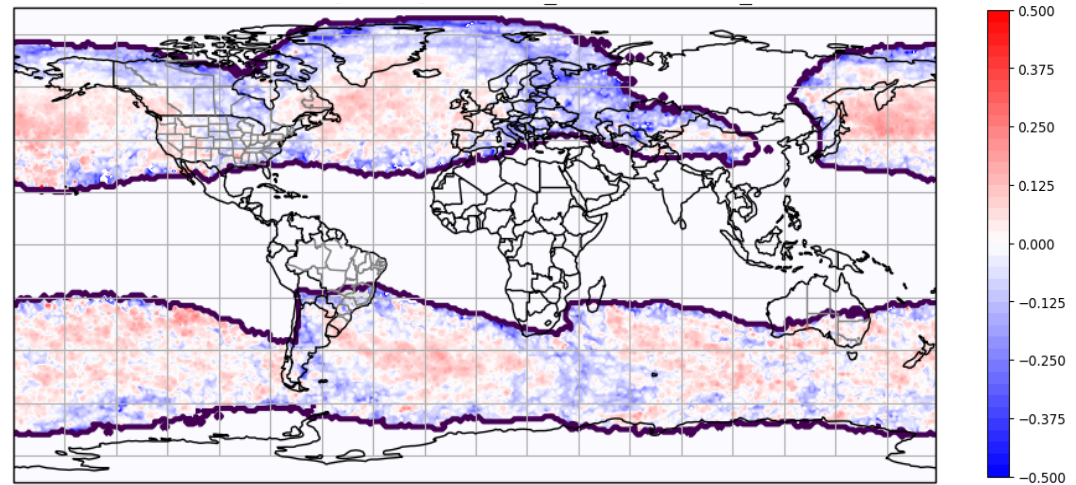
IMK – TRO

Outflow forecast skill in ECMWF IFS reforecasts - DJF
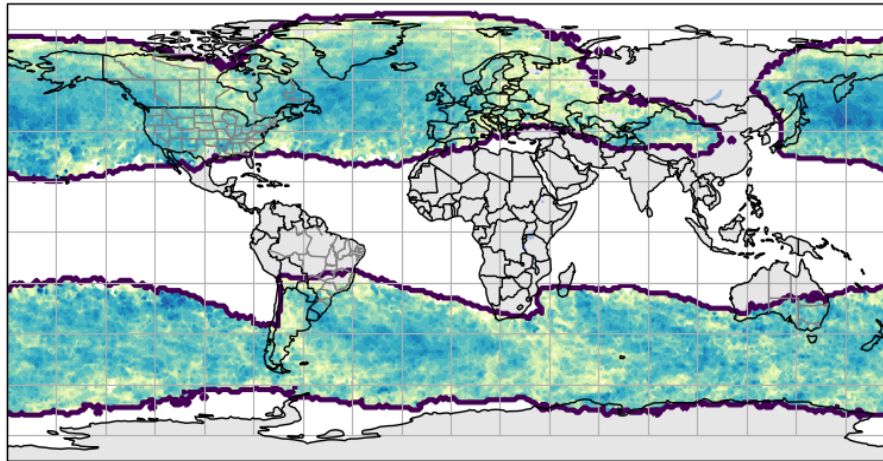
Forecast skill outflow
Day 3

Forecast skill realtive
to hemisphere mean
(NH: 0.34, SH: 0.31)
Day 3
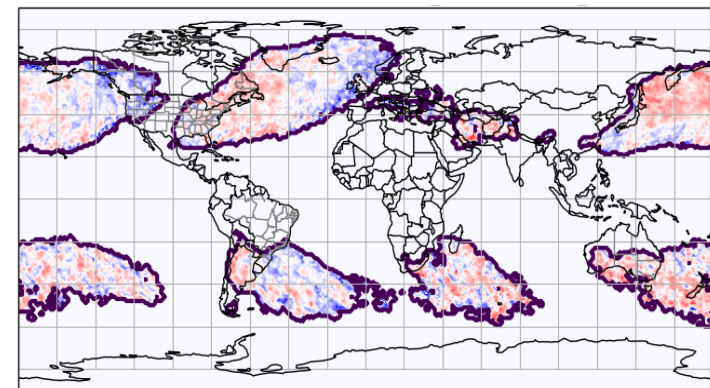
Day 3

