



# Atmospheric Measurements in the Canadian High Arctic: The PEARL Experience



CANDAC

Canadian Network for the Detection of Atmospheric Change





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# The PEARL at Eureka

## Polar Environment Atmospheric Research Laboratory

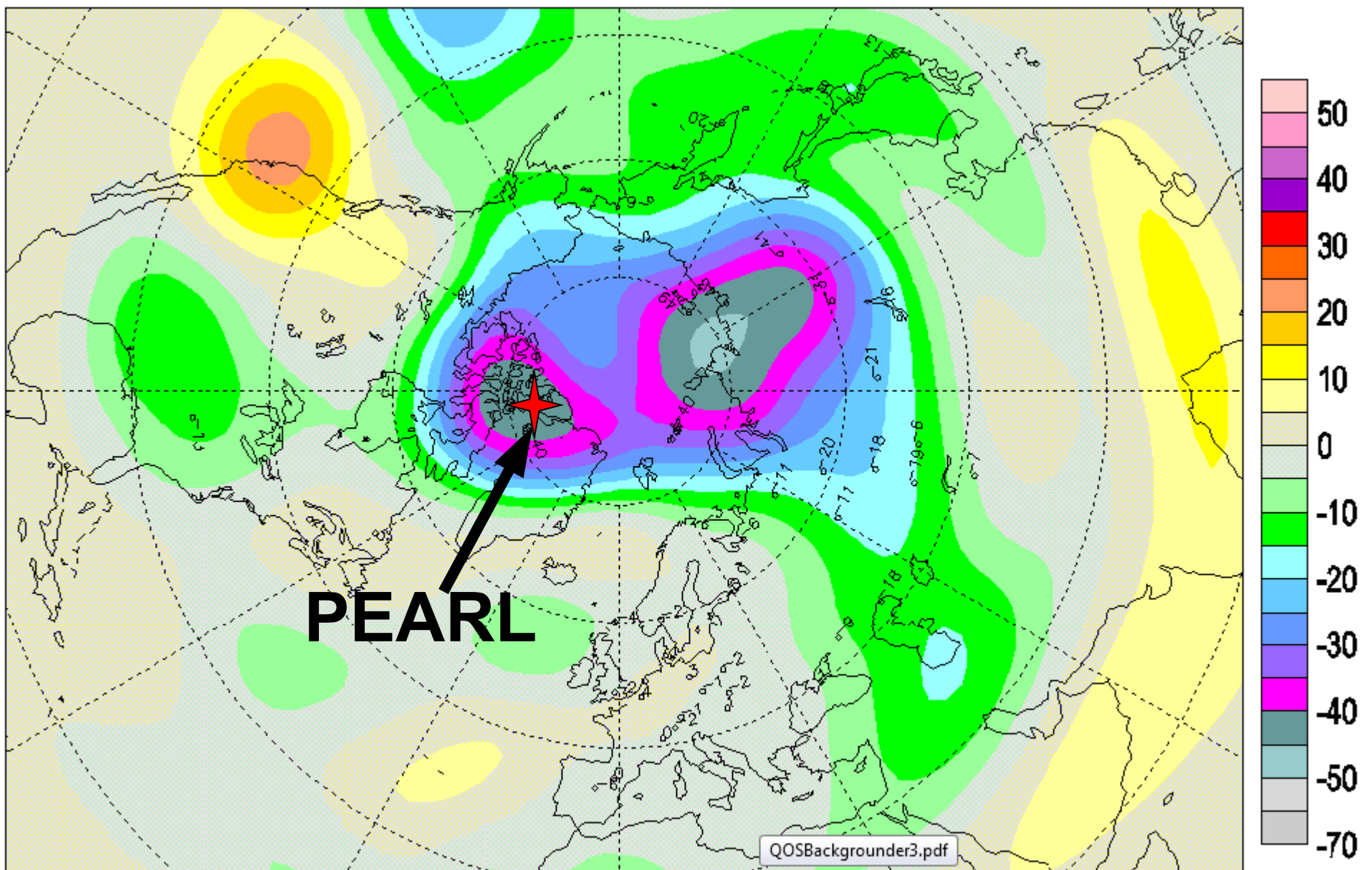
- Formerly Environment Canada's Arctic Stratospheric Ozone Observatory
- Run by the Canadian Network for Detection of Atmospheric Change (CANDAC) since August 2005
- ~25 experiments at 3 facilities



- Located on Ellesmere Island, Nunavut ( $80^{\circ}\text{N}$ ,  $86^{\circ}\text{W}$ )
- 15 km from Env. Canada's Eureka Weather Station
- 1100 km from North Pole



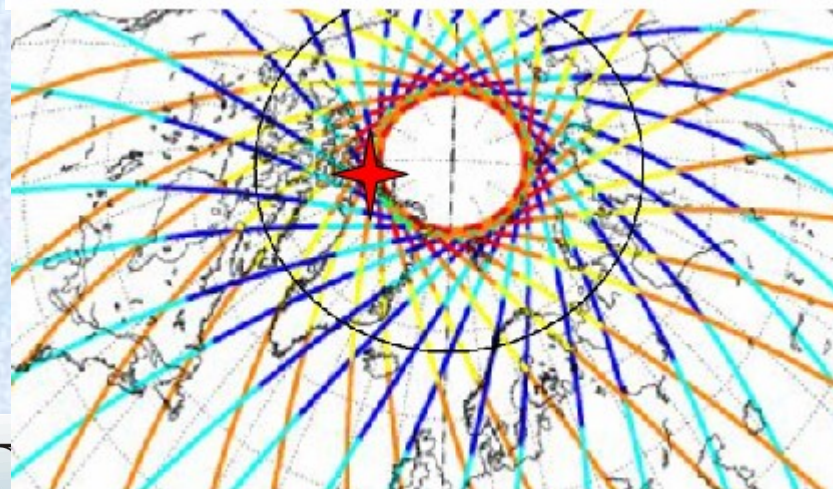
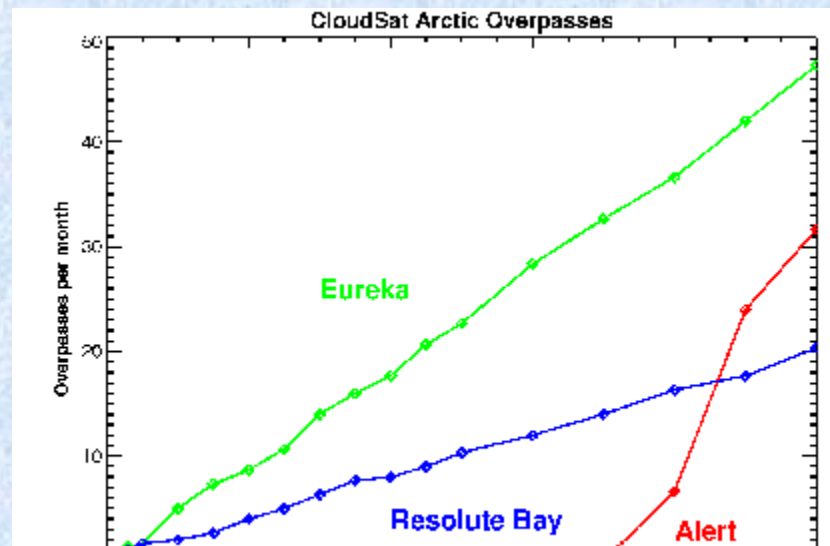
# Ozone March 2011





# Satellite Validation

- Eureka is at the “sweet spot” for polar orbiting satellites
  - **More overpasses at this latitude than any other location on the planet**
- Possible to validate
  - “A-train” (Cloudsat)
  - Scisat
  - Terra/Aqua/Aura
  - Envisat
  - Any sun synchronous satellite











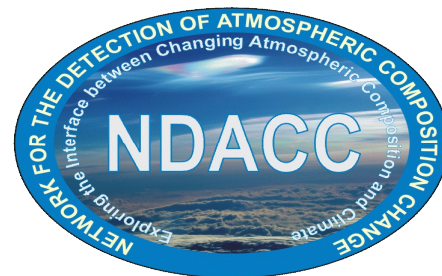








**NSERC  
CRSNG**



# PROBING THE ATMOSPHERE OF THE HIGH ARCTIC (PAHA)



Environment  
Canada

Environnement  
Canada

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# What are We Doing?

