Dynamical conditions of ice supersaturation formation in the extratropical upper troposphere and lower stratosphere

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START08 Science Team; RAF Technical and Ground Crews.

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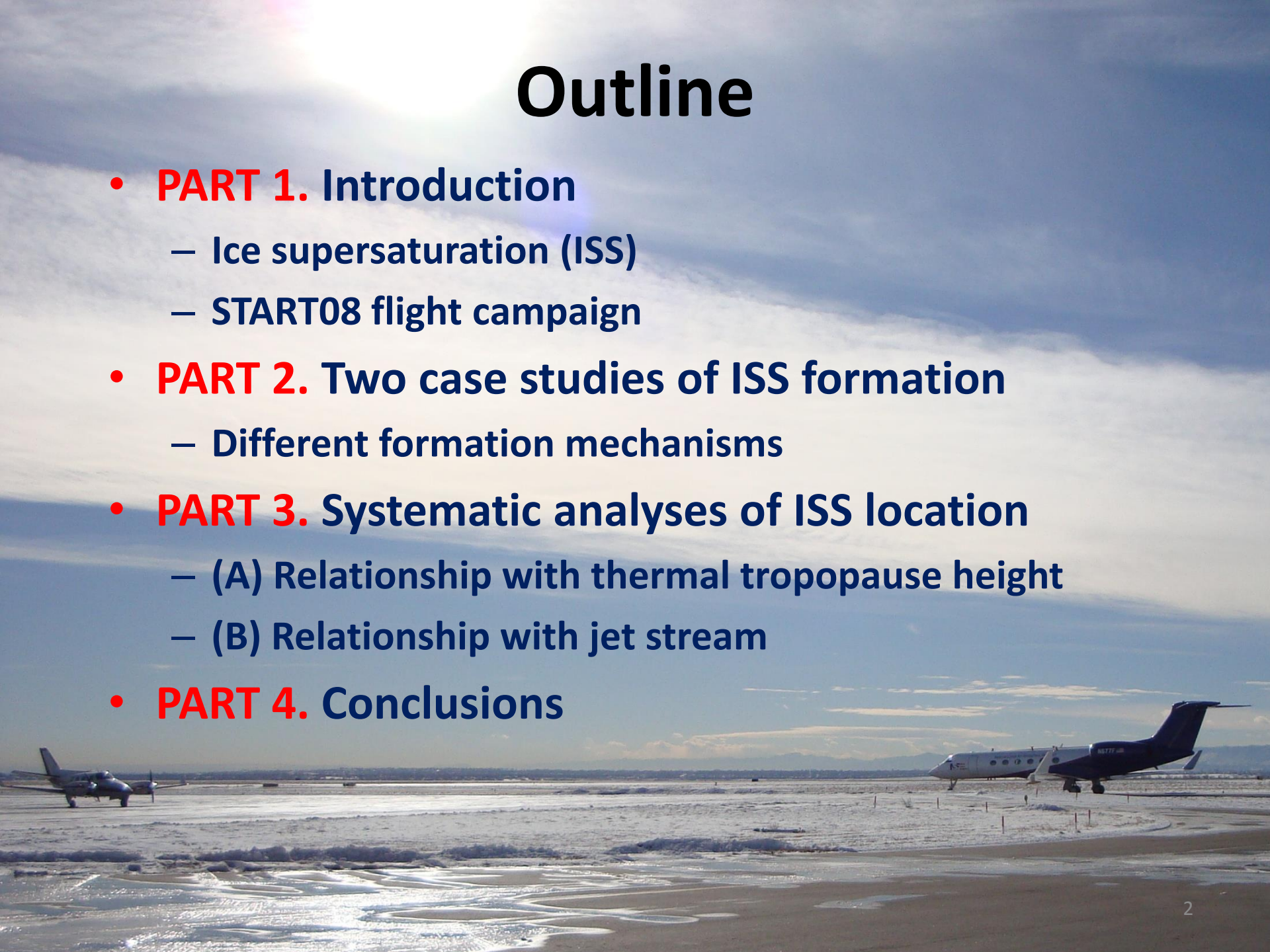
Outline

- **PART 1.** Introduction
  - Ice supersaturation (ISS)
  - START08 flight campaign
- **PART 2.** Two case studies of ISS formation
  - Different formation mechanisms
- **PART 3.** Systematic analyses of ISS location
  - (A) Relationship with thermal tropopause height
  - (B) Relationship with jet stream
- **PART 4.** Conclusions



Introduction

1. Ice supersaturation (ISS)

a) Definition of Ice Supersaturation (ISS)

