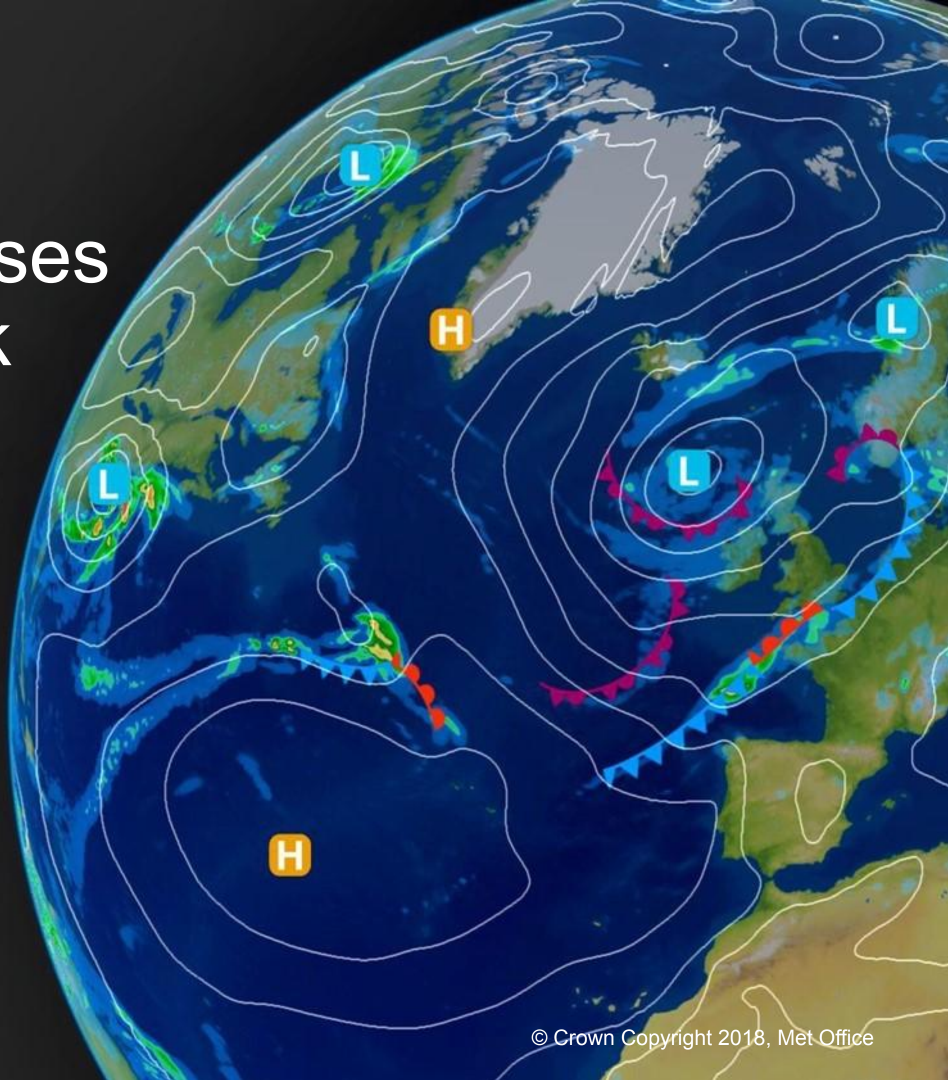
Understanding sea-ice biases in the seamless framework

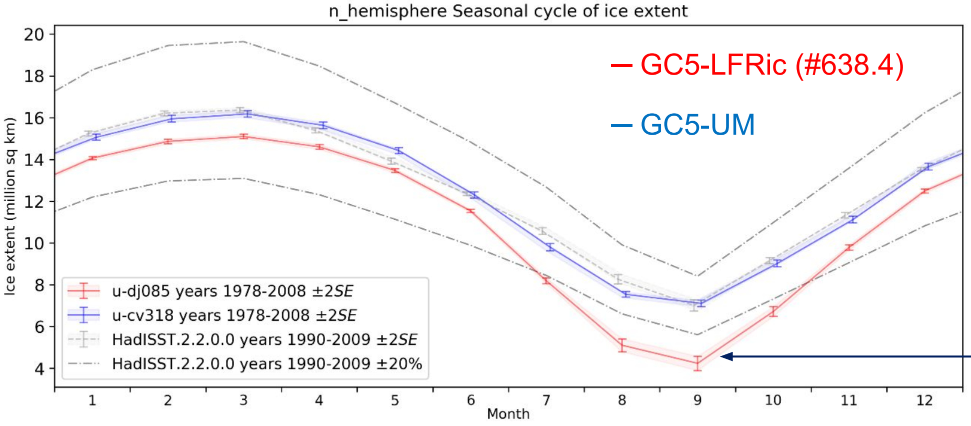
By Dan Copsey and Tim Graham



The new GC5-LFRic model
(compared to the GC5-UM model)

- Uses a new cube-sphere grid.(GC5-UM is regular lat-long)
- Includes a new dynamical core: Gung-Ho. GC5-UM uses EndGame.
- Maintains almost all the same physics parameterisations as GC5-UM (so should perform the same).
- Is still coupled to the same ocean and sea ice models as GC5-UM (GOSI9).

The GC5-LFRic sea ice issue



Model = C144 (or N216) ORCA025
30 year means (present day)

