



Sensitivity of the ECMWF model climate Horizontal resolution: from climate to NWP resolution

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Questions

- **Is increasing horizontal resolution beneficial for the model climate?**
- **What do we gain by going to a resolution used in NWP?**



Experimental Setup

- Seasonal integrations with the ECMWF model
- Cycle 31R1 (oper. since 09/06) + *30Rx for ref*
- Observed SST fields
- Various horizontal resolutions:
 - T_L95 (200 km = climate prediction)
 - T_L159 (120km = seasonal forecasting)
 - T_L255 (80 km = monthly forecasting)
 - T_L511 (40km = NWP)
- 91 levels in the vertical
- Period considered: 1990-2005 (-2006)
- Two seasons
 - DJFM with start on 1st November
 - JJAS with start on 1st May



Computational Effort

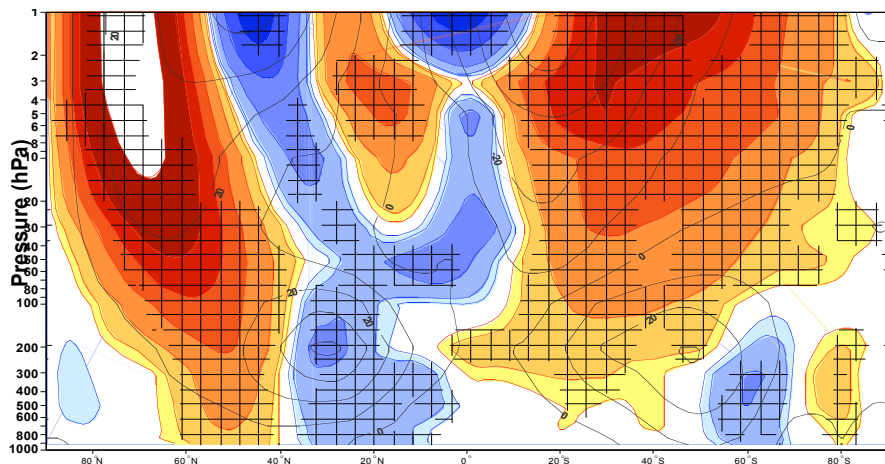
1 Integration (151 days) @ T_L511L91:

- 12% of all CPUs on HPCE cluster
- Wall clock time about 20 hours
- About 70 times more expensive than T_L95

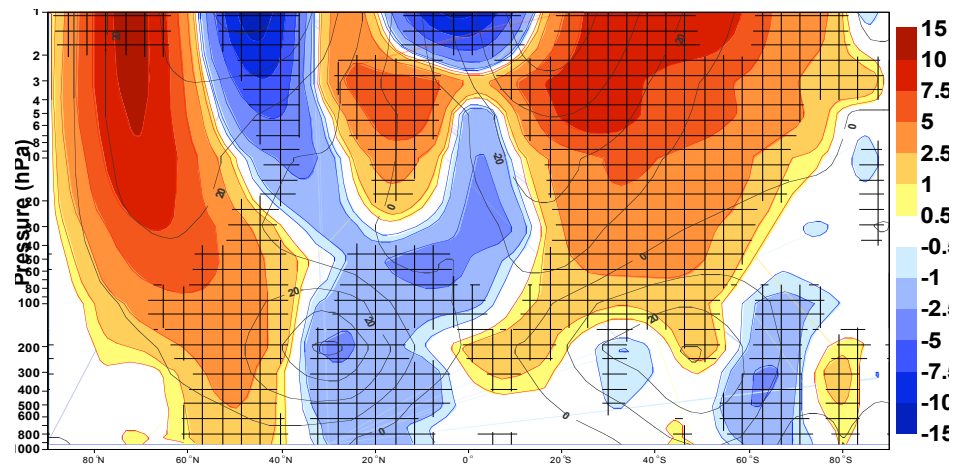


Zonal Mean U Error (DJFM)

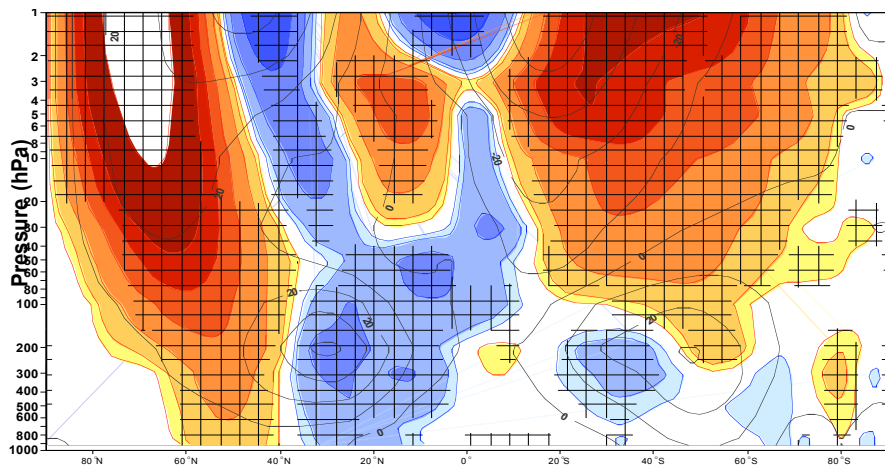
T_L95-ERA40



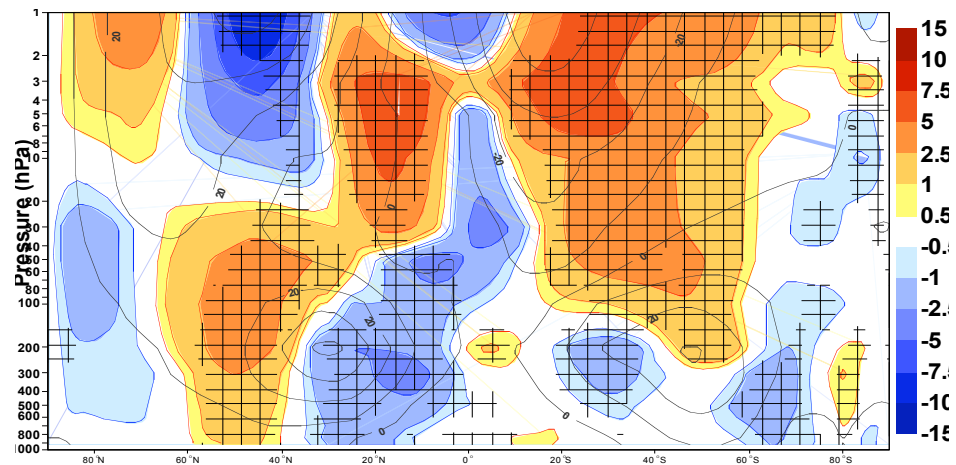
T_L159-ERA40



T_L255-ERA40



T_L511-ERA40





Orographic Gravity Waves above Greenland

T_{L95L60}

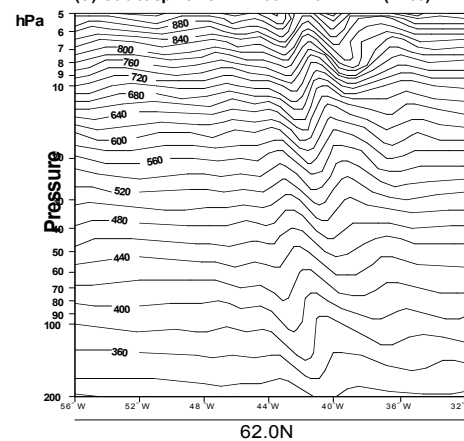
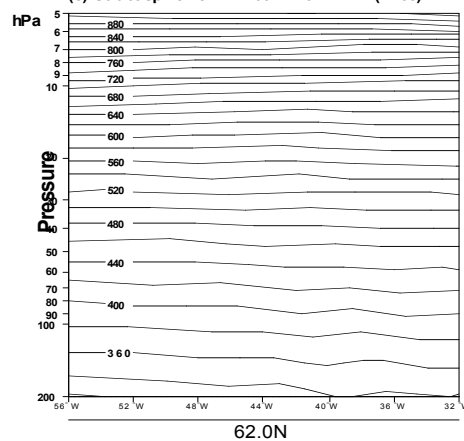
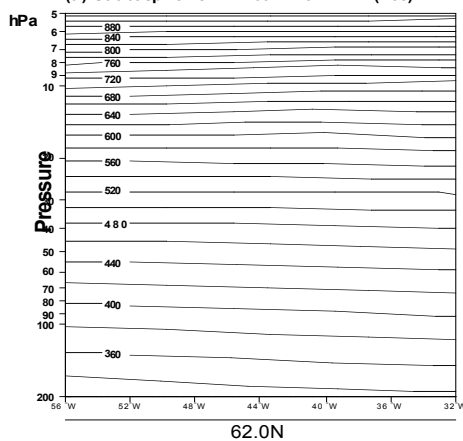
$T_{L255L60}$

$T_{L799L60}$

(a) Stratospheric PT: 20041226 FC+24 (T95)

(c) Stratospheric PT: 20041226 FC+24 (T255)

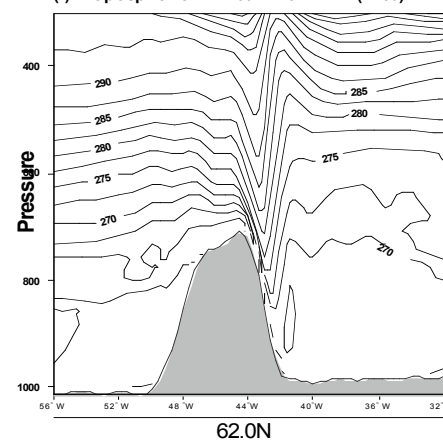
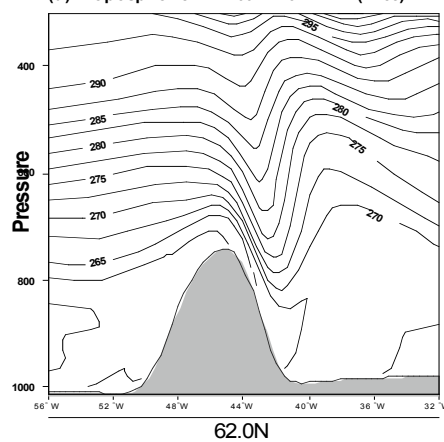
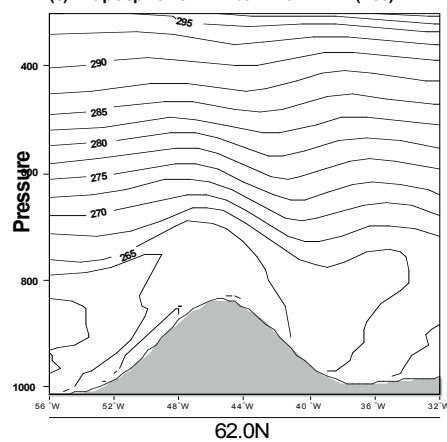
(e) Stratospheric PT: 20041226 FC+24 (T799)



(b) Tropospheric PT: 20041226 FC+24 (T95)

(d) Tropospheric PT: 20041226 FC+24 (T255)

(f) Tropospheric PT: 20041226 FC+24 (T799)



Stratosphere

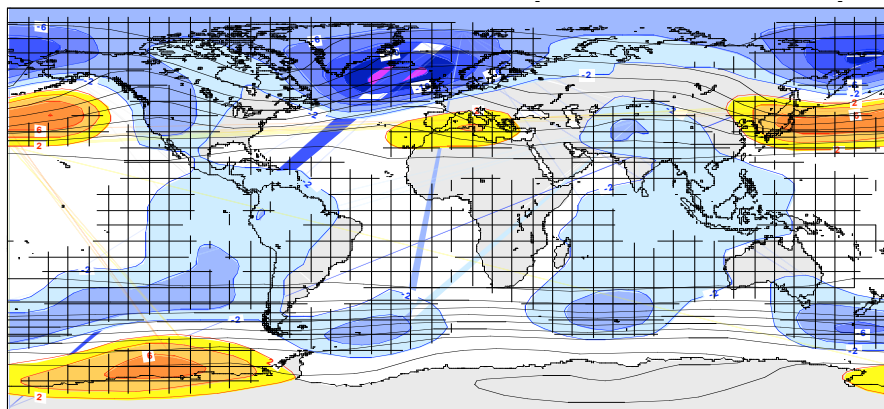
Troposphere

Jung and Rhines, JAS

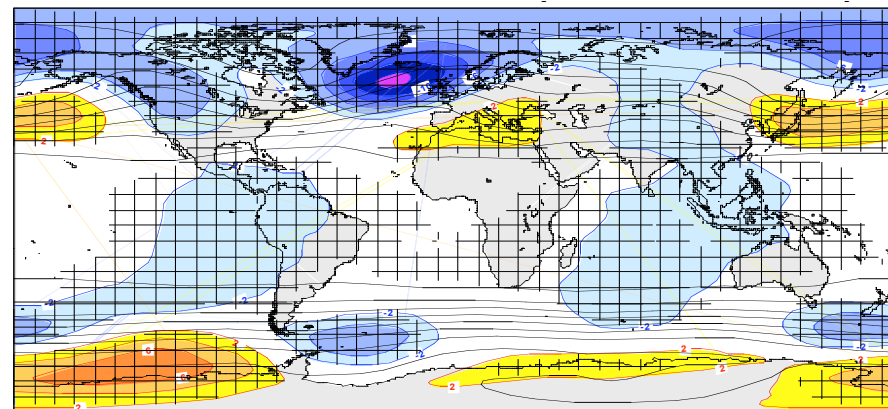


Mean Z500 Error (DJFM)

