

DEVELOPMENT OF A WHOLE ATMOSPHERE MODEL WITH A NON-HYDROSTATIC DYNAMICAL CORE

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NCAR/UCAR
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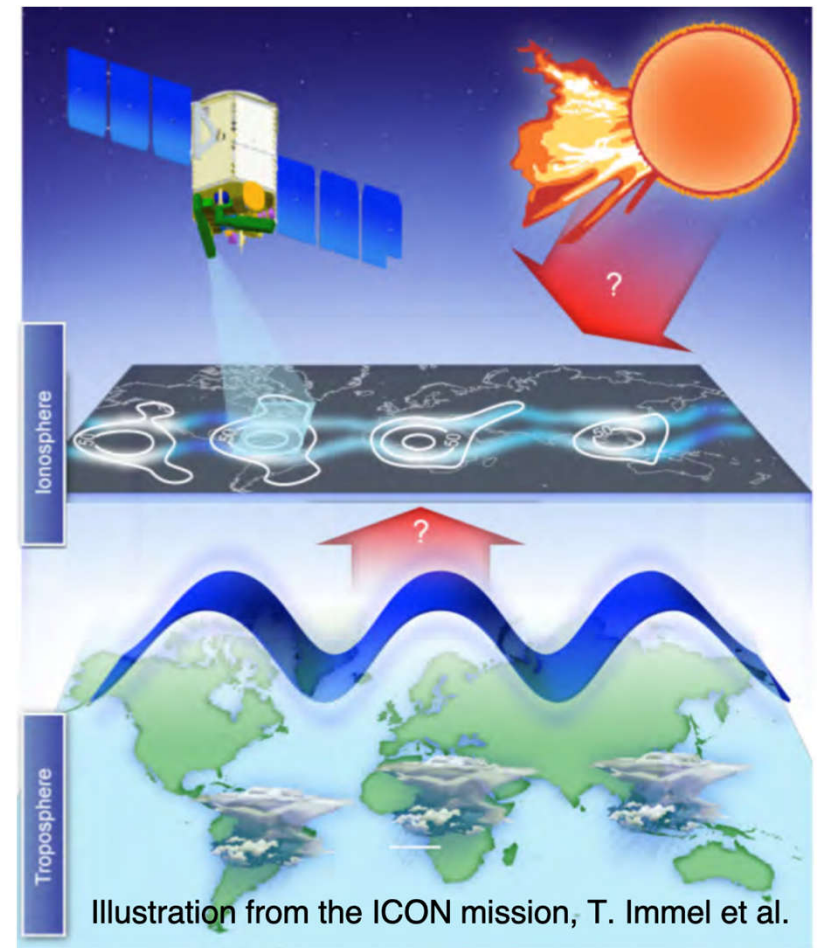


OUTLINE

- ❑ Background & Motivation
- ❑ Dynamical Cores configuration
- ❑ Climatology Comparison
- ❑ Gravity Wave Forcing Analysis
- ❑ Conclusion & Future work

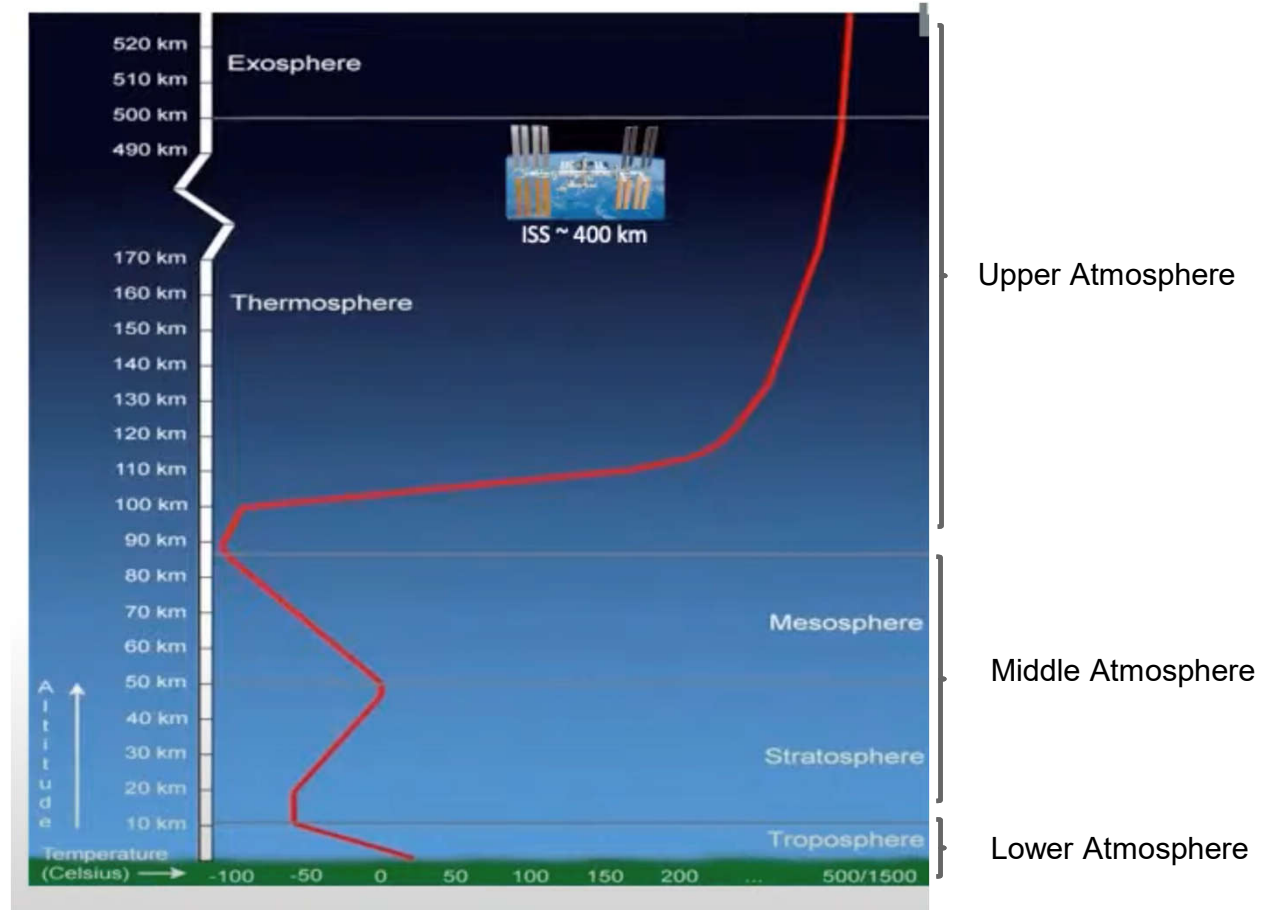
Why Whole Atmosphere Models?

Because the thermosphere/ionosphere system responds to variability from the Earth's lower atmosphere as well as solar-driven "space weather"