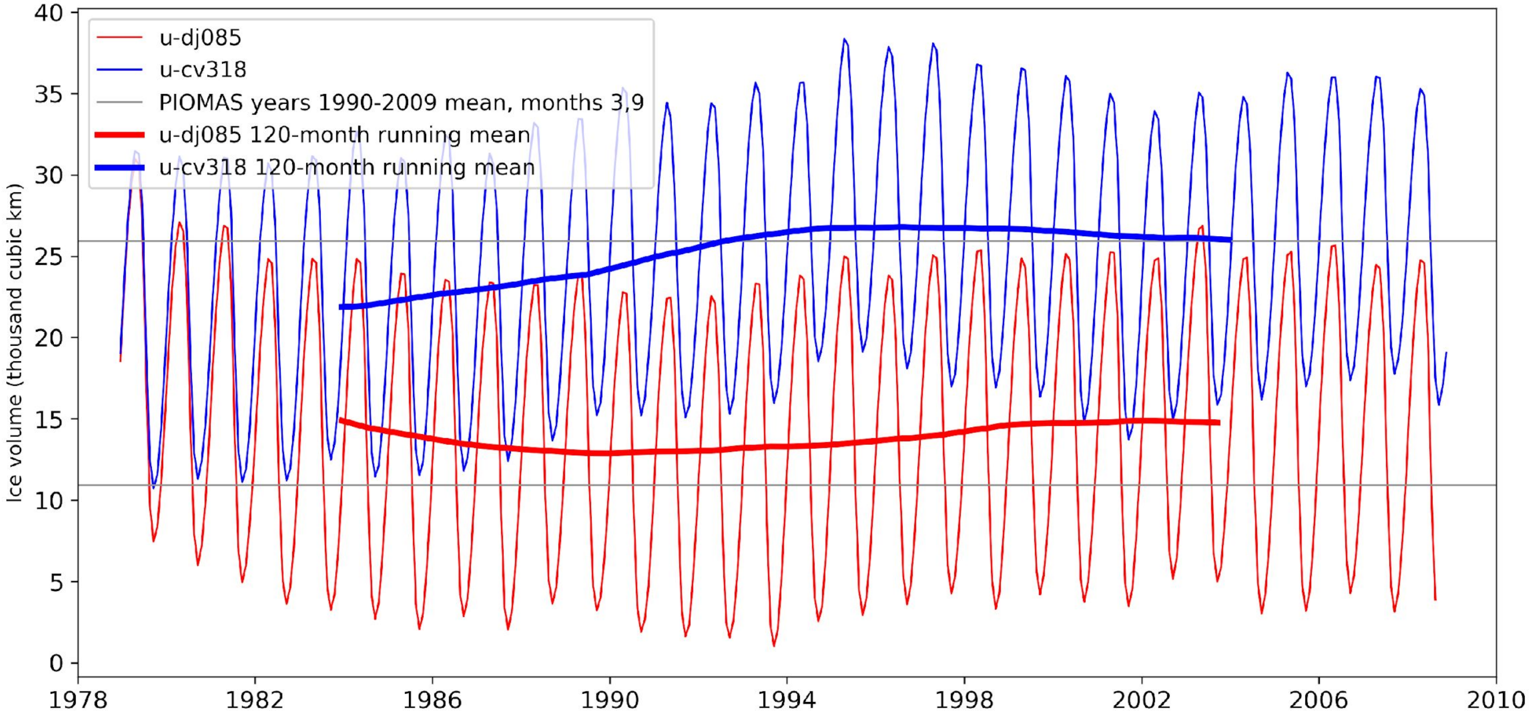
The new GC5-LFRic model experiences excessive Arctic sea ice loss during the summer.

Results

C144ORCA025 u-dj085 (#638.4)

— GC5-LFRic (#638.4)
— GC5-UM

Time series of sea ice volume (Northern Hemisphere)



Sea ice volume substantially reduced throughout the year for GC5-LFRic, particularly in Northern Hemisphere.

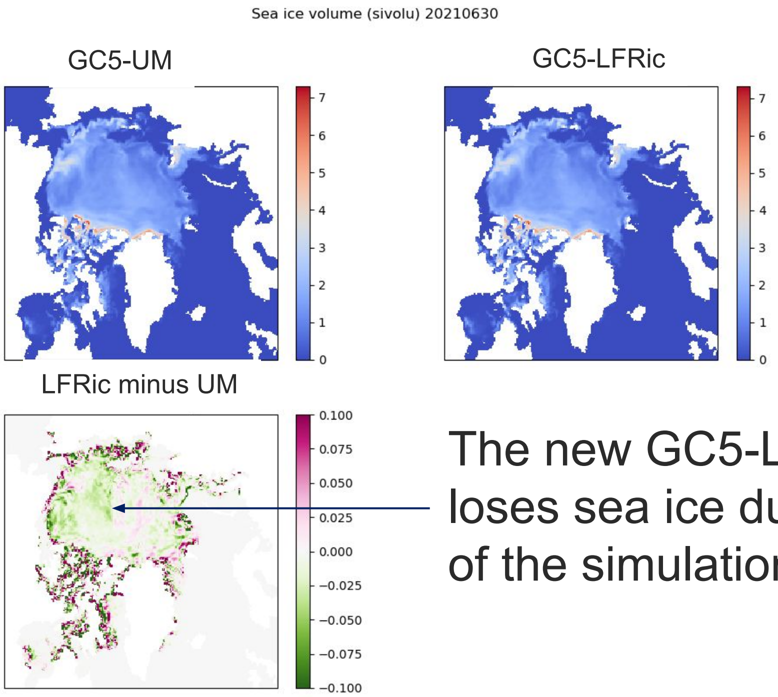
Slide from Emma Fiedler

Met Office Hadley Centre

Identifying similar sea ice loss in coupled NWP simulations

Model = C224 (or N320) ORCA025
6 day means
(initialised on 30th June 2021)

