Multi-Year Characterization of PSCs in the Arctic using Solar Occultation Satellite Observations

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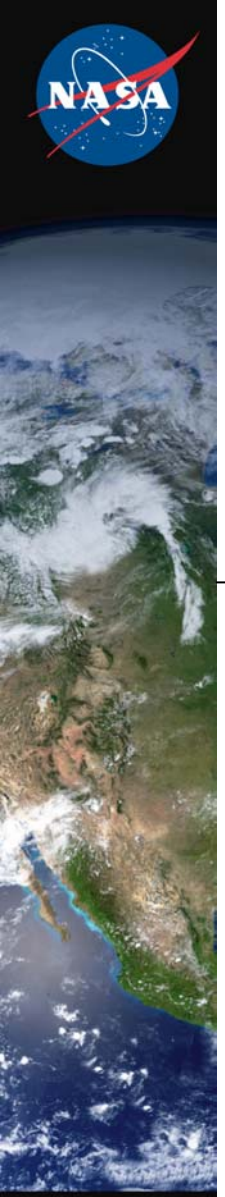
AGU Fall Meeting
Dec. 9-12, 2003
San Fransisco, CA



Summary

- Discriminate Ia and Ib POAM obs from 1998-2003 Arctic winters
- Realign temperatures histories so that first observation of $T = T_{NAT}$ are aligned

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- Early onset of Ia PSCs - Type I PSCs form within days of minimum observed Temp = T_{NAT}
- Ib PSC formation temperature = T_{NAT} -4 K
- Ia PSC formation temperature = T_{NAT} -1 K
- Heterogeneous freezing contributes to the freezing of solid phase (Ia) PSCs

Acknowledgements

- POAM III and SAGE III instrument teams
- Support from
  - Atmospheric and Climate Modeling Program
  - Upper Atmospheric Research Program

Background

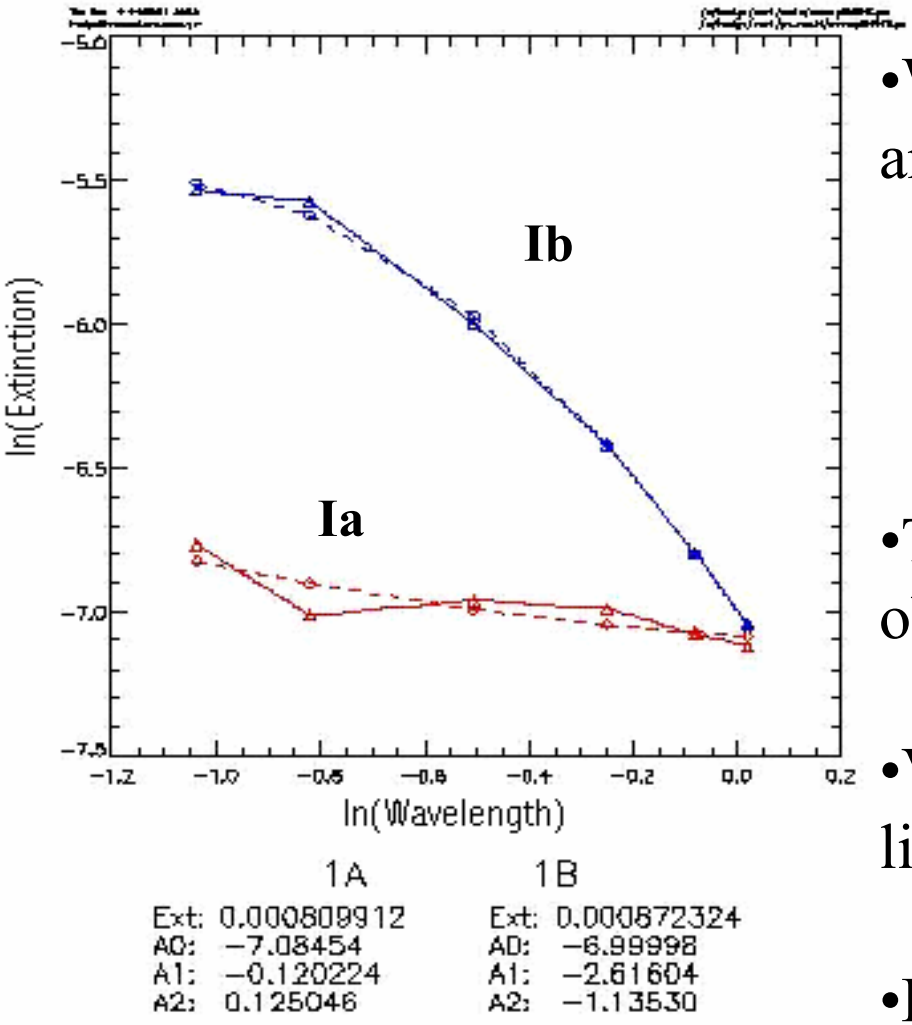
- 2 types of Type I PSCs
  - Type Ia – large, solid hydrates of nitric acid (NAT, NAD)
  - Type Ib – supercooled liquid ternary solutions (STS) of H2SO4, NH4, and H2O
- PSCs are important because
  - provide surfaces for heterogeneous reactions that produce active forms of chlorine
  - Type Ia PSCs can permanently remove nitric acid from the stratosphere by sedimentation
- Currently no models can accurately predict PSC formation and ozone loss

Models of Type I PSC formation

- Homogeneous freezing to water ice at about T_{NAT} - 7 K [Waibel et al., 1999]
- Homogeneous freezing to NAT or NAD with Significant freezing at T_{NAT} - 5 or -6 K
  - Volume-based freezing rates [Salcedo et al., 2001; Tabazedeh et al., 2001]
  - Surface-based freezing rates [Salcedo et al., 2001; Tabazedeh et al., 2002]
- Heterogeneous freezing at T_{NAT} - 1 or - 2 K

- Microphysical model controlls amount of
  - Denitrification
  - Dehydration
  - Ozone loss

Type I PSC Discrimination Method



- Wavelength depedence of Type Ia and Ib
  - Fit quadratic
  - $\ln \sigma_{ext} = a_0 + a_1 \ln \lambda + a_2 (\ln \lambda)^2$
  - A1 = modified Ångström coef
- The method used on POAM observations
- Verified using DIAL and OLEX lidar obs from SOLVE
- Ref. Strawa et al. JGR 107(D20), 8291, 2002.

