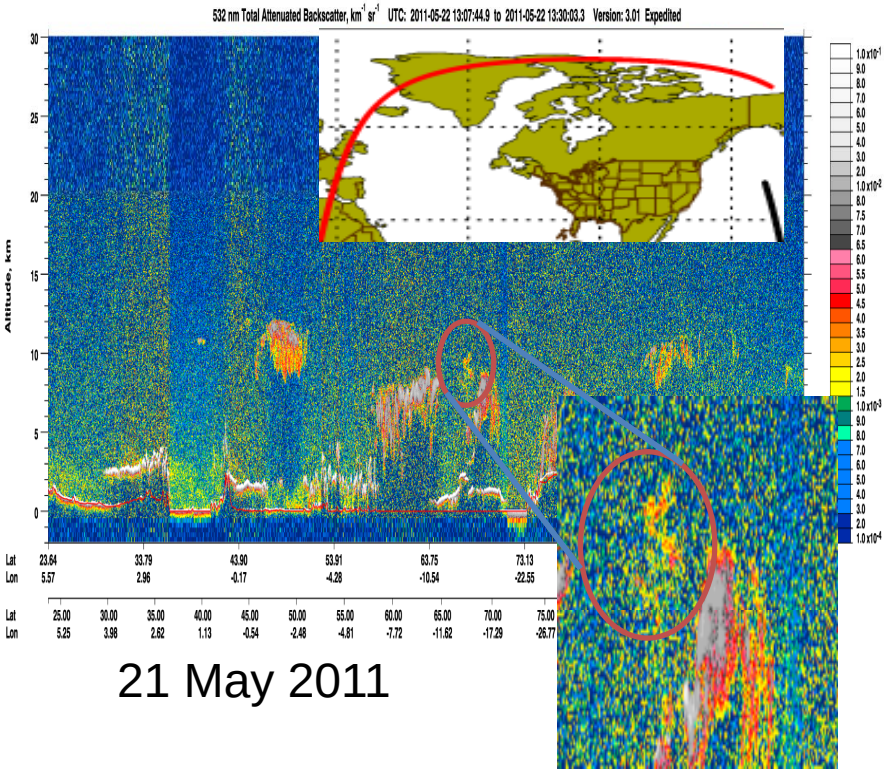
Past, current and planned stratospheric aerosol observations



21 May 2011

J.P Vernier, NASA Langley, Caltech/Pasadena May 2011

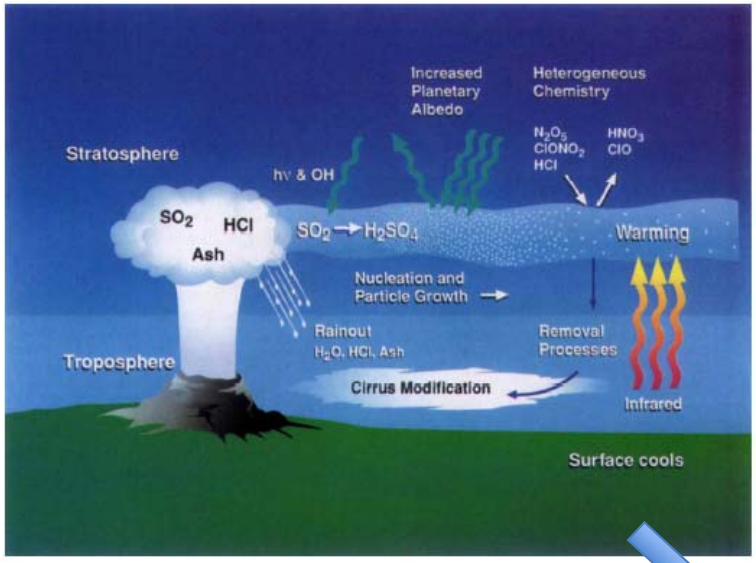
Introduction

- Monitoring stratospheric aerosol to assess their effect on the climate (eg. Mt Pinatubo)
- Understanding stratospheric aerosol life cycle and related atmospheric sink and source processes
- Anticipating geoengineering effects by studying their natural and anthropogenic analogues

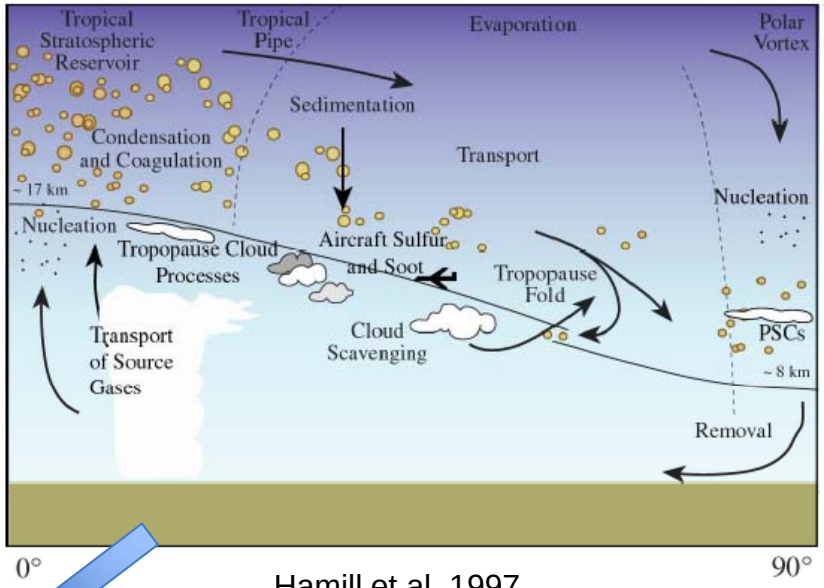
Monitoring stratospheric aerosol from :

- Ground-based lidars (very long term record)
- Balloons and aircrafts (In situ measurements of particles size distribution/composition)
- Satellites (Global remote measurements but limited information on composition)

Origin of the Junge Layer ?

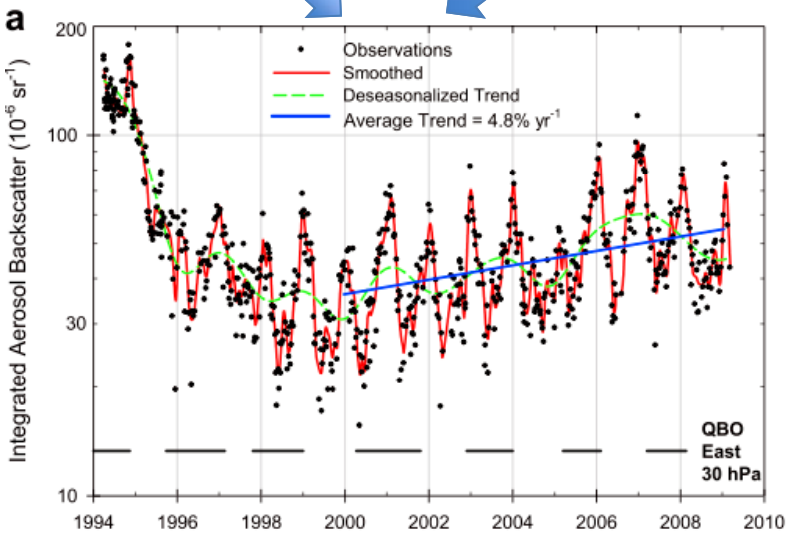


McCormick et al., 1995



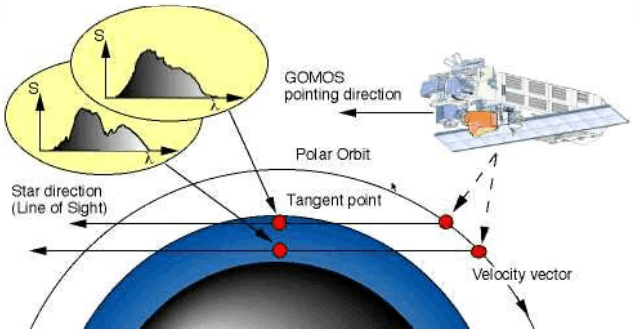
Hamill et al.,1997

- Slow increase of 5%/yr since 2000
- Also reported by ground-based lidars in India and Japon (Kulkarni et al.,2006, Niwano et al.,2010)
- Possible influence of human emission of sulfur dioxide in Asia (Hofmann et al.,2009) ->anthropogenic analogue ?

