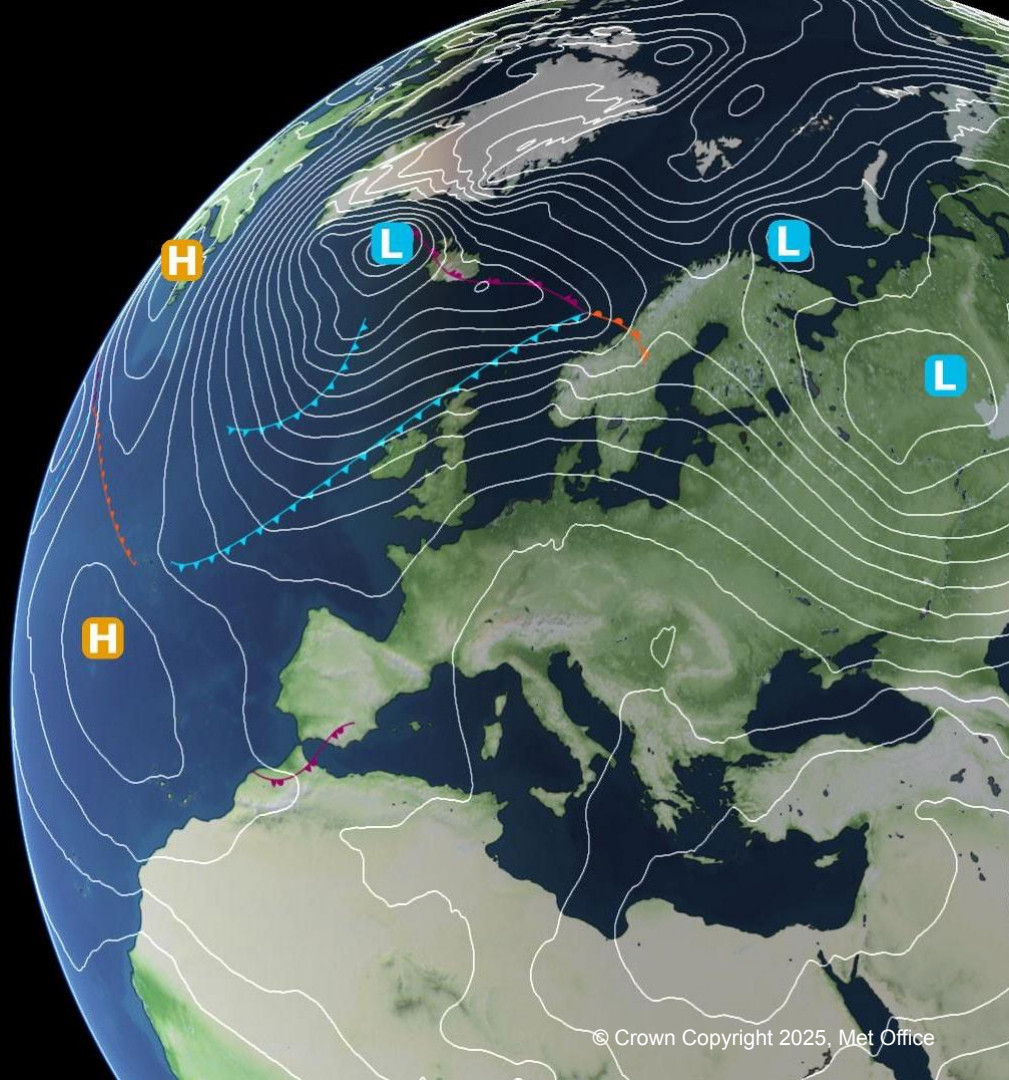


Extratropical cyclones through the ages

Duncan Ackerley

- What is an extratropical cyclone?
- What is the structure?
- Where do you find them?
- Averaging in time smooths them out, so how can we assess their representation in our models?



Finding them in datasets

Cyclone tracking.

- Previously used TRACK, but now experimenting with...
- TempestExtremes (TE) is (from <https://climate.ucdavis.edu/tempestextremes.php>),
- Two steps:
 - DetectNodes: Detects features spatially at each snapshot of a dataset given user specified parameters e.g. look for mean sea level pressure minima below a certain threshold.
 - StitchNodes: Links in time the candidate fields identified in the DetectNodes output within set parameters (user sets these) and outputs tracks.
- Tracking done on MINIMA in the mean sea level pressure field in this analysis.

