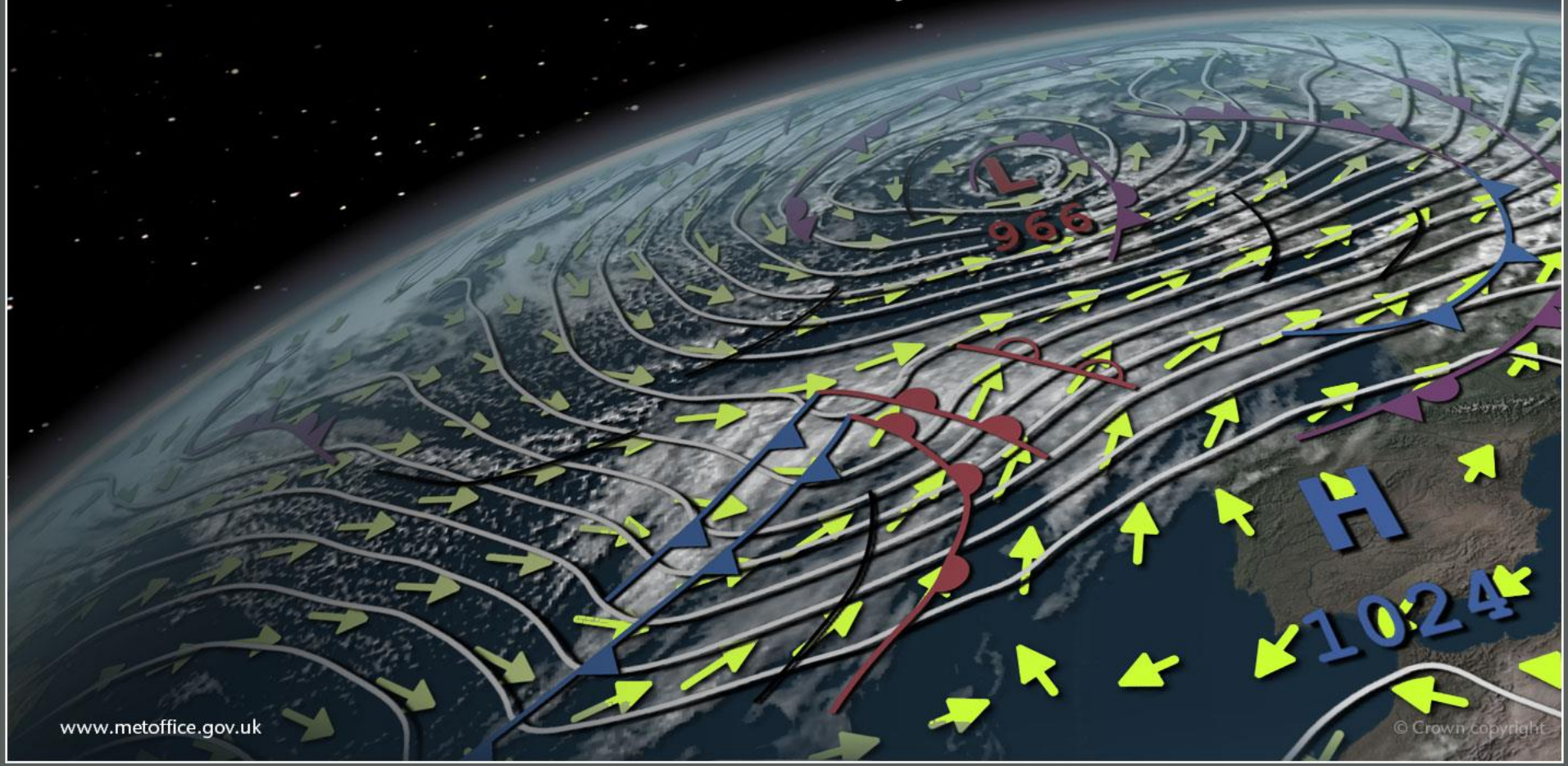
Skilful seasonal predictions of Summer European rainfall

Dunstone et al 2018, GRL

Nick Dunstone

Doug Smith, Adam Scaife, Leon Hermanson, David Fereday, Chris O'Reilly, Alison Stirling, Rosie Eade, Margaret Gordon, Craig MacLachlan, Tim Woollings, Katy Sheen, Stephen Belcher



Summer rainfall extremes

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Summer 1976

Driest UK summer in series back 1910

Severe water shortages

Crop failures (~£500 million)

Heath and forest fires

"Minister for Drought" announced

Summer 2007

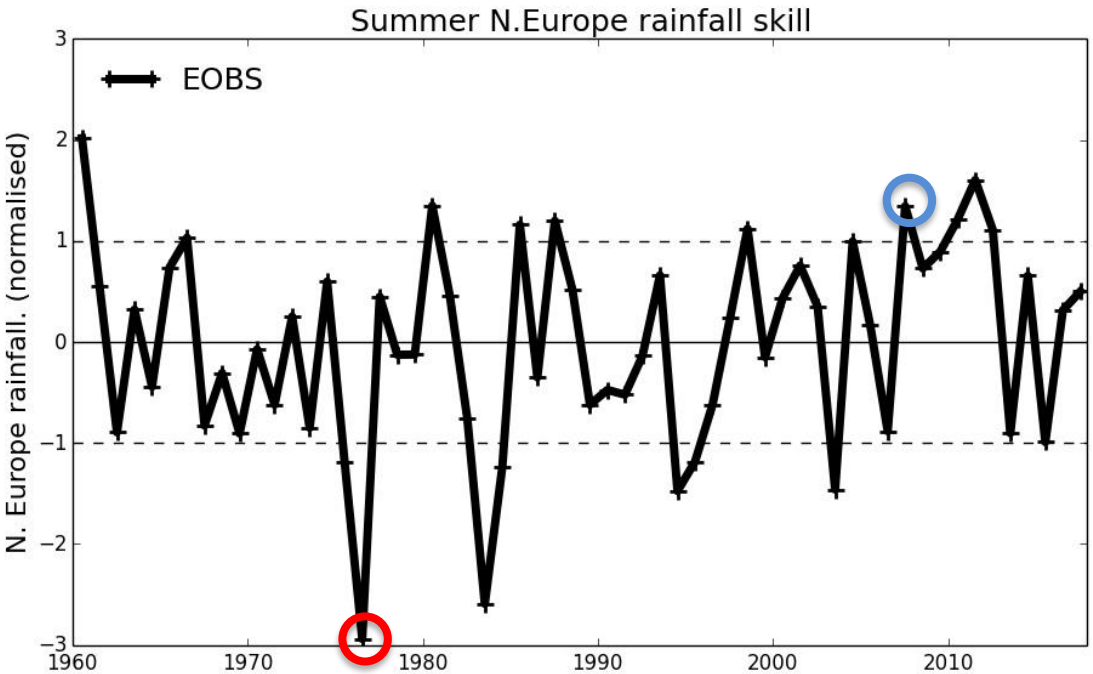
Widespread flooding

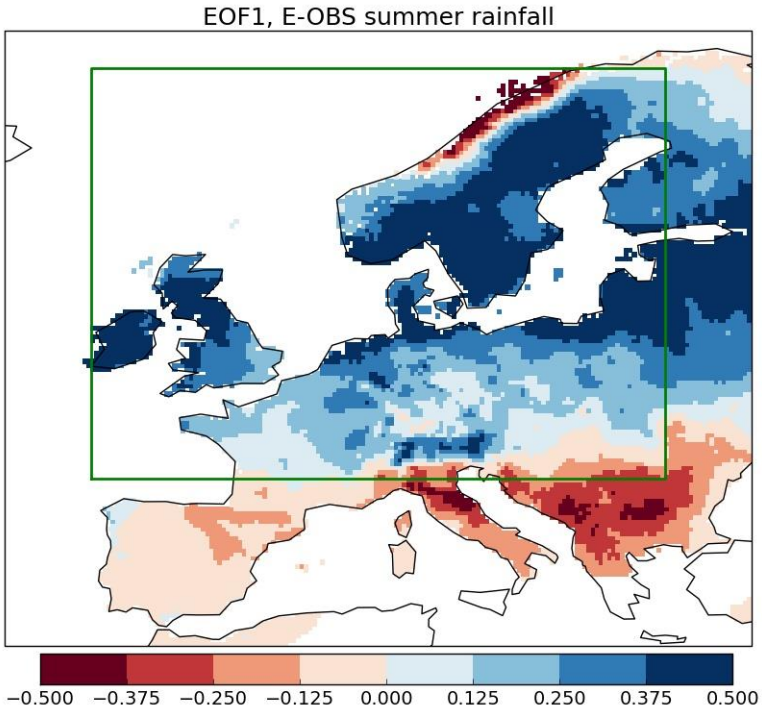
£3.2 billion in property damage

Environment Agency 2010 report: "*the scale and seriousness of the summer 2007 floods were sufficient to classify them as a* ***national disaster***"

Observed summer rainfall variability

- E-OBS European land rainfall dataset
- 1960-2017, using new E-OBS v16e
- 1st EOF shows coherent N. Europe Summer (JJA) rainfall signal





- N. Euro. defined as green box to construct timeseries (Sutton & Dong 2012)
- Use EOF1 as a mask, to remove N. Norwegian coast
  - ➢ makes little difference

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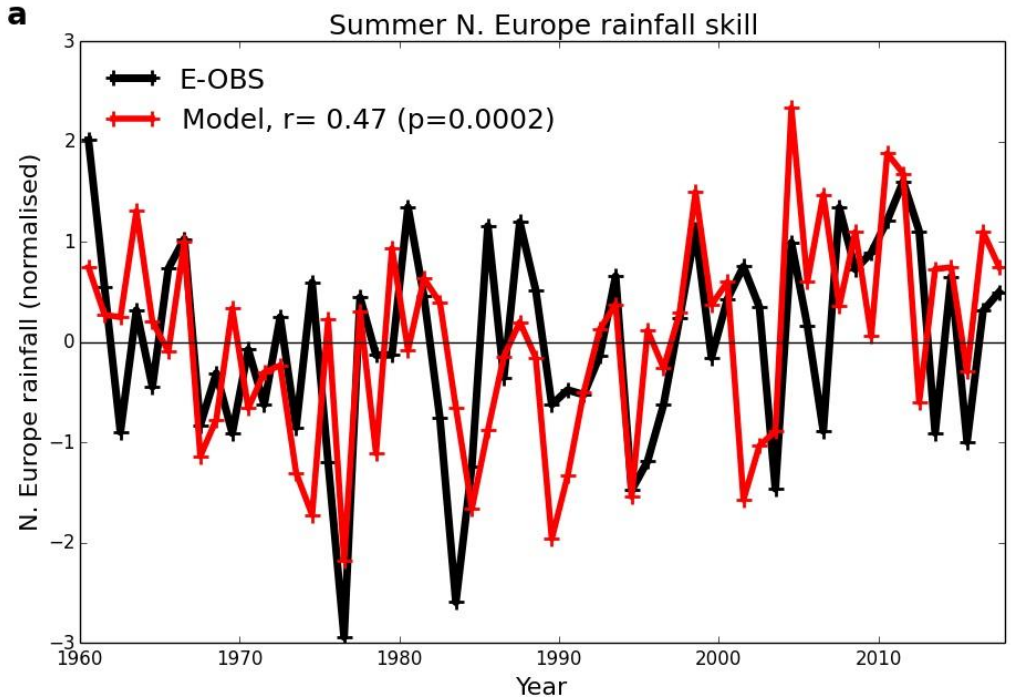
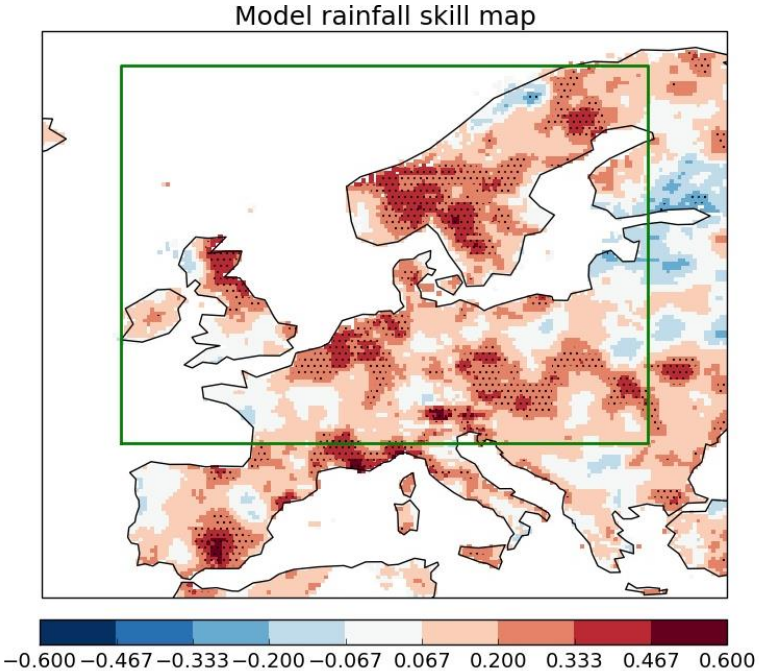
New dynamical seasonal prediction skill for Summer Northern European rainfall