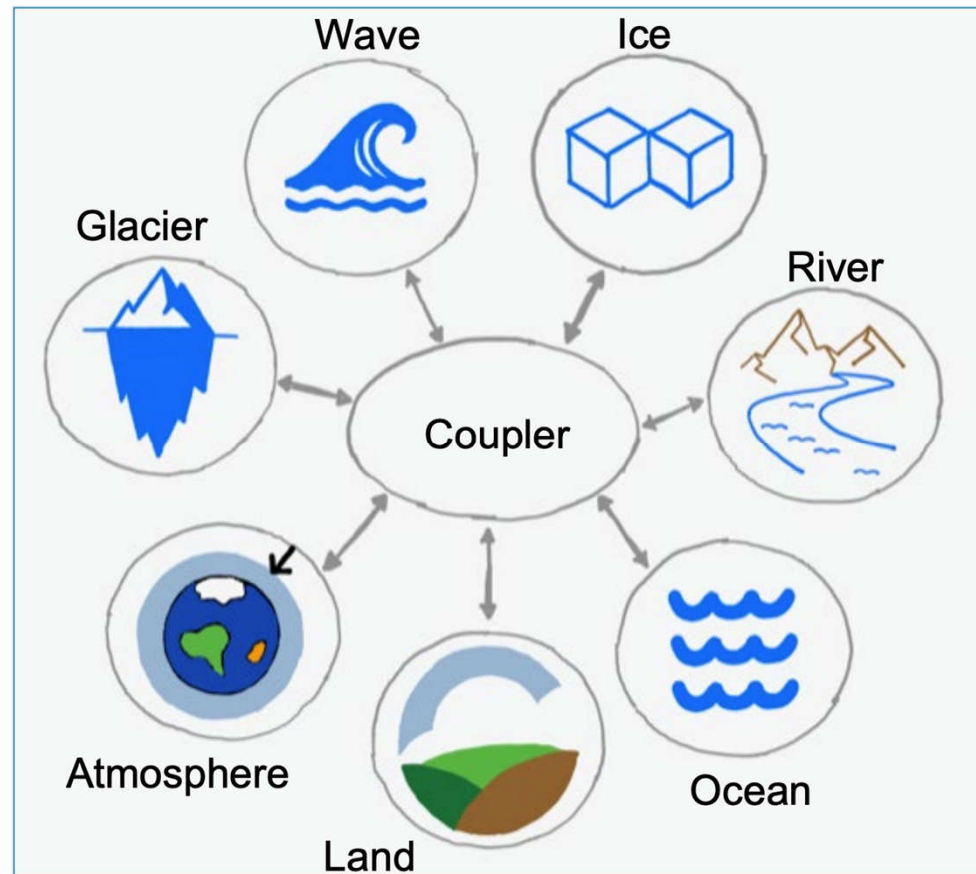


Challenges

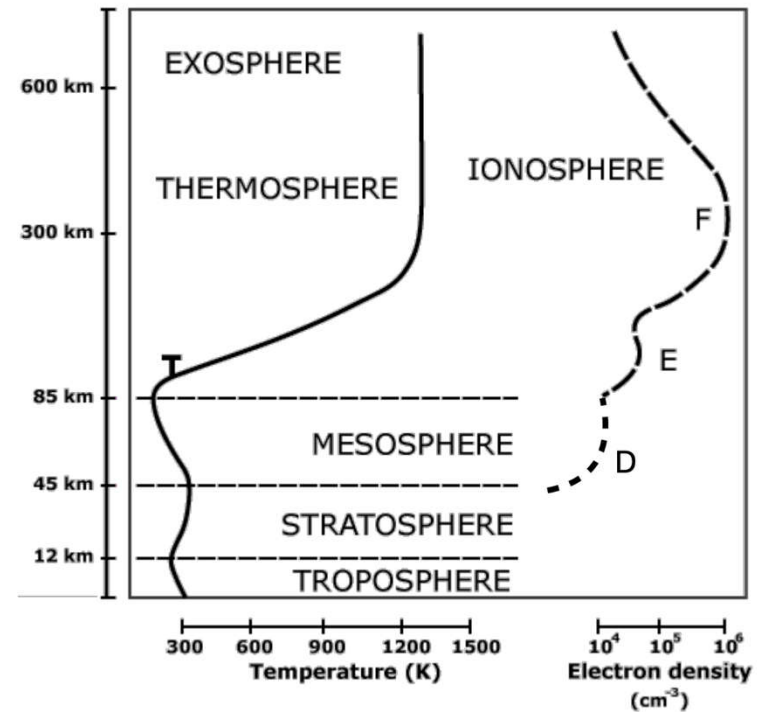
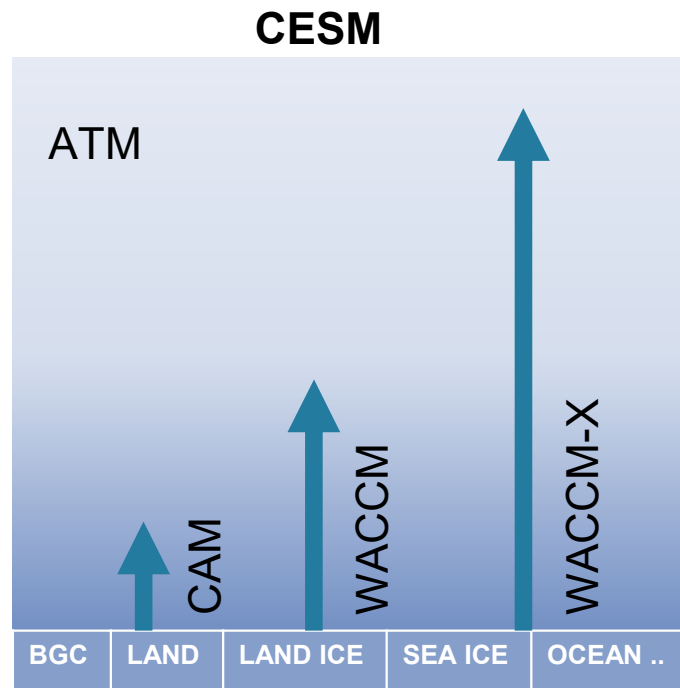
| | | | |
|-----------|-----------------------------|--------------|-------------------------|
| 10^{-8} | 10^{-12} | | 10^7 |
| 10^{-6} | 10^{-9} | 10^7 | |
| | | 10^5 | |
| 10^{-4} | 10^{-6} | 10^4 | 10^2 |
| | | 10^{-1} | |
| 10^0 | 10^{-3} | 10^3 | |
| 10^3 | 10^0 | 300 | 10^{-5} |
| p (hPa) | ρ (kg/m ³) | θ (K) | v (m ² /s) |



NCAR Community Earth System Model (CESM)

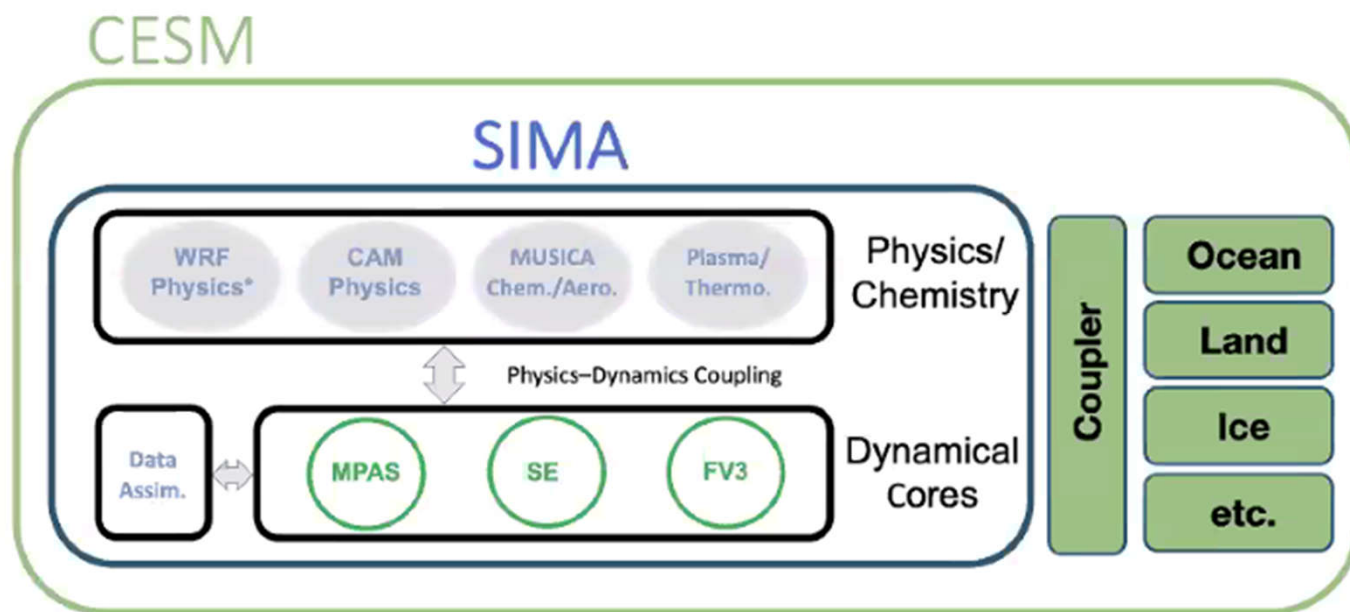


Whole Atmosphere Model at NCAR



Motivation

MPAS-A brings non-hydrostatic modeling capabilities to CESM.