- Addressing the issue of the variability of the atmosphere in the Canadian High Arctic.
- Three major themes: Composition Measurements (CM), Polar Night (PN) and Satellite Validation (SV).
- The strength of this proposal is the extent to which a comprehensive, well-calibrated set of measurements from the High Arctic will be used in multiple ways to produce multiple outcomes.
- Emphasis on the Polar Night



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# Resources

- The dataset from Eureka from inception of: the weather station (1947+), ASTRO (~1993-2002) and PEARL (2005+)
- PEARL and its associated instrumentation (25+ instruments spanning the entire atmosphere)
- Links to other Arctic stations through the Integrated Arctic Stations for Observing the Atmosphere (IASOA) initiative (under SAON)
- Other (inter)national collaborations



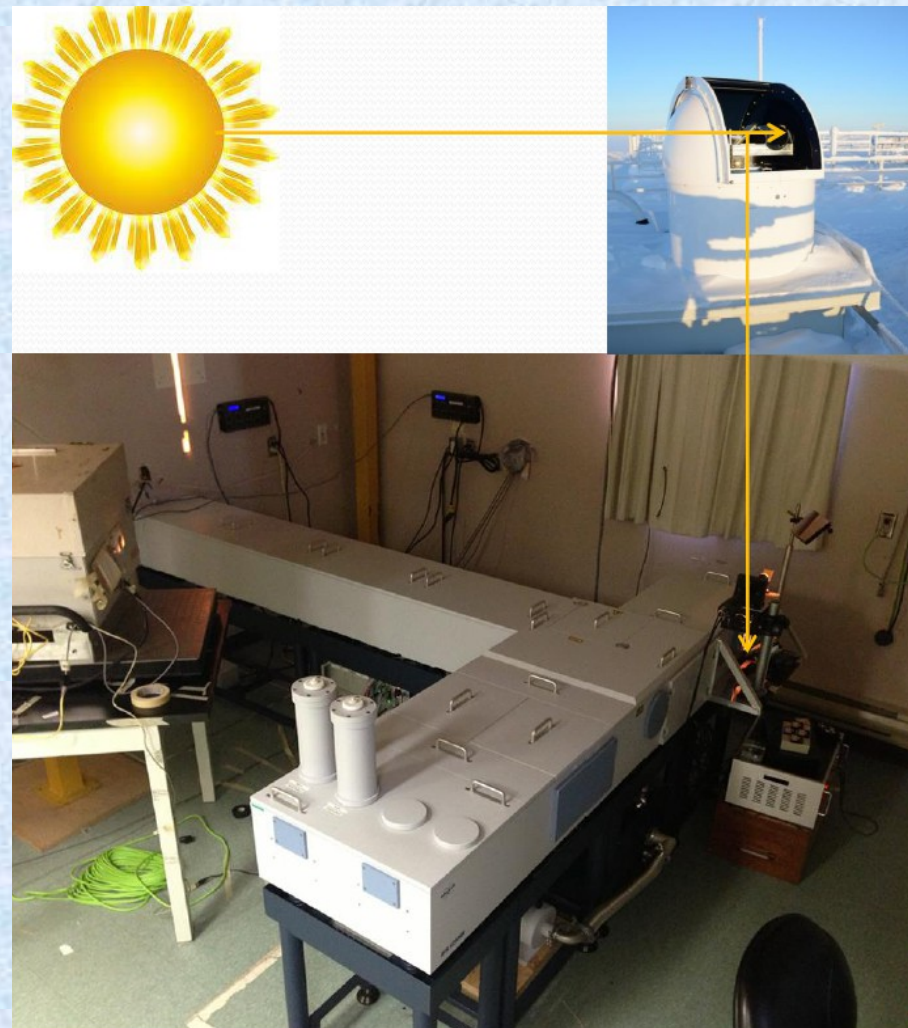
Canadian Network for the Detection of Atmospheric Change





# PEARL FTIR: Bruker 125HR

- Fourier transform infrared (FTIR) spectrometer installed July 2006
  - Replaced EC Bomem DA8, which was removed in 2009
- Daily semi-automated solar infrared absorption measurements
  - Late February to late October
- Vertical profiles and columns of many gases retrieved
  - $O_3$ ,  $NO$ ,  $NO_2$ ,  $HNO_3$ ,  $ClONO_2$ ,  $HCl$ ,  $OCIO$ ,  $HF$ ,  $N_2O$ ,  $CFCs$ ,  $CO$ ,  $CH_4$ ,  $C_2H_6$ ,  $HCN$ ,  $OCS$ , ...

