# G O M A S

## Geostationary Observatory for Microwave Atmospheric Sounding

### A proposal to ESA as an Earth Explorer Opportunity Mission, as forwarded by the European and American Proponents Listed in *Panel 2*

#### Objective

The objective of **GOMAS** is to explore the capabilities of very-high-frequency microwaves and sub-millimetre waves to provide observations, at ***15-min intervals***, of:

- Nearly-all-weather temperature profiles with resolution ~30 km at the s.s.p.[1],
- Nearly-all-weather humidity profiles with resolution ~20 km at the s.s.p.,
- Cloud ice/liquid water, columnar amount and gross profile with resolution ~20 km at s.s.p.,
- Precipitation rate (particularly within convection) with resolution ~10 km at the s.s.p..

#### Principle

In order to use an antenna of affordable size ***( Æ = 3 m)***, GOMAS makes use of frequency bands within the sub-millimetre range. ***Panel 3*** shows the distribution of available bands in the MW/Sub-mm range. The selected ones for GOMAS are: for $O_2$, ~54, ~118 and ~425 GHz; for $H_2O$, ~183 and 380 GHz. The incremental weighting functions (IWFs) of the ~40 channels selected in these bands are reported in ***Panel 4***. The effect of clouds on bands comparable to those to be used on GOMAS is shown in ***Panel 5***. Temperature and humidity profiles retrieved from the various GOMAS sounding bands are affected to differing degrees by cloud liquid or ice content, mixing ratio, vertical distribution, and drop size and shape. Since these are cloud properties closely correlated with precipitation rate, the differential observations enable simultaneous retrieval of temperature/humidity profiles, cloud liquid/ice water columnar amounts and gross profiles, and precipitation rate. Some examples using either simulations or actual data from NOAA AMSU and airborne instruments are shown in ***Panels 6*** and ***7***.

#### Mission concept

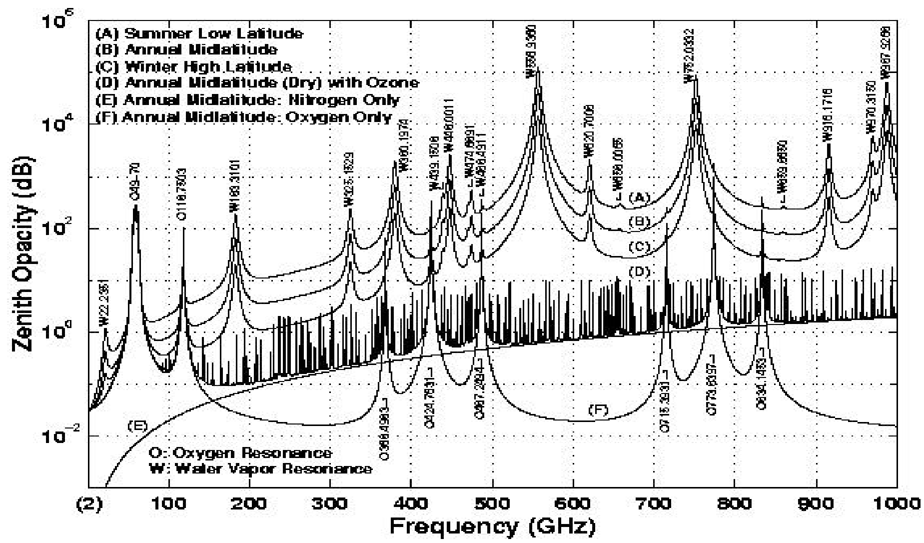
The GOMAS concept is based on a 3-m antenna and 5-band/40-channel spectrometer, depicted in ***Panel 8***. The problem of sensitivity that exists with the current state of receiver technology is solved by limiting the scanned area of the Earth's disk, as suggested in ***Panel 9***. The scanned area can be moved within the disk, and the longitude of geostationarity can be made shifting during the satellite lifetime. Using this scheme, acceptable radiometric performances for sounding are achieved, as listed in ***Panel 10***. The instrument is intended to be flown on a dedicated satellite and a sketch view of the sensor on a "SmallSat" (430 kg "dry" mass, 860 kg mass at launch) is provided in ***Panel 11***. Direct broadcast of raw data is planned so as to be compatible for reception using the existing Low-Rate User Stations (128 kbps) of Meteosat Second Generation. A target launch timeframe is 2007-2009. Conclusions regarding programmatic aspects are in ***Panel 12***.

