Rapid Transpacific Transport in Autumn Observed by the A-train Satellites

Can Li

ESSIC, University of Maryland

Code 614, NASA Goddard Space Flight Center
(can.li@nasa.gov)

NASA Sounder Science Team Meeting

November 14, 2012

Code 613, NASA GSFC:
N. Christina Hsu and Si-Chee Tsay

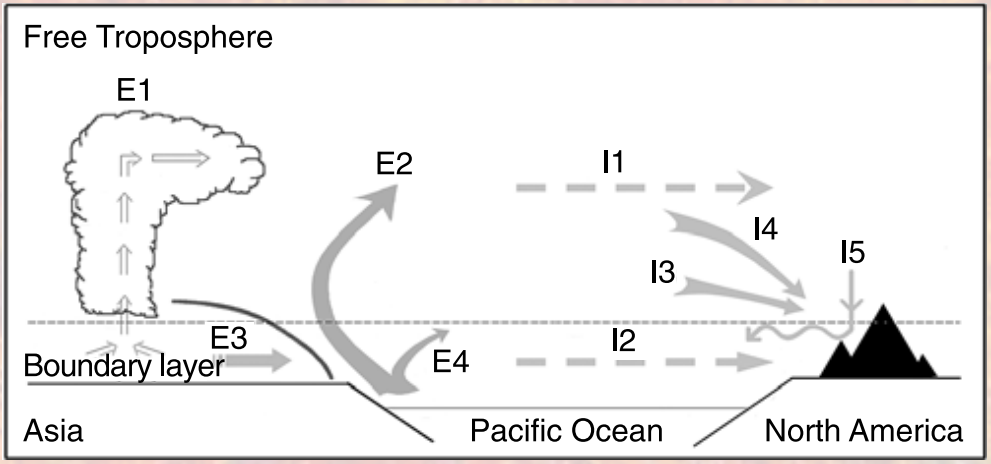
Code 614, NASA GSFC:
Nick Krotkov, Qing Liang, and Kai Yang

Background: Transpacific Transport

- Long-range transport of air pollutants across the Pacific has been:
  - ✓ Long recognized (observational evidence goes back to at least the 1980s [*Kritz et al.*, 1990])
  - ✓ Extensively studied (from PEM-West A/B, TRACE-P, ACE-ASIA, to INTEX-B and ARCTAS)
- Important potential influence on air quality and climate over North America
  - ✓ "Aerosols from Overseas Rival Domestic Emissions over North America" [*Yu et al.*, 2012]

Background: Some Findings from Previous Studies

- Closely associated with mid-latitude cyclones and highly episodic
- Strongest in spring (focus of most studies)
- Warm Conveyor Belt (WCB) is the main mechanism exporting Asian pollution in spring
- Short-lived species can be lofted into FT in WCB, but the export efficiency is low (~10-20% for NO_y and SO_x)

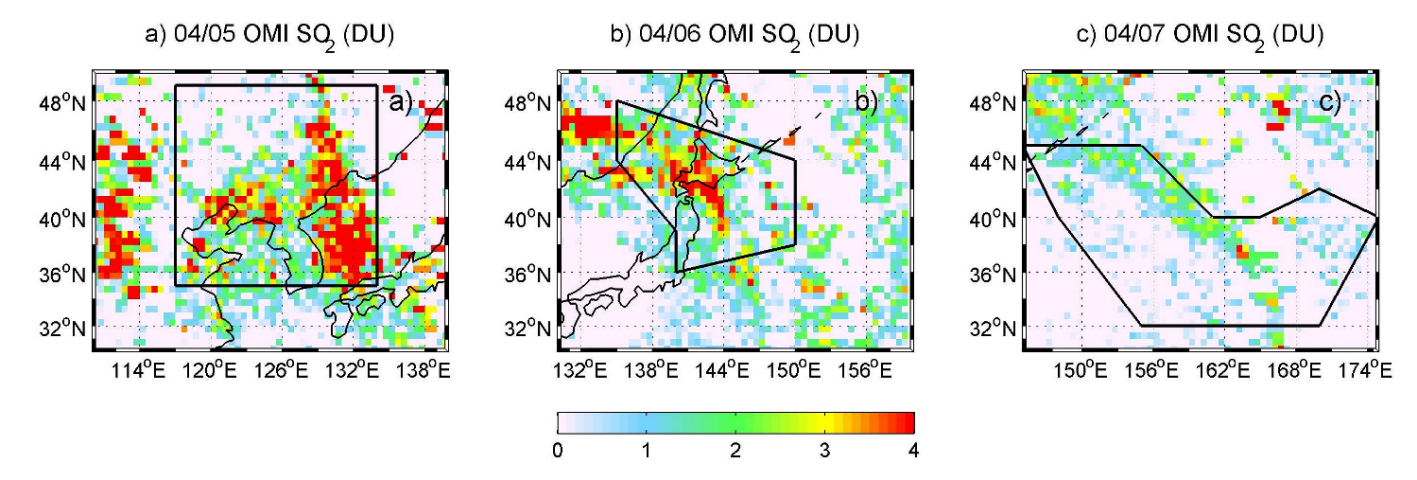


- Once in FT, downwind transport controlled by meto. pattern over E Pacific

[*Liang et al.*, 2004]

Background: Satellite Observation of Long-range Transport

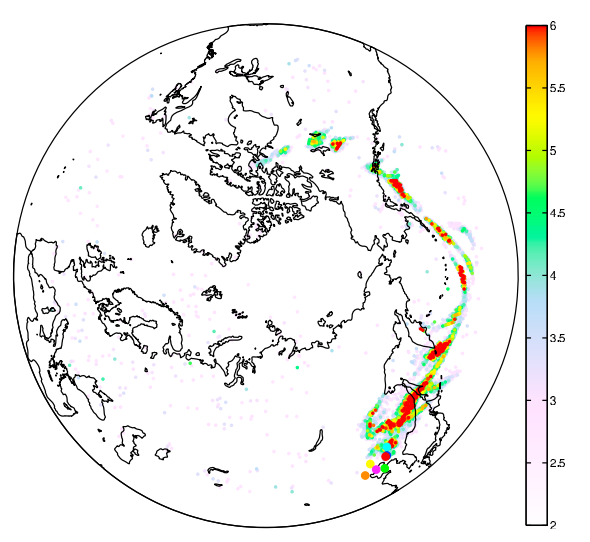
- Tracking Asian super dust storm using TOMS Aerosol Index [*Husar et al.*, 2001]
- CO retrievals combined with aircraft and modeling [e.g., *Zhang et al.*, 2008]
- Flux of aerosol transport estimated using MODIS and CALIPSO [*Yu et al.*, 2012], but for cloud-free conditions only
- Studies on short-lived gaseous species: large uncertainty (S/N)



[*Li et al.*, 2010]

Motivation

Transpacific transport is expected to take place in autumn, but has been rarely studied or reported.



