Polar prediction at ECMWF

Peter Bauer

Magdalena Balmaseda-Alonso, Niels Bormann, Mohamed Dahoui, Laura Ferranti, Martin Janousek, Thomas Jung, Sarah Keeley, Martin Leutbecher, Soumia Serrar, Yongming Tang, Frederic Vitart

ECMWF

Polar prediction at ECMWF

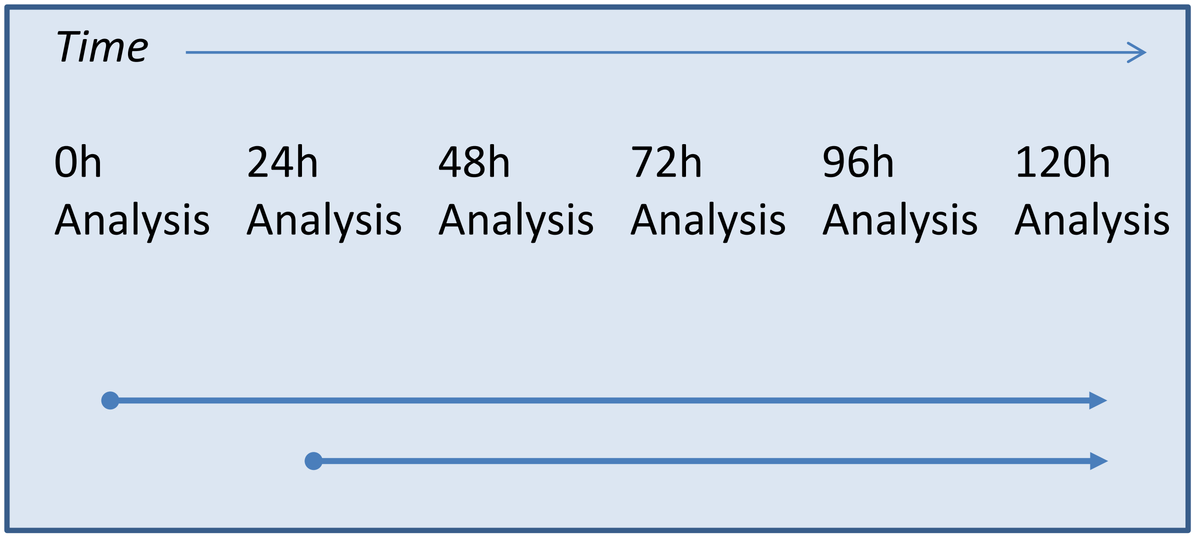
Headline items from WWRP/THORPEX PPP Science Plan:

- User applications and societal benefit
- Verification
- Observations
- Modelling
- Data assimilation
- Ensemble Forecasting
- Predictability & forecast error diagnostic
- Global linkages

Selected ECMWF polar studies:

- Klinker & Ferranti 2000, Tech memo: Summer 1999 forecast performance
- Simmons et al. 2003, J. Atmos. Sci.: Southern polar vortex break-up
- Bormann & Thépaut 2004, Mon. Wea. Rev.: MODIS polar AMVs
- Jung & Leutbecher 2007, QJRMS: Arctic performance
- Jung & Rhines 2007, QJRMS: Greenland orography and storm tracks
- Balmaseda et al. 2008, QJRMS: Role of coupling in seasonal forecasting
- Tang et al. 2013, Ocean Model.: Sea-ice thickness initialization
- 2006 Seminar on polar meteorology

Medium-range predictability



→ < Analysis tendency >
= variability of state

< (forecast$_i$ – analysis)
- (forecast$_{i+1}$ – analysis)>

→ < Forecast error tendency >
≈ forecast consistency

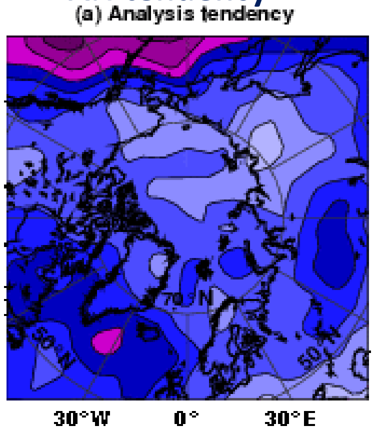
→There is predictability if analysis tendencies > forecast tendencies
(Jung & Leutbecher: true up to day-3, data from 2001-2006)

Medium-range predictability: Error growth z500

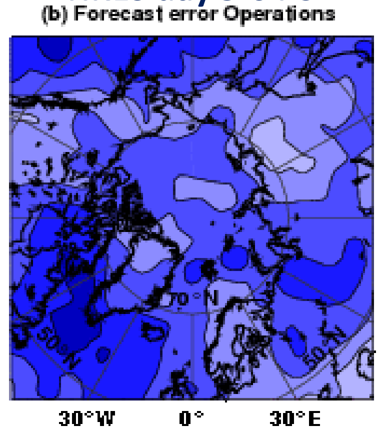
Assumption: predictability exists if forecast error growth ≤ day-to-day variability

MAM 2006

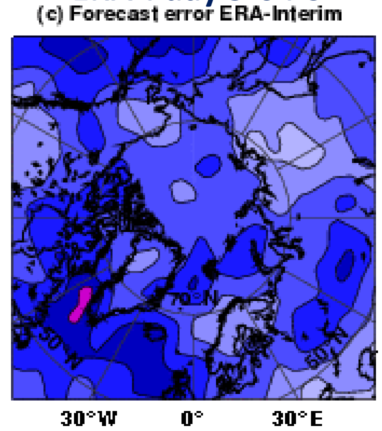
AN tendency



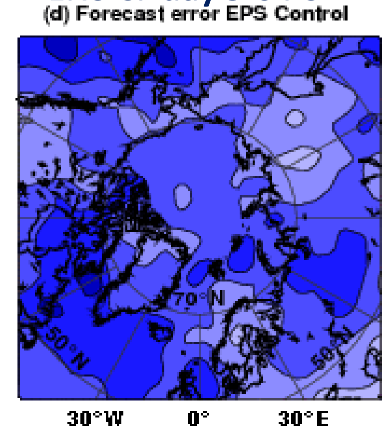
HRES day 5-6 FC



ERA-I day 5-6 FC

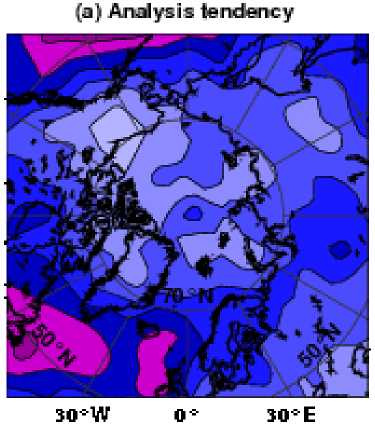


ENS CF day 5-6 FC



MAM 2012

AN tendency



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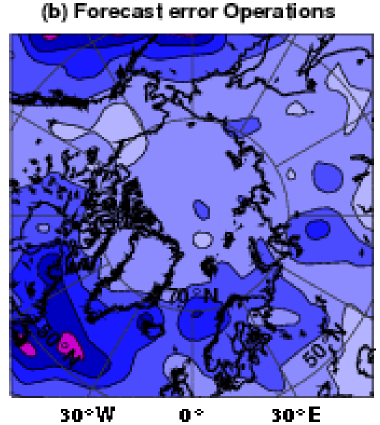
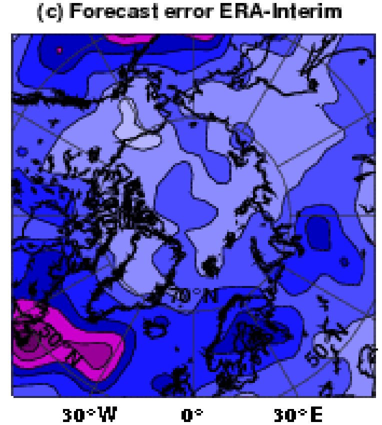
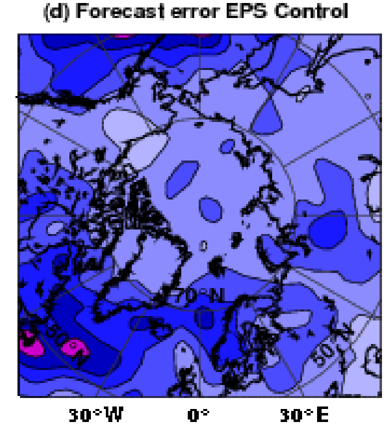


ERA-I day 5-6 FC



ENS CF day 5-6 FC



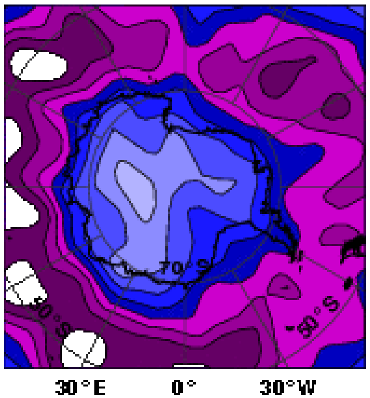
Medium-range predictability: Error growth z500