---

[1] s.s.p. = sub-satellite point

***List of Proponents of GOMAS (undertaking to implement the scientific programme)***

| | |
|---|---|
| **Bizzarro BIZZARRI (P.I.)** | CNR Istituto Scienze dell'Atmosfera e del Clima (ISAC), Roma, Italy |
| **Umberto AMATO** | CNR Istituto Applicazioni della Matematica, Napoli, Italy |
| **John BATES** | NOAA Environmental Technology Laboratory, Boulder Co., USA |
| **Wolfgang BENESCH** | Deutscher Wetterdienst, Offenbach, Germany |
| **Stefan BÜHLER** | Institute of Environmental Physics, University of Bremen, Germany |
| **Massimo CAPALDO**<br>**Marco CERVINO**<br>**Vincenzo CUOMO** | Servizio Meteorologico dell'Aeronautica, Roma, Italy<br>CNR Istituto Science dell'Atmosfera e del Clima, Bologna, Italy<br>CNR Istituto Metodologie Avanzate di Analisi Ambientale, Potenza, Italy |
| **Luigi De LEONIBUS** | Servizio Meteorologico dell'Aeronautica, Roma, Italy |
| **Michel DESBOIS** | CNRS Laboratoire de Météorologie Dynamique, Palaiseau, France |
| **Stefano DIETRICH**<br>**Frank EVANS**<br>**Laurence EYMARD** | CNR Istituto Science dell'Atmosfera e del Clima, Roma, Italy<br>University of Colorado, Atmospheric & Oceanic Sciences, Boulder Co., USA<br>CNRS Centre d'études des Environnement Terrestres et Planétaires, Vélizy, France |
| **Albin GASIEWSKI** | NOAA Environmental Technology Laboratory, Boulder Co., USA |
| **Nils GUSTAFSSON** | Swedish Meteorological and Hydrological Institute, Norrköping, Sweden |
| **Georg HEYGSTER** | Institute of Environmental Physics, University of Bremen, Germany |
| **Marian KLEIN** | NOAA Environmental Technology Laboratory, Boulder Co., USA |
| **Klaus KÜNZI**<br>**Vincenzo LEVIZZANI**<br>**Gian Luigi LIBERTI** | Institute of Environmental Physics, University of Bremen, Germany<br>CNR Istituto Science dell'Atmosfera e del Clima, Bologna, Italy<br>CNR Istituto Science dell'Atmosfera e del Clima, Bologna, Italy |
| **Ernesto LOPEZ-BAEZA** | Department of Thermodynamics, Faculty of Physics, University of Valencia, Spain |
| **Paul MENZEL** | NOAA/NESDIS Office of Research and Application, Madison Wis., USA |
| **Jungang MIAO** | Institute of Environmental Physics, University of Bremen, Germany |
| **Alberto MUGNAI** | CNR Istituto Science dell'Atmosfera e del Clima, Roma, Italy |
| **Paolo PAGANO**<br>**Jean PAILLEUX**<br>**Juan PARDO** | Servizio Meteorologico dell'Aeronautica, Roma, Italy<br>Météo France, Toulouse, France<br>Instituto de Estructura de la Materia, Madrid, Spain |
| **Federico PORCU'** | Department of Physics, University of Ferrara, Italy |
| **Catherine PRIGENT** | Departement de Radioastronomie Millimetrique, Observatoire de Paris, France |
| **Franco PRODI** | CNR Istituto Science dell'Atmosfera e del Clima, Bologna, Italy |
| **Rolando RIZZI** | Department of Physics, University of Bologna, Italy |
| **Guy ROCHARD**<br>**Hans Peter ROESLI**<br>**Carmine SERIO** | MétéoFrance, Centre de Météorologie Spatiale, Lannion, France<br>MétéoSuisse, Locarno-Monti, Switzerland<br>Dipartimento Ingegneria e Fisica Ambiente, University of Basilicata, Potenza, Italy |
| **William SMITH** | NASA Langley Research Center, Hampton VA., USA |
| **Antonio SPERANZA** | Hydrographic and Mareographic Service, Roma, Italy |
| **David STAELIN** | MIT Research Laboratory of Electronics, Cambridge MA., USA |
| **Alfonso SUTERA** | Department of Physics, University of Roma, Italy |
| **Jung-Jung TSOU**<br>**Chris VELDEN** | NASA Langley Research Center, Hampton VA., USA<br>Cooperative Institute for Meteorological Satellite Studies, Madison Wis.,USA |
| **Guido VISCONTI** | Department of Physics, University of L'Aquila, Italy |




***Atmospheric spectrum in the MW/Sub-mm ranges (from Klein and Gasiewski, 2000 [2]).***

The figure shows that:

- For $O_2$, above the 54 GHz band, the desirable temperature sounding bands are at 118 GHz and 425 GHz. Others exist, either too weak or contaminated by water vapour continuum absorption;
- For $H_2O$, above the band at 183 GHz, there are several others, the first at 325 GHz, then at 380 GHz and higher. These bands become progressively less useful because of the increasing continuum absorption contribution.

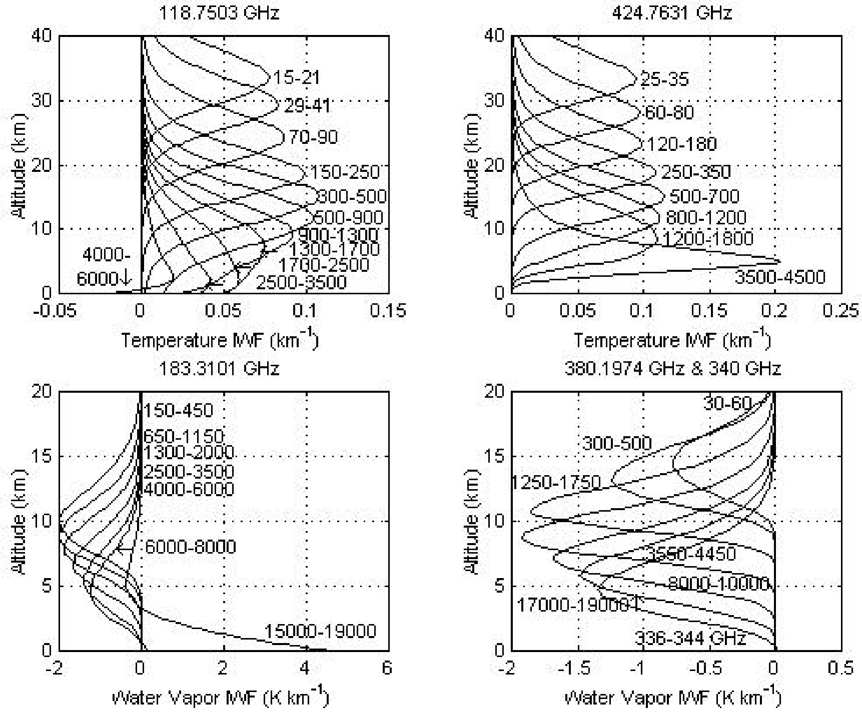
Accordingly, the optimal choice of bands for GOMAS is: ***54 GHz, 118 GHz, 183 GHz, 380 GHz and 425 GHz***. The resolution achievable using several different antenna diameters at these frequencies are tabulated below.

