2015 AOFD

Dynamic Partition on the Stratosphere-Troposphere Exchange (STE) of Air Mass along Isentropic Surface

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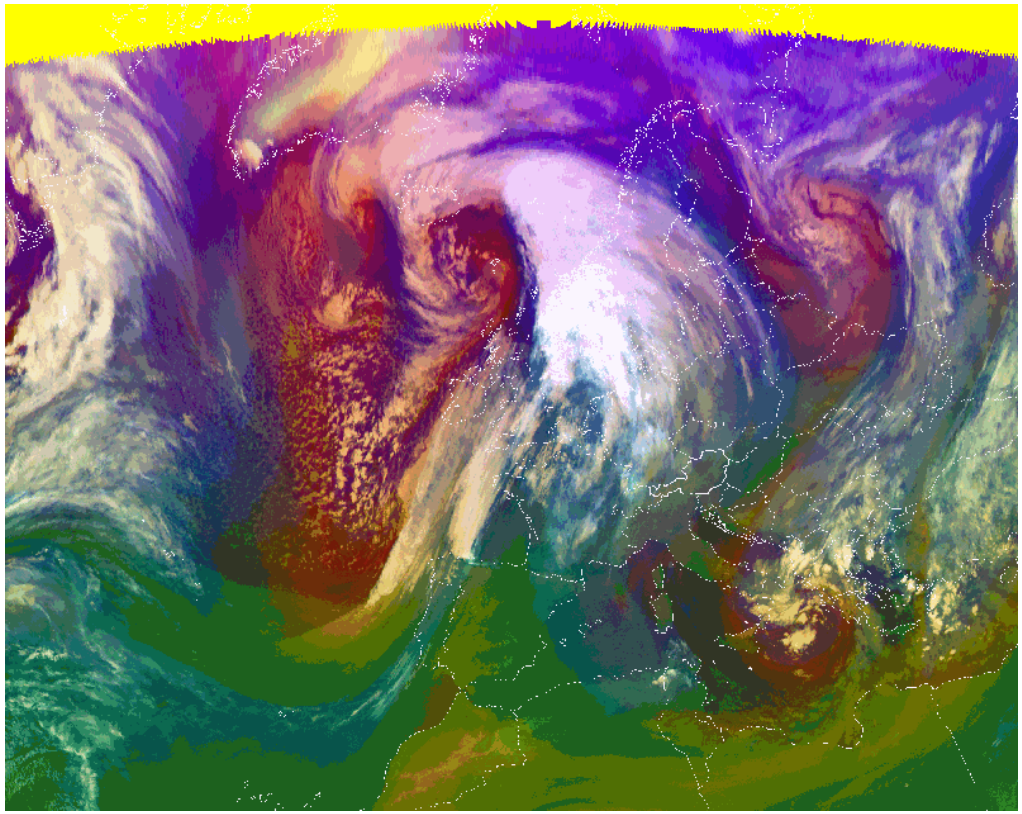
Introduction

Meteosat Second Generation (MSG) satellites **(EUMETRAIN)**



Air mass RGB loop from 03:00 UTC – 09:00 UTC, 29 Dec. 2012

Blue – moist polar air

Green – tropical air

Red – dry stratospheric air intrusion (STE)

Introduction

Impact one:

STE → stratos column ozone → surface radiation

(Hegglin and Shepherd 2009)

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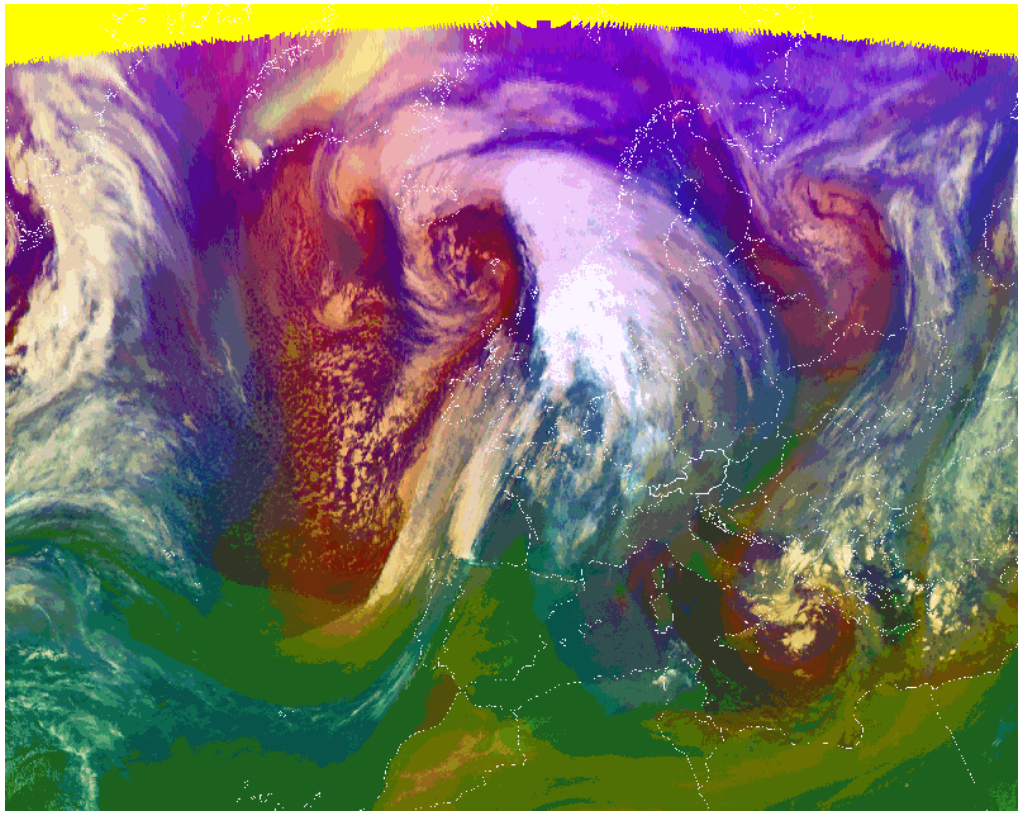

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Introduction

Impact one:

