Interaction of convective parameterization and horizontal resolution in simulating precipitation over the CORDEX Central America domain

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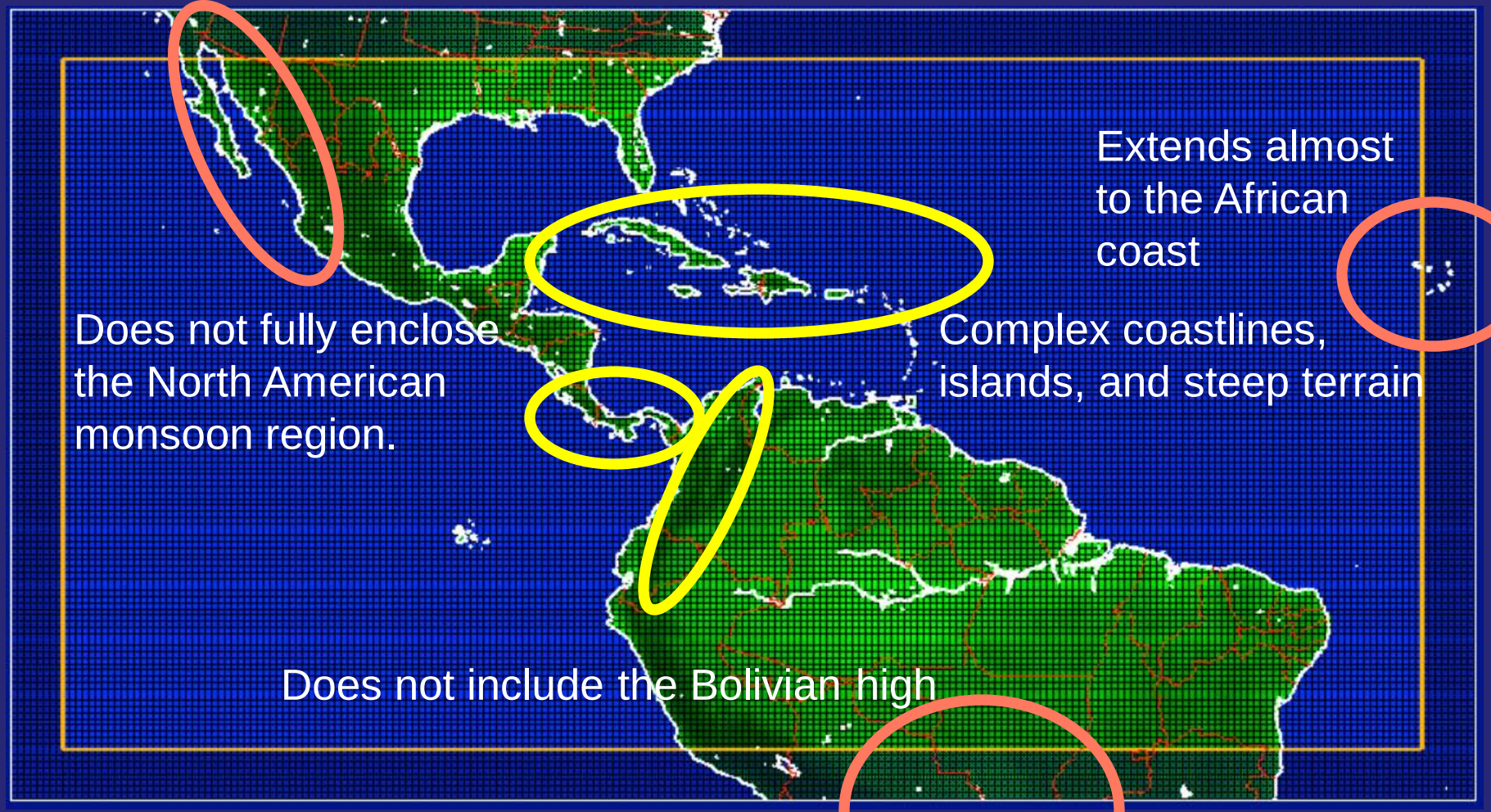
* my son says my titles are always too long