NH: 0.42, SH: 0.24

Inflow
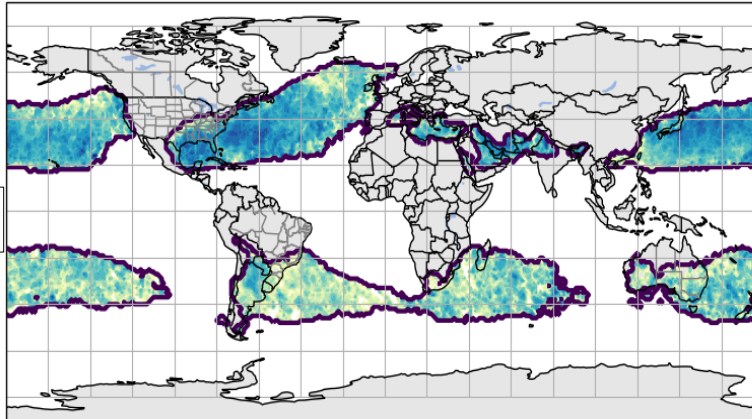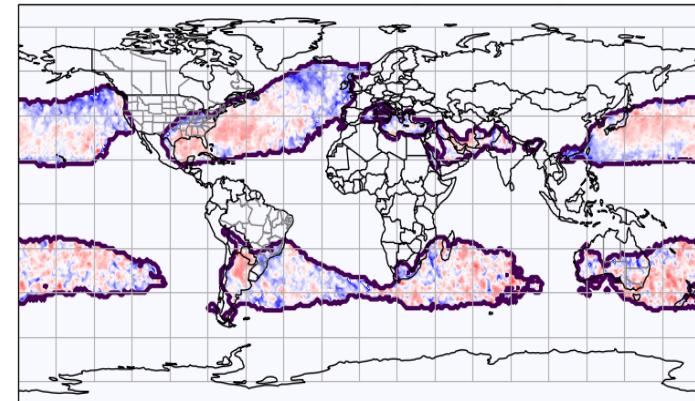
Forecast Skill