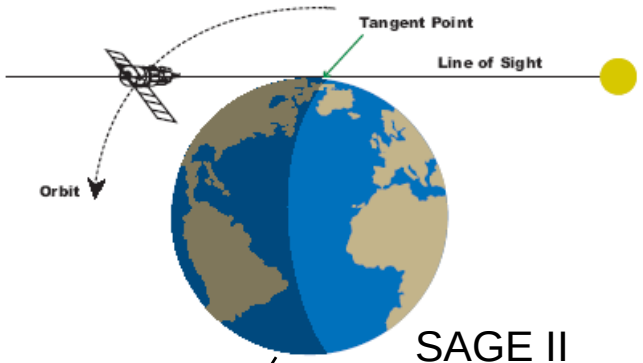


Stratospheric aerosol observations :
Ground based lidar Hawaii

Instrumentation

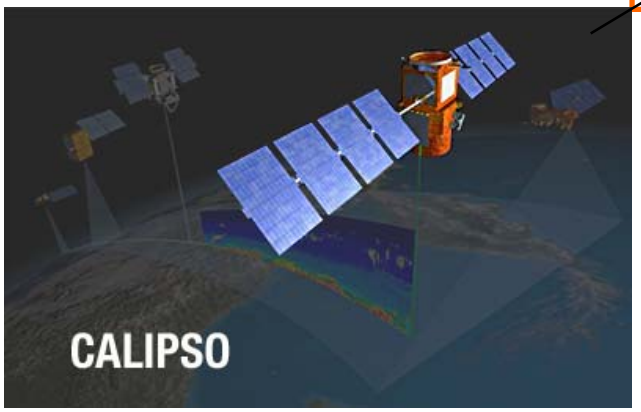


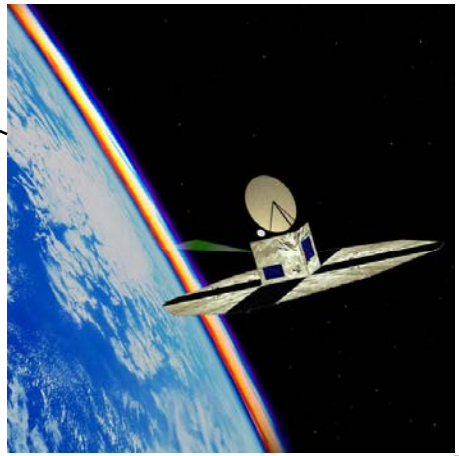
GOMOS/ENVISAT



SAGE II

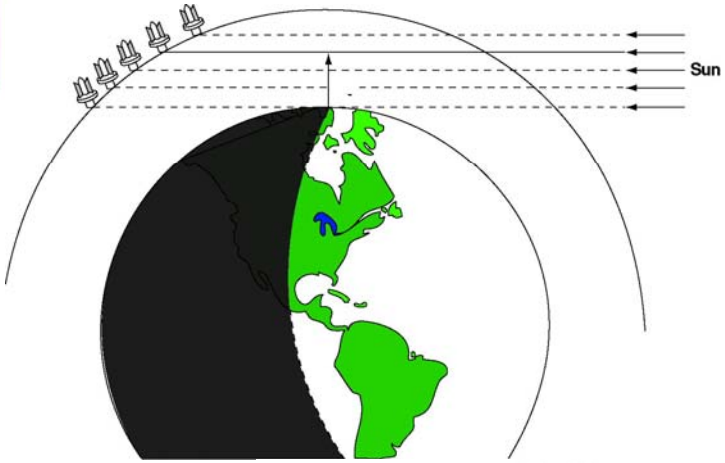
Stratospheric Aerosols

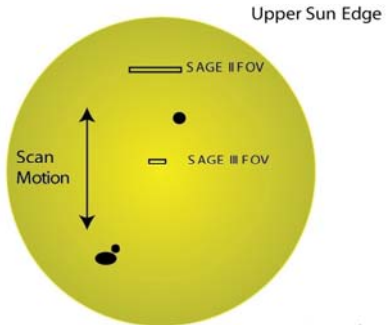




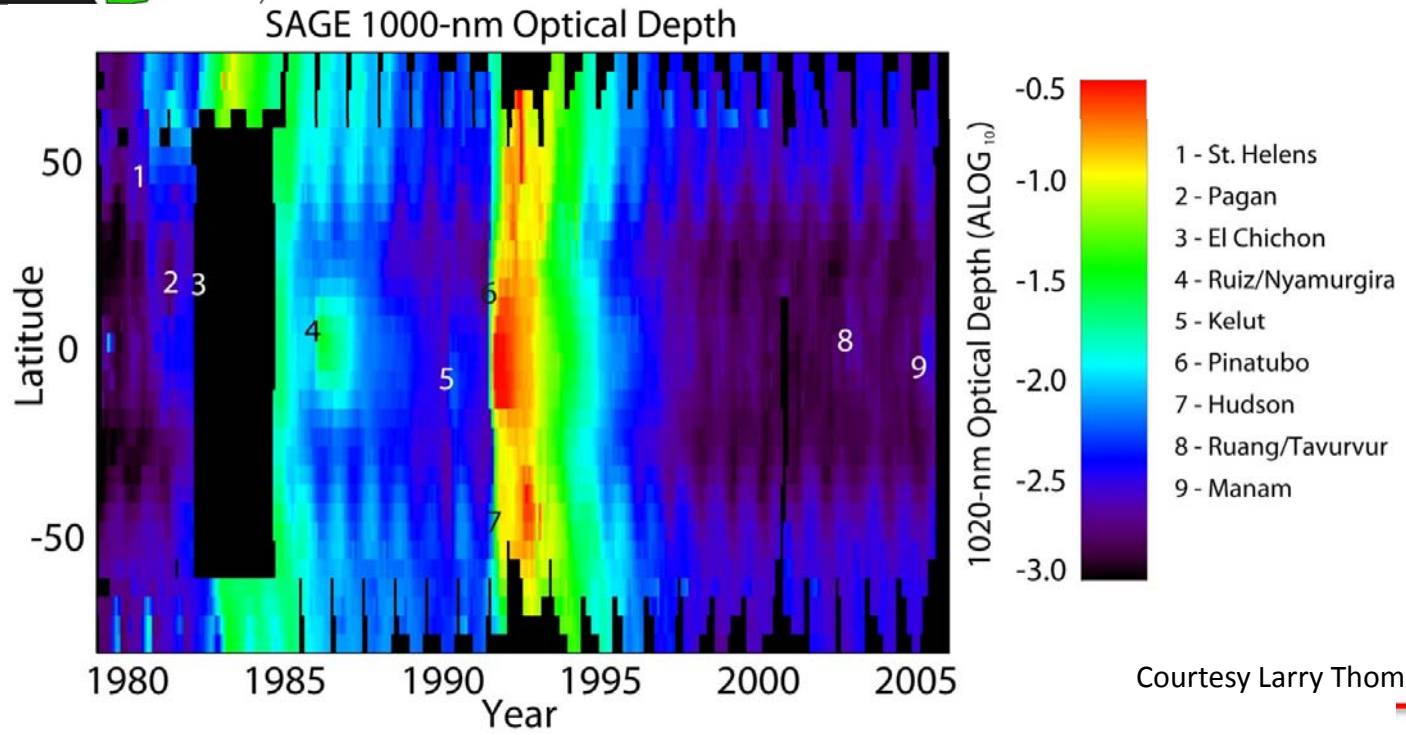
OSIRIS/ODIN

SAGE missions



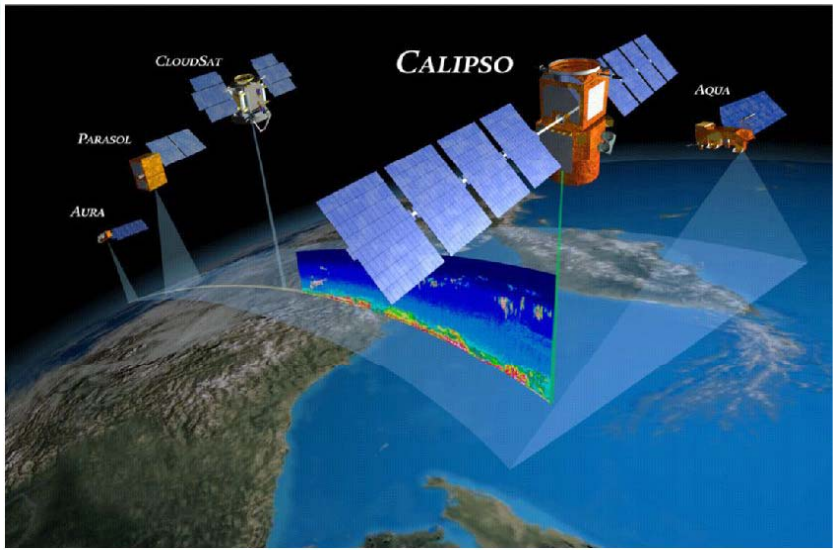


- A UV-VIS-NIR spectrometer
- Multiple modes of operation
  = Solar, lunar, limb scatter
- Surface/cloud top to 85 km, <1 km vertical resolution