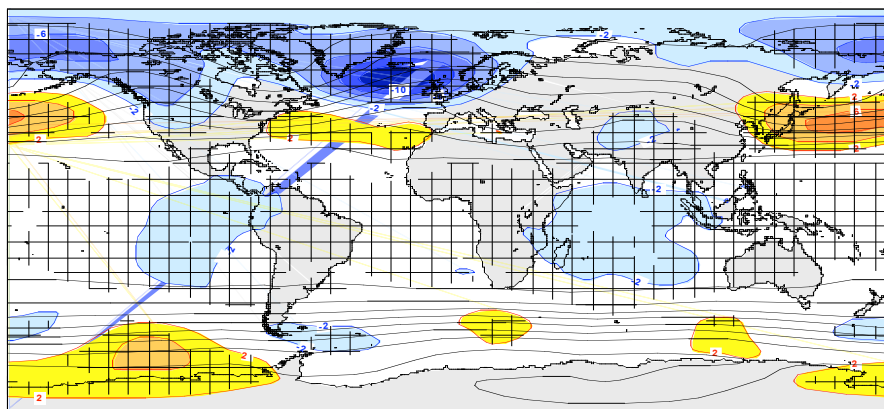
T_L95-ERA40



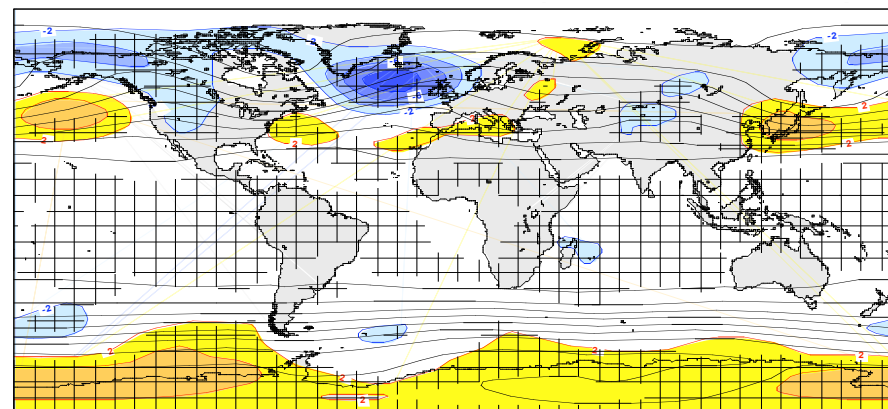
T_L159-ERA40



T_L255-ERA40



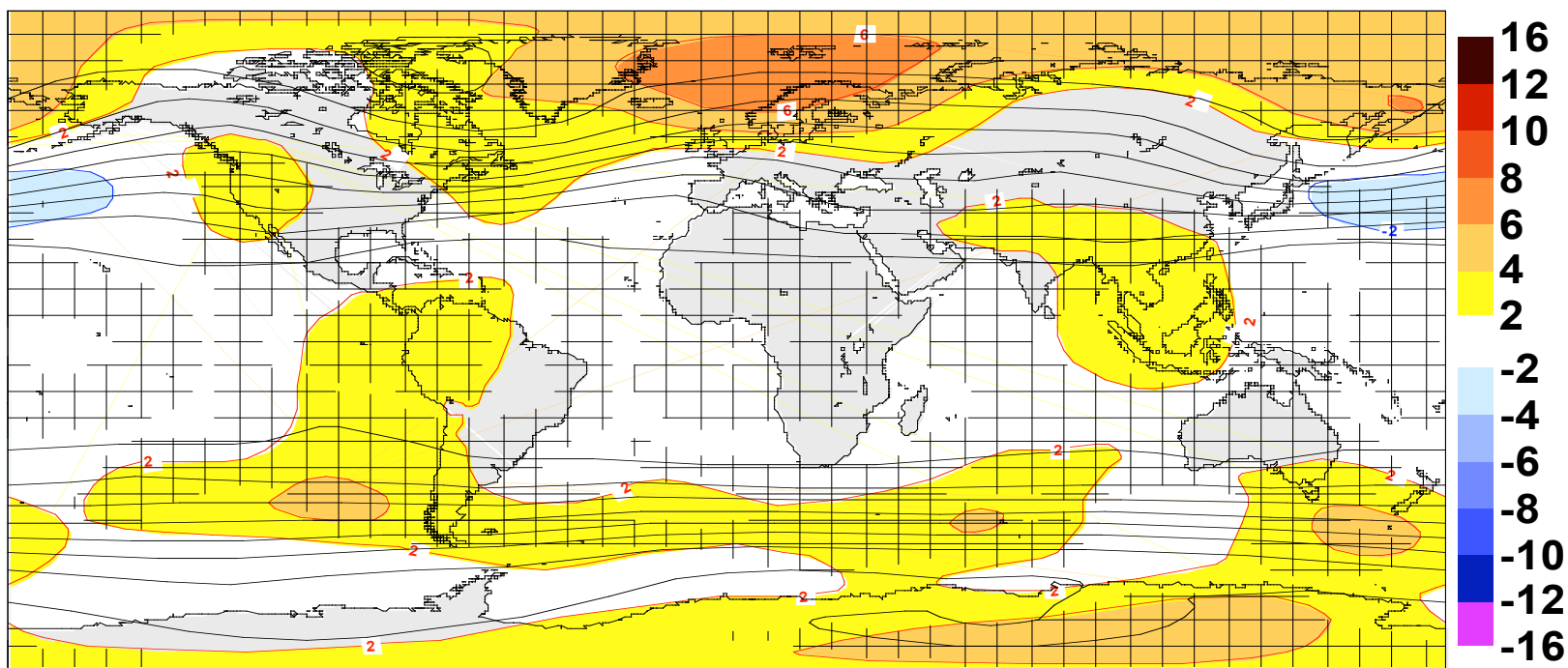
T_L511-ERA40





Mean Z500 Error (DJFM)

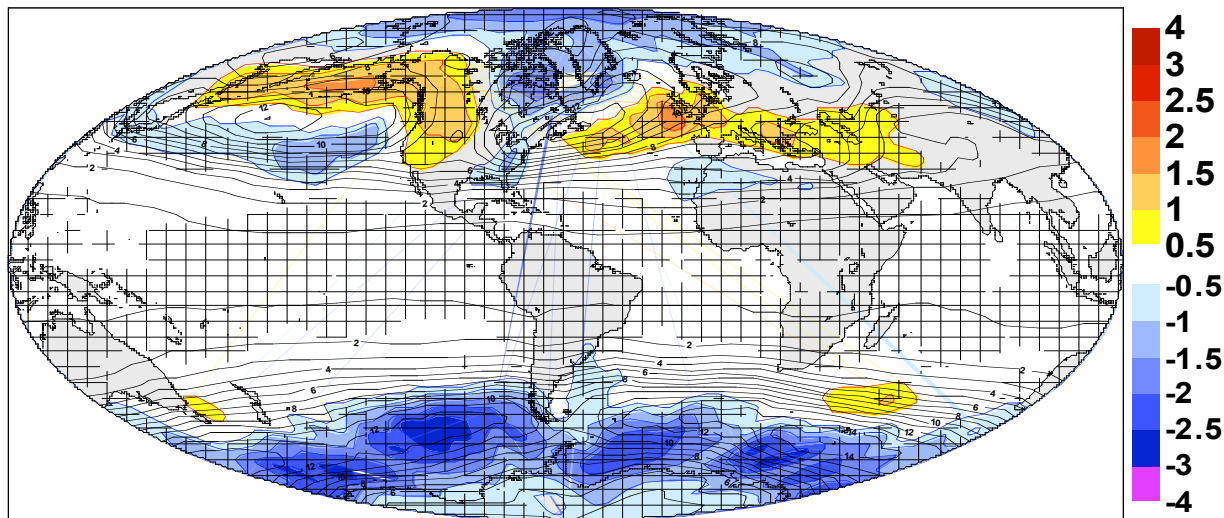
$T_{L511} - T_{L95}$



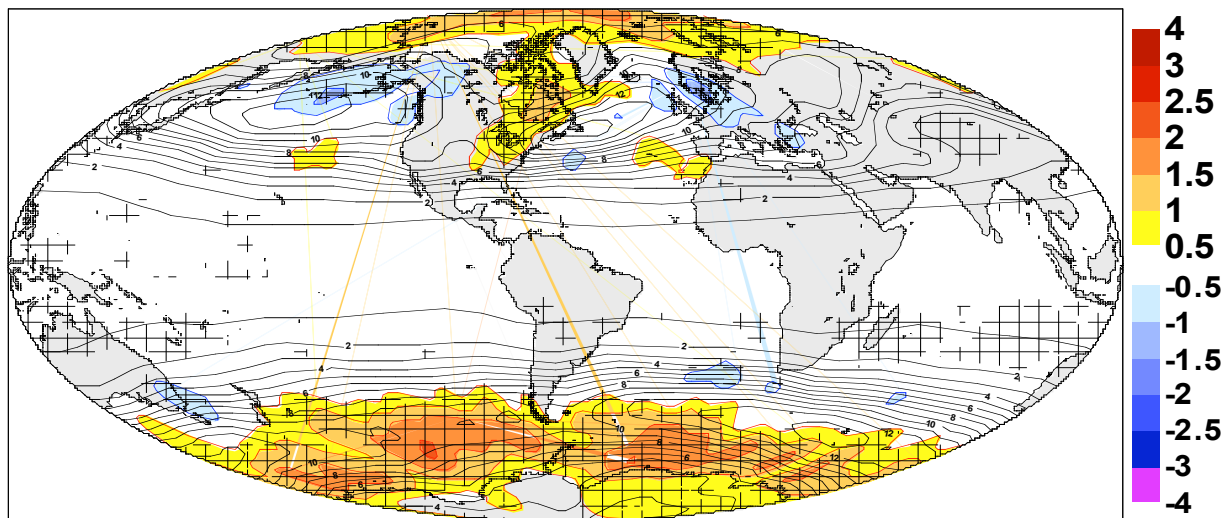


Synoptic Z500 Activity (DJFM)

T_L95-ERA04



T_L511-T_L95





Euro-Atlantic Blocking

Systematic errors in latest IPCC simulations (Boyle 2006):

- “The most prominent systematic error, occurring across all model is the underestimate of the trough/ridge in the Northern Hemisphere winter over the north Atlantic sector, 60°W-0°W.”
- “The models having the coarsest horizontal resolution (lower than 2.5°) consistently underperform compared to the others.”



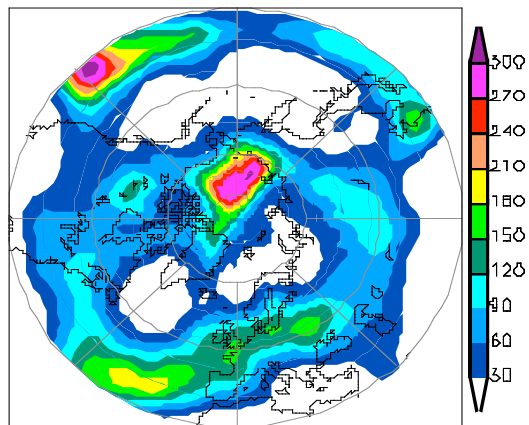
Tracking of Extratropical Anticyclones

- 6-hourly MSLP data
- Transformation into spectral space
- Spectral filtering (retaining T5-T13)
- Backtransformation into gridpoint space
- Searching for and tracking of MSLP minima using algorithm of Gulev et al.
- Application of selection criteria (e.g., minimum MSLP departure, migratory and long-lived systems only)

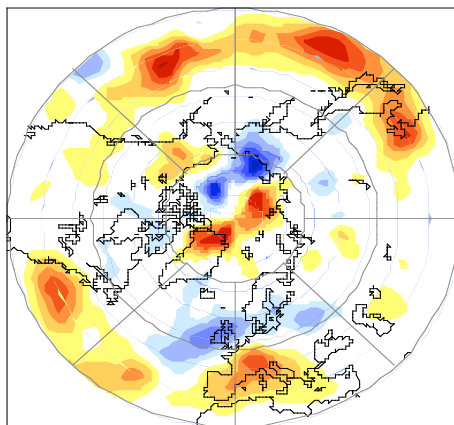


Frequency of Anticyclones (DJFM)

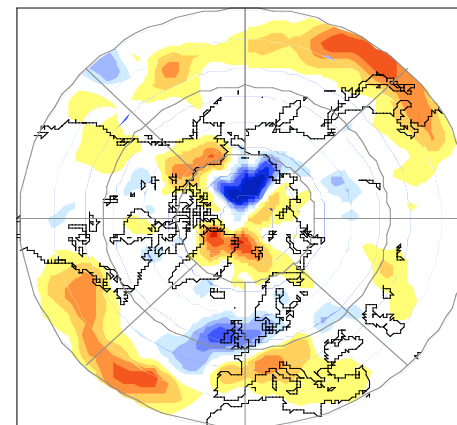
(a) Analysis



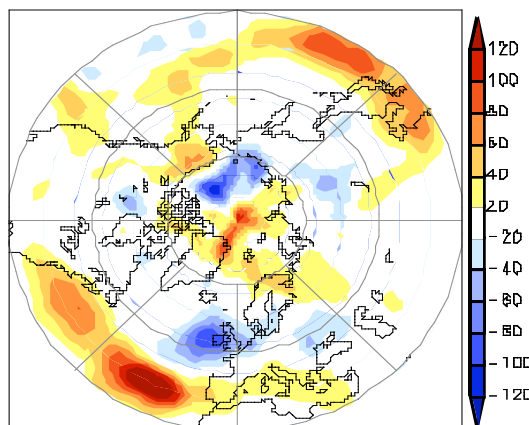
(b) T95L91-Analysis



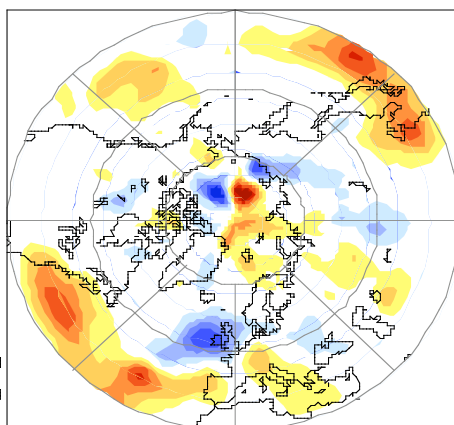
(c) T159L91-Analysis



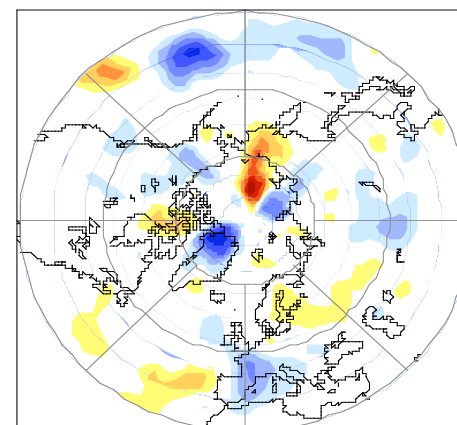
(d) T255L91-Analysis



(e) T511L91-Analysis



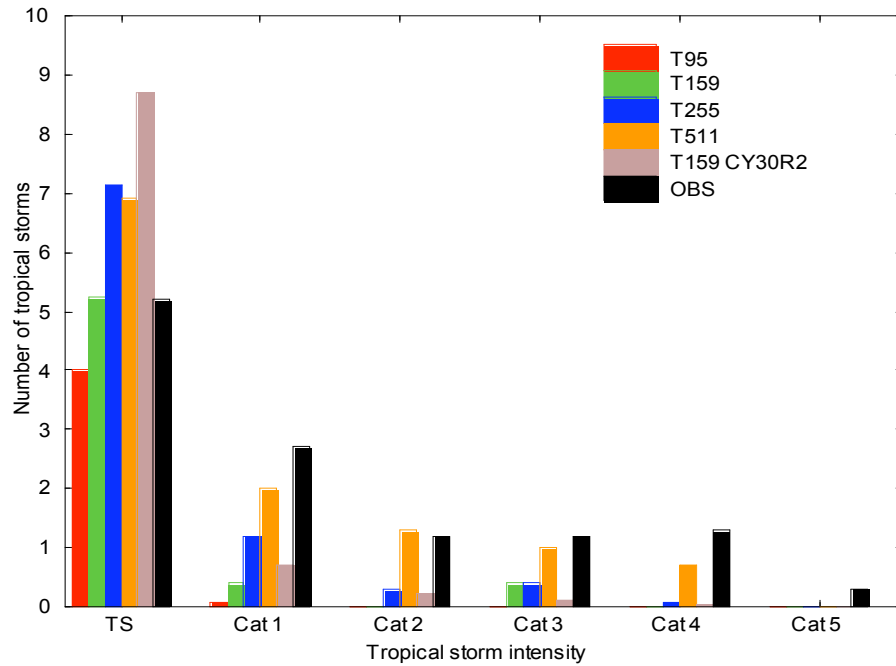
(f) T511L91-T95L91



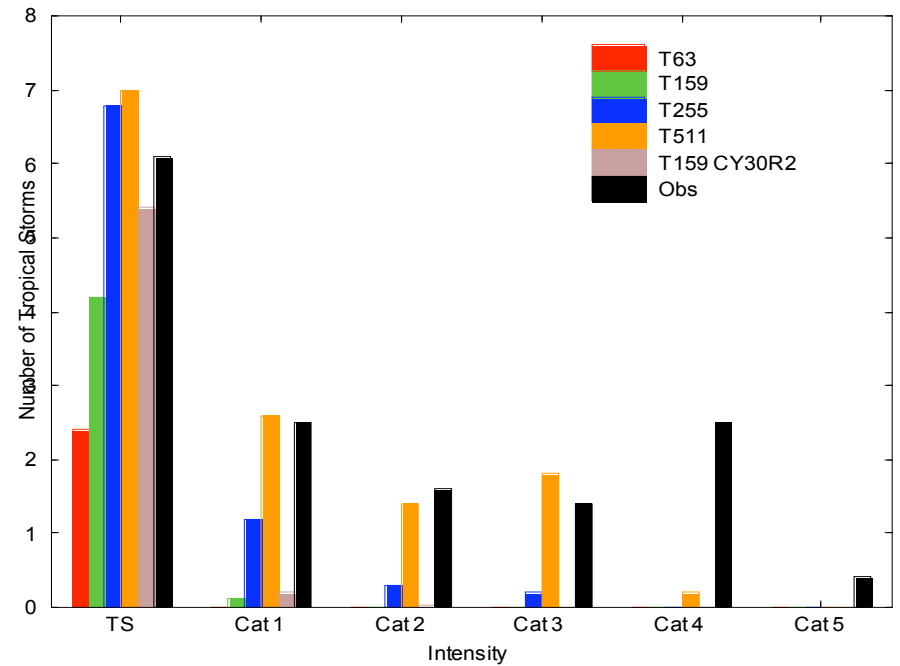


Resolution and Intensity of Tropical Storms (1990-2006)