- IASI detected an SO_2 transport event in November 2010 [*Clarisse et al.*, 2011]
- Presumably anthropogenic SO_2 plume crossed the Pacific in just few days (November 7-11, 2010)
- OMI captured the same event

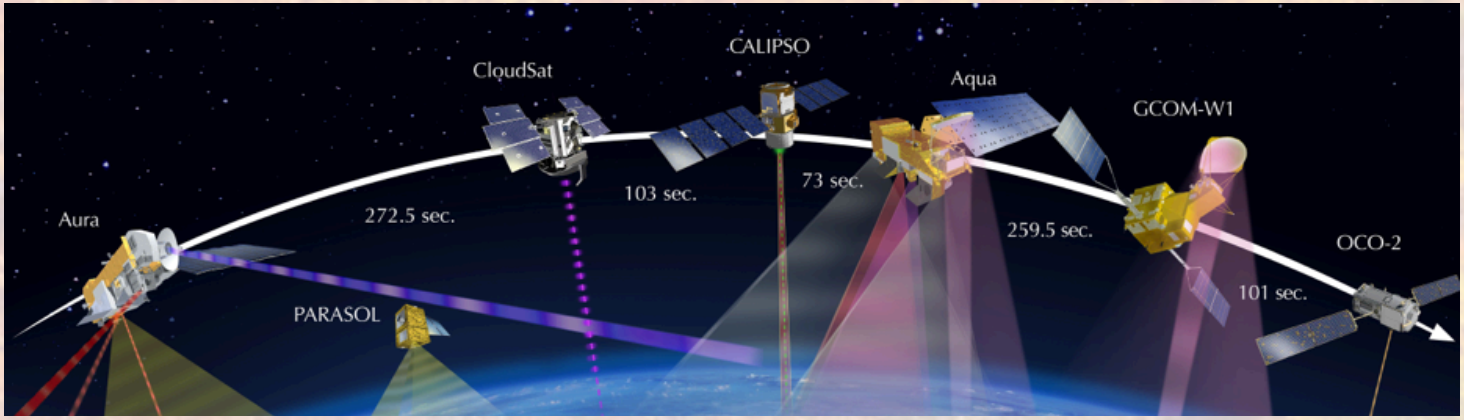
Short transit time means a larger fraction of short-lived species can reach North America

Scientific Questions:

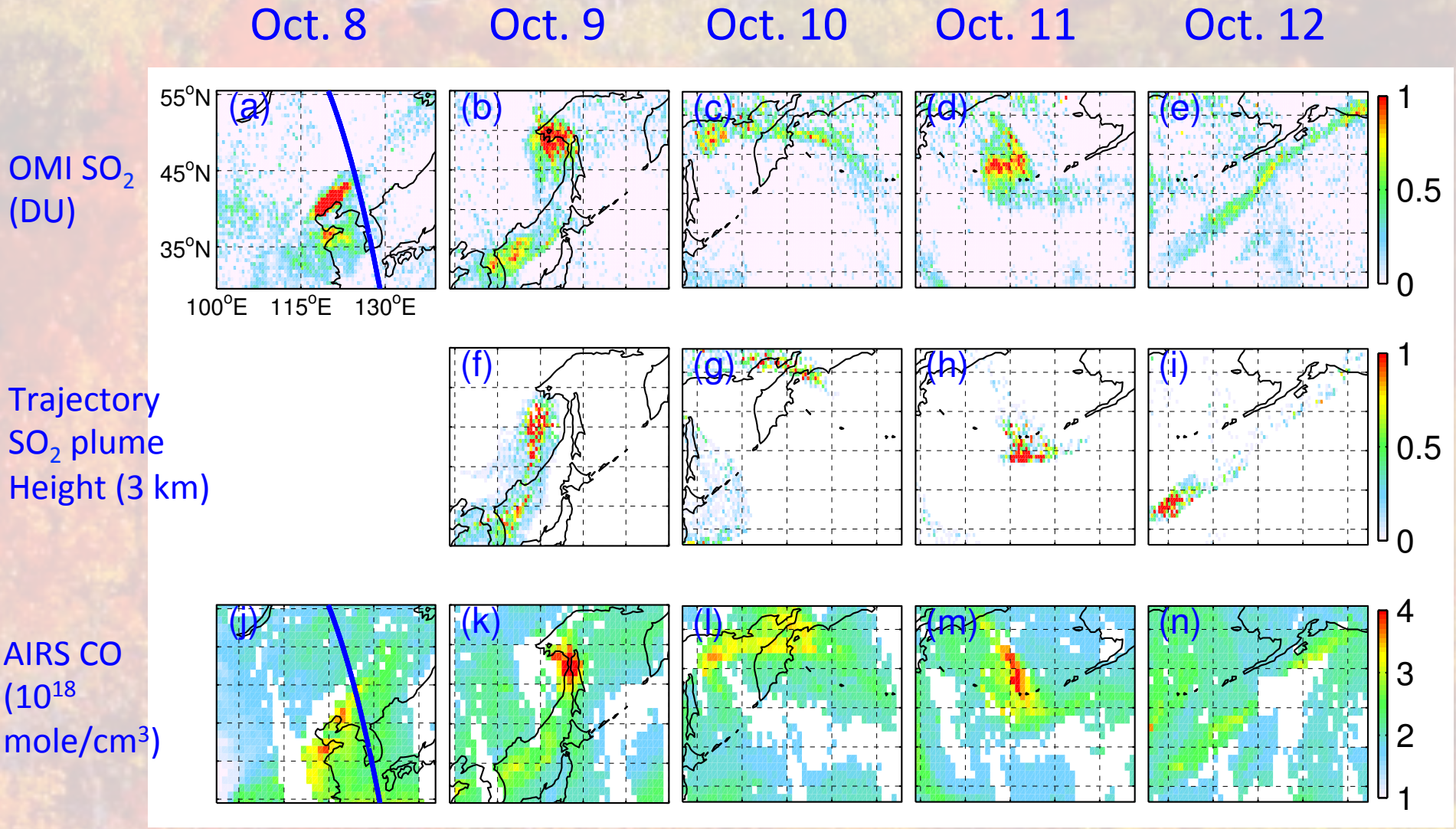
- How do these events occur – Spring vs. Autumn?
- How important are they? (Magnitude? Flux? Frequency?)