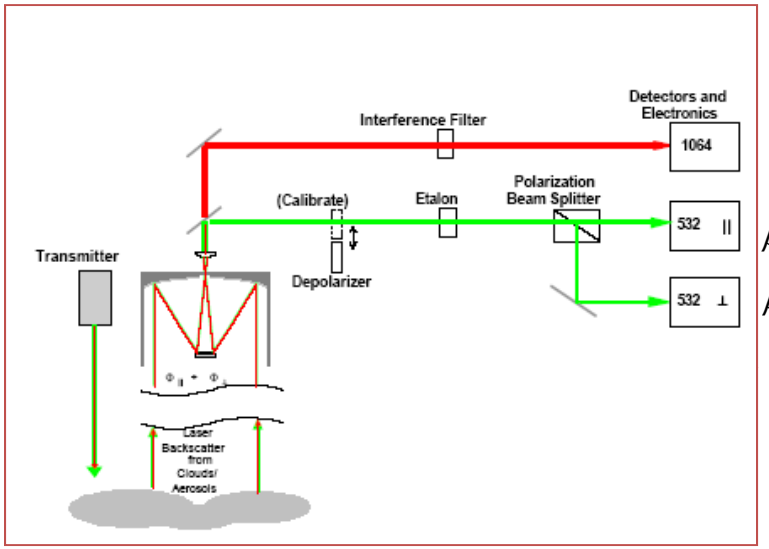


Courtesy Larry Thomason

CALIPSO mission



- Aqua-Train
- Polar Orbit 13h30 & 01h30
- Repeat cycle 16 days
- Instruments : IR radiometer , Visible Camera, lidar

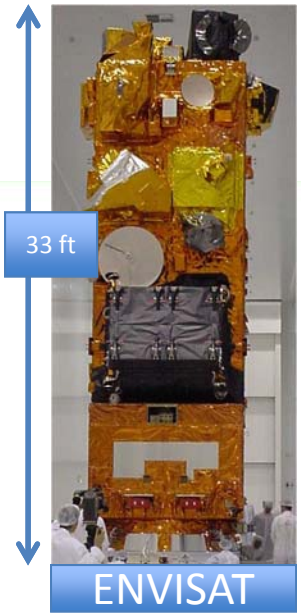


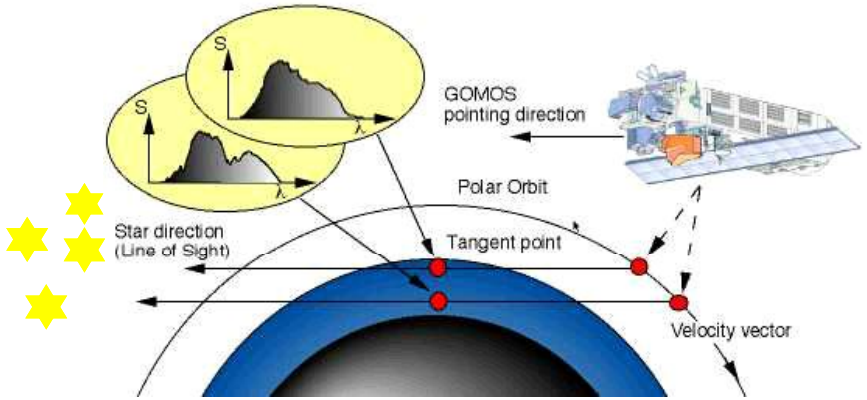
- CALIOP lidar :
- 532nm & 1064nm
- Vertical resolution: - 60m (8-20km); 180m (20-30km);
- horizontal resolution: 1km
- Special algorthym for stratospheric aerosol

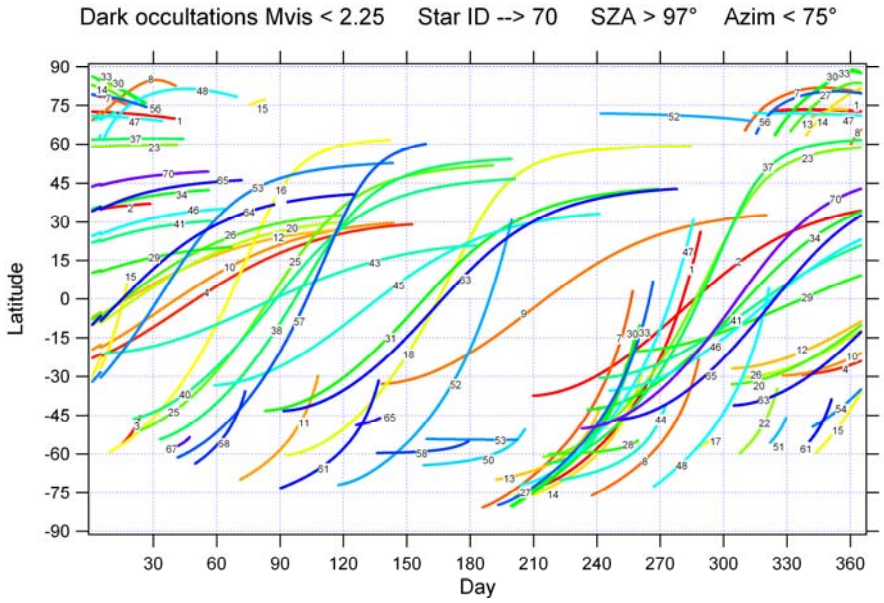
Vernier et al., JGR,2009

GOMOS mission

- Star occultation instrument/On board ENVISAT
- Spectrometer Uv-Vis
- Altitude range : 10-60 km
- Vertical Resolution : 3-4 km
- 700 000 occultations since 2002 !





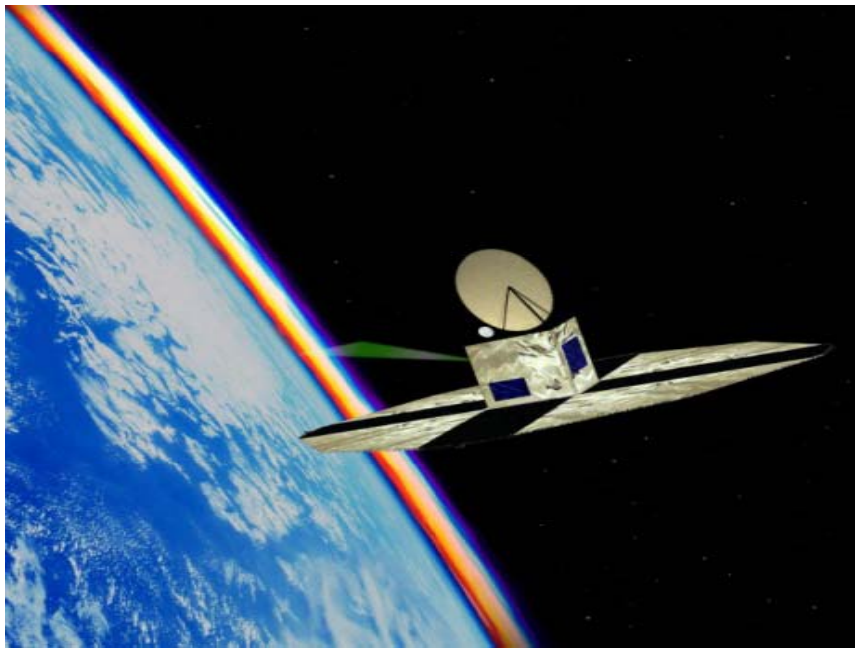


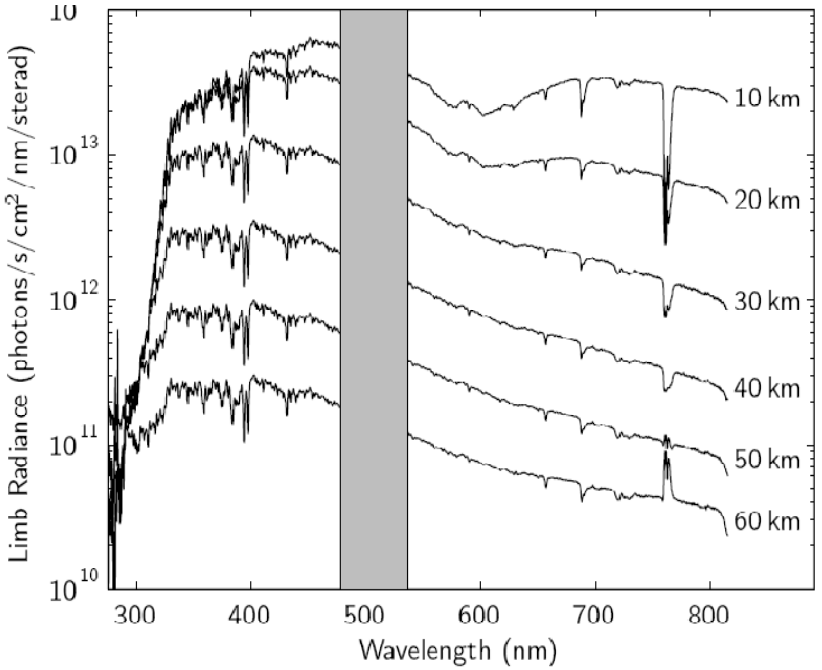
- Good spatial distribution (100 targets)
- Self-calibrated instrument
- Accurate altitude registration
- but star scintillation effect required averaging due to high SNR

