Skilful seasonal predictions of Summer European rainfall

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Dunstone et al 2018, GRL
Summer rainfall extremes

**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
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
Understanding the origin of this skill
- 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 (!?)

![Graph showing comparison of JRA-55 vs E-OBS for N. Europe rainfall anomaly. The chart indicates a strong correlation with a Pearson’s correlation coefficient of 0.92 and a p-value less than 0.001. The data spans from 1960 to 2015, with anomalies measured in millimeters per day.](image-url)
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.
• 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.
Summer real-time forecasts
Summer 2017 rainfall forecast

- 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)

GloSea5 224 members
GloSea5 (KMA) 222 members

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.
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!
• 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...! 😊