Assumption: predictability exists if forecast tendency ≤ day-to-day variability

MAM 2006

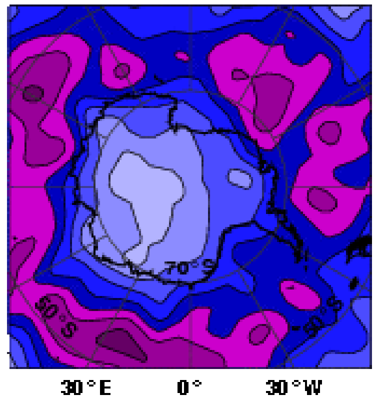
AN tendency

(a) Analysis tendency



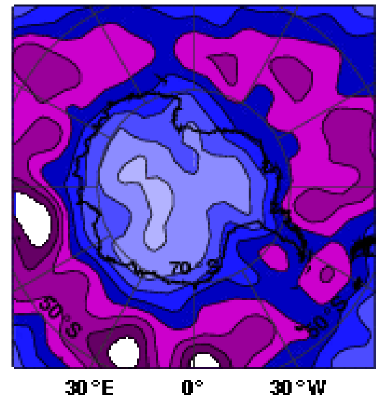
HRES day 5-6 FC

(b) Forecast error Operations



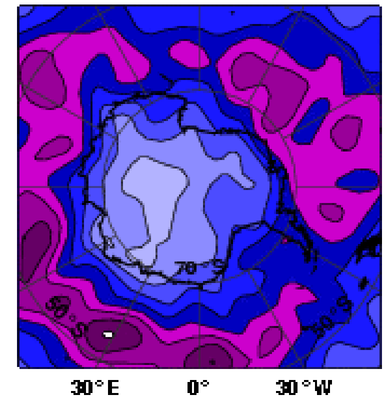
ERA-I day 5-6 FC

(c) Forecast error ERA-Interim



ENS CF day 5-6 FC

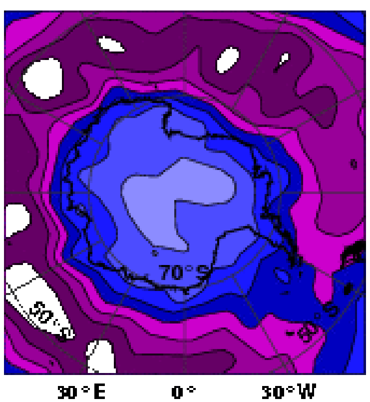
(d) Forecast error EPS Control



MAM 2012

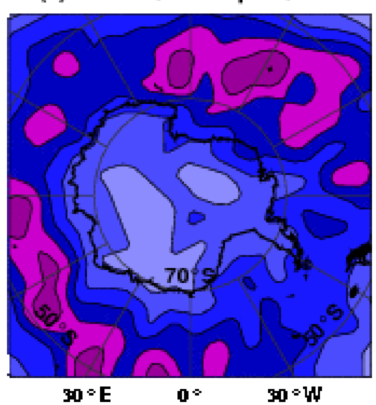
AN tendency

(a) Analysis tendency



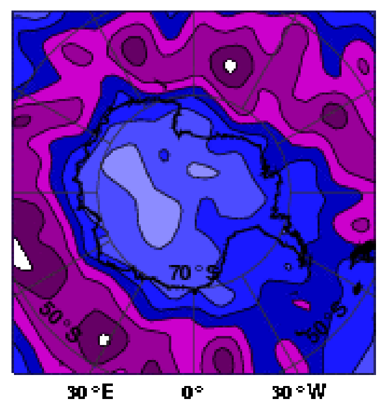
HRES day 5-6 FC

(b) Forecast error Operations



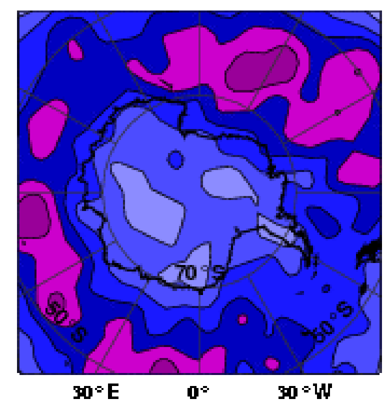
ERA-I day 5-6 FC

(c) Forecast error ERA-Interim

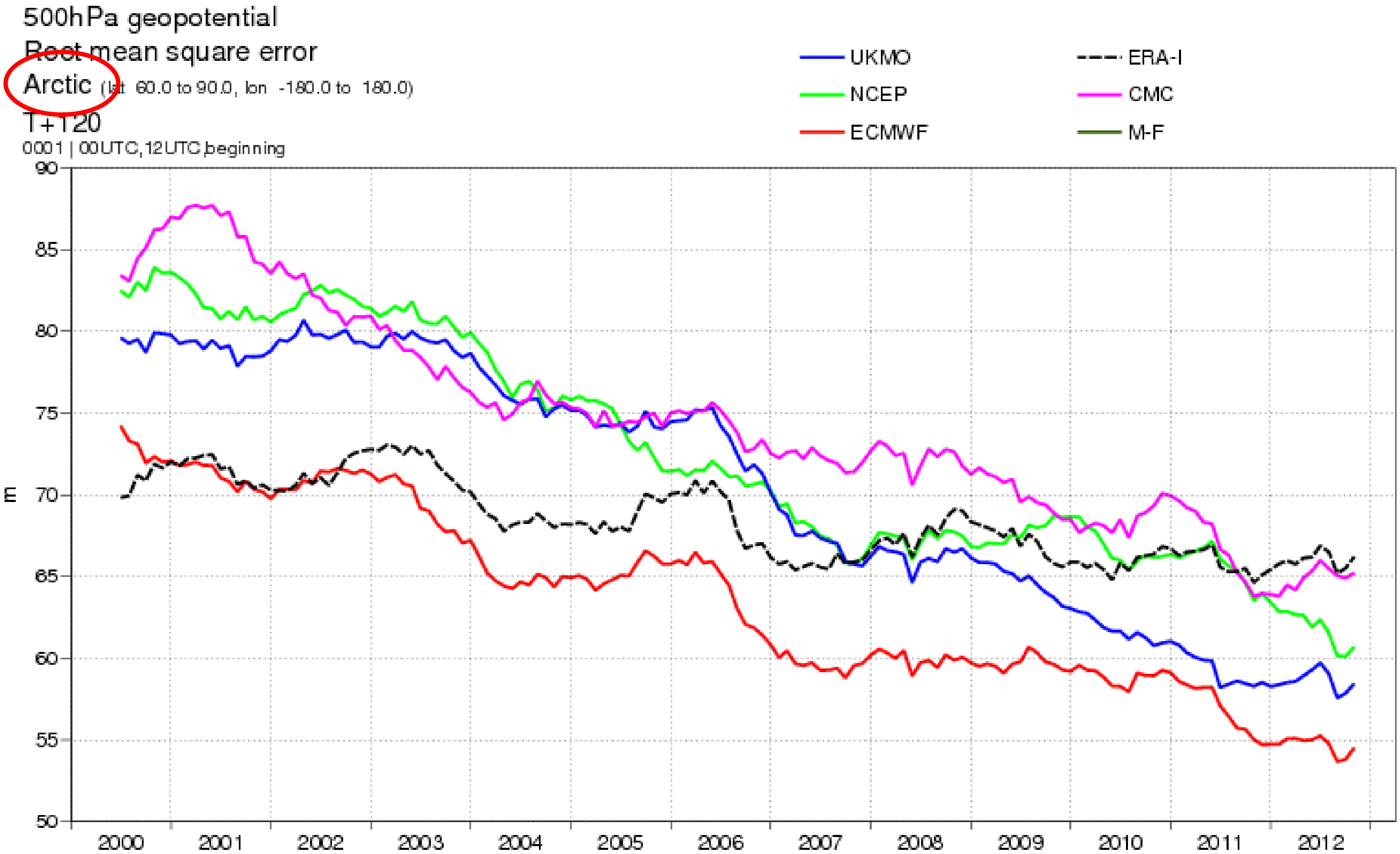


ENS CF day 5-6 FC

(d) Forecast error EPS Control

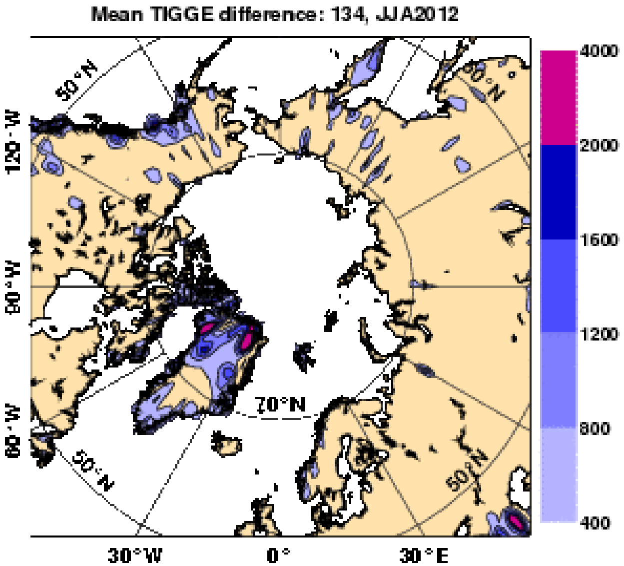


Forecast performance: Day-5 Arctic

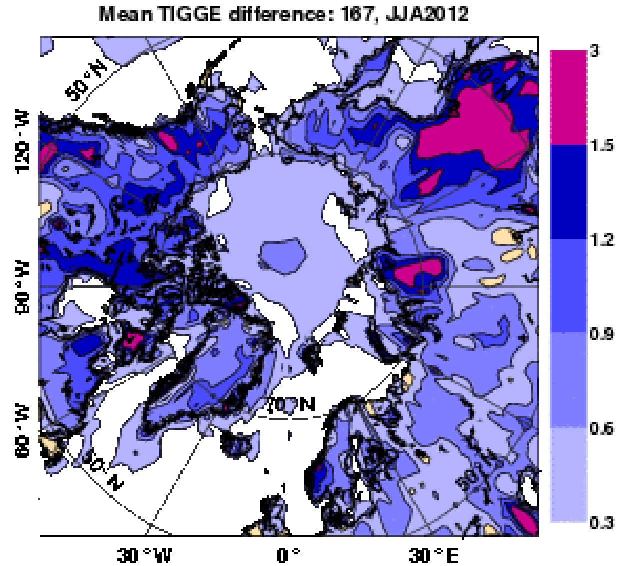


Spread between TIGGE models: Analysis, surface

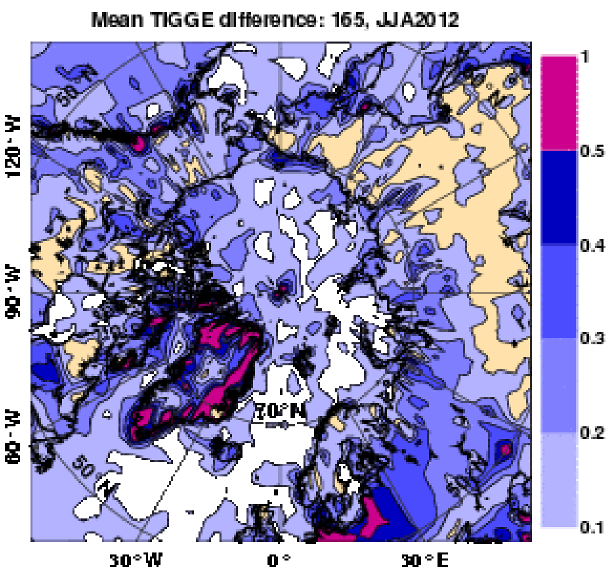
p_s:
[Pa]



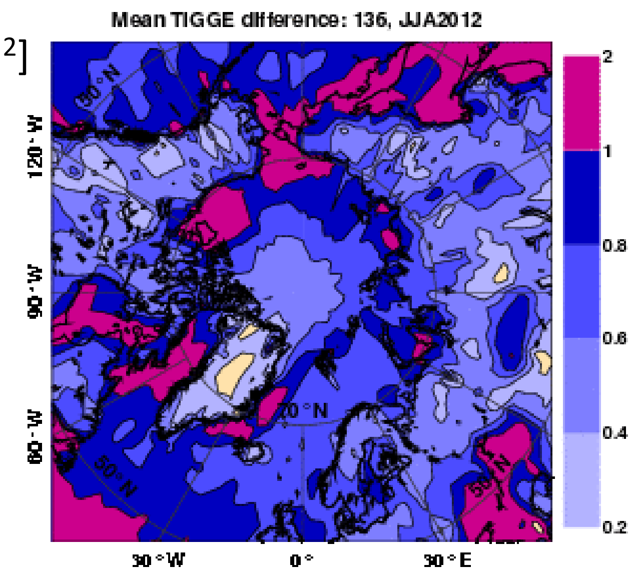
t2m:
[K]



u10m:
[m/s]



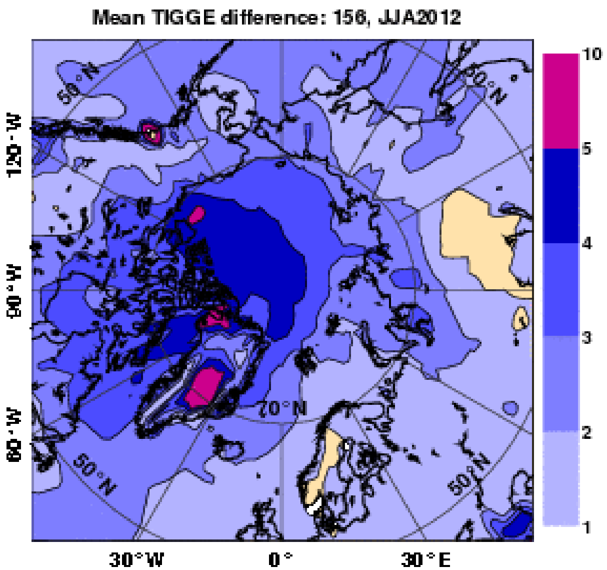
TCW:
[kg/m^2]



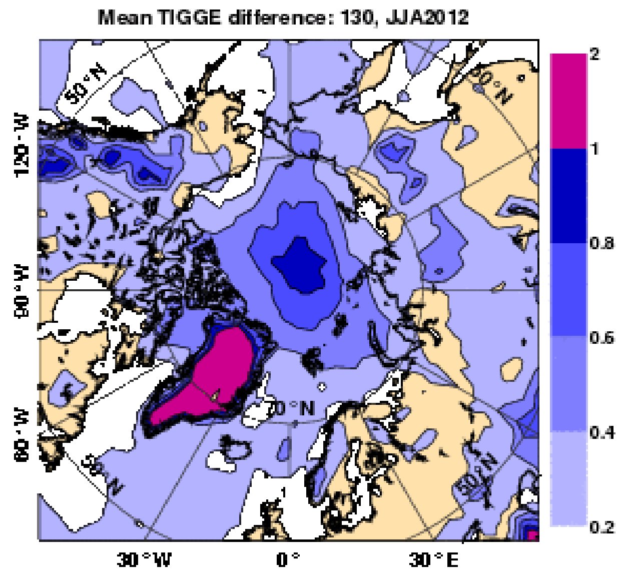
JJA2012

Spread between TIGGE models: Analysis, 850 hPa

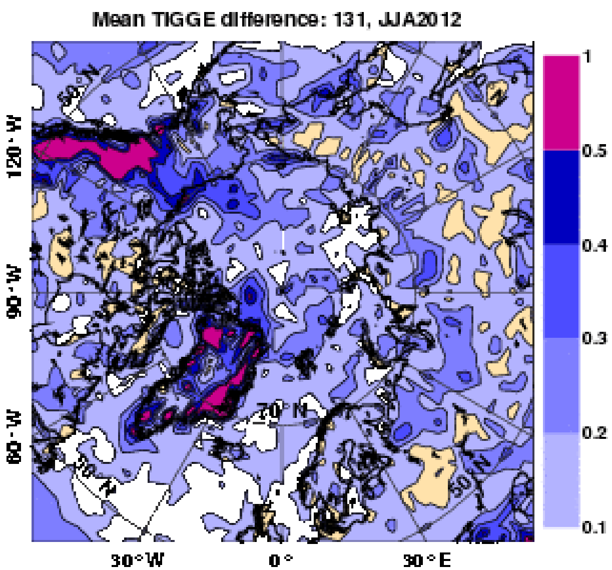
gh:
[m]



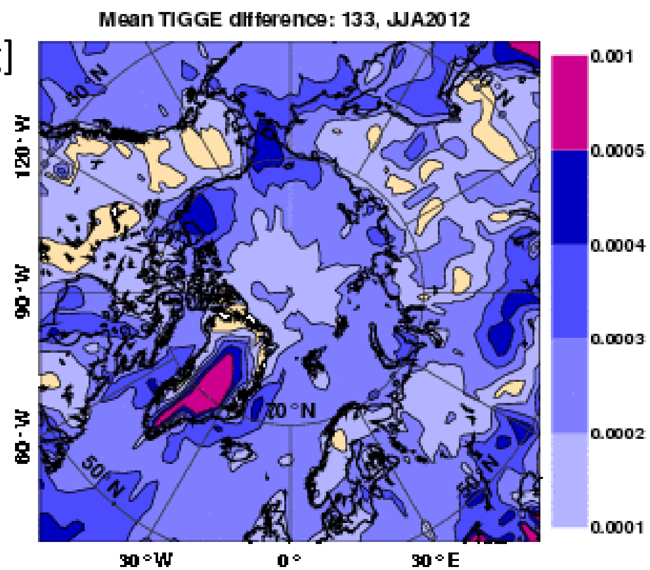
t:
[K]



u:
[m/s]



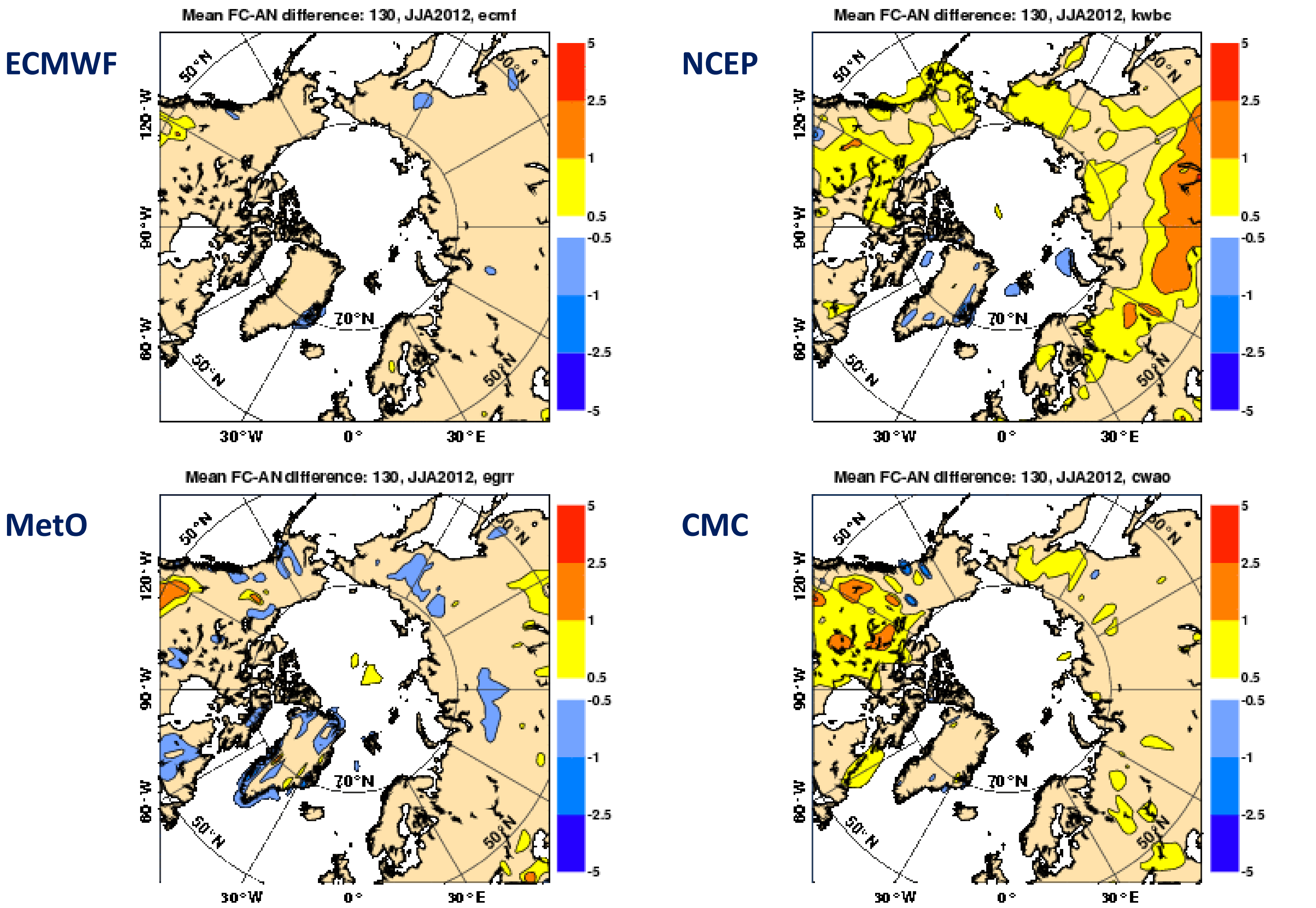
q:
[kg/kg]



JJA2012

24-hour spin-up for TIGGE models: Temperature 850 hPa [K]