What I do

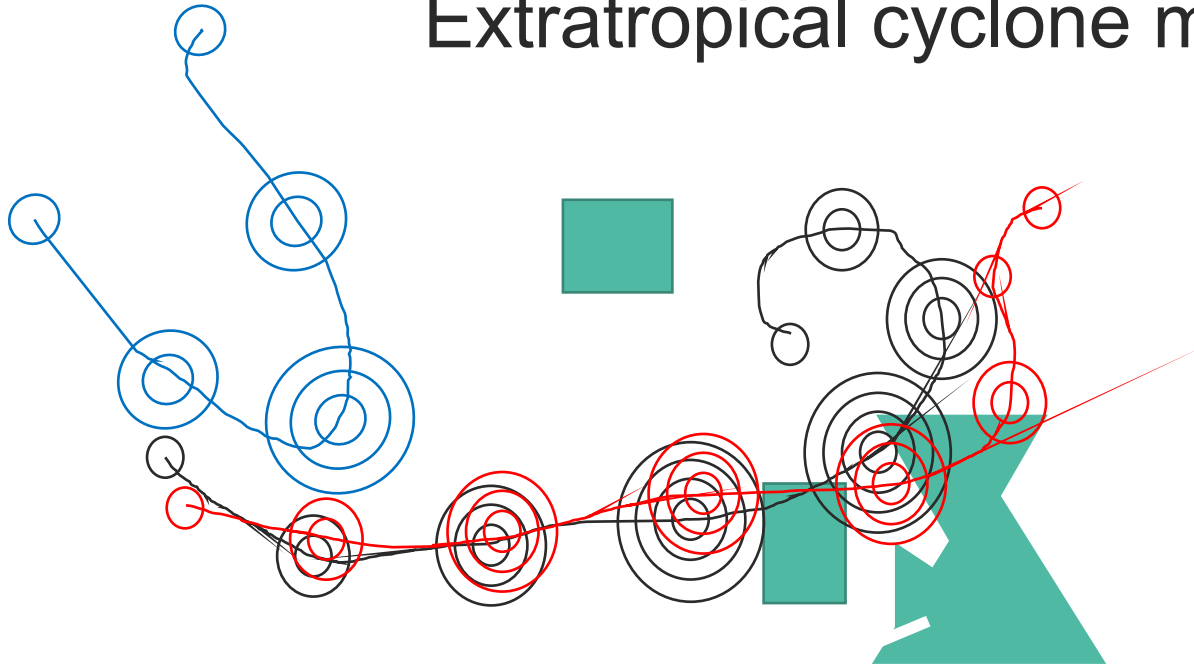
- Evaluate NWP performance.
 - Cyclone matching (next slide).
 - Can compare forecasts of different model configurations.
 - Example: forecast performance from 1995 to present.
- Composite cyclone structure in NWP and climate (seamless approach).
 - NEW WORK
 - Pull out pressure and 850 temperature structure from individual cyclone.
 - Average across all cyclones and compare with analysis.
 - Any common biases to NWP and climate?
- Asses the storm tracks in climate runs.
 - Track density
 - Average over many years shows storm track locations.
 - Differences in track density highlight issues with cyclone activity in climate models relative to reanalyses.

Met Office Operational Model Analysis

Forecast year (Dec.-Jan.-Feb.)	Comments
1995-1996	HadAM, original dynamics (Cullen 1993) – N144
1999-2000	HadAM, original dynamics (Cullen 1993) – N216
2003-2004	New Dynamics from August 2002 – N216
2007-2008	HadGEM1 from January 2005 – N320
2011-2012	GA3/3.1 from March 2011 – N512
2015-2016	GA6/6.1 ENDGame dynamical core July 2014 – N768
2019-2020	GA7.2 implemented December 2019 – N1280
2023-2024	Coupled NWP operational May 2022 – N1280

- Data from December-January-February.
- Using 00Z forecast daily (90 forecasts).
- Retrieved MSLP, and 850 hPa U, V and THETA_w.
- Tracked MSLP features with TempestExtremes.
- Performed cyclone matching against ERA5 analyses to get statistics.