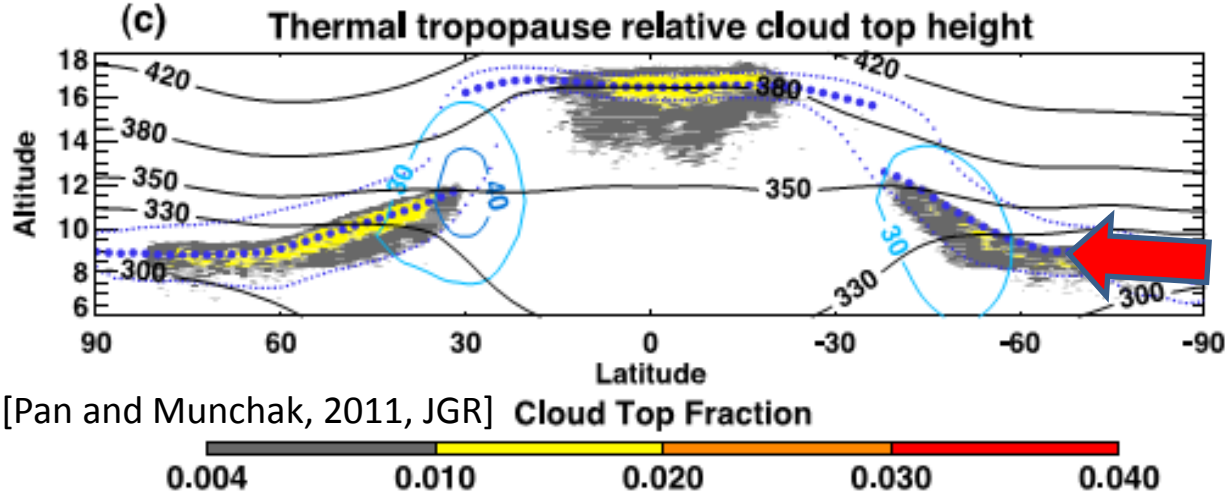
$$ISS = RHi - 1 = e / e_s - 1$$

- **e**: water vapor pressure
- $\mathbf{e_s}$: saturation vapor pressure wrt ice

b) Definition of Ice Supersaturated Regions (ISSRs)

Spatially continuous RHi > 100%

2. Dynamical conditions of ISS formation



[Pan and Munchak, 2011, JGR]

In-situ measurements	Reanalysis data
ISSRs: ~ **1 km** scale [Diao et al. 2014, ACP]	Dynamics: **mesoscale** to **synoptic** scale.

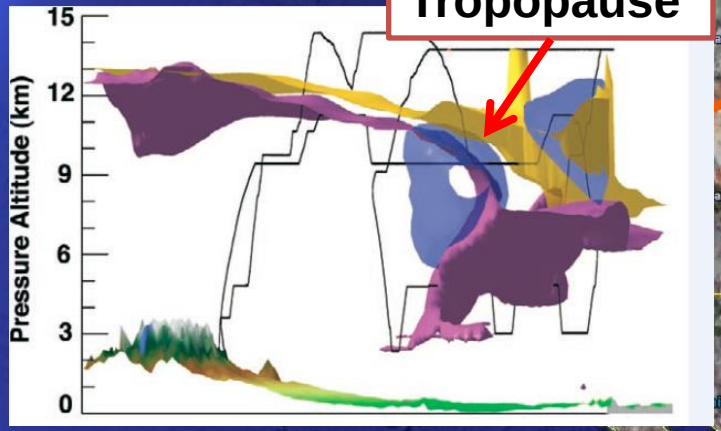
Lack of analyses relating ISS microscale properties with synoptic-scale dynamics

NSF START08 Campaign (The Stratosphere Troposphere Analyses of Regional Transport campaign)

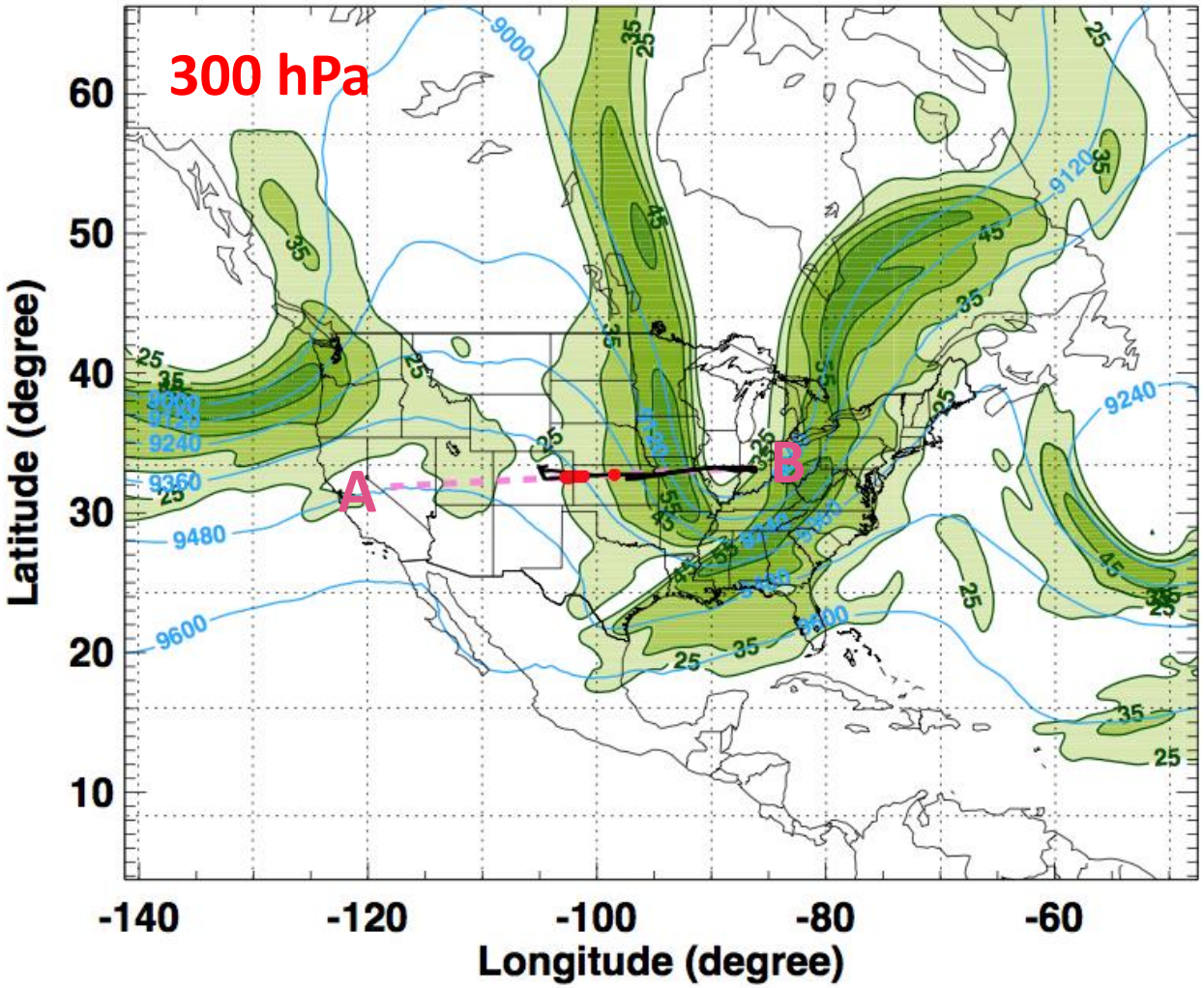
[Pan, 2008]

