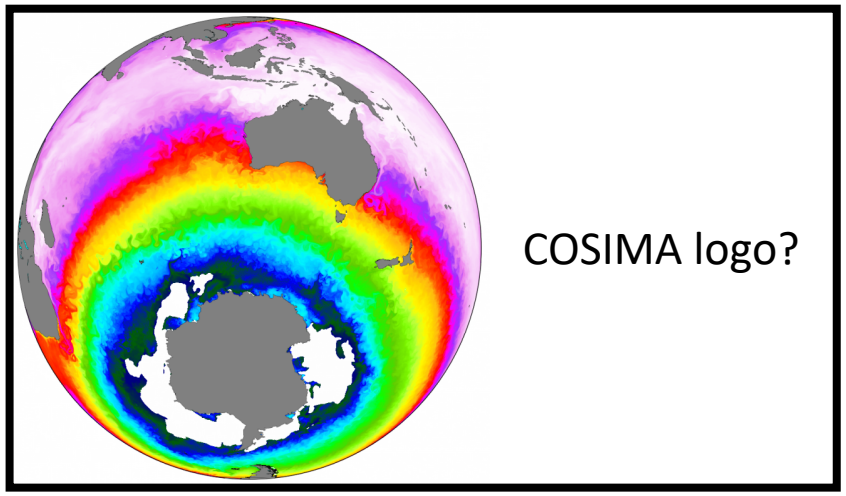
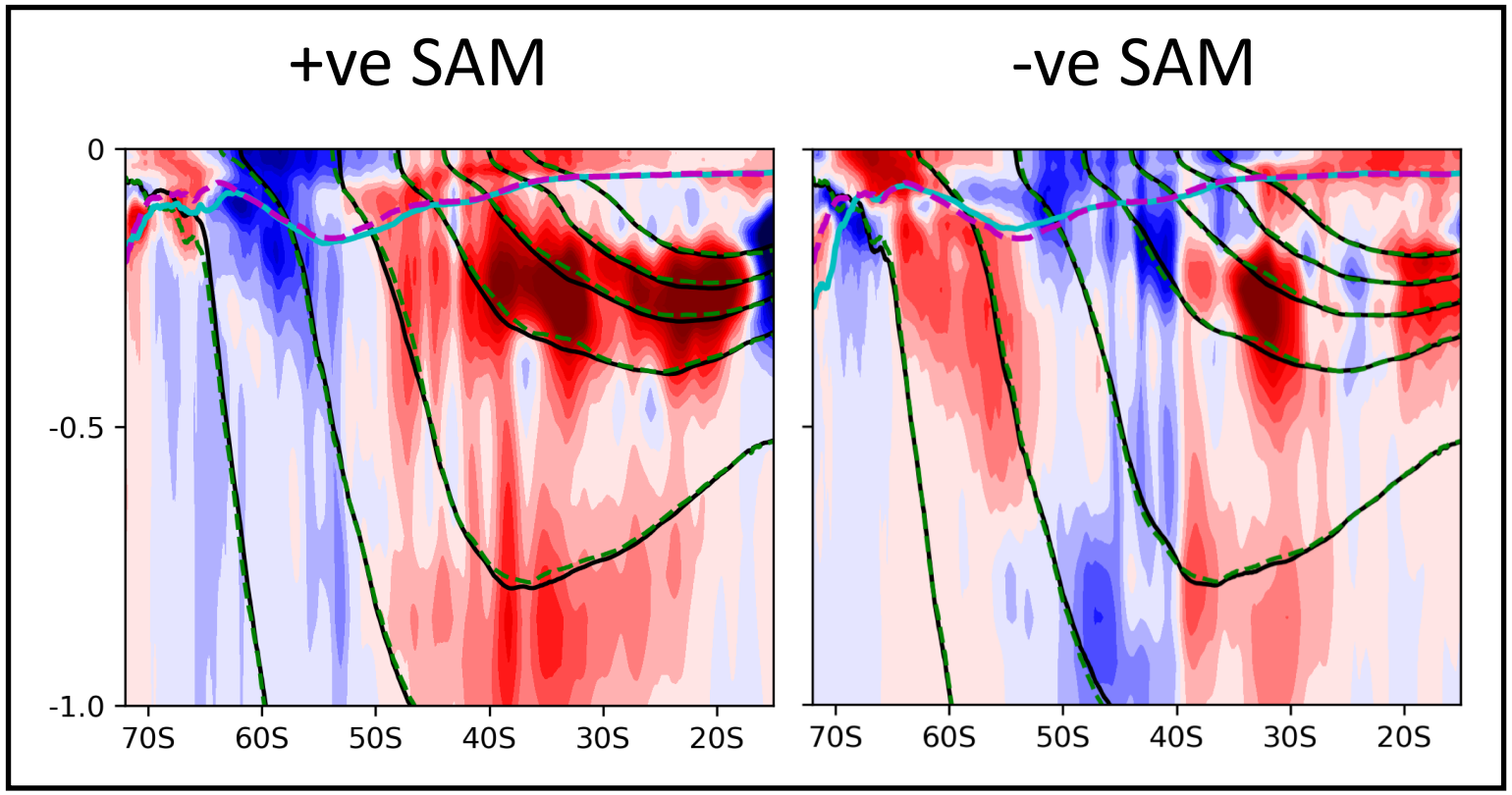
Southern Ocean response to extreme SAM conditions

Kial Stewart, Andy Hogg & Matt England



COSIMA logo?