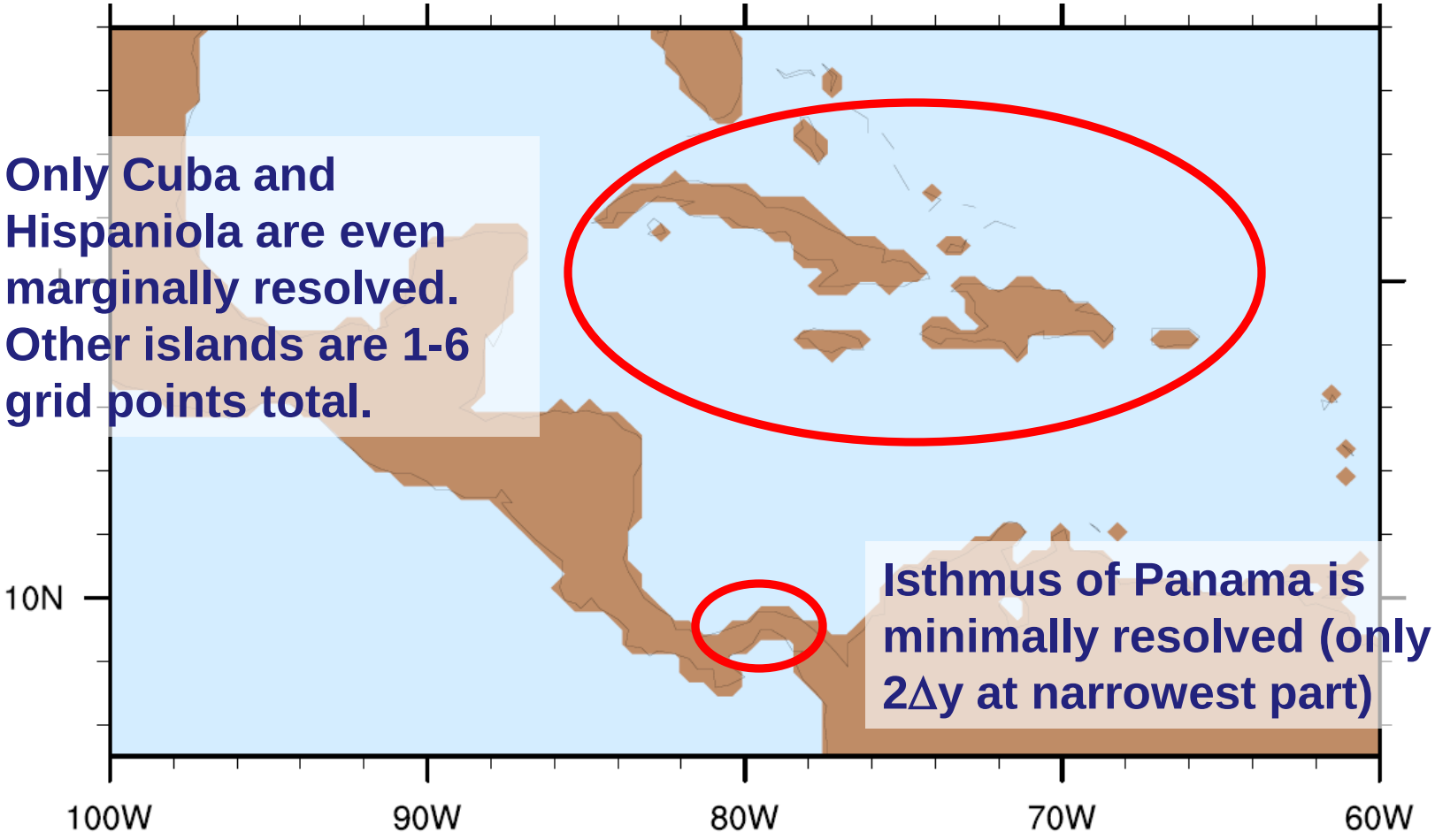
Motivation

- Goal is to perform multiple 150-year (1950-2100) simulations for the CORDEX Central America domain using RegCM4.
  - Ideally at different resolutions (50 km, 25 km).
- These long simulations are very demanding of computational resources.
- Use results of 20-year (1989-2008) simulations with ERA-Interim initial and boundary conditions to assess which configuration(s) to run.

CORDEX Central America domain



Land mask at 50 km grid spacing

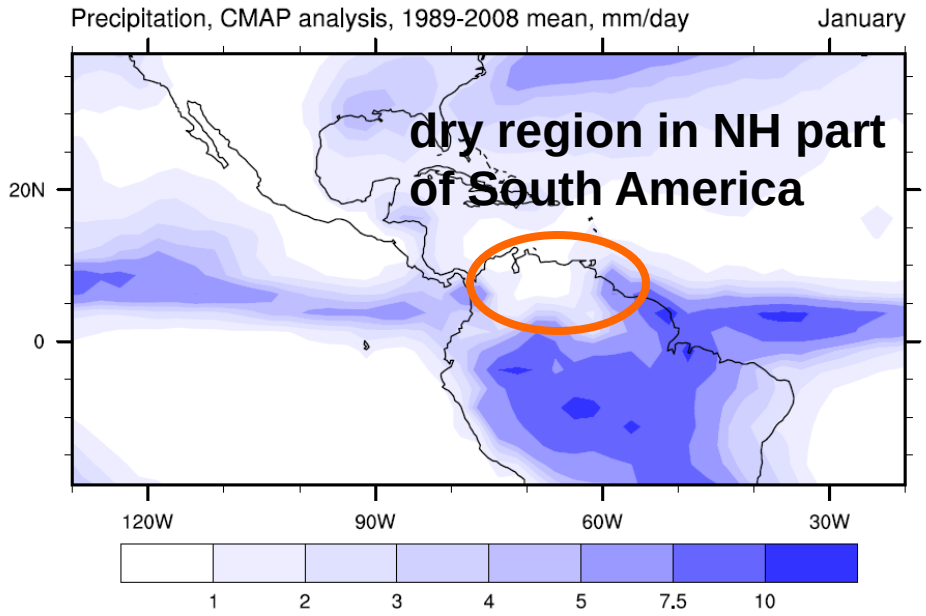


Sensitivity to convective parameterization

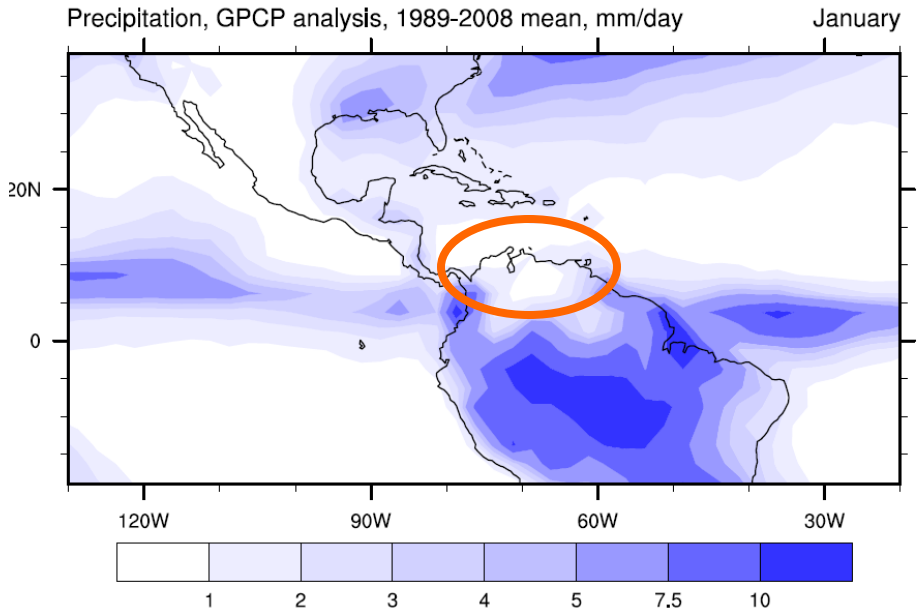
- We expect a tropical domain like this could be sensitive to the convective parameterization.
- Test RegCM4 with four variations of convective parameterization:
  - Anthes-Kuo: based on moisture convergence
  - Grell scheme with two different closure assumptions: quasi-equilibrium (Arakawa-Schubert) or fixed time scale for release of convective instability (Fritsch-Chappell)
  - Emanuel: multiple entraining-detraining plumes