Change in sea ice volume after 6 days

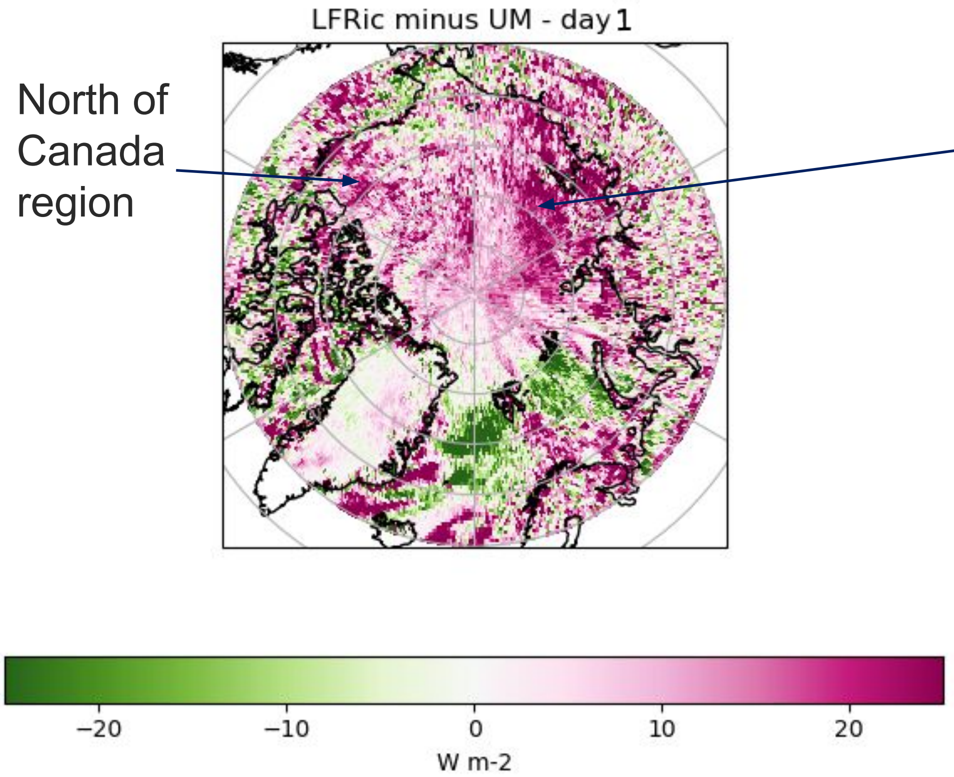


The new GC5-LFRic model loses sea ice during the 6 days of the simulation.

Plots by Naomi Parsons

Analysing net downward surface shortwave fluxes

- Downward net surface shortwave

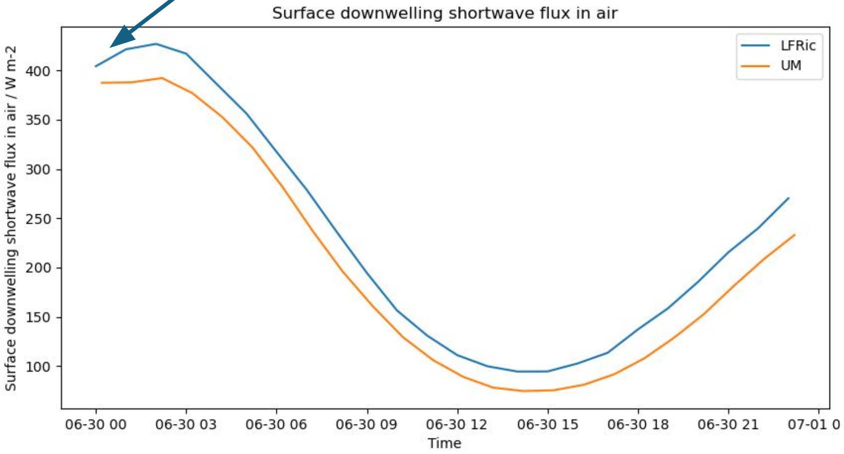


LFRic has increased downward shortwave leading to more sea ice melt in these regions

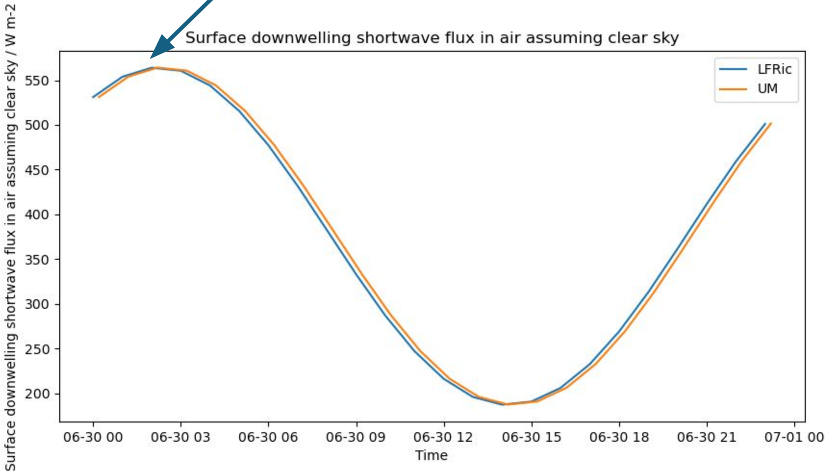
Plots by Naomi Parsons

Timeseries of surface SW fluxes in region North of Russia over first day

LFRic has an immediate increase in surface shortwave at the first call to radiation before any cloud changes can have an effect



Clear sky is virtually identical suggesting the problem is with the clouds (or how the clouds are represented by radiation)



Plots by Naomi Parsons

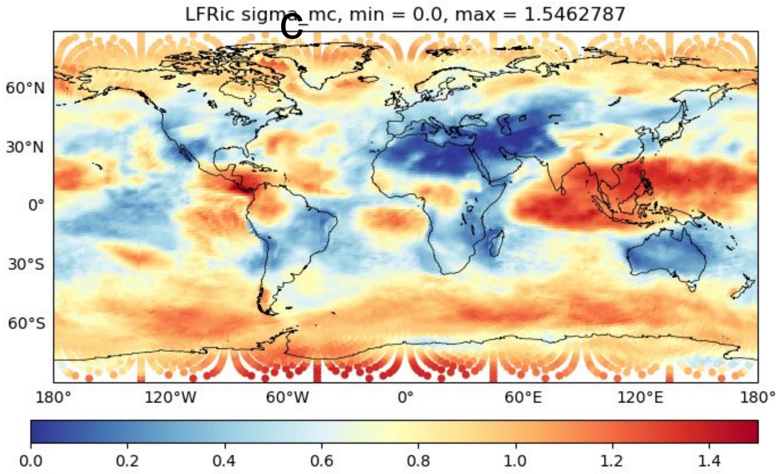
Two theories

- The cloud inhomogeneity is different between UM and LFRic
- The cloud droplet effective radius is different between UM and LFRic

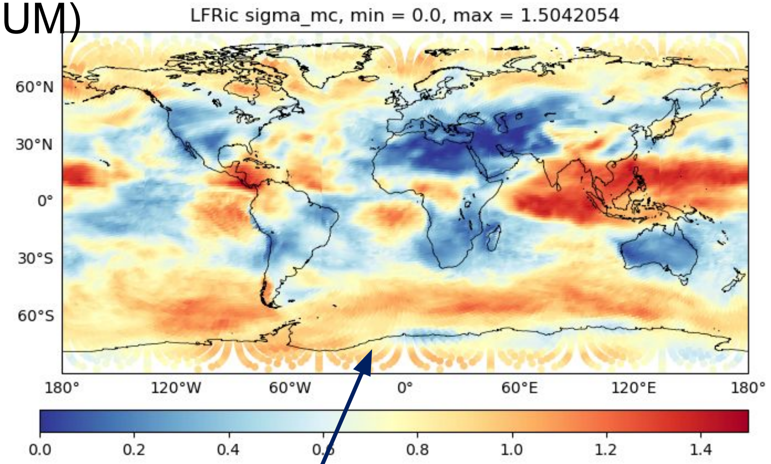
How does the cloud inhomogeneity parameter change (cloud Fractional Standard Deviation - FSD)

The FSD is a measure of how fragmented the clouds are. Larger = more fragmented = more shortwave reaches surface.