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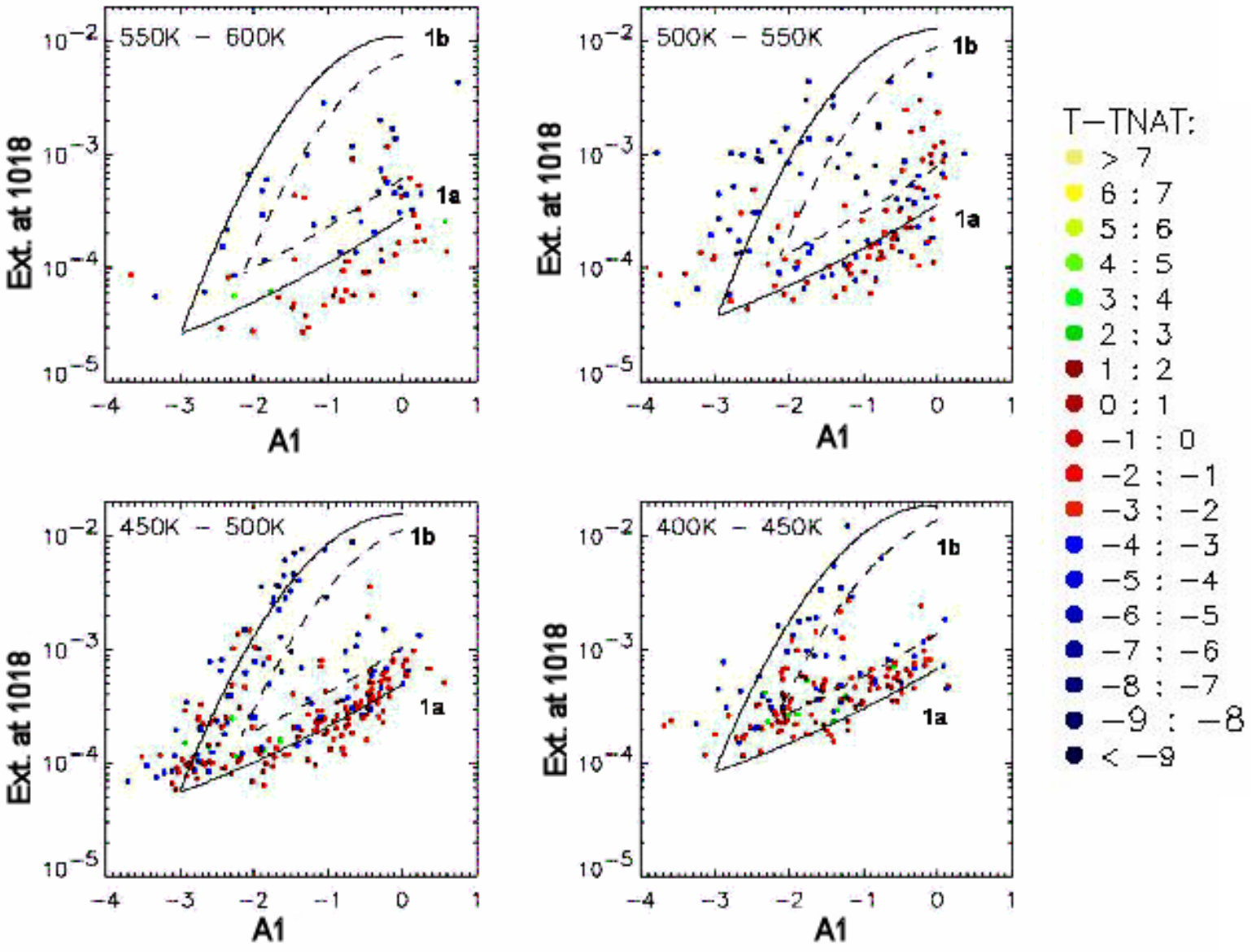
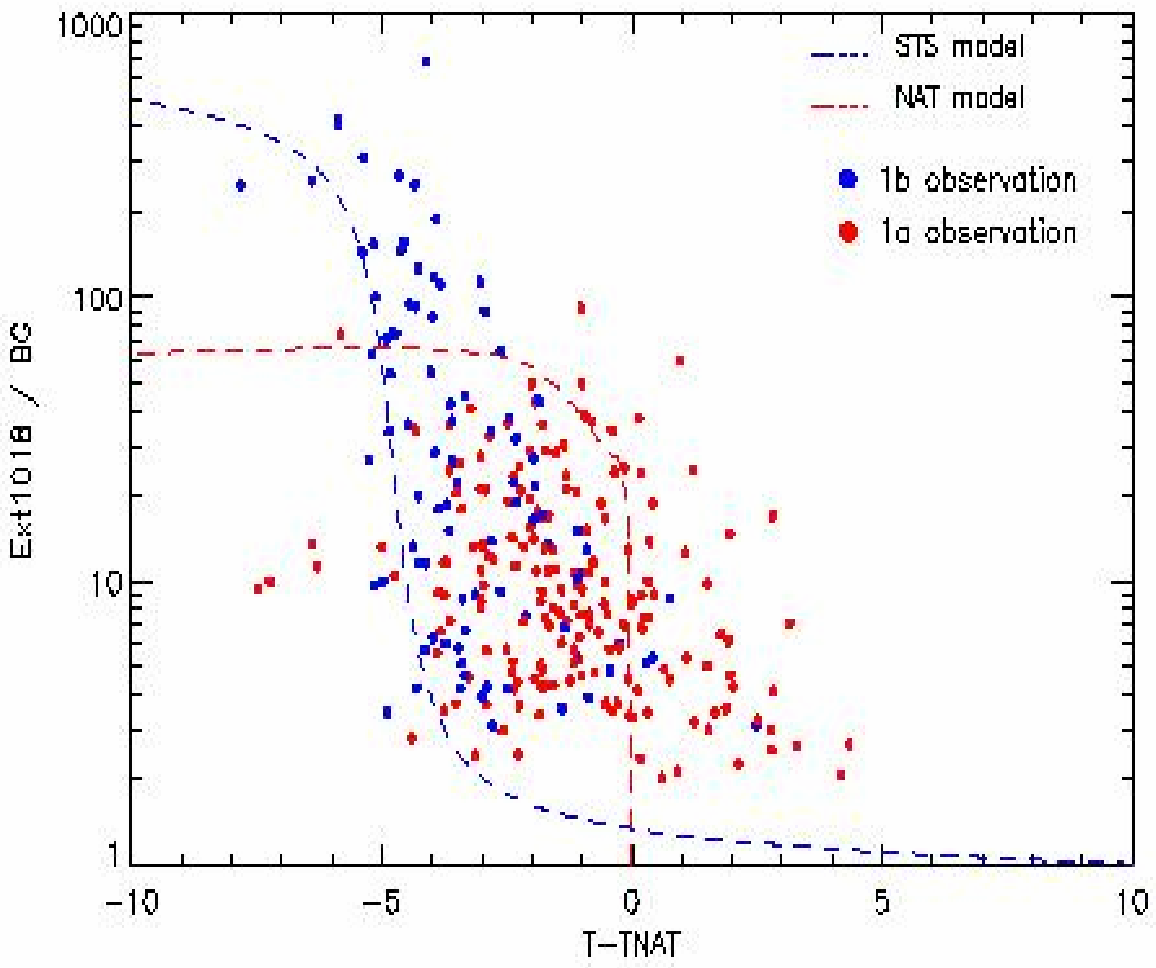
POAM PSC Observations 1998-2003