Atlantic



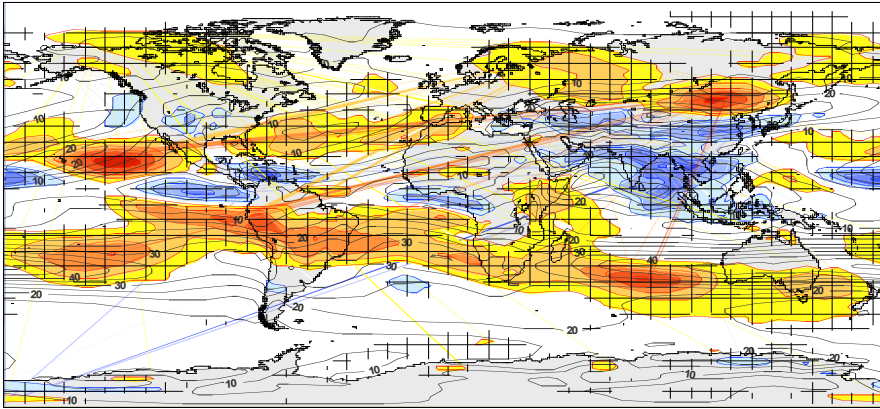
Eastern North Pacific



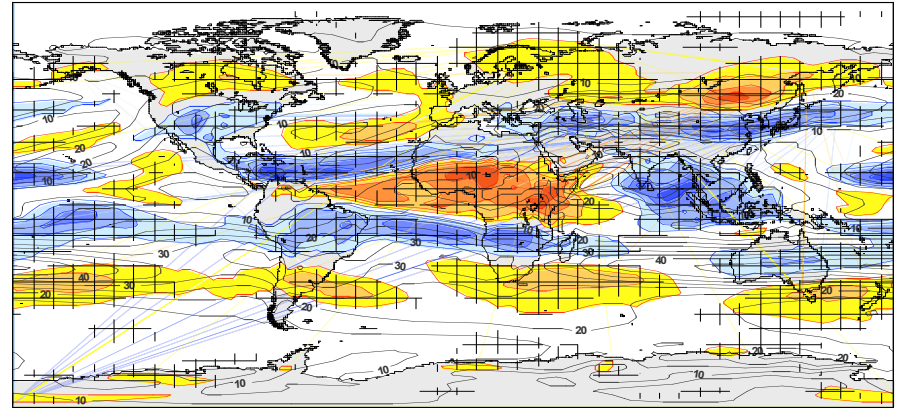


Vertical Wind Shear (JJAS)

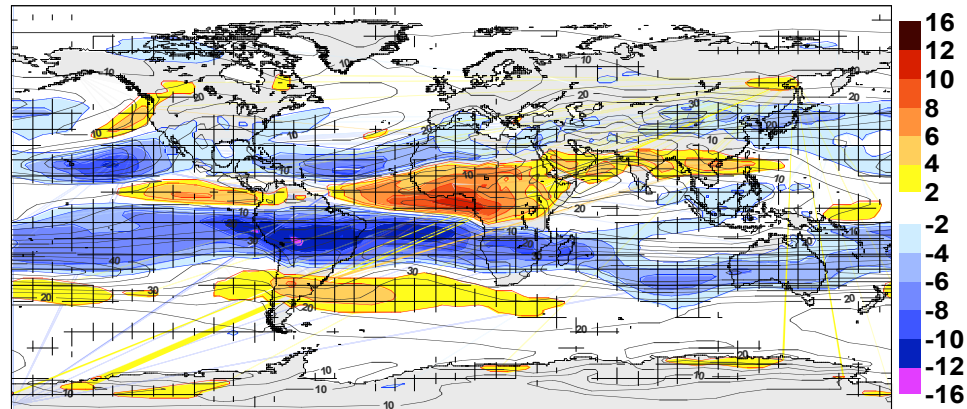
T_L95-ERA40



T_L511-ERA40



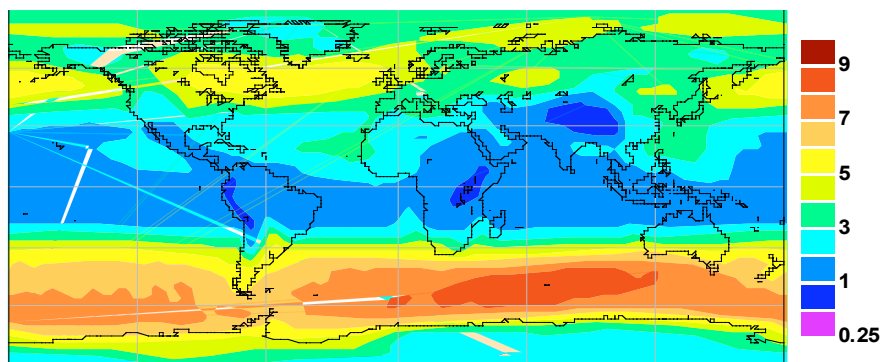
T_L511-T_L95



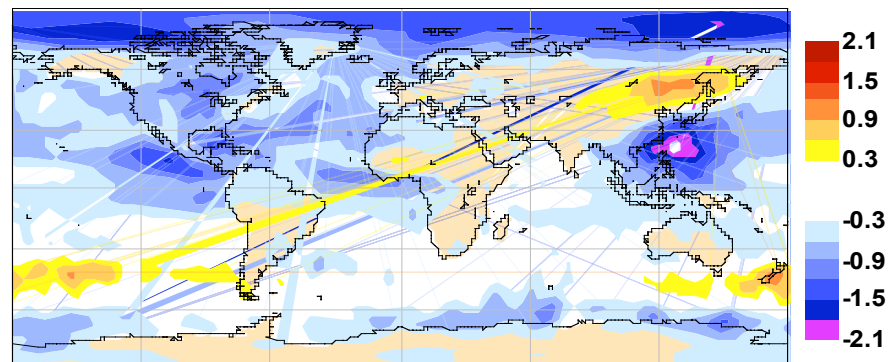


Synoptic Activity: V_{rot} @ 700hPa (JJAS)

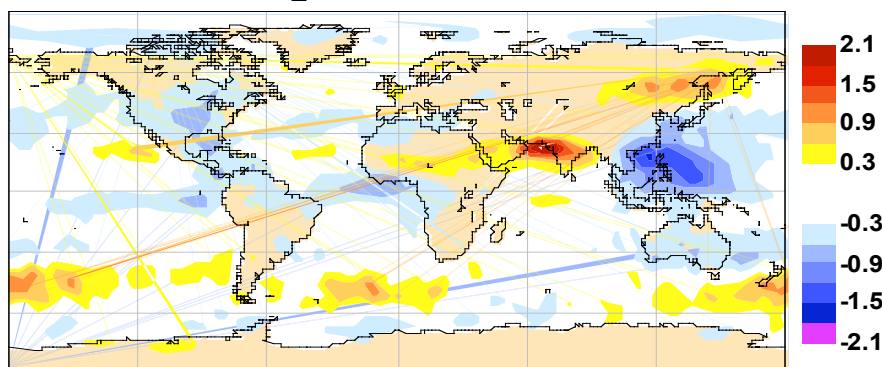
ERA40



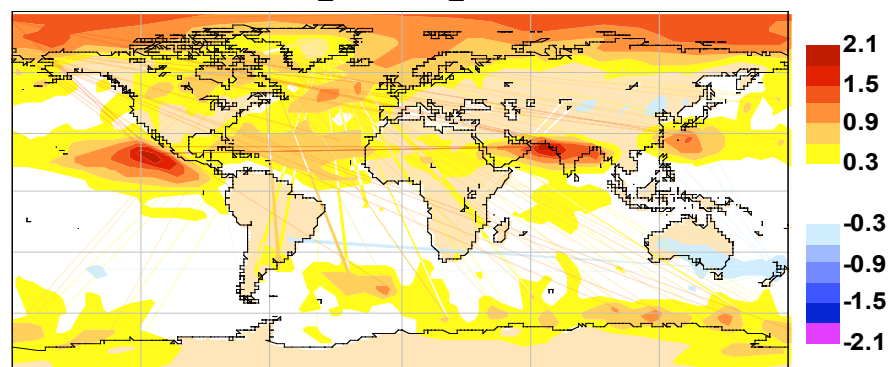
T_{L95} -ERA40



T_{L511} -ERA40



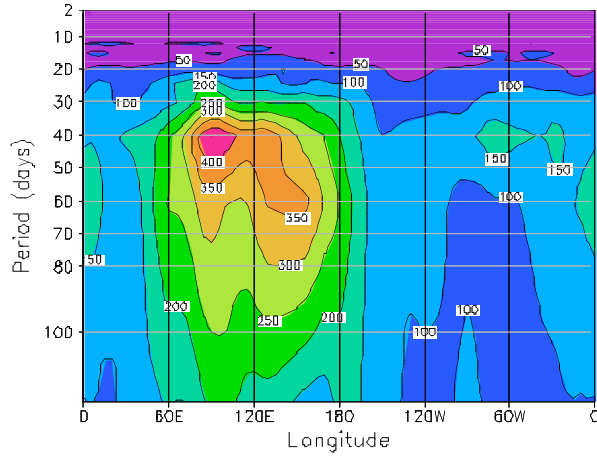
T_{L511} - T_{L95}



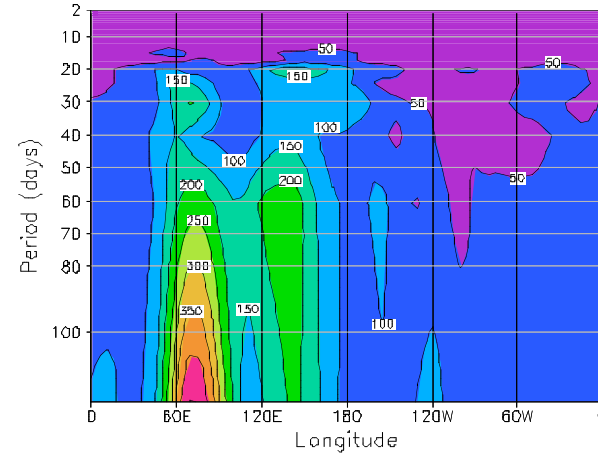


Madden-Julian Oscillation (DJFM)

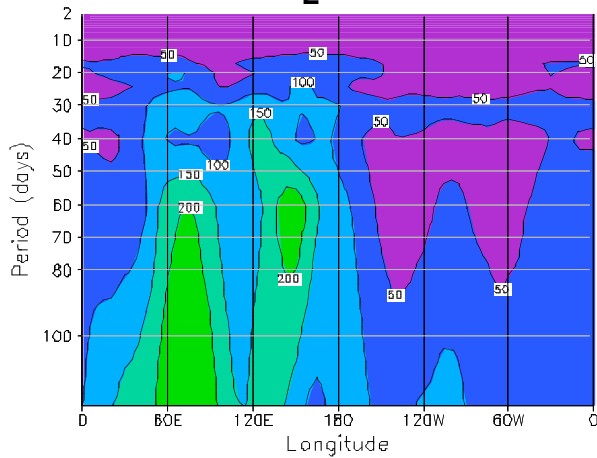
ERA40



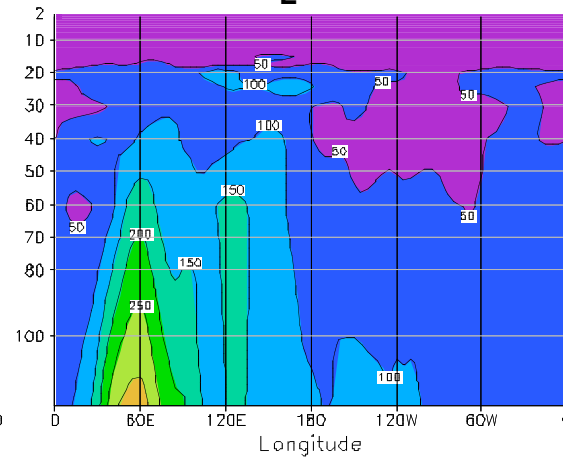
T_L95



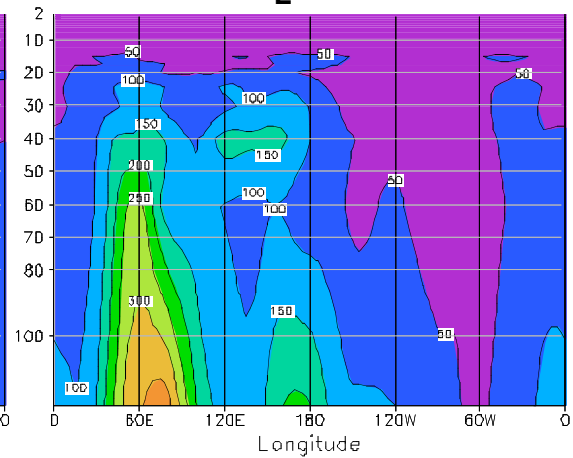
T_L159



T_L255

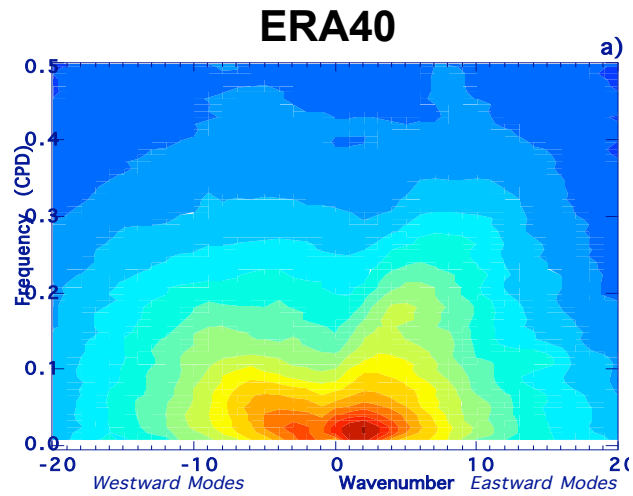


T_L511

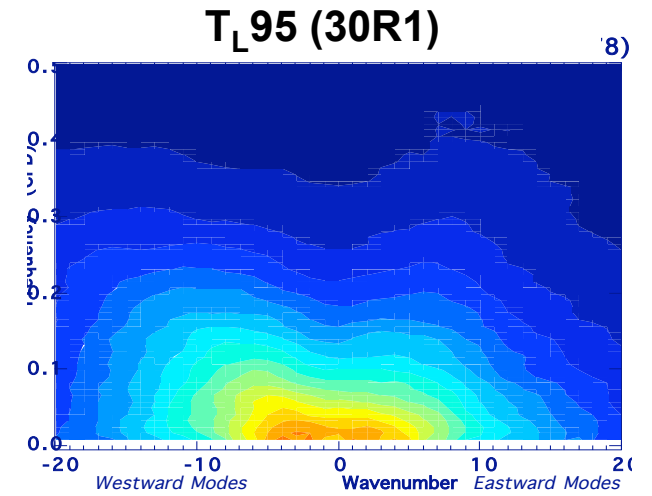




Convectively Coupled Tropical Waves: Symmetric OLR Anomalies (DJFM)

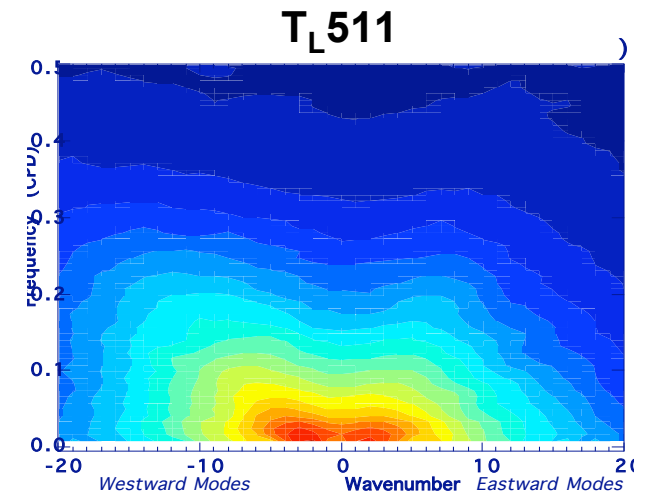


T_L95 (31R1)



