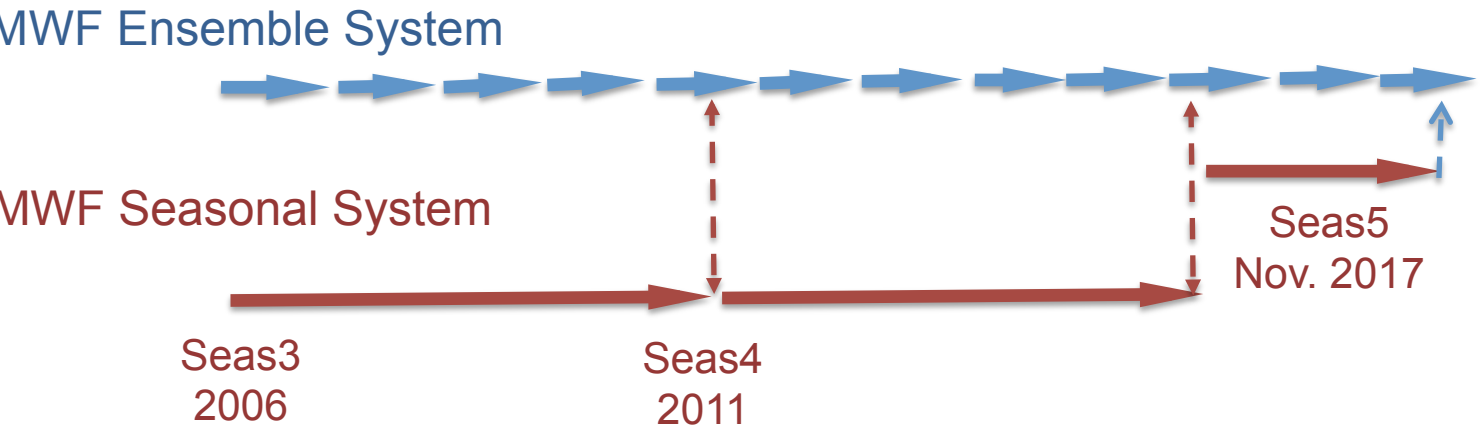
ECMWF update:

SEAS5 : configuration and evaluation
Reanalysis : era5

Laura Ferranti

rking towards a unified ensemble prediction system:



Advantages

- **Confidence on representation of relevant processes**
- **Possibility of Seas results influencing the extended range.**
- **Simplicity**

Trades off:

- Certain aspects of the initialization
- Slowing the inclusion of new earth-system components (such as O3).

SEAS5 Innovations

- More recent model cycle.
- High resolution (ocean and atmosphere
- Sea-Ice
- New ocean reanalysis ORAS5

SEAS5 components:

	SEAS4 (2011)	SEAS5 (2017)
Atmosphere	Cycle 36r4 T_L255 L91	Cycle 43r1 T_{Co}319 L91
Ocean	NEMO v3.0 ORCA 1.0-L42	NEMO v3.4 ORCA 0.25-L75
Sea ice model	Sampled climatology	LIM2
Non-orographic GWD	Altered	Altered
Ozone scheme	Cariolle	BMS
Ozone interactive	Yes	No

ERA5 forcings adopted for SEAS5

- Decadally varying tropospheric sulphate aerosol from CMIP5
- Time varying stratospheric volcanic aerosol from GISS
- GHG forcings from CMIP5 as in 43r1

SEAS5 vs. SEAS4

- Updated IFS cycle with many improvements to model physics
- Increased horizontal resolution in atmosphere and ocean, increased vertical resolution in the ocean
- Introduction of the LIM2 interactive sea ice model
- Ozone scheme non-interactive

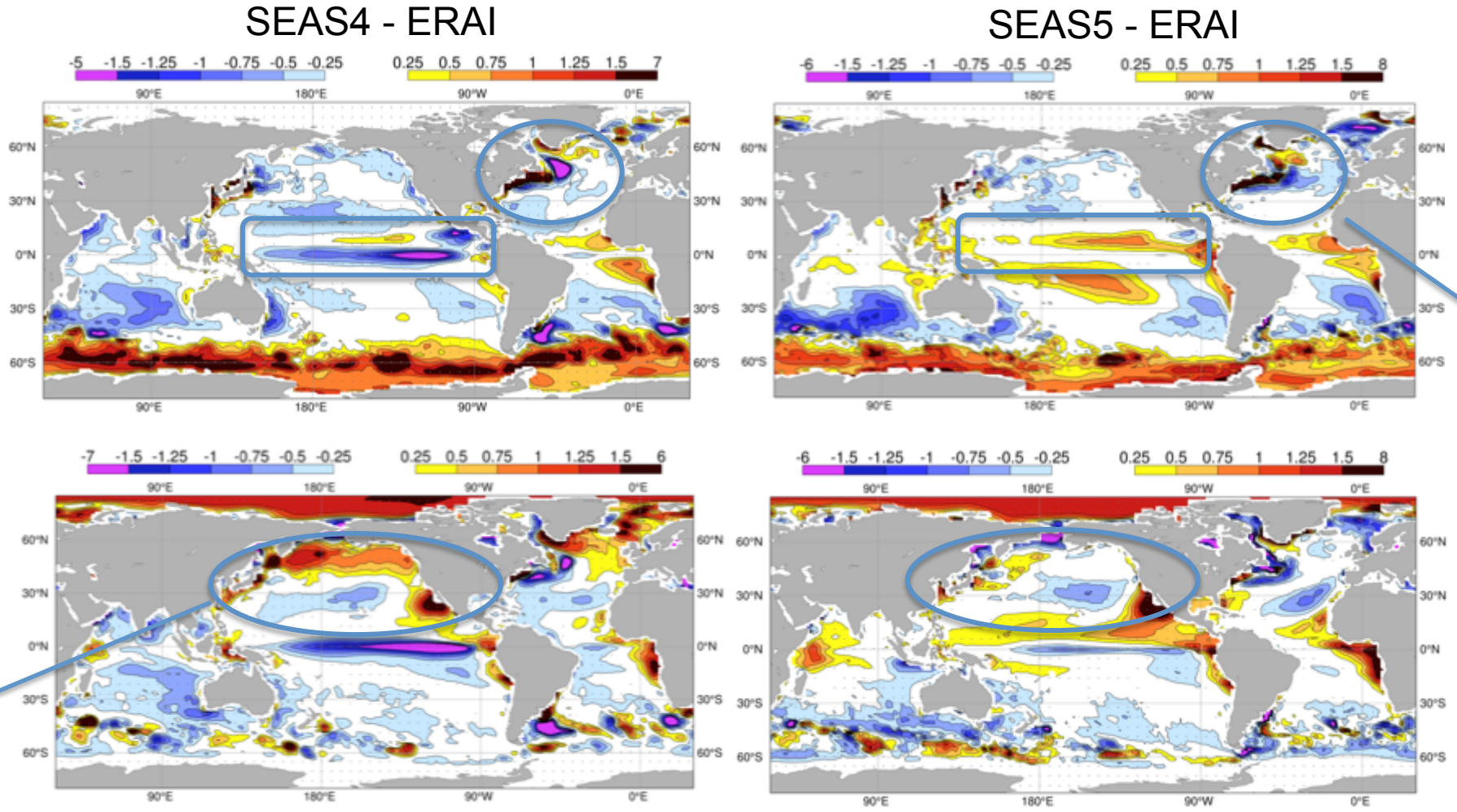
Initialization and forecast strategy

	SEAS4	SEAS5
Atm. Initialization	ERA-Interim	ERA-Interim
Land initialization	ERA-Interim Land 32r3	ERA-Interim Land 43r1
Ocean initialization	ORA-S4	ORA-S5
Ensemble spread	SPPT & SKEB	SPPT& SKEB
Forecast members	51	51
Reforecast members	15	25
Calibration period	1981-2010	1993-2015
Reforecasts period	1981-2010	1981-2015

SEAS4 vs. SEAS5

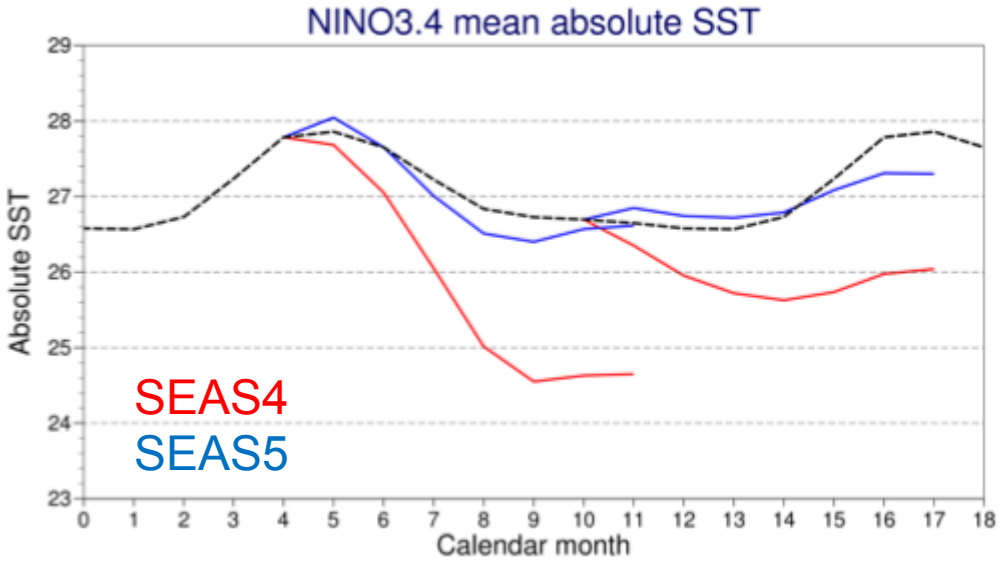
- Updated ocean and land initial conditions
- Updated atmosphere and ocea initial condition perturbations
- Larger reforecast ensemble siz
- Calibration period set by C3S

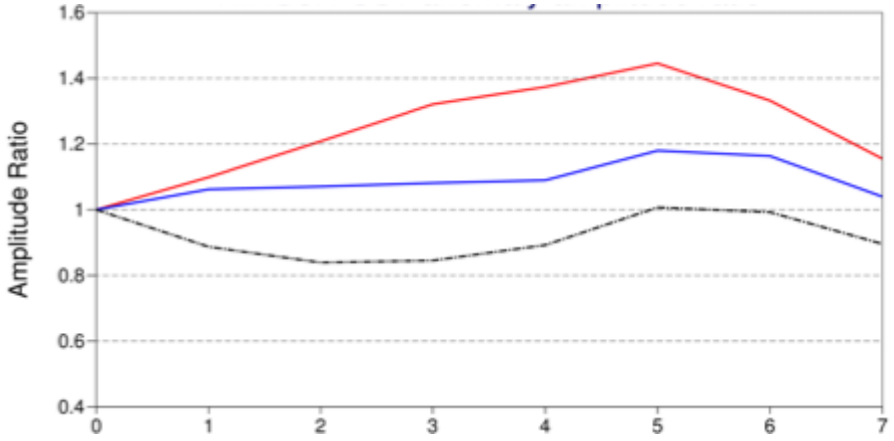
Global SST biases improve, especially in the ENSO regions

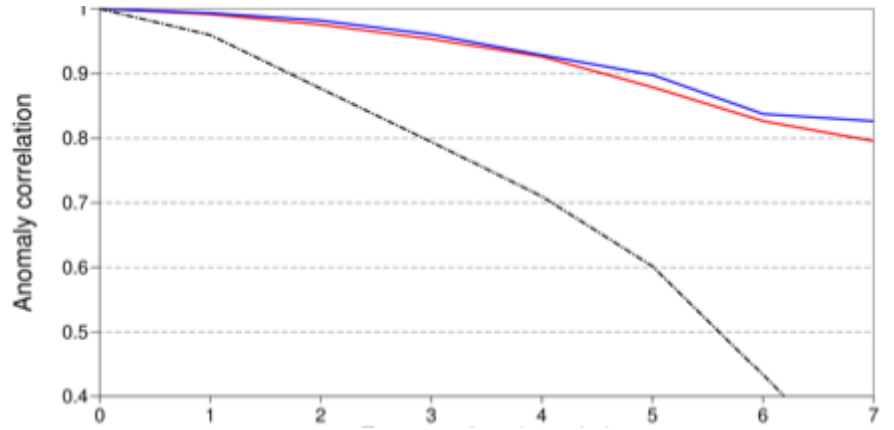


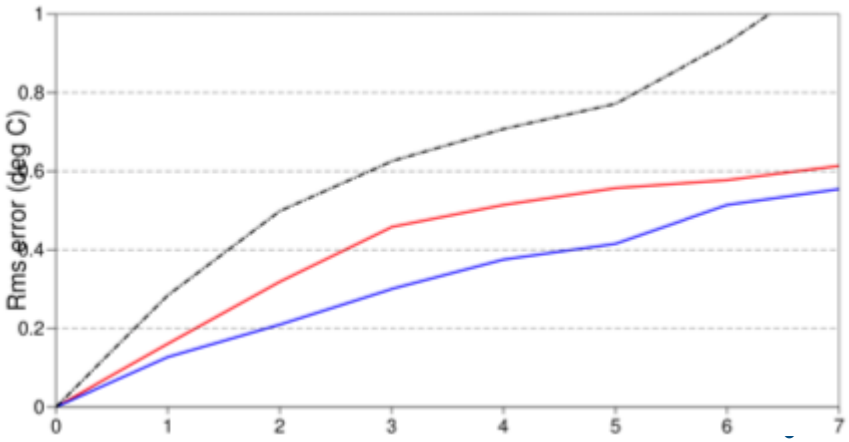
Particular improvement in the ENSO regions, much better foundation for ENSO teleconnections