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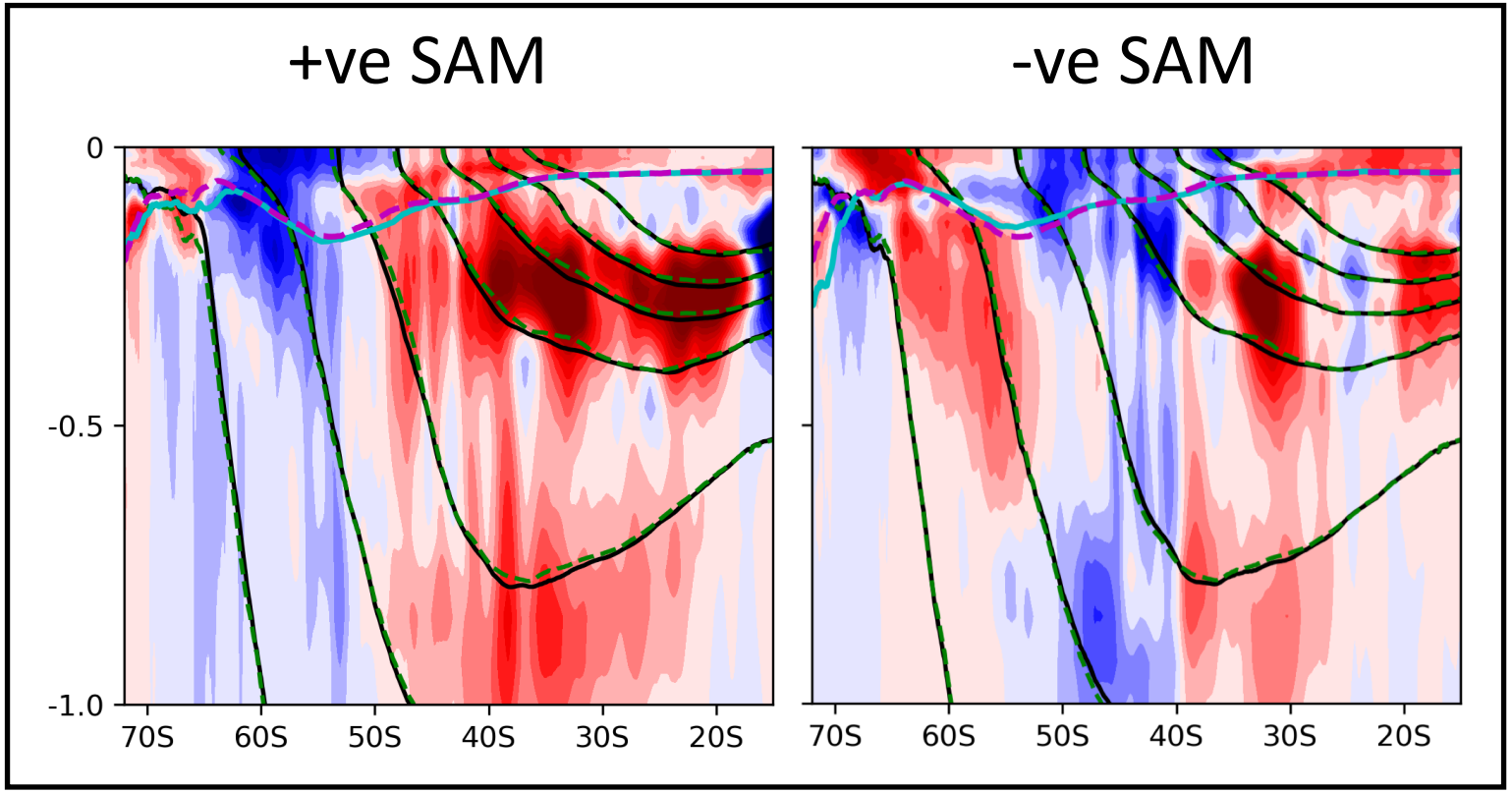
Are “realistic” forcing perturbations a useful approach?

Examine the temporal evolution of the Southern Ocean response to a step change in forcing.

Identify potential metrics for diagnosing/predicting SAM-related changes of the Southern Ocean.



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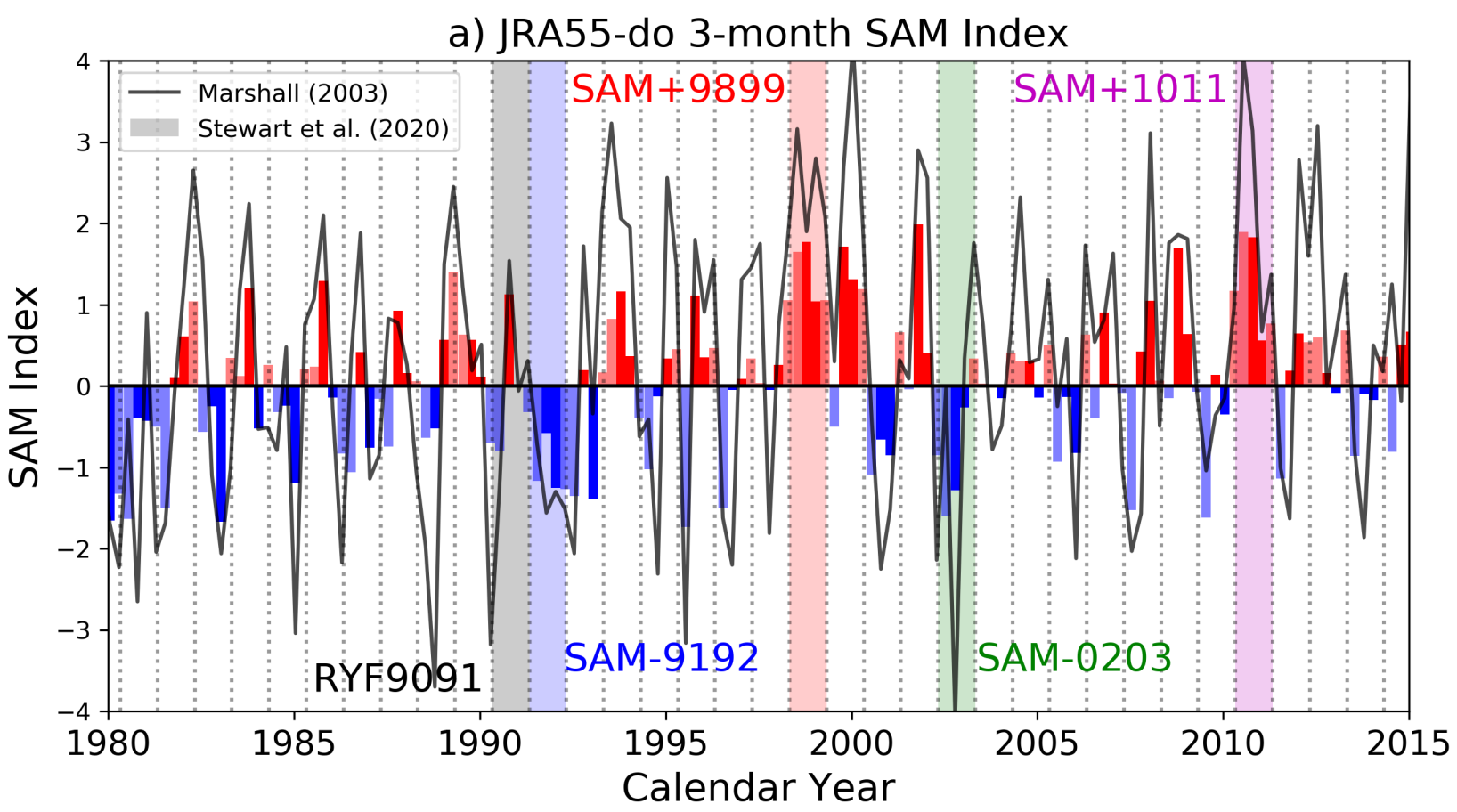

