Monitoring and Detecting Climate Variability and Change – Atmospheric Composition

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Role of Atmospheric Composition in Climate Change

- Greenhouse gases and particles that drive climate change.
- Stratospheric ozone depletion (ozone, source gases, active halogens, reservoir species, particles-PSCs).
- Atmospheric cleansing capacity (hydroxol not usually thought of in a climate context but influences greenhouse gases such as methane).
- Air quality (air pollution produces ozone and particles that are important climate constituents).

In all of these roles there are important sources and sinks for these constituents as well as active atmospheric chemistry that have very important vertical structure.

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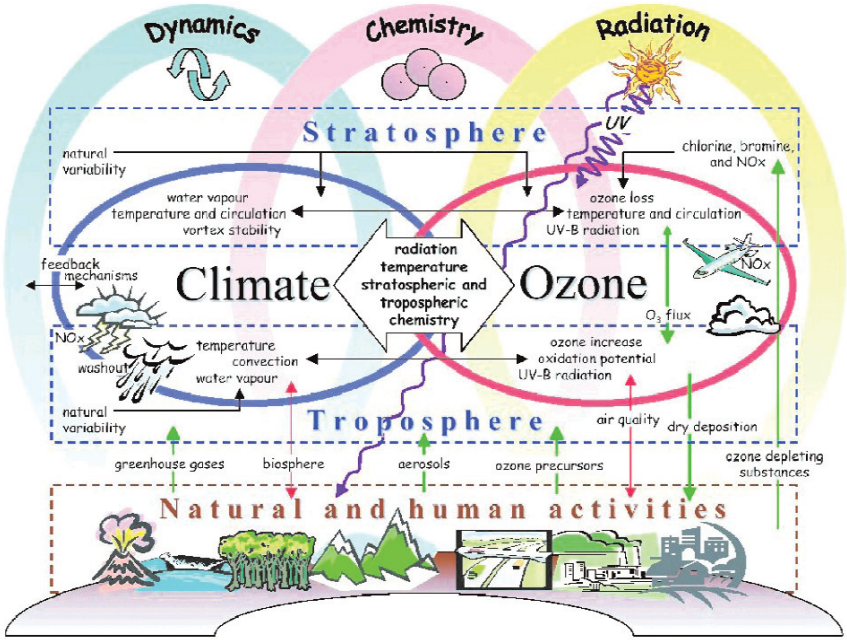
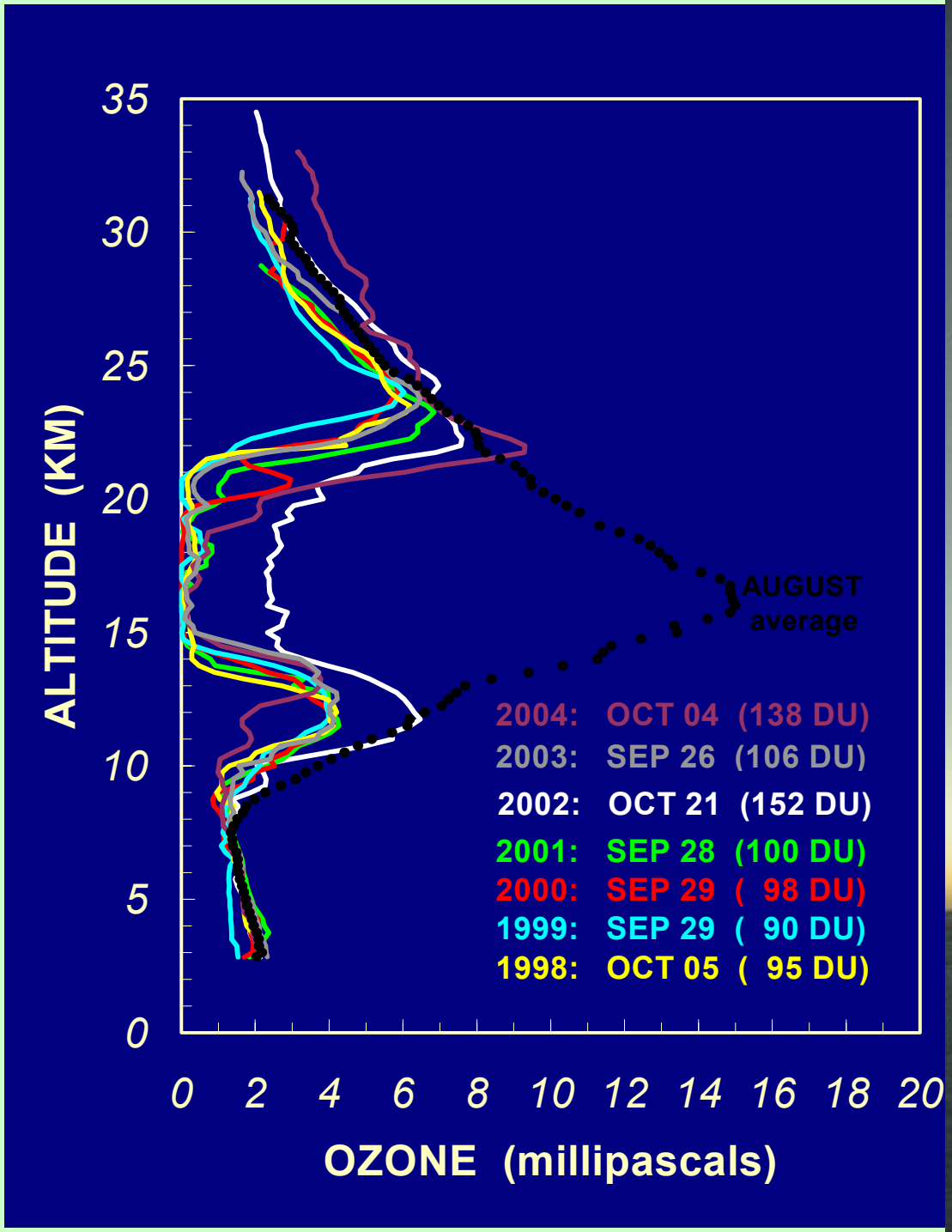
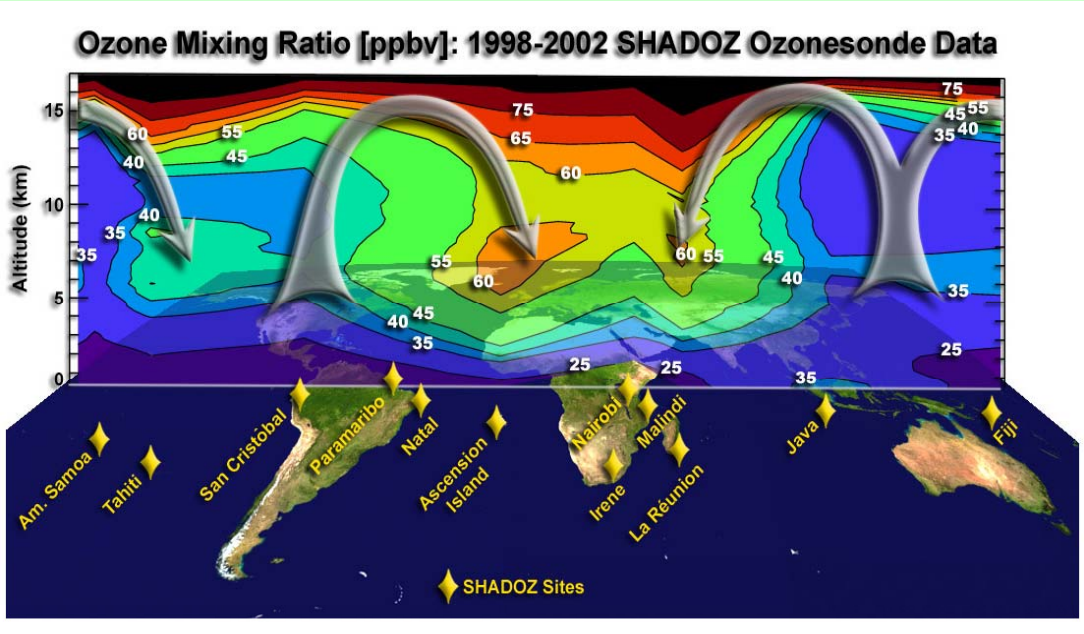