Global SST biases improve, especially in the ENSO regions





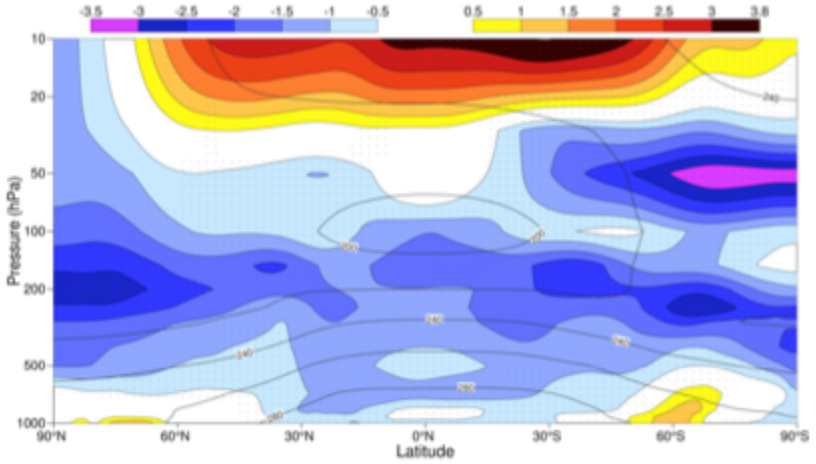




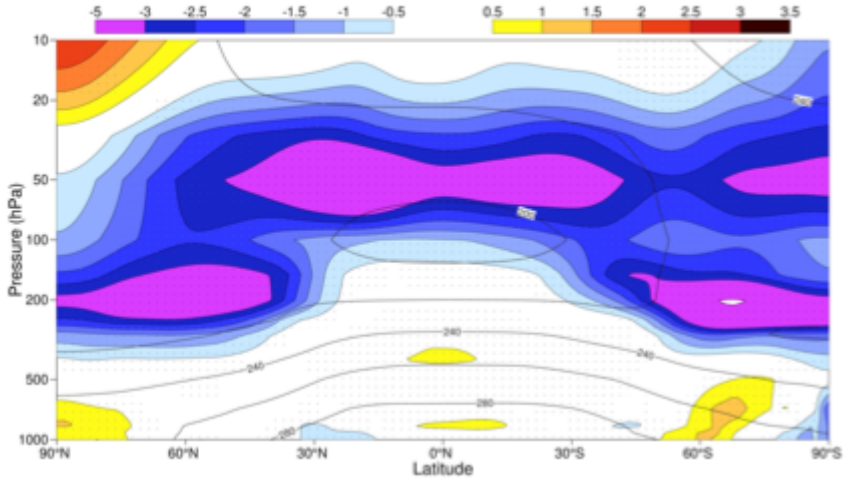
ENSO SST drift improves markedly. Also a small increase in ENSO correlation scores, an improvement in ENSO variance, and a decrease in RMS error.

Stratospheric temperature and winds biases increase

SEAS4 – ERAI (DJF)



SEAS5 – ERAI (DJF)



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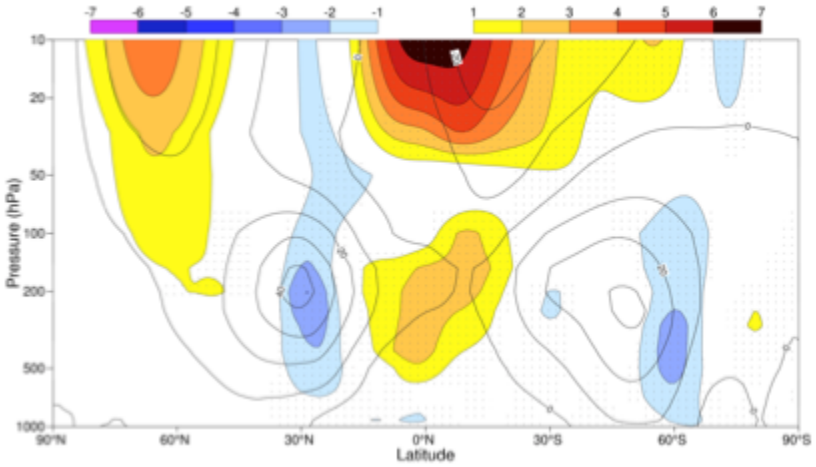

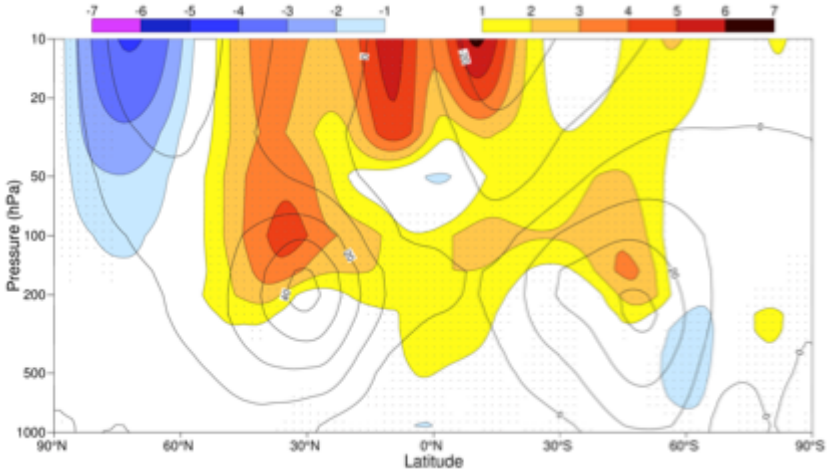

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Stratospheri
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but SEAS5 is w

Particular conc
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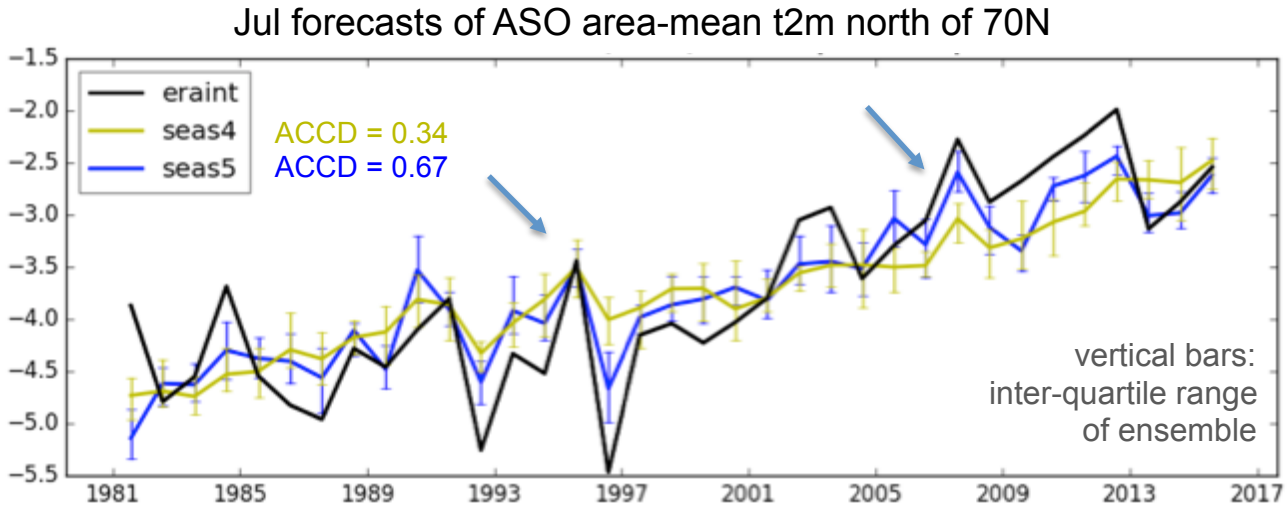
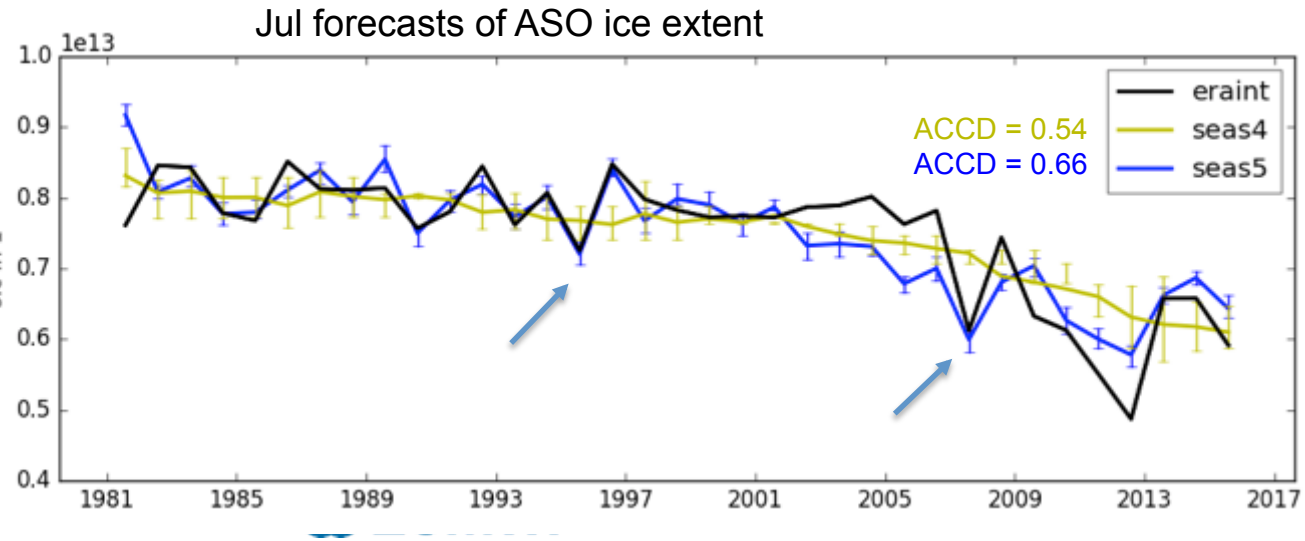
since SEAS4, w
remain despi
adjusting GGAU

SEAS5 improvement in sea ice and high-latitude skill – summer forecasts





ACCD = correlation between forecast and ERA-I anomalies *w.r.t. the linear trend*

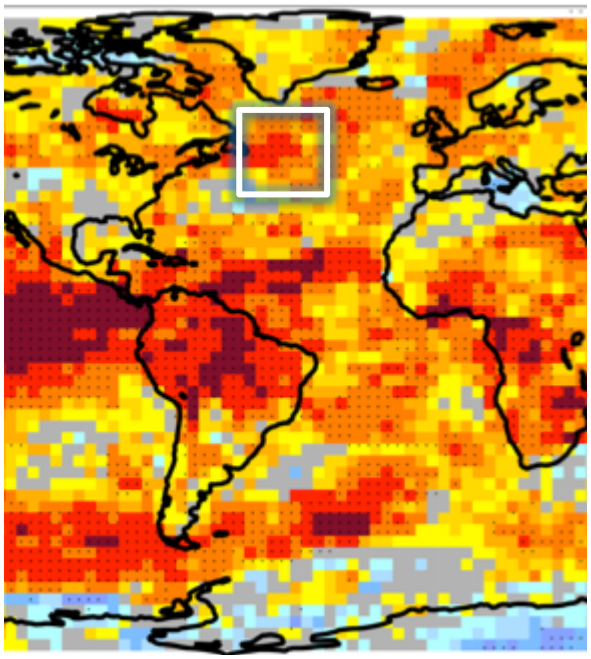
- SEAS4 sea-ice: climatology of last 5 years
- SEAS5 sea ice: prognostic with LIM2

SEAS5 clearly outperforms SEAS4 in summe for both sea-ice extent and 2m temperature. Positive contribution of prognostic sea ice to improved 2m temperature forecasts highly like (to be investigated further).