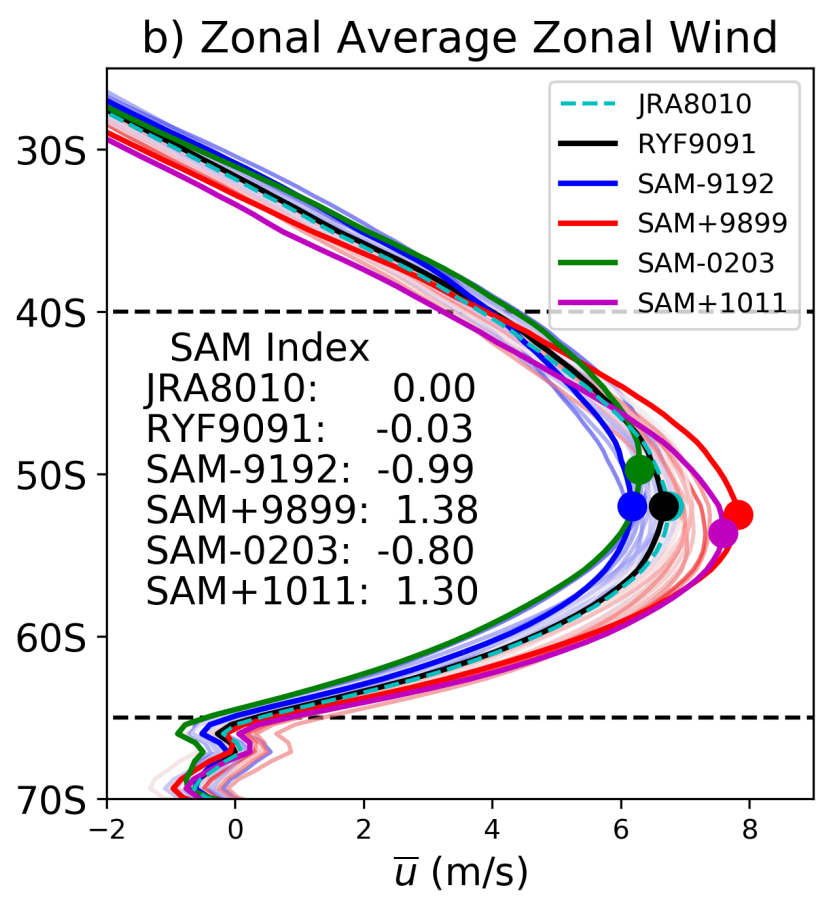

Timeseries of 3-month SAM Index from JRA55-do (bars) and the Marshall (2003) station-based observations (line)

Identify 12-month periods (1st May – 30th April) of extreme +ve and –ve SAM

Compare zonal average zonal winds: clear dependence of strength and location with SAM

Use SAMx periods to drive perturbation simulations branched from RYF9091 control simulation