Using Met Office decadal prediction system, **DePreSys3** - based on HadGEM3-GC2 coupled model (N216, ¼)

Skilful N. Europe summer rainfall

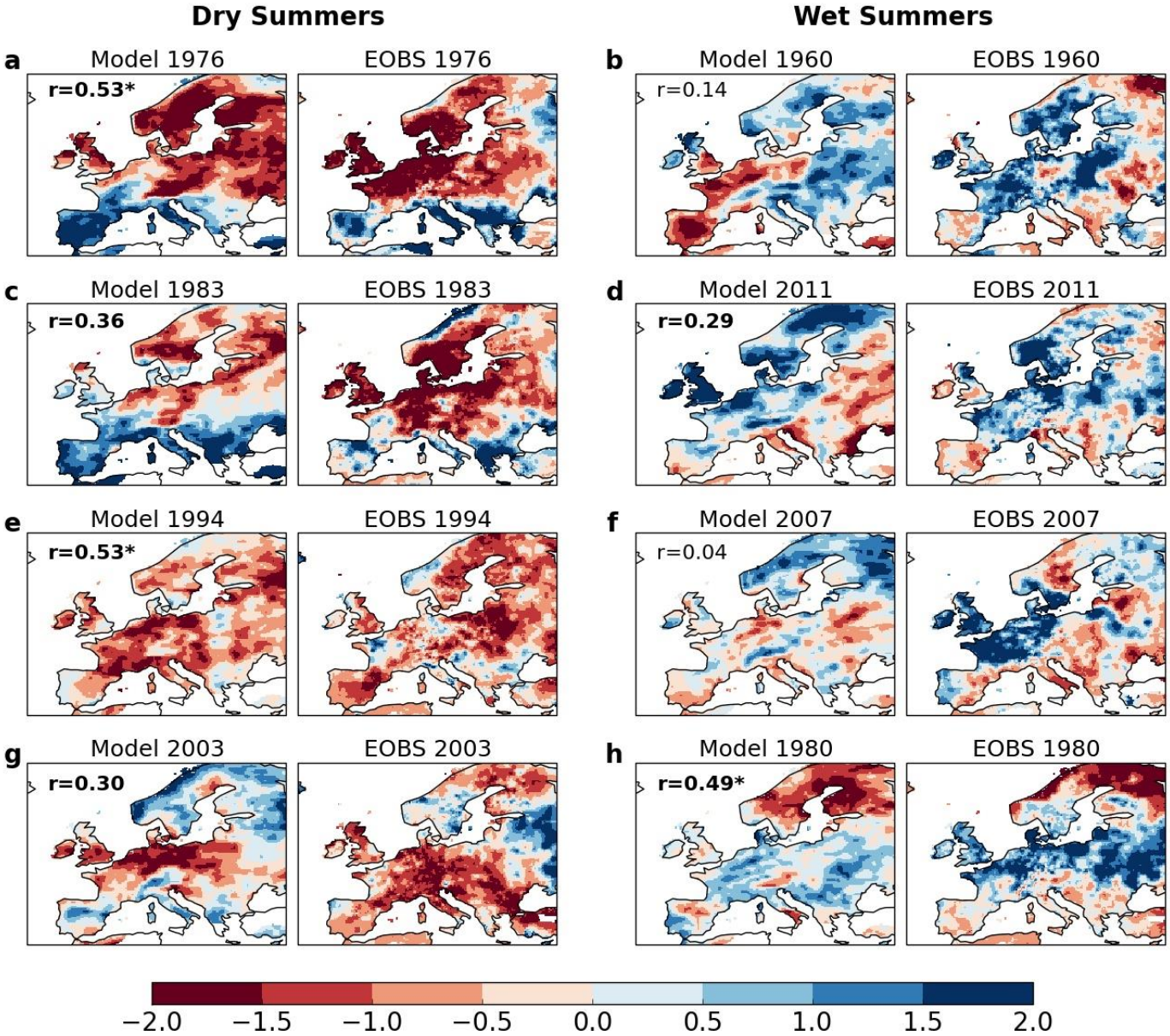
- Predict summer (JJA) Northern European rainfall
- Over 58 years (1960-2017)
- Use 80 ensemble members, combining:
  - 40 November (months 8-10)
  - 40 May (months 2-4)
- First significant skill from dynamical model: **r=0.47 (p<0.001)**





Extreme summer patterns

- Four driest & wettest observed summers
- Normalised anomalies are plotted for EOBS and model hindcast



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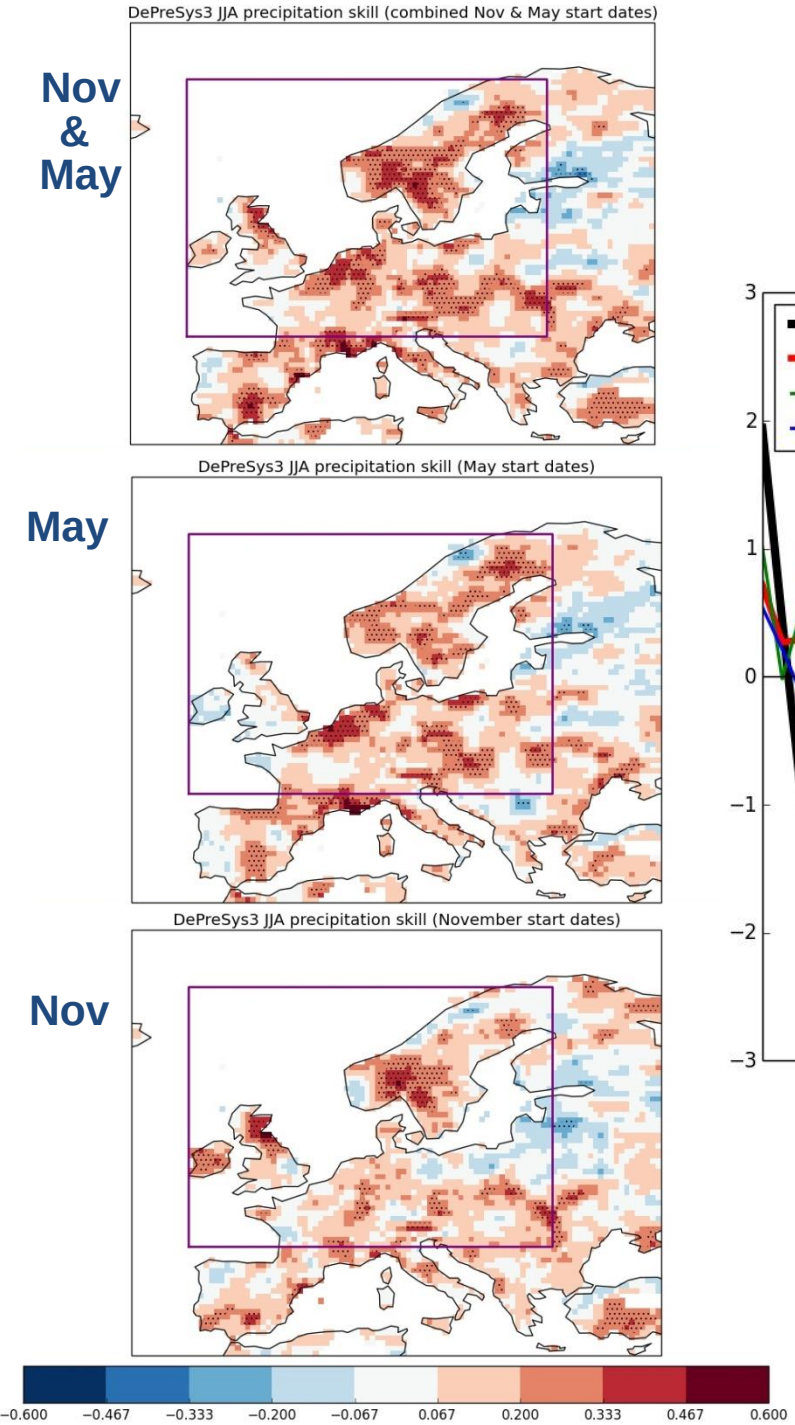
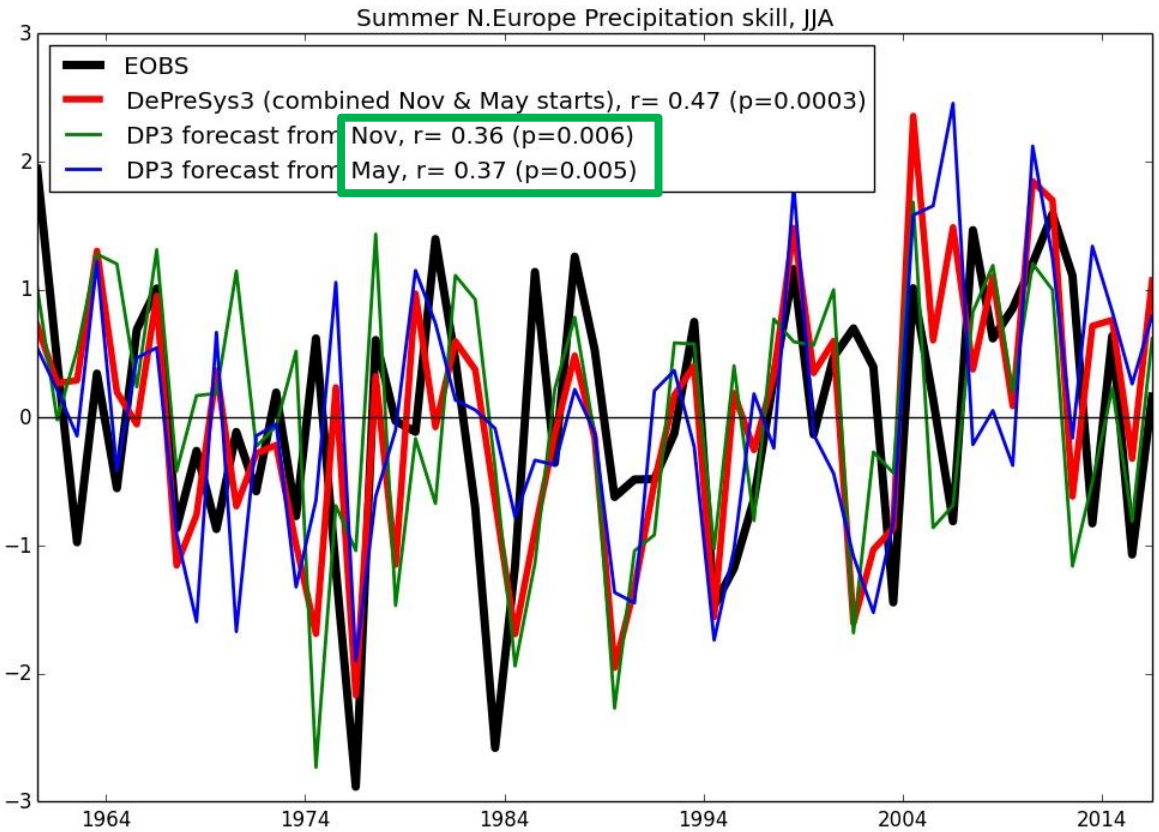
Understanding the origin of this skill

