Multiple Drivers of Arctic Amplification

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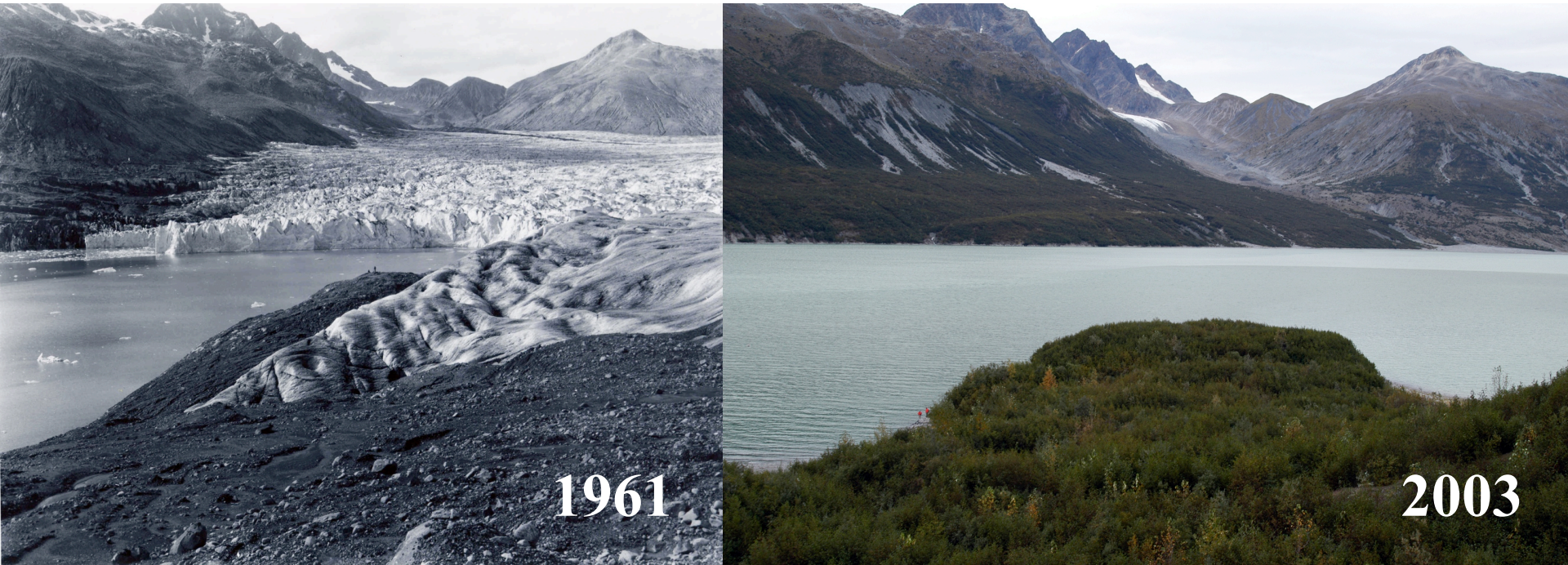


Outline

Arctic Amplification: definition & time scales

AA spatial pattern, seasonality

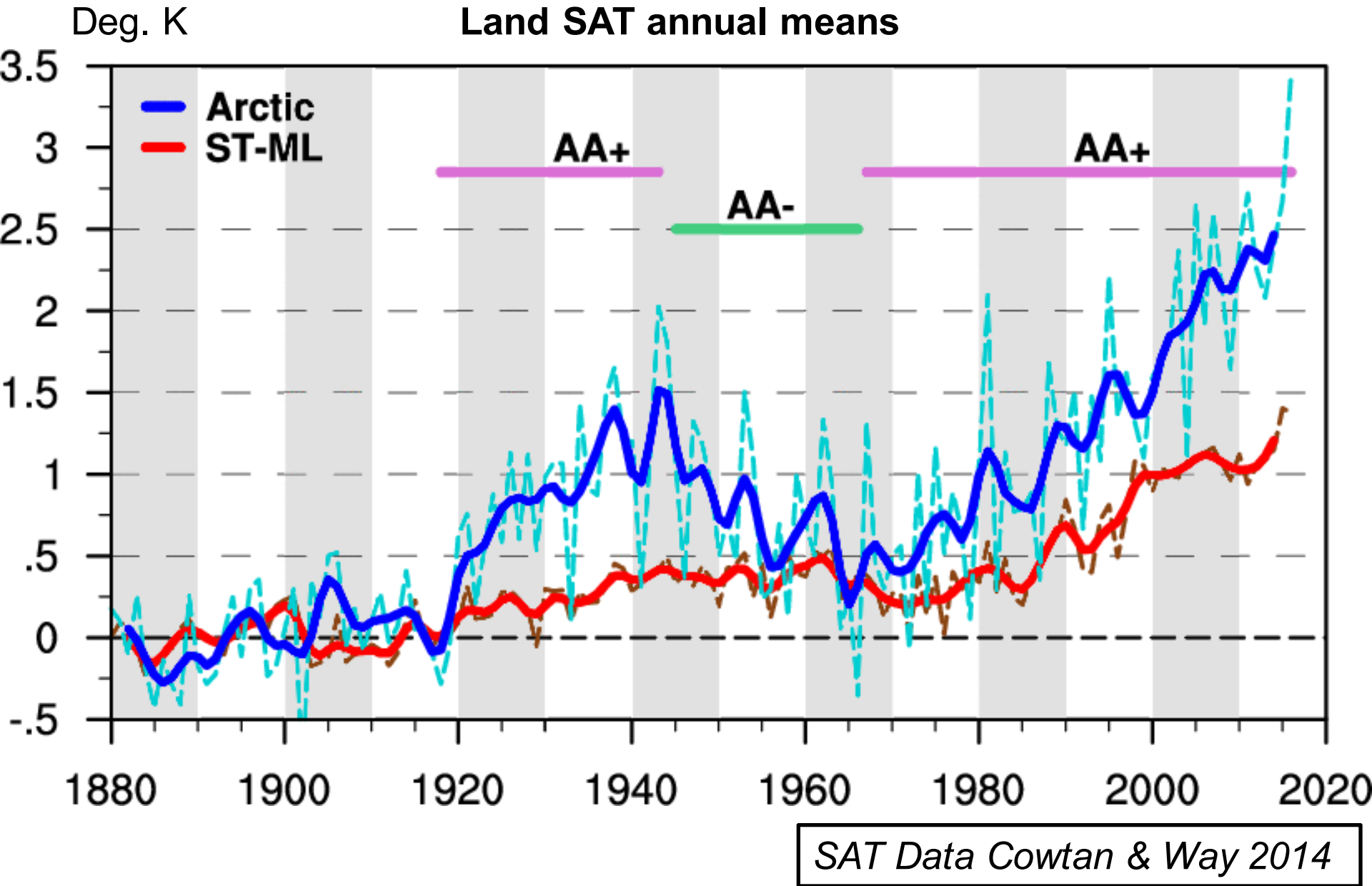
AA drivers: GHGs, aerosols, natural forcings, internal variability

Summary

Arctic Amplification (AA)

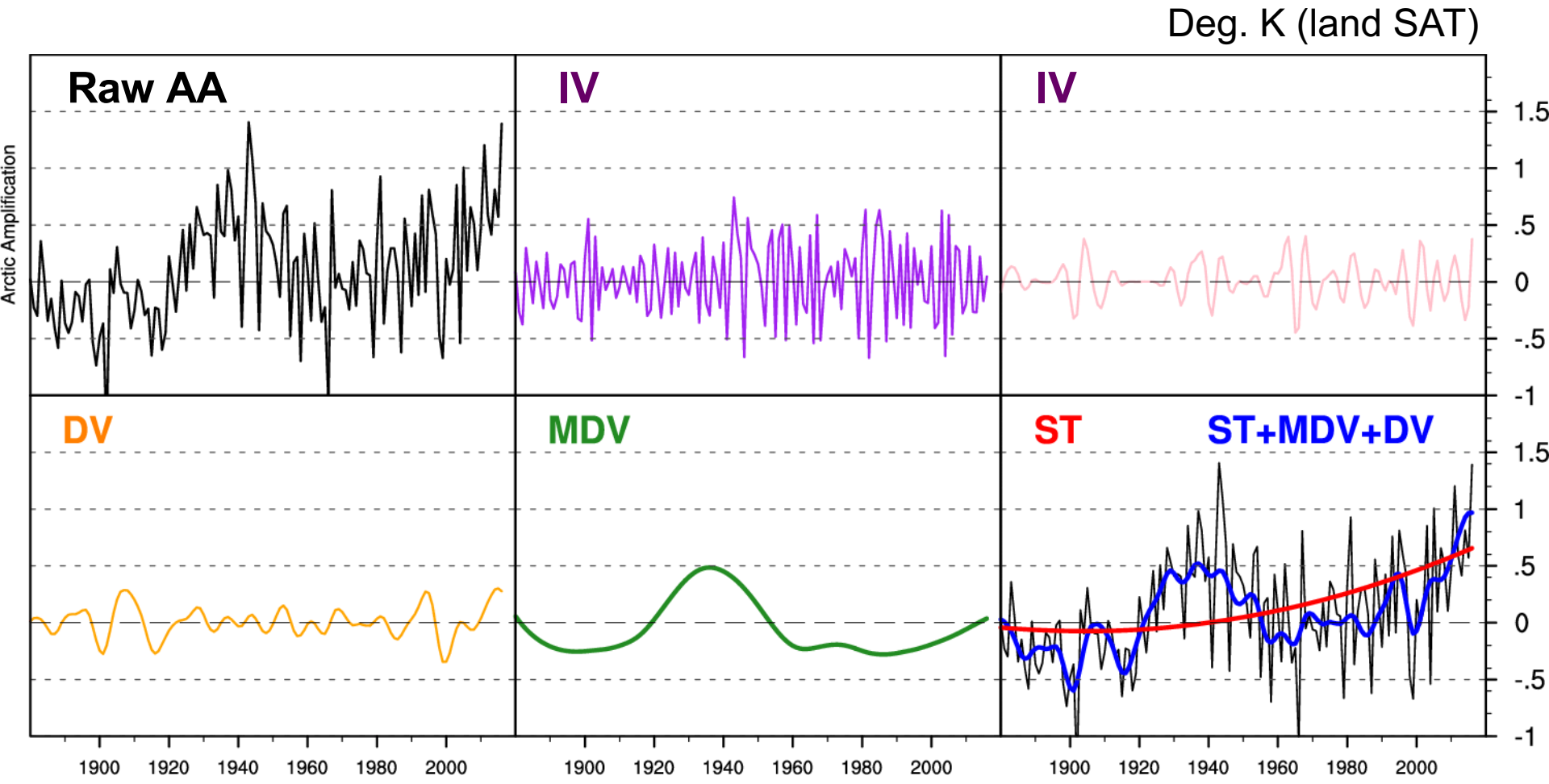
- Focus on land temperature
- Arctic Region defined as areas with latitude > 60°N
- AA metrics: mean change or trend ratio, regression
- Temperature difference between Arctic and ST-ML (20-60°N) region
- Seasonal analysis: JFM, AMJ, JAS, et OND

Transient AA (1880-2016)