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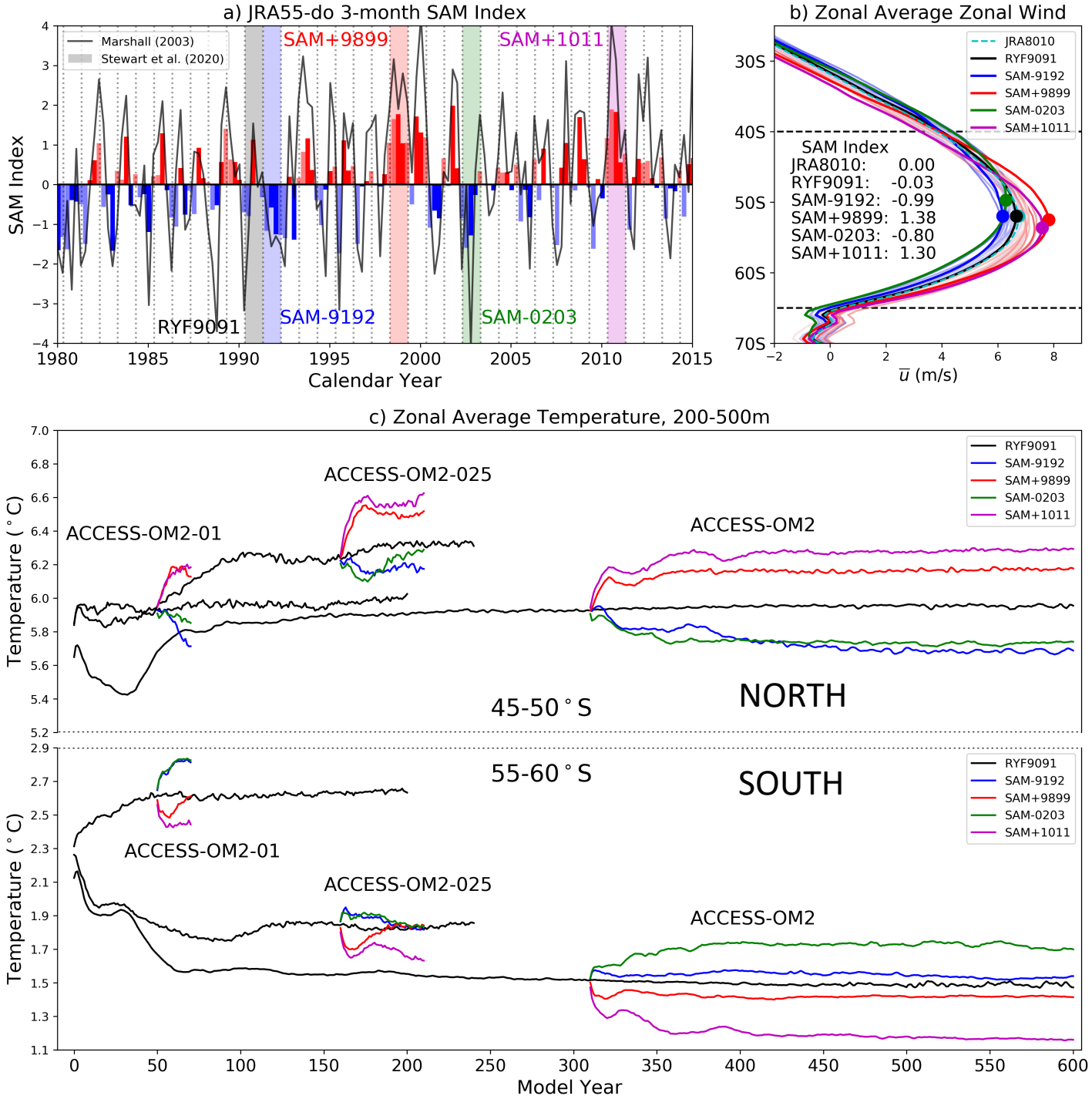
All 3 ACCESS-OM2 configurations: 1°, 0.25° & 0.1°

Spin-up with RYF9091: 310, 160 & 50 years

Branch off SAMx perturbations: 290, 50 & 20 years

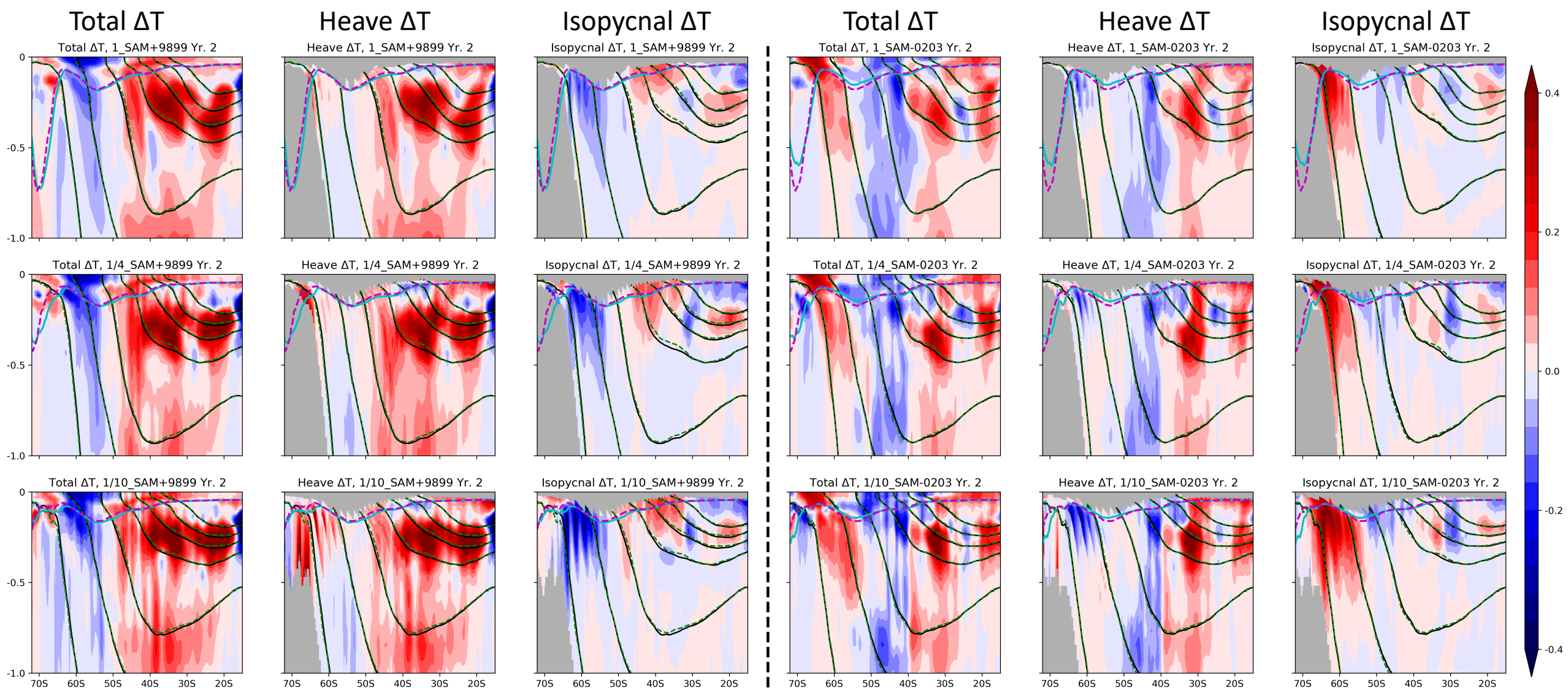
Timeseries of annual average zonal average temperatures between 200-500m north and south of wind speed maximum