Precipitation analyses: January

CMAP



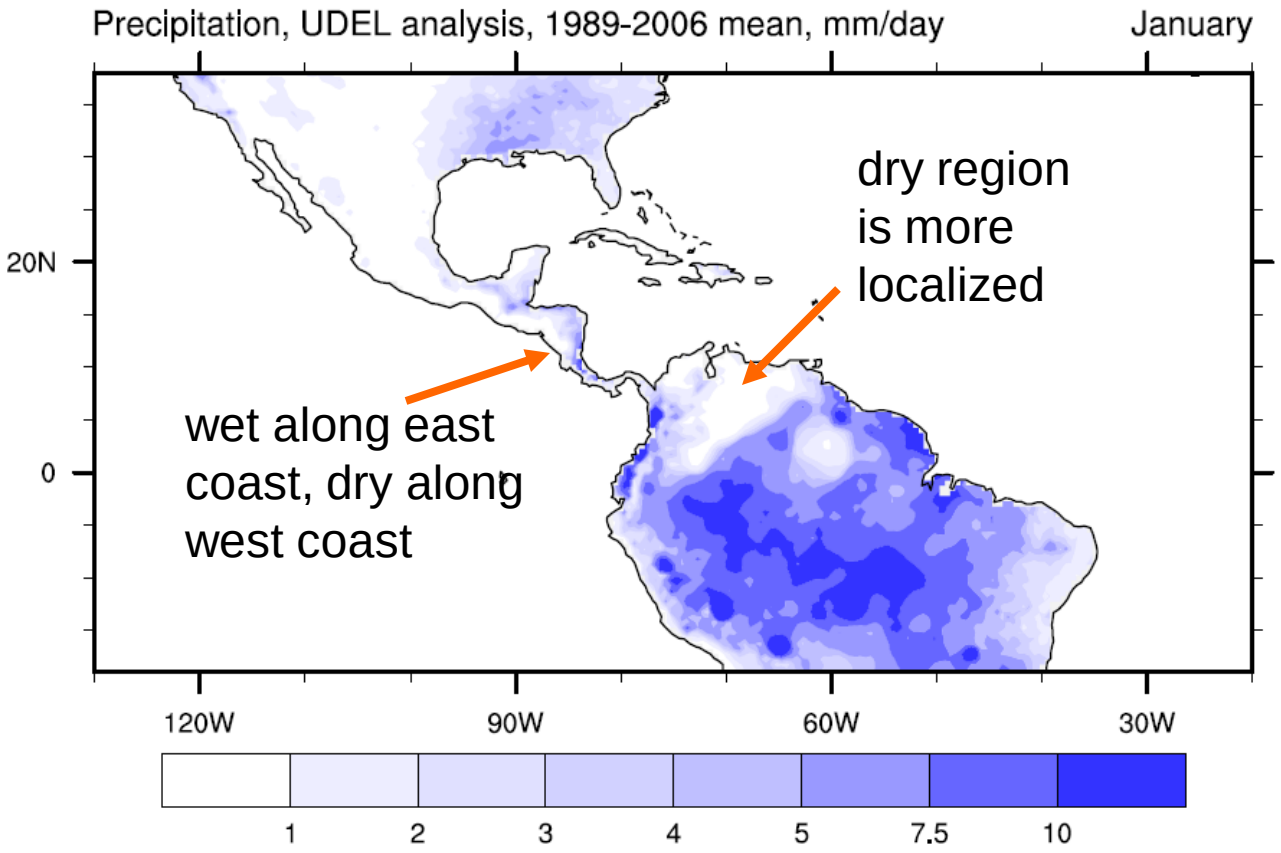
GPCP



Wet in Southern Hemisphere over land, dry in Northern Hemisphere.
Note land-sea contrast in Southern Hemisphere.

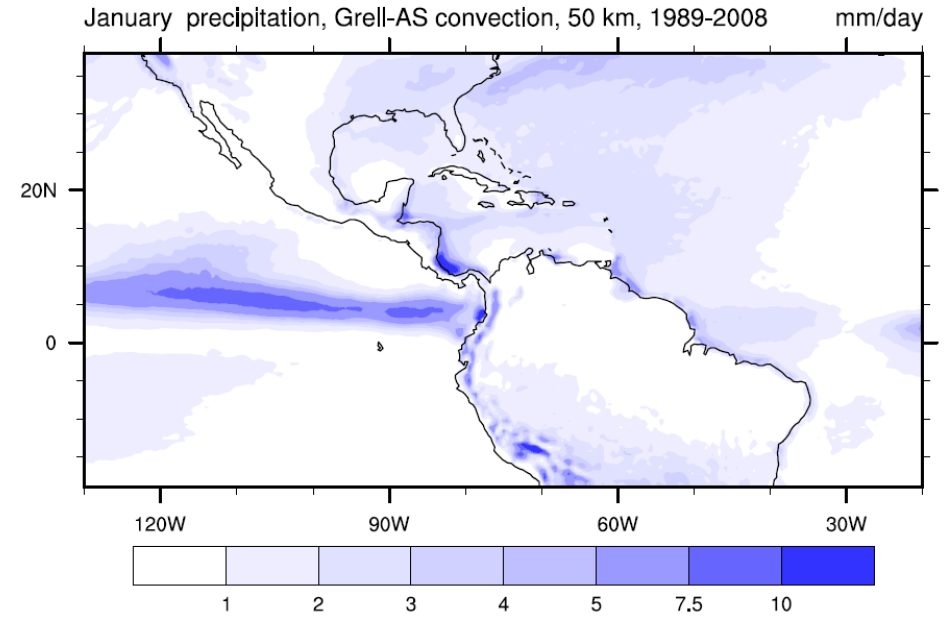
Land precipitation analysis at 0.5º (January)