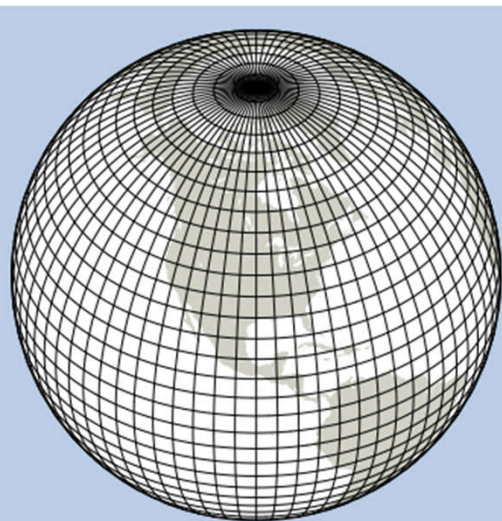


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Dynamical Cores Used with WACCM

Finite Volume (FV)

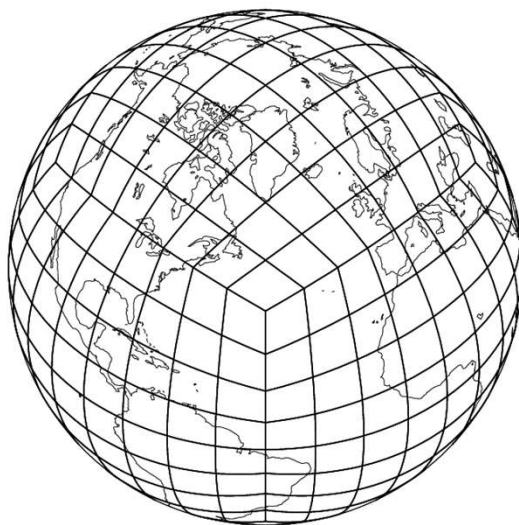


- Lat-Lon global grid, hydrostatic
- Finite-volume, D-grid staggering
- Sigma-pressure vertical coordinate

➤ SC-WACCM

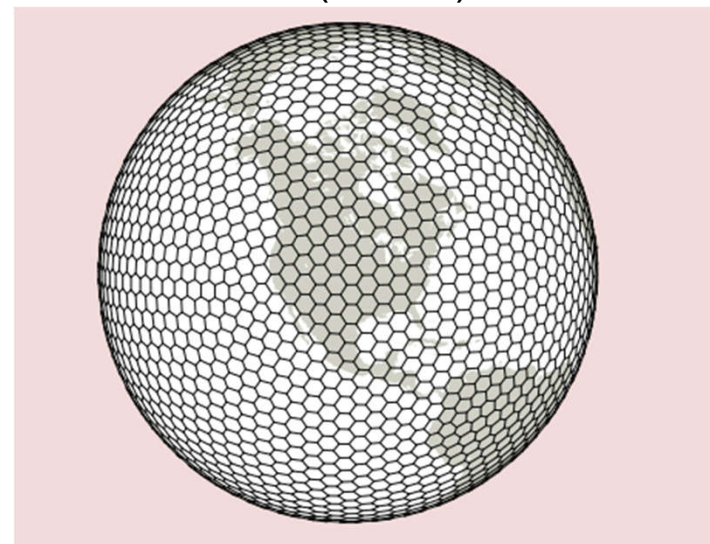
➤ One year simulation on 1° mesh

Spectral Element (SE)



- Cubed-sphere mesh, hydrostatic
- Spectral elements
- Sigma-pressure vertical coordinate

Model for Prediction Across Scale (MPAS)



- Centroidal Voronoi mesh, nonhydrostatic
- Finite-volume, C-grid staggering
- Hybrid terrain-following height vertical coordinate

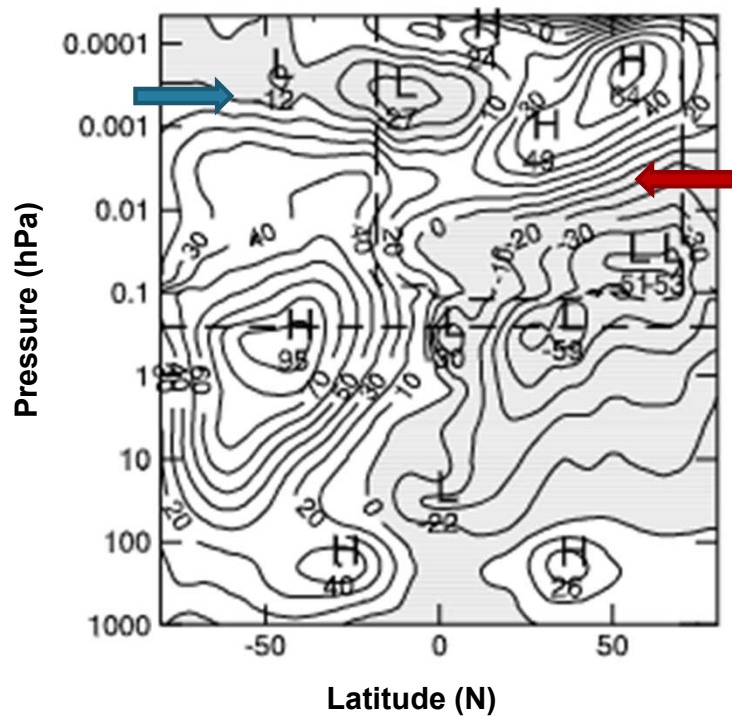
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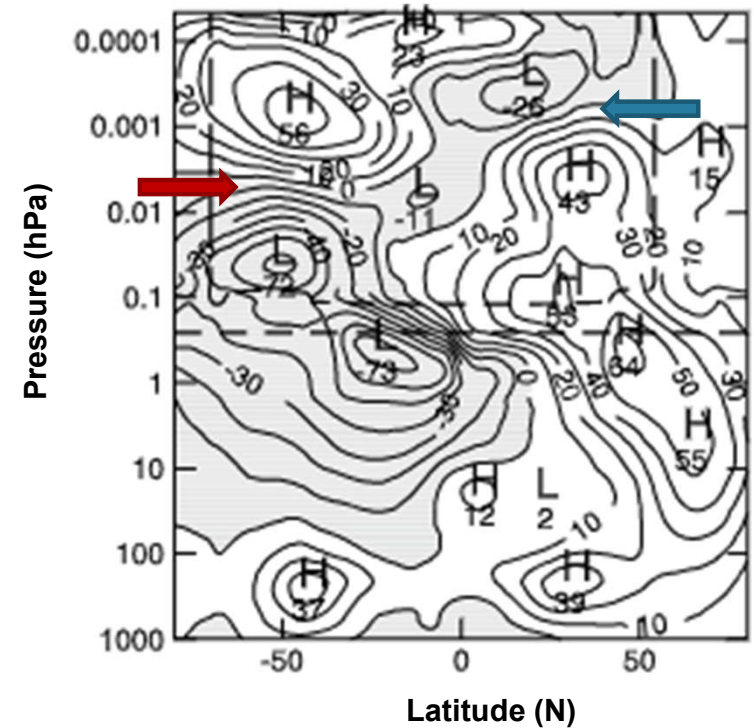
Climatology

Asymmetric Zonal wind reversals near the mesopause have been known in both climatology and recent radar observations.