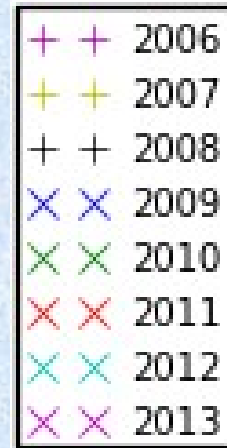
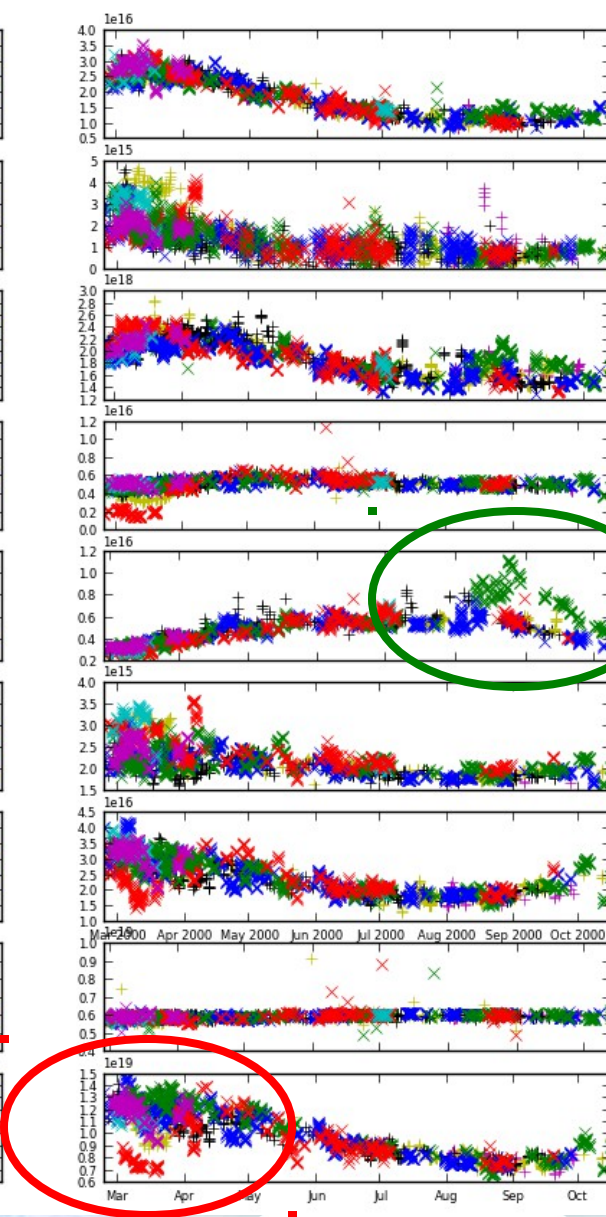
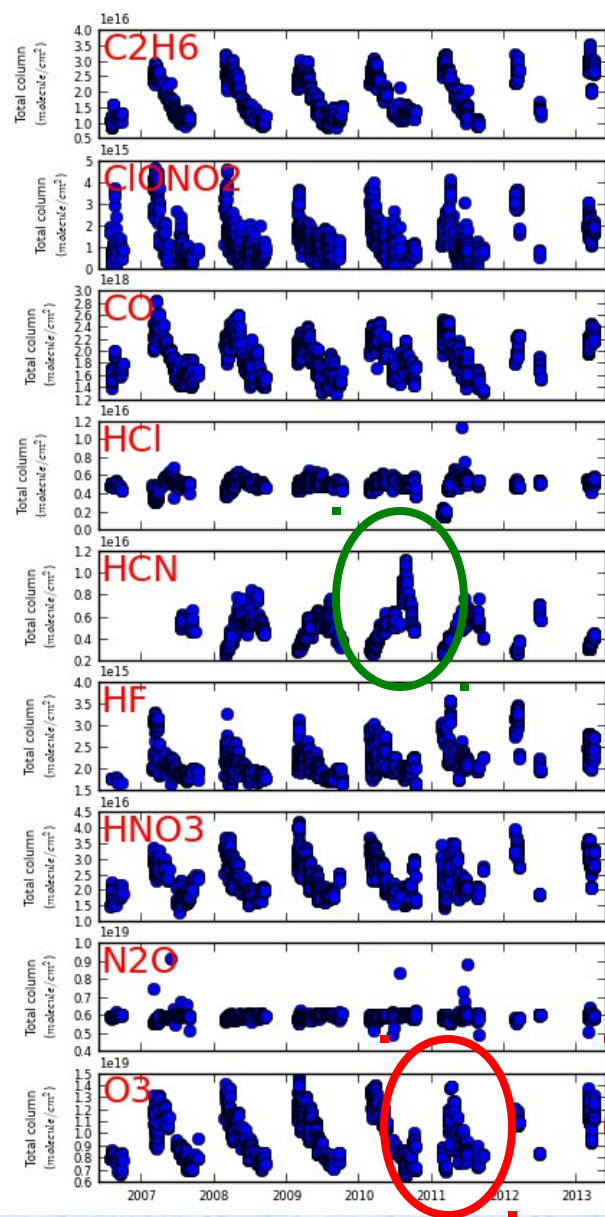


Dan Weaver, Joseph Mendonca





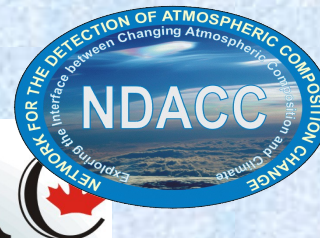
# PEARL FTIR Time Series: 2006-2013



**Total columns**

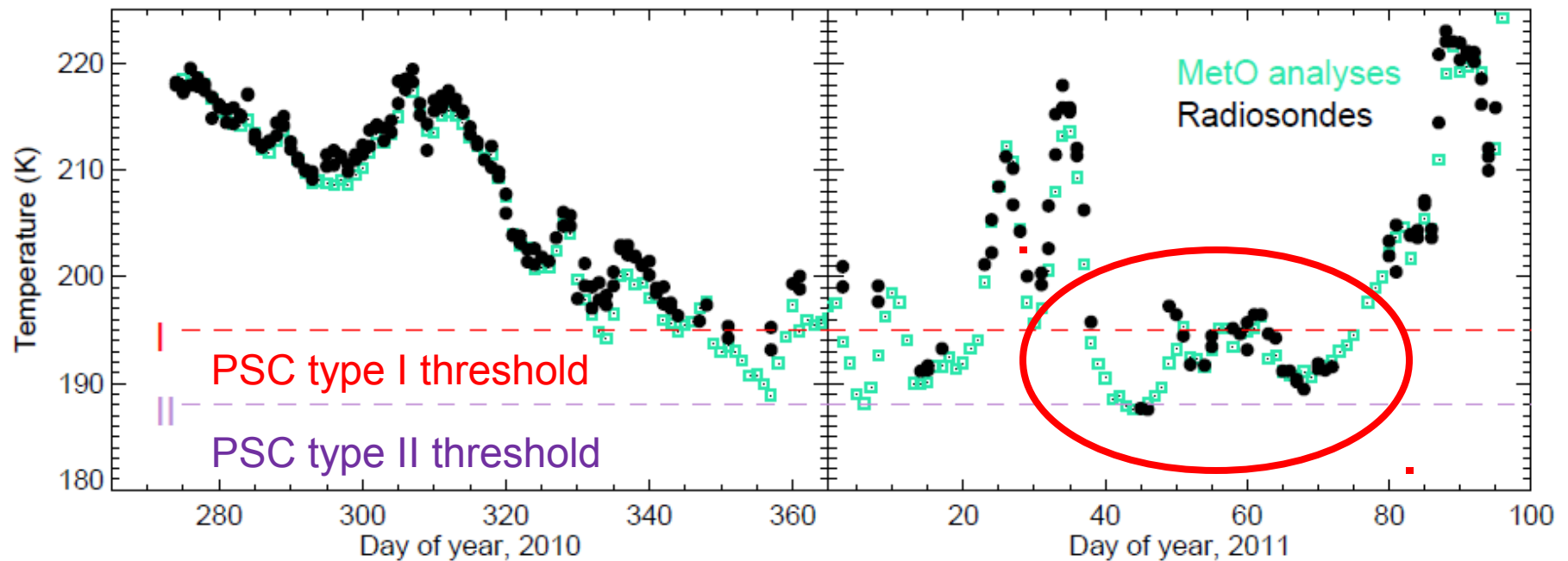
This extends the 1993-2008 springtime dataset acquired by Environment Canada's Bomem DA8 FTIR (H. Fast, R. Mittermeier)

Rodica Lindenmaier,  
Rebecca Batchelor,  
Joseph Mendonca,  
Dan Weaver,  
Camille Viatte,  
Stephanie Conway