University of Delaware

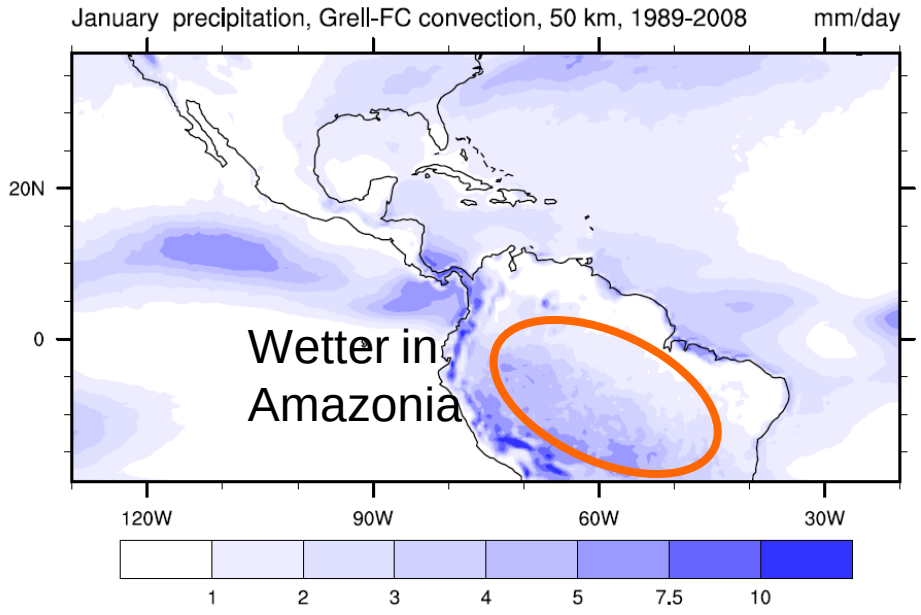


Choice of closure assumption has a large effect on precipitation in the Grell scheme

Grell scheme with Arakawa-Schubert closure, 50 km



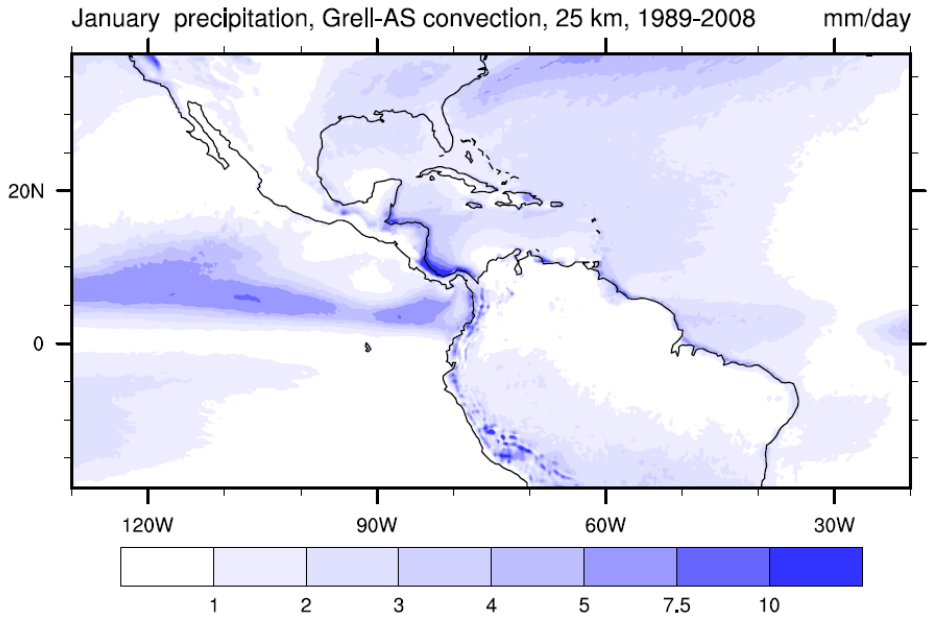
Grell scheme with Fritsch-Chappell closure, 50 km



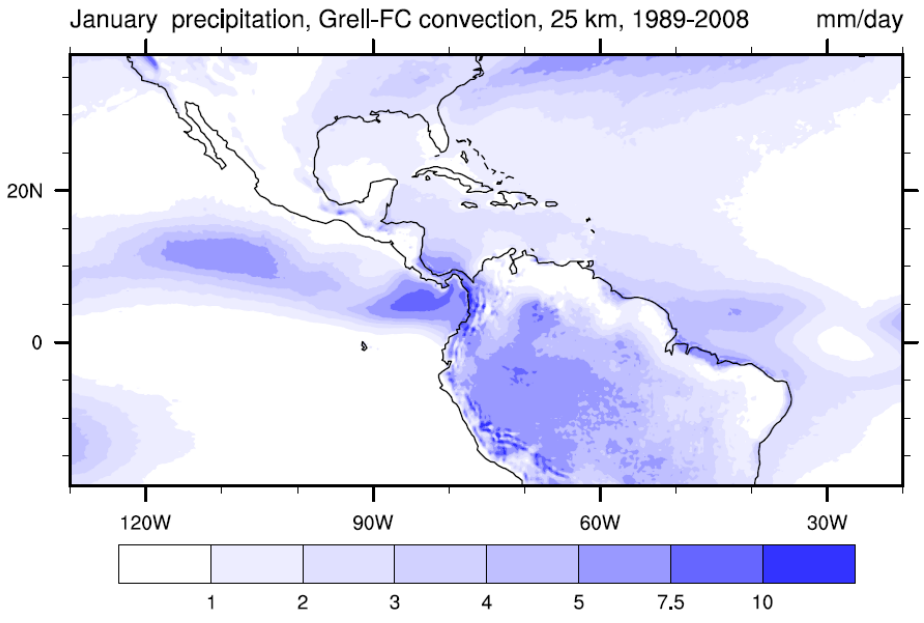
The difference is one line of code!