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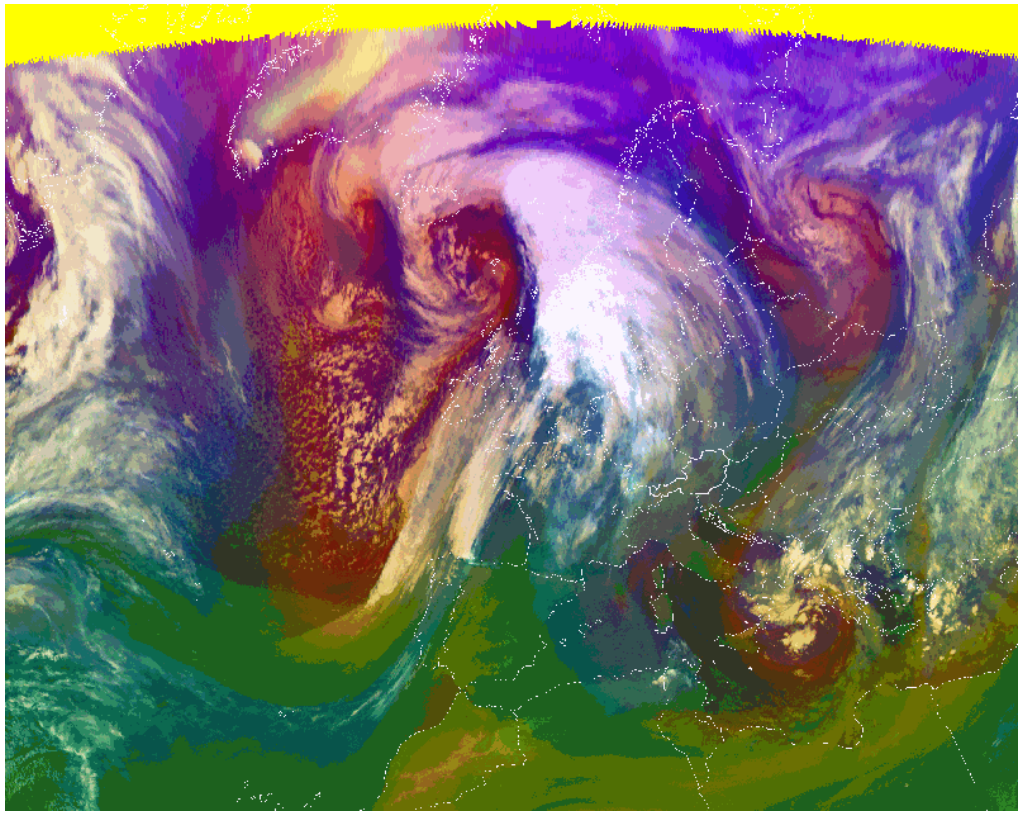
(Hegglin and Shepherd 2009)

Impact two:

STE → ozone → H_2O, CH_4 → atmos. chemistry

(Kentarchos et al. 2003
Lin et al. 2012
Fiore et al. 2002)

Meteosat Second Generation (MSG) satellites **(EUMETRAIN)**



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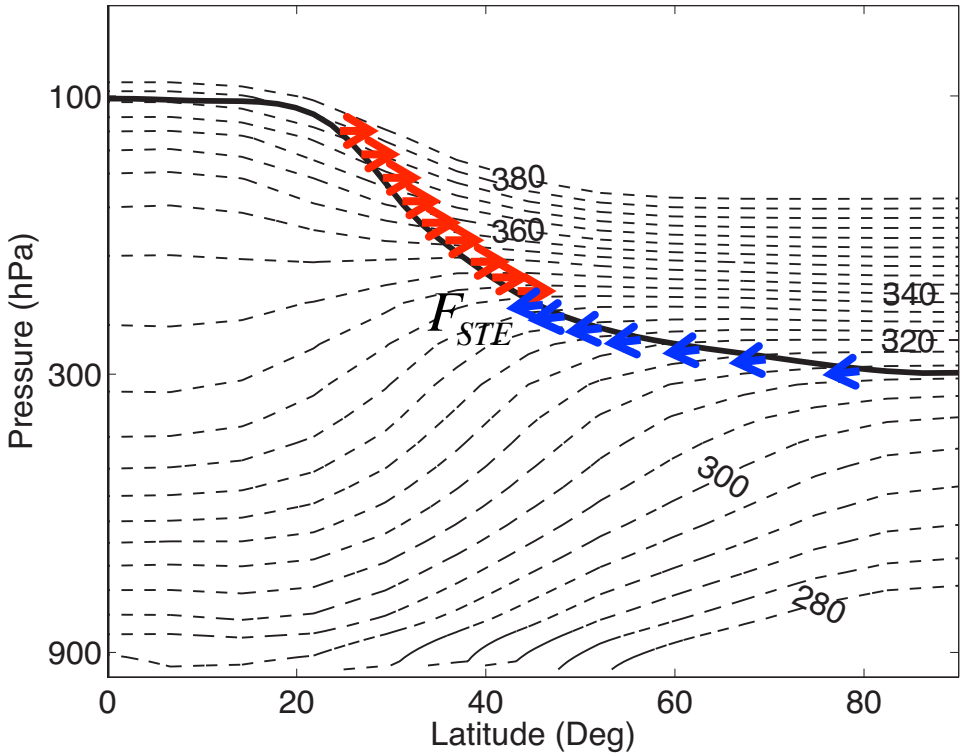
Isentropic STE diagnostic

Nakamura, 2007

- diagnosing STE along individual isentropic surface (i.e. isentropic STE, F_{STE})
- a vertical series of isentropic STE approximately represents its meridional distribution