# 1: Temperatures above Eureka

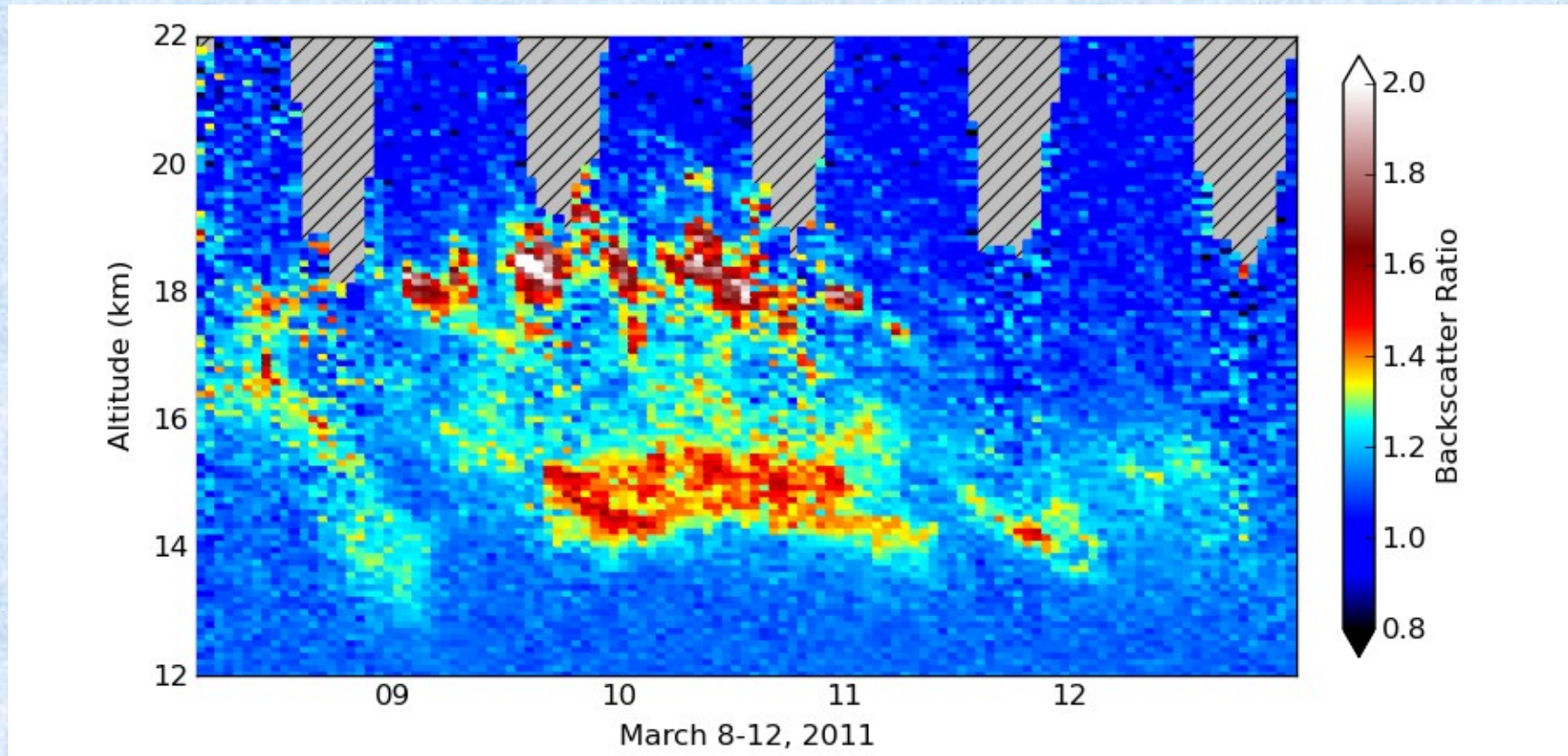


Time series of temperature on the 525-K isentropic surface (~21 km) obtained from the MetO analyses for Eureka, and from radiosondes launched at Eureka.



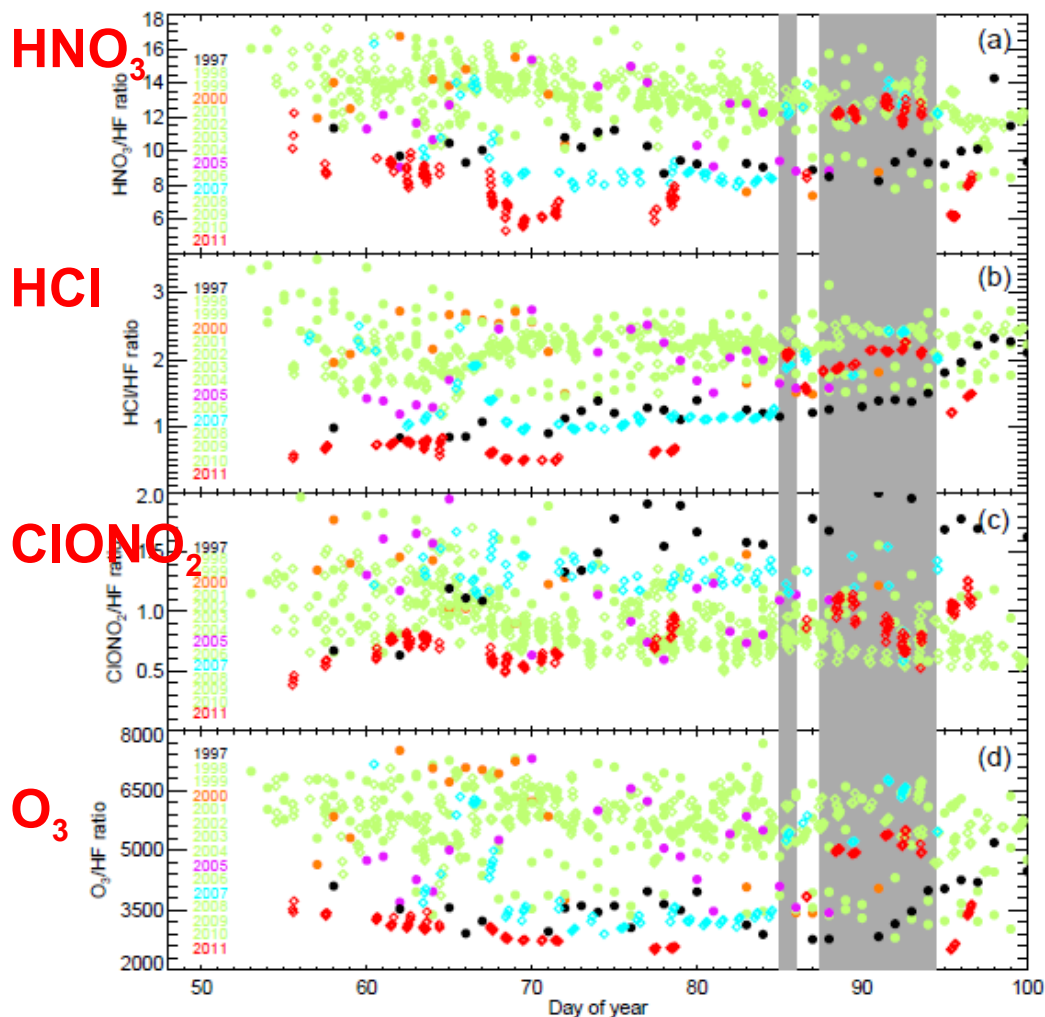
# 2011: Polar Stratospheric Clouds

- PSCs were detected above Eureka from March 8-12 by the CANDAC Rayleigh-Mie-Raman Lidar (run by Tom Duck)





