Decadal Variability and Trend of Upper Troposphere Cloud Variabilities and Stratosphere Gravity Waves Derived from Two Decades of Aura-MLS and Aqua-AIRS Observations

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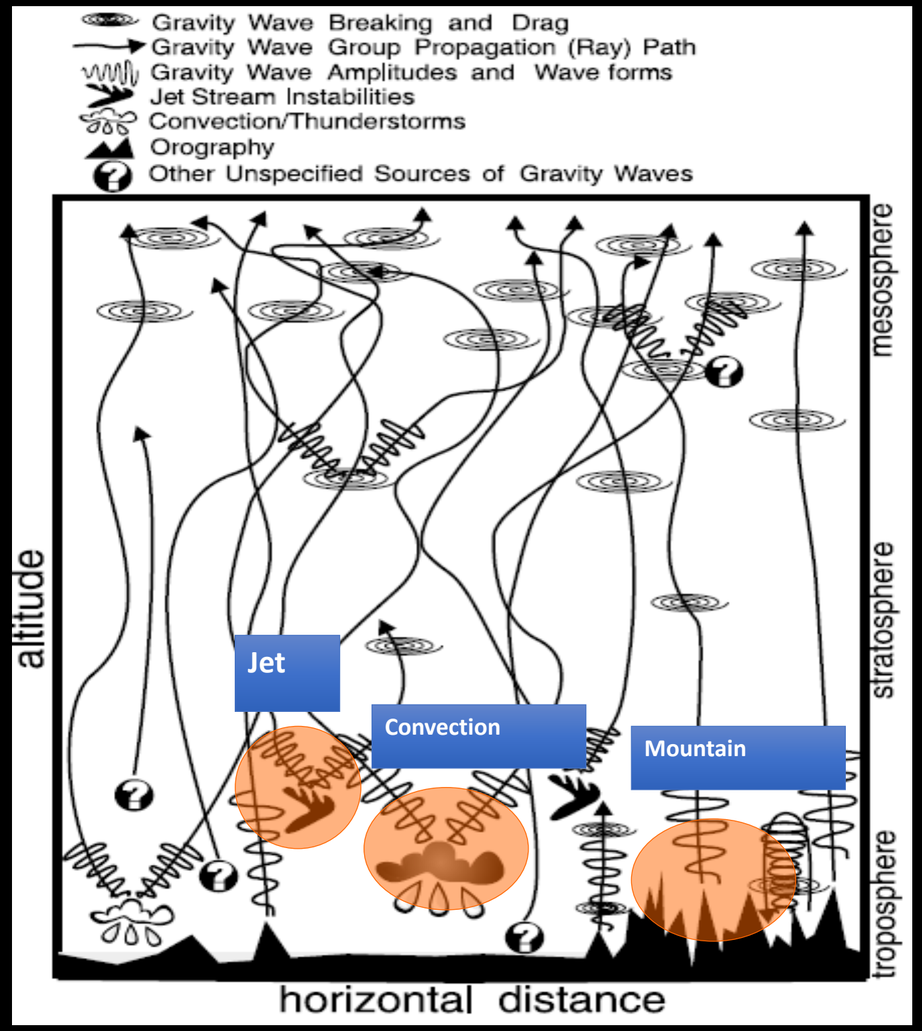
Why are atmospheric gravity waves (AGWs) important?

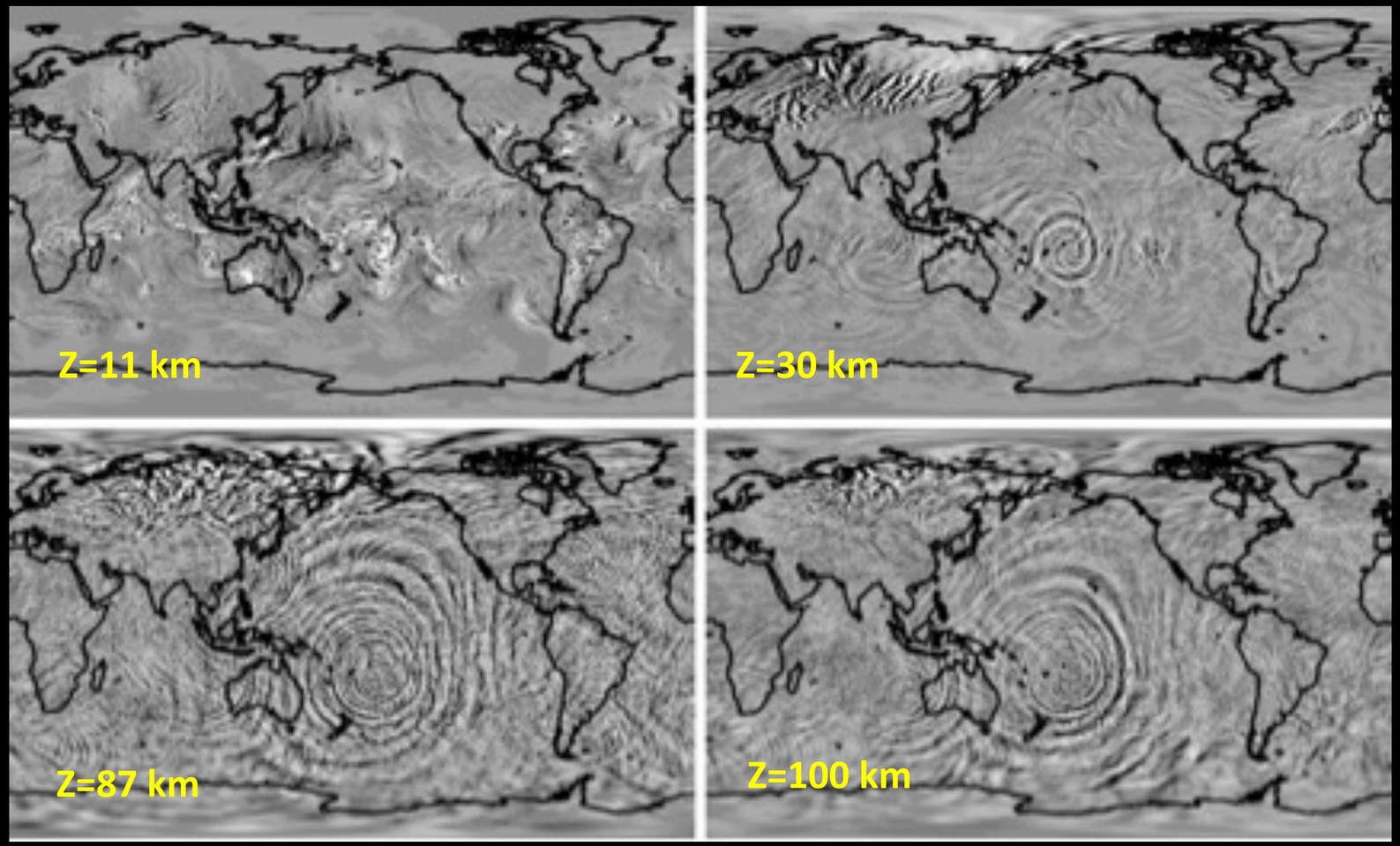
- Gravity waves (GWs) serve as a critical mechanism for lower-upper atmosphere coupling through the vertical propagation and breaking to deposit the momentum flux (MF)

- GWs play a vital role in shaping the mesosphere circulation



(Kim et al., 2003, Atm-Ocn.)