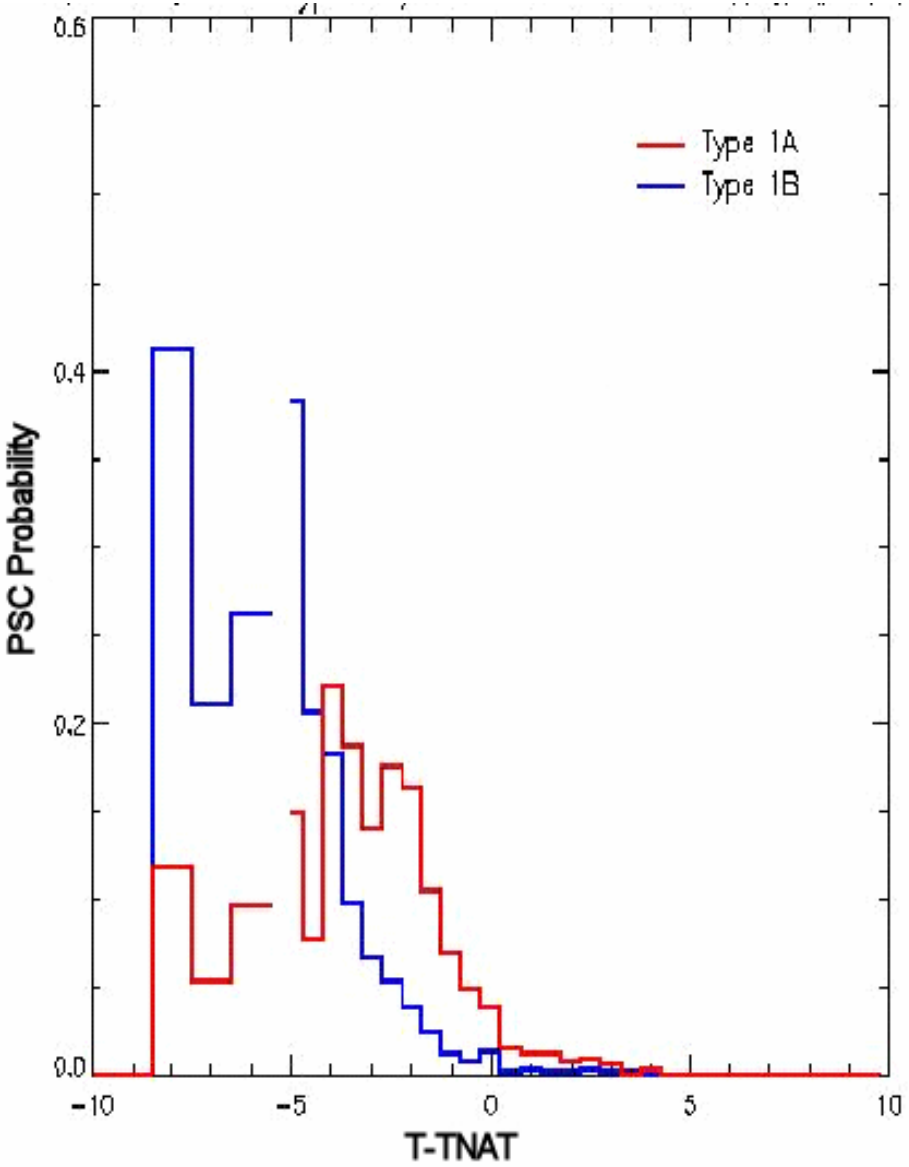
PSC Growth Curves

POAM Obs plotted vs UKMO temp at observation relative to Tnat



Type Ia – Red
Type Ib - Blue

PSC Probability



PSC Prob =
PSC observation as fraction of observations at a given temp

The inflection point of these curves indicates the PSC Formation temp

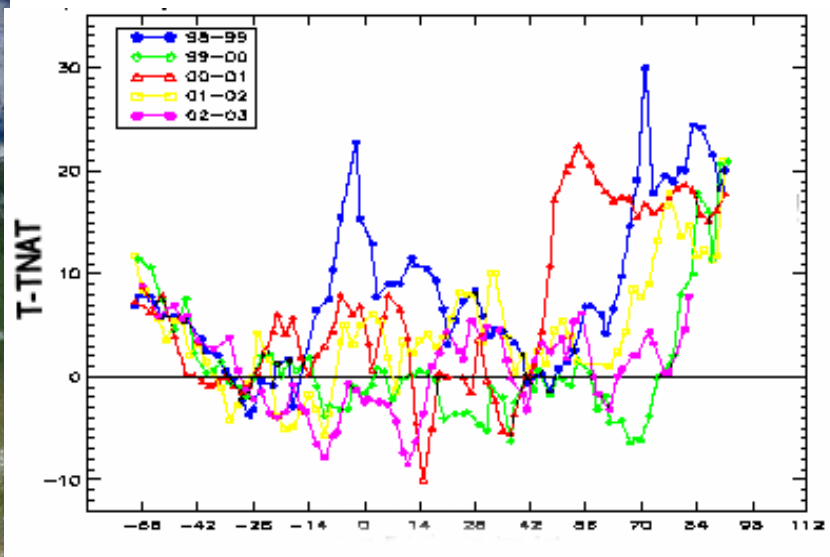
$T_{Ia} = T_{NAT} - 1$ K

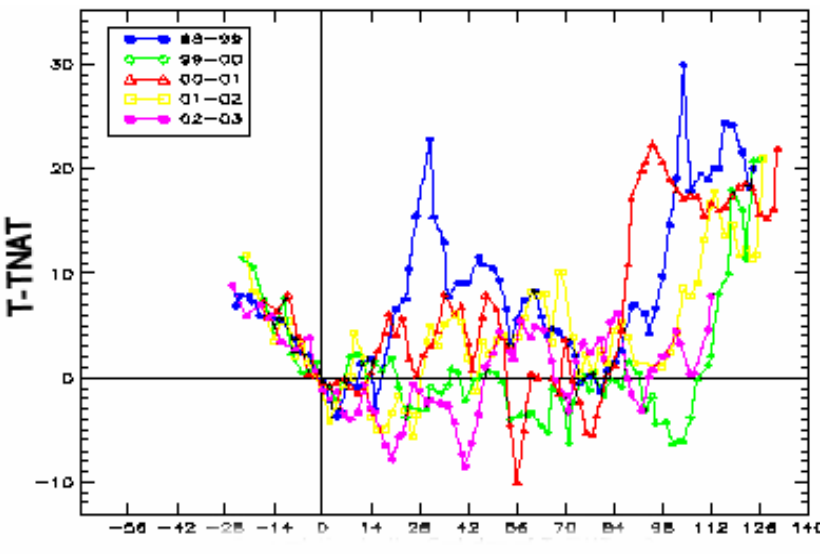
$T_{Ib} = T_{NAT} - 4$ K

Summary of steps to look at Multi –year trends

- Use Strawa + [2000] to Discriminate Type Ia Ib
- Realign Temperature Histories for 1998-2003
- Bin in to 14-day periods
- Look at Multi-Year PSC Characteristics