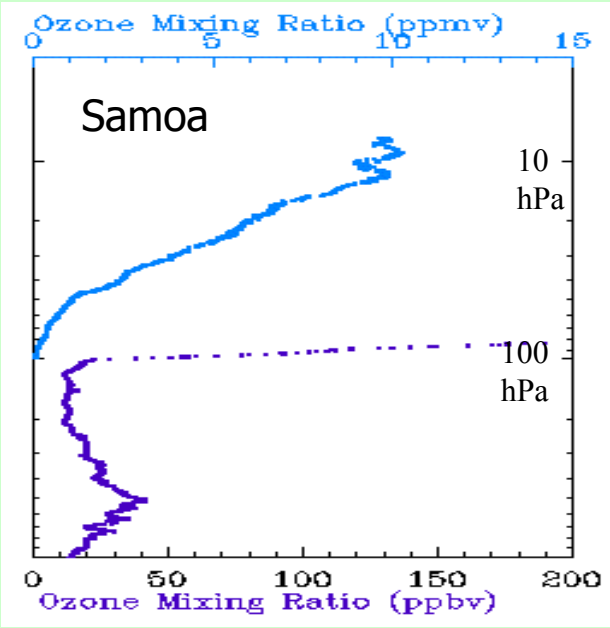
Figure 2.8. Interactions between climate, atmospheric composition, chemical and physical processes and human activities *(after Isaksen, 2003)*.