A hurricane impacts 100 km away from surface



A WACCM simulation illustrating how gravity waves kicked off by a cyclone building up into pan-global perturbation as they travel toward space (Liu et al., 2014, GRL).

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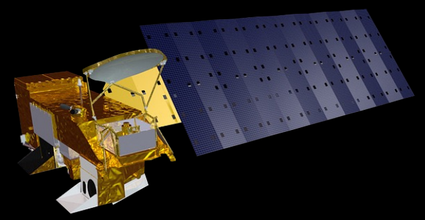
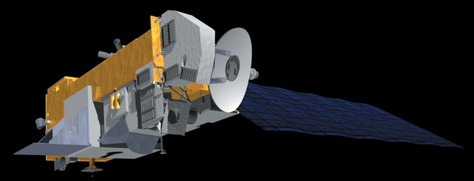
More than Two Decades of A-Train Measurements

Aqua AIRS (2002.08 - now)



Aura MLS (2004.01 - now)



- Global warming --> poleward shift of jets and enhancement of tropical convection
- Ozone recovery --> strengthening of stratosphere polar-night jet

- Can we see any GW fingerprints of response?
- Are these two satellite records good enough for GW trend study?

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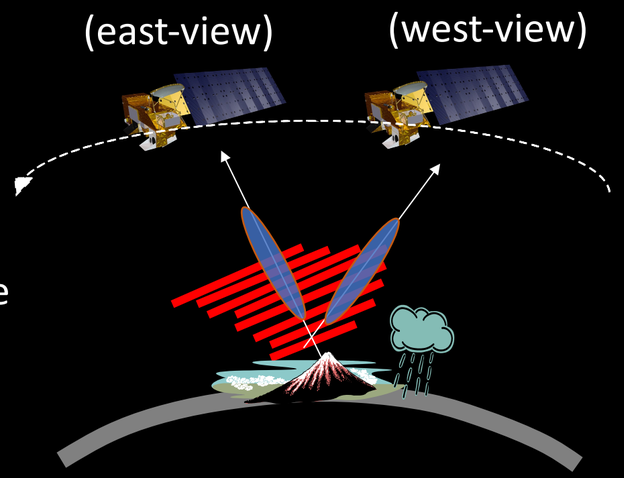
GW amplitudes derived from perturbation of L1 radiance measurements

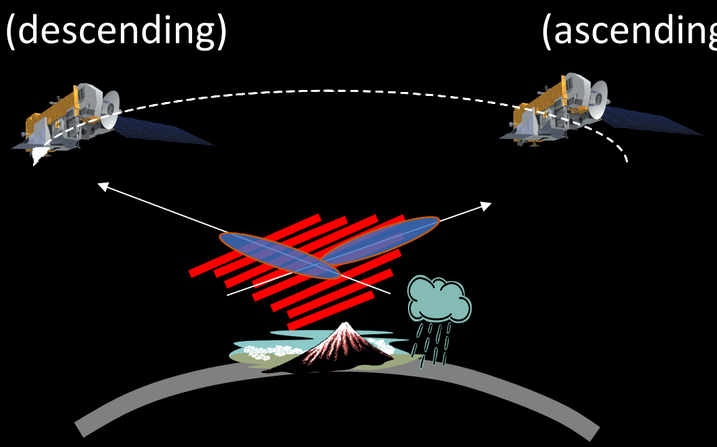


More sensitive to vertically propagating deep GWs

AIRS (nadir or slant path)

$$\sigma_{GW}^2 = \sigma_{rad}^2 - \sigma_{noise}^2$$
$$= \sigma_{13}^2 - \sigma_3^2$$

$$MF_{zonal} \propto \sigma_{GW_{west}}^2 - \sigma_{GW_{east}}^2$$



More sensitive to slantwise propagating shallow GWs

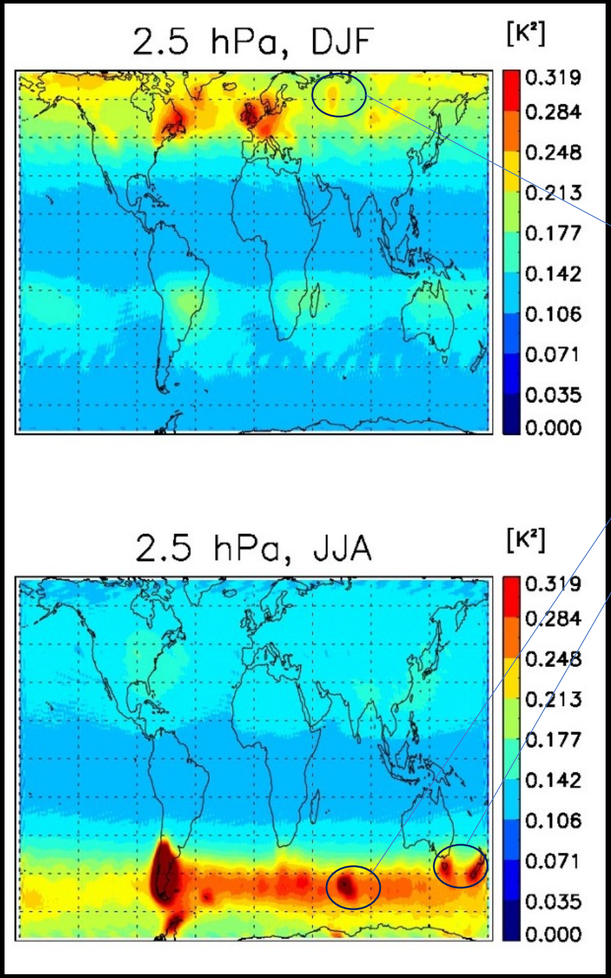
MLS (limb with opaque path)

$$\sigma_{GW}^2 = \sigma_{rad}^2 - \sigma_{noise}^2$$
$$= \sigma_{40}^2 - \sigma_5^2$$

$$MF_{zonal} \propto \sigma_{GW_{asc}}^2 - \sigma_{GW_{des}}^2$$

Gravity Wave Amplitude Climatology

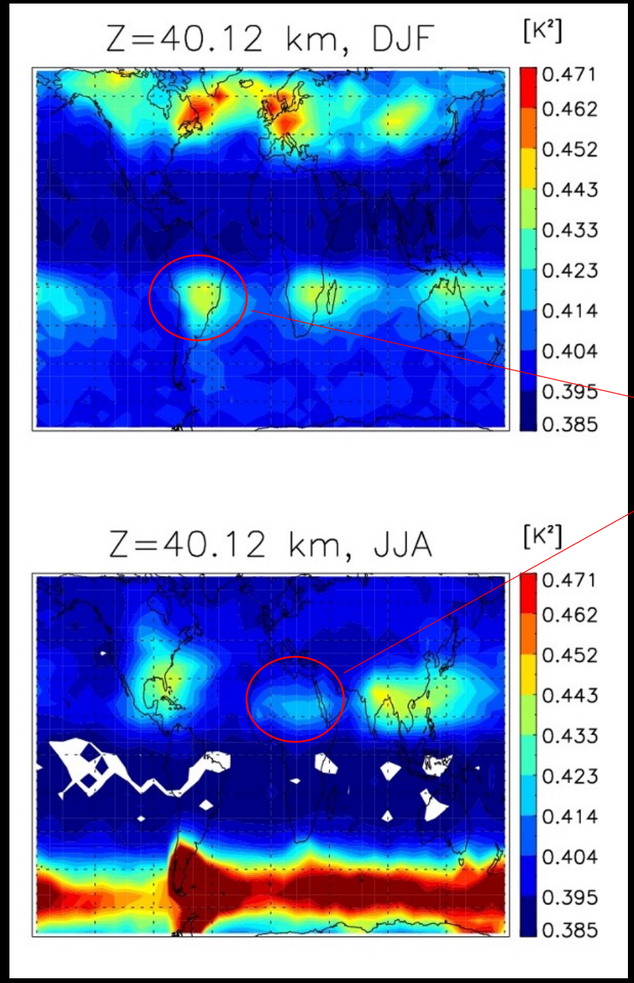
AIRS



(Gong, Wu and Eckermann, 2012)

