POTENTIAL USE OF IASI FOR VOLCANIC CLOUDS DETECTION AND MONITORING

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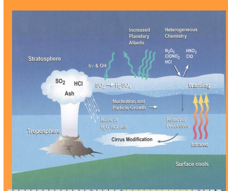
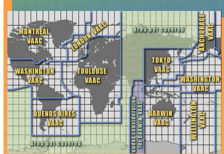




NEEDS

•CLIMATE : Impact of SO_2 and Stratospheric aerosols on climate.

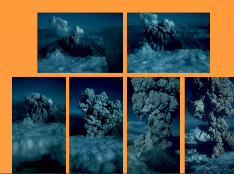
•AERIAL SAFETY

The danger resulting from volcanic explosion has justified the opening by OACI of 9 Volcanic Ash Activity Centers (VAAC) in charge of monitoring and alert

OBJECTIVES

Mapping of sulfur dixoyde or aerosol, Mass loadings, conversion SO_2 to H_2SO_4, transport, depositioo, Radiative properties.

Identification of ash, amount, altitude, transport



Volcanic Cloud Stages

Volcanic Cloud stage	1	2	3
Duration, hrs after eruption stops	~1-2	18-24	24-96+
Ash fallout, km from volcano	<25	25-400	>400
Area of ash fallout, km^2	<300	~5 x10^4	?,discontinuous
Ash fallout diameter range, mm	>0.5	0.5-<0.01	<0.01
Ash fallout rate, kilotonnes/hr	>10^4	<10^4-10^2	"very low"
Fraction of fine ash(d= 1-25 µm), %	<1	10-50	>50
Cloud Area, km^2	<10^4	10^4-10^6	10^6,decreasing
Cloud Area change, %/hr	>100	30-50	-10 to +10
Mean Optical Depth, 11 µm	>2	0.5-2	<0.3
Cloud ash burden, tonnes/km^2	>25	3-10	<3
Fraction of ash mass suspended, %	100-~30	~30-3	<3

MichiganTech Rose *et al*, J Geology, in press

VOLCANIC CLOUD

•Volcanic eruption releases gases (H_2O, SO_2, HCl etc.) and aerosols (ash, sulfates)
•Processes are relatively well known and documented
•Composition is highly variable.
•Particle size varies with time
•Several stages of development during the first hours
•Altitude, vertical extent of cloud varies
•Lifetime is a function of particle size and for SO_2 of the altitude

SATELLITE MONITORING

Current status

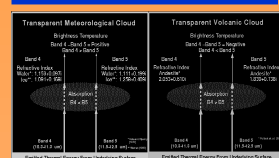
Satellite is the unique tool

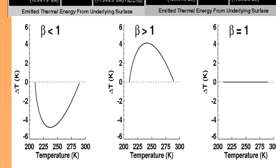
Data Used :

GOES, AVHRR, TOMS, HIRS

SEVIRI, SCHIAMACHY, AIRS

•Single Channel method : Visible or infrared radiance --> Poor but easy
•Two-channel : GOES, AVHRR (e.g. Shneider, Rose) --> Generally efficient
•TOMS: Aerosol Index and SO_2 column (Bluth, 2001)--->Good supplement but no real time
•Multichannel : HIRS (Prata), MODIS (Yu and Rose), --->Good SEVIRI (Watkin)
•AIRS (L. Strow, F. Prata) ---> Added value
•IASI ????





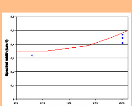
Environmental factors that weaken or obliterate the negative 4-5 BTD signal

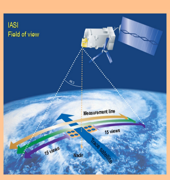
1. Early Opacity of plume (blocks transmission)
 --very cold BT and dramatic buildup
2. Atmospheric water vapor in first 3 km (tropics)
 --clear pixel 4-5 BTD values of +3
3. Cold Background under volcanic cloud (rare)
 --low B4 BT around cloud
4. Presence of ice in the volcanic cloud
 --volcanic source, dynamics

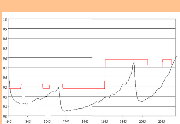
WHAT IASI COULD BRING ?