Data and Methodology

- A-train satellite observation of: SO_2 (Aura/OMI), CO (Aqua/AIRS), and plume height (CALIPSO)
- NOAA ARL HYSPLIT trajectory model
  - ✓ Forward trajectories tagged with SO_2 retrievals (projecting the movement of the plume)
  - ✓ Backward trajectories (locating plume source region)
- NASA GMAO MERRA meteorological data
- Why SO_2 and CO?
  - ✓ Short-lived SO_2 indicator of rapid transport
  - ✓ Noise/bias in operational SO_2 product
  - ✓ Differentiate industrial plumes from volcanic and BB ones

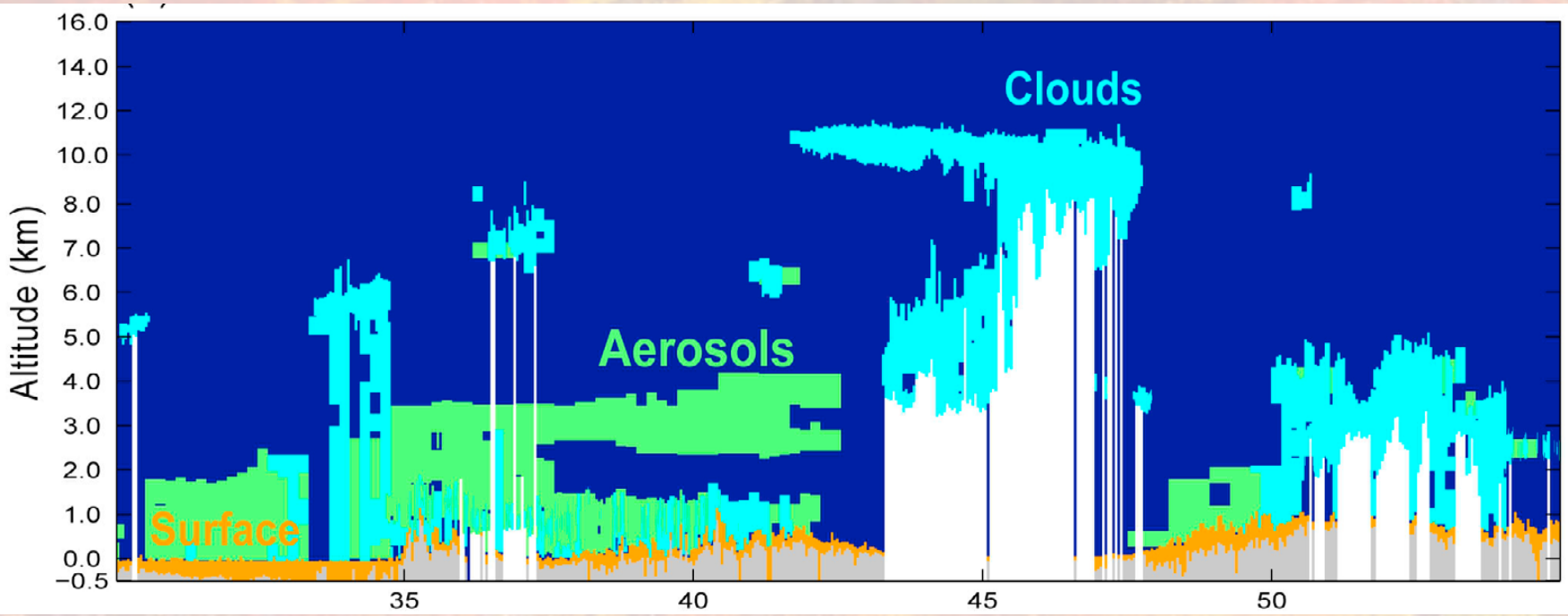


Case One: October 2006



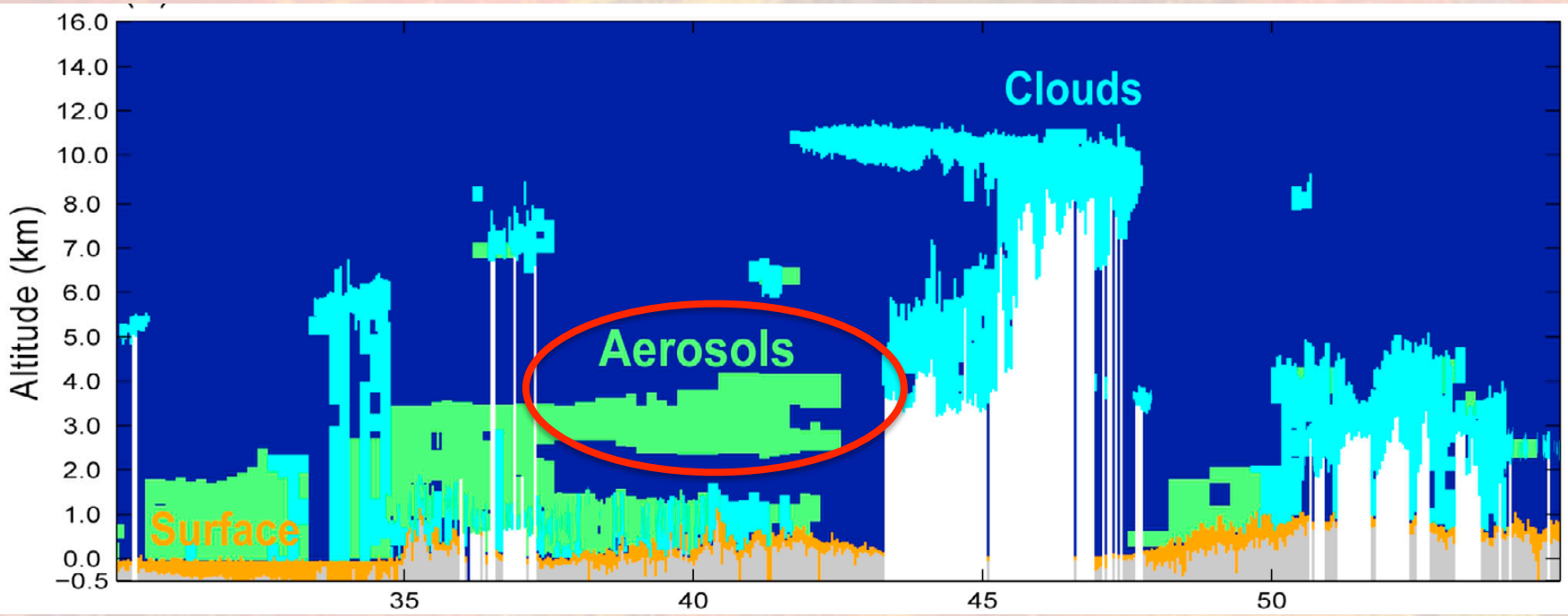
Aerosol Plume Height over NE China on October 8, 2006