24-hour FC - AN

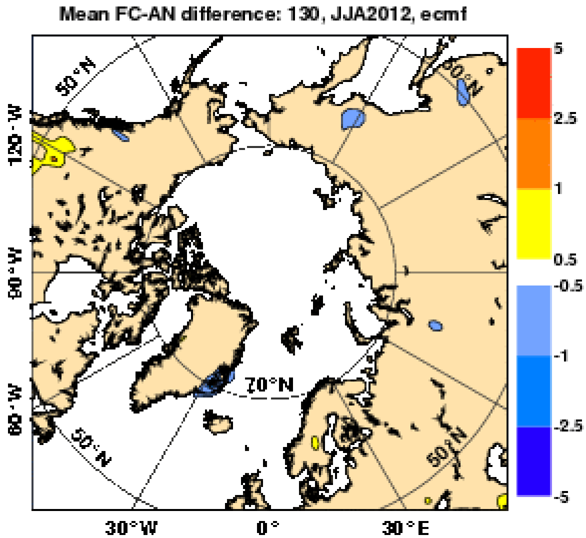


JJA2012

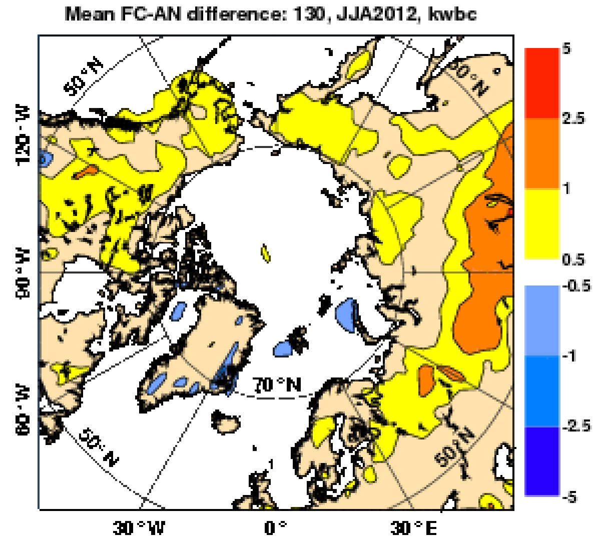
24-hour spin-up for TIGGE models: Temperature 850 hPa [K]

24-hour FC - AN

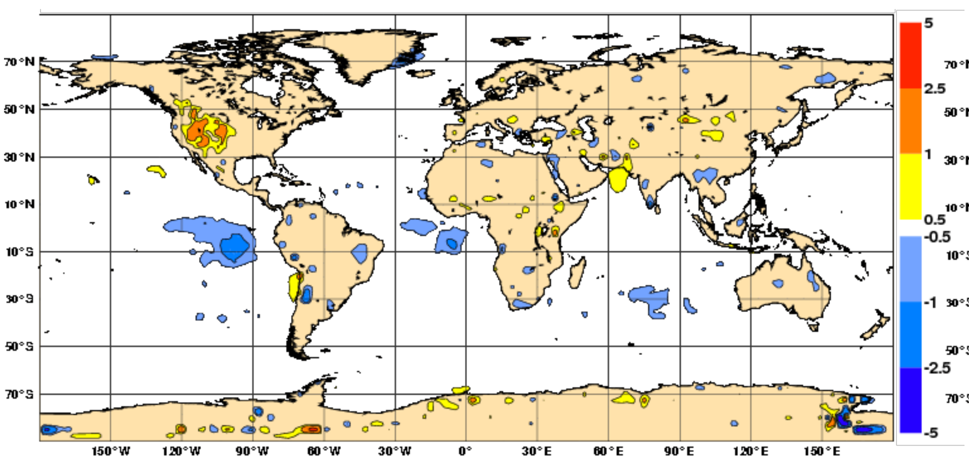
ECMWF



NCEP



ECMWF



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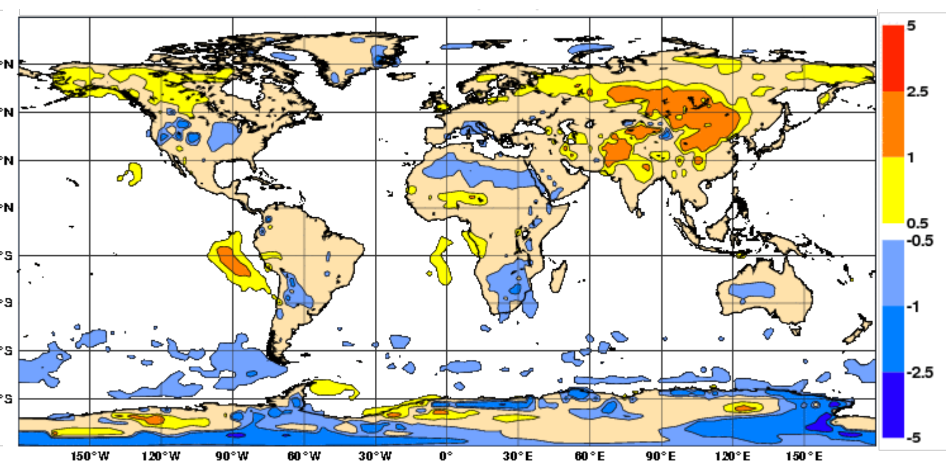
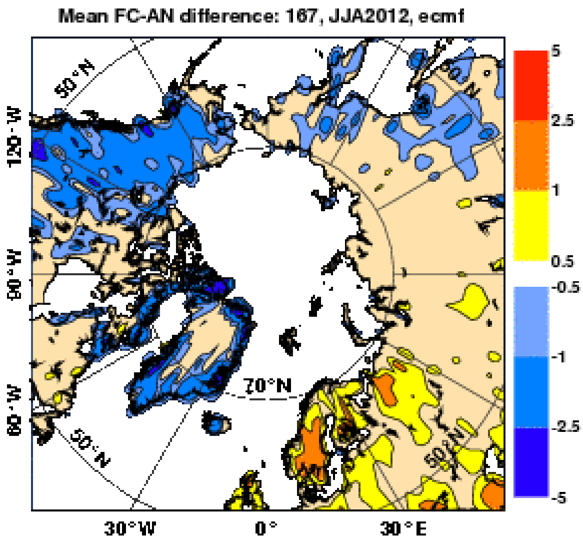


JJA2012

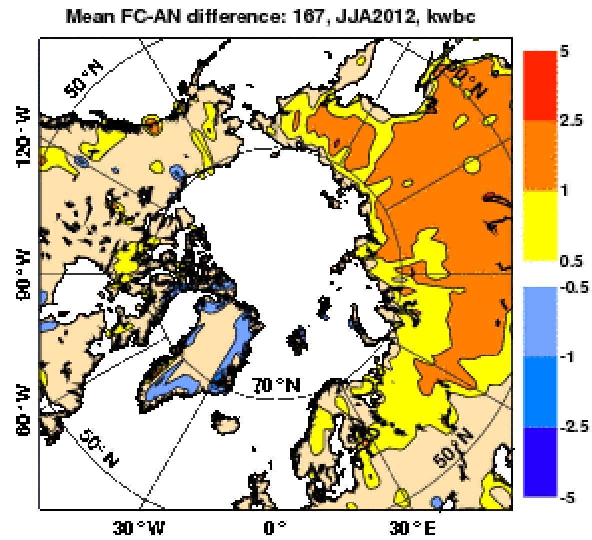
24-hour spin-up for TIGGE models: 2m temperature [K]

24-hour FC - AN

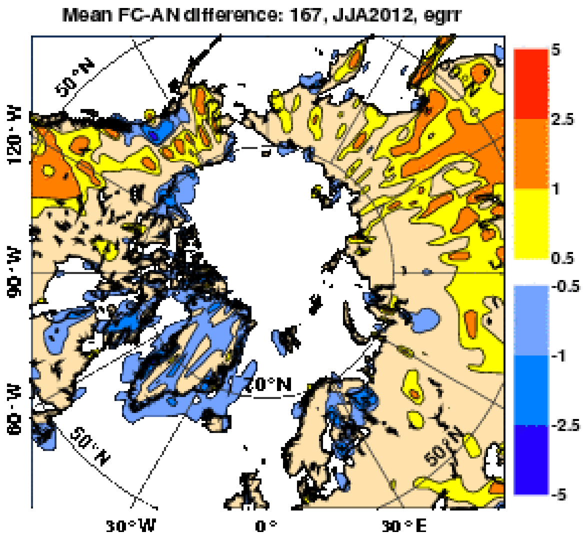
ECMWF



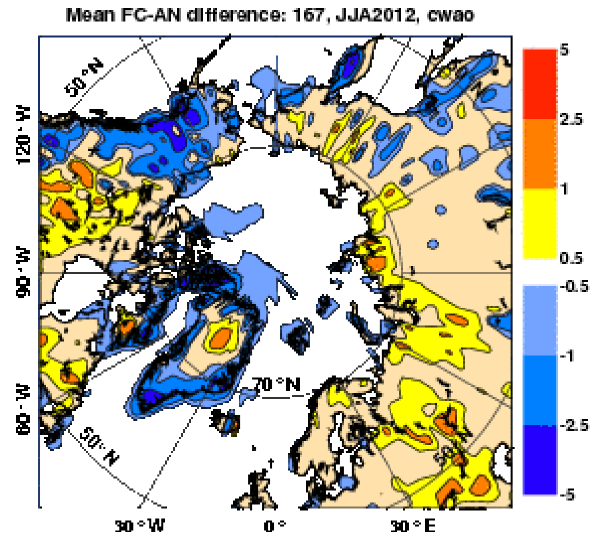
NCEP



MetO



CMC

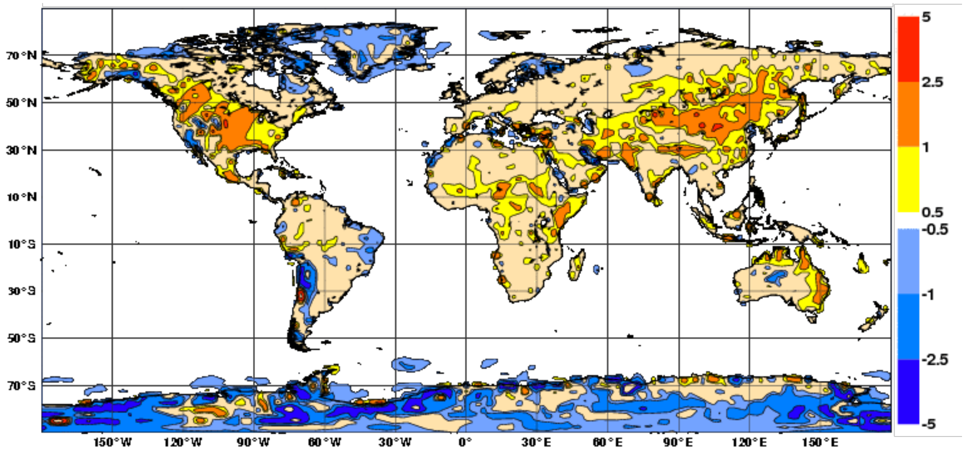


JJA2012

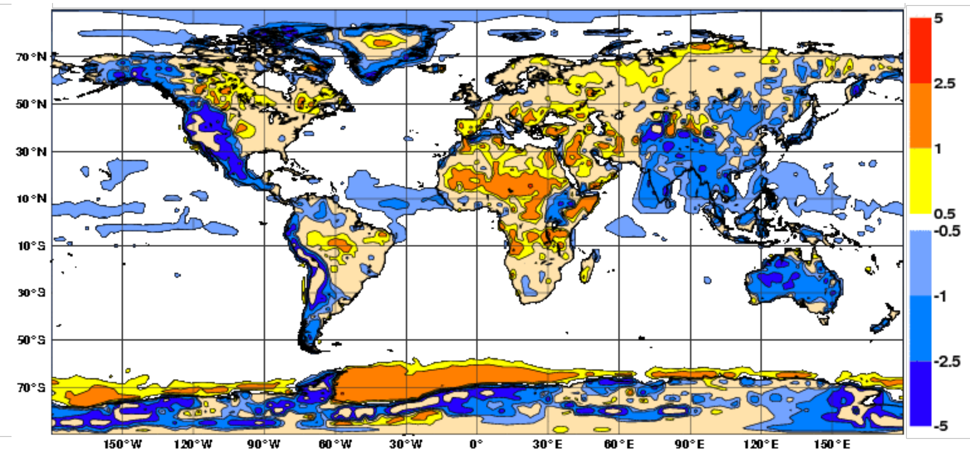
24-hour spin-up for TIGGE models: 2m temperature [K]

24-hour FC - AN

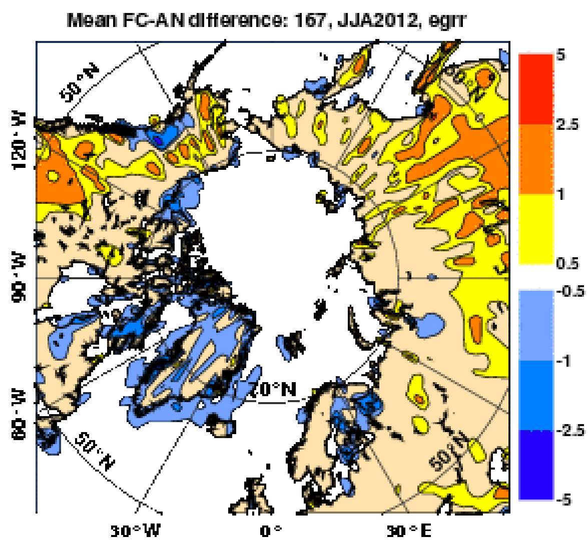
MetO



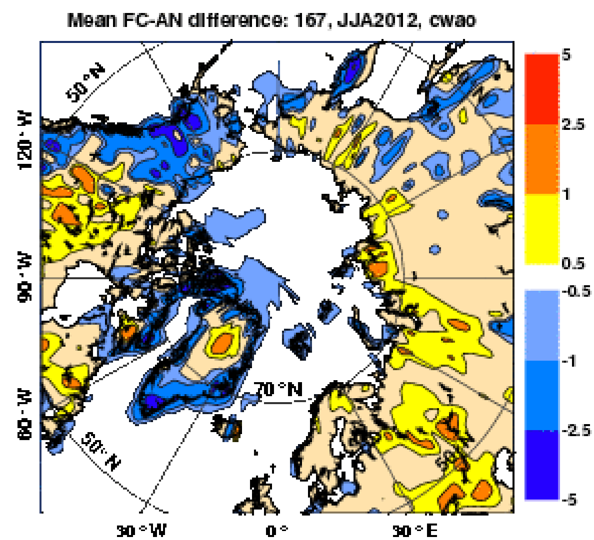
CMC



MetO

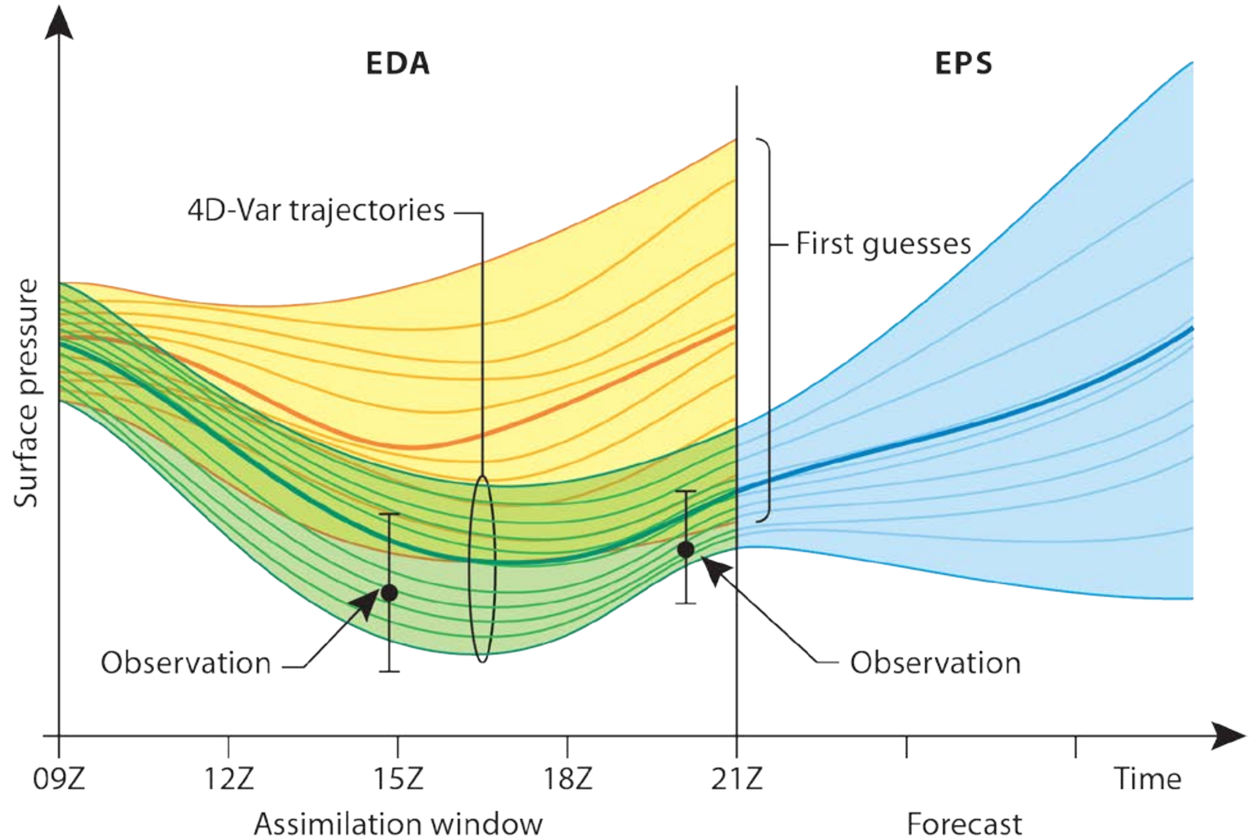


CMC



JJA2012

Polar data assimilation issues



Analysis uncertainty:

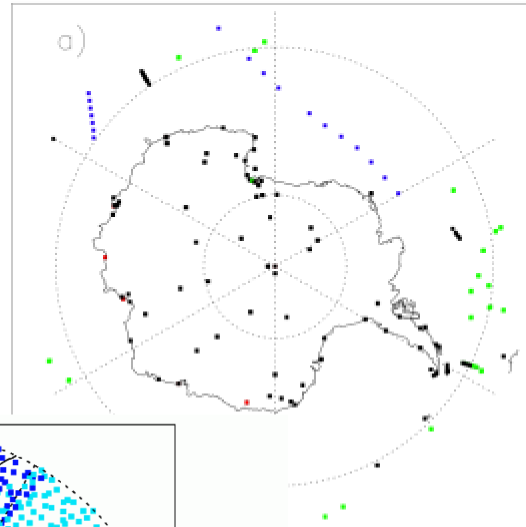
- Perturbed observations (**few**)
- Perturbed SST (**not sea-ice/snow**)
- Perturbed physics tendencies (**weak**)

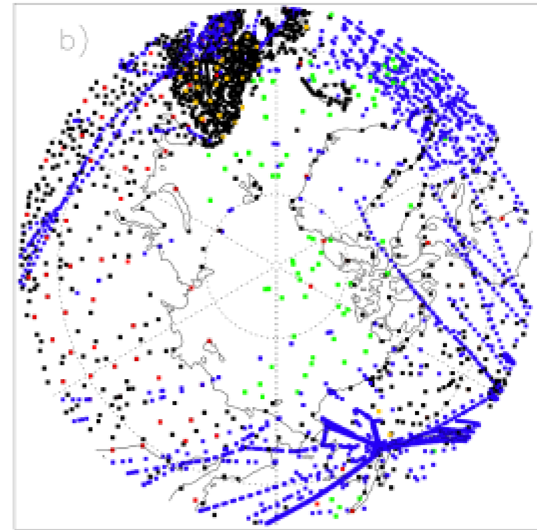
Forecast uncertainty:

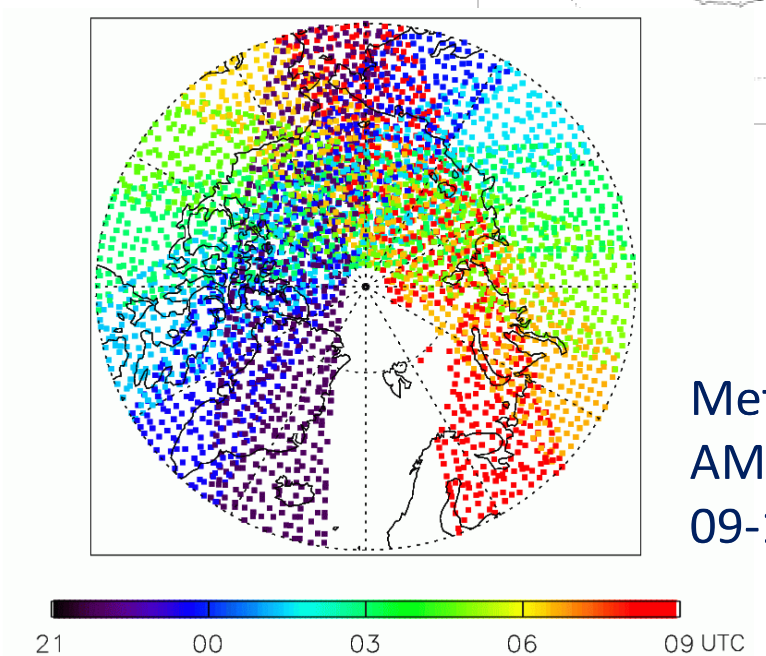
- Perturbed physics tendencies
- Stochastic backscatter
- Singular vectors

Polar data assimilation issues

Conventional
data coverage
09-12 UTC





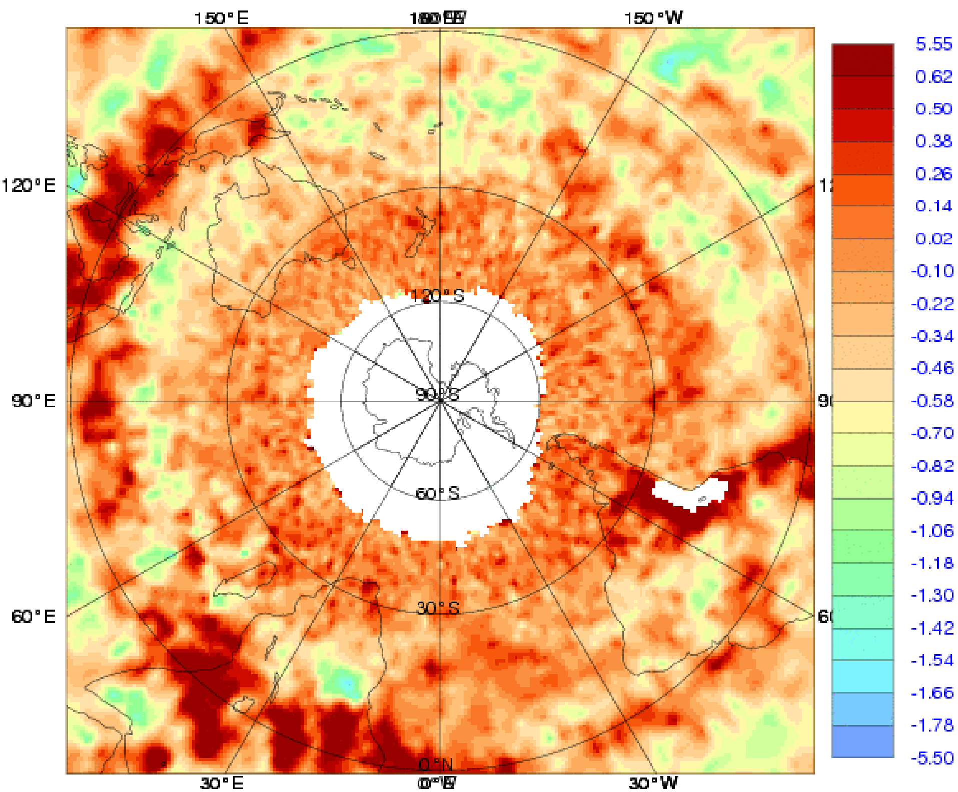


Metop
AMSU-A data coverage
09-12 UTC

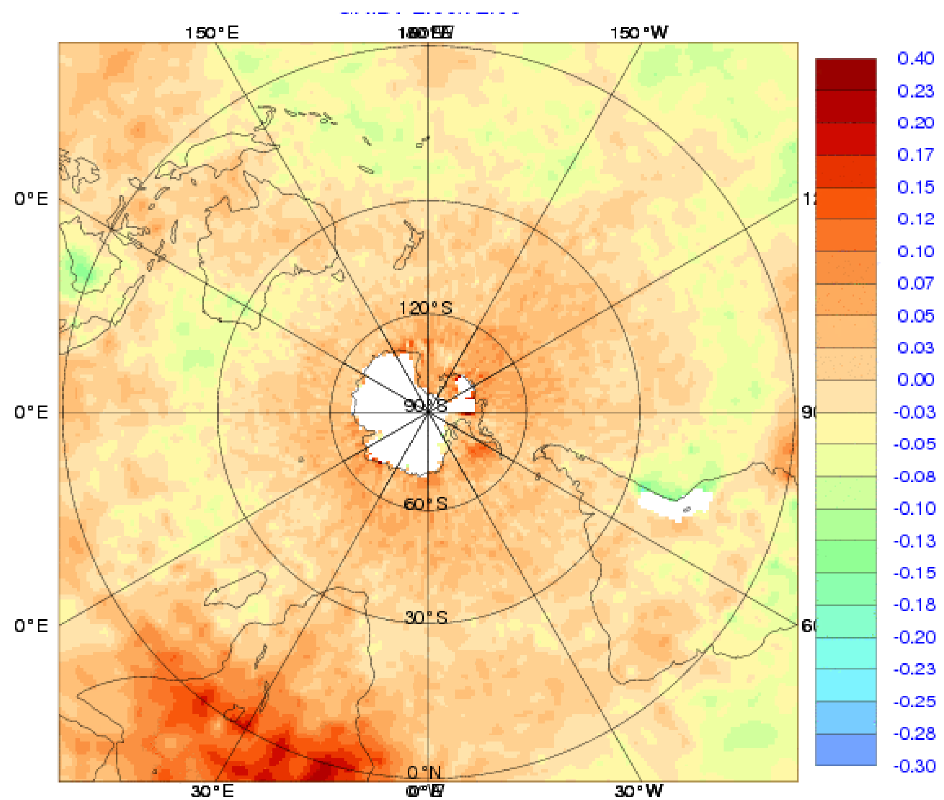
Polar data assimilation issues

Mean April 2013 observation-model radiances

MHS channel 3
upper tropospheric moisture



AMSU-A channel 6
low-mid tropospheric temperature



[Mohamed Dahoui]

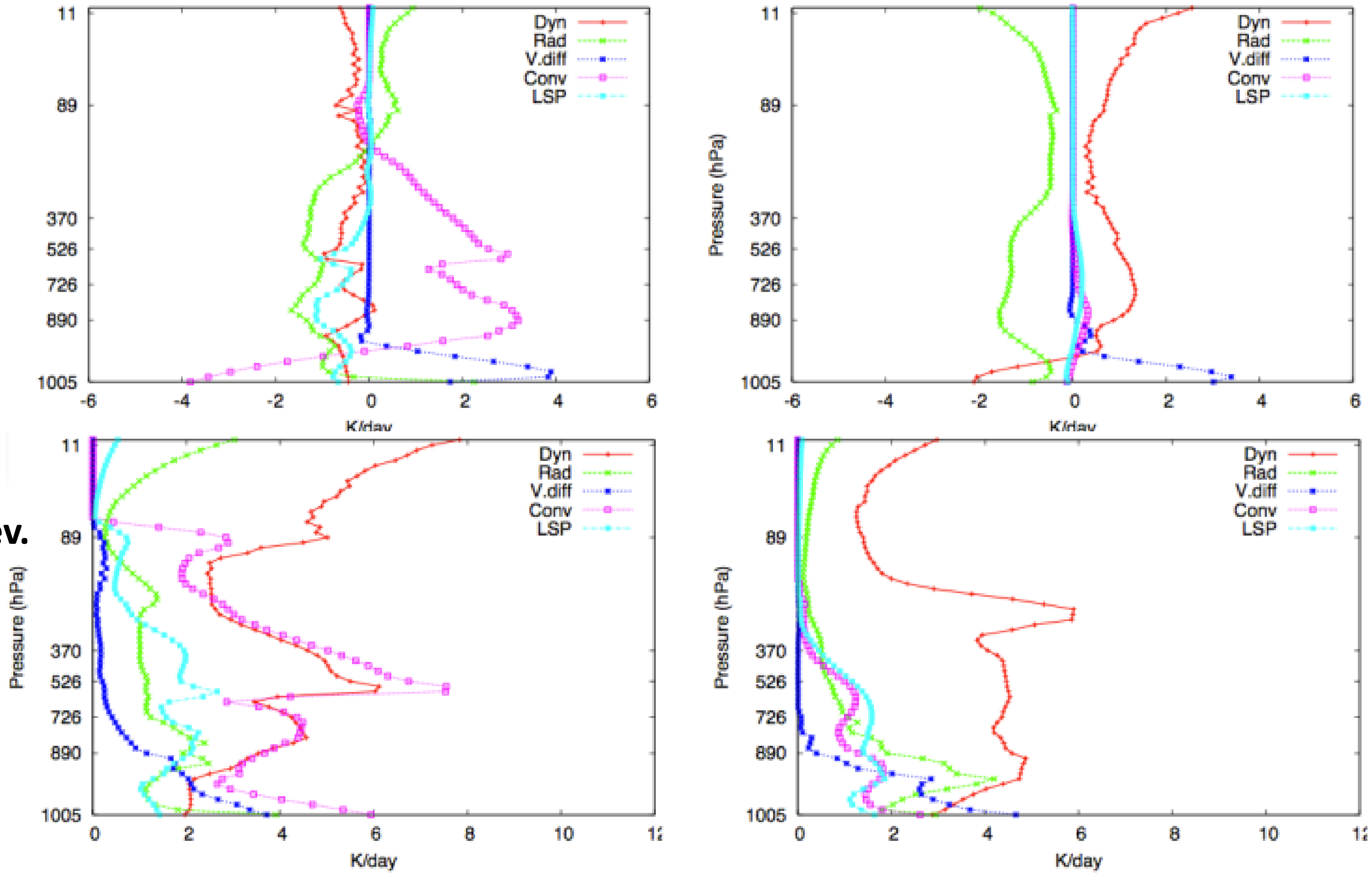
Polar data assimilation issues

Tropics: Sea points

Arctic: Sea and sea ice points

Mean

Std. dev.