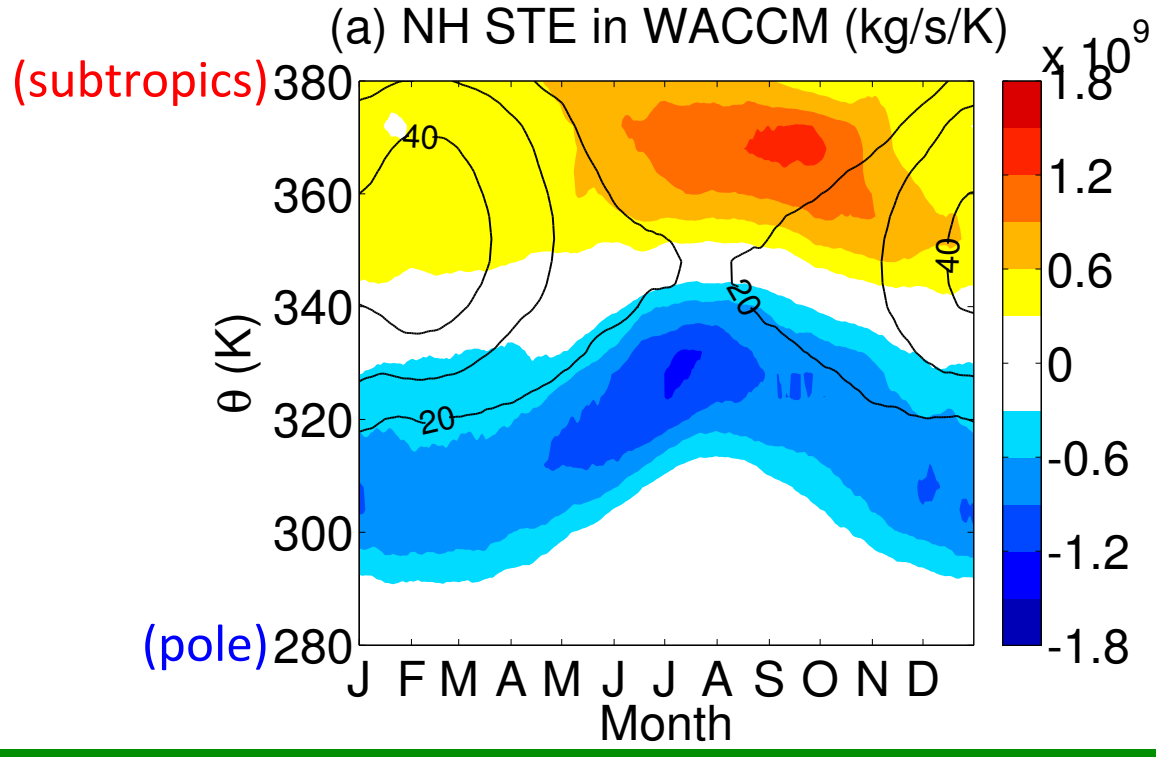


High isentropes <-> **Low latitudes** Low isentropes <-> **High latitudes**

Isentropic STE (colors) w/ zonal wind (contours)

WACCM

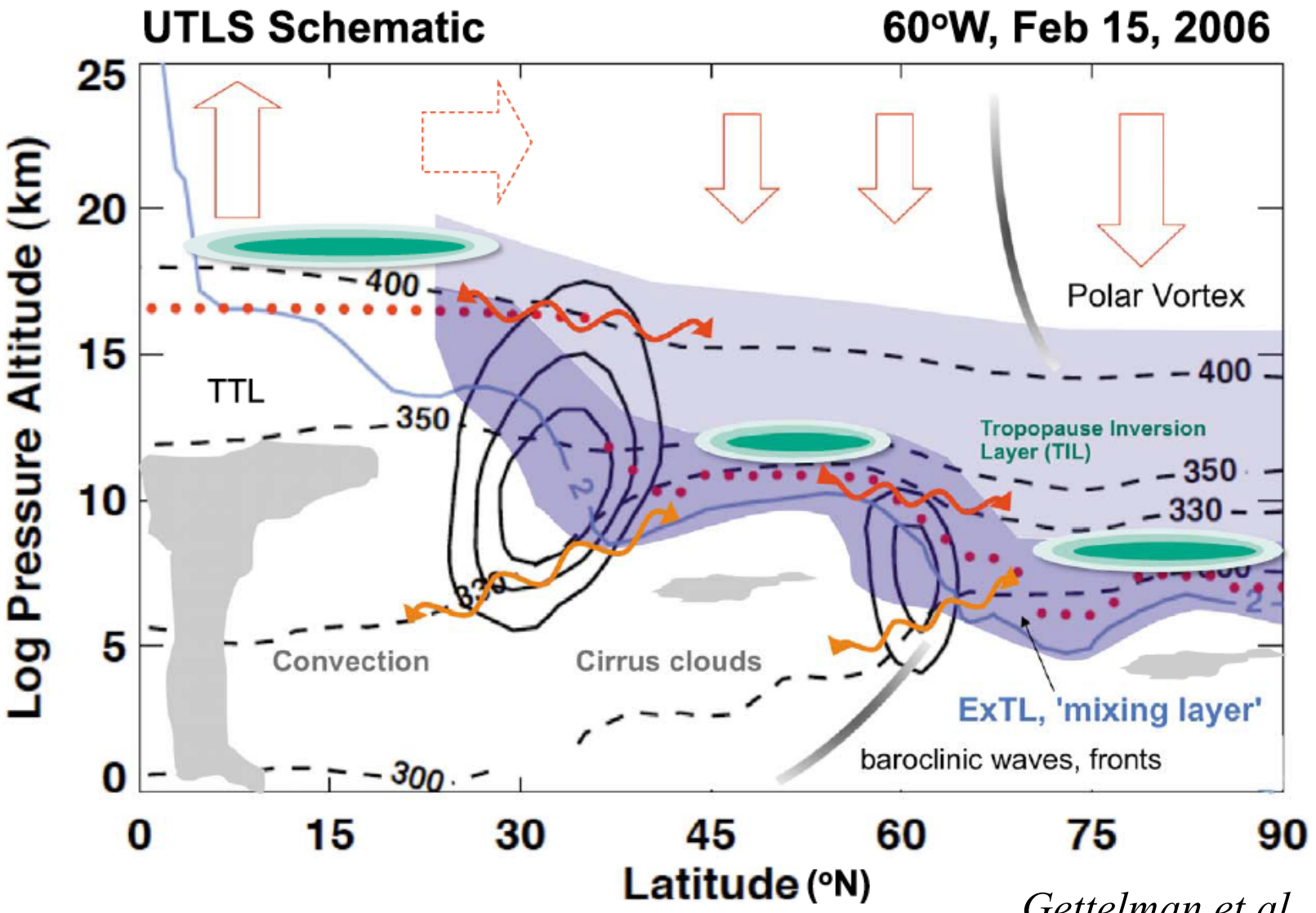
Whole Atmosphere Community Climate Model (1991-2009, 19-yr control run)
Focus on the **NH**, as SH is similar.