Zonal average temperature anomaly: SAMx - RYF9091 Year 2

+ve SAM

-ve SAM

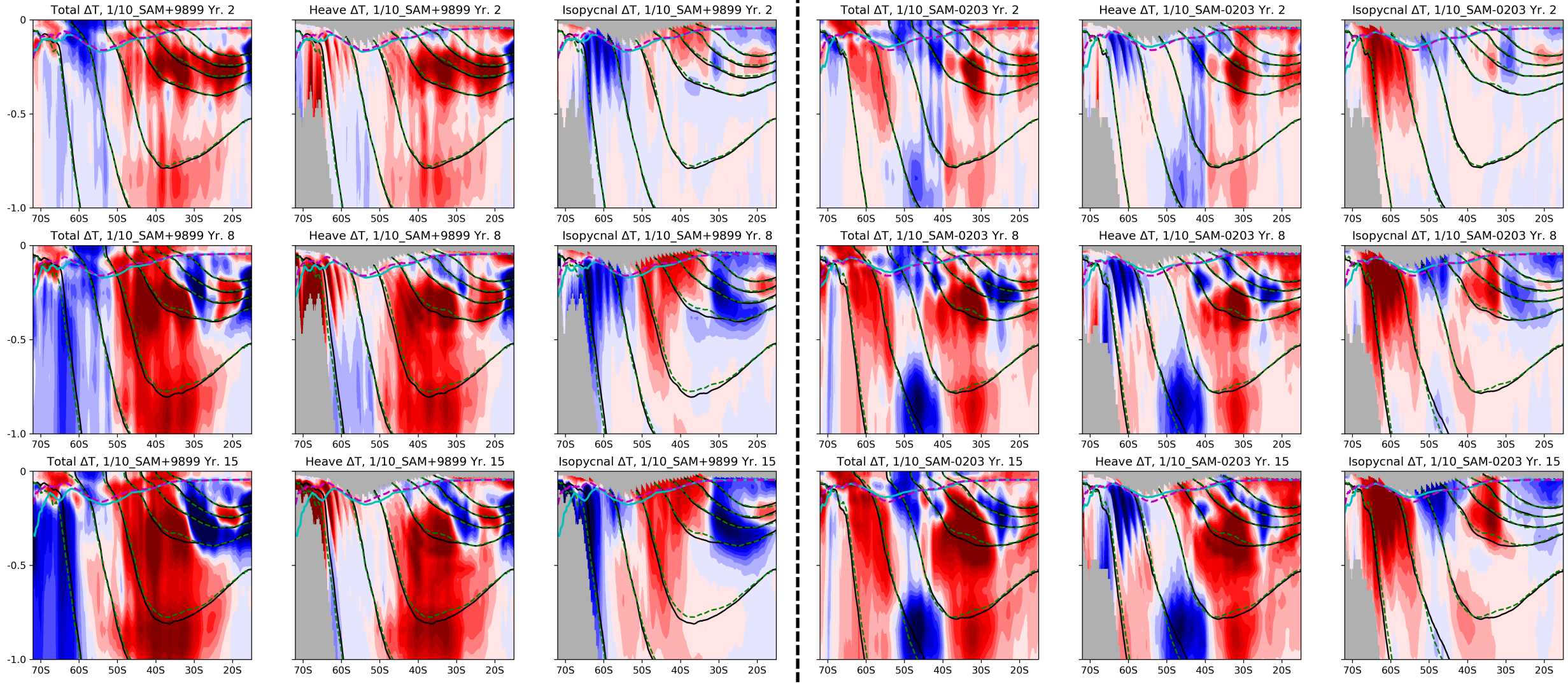


Zonal average temperature anomaly: SAMx - RYF9091
ACCESS-OM2-01 Years 2, 8, 15

+ve SAM

-ve SAM

Total ΔT | Heave ΔT | Isopycnal ΔT | Total ΔT | Heave ΔT | Isopycnal ΔT



Proposed mechanism:

-changes in the wind stress $\boldsymbol{\tau}$ leads to changes in the Ekman pumping

Ekman pumping velocity

$$w_{Ek}(x,y,t) = \frac{\nabla \times \tau(x,y,t)}{\rho_0 f(y)}$$

Characterise and compare changes in w_{Ek} to model output diagnostics:

Ekman streamfunction in latitude space

$$\Psi_{Ek}(y,t) = \int_{90^\circ S}^{y} \int w_{Ek}(x,y',t) dx dy'$$

Ekman streamfunction in density space

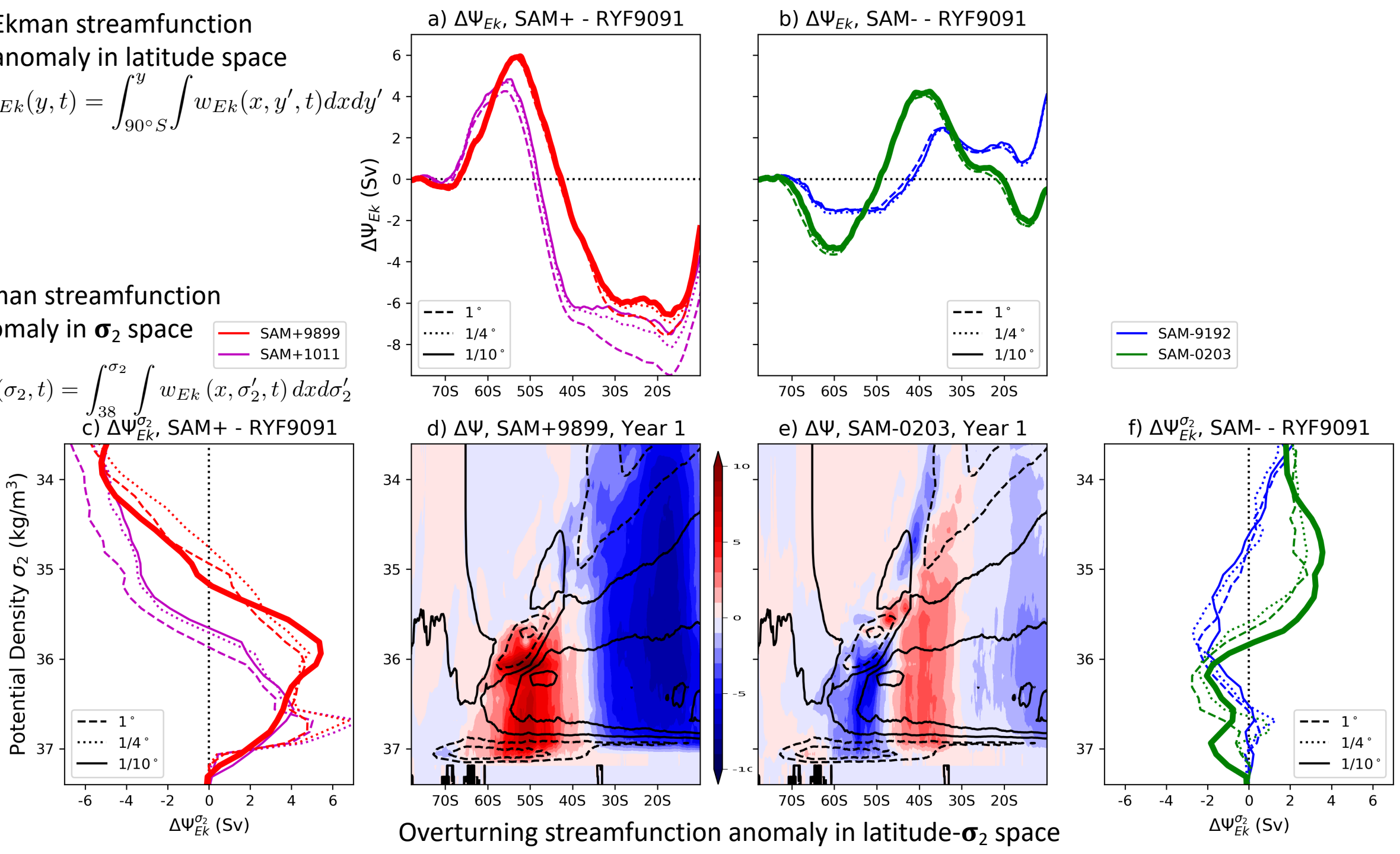
$$\Psi_{Ek}^{\sigma_2}(\sigma_2,t) = \int_{38}^{\sigma_2} \int w_{Ek}(x,\sigma_2',t)\, dx d\sigma_2'$$

Ekman streamfunction anomaly in latitude space

$$\Psi_{Ek}(y,t) = \int_{90^\circ S}^{y} \int w_{Ek}(x,y',t)\,dx\,dy'$$

Ekman streamfunction anomaly in $\boldsymbol{\sigma_2}$ space

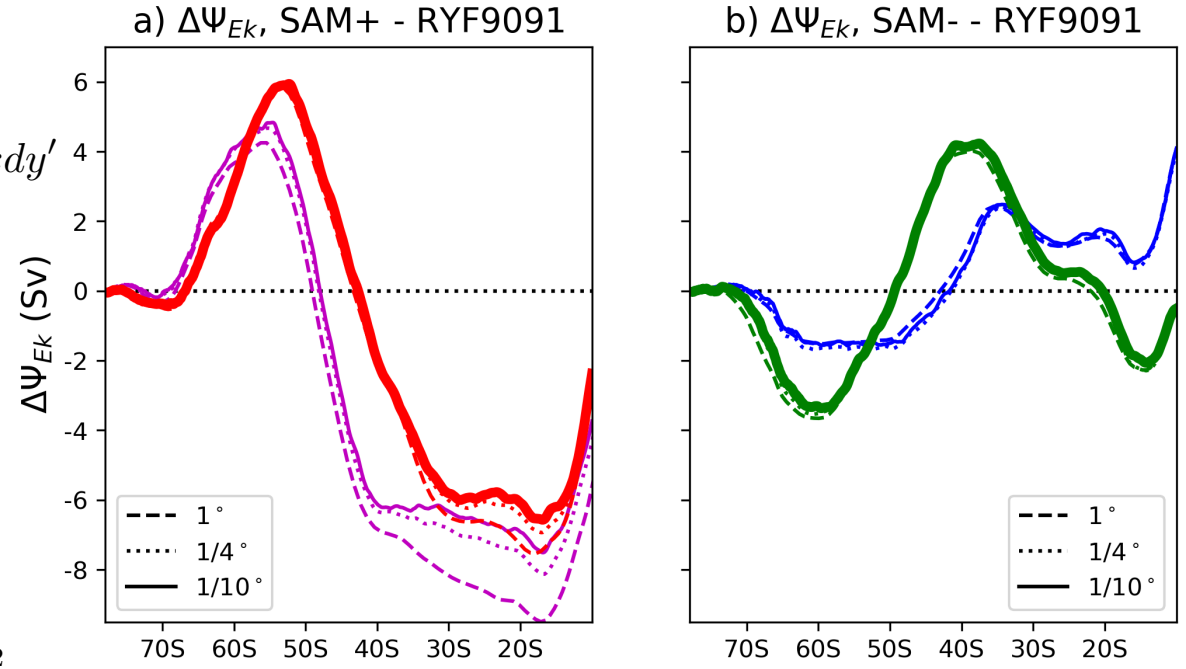
$$\Psi_{Ek}^{\sigma_2}(\sigma_2,t) = \int_{38}^{\sigma_2} \int w_{Ek}(x,\sigma_2',t)\,dx\,d\sigma_2'$$