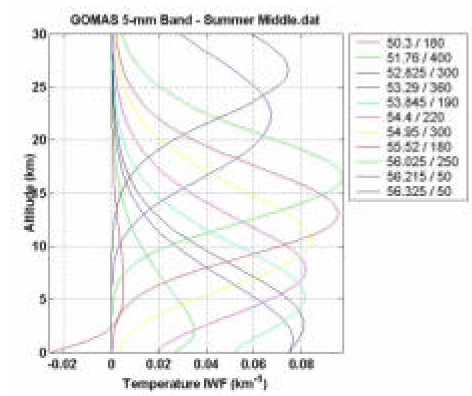
***Variation of resolution at s.s.p. with frequency at reference antenna diameters***

| Antenna Ø | 54 GHz | 118 GHz | 183 GHz | 380 GHz | 425 GHz |
|---|---|---|---|---|---|
| **1 m** | 242 km | 112 km | 73 km | 35 km | 31 km |
| **2 m** | 121 km | 56 km | 36 km | 18 km | 16 km |
| **3 m** | 81 km | 37 km | 24 km | 12 km | 10 km |
| **4 m** | 60 km | 28 km | 18 km | 8.8 km | 7.8 km |

The selected GOMAS antenna diameter is ***3 metres*** so as to allow good spatial resolution at the high European latitudes.

[2] Klein M. and A.J. Gasiewski, 2000 - The Sensitivity of Millimeter and Sub-millimeter Frequencies to Atmospheric Temperature and Water Vapour Variations - *J. Geophys. Res., Atmospheres*, v. 13, p.17481-17511.




***Incremental weighting functions (IWF) for temperature and humidity in the bands 118, 183, 380 and 425 GHz (above). The numbers attached to the curves indicate the distance (in MHz) from the frequency of the peak (from Klein and Gasiewski, 2000, same reference as Panel 3). The IWF's relative to the 54 GHz band, more familiarly used, also are plotted (aside) (courtesy of A. Gasiewski).***

The figure shows that the higher-frequency bands (380 and 425 GHz) are useful down to the top of the lower troposphere, whereas both the 118 and 183 GHz bands reach the surface and are thus indispensable for a geostationary satellite mission. The 54 GHz band is somewhat redundant and of limited resolution but nonetheless very useful due to both a minimum sensitivity to liquid water and ice and for cross-calibration purposes using AMSU (the 183 GHz band also serve this purpose).

