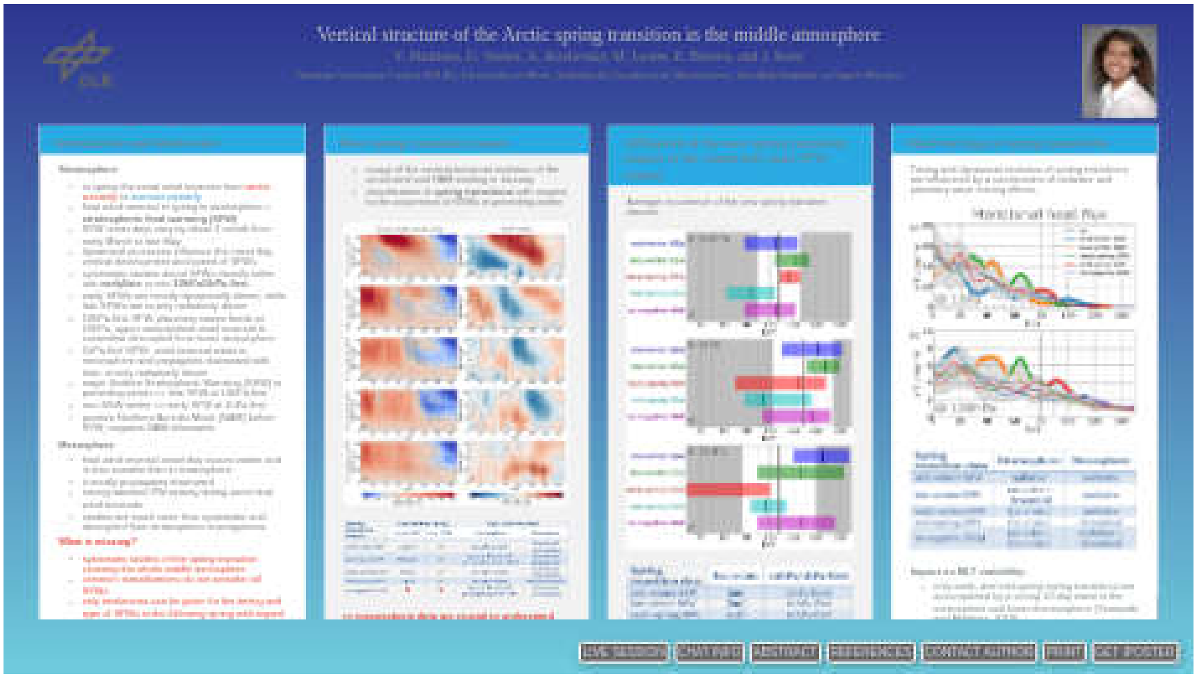
Vertical structure of the Arctic spring transition in the middle atmosphere



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PRESENTED AT:

INTRODUCTION AND MOTIVATION

Stratosphere

- in spring the zonal wind reverses from winter westerly to summer easterly
- final wind reversal in spring in stratosphere = **stratospheric final warming (SFW)**
- SFW onset days vary by about 2 month from early March to late May
- dynamical processes influence the onset day, vertical development and speed of SFWs
- systematic studies about SFWs classify either into **early/late** or into **10hPa/1hPa-first**
- early SFWs are mostly dynamically driven, while late SFWs are mostly radiatively driven
- 10hPa-first SFW: planetary waves break at 10hPa, upper stratospheric wind reversal is somewhat decoupled from lower stratosphere
- 1hPa-first SFW: wind reversal starts in mesosphere and propagates downward with time, mostly radiatively driven
- major Sudden Stratospheric Warming (SSW) in preceding winter => late SFW at 10hPa-first
- non-SSW winter => early SFW at 1hPa first
- positive Northern Annular Mode (NAM) before SFW, negative NAM afterwards

Mesosphere

- final wind reversal onset day occurs earlier and is less variable than in stratosphere
- it mostly propagates downward
- strong transient PW activity during some final wind reversals
- studies are much rarer, less systematic and decoupled from stratospheric investigations

What is missing?