- Troposphere-to-stratosphere (upward) STE on higher isentropes (subtropics), stratosphere-to-troposphere (downward) STE on lower isentropes (extratropics)
- Maximum downward STE occurs on the poleward flank of the tropospheric jet, and moves seasonally with the jet

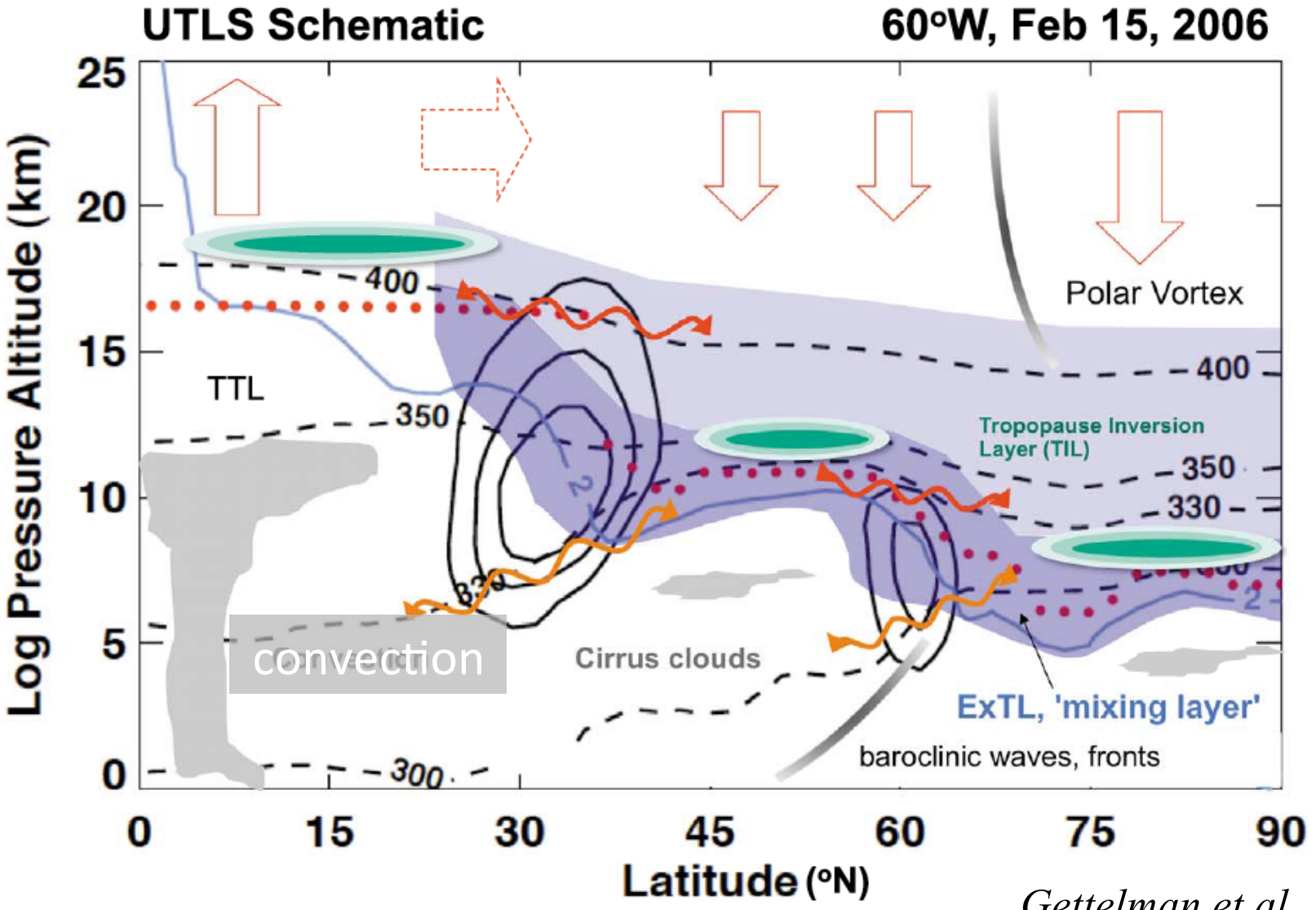
When and where STE occurs?

Processes controlling the STE



Gettelman et al. 2011

What cause this spatial distribution of STE?



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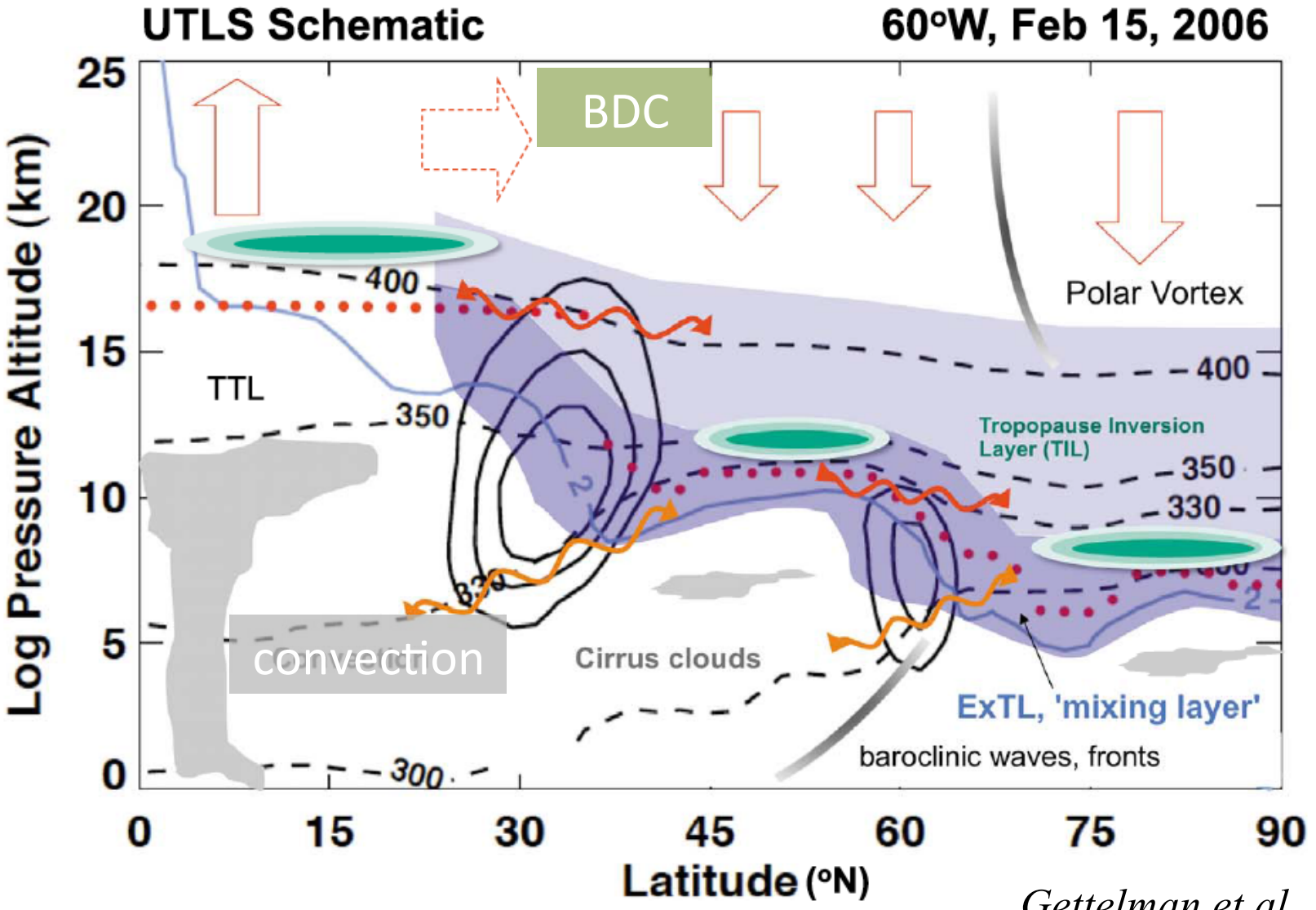