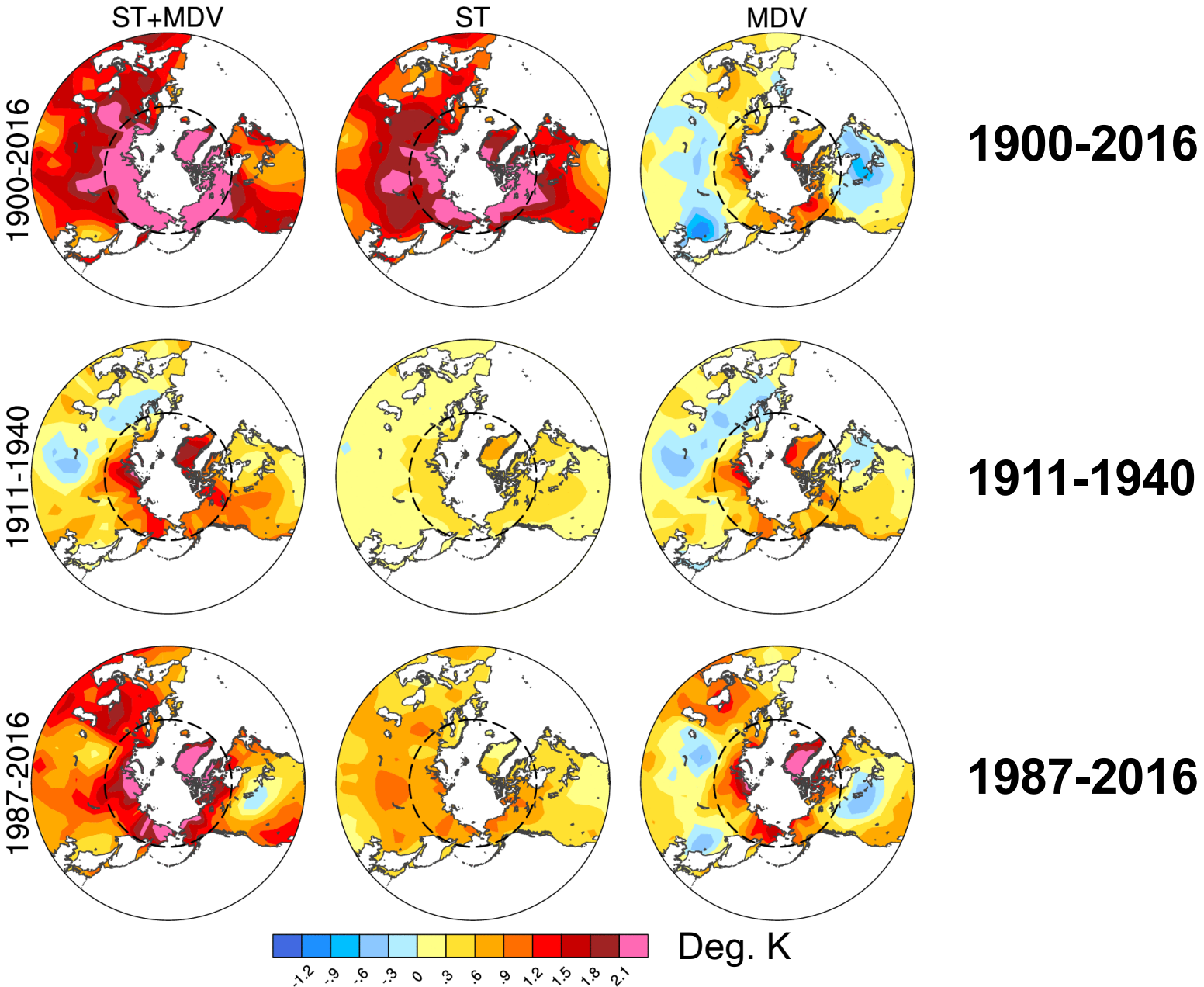


SAT Data Cowtan & Way 2014

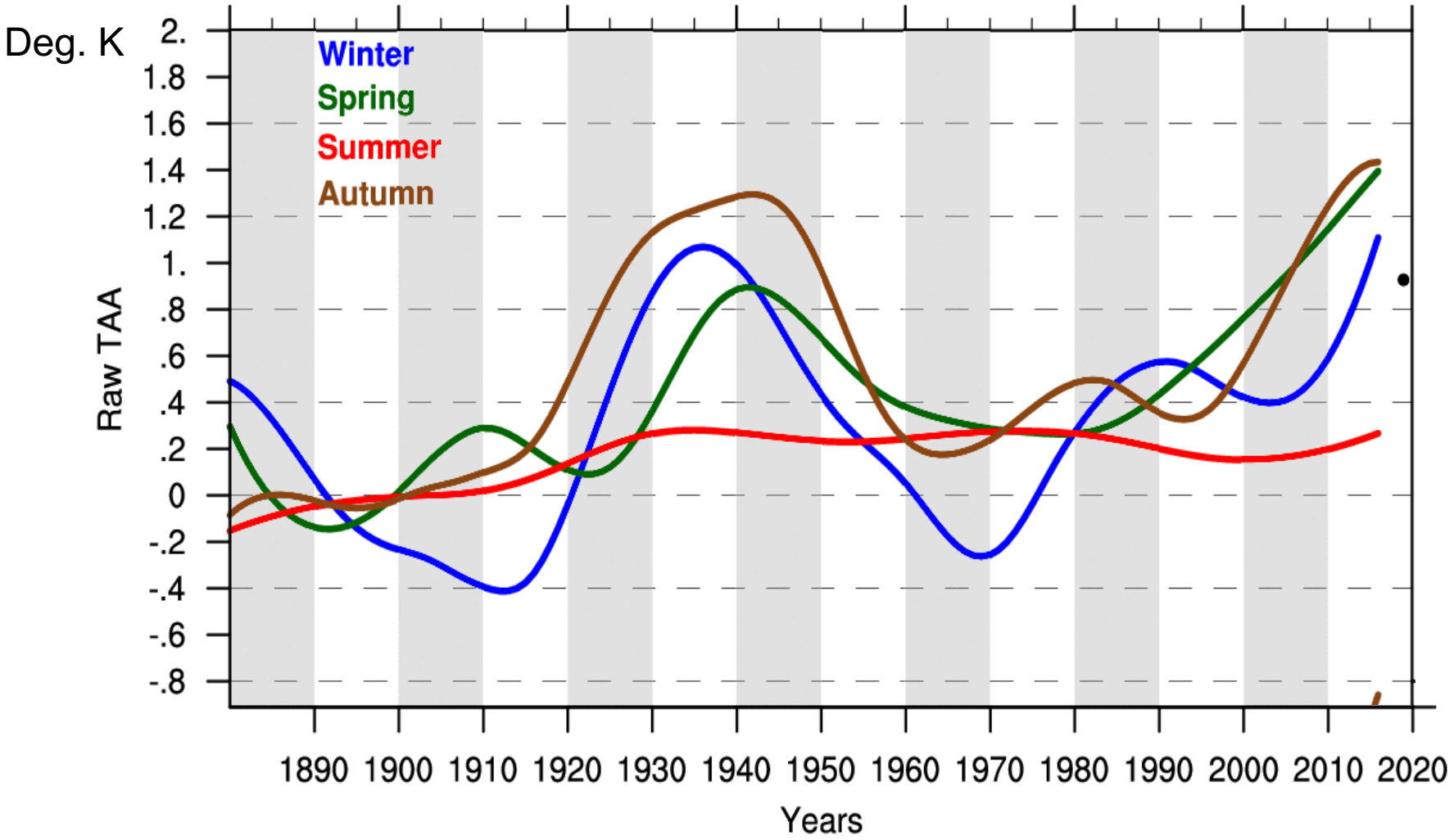
AA time scales: EEMD analysis



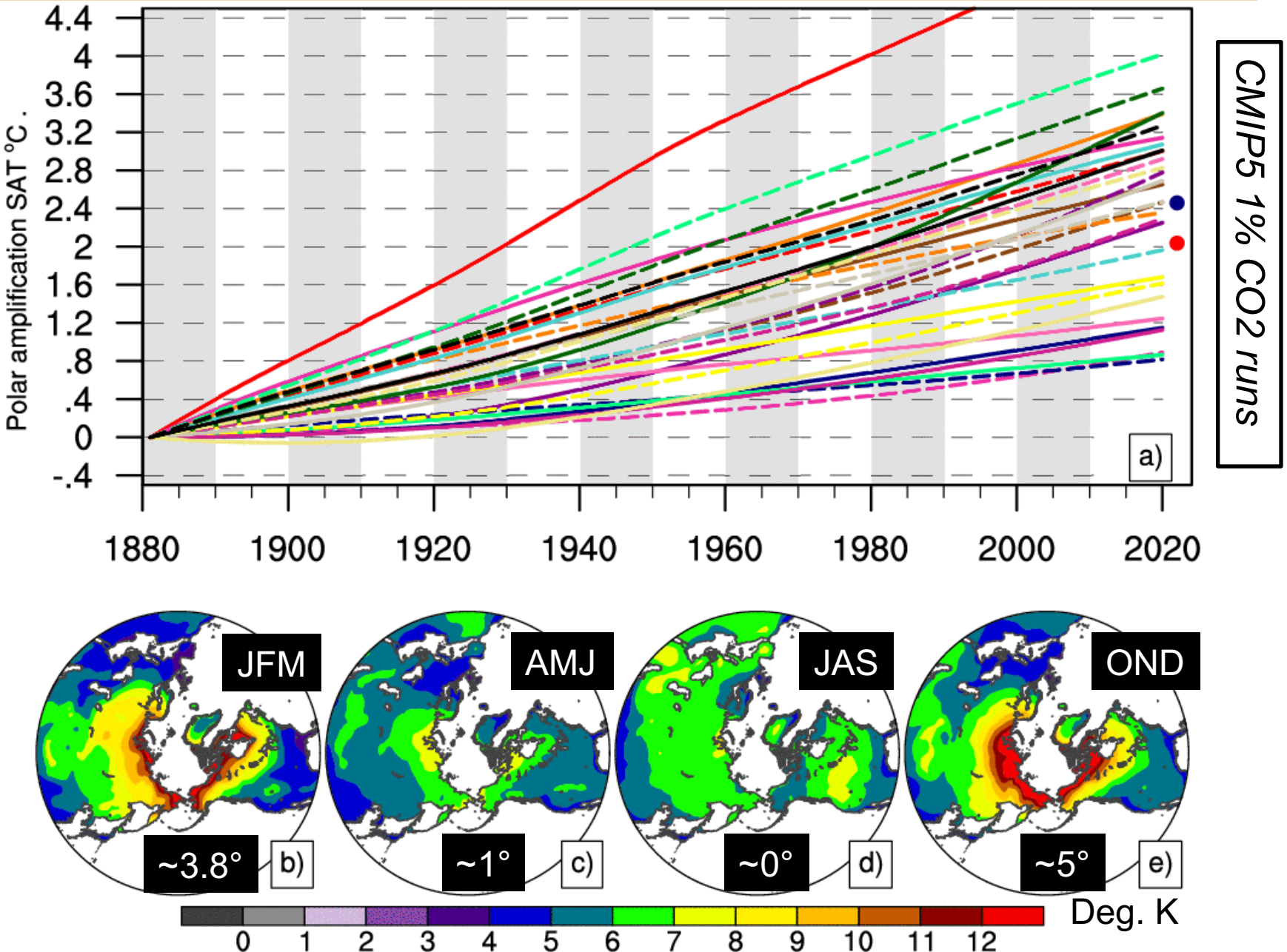
AA spatial patterm: ST & MDV



AA (ST+MDV) Seasonality



AA Drivers: CO_2 forcing



CMIP5 1% CO_2 runs: surface heat budget

$$Q = (1 - \alpha)\, SW_d + LW_d - LW_u - H - LE$$

$$4.\sigma.\mathbf{T_s}^3 . \Delta T_s \approx -(\Delta\alpha).(\mathbf{SW_d} + \Delta SW_d)$$ Surface albedo feedback

$$+ \Delta(CRF_s)$$ cloud radiative forcing

$$+ (1 - \boldsymbol{\alpha}).\Delta(SW_{d,clr})$$ Non-SAF clear-sky shortwave radiation