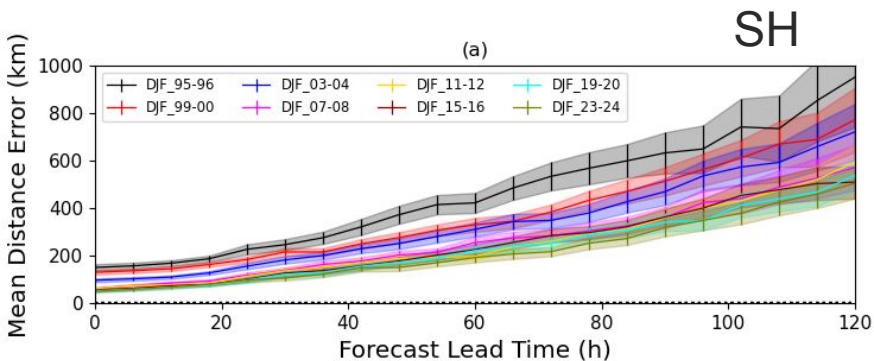
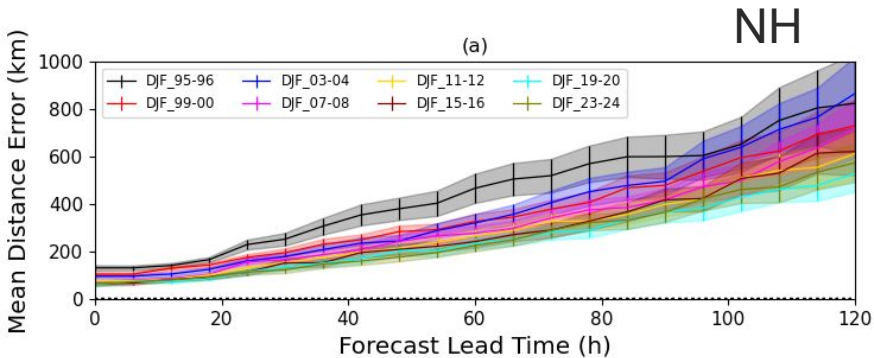
Met Office NWP assessment: Extratropical cyclone matching



- Cyclone matching
 - Cyclones must be within 4° of each other for the first 4 points of their tracks
 - 60% of the forecast and analysis tracks must overlap in time.
 - Save cyclones that fulfil criteria above for further processing.
- Retrieve mean error statistics for matched cyclones (i.e. what are the errors, on average, for matches):
 - Separation distance (km)
 - Intensity (mean sea level pressure, hPa)
 - speed errors (km / hr)
 - plus other things if wanted...

Collate matched cyclone bias information, average in over forecast lead time and then...

Cyclone matching results

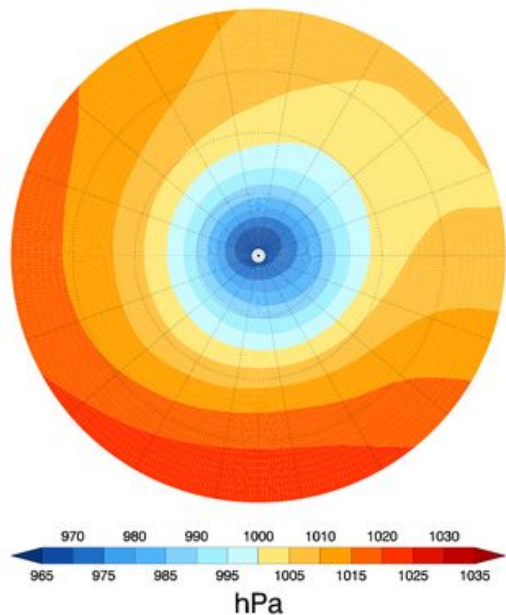


- Mean distance error as functions of forecast lead time in both hemispheres.
- T+72 forecast errors for 2023-24 setup is equivalent to T+24 error in 1995-96.
- Nice to show forecast improvement, but we can do more.

What does a cyclone look like in ERA5 and the UM?