Courtesy Alain Hauchecorne

OSIRIS mission

- Limb emission/On board Odin
- Spectrometer 280-810 nm
- Altitude range : 10-120 km
-Vertical Resolution : 3-4 km
- period : 2002-now

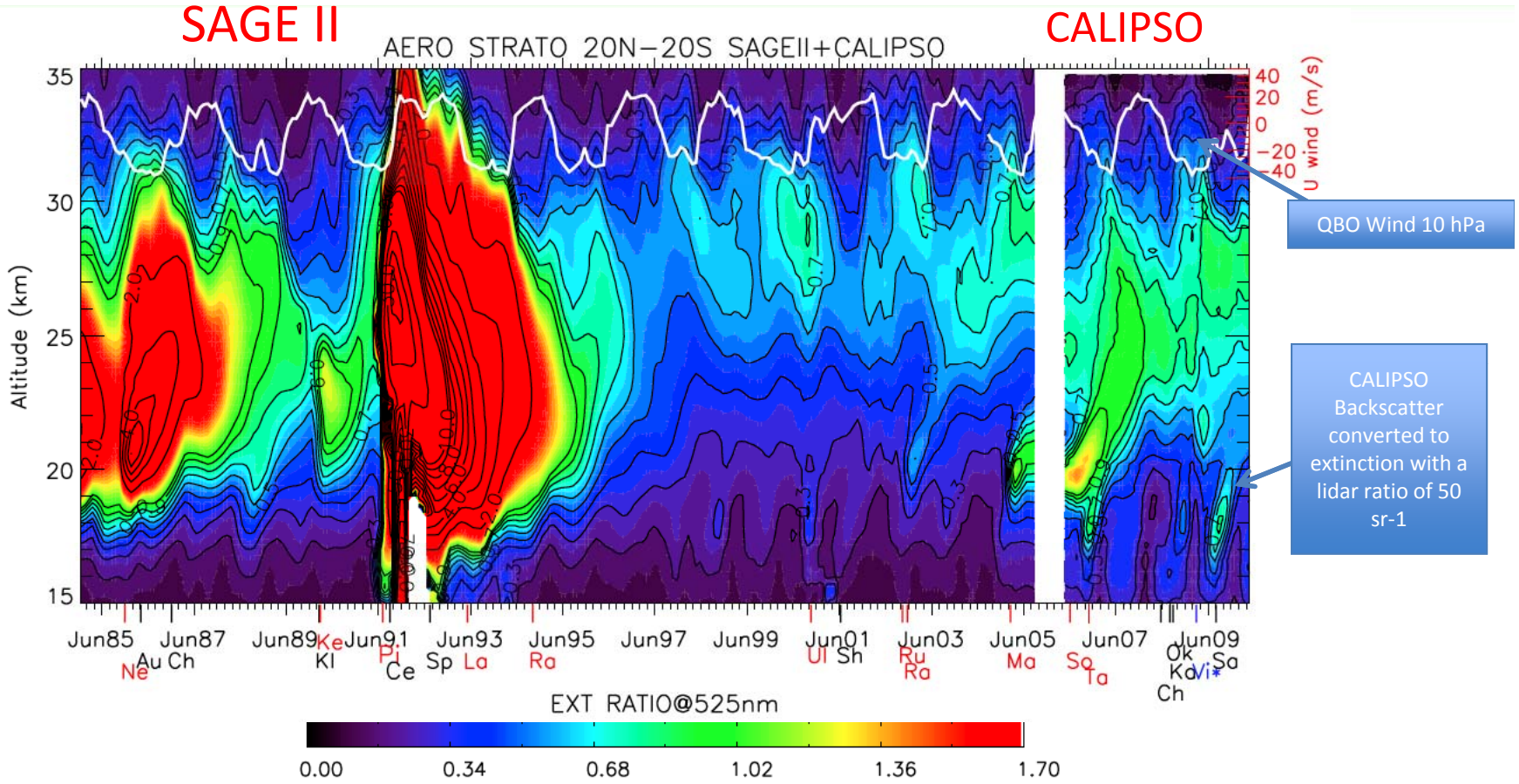




-Good spatial coverage
- Assumption of a size distribution for stratospheric aerosol

Courtesy Adam Bourassa

Stratospheric aerosol level since Mt Pinatubo



- 1994-1996 : Mt Pinatubo plume decay

- 1996-2002 : Relative clean period

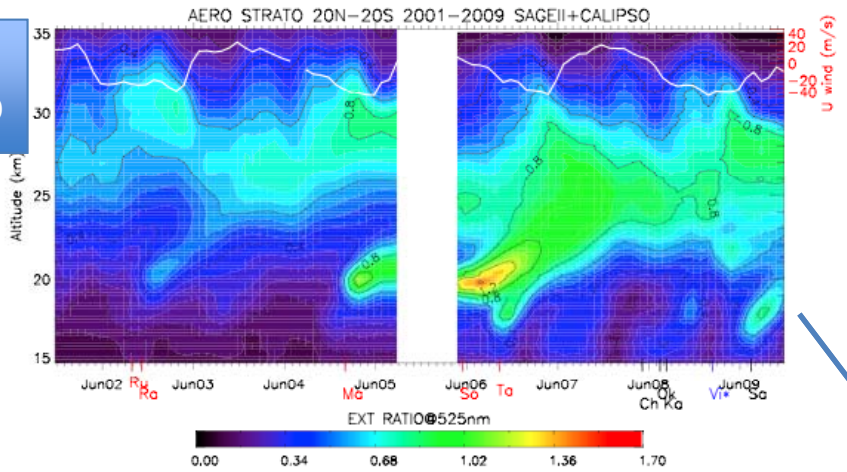
- 2002-2010 : Influence of moderate volcanic eruptions (VEI=4) ->

Volcanic Explosivity Index

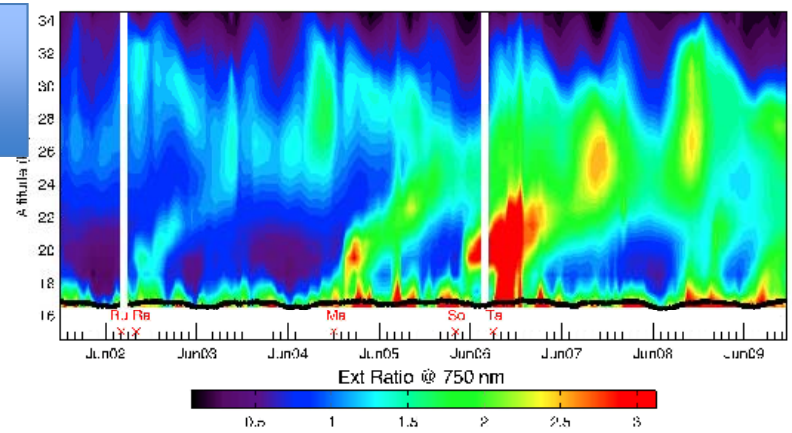
Ruang-Raventador (2002), Manam (2005), Soufriere Hills (2006)