GC5-LFRic



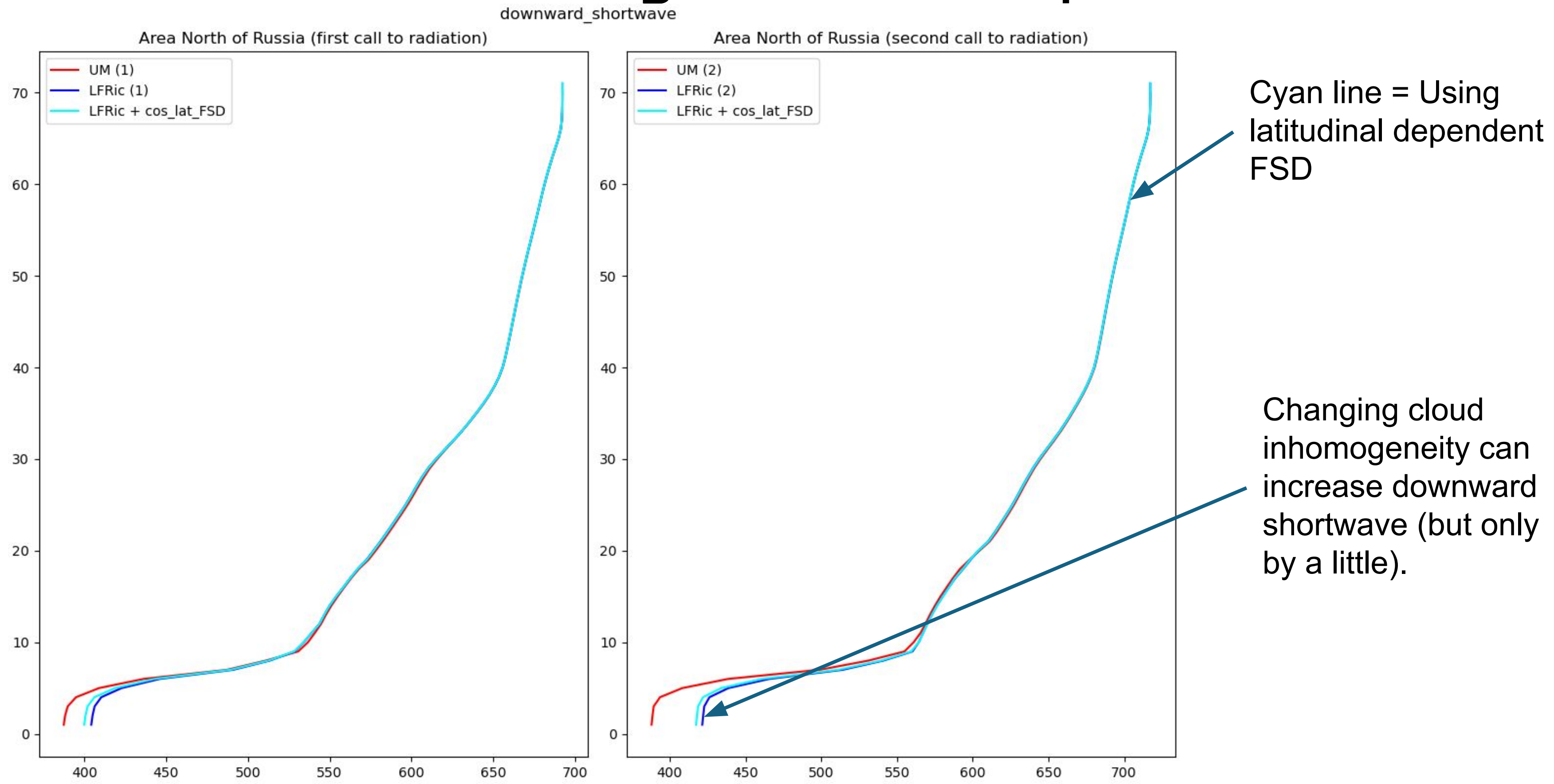
GC5-LFRic but with latitudinal FSD (like the UM)



Adding latitudes to FSD calculations reduce FSD near poles. Clouds are more uniform.

Plots by Ian Boutle

How does changing FSD change the solar flux as it descends through the atmosphere

