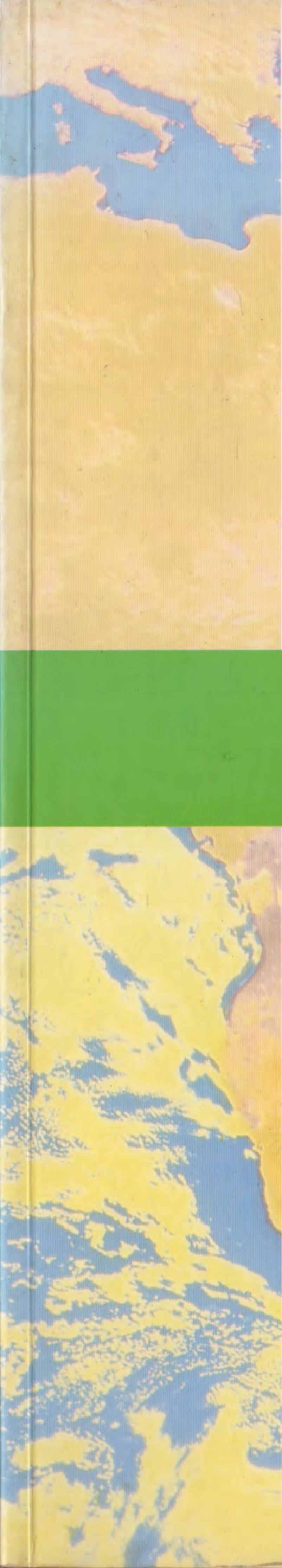
CEOS

Committee on Earth Observations Satellites



The relevance of satellite missions to the study of the global environment

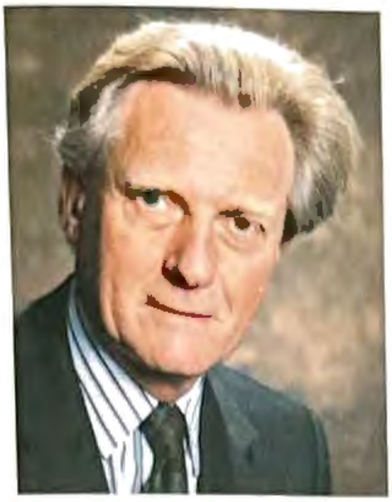
UNCED Conference Rio de Janeiro 1992

Committee on Earth Observations Satellites

The relevance of satellite missions to the study of the global environment

UNCED Conference Rio de Janeiro 1992

FOREWORD

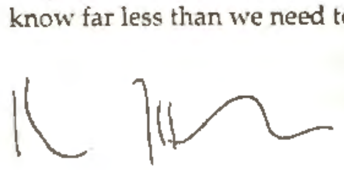


As President of the Board of Trade, I am pleased to have overall responsibility for civil space policy within the United Kingdom. For 1992 the UK provides the Chairmanship of CEOS. I therefore take great pleasure in presenting this report which provides a comprehensive account of satellite measurements and their relevance to global environmental programmes.

CEOS, the Committee on Earth Observations Satellites, is an international organisation with a remit to bring about better cooperation in space missions aimed at observing the Earth. The report has been prepared on behalf of CEOS and sets out the existing and proposed Earth observation satellite missions anticipated over the next 15 years. It describes how these programmes provide information that is crucial to the success of global environmental programmes. It is the first attempt to present existing and future programmes in this unified way.

I am confident you will find it a useful statement of the contribution of satellite programmes as you prepare for the meeting in Brazil. Many of the issues that will face you there are global problems. They will require global solutions and these in their turn require information on a global scale. Earth observation from space offers unique opportunities to obtain that information.

I myself have no doubt that without these space programmes we would know far less than we need to know about what is happening on Earth.



Michael Heseltine
President of the Board of Trade
United Kingdom

LIST OF CONTENTS

1 CONTEXT OF THIS STATEMENT

1.1 Introduction

Earth observation from space offers unique opportunities for obtaining information on a global scale that is directly relevant to our endeavours to understand the global environment and how it is changing. These data include, for example:

- atmospheric physics (temperature, humidity, winds, rainfall, radiation balance);
- atmospheric chemistry (ozone, greenhouse gases, chemical reactions in the atmosphere);
- oceans (sea surface temperature, circulation and heat transport, marine biosphere, topography and roughness);
- land (land biosphere, vegetation structure and functions, ice and snow cover, water cycle, radiative properties, soil moisture);
- solid Earth (crustal movements, gravity and magnetic fields).

This report, prepared by the British National Space Centre as the 1992 secretariat for the Committee on Earth Observations Satellites (CEOS), sets out, as a unified schedule, the existing and planned Earth observation satellite missions for the next fifteen years. It provides a statement of the collaboration and commitment being made by those nations with access to satellite technology to achieve a truly global observing system for the environment. By its nature, this report has focused on the relevance of these space missions to international environmental programmes. This reflects the current emphasis on global environmental change and does not diminish the value of satellite data for environmental purposes at a regional or national level.

1.2 Committee on Earth Observations Satellites (CEOS)

The Committee on Earth Observations Satellites (originally named the International Earth Observation Satellite Committee, IEOSC) was created in 1984, in response to a recommendation from a panel of experts on Satellite Remote Sensing under the aegis of the Economic Summit of Industrialized Nations Working Group on Growth, Technology and Employment. This group recognised the multidisciplinary nature of satellite Earth observations and the value of coordinating all proposed missions. Thus, CEOS has established a broad framework for coordination across all spaceborne Earth observations missions.

The primary objectives of CEOS are:

- to optimise the benefits of spaceborne observations through cooperation of its members in mission planning and in the development of compatible data products, formats, services, applications and policies;
- to aid both its members and the international user community by, *inter alia*, serving as the focal point for international coordination of space-related Earth observations activities, including those related to global change;

- to exchange policy and technical information to encourage complementarity and compatibility among spaceborne Earth observations systems currently in service or development and the data received from them;
- to address issues of common interest across the spectrum of Earth observations satellite missions.

To achieve these objectives, CEOS has as members or observers representatives of states and agencies – both national and international – that are responsible for civil spaceborne Earth observing programmes. Affiliate members are scientific or governmental bodies that are international in nature and whose programmes will utilise data flowing from satellite missions.

1.3 Scope

The information contained within this report details the current status and plans for future space missions and how they relate to major international environmental programmes. The information has been drawn from space agencies and environmental programme managers, but at present the missions of the Commonwealth of Independent States (formerly the USSR) have not been incorporated. It identifies missions over the next 15 years according to whether they are:

- firm/approved missions which are flying, in manufacture or to be funded within existing resources;
- proposed missions where plans are formulated but which are, as yet, outside existing resources or beyond the normal timescales for approval.

The presentation of the information is orientated by measurement rather than mission. Six major categories of measurement have been identified:

- atmospheric dynamics/water and energy cycles;
- atmospheric chemistry;
- land;
- ice and snow;
- ocean dynamics;
- ocean biology;

and within these six categories, further subdivisions have been made.

1.4 Major conclusions

At the present time, there are over a dozen satellites flying that provide data about the Earth and its environment (annexes A and B). These existing satellites are providing important data and are improving our ability to understand how the Earth is operating and the environment changing. These data cover the whole spectrum of the environment including atmosphere, land, ice and snow and oceans. The current data flow itself presents a challenge to scientists and environmentalists who must harness the resources to utilise the data and extract the information that is relevant to their needs.

The planned missions will provide a significant increase in data over the existing suite of missions and are a clear statement of the contribution to be made by those nations with access to satellite technology. In total some fifty space missions are planned and they will satisfy many of the currently known requirements for studying the global environment. These requirements are drawn from the programmes of the World Meteorological Organisation (WMO), the International Council of Scientific Unions (ICSU), the Intergovernmental Oceanographic Commission (IOC), the United Nations Environment Programme (UNEP) and Food and Agriculture Organisation (FAO) and the Commission of the European Communities (CEC). They include major international, interagency programmes such as the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), the World Climate Research Programme (WCRP) and the International Geosphere-Biosphere Programme (IGBP) (annex C). CEOS members recognise that the requirements themselves will change and indeed in some areas still have to be defined in detail. Thus it is the intention of CEOS to strengthen the dialogue with these communities in order to ensure the maximum return – in terms of data utilisation – from the total effort and resources mobilised in support of Earth observing space missions. The correlation of satellite missions and user programme requirements is detailed in section 2.

Areas of current strengths are wide ranging and include the following:

- **The chemistry and dynamics of the stratosphere** are currently being measured by the NASA UARS mission. These measurements are for the first time providing a truly global picture of the atmosphere of the stratosphere and how it is varying on a daily and seasonal basis. Beyond UARS, there are a number of missions planned that will provide stratospheric data into the next century.
- **Ozone** measurements are important and a range of instruments will provide ongoing column integrated data before instruments capable of measuring profiles, throughout the atmosphere, become available.
- **Land cover** mapping is possible from a number of satellites both in geostationary and low Earth orbit. From these, a 4km resolution data set of land cover at the global level is already being generated. There are plans in place to improve this to a 1km resolution grid and future missions will serve to improve the accuracy of these products. At a regional level, high resolution imagery is provided by optical systems such as LANDSAT and SPOT and the recent addition of synthetic aperture radar systems such as those on board ERS-1 and JERS-1 ensure that data can be provided on an all weather basis.
- **Land surface temperature and albedo** are being measured from the meteorological satellites and through utilisation of, for example, instrumentation on board ERS-1. Future missions are set to provide continuity.

- Similarly, the extent of **ice sheets** and **sea ice** are being measured with a range of instruments on various missions and continuity is planned.
- Measurements of the **Earth radiation budget** are historically well covered. There may be a gap in measurements in the mid-1990s if some missions are not implemented, however beyond this period adequate provision is planned.
- Data on **ocean biology** will begin to be provided with the launch of the SeaWiFS sensor by the USA in 1993. These data will be complemented by future instrumentation first flown on Japanese, NASA and ESA platforms in the 1996-1998 timescale.
- **Sea surface temperature** information is being generated by data from existing meteorological satellites and the novel instrumentation on board ERS-1. Future plans provide continuity. Satellites are now also making consistent and continuous measurements of other important oceanographic parameters such as **ocean topography, ocean currents, sea state** and **wind stress**. Current satellites contributing include ERS-1 and JERS-1. For the future, the planned missions will continue to improve our knowledge of the ocean and its variation. With respect to **ocean measurements** overall, for the first time satellites are providing the means to produce detailed and accurate measurement of the forces that drive the transfer of energy from the ocean to the atmosphere and the ocean surface circulation patterns.

In summary, the current suite of satellites provides data of value in global environmental studies. Future missions will significantly improve the situation and when implemented will satisfy many of the known requirements. A major issue is data continuity and this in turn requires mission continuity throughout the period. There is no room for complacency. There are measurements where the current plans do not meet known requirements, for example precipitation measurement, vertical profiles of temperature and water, the chemistry of the troposphere, aerosol distribution and soil moisture measurement. These areas present challenges to the space agencies of the world who will be considering the issues in their future programmes. There will, of course, remain a need for regular iteration and dialogue between the major programmes and the space agencies. This dialogue will reflect changes in requirements as well as developments in technology that will fulfil them.

2 CORRELATION OF SATELLITE MEASUREMENTS WITH ENVIRONMENTAL PROGRAMMES

2.1 Introduction

This section catalogues the space-based Earth observation measurements which are planned over the next 15 years and correlates these with the data requirements of current or planned international environmental programmes. For each measurement, there is a timeline diagram showing relevant instruments and the missions on which they are expected to fly for the period 1992-2007. Under the cluster of instrument timelines, there are environmental programme timelines indicating, wherever possible, the programmes that are interested in those measurements.

The instrument timelines are shaded to show if the missions are firm/ approved (solid black colouring) or proposed (grey colouring). The missions, associated instruments and environmental programmes are described in further detail in the annexes of this document as follows:

- missions are listed in chronological order in annex A, together with status, launch date and duration, orbit details, payloads and primary application areas. A summary timeline diagram and a brief description of current missions are also provided;
- instruments are listed in alphabetical order in annex B, together with the missions on which they appear and a listing of the measurements they are able to make;
- the environmental programmes which have been included are described briefly in annex C, by programme/agency.

CEOS members, observers and affiliates provided the information for this section and are listed in annex D. A list of abbreviations is given in annex E. Satellite mission and instrument acronyms can be found in annexes A and B.

There are many ways of describing the measurements made and the requirements of the environmental programmes. The approach taken in this section has been to use the list in table 2.1 as the basis for the timeline diagrams.

Associated with each diagram there is text, in note form, to bring out the nuances that have not been coded into the diagram; for example, where there are issues relating to continuity of measurements, accuracy, temporal and spatial resolution, global coverage, or requirements for simultaneous measurements of a number of parameters.

Table 2.1

List of measurements and diagram reference codes

Reference Code	Measurement
	Atmospheric dynamics/ water and energy cycles
2.1.1	vertical profiles of temperature
2.1.2	vertical profiles of water vapour
2.1.3	precipitation
2.1.4	tropospheric winds
2.1.5	stratospheric/mesospheric winds
2.1.6	cloud cover
2.1.7	cloud liquid water content
2.1.8	cloud top height/vertical distribution
2.1.9	radiation budget
	Atmospheric chemistry
2.2.1	tropospheric profiles of aerosols
2.2.2	tropospheric profiles of CH_4
2.2.3	tropospheric profiles of NO_2
2.2.4	tropospheric profiles of CO
2.2.5	tropospheric profiles of O_3
2.2.6	stratospheric profiles of aerosols
2.2.7	stratospheric profiles of CH_4
2.2.8	stratospheric profiles of NO_x (including NO_2)
2.2.9	stratospheric profiles of CO
2.2.10	stratospheric profiles of ClO_x
2.2.11	stratospheric profiles of HO_x
2.2.12	stratospheric profiles of O_3
	Land
2.3.1	global land cover
2.3.2	regional land cover
2.3.3	land surface temperature
2.3.4	soil moisture
2.3.5	water on land
2.3.6	albedo
2.3.7	geoid measurements
	Ice and snow
2.4.1	ice sheets
2.4.2	sea ice
2.4.3	snow cover
	Ocean dynamics
2.5.1	ocean topography/currents
2.5.2	wind stress
2.5.3	sea state/spectrum
2.5.4	sea surface temperature
	Ocean biology
2.6.1	ocean biological parameters

2.2 Measurement timelines

There are a number of general observations regarding the diagrams on the following pages:

- All missions, except those currently flying, have a degree of uncertainty. The coding of missions as firm/approved and proposed has been used to indicate increasing levels of uncertainty, as confirmed by the relevant agencies at this time.
- Although future missions are often coded as firm/approved, the final payload may still be under discussion. This is true, for example, for the

POEM-1 payload; ASAR, MIMR and IASI are not in the current declaration but are still regarded as optional. To indicate their present status on the POEM-1 mission, they have been marked with a '?' on the diagrams. Payloads on EOS platforms, following the initial suite of six (AM, PM, CHEM, ALT, AERO, COLOR), may change, depending on the evolution of scientific understanding of global change and the development of technology. The current EOS programme has been approved by NASA, and accommodates funding targets through to the year 2000, as directed by the US Congress.

- Information on current and planned Earth observation missions of the Commonwealth of Independent States (CIS), formerly the Soviet Union, has not been gathered and presented systematically, but where specific user requirements for CIS data have been identified, this is mentioned in the text. Joint missions with CEOS member states and agencies (eg ScaRaB) have been included. It is hoped to include CIS mission data during future dialogue between CEOS and environmental programmes, once it is clear who should be approached regarding plans.
- There are a number of instruments being designed or under development which have, at present, no flight opportunities. These have not been included in this document.
- The requirements of the major international environmental programmes are not yet finalised. Different programmes are at different states of development and hence at different stages of being able to specify requirements. Also, it has not yet been possible to determine whether data are required for the full duration of the listed programmes or only part. Some measurements do not show a user requirement, eg atmospheric chemistry measurements because information has not yet been received. It is intended to improve and update the information as the dialogue between CEOS and user programmes develops. For example, principal investigator projects linked with satellite programmes have not been included, nor have many potential requirements of the proposed Global Climate Observing System (GCOS).
- The diagrams in this section show a qualitative comparison between provision of data and user programme requirements. Statements regarding adequacy, or otherwise, of measurements in this section are generally with regard to global environmental/climate change programmes, where long term continuity and high data accuracy are primary needs. The diagrams will be used as the basis of continuing dialogue between the space agencies and user programmes and it may be expected that a number of requirements will become more stringent, over time, as new user programmes become active and existing programmes evolve.

2.1.1 Vertical profiles of temperature

Current sounders are neither accurate enough nor do they have the required vertical resolution to meet the needs of current operational weather forecasting models and environmental/climate applications. There is an operational meteorological requirement for continuous soundings from both morning and afternoon polar orbits.

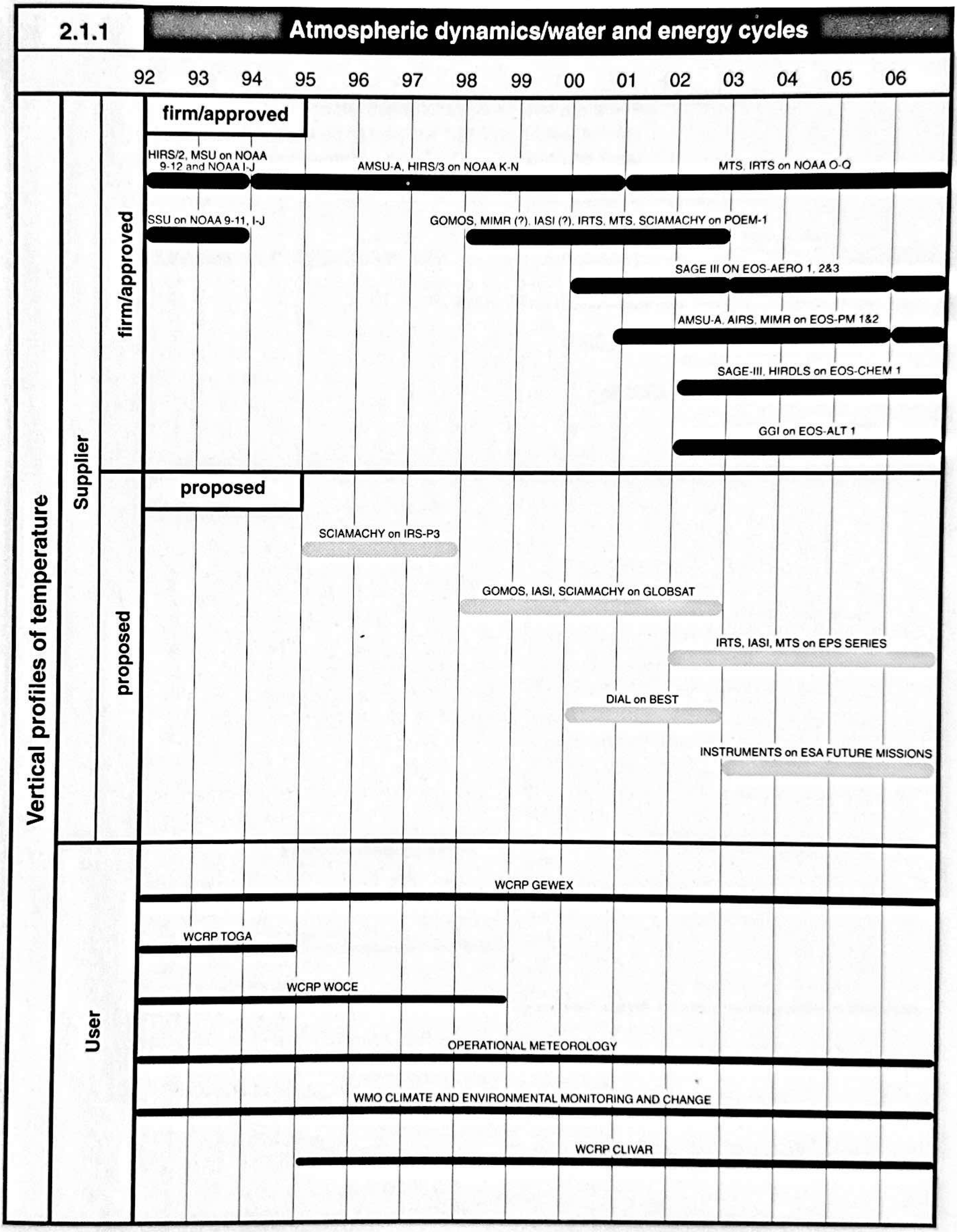
The new series of infrared sounders (particularly IASI and AIRS) should go some way towards alleviating the accuracy problem. As shown, IASI is a possible candidate for the ESA morning orbit POEM-1 payload and is likely to fly on ESA future missions and/or EPS platforms. AIRS is a candidate instrument for the afternoon orbit EOS-PM series. For climate change studies, some overlap will be required between the new IASI and AIRS and the previous operational instrument, IRTS, to provide adequate continuity and cross calibration. Cross calibration of IASI and AIRS will also need to be carefully considered since they are to fly on separate platforms with different equatorial crossing times.

The next generation of sounders, after IASI and AIRS, are envisaged to be active instruments, eg DIAL lidars, which will improve accuracy further. They will allow near surface atmospheric temperature to be measured accurately from space for the first time, which is of particular importance over the oceans where terrestrial data acquisition systems are very sparse. The first such instrument has been proposed for the French BEST mission, although with its low inclination orbit it will not provide global coverage.

Microwave temperature sounders, capable of sounding through cloud (eg AMSU A and its successor MTS), will continue to be required to ensure an all weather capability.

Instruments such as GOMOS, SCIAMACHY, HIRDLS and SAGE III only provide information on the middle/upper part of the atmosphere. They do not measure temperature in the lower troposphere.

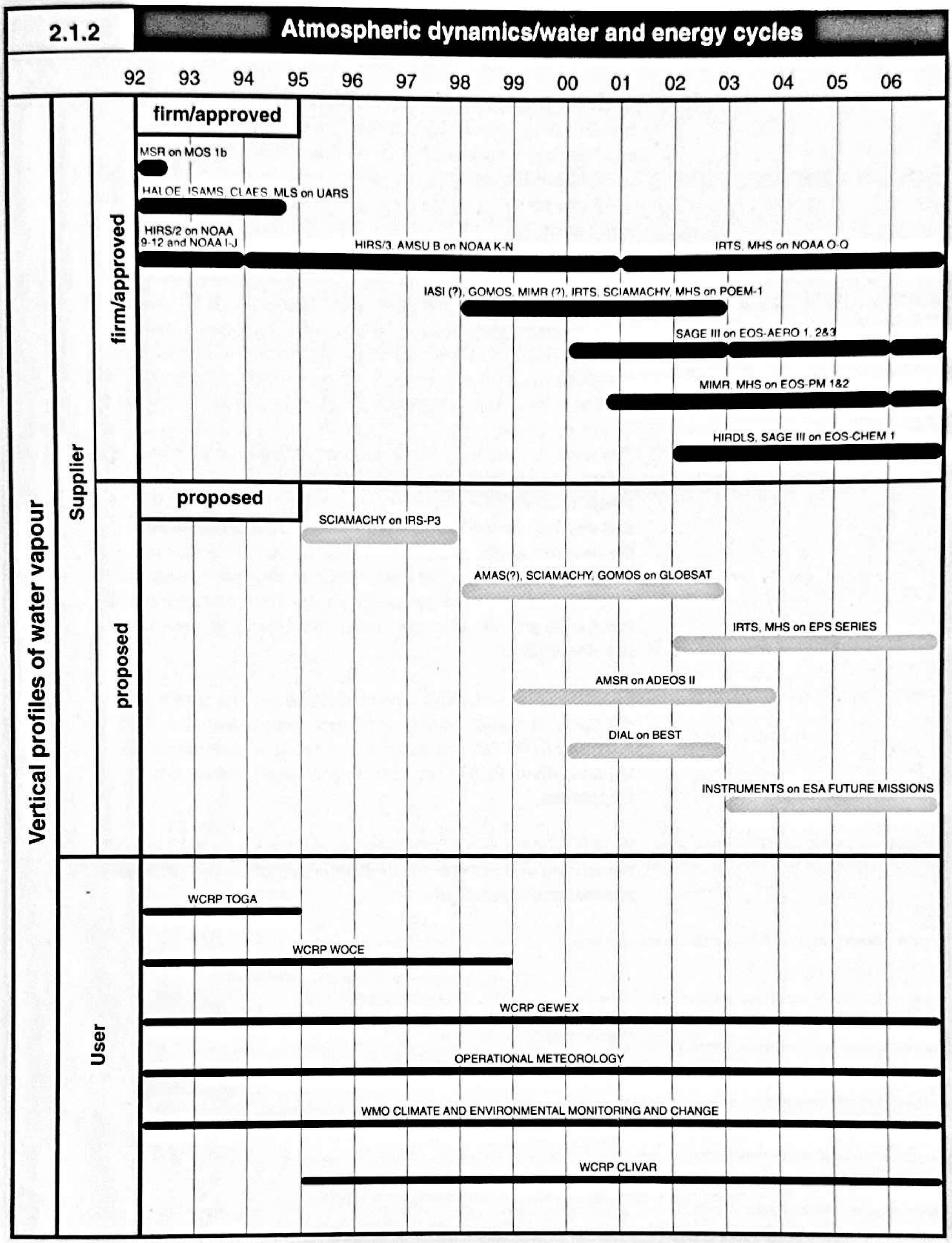
With regard to user requirements, the WCRP GEWEX project is particularly demanding, needing vertical profiles of temperature together with simultaneous measurements of properties of the top of the atmosphere (cloud tops, Earth radiation), underlying vertical profiles of water vapour and clouds and precipitation estimates. ESA POEM-1 (1998) is the first mission to approach meeting the requirement, particularly if MIMR and IASI are chosen. Following this, EOS-PM 1 and subsequent missions will provide useful data. Neither mission fulfils requirements completely as there is also a need for a 3-D cloud structure profiler. A cloud radar is being considered for this by ESA for future missions from 2003 onwards.