Origin of the last decade trend in stratospheric aerosol

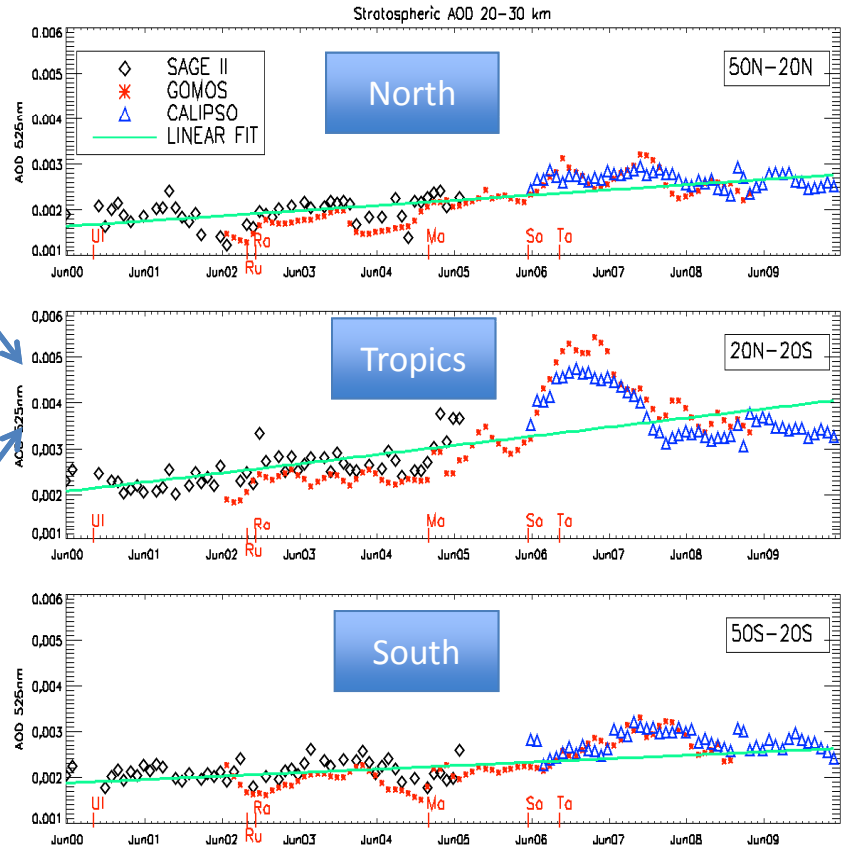
SAGE II +CALIPSO



OSIRIS



Stratospheric AOD

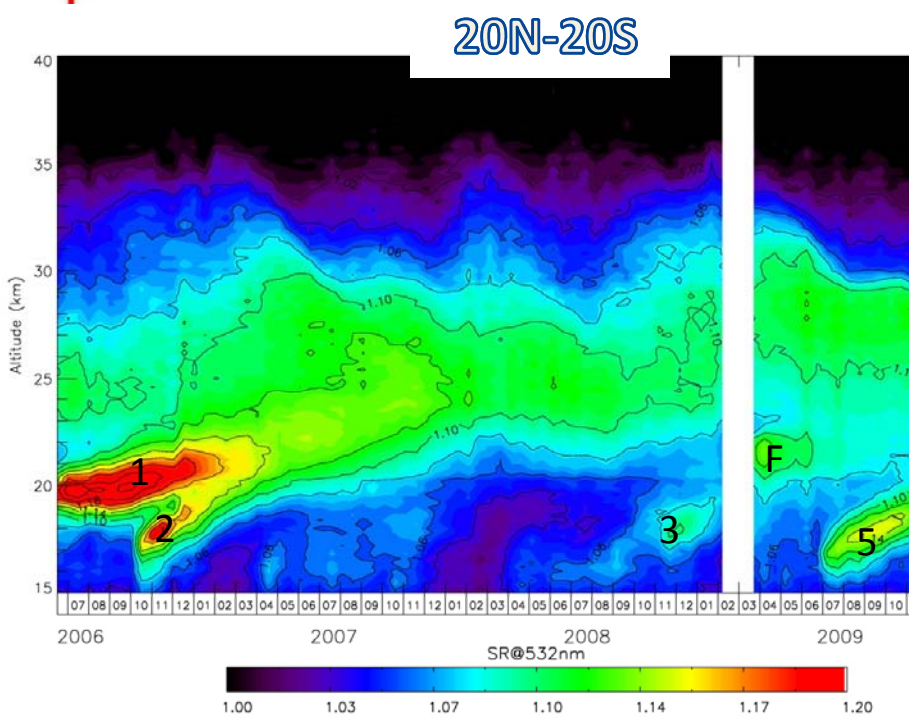


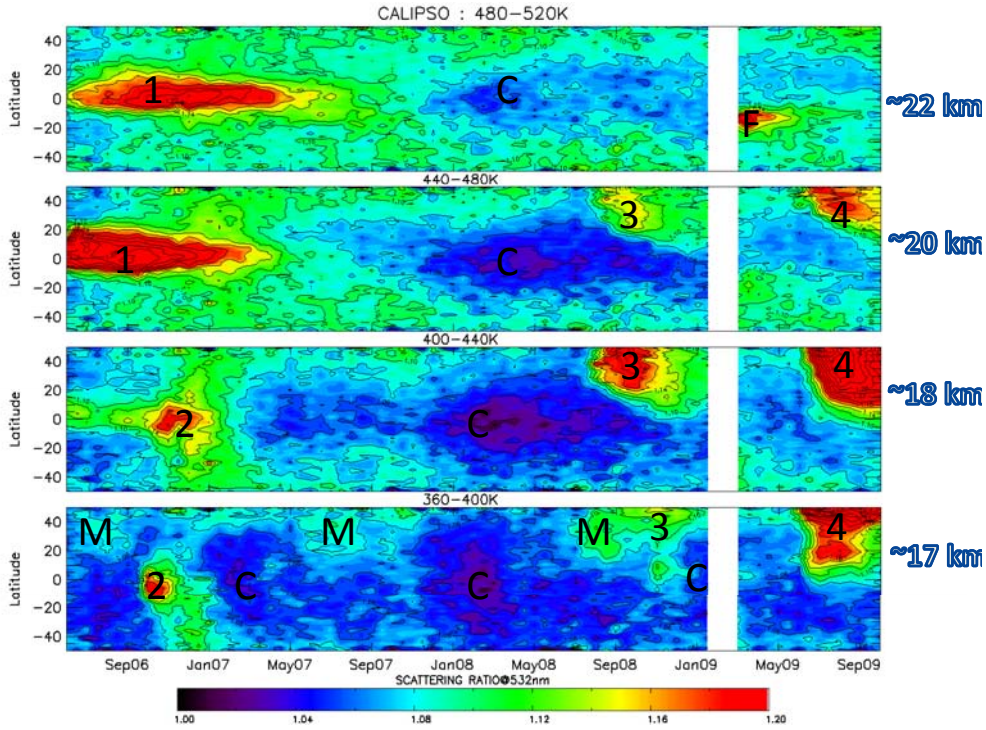
Vernier et al., GRL 2011b, in press

- Initial volcanic injection at 19-20 km
- Slow ascent by the BD circulation up to 25 km
- Modulation of the transport by the QBO