GW hotspots from islands and small mountain ranges

MLS

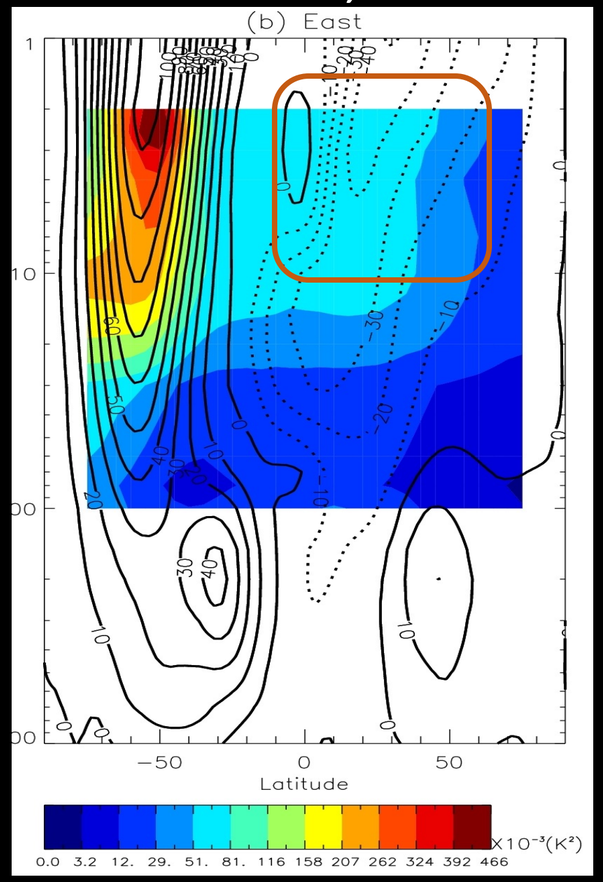


(Wu and Eckermann, 2008)

Convective GW more pronounced

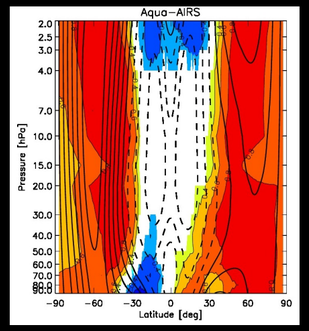
Gravity Wave Momentum Flux Climatology

AIRS, JJA

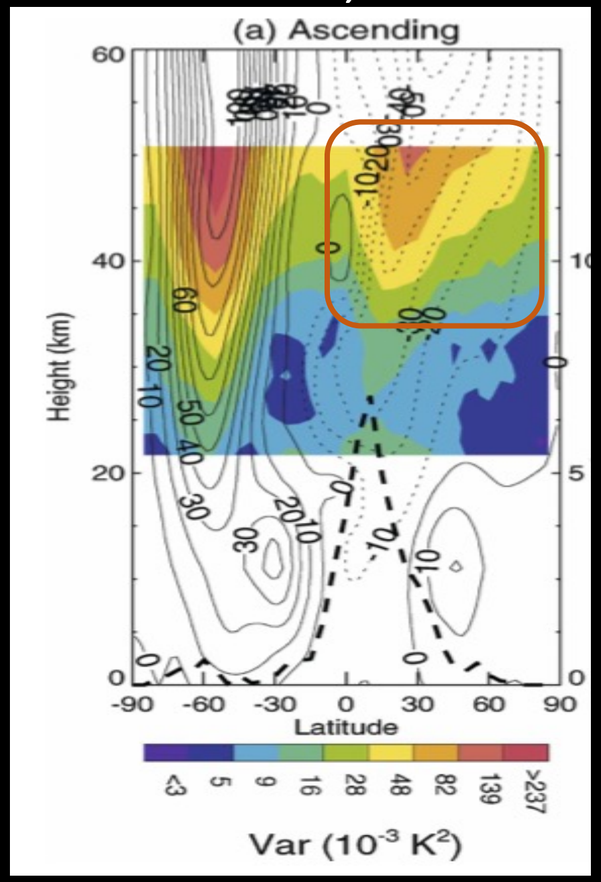


(Gong et al., 2012)

AIRS GW Correlation with Zonal wind

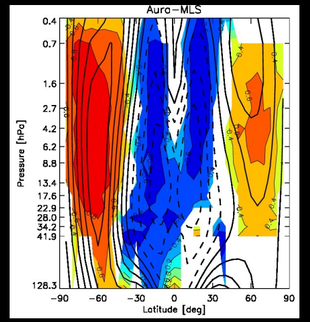


MLS, JJA



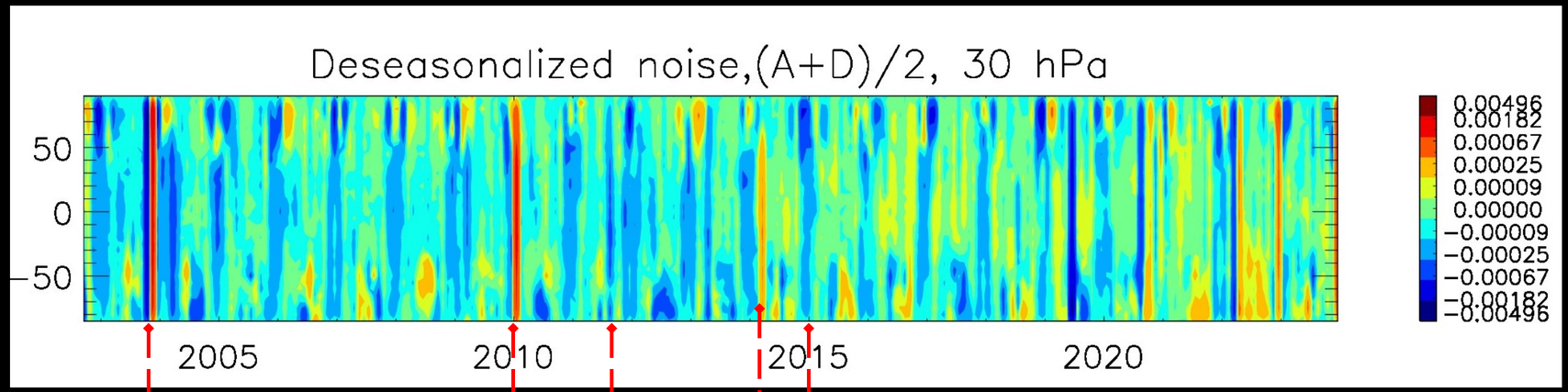
(Wu and Eckermann, 2008)