Overturning streamfunction anomaly in latitude-$\boldsymbol{\sigma_2}$ space

Ekman streamfunction anomaly in latitude space

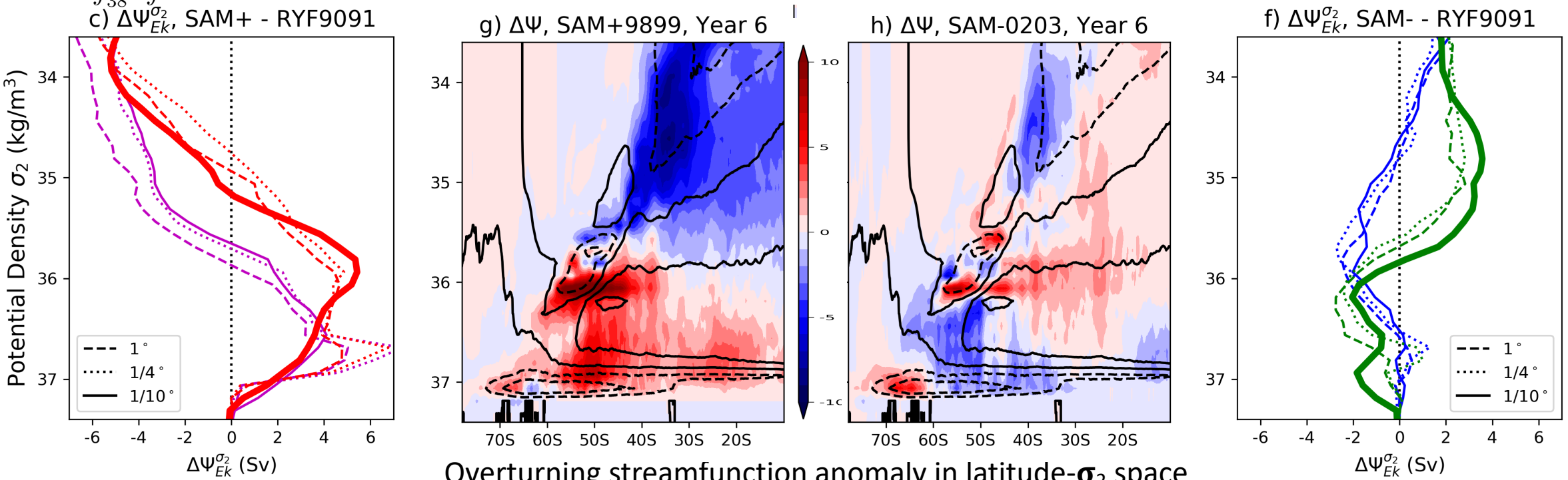
$$\Psi_{Ek}(y,t) = \int_{90^\circ S}^{y} \int w_{Ek}(x,y',t)\,dx\,dy'$$



Ekman streamfunction anomaly in $\boldsymbol{\sigma_2}$ space

$$\Psi_{Ek}^{\sigma_2}(\sigma_2,t) = \int_{38}^{\sigma_2} \int w_{Ek}(x,\sigma_2',t)\,dx\,d\sigma_2'$$

SAM+9899
SAM+1011
SAM-9192
SAM-0203



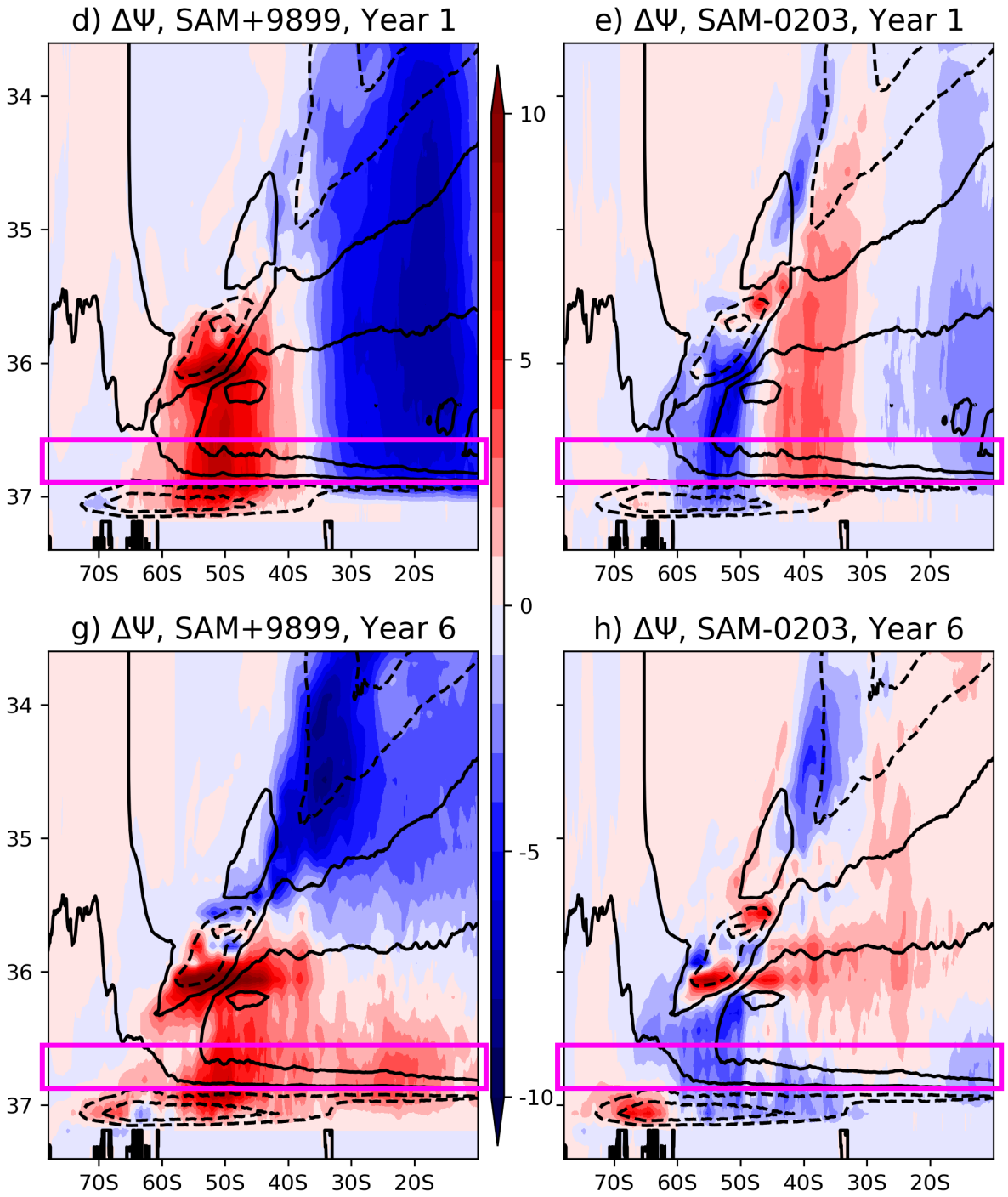
Overturning streamfunction anomaly in latitude-$\boldsymbol{\sigma_2}$ space