-> Three consecutive tropical volcanic eruptions: natural volcanic trend

New insight about UTLS aerosol with CALIPSO



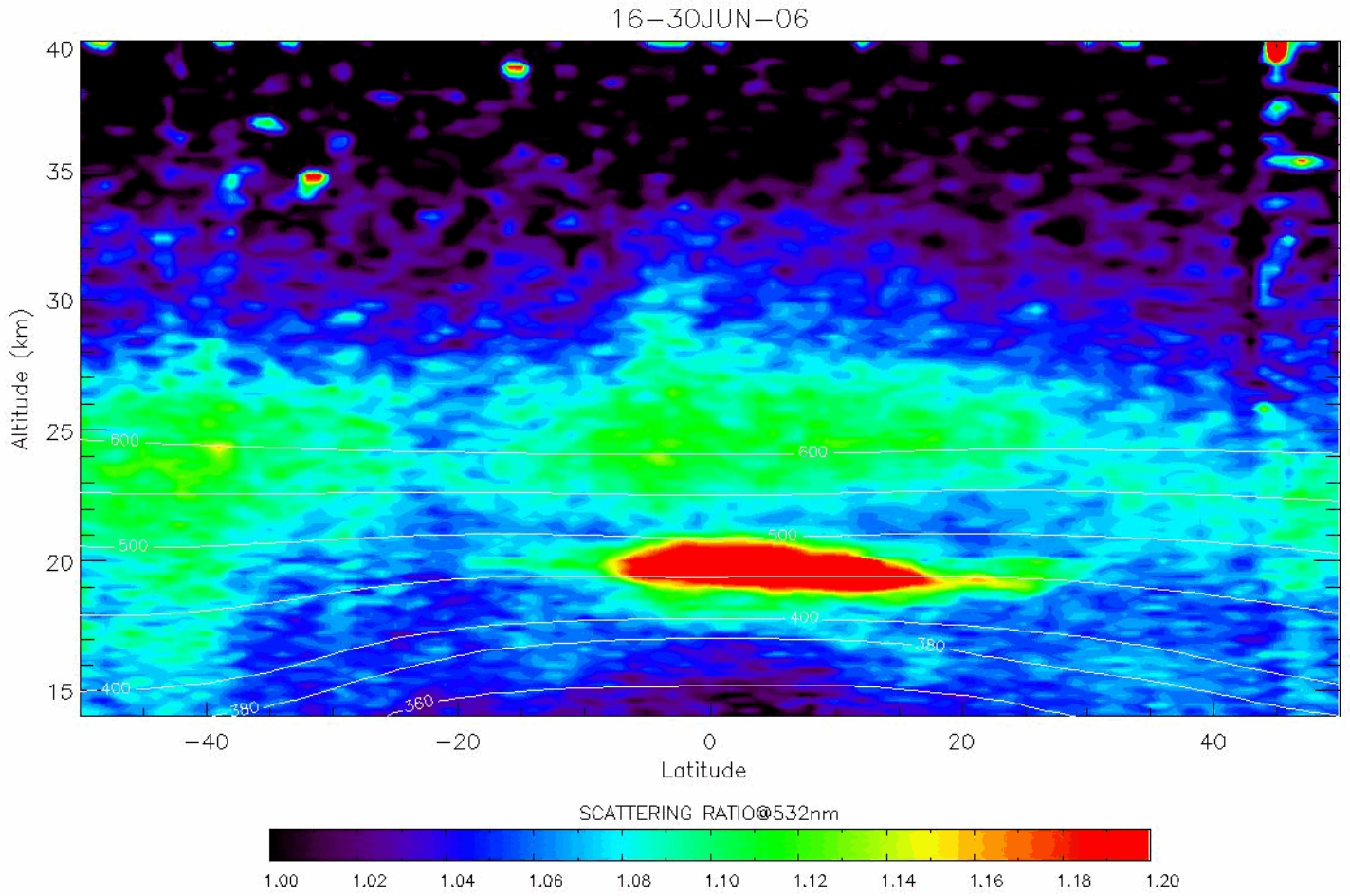


Vernier et al.,2011c, ACPD

1. Soufrière Hills	20-mai-06	16°N	4 ?	0.2Tg
2. Tavurvur	07-oct-06	4°S	4	
3. Kasatochi	07-août-08	55°N	4	1.5Tg
4. Fire Victoria	7-feb-08	45°S		
F. Sarychev	12-june-09	48°N	4	1Tg
C. Clean air	Winter-Spring	20S-10N		
M. Monsoon feature	Summer	20-40N		

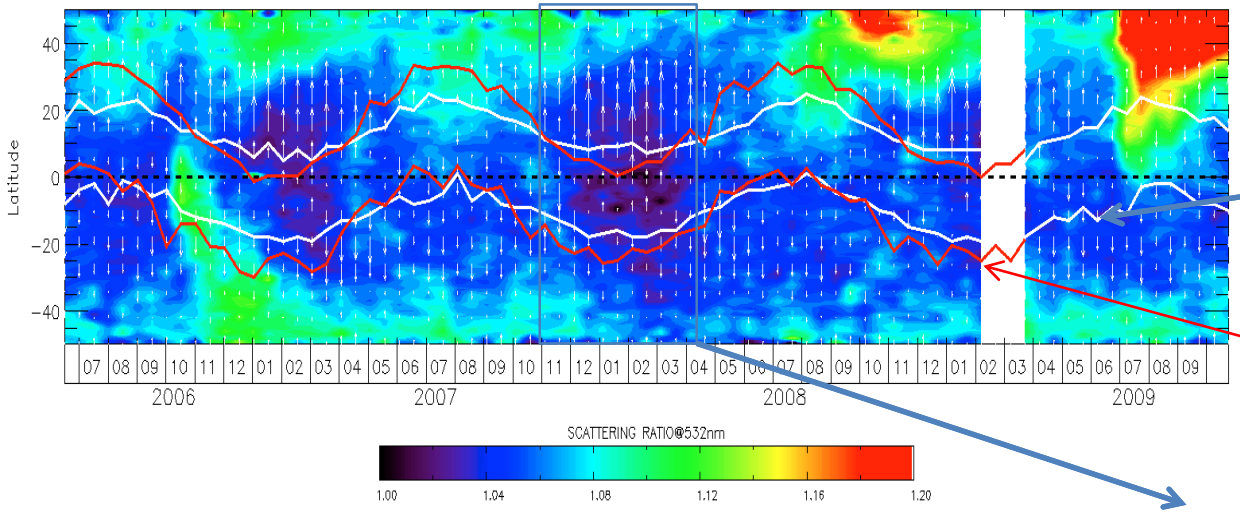
- Quasi permanent influence of small volcanic eruptions
- Stratospheric soot from extreme fires. Isolated case ?
- Source of aerosols associated with the Asian monsoon :primary or secondary formation ?
- Rapid cleansing of the lower stratosphere : Influence of deep convection ?

Evolution Stratospheric Aerosol CALIPSO



Cleansing of the TTL and lower tropical stratosphere

CALIPSO 14-18 km and ITCZ



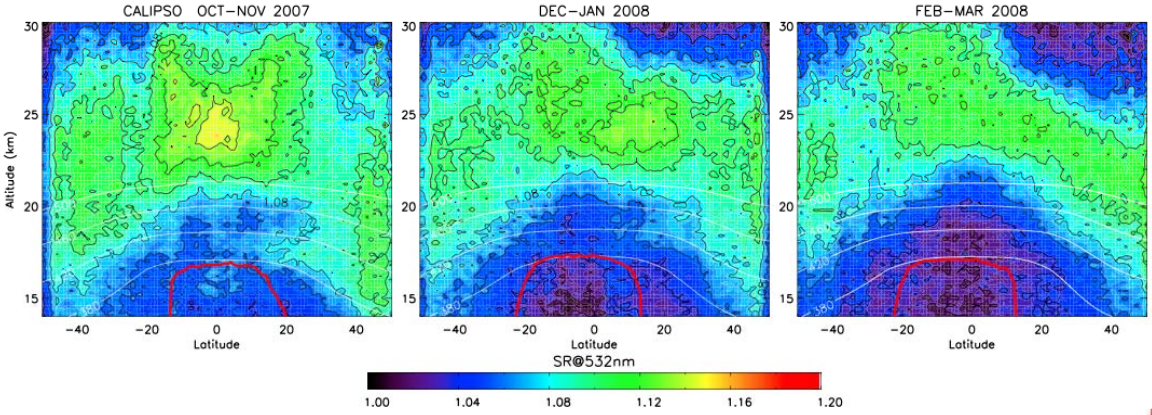
CALIPSO cirrus

TRMM deep convection

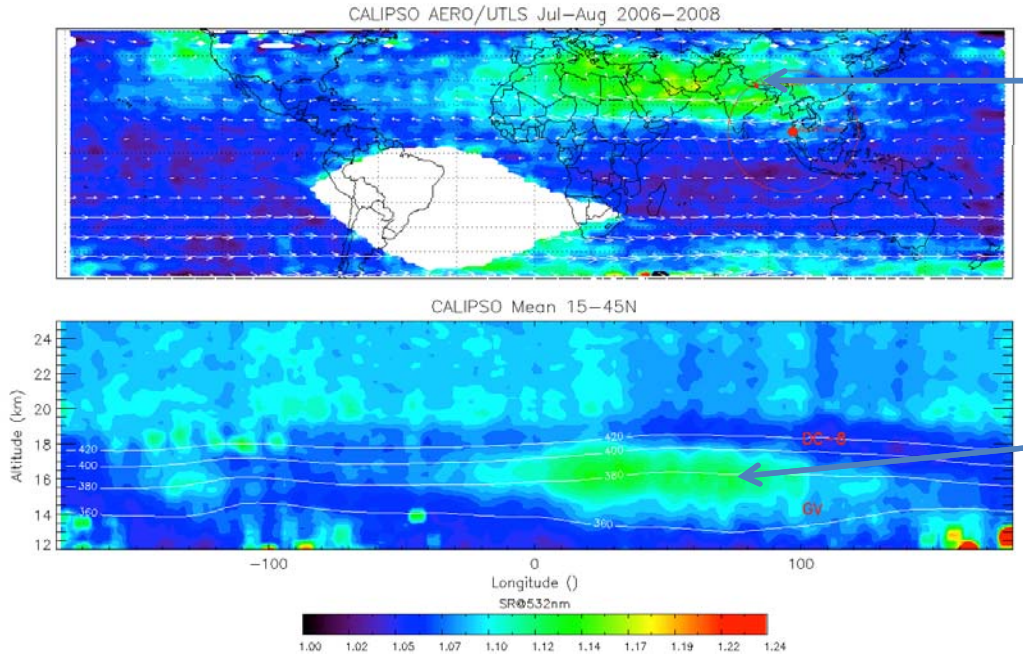
-Cleansing in phase with SH deep convection

- Drastic reduction of aerosol lifetime in the TTL/LS up to 20 km : implication for geoengineering

- Aerosol enhancement associated with the NH convection : source ?