- 18 flights , 120 hours, 1 Hz
- April 21 to June 28, 2008 over North America.
- Science Objective:

  Dynamical and chemical processes in the extratropical Upper troposphere and Lower stratosphere (Ex-UT/LS)
  - T <= - 40 ℃
- Meteorological analyses: NCEP GFS reanalysis (thermal tropopause and wind map)
  - ~35 km horizontally
  - ~500-1000 m vertically (UT/LS)



Case study of ISS formation in the Ex-UT/LS (Research flight RF04, April 28 2008)

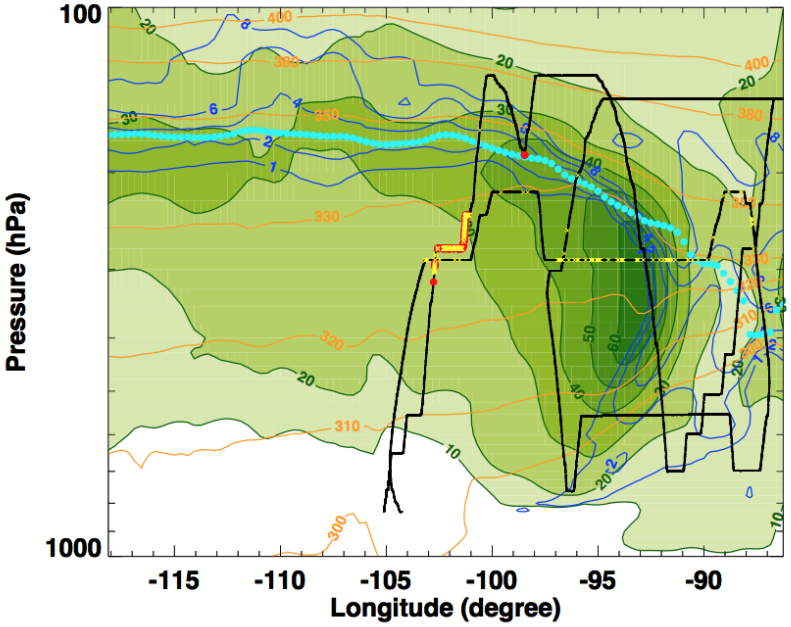


RF04 sampling across the **polar jet core** (both cyclonic and anticyclonic sides)

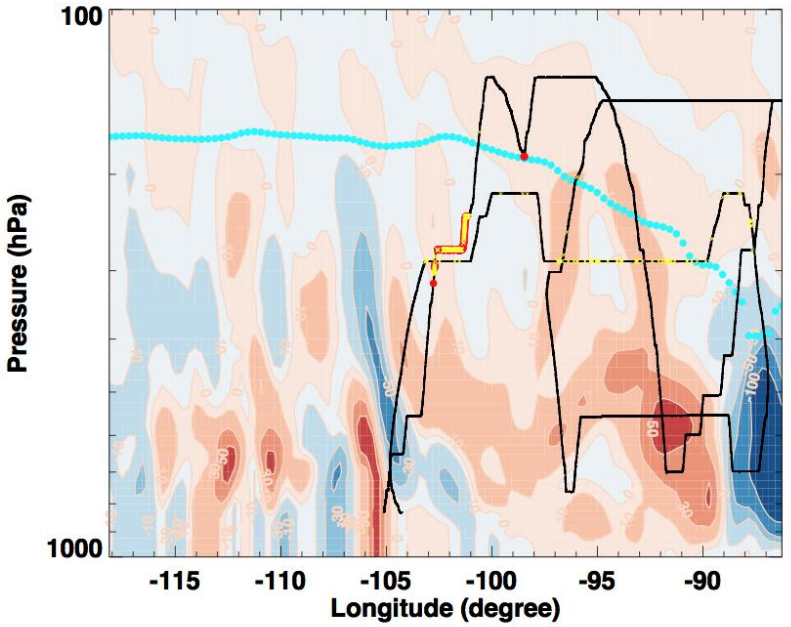
Green contour: horizontal wind speed (10-55 m/s); **Light blue**: geopotential height
Black line: GV; **Red dots**: ice supersaturation;
Pink dashed line: A-B transect (118 – 86 W, and 38.4 – 39.8 N)