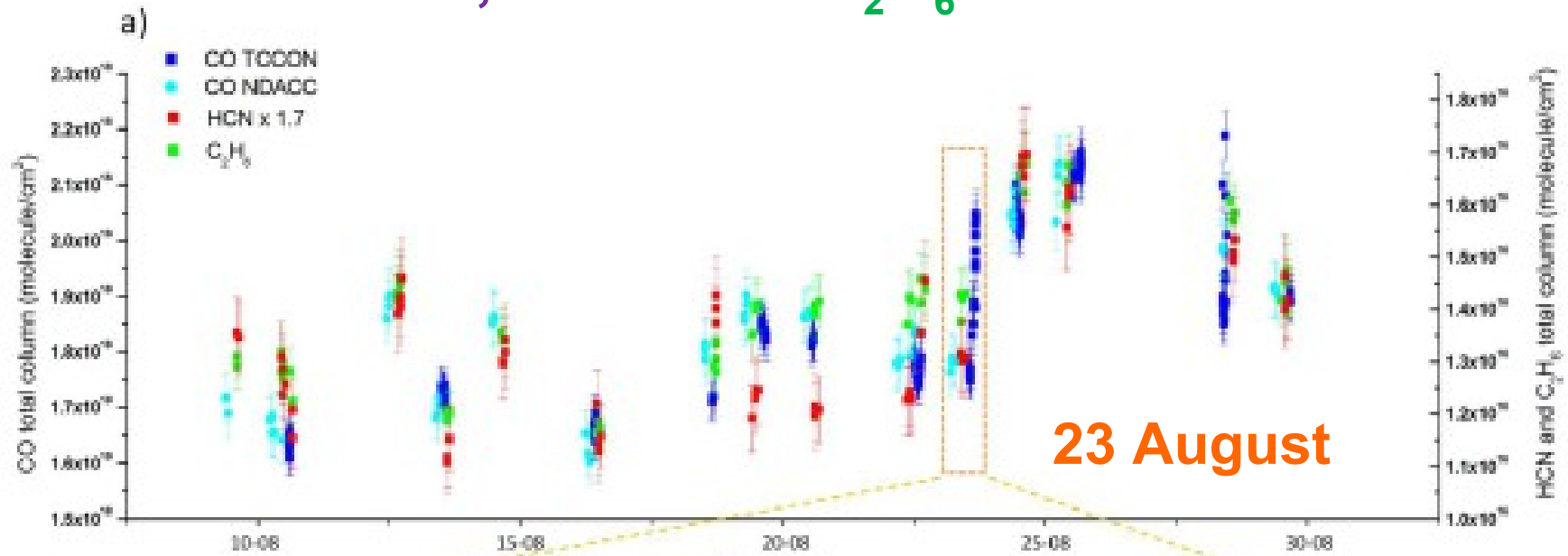
# 2011: Stratospheric Ozone Depletion



- Total Columns: 1997-2011
  - 1997-2006 EC Bomem DA8
  - 2007-2011 Bruker 125HR
  - Normalized by HF to remove dynamical effects
  - Shading = outside vortex
- Most years in green
- Years with significant ozone depletion in colours
- 2011 in red
  - Low  $\text{HNO}_3$ ,  $\text{HCl}$ ,  $\text{ClONO}_2$ ,  $\text{O}_3$  indicate chemical processing
  - 35% chemical ozone loss

# August 2010 Biomass Burning Event

August 10 to 30, 2010  
**CO**, **HCN** and **C<sub>2</sub>H<sub>6</sub>** columns



**HCN** total columns are **enhanced** by more than **50%** compared to the four-year (2008-2011) monthly mean for August



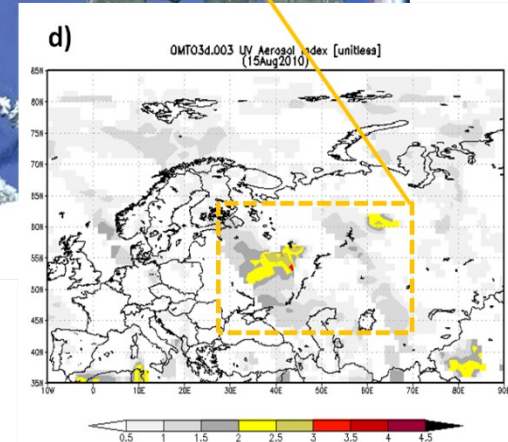
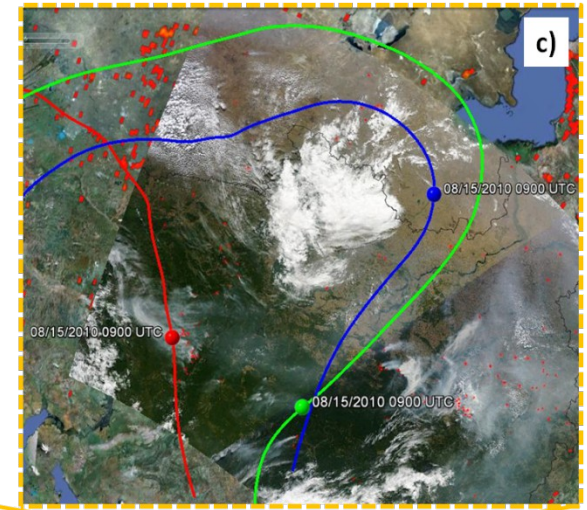
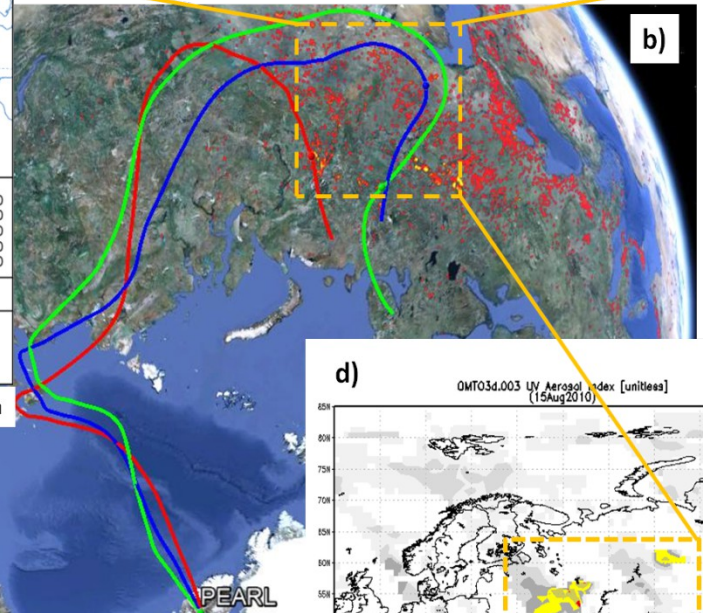
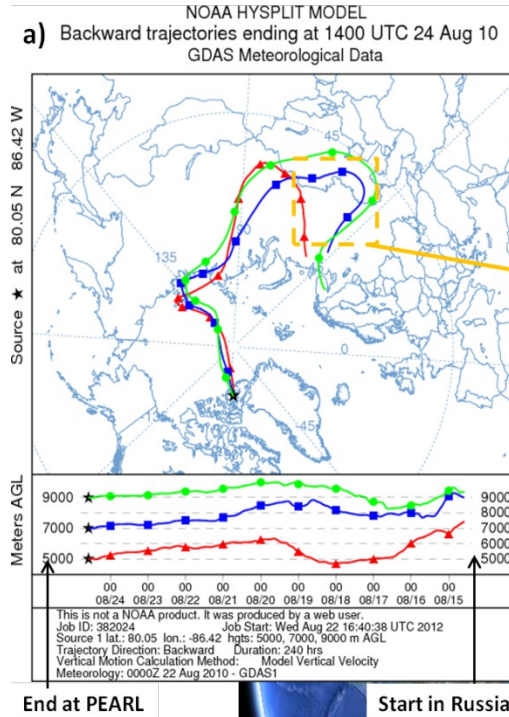
# Tracking the Origin of August 2010 Event