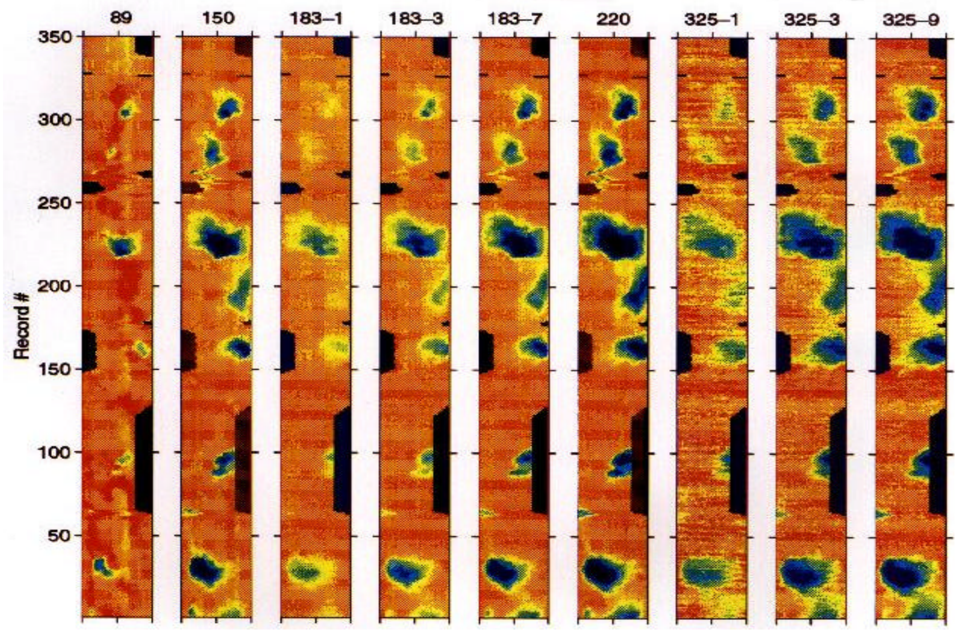


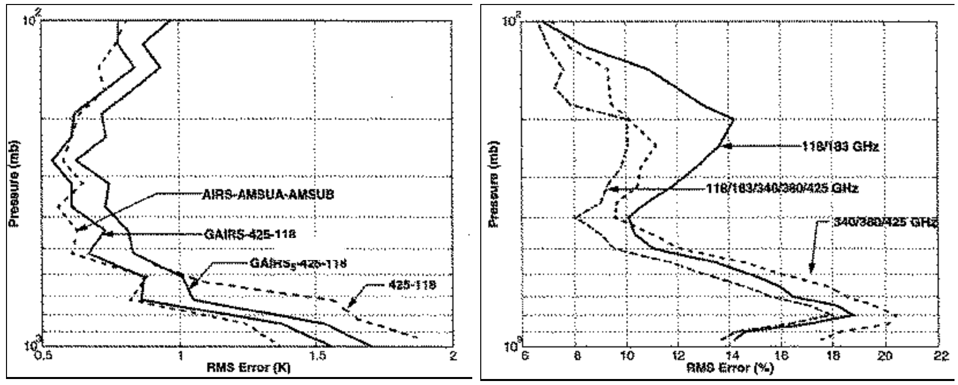

***Image strips of convective precipitation cells over ocean obtained by a multi-channel airborne radiometer. Scenes of 40 km (width) x 200 km (length) (from Gasiewski et al., 1994 [3]).***

The above strip maps show the impact of clouds as a function of frequency and absorption for a set of channels comparable to GOMAS. Cloud impact is as follows:

- An increasing impact with increasing frequency as detectable in "window" or "nearly-transparent" channels (89 GHz, 150 GHz, 183 ± 7 GHz, 220 GHz, 325 ± 9 GHz); Cloud and raincell brightness signatures become monotonic at the Sub-mm channels, thus eliminating detection ambiguities that occur within the window channel at 89;
- Cloud "altitude slicing" from the lower to upper troposphere occurs when moving towards the band absorption peaks (from 183 ± 7 GHz to 183 ± 3 GHz and 183 ± 1 GHz; and from 325 ± 9 GHz to 325 ± 3 GHz and 325 ± 1 GHz).

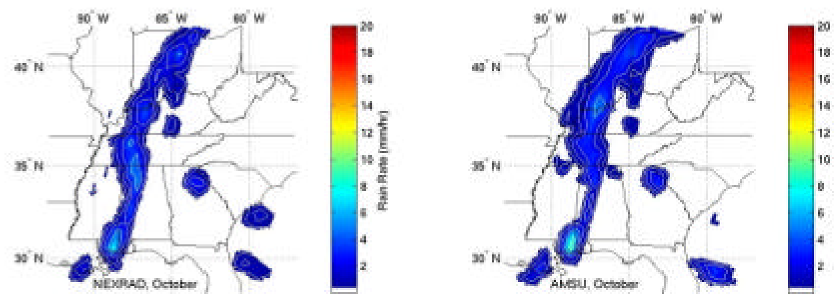
The 380 GHz band is anticipated to behave similarly to the 325 GHz band.

[3] Gasiewski A.J., D.M. Jackson, J.R. Wang, P.E. Racette and D.S. Zacharias, 1994 - Airborne imaging of tropospheric emission at millimeter and submillimeter wavelengths - *Proc. of the International Geoscience and Remote Sensing Symposium,* Pasadena, Ca., August 8-12 1994, p.663-665.




***Expected retrieval errors (RMS) for bands 118, 183, 340/380 and 425 GHz, as stand-alone or in association with an IR sounder of the AIRS class (GAIRS). (Left) temperature, (right) humidity. In the left, the case of GAIRS-425-118 is compared with GAIRS alone and 425-118 alone. The EOS -Aqua AIRS-AMSU/A-AMSU/B is shown as reference.***

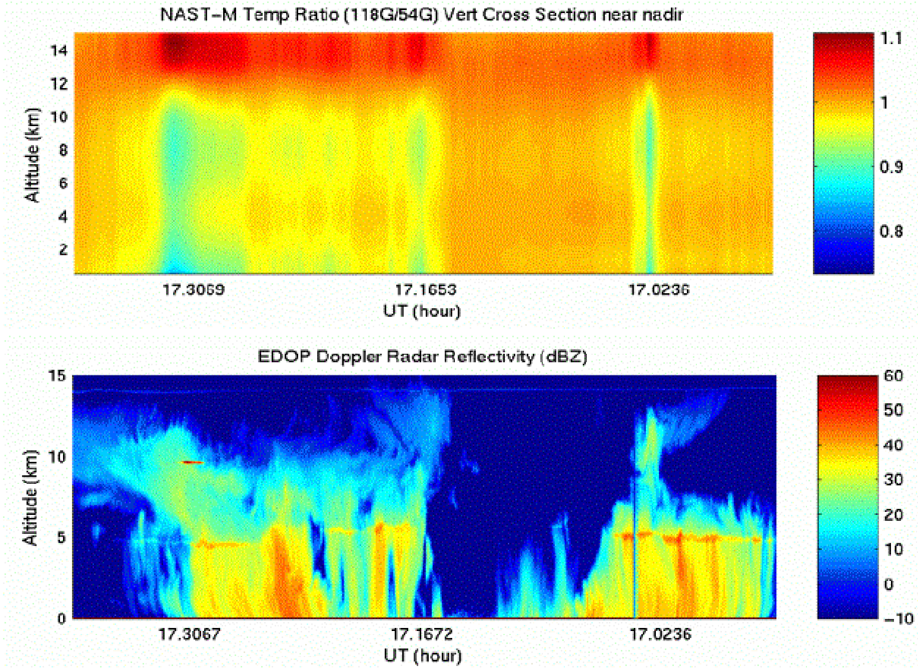
From the left-hand figure, it is interesting to note that the bands 425+118 GHz have the same performance as GAIRS for altitudes above 600 hPa, and that the association GAIRS+425+118 closely approaches the performance of AIRS+AMSU/A+AMSU/B, except for the lower troposphere. In GOMAS, the addition of the 54 GHz band would reduce this gap. In the right-hand figure, it is interesting to note the strongest impact of the 380+425 GHz bands in the high troposphere. These simulations show that GOMAS retrievals will be accurate enough to initialise NWP models, and their use in combination with an IR spectrometer of the AIRS class (GAIRS), or of the IASI class (GIASI) would approach polar satellite sounding performance. A GOMAS launch during the window of operation of the NMP-EO3 GIFTS would provide excellent cross-validation and would extend GIFTS' capabilities into cloudy regions.