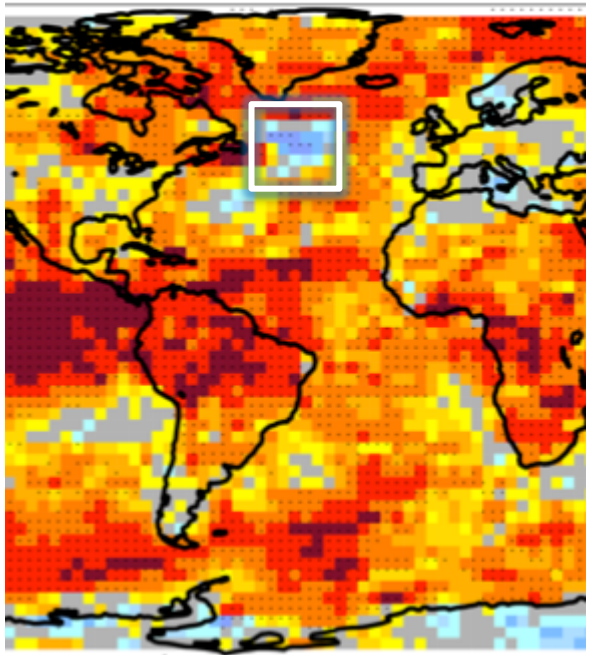
From: Steffen Tietsche
Steffen.Tietsche@ecmwf.int

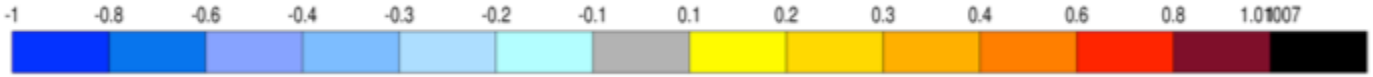
SEAS5 loss of DJF surface temperature skill over parts of the North Atlantic

SEAS4



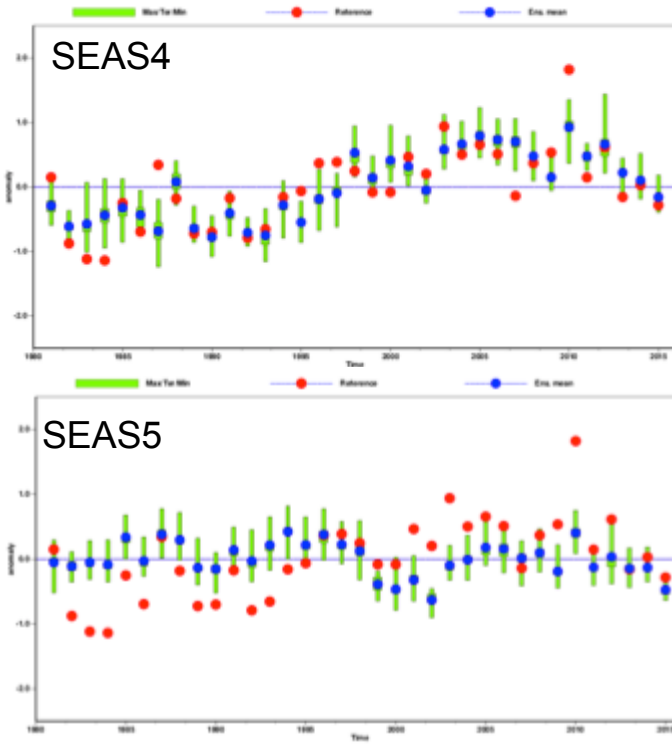
SEAS5





ROC skill score, DJF t2m in lower tercile, hindcasts Nov **1981-2015**

North Atlantic DJF SST anomalies

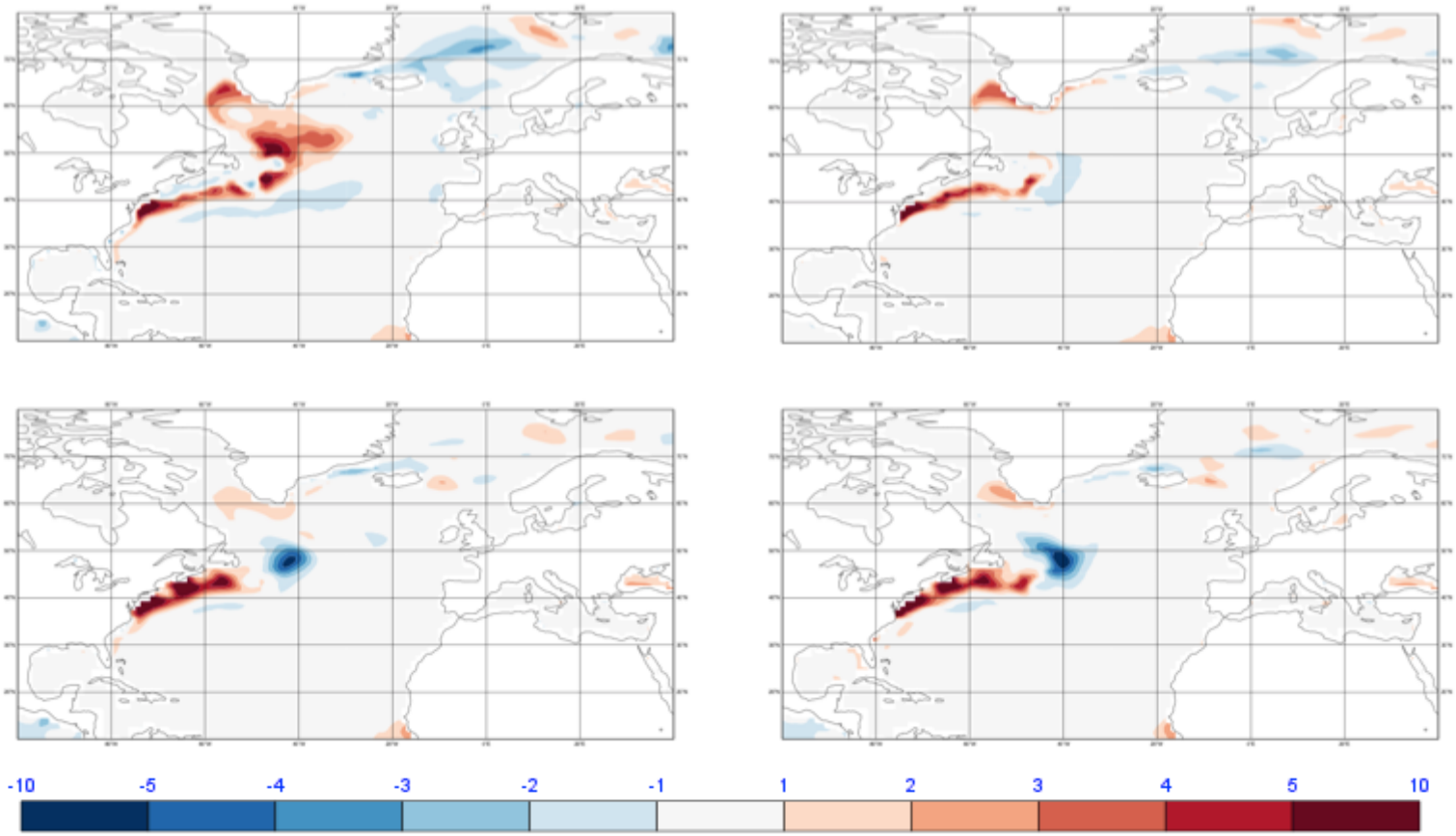


ECMWF

Loss of skill, calibration, and nonstationary SST bias

1981 - 1995

2000 - 2015

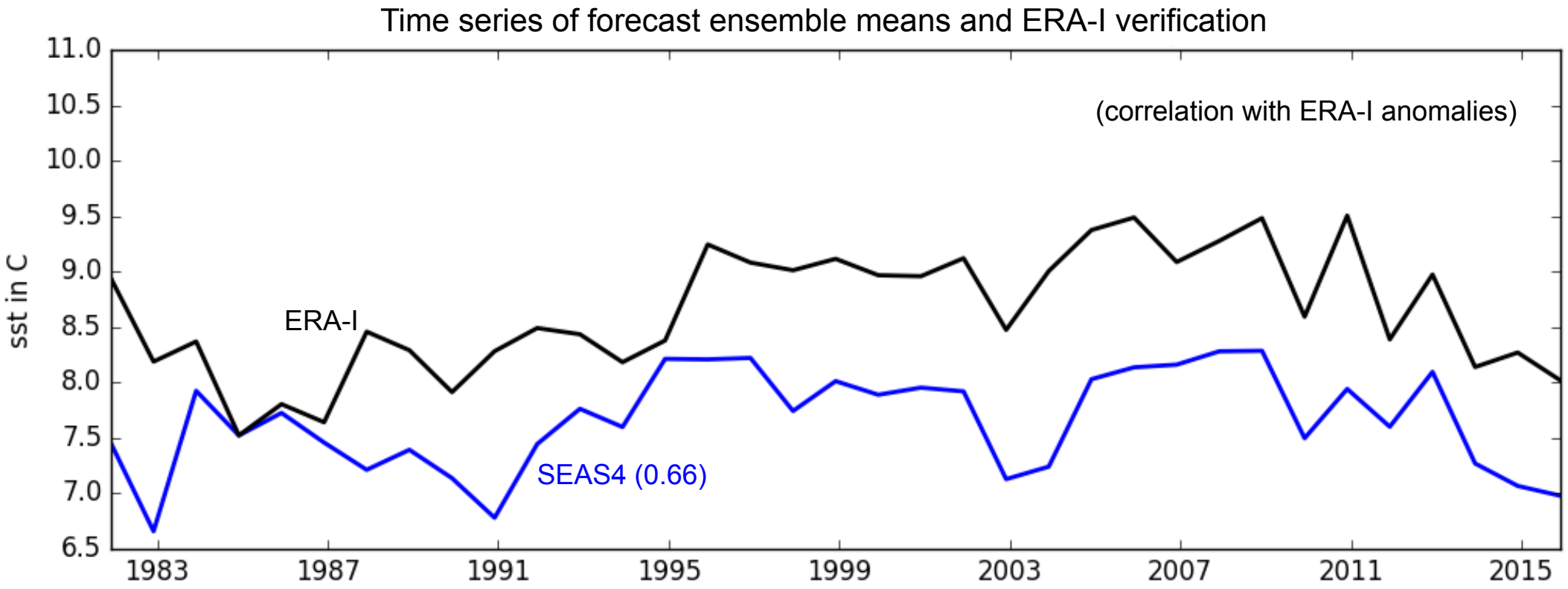


DJF SST forecast bias (K) for Nov initialization

- All scores for SEAS are calcul
  on calibrated data (bias remov
- SEAS4: stationary cold bias
  → forecasts can be calibrated
- SEAS5: strong warm bias befo
  year 2000, little bias after
  → calibration fails, no apparen

ECMWF

DJF SST in “no-skill” box for November initialization



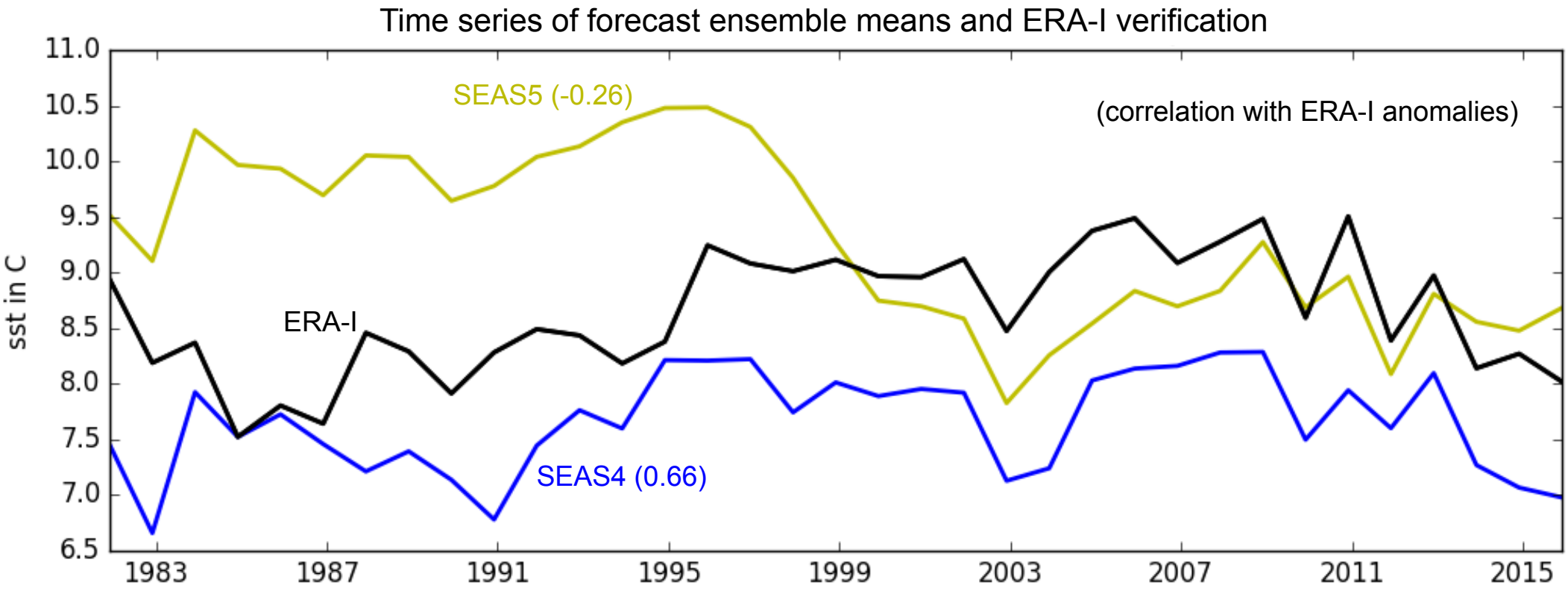
SEAS4:

- *constant cold bias of ~1.5K*
- *both year-to-year and long-term variability well captured*