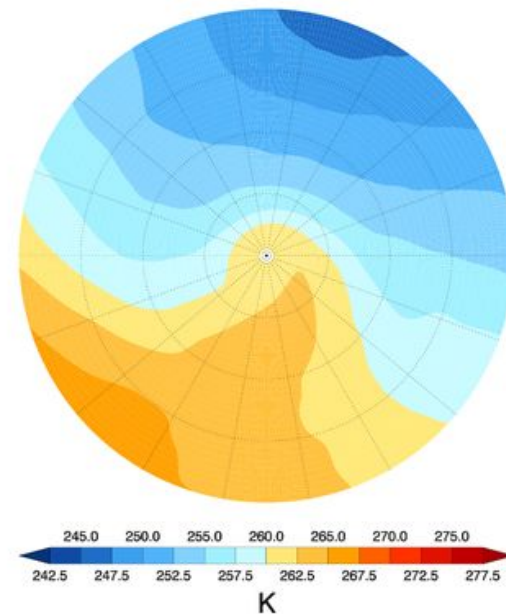
- Great Storm October 1987 – sting jet responsible for damage.
- Knowing the track is only part of the story – knowing the structure also matters!
- Using the cyclone tracks, I can use TE to composite fields around the cyclone.
- The seamless approach to modelling means I can compare storm composites in the NWP setup AND the climate setup.
- Are there any common biases?

What do these storm look like? Compositing...



- Maximum intensity composites of top-200 NH storms.
- Mean Sea level Pressure (left).
- 850 hPa temperature (right).

Figures created using:
STORMS Extratropical
Cyclone Atlas (2011,
reference below).



Met Office Both climate and NWP cyclones now

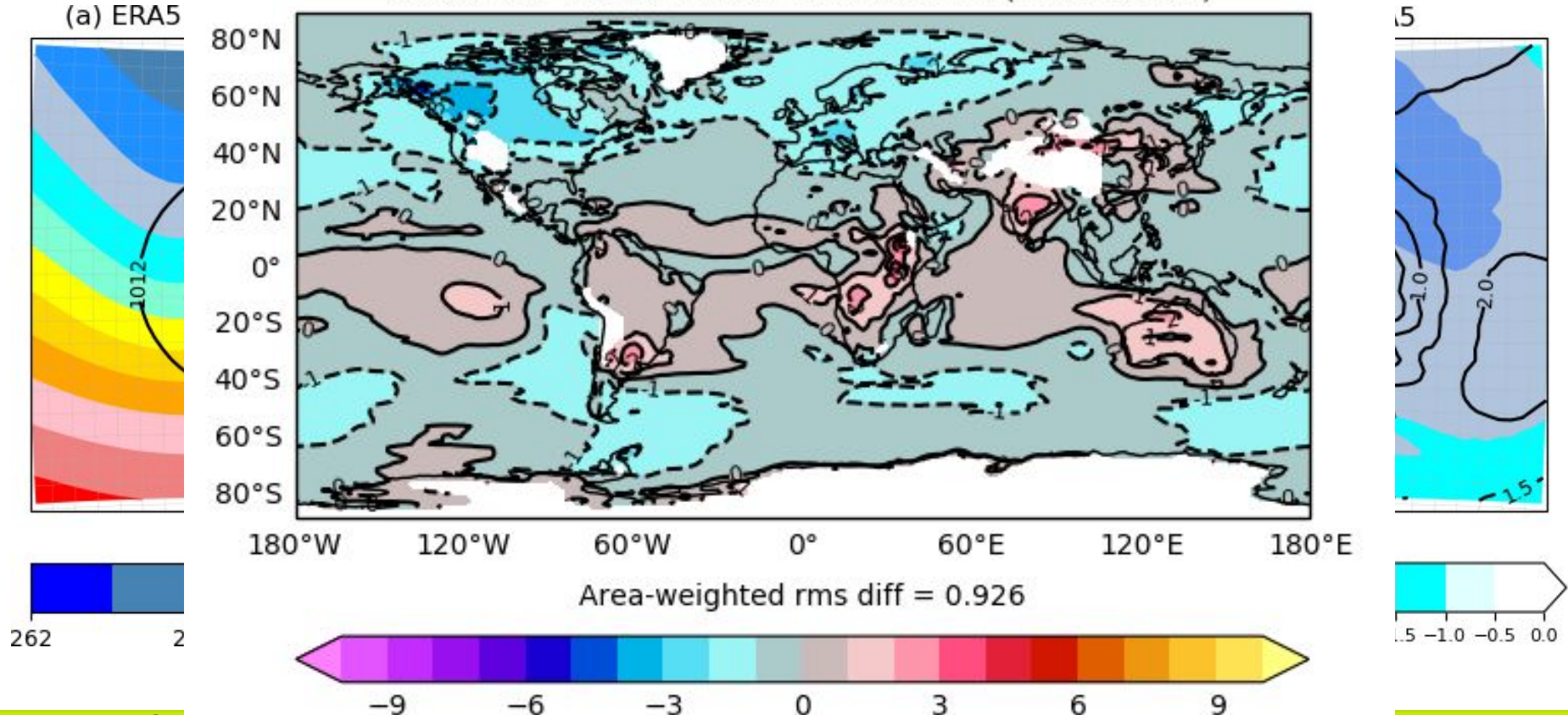
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- Composite NWP cyclones:
 - 2011-12 GA3 vs ERA5
 - 2023-24 GA8 vs ERA5
- Composite equivalent climate run cyclones
 - GA3 (20 yrs) vs ERA5 (1979-2024)
 - GA8 (20 yrs) vs ERA5 (1979-2024)