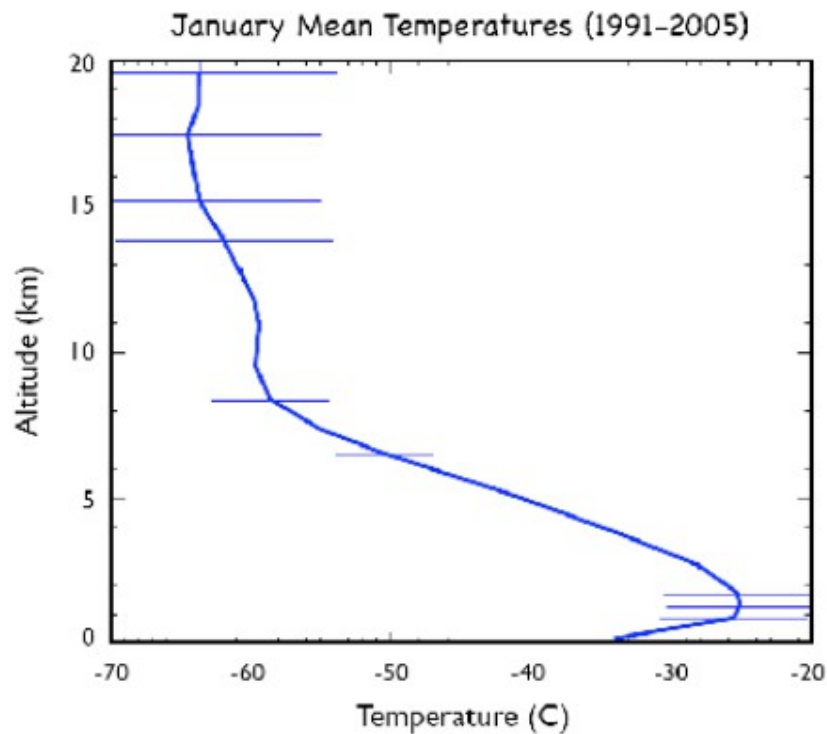
Russian wildfires covered ~5M hectares by early August 2010

Smoke extended  
over about 3,000 km  
(E to W) and  
sometimes reached  
altitudes of 12 km

# Plumes from fires on August 15 arrived at PEARL on August 24

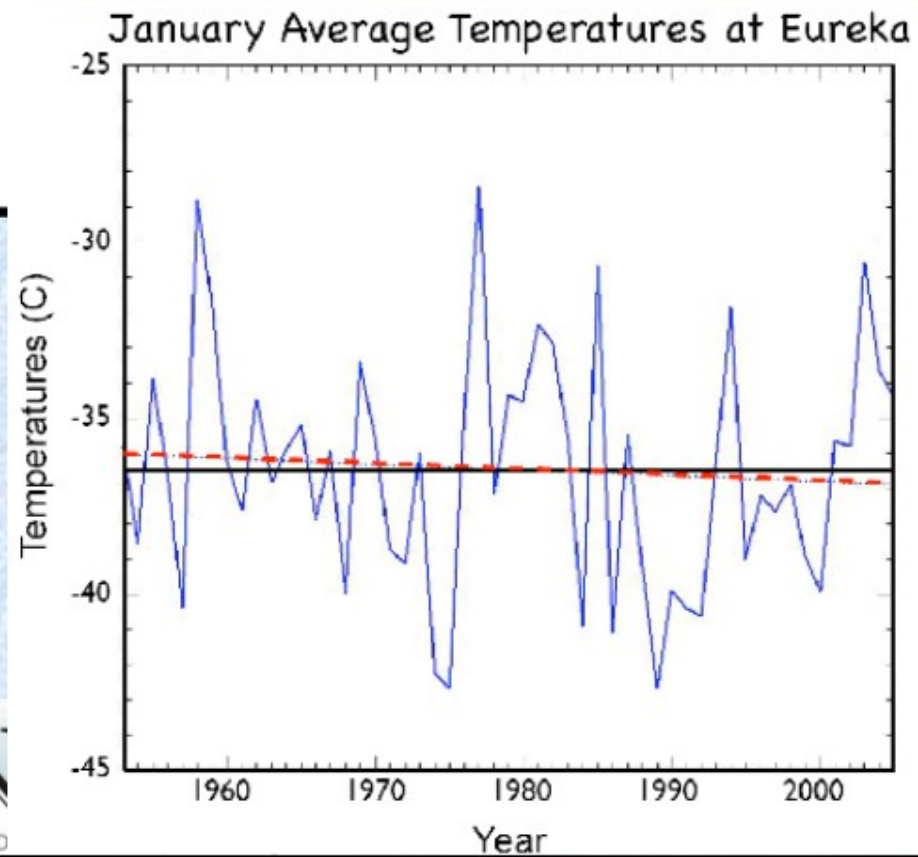
- a) HYSPLIT back-trajectories
- b) Back-trajectories on Google ma
- c) MODIS fire image
- d) OMI aerosol index





# The Polar Night

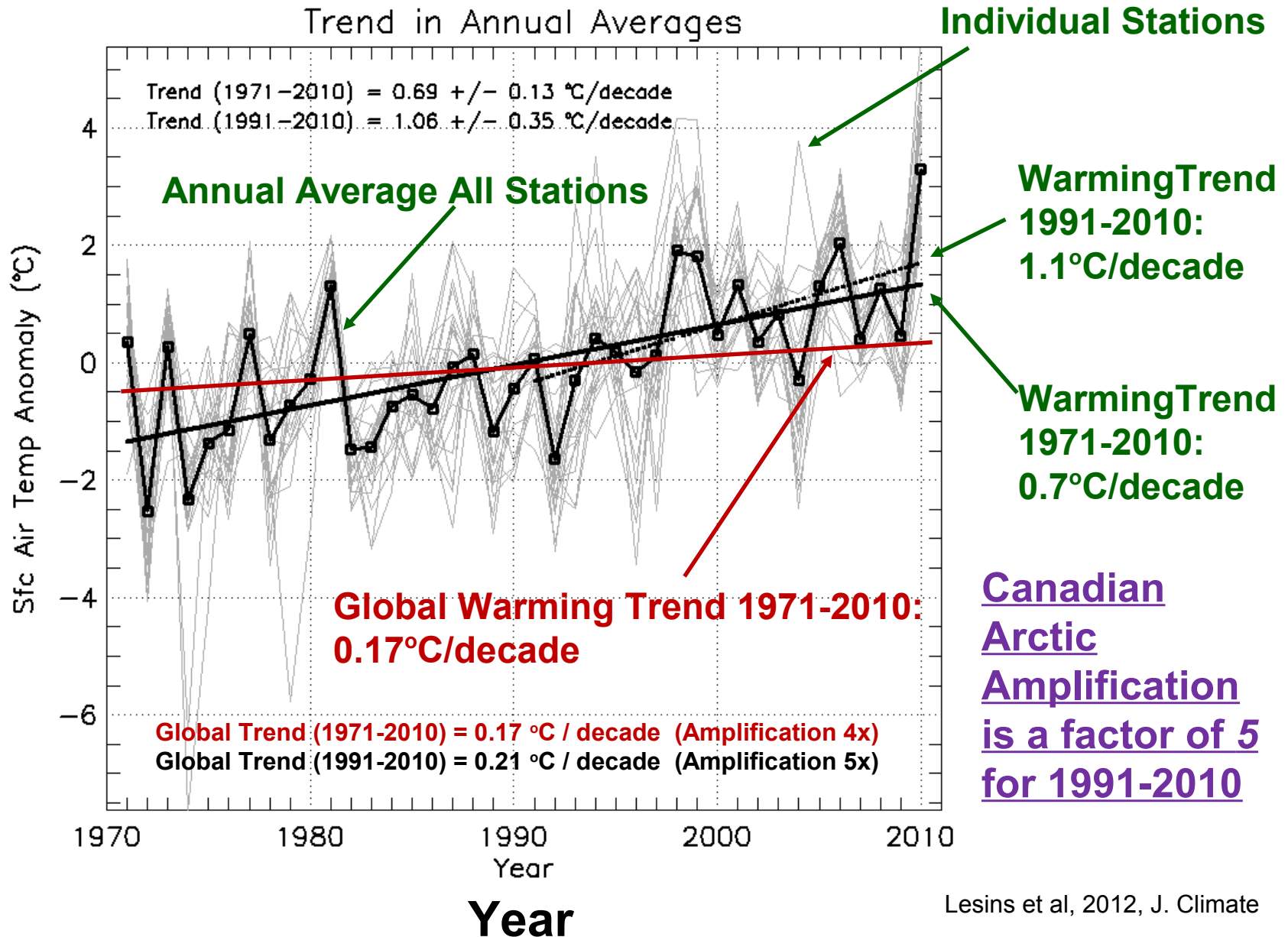
**In winter it is permanently cold!**  
**There is a persistent inversion**