Influence of closure is even larger at fine grid spacing

Grell scheme with Arakawa-Schubert closure, 25 km



Grell scheme with Fritsch-Chappell closure, 25 km



Factor separation

- Suppose we have a control experiment
  - Call the resulting precipitation P_0
- We change something about the experiment
  - Call the result P_1
- We change something different
  - Call the result P_2
- We make both of these changes
  - Call the result P_{12}
  - **Can we identify the interaction between the two changes when we make both changes?**

Stein and Alpert 1993, JAS

Factor separation

- The effect of the first change alone is

  $P_1' = P_1 - P_0$

- Likewise the effect of the second change alone is

  $P_2' = P_2 - P_0$

- If the changes **do not** interact, then the effect of both changes is the sum of the two changes

  $P_{12} = P_0 + P_1' + P_2'$

- But if the changes interact, we have an extra term

  $P_{12} = P_0 + P_1' + P_2' + P_{12}'$

- So we can identify the interaction term as

  $P_{12}' = P_{12} - P_0 - P_1' - P_2'$

Application: Convective parameterization and resolution

- Start with a simulation using the Grell scheme with Arakawa-Schubert closure at 50 km

  P_0 = (Grell A-S, 50 km)

- Factor 1: Change **only** to Fritsch-Chappell closure

  P_1 = (Grell F-C, 50 km)

- Factor 2: Change **only** to 25 km

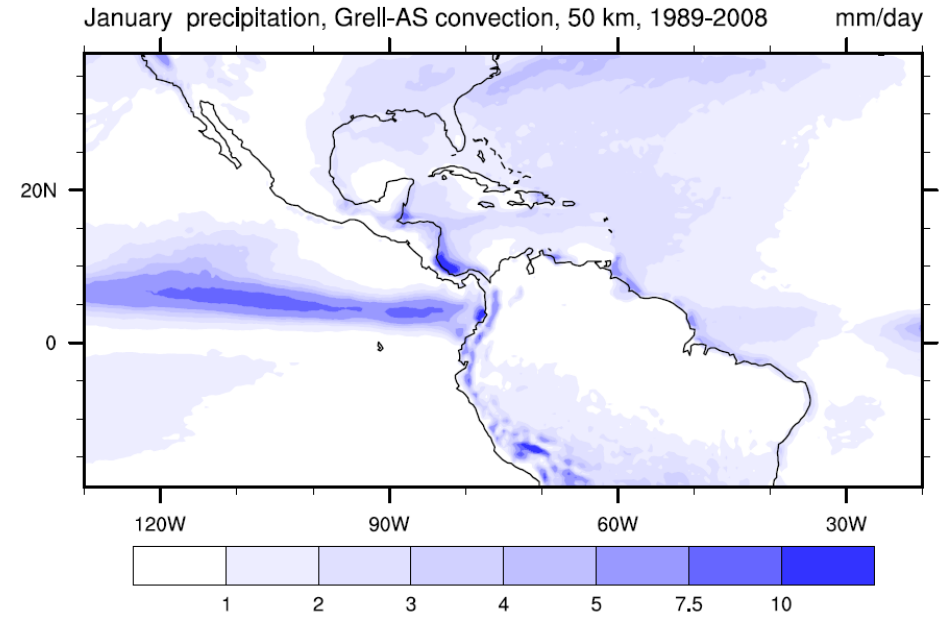
  P_2 = (Grell A-S, 25 km)

- Make both changes:

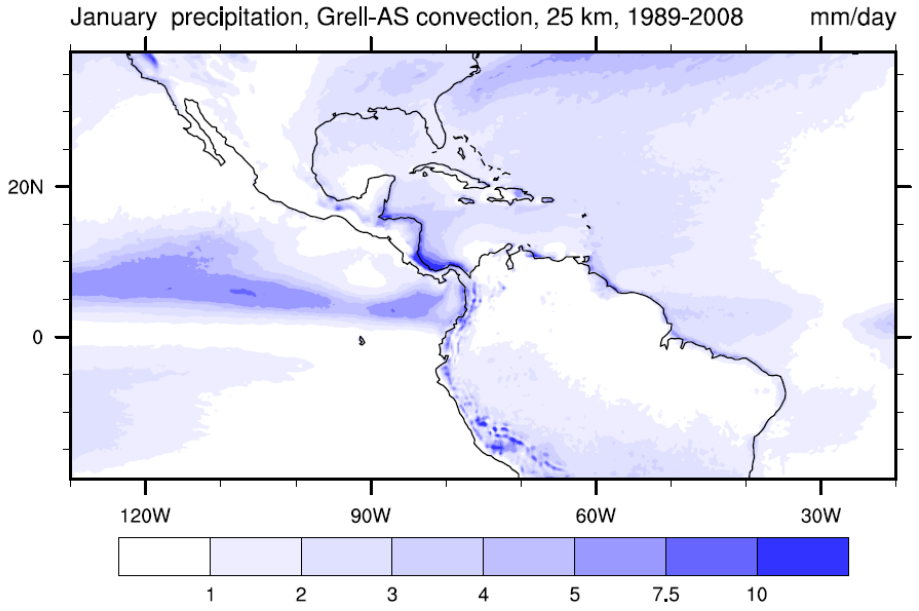
  P_{12} = (Grell F-C, 25 km)