$$+ \Delta(LW_{d,clr})$$ Downward clear-sky longwave radiation

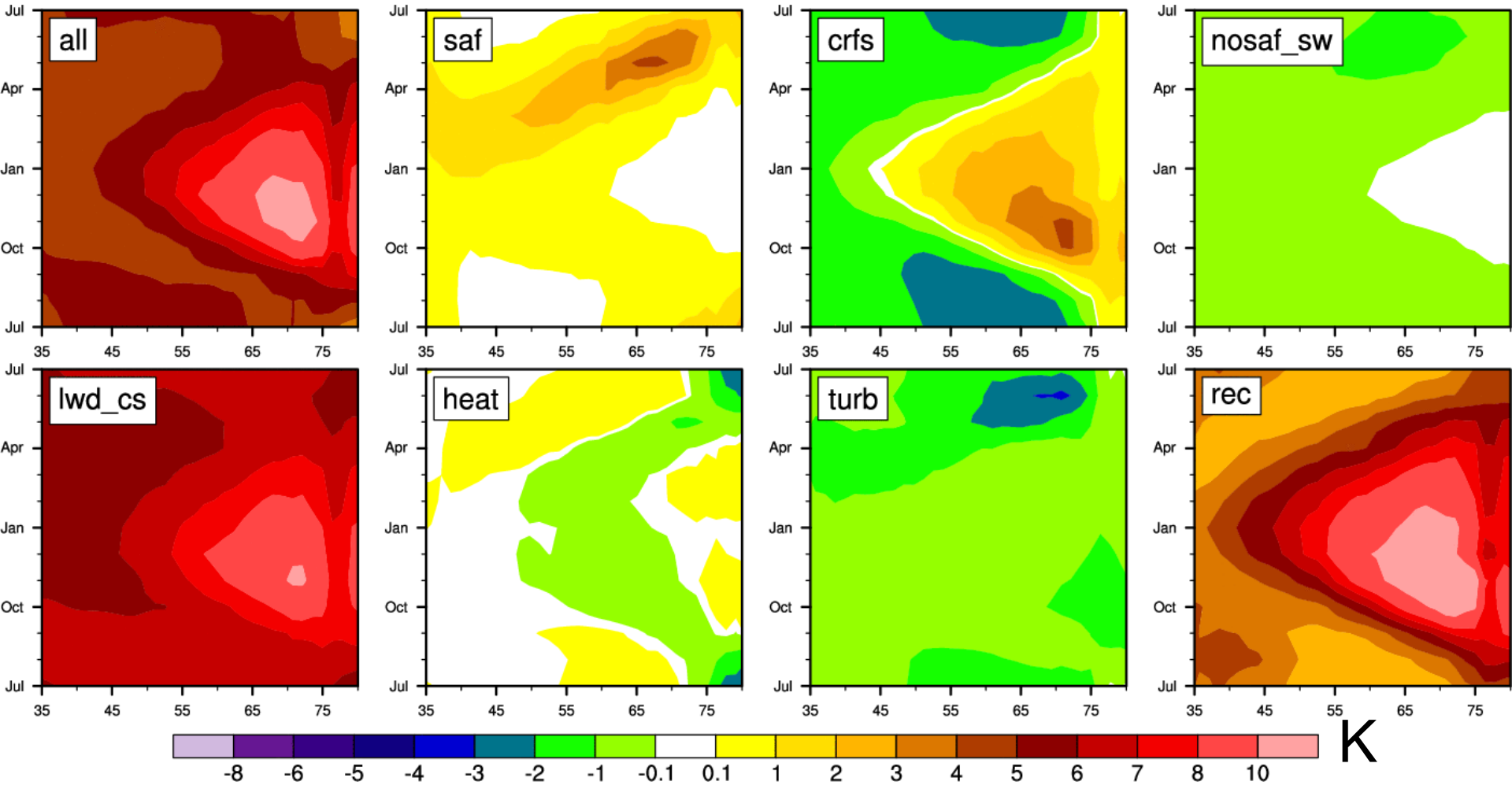
$$+ \Delta(Q)$$ Heat storage

$$- \Delta(H + LE)$$ Turbulent fluxes

Lu and Cai 2009

AA: driving mechanisms

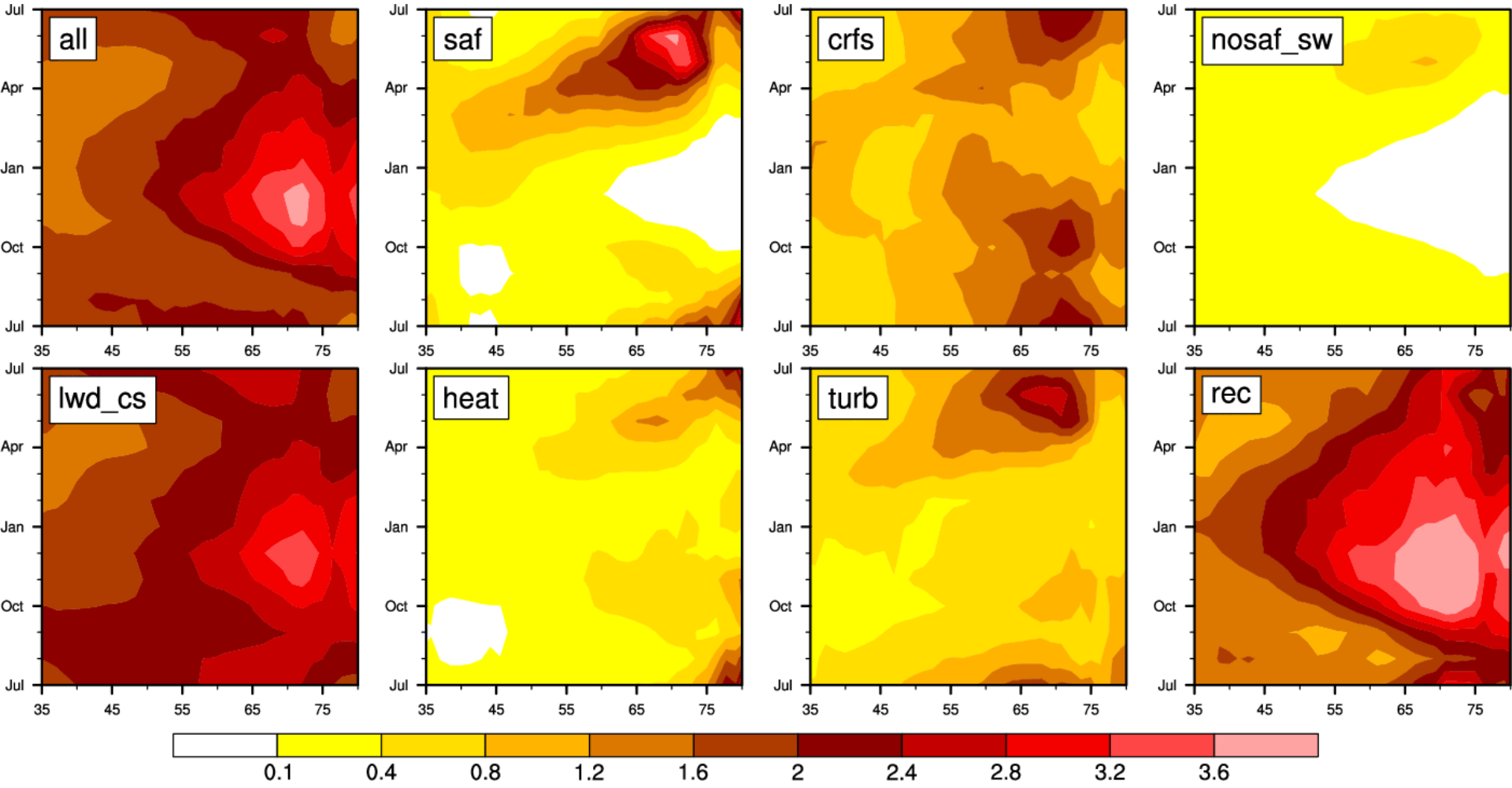
4 x CO_2 : CMIP5 multimodel mean



Drivers: clear-sky downward LW, clouds

AA: processes

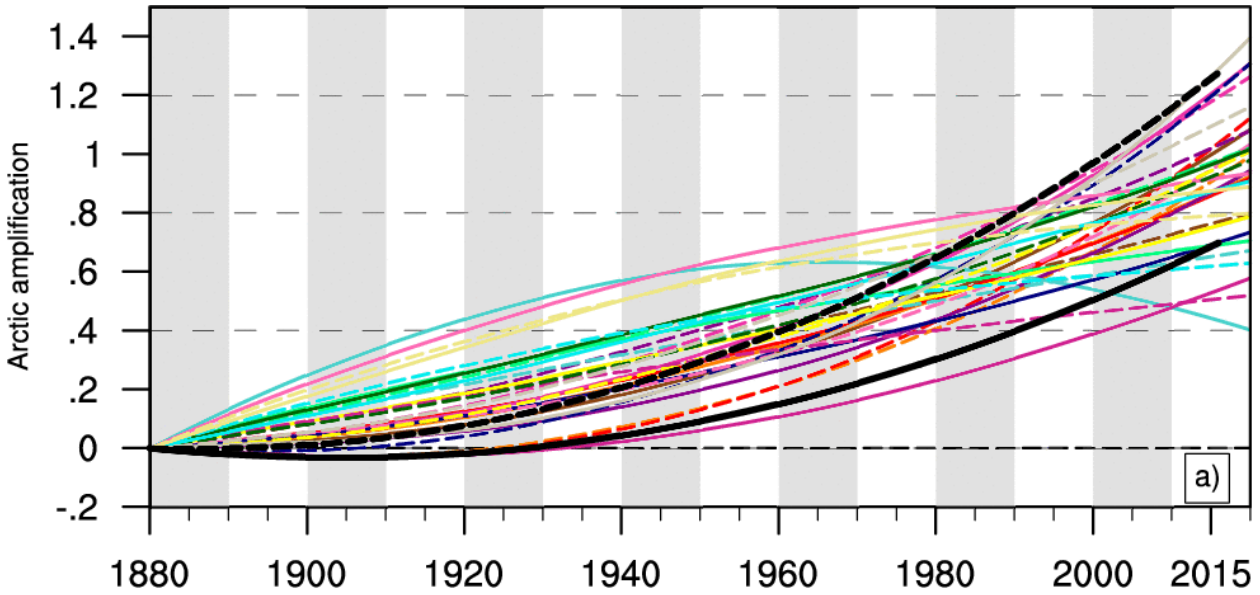
4 x CO_2 : CMIP5 inter-model spread



Main processes: clear-sky downward LW, SAF, clouds

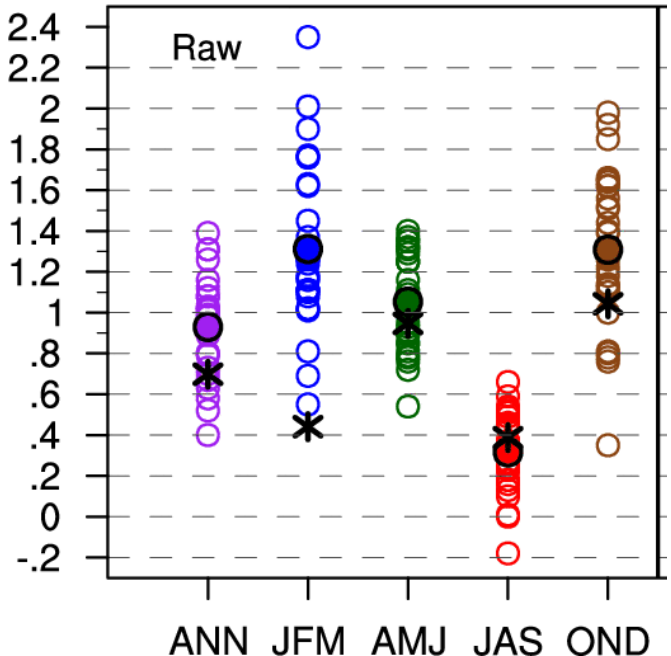
AA (ST only) Drivers: internal variability