November vs May start dates



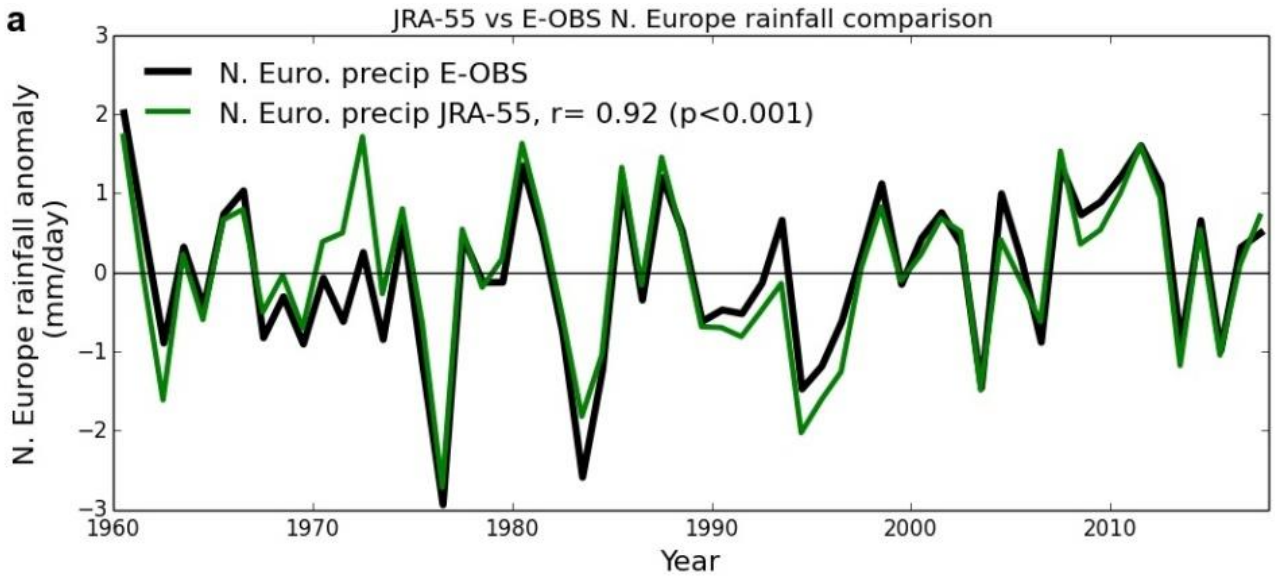


- Both forecast lead times (months 2-4 and 8-10) show similar (reduced) skill
- Suggests both a low frequency driver and that skill is sensitive to ensemble size

Using JRA-55 reanalysis rainfall

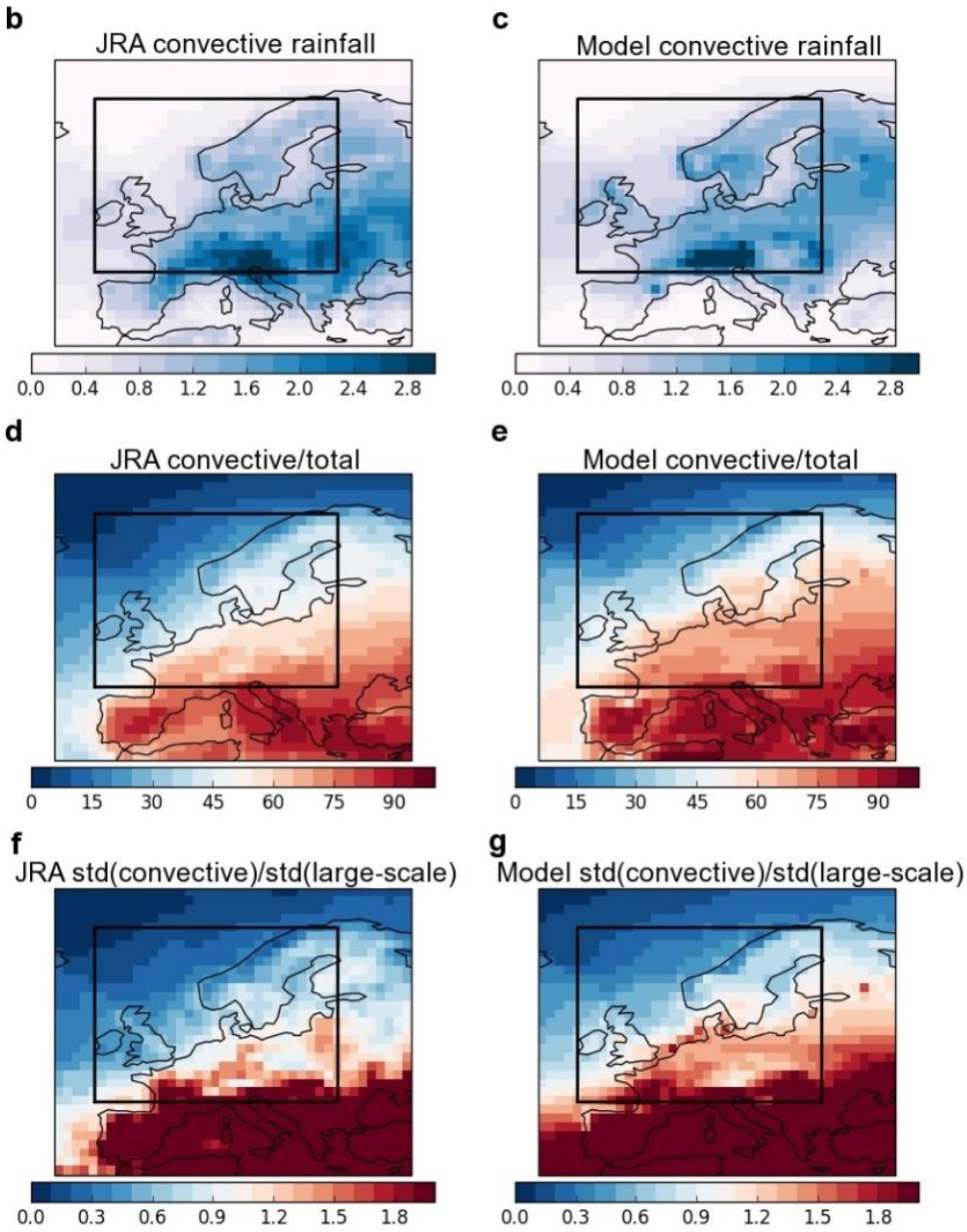
- Using JRA-55 reanalysis to further probe model skill

- JRA-55 has faithful reproduction of EOBS (r=0.92), except for 1972/3 (!?)

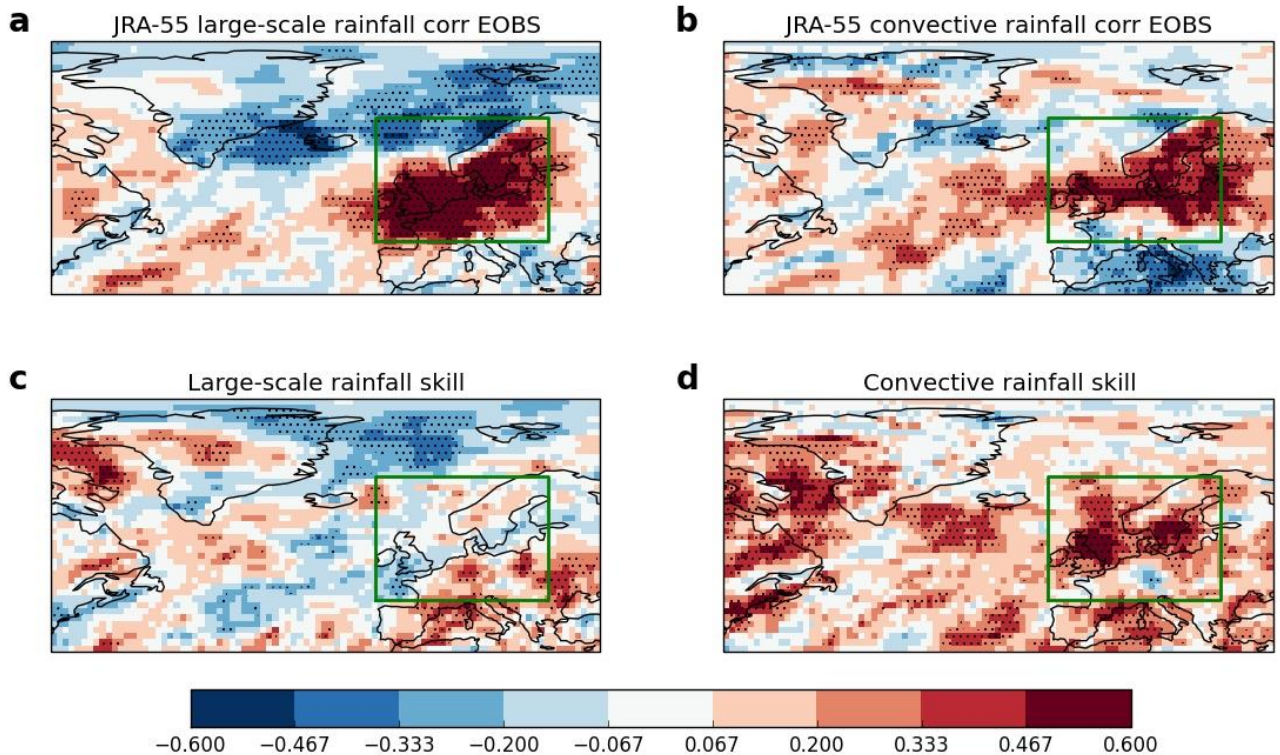


Large-scale vs convective rainfall

- Can use JRA-55 reanalysis to split rainfall into ***convective*** and ***large-scale*** components
- ‘Convective’ rainfall is that from the convective parametrisation scheme
- ‘Large-scale’ is the ‘frontal’ rainfall
- Imperfect split that is model dependent but allows us to probe mechanisms
- DePreSys3 and JRA-55 show broadly similar patterns, with convective rainfall dominating over Southern Europe and large-scale rainfall dominating over Northern Europe