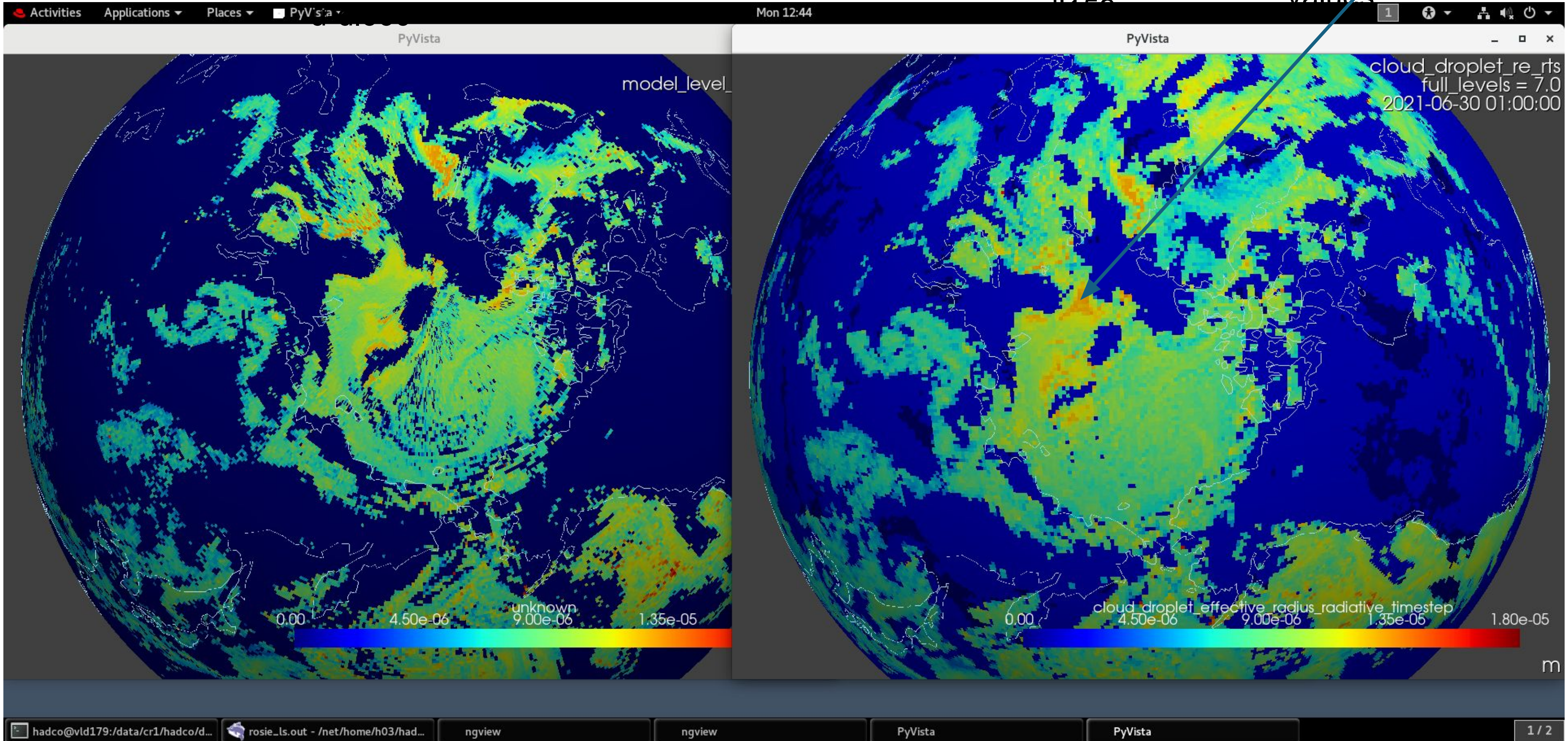


Cloud droplet effective radius on level 7 at first call to radiation

UM

LFRic

LFRic has larger values

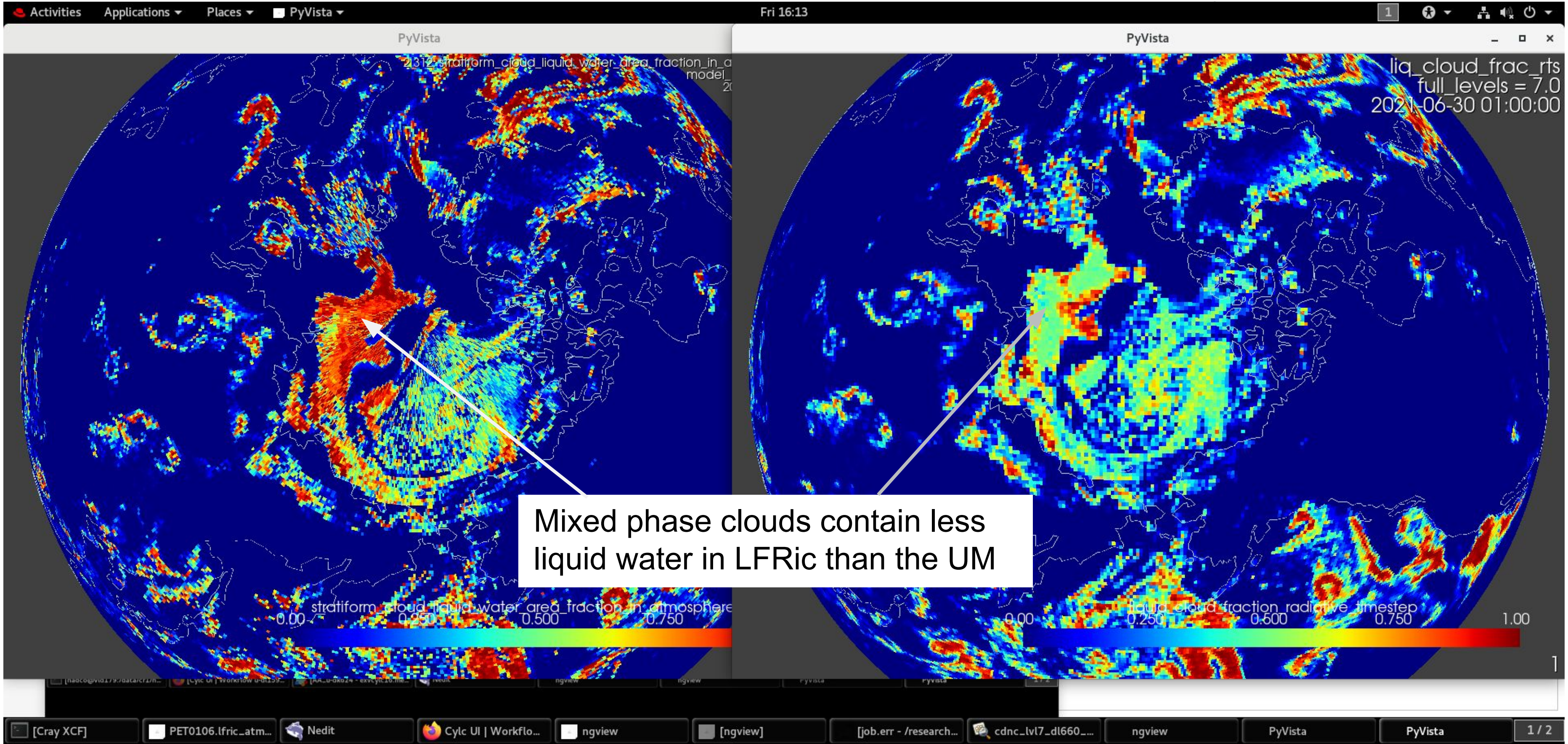


Liquid cloud fraction (as used by radiation) on level 7 at first call to radiation