CALIPSO Vertical Feature Mask Product over NE China



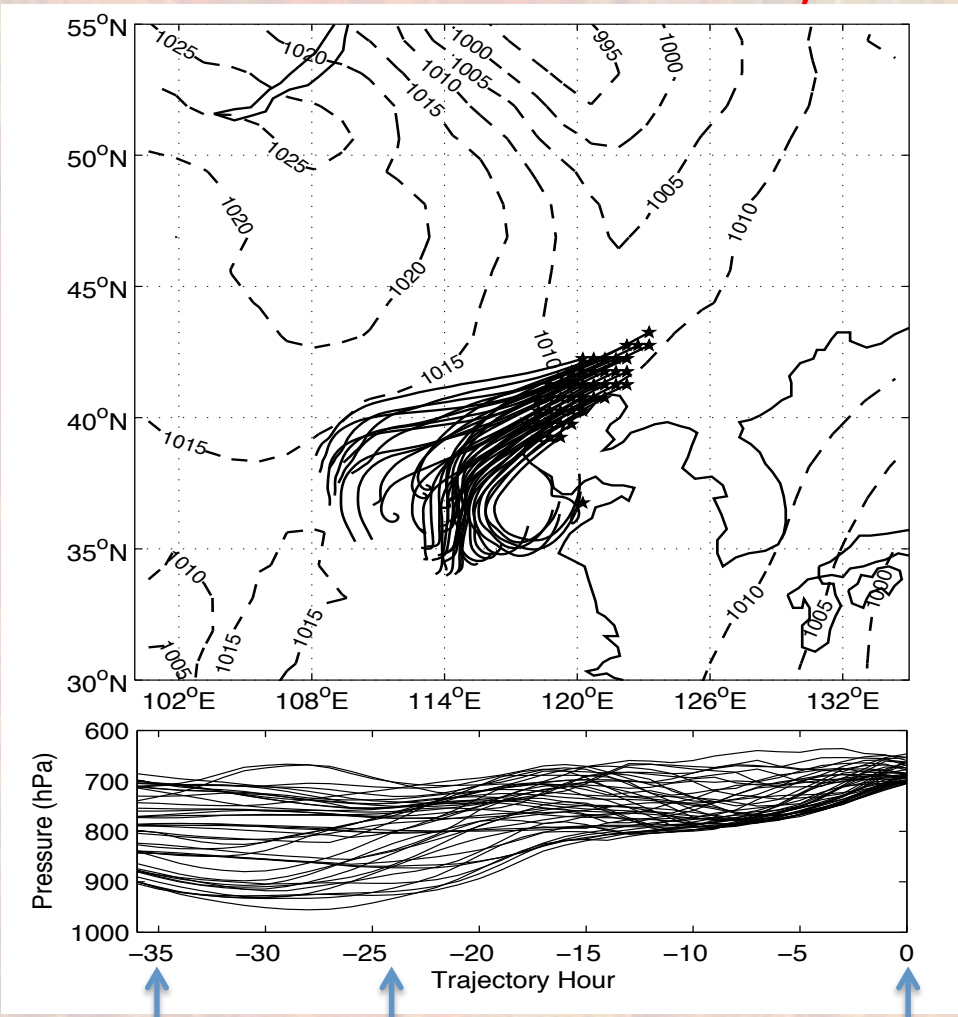
Aerosol Plume Height over NE China on October 8, 2006

CALIPSO Vertical Feature Mask Product over NE China



Trace back to the Source Region

Sea Level Pressure at 18Z 10/06



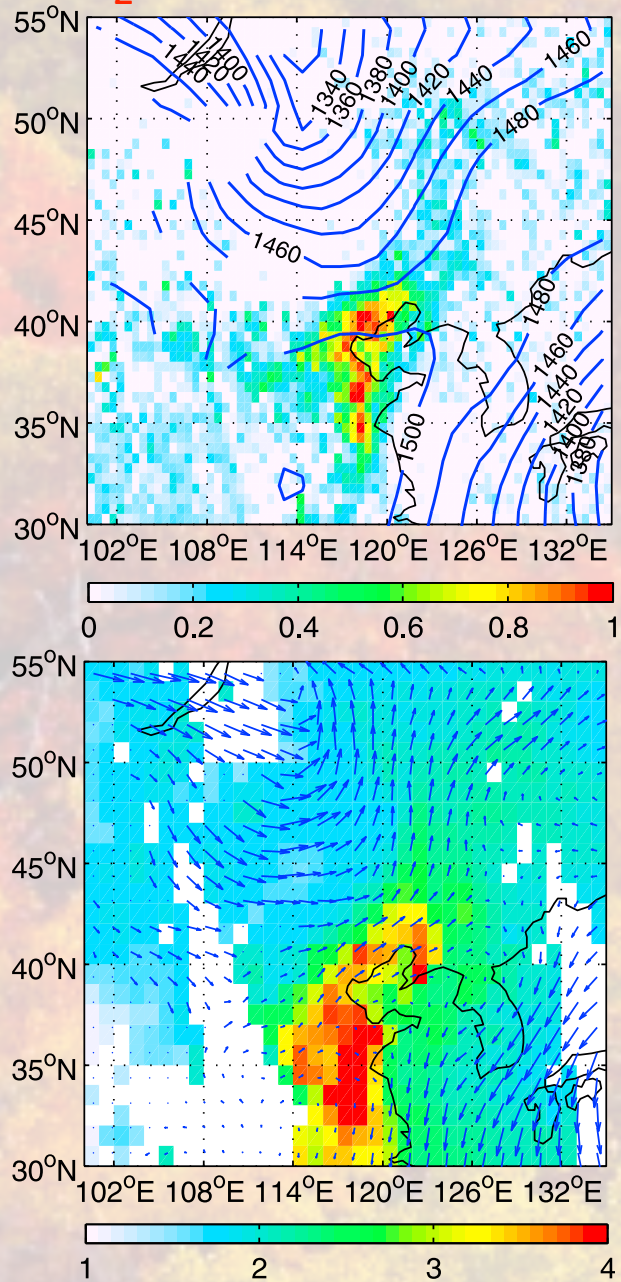
18Z 10/06

05Z 10/07 (sat. overpass)