T_L159

T_L255



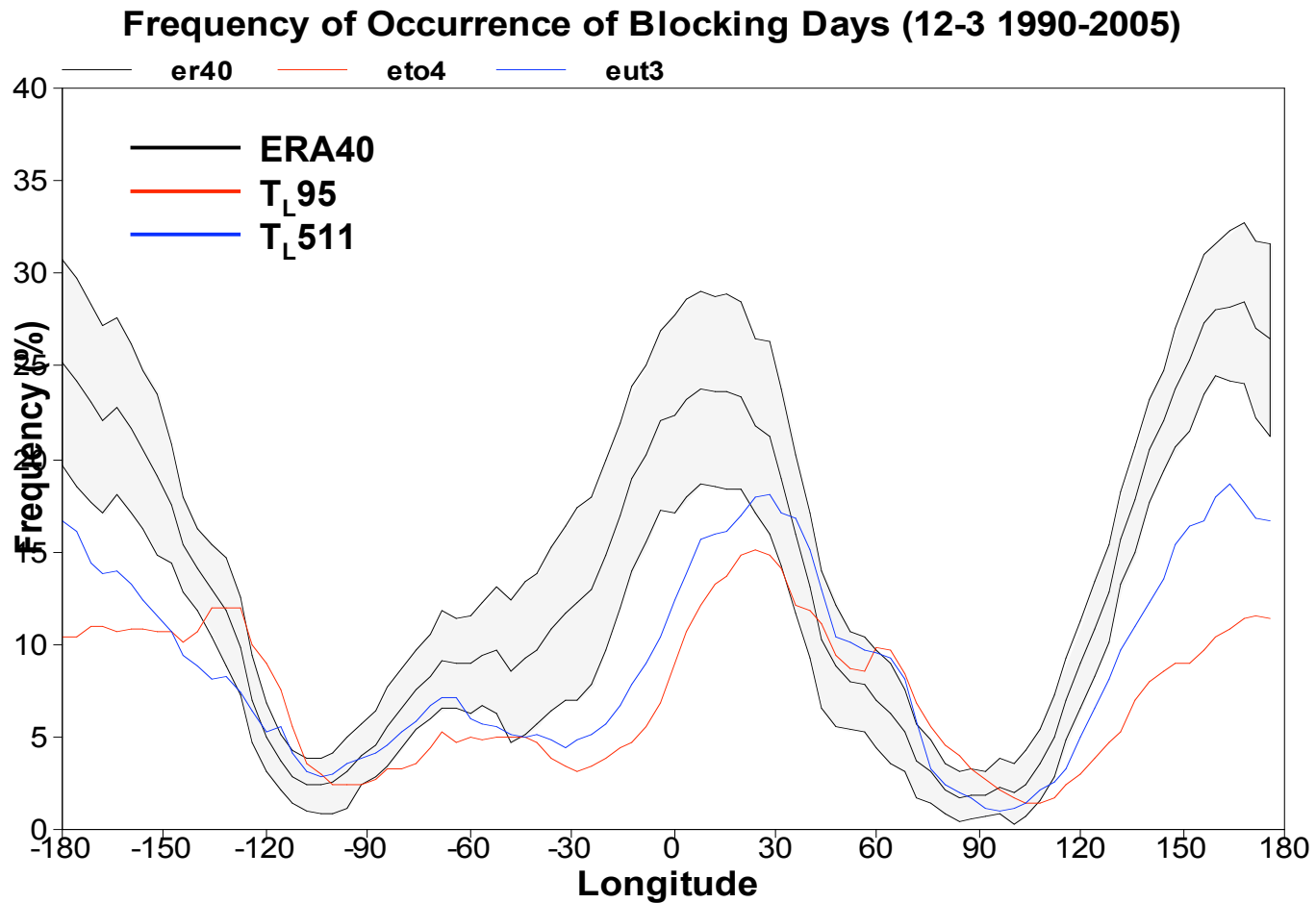


Conclusions

- Influence of increasing resolution from T_L95 to T_L511 has been studied.
- For many aspects of the model climate using high resolution is beneficial.
- It is not always necessary to go all the way to T_L511.
- Some model aspects are independent of resolution.
- Few deteriorations.
- The impact of resolution seems to be model dependent.
- Full benefit of resolution for coupled models?
- Impact of resolution on seasonal and climate predictability?



Northern Hemisphere Blocking Frequency (DJFM)





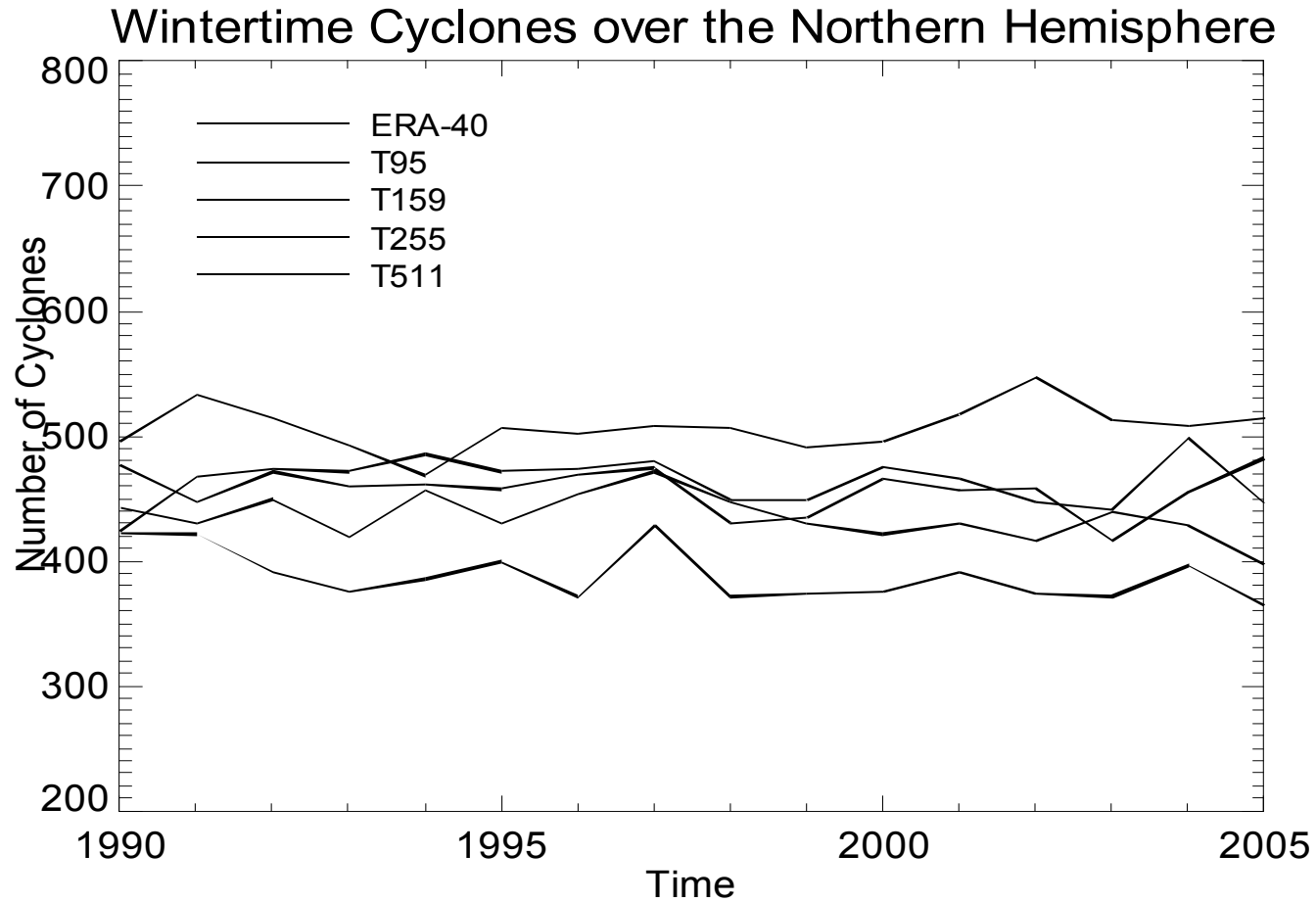
Extratropical Cyclone Tracking

Method of Gulev et al.:

- 6-hourly MSLP data
- All data truncated to T40 prior to tracking
- Searching for and tracking of MSLP minima
- Application of selection criteria (e.g., migratory long-lived systems only)
- Details: Jung et al., 2006, QJ



Number of Extratropical Cyclones (Winter)



Lifetime > 1day



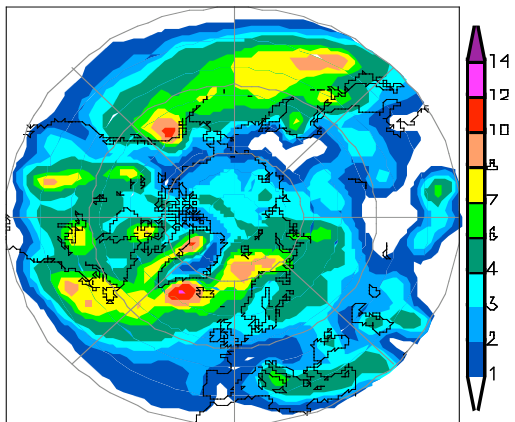
Tropical Cyclone Tracking

- Detection:
 - Find area with MSLP below a certain threshold
 - Check whether there is a warm core above the MSL minimum
- Tracking:
 - Compute trajectories from “different” low pressure minima

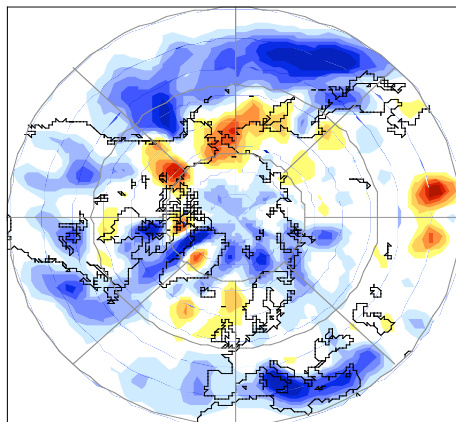


Number of Extratropical Cyclones (DJFM)

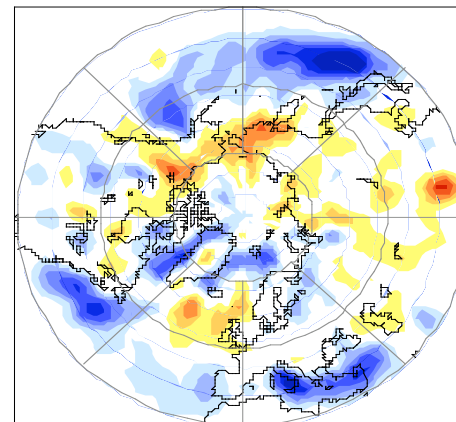
(a) Analysis



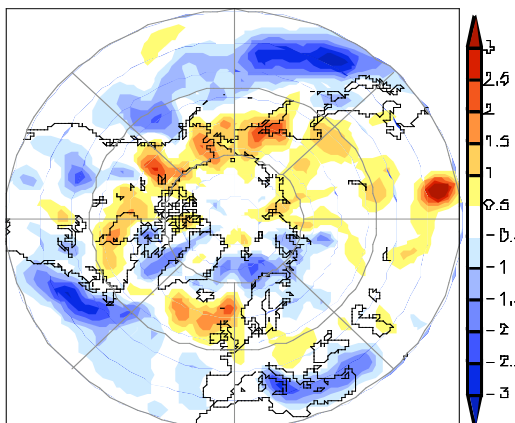
(b) T95L91-Analysis



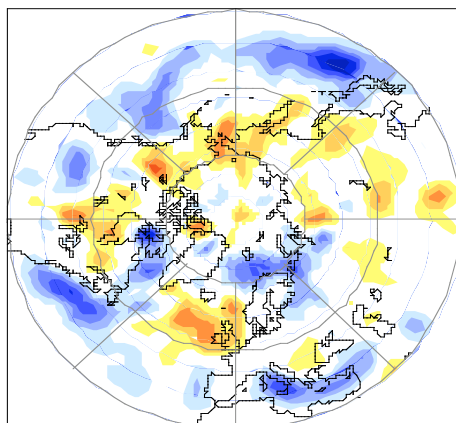
(c) T159L91-Analysis



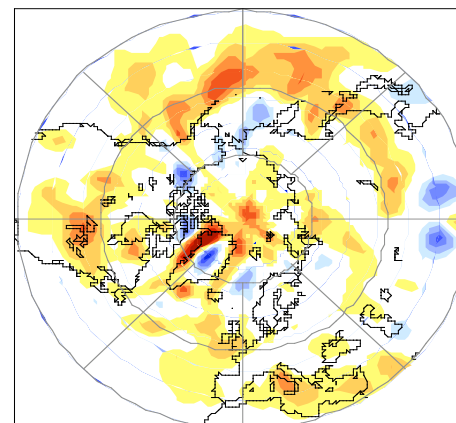
(d) T255L91-Analysis



(e) T511L91-Analysis



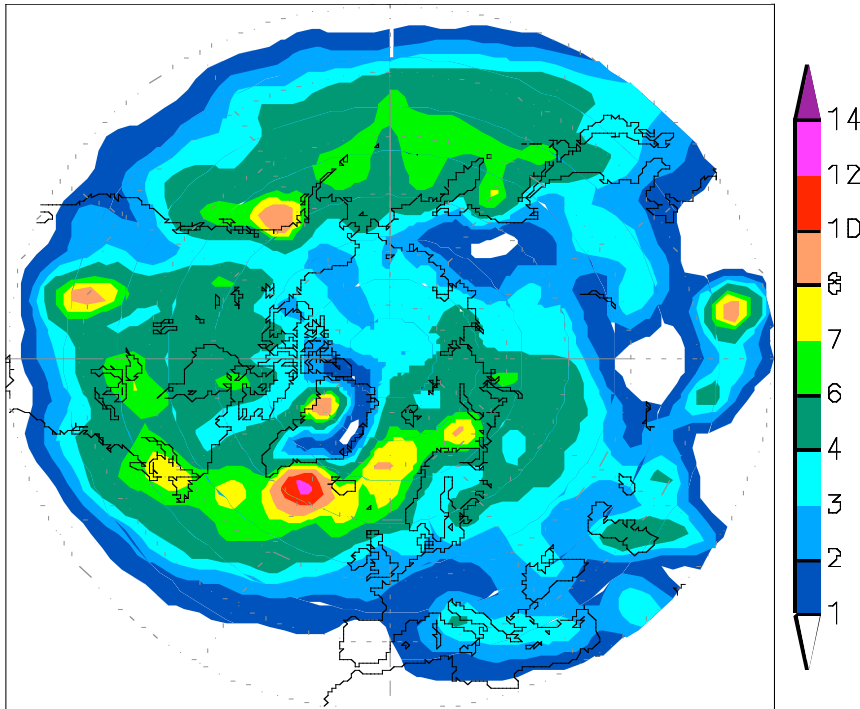
(f) T511L91-T95L91



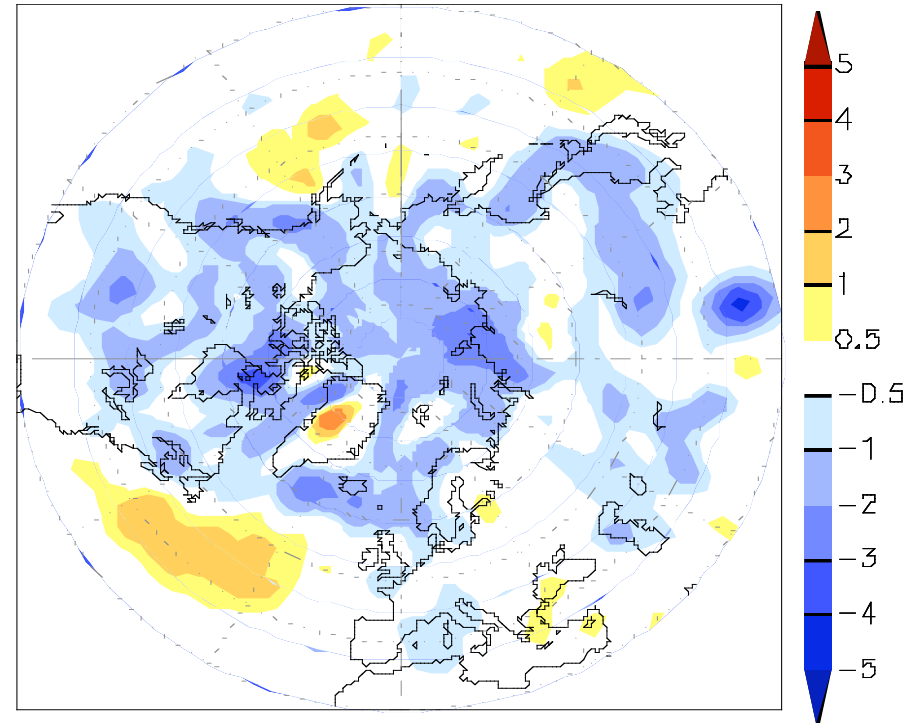


Sensitivity to Model Formulation

Cy31R1 (T159_L91)



Cy30R2-Cy31R1 (T159_L91)