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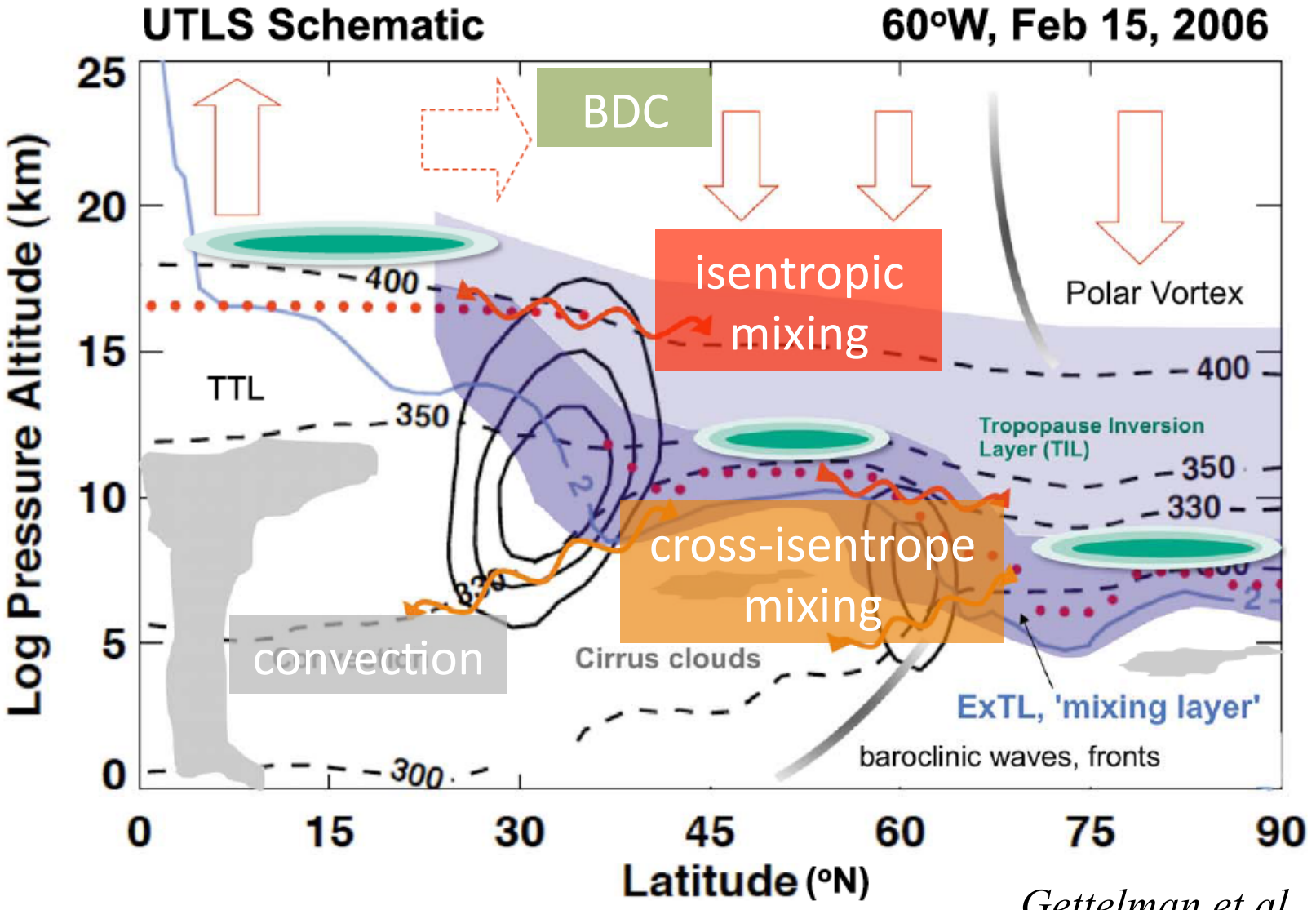


Gettelman et al. 2011

Dynamic Partition – PV Sources

$$F_{STE} = -\frac{\partial M(\dot{q})}{\partial q}\Big|_{q=Q}$$

STE flux (F_{STE}) across a potential vorticity (PV) tropopause Q is affected by the PV tendency dq/dt.

where $M(\cdot) = \int_{STRATO} \sigma(\cdot)\, dS$ denotes the air mass weighted integration in the stratosphere