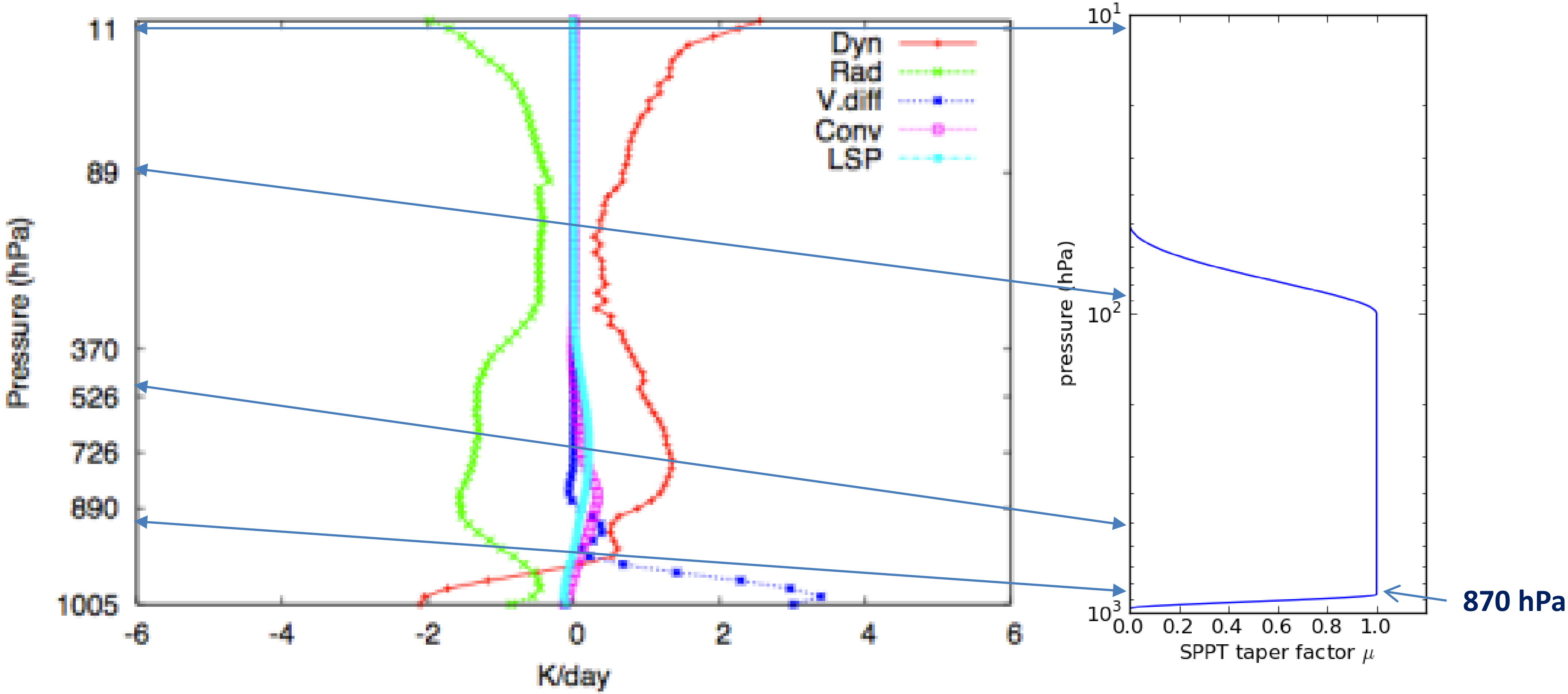
Inital 6-hour tendencies (DJF 1989-2010)

[Soumia Serrar]

Polar data assimilation issues

EDA-SPREAD = f (observation errors, SST, SPPT)

SPPT-tendency perturbations = tendency x tapering x 2d horizontal random pattern



Polar areas:

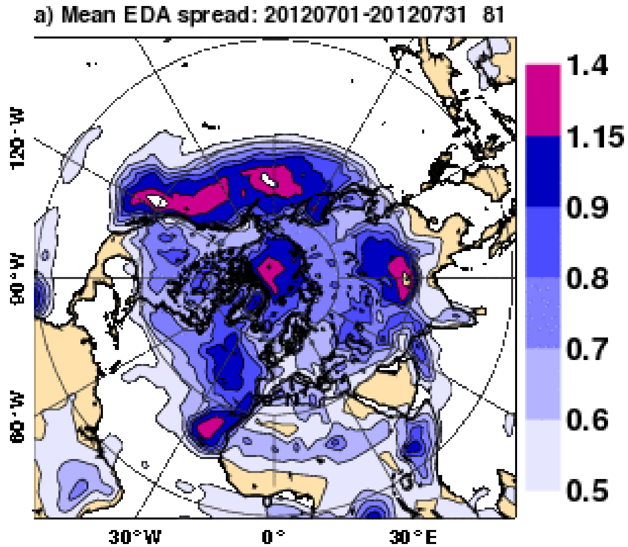
- Few observations
- Tapering affects low-level tendency structures (radiation & low cloud/albedo errors)
- No sea-ice/land surface perturbations

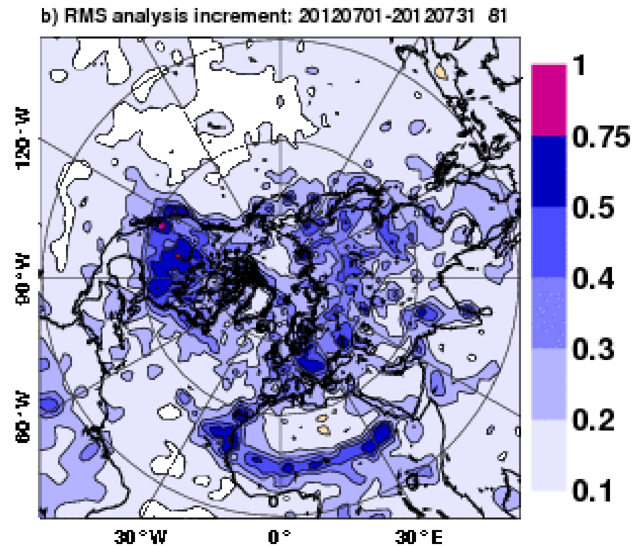
[Soumia Serrar, Martin Leutbecher]

Polar data assimilation issues

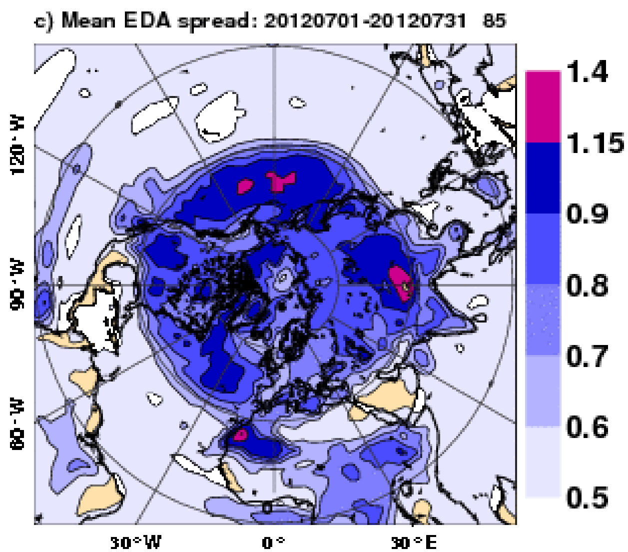
EDA spread = AN uncertainty | **RMS AN increment**