Vertical cross section analyses of RF04

(A) Horizontal wind (10–55 m/s)



(B) Vertical velocity (w)



Green contour: horizontal wind (10-55 m/s);
Light blue dots: thermal tropopause;
Blue lines: PVU; Yellow crosses: ice crystals

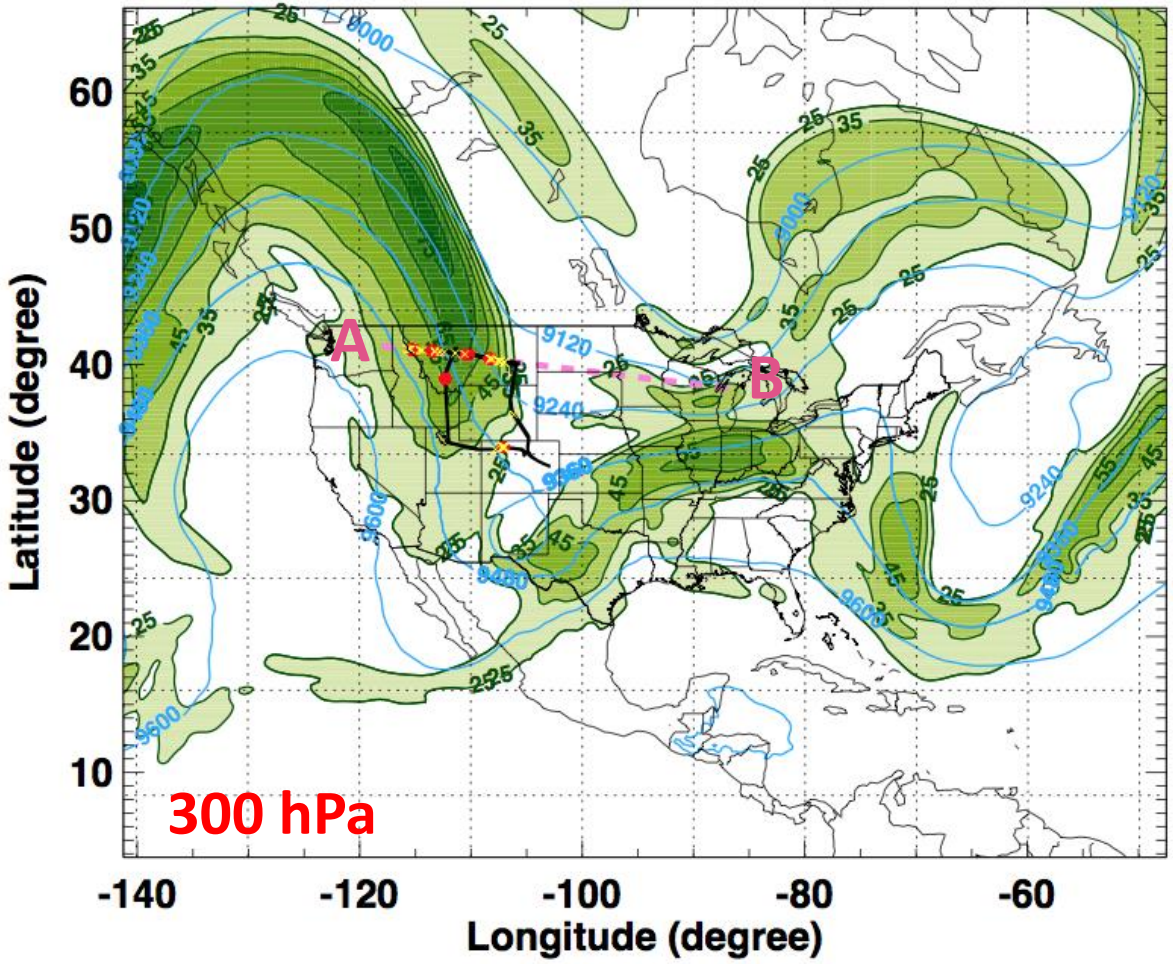
Vertical velocity (w)
Red: positive; Blue: negative

ISS formation dynamical conditions:

1. **Below the thermal tropopause**
2. **Anticyclonic** side of jet core
3. GFS data show **positive** vertical velocity: **Mesoscale uplifting**

   Importance of large scale uplift consistent with warm conveyor belt case study (Spichtinger et al. 2005)

Case study of ISS formation in the Ex-UT/LS (Research flight RF11, May 14 2008)