Realigning Minimum Temperature Histories

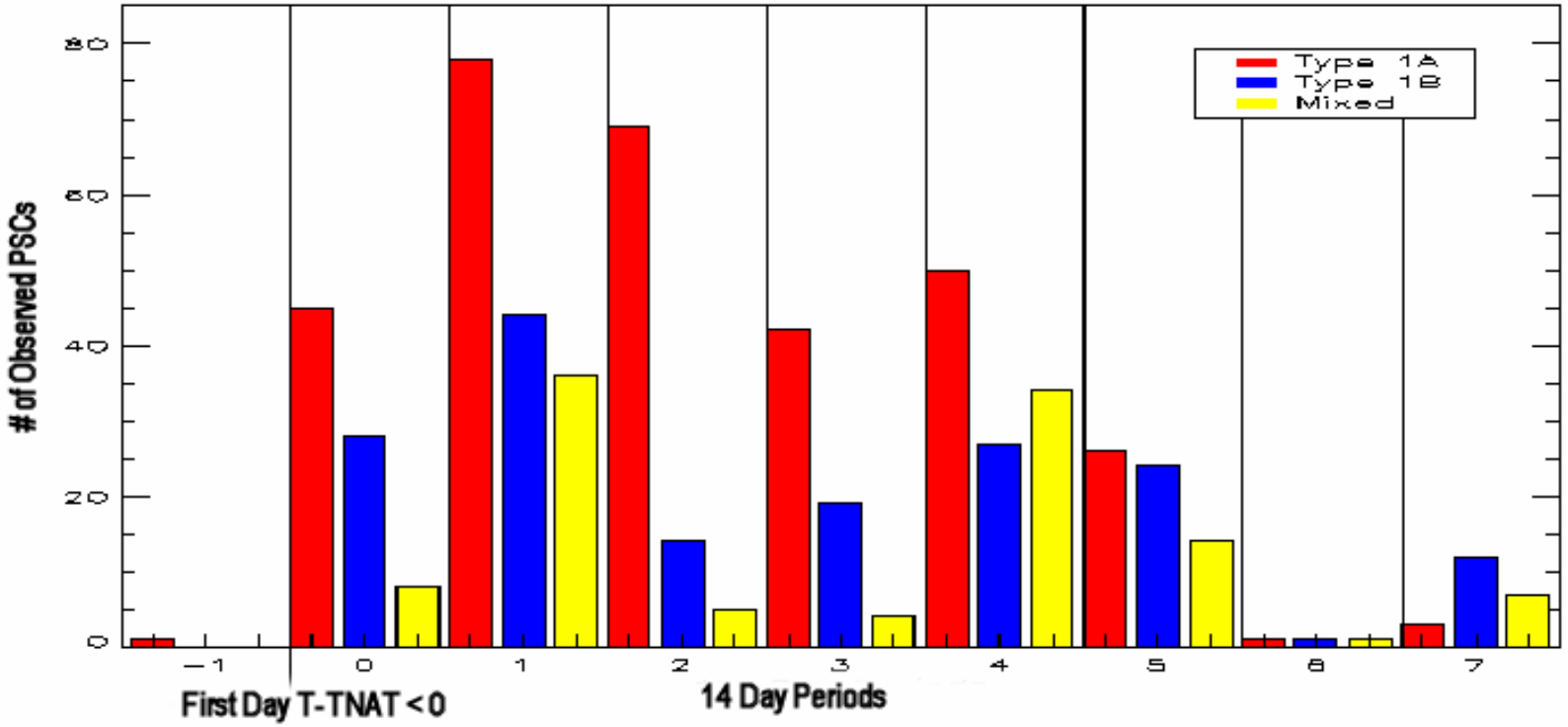




Minimum UKMO Temp at POAM observations for a given day

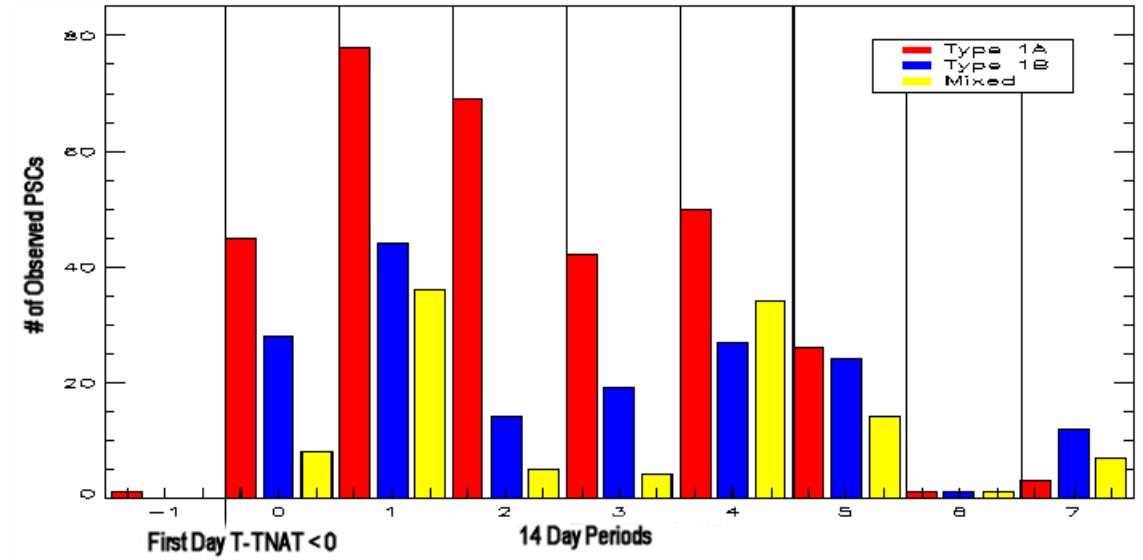
Shift days so that the first day T = T_{NAT} for a given year is aligned

PSC Observations binned into 14-Day Periods

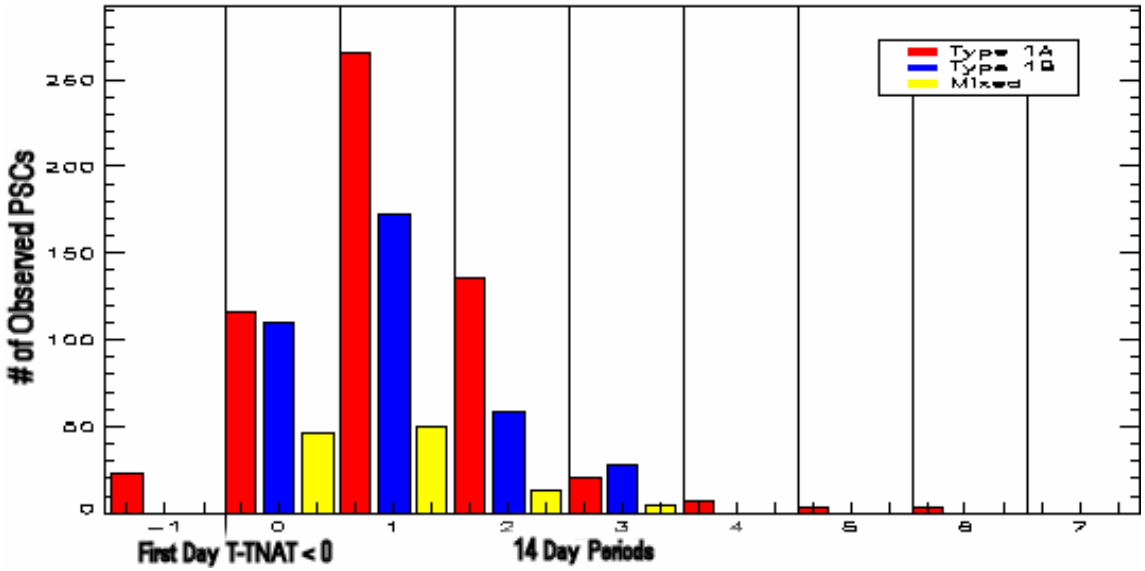


Large no of IA in period 0
Peak Ia and PSC in period 1
Temperature minimum is period 2
Steady decrease in PSC after period 1
1 PSC in period -1