ECMWF

From: Steffen Tietsc
Steffen.Tietsche@ec

DJF SST in “no-skill” box for November initialization



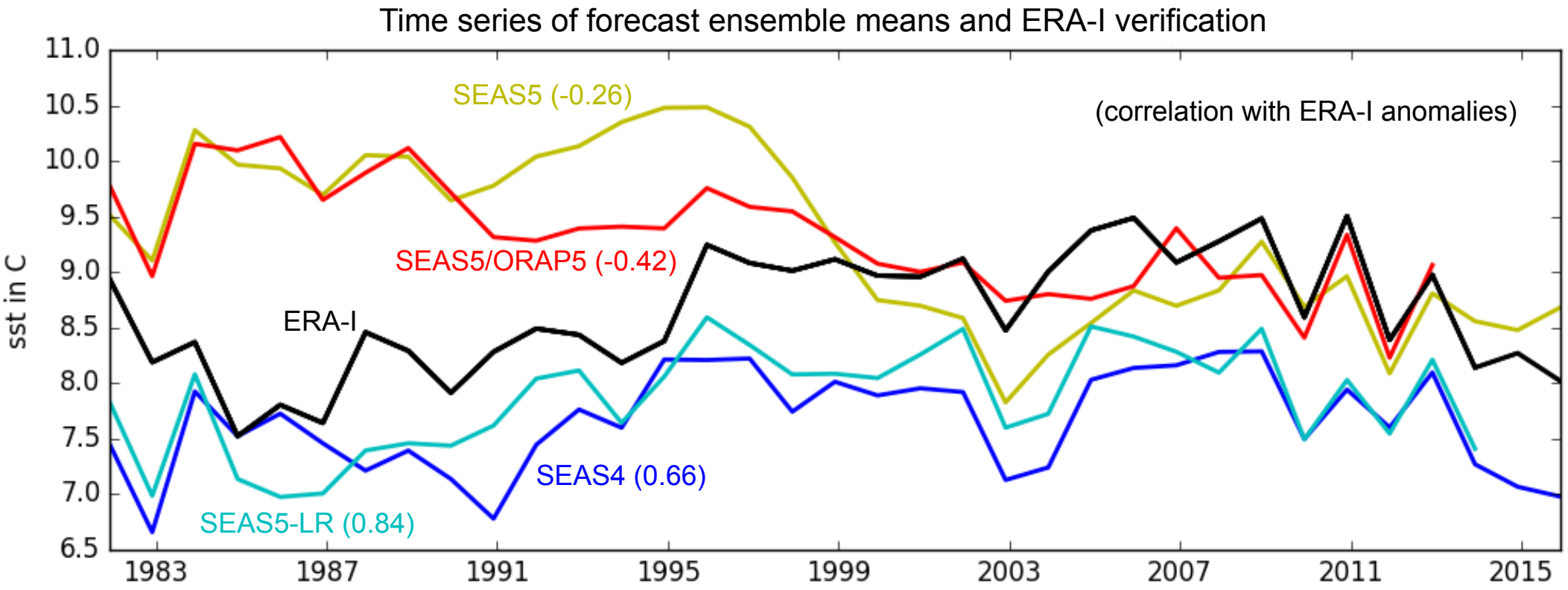
SEAS5:

- *warm bias of ~2 K before 2000, little bias afterwards*
- *prediction of year-to-year variability okay, but decadal signal wrong*

ECMWF

From: Steffen Tietsc
Steffen.Tietsche@ec

DJF SST in “no-skill” box for November initialization



Sensitivity experiment #2: high-resolution ocean, but initial conditions from ORAP5

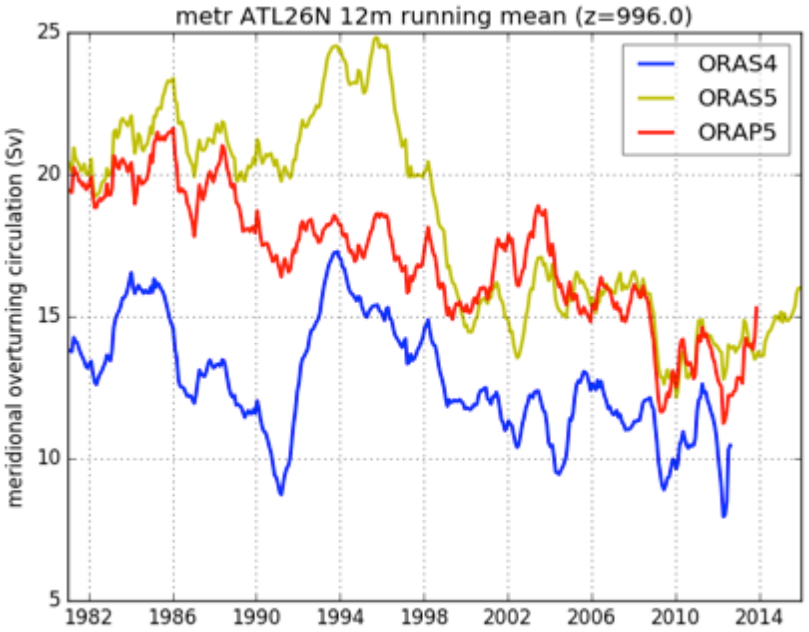
- *Similar to SEAS5, but reduced bias in the 1990s → problem present, yet slightly better*

onclusion so far: problem lies in the high-resolution initial conditions (ORAS5/ORAP5)

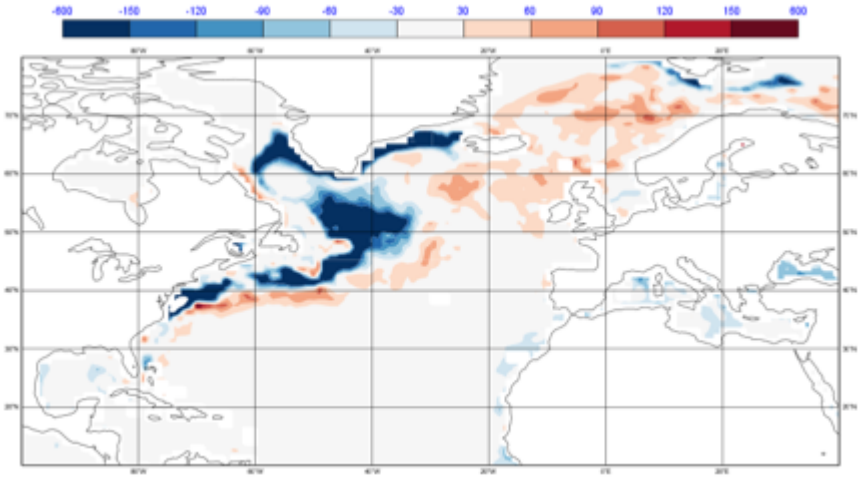
ECMWF

From: Steffen Tietsc
Steffen.Tietsche@ec

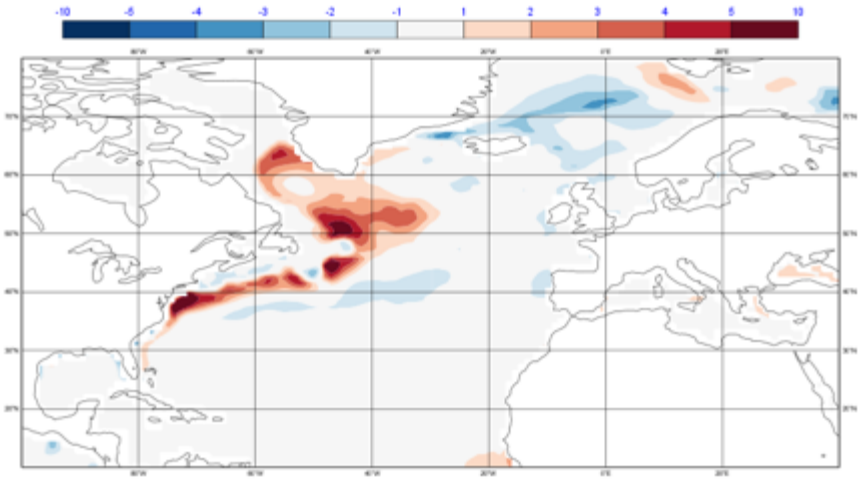
tlantic ocean heat transport and SST relaxation



SST relaxation heat flux ORAS5 (W/m2)
Nov 1981-1995



SEAS5 forecast bias (K)
DJF 1981-1995



ORAS5 before 2000 has two compensating errors:
1) too high northward ocean heat transport
2) artificial heat removal via SST nudging (~300 W/m^2)
In the forecast, SST nudging abruptly disappears, but density-driven ocean circulation continues

→ strong warm bias in SST and upper ocean heat content

ECMWF

From: Steffen Tietsche
Steffen.Tietsche@ecmwf.int

SEAS5

EAS5 becomes operational on Nov 1, 2017, replacing System 4 which as been operational since 2011.

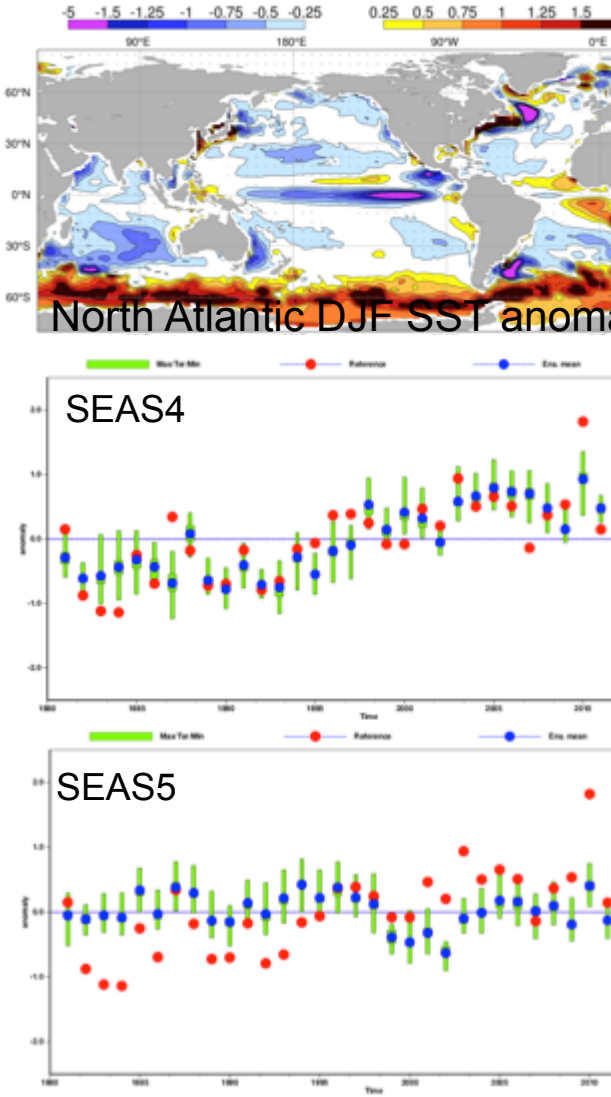
cientific highlights

- Improved ENSO biases and scores.
- Improved 2m temperature skill in the tropics due to accumulated improvements in model physics.
- Inclusion of the LIM2 interactive sea ice model improves sea ice prediction skill.

ssues

- Skill over Europe is comparable to that in System 4. However, a new hole in skill is present in at the tip of the Gulf stream in the North Atlantic, where decadal variability is not captured.
- The hole is due to warm SST bias in early period that disappears around 2000. Sensitivity experiments suggest problem with initial conditions (ORAS5). ORAS5 before 2000 has error balance: too high northward ocean heat transport and high artificial heat extracting through relaxation to observed SST.
- Stratospheric mean temperature and wind profiles degraded.

DJF SST bias: SEAS4



News from C3S : ERA5

Climate Change Service

Hans Hersbach, ECMWF,
and many, many colleagues

Climate Change

Copernicus Europe's eyes on Earth | European Commission | ECMWF

What is new in ERA5?