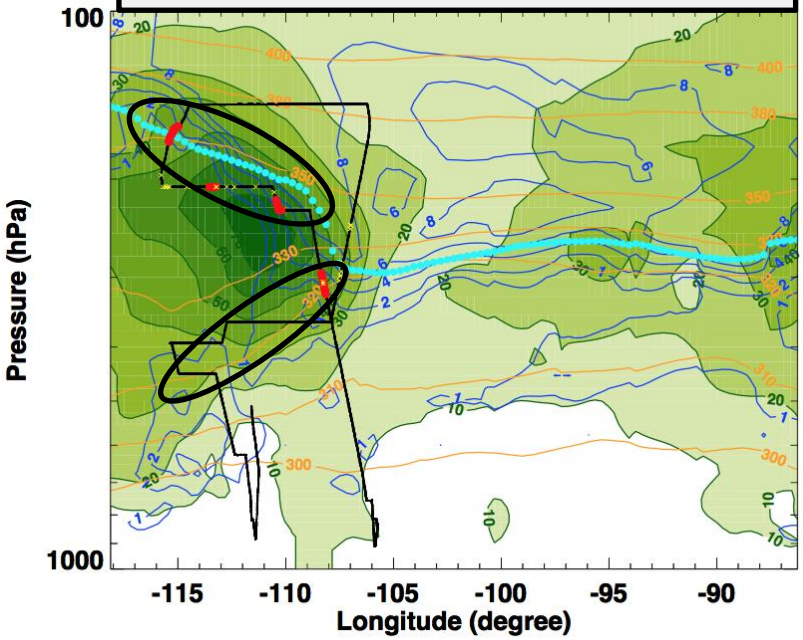


RF11 flight plan:
Similar to RF04:
across **polar jet core**

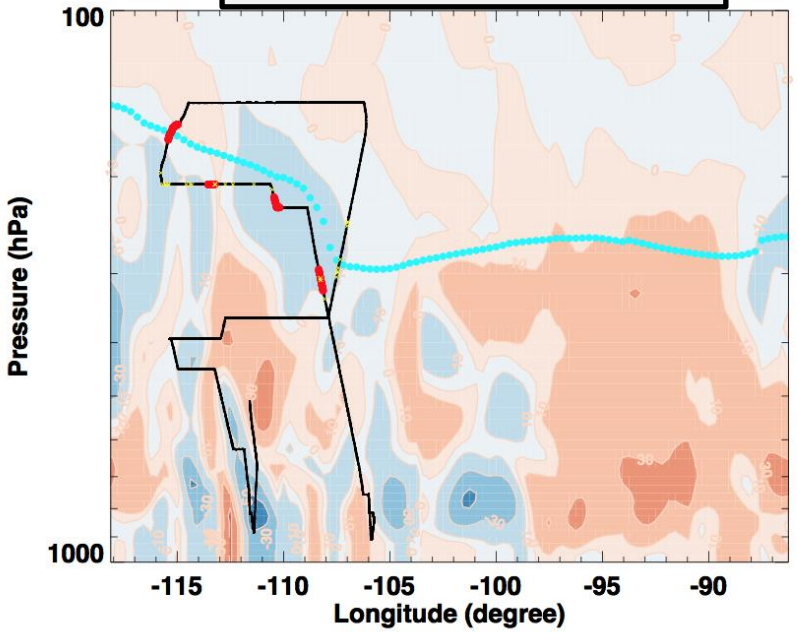
Green contour: horizontal wind speed (10-55 m/s); **Light blue**: geopotential height
Black line: GV; **Red dots**: ice supersaturation; **Yellow** crosses: ice crystals;
Pink dashed line: A-B transect (118 – 86 W, and 47.4 – 44.7 N)

Vertical cross section analyses of RF11

(A) Horizontal wind (10–55 m/s)



(B) Vertical velocity (w)

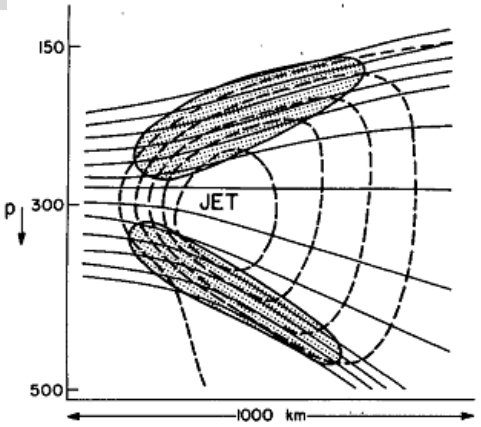


Green contour: horizontal wind (10-55 m/s);
Light blue dots: thermal tropopause;
Blue lines: PVU; Yellow crosses: ice crystals

Vertical velocity (w)
Red: positive; Blue: negative

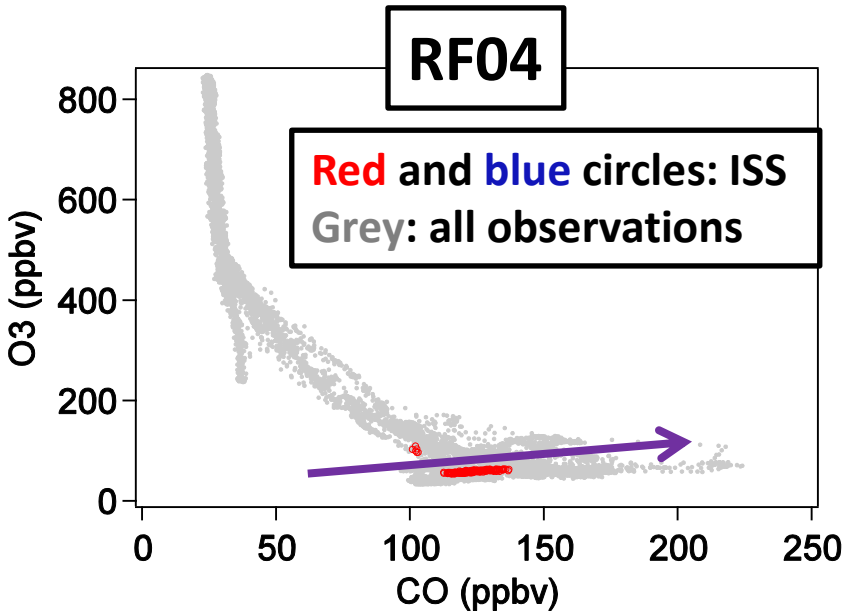
***Different* ISS formation mechanisms RF11 vs. RF04:**