POAM 3 compared to SAGE 3



POAM 3
1998-2003



SAGE 3
2002-03

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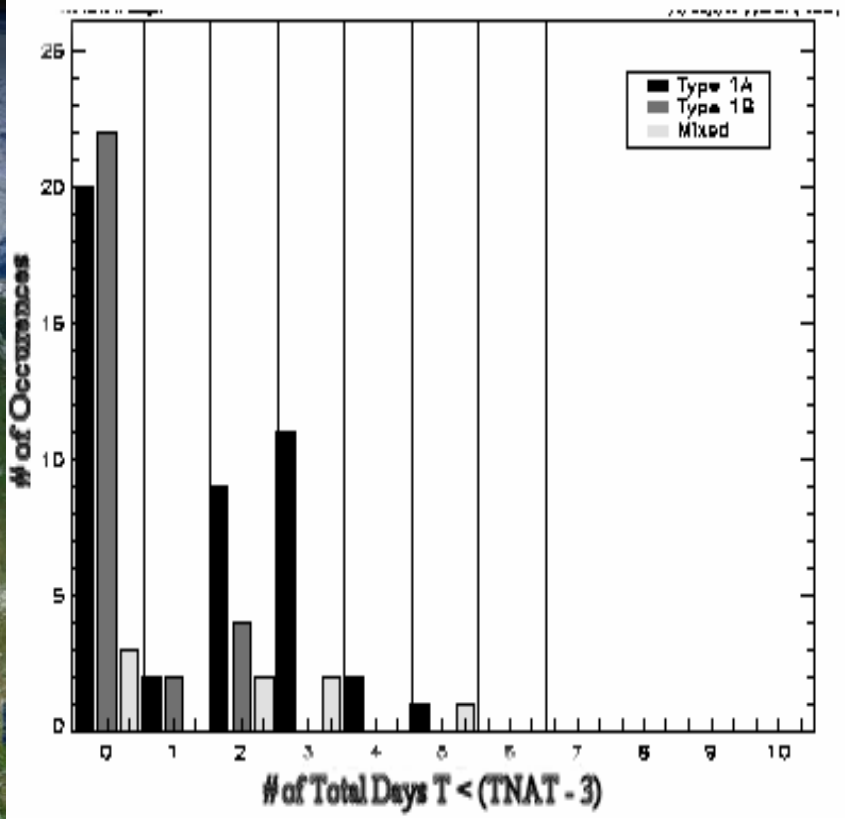
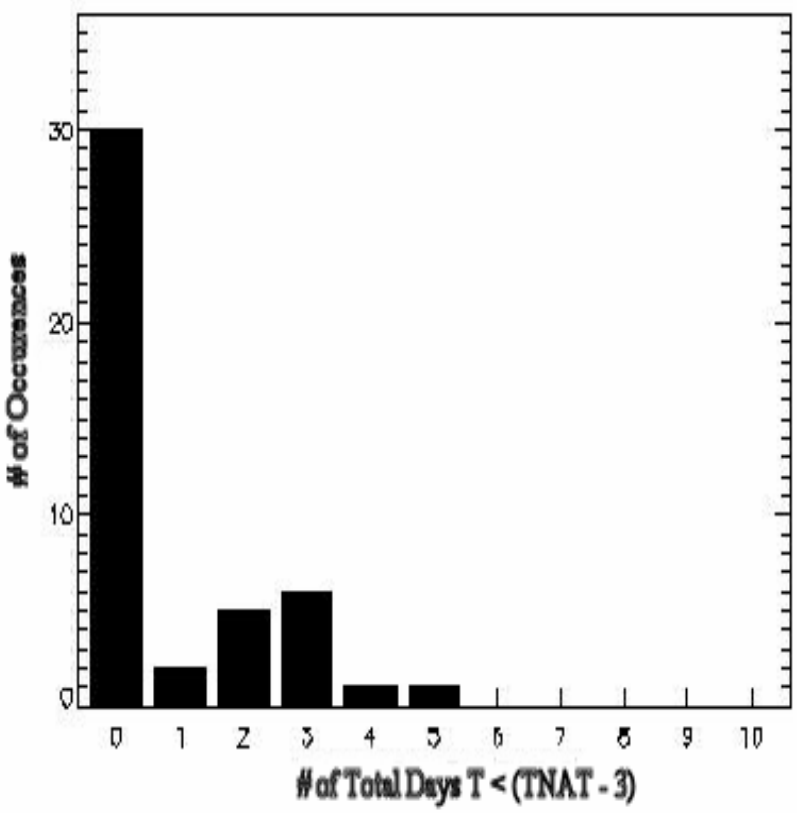
A closer look at period 1





Period 1
10- Day Back trajectories
T < TNAT - 3

Period 1- 2Kft higher
10-Day Back trajectoies
T < TNAT -3

Summary

- We use our discrimination scheme on POAM data from 1998-2003
- Realign temperatures histories so that first observation of $T < T_{NAT}$ are aligned
- Type I PSCs form within days of minimum observed Temp $< T_{NAT}$
- The number of Ia obs. > number of Ib obs.
- PSC obs peaked within 28 days of first $T < T_{NAT}$ while minimum Temperature is usually 28 to 42 days after
- PSC observations steadily decrease after peak in late Dec / early Jan
- Ia PSC formation temperature = T_{NAT} -1 K
- Ib PSC formation temperature = T_{NAT} -4 K

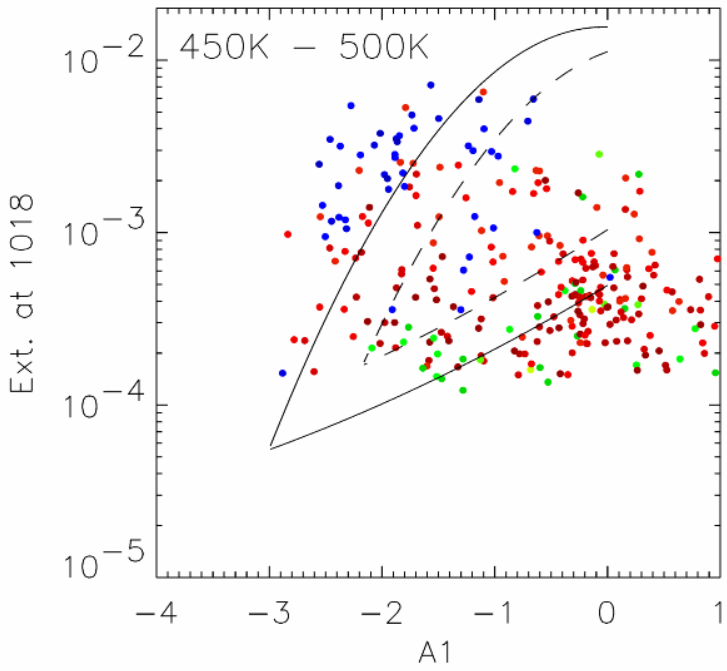
Limitations

- POAM observations in Arctic are limited to 60˚ – 75 ˚ N Latidude which may miss the coldest part of the vortex
- Sample volume of Solar Occultation Instruments is large – some separate colouds may appear mixed