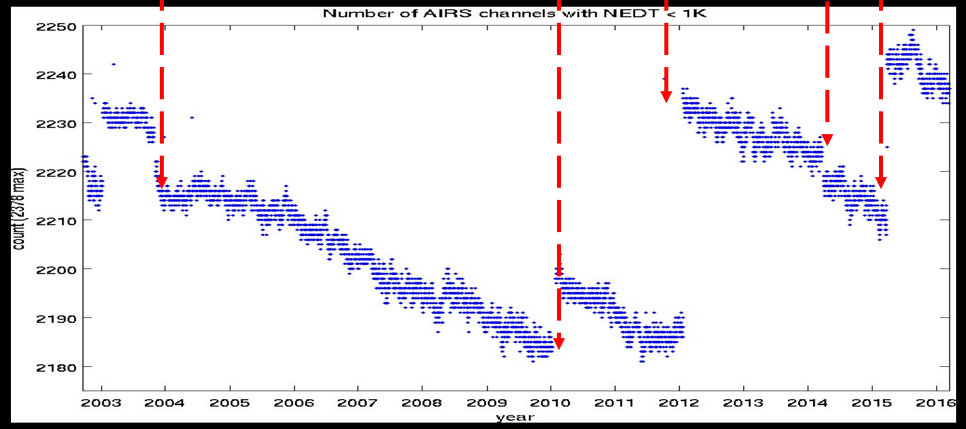
MLS GW Correlation with Zonal wind



σ^2_{noise} timeseries: instrument anomalies and degradation

Aqua-AIRS (deseasonalized)



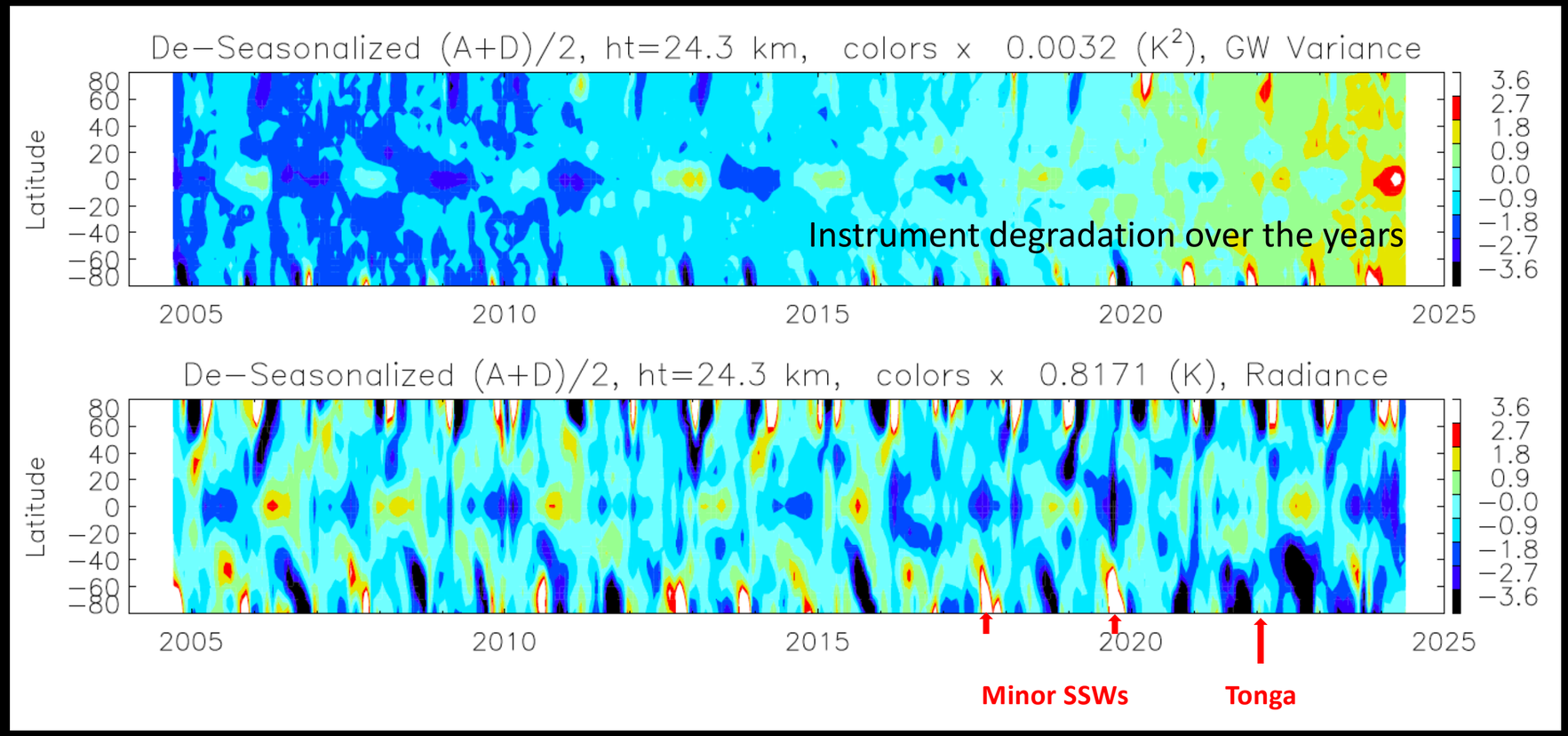


Instrument slight degradation over the years

Major instrument recalibration events
(Credit: Denis Elliott)