Resolution

Grell scheme with Arakawa-Schubert closure, 50 km

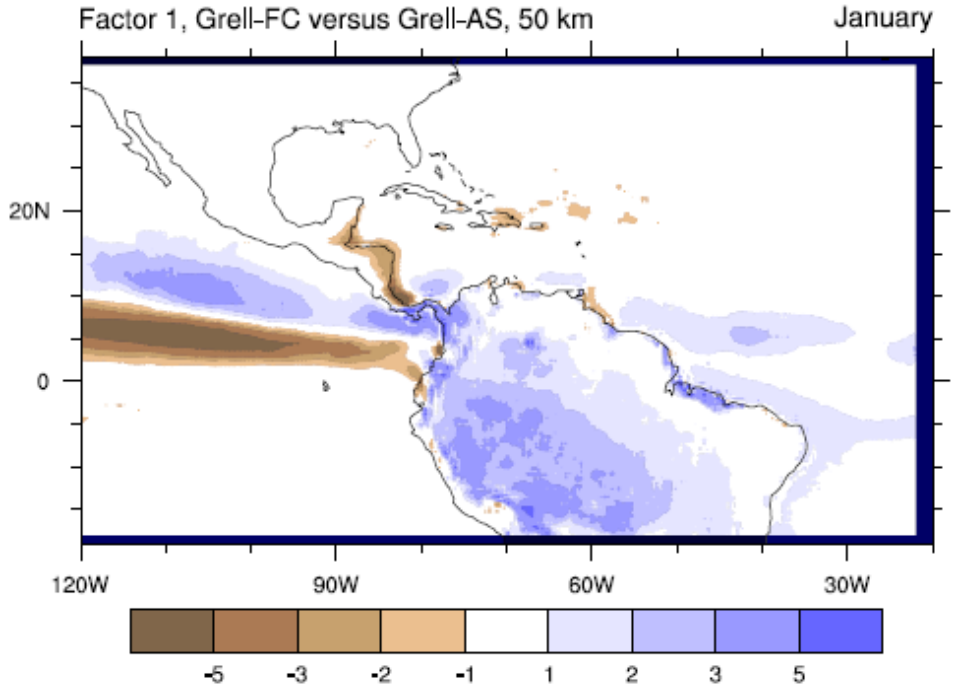


Grell scheme with Arakawa-Schubert closure, 25 km

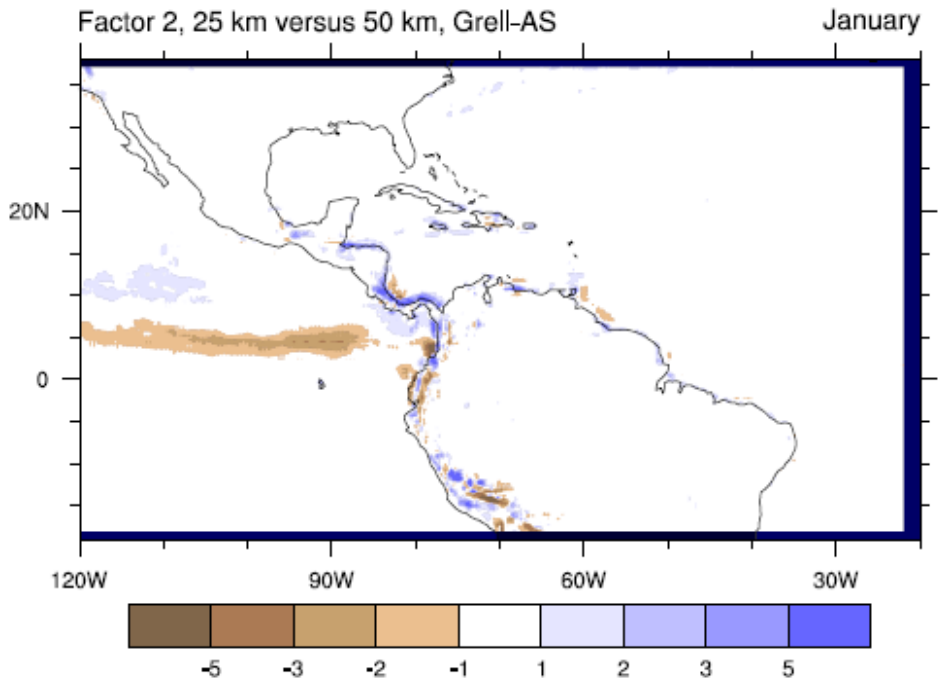


Choice of closure assumption has a large effect on precipitation in the Grell scheme