UM

LFRic

LFRic has less cloud

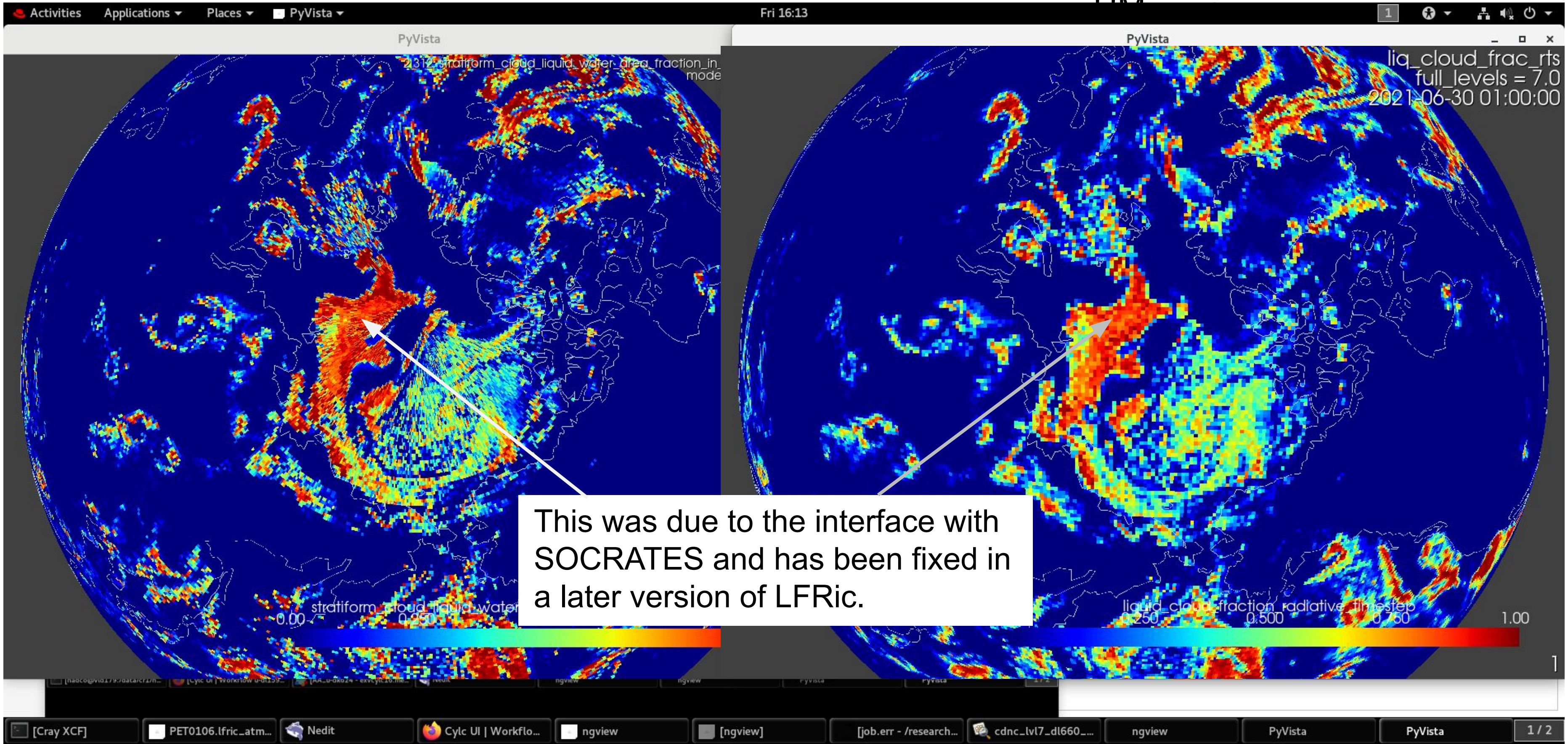


Mixed phase clouds contain less liquid water in LFRic than the UM

Fixed liquid cloud fraction (as used by radiation) on level 7 at first call to radiation

UM

LFRic u-dn080 LFRic now matches UM



This was due to the interface with SOCRATES and has been fixed in a later version of LFRic.

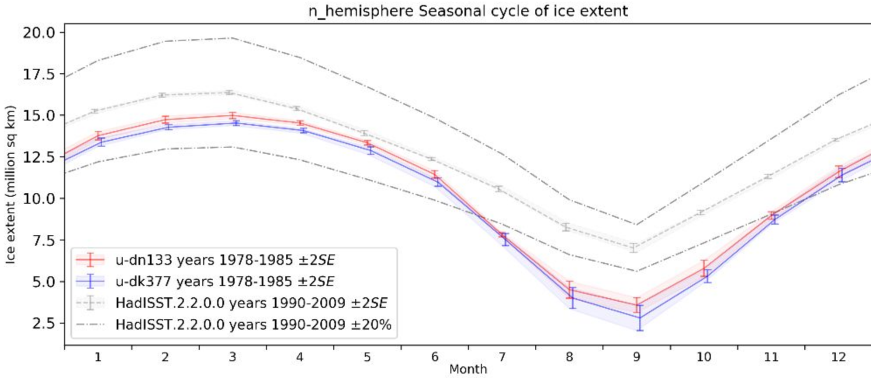
Met Office

Summary of coupled NWP investigations

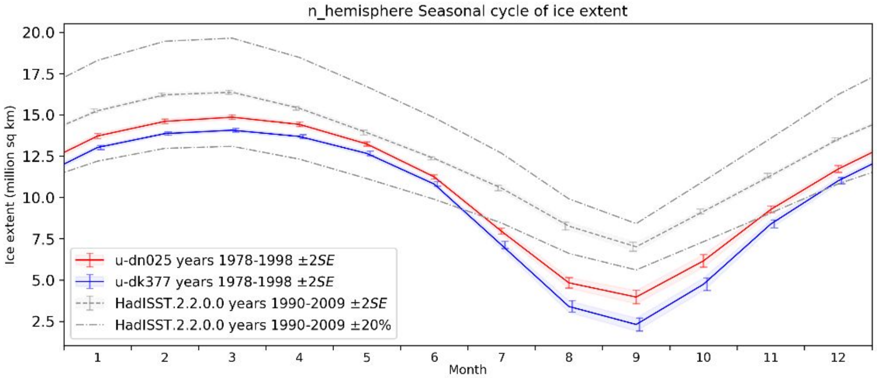
- Over the Arctic, in locations where there are mixed phase clouds, LFRic underestimated the contribution from liquid cloud to the radiation scheme. This has now been fixed because of this investigation.
- Over the Arctic the cloud inhomogeneity scheme behaves differently because it is dependent on the grid spacing and that is different between the UM and LFRic. This investigation has shown that some cloud inhomogeneity tuning can go some way to improve the model.