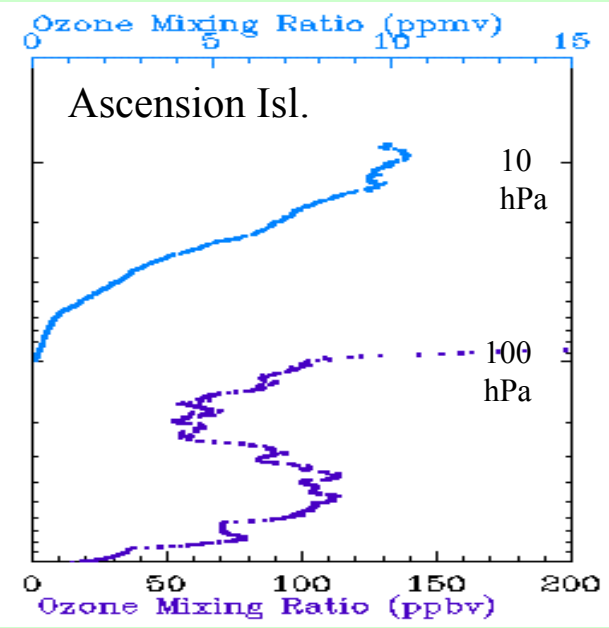
SOUTH POLE OZONESONDE MINIMUM PROFILES

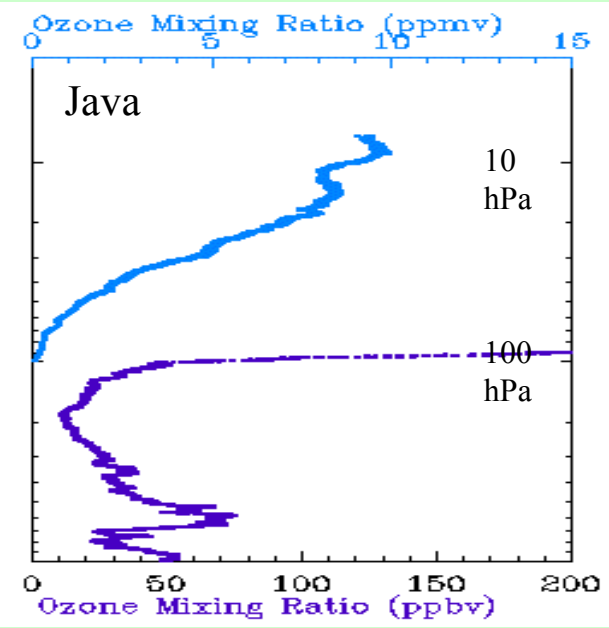


Tropical Tropospheric Ozone: Wave-one Phenomena in S.H. ozonesonde data

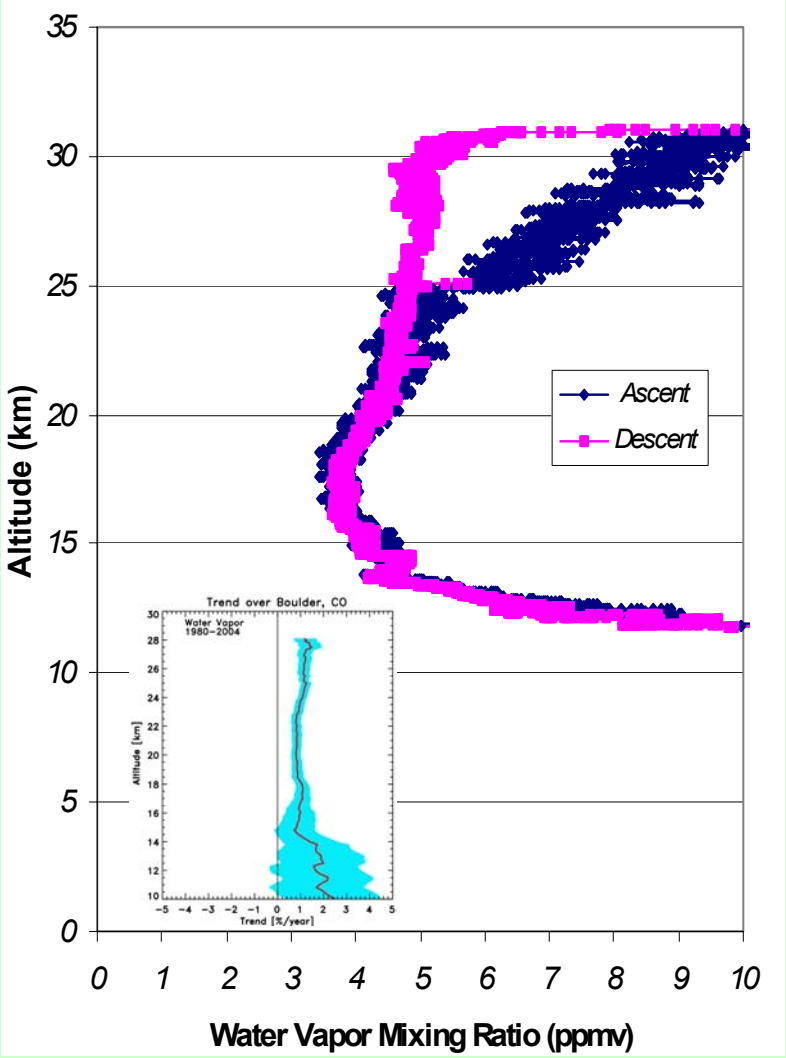


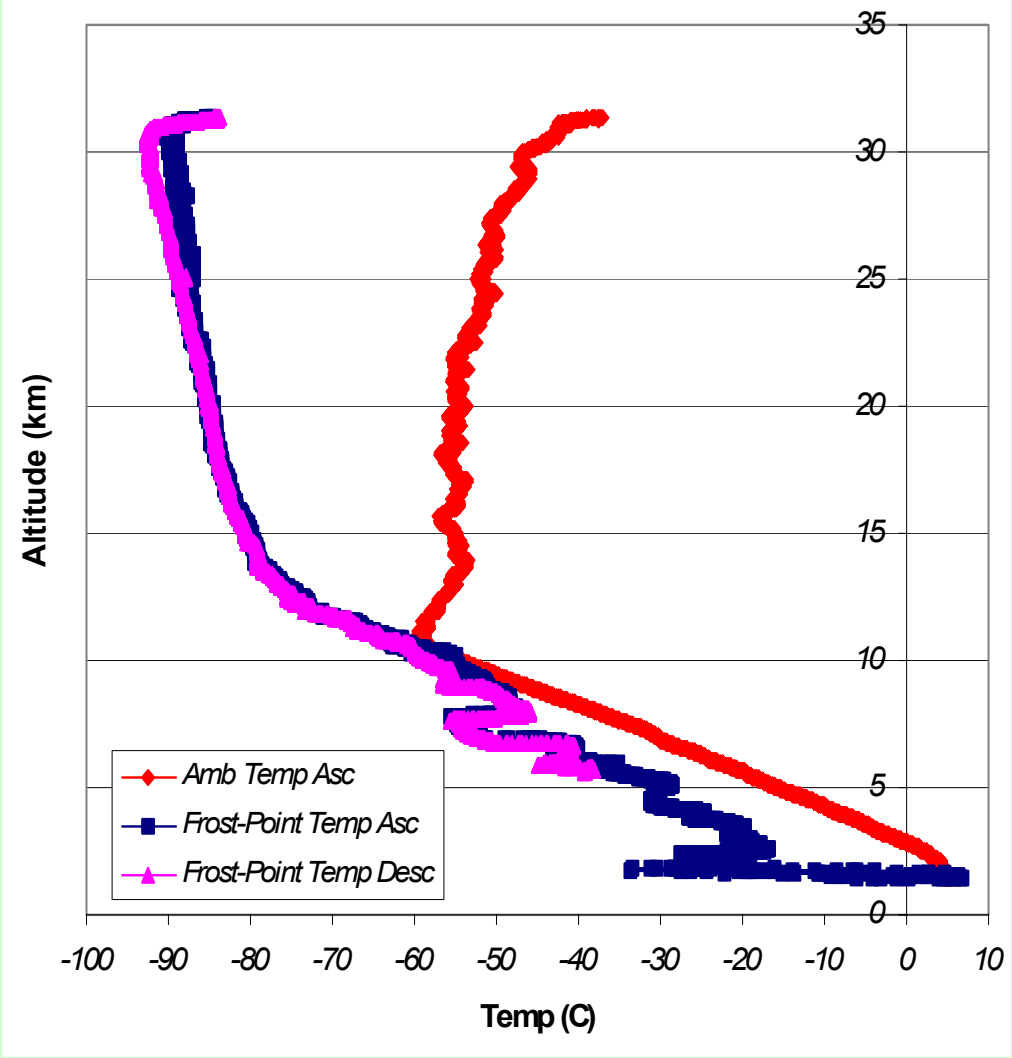






Water Vapor Profile Over Lauder, NZ on November 11, 2004





Composition Requirements

- Report of "The Integrated Global Atmospheric Chemistry Observations (IGACO) Theme" of the Integrated Observing Strategy.
  - Can serve as basis for developing requirements for measurement of atmospheric constituents.
  - Provides examples of existing and planned observing systems including profile measurements (ground-based, aircraft, satellite).