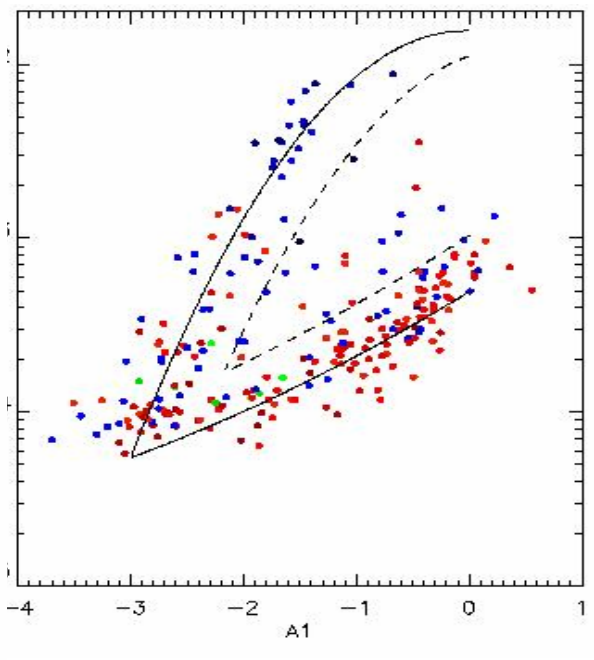
Future Work

- Include SAGE III Observations in this analysis
- Explore reasons for the differences between ‘clean’ and post-volcanic years
- Extend this analysis to Antarctic