Factor 1: Change closure from Arakawa-Schubert to Fritsch-Chappel

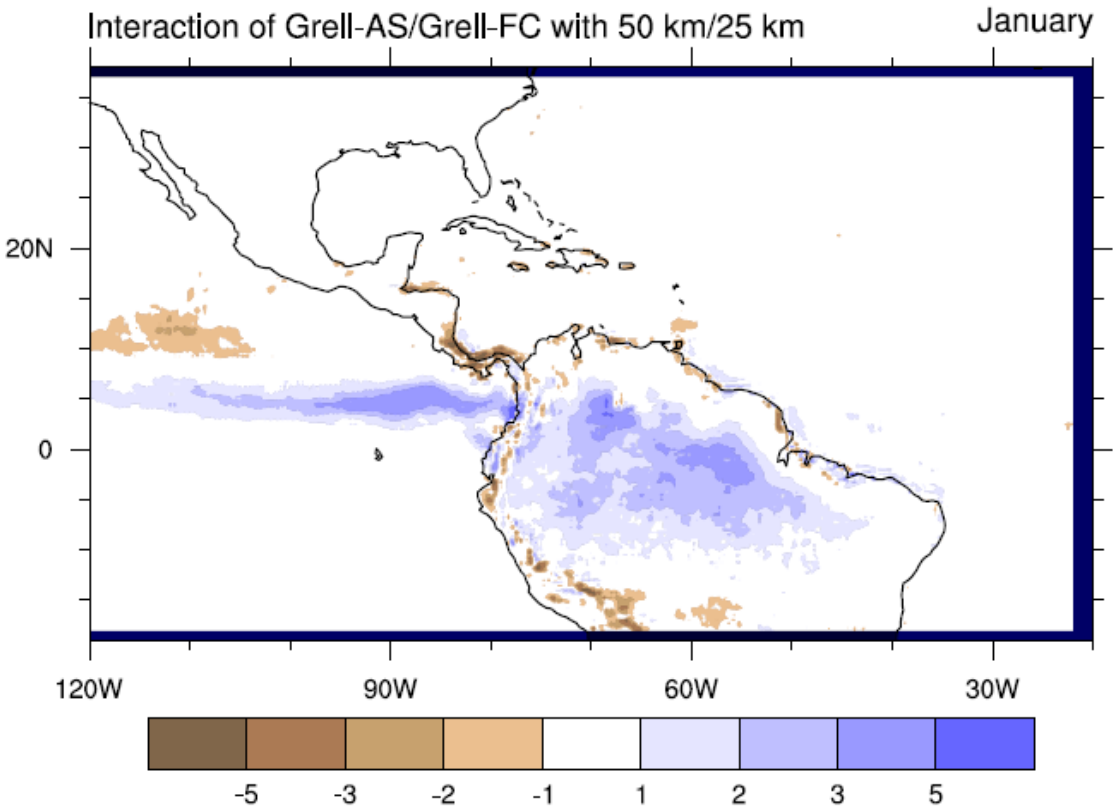


Factor 2: Change resolution from 50 km to 25 km



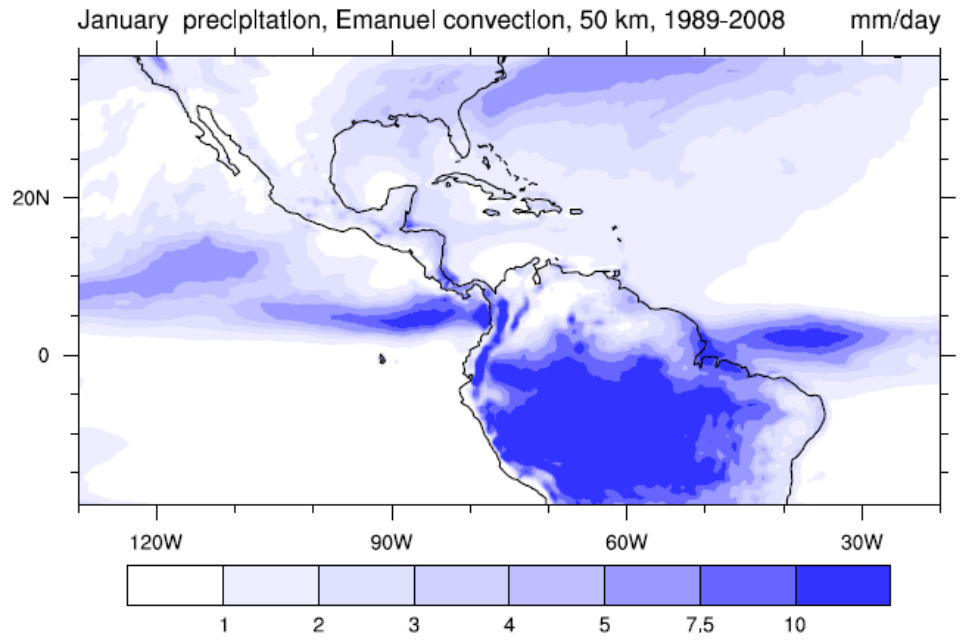
Choice of closure assumption has a large effect on precipitation in the Grell scheme

Interaction term: Change closure from F-C to A-S **and** change resolution from 50 km to 25 km, versus sum of separate changes.