2.1.1
Atmospheric dynamics/water and energy cycles
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Vertical profiles of temperature
Supplier
firm/approved
firm/approved
HIRS/2, MSU on NOAA 9-12 and NOAA I-J
AMSU-A, HIRS/3 on NOAA K-N
MTS, IRTS on NOAA O-Q
SSU on NOAA 9-11, I-J
GOMOS, MIMR (?), IASI (?), IRTS, MTS, SCIAMACHY on POEM-1
SAGE III ON EOS-AERO 1, 2&3
AMSU-A, AIRS, MIMR on EOS-PM 1&2
SAGE-III, HIRDLS on EOS-CHEM 1
GGI on EOS-ALT 1
proposed
proposed
SCIAMACHY on IRS-P3
GOMOS, IASI, SCIAMACHY on GLOBSAT
IRTS, IASI, MTS on EPS SERIES
DIAL on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP GEWEX
WCRP TOGA
WCRP WOCE
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WCRP CLIVAR

2.1.2 Vertical profiles of water vapour

There are requirements for improved accuracy and vertical resolution which will start to be met towards the latter part of the decade. The comments associated with figure 2.1.1 in relation to temperature sounders generally apply.


2.1.2
Atmospheric dynamics/water and energy cycles
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Vertical profiles of water vapour
Supplier
firm/approved
firm/approved
MSR on MOS 1b
HALOE, ISAMS, CLAES, MLS on UARS
HIRS/2 on NOAA 9-12 and NOAA I-J
HIRS/3, AMSU B on NOAA K-N
IRTS, MHS on NOAA O-Q
IASI (?), GOMOS, MIMR (?), IRTS, SCIAMACHY, MHS on POEM-1
SAGE III on EOS-AERO 1, 2&3
MIMR, MHS on EOS-PM 1&2
HIRDLS, SAGE III on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
AMAS(?), SCIAMACHY, GOMOS on GLOBSAT
IRTS, MHS on EPS SERIES
AMSR on ADEOS II
DIAL on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP TOGA
WCRP WOCE
WCRP GEWEX
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WCRP CLIVAR

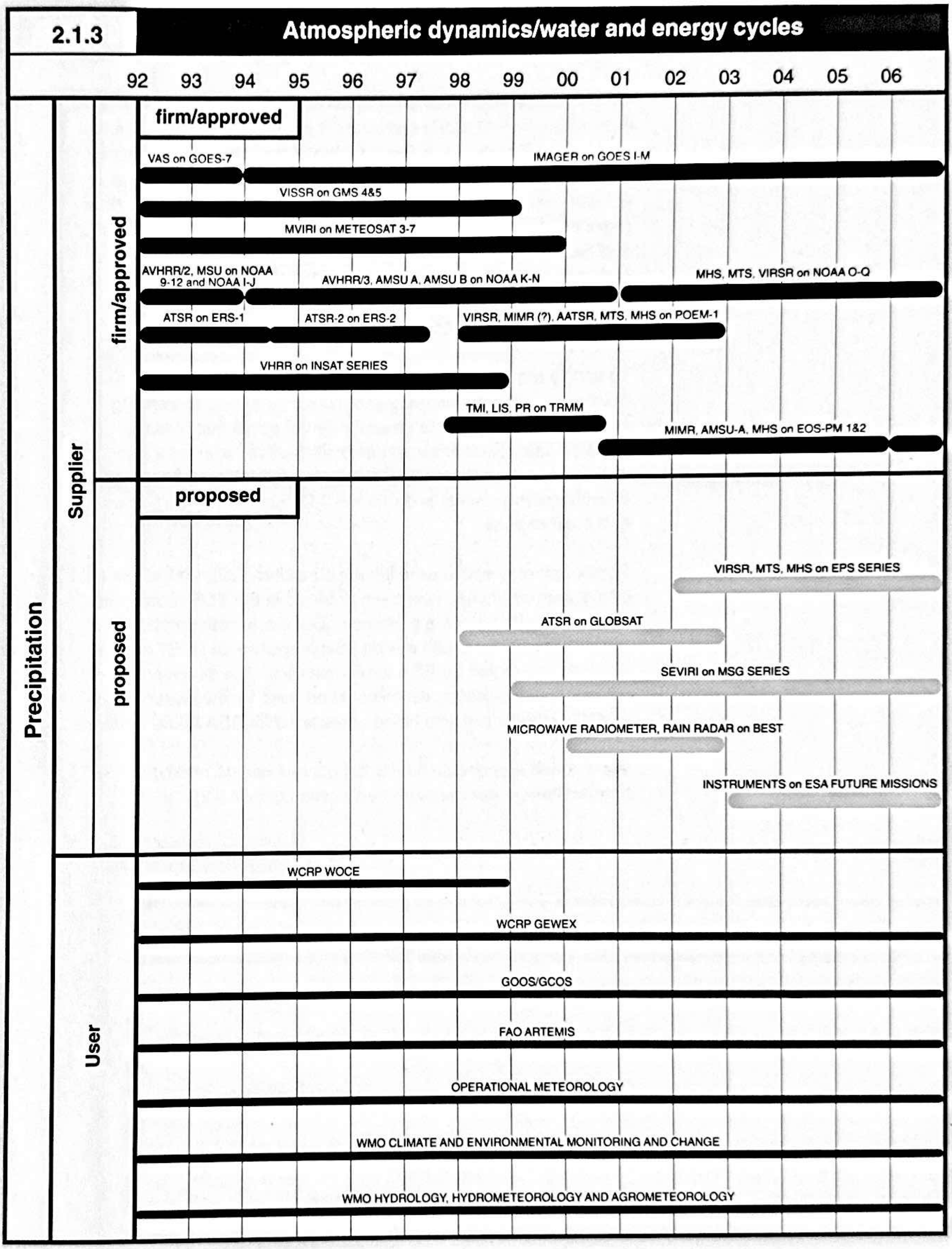
2.1.3 Precipitation

Spatial and temporal resolutions and accuracy requirements are difficult to achieve from space. There is no satisfactory way, at present, of measuring the amount and distribution of global precipitation. The geostationary meteorological satellites (eg GOES, GMS and METEOSAT series) can be used to provide some useful information. For example, programmes such as FAO ARTEMIS use METEOSAT data to make estimates of rainfall over the tropics. Useful information is also obtained from passive microwave imaging sensors, particularly the Special Sensor Microwave Imager (SSM/I), flown on platforms of the US Defense Meteorological Satellite Program (DMSP), not shown on the figure. There is a gap during the 1990s in civil provision for this type of sensor in polar orbit until the first flight of MIMR (1998 on POEM-1 or 2000 on EOS-PM 1).

The requirements for global measurements can only be met with synergistic payloads comprising active rain radar (for 3-D measurements), passive microwave instruments (eg MIMR) and visible/infra-red imagers (eg AVHRR, AATSR). Even then, the required spatial and temporal resolutions will be difficult to achieve, with geostationary satellites providing good temporal resolution over much of the world but low Earth orbiting systems required to provide adequate spatial resolution and coverage of polar regions.

TRMM is an important mission as it will be the first determination of tropical rainfall using both active and passive instruments. A follow-on, TRMM-2, mission is also being considered by the US and Japan. BEST may also continue these measurements, if approved.

WCRP GEWEX requirements for precipitation data are particularly demanding and are summarised in the section on temperature profiles, above (see figure 2.1.1).


2.1.3
Atmospheric dynamics/water and energy cycles
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Precipitation
Supplier
User
firm/approved
VAS on GOES-7
IMAGER on GOES I-M
VISSR on GMS 4&5
MVIRI on METEOSAT 3-7
AVHRR/2, MSU on NOAA 9-12 and NOAA I-J
AVHRR/3, AMSU A, AMSU B on NOAA K-N
MHS, MTS, VIRSR on NOAA O-Q
ATSR on ERS-1
ATSR-2 on ERS-2
VIRSR, MIMR (?), AATSR, MTS, MHS on POEM-1
VHRR on INSAT SERIES
TMI, LIS, PR on TRMM
MIMR, AMSU-A, MHS on EOS-PM 1&2
proposed
VIRSR, MTS, MHS on EPS SERIES
ATSR on GLOBSAT
SEVIRI on MSG SERIES
MICROWAVE RADIOMETER, RAIN RADAR on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
WCRP WOCE
WCRP GEWEX
GOOS/GCOS
FAO ARTEMIS
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WMO HYDROLOGY, HYDROMETEOROLOGY AND AGROMETEOROLOGY

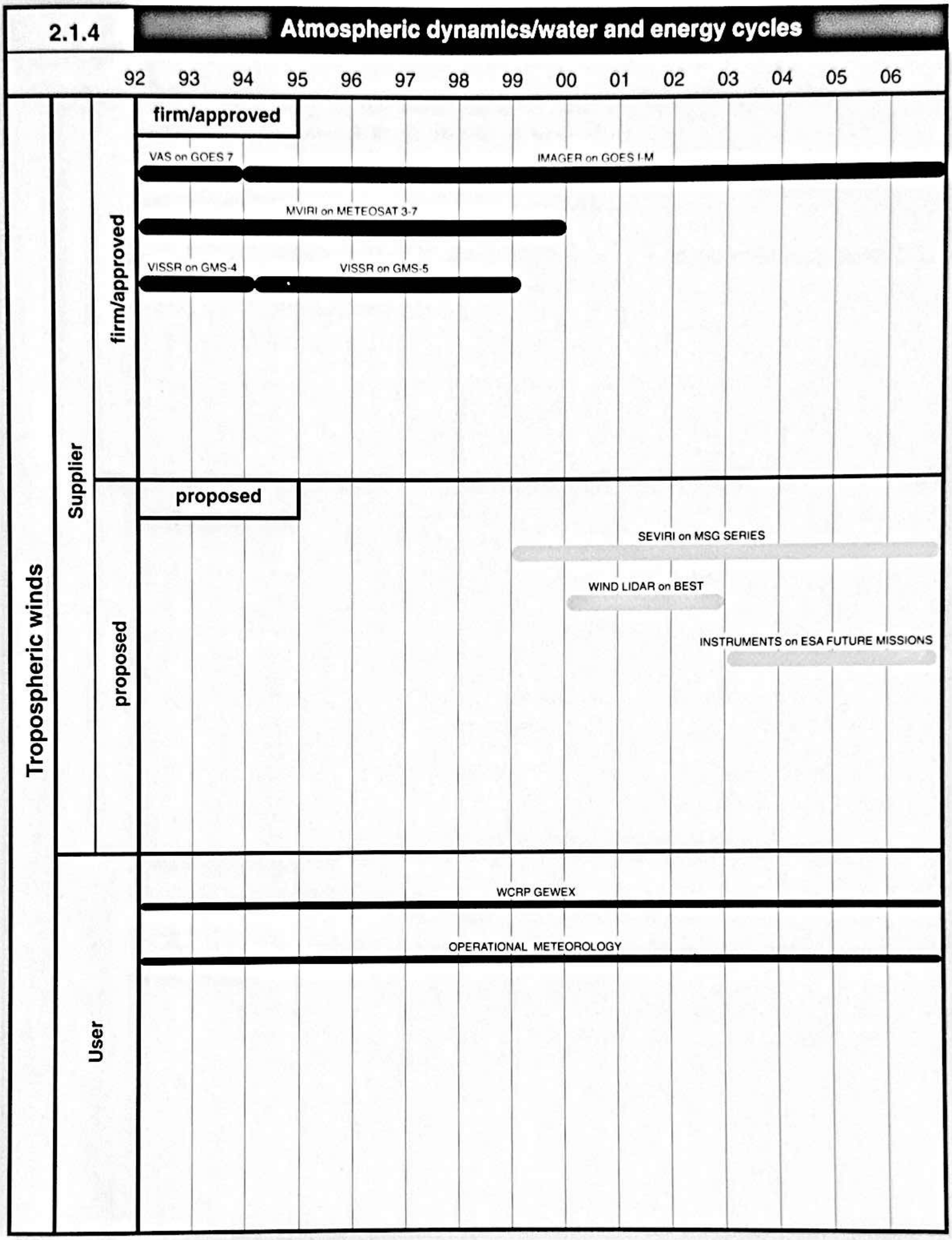
2.1.4 Tropospheric winds

Meteorological and other environmental requirements for global information on 3-D winds cannot be met at present, either in terms of global coverage or accuracy. Winds in the tropics are currently inferred from cloud and water vapour motion vectors using the geostationary operational meteorological satellites. In non-tropical regions, winds can be derived from the vertical temperature profile and the thermal winds equation, so the temperature sounders shown in figure 2.1.1, such as HIRS, AMSU and IRTS have a role to play. The temperature profile is also key to height allocation of the cloud track winds from geostationary satellites.

To satisfy requirements for meteorological purposes, data are needed from 5 geostationary and 2 polar satellites, all carrying suitable instruments. The development of active instruments (eg wind lidar for clear air and millimetre wave radar for winds in clouds) for launch into low Earth orbits will improve the accuracy of wind measurements and provide 3-D data both in the tropics and polar regions.

Development of active wind lidar is considered difficult and the US LAWS instrument has now been deferred in the EOS programme. Developments are being pursued in Europe, in collaboration with the US LAWS team, with a wind lidar proposed for BEST and the ALADIN instrument for ESA future missions. The development of millimetre wave radars, which could be used for measurement of winds in clouds, are also being considered for ESA future missions.

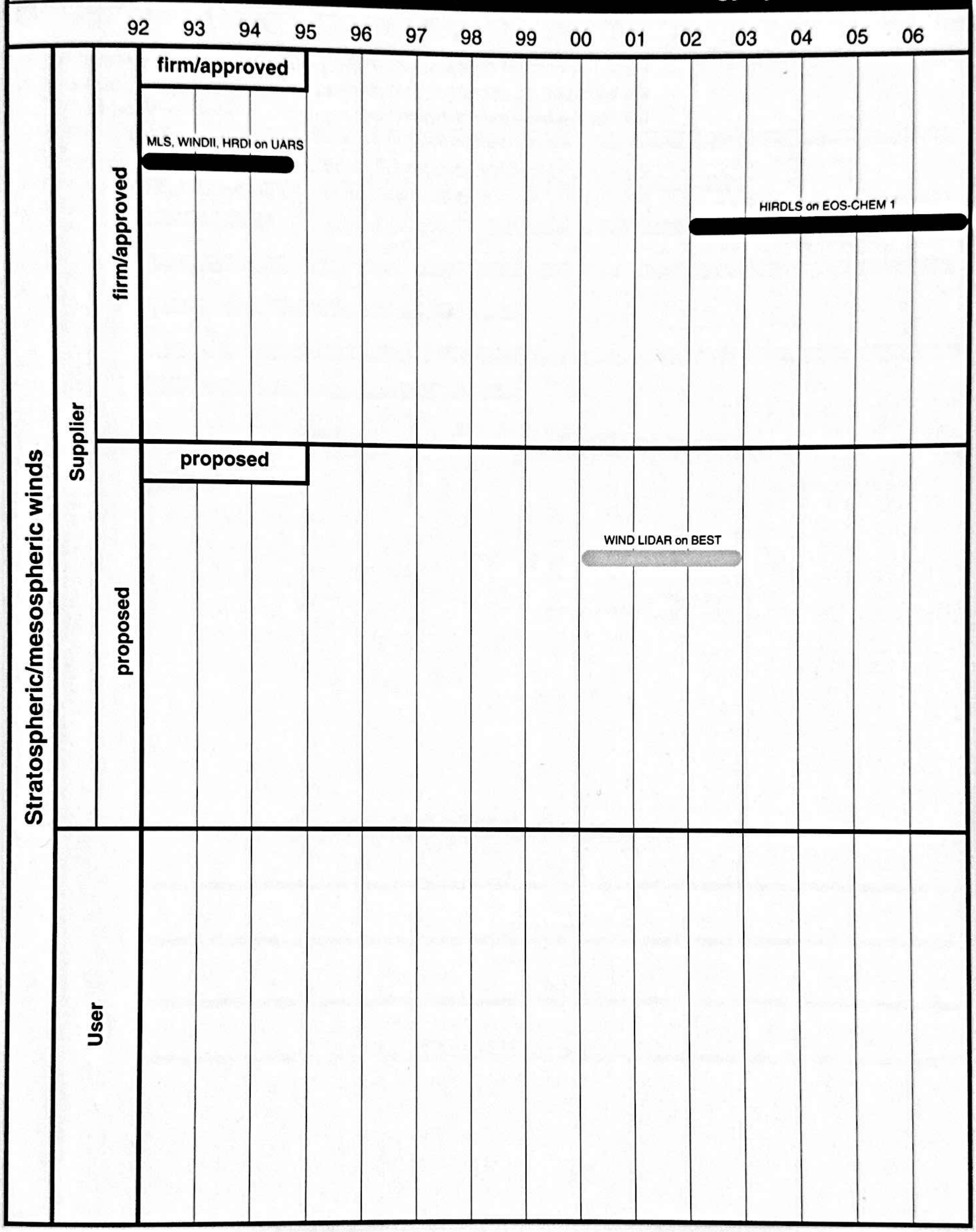
Wind speed and direction over the oceans can be retrieved from scatterometer measurements (see figure 2.5.2).


2.1.4
Atmospheric dynamics/water and energy cycles
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Tropospheric winds
Supplier
firm/approved
firm/approved
VAS on GOES 7
IMAGER on GOES I-M
MVIRI on METEOSAT 3-7
VISSR on GMS-4
VISSR on GMS-5
proposed
proposed
SEVIRI on MSG SERIES
WIND LIDAR on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP GEWEX
OPERATIONAL METEOROLOGY

2.1.5 Stratospheric/mesospheric winds

Presently, requirements are met using instruments on the research satellite UARS. Few measurements are planned for the future. A more detailed requirements analysis is needed to assess the importance of these measurements.

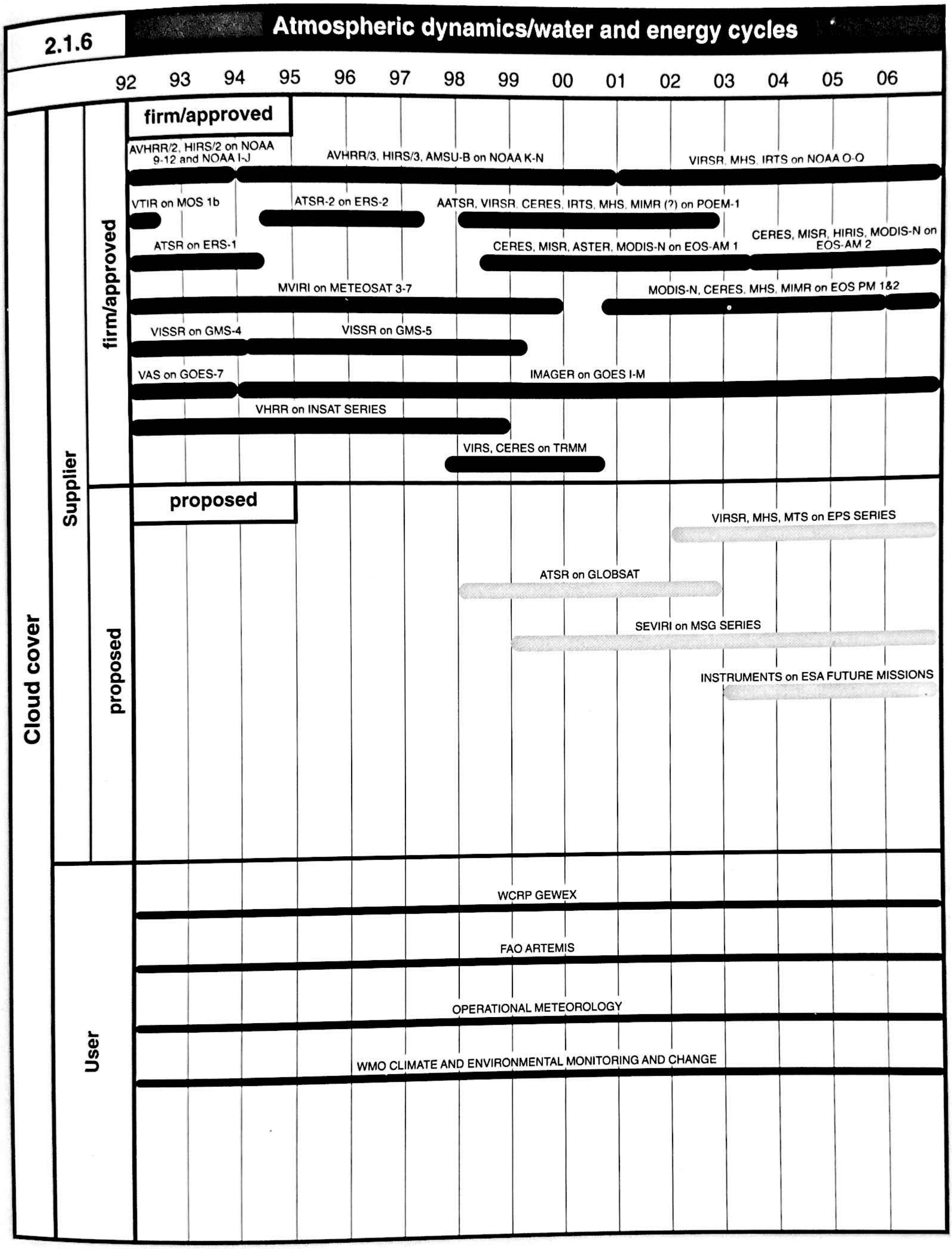
2.1.5 Atmospheric dynamics/water and energy cycles



2.1.6 Cloud cover

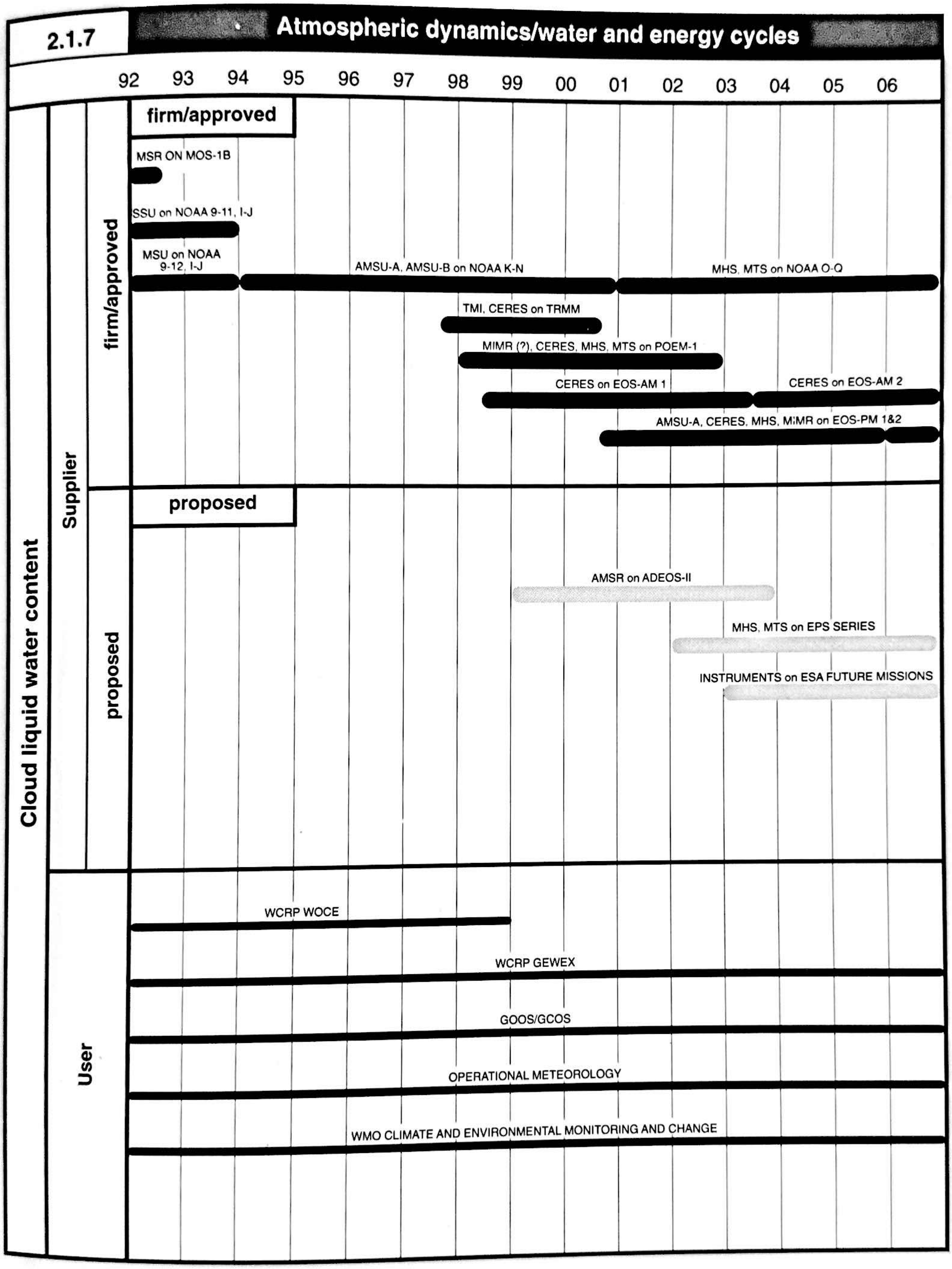
Requirements for data can generally be satisfied by making use of the wide variety of current and planned visible, infrared and passive microwave instruments in both geostationary and low Earth orbits.