And now for the simulated storms... but first some caveats

- All cyclones
 - Not composited on time i.e. plots are average over all points in lifecycle of all cyclones.
- NWP cyclones
 - Composites done on 5-day forecasts so includes repeats of the same storm (same for ERA5 too).
 - Biases representative of first 5 days of a forecast (do not assume analysis is unbiased).
 - Temperature field is wet bulb potential temperature at 850 hPa.
- Climate cyclones
 - 850 hPa Temperature not wet bulb potential temperature
 - Had to extrapolate over missing points, which may affect composites.
 - N96 simulations – not good for simulating extratropical cyclones (nor the storm tracks).

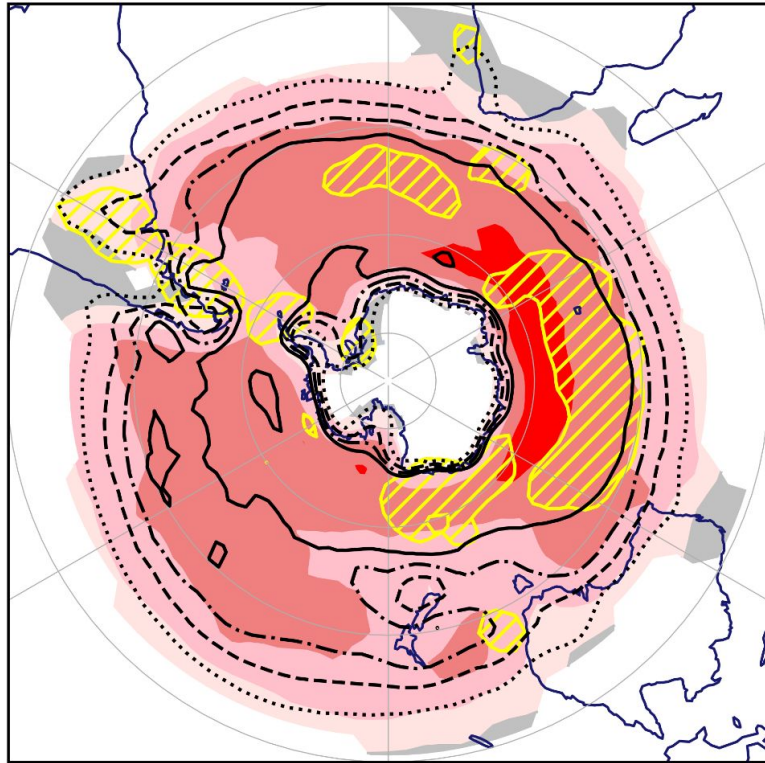
c) Temperature at 850 mb for djf
U-BS778: GA8.0 minus ERA-Interim (1989-2008)