Deg. K



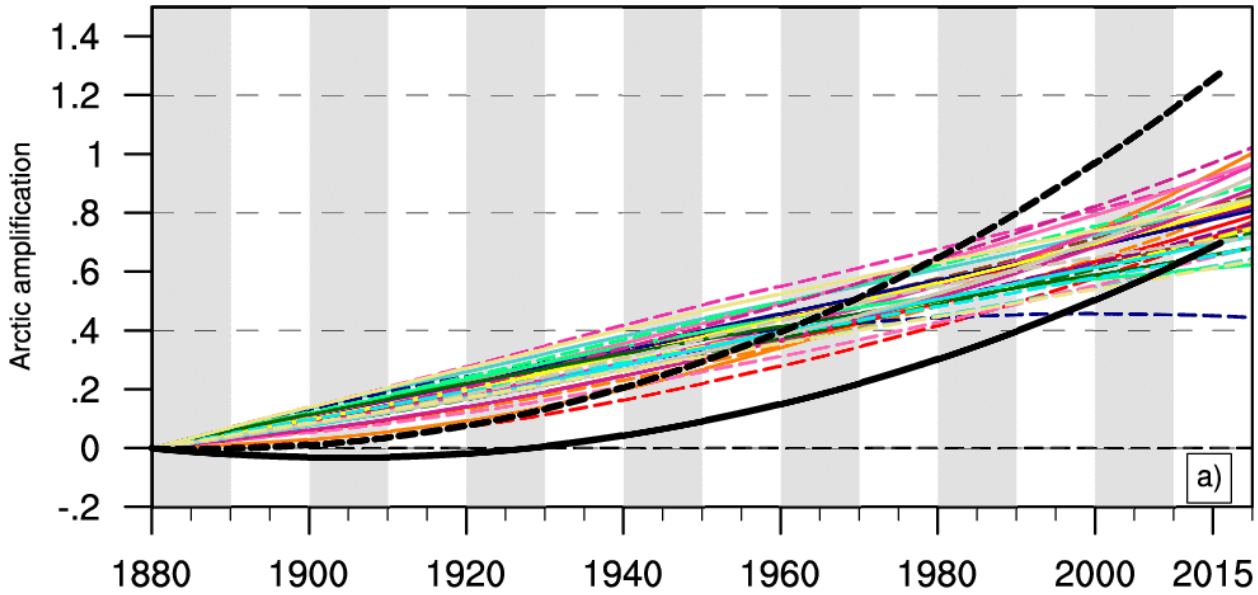
CESM LENS

Deg. K

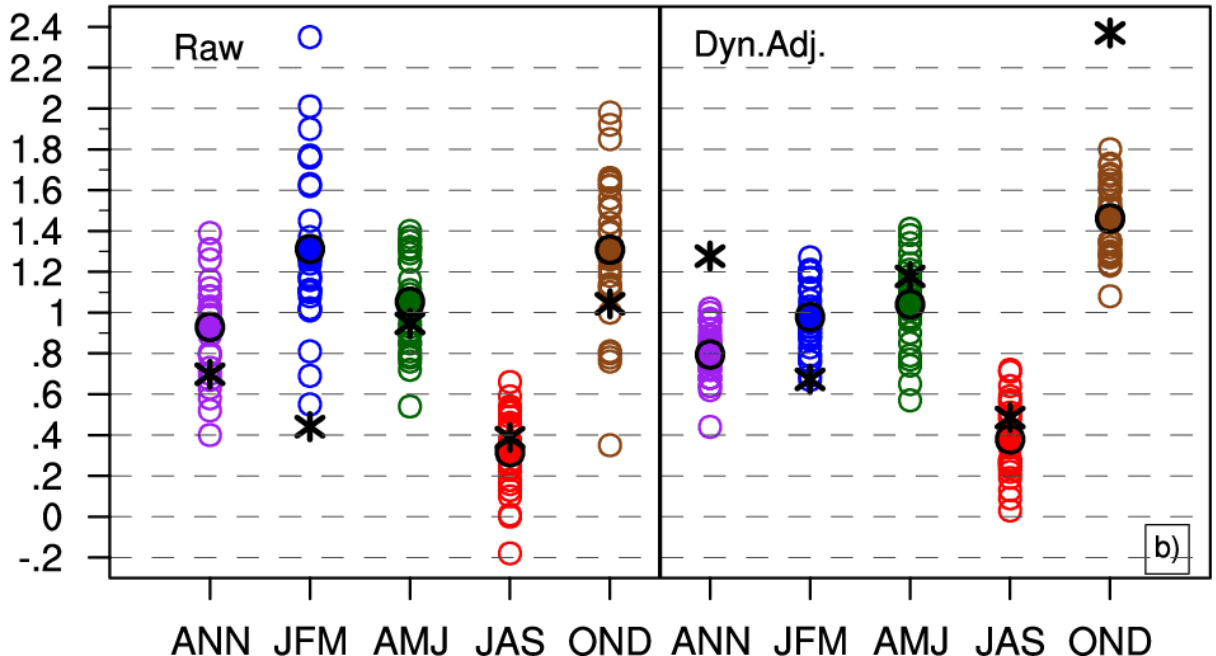


AA (ST only) Drivers: internal variability

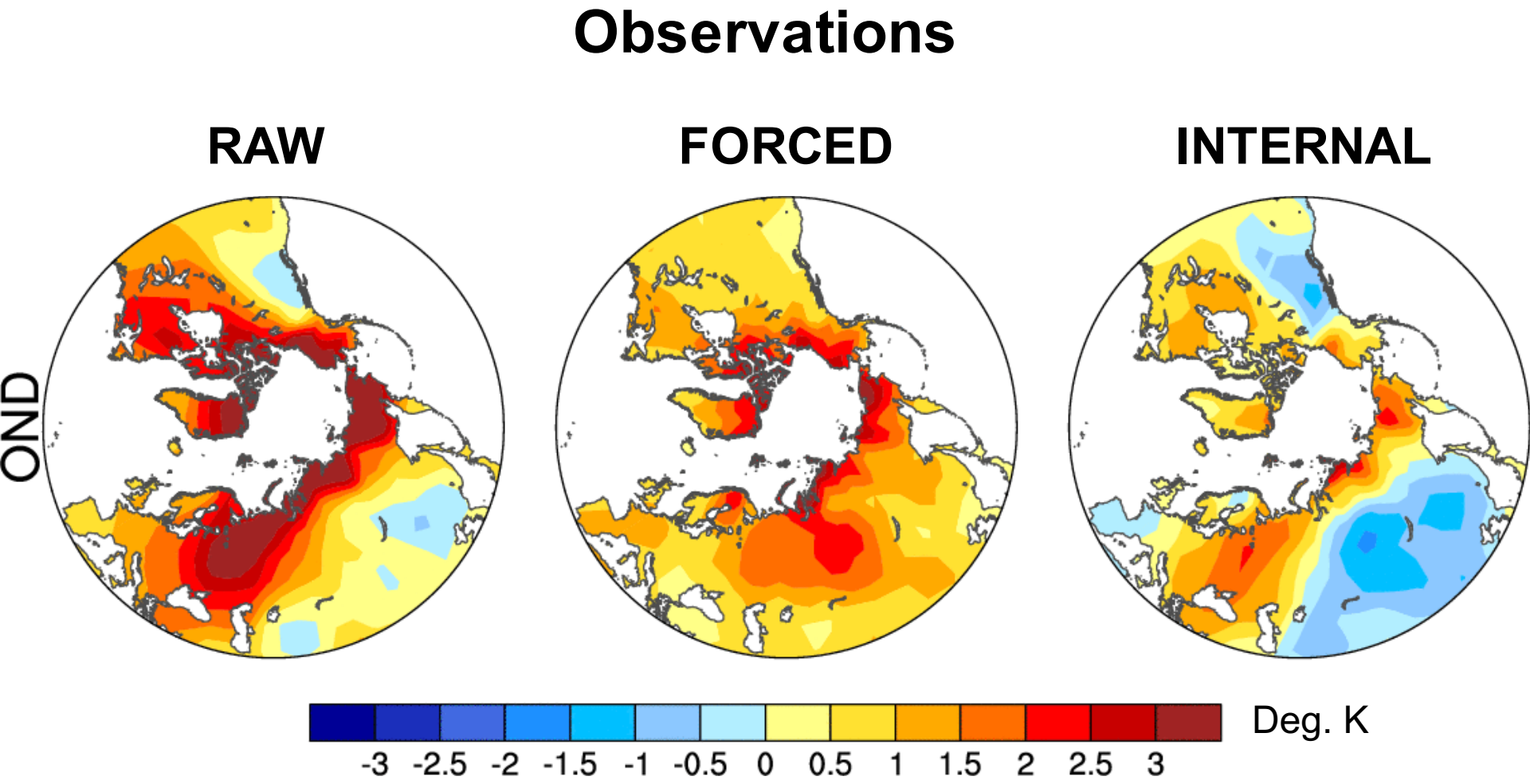
Deg. K



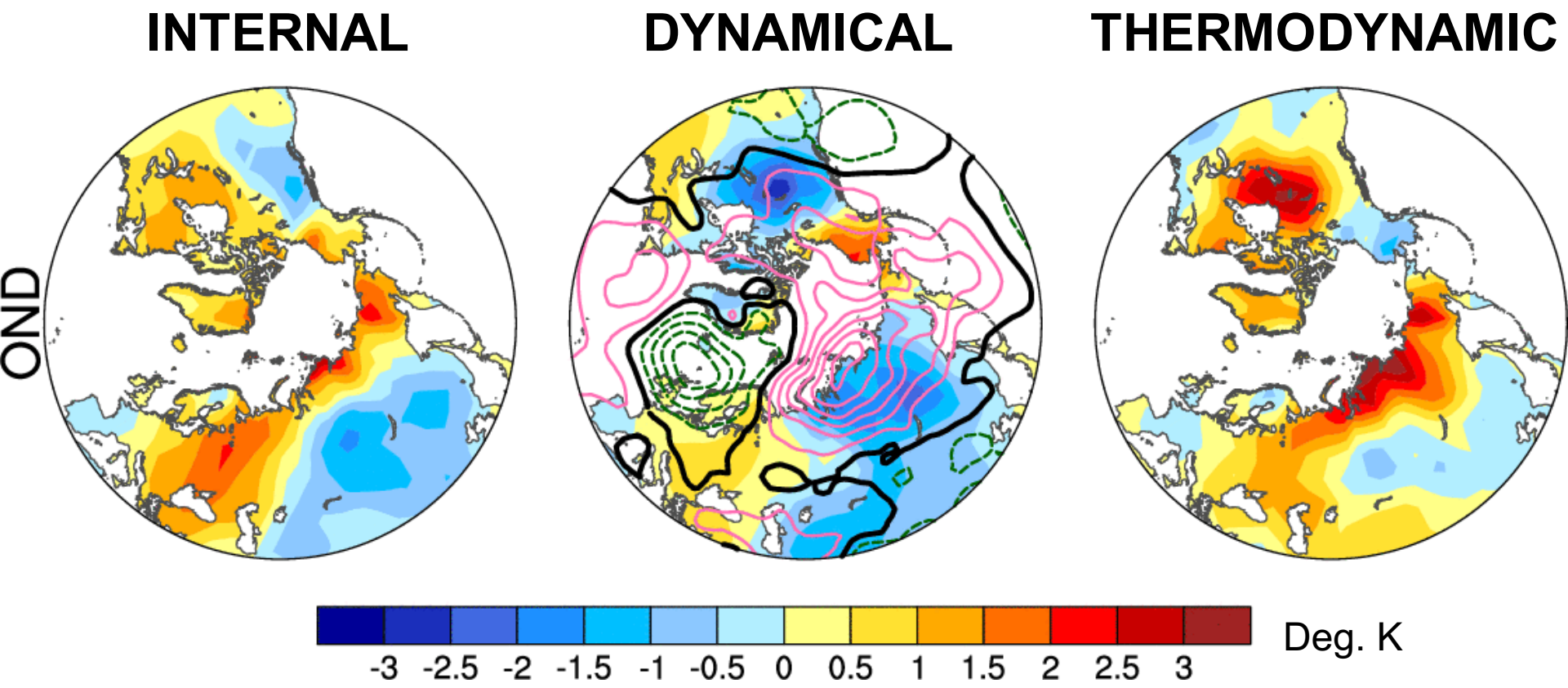
Deg. K



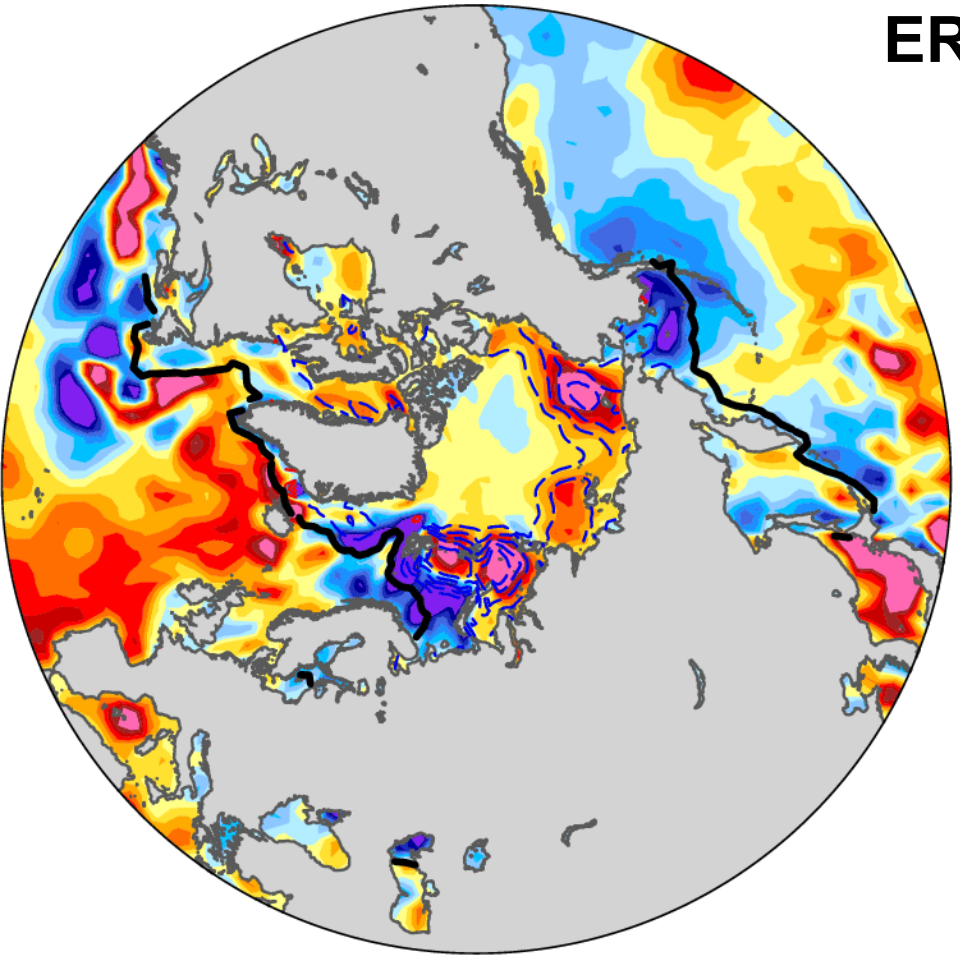
Focus on Autumn SAT 1987-2016 trend



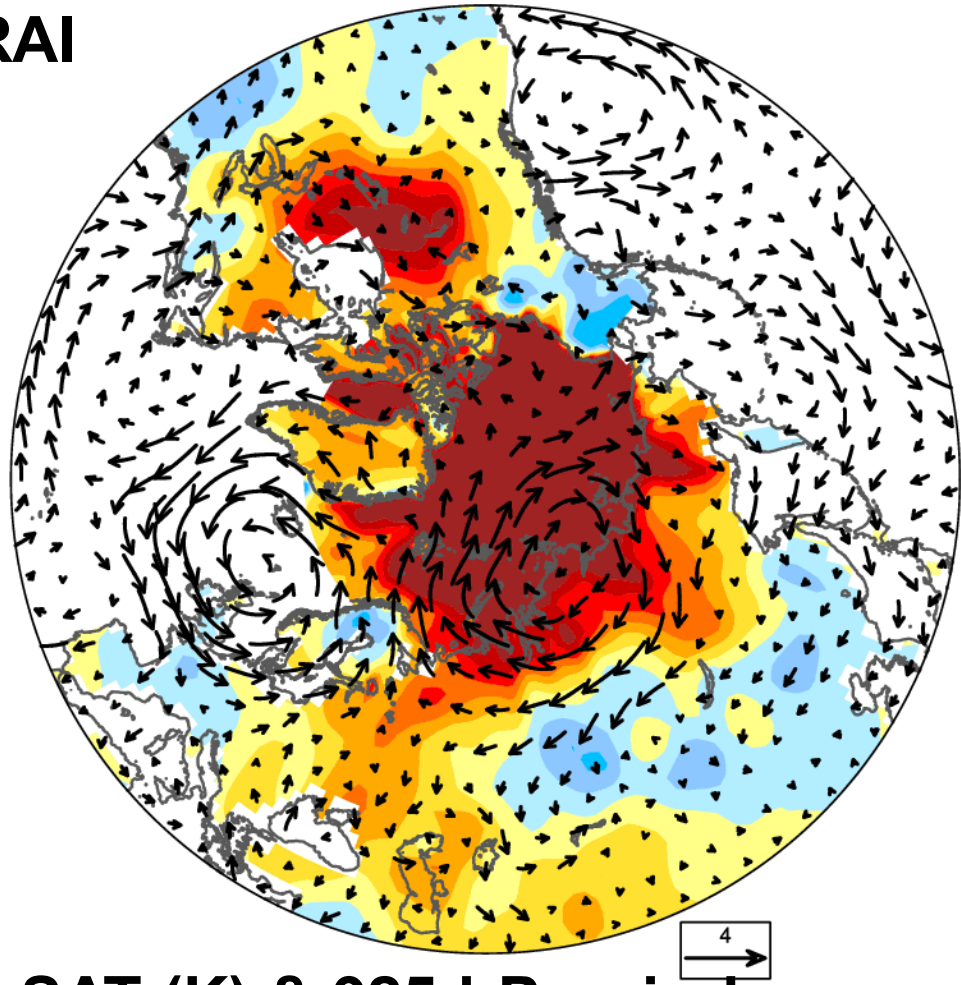
Internal = dynamical + thermodynamic



Origin of thermodynamical SAT



ERAI



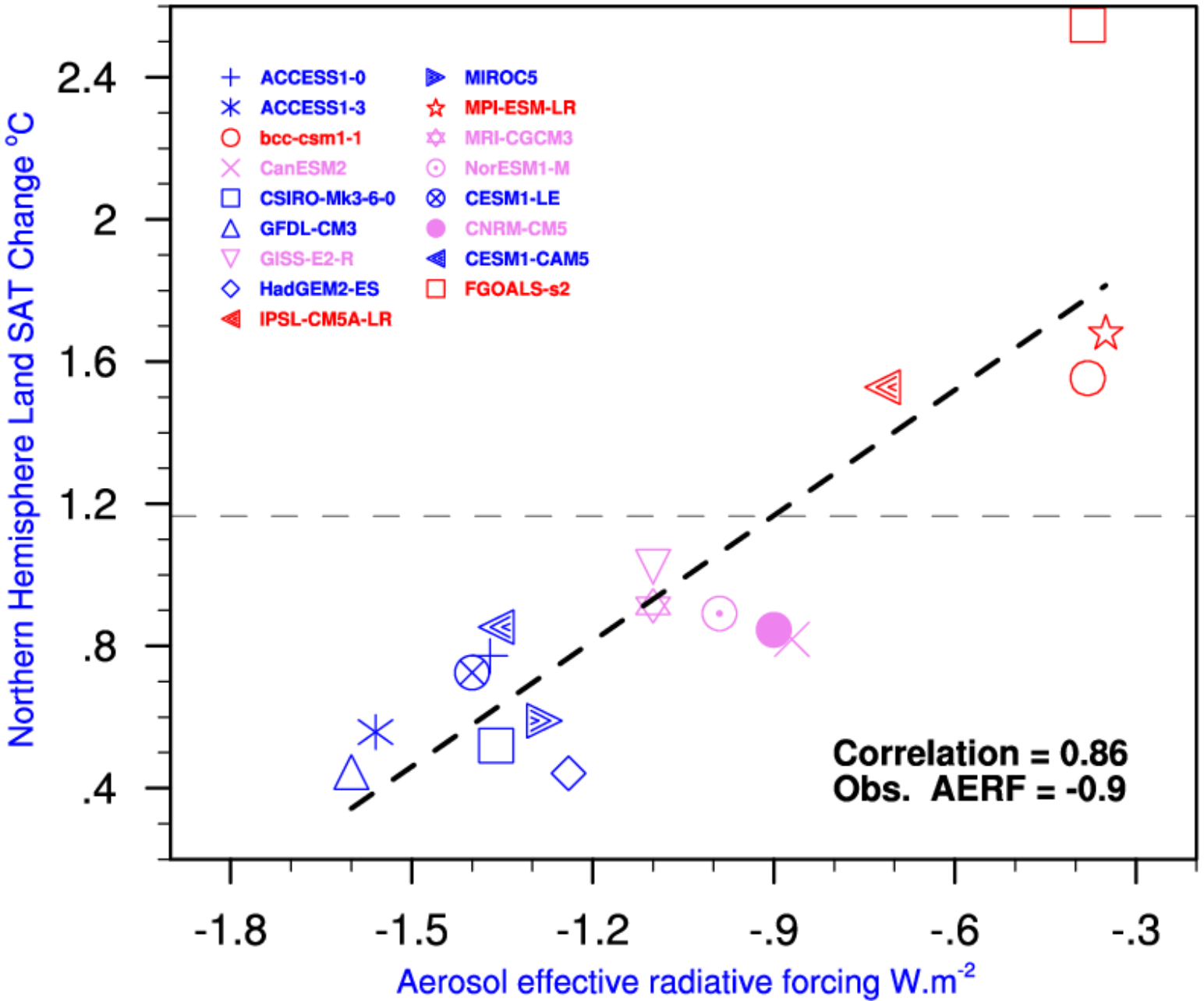