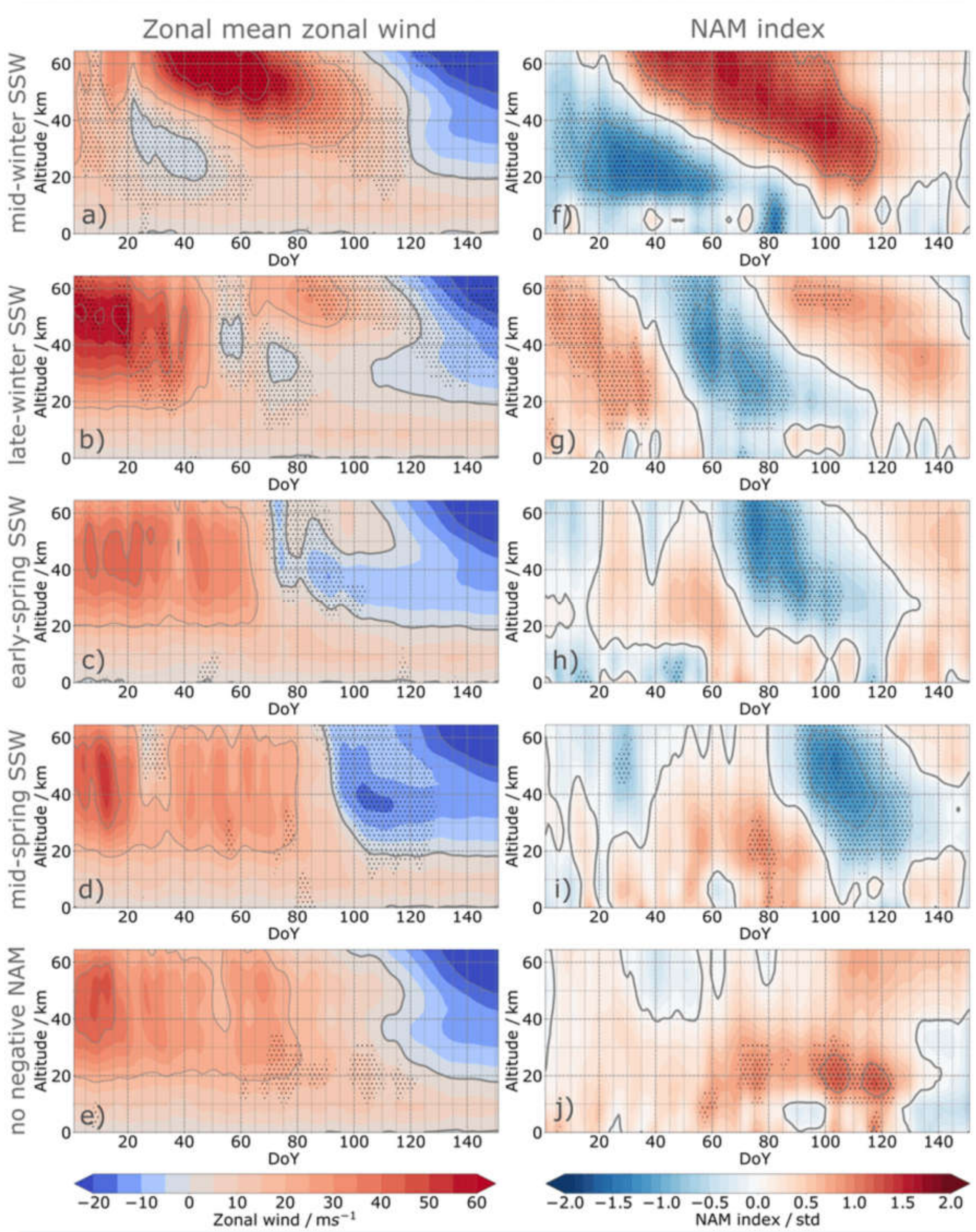
- systematic studies of the spring transition covering the whole middle atmosphere
- common classifications do not consider all SFWs
- only tendencies can be given for the timing and type of SFWs in the following spring with regard to SSW occurrence in preceding winter