Chemical Species	Air Quality	Oxidation Efficiency	Climate	Stratospheric Ozone Depletion
O_3	✓	✓	✓	✓
CO	✓	✓	–	–
$j(NO_2)$	✓	✓	–	–
$j(O^1D)$	✓	✓	–	–
H_2O (water vapour)	✓	✓	✓	✓
HCHO	✓	✓	–	–
VOCs	✓	✓	–	–
Active nitrogen: $NO_x = NO+NO_2$ *Reservoir species*: HNO_3	✓ ✓	✓ ✓	– –	✓ ✓
N_2O	–	–	✓	✓
SO_2	✓	–	✓	–
Active halogens: BrO, ClO, OClO *Reservoir species*: HCl, $ClONO_2$ *Sources*: CH_3Br, CFC-12, HCFC-22, halons	– – –	– – –	– – –	✓ ✓ ✓
Aerosol optical properties	✓	–	✓	✓
CO_2	–	–	✓	–
CH_4	–	✓	✓	✓
Critical Ancillary Parameters				
Temperature	✓	✓	✓	✓
Pressure	✓	✓	✓	✓
Wind speed (u, v, w)	✓	✓	✓	✓
Cloud-top height	✓	✓	✓	✓
Cloud coverage	✓	✓	✓	✓
Albedo	✓	✓	✓	✓
Lightning flash frequency	✓	✓	✓	✓
Fires	✓	✓	✓	–
Solar radiation	✓	✓	✓	✓

ATMOSPHERIC SPECIES IN GROUP 1 TO BE MEASURED BY AN INTEGRATED GLOBAL OBSERVING SYSTEM												
Atmospheric Region	Requirement	Unit	H_2O	O_3	CH_4	CO_2	CO	NO_2	BrO	ClO	HCl	CFC-12
1. Lower troposphere	Δx	km	5/25	<5/50	10/50	10/500	10/250	0/250	50			
	Δz	km	0.1/1	0.5/2	2/3	0.5/2	0.5/2	0.5/3	2			
	Δt		1hr	1hr	2hr	2hr	2hr	1hr	1hr			10d
	precision	%	1/10	3/20	1/5	0.2/1	1/20	10/30	10			2*
	trueness	%	2/15	5/20	2/10	1/2	2/25	15/40	15			4*
	delay		(1)/(2)	(1)/(2)	(1)/(2)	(1)/(2)	(1)/(2)	(1)	(2)			
2. Upper troposphere	Δx	km	20/100	10/100	50/250	50/500	10/250	30/250				
	Δz	km	0.5/2	0.5/2	2/4	1/2	1/4	0.5/3				
	Δt		1hr	1hr	2hr	2hr	2hr	1hr				
	precision	%	2/20	3/20	1/10	0.5/2	1/20	10/30				
	trueness	%	2/20	5/30	2/20	1/2	2/25	15/40				
	delay		(1)/(2	(1)/(2)	(1)/(2)	(1)/(2	(1)/(2)	(1)				
3. Lower stratosphere	Δx	km	50/200	50/100	50/250	250/500	50/250	30/250	100	100	50/250	1000
	Δz	km	1/3	0.5/3	2/4	1/4	2/5	1/4	1	1	1/4	
	Δt		1d	1d	6-12hr	1d	1d	6-12hr	6hr	6hr	6-12hr	10d
	precision	%	5/20	3/15	2/20	1/2	5/15	10/30	10	10	5/10	6
	trueness	%	5/20	5/20	5/30	1/2	10/25	15/40	15	15	15	15
	delay		(1)/(2	(1)/(2)	(1)/(2)	(2)/(3)	(2)/(3)	(1)	(2)	(2)		
4. Upper stratosphere, mesosphere	Δx	km	50/200	50/200	50/250	250/500	100/500	30/250	100	100	50/250	
	Δz	km	2/5	0.5/3	2/4	2/4	3/10	1/4	1	1	1/4	
	Δt		1d	1d	1d	1d	1d	1d	1d	1d	1d	
	precision	%	5/20	3/15	2/4	1/2	10/20	10/30	10	10	5/10	
	trueness	%	5/20	5/20	5/30	1/2	10/25	15/40	20	20	15	
	delay		(1)/(2	(1)/(2)	(1)/(2)	(2)/(3)	(2)/(3)	((1)/(2)	(2)	(2)		
5. Total column	Δx	km	50/200	10/50	10/250	50/500	10/250	30/250	100	100	30/250	1000
	Δt		1d	1d	12hr	1d	1d	12hr	12hr	12hr	6-12	10d
	precision	%	0.5/2	1/5	1/5	0.5/1	1/10	1/10	10	10	4	4
	trueness	%	1/3	2/5	2/10	1/2	2/20	2/20	15	15	6	10
	delay		(1)/(2)	(1)/(2)	(1)/(2)	(2)/(3)	(1)/(2)	(1)	(2)			
6. Tropospheric column	Δx	km	10/200	10/50	10/50	10/500	10/250	10/250	25			1000
	Δt		1hr	1hr	2hr	2hr	2hr	1hr	1hr			10d
	precision	%	0.5/2	5/15	1/5	0.5/1	2/20	1/10				4
	trueness	%	1/3	5/15	2/10	1/2	5/25	2/10				10
	delay		(1)/(2)	(1)/(2)	(1)/(2)	(1)/(2)	(1)/(2)	(1)				

ATMOSPHERIC SPECIES IN GROUP 2 TO BE MEASURED BY AN INTEGRATED GLOBAL OBSERVING SYSTEM												
Atmospheric Region	Requirement	Unit	NO	HNO_3	C_2H_6	CH_3Br	Halons	HCFC-22	$ClONO_2$	HCHO	SO_2	UVA $j(NO_2)$ UVB $j(O^1D)$
1. Lower troposphere	Δx	km	10/250	10/250	50	500*				1	1	
	Δz	km	0.5/3	1/3	?					2-5	2-5	2-5
	Δt		1hr	1d	1hr	10d	10d	10d		1hr	1hr	1hr
	precision	%	10/30	10/30	10	4*	15*	2*		10	5	7/10*
	trueness	%	15/40	15/40	15	8*	20*	4*		15	10	15*
	delay		(1)	(1)/(2)						(1)	(1)	
2. Upper troposphere	Δx	km	30/250	10/250	50					10	10	50/500
	Δz	km	0.5/3	1/3	2					0.5	0.5	3**
	Δt		1hr	1d	1hr						1hr	1hr
	precision	%	10/30	10/30	10					10	5	10
	trueness	%	15/40	15/40	15					15	10	15
	delay		(1)	(1)/(2)						(1)	(1)	
3. Lower stratosphere	Δx	km	30/250	50/250		500	500	1000	50/250			
	Δz	km	1/4	1/4		5	5	5	1/4			
	Δt		12hr	12hr		3d	3d	3d	6-12hr			
	precision	%	10/30	10/30		4	4	8	20			
	trueness	%	15/40	15/40		8	8	15	30			
	delay		(1)	(1)/(2)								
4. Upper stratosphere, mesosphere	Δx	km	30/250	50/250					50/250			
	Δz	km	1/4	1/4					2/6			
	Δt		1d	1d					1d			
	precision	%	10/30	10/30					20			
	trueness	%	15/40	15/40					30			
	delay		(1)/(2	(2)/(3)								
5. Total column	Δx	km	30/250	30/250	50			1000	30/250		50	
	Δt		1d	1d	1hr			10d	6-12hr		1hr	
	precision	%	1/10	1/10	1			5	20		1	
	trueness	%	2/20	2/20	2			15	30		2	
	delay		(1)	(2)/(3)							(2)	
6. Tropospheric column	Δx	km	10/250	10/250		1000	1000	1000				
	Δt		1hr	1d		10d	10d	10d				
	precision	%	1/10	1/10		4	4	6				
	trueness	%	2/20	2/20		8	8	15				
	delay		(1)	(1)/(2)								