Turb. Heat Flux W.m^{-2} & SIC

-35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35

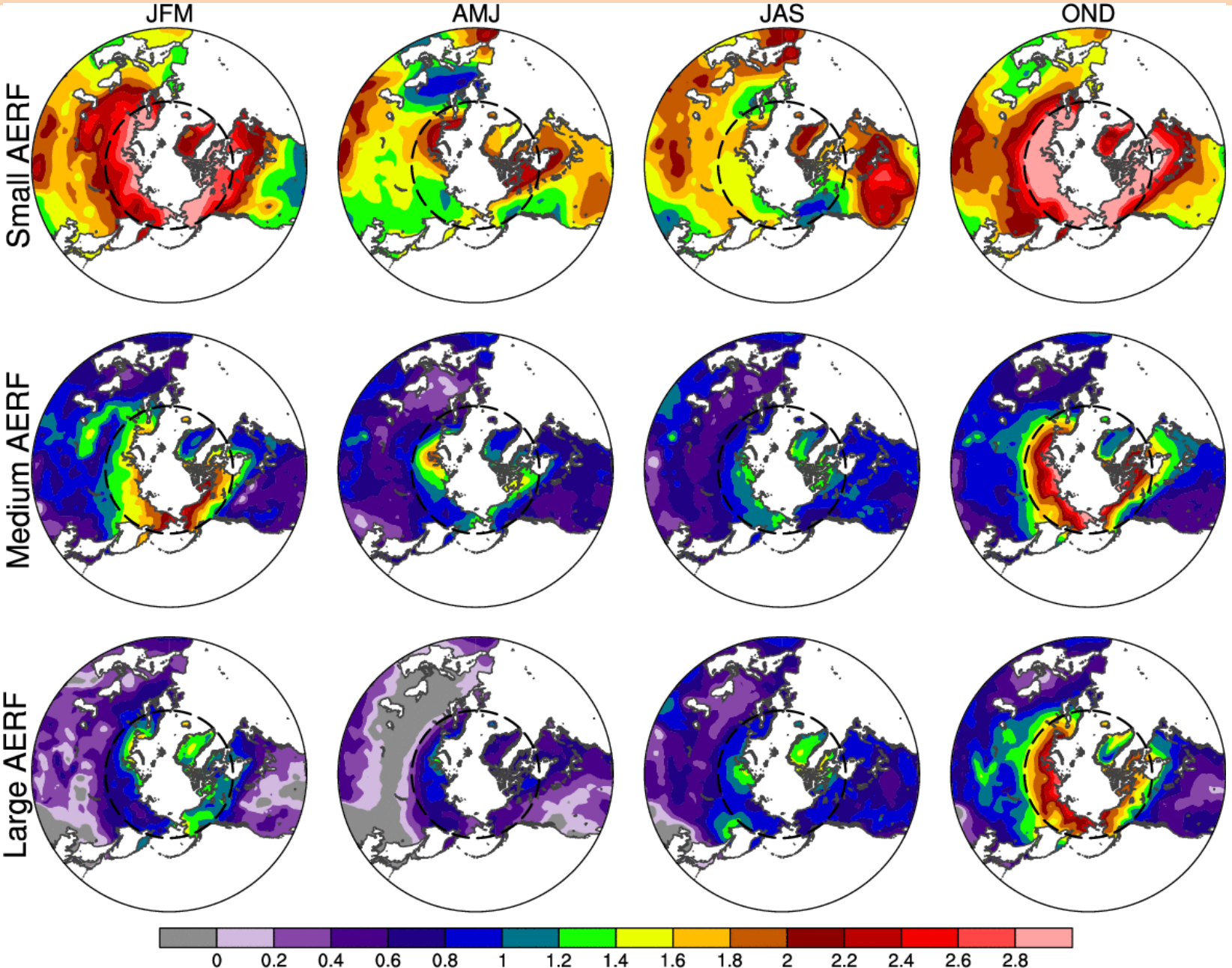
SAT (K) & 925 hPa winds

-3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5 3

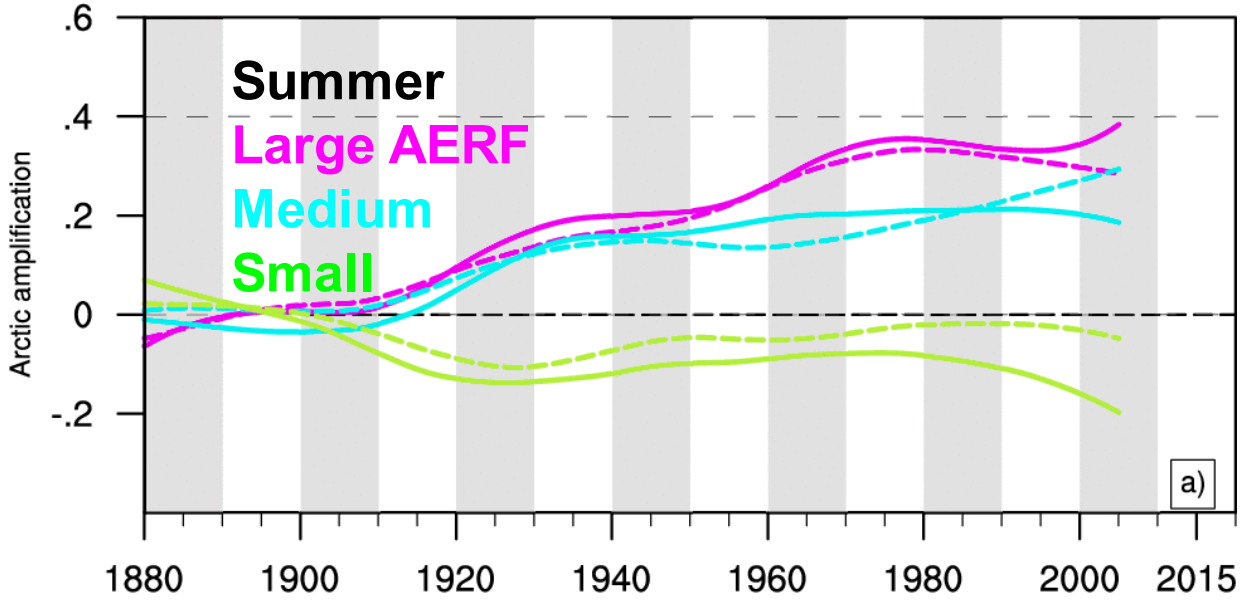
AA Drivers: aerosols

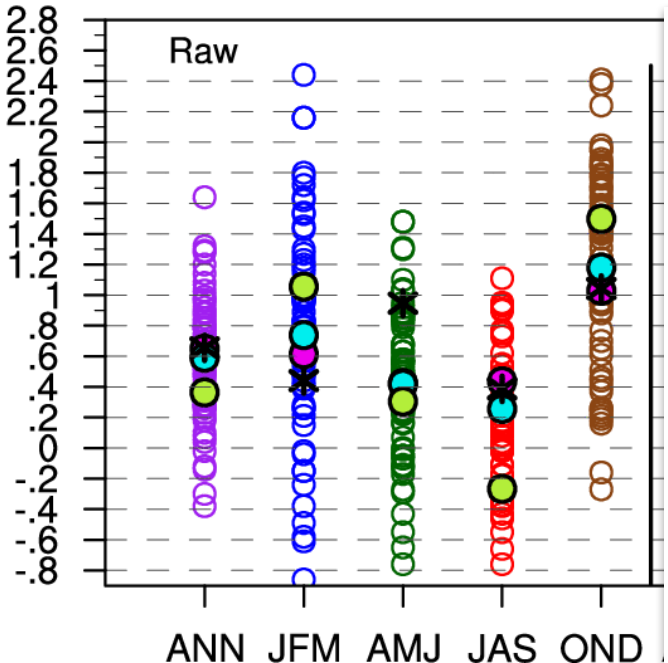


AA drivers: aerosols



AA drivers: aerosols





Aerosols:

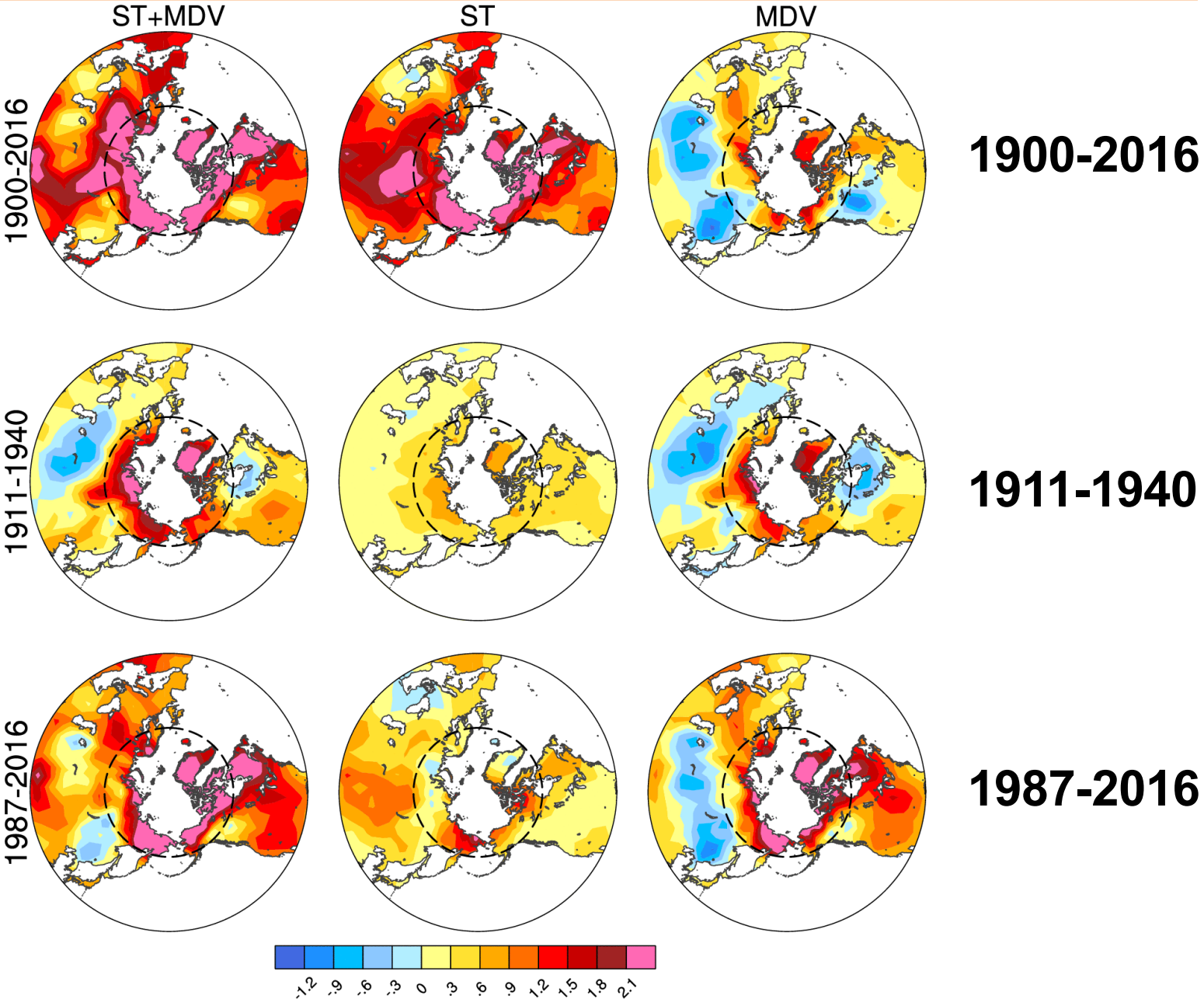
- **Increase AA in JAS**
- **Decrease AA in OND JFM**
- **(Very) Low S/N ratio**