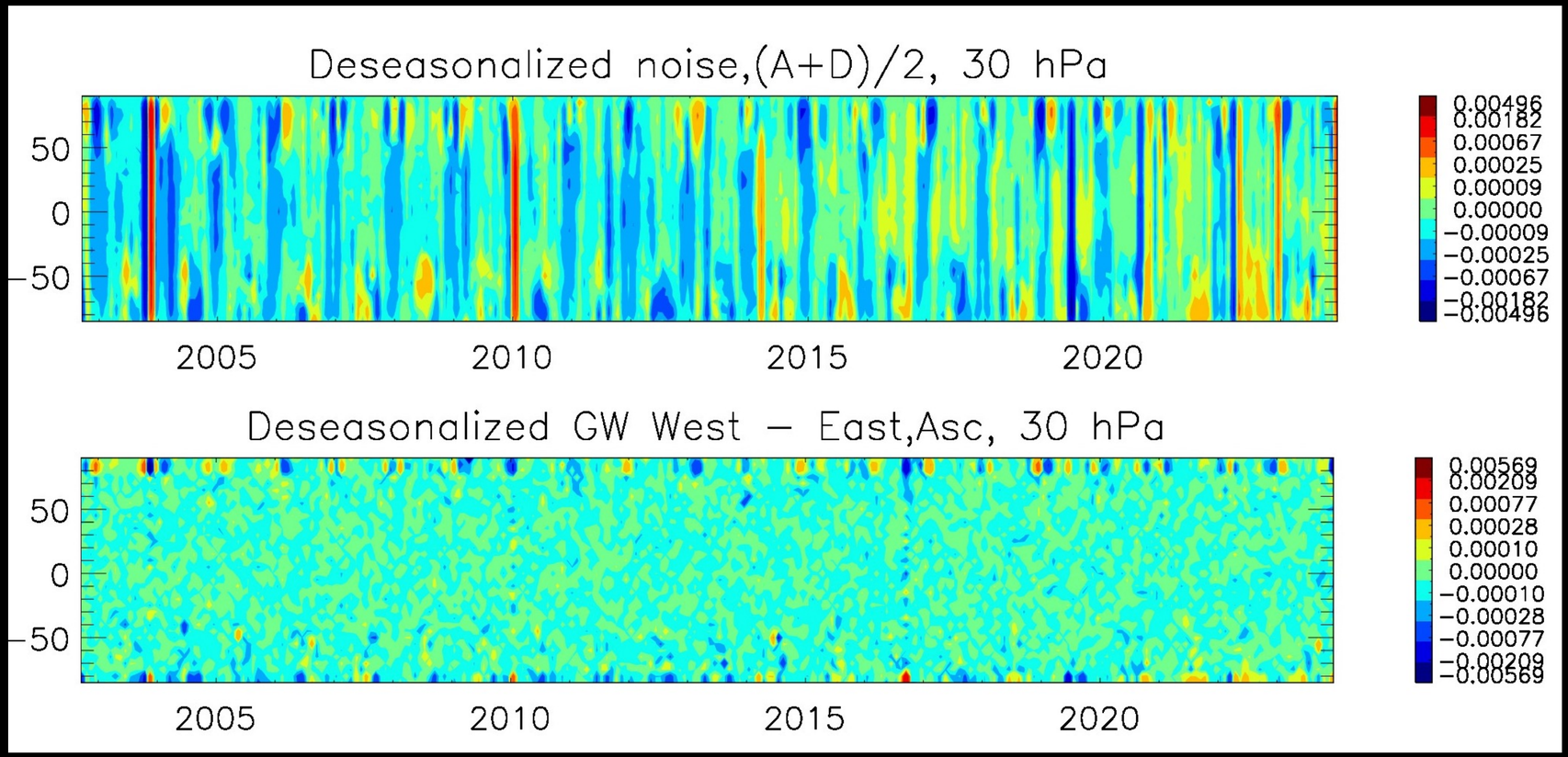
σ^2_{noise} timeseries: instrument anomalies and degradation

Aura-MLS (de-seasonalized)

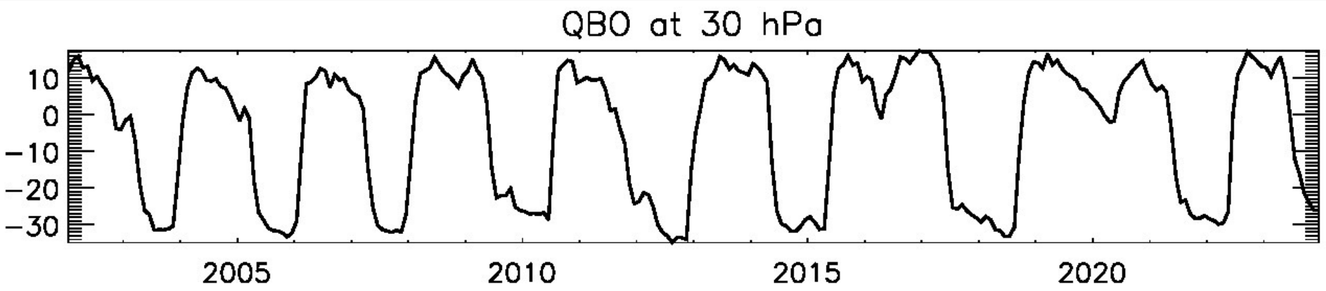


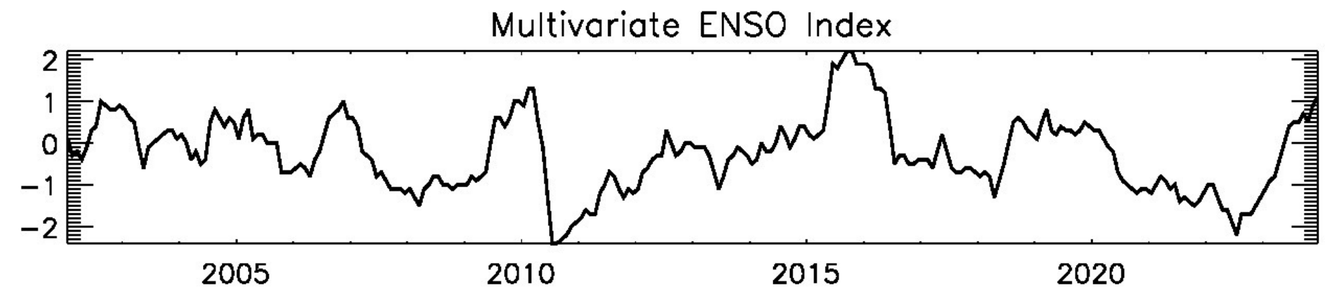
σ^2_{diff} timeseries: Effective way to remove the jumps and degradation effect

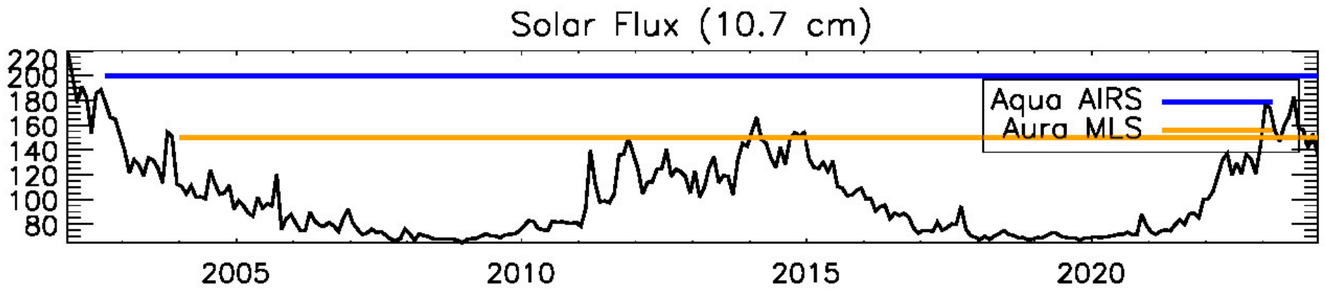
Aqua-AIRS (deseasonalized)