IUOS/Climate			SPATIAL					MEASUREMENTS			TEMPORAL		
Observational Requirement	Obs Req Pri	User	T/O	Geo Cover	Vert Range	Vert Res	Horz Res	Msmnt Range	Msmnt Accuracy	Msmnt Precsn	Sampling Interval	Data Latency	Long-Term Stability
Air Temperature: Surface	1	NOAA / COA	T	Global and Hemispheric	Sfc	na	10 km	170 -350 K	0.1 K	0.5 K	60 min	6 hr	0.04 K/Decade
			O	Land	Sfc	na	5 km	tbs	tbs	tbs	tbs	tbs	tbs
	UA	GCOS	T	Global	Sfc	na	100 km	tbs	0.5 K	tbs	12 hr	48 hr	tbs
			O	Global	Sfc	na	25 km	tbs	0.2 K	tbs	3 hr	24 hr	tbs
Ozone: Profiles	**1**	**IUAOS**	**T**	**Global**									
			O										
	1	NOAA / CF-LTM	T	Global	0.1 - 35 km	100 m	2500 km	0 - 10 ppm	5 %	5 %	1 wk	1 mon	5 %/Decade
			0	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs
	1	NOAA / CF-PS	T	CONUS and Global	0 - 15 km	100 m	100 m	0.001 - 10K ppb	20 %	20 %	0.2 sec	1 day	30 %/Decade
			0	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs	tbs
	UA	GCOS	T	Global	tbs	tbs	8 km	tbs	tbs	tbs	48 hr	720 hr	tbs
			O	Global	tbs	tbs	1 km	tbs	tbs	tbs	24 hr	240 hr	tbs

IUOS/Climate			SPATIAL					MEASUREMENTS			TEMPORAL		
Observational Requirement	Obs Req Pri	User	T/O	Geo Cover	Vert Range	Vert Res	Horz Res	Msmnt Range	Msmnt Accuracy	Msmnt Precsn	Sampling Interval	Data Latency	Long-Term Stability
Water Vapor: Profiles	**1**	**IUAOS**	**T**	**Global**									
			O										
	1	*NOAA / COA*	*T*	*Global and Hemispheric*	*Sfc - Meso*	*HS/M: 3 km LS/HT: 1 km LT: 0.5 km*	*10 km*	*0 - 20 gm/Kg*	*5 %*	*10 %*	*60 min*	*6 hr*	*2.5 %/Decade [1] %/Decade*
			O	*tbs*	*tbs*	*tbs*	*tbs*	*tbs*	*5 %*	*tbs*	*tbs*	*tbs*	*0.026 %/Decade*
	UA	*GCOS*	*T*	*Global*	*tbs*	*HS/M: 3 km LS/HT: 1 km LT: 2 km*	*500 km*	*tbs*	*10 %*	*tbs*	*6 hr*	*12 hr*	*tbs*
			O	*Global*	*tbs*	*HS/M: 2 km LS/HT: 0.5 km LT: 0.1 km*	*100 km*	*tbs*	*5 %*	*tbs*	*3 hr*	*3 hr*	*tbs*
Water Vapor: Surface	**?**	**IUAOS**	**T**	**Global**									
			O										
	1	*NOAA / COA*	*T*	*Global and Hemispheric*	*Sfc*	*na*	*10 km*	*1 - 20 gm/Kg*	*5 %*	*10 %*	*60 min*	*6 hr*	*2.5 %/Decade [1] %/Decade*
			O	*tbs*	*Sfc*	*na*	*tbs*	*tbs*	*tbs*	*tbs*	*tbs*	*tbs*	*0.026 %/Decade*
	UA	*GCOS*	*T*	*Global*	*Sfc*	*na*	*100 km*	*tbs*	*2 %*	*tbs*	*6 hr*	*72 hr*	*tbs*
			O	*Global*	*Sfc*	*na*	*25 km*	*tbs*	*1 %*	*tbs*	*3 hr*	*24 hr*	*tbs*