For complete global coverage, 5 geostationary and 2 polar satellites are needed. A suitable constellation should be available from the end of 1992.


2.1.6
Atmospheric dynamics/water and energy cycles
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Cloud cover
Supplier
firm/approved
firm/approved
AVHRR/2, HIRS/2 on NOAA 9-12 and NOAA I-J
AVHRR/3, HIRS/3, AMSU-B on NOAA K-N
VIRSR, MHS, IRTS on NOAA O-Q
VTIR on MOS 1b
ATSR-2 on ERS-2
AATSR, VIRSR, CERES, IRTS, MHS, MIMR (?) on POEM-1
ATSR on ERS-1
CERES, MISR, ASTER, MODIS-N on EOS-AM 1
CERES, MISR, HIRIS, MODIS-N on EOS-AM 2
MVIRI on METEOSAT 3-7
MODIS-N, CERES, MHS, MIMR on EOS PM 1&2
VISSR on GMS-4
VISSR on GMS-5
VAS on GOES-7
IMAGER on GOES I-M
VHRR on INSAT SERIES
VIRS, CERES on TRMM
proposed
proposed
VIRSR, MHS, MTS on EPS SERIES
ATSR on GLOBSAT
SEVIRI on MSG SERIES
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP GEWEX
FAO ARTEMIS
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE

2.1.7 Cloud liquid water content

Requirements are currently being met primarily by using data from the passive microwave sensor, SSM/I, on the US military DMSP series of satellites. There will be no civil source of passive microwave data between the end of the Japanese MOS-1B mission (mid-1992) and the end of the century, with first flights of MIMR (1998, if it is accepted for POEM-1, or 2000 on EOS-PM 1) and AMSR on ADEOS II (1999, if the flight is confirmed).

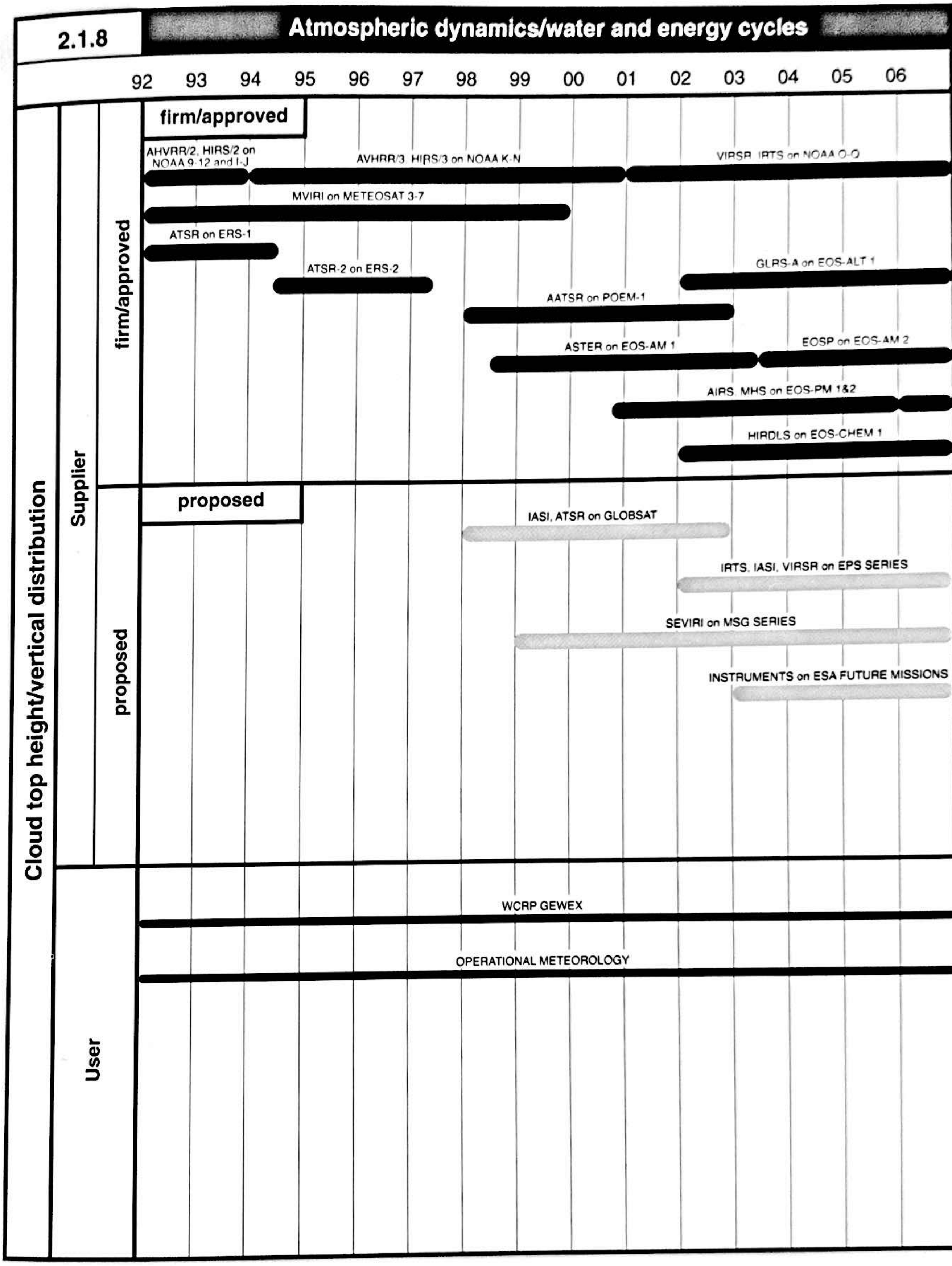

2.1.7
Atmospheric dynamics/water and energy cycles
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Cloud liquid water content
Supplier
firm/approved
firm/approved
MSR ON MOS-1B
SSU on NOAA 9-11, I-J
MSU on NOAA 9-12, I-J
AMSU-A, AMSU-B on NOAA K-N
MHS, MTS on NOAA O-Q
TMI, CERES on TRMM
MIMR (?), CERES, MHS, MTS on POEM-1
CERES on EOS-AM 1
CERES on EOS-AM 2
AMSU-A, CERES, MHS, MIMR on EOS-PM 1&2
proposed
proposed
AMSR on ADEOS-II
MHS, MTS on EPS SERIES
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP WOCE
WCRP GEWEX
GOOS/GCOS
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE

2.1.8 Cloud top height/vertical distribution

Visible/infrared imagers can provide useful data. Measurements of cloud top temperature are needed to assign cloud height and hence imager/sounder pairs such as AVHRR/HIRS and VIRSR/IRTS have roles to play.

Enhanced accuracy will be available from active instruments such as ATLID (under consideration on ESA future missions).

More detailed observations of 3-D cloud structure, as required by the WCRP GEWEX initiative must await the development of a millimetre wave radar, being considered for ESA future missions after 2003.



2.1.8
Atmospheric dynamics/water and energy cycles
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
Cloud top height/vertical distribution
Supplier
firm/approved
firm/approved
AHVRR/2, HIRS/2 on NOAA 9-12 and I-J
AVHRR/3, HIRS/3 on NOAA K-N
VIRSR, IRTS on NOAA O-Q
MVIRI on METEOSAT 3-7
ATSR on ERS-1
ATSR-2 on ERS-2
GLRS-A on EOS-ALT 1
AATSR on POEM-1
ASTER on EOS-AM 1
EOSP on EOS-AM 2
AIRS, MHS on EOS-PM 1&2
HIRDLS on EOS-CHEM 1
proposed
proposed
IASI, ATSR on GLOBSAT
IRTS, IASI, VIRSR on EPS SERIES
SEVIRI on MSG SERIES
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP GEWEX
OPERATIONAL METEOROLOGY

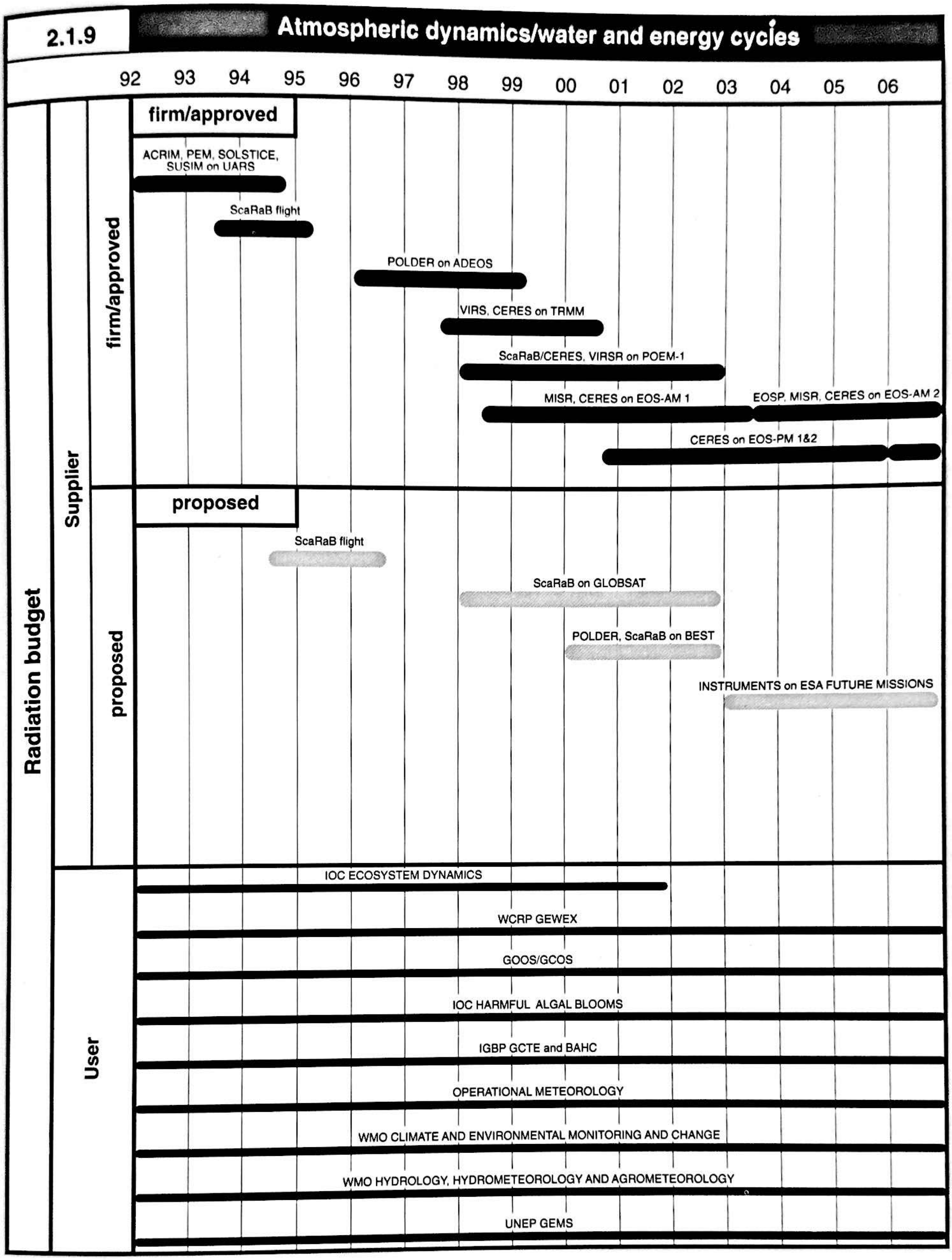
2.1.9 Radiation budget

A range of instruments are planned but global coverage and data continuity are not assured over the next 15 years. The essential requirement is for broad-band, high radiometric accuracy, well calibrated instruments to measure incoming solar radiance, reflected shortwave and emitted longwave radiation over a long time span. The ScaRaB sensors will provide useful data until the flights of the more advanced CERES sensor towards the end of the decade. POLDER provides complementary, rather than similar, information.

CERES will fly on several sun-synchronous polar orbiters (both morning and afternoon crossing) in the period 1998 onwards. It will also fly in an inclined orbit on TRMM and hence take data over the tropics.

Time sampling and angular sampling requirements imply that CERES should fly simultaneously on platforms in am and pm sun synchronous orbits as well as in an inclined orbit. Morning crossing measuring systems will be provided by POEM-1 (and possibly follow-on ESA missions) and EOS-AM 1 (and follow-ons). Afternoon crossing missions will be provided by the EOS-PM series and have also been suggested for the NOAA O, P, Q series early in the next century. Coverage requirements suggest follow-ons to TRMM (which are currently under consideration by the US and Japan) would be desirable.

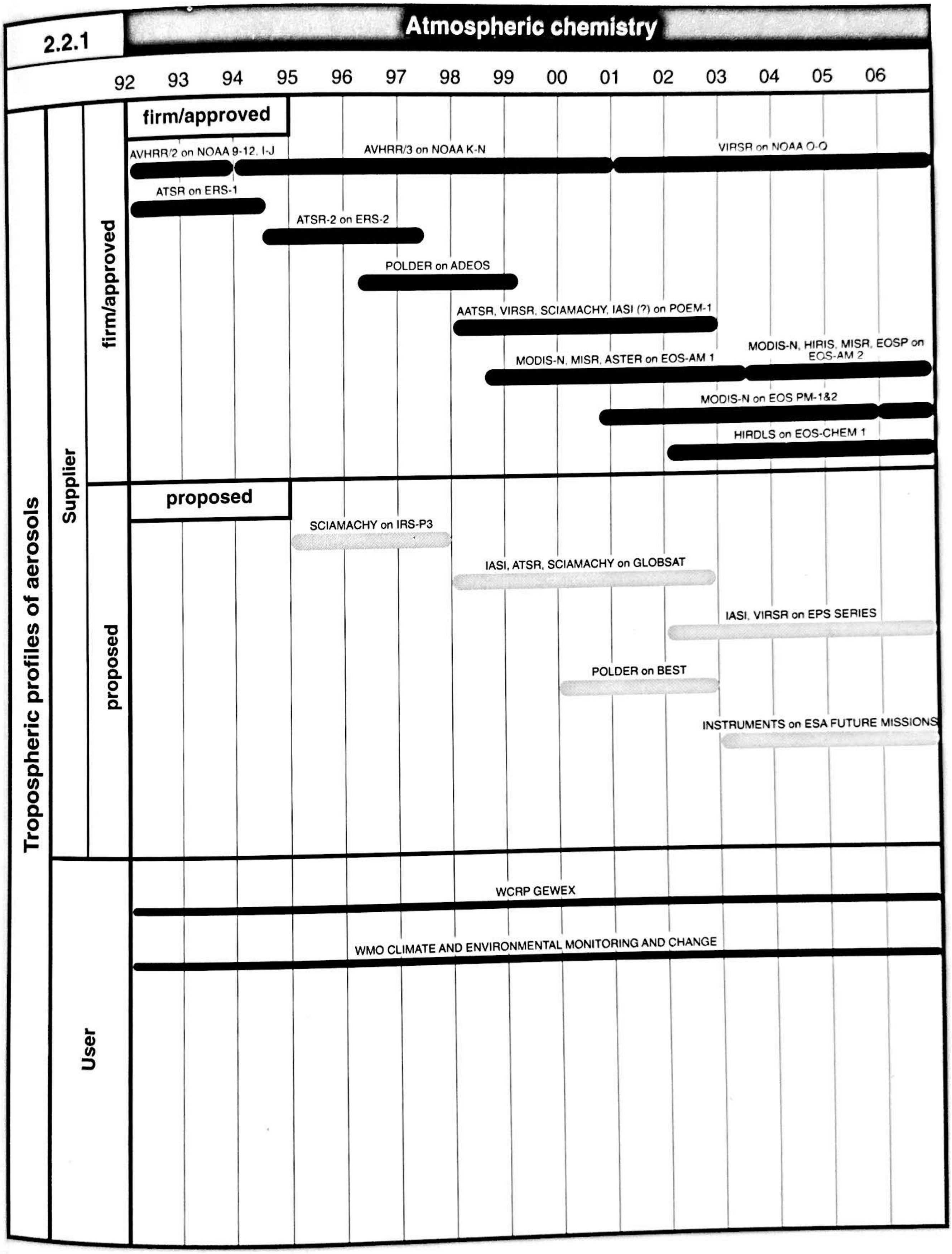
Measurements of the incoming solar radiation are not well catered for and indeed stop after UARS ceases to function (expected to be late 1994). Instruments such as SOLSTICE and ACRIM that can measure broad-band incoming radiation are, however, being considered by the USA for accommodation on flights of opportunity.


2.1.9
Atmospheric dynamics/water and energy cycles
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Radiation budget
Supplier
firm/approved
ACRIM, PEM, SOLSTICE, SUSIM on UARS
ScaRaB flight
POLDER on ADEOS
VIRS, CERES on TRMM
ScaRaB/CERES, VIRSR on POEM-1
MISR, CERES on EOS-AM 1
EOSP, MISR, CERES on EOS-AM 2
CERES on EOS-PM 1&2
proposed
ScaRaB flight
ScaRaB on GLOBSAT
POLDER, ScaRaB on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
User
IOC ECOSYSTEM DYNAMICS
WCRP GEWEX
GOOS/GCOS
IOC HARMFUL ALGAL BLOOMS
IGBP GCTE and BAHC
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WMO HYDROLOGY, HYDROMETEOROLOGY AND AGROMETEOROLOGY
UNEP GEMS

2.2.1 Tropospheric profiles of aerosols

Tropospheric profiling using satellite instruments is notoriously difficult. However, ATSR and its associated developments can provide some useful column integrated data. AVHRR (and its successor VIRSR) can provide data on aerosol depth. The new generation of sensors, SCIAMACHY, HIRDLS and EOSP should provide enhanced data, but not in the lower atmosphere. MISR will measure aerosol phase function, but not profiles.

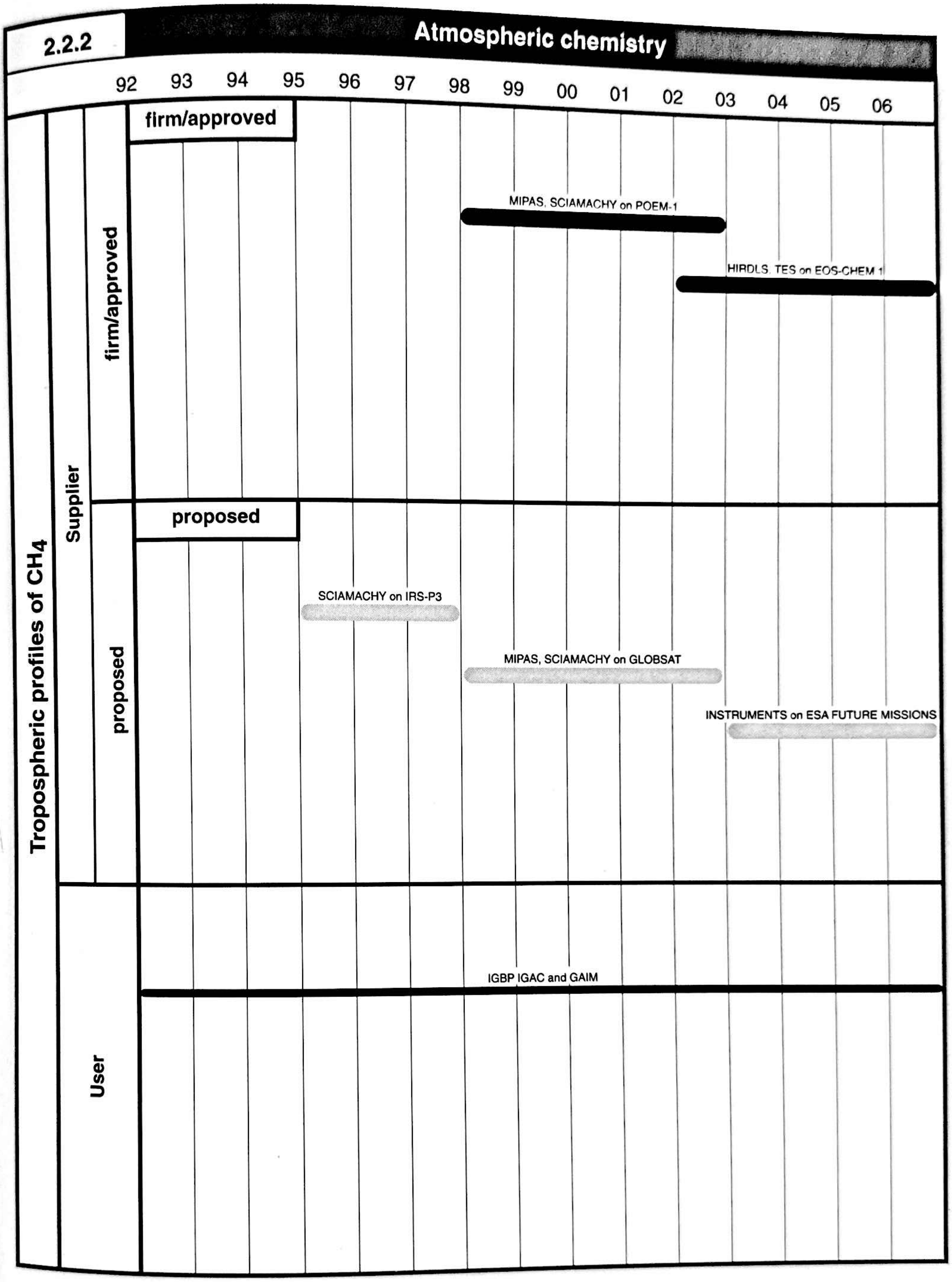
The development of active instruments such as ATLID, proposed for ESA future missions beyond POEM-1 will greatly enhance measurement capabilities.


2.2.1
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Tropospheric profiles of aerosols
Supplier
firm/approved
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
ATSR on ERS-1
ATSR-2 on ERS-2
POLDER on ADEOS
AATSR, VIRSR, SCIAMACHY, IASI (?) on POEM-1
MODIS-N, MISR, ASTER on EOS-AM 1
MODIS-N, HIRIS, MISR, EOSP on EOS-AM 2
MODIS-N on EOS PM-1&2
HIRDLS on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
IASI, ATSR, SCIAMACHY on GLOBSAT
IASI, VIRSR on EPS SERIES
POLDER on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP GEWEX
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE

2.2.2 Tropospheric profiles of CH_4

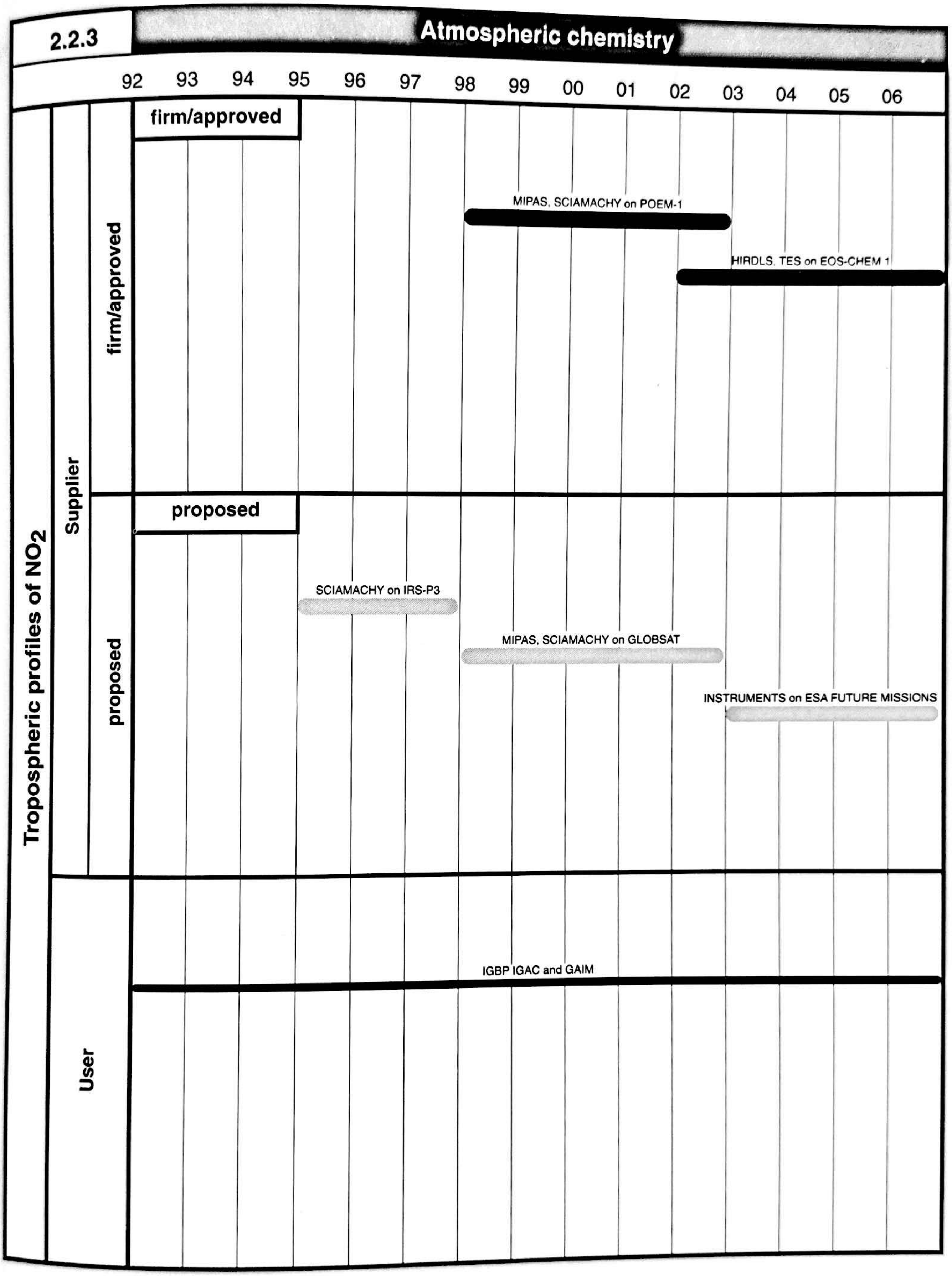
Tropospheric profiles of methane cannot be obtained from satellite measurements at present. HIRDLS, SCIAMACHY and MIPAS will not measure in the lower troposphere. TES is the only instrument envisaged capable of measuring profiles from the Earth's surface through to the top of the troposphere.