***Precipitation images from a cold front on October 7, 1998: NEXRAD precipitation map smoothed to 15 km resolution (left image), and NOAA/AMSU precipitation map obtained using a neural net retrieval technique (right image) (from Staelin and Chen, 2000 [4]).***

The figure shows an early investigation on using the operational AMSU sounder to infer precipitation rate. The comparison with radar imagery is surprisingly good, over both land and ocean. Observing precipitation using absorption bands instead of windows, as generally practised in MW radiometry, is particularly advantageous over land.

[4] Staelin, D. H. and F. W. Chen, 2000 - Precipitation Observation near 54 and 183 GHz using the NOAA 15 Satellite - *IEEE Trans. Geoscience Remote Sensing*, vol. 38, no. 5, pp. 2322-2332




***Comparison between the 118/54 GHz profile ratio from the NAST-M [5] microwave radiometer being flown on the NASA ER-2 aircraft and simultaneous EDOP Doppler radar reflectivity observation. Hurricane Bonnie at 17 GMT on August 26, 1998. (from Tso u et al., 2001 [6]).***

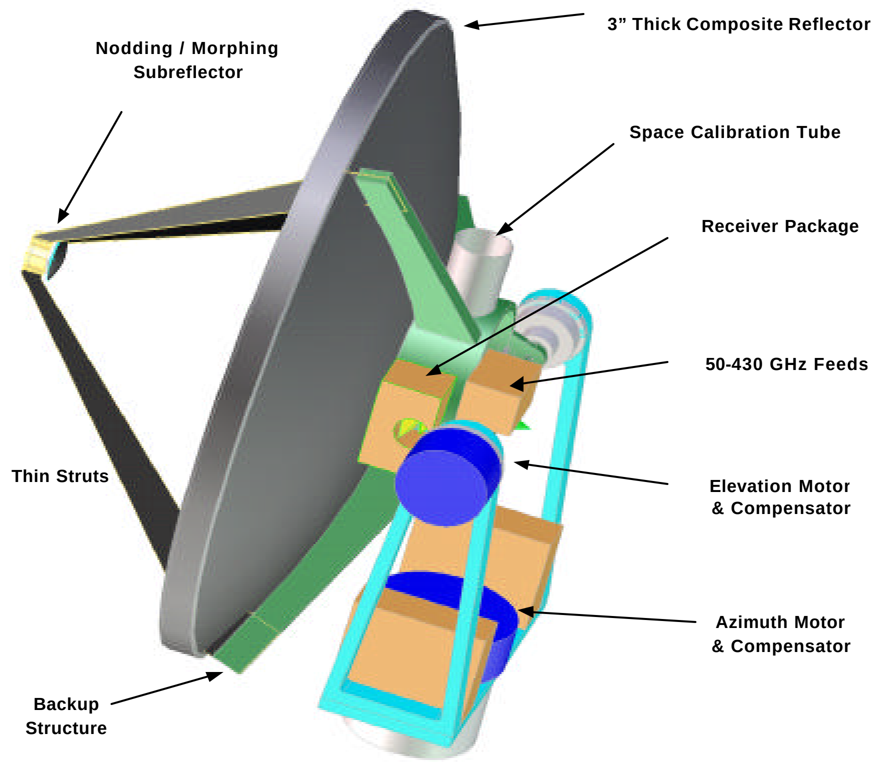
The figure shows what can be inferred by exploiting differential information from the 54 and 118 GHz bands. In the top figure the ratio between temperature profiles obtained independently from the 118 and the 54 GHz bands is reported, as the aircraft travels. If there is no precipitation the ratio of the two temperature profiles is unity throughout the entire vertical range. When precipitation is present the ratio becomes less than unity below the altitude of the precipitation cell due to the higher attenuation at 118 GHz than at 54 GHz. The effect is the result of the use of "similar clear-air weighting functions" along with the difference in ice scattering characteristics for the two wavelength regions [7]. A similar effect will be observed using 118 and 425 GHz, and 183 and 380 GHz, albeit these ratio signatures will be more closely related to cloud top particle size and less to low-level precipitation. The bottom figure reports the precipitation profile simultaneously recorded by the Doppler radar onboard ER-2 (EDOP). The agreement is striking, and it can be inferred that GOMAS would give information similar to what is currently obtained by ground-based radar. Pending confirmation by GOMAS multi-band sounding at 15 min intervals, meteorologists will have available ***a proxy rain radar operating over continental field of view, and particularly over oceans and mountainous terrain.***

---

[5] NAST = NPOESS Aircraft Sounding Testbed.