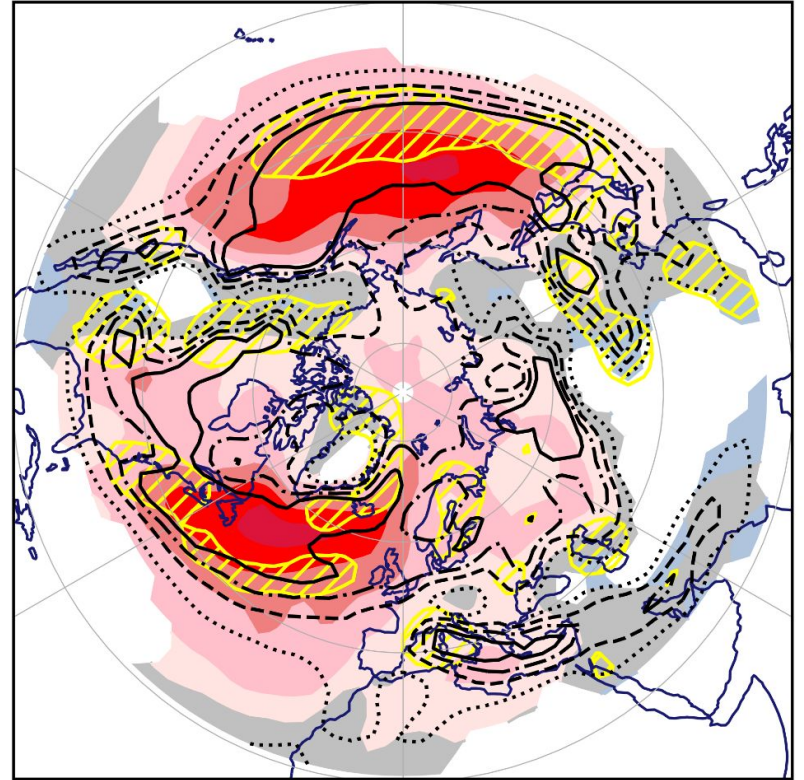
NOTE: Initial conditions important here e.g. ERA5 may have a cold bias making UM appear erroneously warm.
Doing the above with DIMOSIC data would be interesting!