MOPITT on EOS-AM 1 (from 1998 for 5 years) will provide retrievals of column CH_4.


2.2.2
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Tropospheric profiles of CH_4
Supplier
firm/approved
firm/approved
MIPAS, SCIAMACHY on POEM-1
HIRDLS, TES on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
MIPAS, SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS
User
IGBP IGAC and GAIM

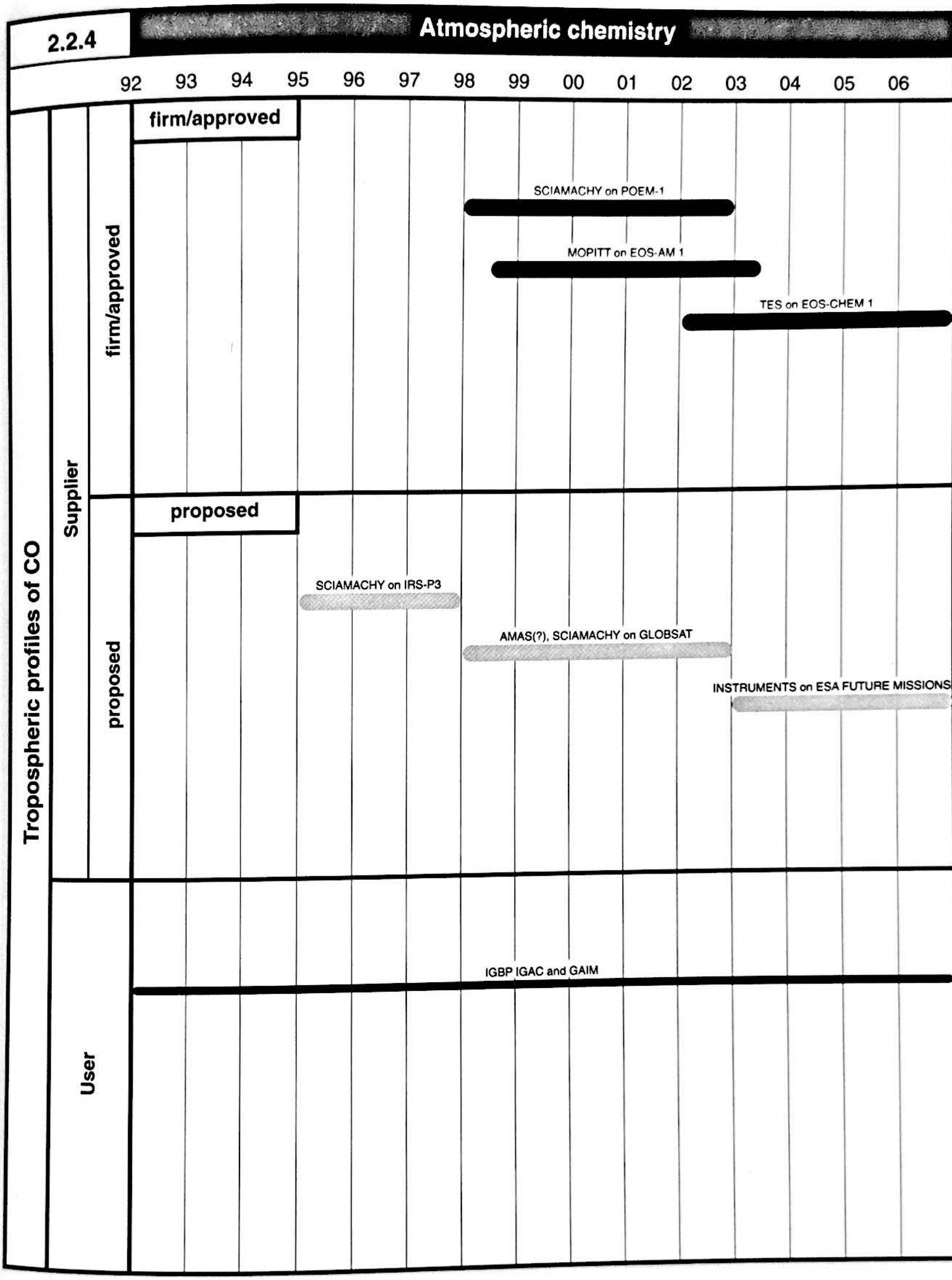
2.2.3 Tropospheric profiles of NO_2

Tropospheric profiles of nitrogen dioxide cannot be obtained from satellite measurements at present. HIRDLS, SCIAMACHY and MIPAS will not measure in the lower troposphere. TES is the only instrument envisaged capable of measuring profiles from the Earth's surface through to the top of the troposphere.


2.2.3
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Tropospheric profiles of NO_2
Supplier
User
firm/approved
firm/approved
MIPAS, SCIAMACHY on POEM-1
HIRDLS, TES on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
MIPAS, SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS
IGBP IGAC and GAIM

2.2.4 Tropospheric profiles of CO

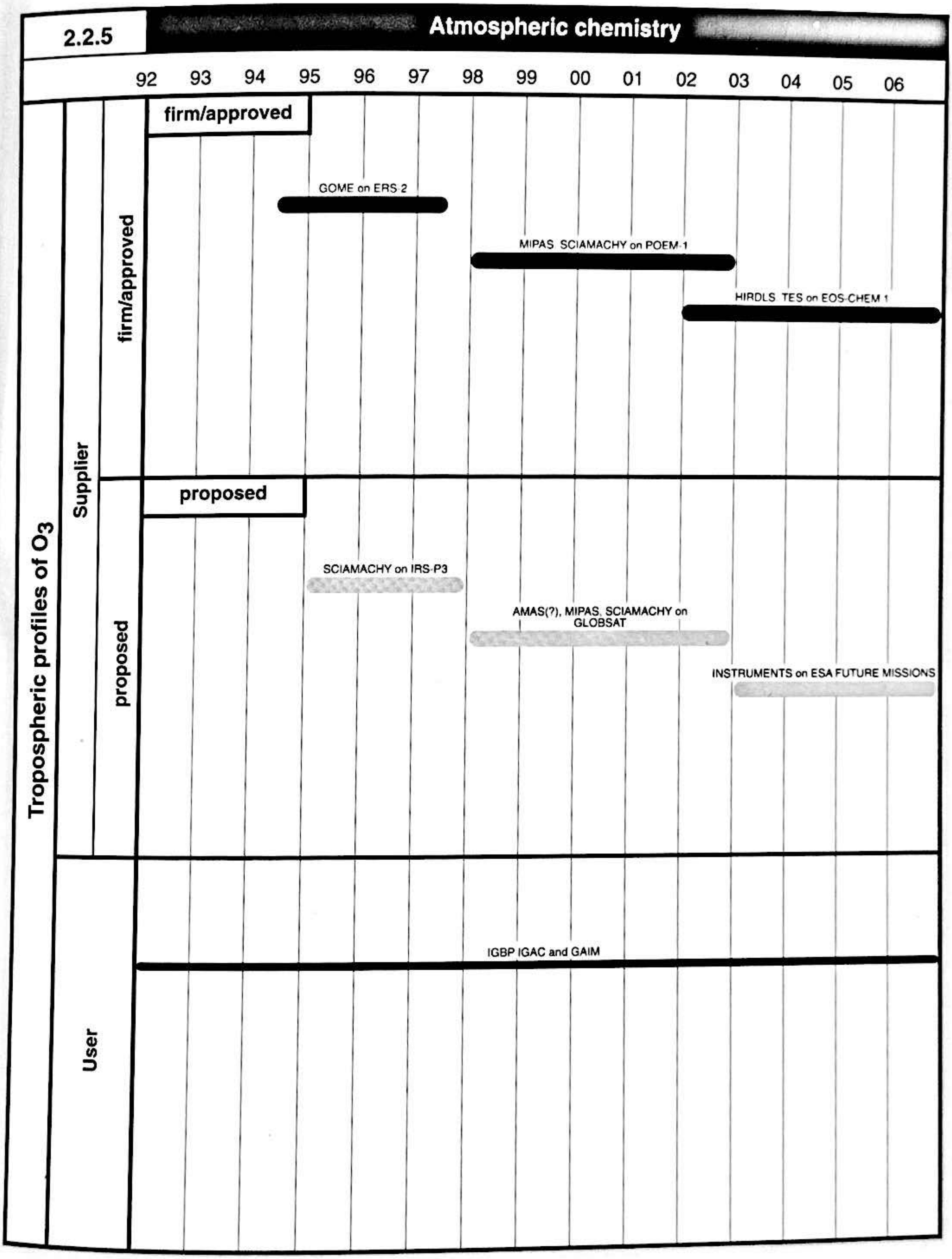
MOPITT and TES are capable of measuring carbon monoxide profiles from the Earth's surface to the top of the troposphere. SCIAMACHY and AMAS take measurements in the upper troposphere. MOPITT does not have a flight opportunity after EOS-AM 1, on the assumption that the more advanced TES will replace it.


2.2.4
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Tropospheric profiles of CO
Supplier
firm/approved
firm/approved
SCIAMACHY on POEM-1
MOPITT on EOS-AM 1
TES on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
AMAS(?), SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS
User
IGBP IGAC and GAIM

2.2.5 Tropospheric profiles of O_3

Ozone measurements are reasonably well catered for from 1994 (ERS-2 launch). Measurements should improve with the flight of SCIAMACHY, AMAS, MIPAS, and HIRDLS (upper troposphere and above) and TES (vertical profiles from the Earth's surface).

Column integrated information is particularly important before tropospheric profiles become available. The main sensors carrying out measurements are, or will be, SBUV (NOAA afternoon missions) and TOMS (NOAA O-Q, Earth Probe and ADEOS) and IASI (perhaps POEM-1, ESA future missions, EPS series).

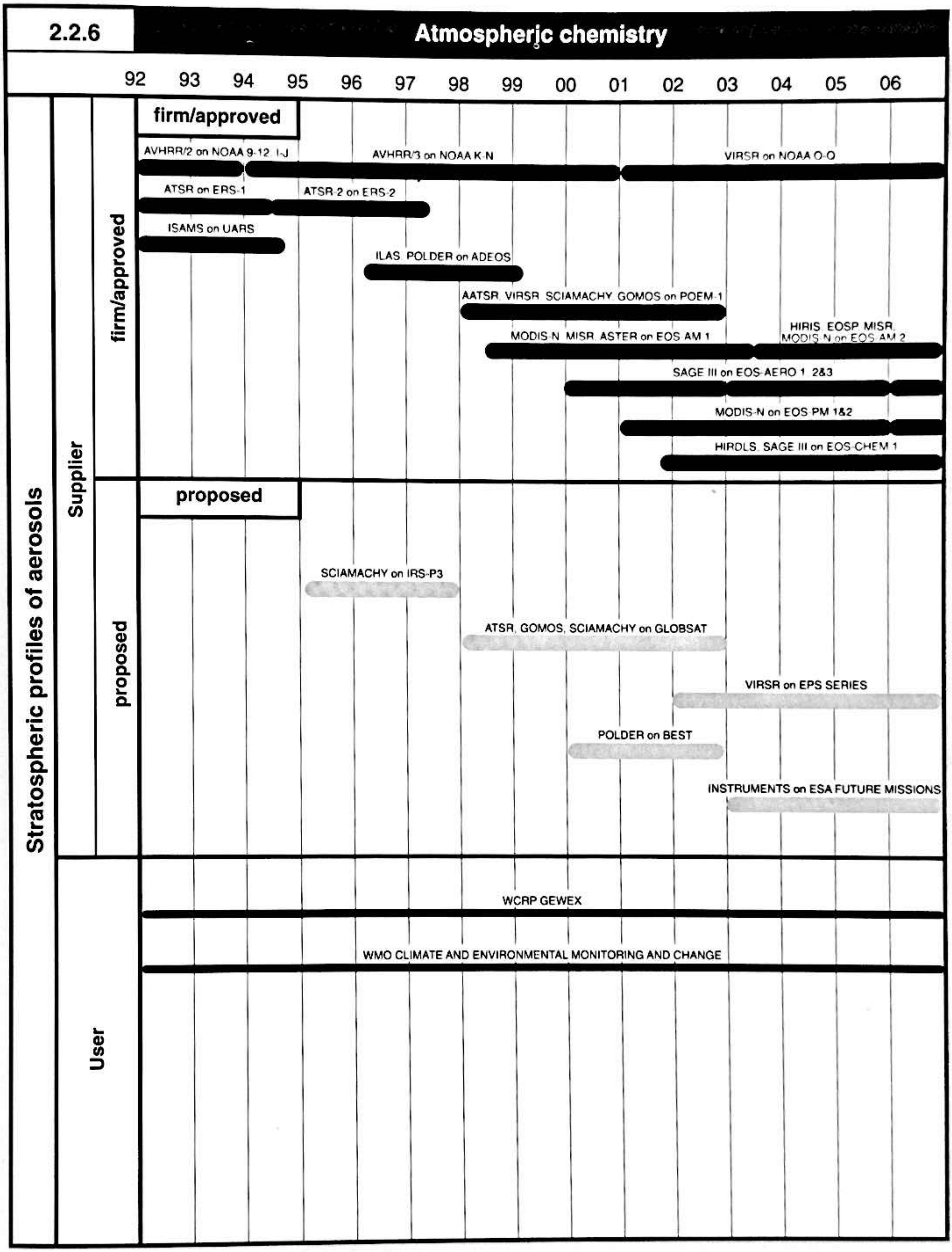

2.2.5
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Tropospheric profiles of O_3
Supplier
firm/approved
firm/approved
GOME on ERS-2
MIPAS SCIAMACHY on POEM-1
HIRDLS TES on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
AMAS(?), MIPAS, SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS
User
IGBP IGAC and GAIM

2.2.6 Stratospheric profiles of aerosols

ISAMS on UARS is currently making these measurements.

Prior to the launch of POEM-1, column integrated measurements can be made with ATSR and its developments. Aerosol depth is also provided by AVHRR (and its successor VIRSR).

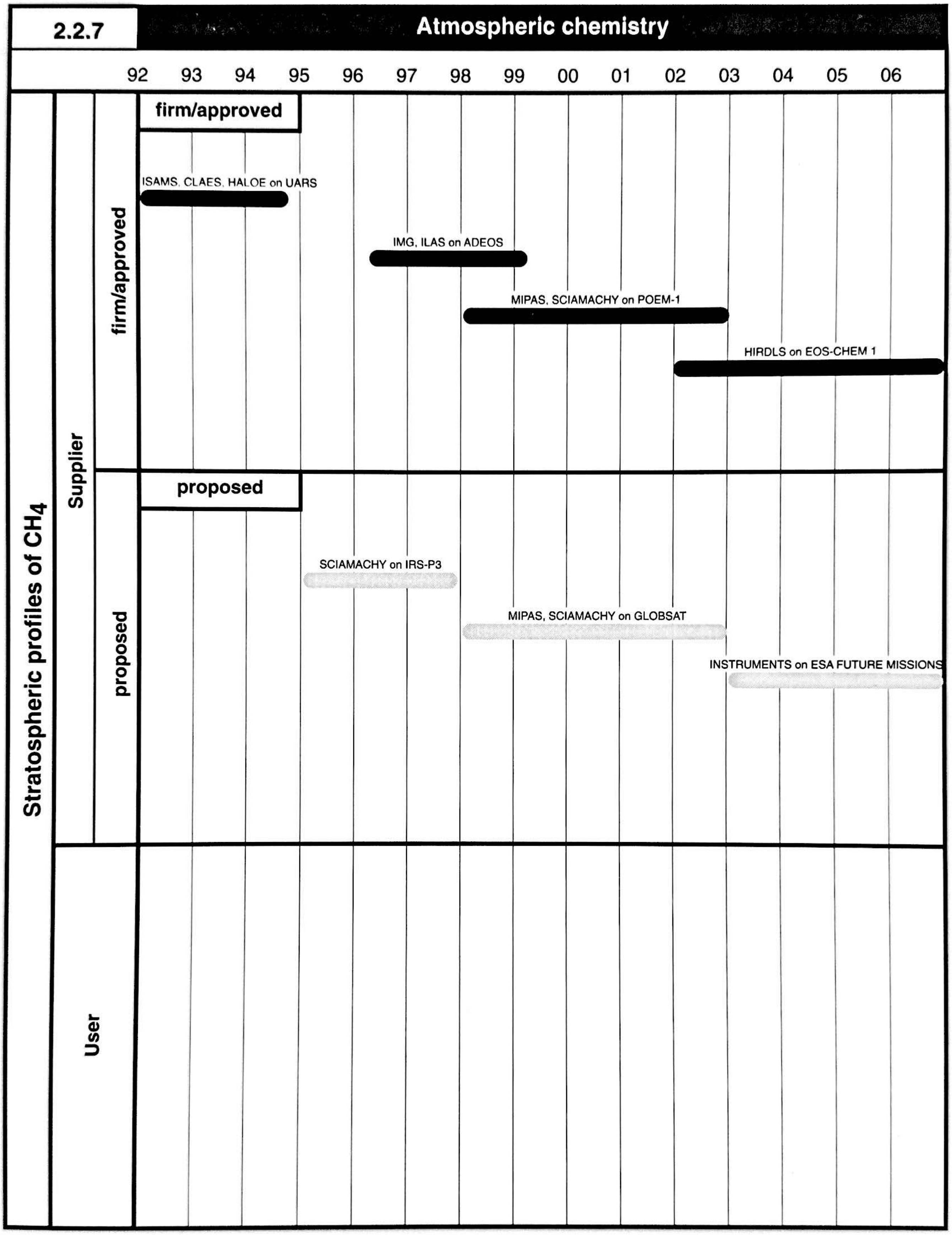
The new series of instruments, such as GOMOS, SCIAMACHY, EOSP and SAGE-III will continue these measurements and provide more accurate profile data.


2.2.6
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Stratospheric profiles of aerosols
Supplier
firm/approved
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
ATSR on ERS-1
ATSR-2 on ERS-2
ISAMS on UARS
ILAS, POLDER on ADEOS
AATSR, VIRSR, SCIAMACHY, GOMOS on POEM-1
MODIS-N, MISR, ASTER on EOS AM 1
HIRIS, EOSP, MISR, MODIS-N on EOS AM 2
SAGE III on EOS-AERO 1, 2&3
MODIS-N on EOS PM 1&2
HIRDLS, SAGE III on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
ATSR, GOMOS, SCIAMACHY on GLOBSAT
VIRSR on EPS SERIES
POLDER on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP GEWEX
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE

2.2.7 Stratospheric profiles of CH_4

There is a gap in measurements in the mid 1990s after the end of the UARS mission.

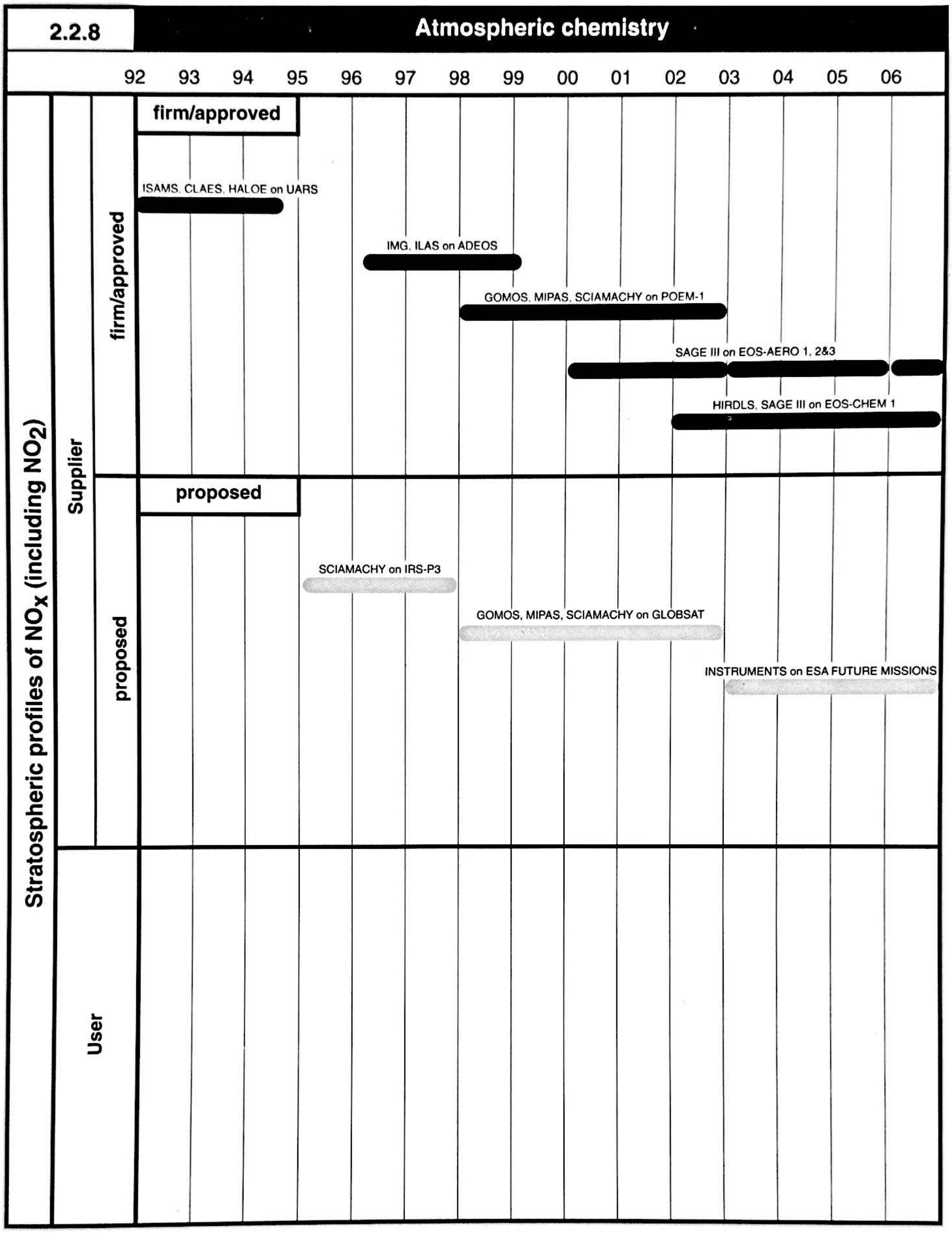
ADEOS, 1996-1999, will carry a number of instruments to measure chemical species, which may help to alleviate this shortfall in measurements. A flight of the SCIAMACHY sensor on the Indian IRS-P3 platform would also help if the launch takes place as proposed.


2.2.7
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Stratospheric profiles of CH_4
Supplier
User
firm/approved
firm/approved
ISAMS, CLAES, HALOE on UARS
IMG, ILAS on ADEOS
MIPAS, SCIAMACHY on POEM-1
HIRDLS on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
MIPAS, SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS

2.2.8 Stratospheric profiles of NO_x (including NO_2)

There is a gap in measurements in the mid 1990s after the end of the UARS mission.