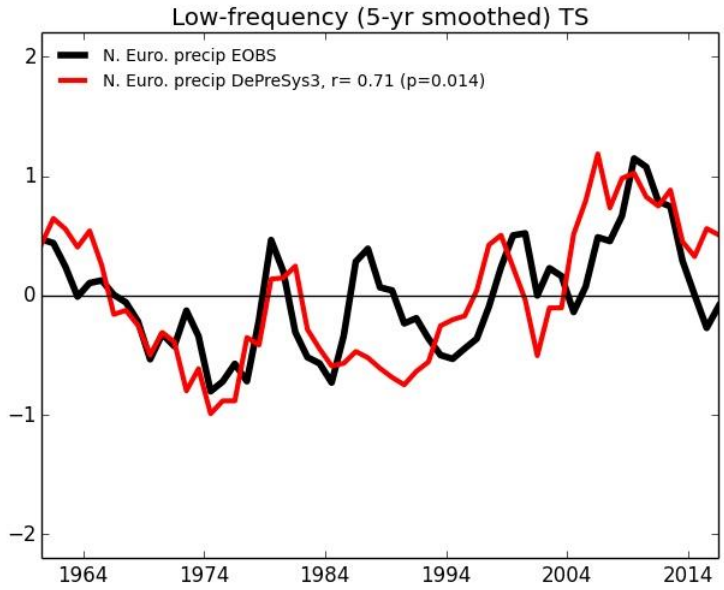
Large-scale vs convective rainfall

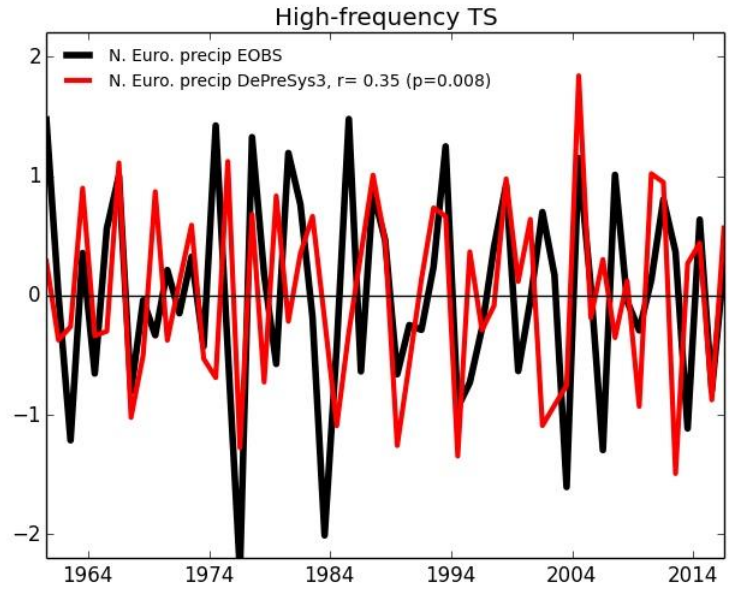


- JRA-55 shows strong connection between European precipitation and both large-scale (r=0.87) and convective precipitation (r=0.56), with little cross-correlation (r=0.26)

- Assess gridpoint skill of model and find skill predominantly in convective precipitation

Split into low & high frequencies

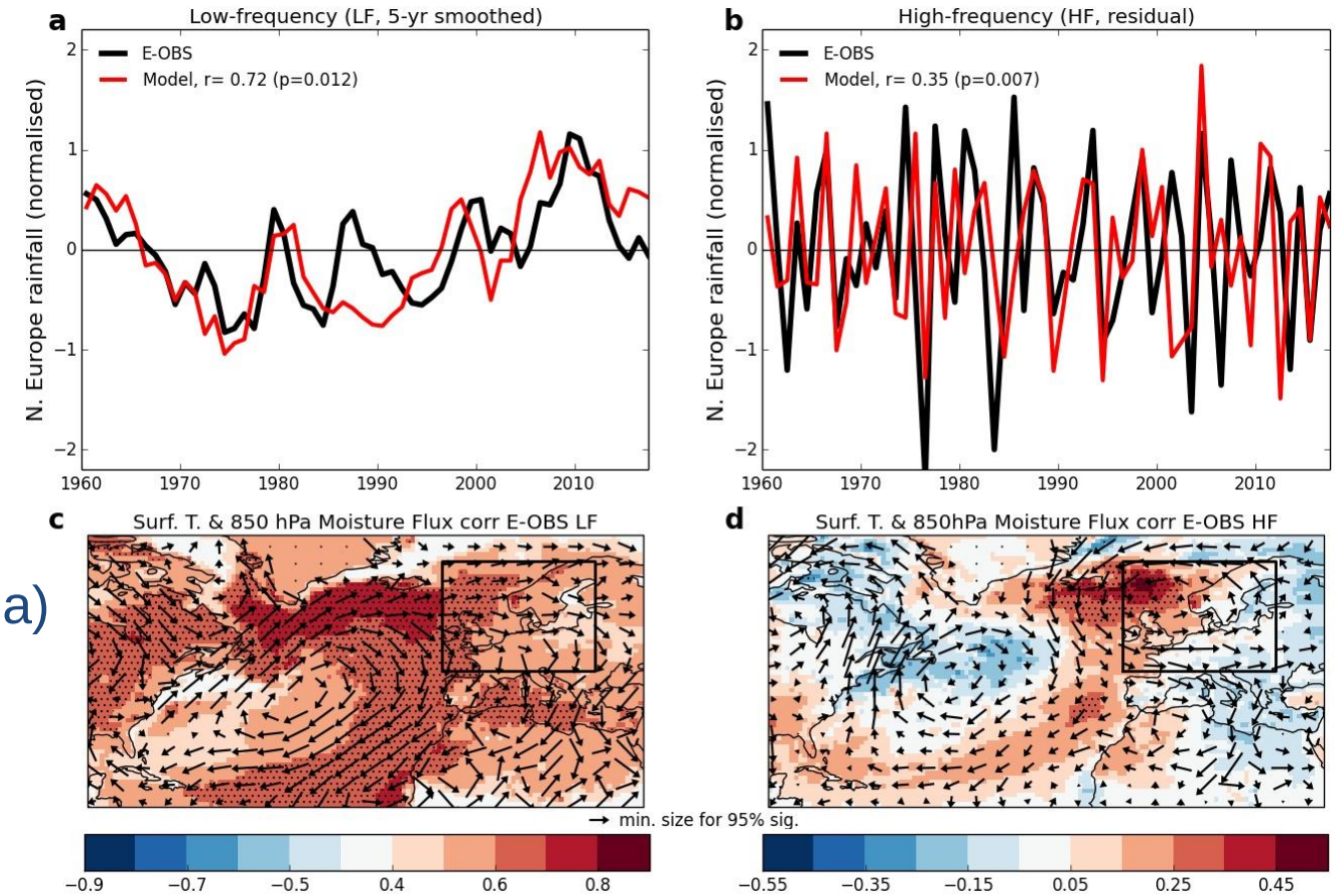




- Skilful predictions on both high and low frequency
- Both timescales contribute equally to total model variance

Probing mechanisms...

- Correlation of observed timeseries and model predicted fields of surface temperature and moisture flux (850 hPa) on low and high freq.



- Clear connection to warm North Atlantic SSTs, horseshoe similar to AMO/AMV. Anticyclonic moisture circulation feeding N.Europe

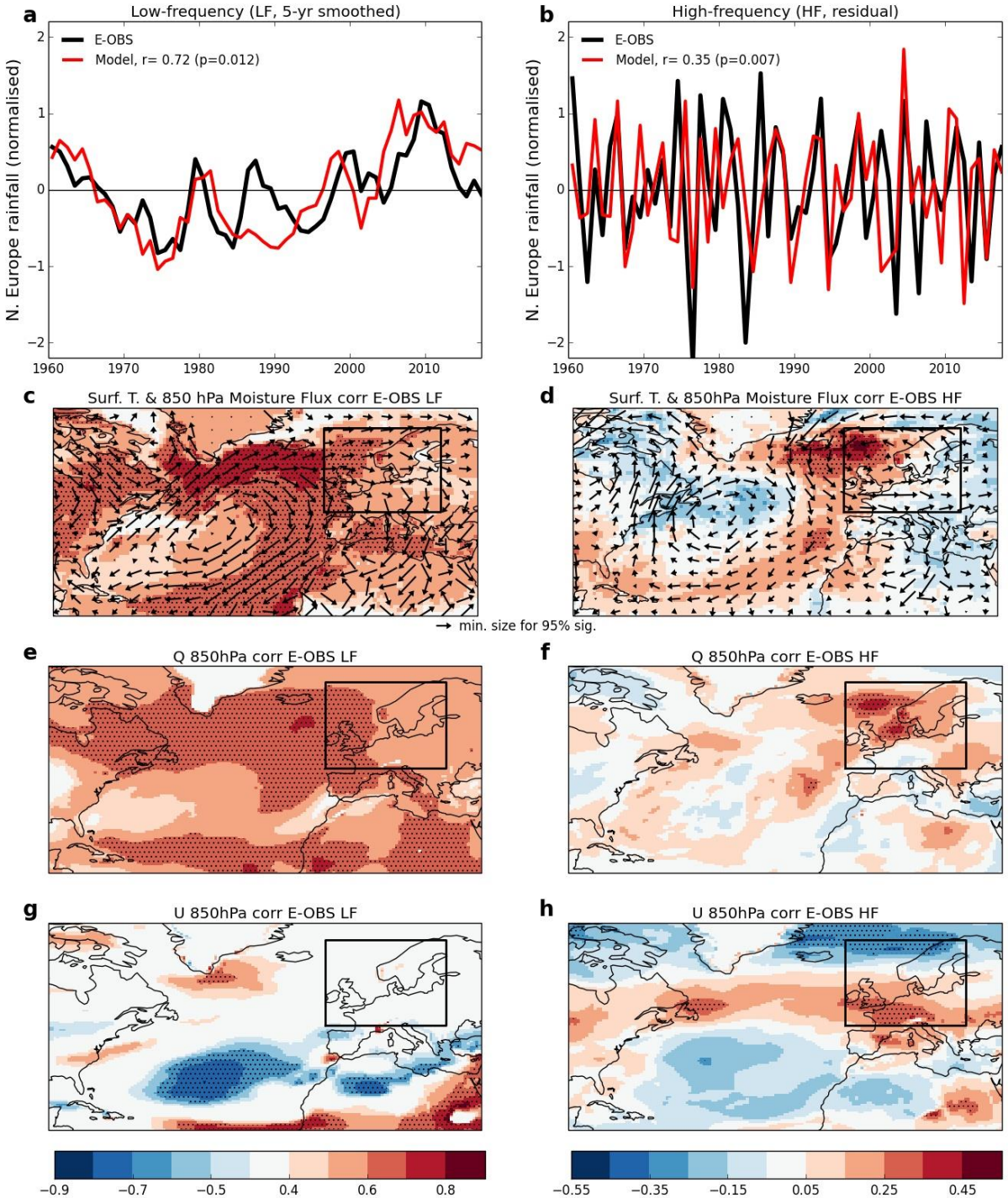
- Local connection to SST dipole. Atlantic anticyclonic and local cyclonic moisture circulations feed N.Europe

Q or U?

- Split moisture flux into specific humidity and circulation components...