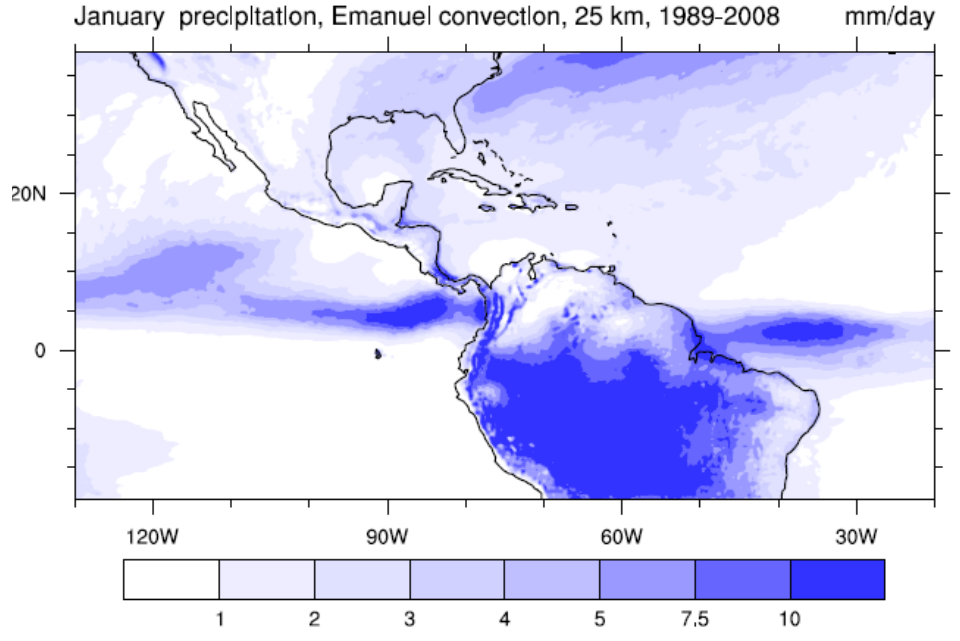


Emanuel scheme reproduces heavy precipitation in the interior of South America

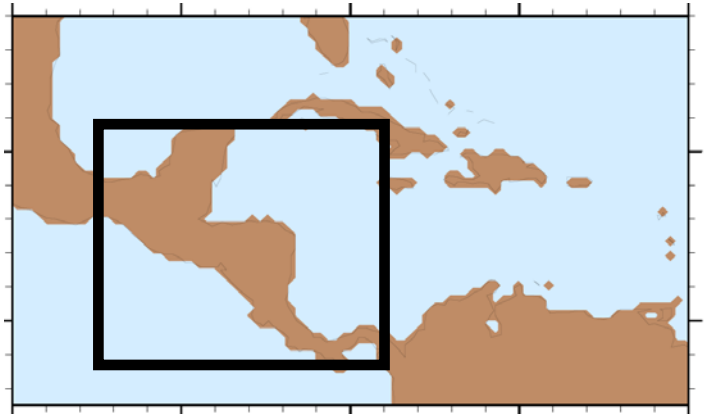
Emanuel scheme, 50 km

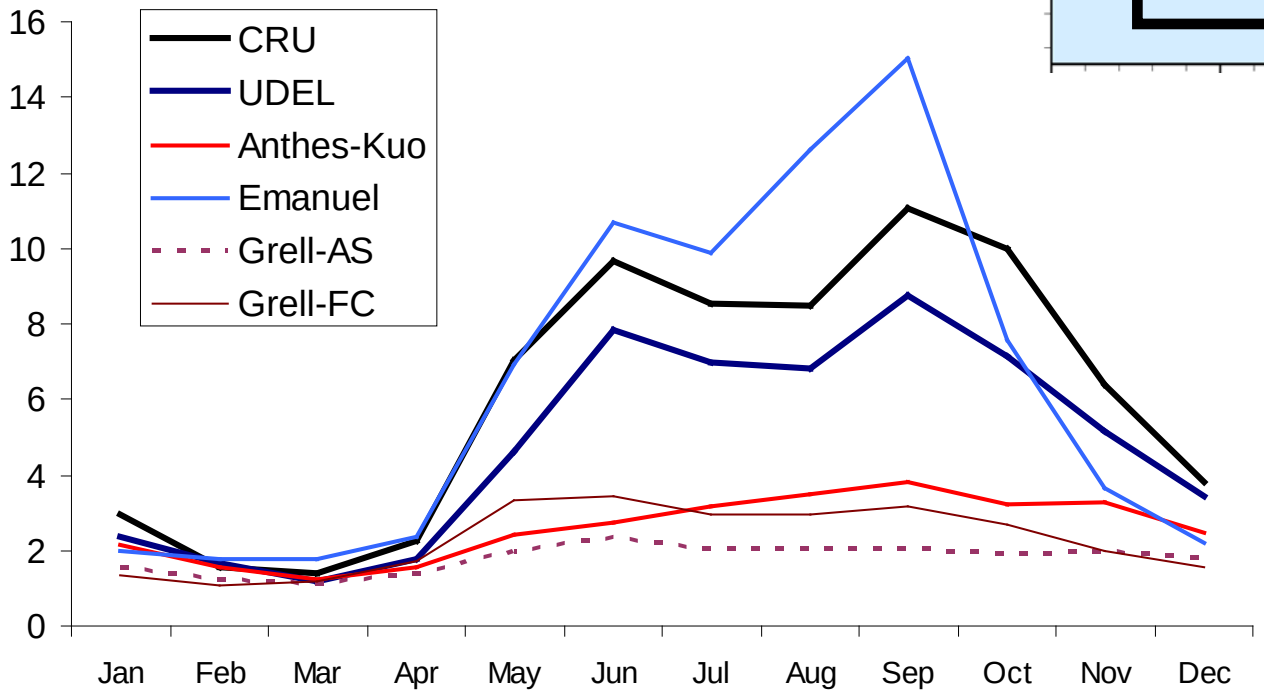


Emanuel scheme, 25 km



Emanuel scheme best reproduces the annual cycle of precipitation in Central America

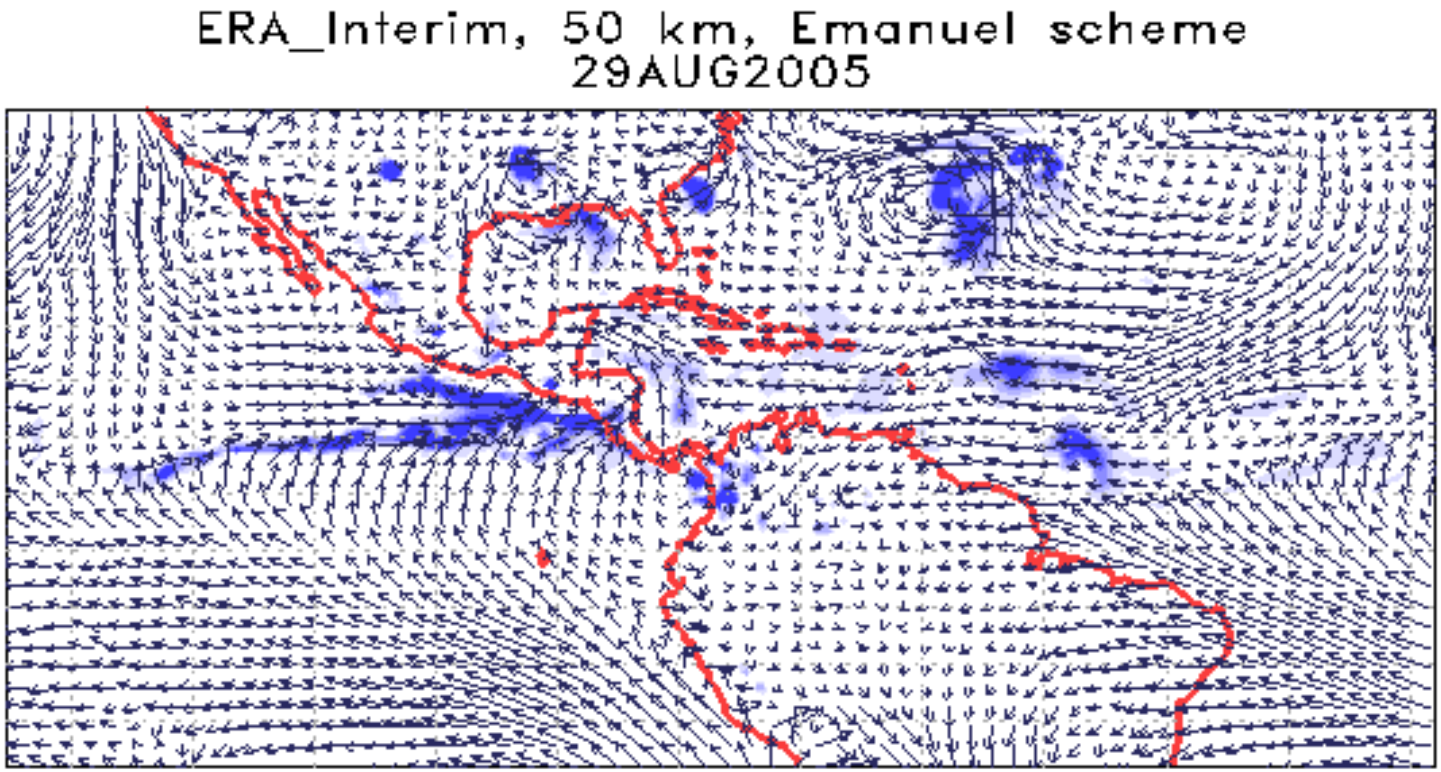




50 km grid

Tropical cyclones

- Can the schemes depict tropical cyclones at this resolution?
  - Animation (if it works)



Summary

- RegCM4 results for the CORDEX-Central America domain depend strongly on convective parameterization:
  - Anthes-Kuo scheme and Grell scheme with Arakawa-Schubert closure are much too dry.
  - Emanuel scheme is more realistic over South America but too wet in Central America.
  - Grell scheme with Fritsch-Chappell closure is between these but is also sensitive to resolution.
- Future runs will use the Emanuel and Grell-FC schemes.
  - May be able to reduce wet bias in Emanuel scheme through altering the trigger function.
- Will use both 50 km and 25 km grid spacing in climate change runs.