[6] Tsou J.J., W.L. Smith, P.W. Rosenkranz, G.M. Heymsfiels, W.J. Blackwell and M.J. Schwartz, 2001 - Precipitation Study Using Millimeter-wave Temperature Sounding channels - *Special Meeting on Microwave Remote Sensing*, Boulder, CO.

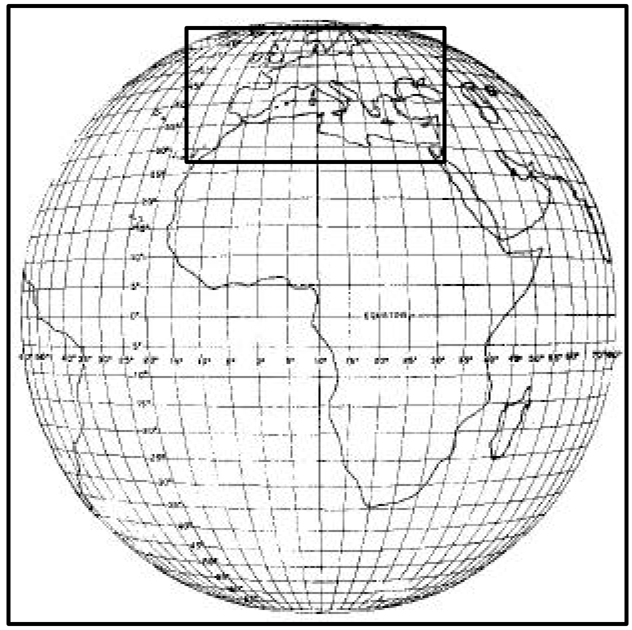
[7] Gasiewski, A.J., 1992 - Numerical Sensitivity Analysis of Passive EHF and SMMW Channels to Tropospheric Water Vapor, Clouds, and Precipitation - *IEEE Trans. Geosci. Remote Sensing*, vol. 30, no. 5, pp.859-870.




***GOMAS antenna system (as from the GEM concept, i.e. before adaptation for accommodation on a dedicated platform (see Panel 11).***

The antenna surface has a quiescent accuracy of ~10 µm. Thermal and inertial deformations are monitored by a series of sensors on the antenna border and actively compensated using a nodding/morphing subreflector, which also provides for limited image scanning. Gross movements (e.g., to change the observation sector) are performed by the elevation and azimuth motors, although the possibility of using the satellite attitude control system in combination or as alternative is being studied. A single feedhorn path is baselined so as to provide hardware co-alignment of all feeds for the five bands. An option of a feed cluster to simplify the receiver design is still being studied. The baseline receiver uses a quasi-optical multiplexer and includes five individual spectrometers for the five bands. State-of-the-art HEMT technology for high performance, reduced volumes, and low electrical consumption is exploited. Critical parameters are:

- ***antenna - mass: 40 kg ; electrical power: 40 W ; reflector diameter: 3 m***
- ***radiometer - mass: 67 kg ; electrical power: 95 W ; volume: 30 cm x 50 cm x 50 cm***
- ***total payload - mass: 107 kg ; electrical power: 135 W ; data rate: 115 kbps .***