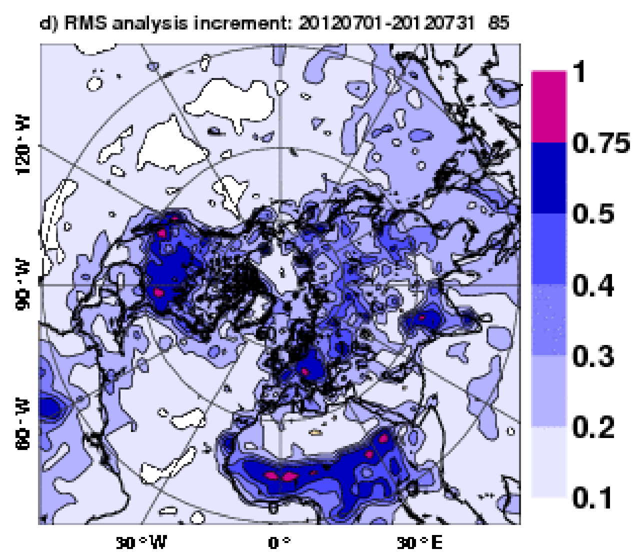
925 hPa





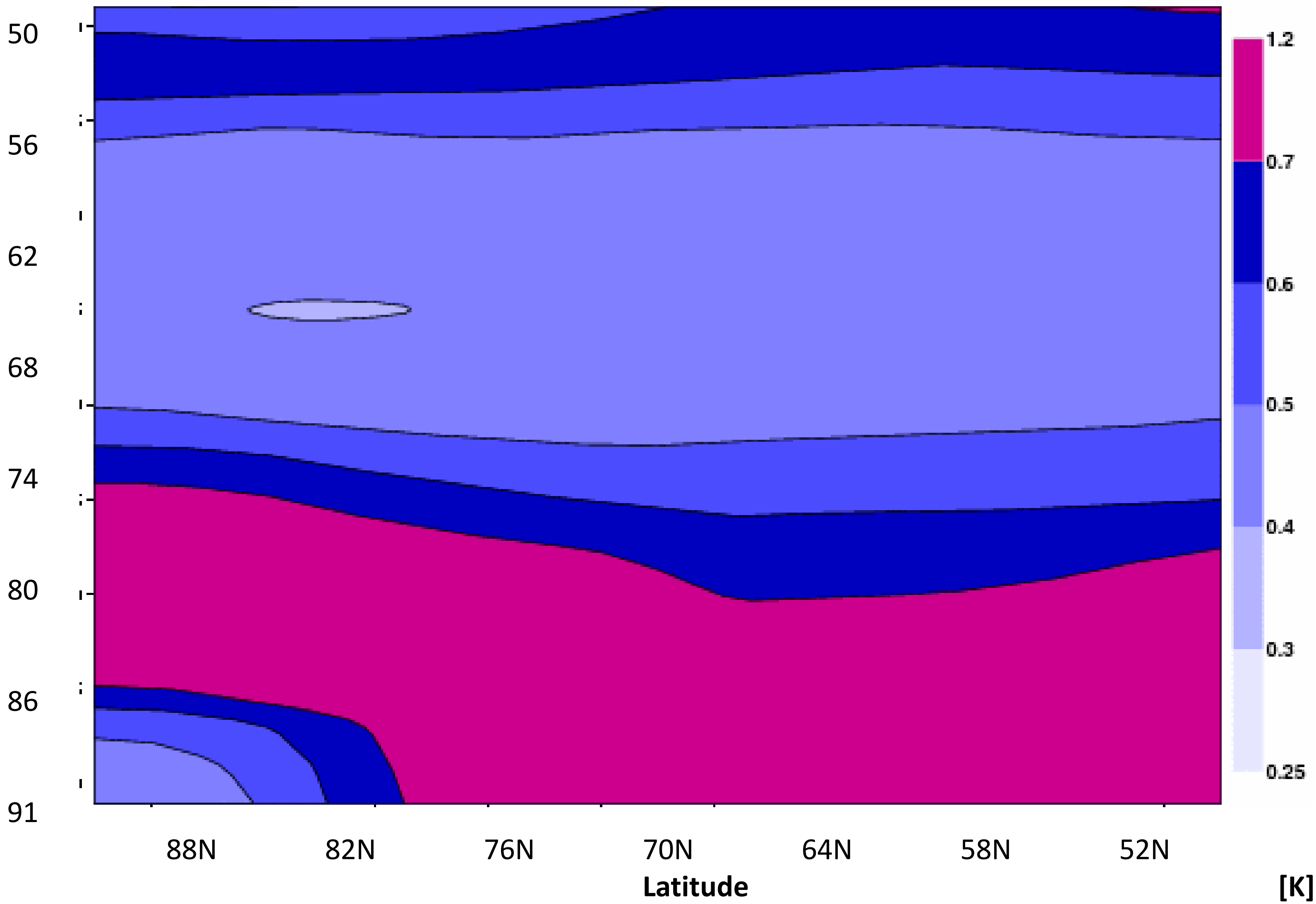
975 hPa





Polar data assimilation issues

Mean EDA T-spread July 2012

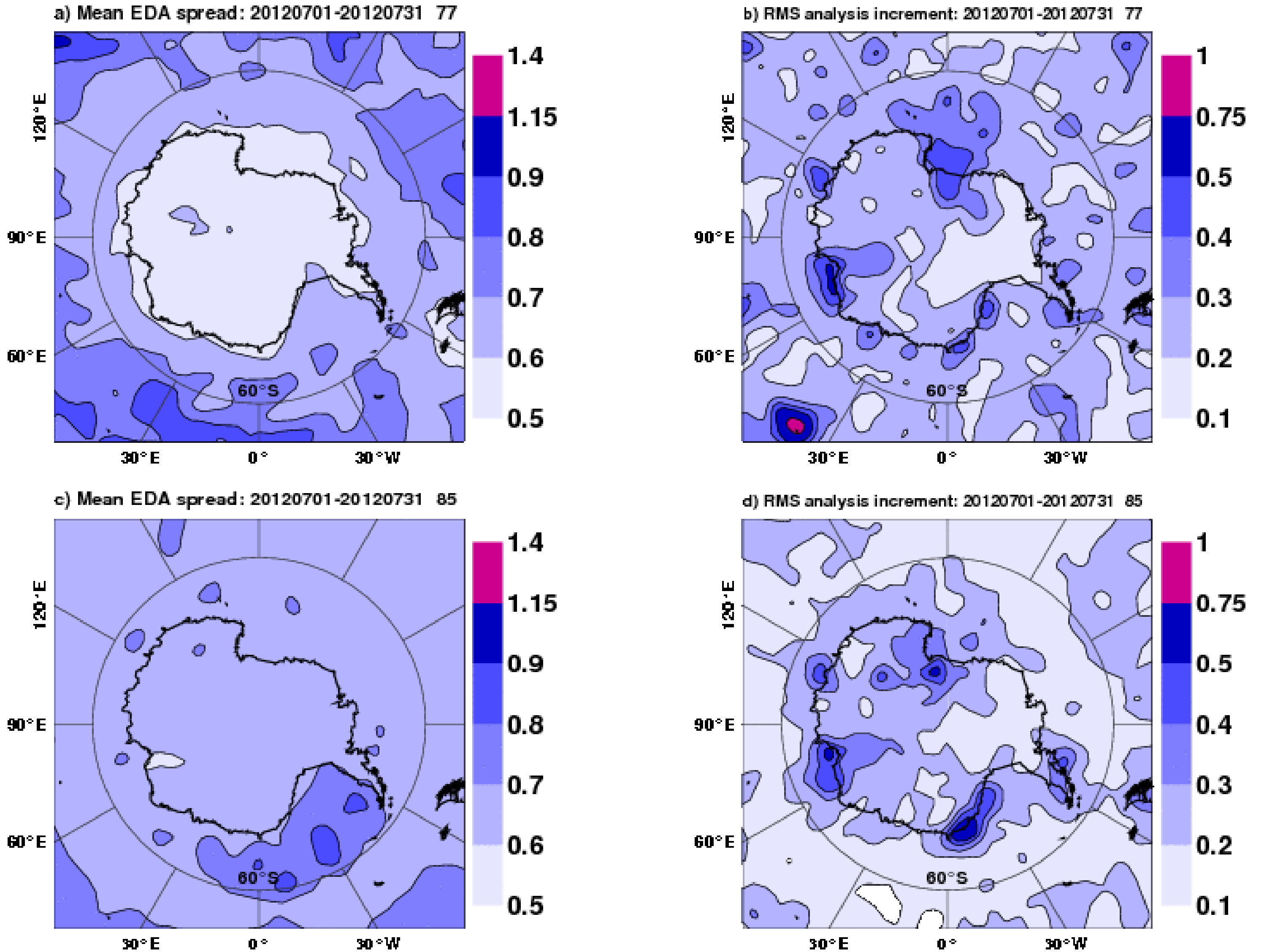


Polar data assimilation issues

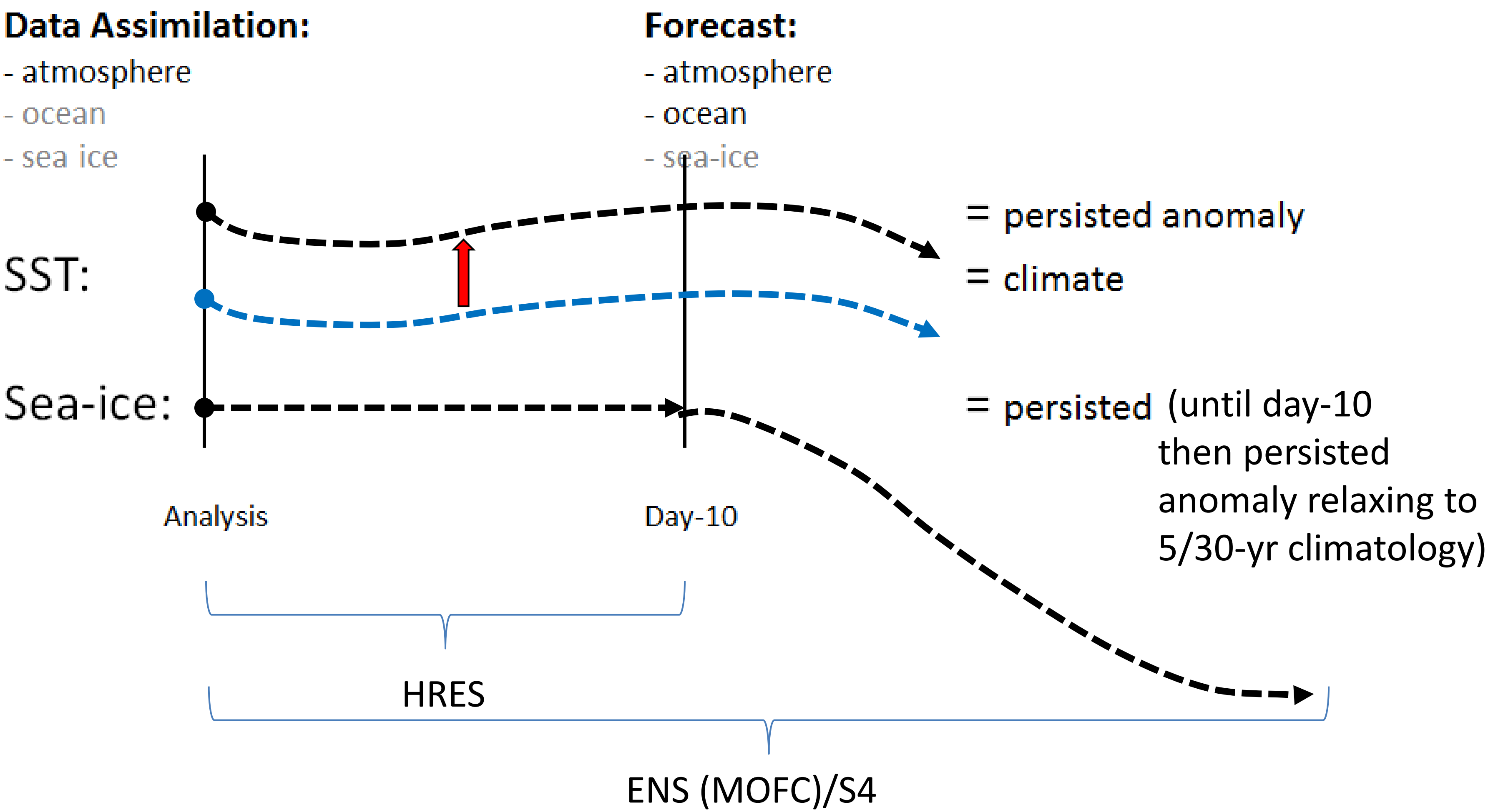
EDA spread = AN uncertainty | **RMS AN increment**

ML 77
925 hPa

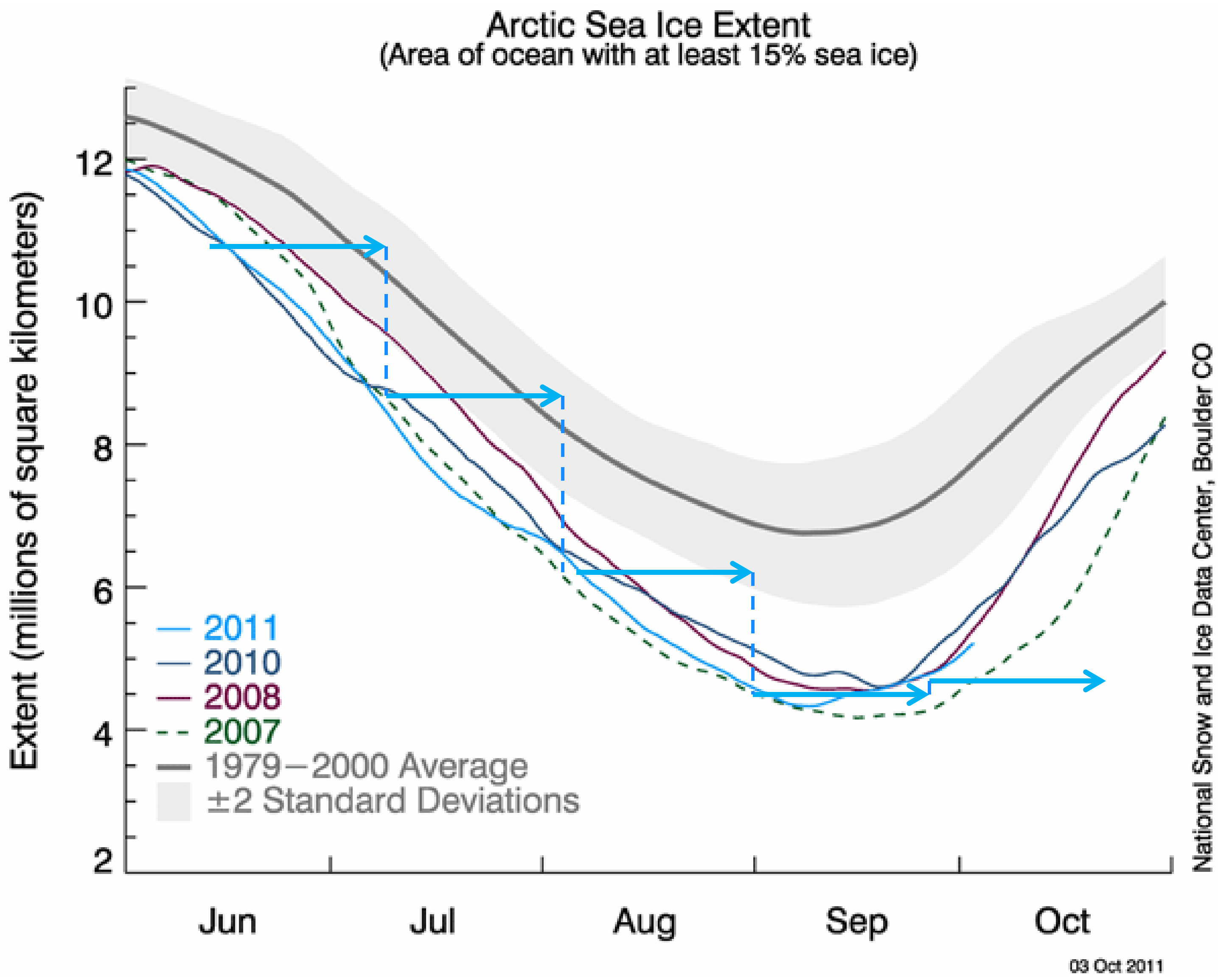
ML 85
975 hPa



Role of sea-ice in medium/extended range prediction



Role of sea-ice in medium-range prediction

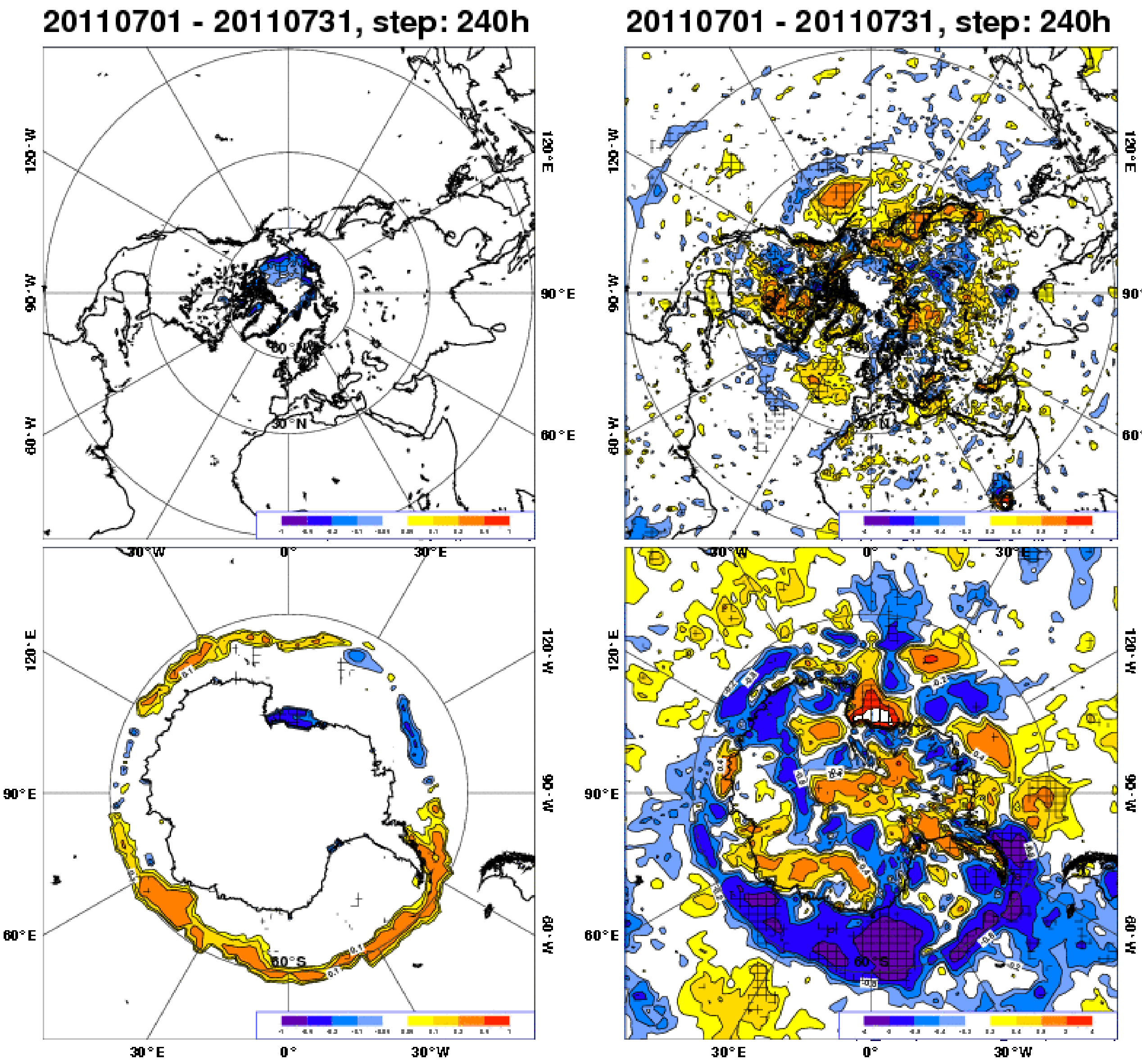


Role of sea-ice in medium-range prediction

Observed minus persisted:

Sea-ice

T2m



Sea-ice

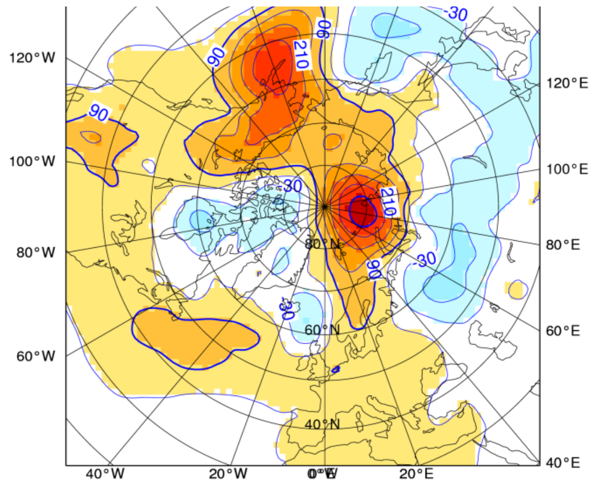
T2m

Role of sea-ice in seasonal prediction

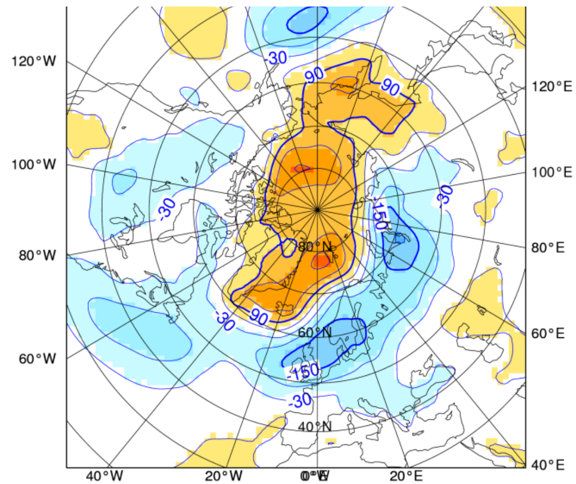
z500 anomaly, JA 2012

Difference between exps.