$$\dot{q} = \dot{q}_K + \dot{q}_S$$

Isentropic Mixing

Differential Diabatic Heating

$$F_{STE} = F_{mix} + F_{dia}$$

residual component

directly calculated

where $F_{dia} = -\frac{\partial M(\dot{q}_S)}{\partial q}\Big|_{q=Q}$

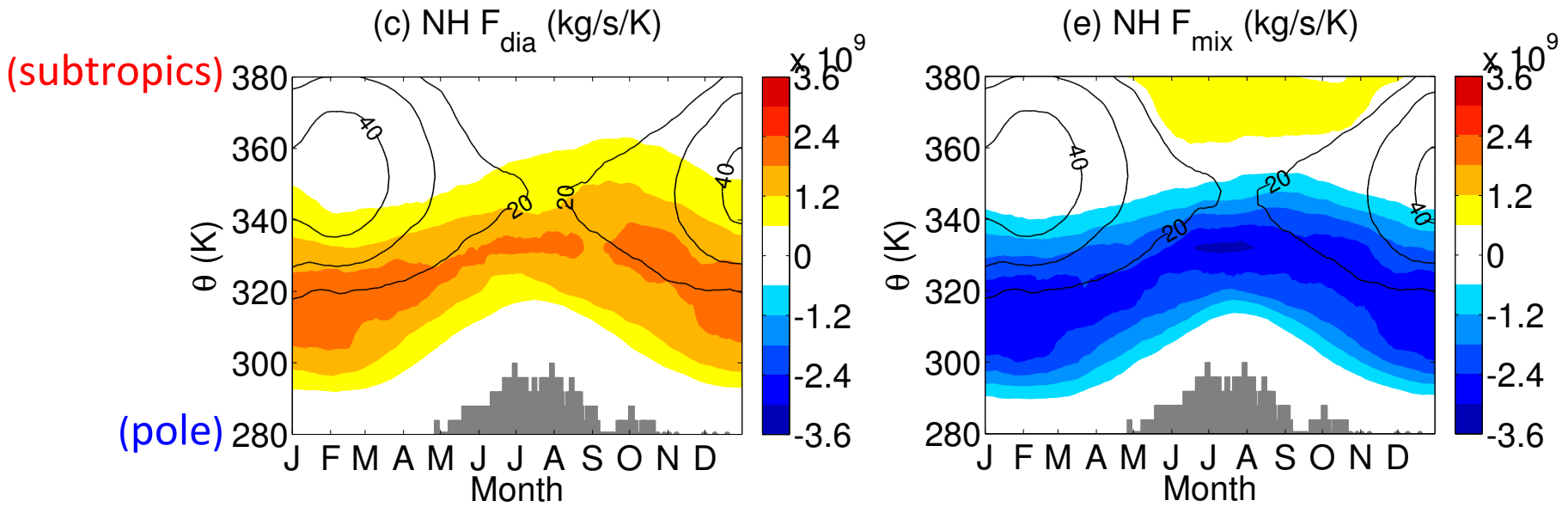
and $\dot{q}_S = \frac{q}{\sigma}\frac{\partial}{\partial \theta}(\sigma\dot{\theta})$

σ isentropic density
θ isentropic temperature
$\dot{\theta}$ diabatic heating rate

F_{dia} and F_{mix}

F_{dia}
diabatic heating

F_{mix}
isentropic mixing



grey shades: underworld, no STE zone
contours: zonal winds

- Upward F_{dia} vs. downward F_{mix}
- Large cancellation

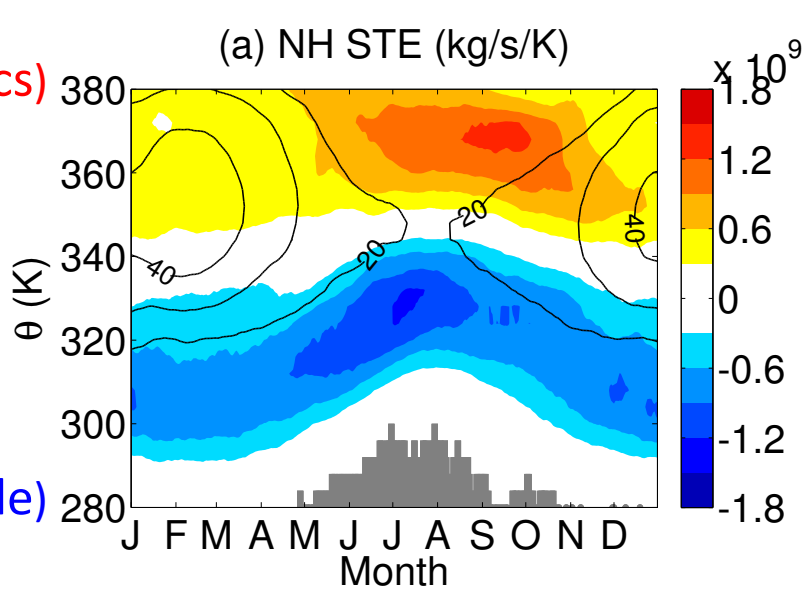
F_{STE} and F_{mix}

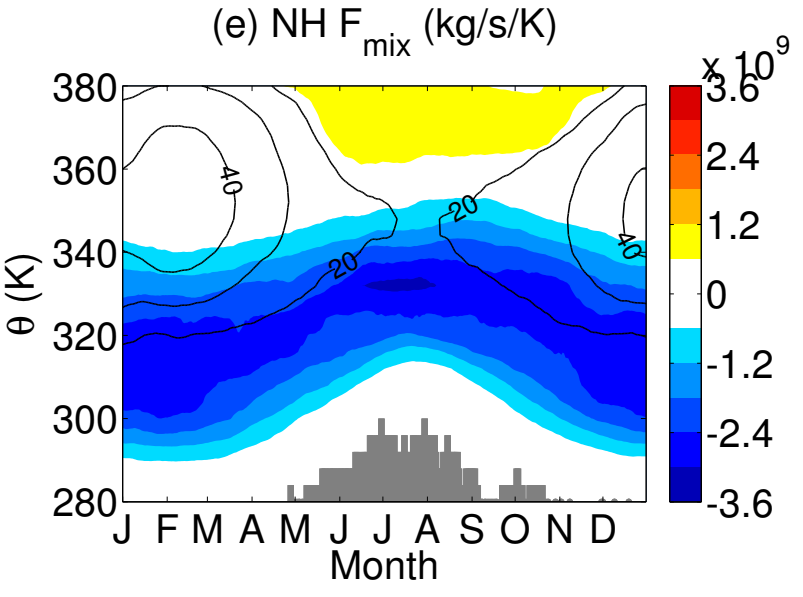
F_{STE}
net flux

F_{mix}
isentropic mixing

(subtropics)

(pole)





grey shades: underworld, no STE zone
contours: zonal winds

- $F_{dia} < F_{mix}$, the net flux F_{STE} displays a similar spatiotemporal pattern as F_{mix}