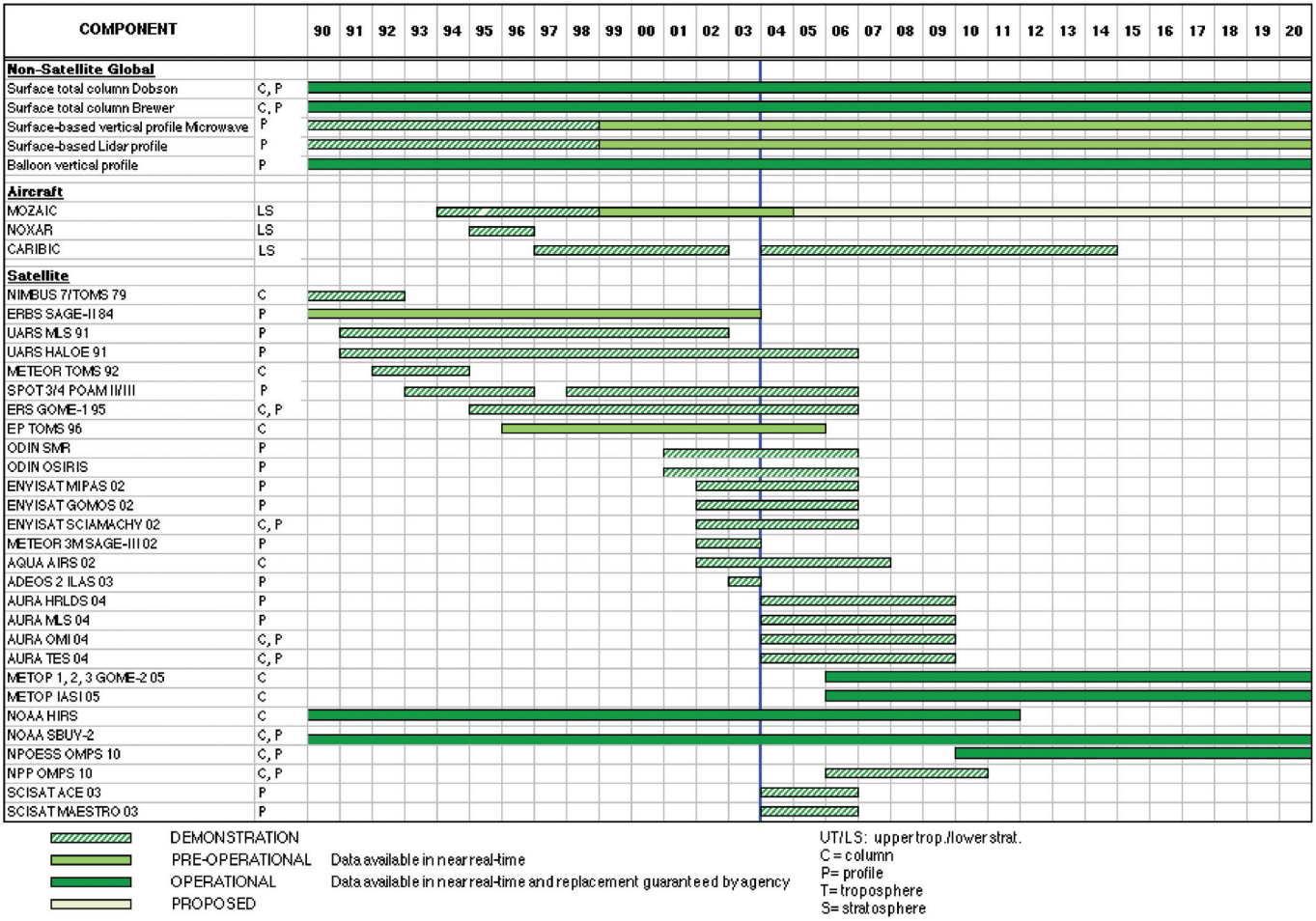


Figure 4.2: An Overview of satellite, ground-based and aircraft measurements for stratospheric O_3.