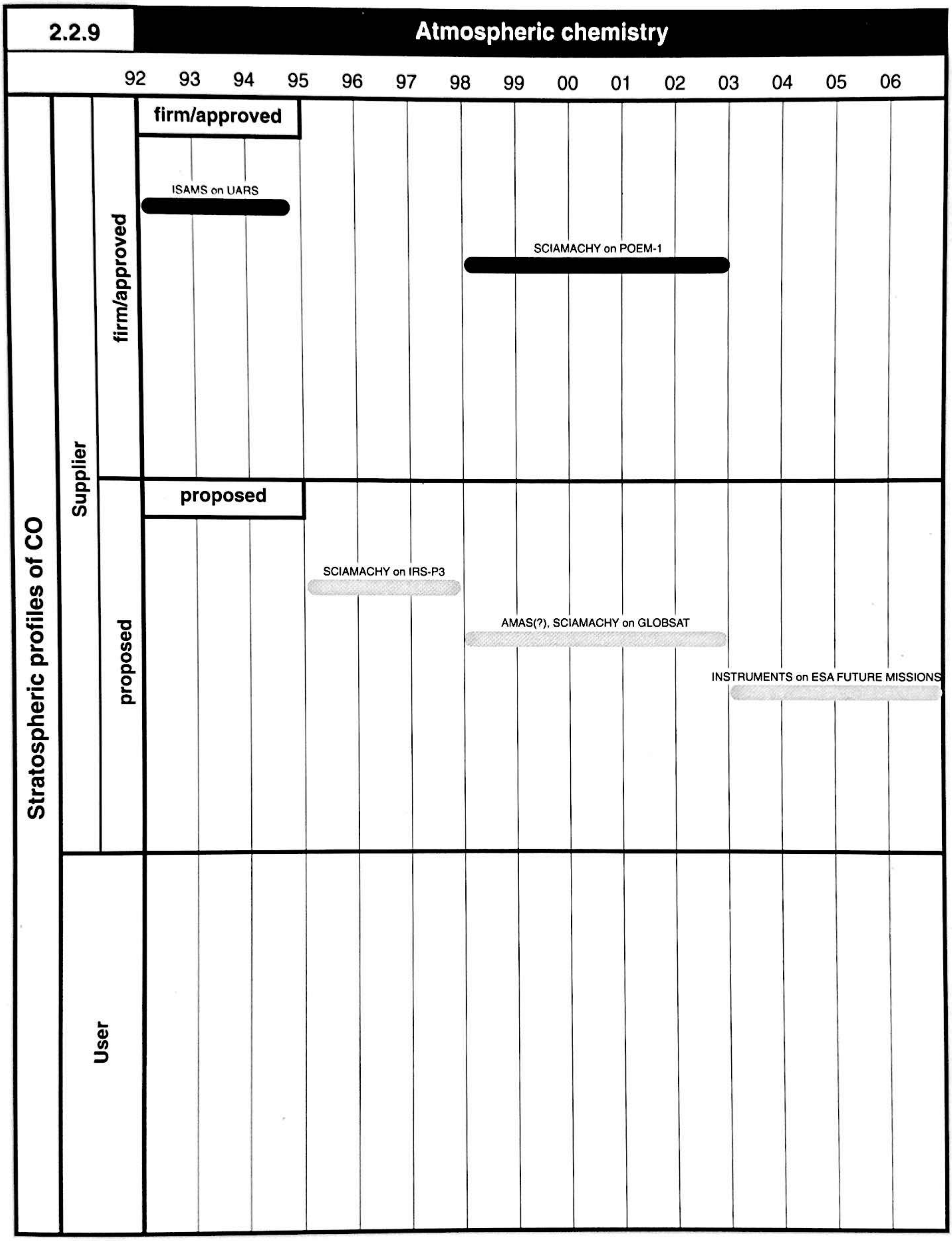
ADEOS, 1996-1999, will carry a number of instruments to measure chemical species, which may help to alleviate this shortfall in measurements. A flight of the SCIAMACHY sensor on the Indian IRS-P3 platform would also help if the launch takes place as proposed.


2.2.8
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Stratospheric profiles of NOx (including NO2)
Supplier
User
firm/approved
proposed
ISAMS, CLAES, HALOE on UARS
IMG, ILAS on ADEOS
GOMOS, MIPAS, SCIAMACHY on POEM-1
SAGE III on EOS-AERO 1, 2&3
HIRDLS, SAGE III on EOS-CHEM 1
SCIAMACHY on IRS-P3
GOMOS, MIPAS, SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS

2.2.9 Stratospheric profiles of CO

There is a gap in measurements in the mid 1990s after the end of the UARS mission.

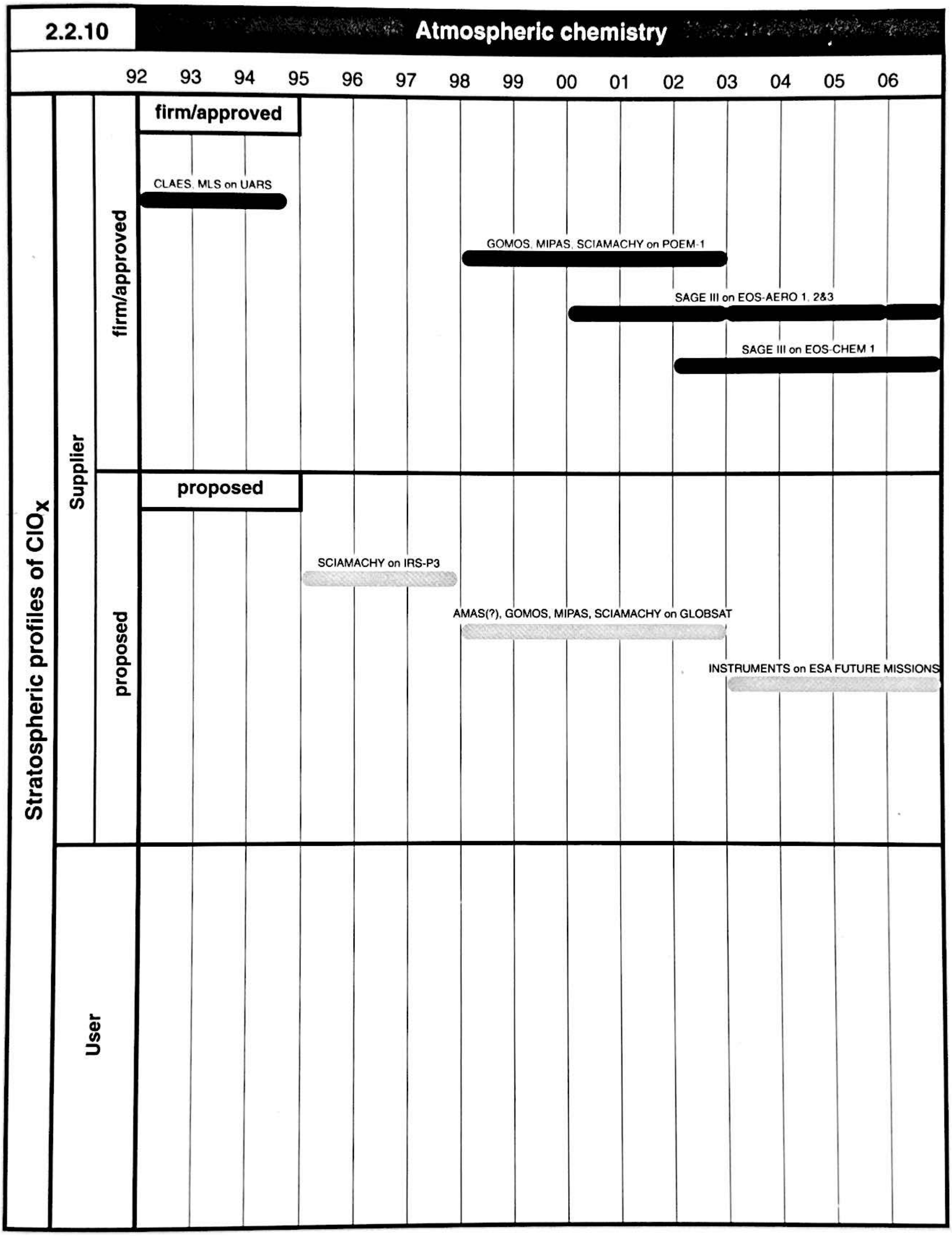
A flight of the SCIAMACHY sensor on the Indian IRS-P3 platform would help if the launch takes place as proposed.


2.2.9
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Stratospheric profiles of CO
Supplier
firm/approved
firm/approved
ISAMS on UARS
SCIAMACHY on POEM-1
proposed
proposed
SCIAMACHY on IRS-P3
AMAS(?), SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS
User

2.2.10 Stratospheric profiles of ClO_x

There is a gap in measurements in the mid 1990s after the end of the UARS mission.

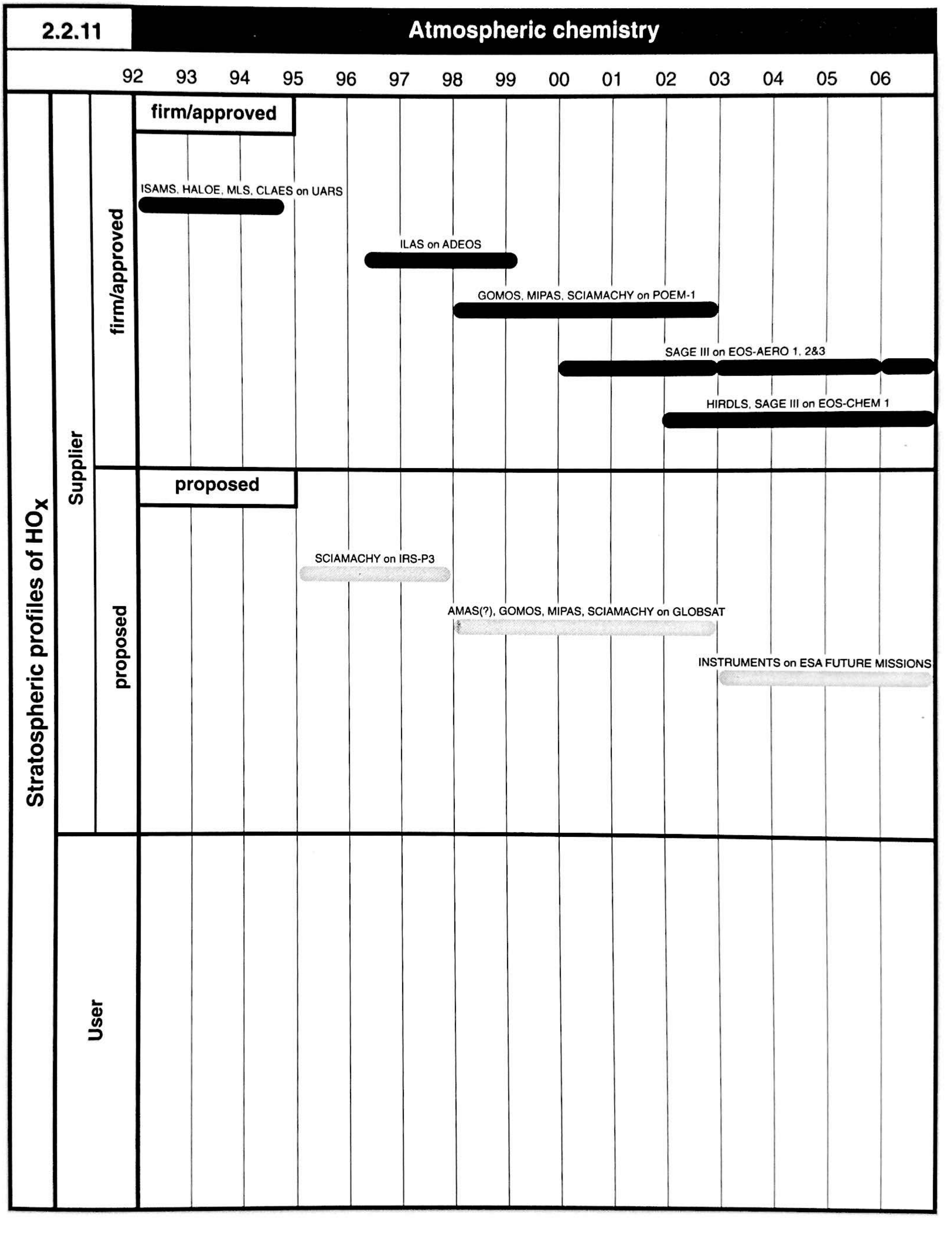
ADEOS, 1996-1999, will carry a number of instruments to measure chemical species, which may help to alleviate this shortfall in measurements. A flight of the SCIAMACHY sensor on the Indian IRS-P3 platform would also help if the launch takes place as proposed.


2.2.10
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Stratospheric profiles of ClO_x
Supplier
User
firm/approved
proposed
CLAES, MLS on UARS
GOMOS, MIPAS, SCIAMACHY on POEM-1
SAGE III on EOS-AERO 1, 2&3
SAGE III on EOS-CHEM 1
SCIAMACHY on IRS-P3
AMAS(?), GOMOS, MIPAS, SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS

2.2.11 Stratospheric profiles of HO_x

There is a gap in measurements in the mid 1990s after the end of the UARS mission.

ADEOS, 1996-1999, will carry a number of instruments to measure chemical species, which may help to alleviate this shortfall in measurements. A flight of the SCIAMACHY sensor on the Indian IRS-P3 platform would also help if the launch takes place as proposed.



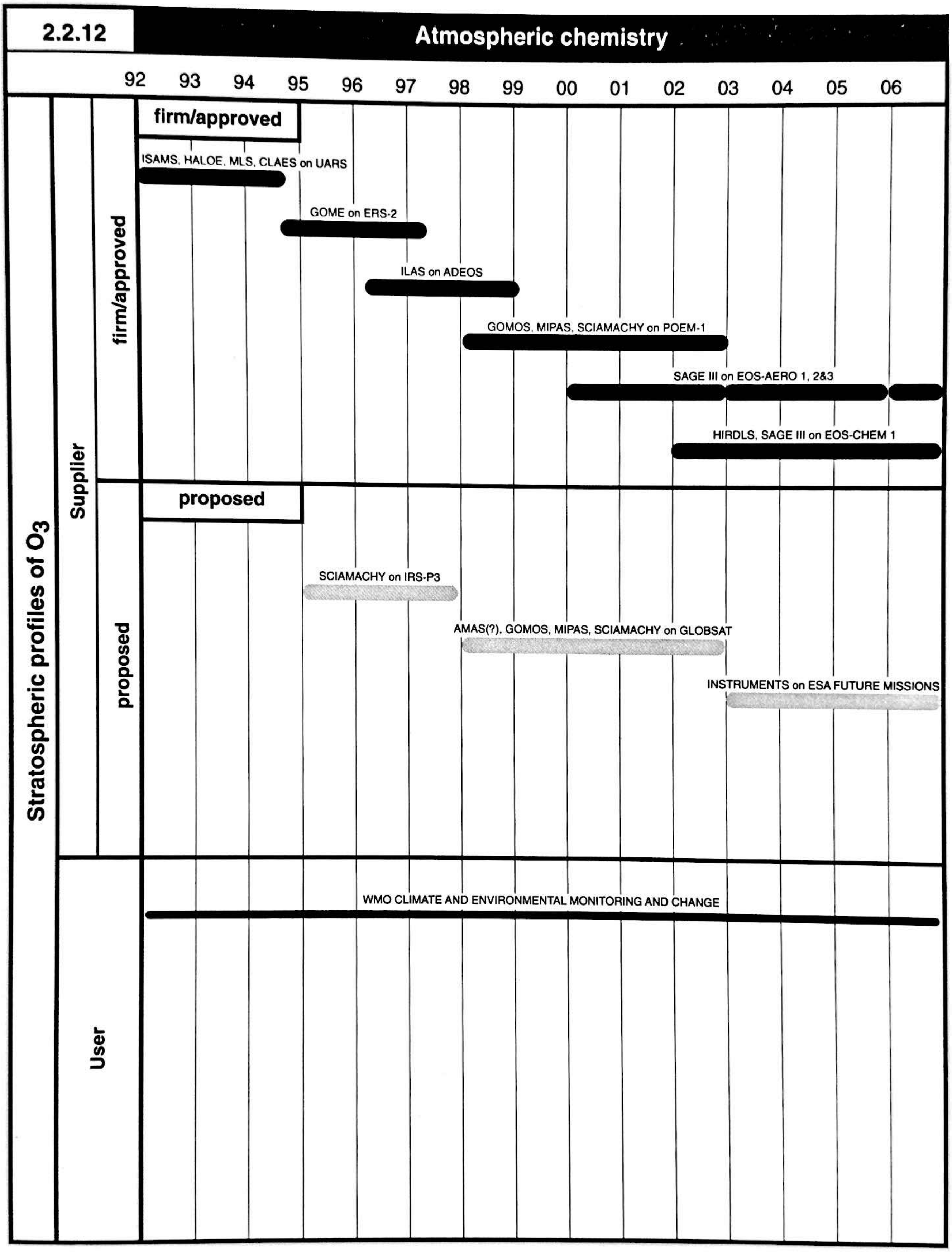
2.2.11
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Stratospheric profiles of HO_x
Supplier
User
firm/approved
proposed
ISAMS, HALOE, MLS, CLAES on UARS
ILAS on ADEOS
GOMOS, MIPAS, SCIAMACHY on POEM-1
SAGE III on EOS-AERO 1, 2&3
HIRDLS, SAGE III on EOS-CHEM 1
SCIAMACHY on IRS-P3
AMAS(?), GOMOS, MIPAS, SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS

2.2.12 Stratospheric profiles of O_3

The recent concern over the depletion of stratospheric ozone suggests that maintaining a global data set is vital.

GOME and ILAS provide vital continuity of data for ozone profiles between the end of UARS and the start of the ESA/EOS polar missions.

In addition to profiles of ozone, column integrated amounts are also of interest for climate monitoring purposes. The main sensors carrying out measurements are SBUV (NOAA afternoon missions) and TOMS (NOAA O-Q, Earth Probe and ADEOS) and IASI (perhaps POEM-1, ESA future missions, EPS series).

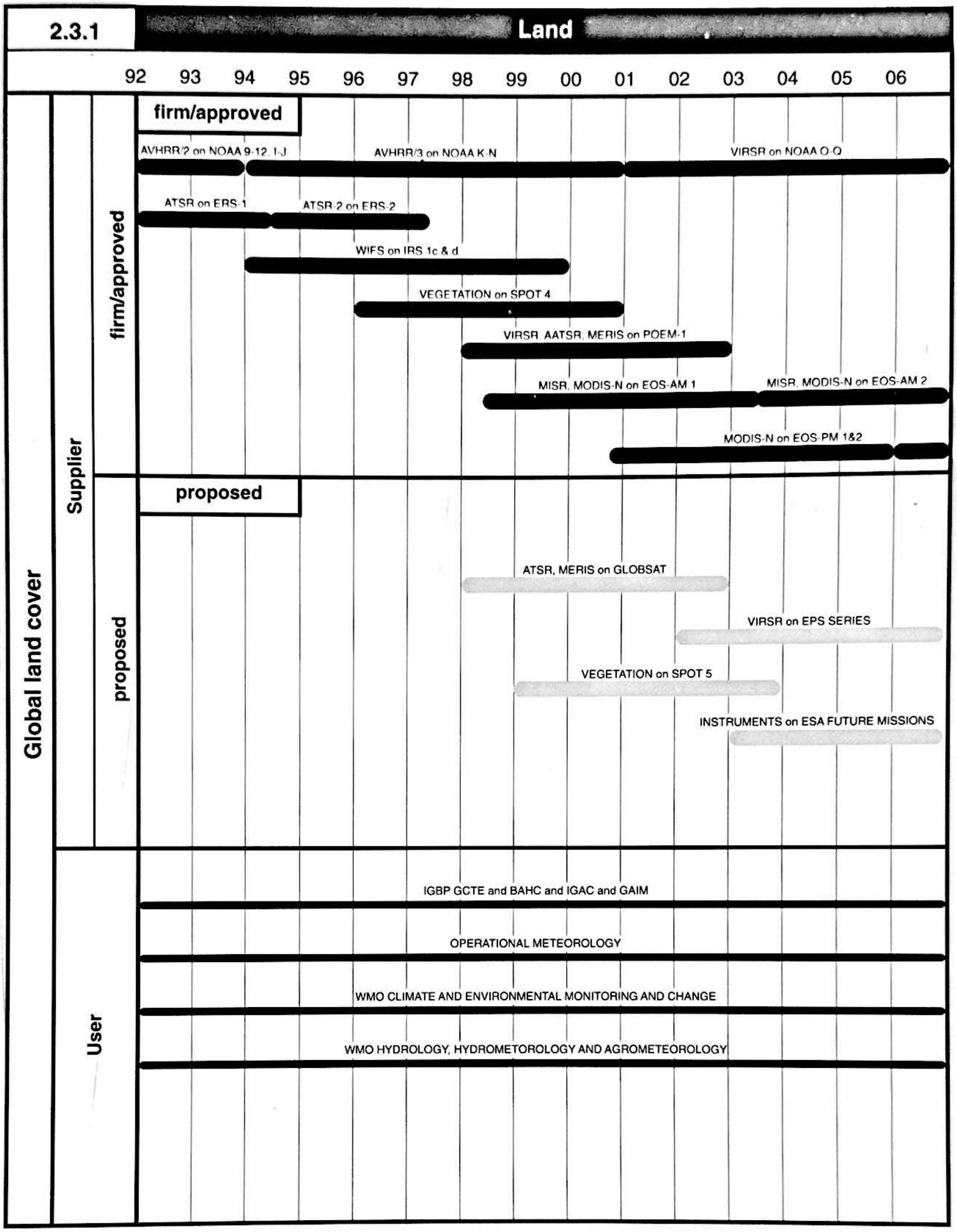

2.2.12
Atmospheric chemistry
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Stratospheric profiles of O_3
Supplier
firm/approved
firm/approved
ISAMS, HALOE, MLS, CLAES on UARS
GOME on ERS-2
ILAS on ADEOS
GOMOS, MIPAS, SCIAMACHY on POEM-1
SAGE III on EOS-AERO 1, 2&3
HIRDLS, SAGE III on EOS-CHEM 1
proposed
proposed
SCIAMACHY on IRS-P3
AMAS(?), GOMOS, MIPAS, SCIAMACHY on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS
User
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE

2.3.1 Global land cover

Presently, AVHRR has been chosen by IGBP to provide data for its global land cover project, currently at 4km resolution, with plans to move to a 1km grid.

In 1996, the VEGETATION instrument (SPOT 4, 5), specifically designed for the proposed routine monitoring of the continental biosphere, will provide appropriate information for land cover change.

Towards the end of the decade, MODIS-N, MISR and MERIS will provide high spectral resolution data which will result in better land cover information.


2.3.1
Land
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
Global land cover
Supplier
User
firm/approved
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
ATSR on ERS-1
ATSR-2 on ERS-2
WIFS on IRS 1c & d
VEGETATION on SPOT 4
VIRSR, AATSR, MERIS on POEM-1
MISR, MODIS-N on EOS-AM 1
MISR, MODIS-N on EOS-AM 2
MODIS-N on EOS-PM 1&2
proposed
proposed
ATSR, MERIS on GLOBSAT
VIRSR on EPS SERIES
VEGETATION on SPOT 5
INSTRUMENTS on ESA FUTURE MISSIONS
IGBP GCTE and BAHC and IGAC and GAIM
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WMO HYDROLOGY, HYDROMETOROLOGY AND AGROMETEOROLOGY

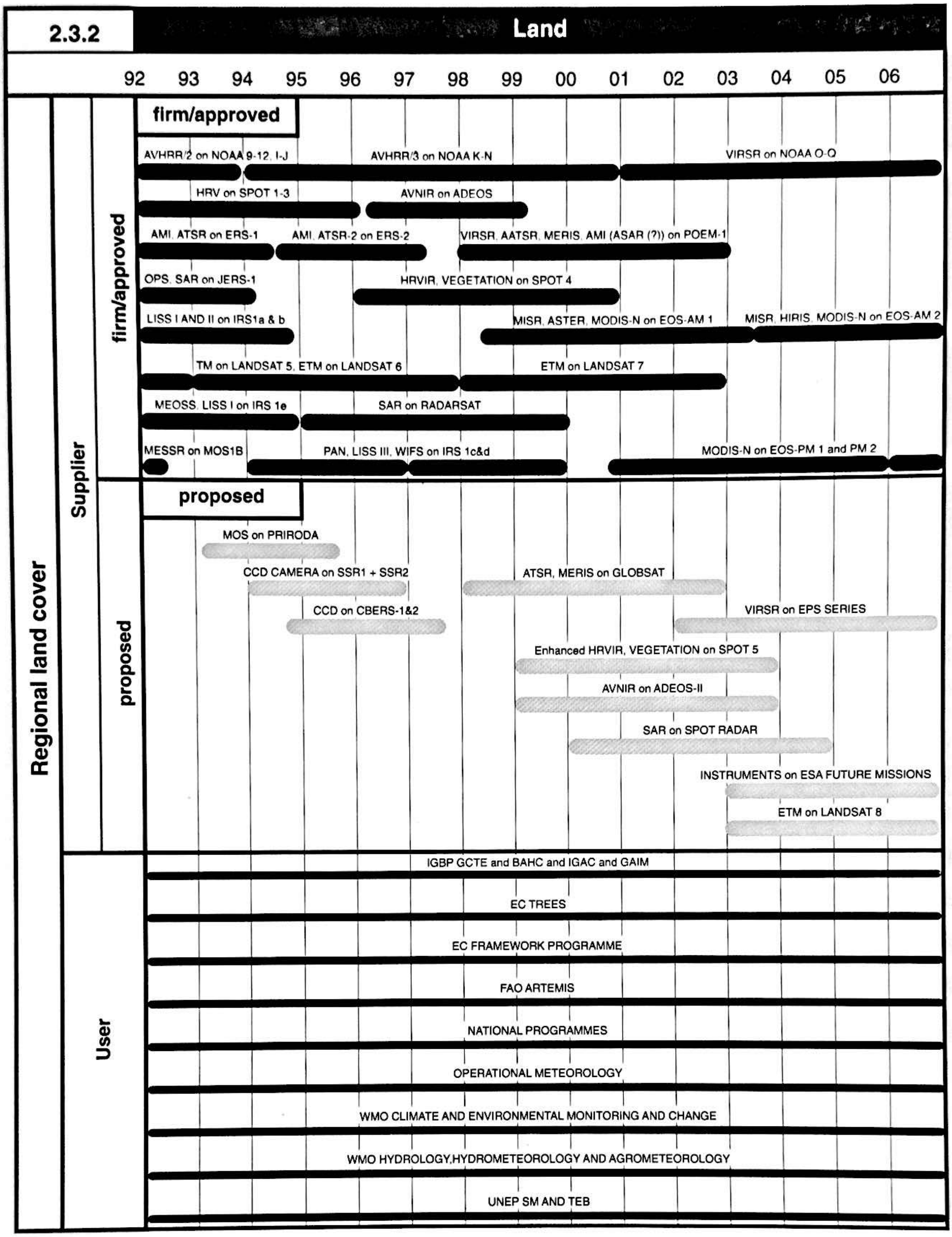
2.3.2 Regional land cover

There is a large demand for high resolution land cover data. The main sensors such as AVHRR together with its successor VIRSR, MISR and LANDSAT and SPOT payloads may be expected to provide long term continuity. They cannot, however, satisfy all data requirements, and a number on national missions (eg Japan, Brazil, India, China) are being planned.