Summary

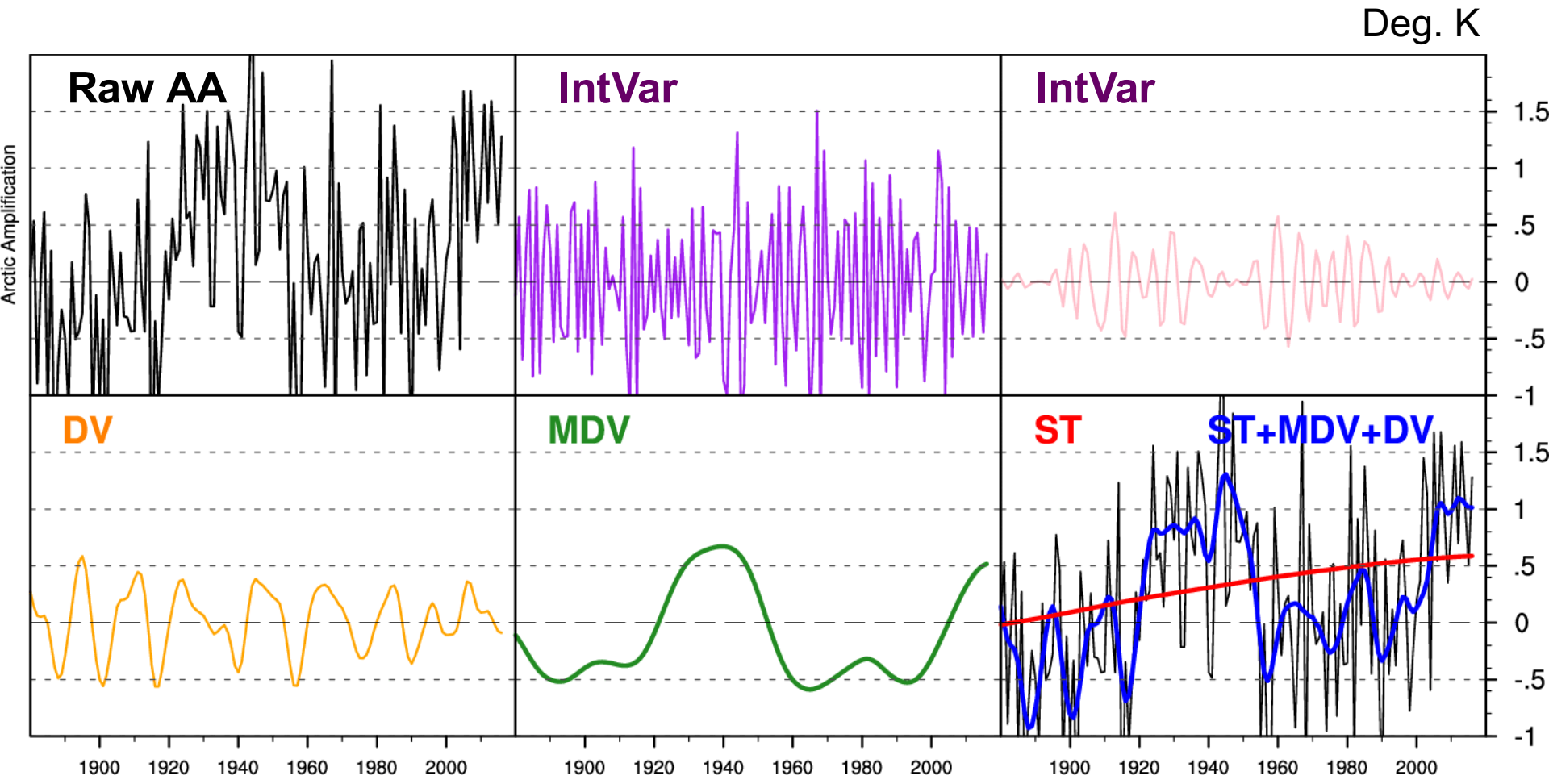
- Transient AA exhibits different time scales
- The current and ETCAW warming are mainly due to the MDV contribution
- Strong seasonality in observed AA (ST + MDV)
- Autumn has the largest observed AA
- Recent AA increase is linked to sea-ice melt
- 4 X CO_2 : multimodel mean AA ~ 2.5°C (5°C OND – 0 JAS)
- Large inter-model spread in projected AA
- Main sources of spread are LW (clear sky) and clouds
- Internal variability is still large with a significant contribution from purely atmospheric variability.
- Difficult to assess aerosol contribution to AA from CMIP5
- Aerosols increase AA in summer
- **Need for dedicated experiments to perform a full AA attribution study**

Thanks !