# Trend in the annual mean surface air temperature averaged over 22 stations covering most of Canada.

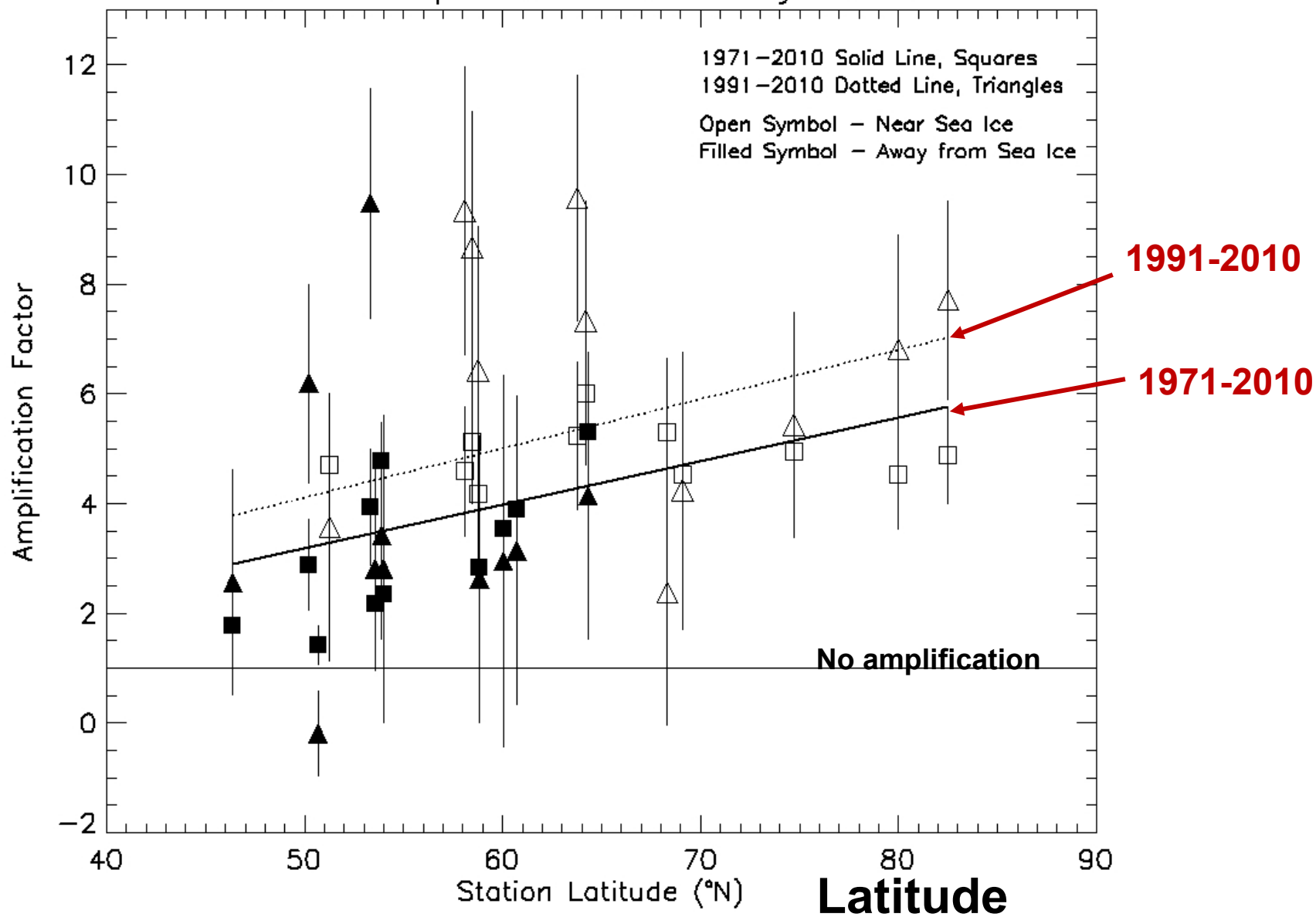
Surface Air Temperature Anomaly (°C)



# Amplification Factor Increases by about 80 % from 50° to 80°N latitude

Annual Amplification Factors by Latitude

Amplification Factor

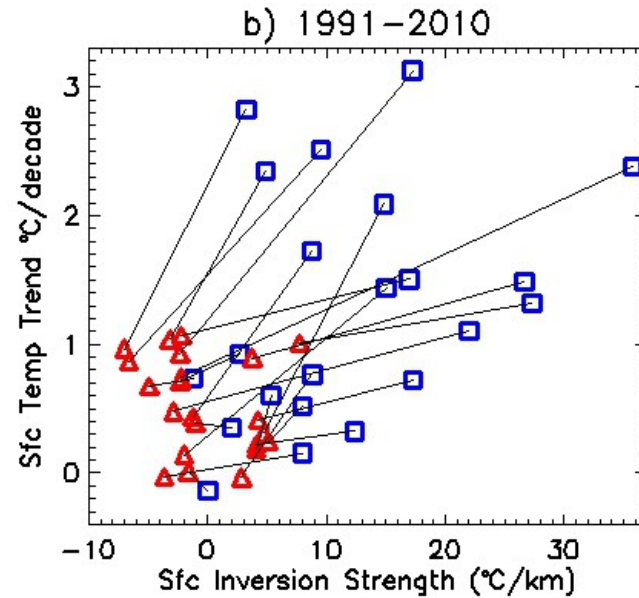
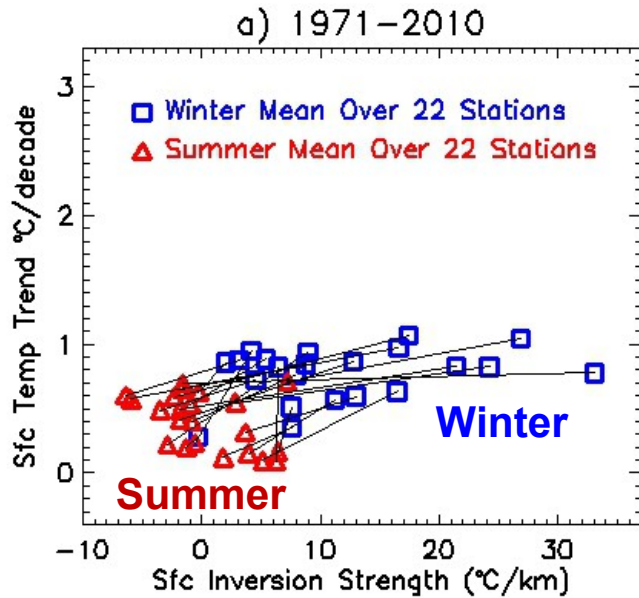