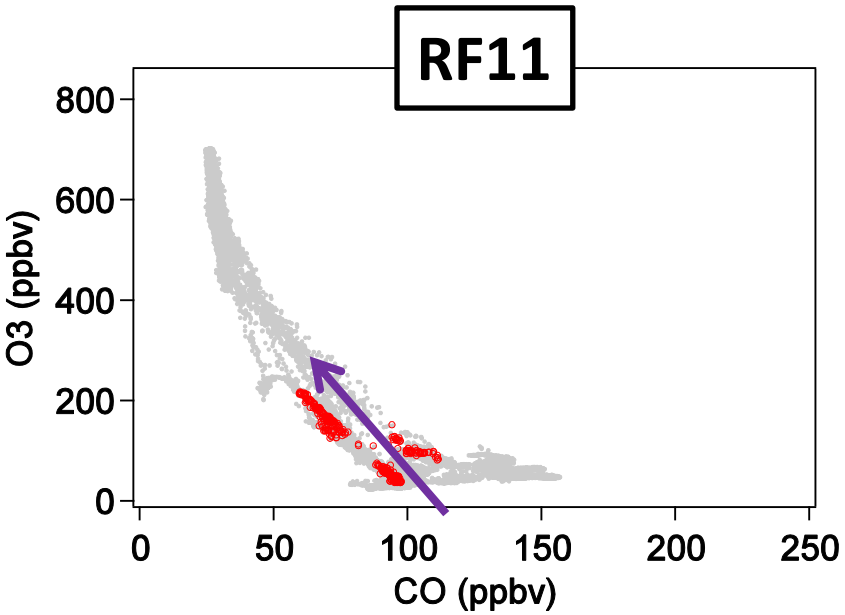
1. **Around the thermal tropopause**
2. **Both sides** of jet core
3. GFS data show both **negative** and **positive** vertical velocity

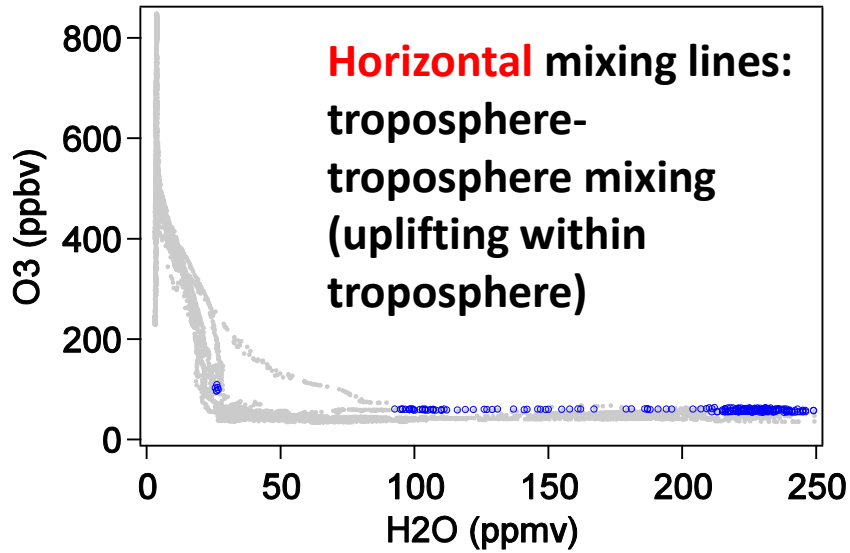


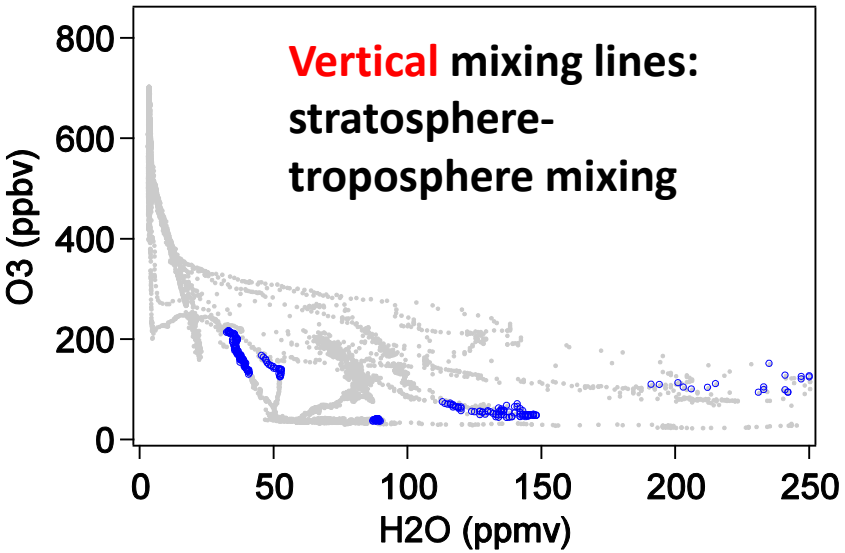
Clear-air turbulence around jet stream
[Shapiro 1976]