IASI

•Fourier transform spectrometer on Metop
=>15 years of high quality data
•Spectral range: 2760 to 645 cm^{-1}
•Spectral resolution: 0.35 to 0.5 cm^{-1}
•Radiometric performances
•Spatial sampling







SIMULATIONS

SO2 only

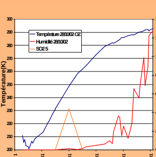
Modelling Radiances

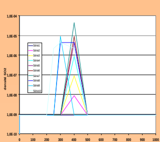
•4A (version 4AOP) Includes continuum (CKD2.0), H_2O, CO_2, N_2O, CO, CH_4, SO_2, HNO_3, CFCs.

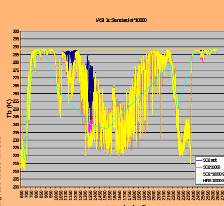
•Simulation for HIRS 3 (NOAA 16), AIRS, IASI

•Profiles P,T,U from Raob Tunis 28/09/02 0Z

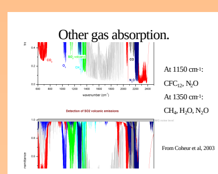
• 10 profiles SO_2 around 8 km for sensitivity study



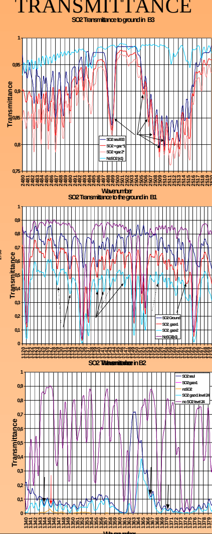




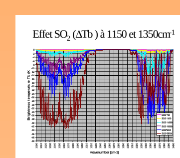
3 absorption bands but mixed with other gases



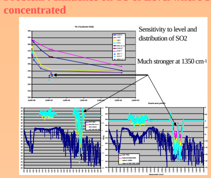
TRANSMITTANCE



BRIGHTNESS TEMPERATURE

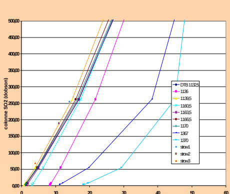


• USING HIGH SPECTRAL RESOLUTION OF IASI AND AIRS WILL REDUCE INFLUENCE OF OTHER GASES AND IMPROVE DETECTION AND TOTAL AMOUNT
• SENSITIVITY IN B2 > B1 > B3 But SATURATION FOR HIGH CONTENT AND LINE MIXING CHANNELS GOOD FOR SPECTROSCOPY :
B2: For low amounts : 1344, 1345.5. Possibly 1366.5 and 1370.5
B1 : For mean amounts : 1132.75, 1139.75, 1141.5, 1147, 1163.25 + 1129.25, 1143.75, 1156
B3 :For very large amounts :2499, 2508,2509, 2510
Problem : Influence on Tb of Level where SO2 is concentrated



SO_2 DETECTION AND CHARACTERIZATION WITH IASI

- Use channels at 1150, 1350, 2500 cm^{-1}.
- Use microwindow at 1210 cm^{-1}
- Maps of ΔTb= Tbi-T1210 (i=1132.75, 1139.75, 1141.5, 1147, 1163.25 + 1129.25, 1143.75, 1156 and 1344.5, 1345, 1370.5).
- Detect SO_2 (ΔTb > S) and evaluate if amount is High, Mean or Low.
- Best estimate with different methods :
  - Local Differential absorption
  - Contrast with clear pixels
  - Differential absorption with microwindow.
- Then, with the retrieved column and the retrieved temperature profile, simulate radiance at 1350 with different SO_2 levels. Select by minimization.



AEROSOLS

Aerosols. Types, distribution et data

- 2 types :
  - Sulfates (H2SO4) : Background et Ash (Andesite)
- Data :
  - OPAC
  - GADS
  - Modtran : 8*2 models
- Models :

Current version of 4A does not include scattering
Modtran + Disort adequate but
Not possible to have a complete parametric study (Various refractive indices m, distribution laws or efficient radii).