+ve SAM

-ve SAM

Streamfunction anomaly Year 1

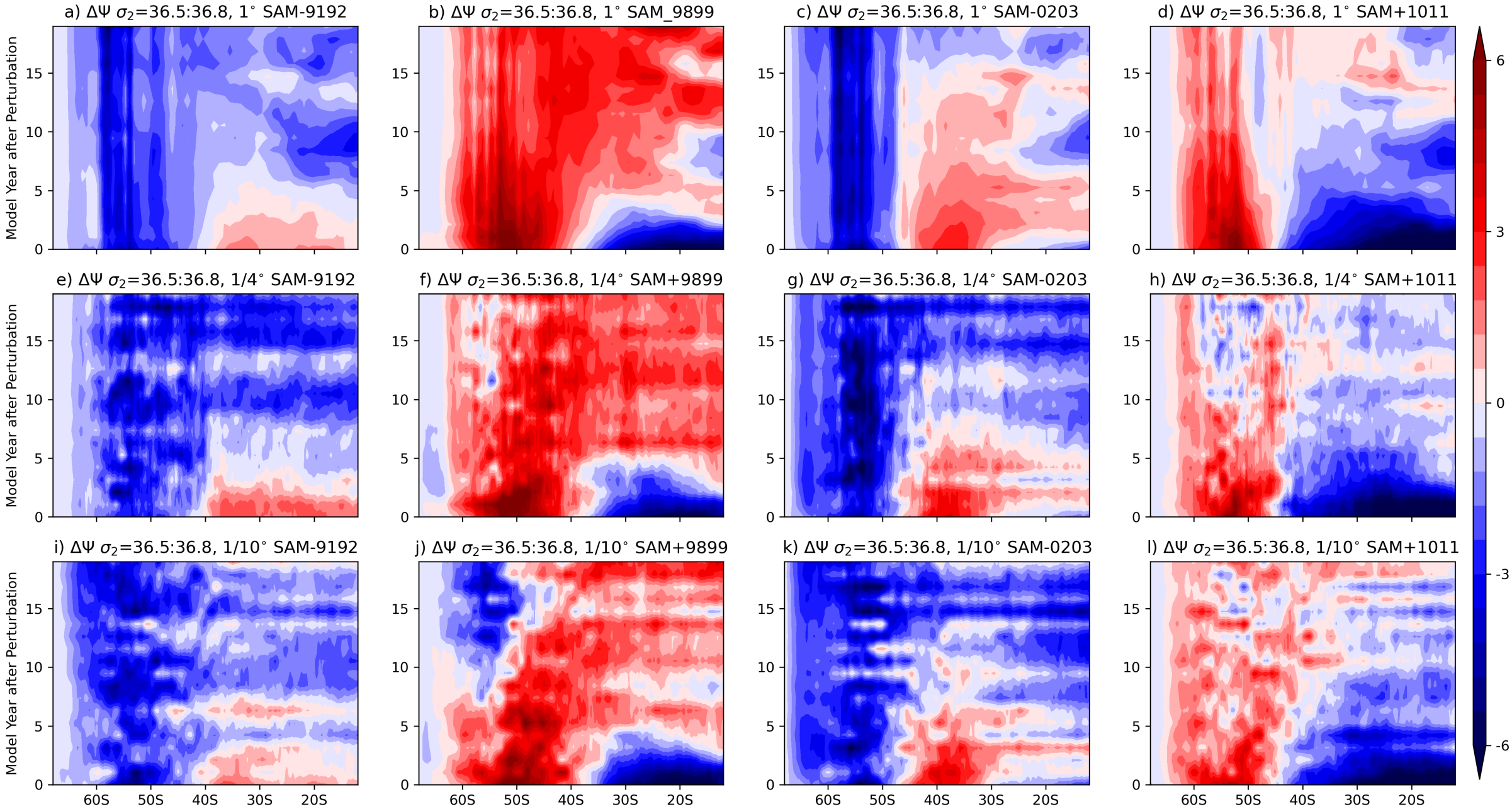
Streamfunction anomaly Year 6



Initially “barotropic”…

becomes “baroclinic”.

Hovmöllers of ΔΨ for $\boldsymbol{\sigma_2}$ = 36.5..36.8



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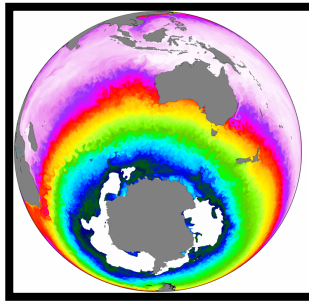
SUMMARY

Are “realistic” forcing perturbations a useful approach?

Examine the temporal evolution of the Southern Ocean response to a step change in forcing.

Identify potential metrics for diagnosing/predicting SAM-related changes of the Southern Ocean.

Yes. Provides both +ve and –ve anomalies.



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Thermal response depends on location relative to the wind speed maximum; strongest thermal response is isopycnal ΔT south of wsm, ±0.2^{o}C/decade. Overturning response is awesome.

Ekman streamfunction is derivable from satellite products and can give insight into the initial (latitude) and ongoing ($\boldsymbol{\sigma}_2$) overturning circulation response.