05Z 10/08 (sat. overpass)

SO_2 and CO, 05Z 10/07

850 mb geo. height and wind, 06Z

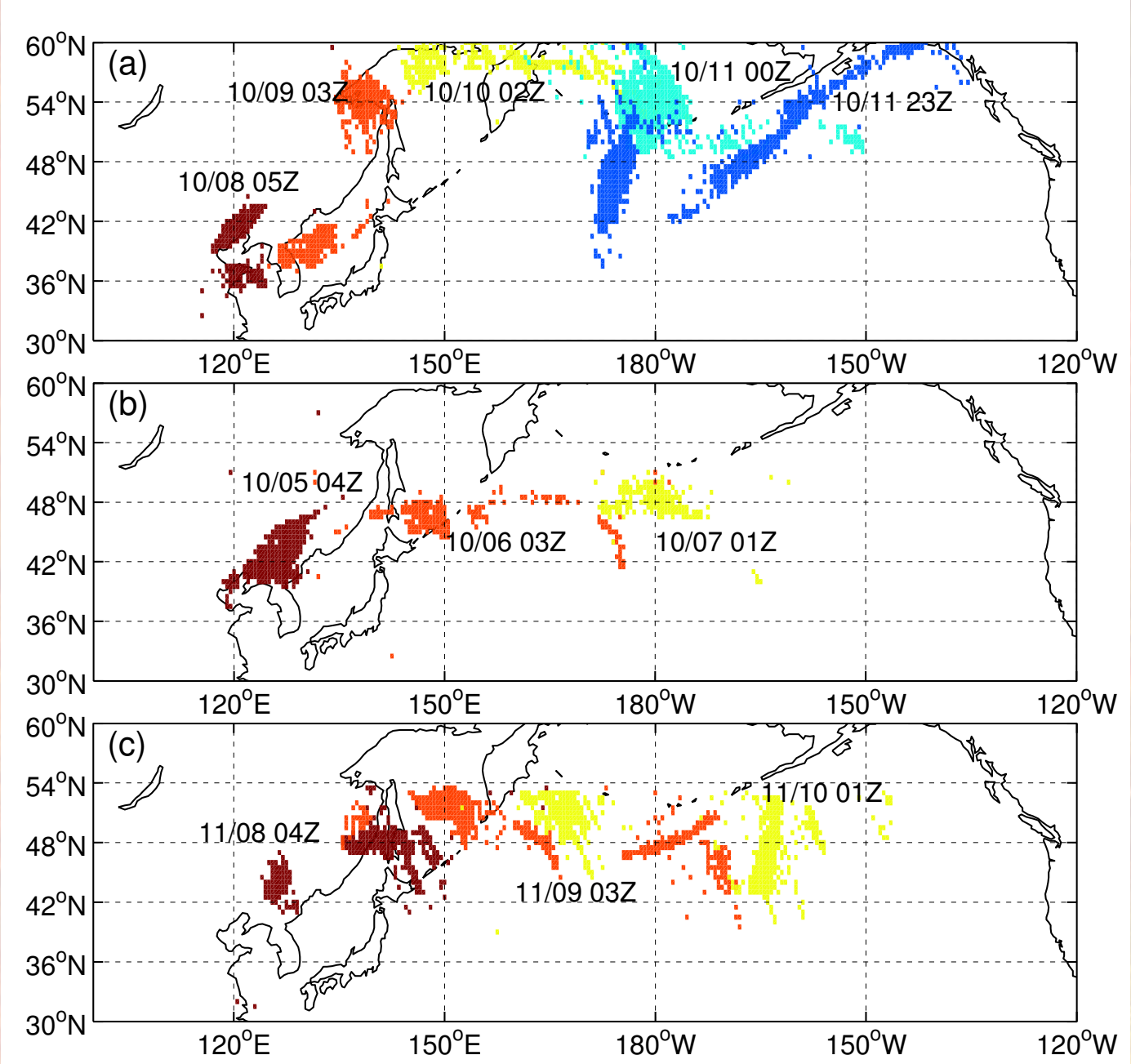


Downstream Transport: More Cases

Oct. 2006

Oct. 2008

Nov. 2011

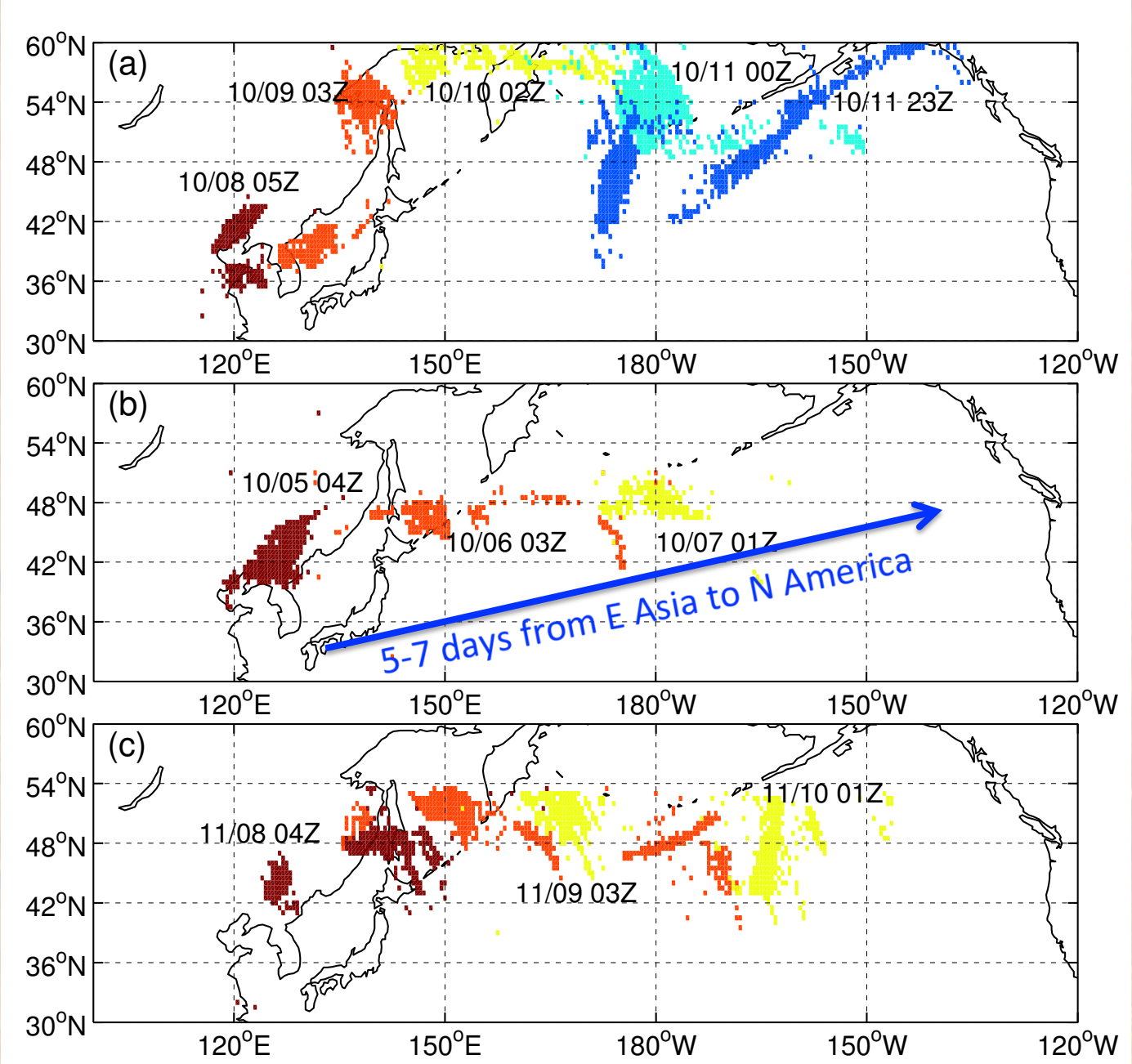


Downstream Transport: More Cases

Oct. 2006

Oct. 2008