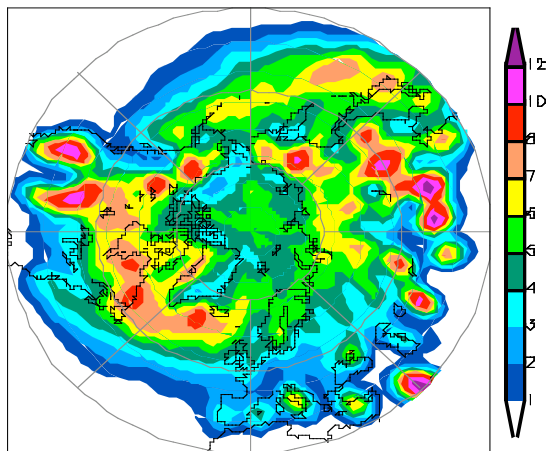


- Revised cloud scheme
- Implicit calculation of convective transports
- Modifications to the treatment of orography

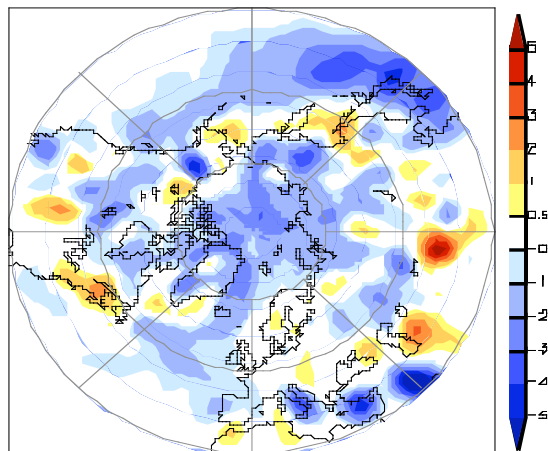


Number of Long-lived Migratory Cyclones (Summer)

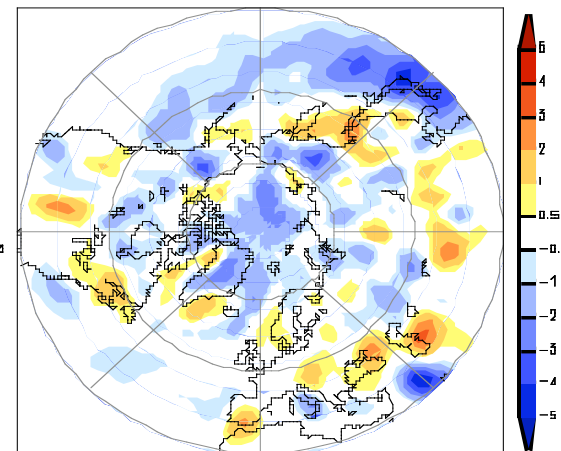
(a) Analysis



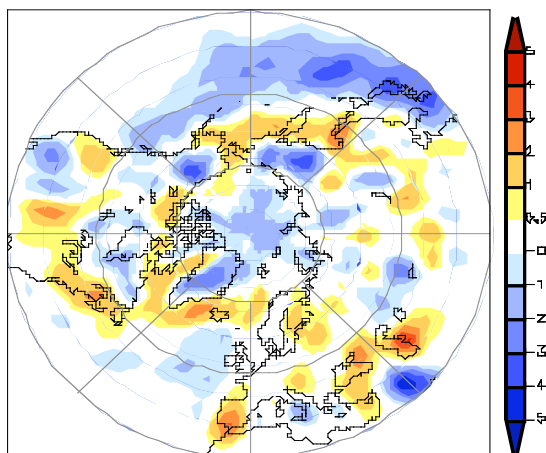
(b) T95L91 - Analysis



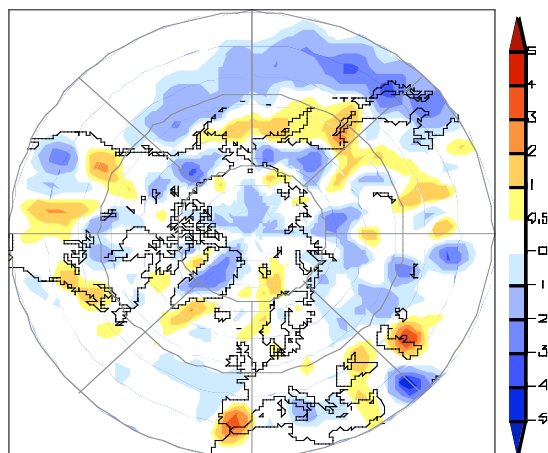
(c) T159L91 - Analysis



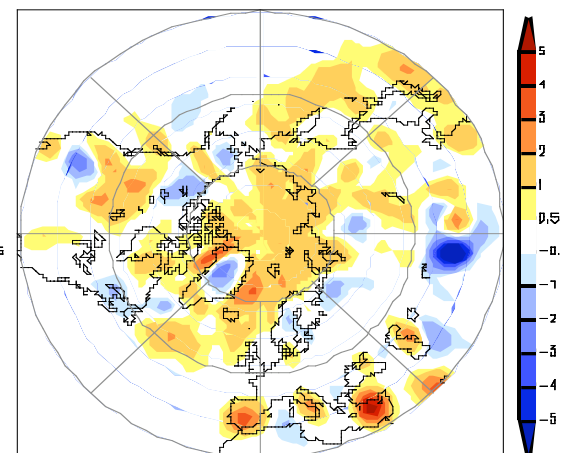
(d) T255L91 - Analysis



(e) T511L91 - Analysis

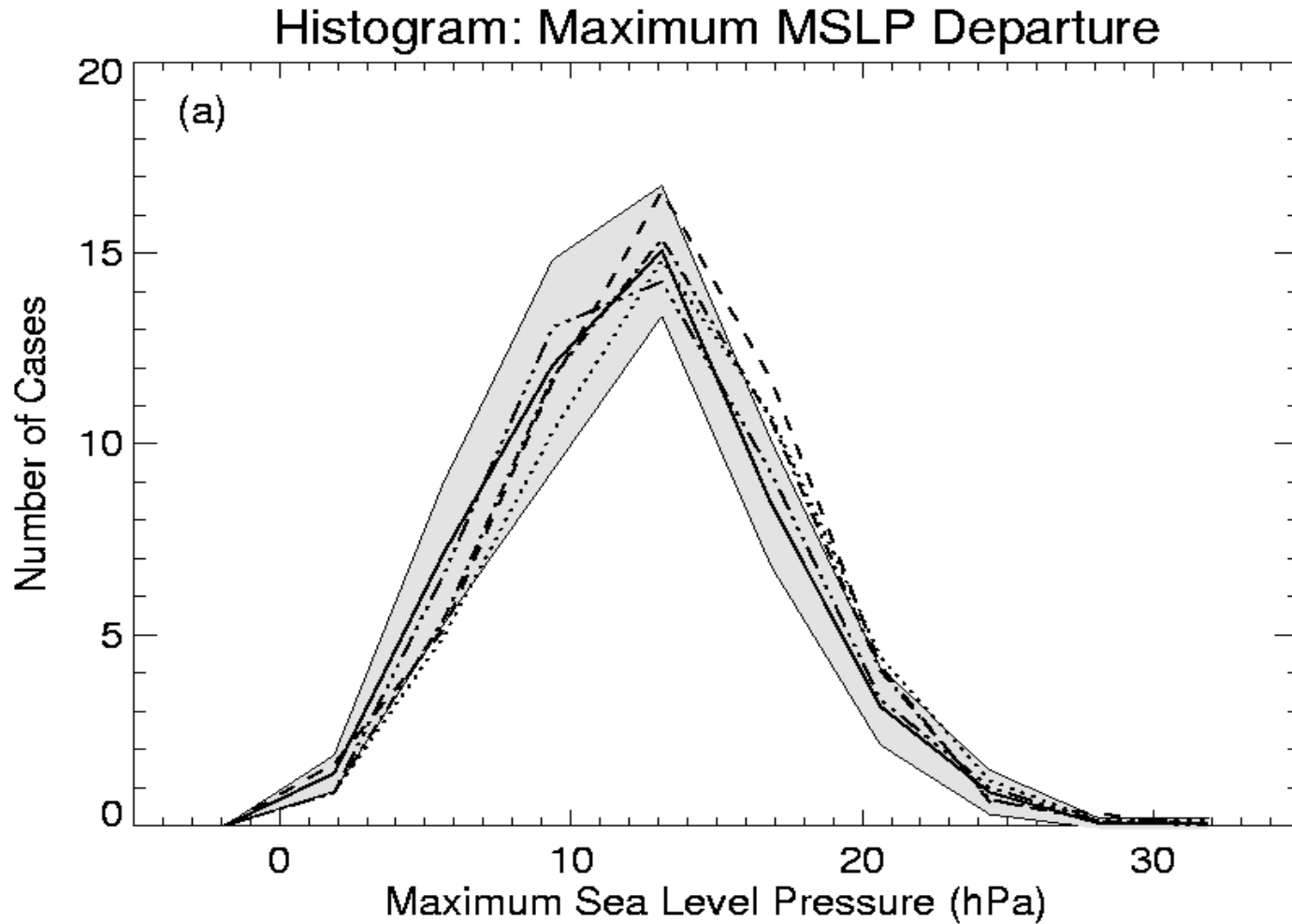


(f) T511L91 - T95L91





Intensity of Euro-Atlantic Blocking (DJFM)





Predictability of Tropical Storms and Resolution

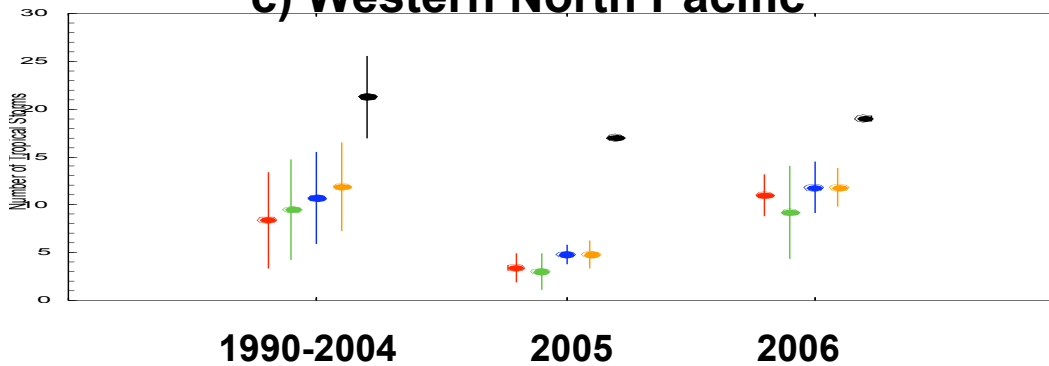
a) North Atlantic

Number of tropical storms

- T_L95
- T_L159
- T_L255
- T_L511
- Obs.

b) Eastern North Pacific

c) Western North Pacific

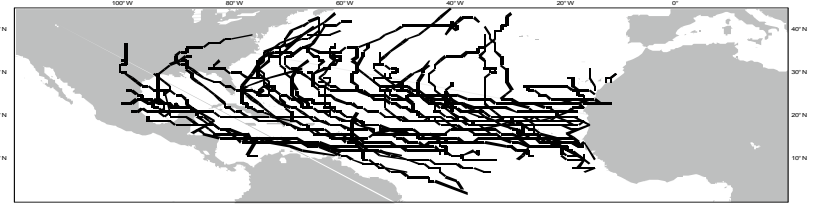




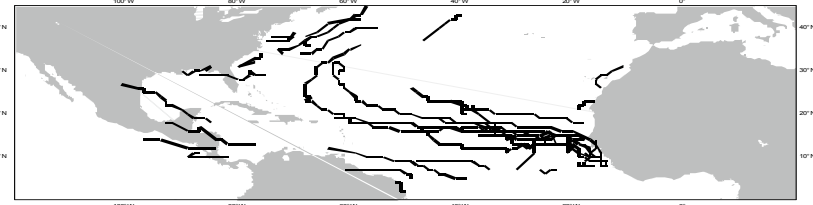
2005

2006

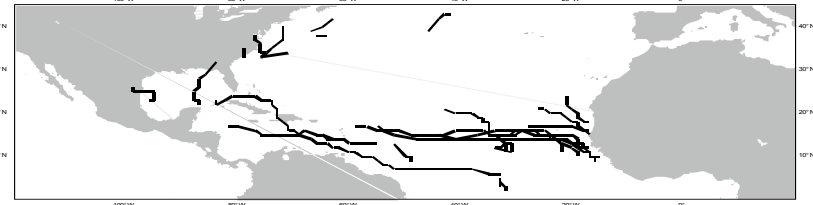
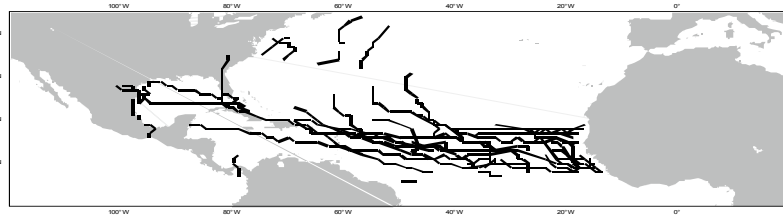
T_L511



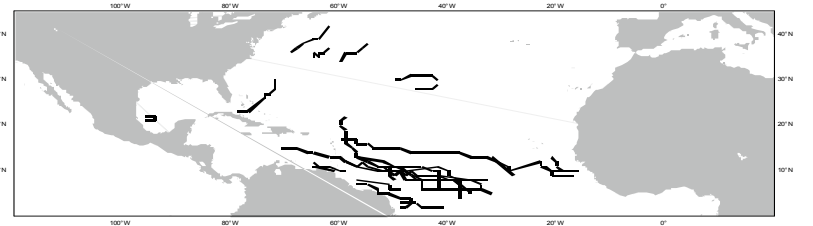
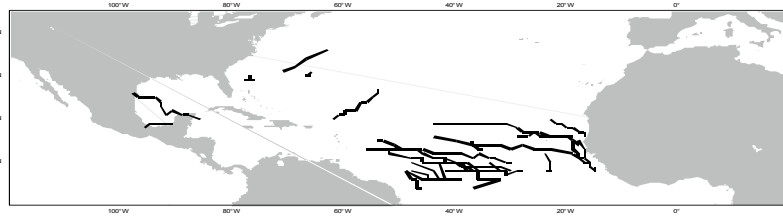
T_L255



T_L159



T_L95





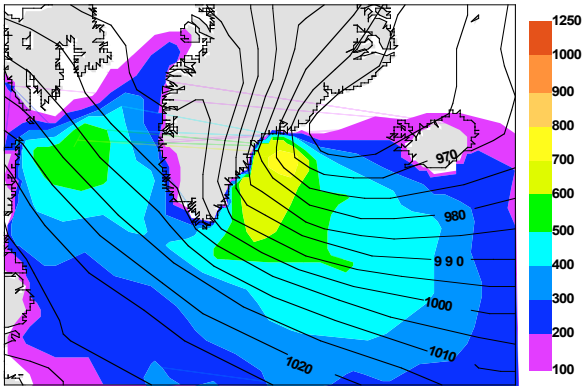
D+1 FC: MSLP and Surface Heat Fluxes

T_L95L60

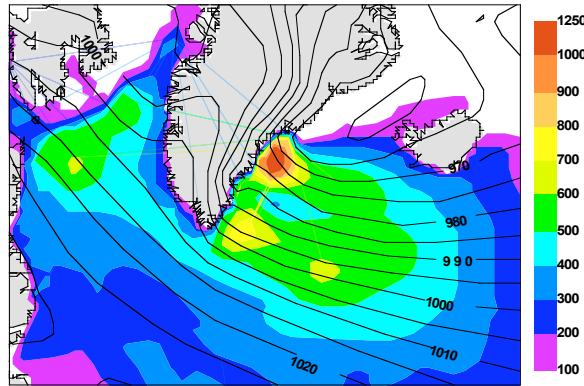
T_L255L60

T_L511L60

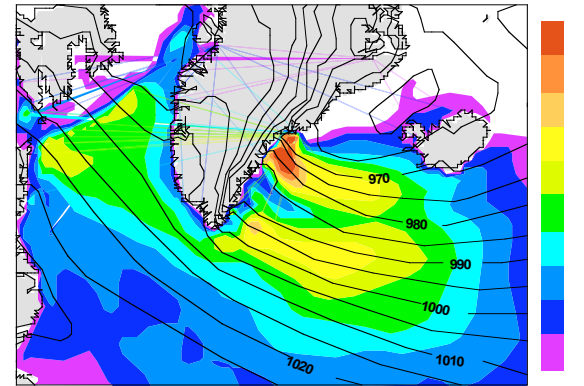
(a) SLP and Turbulent Heat Fluxes: 20041226 12z FC+24h (T95)