Applying these fixes back to the GC5-LFRic coupled climate model

The effect of the mixed phase fix



The effect of adding latitude dependence to cloud inhomogeneity calculations

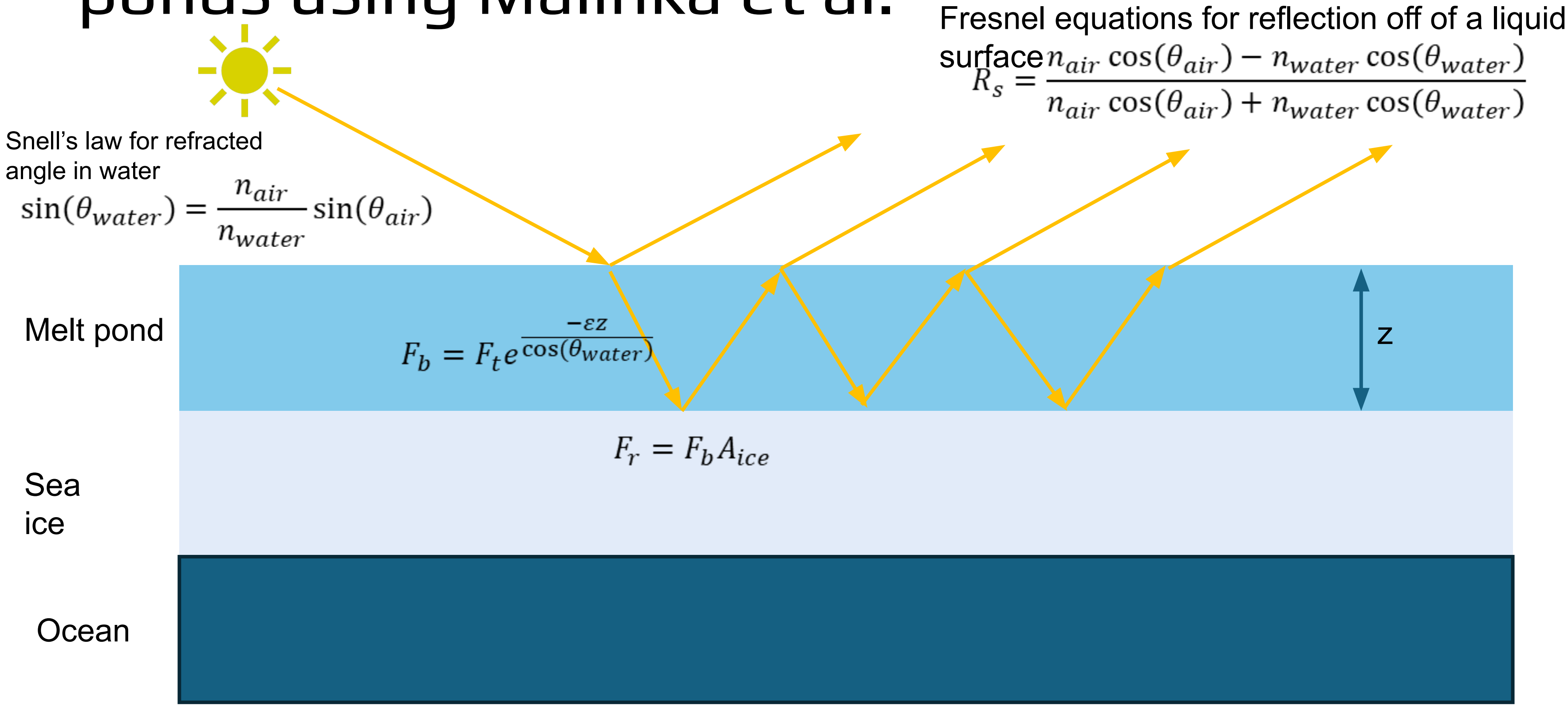


Blue = GC5-LFRic control

Red = GC5-LFRic with mixed_phase_fix

Red = GC5-LFRic with latitude dependence in cloud inhomogeneity

Coding up a new albedo scheme for melt ponds using Malinka et al.



Coding up a new albedo scheme for melt ponds using Malinka et al.

- Makshtas and Podgorny initially combined the above equations from the previous slide into 1 equation and then Malinka et al rewrote them into a simple form:

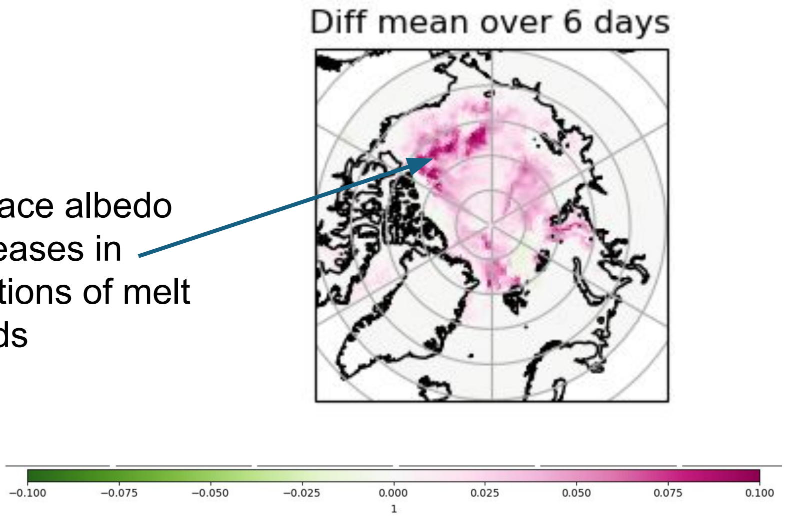
$$A(\mu_0) = R^{\mathrm{F}}(\mu_0) + \frac{T^{\mathrm{F}}(\mu_0)\exp\left(-\varepsilon_{\mathrm{w}} z/\mu_0^{\mathrm{w}}\right) f_{\mathrm{out}}(\varepsilon_{\mathrm{w}} z)\, A_{\mathrm{b}}}{n^2\left(1 - A_{\mathrm{b}} f_{\mathrm{in}}(\varepsilon_{\mathrm{w}} z)\right)}, \qquad (1)$$

This does the direct albedo but for the diffuse albedo this is integrated over all incident angles. A best-fit curve is applied as a full integral would be too slow for a physics parameterisation.