Nov. 2011

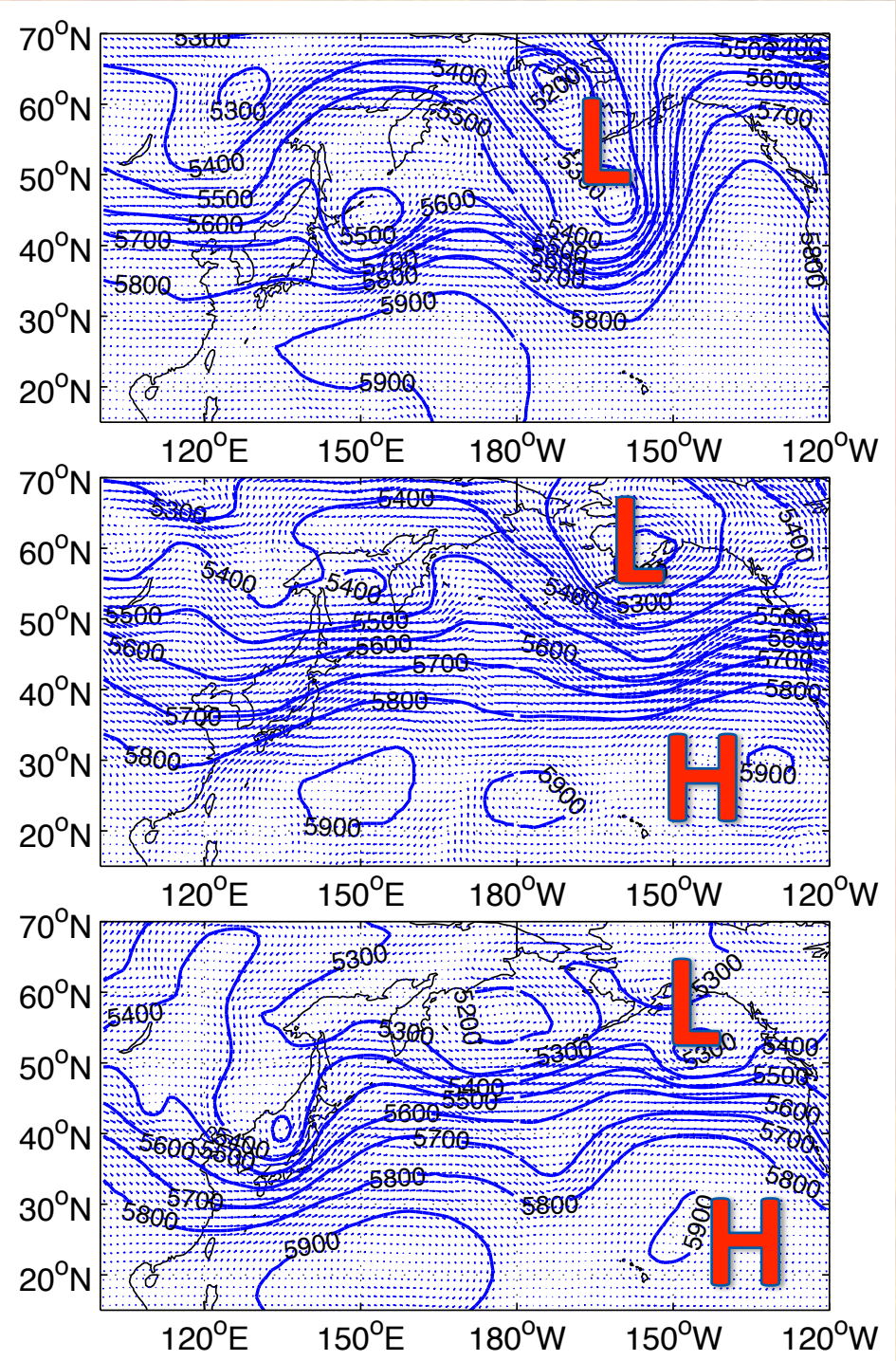


Downwind Meteorological Setup

Streamlined Transport Pathway:

A strong Aleutian Low or a north-south alignment of the subtropical high and Aleutian low

Consistent with some previous studies on transport in spring [e.g., Liang et al., 2005]