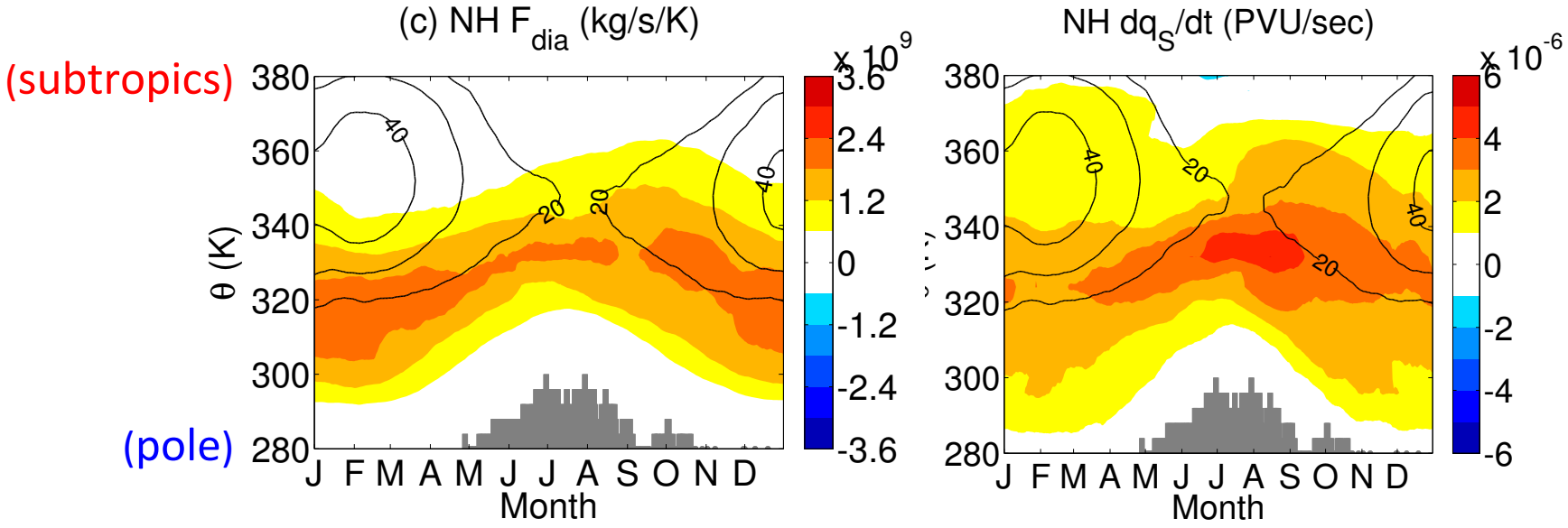
F_{dia} & diabatic heating

$$F_{dia} = -\frac{\partial M(\dot{q}_S)}{\partial q}\Big|_{q=Q} \propto \dot{q}_S\Big|_{q=Q}$$

PV tendency due to diabatic heating

F_{dia}
diabatic heaitng

dq/dt
diabatic heating



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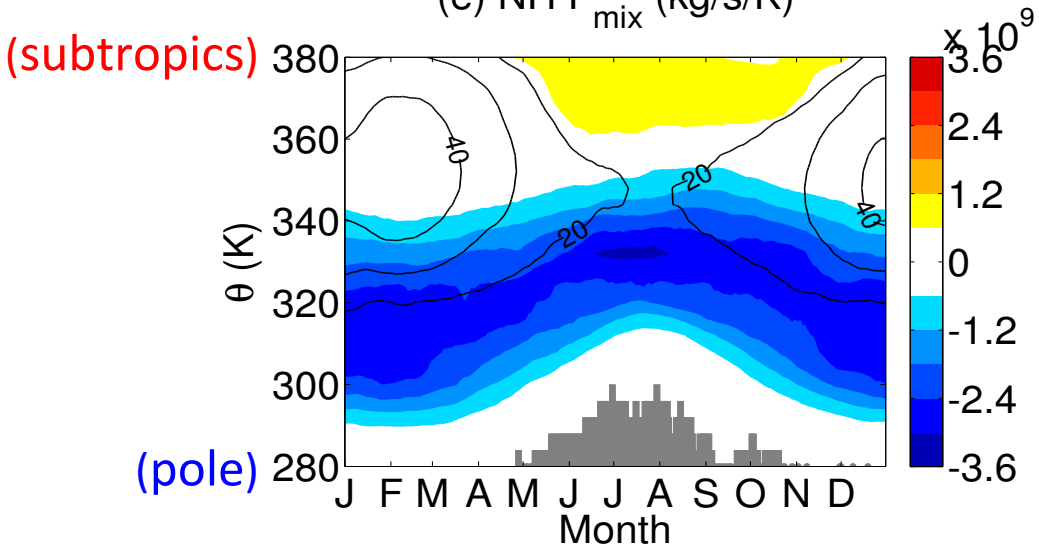
- Strong dq_S/dt <-> strong F_{dia}

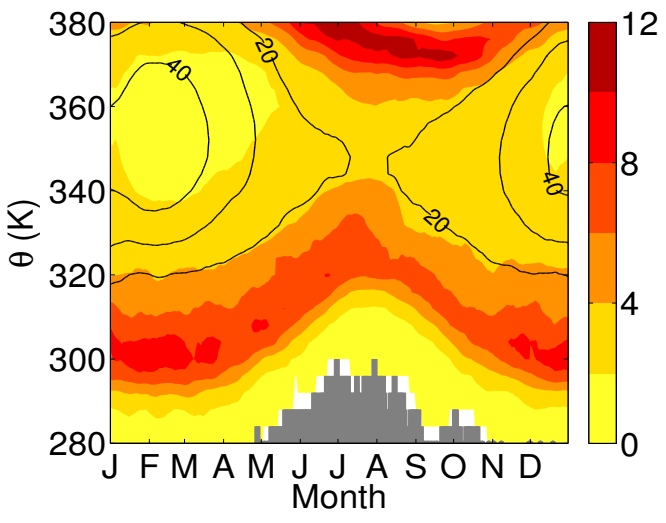
F_{mix} & isentropic mixing

F_{mix}
isentropic mixing



K_{eff}
equivalent length ratio

independently assess the extent of mixing solely on the distortion rate of PV contours



grey shades: underworld, no STE zone

contours: zonal winds

- Strong mixing <-> strong F_{mix}
- Poleward flank of jet: weak winds, strong mixing, and strong F_{mix}
- Jet core: strong winds, weak mixing, and weak F_{mix}