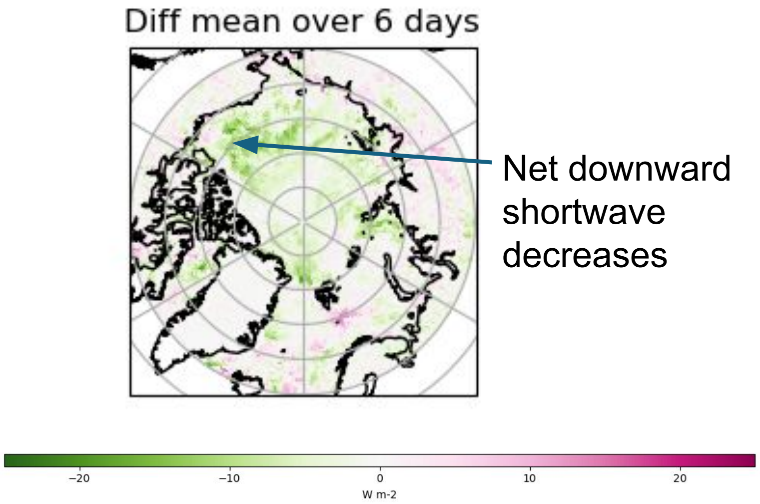
Effect of Malinka et al melt pond albedo scheme on coupled NWP case study (30/06/2021)

Surface

Surface albedo increases in locations of melt ponds



Net down surface sh

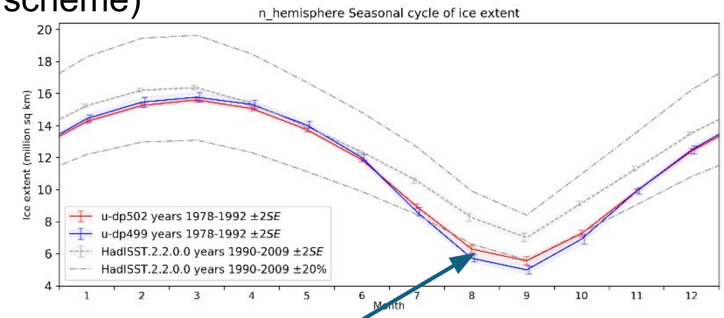


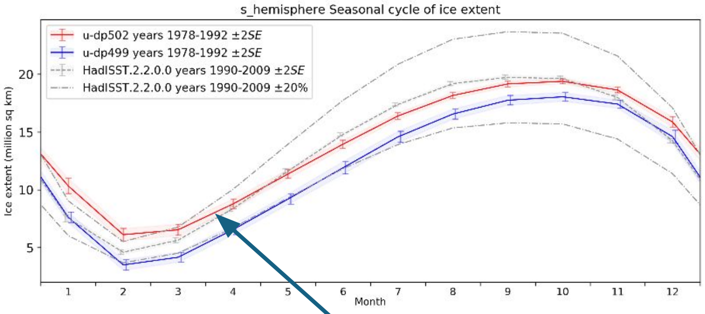
Net downward shortwave decreases

Effect of Malinka et al melt pond albedo scheme on 14 year climate run

u-dp499 = Control (GC5-lfric with no sea ice albedo changes)

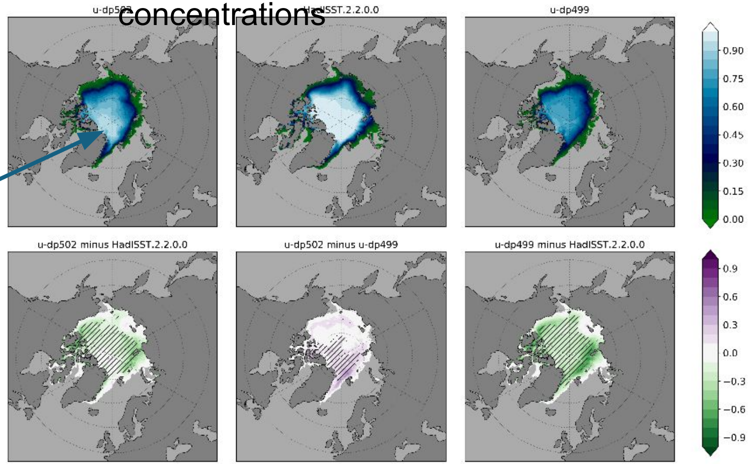
u-dp502 = Experiment (GC5-lfric with zenith angle albedo changes plus Malinka et al melt pond albedo scheme)





Increasing Northern Hemisphere sea ice a bit

September sea ice concentrations



Increasing Southern Hemisphere sea ice a lot more (maybe too much)

The increases in Arctic sea ice are in the right place (near Greenland)

Summary

- We have used coupled NWP experiments to understand biases and test fixes for problems in climate experiments.
- This massively reduced the cost of the investigations and testing allowing quicker understanding.
- The coupled NWP investigation into LFRic vs UM differences have revealed two discrepancies that make GC5-LFRic have less sea ice than GC5-UM when the same model is used for climate simulations:

  - A difference in the mixed phase clouds

  - A difference in the cloud inhomogeneity (FSD)
- A new melt pond albedo scheme has been developed (using Malinka et al) that is more physically realistic and shows improvements (increases) to the sea ice in both coupled NWP and climate simulations.
- Package tests are underway that combine all these improvements (and more) for GC6.0

Questions?