Major Interannual Variabilities Impacting the Stratosphere







$$GW(t) = a_1 * QBO + a_2 * ENSO + a_3 * Solar + a_4 * t$$

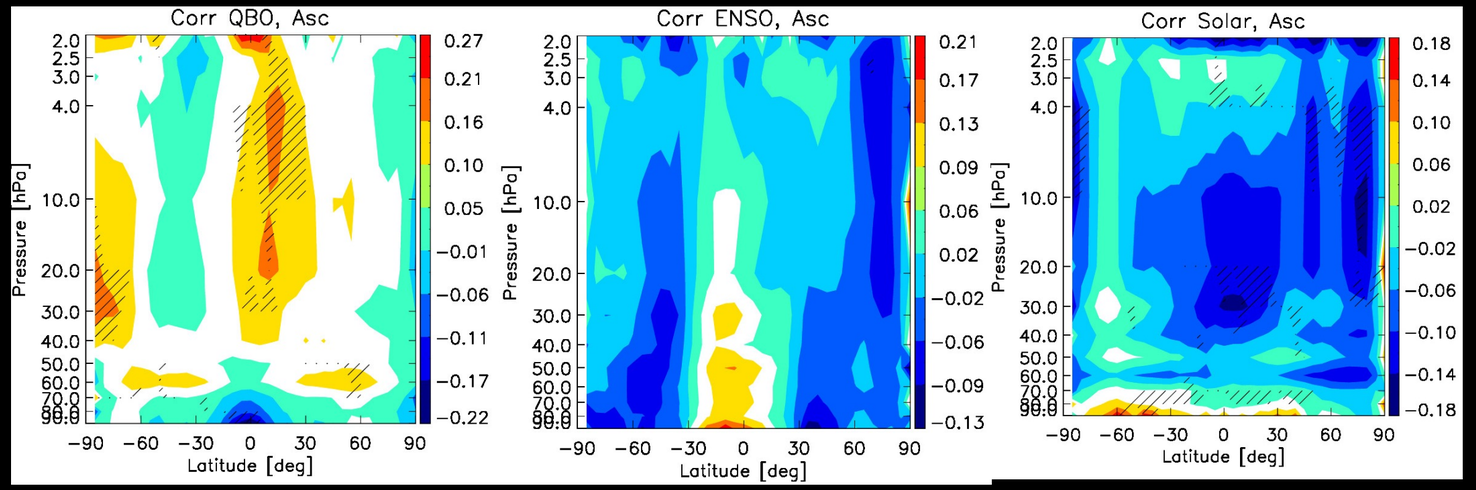
Interannual Variabilities

QBO

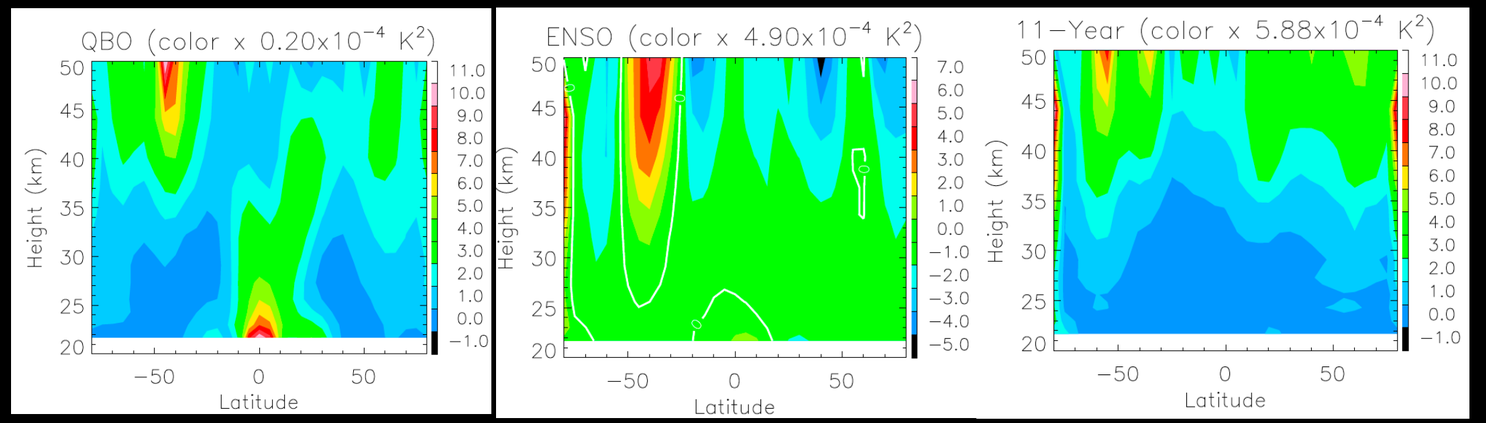