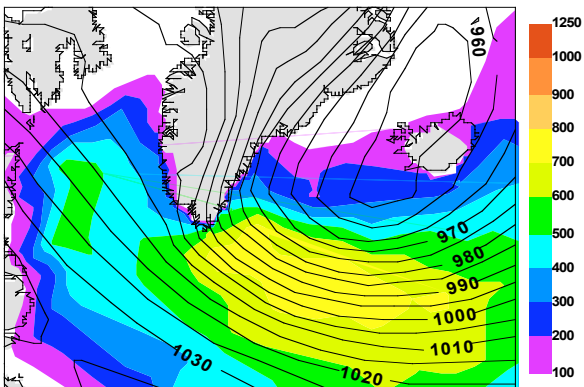
(b) SLP and Turbulent Heat Fluxes: 20041226 12z FC+24h (T255)



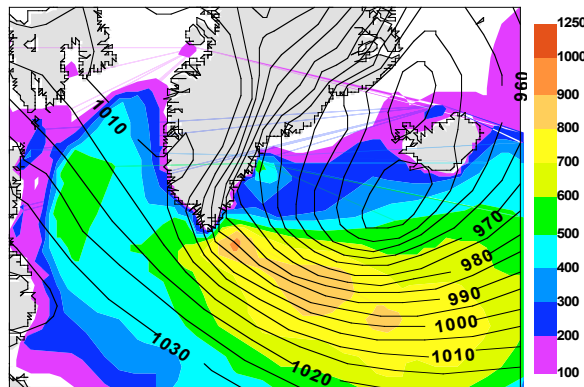
(c) SLP and Turbulent Heat Fluxes: 20041226 12z FC+24h (T799)



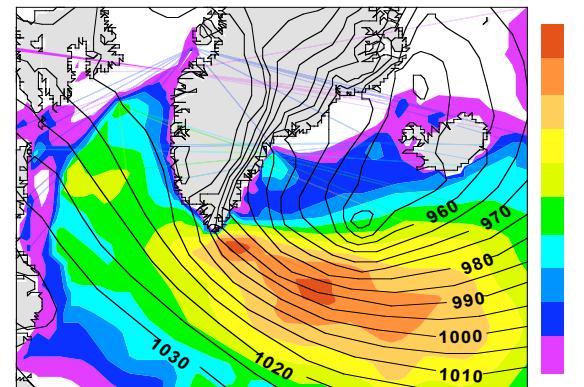
(d) SLP and Turbulent Heat Fluxes: 20050116 12z FC+24h (T95)



(e) SLP and Turbulent Heat Fluxes: 20050116 12z FC+24h (T255)



(f) SLP and Turbulent Heat Fluxes: 20050116 12z FC+24h (T799)



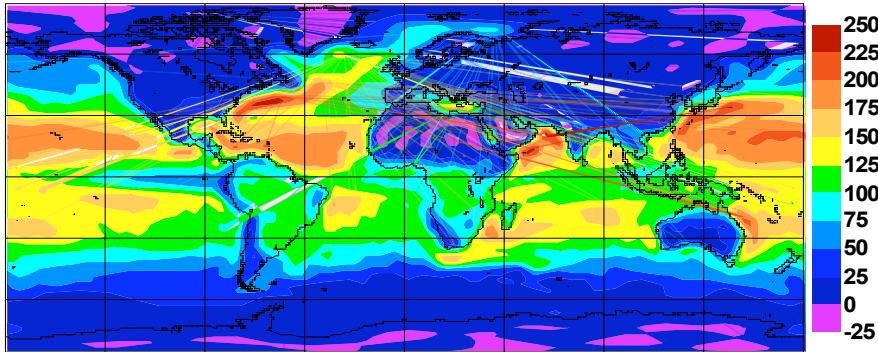


Surface Latent Heat Fluxes and Near-Surface Winds

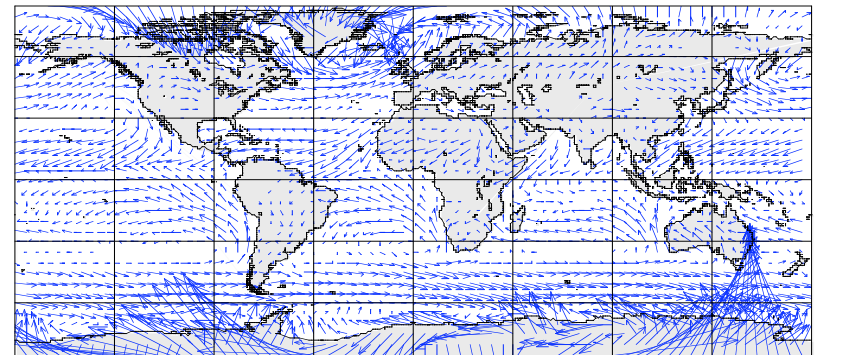
Surface Latent Heat Flux

Mean 10m Wind

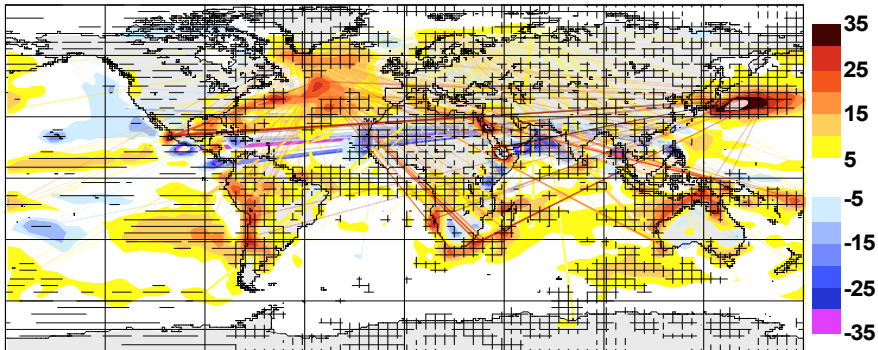
Surface Latent Heat Flux eto4 (12-3 1990-2005)



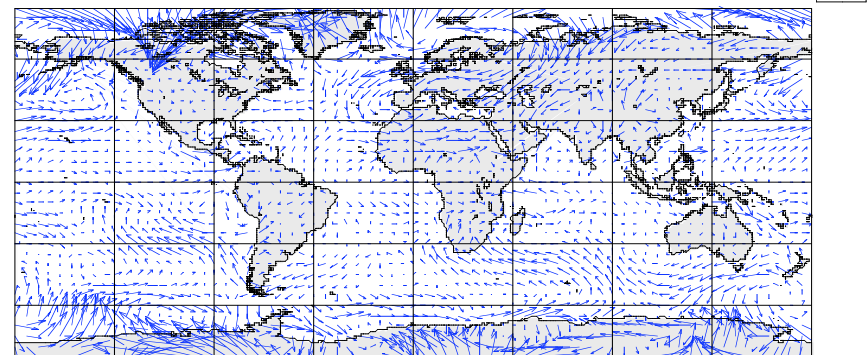
Mean Wind 10m eto4 (12-3 1990-2005)



Surface Latent Heat Flux eut3-eto4 (12-3 1990-2005)



Wind Difference 10m eut3-eto4 (12-3 1990-2005)





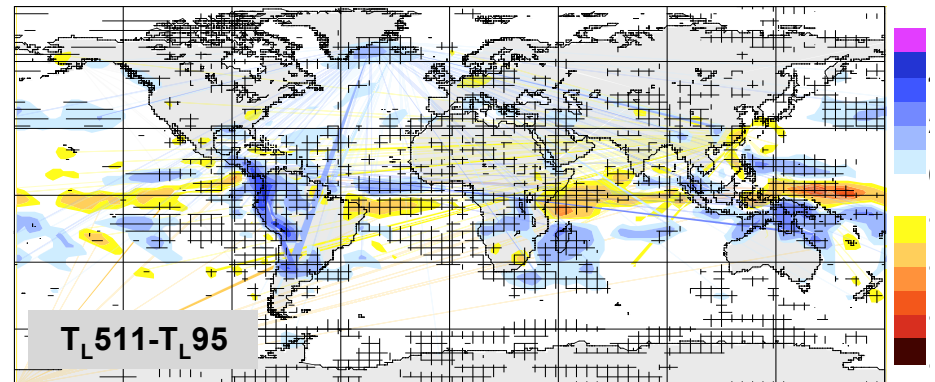
Mean Total Precipitation (DJFM)

GPCP

T_{L511} -GPCP

T_{L95} -GPCP

Total Precipitation eut3-eto4 (12-3 1990-2005)



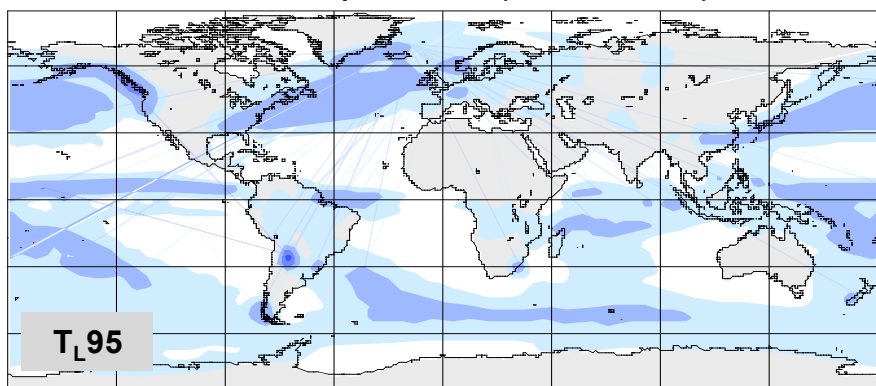


Large-Scale vs Convective Precipitation (DJFM)

Large-Scale Precipitation

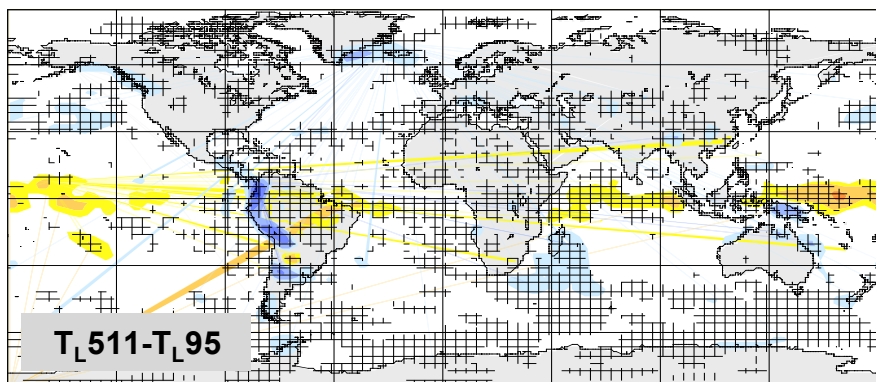
Convective Precipitation

Stratiform Precipitation eto4 (12-3 1990-2005)



T_{L95}

Stratiform Precipitation eut3-eto4 (12-3 1990-2005)

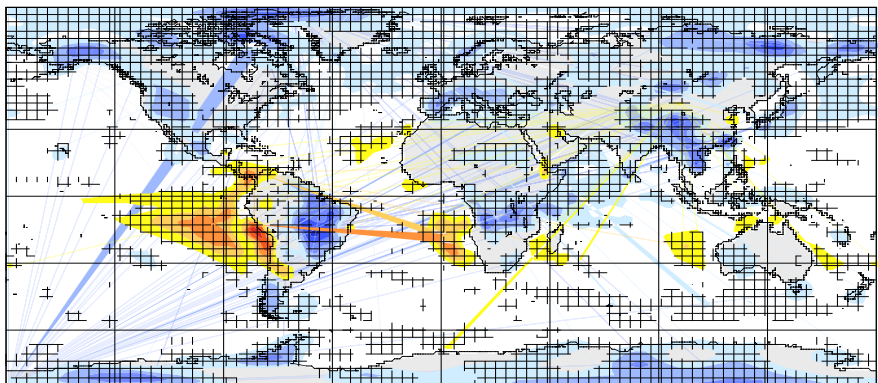


$T_{L511}-T_{L95}$

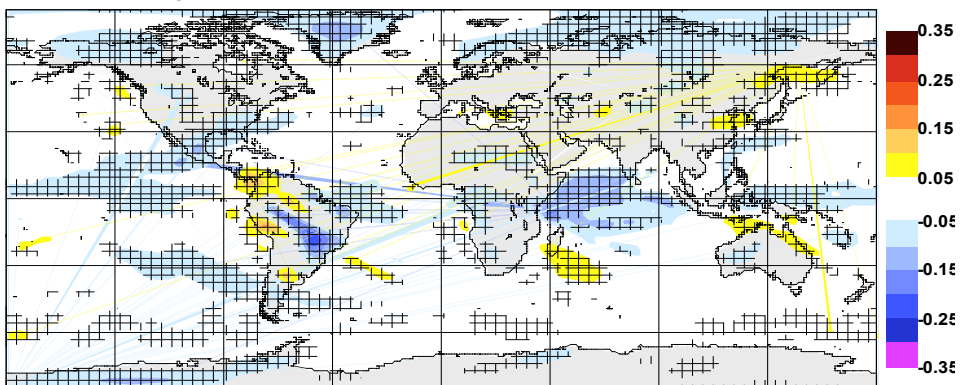


Resolution and Cloud Cover: T_L511-T_L95 (DJFM)