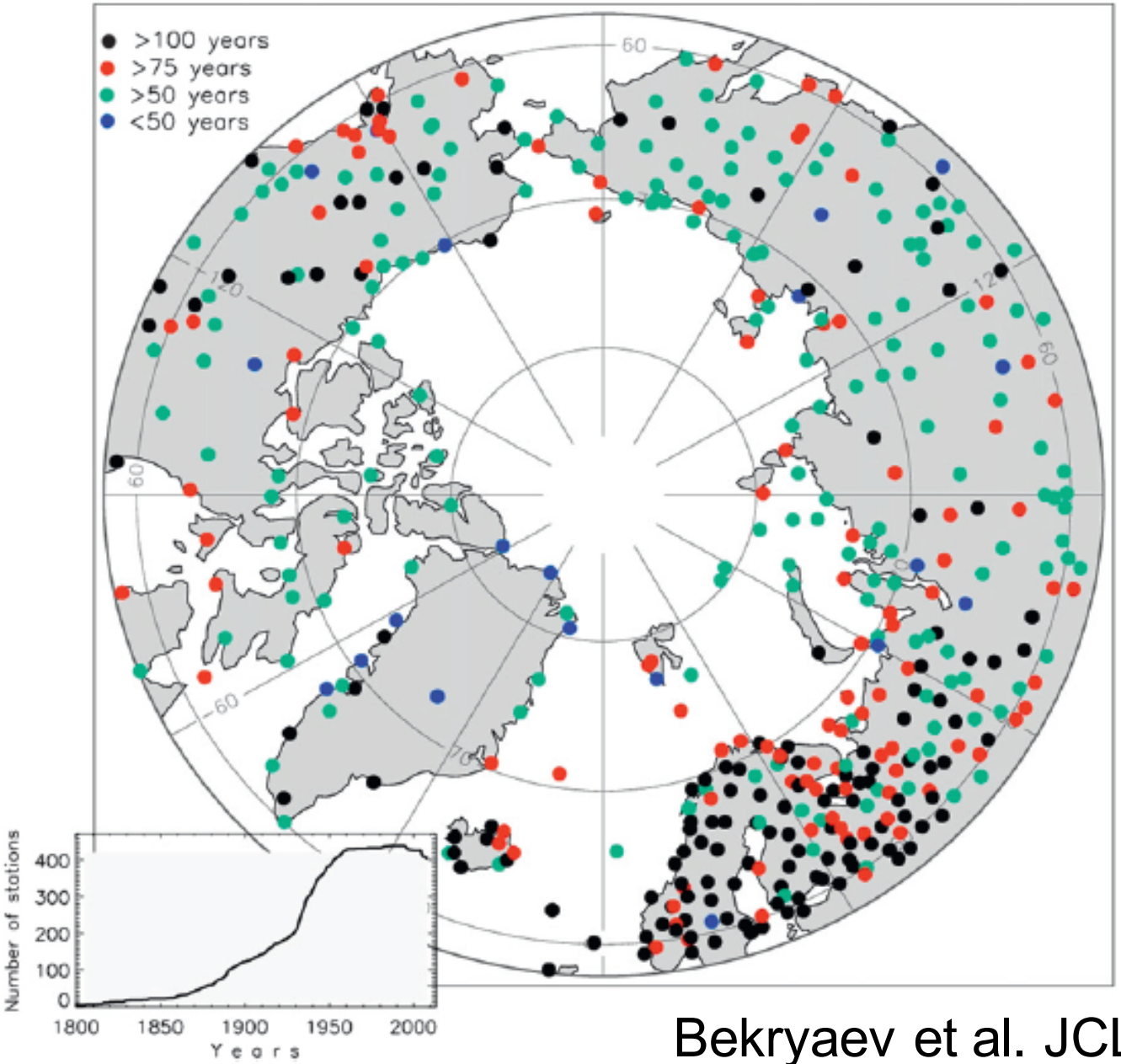
AA Autumn: spatial patterns



AA Autumn: EEMD modes

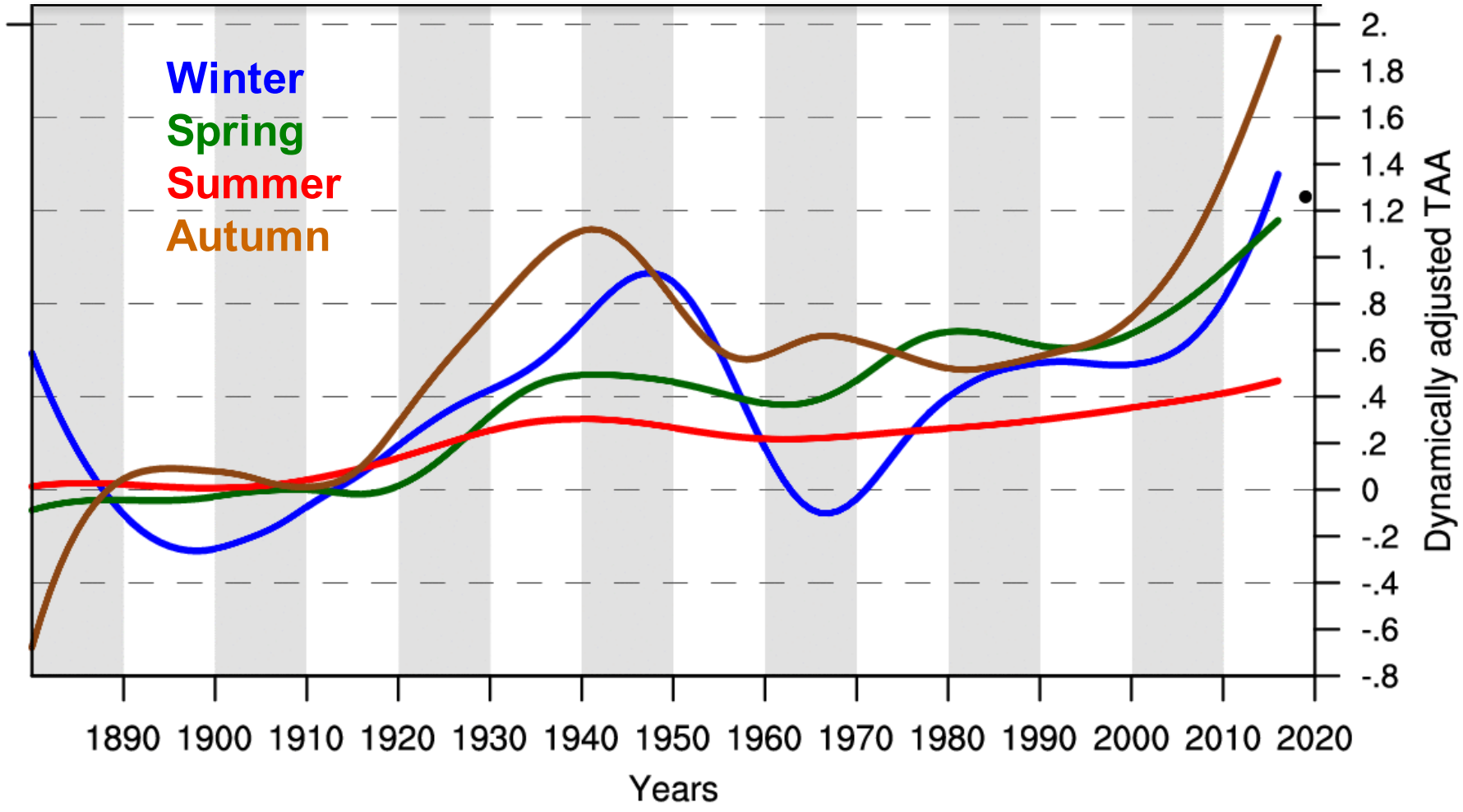


Data availability



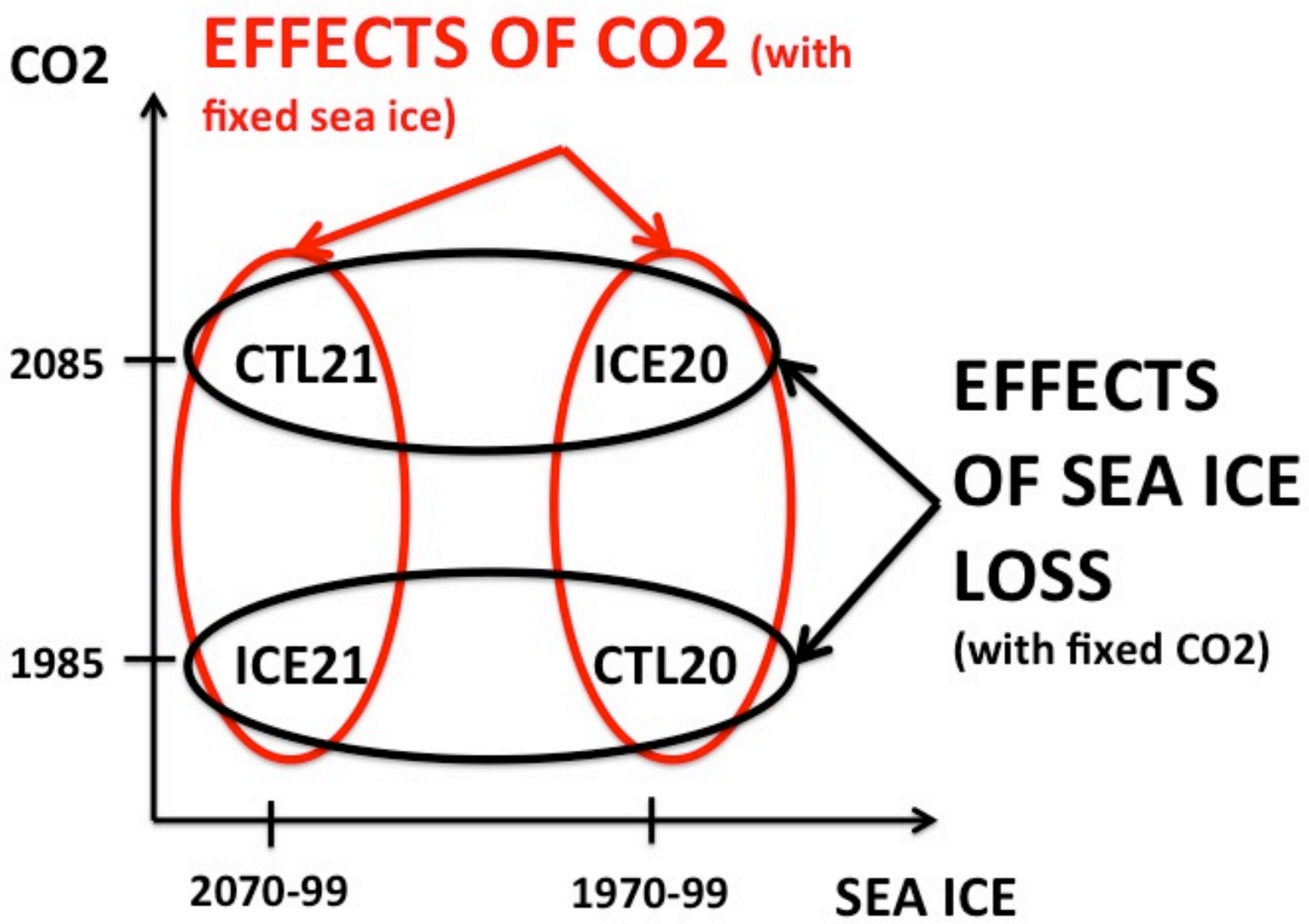
Bekryaev et al. JCLIM 2010

Observed AA dynamically adjusted

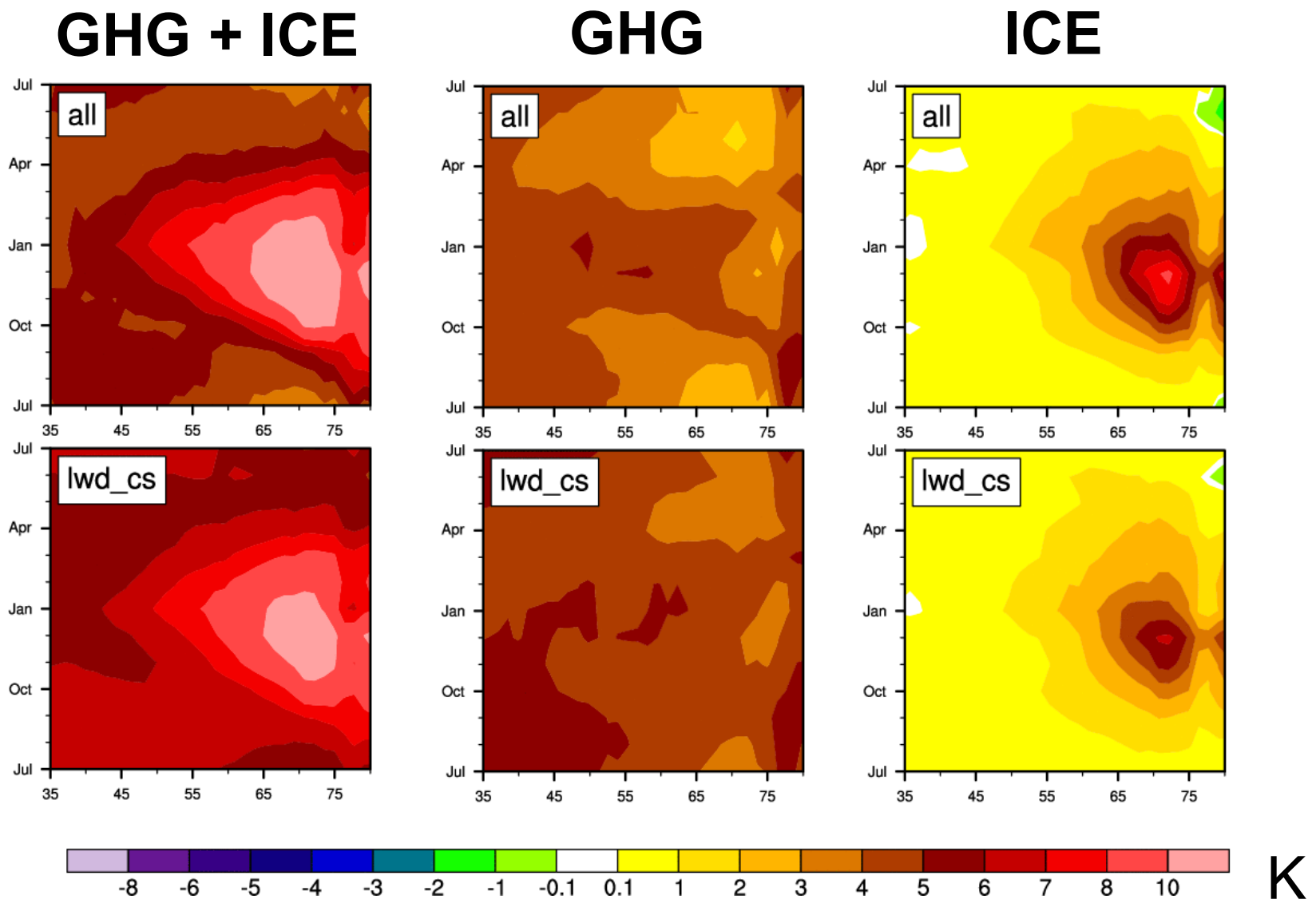


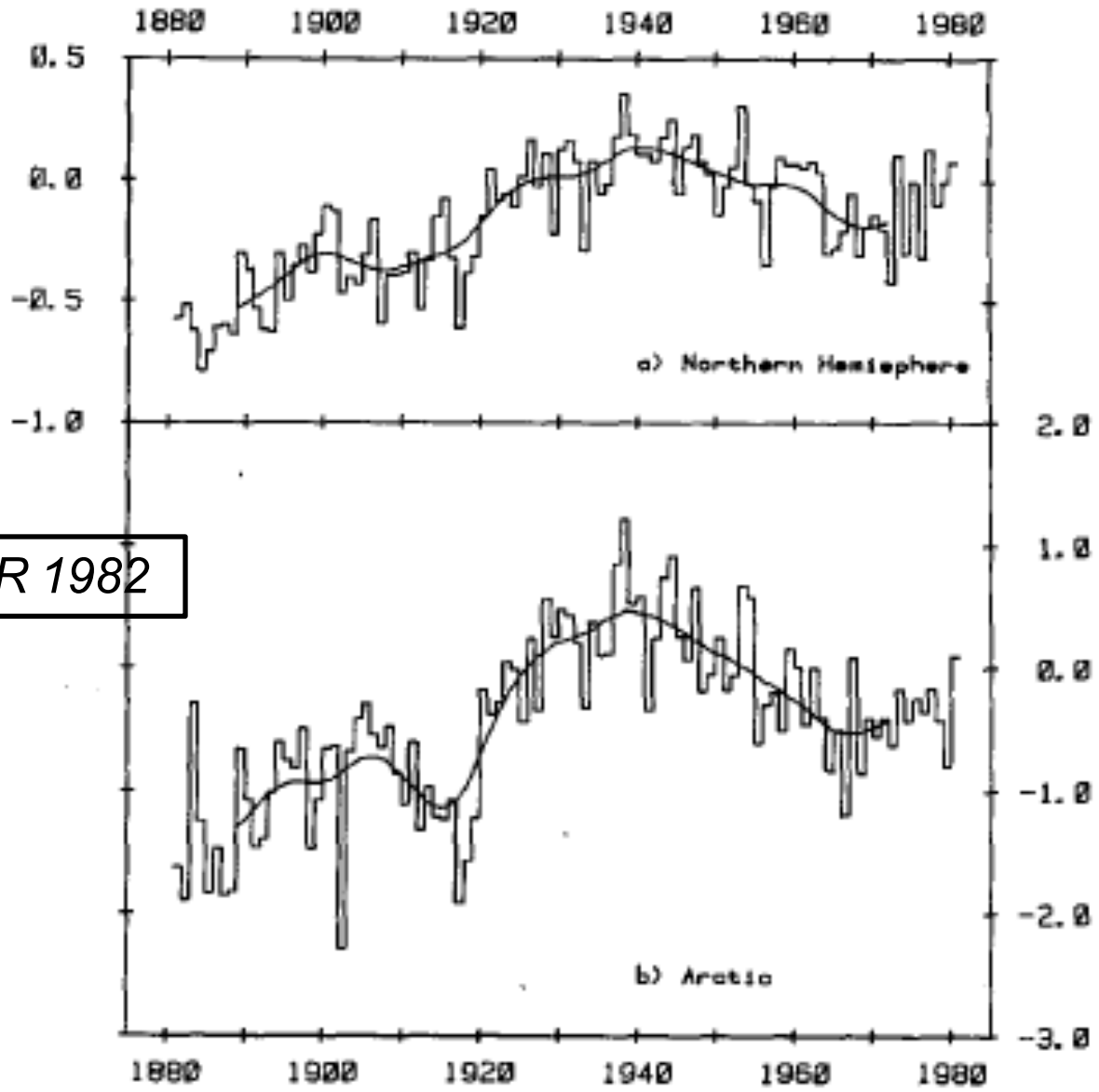
Mécanismes: effets directs GHGs et banquise