What we want to do:

- introduce a new type of classification based on temporal-vertical evolution of polar vortex
- includes: stratosphere and mesosphere, all spring transitions, SSWs in preceding winter

NEW SPRING TRANSITION CLASSES

- usage of the vertical-temporal evolution of the zonal wind and NAM starting in January
- classification of **spring transitions** with respect to the occurrence of SSWs in preceding winter

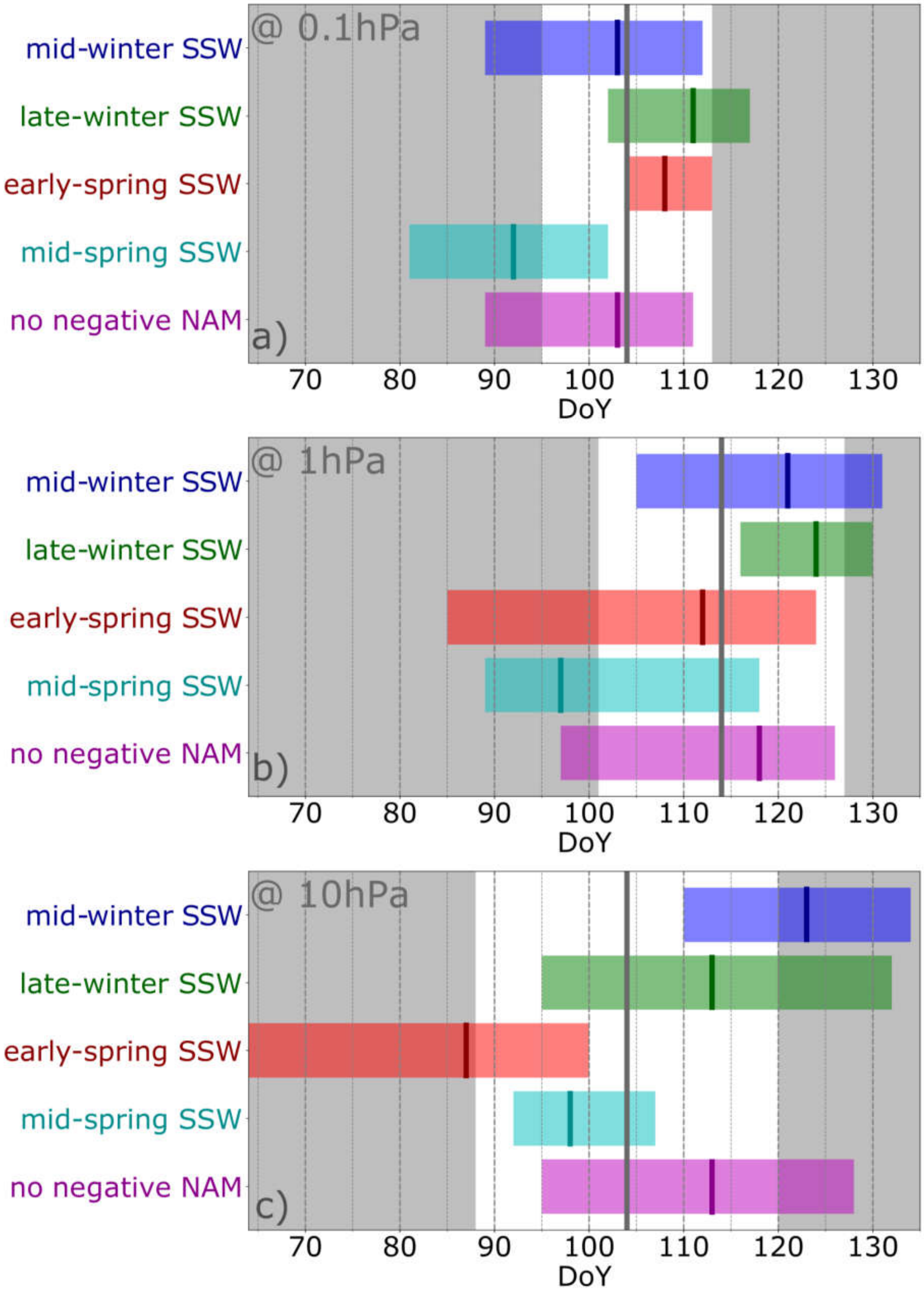


Spring transition classes	Pre-winter/spring		Final wind reversal	
	major SSW	neg. NAM	Stratosphere	Mesosphere
mid-winter SSW	January	✓	simultaneously	downward propagating
late-winter SSW	February	✓	up and downward propagating from 10hPa	downward propagating
early-spring SSW	March	✓	simultaneously	downward propagating
mid-spring SSW	April	✓	simultaneously	simultaneously
no negative NAM	✗	✗	up and downward propagating from 6hPa	downward propagating

=> mesospheric data are crucial to understand and predict spring transitions

AFFILIATION OF THE NEW SPRING TRANSITION CLASSES TO THE COMMONLY USED SFW CLASSES

Average occurrence of the new spring transition classes.