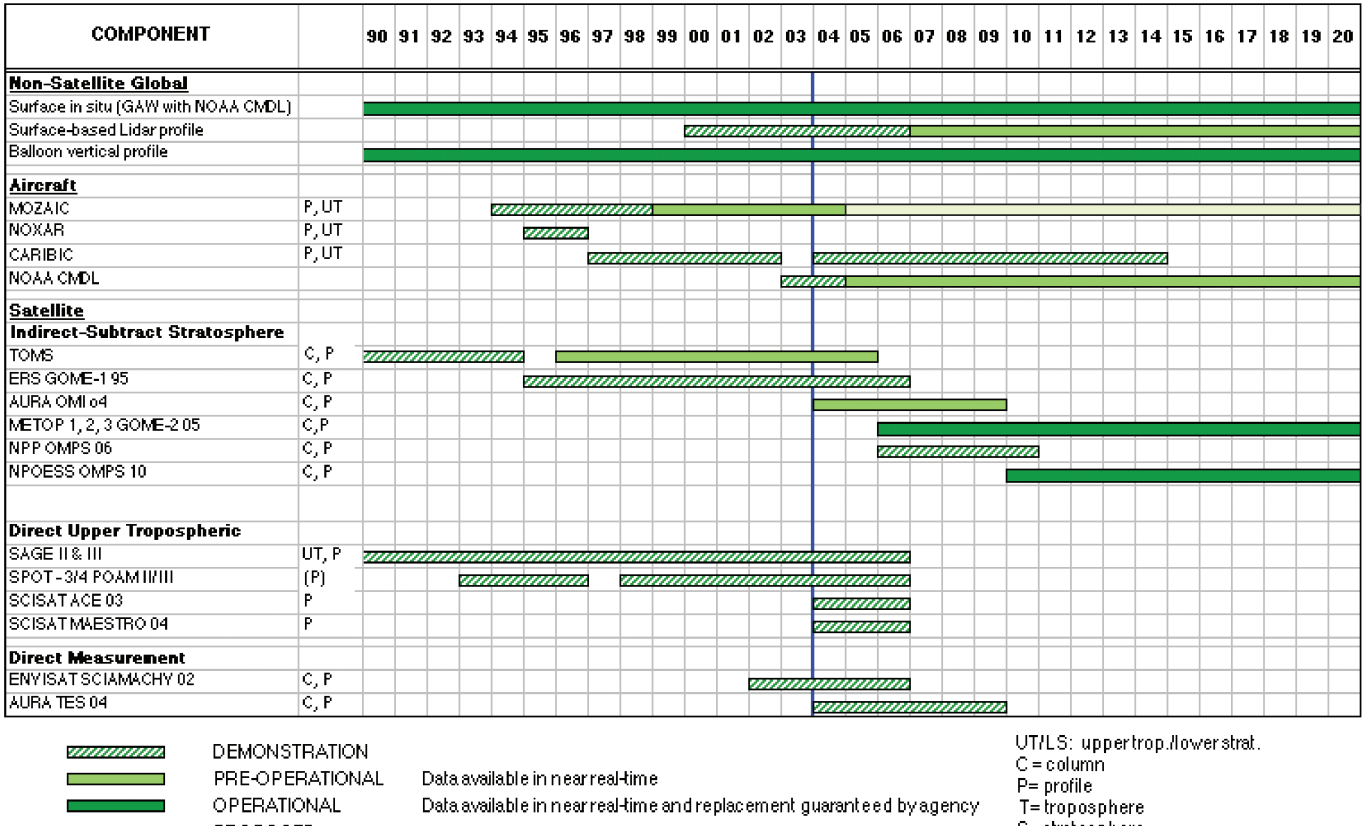
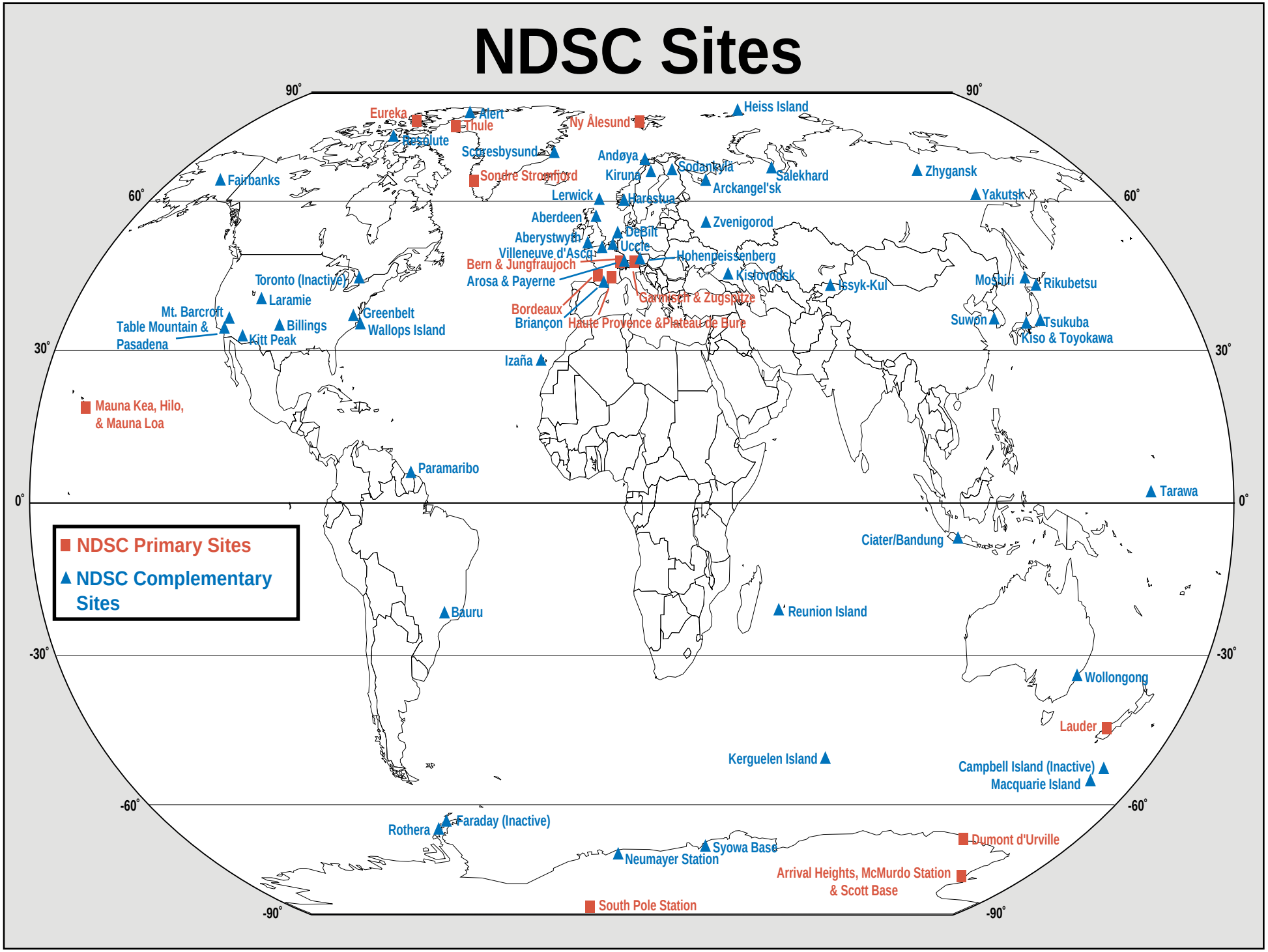
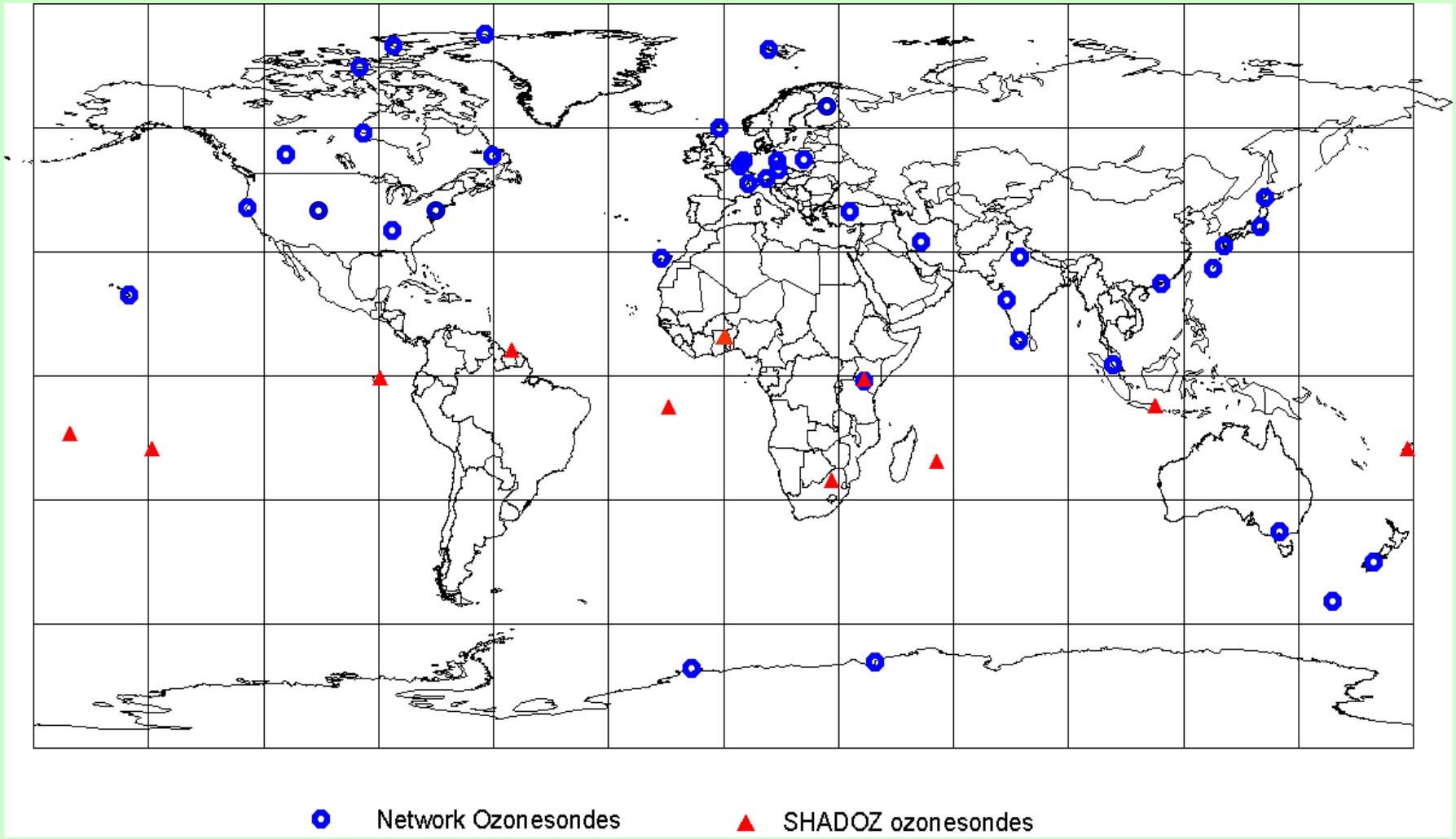