URAP Zonal wind June 92



URAP Zonal wind January 93

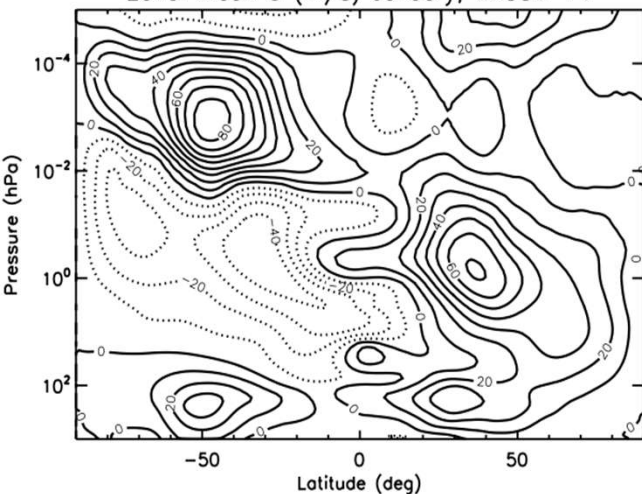


Swinbank and Ortland, 2003

Zonal Mean Wind Climatology Comparison - January

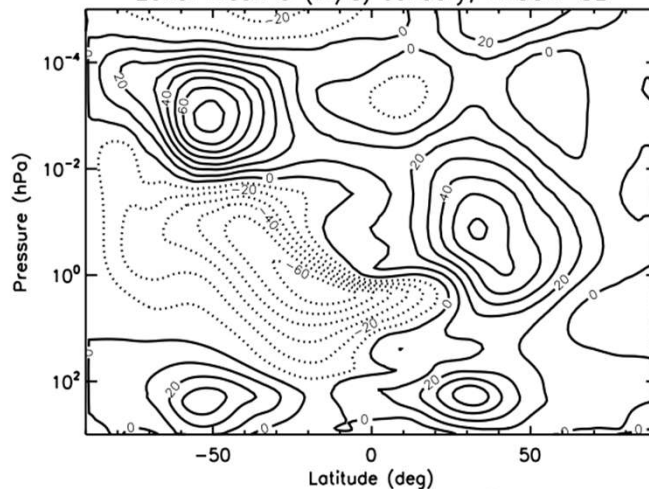
Finite Volume (FV)

Zonal mean U (m/s) January, WACCM-FV



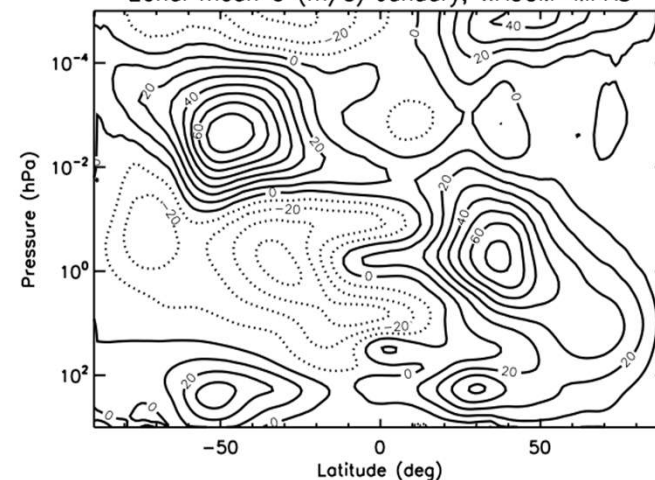
Spectral Element (SE)

Zonal mean U (m/s) January, WACCM-SE

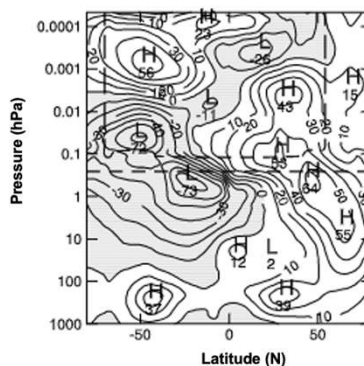


MPAS-A

Zonal mean U (m/s) January, WACCM-MPAS



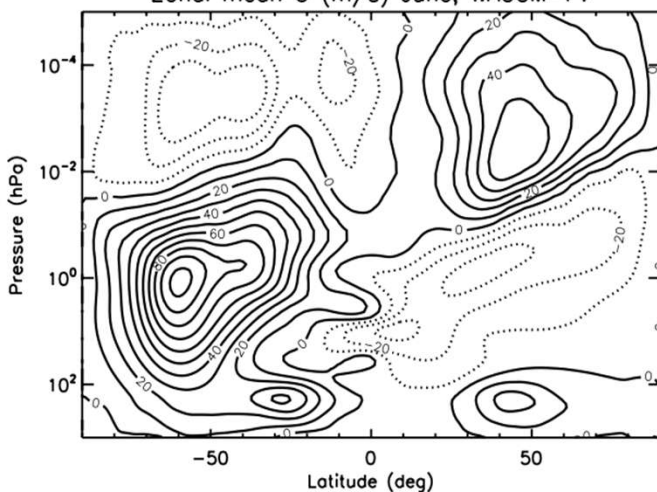
URAP Zonal wind January 93



Zonal Mean Wind Climatology Comparison- June

Finite Volume (FV)

Zonal mean U (m/s) June, WACCM-FV

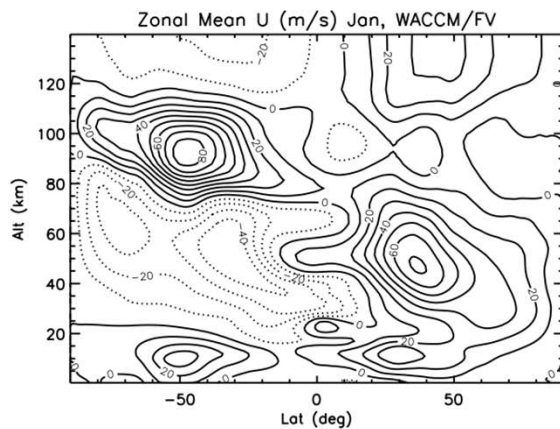
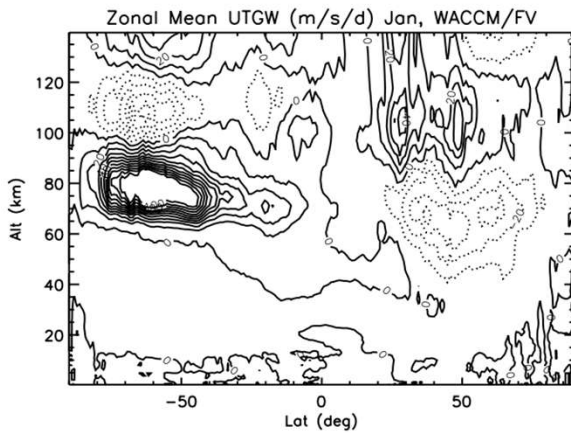


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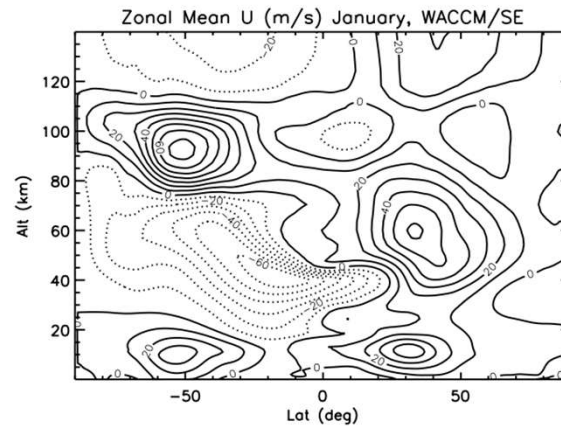
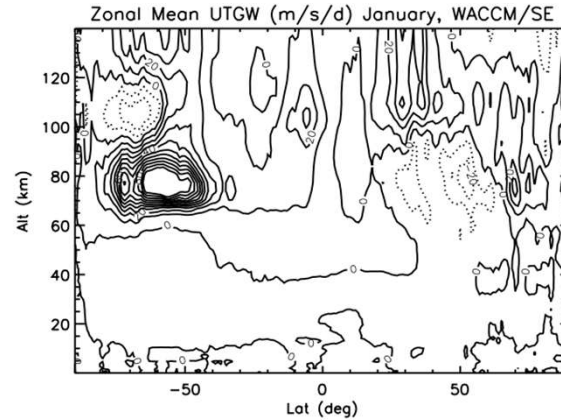
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Total Parameterized Gravity Wave Forcing - January