The Asian Tropopause Aerosol Layer

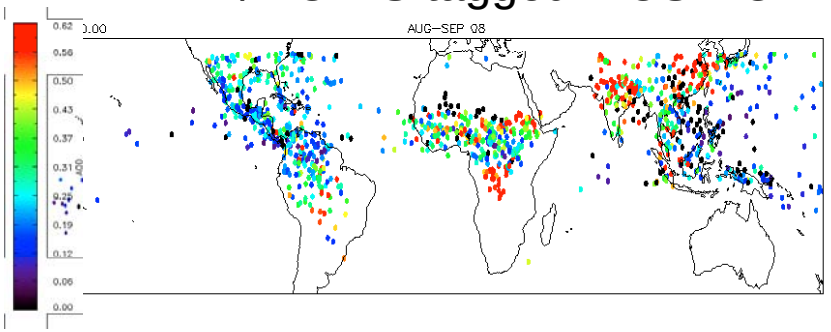


Aerosol layer within the Asian Anticyclone

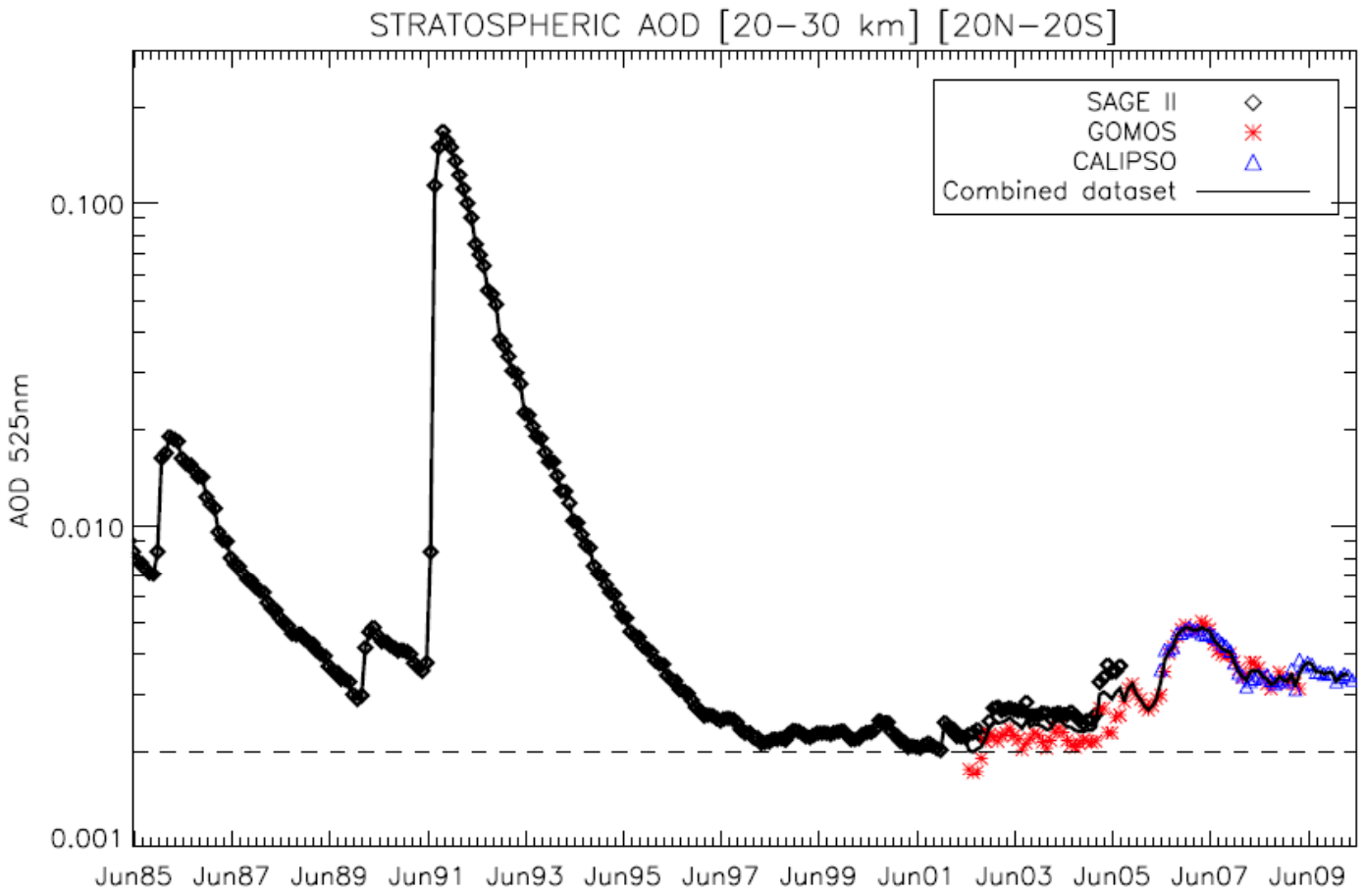
At the convective outflow of the monsoon : primary or secondary formation ?

-Deep Convection occurring in polluted places (India/China)
- Transport of aerosol and/or their gas precursors (organics ?)
- > Anthropogenic analogue

TRMM /MODIS tagged MCS-AOD



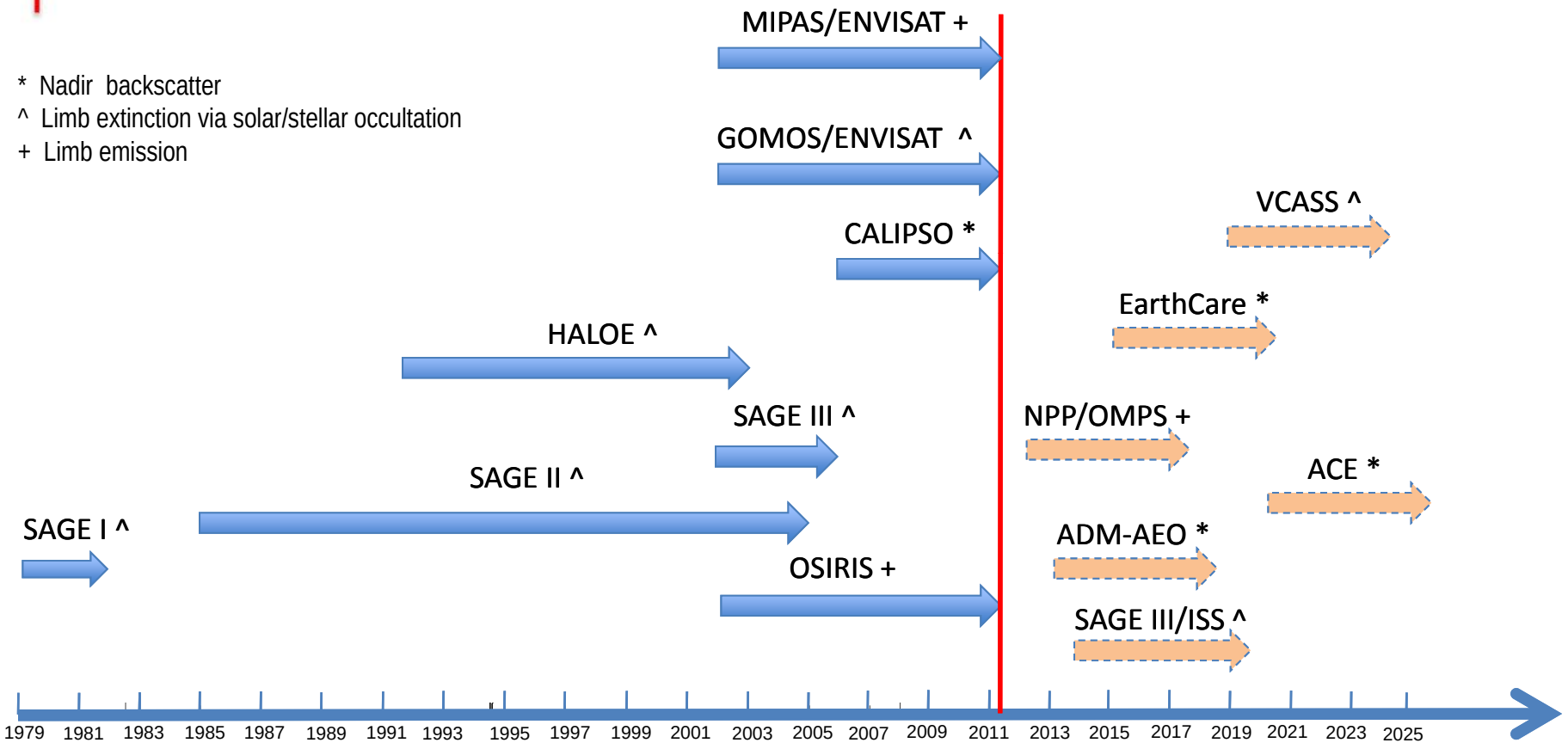
25 years of stratospheric aerosol record



- No large eruptions over the last decade : but small and frequent one

- Important to continue this record ….especially to monitor the impact of stratospheric aerosol on the climate :

Stratospheric aerosol observation : past, present and future



- Future missions : always uncertain especially after 2020
- Improving international collaboration
- Remote sensing for inferring aerosol composition ?