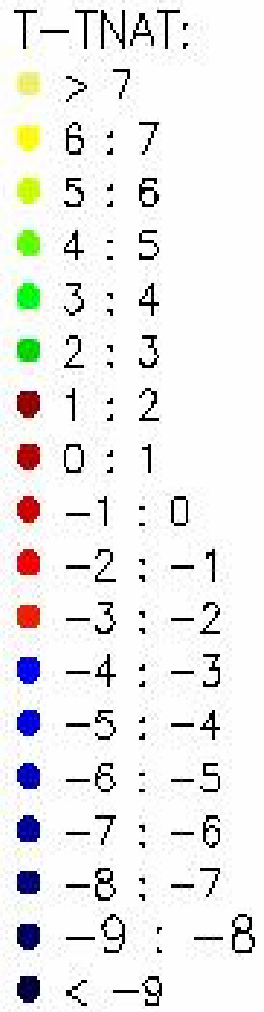
1994-96 vs 1998-2003



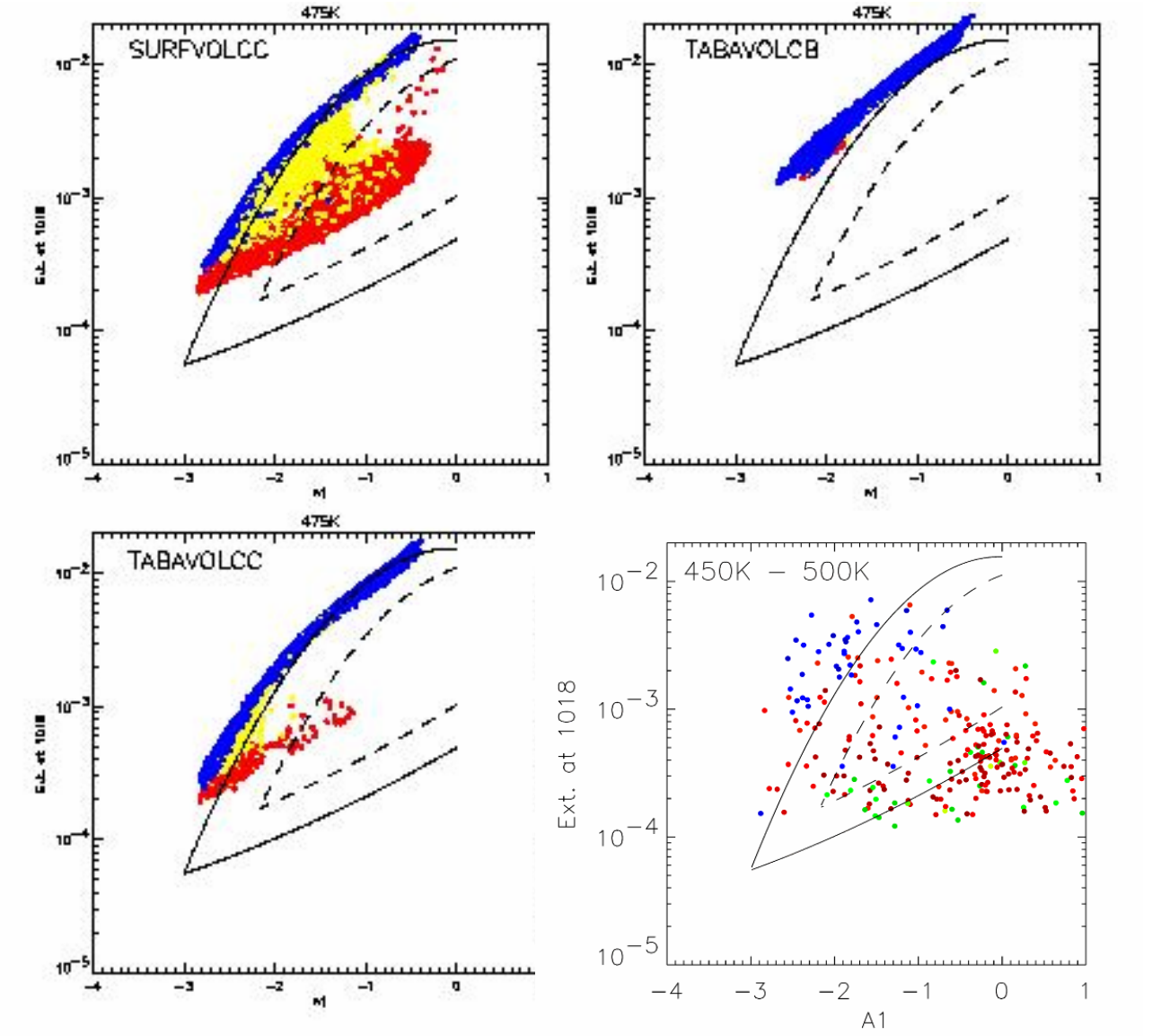
1994-1996



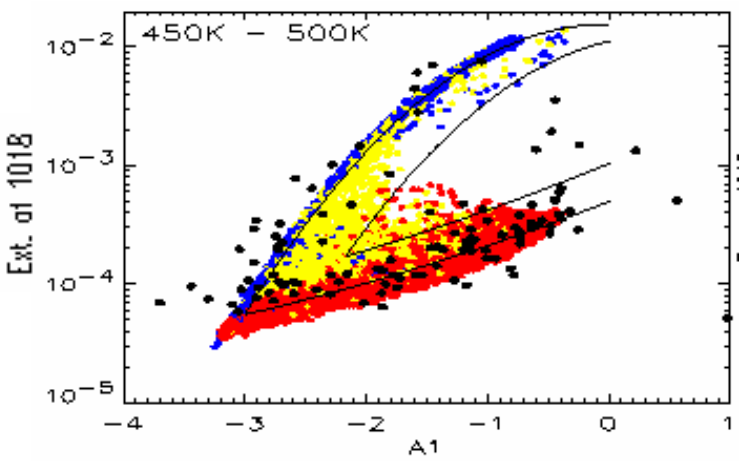
1998-2003



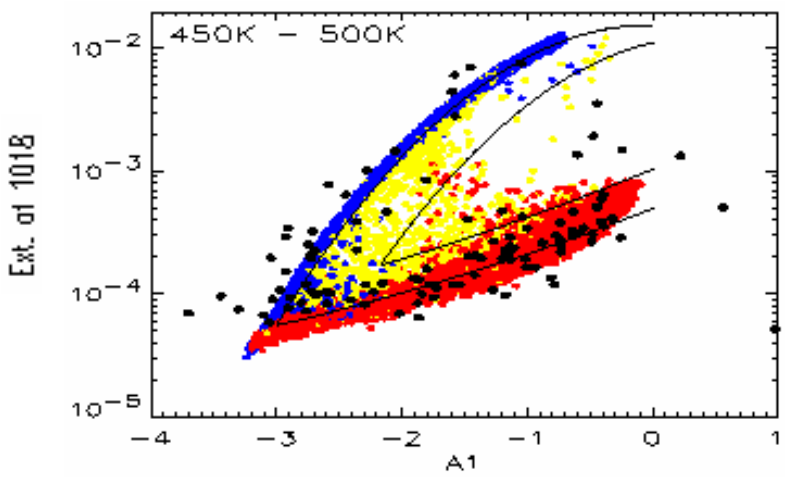