Oct. 2006

Oct. 2008

Nov. 2011

A few Observations on the Cases

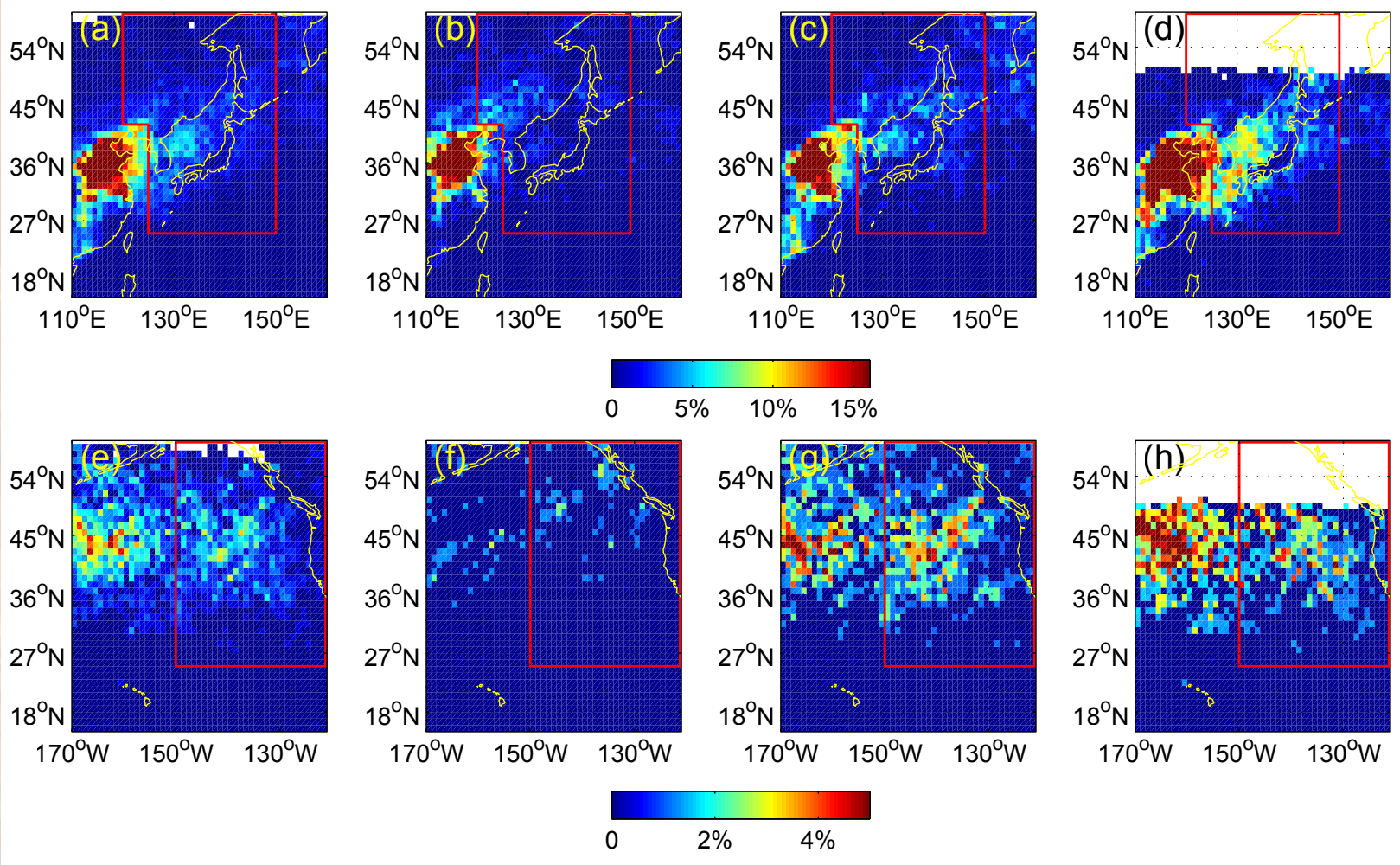
- Similar mechanism (frontal systems, and WCB) and transpacific transit time (~6 days) between autumn and spring
- Asian SO_2 and sulfate previously observed over the remote Pacific in spring (typically less than 1 ppb), but the magnitude of transport observed by satellites is much larger (several ppb)
- WCB is an important rain producer, but some of the SO_2 can survive the washout during the ascent and will form fine sulfate particles during transport across the Pacific (mechanism first proposed by *Brock et al.*, [2004])

How often do they happen? 62 outflow events, 14 inflow events in 4 years

SON September October November

Asian Outflow Region:

N America Inflow Region



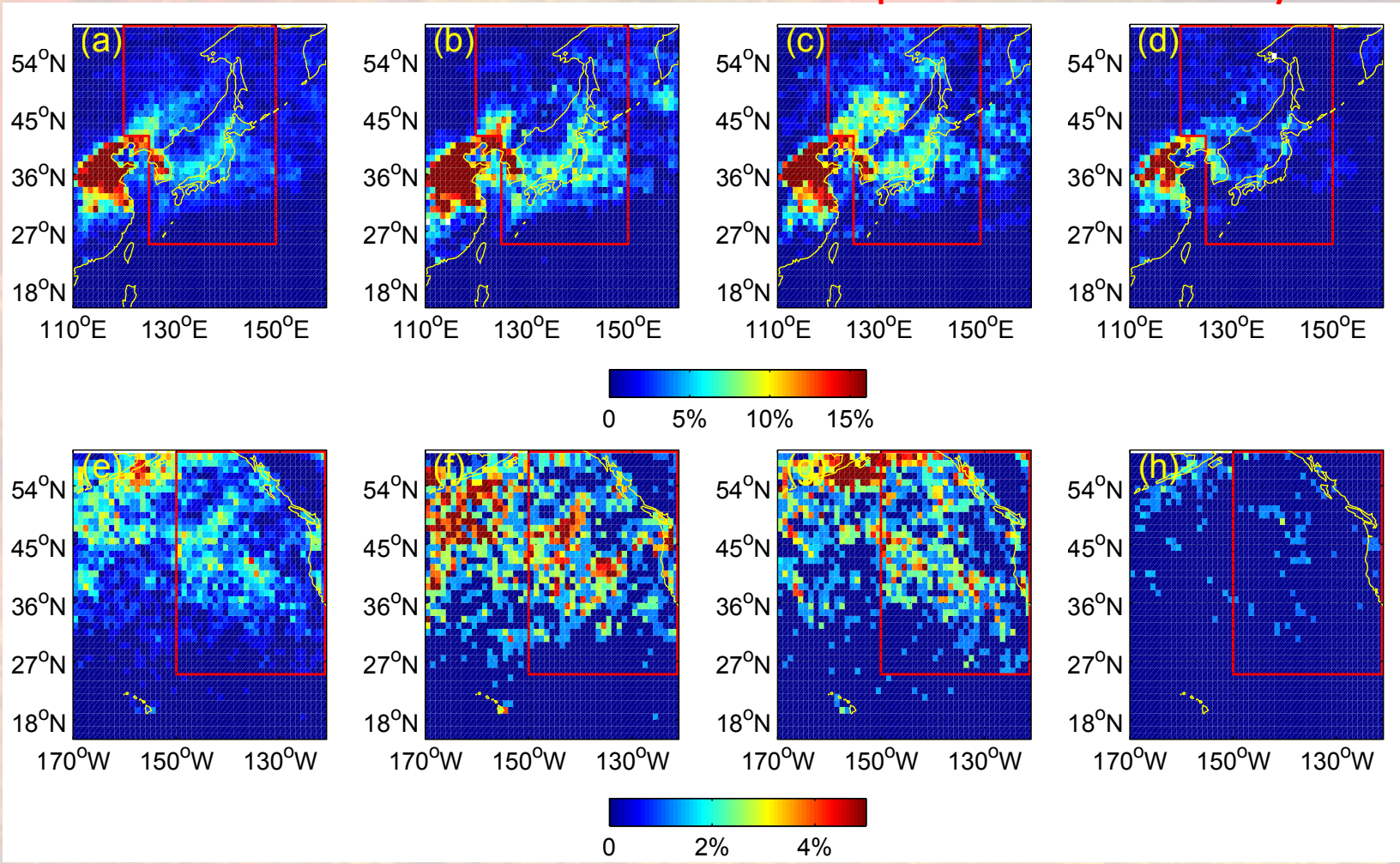
Frequency of high SO2 (> 0.2 DU) and CO (> 2.5×10^{18} mole./cm^2) in SON 2005-2008