Conclusion

- Important variability of the stratospheric aerosol layer due to frequent volcanic eruptions :
  - possible small radiative cooling impact that should be determined
- Aerosol in the UTLS:
  - Active removal process associated with deep convection during NH winter
  - Enhancement above the Asian monsoon in July-August : origin and nature ?
- Aerosol composition in the Upper troposphere ? Very likely complicated influenced by convection and local emission : strategy for global measurements of composition ?

Thanks to :

L. Thomason[1],J.P Pommereau[2], A. Bourassa[3], J. Pelon[2], A. Garnier[2], J. Jumelet[2], A. Hauchecorne[2], L. Blanot[2], J.C. Lebrun[2],C. Trepte[1], D. Degenstein[3] , D. Winker [1], D. Renaul[1] ,D. Witter [1],C. Hostetler [1]

1) NASA Langley Research Center, Hampton, VA 23666, USA
2) LATMOS, CNRS-INSU, Université de Versailles St Quentin, Université de Paris 6 , France
3) Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, SK, Canada

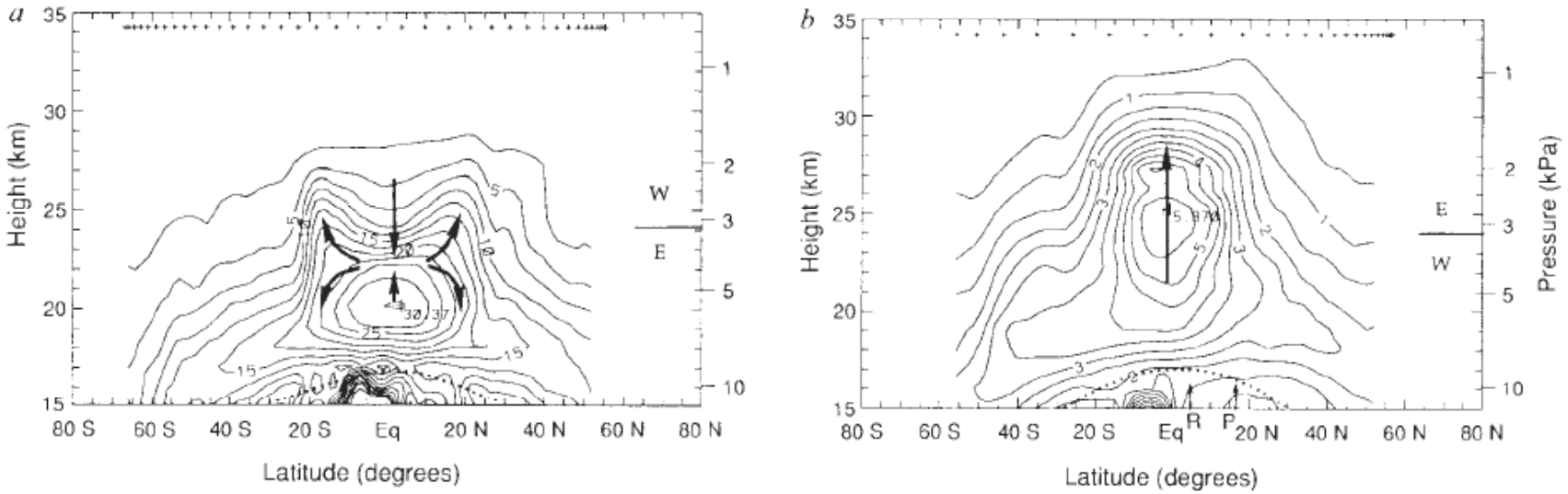
Thank you for your attention !

Stratospheric aerosol lifetime and strategy of injection

- Aerosol lifetime limited by condensation of SO2 on pre-existing particles : removal by sedimentation

Is it the main limited process ?

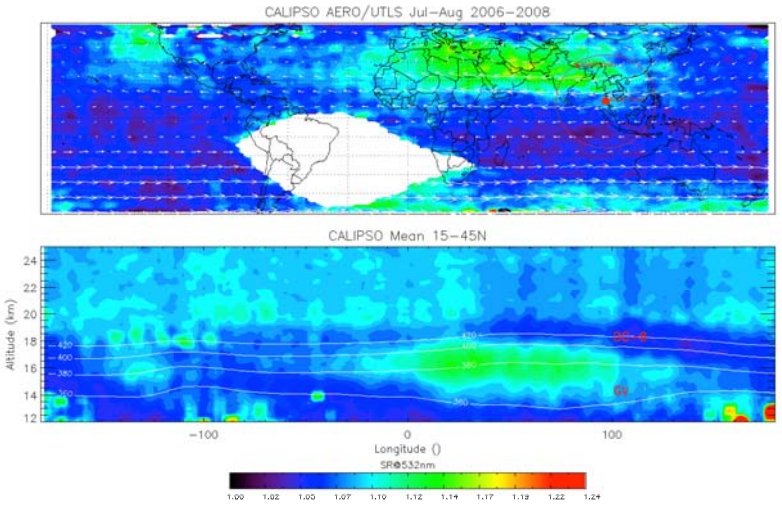
- But stratospheric circulation modulated by the phase of the QBO :



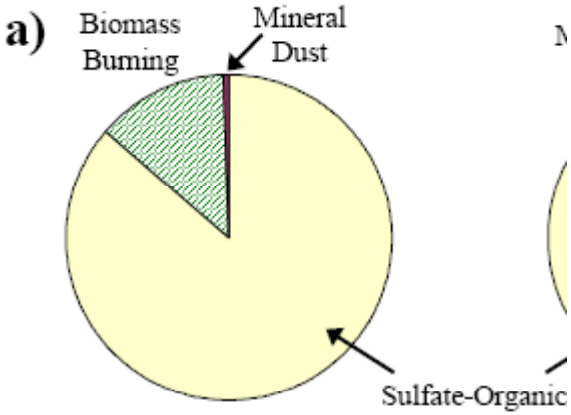
(Trepte et al., 1992)

Aerosol composition in the upper troposphere / strategy for global measurements ?

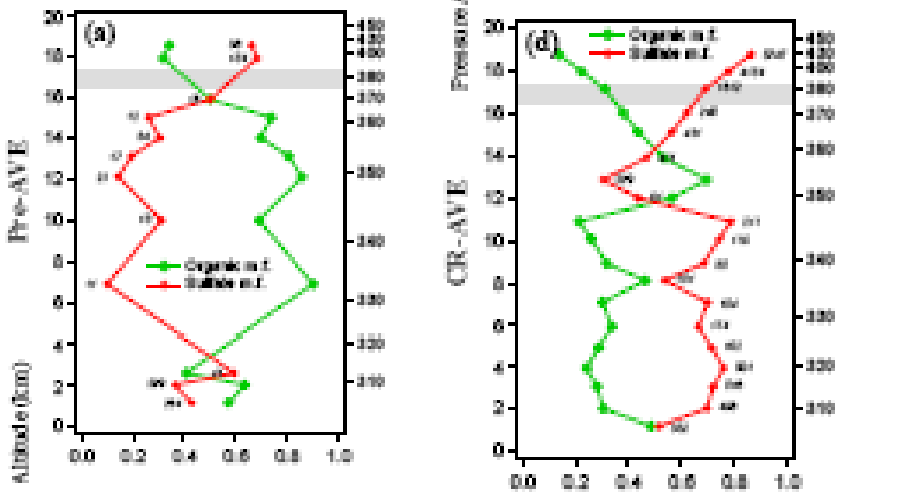
- Stratospheric aerosol layer mainly sulfate : what about upper tropospheric aerosol ?
- Potential affect on the climate since a significant fraction could be composed of organics/soots



Vernier et al.,GRL 2011



Fryod et al., 2010



Fryod et al., 2009