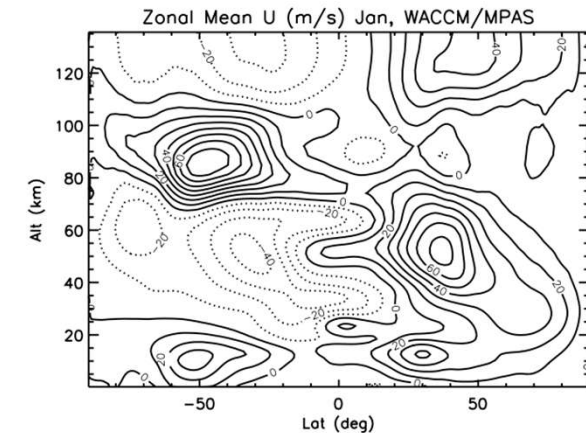
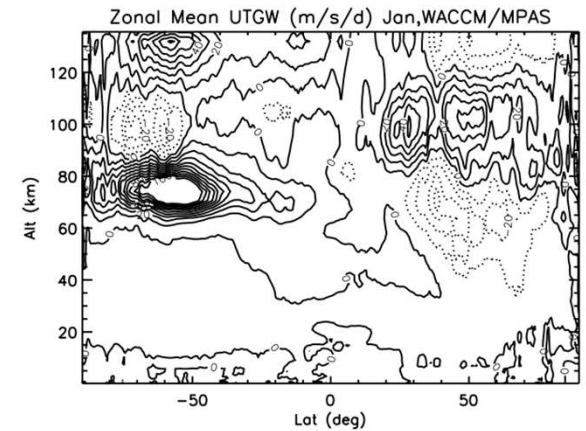
Finite Volume (FV)



Spectral Element (SE)



MPAS-A

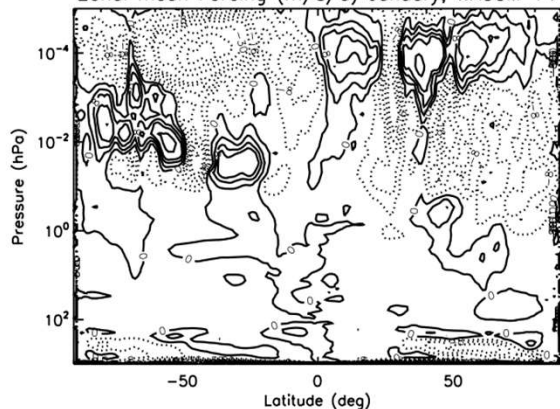


Resolved Wave Forcing - January

The wave forcing is diagnosed through the Transformed Eulerian Mean Method (TEM)

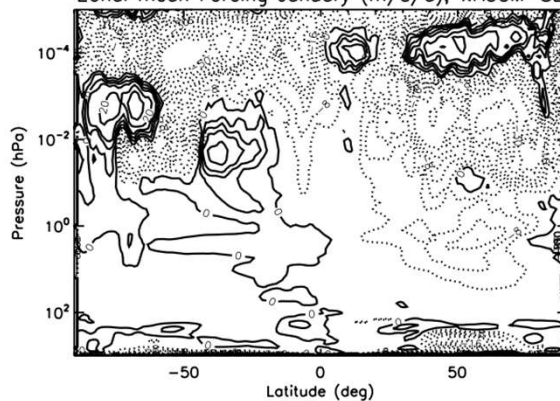
Finite Volume (FV)

Zonal mean Forcing (m/s/d) January, WACCM-FV



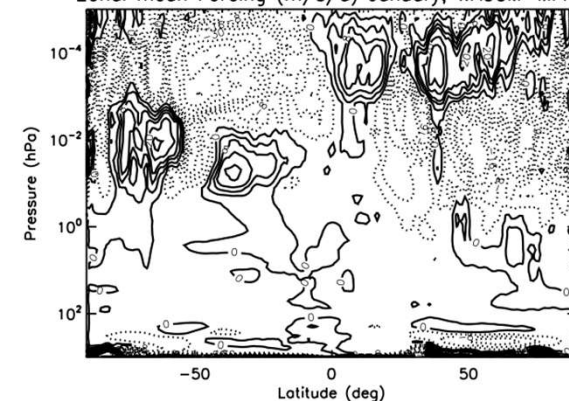
Spectral Element (SE)

Zonal mean Forcing January (m/s/d), WACCM-SE

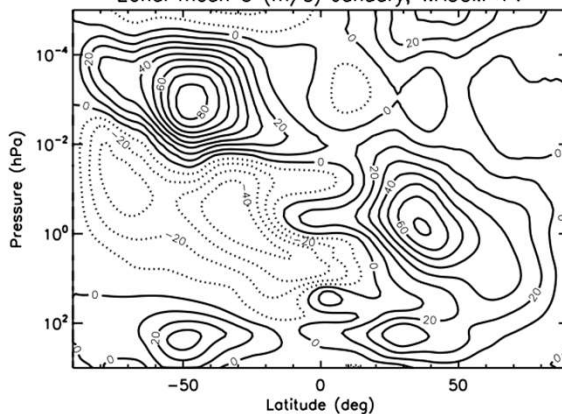


MPAS-A

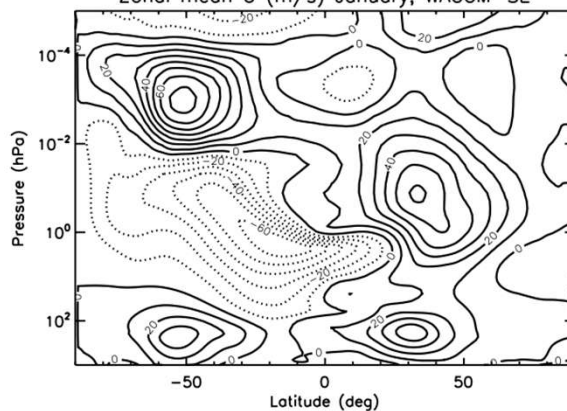
Zonal mean Forcing (m/s/d) January, WACCM-MPAS



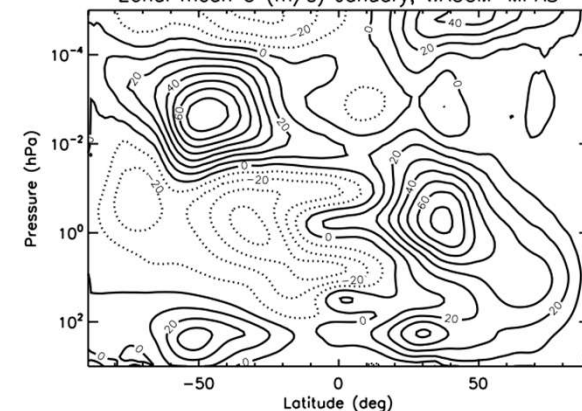
Zonal mean U (m/s) January, WACCM-FV



Zonal mean U (m/s) January, WACCM-SE



Zonal mean U (m/s) January, WACCM-MPAS



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Conclusion & Future Work

- As part of the **SIMA** effort we have developed and tested the **WACCM** with the non-hydrostatic Model for Prediction Across Scales-Atmosphere (**MPAS-A**).
- The mean zonal wind and temperature **climatology** from **WACCM/MPAS-A** compares well with the results from WACCM using **FV** and **SE** dynamical cores.
- **Gravity wave forcing (GWF)** is a key driver of the wind and temperature structure in the middle atmosphere. GWF from these simulations also compare well.

Future work:

- Further study the effects of resolved and parametrized waves among the models.
- Run model at higher resolutions which would eliminate the need for parametrized GW.
- Adapt the non-hydrostatic deep atmosphere MPAS-A to work with WACCM-X.

THANK YOU!!