- On low frequency the SSTs and water vapour appear dominant over the circulation (no skill in N.Atlantic jet/SNAO)

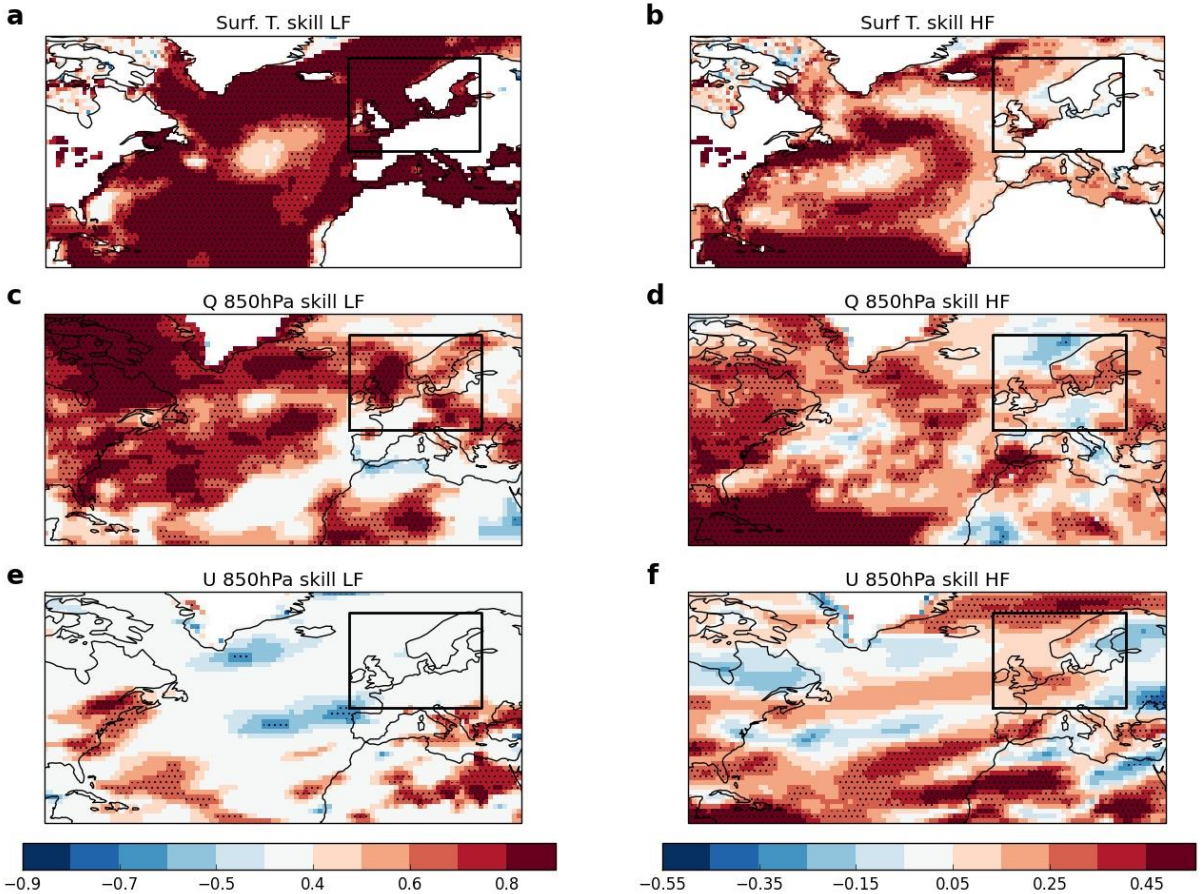
- However, on the high frequency there is both a local connection to humidity and an apparent connection to N.Atlantic jet



Are these drivers well predicted?

- Consistent with our findings, SST and specific humidity are well predicted but circulation is not on the low frequency

- High frequency does show some significant skill for winds over N.Europe



In summary, model European rainfall skill appears to be driven partly by predictable low-frequency N. Atlantic SST variability driving changes in **moisture availability** which is advected on the climatological westerly flow and also high-frequency skill in predicting the **strength of the winds**.

“Signal-to-noise paradox”

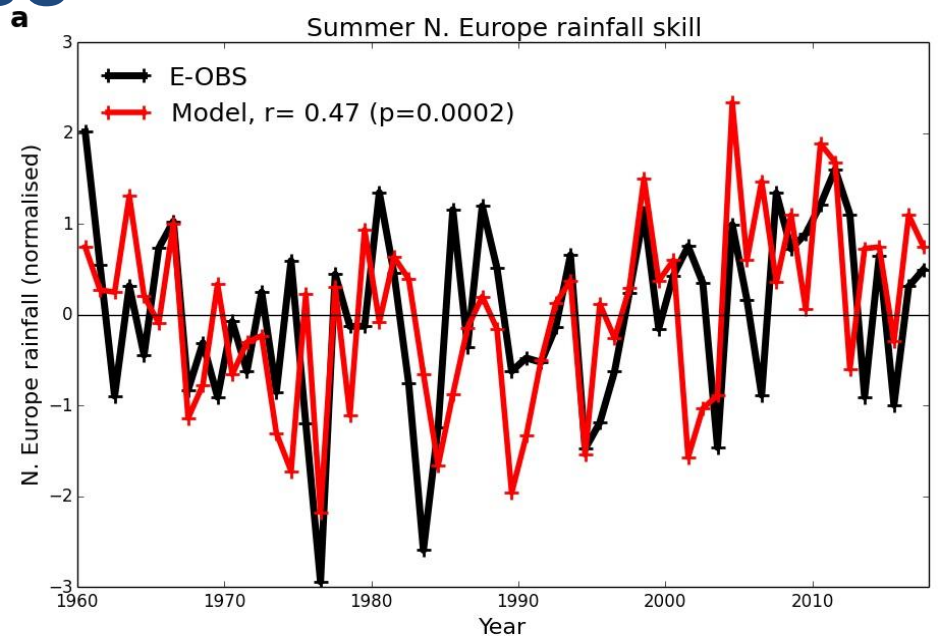
- Plotted in absolute units (mm/day), ensemble members (green) have similar amplitude variability to observed (black)

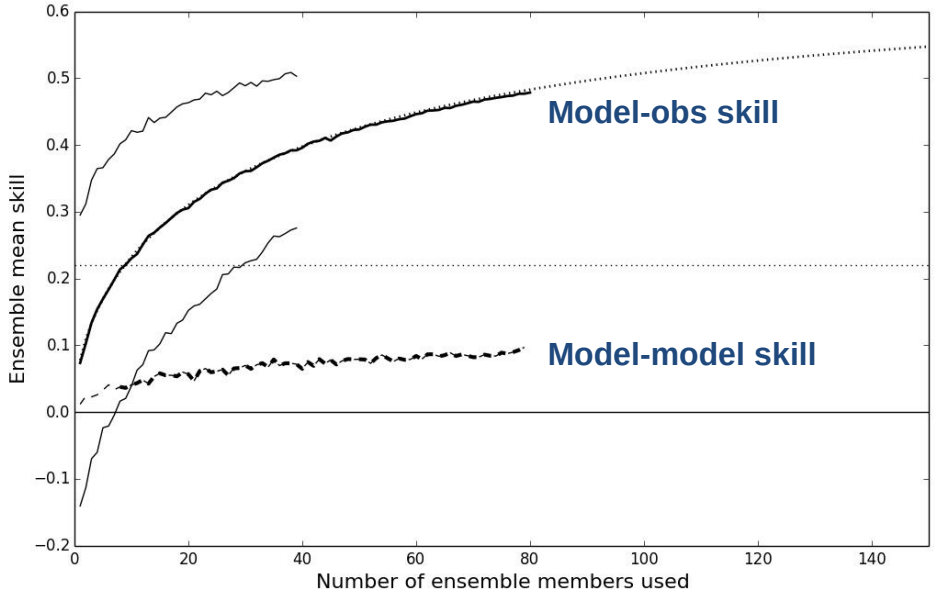
- However, ensemble mean (red) shows very weak (factor of 7) model predictable signal. High skill found is at odds with this – suggesting model members not interchangeable with real-world

- Can demonstrate this by calculating model-model skill, reveals strange situation where model has higher skill for predicting the real-world than it does itself

- Very similar to winter NAO, where signal-to-noise paradox identified. Common cause or different mechanism?

- Practically, large ensembles required for skilful European summer rainfall forecasts





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Summer
real-time forecasts

www.metoffice.gov.uk

Summer 2017 rainfall forecast

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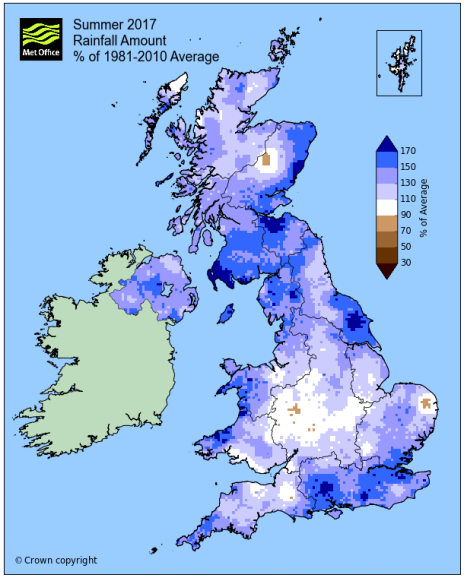
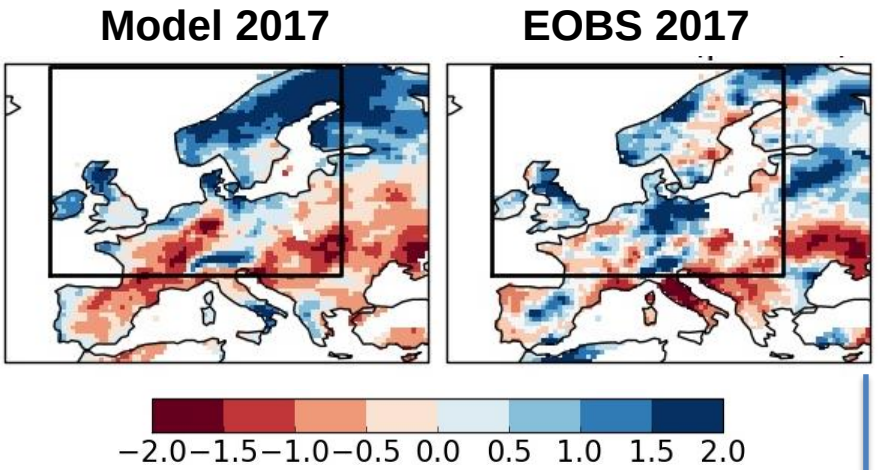
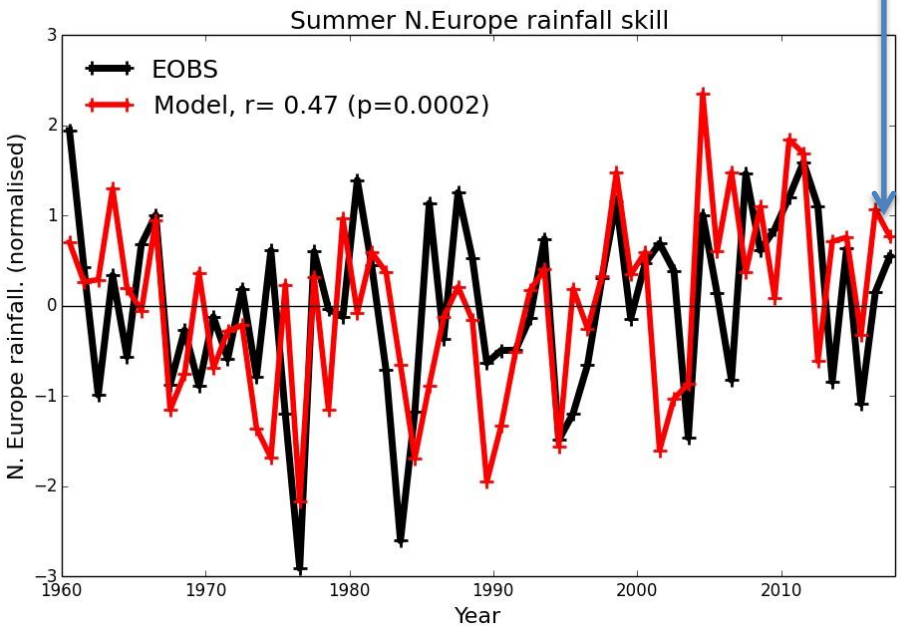
- Added a forecast for Summer 2017
- Model predicted wet over N. Europe, with wettest anomalies to the North and drier anomalies to the South

UK perspective – wet (135% of average):