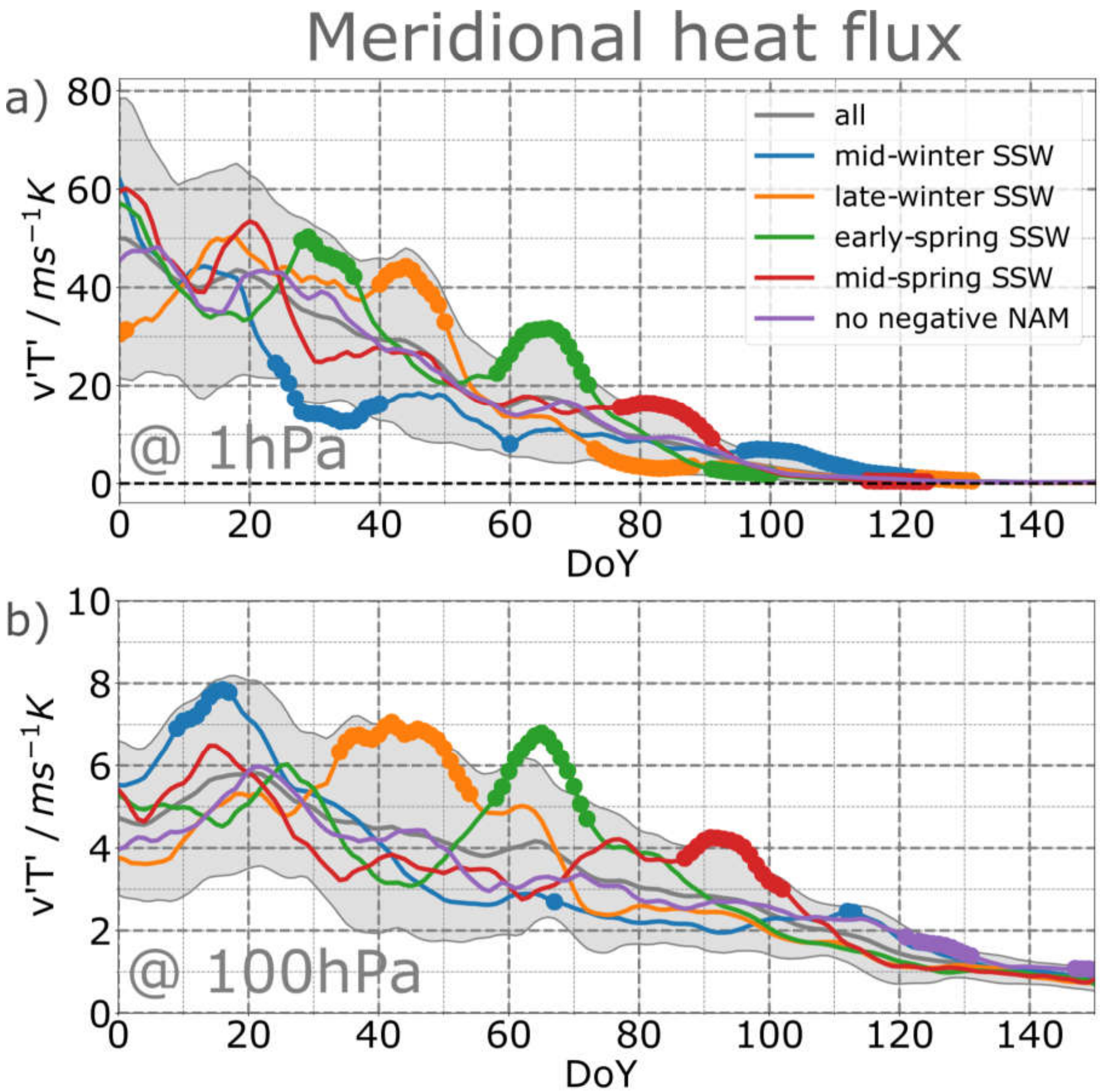


Spring transition class	Early/late	10hPa/1hPa-first
mid-winter SSW	late	(1hPa-first)
late-winter SSW	(late)	10hPa-first
early-spring SSW	early	10hPa-first
mid-spring SSW	✕	✕
no negative NAM	(late)	10hPa-first

=> strong mixture of spring transition types in the commonly used SFW classifications

MAIN FORCINGS OF SPRING TRANSITIONS

Timing and dynamical evolution of spring transitions are influenced by a combination of radiative and planetary wave forcing effects.



Spring transition class	Stratosphere	Mesosphere
mid-winter SSW	radiative	radiative
late-winter SSW	radiative + dynamical	radiative
early-spring SSW	dynamical	radiative
mid-spring SSW	dynamical	dynamical
no negative NAM	radiative + dynamical	radiative + dynamical

Impact on MLT variability:

- only *early- and mid-spring* spring transitions are accompained by a strong 10-day wave in the mesosphere and lower thermosphere (Yamazaki and Matthias, 2019)

=> more detailed view on processes leading to different types of spring transitions in the stratosphere *and* mesosphere

ABSTRACT

In the middle atmosphere, spring transition is the time period where the zonal circulation reverses from westerly in winter to easterly in summer which has a strong impact on the vertical wave propagation influencing the variability of the ionosphere. The spring transition itself can be rapid in form of a final sudden stratospheric warming (SSW, mainly dynamically driven) or slow (mainly radiatively driven) but also intermediate stages can occur. Many studies investigate the spring transition by first defining an onset day (e.g., the zonal mean zonal wind reversal at 10hPa and 60°N) and then dividing all available spring transitions into early and late occurring spring transitions. However, all these studies focus exclusively on the stratosphere and give only tendencies under which pre-winter conditions an early or late spring transition takes place and how it takes place (rapid or slow).

Here we classify the spring transitions regarding their temporal development beginning in January of the same year and additionally regarding their vertical structure in the stratosphere and mesosphere in the core region of the polar vortex. This leads to five classes where the timing of the SSW as well as a downward propagating Northern Annular Mode (NAM) plays a crucial role. First we use MLS satellite data to describe the five classes for recent single years, and then we use MERRA2 reanalysis data for a composite analysis. The results show distinctive differences between the five classes in the months before the spring transition especially in the mesosphere. This allows a certain prediction at least for some of the five classes of spring transition. The impact of these spring transitions on the ionospheric variability is discussed.

REFERENCES

Yamazaki, Y., & Matthias, V. (2019). Large-amplitude quasi-10-day waves in the middle atmosphere during final warmings. J. Geophys. Res.: Atmospheres, 124 (17-18), 9874-9892. doi: 10.1029/2019JD030634