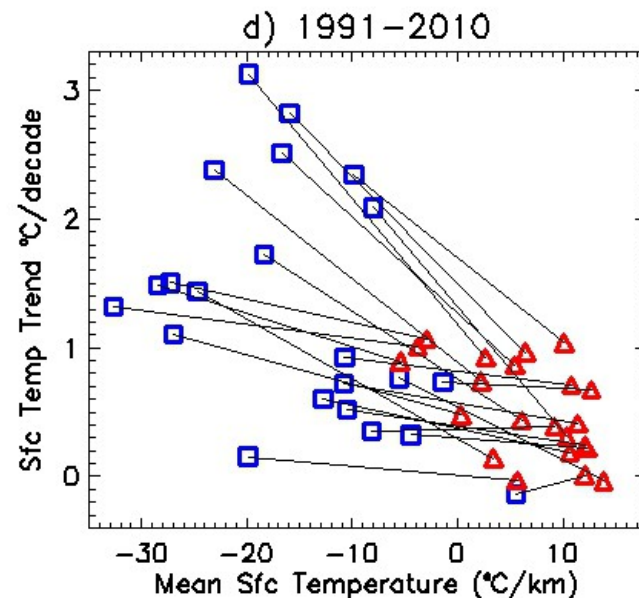
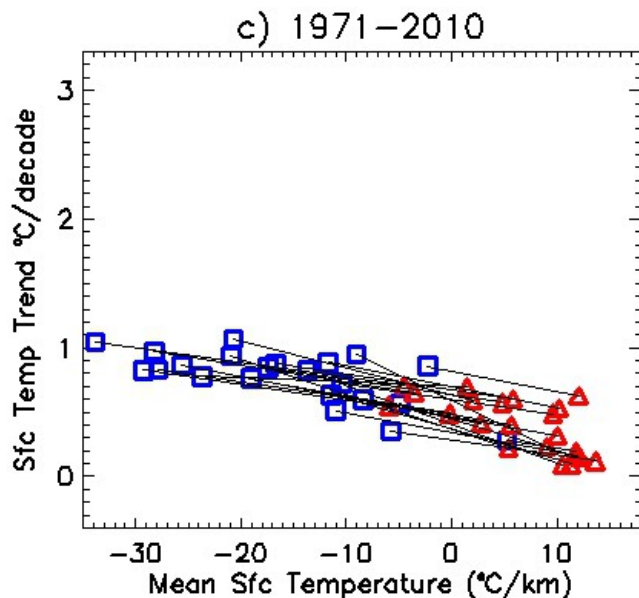
# The Warming Trend is Amplified in the Winter

Related to the temperature inversion and cold surface temperatures.

Surface Temperature Warming Trend ( $^{\circ}\text{C}/\text{decade}$ )



Top 2 plots:  
Warming trend  
increases with  
inversion  
strength



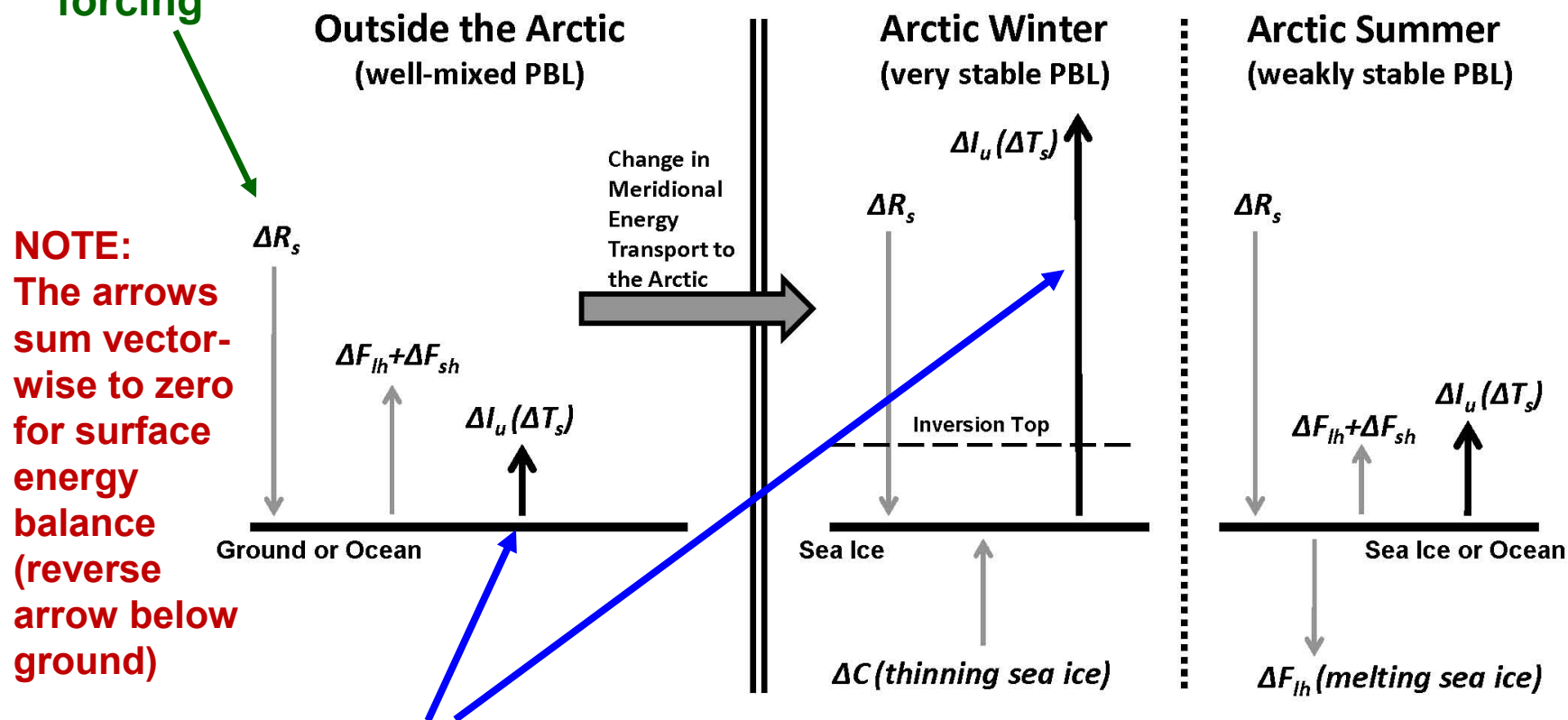
Bottom 2 plots:  
Warming trend  
increases with  
colder surface  
temperatures

**Much of Arctic Amplification is a consequence of a suppressed latent and sensible heat response due to the stable boundary layer.**

$$\Delta I_u (\Delta T_s) = \Delta R_s + \Delta C + \Delta F_{sh} + \Delta F_{lh}$$

Change in  
surface  
radiative  
forcing

$$\Delta R_s (\Delta T, \Delta CO_{2,eq}, \Delta \text{water vapor}, \Delta \text{clouds}, \Delta \text{aerosols})$$



**NOTE:**  
The arrows  
sum vector-  
wise to zero  
for surface  
energy  
balance  
(reverse  
arrow below  
ground)

The length of the bold black arrow ( $\Delta I_u$ ) gives the amount of surface warming



A close-up photograph of a white dog's face, focusing on its eyes and nose. The dog has light-colored eyes and a black nose. The background is a soft, out-of-focus white.

*Thank You for Your  
Attention!*

*<http://www.candac.ca>*