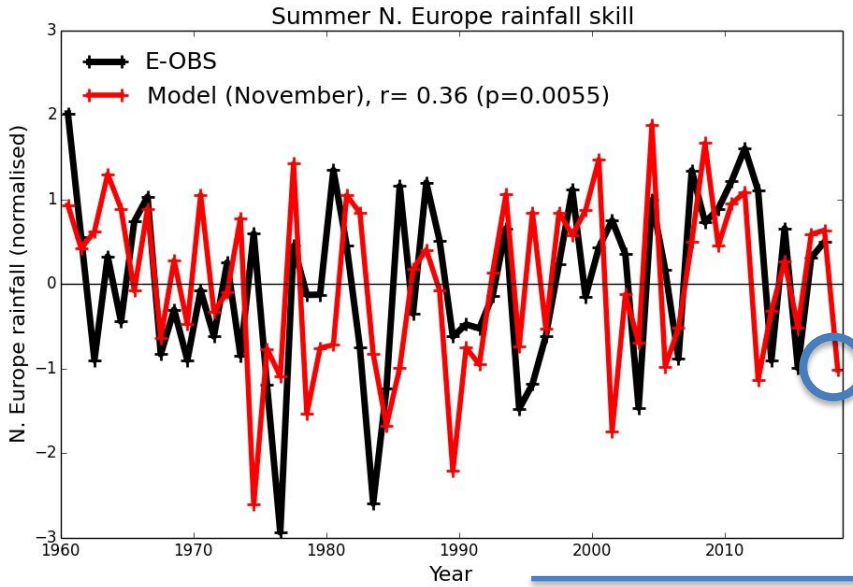
"The summer was rather wet, with rainfall above average for the UK in each individual month. Provisionally this ranks as the **ninth wettest** summer in the UK in a series since 1910."
- National Climate Information Centre (NCIC)



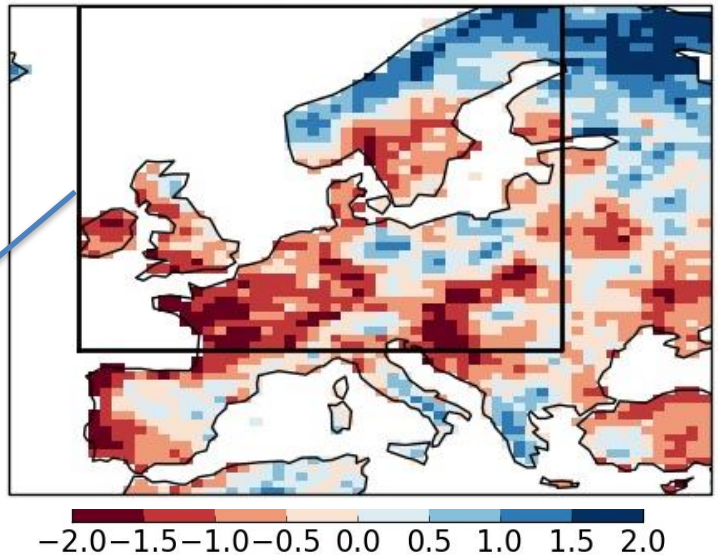


Summer 2018 rainfall forecast

- Summer 2018 forecast
- Only November start date run so far (40 members)



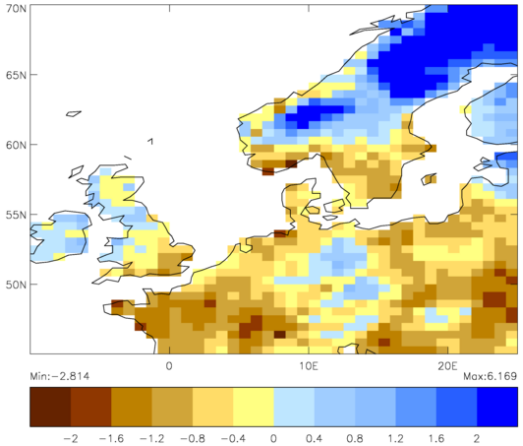
Model 2018 (from November)



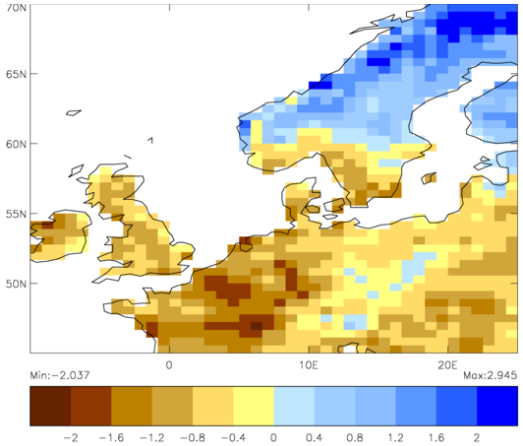
- Apply same philosophy for GloSea5 forecasts – maximise number of ensemble members by creating lagged ensemble

- February-May GloSea5 forecasts gives 200+ members and the system is run independently by the Korean Meteorological Agency too.

GloSea5 224 members



GloSea5 (KMA) 222 members

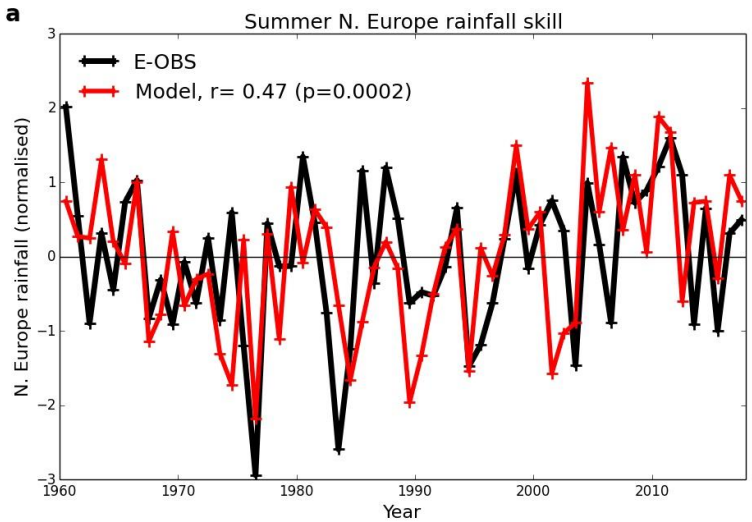


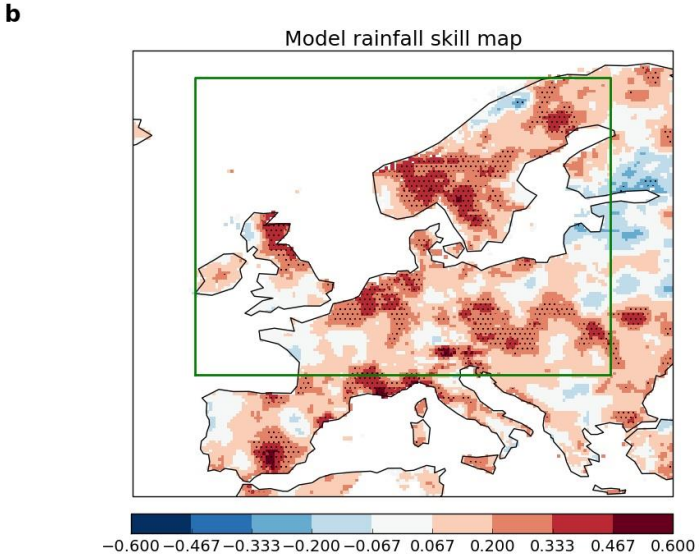
Summary

- Skilful initialised predictions of European summer rainfall, including prolonged wet periods (e.g. 2007-2011) and individual dry years (e.g. 1976 or 2003)

- Skill appears to originate via thermodynamic processes on low-frequency, through skilful prediction of North Atlantic SSTs, moisture availability and thus convective precipitation – poor skill for dynamic jet/SNAO

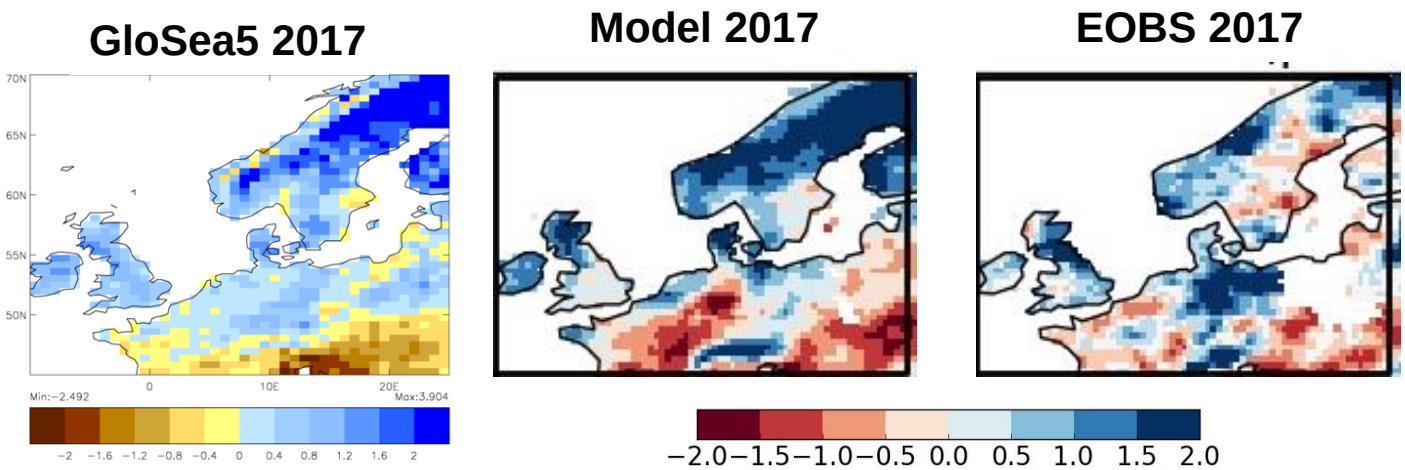
- However, evidence of skilful prediction of Atlantic jet on interannual timescales





- Model response is far too weak and requires a very large ensemble (80+ members) to achieve skilful predictions of the (single realisation) real-world – further work needed to understand this ‘signal-to-noise paradox’, but exciting that real-world summer rainfall appears highly predictable!

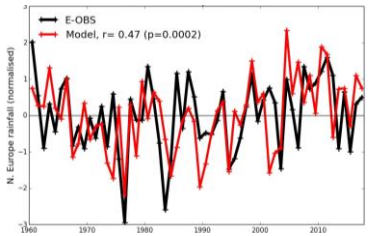
Summer 2017 forecast GloSea5



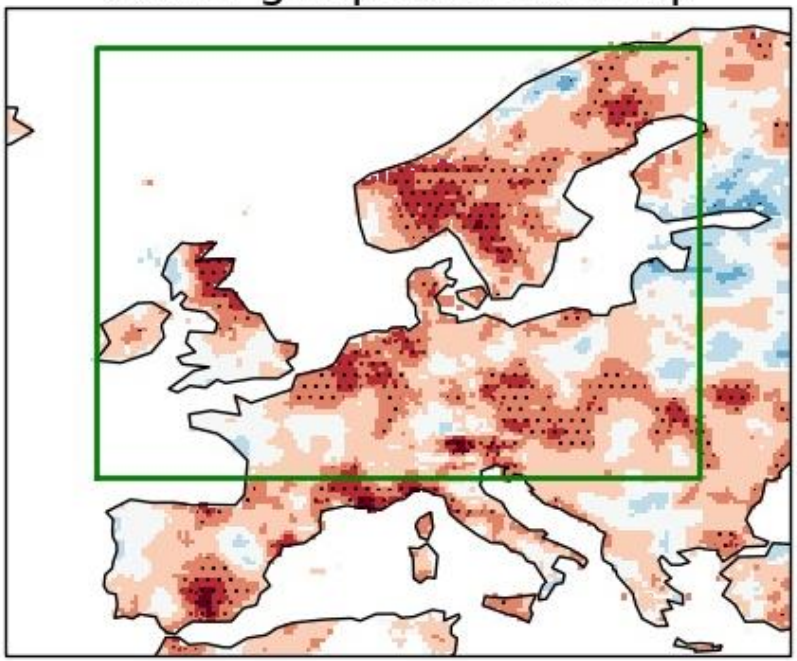
- Apply same philosophy for GloSea5 forecasts – maximise number of ensemble members by creating lagged ensemble
- Standard GloSea5 procedure looks at last 42 members, corresponding to last 3 weeks of forecasts
- Here we use 6th Feb – 15th May 2017, ~200 members
- Will hopefully use this to inform summer 2018 forecast

Extra slides...