SAR data is of growing interest with the launch of ERS-1 and JERS-1.

There are requirements for even higher resolutions for some applications (eg study of ecosystems).

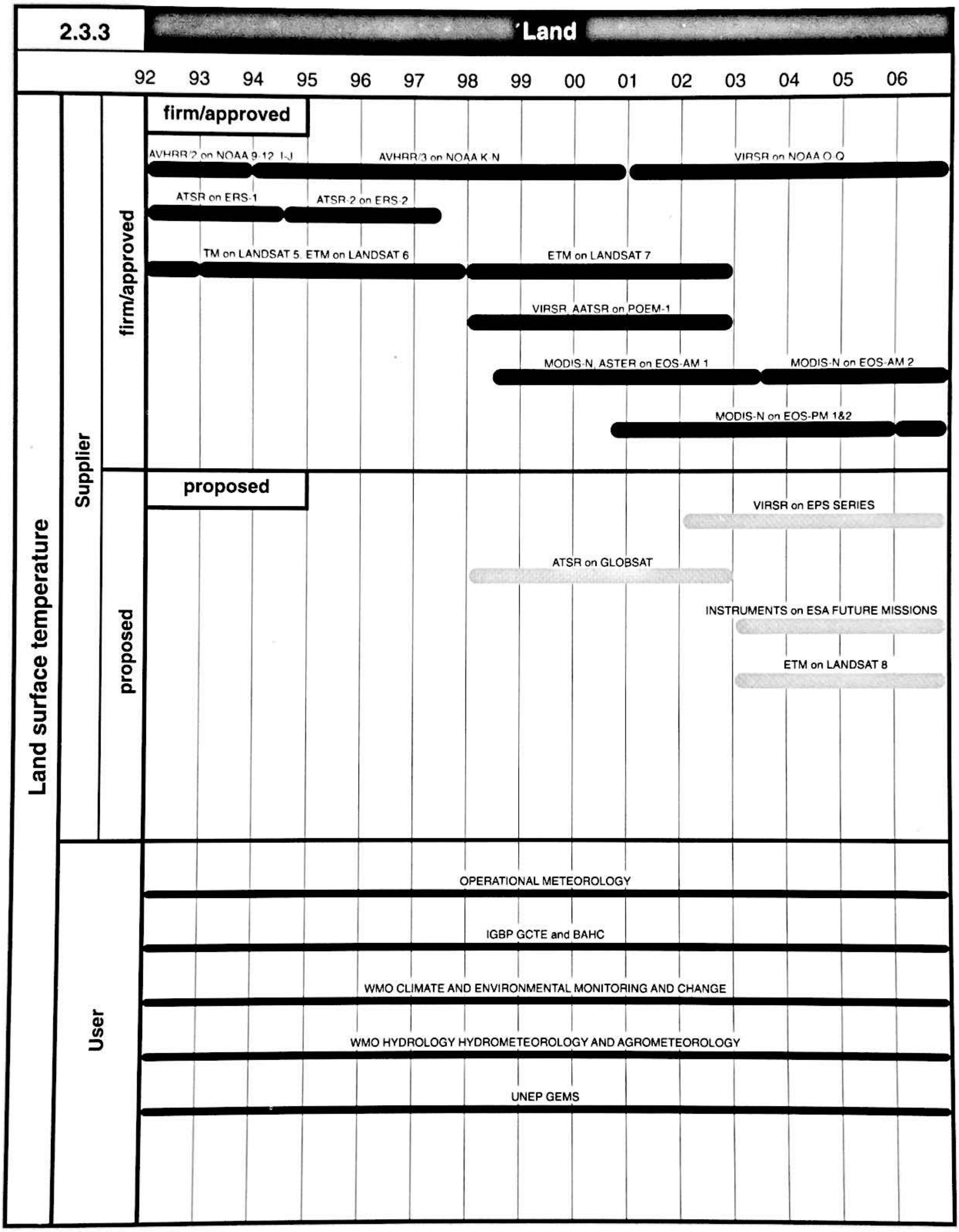
Some users have also expressed an interest in data from satellites operated by the former Soviet Union, such as ALMAZ SAR data and KFA 1000 Soyuz optical data.



2.3.2
Land
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Regional land cover
Supplier
firm/approved
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
HRV on SPOT 1-3
AVNIR on ADEOS
AMI, ATSR on ERS-1
AMI, ATSR-2 on ERS-2
VIRSR, AATSR, MERIS, AMI (ASAR (?)) on POEM-1
OPS, SAR on JERS-1
HRVIR, VEGETATION on SPOT 4
LISS I AND II on IRS1a & b
MISR, ASTER, MODIS-N on EOS-AM 1
MISR, HIRIS, MODIS-N on EOS-AM 2
TM on LANDSAT 5, ETM on LANDSAT 6
ETM on LANDSAT 7
MEOSS, LISS I on IRS 1e
SAR on RADARSAT
MESSR on MOS1B
PAN, LISS III, WIFS on IRS 1c&d
MODIS-N on EOS-PM 1 and PM 2
proposed
proposed
MOS on PRIRODA
CCD CAMERA on SSR1 + SSR2
ATSR, MERIS on GLOBSAT
CCD on CBERS-1&2
VIRSR on EPS SERIES
Enhanced HRVIR, VEGETATION on SPOT 5
AVNIR on ADEOS-II
SAR on SPOT RADAR
INSTRUMENTS on ESA FUTURE MISSIONS
ETM on LANDSAT 8
User
IGBP GCTE and BAHC and IGAC and GAIM
EC TREES
EC FRAMEWORK PROGRAMME
FAO ARTEMIS
NATIONAL PROGRAMMES
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WMO HYDROLOGY,HYDROMETEOROLOGY AND AGROMETEOROLOGY
UNEP SM AND TEB

2.3.3 Land surface temperature

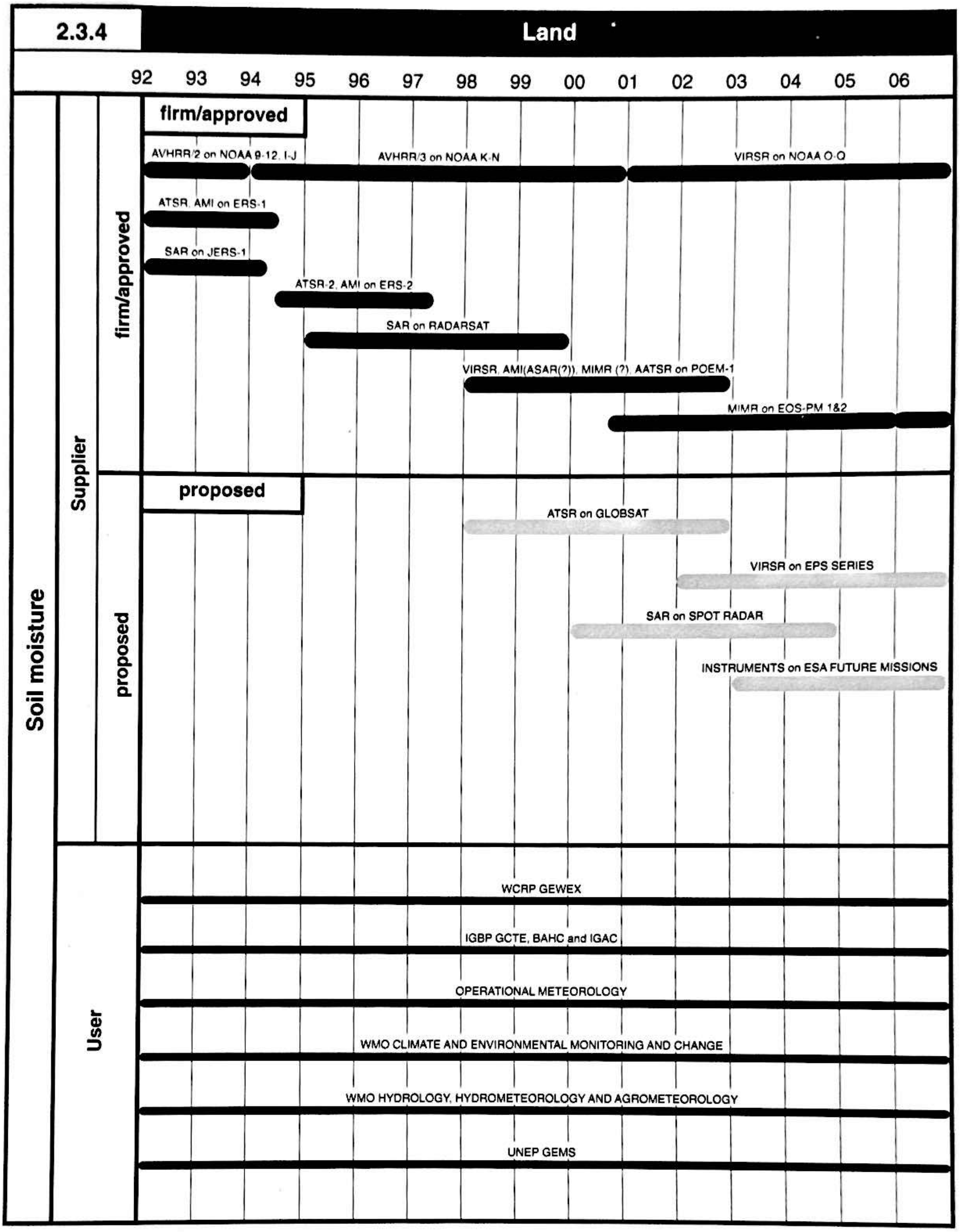
Accuracy of current measurements should improve, particularly with the launch of ATSR-2 on ERS-2, to meet requirements.


2.3.3
Land
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Land surface temperature
Supplier
firm/approved
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
ATSR on ERS-1
ATSR-2 on ERS-2
TM on LANDSAT 5, ETM on LANDSAT 6
ETM on LANDSAT 7
VIRSR, AATSR on POEM-1
MODIS-N, ASTER on EOS-AM 1
MODIS-N on EOS-AM 2
MODIS-N on EOS-PM 1&2
proposed
proposed
VIRSR on EPS SERIES
ATSR on GLOBSAT
INSTRUMENTS on ESA FUTURE MISSIONS
ETM on LANDSAT 8
User
OPERATIONAL METEOROLOGY
IGBP GCTE and BAHC
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WMO HYDROLOGY HYDROMETEOROLOGY AND AGROMETEOROLOGY
UNEP GEMS

2.3.4 Soil moisture

The requirement cannot be met at present as this is a very difficult parameter to measure with the required accuracy from space. Measurements can be made using visible/infrared imagers such as ATSR and AVHRR but improvements are required. MIMR and SAR also provide data on soil moisture.

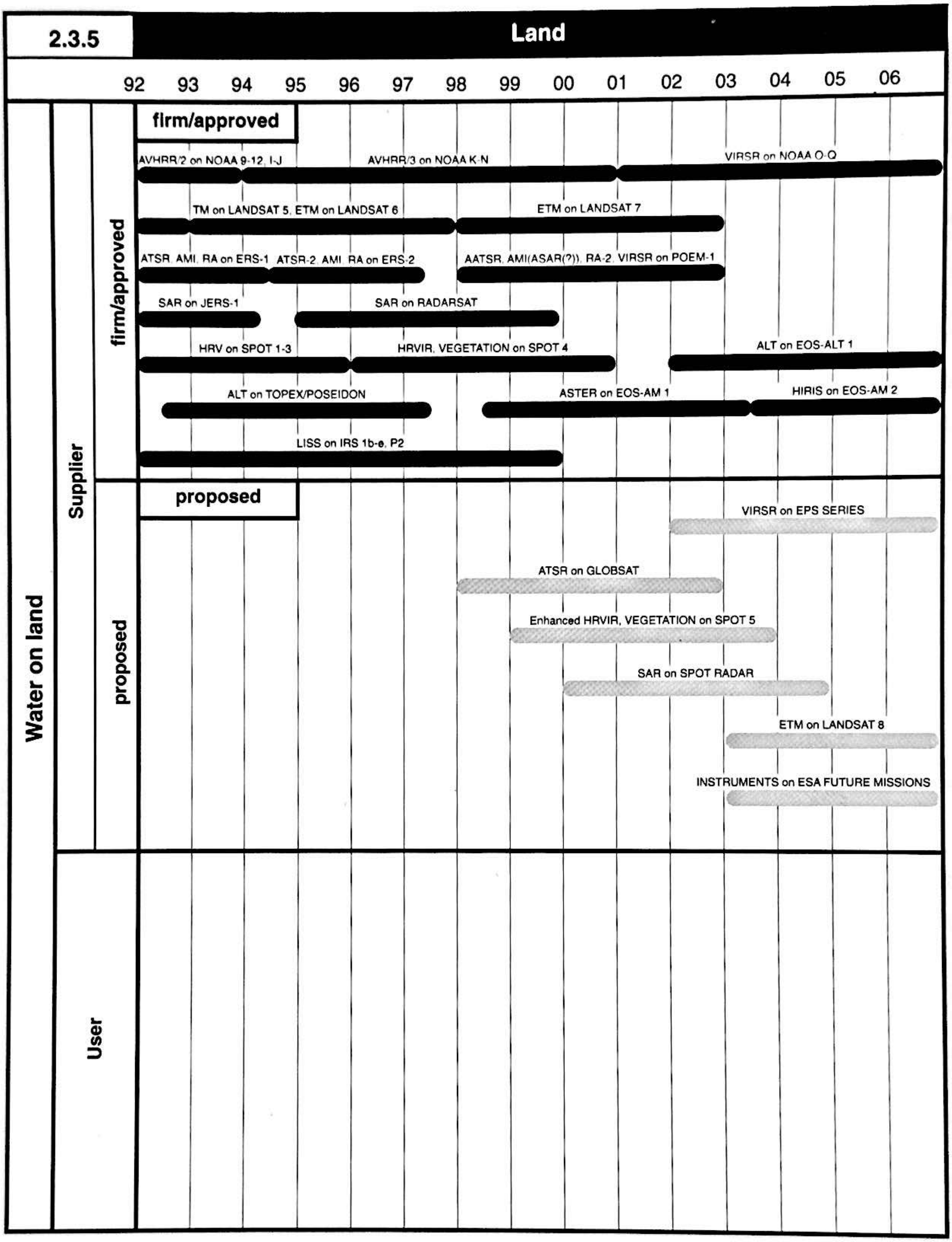
Combined ERS-1 (C-band) and JERS-1 (L-band) SAR data will estimates of near-surface soil moisture.


2.3.4
Land
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Soil moisture
Supplier
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
ATSR, AMI on ERS-1
SAR on JERS-1
ATSR-2, AMI on ERS-2
SAR on RADARSAT
VIRSR, AMI(ASAR(?)), MIMR (?), AATSR on POEM-1
MIMR on EOS-PM 1&2
proposed
ATSR on GLOBSAT
VIRSR on EPS SERIES
SAR on SPOT RADAR
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP GEWEX
IGBP GCTE, BAHC and IGAC
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WMO HYDROLOGY, HYDROMETEOROLOGY AND AGROMETEOROLOGY
UNEP GEMS

2.3.5 Water on land

Although this is a relatively easy measurement to make, the challenge is to measure seasonal variations of lake and river levels, to provide indicators of climate change, and regional flood warnings in real time.

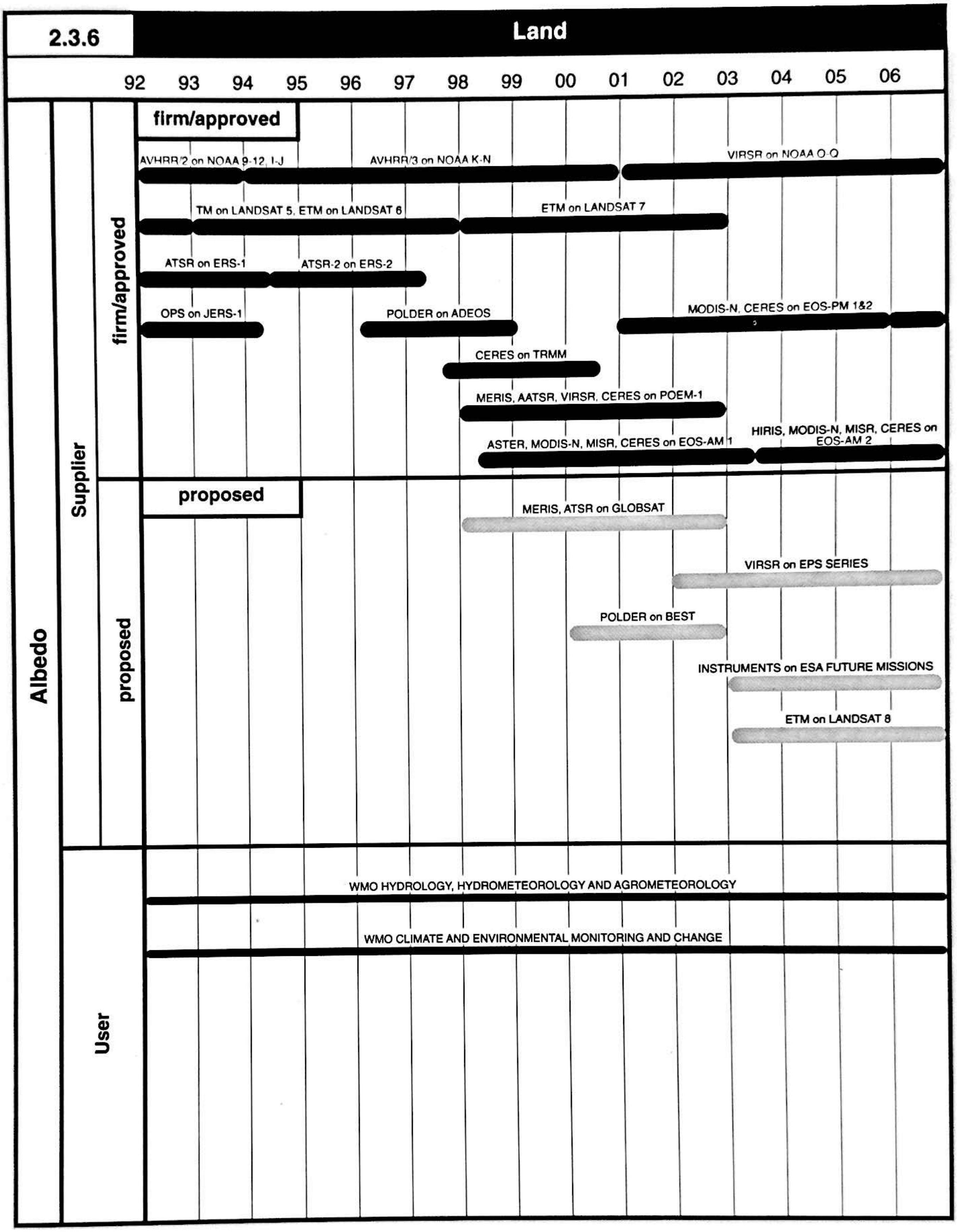
The biogeochemistry of inland waters can be measured using LANDSAT sensors, ASTER and HIRIS.


2.3.5
Land
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Water on land
Supplier
User
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
TM on LANDSAT 5, ETM on LANDSAT 6
ETM on LANDSAT 7
ATSR, AMI, RA on ERS-1
ATSR-2, AMI, RA on ERS-2
AATSR, AMI(ASAR(?)), RA-2, VIRSR on POEM-1
SAR on JERS-1
SAR on RADARSAT
HRV on SPOT 1-3
HRVIR, VEGETATION on SPOT 4
ALT on EOS-ALT 1
ALT on TOPEX/POSEIDON
ASTER on EOS-AM 1
HIRIS on EOS-AM 2
LISS on IRS 1b-e, P2
proposed
VIRSR on EPS SERIES
ATSR on GLOBSAT
Enhanced HRVIR, VEGETATION on SPOT 5
SAR on SPOT RADAR
ETM on LANDSAT 8
INSTRUMENTS on ESA FUTURE MISSIONS

2.3.6 Albedo

Current measurements are useful, although the quality of measurements will improve with the provision of high spectral resolution sensors such as MERIS and MODIS-N on ESA and NASA polar platforms.

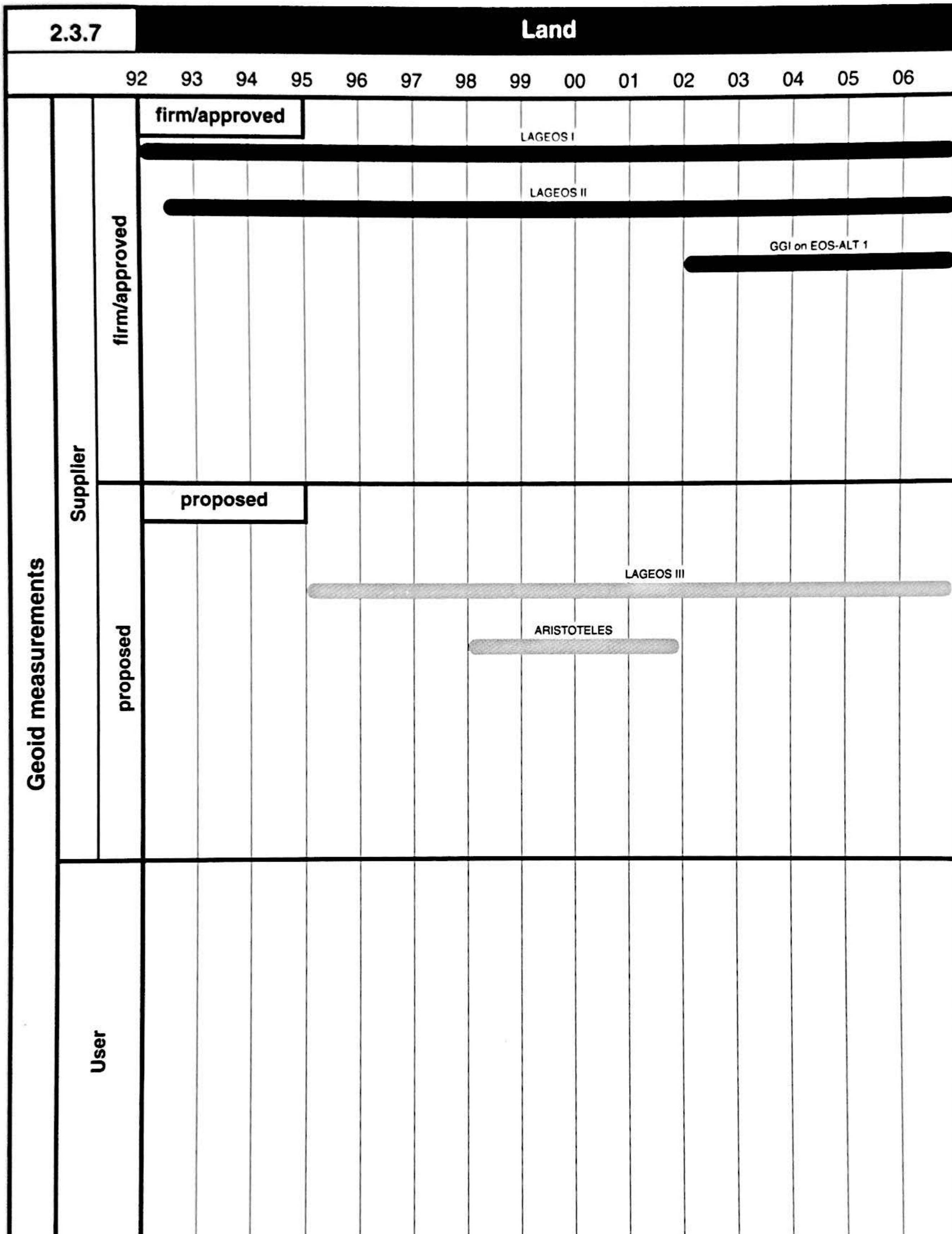
Angular measurements are needed to resolve the directional nature of surface reflectance. LANDSAT instruments and the EOS instruments MISR, ASTER and HIRIS are key. OPS on JERS-1 and POLDER on ADEOS will also make valuable contributions.


2.3.6
Land
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
Albedo
Supplier
firm/approved
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
TM on LANDSAT 5, ETM on LANDSAT 6
ETM on LANDSAT 7
ATSR on ERS-1
ATSR-2 on ERS-2
OPS on JERS-1
POLDER on ADEOS
MODIS-N, CERES on EOS-PM 1&2
CERES on TRMM
MERIS, AATSR, VIRSR, CERES on POEM-1
ASTER, MODIS-N, MISR, CERES on EOS-AM 1
HIRIS, MODIS-N, MISR, CERES on EOS-AM 2
proposed
proposed
MERIS, ATSR on GLOBSAT
VIRSR on EPS SERIES
POLDER on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
ETM on LANDSAT 8
User
WMO HYDROLOGY, HYDROMETEOROLOGY AND AGROMETEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE

2.3.7 Geoid measurements

The progressive increase in the number of LAGEOS satellites will improve the accuracy of plate motion measurements (in association with the Global Positioning System (GPS) and Very Long Baseline Interferometric (VLBI) techniques).