ENSO

Solar

AIRS

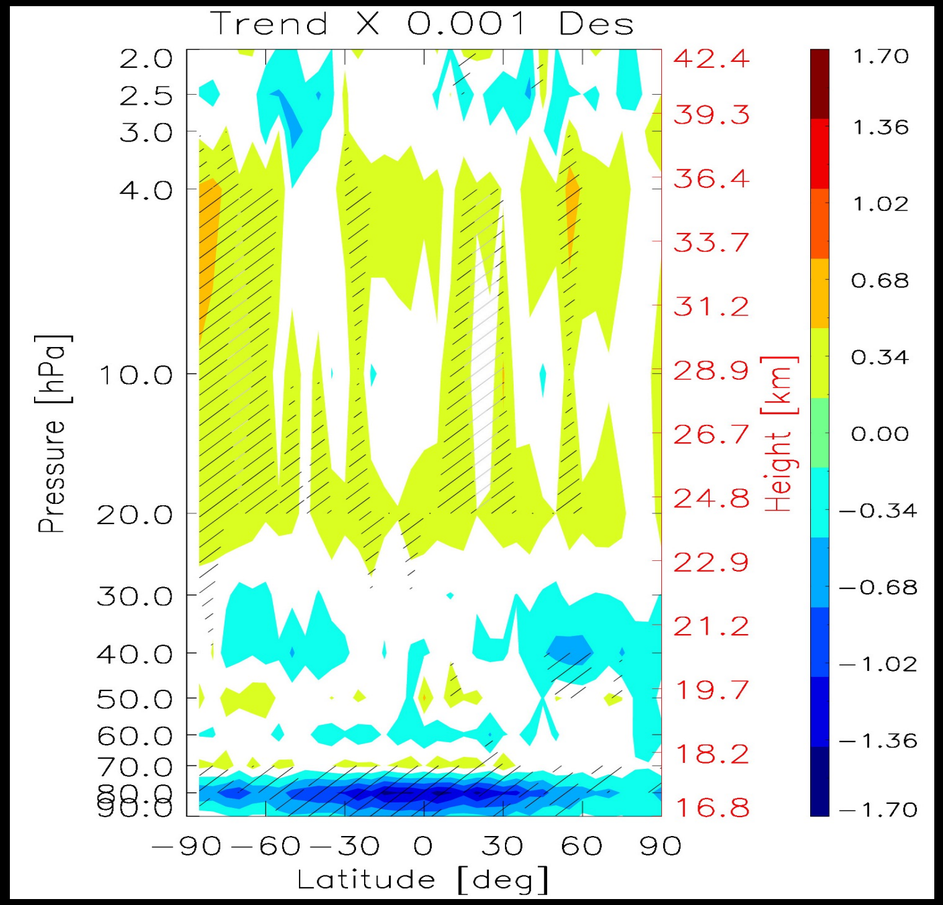


MLS



Decadal Trend

AIRS



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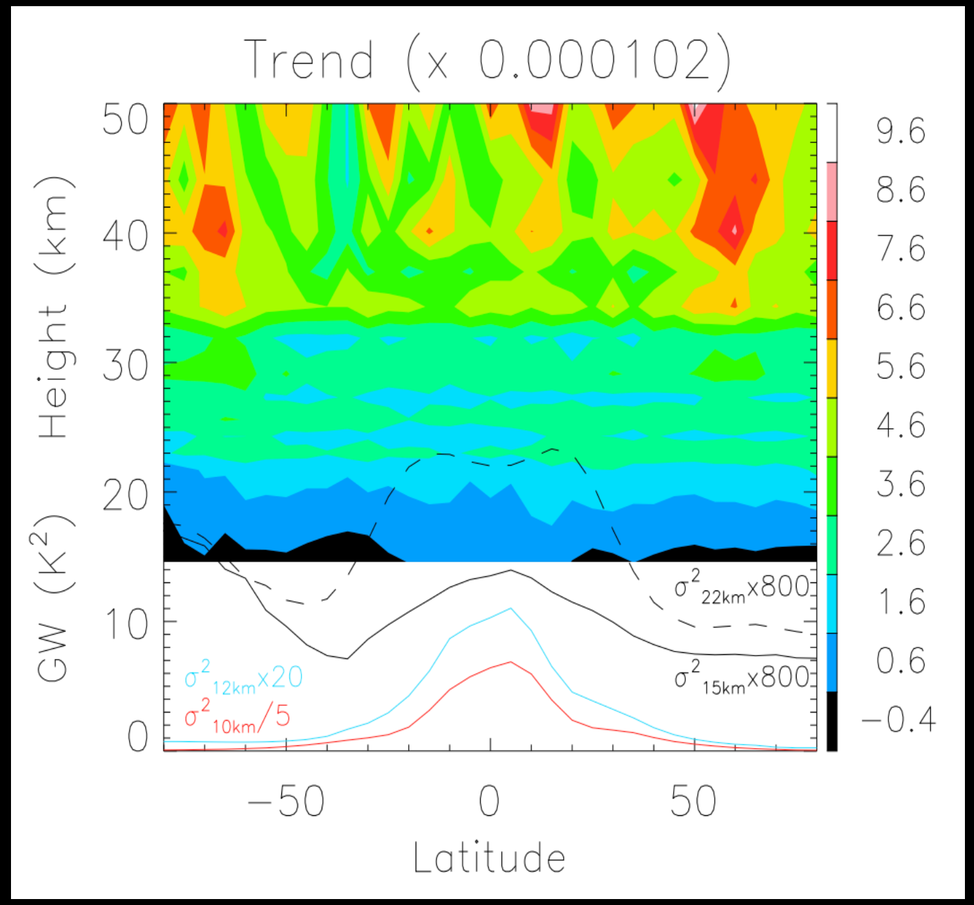
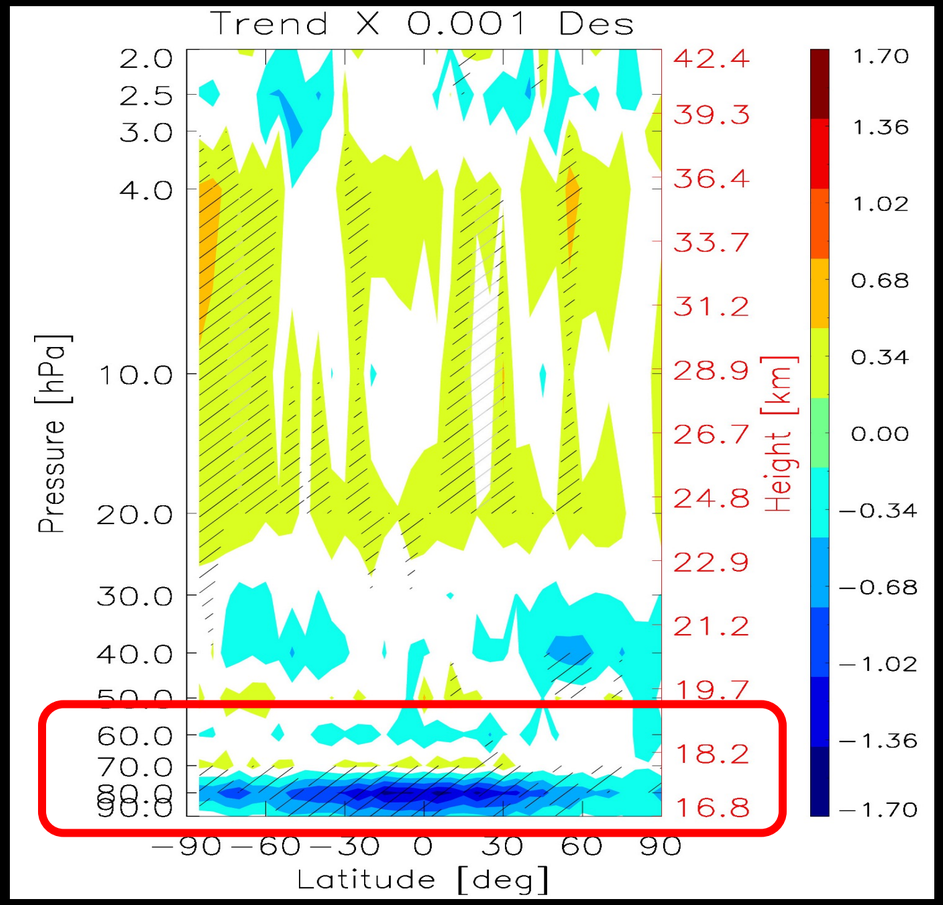