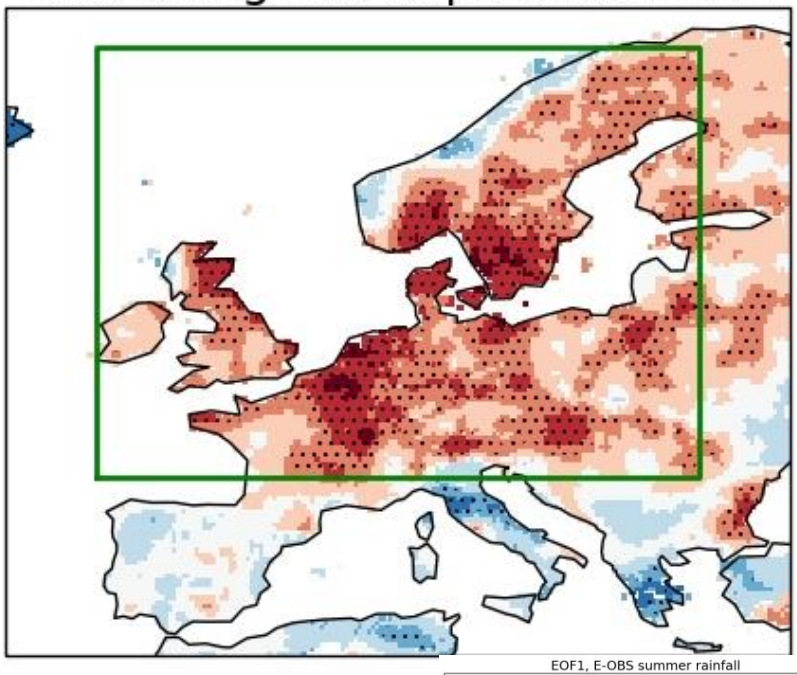
Skill at gridpoints

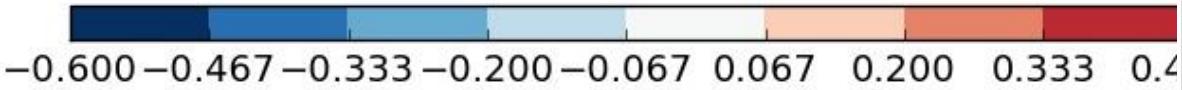


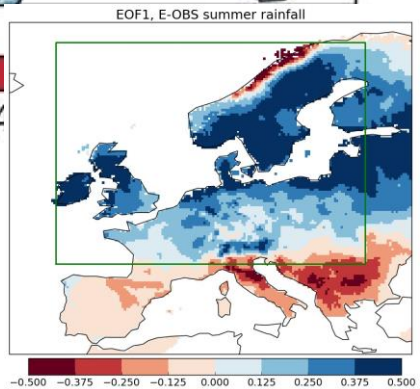
Model gridpoint skill map



Skill using N.Europe timeseries







Other challenges

- ...what is the root cause of the “Signal-to-noise” paradox?

- Is UM convective parametrisation scheme entrainment sufficiently sensitive to environment changes (such as low-level humidity/stability)?
    - changes planned in GA8 and 9 may test this (*Alison Stirling*)

- Why can we not predict low-frequency N. Atlantic jet shifts (SNAO)?

- Why are forecasts from November as skilful as those from May?

- Northern European air temperature is poorly forecast (not significant)
    - unusual as normally find temperature is more skilful than rainfall

    - in observations summers are ‘cold & wet’ or ‘hot & dry’
    - however, model summers are ‘cold & dry’ or ‘hot & wet’
    - clearly an error here!

    - is this because missing SNAO and storm track shifts?
    - small model rainfall signal does not drive significant cloud changes and hence we miss shortwave radiation changes?

So, as ever, plenty more work to do...! ☺

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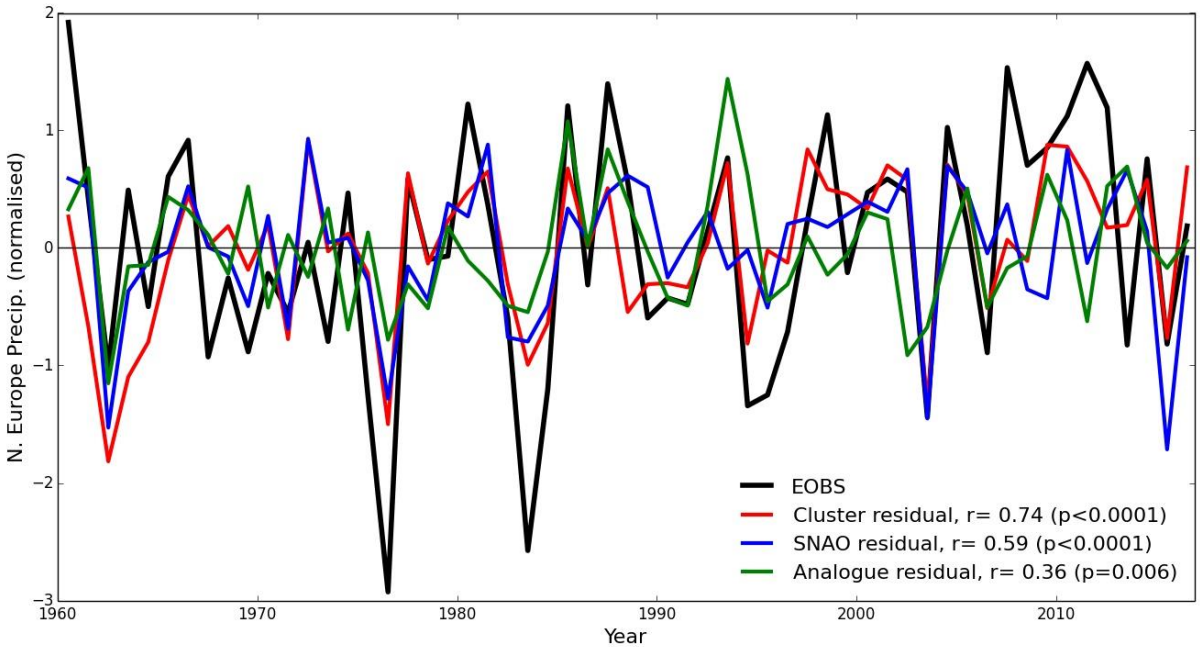

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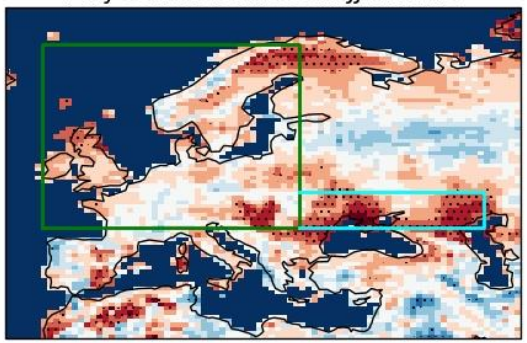
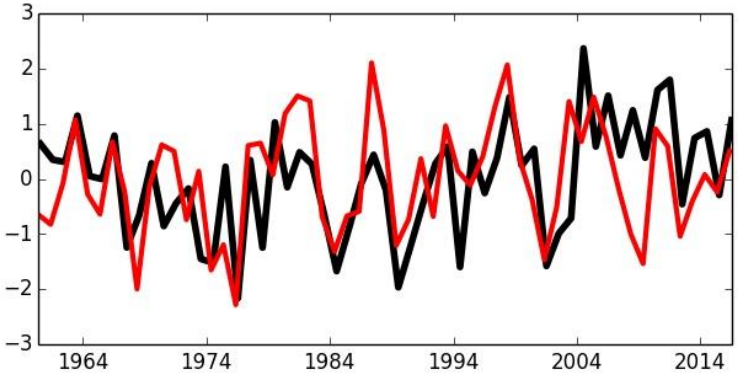
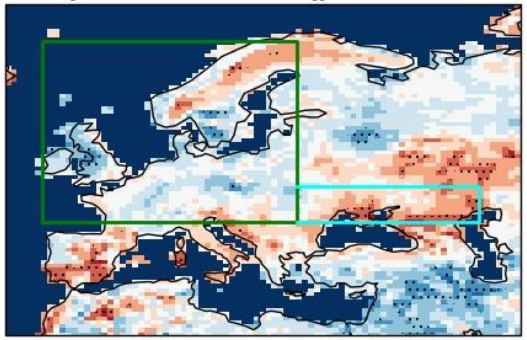
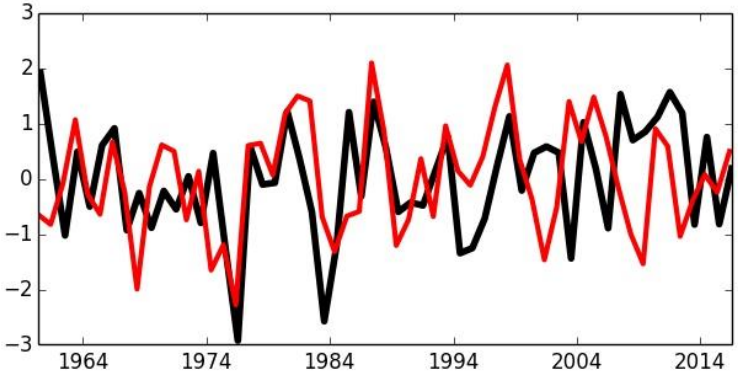
May Soil Moisture corr JJA NEuro





May Soil Moisture corr JJA NEuroEOBS





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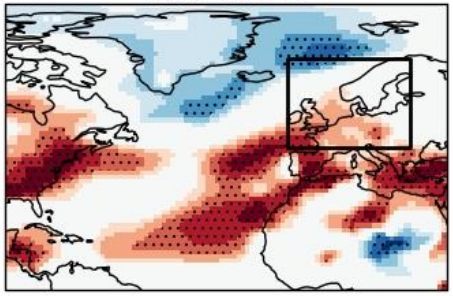
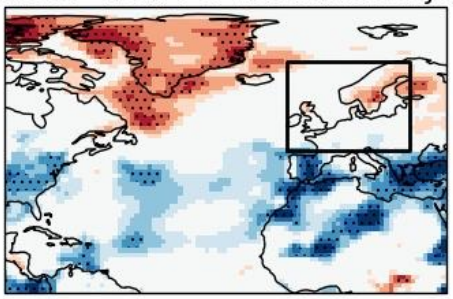
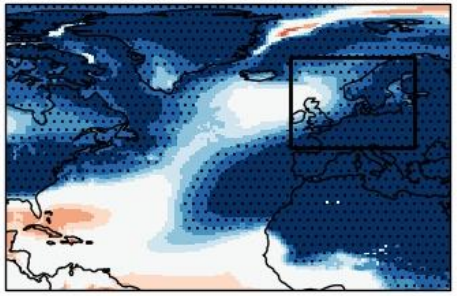
MSLP skill LF



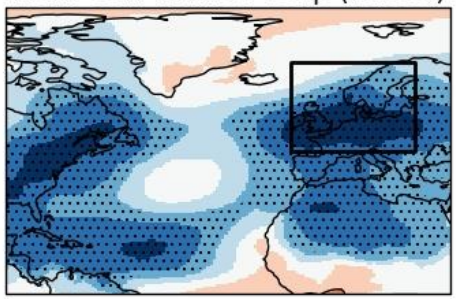
Local MSLP vs airT LF correlation in JRA-55