***Earth's disk observed by Meteosat and reference coverage from GOMAS.***

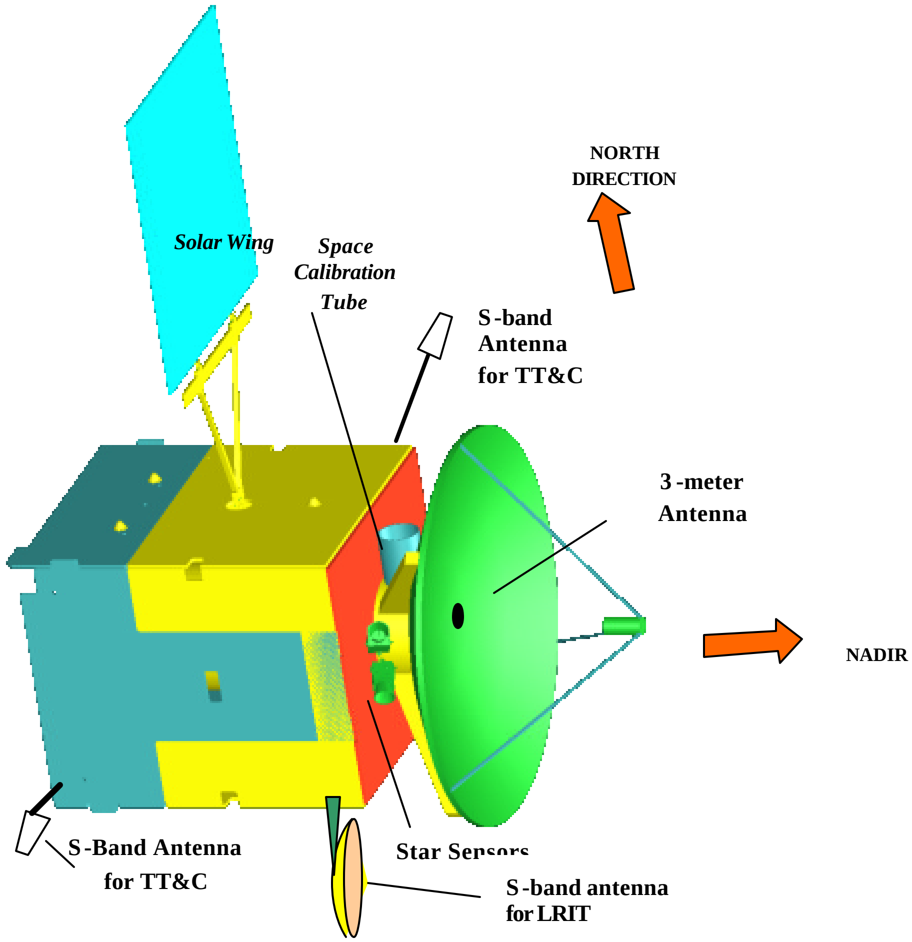
Within the current technological state-of-art it is not possible to scan the full Earth disk in the required short time at the required resolution. Assuming a 10-km sampling interval in 15 min, (required for precipitation), the full disk includes 1250 x 1250 pixels. Using an integration time of 0.5 ms one cannot achieve the radiometric accuracy necessary for sounding (SNR $\geq$ 100). A compromise is achieved by scanning a sector of about 1/12 of the disk (250 x 500 pixels) with an integration time of ~6 ms per pixel. Averaging over a convenient number of 10-km pixels provides the required radiometric sounding accuracy. The number of pixels to be averaged (during ground-processing) is consistent with the required resolution (~30 km at the s.s.p. for temperature profiles, ~20 km at the s.s.p. for water vapor profiles and cloud liquid/ice water, and ~10 km at the s.s.p. for precipitation). In ***Panel 10*** the estimated radiometric performance of the various channels is reported, after averaging over the indicated number of pixels. It can be observed that GOMAS will meet the requirement for full tropospheric sounding in 15 min intervals over within all bands. Sounding in the stratosphere will require averaging over a larger number of pixels in certain bands.

Actually, these figures only represent a reference for radiometric computation. In practice it will be possible to drive the scanning mechanism with different speeds and over areas of different sizes. The reference sector of 1/12 of the disk can be selected everywhere within the disk so as to track interesting events. In addition, during the satellite lifetime the longitude of stationarity can be shifted so as to allow observation over the American continents to the Indian ocean, following seasonal events.

***Radiometric performance assessment for 15 min observing cycle***

| Compliant | Nearly compliant | Compliant on 2Δx or 1 h | Candidate to be dropped |
|---|---|---|---|

| ν (GHz) | Δν (MHz) | Averaged pixels (product resolution) | IFOV at s.s.p. | Required NEΔT (K) (SNR = 100) | Expected NEΔT (K) | Peak of incremental weighting function |
|---|---|---|---|---|---|---|
| 56.325 | 50 | | | 0.6 | 0.15 | 27 km |
| 56.215 | 50 | | | 0.5 | 0.15 | 23 km |
| 56.025 | 250 | | | 0.5 | 0.07 | 17 km |
| 55.520 | 180 | | | 0.4 | 0.08 | 13 km |
| 54.950 | 300 | 6 x 6 | | 0.4 | 0.06 | 10 km |
| 54.400 | 220 | (60 km) | 81 km | 0.3 | 0.07 | 8 km |
| 53.845 | 190 | | | 0.3 | 0.08 | 5 km |
| 53.290 | 360 | | | 0.3 | 0.06 | 3 km |
| 52.825 | 300 | | | 0.2 | 0.06 | 2 km |
| 51.760 | 400 | | | 0.1 | 0.05 | 1 km |
| 50.300 | 180 | | | 0.1 | 0.08 | surface |
| 118.7503 ± 0.018 | 6 | | | 0.5 | 1.32 | 34 km |
| 118.7503 ± 0.035 | 12 | | | 0.6 | 0.93 | 29 km |
| 118.7503 ± 0.080 | 20 | | | 0.6 | 0.72 | 24 km |
| 118.7503 ± 0.200 | 100 | | | 0.5 | 0.32 | 19 km |
| 118.7503 ± 0.400 | 200 | 3 x 3 | | 0.5 | 0.23 | 15 km |
| 118.7503 ± 0.700 | 400 | (30 km) | 37 km | 0.5 | 0.16 | 12 km |
| 118.7503 ± 1.100 | 400 | | | 0.4 | 0.16 | 9 km |
| 118.7503 ± 1.500 | 400 | | | 0.4 | 0.16 | 7 km |
| 118.7503 ± 2.100 | 800 | | | 0.3 | 0.11 | 5 km |
| 118.7503 ± 3.000 | 1000 | | | 0.2 | 0.10 | 3 km |
| 118.7503 ± 5.000 | 2000 | | | 0.1 | 0.07 | surface |
| 183.3101 ± 0.300 | 300 | | | 0.6 | 0.45 | 10 km |
| 183.3101 ± 0.900 | 500 | | | 0.6 | 0.35 | 8.5 km |
| 183.3101 ± 1.650 | 700 | 2 x 2 | | 0.5 | 0.29 | 7 km |
| 183.3101 ± 3.000 | 1000 | (20 km) | 24 km | 0.3 | 0.24 | 6 km |
| 183.3101 ± 5.000 | 2000 | | | 0.4 | 0.17 | 5 km |
| 183.3101 ± 7.000 | 2000 | | | 0.6 | 0.17 | 4 km |
| 183.3101 ± 17.000 | 4000 | | | 0.3 | 0.18 | surface |
| 380.1974 ± 0.045 | 30 | | | 0.3 | 2.36 | 15 km |
| 380.1974 ± 0.400 | 200 | | | 0.5 | 0.91 | 13 km |
| 380.1974 ± 1.500 | 500 | 2 x 2 | | 0.5 | 0.58 | 11 km |
| 380.1974 ± 4.000 | 900 | (20 km) | 12 km | 0.5 | 0.43 | 9 km |
| 380.1974 ± 9.000 | 2000 | | | 0.4 | 0.29 | 7 km |
| 380.1974 ± 18.000 | 2000 | | | 0.3 | 0.36 | 6 km |
| 424.7631 ± 0.030 | 10 | | | 0.5 | 3.40 | 34 km |
| 424.7631 ± 0.070 | 20 | | | 0.6 | 2.41 | 28 km |
| 424.7631 ± 0.150 | 60 | | | 0.6 | 1.39 | 23 km |
| 424.7631 ± 0.300 | 100 | 3 x 3 | | 0.5 | 1.08 | 18 km |
| 424.7631 ± 0.600 | 200 | (30 km) | 10 km | 0.5 | 0.76 | 15 km |
| 424.7631 ± 1.000 | 400 | | | 0.5 | 0.54 | 12 km |
| 424.7631 ± 1.500 | 600 | | | 0.5 | 0.44 | 8 km |
| 424.7631 ± 4.000 | 1000 | | | 0.4 | 0.34 | 5 km |
| 380.1974 ± 18.000 | 2000 | 1 | 12 km | 1.0 | 0.72 | 6 km |
| 424.7631 ± 4.000 | 1000 | (10 km) | 10 km | 1.0 | 1.02 | 5 km |