Lower Stratosphere Cloud Perturbation Negative Trend

AIRS



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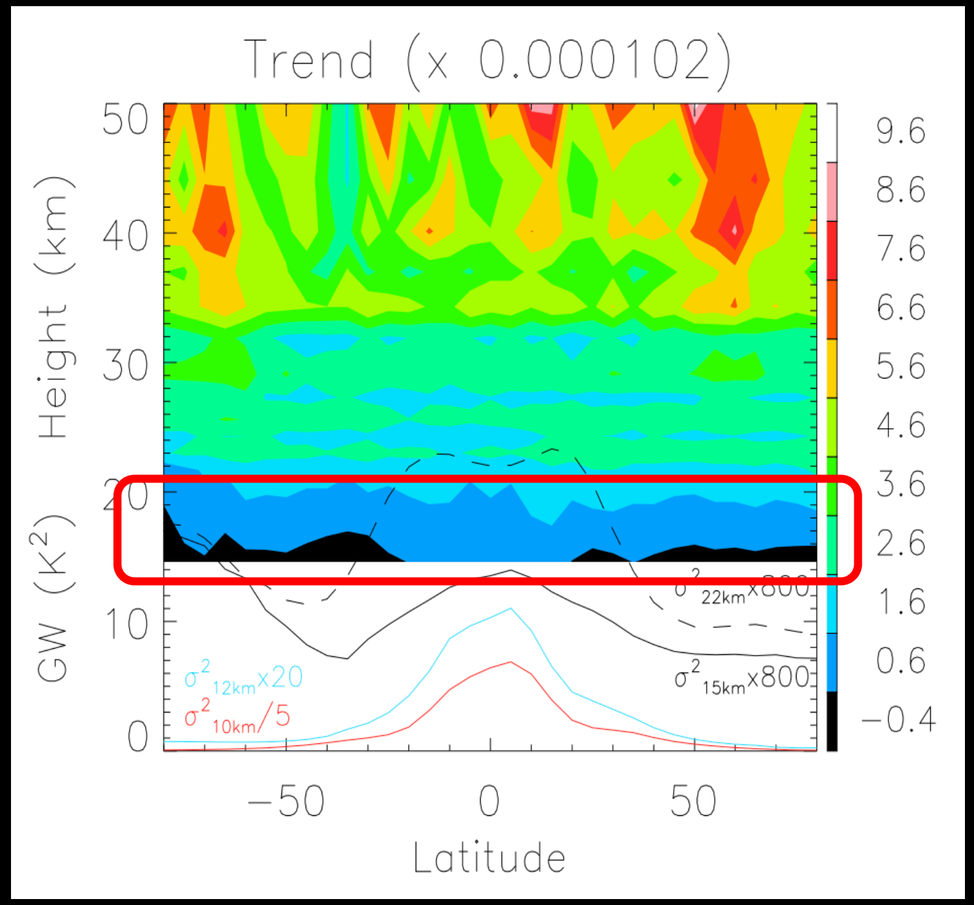
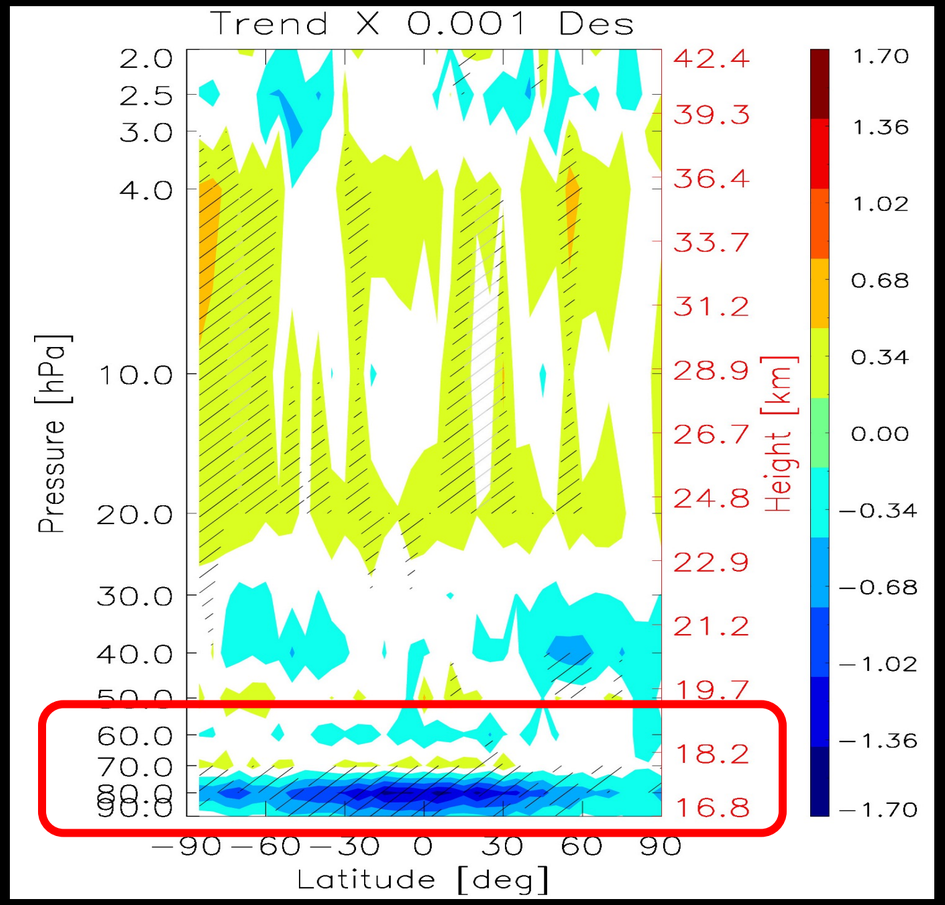


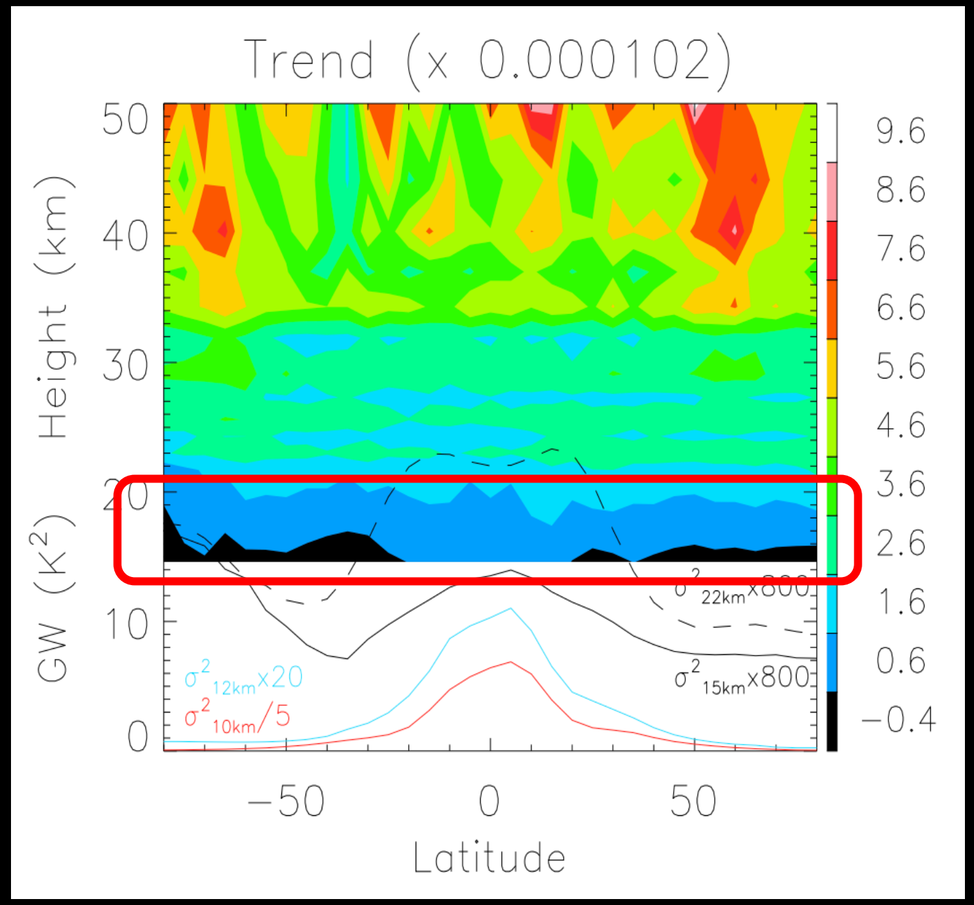
Conclusion #1: cloud variability near tropopause decreasing → more large-scale convections?

Upper Stratosphere Positive GW Trend

AIRS



MLS



Conclusion #2: GW variability in upper stratosphere increases, especially at polar regions → ozone recovery induced stronger polar-night jet?

Conclusions

- Aqua-AIRS and Aura-MLS had flown for 22+ and 20+ years and had started to drift orbit and entering their final stages. Now it's the time to study various trends.
- Atmospheric gravity waves (GWs) are small-scale perturbations that can be revealed from radiance (or brightness temperature) perturbations in satellite imageries if the satellite noise is small. Because of excellent instrument performance and superb calibration, AIRS and MLS are widely used for studying and monitoring GWs in the community.
- Due to instrument operation change and degradation over the years, it's easy to get artificial positive trends for GWs if these instrument effects are not carefully removed.
- After removing the instrument effects, and removing the variabilities associated with interannual forcings (QBO, ENSO and Solar), we derive negative trends near the tropopause (dominated by cloud variabilities) and positive trends in the upper stratosphere in both AIRS and MLS measurements.
- The causes of the trends need to be further investigated.