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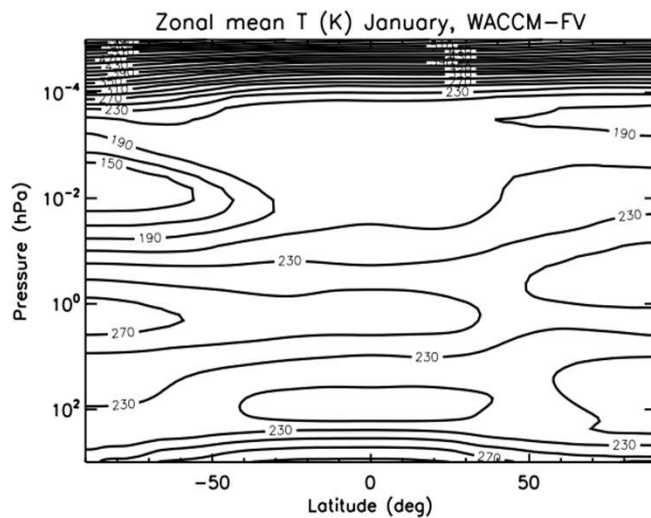
Back-up Slides

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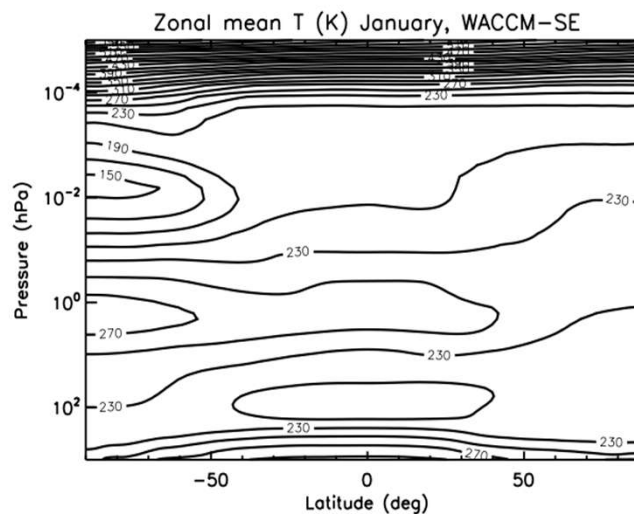


Mean Zonal Temperature Comparison- January

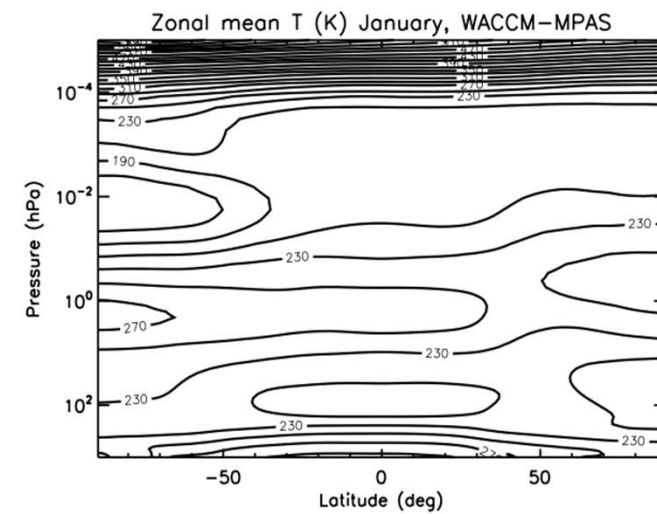
Finite Volume (FV)



Spectral Element (SE)

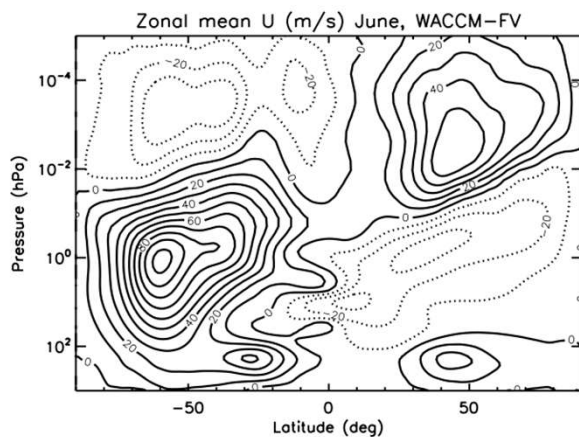


MPAS-A

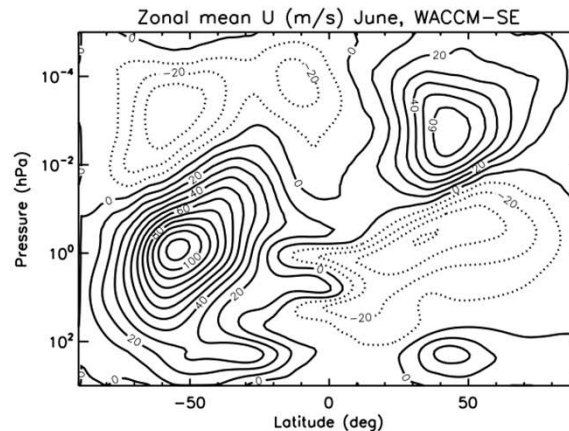


Zonal Mean Wind Climatology Comparison- June

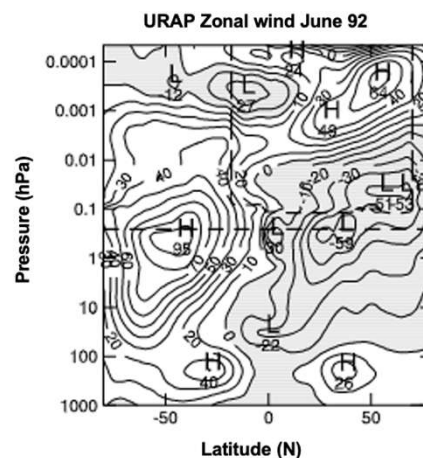
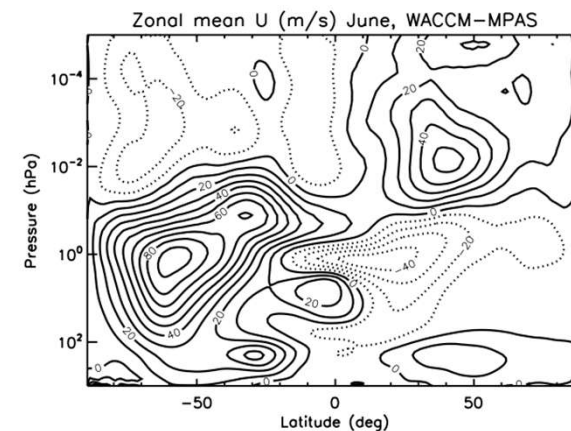
Finite Volume (FV)



Spectral Element (SE)



MPAS-A



MPAS Horizontal Mesh

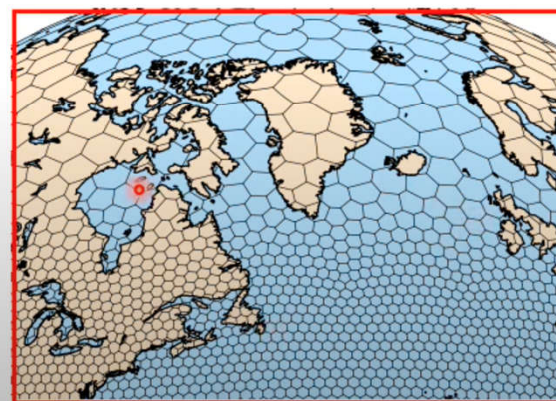
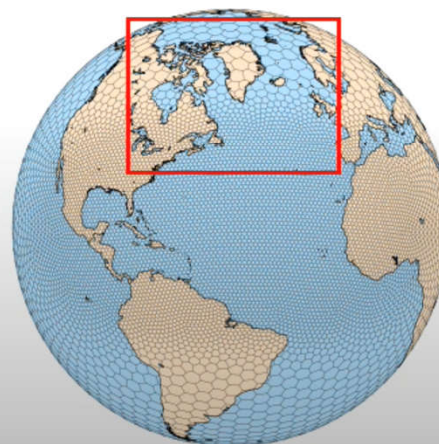
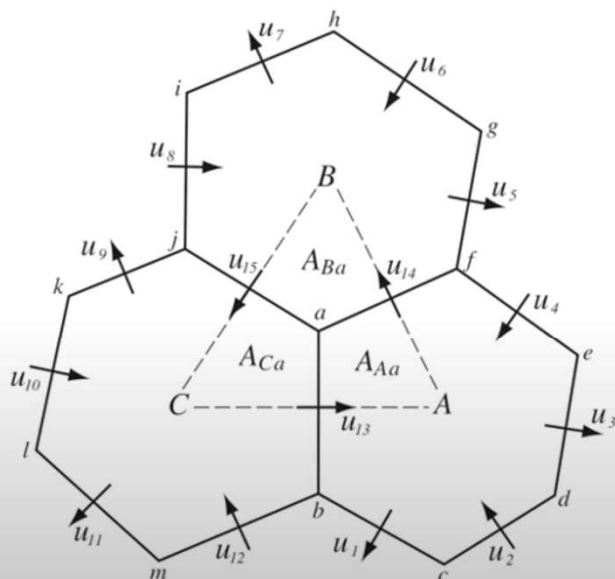
MPAS