	ERA-Interim	ERA5
Period	1979 – present	Initially 1979 – present, later addition 1950-1978
Streams	1979-1989, 1989-present	Parallel streams, one per decade
Assimilation system	2006, 4D-Var	2016 ECMWF model cycle (41r2), 4D-Var
Model input (radiation and surface)	As in operations, *(inconsistent sea surface temperature)*	***Appropriate for climate***, e.g., evolution greenhouse gases, volcanic eruptions, sea surface temperature and sea ice
Spatial resolution	79 km globally 60 levels to 10 Pa	***31 km globally*** 137 levels to 1 Pa
Uncertainty estimate		Based on a 10-member ***4D-Var ensemble*** at 62 km
Land Component	79km	ERA5L, 9km (separate, forced by ERA5)
Output frequency	6-hourly Analysis fields	***Hourly*** (three-hourly for the ensemble), ***Extended list of parameters*** ***~ 5 Peta Byte (1979-NRT)***
Extra Observations	Mostly ERA-40, GTS	Various ***reprocessed CDRs***, ***latest instruments***
Variational Bias correction	Satellite radiances	Also ozone, aircraft, surface pressure

The evolving observing system

Newly reprocessed data sets

Radiances: SSM/I brightness temp from CM-SAF METEOSAT from EUMETSAT

Atmospheric motion vector winds: METEOSAT, GMS/ GOES-9/MTSAT, GOES-8 to 15, AVHRR METOP and NOAA

Scatterometers: ASCAT-A, ERS 1/2 soil moisture

Radio Occultation: METOP GRAS, COSMIC, CHAMP, GRACE, SAC-C, TERRASAR-x

Ozone: NIMBUS-7, EP TOMS, ERS-2 GOME, ENVISAT SCIAMACHY, Aura MLS, OMI

Altimeter: ERS1/2, ENVISAT, Jason-1

Extra data (not used in ERA-Interim)

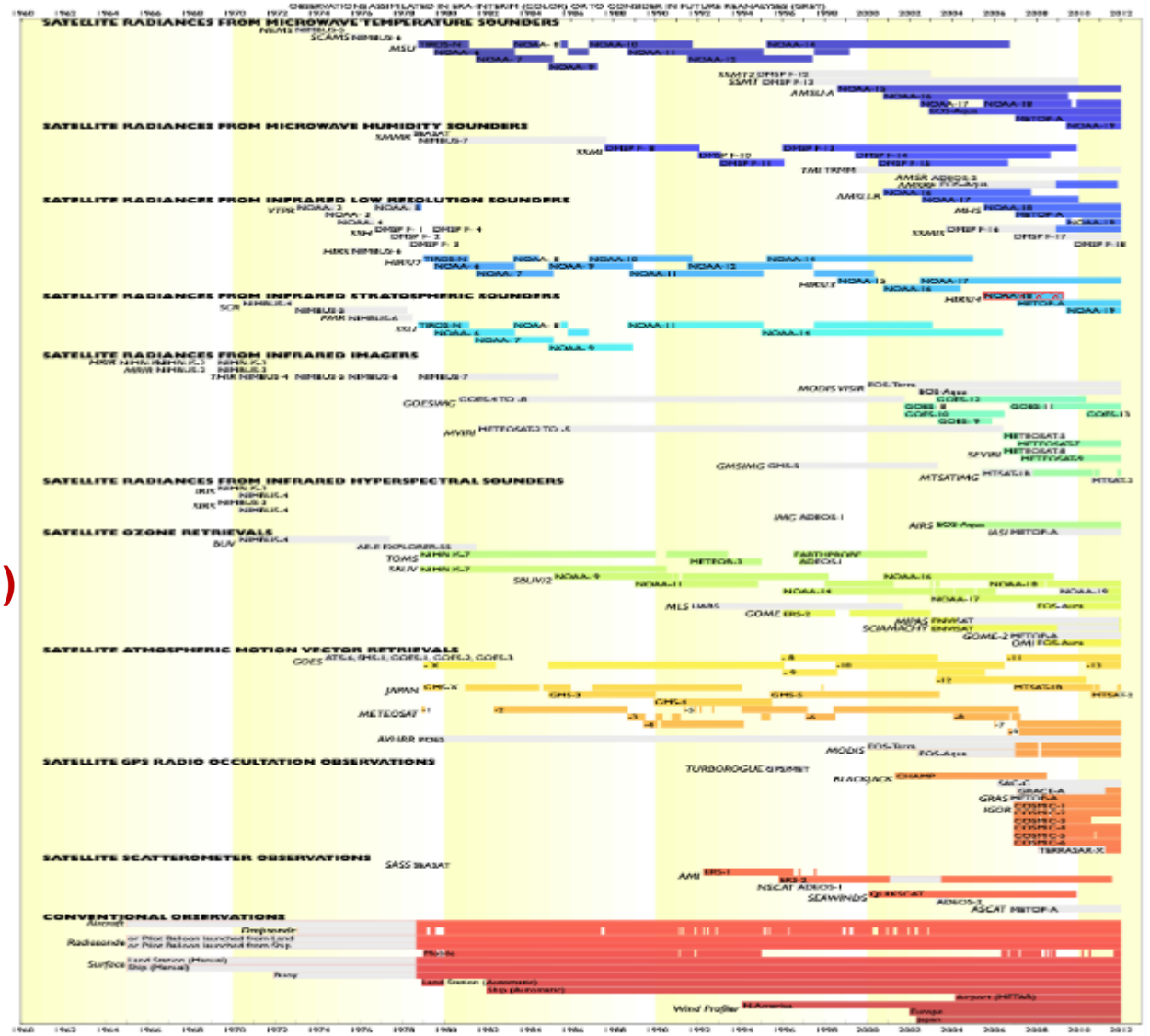
lack of infrastructure ERA-Interim

IASI, ASCAT, ATMS, Cris, MWHS2, Himawari-8, …

Typically the latest instruments:
ERA5 is more future proof!

Improved data usage

all-sky vs clear-sky assimilation,
latest radiative transfer function,
…



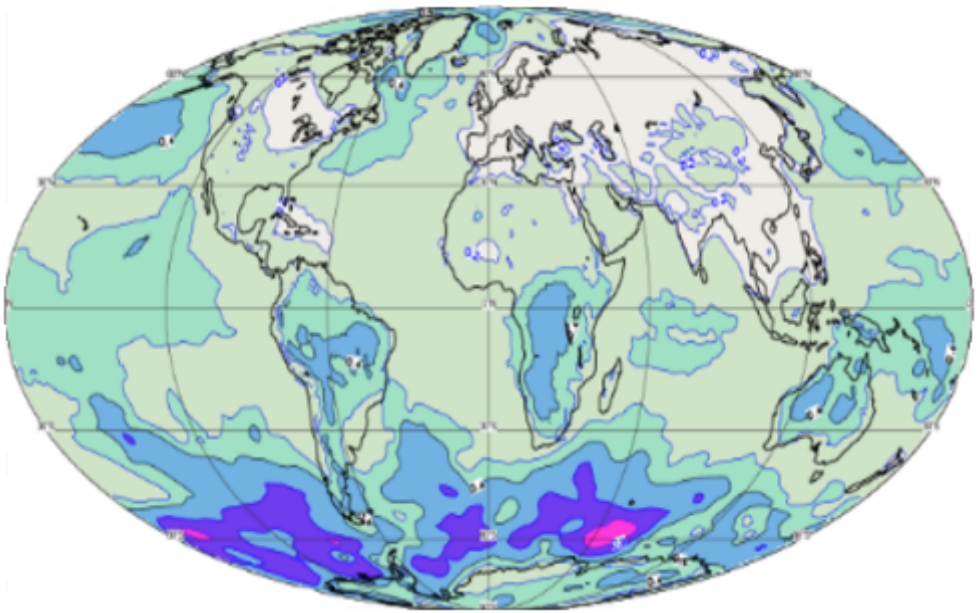
ERA5 provides an estimate for

ERA5 is based on a 10-member EDA system

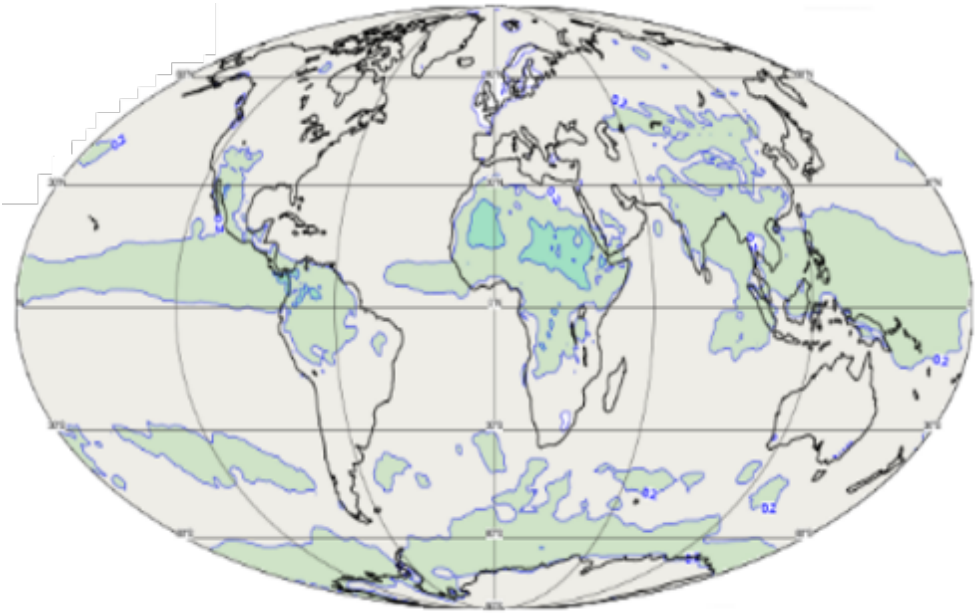
Spread in Surface Pressure (hPa)