Figure 4.1. An overview of satellite, ground-based and aircraft meaasurements for tropospheric O_3

NDSC Sites


90°
60°
30°
0°
-30°
-60°
-90°
Eureka
Alert
Thule
Ny Ålesund
Heiss Island
Hareskute
Scoresbysund
Andøya
Kiruna
Sodankylä
Salekhard
Arckangel'sk
Zhygansk
Yakutsk
Sondre Stromfjord
Fairbanks
Lerwick
Harestua
Aberdeen
Zvenigorod
Aberystwyth
DeBilt
Uccle
Villeneuve d'Ascq
Bern & Jungfraujoch
Hohenpeissenberg
Arosa & Payerne
Kislovodsk
Issyk-Kul
Toronto (Inactive)
Laramie
Garmisch & Zugspitze
Moshiri
Rikubetsu
Mt. Barcroft
Table Mountain &
Pasadena
Billings
Kitt Peak
Greenbelt
Wallops Island
Bordeaux
Briançon
Haute Provence &Plateau de Bure
Suwon
Tsukuba
Kiso & Toyokawa
Izaña
Mauna Kea, Hilo,
& Mauna Loa
Paramaribo
Tarawa
Ciater/Bandung
NDSC Primary Sites
NDSC Complementary Sites
Bauru
Reunion Island
Wollongong
Lauder
Kerguelen Island
Campbell Island (Inactive)
Macquarie Island
Rothera
Faraday (Inactive)
Dumont d'Urville
Syowa Base
Neumayer Station
Arrival Heights, McMurdo Station
& Scott Base
South Pole Station

Ozonesonde Stations in the WMO/GAW and SHADOZ Networks



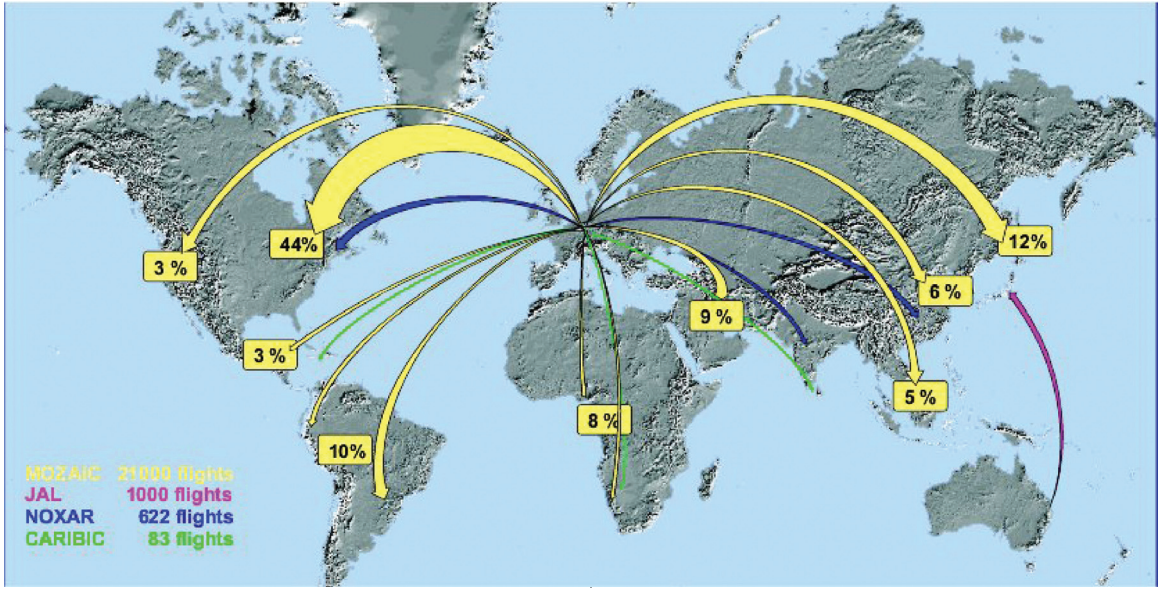


Figure 3.3. Flight routes of MOZAIC (21000 flights 1994-2003, yellow), JAL (ca 1000 flights 1993-2003, purple), NOXAR (622 flights, blue), and CARIBIC (83 flights 1997-2001, green). *[Picture courtesy of Andreas Volz-Thomas, Jülich]*

Lidar measurements within NDSC

- Measurements generally performed during the night (better SN ratio) and in clear sky conditions
- Accuracy, Temporal and Vertical resolution differ according to instrumental set up (Laser power, …)
- Long term lidar time series:
  - Stratospheric ozone
  - Tropospheric ozone (different instrumental set up)
  - Temperature
  - Aerosol Backscatter Ratio and Backscatter coefficient (at 532 nm or 355 nm)
- Water vapor lidar measurements (~ 2 - 15 km) considered for inclusion within NDSC

Lidar measurements within NDSC

Parameter	Altitude	Accuracy	Precision	Vertical Resolution	Temporal Resolution
Trop. Ozone	< 10 km	5-20 %	<10 %	0.2 km	2 hours
	10-15 km	5 %	10 %	0.5 km	2 hours
Strat. Ozone	< 20 km	5-20 %	<5 %	0.6 km	2 – 4 hours
	20-40 km	<5 %	<5 %	0.6-2 km	2 – 4 hours
	> 40 km	5-20 %	10-40 %	2-8 km	2 – 4 hours
Temperature	10-20 km	<2 K	0.1 K	0.3 km	2 – 4 hours
	20-40 km	1-2 K	0.2-2 K	0.3-1 km	2 – 4 hours
	40-65 km	2-5 K	2-5 K	1-3 km	2 – 4 hours
	>65 km	5 – 10 K	5 – 10 K	3-8 km	2 – 4 hours
Aerosols Backscatter Ratio	8-40 km	5 %	5 %	0.3-1 km	2 hours

Conclusions

- An extensive suite of constituent measurements is required to meet the need for monitoring atmospheric composition to meet climate requirements.
- Vertical structure plays a key role in determining the climate impact of atmospheric trace constituents.
- Significant work has already been done in developing measurement requirements related to atmospheric composition.
- Adequate monitoring of atmospheric composition related to climate requires an integrated global observing strategy that includes satellite, aircraft, and ground-based systems using remote sensing and in situ techniques.
- Networks currently exist for measuring atmospheric composition that require expansion in both spatial and temporal density.