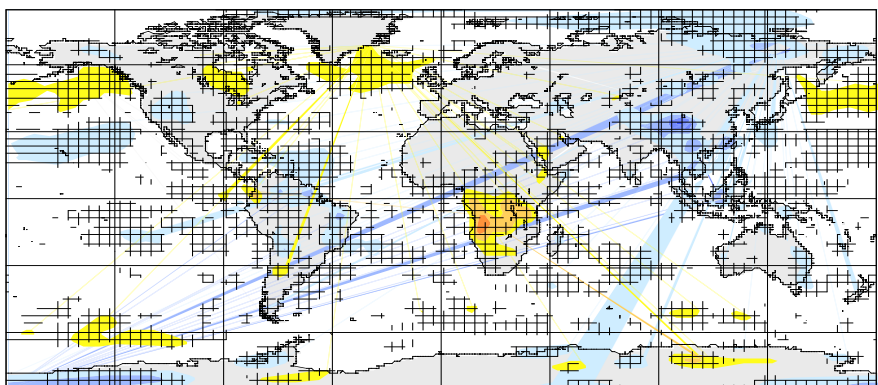
Total Cloud Cover



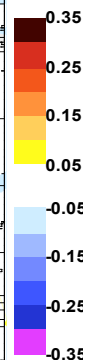
Low Cloud Cover



Medium Cloud Cover

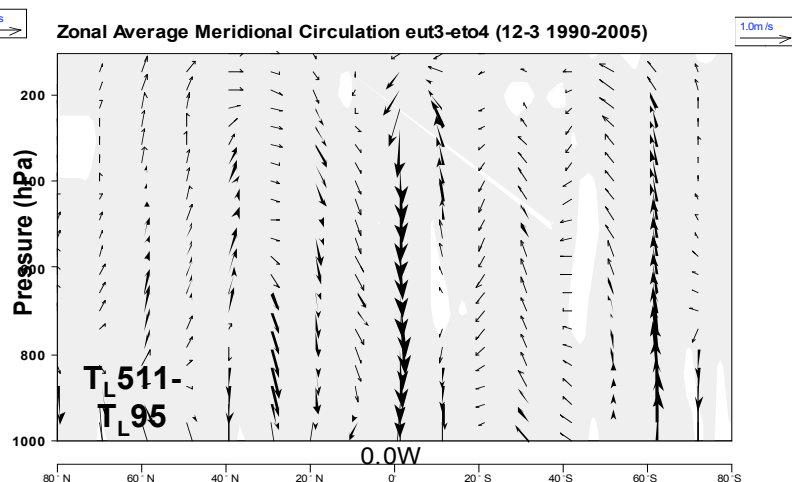
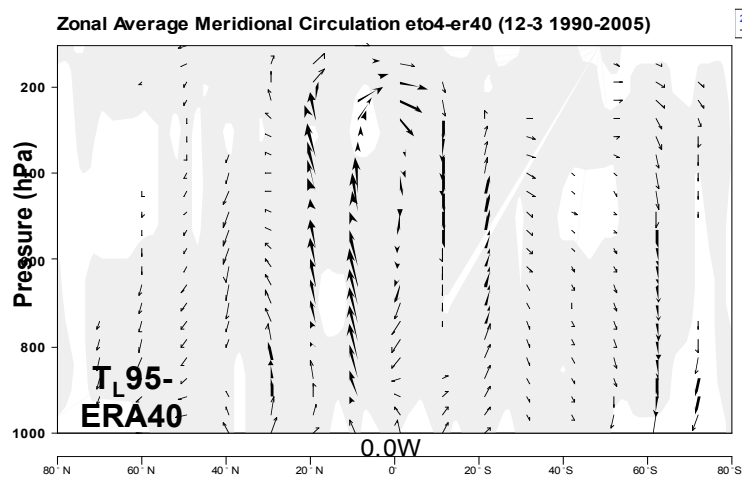
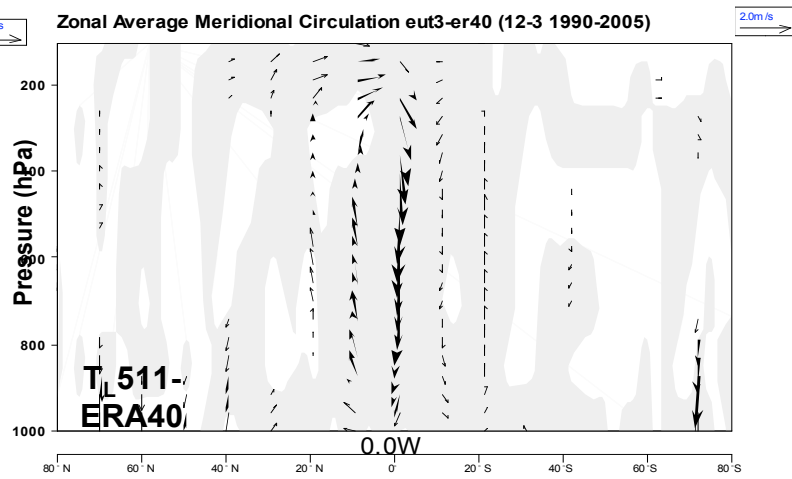
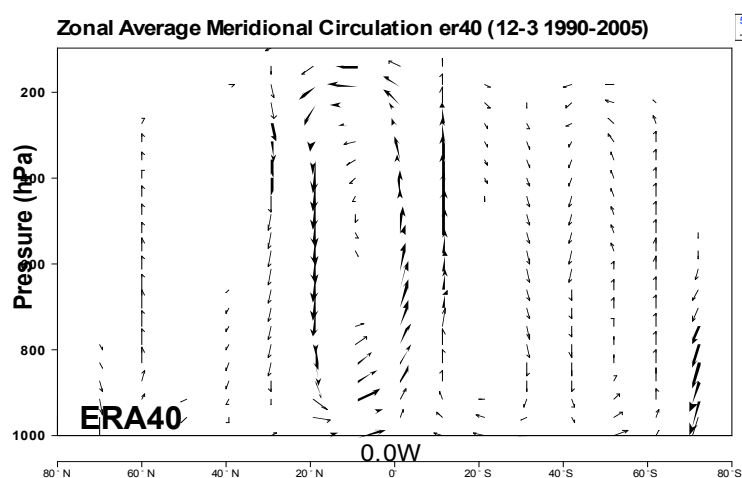


High Cloud Cover





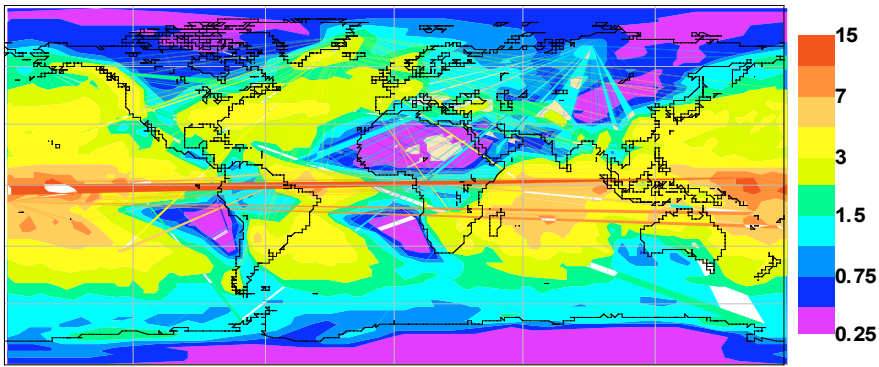
Zonal Mean Meridional Circulation (DJFM)



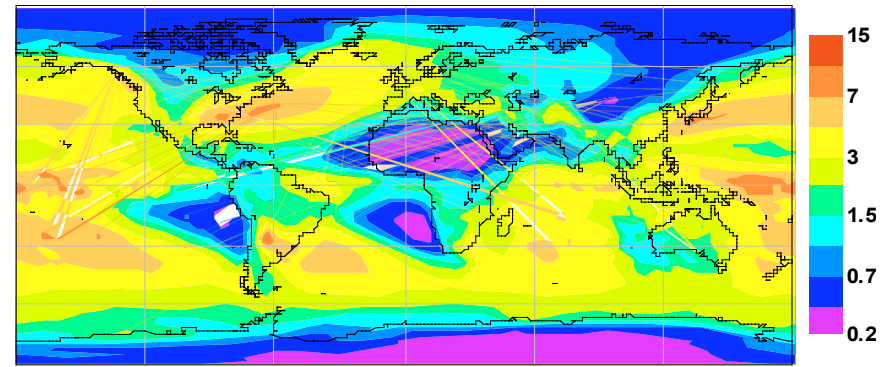


Variability of Precipitation (DJFM)

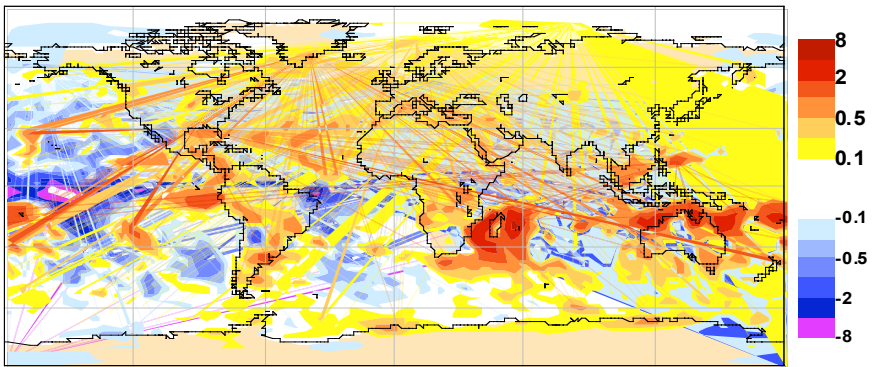
Lowpass-Filtered T_{L95}



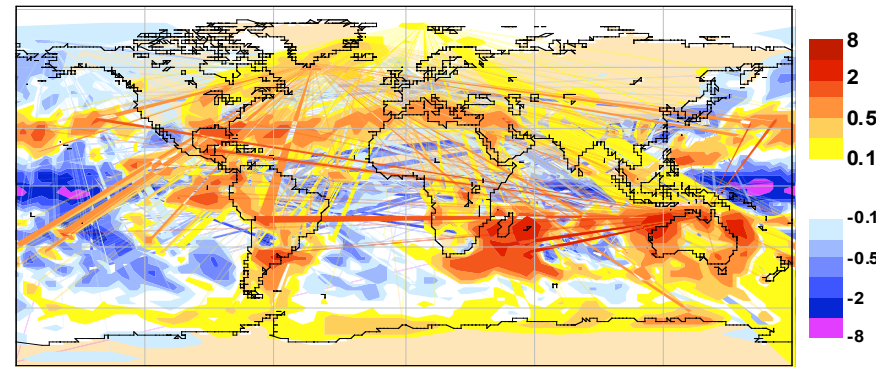
Highpass-Filtered T_{L95}



Lowpass-Filtered $T_{L511}-T_{L95}$



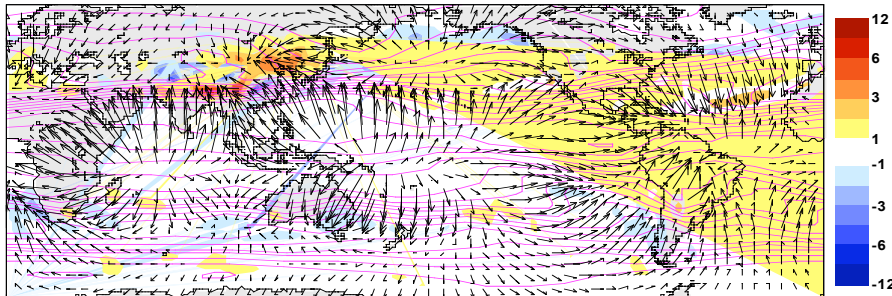
Highpass-Filtered $T_{L511}-T_{L95}$



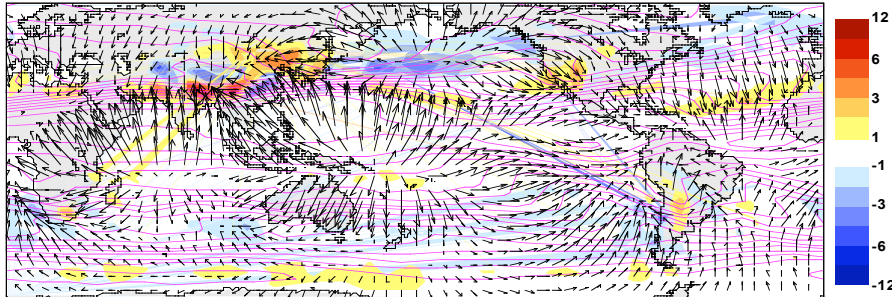


Tropical-Extratropical Interactions (DJFM)

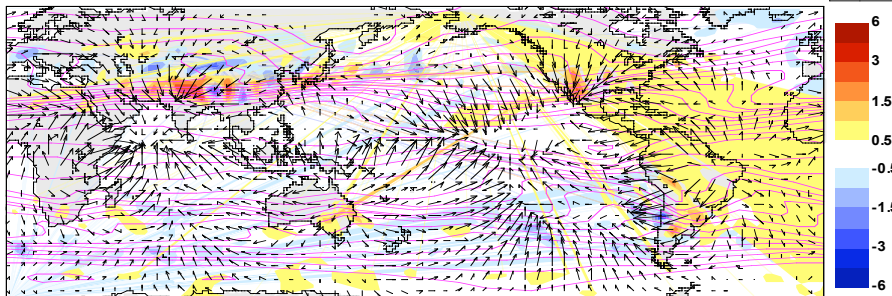
eto4 200hPa divergent w ind, absolute vorticity (Cl:1.E-5 s-1) and Rossby w ave source (St:1.E-10 s-2)



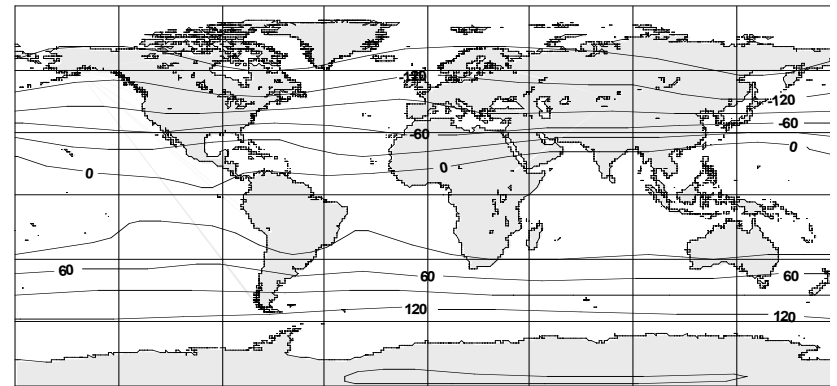
eut3 200hPa divergent w ind, absolute vorticity (Cl:1.E-5 s-1) and Rossby w ave source (St:1.E-10 s-2)



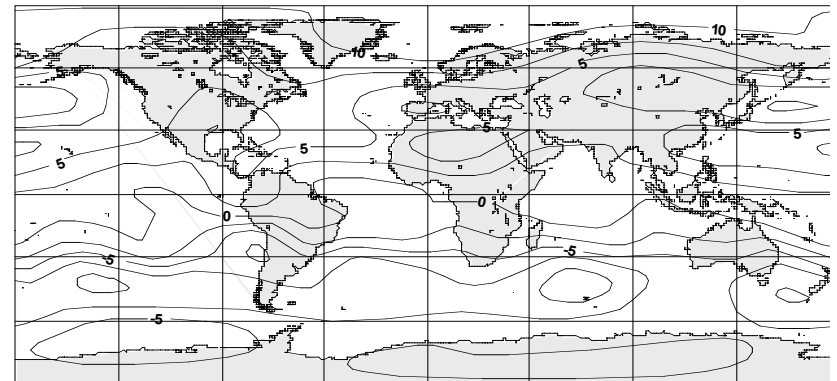
eut3-eto4 200hPa divergent w ind, absolute vorticity (Cl:1.E-5 s-1) and Rossby w ave source (St:1.E-10 s-2)



Streamfunction 200hPa eto4 (12-3 1990-2005)



Streamfunction 200hPa eut3-eto4 (12-3 1990-2005)



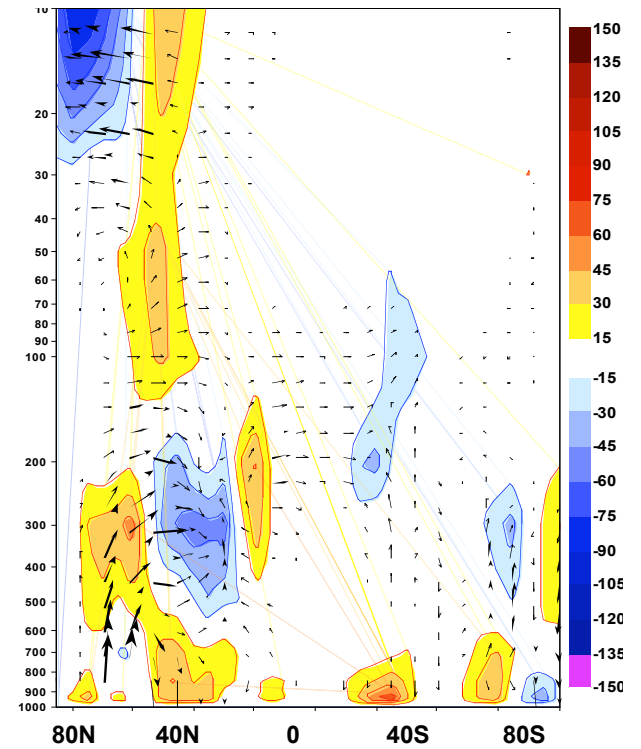
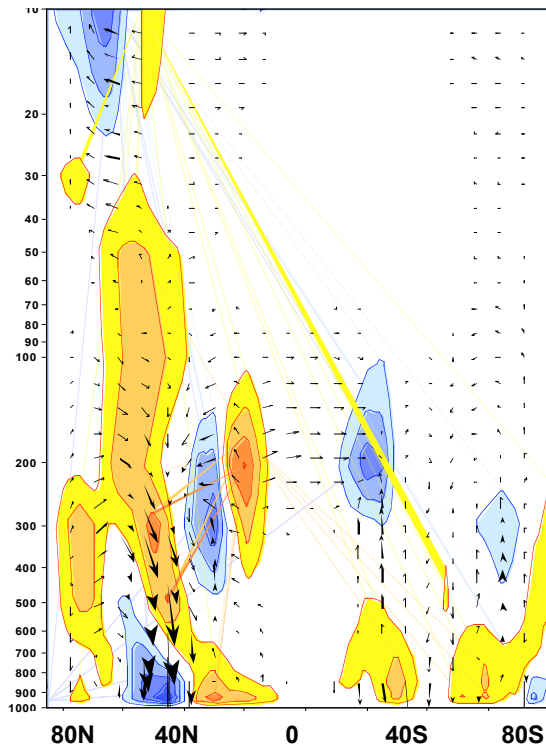
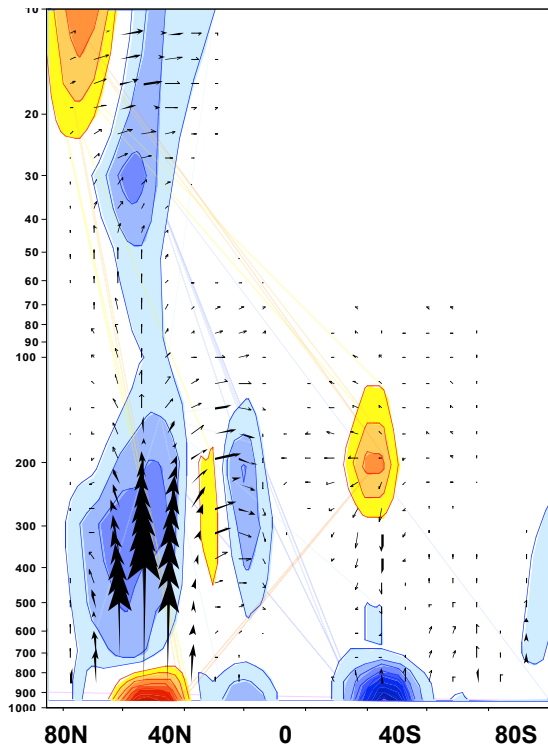