0-0.1 0.1-0.2 0.2-0.3 0.3-0.4 0.4-0.6 0.6-0.8 0.8-1

January 1979

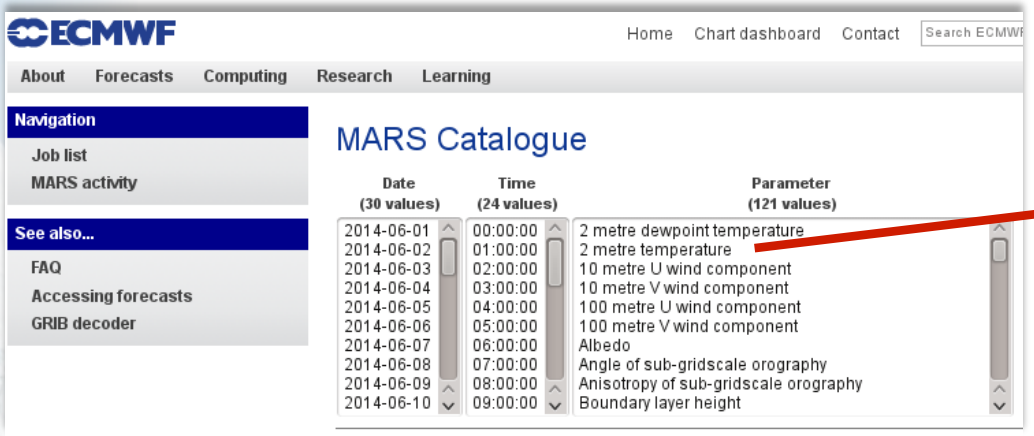


July 2014

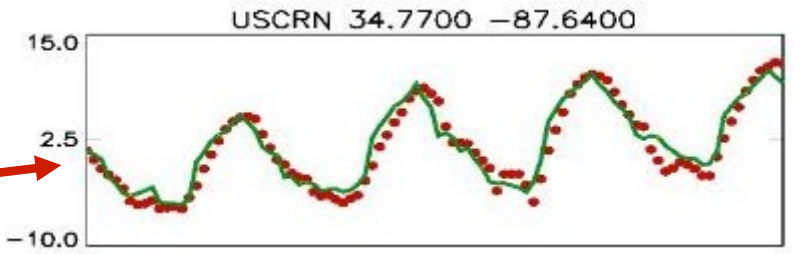


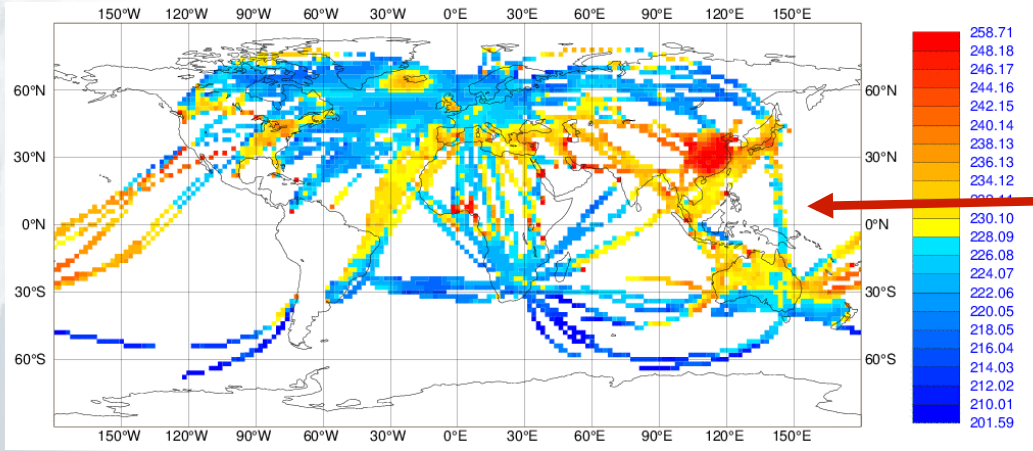
Hourly data and access to observations

Hourly reanalysis fields

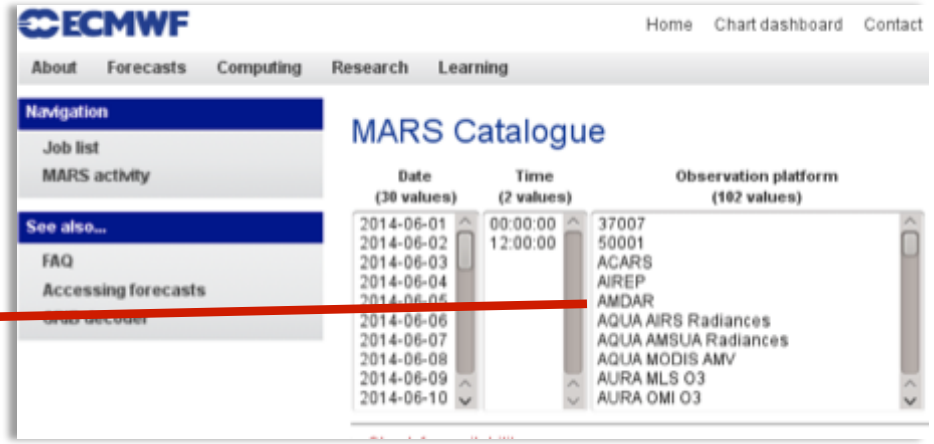


ERA5 2-metre temperature compared to independent data

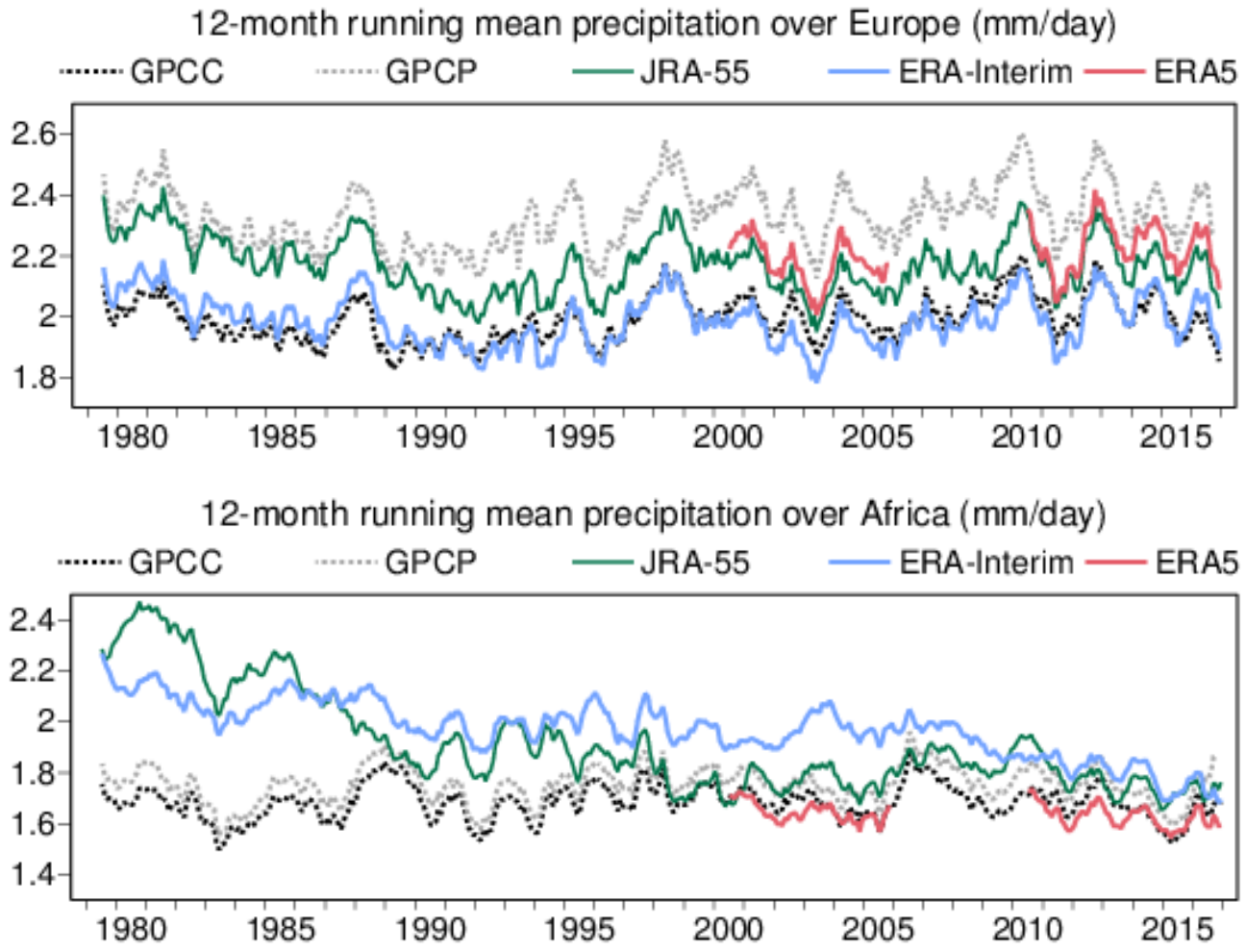




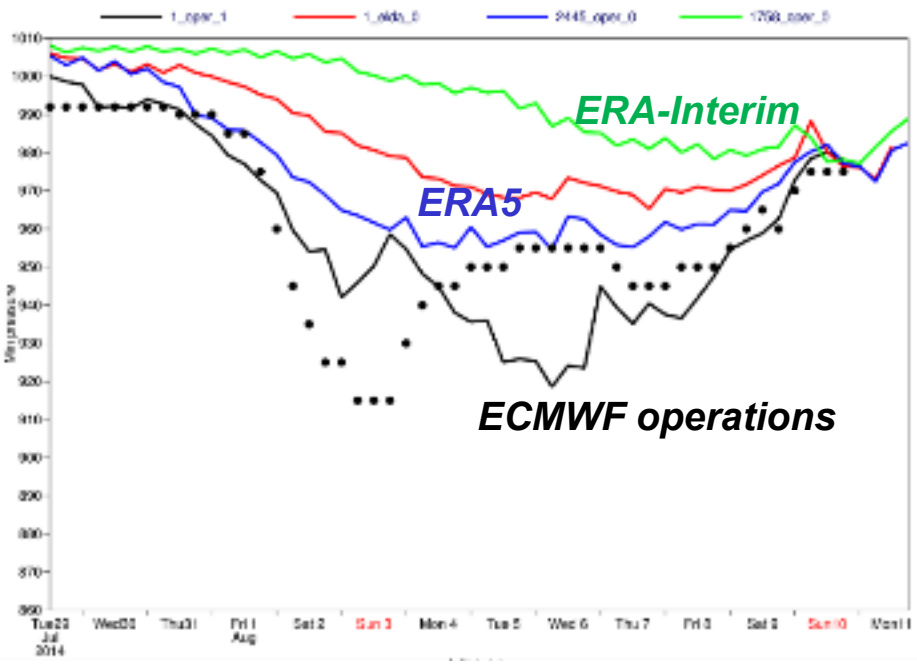
Observation feedback archive

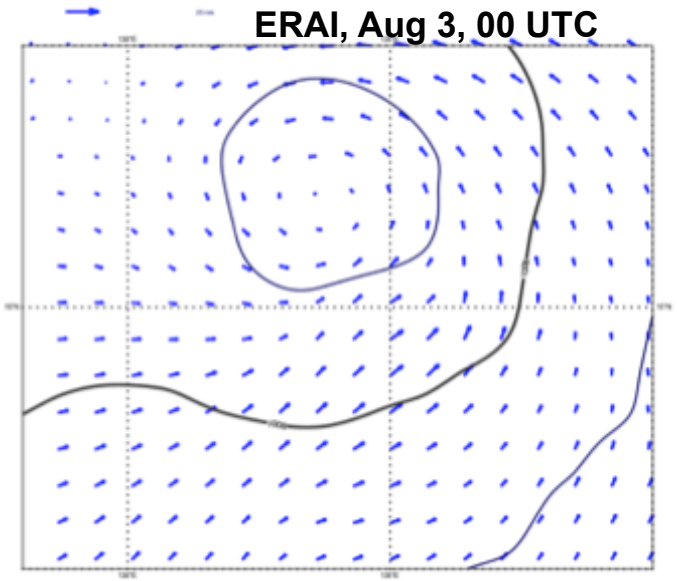


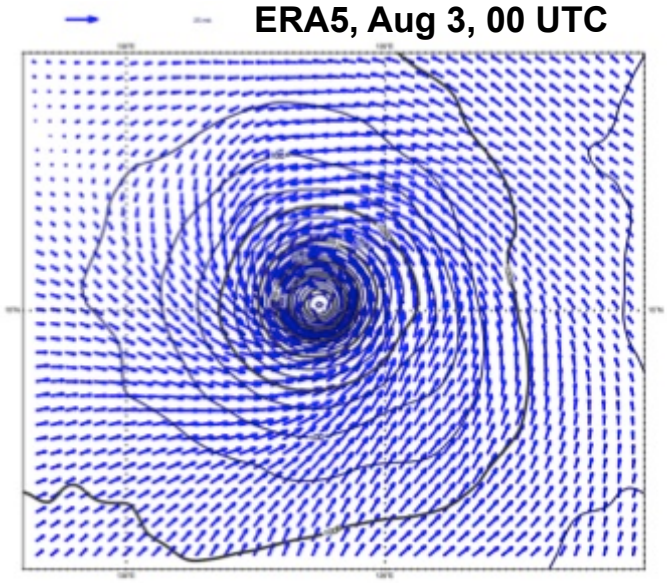
Comparion with other long data se



Super Typhoon Halong (August 20







- ERA5 much better than ERA-Interim,
- but not as good as ECMWF operations

Update on ERA5

ERA-Interim is 10 years old and needs replacement

The production of ERA5 is well underway:

- Higher resolution, hourly output, uncertainty estimate.
- Produced in parallel streams
- Public Release 2010-2016 end July 2017
- Release other stream to be done in stages within CDS

The performance of ERA5 is very promising in the troposphere.

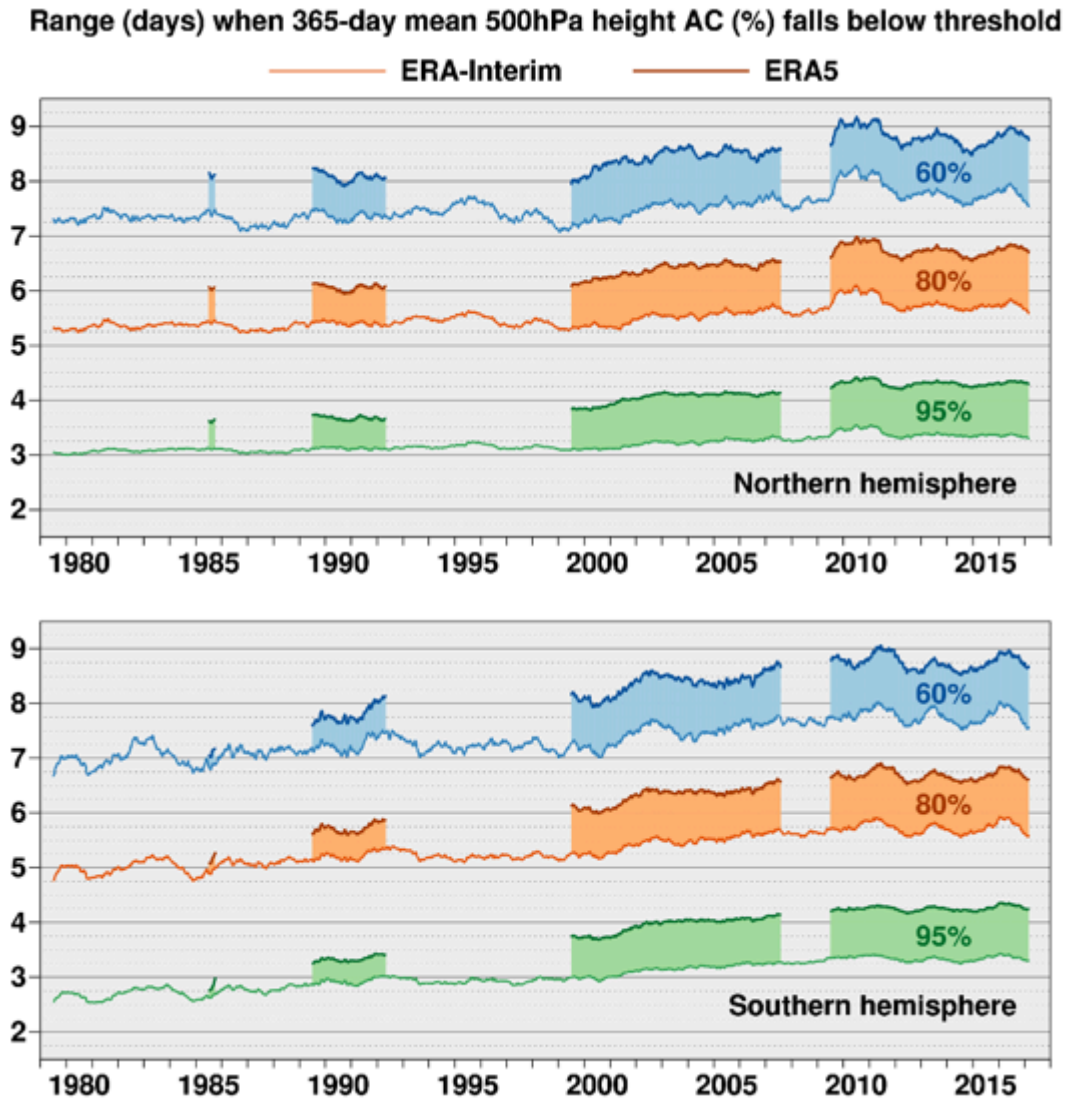
- improved global hydrological and mass balance
- reduced biases in precipitation,
- refinement of the variability and trends of surface air temperature.
- …