Model for Prediction Across Scales

MPAS Horizontal Mesh

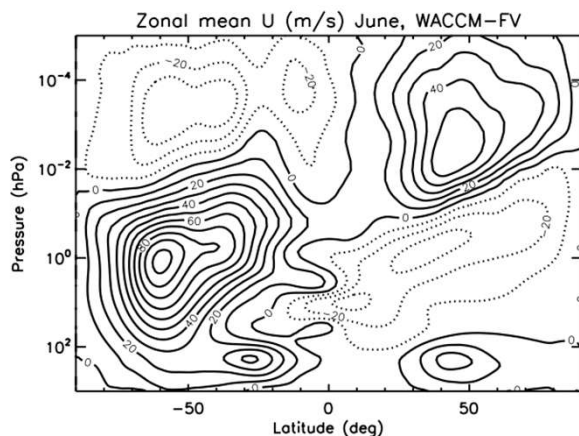
Unstructured spherical centroidal Voronoi meshes

- Mostly *hexagons*, some pentagons (5-sided cells) and heptagons (7-sided cells).
- Cell centers are at cell center-of-mass (centroidal).
- Cell edges bisect lines connecting cell centers; perpendicular.
- C-grid staggering of velocities (velocities are perpendicular to cell faces).
- Uniform resolution – traditional icosahedral mesh.

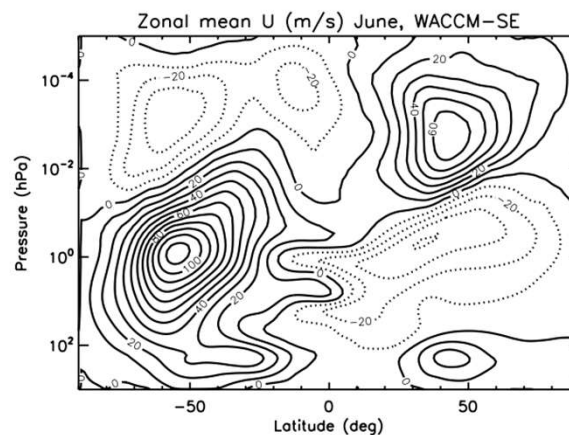


Zonal Mean Wind Climatology Comparison- June

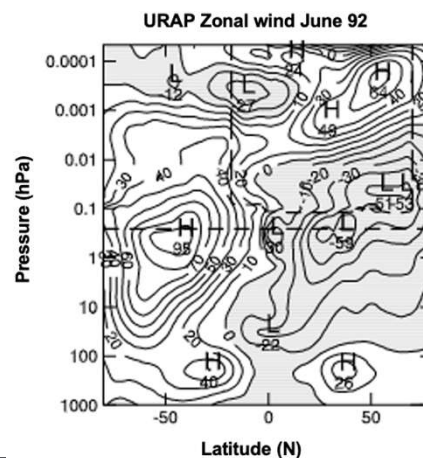
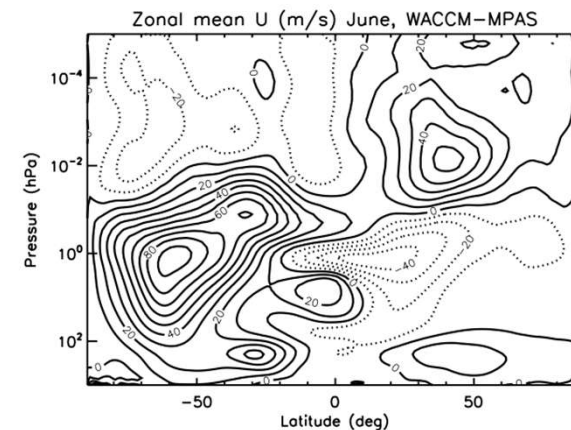
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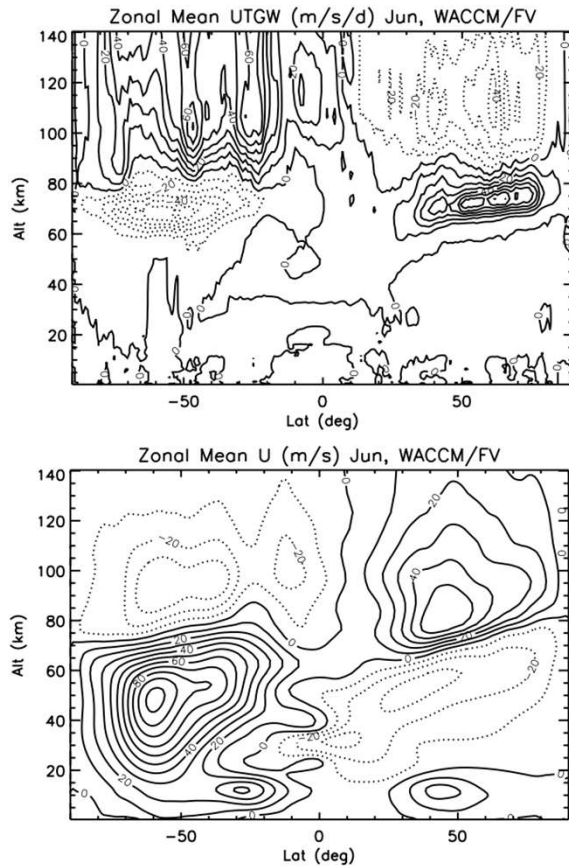