Aerosols in Modtran

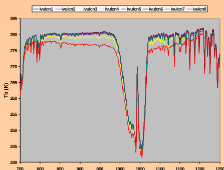
- aerosols only defined by a vertical distribution and spectral extinction
- optical properties linked to refractive index

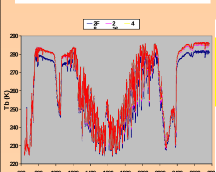
$b_{ext}(z,l)=s(z)\times k_{ext}(l)$

MODELE D'EXTINCTION	DISTRIBUTION VERTICALE: BACKGROUND STRATOSPHERIC	MODERATE VOLCANIC	HIGH VOLCANIC	EXTREME VOLCANIC
BACKGROUND STRATOSPHERIC	1	6	7	-
AGED VOLCANIC	-	2	4	-
FRESH VOLCANIC	-	5	3	8

$t_l(z_1,z_2)=\int_{z_1}^{z_2} b_{ext}(z,l)dz=\int_{z_1}^{z_2} k_{ext}(l)s(z)dz=k_{ext}(l)\int_{z_1}^{z_2} s(z)dz$ avec $t_{0.55}=\int_{z_1}^{z_2} s(z).dz$

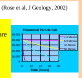
IVULCN	1	2	3	4	5	6	7	8
$t_{0.55}$	0.00688	0.0271	0.0946	0.0946	0.0271	0.0271	0.0946	0.274

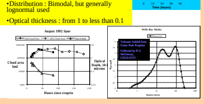




What we know about volcanic Ash aerosol (Rose et al, J Geology, 2002)

•Nature : andesite, silicates
•Time of residence: until 200 hours or more
•Altitude: up to 20 km
•Particle size : from 500 µm to 5 µm
•Distribution : Bimodal, but generally lognormal used
•Optical thickness : from 1 to less than 0.1

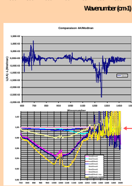




What we know about sulfate aerosol

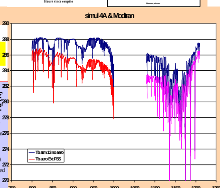
•Originated from atmospheric sulfur gases oxydation
•Nature : H_2SO_4 (75% on average) + water (25%)
•Time of residence: several months
•Altitude: stratosphere
•Particle size : Typically 0.1 µm (background), 0.5-1 µm (eruption)
•Density at maximum concentration : 10 cm^{-3} to 50 cm^{-3} (15 months after eruption (SAGE II)
•Distribution : Lognormal, monomodal (background) but bimodal in case of eruption
•Optical thickness : from 0.015 to 0.086 (or More)

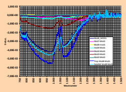
Data still missing to characterize these aerosols
Large variability
=> ***Sensitivity study must account for different distribution, density, efficient radii***



Modtran at 1cm^{-1} close to 4A (degraded)

Ratio or difference are a function of aerosol type.
But for same aerosol function of atmosphere
Ratio smoother than difference
Small lines slightly visible even in the continuous part.
=> Effect cannot be simply added (better coupling needed)
=> can be neglected to simulated aerosol with 4A in [800-1000] and [1100-1240]





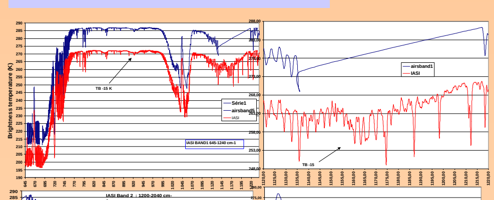
Conclusions

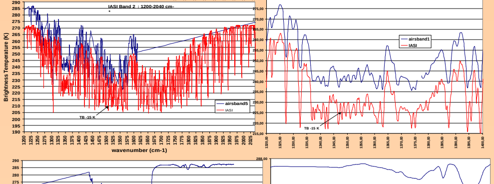
- **MODTRAN (+DISORT) not suited since**
  - **spectral resolution (2cm^{-1}) not sufficient to resolve interactions between scattering and gaseous absorption lines**
  - **No possibility to vary independently the various parameters : distribution n(r), mean radius and variance, efficient radius, density N(z).**

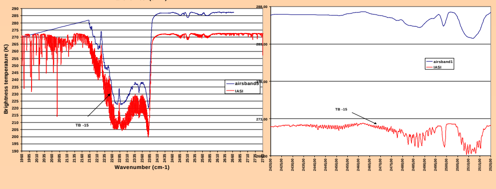
•Study needs to be complemented with a High Spectral resolution RTM including multiple scattering.

•A priori first results (consolidated by AIRS results) show that with IASI it is possible
- **•to discriminate SO2, water, Ash and SO4 aerosols.**
- **•to retrieve Total amount SO2 and altitude of maximum.**
- **•Optical thickness of ash aerosol and efficient radius**
- **•Optical thickness of ash aerosol and efficient radius**

IASI versus AIRS







Having a better resolution than AIRS and a better spectral coverage of SO2 bands IASI is very promising for Volcanic activity and climate monitoring