There are some imperfections, though

- Bias upper stratosphere
- Tropical jet mesosphere
- Initially there were quality issues over the southern hemisphere in the 1980s (delay in production stream)

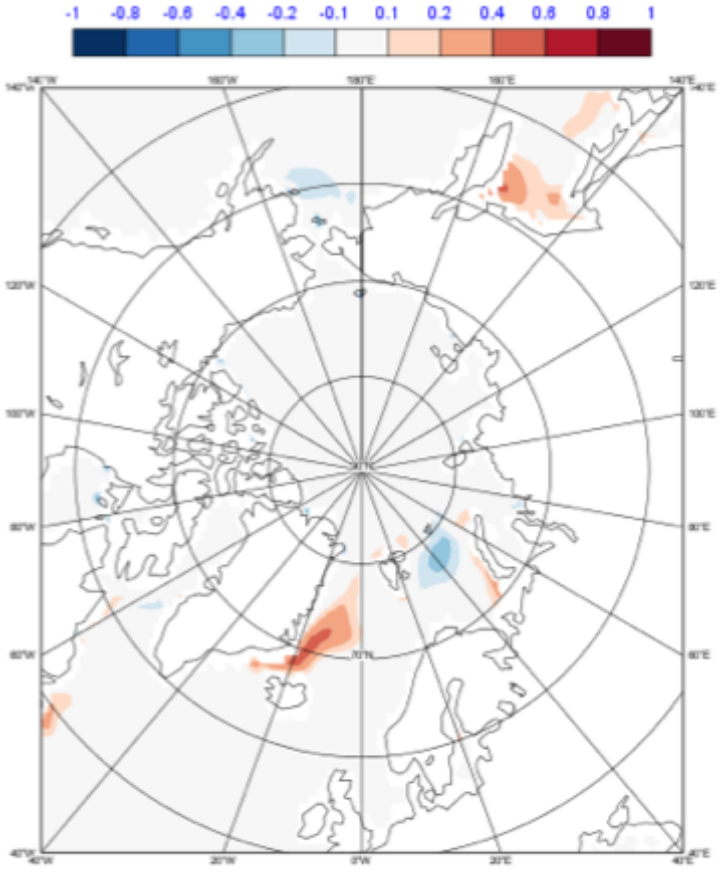
At ECMWF activities are focused towards a coupled Earth system

- Benefit to reanalysis (ERA6)

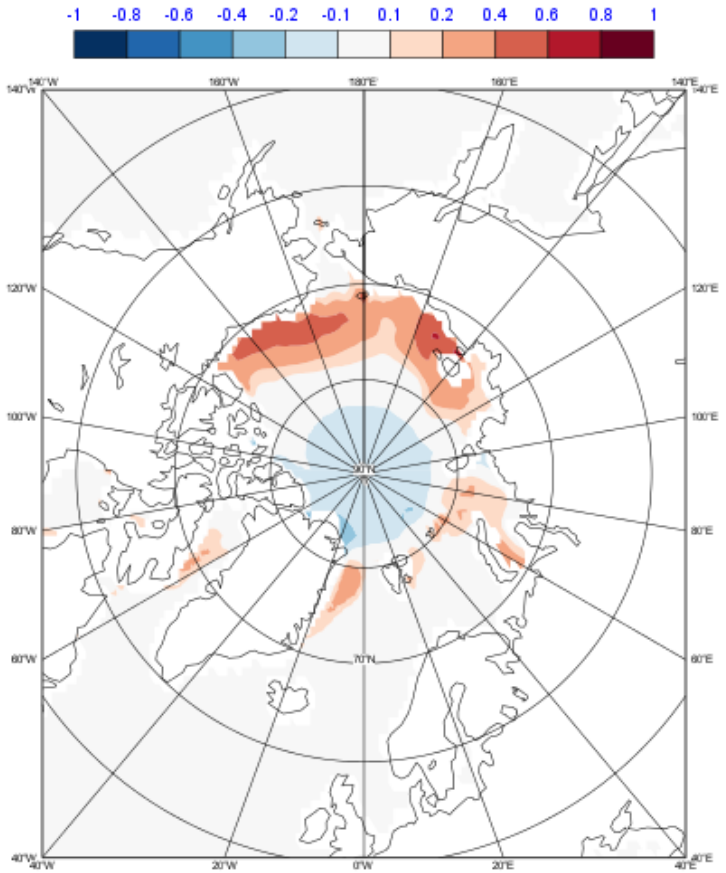


Sea ice cover – bias against ERA-Interim

February



August



….at the expense of the introduction of sea ice biases.

ERA5 Release Plan

Q2 2017: public release 2010 – 2016

Access: initially similar to ERA-Interim (Web-API)

later (Jan 2018) via the **C3S Climate Data Store**

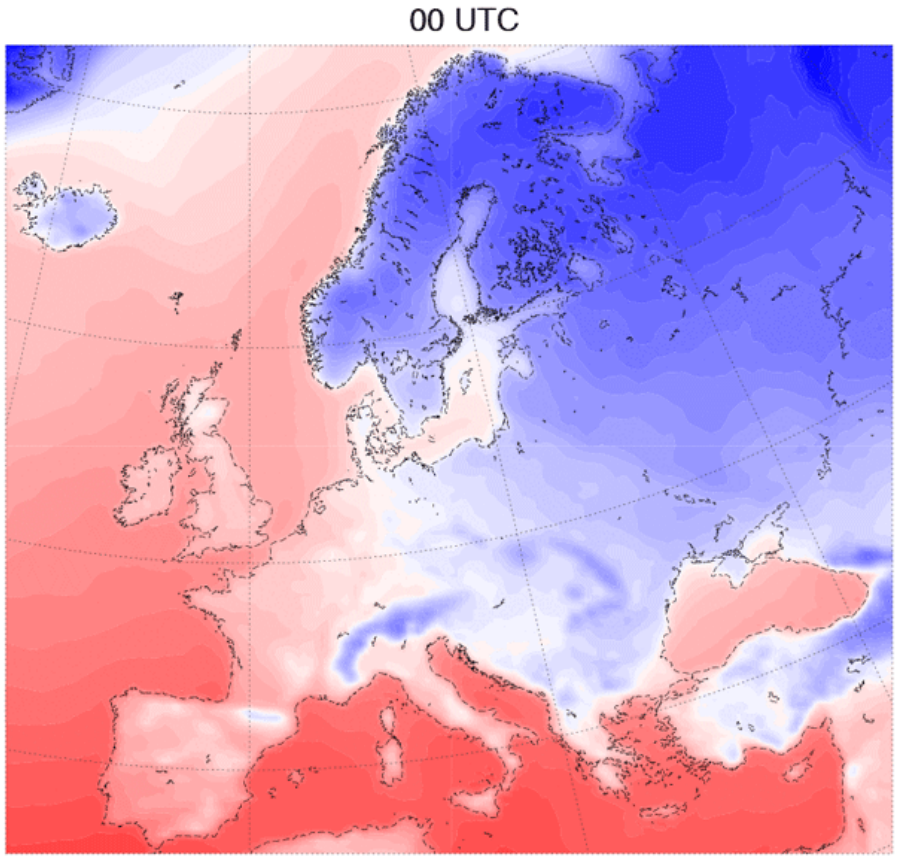
Q3/4 2017: 2017 – timely updates

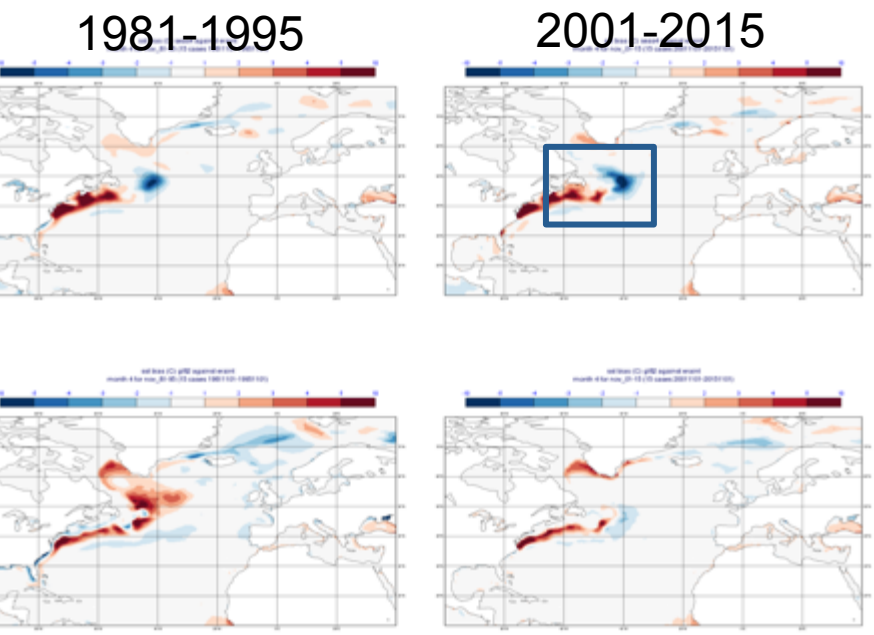
- ERA5: Updates with about 2-months delay (final product)
- ERA5T: Updates with short delay (<1 week, preliminary product)

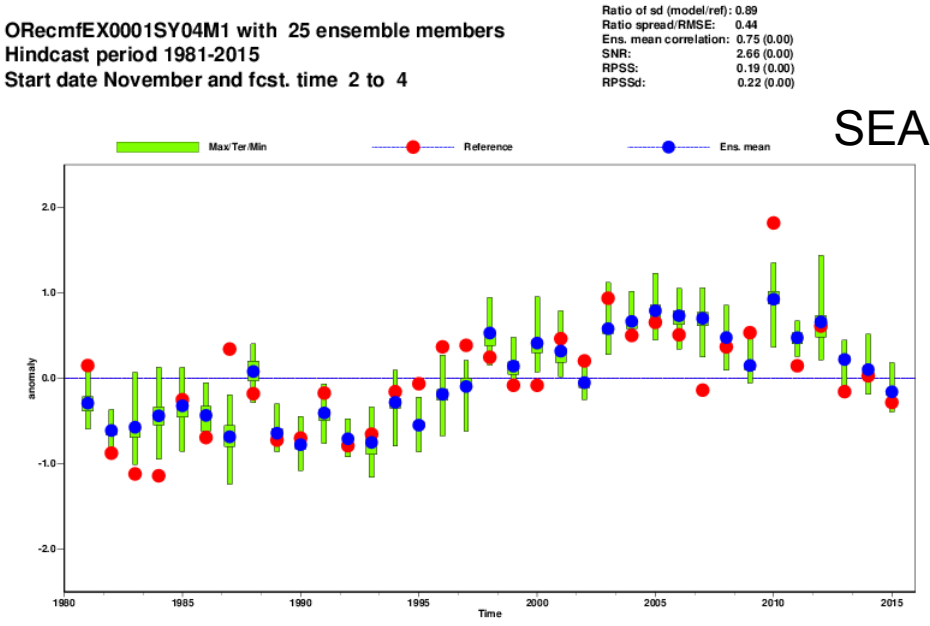
Q1/2 2018: Release 1979 – 2009:

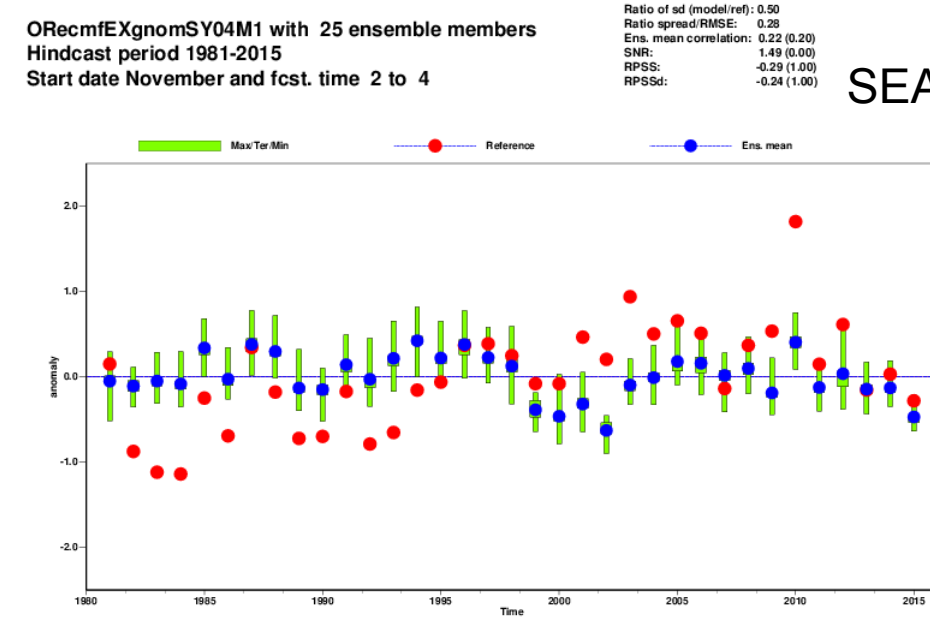
- Continue ERA5 timely updates
- Continue ERA-Interim for another 6 months