How about Spring? Stronger Transport

MAM March April May

Asian Outflow Region:

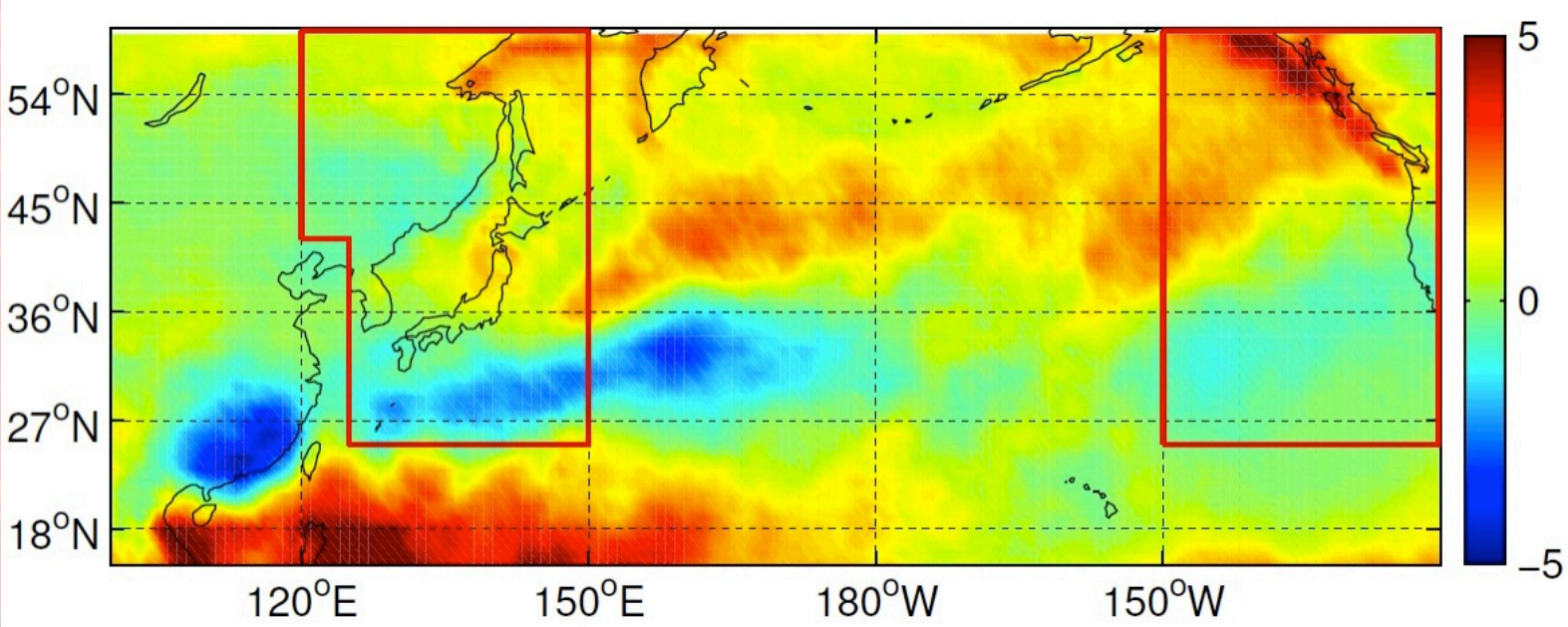
N America Inflow Region



Preliminary results sensitive to selection of threshold, particularly AIRS CO.

Why Transpacific Transport more Active in Spring?

- Number of frontal passages and pollution lifting events in East Asia: similar between Spring and Autumn [*Liang et al.*, 2004]
- But spring can be drier – less washout



The difference in mean precipitation (mm/day) between autumn and spring during 2005-2008. The precipitation data are from the GPCP daily one-degree resolution data set.

Issues

- Estimated frequency of transport events sensitive to threshold (AIRS CO, OMI SO_2, and number of grid cells)
  - A more objective, sophisticated method for pattern recognition and tracking is needed
- How to quantify the amount of SO_2 (or other pollutants) exported from E Asia and imported into N America using satellite data?
  - An approach utilizing aircraft measurements and tracer modeling has been demonstrated, but only works on a case-to-case basis
- Improvement in retrievals may reduce the noise/bias, making satellite data more useful in long-range transport studies
  - A spectral fit algorithm for OMI SO_2 retrievals is being developed, which has the potential in significantly reducing the noise in SO_2 product

Summary

- A number of transpacific transport events observed by Aura/OMI and Aqua/AIRS sensors in autumn (~4 events/year)
- WCB's are the main mechanism for exporting Asian pollution, meteorology over E Pacific is important for the rapid transport events
- Satellite observations suggest the magnitude of such rapid transport events can be much stronger than previously observed in field experiments
- Combined use of AIRS CO and OMI SO_2 helps improve confidence in detection of such events, and also differentiate different types of plumes
- Paper # 2011JD016626 in JGR, 2012