MPAS-A

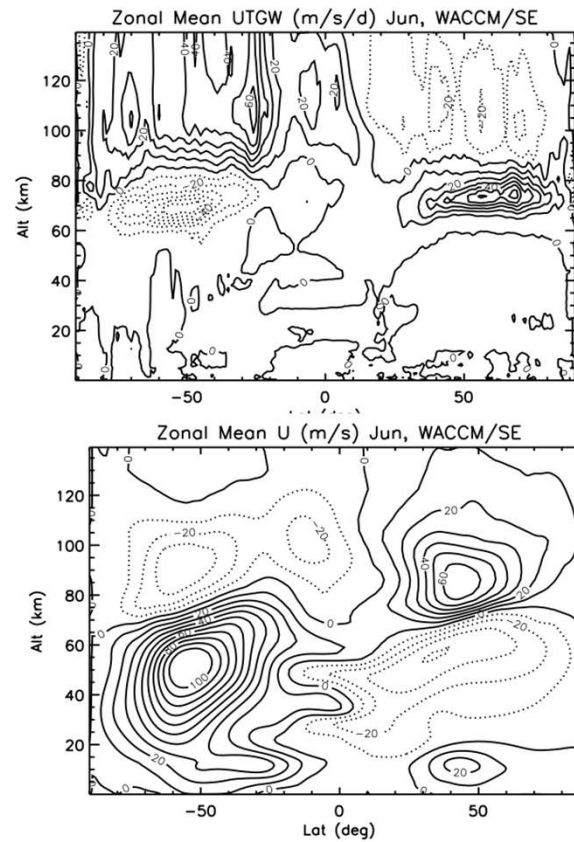


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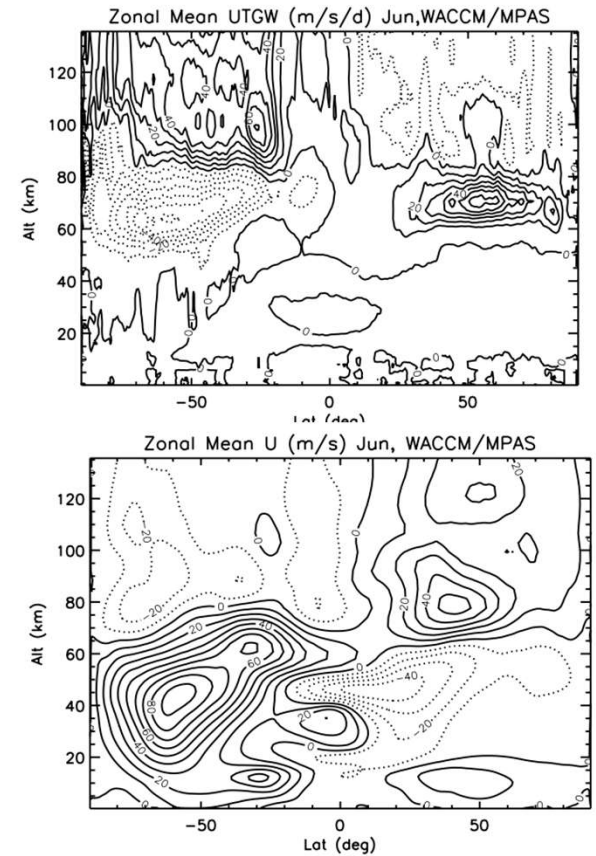
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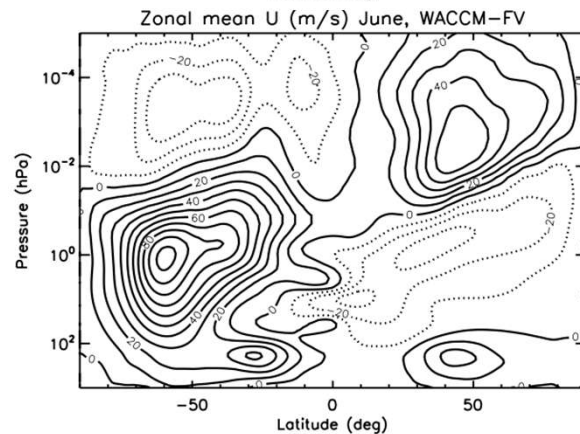
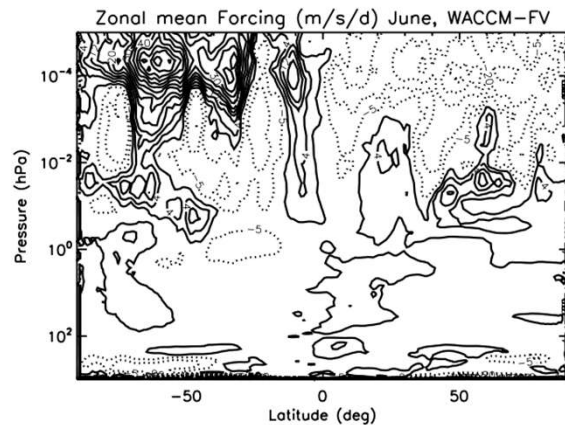
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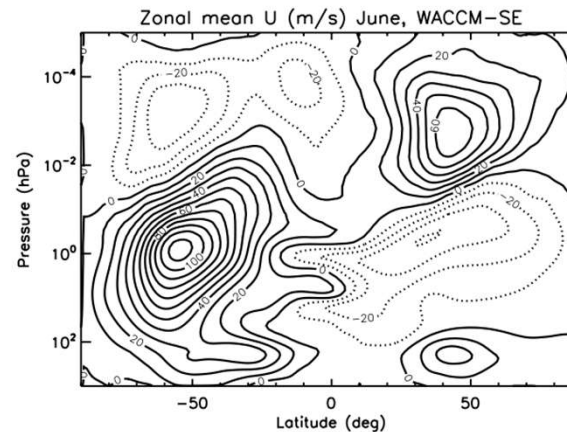
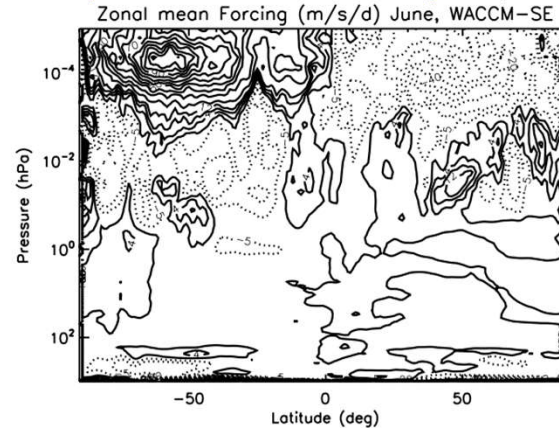
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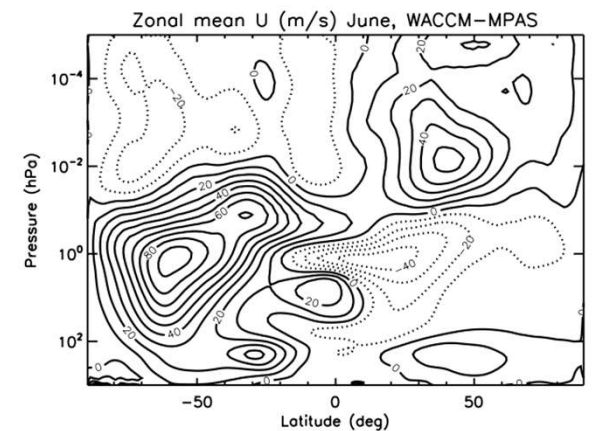
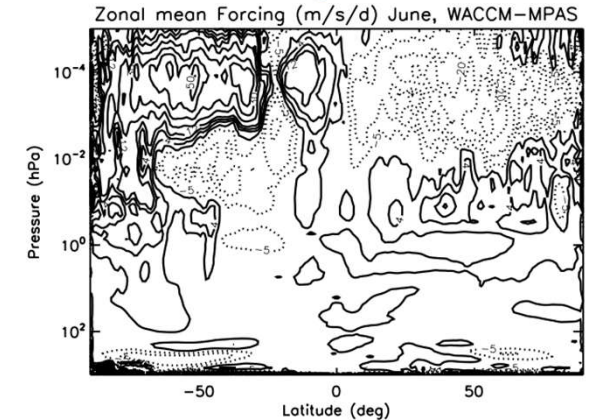
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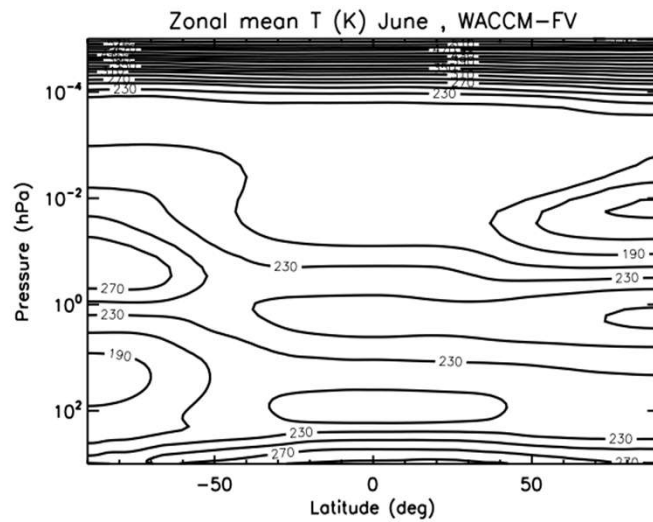


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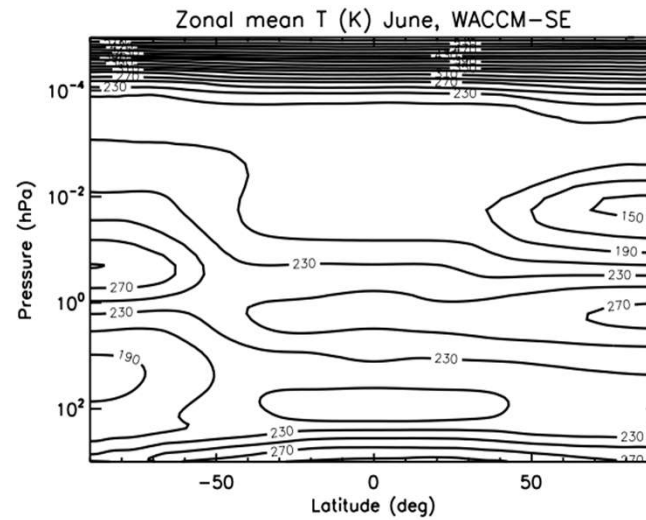


Mean Zonal Temperature Comparison- June

Finite Volume (FV)



Spectral Element (SE)



MPAS-A