Relative Skill

Ascent
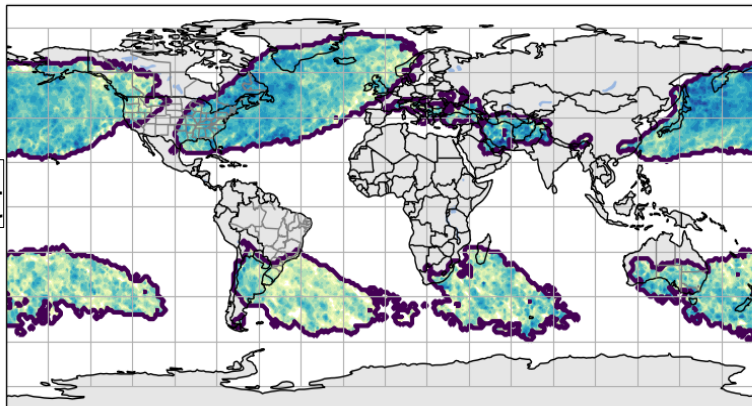
NH: 0.36, SH: 0.22

Forecast skill of weekly outflow frequencies - DJF

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts   IMK – TRO
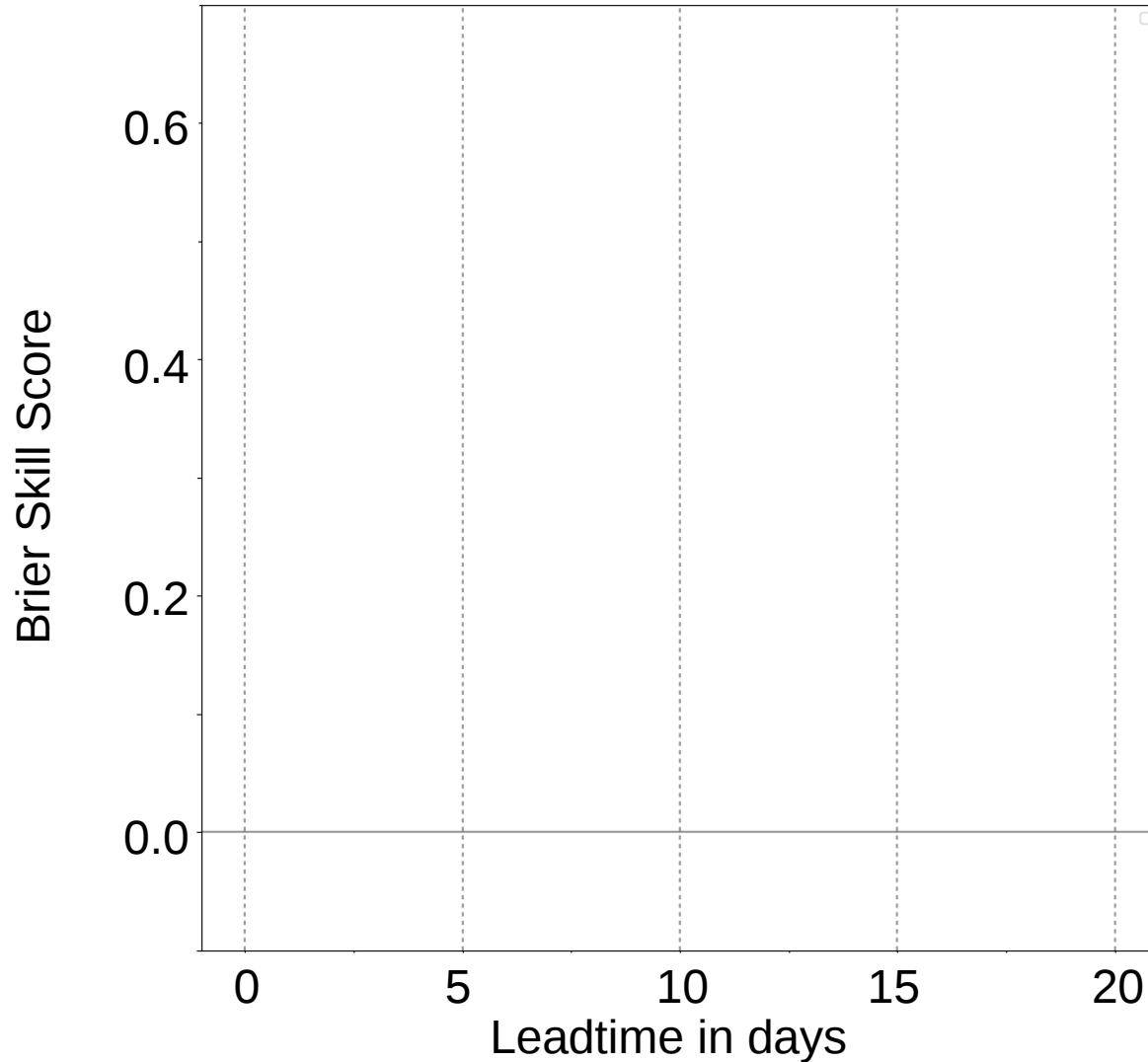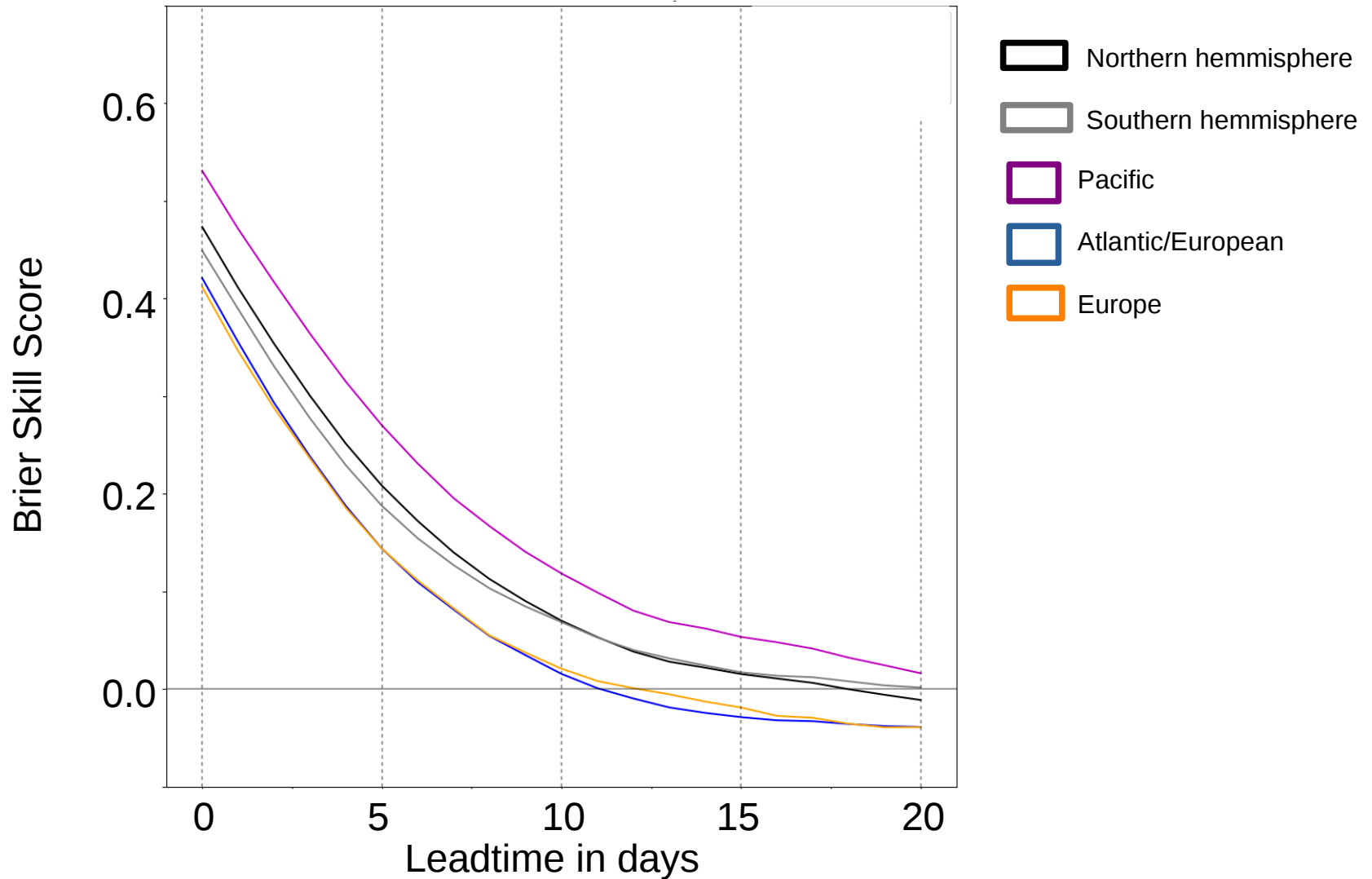
Forecast skill of weekly outflow frequencies - DJF
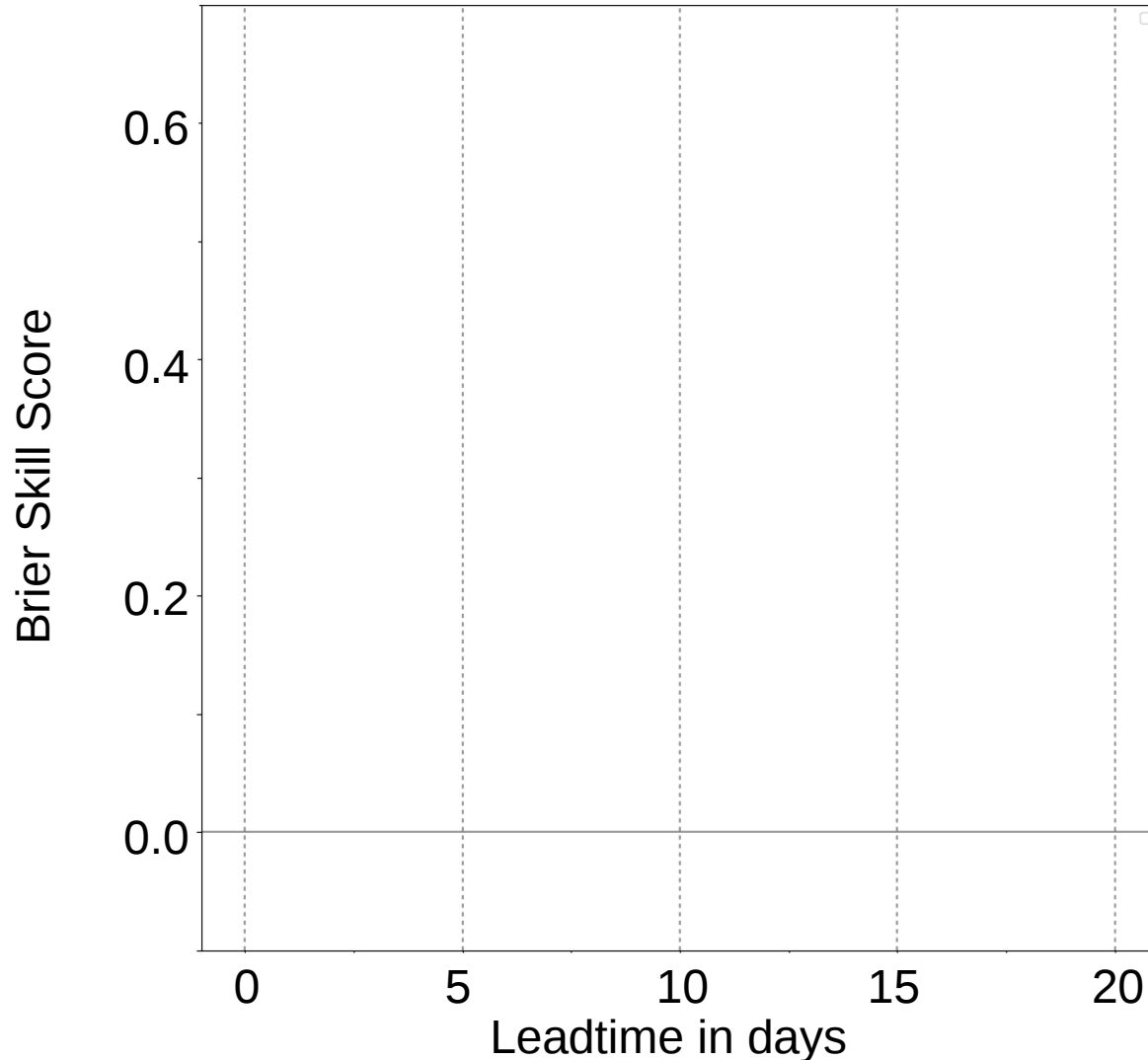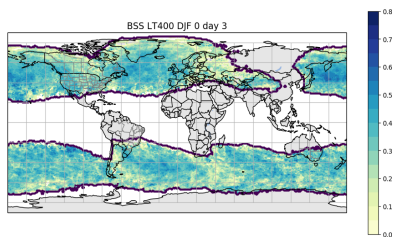