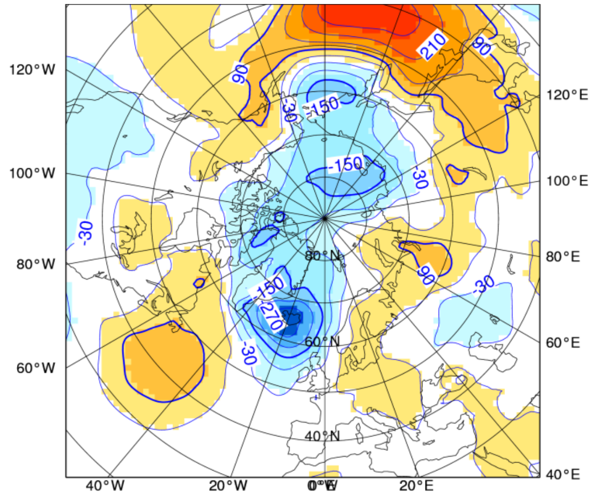
SST climate
SI observed- climate



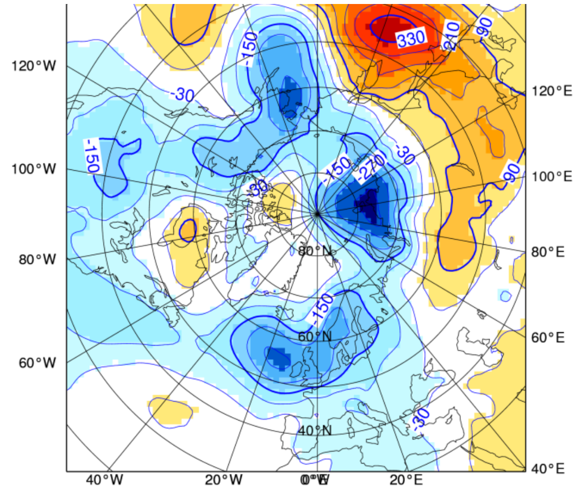
SST observed
SI observed -climate



SI climate
SST observed-climate

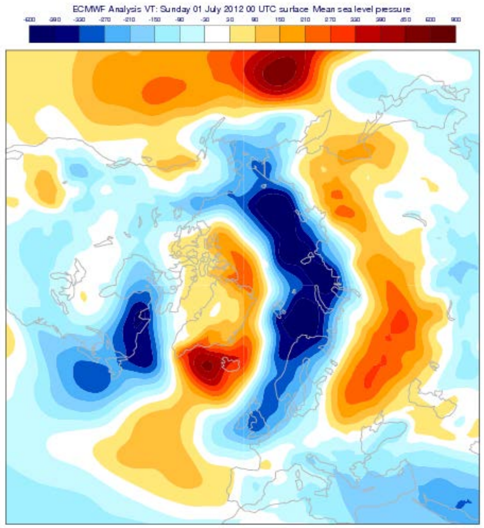


SI observed
SST observed-climate



Analysis

ERA-Interim

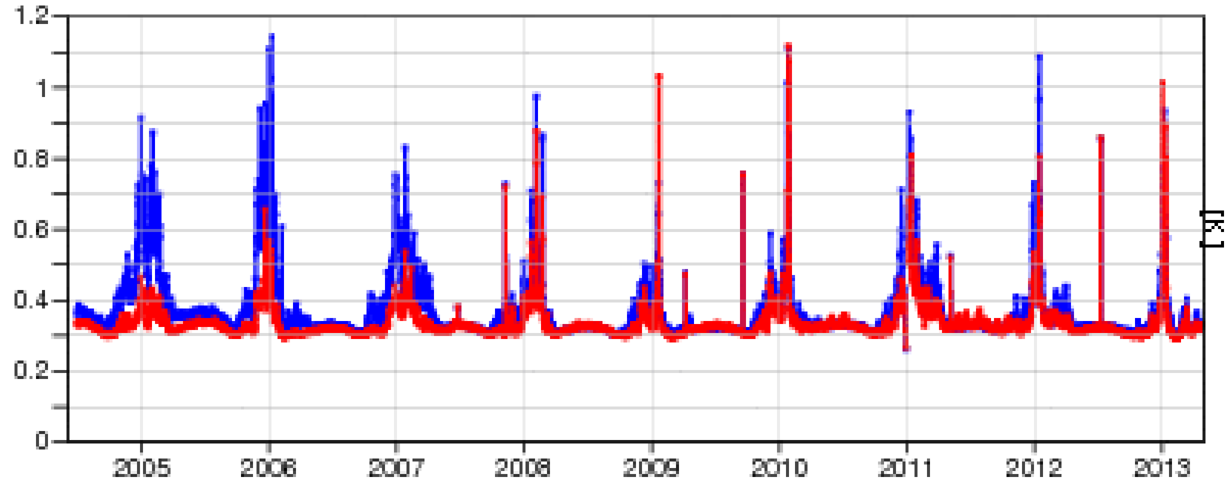


[Sarah Keeley et al.]

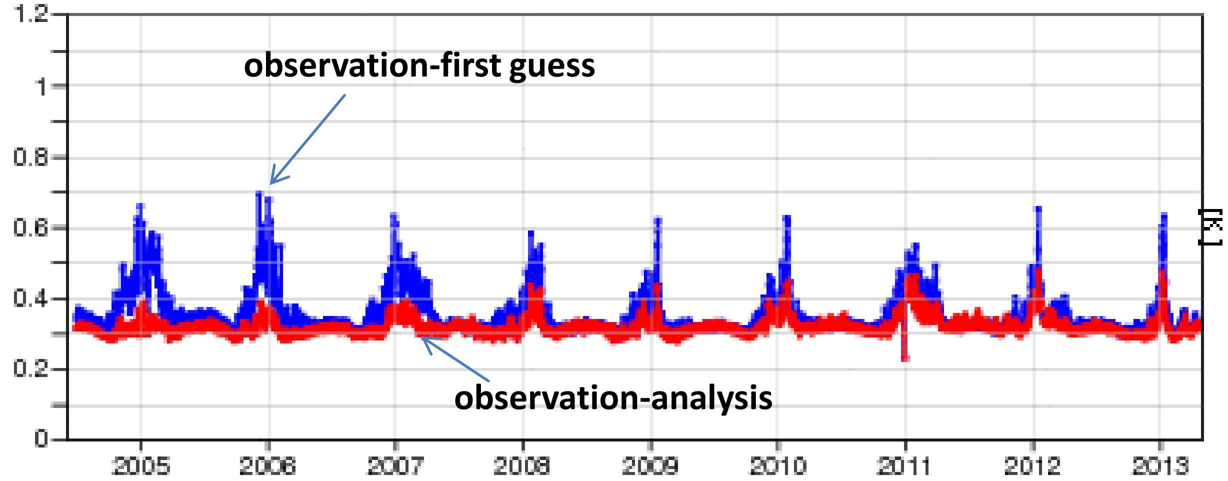
Medium-range predictability – SSW

NOAA-15 channel 12 (10 hPa) departure standard deviations - Northern polar

All data

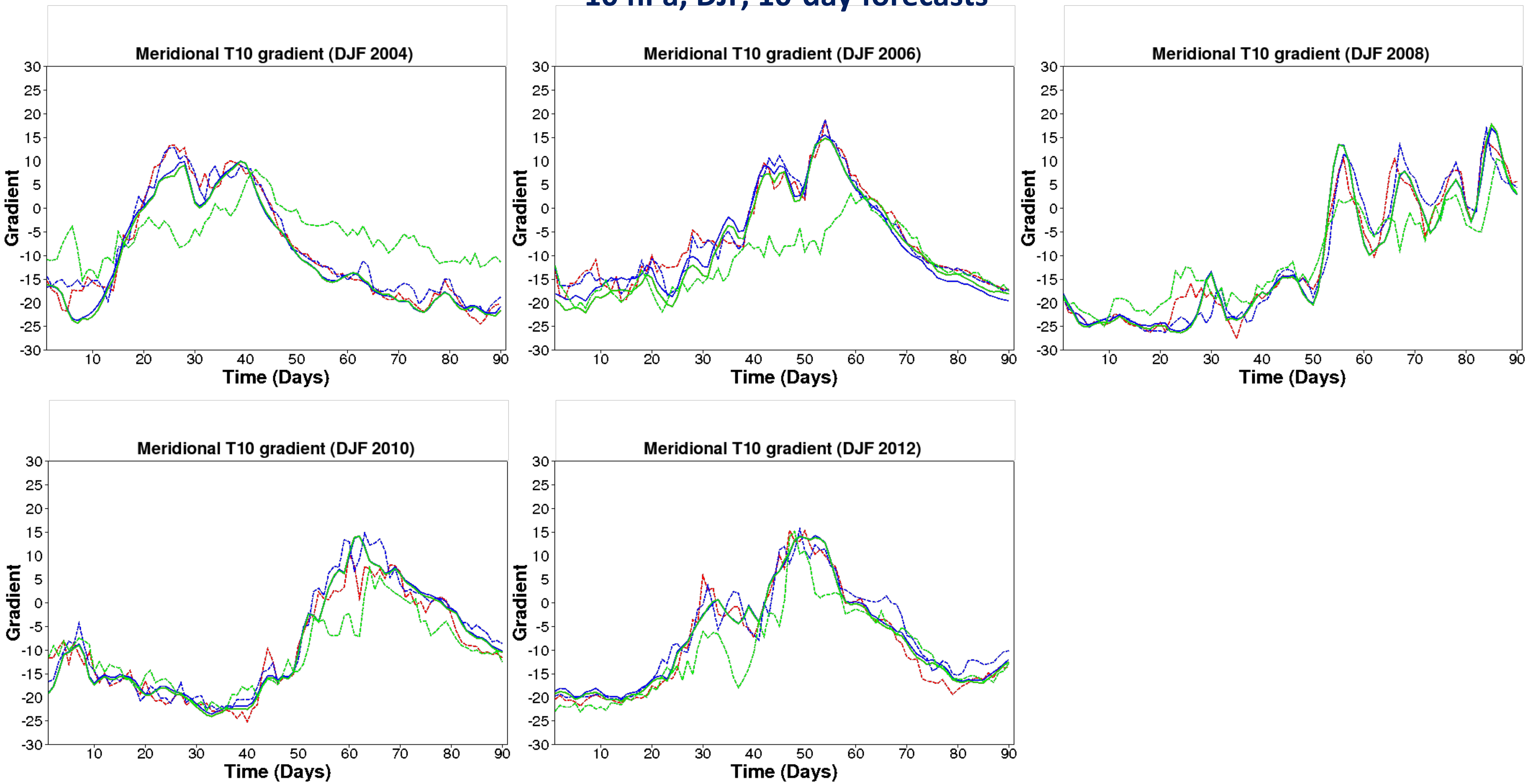


Used data
(~10% of all data)



Medium-range predictability – SSW

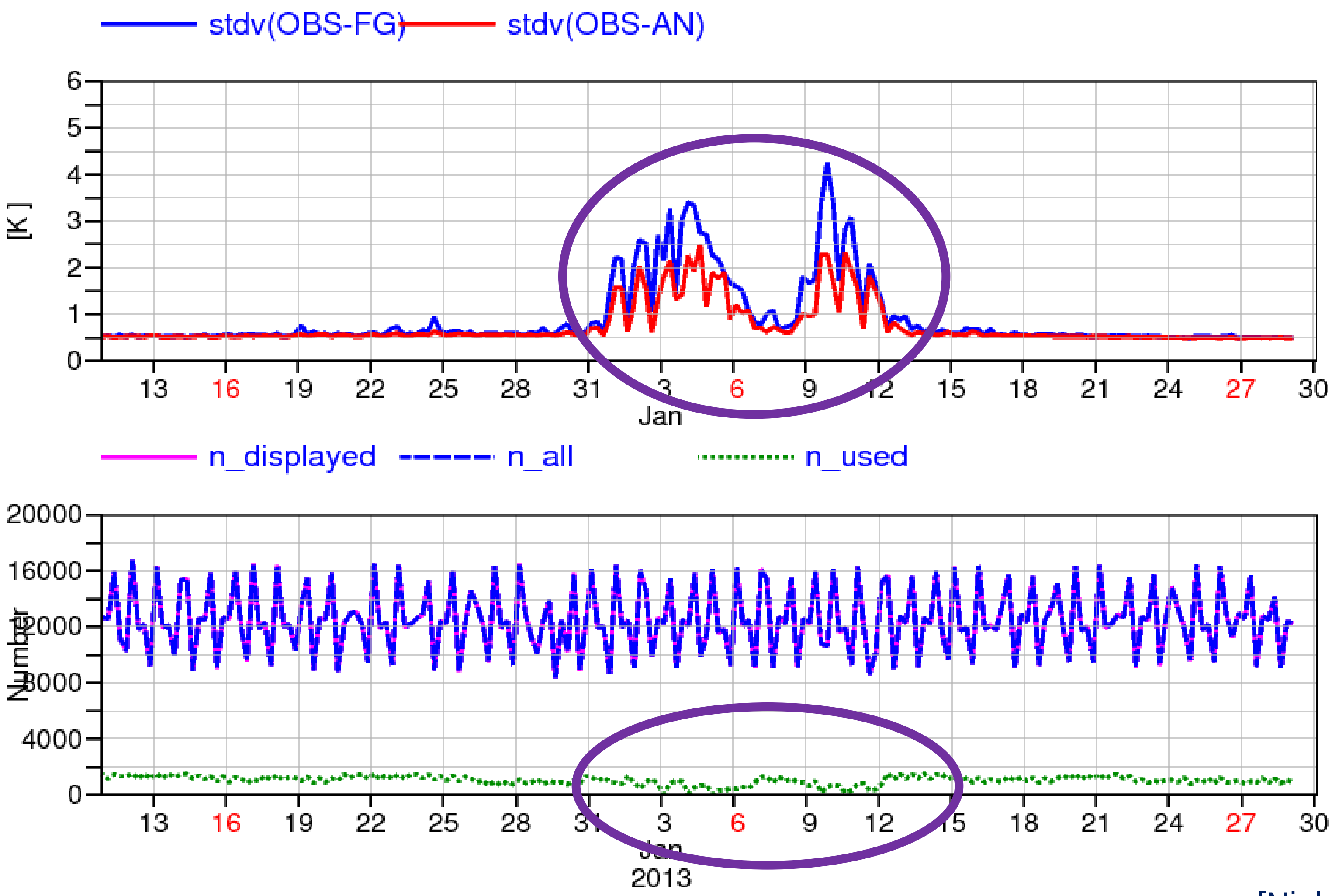
Time series of meridional temperature gradient (60-90N – 20-50N)
10 hPa, DJF, 10-day forecasts



HRES   ENS control   ERA Interim   AN: solid, FC: dashed

SSW event January 2013

Metop-A, AMSU-A, Channel 13 (~5 hPa), N. polar region



[Niels Bormann]

Spring 2013 not a spring in UK

Why was the start to spring 2013 so cold?

April 2013

Professor Julia Slingo,
Met Office Chief Scientist

Summary

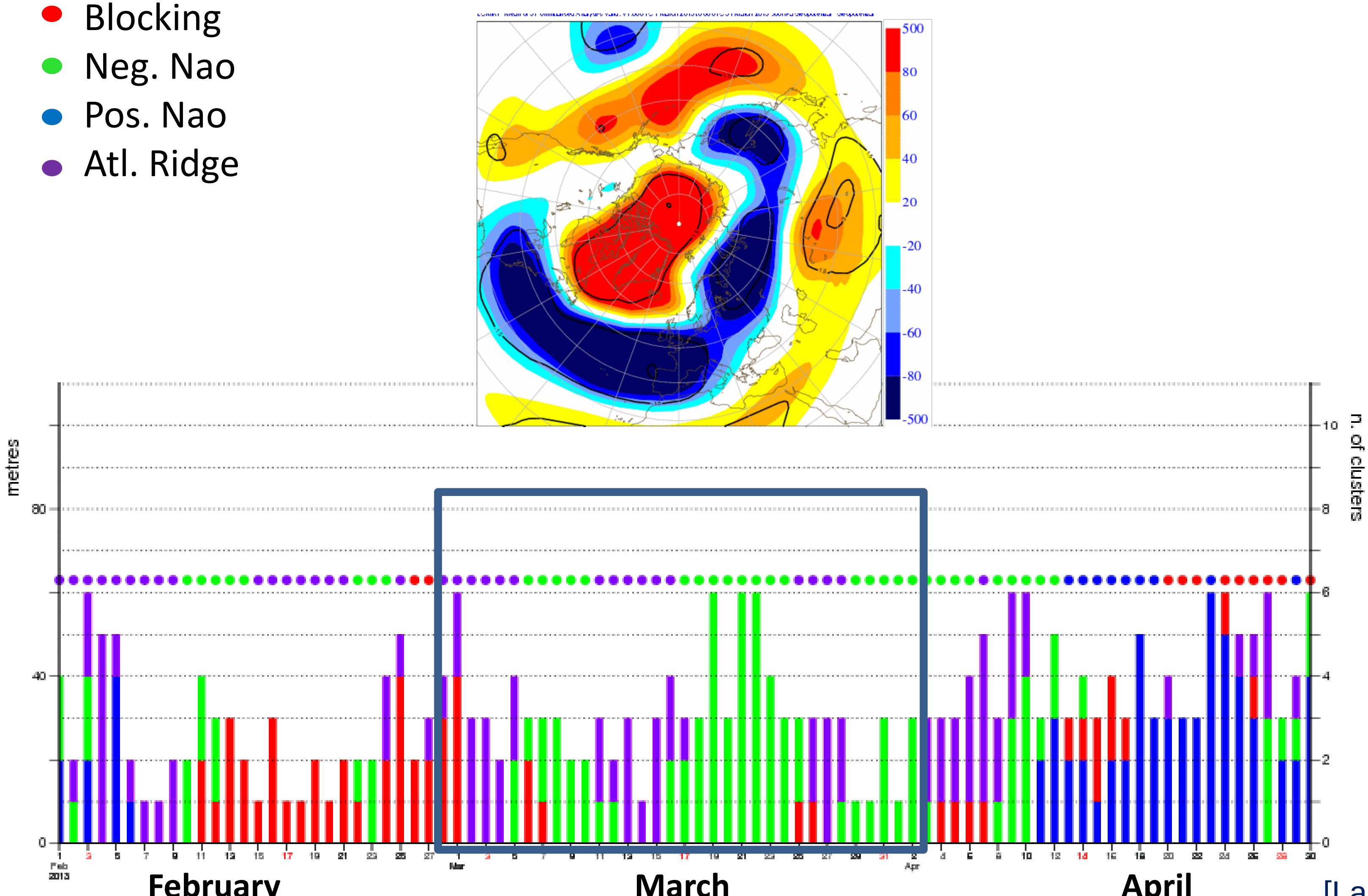
March 2013 was the second coldest March in the UK record since 1910, and was associated with a negative phase of the North Atlantic Oscillation. A number of potential drivers may predispose the climate system to a state which accounts for these conditions.