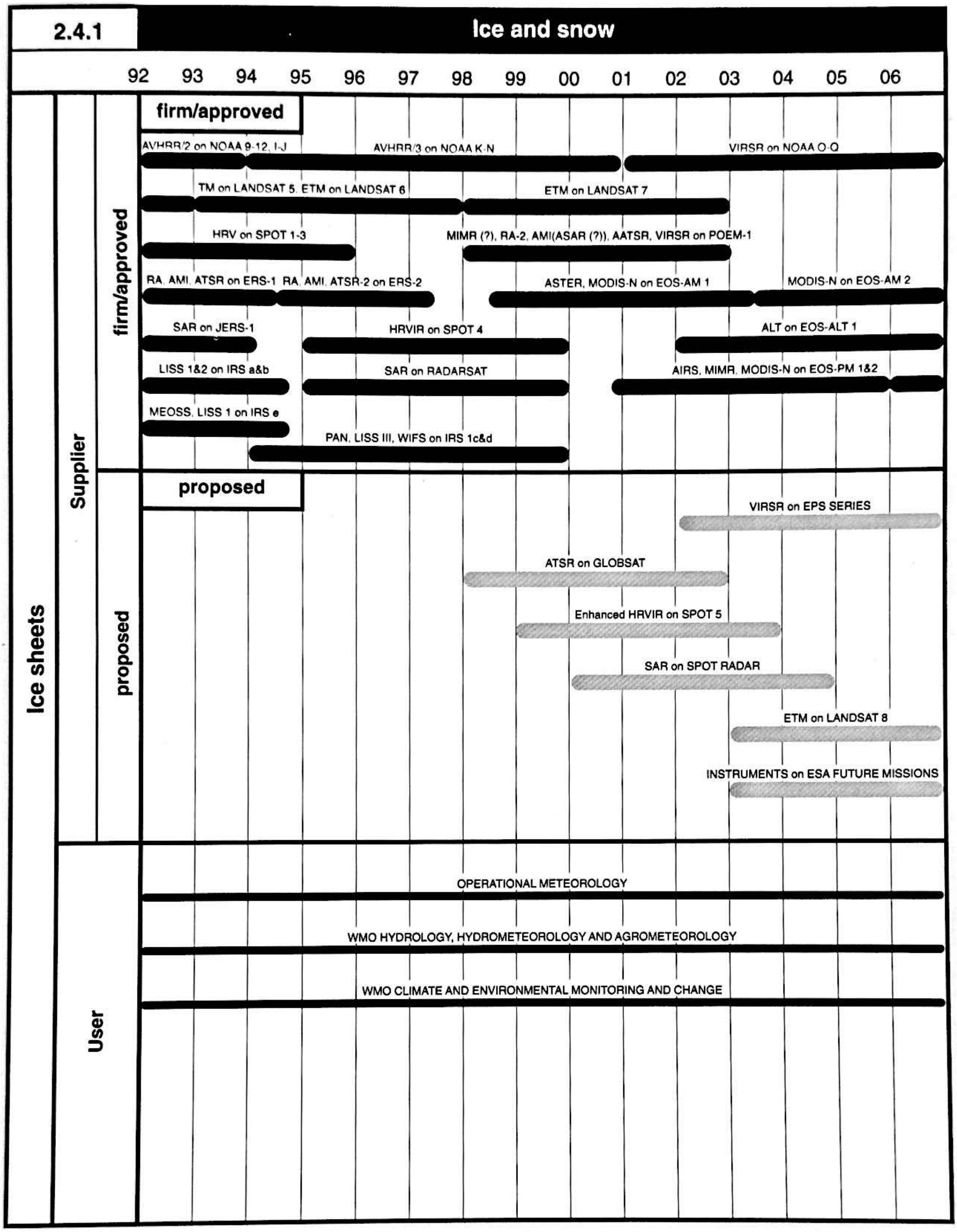
ARISTOTELES is crucial to the exploration of the Earth's interior, as well as in support of the applications based on accurate knowledge of the geoid (eg mean sea level and ocean currents).


2.3.7
Land
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Geoid measurements
Supplier
firm/approved
firm/approved
LAGEOS I
LAGEOS II
GGI on EOS-ALT 1
proposed
proposed
LAGEOS III
ARISTOTELES
User

2.4.1 Ice sheets

Requirements can be met for a number of parameters of interest including ice sheet surface profiles (altimeters), surface condition of ice sheets including accumulation rate and freeze/melt states (visible, infrared and passive microwave imagers) and ice sheet and glacier velocities (SAR and visible imagers).

Passive microwave and active radar instruments are both important as they are unaffected by cloud cover. It was noted in figure 2.1.7 that there is no planned civil source of passive microwave imaging after the end of the Japanese MOS-1B mission (mid-1992) until the end of the decade. During this period, the environmental community will rely on access to SSM/I data from the US military DMSP series.

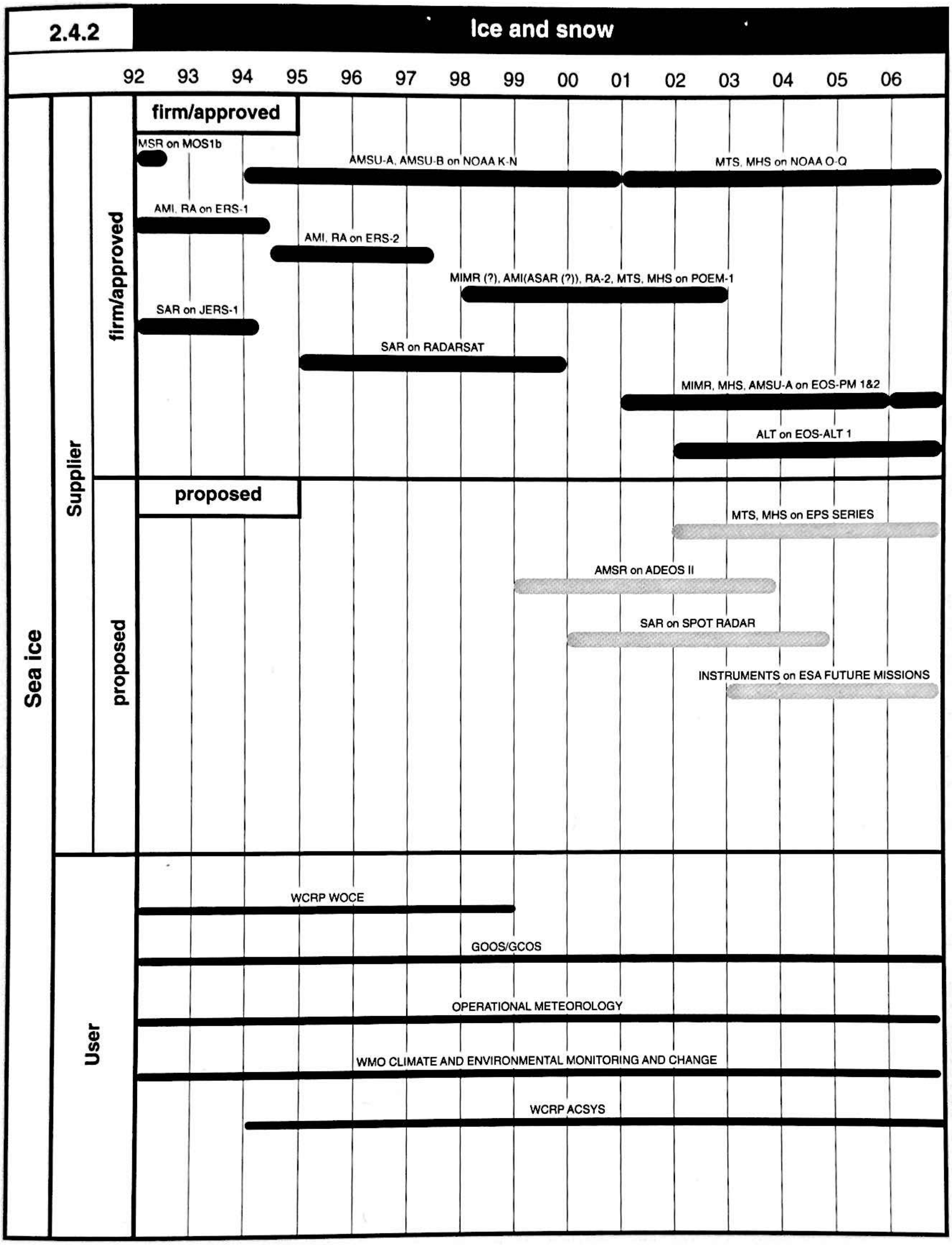


2.4.1
Ice and snow
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Ice sheets
Supplier
User
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
TM on LANDSAT 5
ETM on LANDSAT 6
ETM on LANDSAT 7
HRV on SPOT 1-3
MIMR (?), RA-2, AMI(ASAR (?)), AATSR, VIRSR on POEM-1
RA, AMI, ATSR on ERS-1
RA, AMI, ATSR-2 on ERS-2
ASTER, MODIS-N on EOS-AM 1
MODIS-N on EOS-AM 2
SAR on JERS-1
HRVIR on SPOT 4
ALT on EOS-ALT 1
LISS 1&2 on IRS a&b
SAR on RADARSAT
AIRS, MIMR, MODIS-N on EOS-PM 1&2
MEOSS, LISS 1 on IRS e
PAN, LISS III, WIFS on IRS 1c&d
proposed
VIRSR on EPS SERIES
ATSR on GLOBSAT
Enhanced HRVIR on SPOT 5
SAR on SPOT RADAR
ETM on LANDSAT 8
INSTRUMENTS on ESA FUTURE MISSIONS
OPERATIONAL METEOROLOGY
WMO HYDROLOGY, HYDROMETEOROLOGY AND AGROMETEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE

2.4.2 Sea ice

Sea ice type, concentration and dynamics are all of interest with passive microwave imagers and SAR being the main sensors of interest. Requirements for passive microwave imaging data can be met if SSM/I data can be accessed (see comments associated with figure 2.4.1). Sufficient SAR data should, in principle, be available provided the low duty cycle does not prevent coverage requirements being met. Provision of the Data Relay Satellite (DRS) and Tracking and Data Relay Satellite System (TDRSS) networks should help alleviate problems associated will lack of on-board storage capacity and ground stations.

Radar altimeters are included in the diagram on the grounds that they may be able to provide some information regarding thickness of sea ice. Ideally, high resolution instruments are needed and laser profilers have been suggested. These suffer from the double disadvantage of requiring considerable technological development and not being able to operate in cloudy conditions.



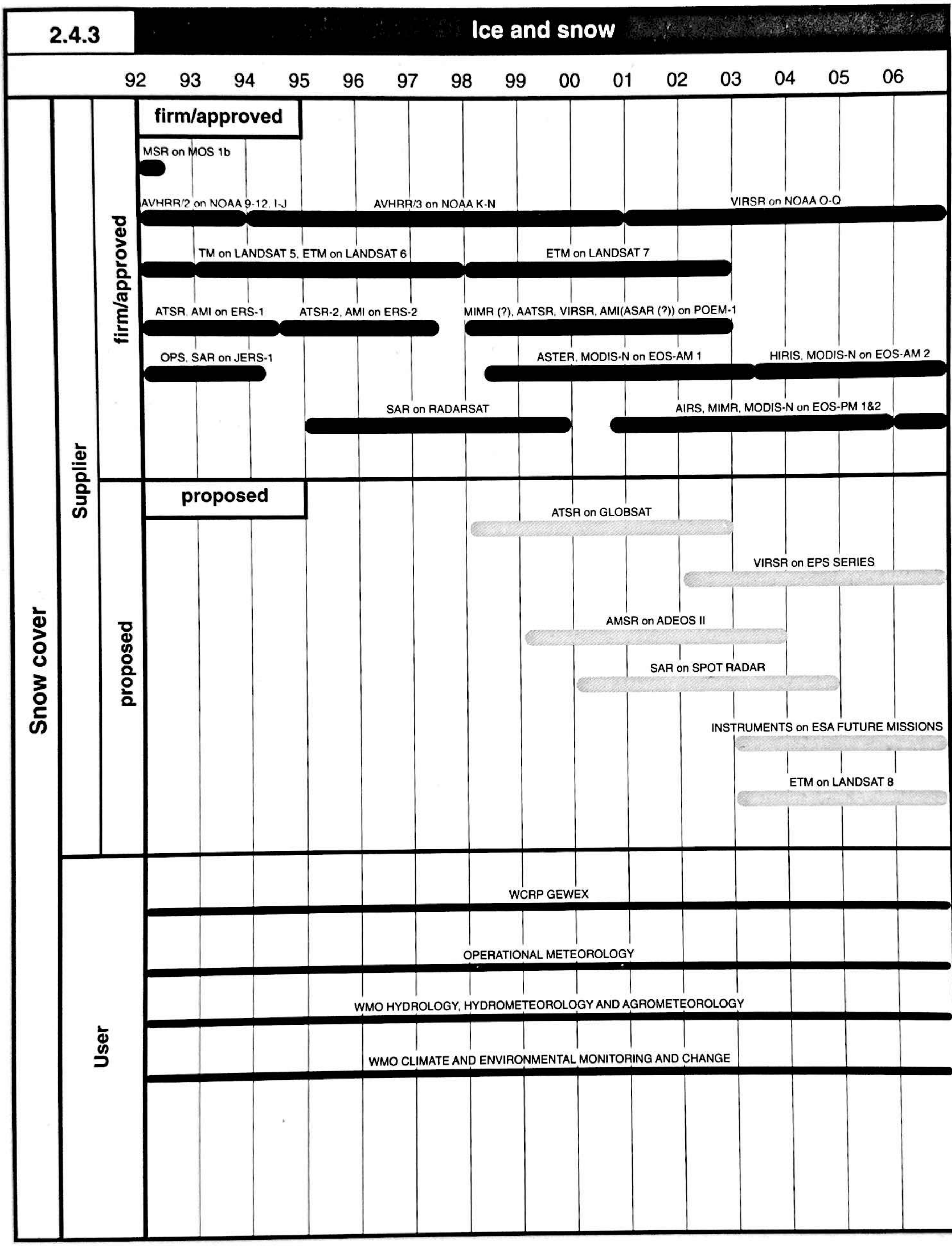
2.4.2
Ice and snow
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Sea ice
Supplier
User
firm/approved
MSR on MOS1b
AMSU-A, AMSU-B on NOAA K-N
MTS, MHS on NOAA O-Q
AMI, RA on ERS-1
AMI, RA on ERS-2
MIMR (?), AMI(ASAR (?)), RA-2, MTS, MHS on POEM-1
SAR on JERS-1
SAR on RADARSAT
MIMR, MHS, AMSU-A on EOS-PM 1&2
ALT on EOS-ALT 1
proposed
MTS, MHS on EPS SERIES
AMSR on ADEOS II
SAR on SPOT RADAR
INSTRUMENTS on ESA FUTURE MISSIONS
WCRP WOCE
GOOS/GCOS
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
WCRP ACSYS

2.4.3 Snow cover

Requirements can generally be met for snow cover assessment using visible, infrared and microwave sensors. Again, provision of microwave sensors is important for imaging through cloud.

Changes in snow cover patterns also affect the radiation budget, as the albedo and thermal properties of snow are different from those of underlying land.

Water content and snow depth cannot be currently measured by space based instruments. Some first order estimates of snow water equivalent are being made from SSM/I on the US military DMSP satellites. A combination of optical and microwave data is needed for snow grain size distribution and thus more accurate estimates of snow water equivalent.

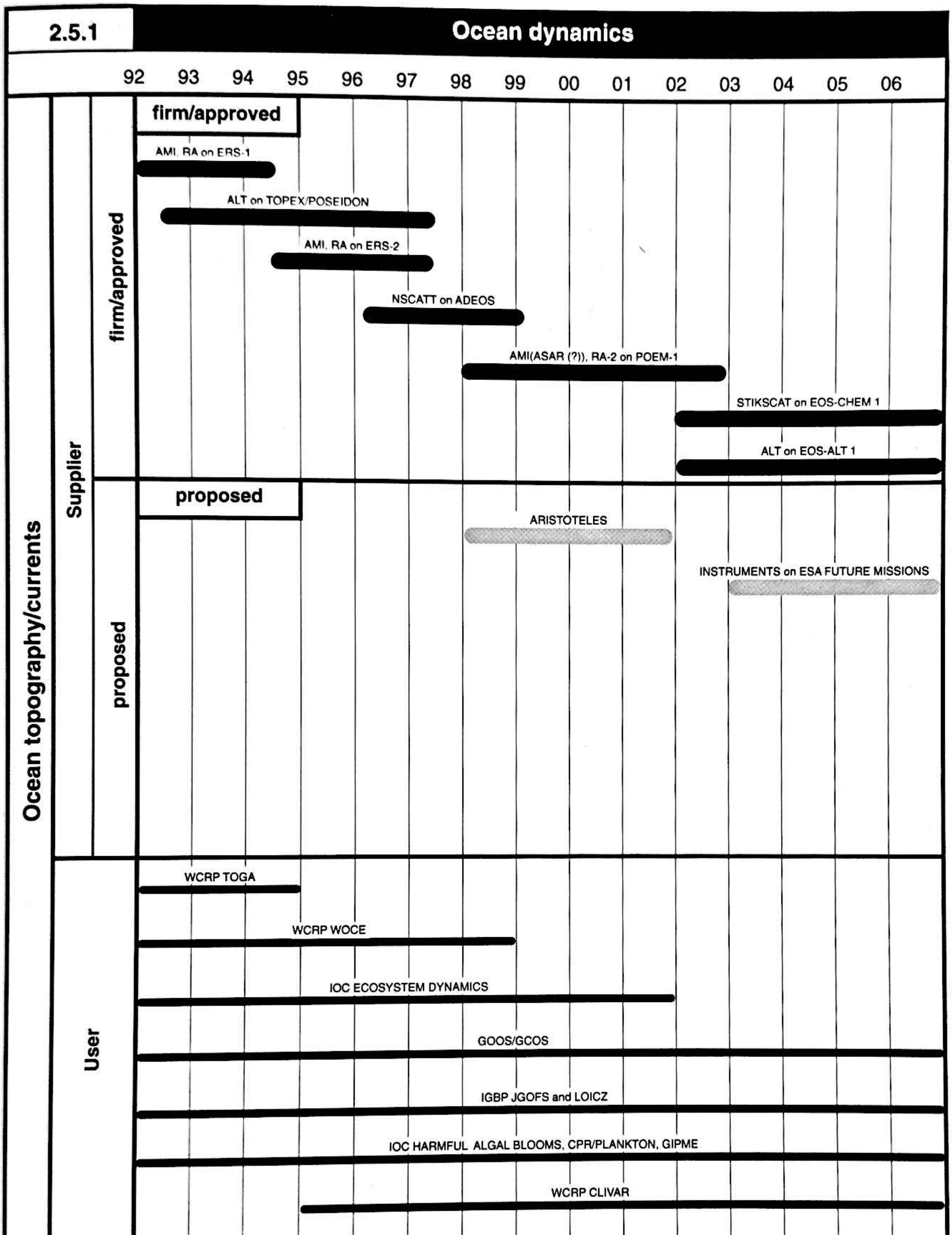

2.4.3
Ice and snow
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Snow cover
Supplier
firm/approved
MSR on MOS 1b
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
TM on LANDSAT 5, ETM on LANDSAT 6
ETM on LANDSAT 7
ATSR, AMI on ERS-1
ATSR-2, AMI on ERS-2
MIMR (?), AATSR, VIRSR, AMI(ASAR (?)) on POEM-1
OPS, SAR on JERS-1
ASTER, MODIS-N on EOS-AM 1
HIRIS, MODIS-N on EOS-AM 2
SAR on RADARSAT
AIRS, MIMR, MODIS-N on EOS-PM 1&2
proposed
ATSR on GLOBSAT
VIRSR on EPS SERIES
AMSR on ADEOS II
SAR on SPOT RADAR
INSTRUMENTS on ESA FUTURE MISSIONS
ETM on LANDSAT 8
User
WCRP GEWEX
OPERATIONAL METEOROLOGY
WMO HYDROLOGY, HYDROMETEOROLOGY AND AGROMETEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE

2.5.1 Ocean topography/currents

A range of instruments is shown to meet the requirements. Altimeters require very stable platforms and maximum stability is of high importance in the major environmental programmes using the data.

Additional data, not included in the figure, will be collected by the US military GEOSAT programme.

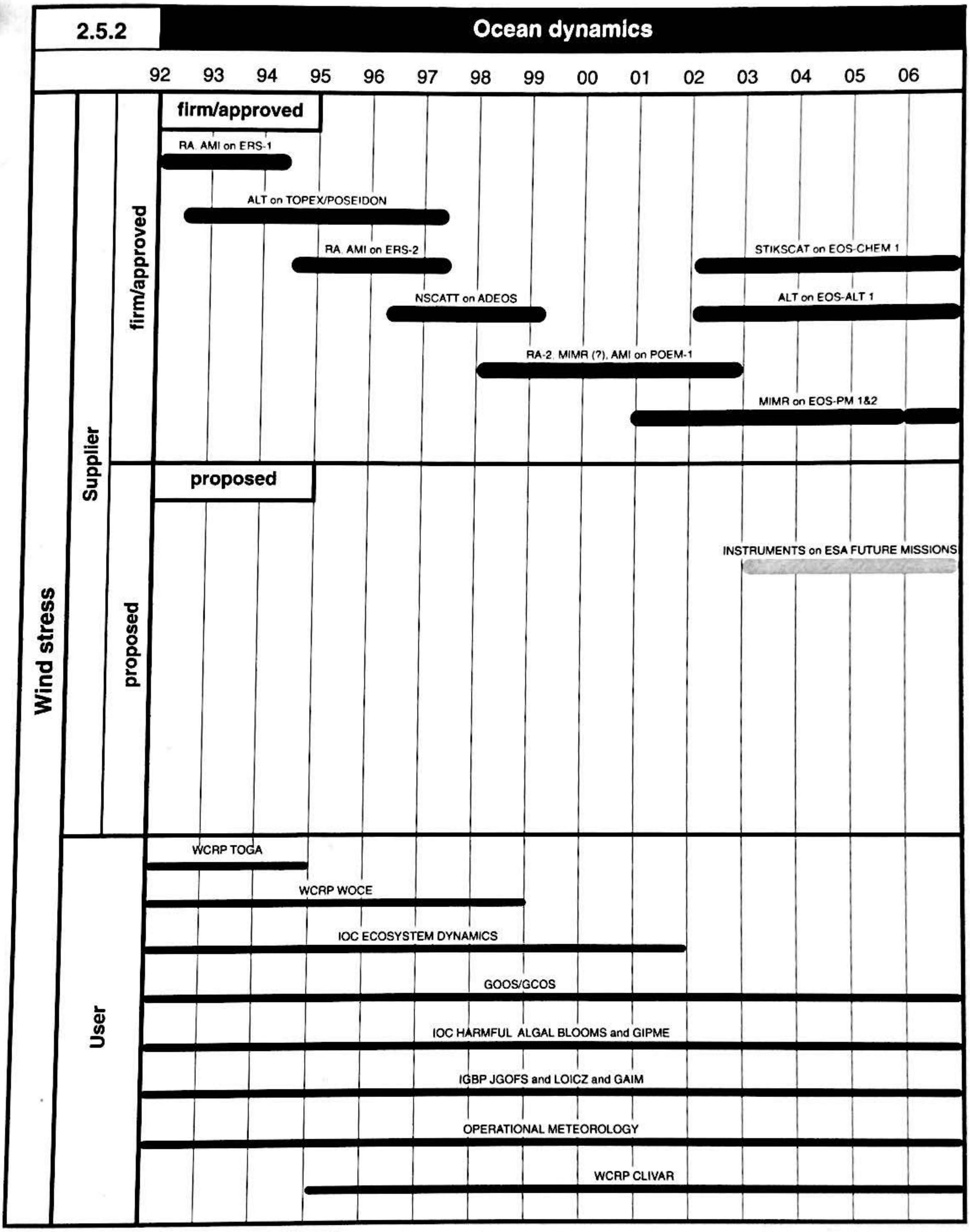
Missions such ARISTOTELES are seen as useful in providing better measurements of the Earth's geoid, which in turn provides enhanced topographic accuracy.