ISS formation mechanisms (RF04 vs RF11)
Chemical tracer analyses (O_3-CO and O_3-H_2O)

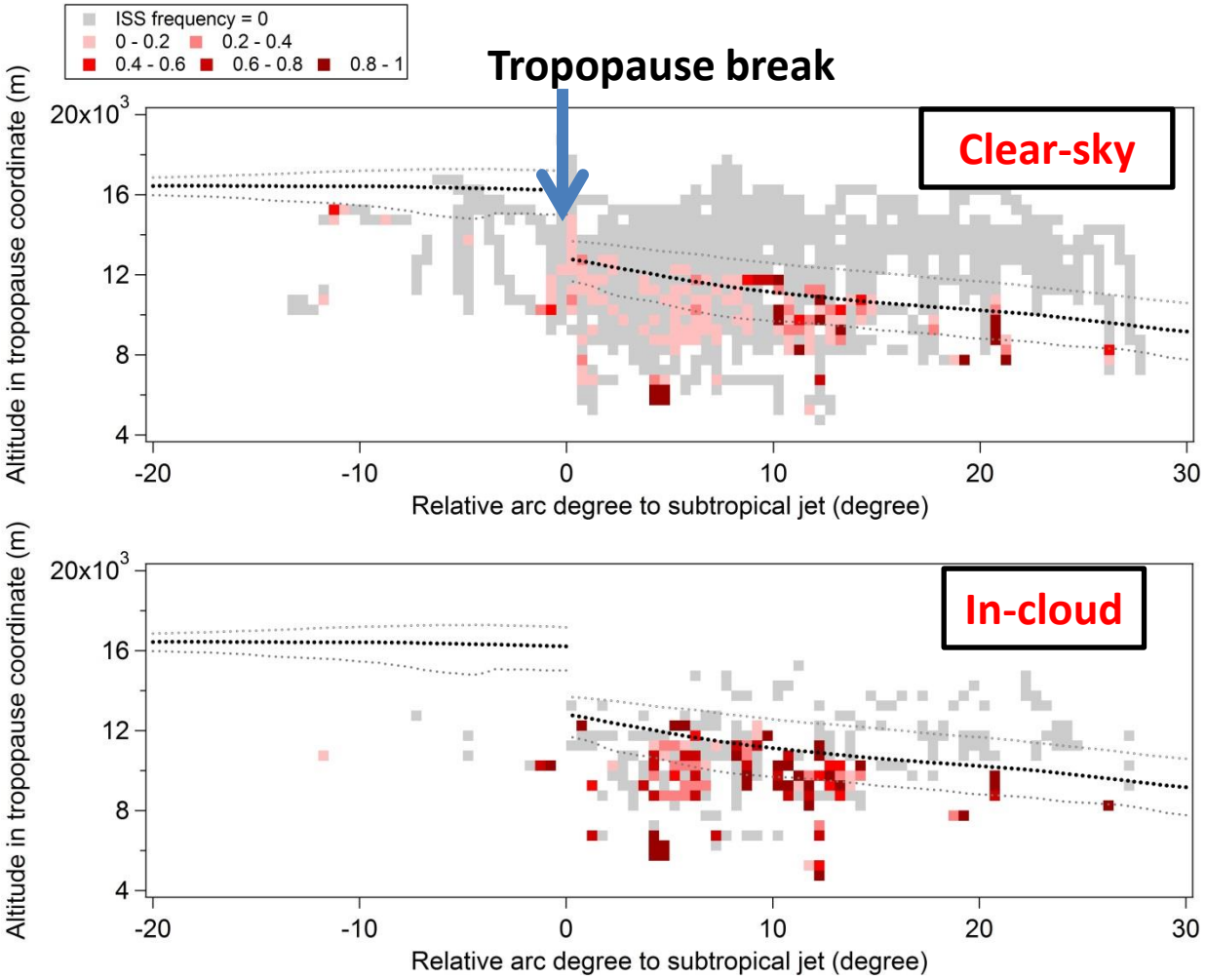


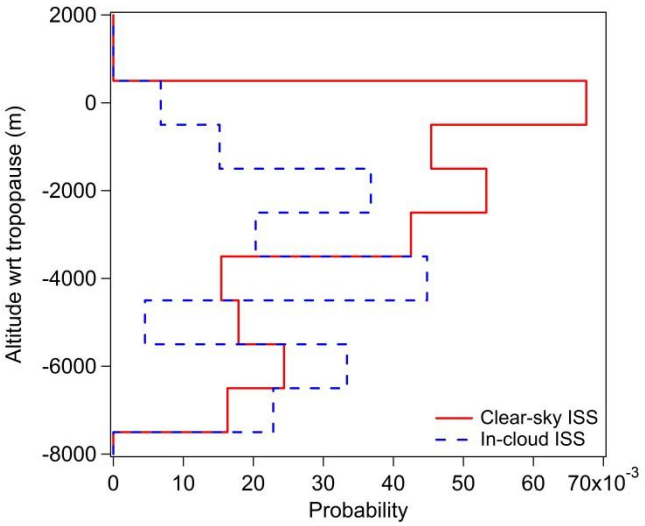






Ice supersaturation frequency related to thermal tropopause and tropopause break



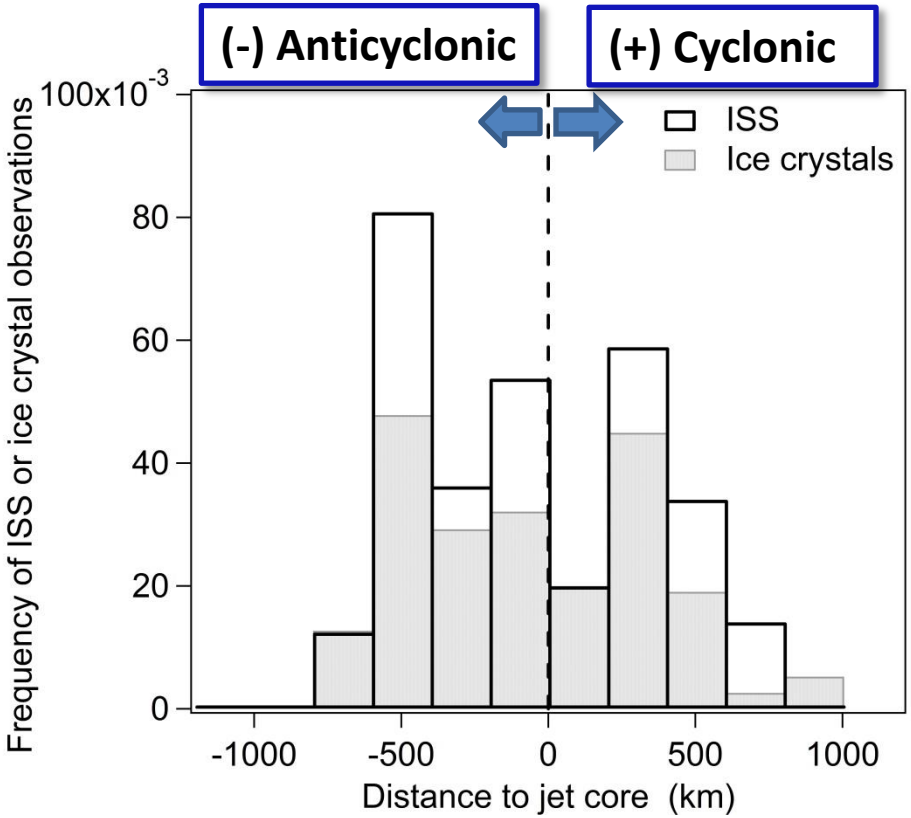


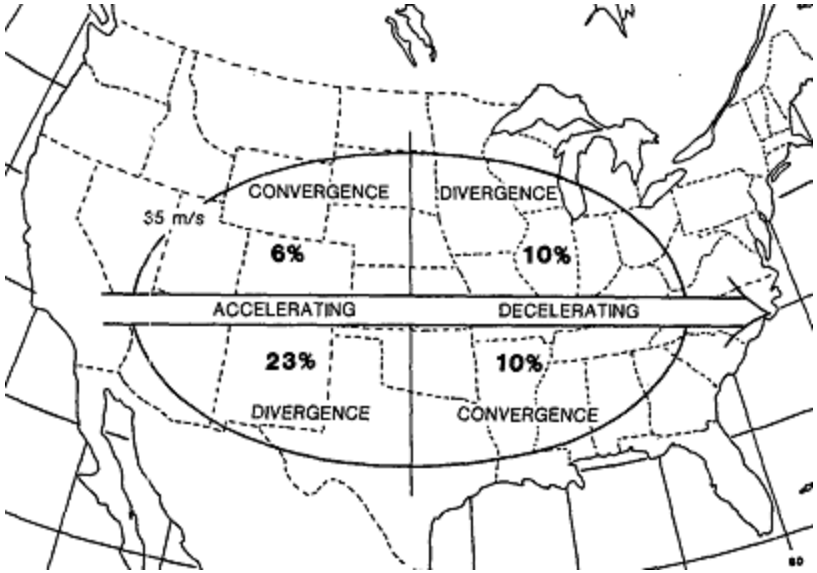
Clear-sky ISS: peak **around tropopause**,
In-cloud ISS: peaks at **lower** altitude .

ISS frequency:

1) Below thermal tropopause height (vertical)
2) Sampling polar side of tropopause break (horizontal)

ISS location related to jet core (U_{max})





[Menzel et al. 1992]

Ratio of anticyclonic / cyclonic frequencies in START08:

ISS: 1.6

Ice crystals: 1.3

Consistent with previous studies:

- **4 years satellite observations** [Menzel et al. 1992]
- **ECMWF model data** [Gierens et al. 2012]

Conclusions

- **Case studies of ISS observations around the extratropical thermal tropopause**
  - Two different mechanisms
    (***mesoscale*** ***uplifting*** vs. ***small scale*** ***waves/turbulences***)
  - Tracer analyses: Troposphere-troposphere mixing vs.
    Stratosphere-troposphere mixing

- **ISS formation dynamical conditions:**
  - Vertically: mostly confined by ***thermal tropopause height***
  - Horizontally: higher ISS frequency in the ***anticylonic*** side of jet core

- **Future work**
  - Evaluate the representation of two ISS formation mechanisms in cloud models.
  - Compare the influences of different scales of dynamics on ISS formation.

Thank you!

Questions?