***Artist's view of GOMAS in orbit (pending a size reduction exercise of the bus).***

A dedicated satellite is the baseline for GOMAS. The study so far performed is based on the adaptation of a current-generation bus in a basic configuration designed to support medium-size sensors. The figure shows that this bus is somewhat oversized, and will be made more compact with further study. The elevation and azimuth motors of the antenna shown in ***Panel 8*** could be combined with the satellite attitude control system. The satellite should be launched as co-passenger of MSG-3 (2007) or MSG-4 (2009), or perhaps GOES-P (2007). It is designed for a 5-year lifetime of which the first three would be a scientific/demonstration phase and the last two for pre-operational exploitation. Critical parameters are:

- Mass: 860 kg ("dry": 430 kg); electrical power: 600 W (peak), 440 W (average); volume (stowed): 3.0 x 3.0 x 3.0 $m^3$; data rate: 128 kbps (S-band), compatible with the MSG Low-Rate Information Transmission (LRIT) standard, to be received at Low-Rate User Stations (LRUS).

# Conclusions

GOMAS is proposed as a ***demonstration mission*** in the framework of the ESA Earth Explorer Opportunity Mission. If accepted, GOMAS would be a ***precursor*** for future operational applications since frequent observations of temperature/humidity, cloud liquid/ice water, and precipitation rate are of primary importance for both nowcasting and regional/global NWP, as well as for hydrological climate characterisation and improved descriptions of the water cycle in general circulation models. Direct use in hydro-agro-meteorology would also be important.

From the technical standpoint, after the studies conducted in the framework of the U.S. GEM concept, it is believed that no enabling technology is currently missing and that the satellite could be developed in time for a launch in the 2007-2009 timeframe. This window would permit co-flight with the NMP-EO3 GIFTS and within the Global Precipitation Mission (GPM) constellation.

The technical activity of developing GOMAS will be accompanied by a robust scientific program. This program is a natural requirement of the novel range of the spectrum to be used along with the need to better characterise the relationships between observed brightness temperatures and addressed geophysical parameters. Four closely-interlinked activities have been defined:

- Consolidation of instrument requirements and support to instrument development throughout project implementation - This basic activity will first consolidate the GOMAS instrument requirements, and then assist the project throughout its evolution to solve any trade-off problems that should arise. Both theoretical models and airborne campaigns will be utilised.
- Focus on sounding - This activity aims to characterise temperature/humidity profiling and cloud ice/liquid water total columns or gross profile retrieval in terms of what is inferred by IR spectroscopy form geostationary (GIFTS) and by AIRS/IASI + AMSU in low orbit. This also will substantially benefit of the results of airborne campaigns.
- Focus on precipitation - This activity aims to characterise the precipitation measurements from MW/Sub-mm spectra in terms of what is inferred by VIS/IR imagery (MSG/SEVIRI) and low-medium frequency MW radiometers calibrated by rain radar (GPM). It will substantially benefit of the results of the campaigns mentioned under the first activity.
- Focus on applications - This activity attempts to anticipate what can be achieved by using GOMAS data in several applications, addressing both operational meteorology and climate, and prepares for data validation and assimilation soon after launch.

The scientific program will be implemented by the U.S. and European GOMAS proponents (see ***Panel 2***).