- The cold temperatures were part of a larger-scale weather pattern in the Northern Hemisphere.
- This pattern was associated with the negative phase of the North Atlantic Oscillation, which leads to the prevalence of easterly winds and cold conditions over the UK.
- There are a number of similarities between the climatological context of the March 2013 cold weather and that observed in 1962 (the coldest March on record).
- A number of potential drivers may predispose the climate system to negative NAO states in early spring. These include:
  - weather in the Tropics
  - the Stratosphere
  - conditions in the North Atlantic
  - the state of the Arctic
- These drivers are not necessarily independent, and no single explanation can account for the cold conditions observed.

Regimes derived from ENS forecasts

- Blocking
- Neg. Nao
- Pos. Nao
- Atl. Ridge

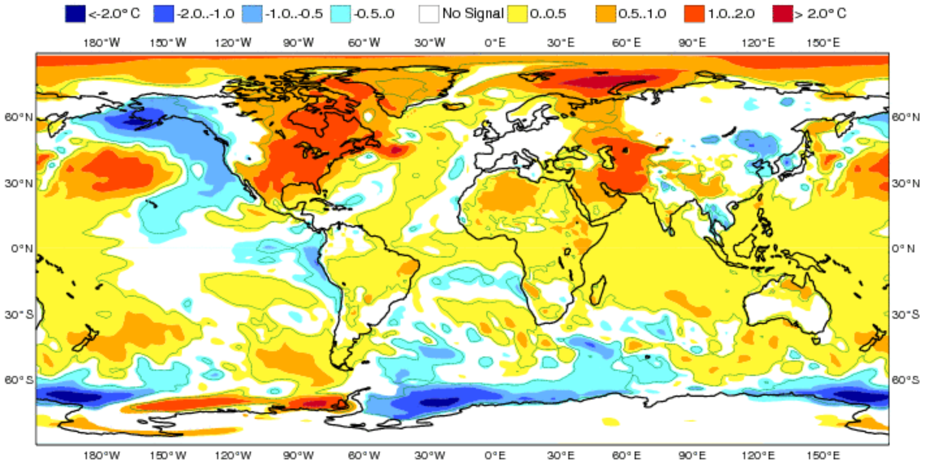
March 2013



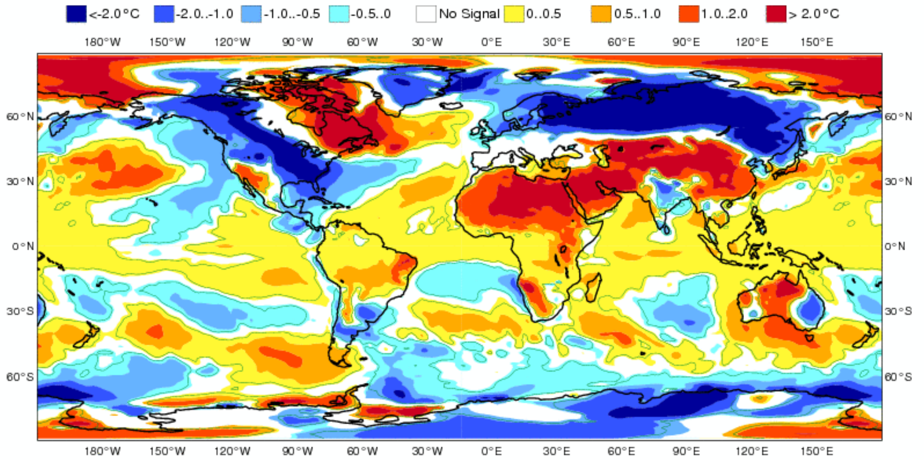
[Laura Ferranti]

S4 performance March 2013

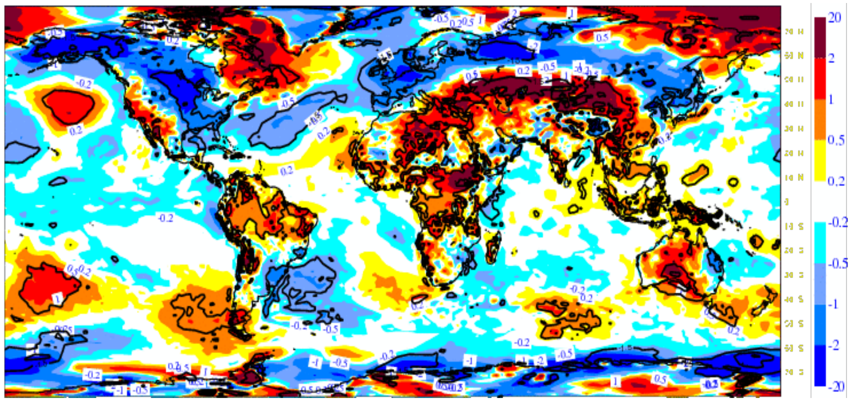
March forecast initialized on 1 Feb.



March forecast initialized on 1 Mar.

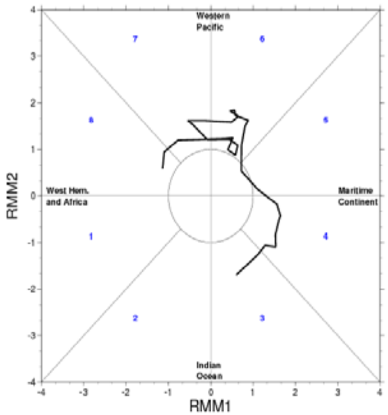


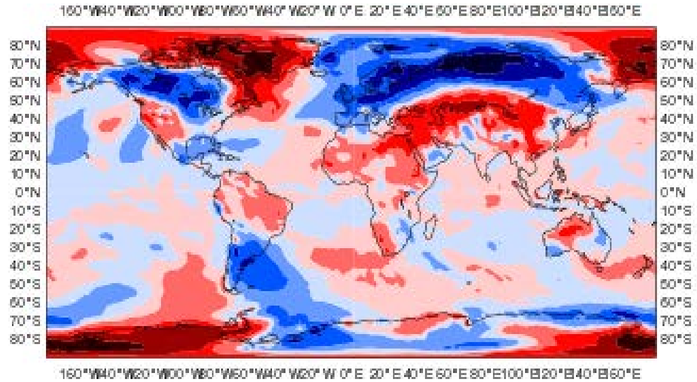
Analysis



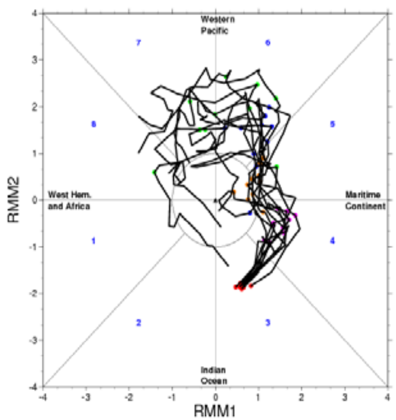
[Laura Ferranti]

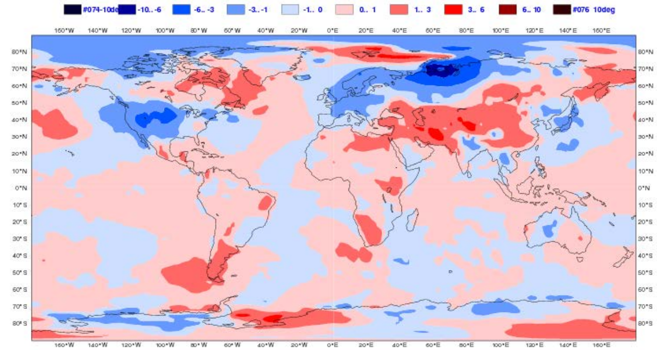
MOFC performance



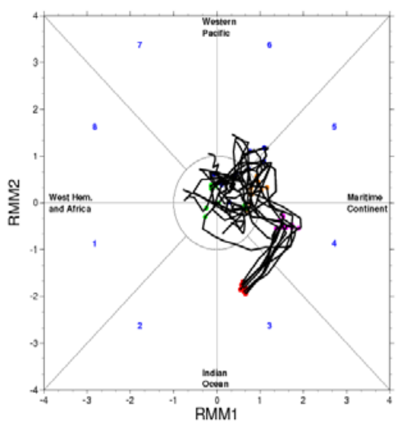


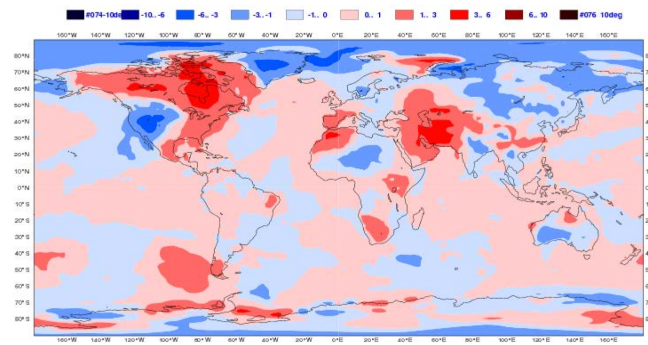
Analysis
T2m anomaly
11-17/03/2013





Forecast 14/02/13
T2m anomaly
Week 4
10 best MJO members

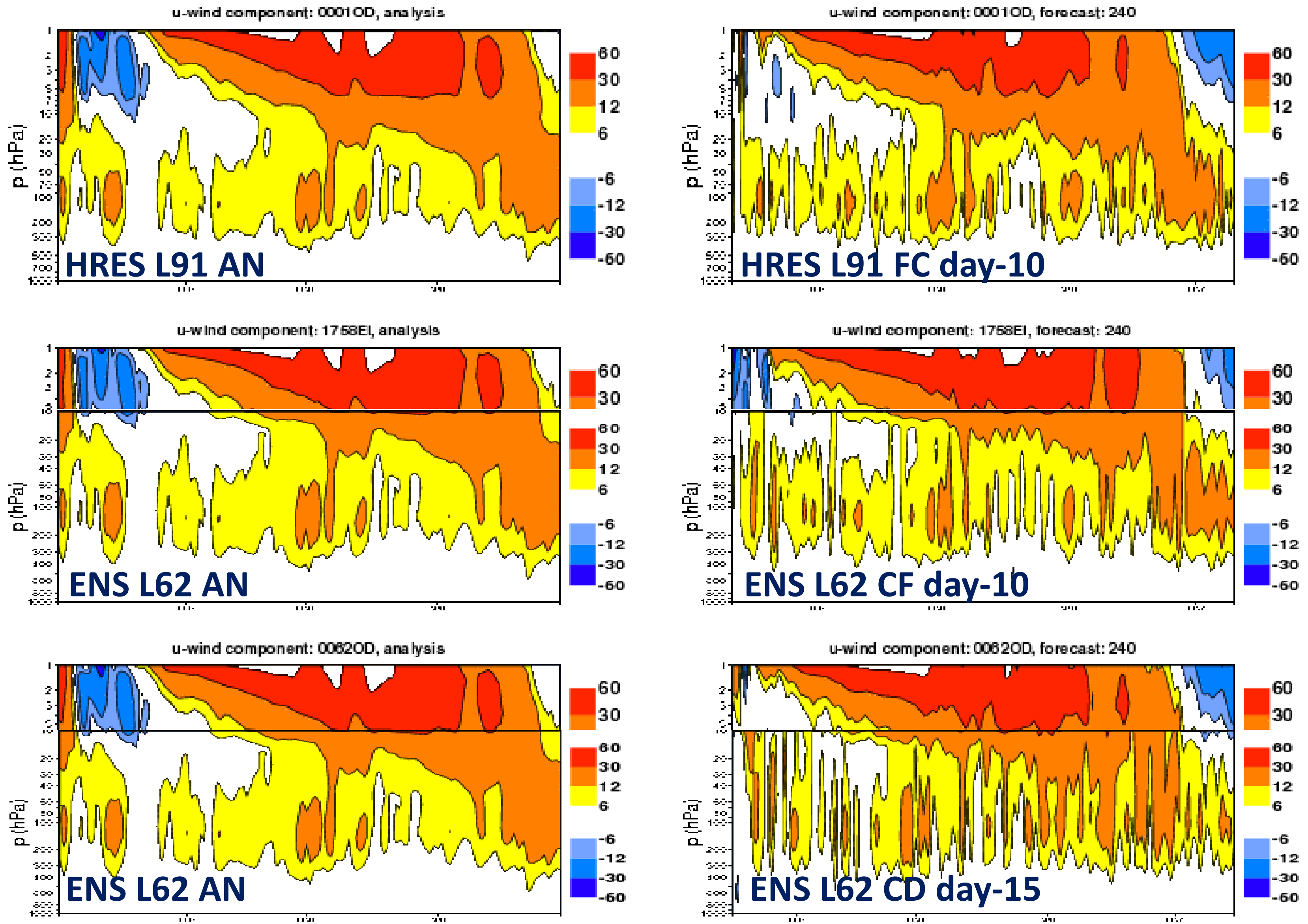




Forecast 14/02/13
T2m anomaly
Week 4
10 worst MJO members

[Frederic Vitart]

Time series u-wind spring 2013



Conclusions

The global system (forecast + analysis) is well constrained and stable, but:

- It is tuned to produce consistent performance at large scales (metrics)
- It is optimized for the medium range
- It is optimized for the troposphere

Problem areas:

- Physics of polar atmospheres (boundary layer, mixed phase, snow etc.)
- Sea-ice, ocean
- Stratosphere-troposphere interaction
- Representation of model uncertainty
- Analysis:
    - Surface/lower troposphere sensitive satellite observations
    - Sparse networks
    - Observation/model error representation
    - Coupling

PPP research areas

Predictability
- processes
- tele-connections

Analysis (initial conditions)→**Forecast**
- spheres
- scales
- range

Observations
- state/uncertainty

Models
- state/uncertainty
- processes
- coupling

Algorithms
- numerical model
- data assimilation
- ensemble technique

Metrics
- diagnostics
- verification