 Met Office 20-year averages: Winter Storm tracks

(c) JJA



(a) DJF

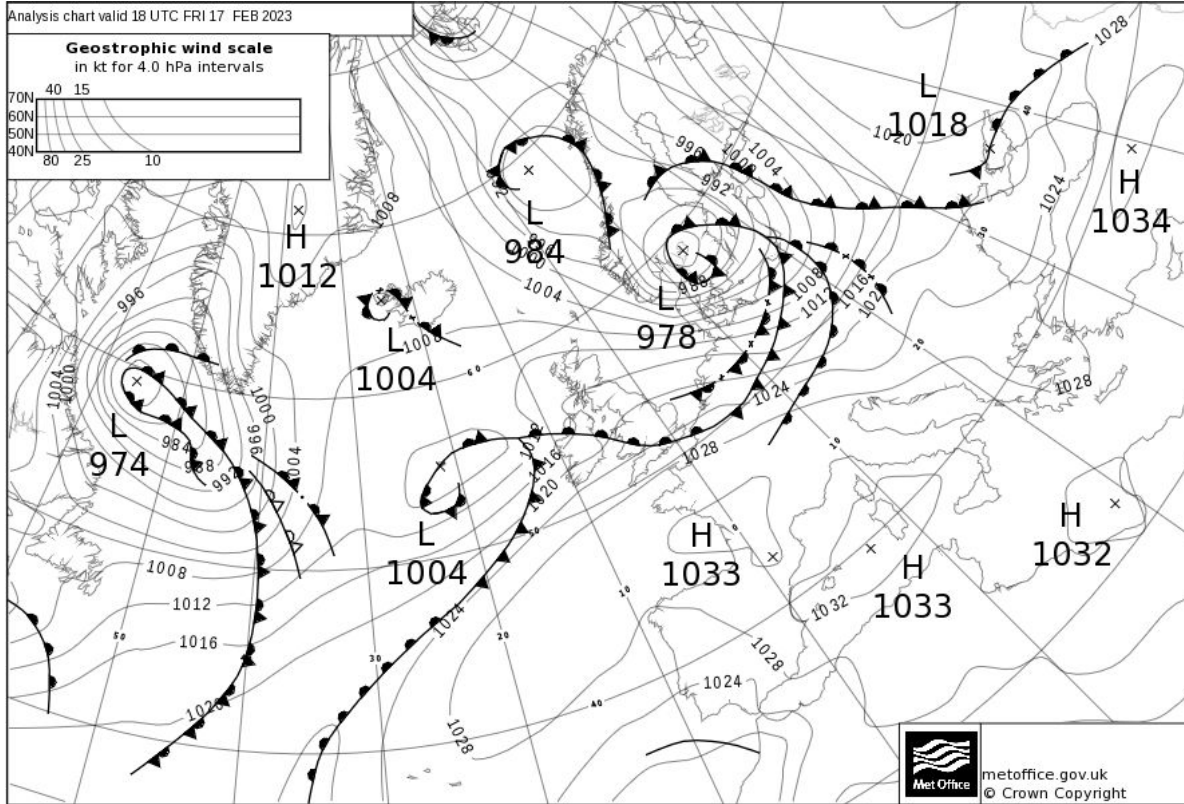


Learned so far...

- Forecasting and climate simulations have improved markedly in 30 years extratropical cyclones.
- UM composite cyclones resemble ERA5.
- Hints of Northern Hemisphere west-east temperature bias for NWP cyclones visible in climate simulations – when allowing for systematic cold bias.
- N96 simulations perform less well than N216 for the storm tracks.
- Nevertheless, N96 had been improving from HadGEM2-A to GA8 until GA9 significantly degraded, but N216 improved a lot!

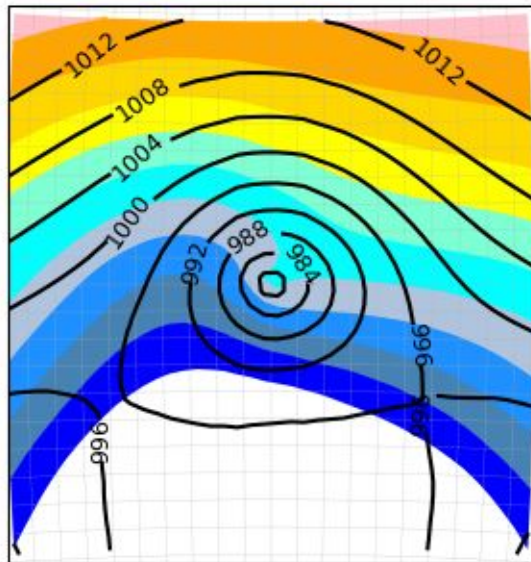
- Composite matched cyclones for NWP (not all cyclones).
- Composite on time in cyclone lifecycle (e.g. maximum intensity).
- Rotate cyclones based on direction of propagation (like in the Storm Atlas and other studies).
- Tidy up climate model data (better accounting of missing points).
 - Impact of Greenland, Rockies and Himalaya for Northern Hemisphere
 - BIG impact of Antarctica for the Southern Hemisphere.
- Perhaps focus the analysis on ocean basins (no missing data).
- Revisit NWP vs Climate cyclones once the above has been done – what biases common (or not!) to both setups.
- Extend the analysis above to LFRic – TE can run on unstructured grids!!
- Work is in very early stages so suggestions from anyone else would be very welcome!

Met Office An LFRic cyclone

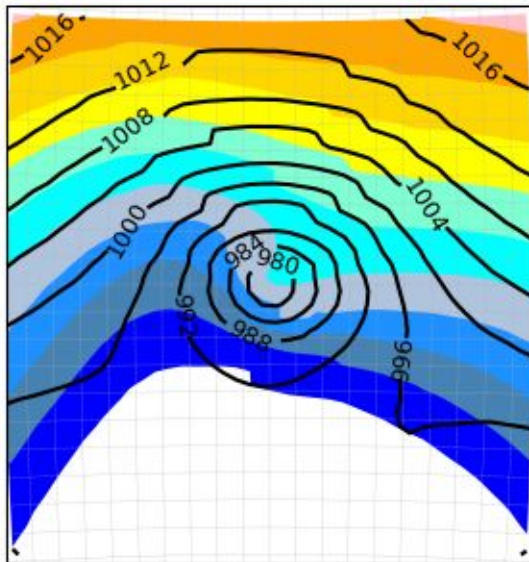


- LFRic and the UM set up to run NWP simulations.
- Forecasts run for January – March 2023.
- Storm Otto (named by Danish Met Service) occurred in February 2023.
- What does the pressure field look like in ERA5, LFRic and the UM?

(a) ERA5 SH DJF 1979-2024



(b) GA8 DJF (20 yrs)



(c) UM - ERA5