2018: integration of ERA5 segment from 1950





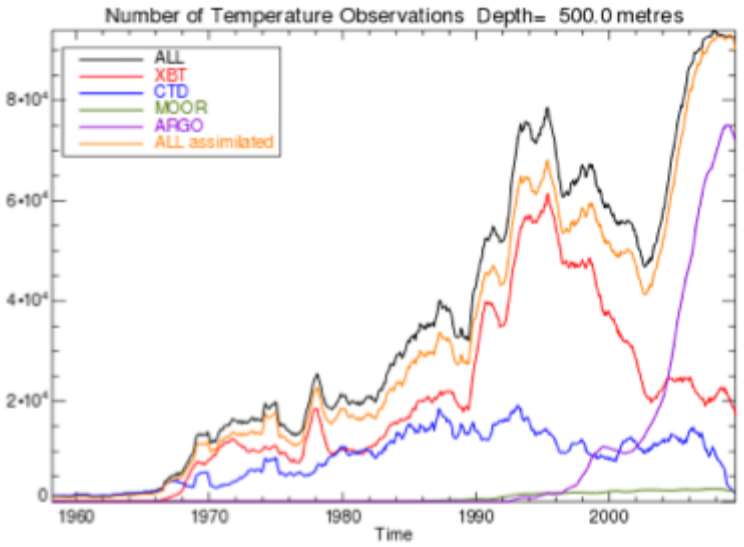




AS5 loss of DJF surface temperature skill over part of North ntic:

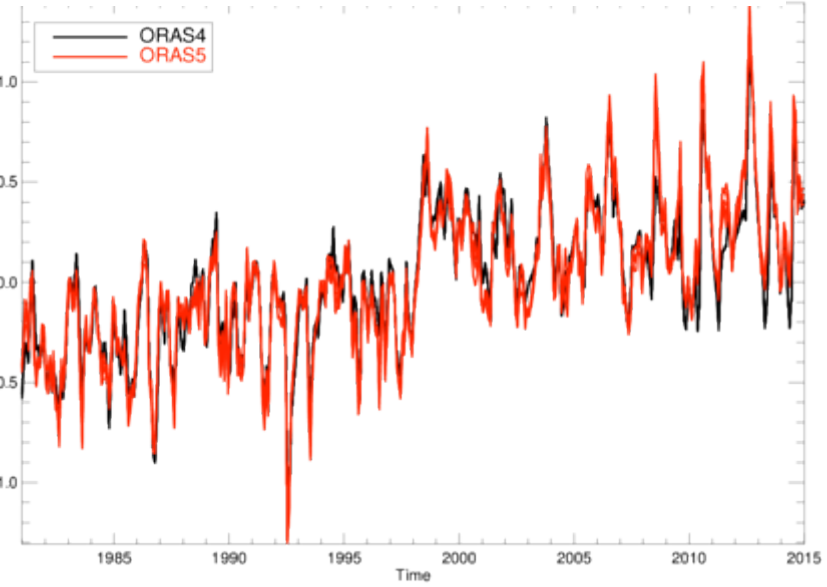
- due to warm SST bias in early period that disappears around 2000
- sensitivity experiments suggest problem with initial conditions (ORAS5)
- ORAS5 before 2000 has error balance: too high northward ocean heat transport and high artificial heat extracting through relaxation to observed SST

1) Changing observing system
Quality of ocean initial conditions not constant in time

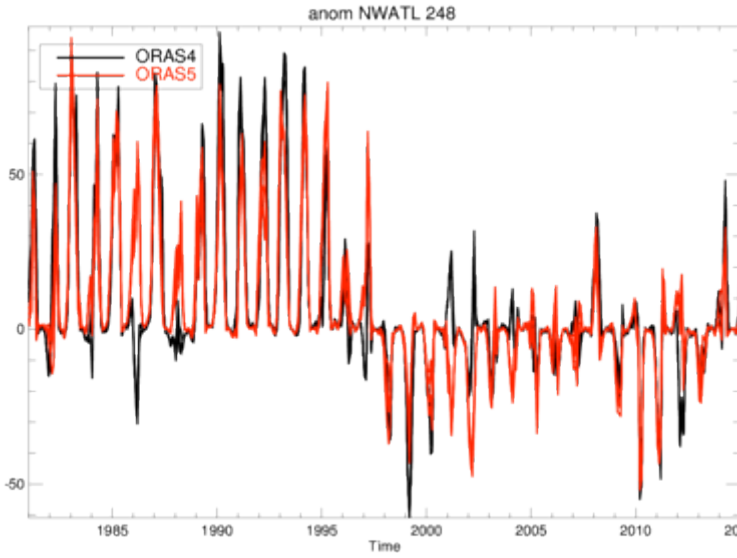


2) Decadal Signals and Regime shifts:
Non stationary climate may lead to **non stationary errors**.

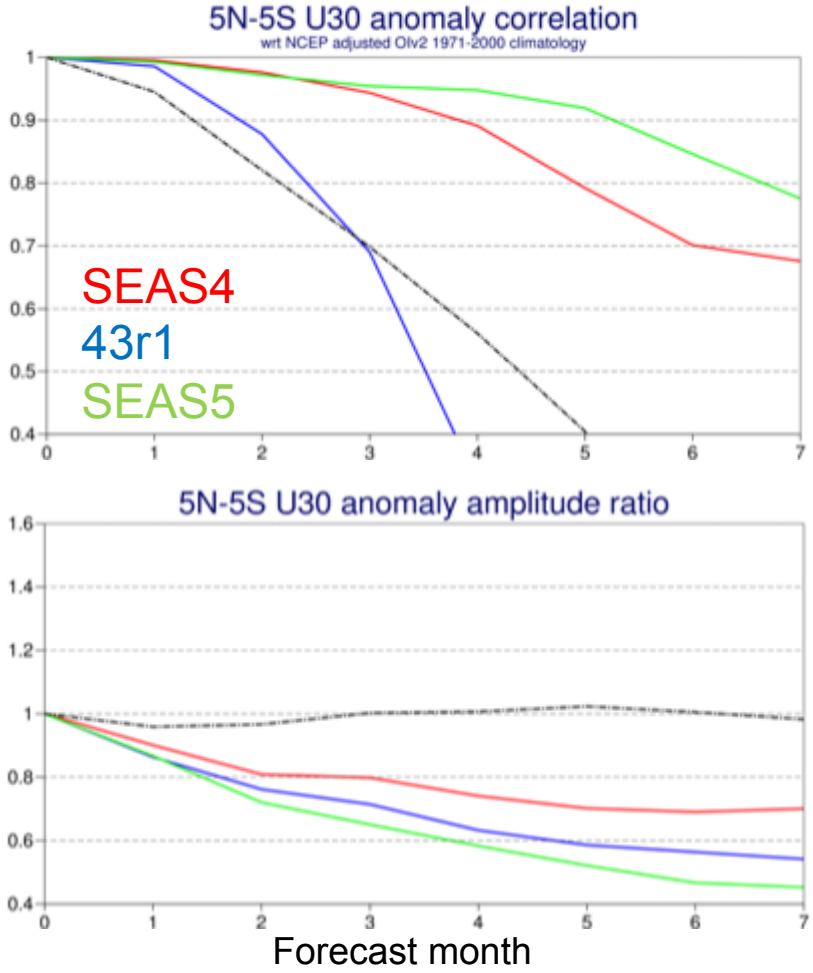
SST anomalies in Nwest Atlantic



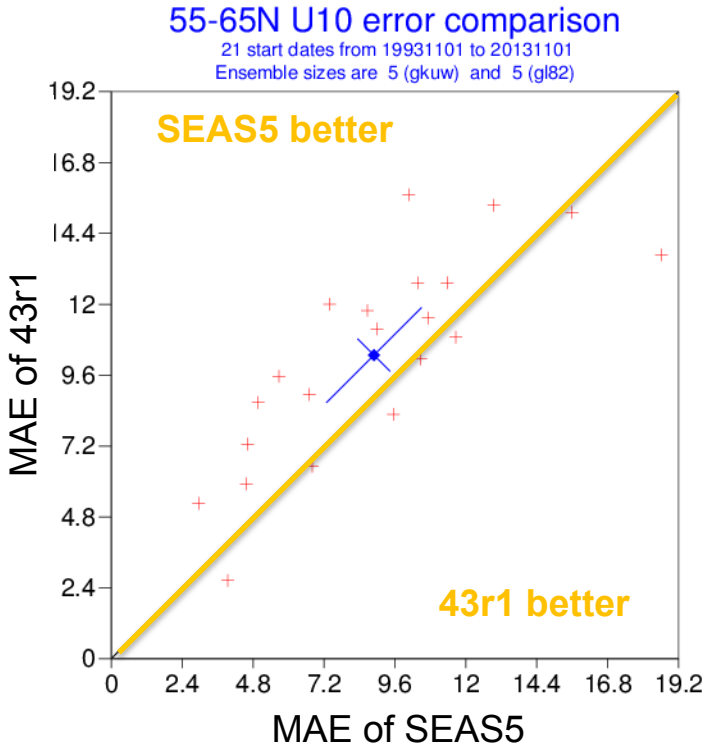
Mixed Layer depth in Nwest Atlant



QBO



The improved mean state winds improve the forecasts of the QBO to be comparable with, or better than, SEAS4.

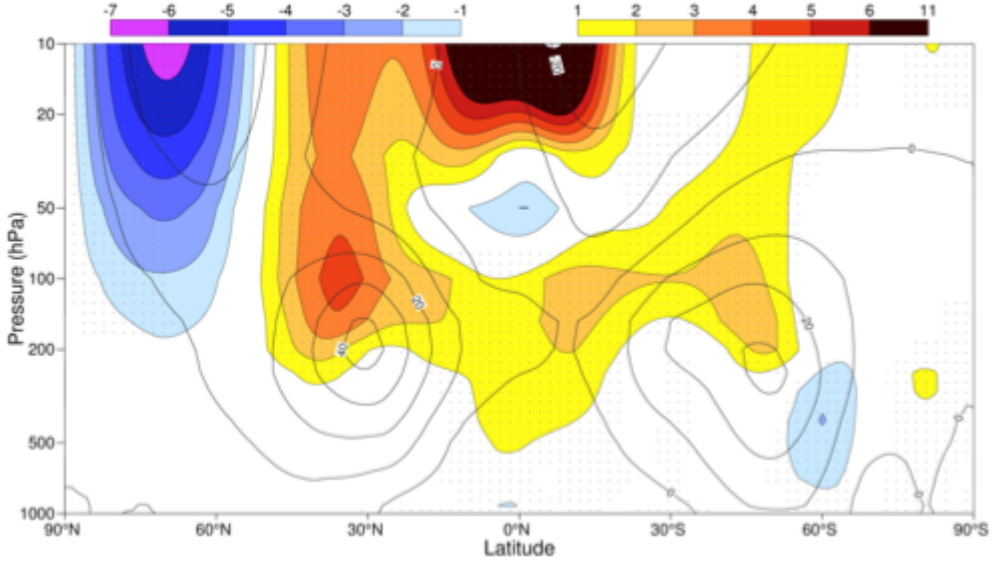


Decreasing GGAUSSB also improves DJF 60N U10 forecasts. Polar vortex forecasts improved from 1-100 hPa.

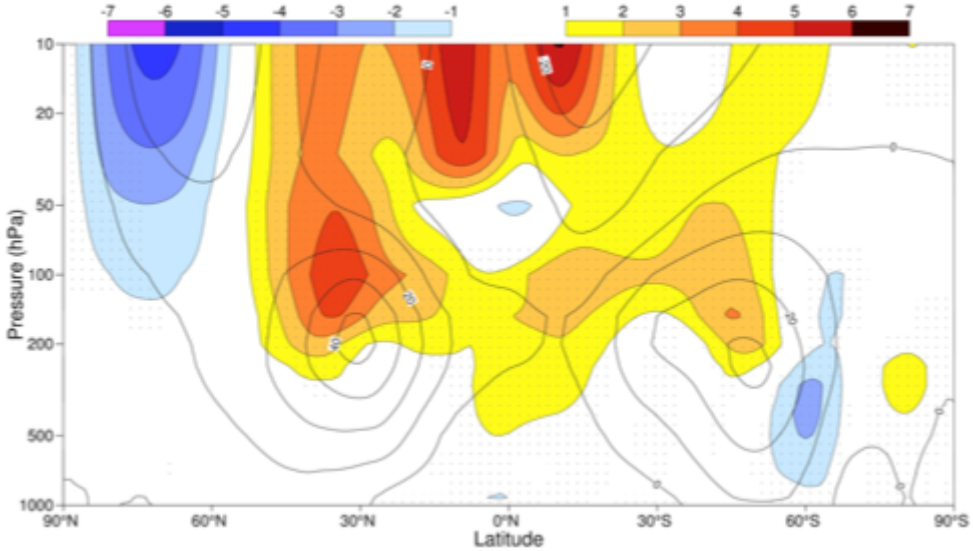
Stratosphere: adjusting tropical non-orographic GWD

DJF zonal winds biases with respect to ERA-Interim

43r1



SEAS5: GGAUSSB=-0.95



To improve the winds biases in SEAS5, non-orographic gravity wave drag in the tropics is reduced by decreasing GGAUSSB from -0.25 to -0.95. This is being considered for inclusion in a future IFS cycle.

Decreasing GGAUSSB significantly improves the zonal winds in the stratosphere, but has only a small impact on the temperature.