Day 0:

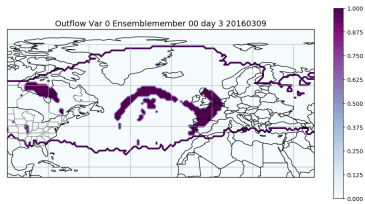→ Mean outflow probability

Day 0-6 (Model and observations)

Day 1:

→ Mean Day 1-7

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Day 15:

→ Mean Day 15-21

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts

IMK – TRO

Forecast skill of weekly WCB frequencies - DJF

Jan Wandel – Verification of warm conveyor belts in ECMWF IFS reforecasts IMK – TRO

Summary WCB verification (from statisitcal model)
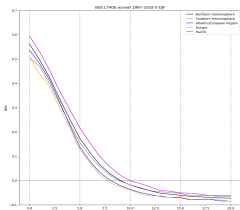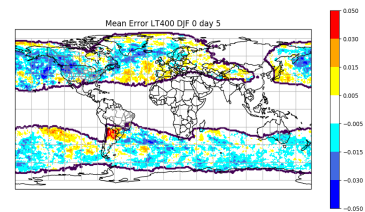
- Systematic investigation of WCBs (calculated with **statistical model**) in ECMWF IFS reforecasts **(20 years: 1997-2017)**

- Outflow of WCB: **Negative bias** over North Atlantic and East Pacific**, positive bias** over south Atlantic

- **Similar forecast skill** for inflow, ascent and outflow phase of WCB

- Forecast skill up to **day 7-10** with relatively more skill in **Pacific region** compared to Atlantic/European

- **Atlantic/European**: More skill over major storm track and towards western Europe

Outlook: bias correction
flow dependent forecast skill of WCBS

→ Bias correction of **variables used in statistical model**

→ Bias correction of **conditional probabilities**

Flow dependent forecast skill outflow (weekly mean probabilities)