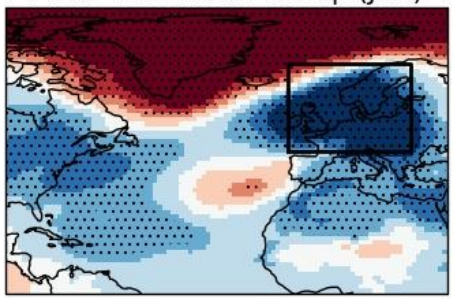
Local MSLP vs airT LF correlation in Model



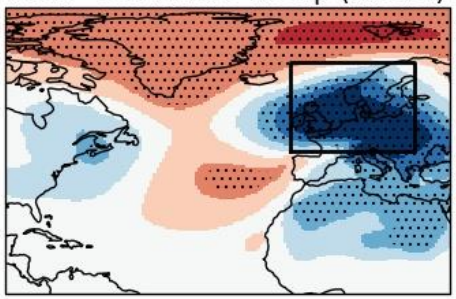
MSLP corr NEuro Precip (forced)



MSLP corr NEuro Precip (JRA)



MSLP corr NEuro Precip (model)



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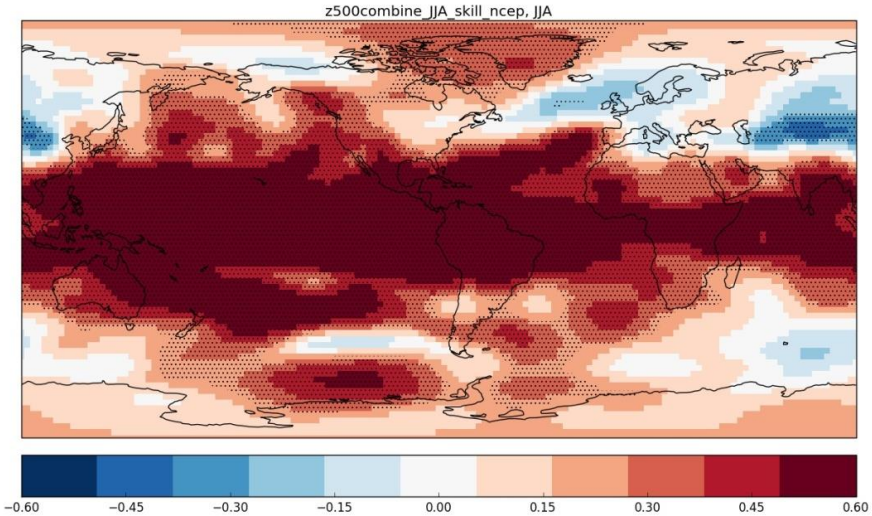
z500combine_JJA_skill_ncep, JJA
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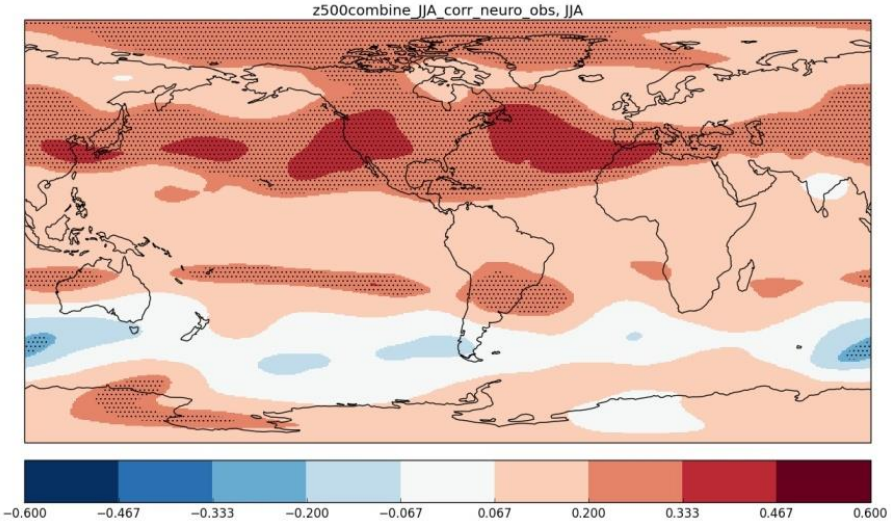
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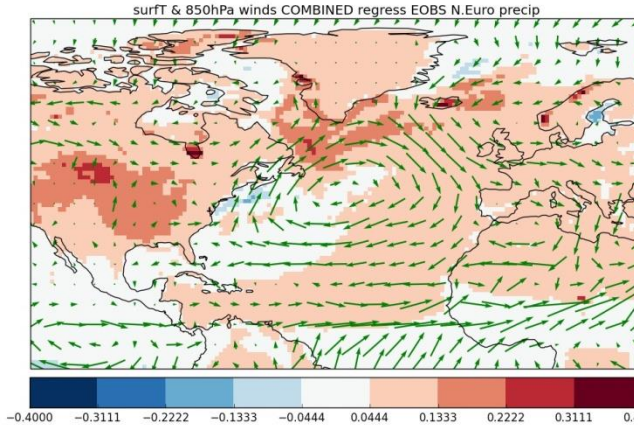
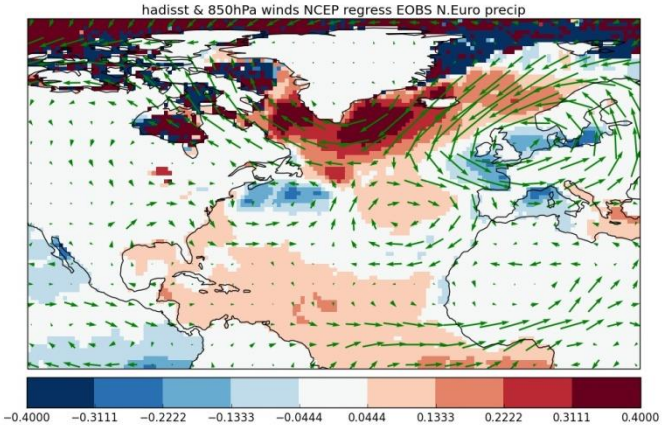
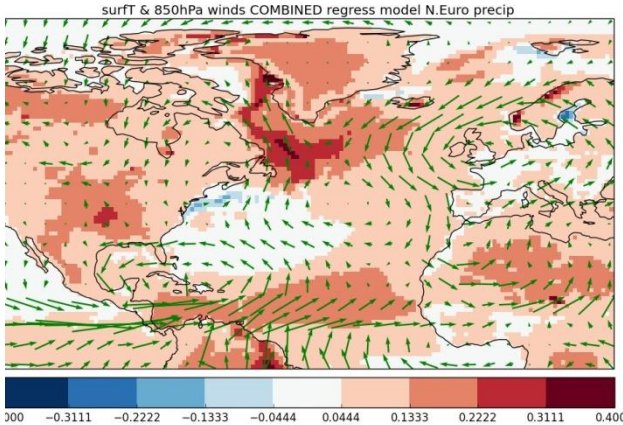
−0.067
0.067
0.200
0.333
0.467
0.600

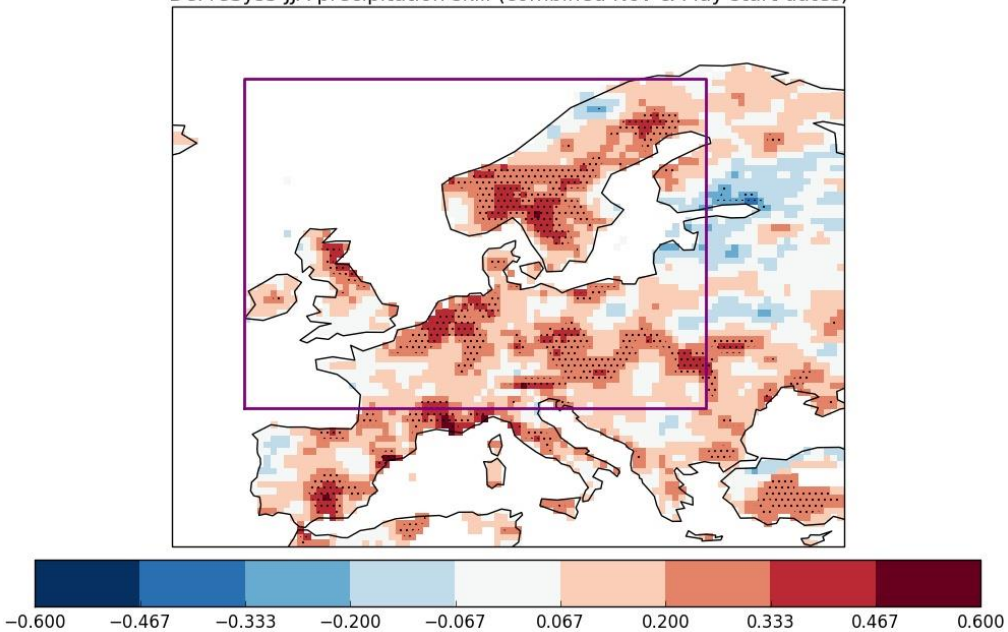

surfT & 850hPa winds COMBINED regress EOBS N.Euro precip
−0.4000
−0.3111
−0.2222
−0.1333
−0.0444
0.0444
0.1333
0.2222
0.3111


hadisst & 850hPa winds NCEP regress EOBS N.Euro precip
−0.4000
−0.3111
−0.2222
−0.1333
−0.0444
0.0444
0.1333
0.2222
0.3111
0.4000

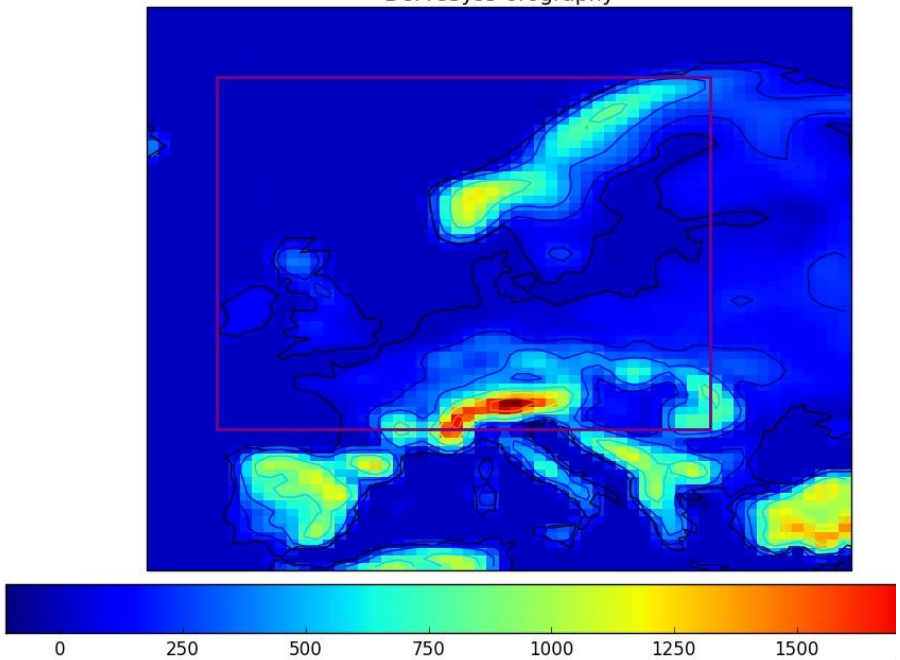

surfT & 850hPa winds COMBINED regress model N.Euro precip
−0.3111
−0.2222
−0.1333
−0.0444
0.0444
0.1333
0.2222
0.3111

Met Office
Hadley Centre

DePreSys3 JJA precipitation skill (combined Nov & May start dates)



DePreSys3 orography



DePreSys3 JJA climatological precipitation (combined Nov & May start dates)