Is this due to volcanic injection?



Comparison at 475˚K



Het02



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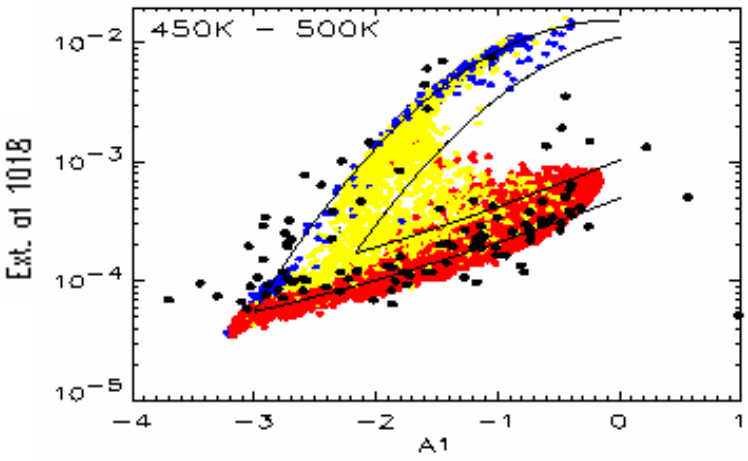
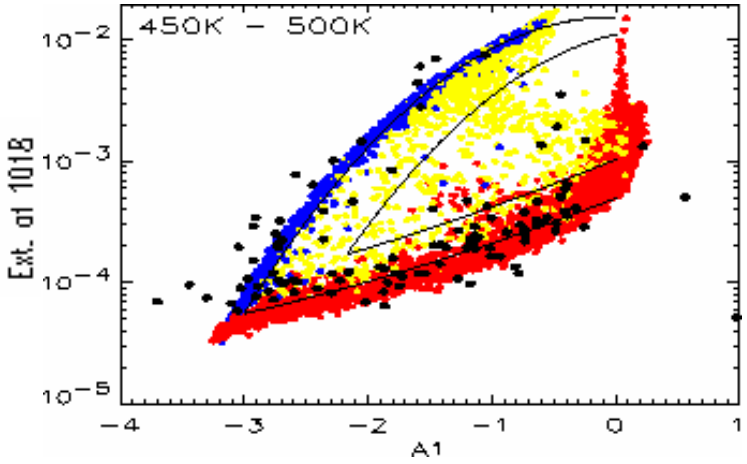


NADHet



Surf2NAT