Consistency in the CMAM

WACCM

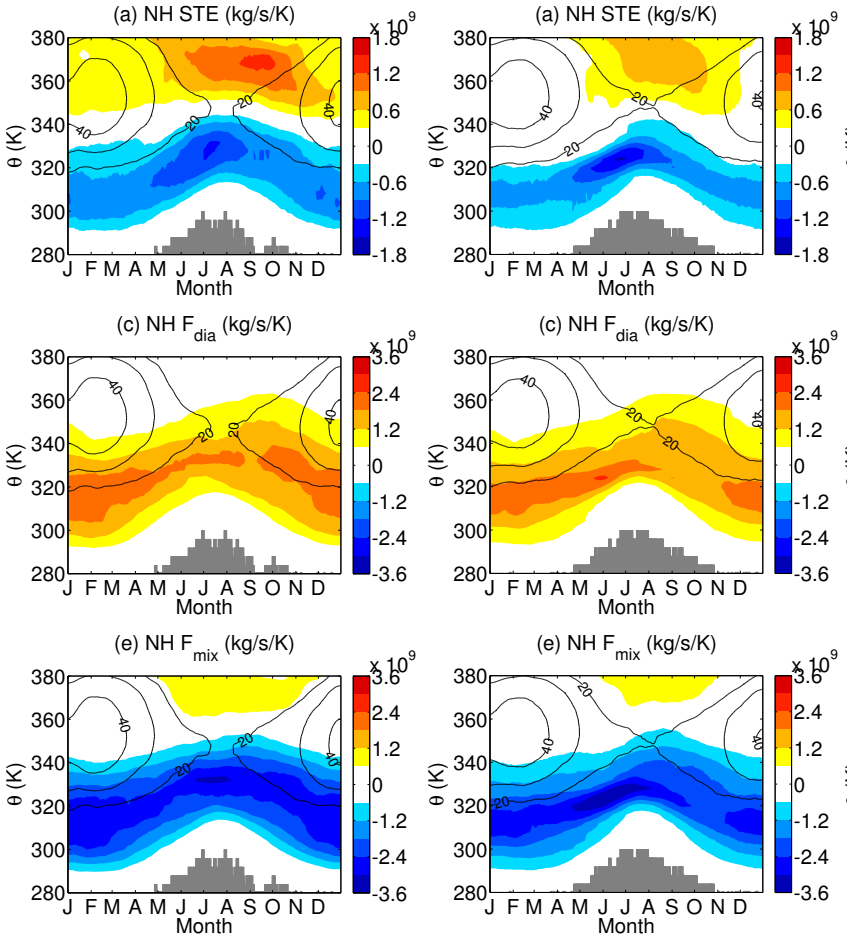
Whole Atmosphere Community Climate Model

(1991-2009, 19-yr control run)

CMAM

Canadian Middle Atmosphere Model

(1981-2010, 30-yr control run)

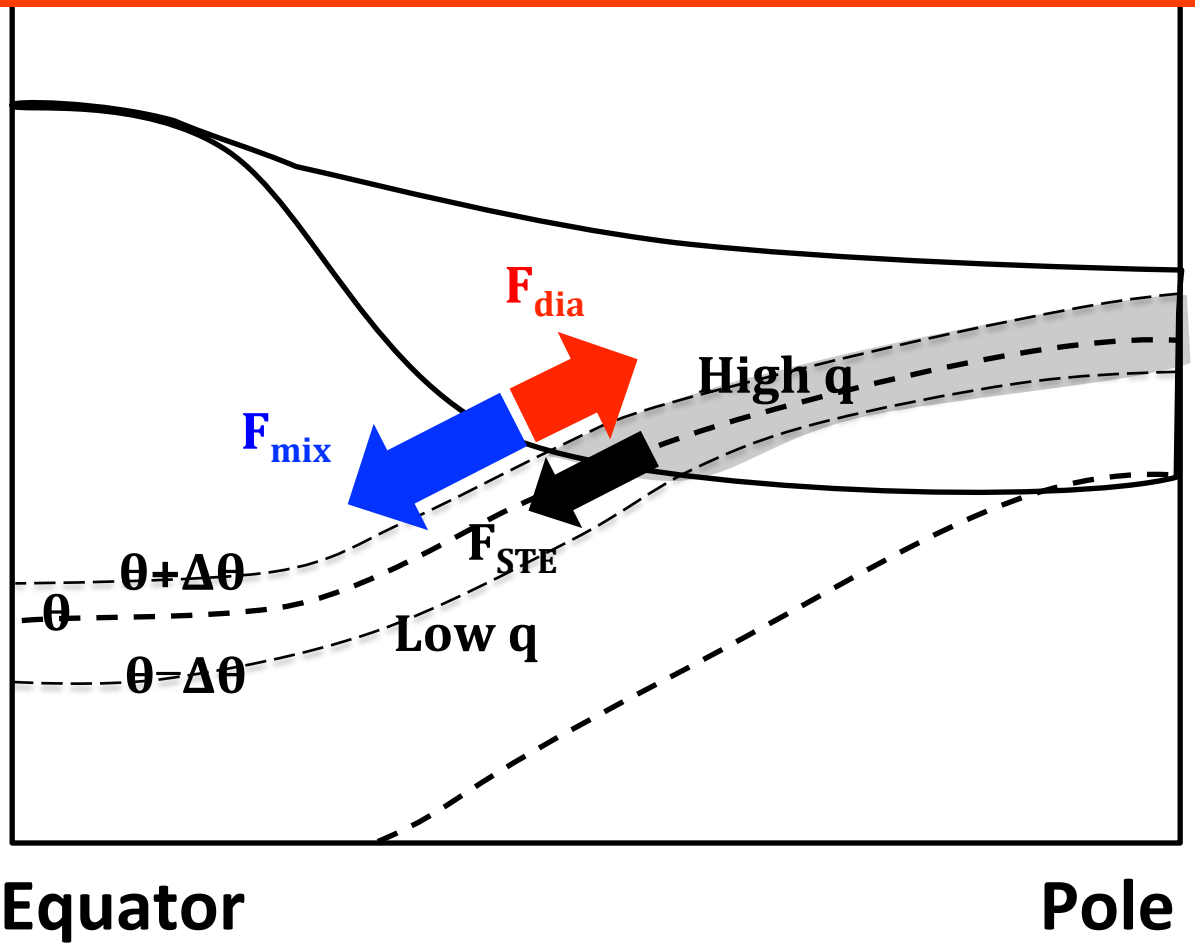


F_{STE}
net flux

F_{dia}
diabatic heating

F_{mix}
isentropic mixing

Summary



- Upward F_{dia} vs. downward F_{mix}, yielding downward F_{STE}
- F_{dia} – diabatic heating: positive dq/dt, descending tropopause height
- F_{mix} – isentropic mixing: negative dq/dt, ascending tropopause height