EP-Fluxes: Stationary Eddies (DJFM)

ERA40

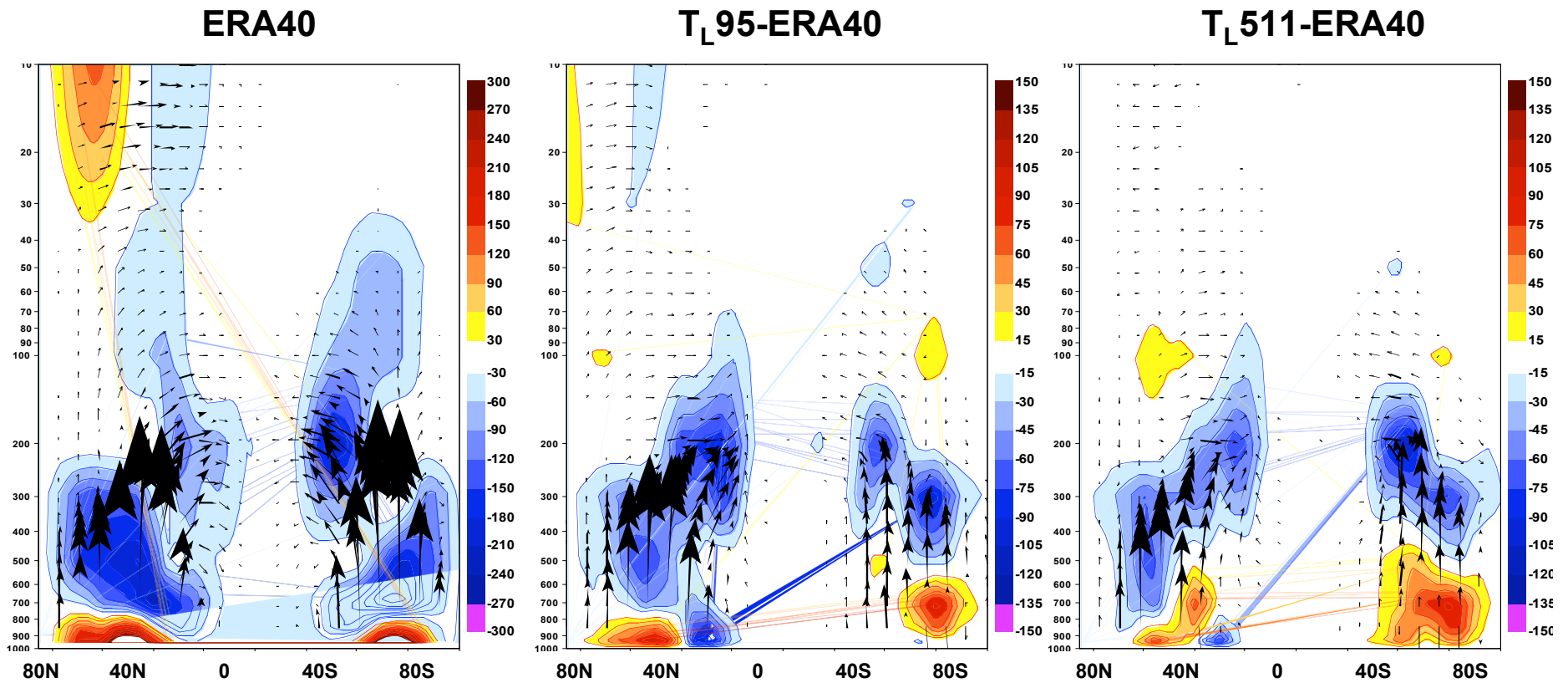
T_L95-ERA40

T_L511-ERA40



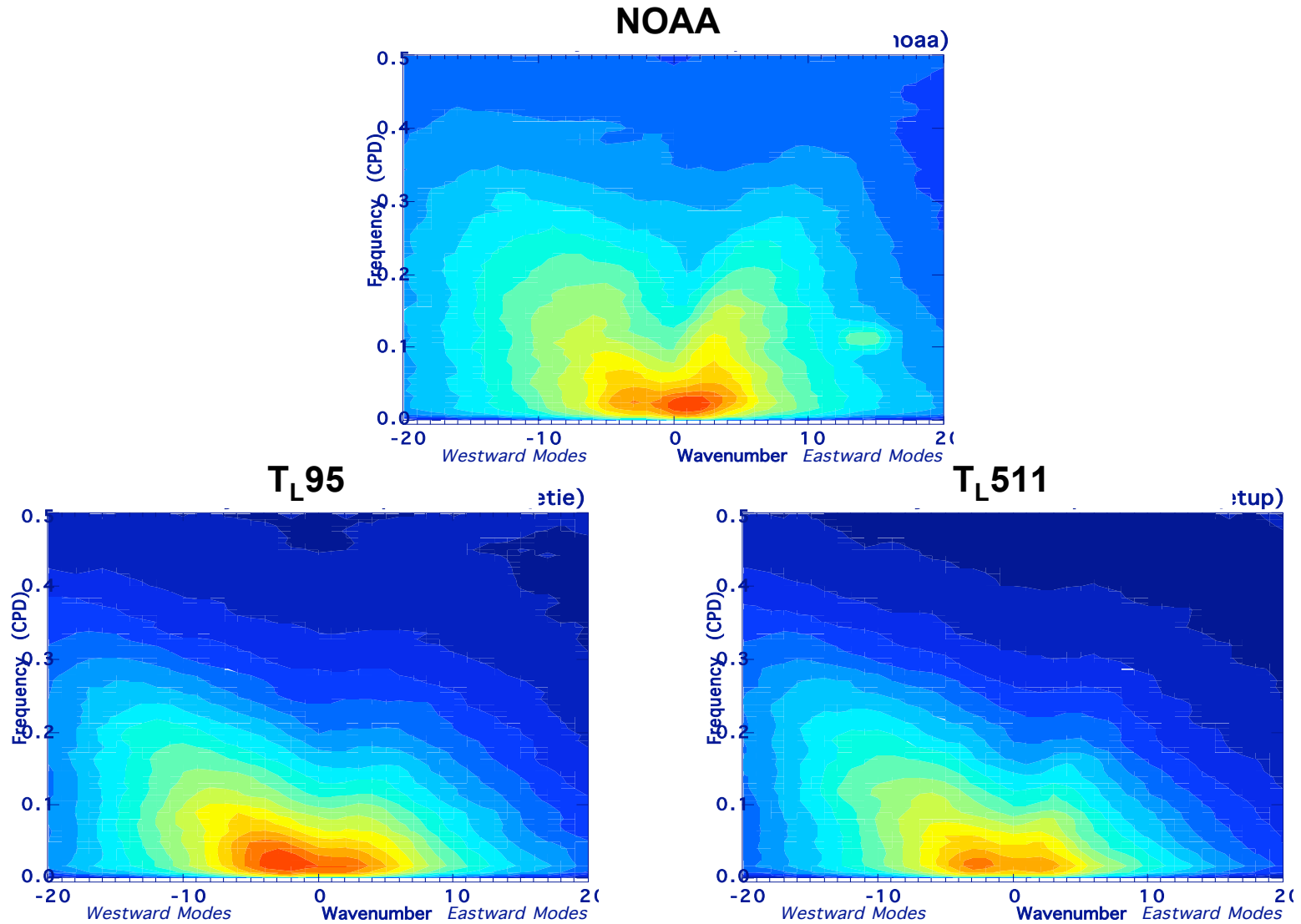


EP-Fluxes: Transient Eddies (DJFM)





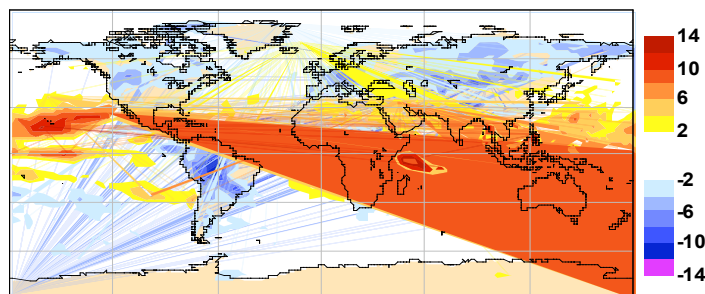
Convectively Coupled Tropical Waves: Symmetric OLR Anomalies (JJAS)



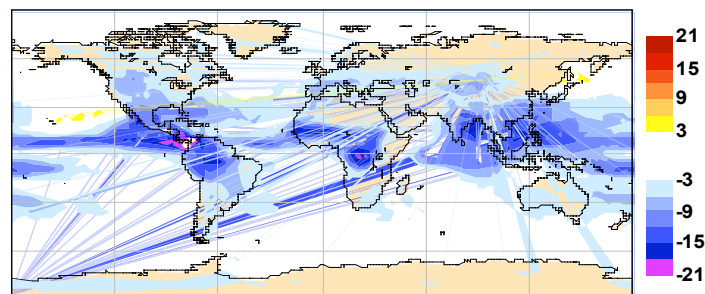


OLR Variability (JJAS)

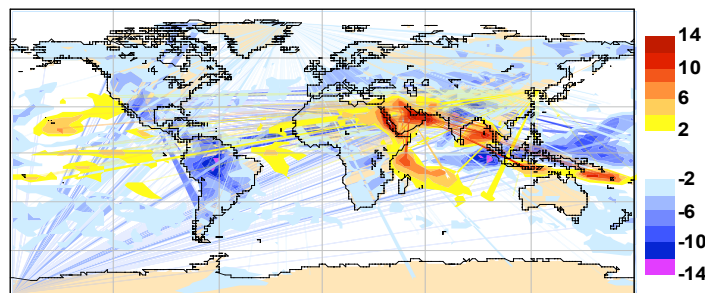
Lowpass: T_L95-NOAA



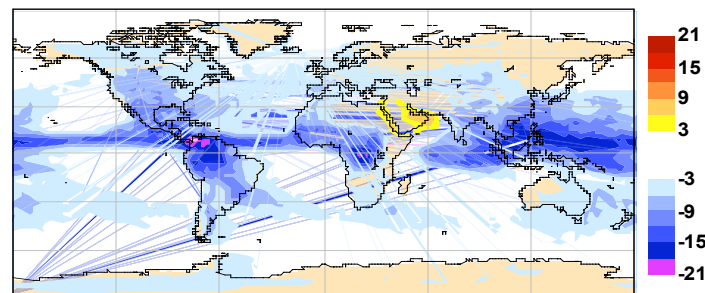
Highpass: T_L95-NOAA



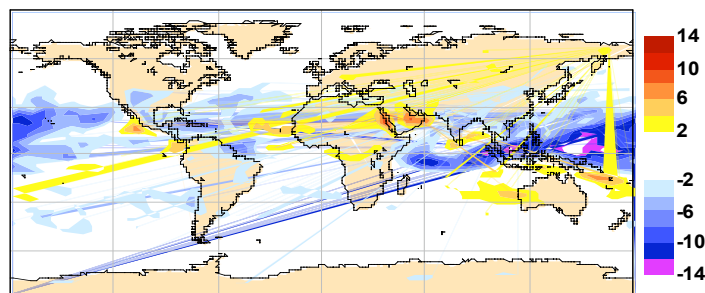
Lowpass: T_L511-NOAA



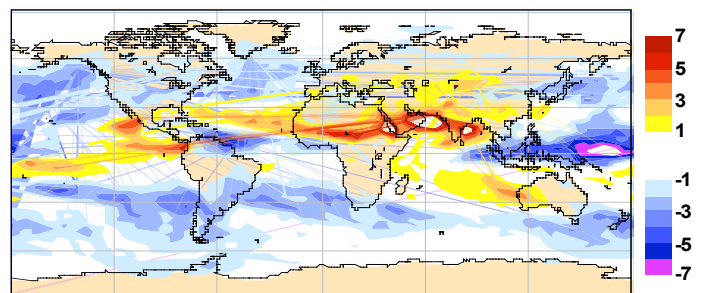
Highpass: T_L511-NOAA



Lowpass: T_L511-T_L95

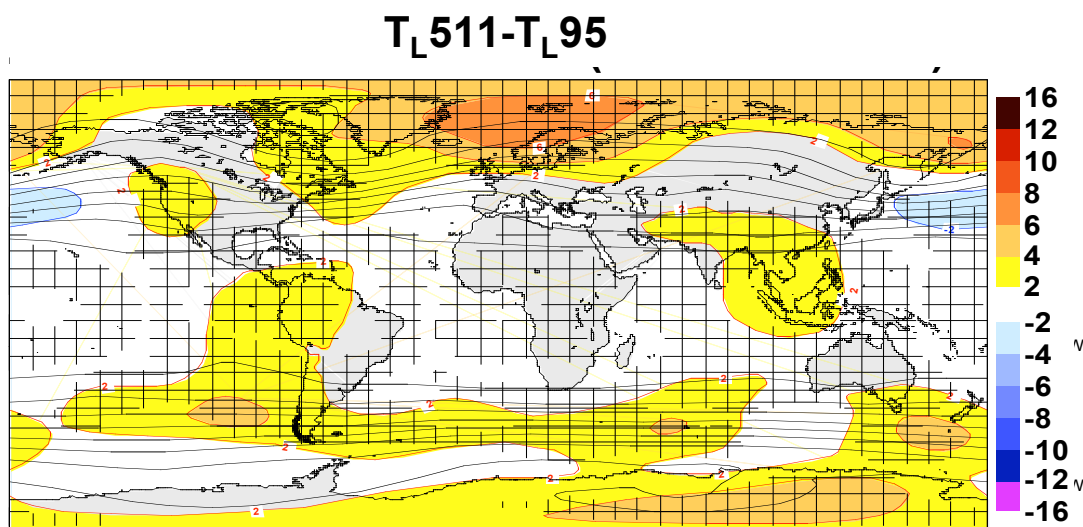


Highpass: T_L511-T_L95

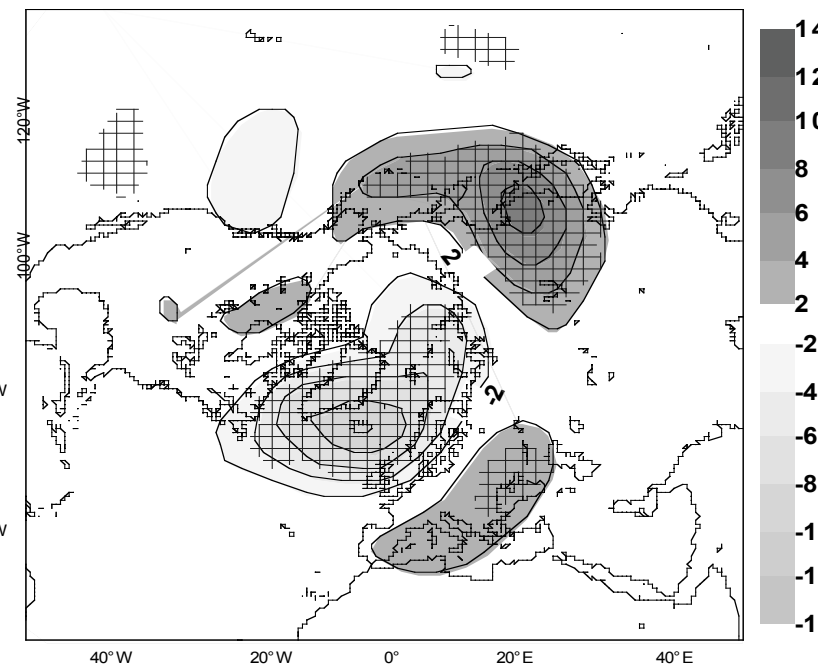




Mean Z500 Error (DJFM)



(d) Z500 Difference STRONG-CNTL D+31-D+40



Jung and Barkmeijer, MWR, 2006



"Observed" Tracks of Long-lived Cyclones (Winter)

ETC ECMWF Analysis (DJFM 05/06)