Experiences *couplées* avec CNRM-CM5



Land AA: Ice effect dominant



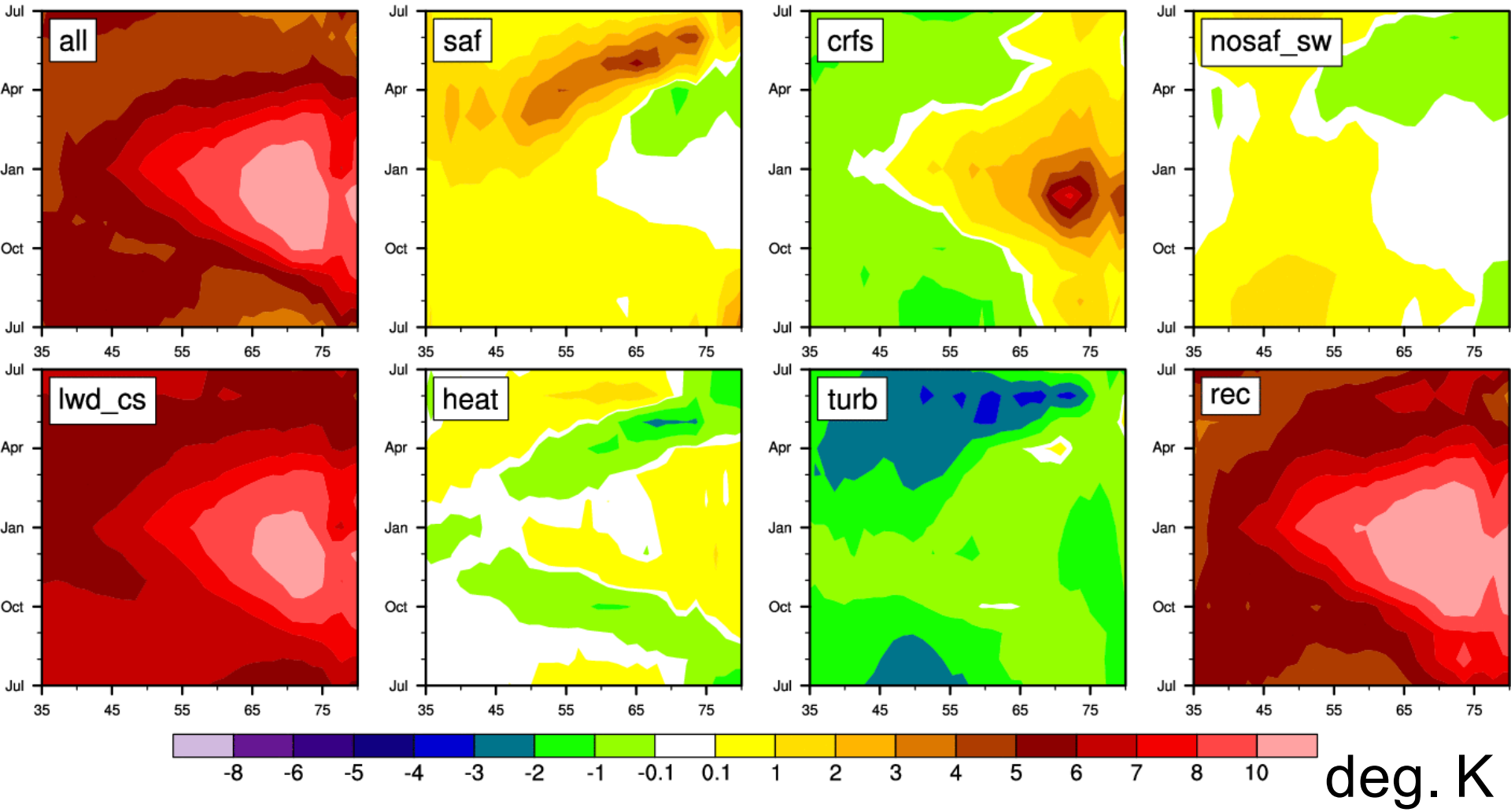


Kelly et al. MWR 1982

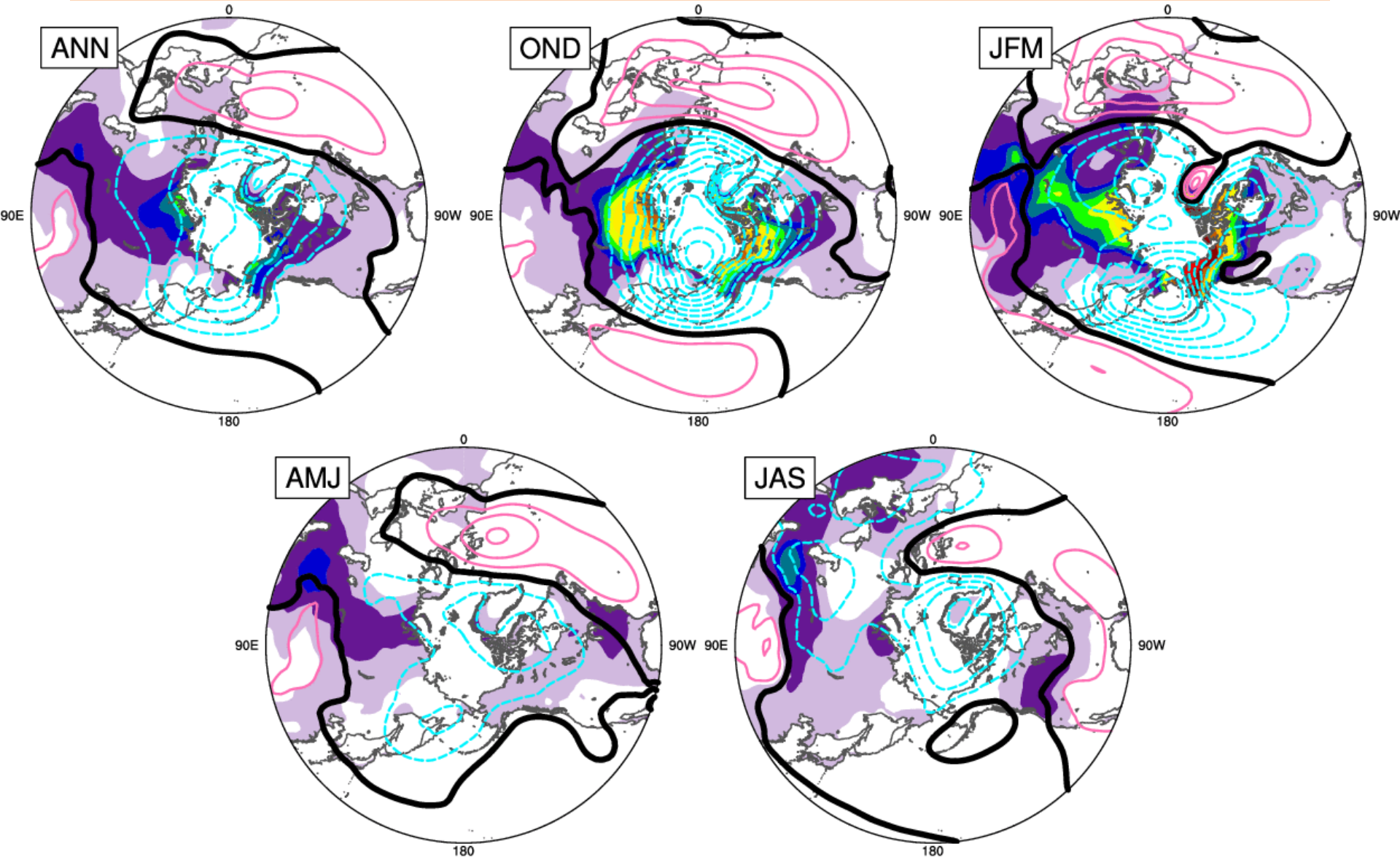
FIG. 2. Annual temperatures (°C) as departures from the reference period 1946–60 averaged over (a) the Northern Hemisphere (0–85°N) and (b) the Arctic (65–85°N).

Effets combinés des GHGs de la banquise

CNRM-CM5: CTL21 – CTL20



Réponse dynamique atmosphérique au CO_2



Summary

- L'amplitude de l'AA continentale en réponse au forçage CO_2 est de l'ordre de 30% (estimation multi-modèle CMIP5 $\beta \approx 1.3$ [1.1 – 1.5])
- Le cycle saisonnier de l'AA simulée en réponse au CO_2 est fort avec une AA forte en automne et hiver ($\beta \approx 1.5$), faible au printemps et nulle en été
- Pour un doublement (ou plus) du CO_2, la réponse atmosphérique est une phase positive du mode annulaire de l'HN qui augmente l'AA de 15%.
- Les changements de flux IR descendants en ciel clair sont responsables de l'AA en automne et hiver (et de la dispersion entre les modèles CMIP5)
- Ils sont liés principalement à des effets associés à la fonte de la banquise Arctique

Dynamical adjustment

Reconstruct les variations *moyennes* de température (TAS) sur l'hémisphère Nord (> 20°N) liées à des changements de la circulation atmosphérique de grande échelle (dynamical contribution)

Moyennes: moyennées par rapport aux conditions de surface océaniques et continentales.

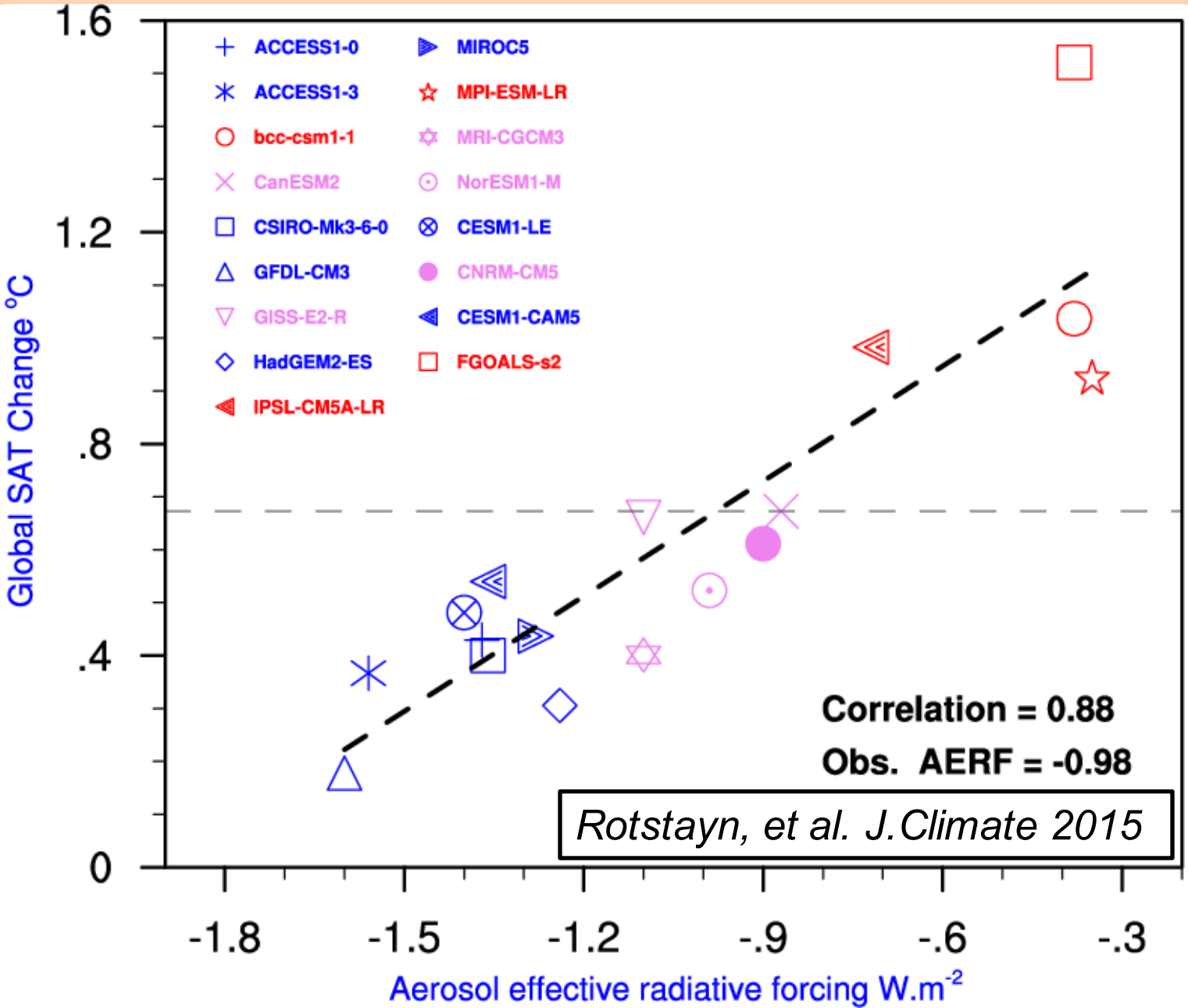
Approach based on constructed analogues

(Van den Dool 1984)

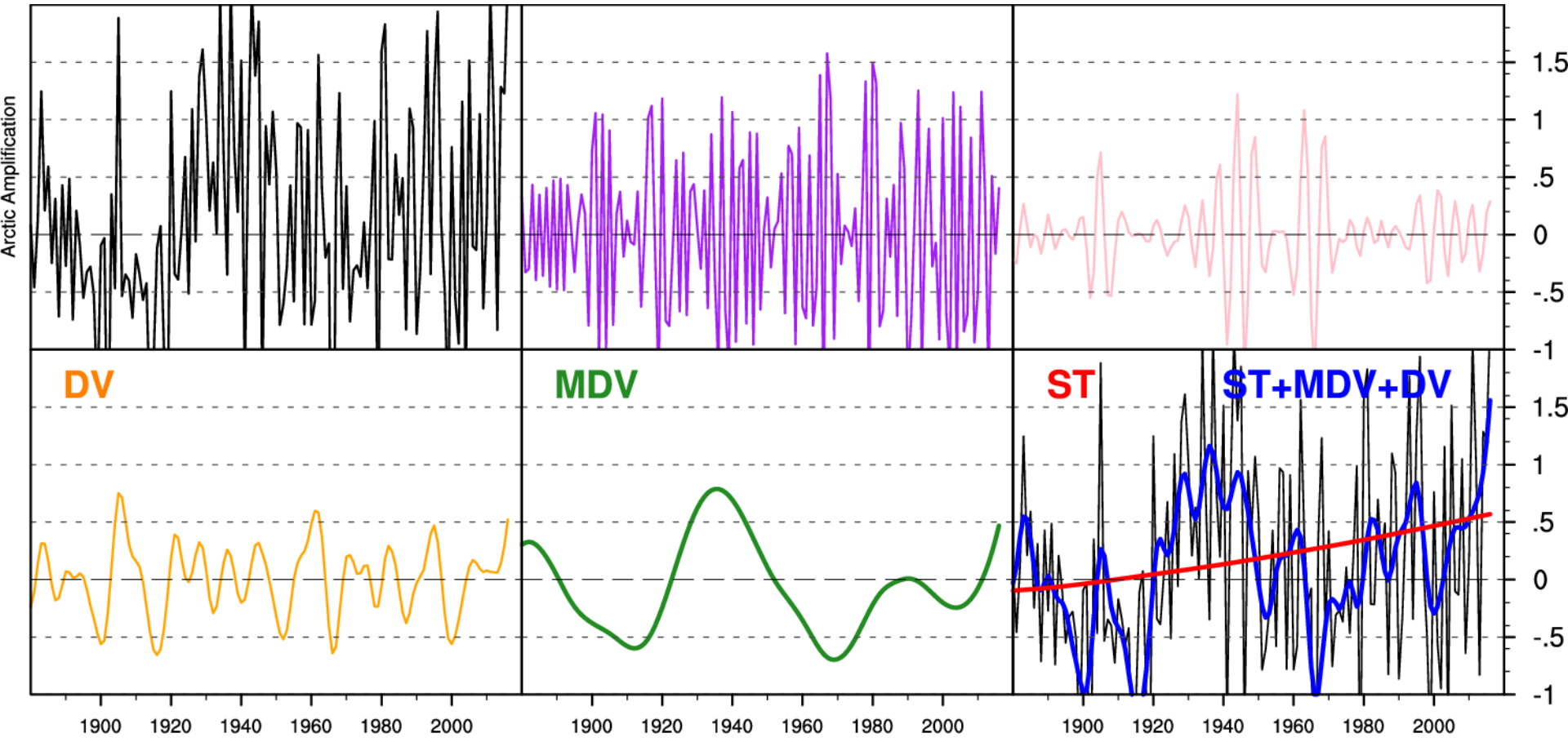
Application aux observations: on retranche l'effet anthropique sur les températures avant d'estimer les températures associées à un changement de circulation

Deser, Terray, Phillips J.Climate 2016

AA Drivers: aerosols

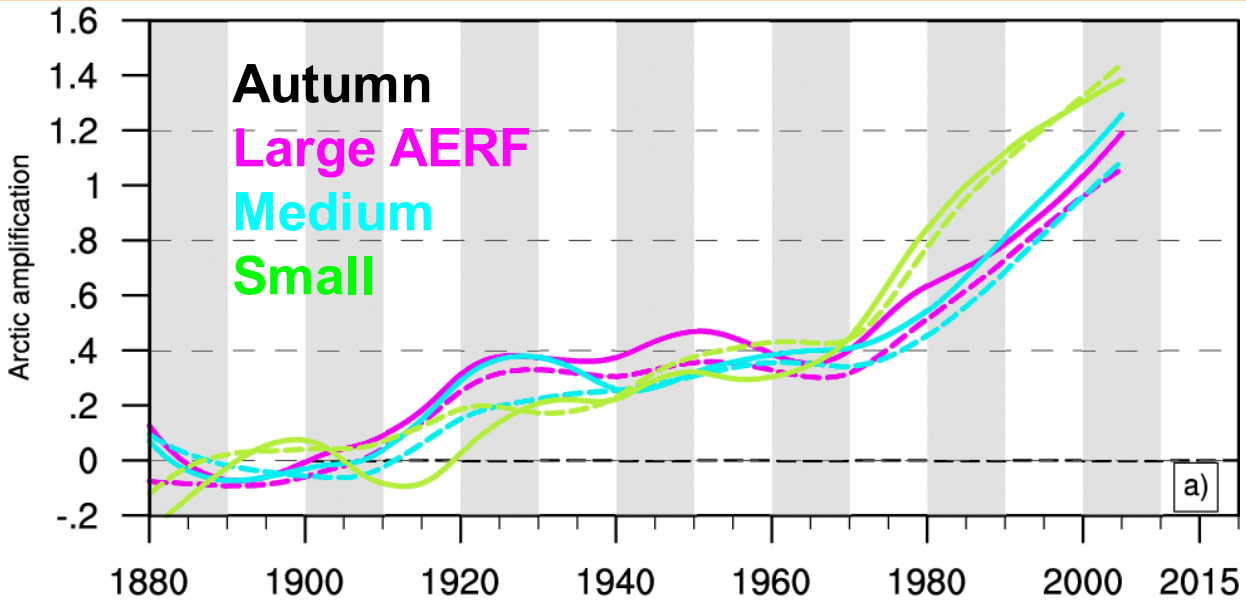


AA Winter: EEMD modes



AA Drivers: aerosols

Deg. K



Deg. K