2.5.1
Ocean dynamics
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Ocean topography/currents
Supplier
firm/approved
firm/approved
AMI, RA on ERS-1
ALT on TOPEX/POSEIDON
AMI, RA on ERS-2
NSCATT on ADEOS
AMI(ASAR (?)), RA-2 on POEM-1
STIKSCAT on EOS-CHEM 1
ALT on EOS-ALT 1
proposed
proposed
ARISTOTELES
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP TOGA
WCRP WOCE
IOC ECOSYSTEM DYNAMICS
GOOS/GCOS
IGBP JGOFS and LOICZ
IOC HARMFUL ALGAL BLOOMS, CPR/PLANKTON, GIPME
WCRP CLIVAR

2.5.2 Wind stress

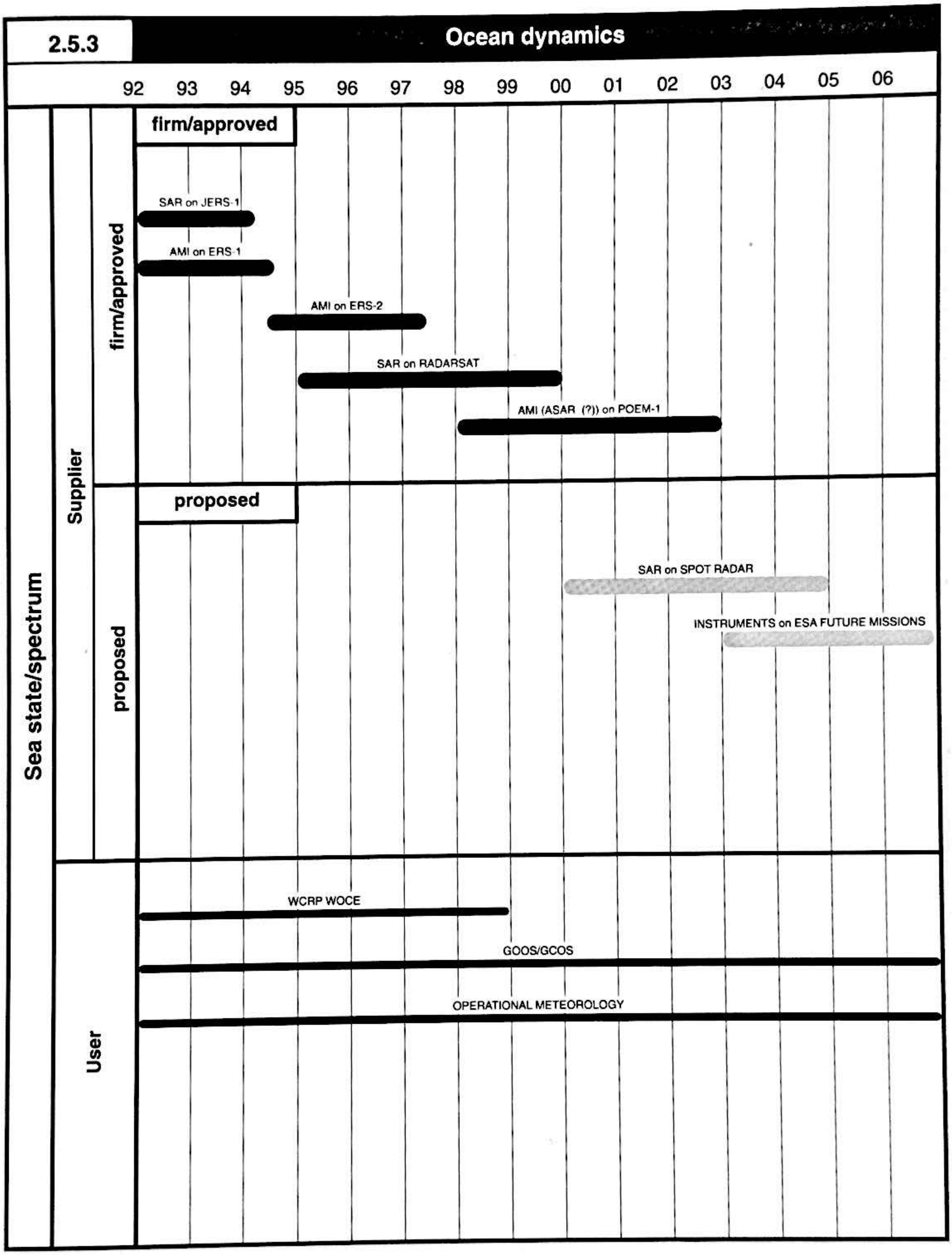
The active microwave scatterometer instrument currently flying on ERS-1 and planned for ERS-2 and POEM-1 does not meet the requirements for global coverage because it is a single side view instrument. An independent scatterometer, such as NSCATT on ADEOS or STIKSCAT on EOS-CHEM, will provide a wider swath width and hence better coverage, and is therefore preferred.

It should, however, be noted that if a scatterometer is not included on POEM-1, then there will be a 3 year gap in scatterometer data collection.


2.5.2
Ocean dynamics
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Wind stress
Supplier
firm/approved
firm/approved
RA. AMI on ERS-1
ALT on TOPEX/POSEIDON
RA. AMI on ERS-2
STIKSCAT on EOS-CHEM 1
NSCATT on ADEOS
ALT on EOS-ALT 1
RA-2. MIMR (?), AMI on POEM-1
MIMR on EOS-PM 1&2
proposed
proposed
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP TOGA
WCRP WOCE
IOC ECOSYSTEM DYNAMICS
GOOS/GCOS
IOC HARMFUL ALGAL BLOOMS and GIPME
IGBP JGOFS and LOICZ and GAIM
OPERATIONAL METEOROLOGY
WCRP CLIVAR

2.5.3 Sea state/spectrum

This can be measured using the SAR instrument but global coverage is a problem. DRS and TDRSS data relay networks should help to alleviate this issue.

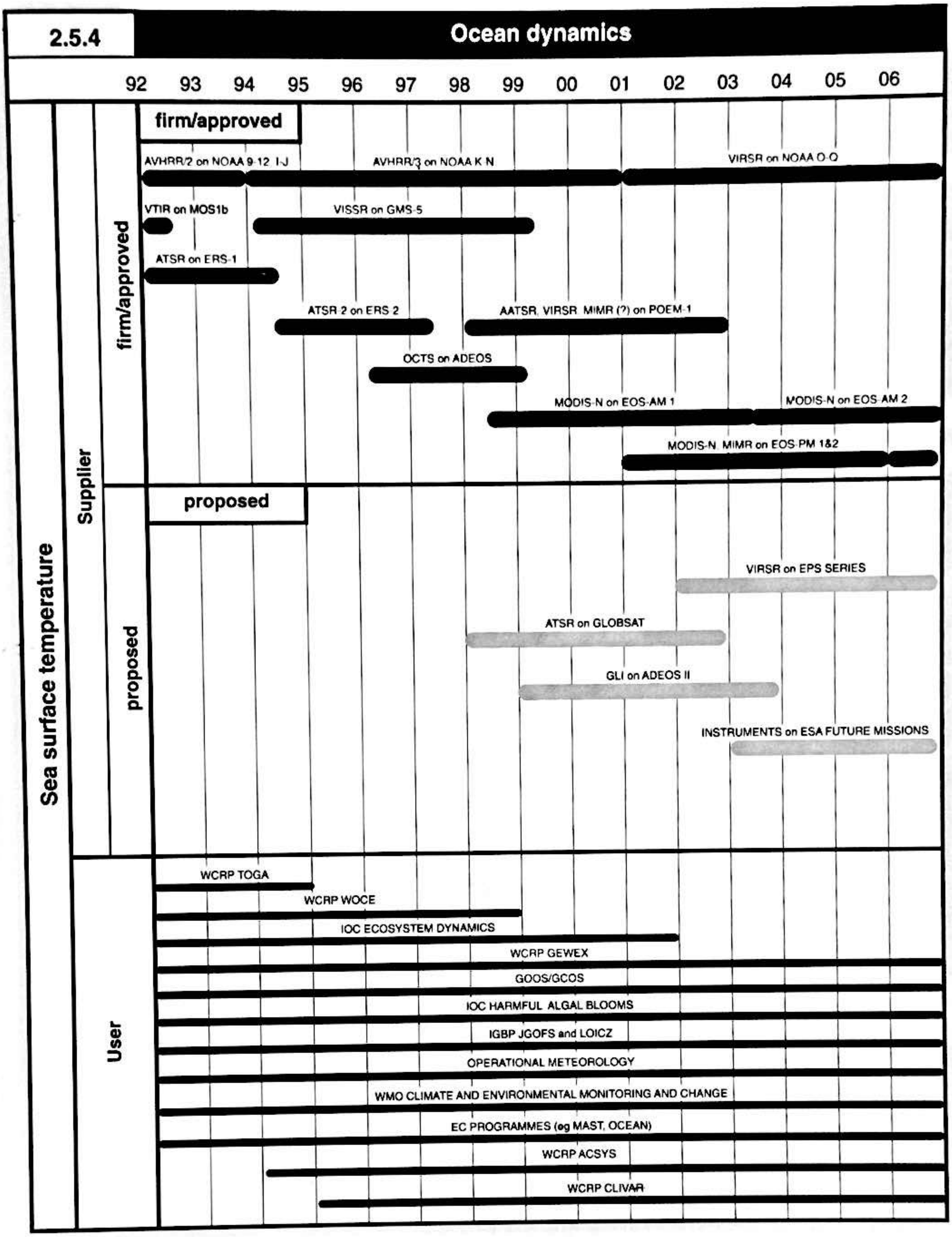


2.5.3
Ocean dynamics
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Sea state/spectrum
Supplier
User
firm/approved
SAR on JERS-1
AMI on ERS-1
AMI on ERS-2
SAR on RADARSAT
AMI (ASAR (?)) on POEM-1
proposed
SAR on SPOT RADAR
INSTRUMENTS on ESA FUTURE MISSIONS
WCRP WOCE
GOOS/GCOS
OPERATIONAL METEOROLOGY

2.5.4 Sea surface temperature

ATSR and AVHRR are the main instruments that provide data. ATSR measures temperature to higher accuracy but with poorer coverage than AVHRR.

MIMR will provide useful data during cloudy conditions, ensuring coverage and temporal resolution requirements can be met, although MIMR will not provide the high accuracy required for climate change studies.



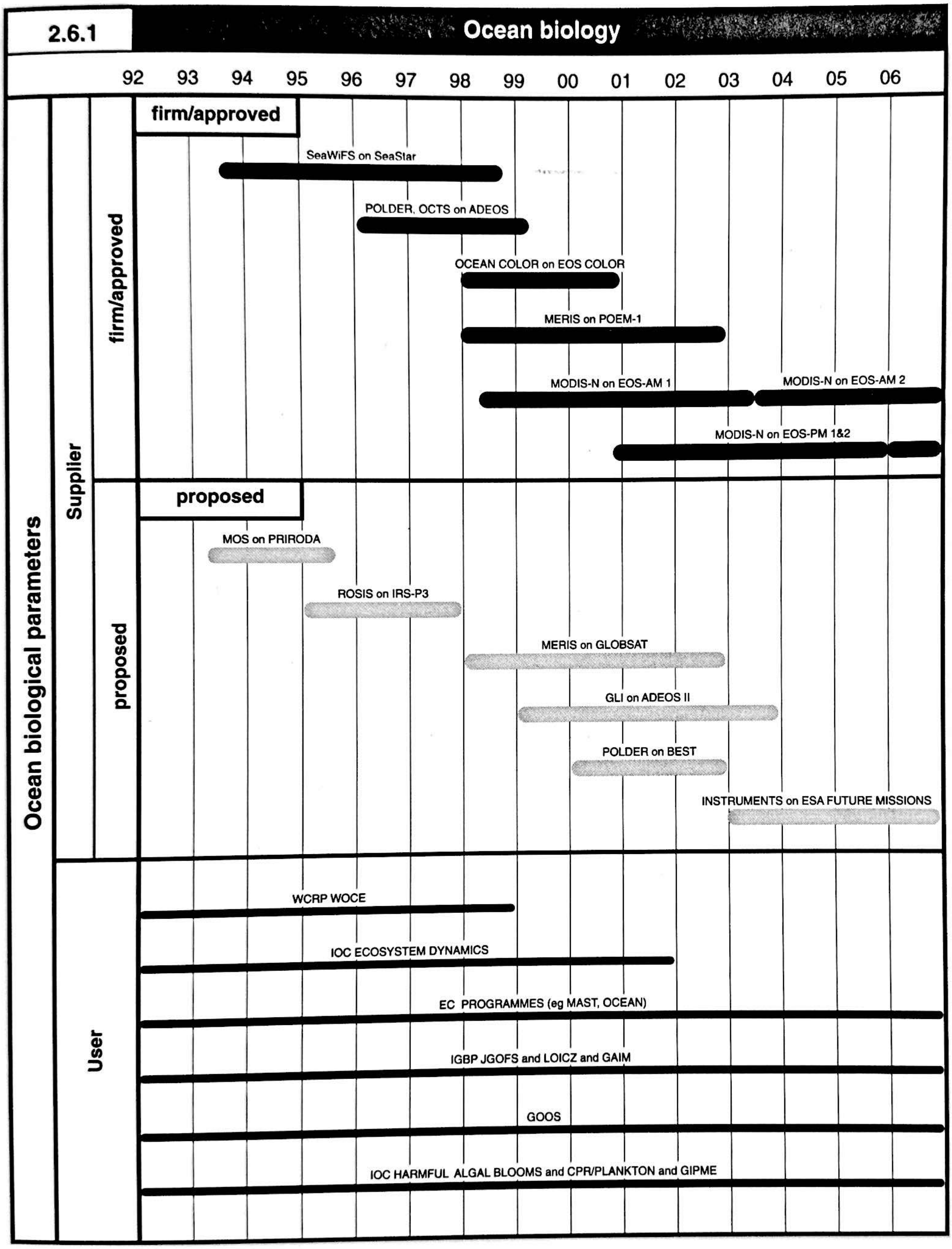
2.5.4
Ocean dynamics
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Sea surface temperature
Supplier
firm/approved
firm/approved
AVHRR/2 on NOAA 9-12, I-J
AVHRR/3 on NOAA K-N
VIRSR on NOAA O-Q
VTIR on MOS1b
VISSR on GMS-5
ATSR on ERS-1
ATSR-2 on ERS 2
AATSR, VIRSR, MIMR (?) on POEM-1
OCTS on ADEOS
MODIS-N on EOS-AM 1
MODIS-N on EOS-AM 2
MODIS-N, MIMR on EOS-PM 1&2
proposed
proposed
VIRSR on EPS SERIES
ATSR on GLOBSAT
GLI on ADEOS II
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP TOGA
WCRP WOCE
IOC ECOSYSTEM DYNAMICS
WCRP GEWEX
GOOS/GCOS
IOC HARMFUL ALGAL BLOOMS
IGBP JGOFS and LOICZ
OPERATIONAL METEOROLOGY
WMO CLIMATE AND ENVIRONMENTAL MONITORING AND CHANGE
EC PROGRAMMES (eg MAST, OCEAN)
WCRP ACSYS
WCRP CLIVAR

2.6.1 Ocean biological parameters

Until the flight of SeaWiFS in 1993, there is no instrument capable of measuring ocean colour in orbit. The upgraded sensors, capable of determining ocean biological parameters more accurately (higher spectral bandwidth and resolution) such as MERIS and MODIS-N, are extremely important.

Current NASA plans call for the instrument on the EOS-COLOR spacecraft to be a replica of the SeaWiFS instrument flown on the SeaStar mission.

For some programmes, the SeaWiFS mission, alone, will not provide sufficient global coverage. From 1998 adequate coverage should be provided with a variety of instruments in orbit.


2.6.1
Ocean biology
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Ocean biological parameters
Supplier
firm/approved
firm/approved
SeaWiFS on SeaStar
POLDER, OCTS on ADEOS
OCEAN COLOR on EOS COLOR
MERIS on POEM-1
MODIS-N on EOS-AM 1
MODIS-N on EOS-AM 2
MODIS-N on EOS-PM 1&2
proposed
proposed
MOS on PRIRODA
ROSIS on IRS-P3
MERIS on GLOBSAT
GLI on ADEOS II
POLDER on BEST
INSTRUMENTS on ESA FUTURE MISSIONS
User
WCRP WOCE
IOC ECOSYSTEM DYNAMICS
EC PROGRAMMES (eg MAST, OCEAN)
IGBP JGOFS and LOICZ and GAIM
GOOS
IOC HARMFUL ALGAL BLOOMS and CPR/PLANKTON and GIPME

A Satellite Missions

A.1 Introduction

This section gives details of the satellite missions of CEOS members. A brief description of those missions that are currently in service is given, with follow-on missions and new initiatives being displayed graphically in a conventional timeline figure. The lines shaded black in the figure represent missions that are currently in service, whilst those shaded grey represent all other missions that are planned but are not yet launched.

There are various levels of uncertainty associated with the planned missions. This uncertainty can arise from several sources:

- changes in funding levels;
- policy changes;
- changes in instrument suites, eg to minimise technical risks, as a result of inter-agency negotiations or in response to user requirements.

Thus, although there are many missions shown in the following figure, it must be remembered that the majority of these are not guaranteed. Any decisions based on planned missions must, therefore, be caveated to reflect this fact.

This annex details all the missions chronologically by launch date. For each of the missions, the following information is supplied:

- status, ie in service or planned, the latter comprising firm/approved, probable and possible categories indicating increasing uncertainty;
- launch date and expected mission duration;
- orbit details;
- instrument suite;
- primary mission application areas corresponding to those discussed in section 2.

Instruments on these missions are listed alphabetically in annex B. The mission(s) on which they feature and the detailed measurements that they perform are also given.

Where the instrument suite is very uncertain or the subject of negotiation, particular instruments have been marked with a question mark (?) or with the acronym TBC (to be confirmed).

A.2 Current missions

The missions currently in orbit and taking data are discussed briefly below.

Landsat and SPOT: The US operated Landsat and French operated SPOT satellites provide high resolution imagery in a range of visible and infrared bands. They are used extensively for high resolution land studies.

Geostationary meteorological satellites: There is a worldwide network of operational geostationary meteorological satellites which provides visible and infrared images of the Earth's surface and atmosphere. Countries with current geostationary operational meteorological satellites include the USA (GOES series), Europe (METEOSAT series) and Japan (GMS series).

IRS series: The Indian IRS satellites provide high resolution imagery in a range of visible and infrared bands. Their primary objectives are national mappings of various resources.

NOAA polar orbiters: The current series of operational polar orbiting meteorological satellites is provided by NOAA. Two satellites are maintained in polar orbit at any one time, one in a "morning" orbit and one in an "afternoon" orbit. The series provides a wide range of data of interest, including sea surface temperature, cloud cover, data for land studies, temperature and humidity profiles and ozone concentrations.

MOS 1b: The main purpose of this Japanese satellite is to establish the fundamental technologies for Earth observation and to carry out practical observations of the Earth, primarily of the ocean. Its sensors operate in the visible, near infrared, thermal infrared and microwave bands.

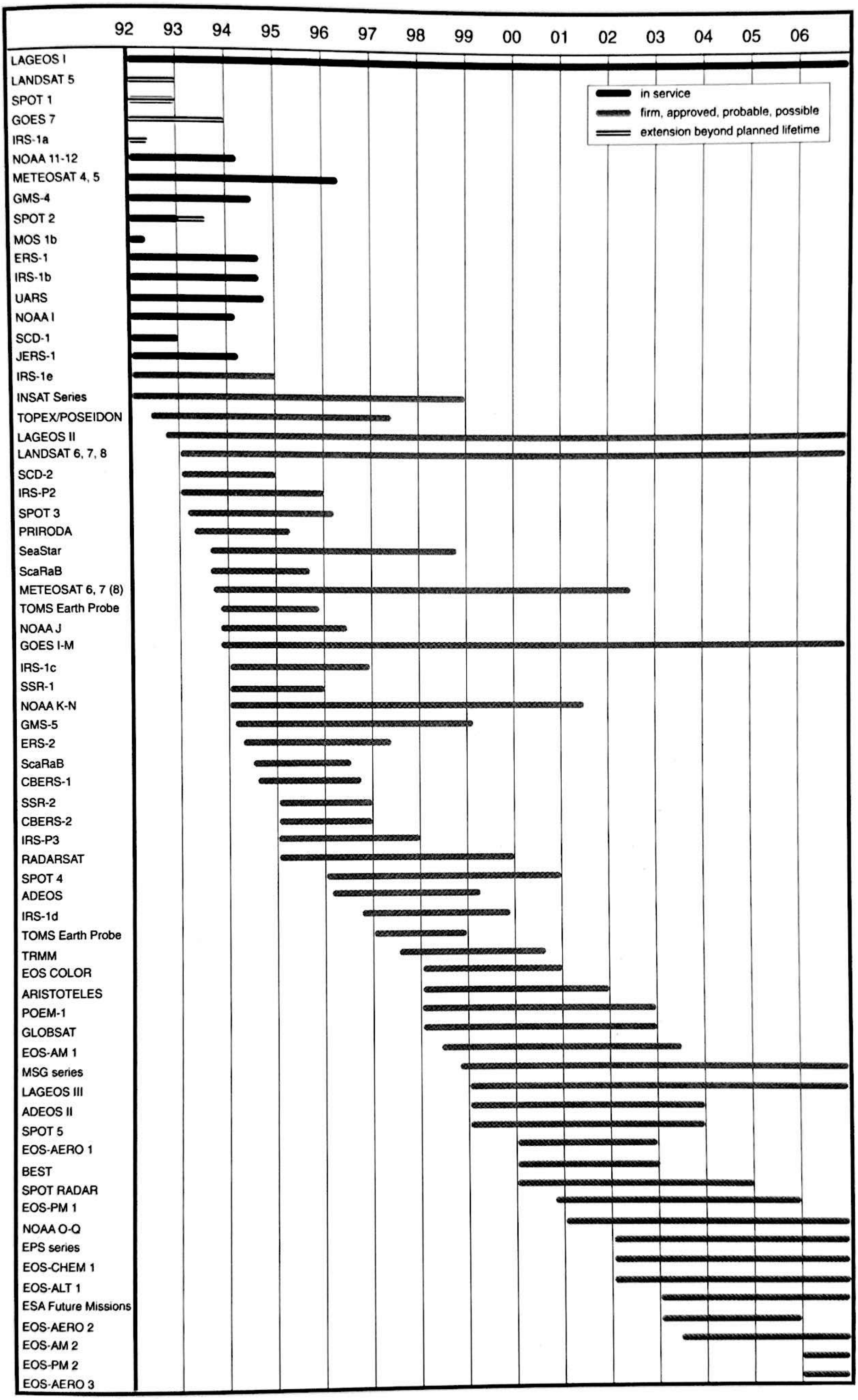
ERS-1: This was launched by ESA in July 1991. It is the first of a series of missions planned for the 1990s that concentrate on global and regional environmental issues. It makes use of active microwave techniques that enable a range of measurements to be made of land, sea and ice surfaces independent of cloud cover. In addition, the ATSR instrument provides images of the surface or cloud top.

UARS: Launched in September 1991 by NASA, this provides a comprehensive platform for the study of middle atmosphere chemistry and physics.

JERS-1: The aim of JERS-1 is to observe the Earth using optical sensors and a high resolution synthetic aperture radar. Land surveys and monitoring of various resources are the main application areas of this satellite.

SCD-1: This Brazilian satellite receives environmental data gathered on the ground and transmits it to other locations.

LAGEOS: This mission is designed to measure the Earth's crustal motion and the Earth's gravitational field. The space segment comprises corner cube laser retroreflectors and the ground segment is a global network of transportable laser sites. The design life of the space segment is 10000 years.


92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
in service
firm, approved, probable, possible
extension beyond planned lifetime
LAGEOS I
LANDSAT 5
SPOT 1
GOES 7
IRS-1a
NOAA 11-12
METEOSAT 4, 5
GMS-4
SPOT 2
MOS 1b
ERS-1
IRS-1b
UARS
NOAA I
SCD-1
JERS-1
IRS-1e
INSAT Series
TOPEX/POSEIDON
LAGEOS II
LANDSAT 6, 7, 8
SCD-2
IRS-P2
SPOT 3
PRIRODA
SeaStar
ScaRaB
METEOSAT 6, 7 (8)
TOMS Earth Probe
NOAA J
GOES I-M
IRS-1c
SSR-1
NOAA K-N
GMS-5
ERS-2
ScaRaB
CBERS-1
SSR-2
CBERS-2
IRS-P3
RADARSAT
SPOT 4
ADEOS
IRS-1d
TOMS Earth Probe
TRMM
EOS COLOR
ARISTOTELES
POEM-1
GLOBSAT
EOS-AM 1
MSG series
LAGEOS III
ADEOS II
SPOT 5
EOS-AERO 1
BEST
SPOT RADAR
EOS-PM 1
NOAA O-Q
EPS series
EOS-CHEM 1
EOS-ALT 1
ESA Future Missions
EOS-AERO 2
EOS-AM 2
EOS-PM 2
EOS-AERO 3

Mission (Agency)	Status	Launch Date/ Duration	Orbit Details	Instruments	Primary Application Areas
LAGEOS I (NASA)	in service	1976 10000 year design life	110 degree inclination, 5900km	Laser retroreflectors	Crustal motion, Gravity field
LANDSAT 4 (NOAA)	in service	July 1982 3 years	Near polar sun synchronous, 705km	MSS, TM	Land
LANDSAT 5 (NOAA)	in service	Mar 1984 3 years	Near polar sun synchronous, 705km	MSS, TM	Land
SPOT 1 (CNES)	in service	Feb 1986 3 years	Sun synchronous	HRV	Land
GOES 7 Geostationary Operational Environmental Satellite (NOAA)	in service	Feb 1987 5 years	Geostationary	VAS, SEM, WEFAX, DCS	Atmospheric dynamics/water and energy cycles
IRS-1a Indian Remote Sensing Satellite (ISRO)	in service	Mar 1988 3 years	Polar, sun-synchronous	LISS I&II	Land
METEOSAT 3 (EUMETSAT)	in service	June 1988 3 years	Geostationary	MVIRI	Atmospheric dynamics/water and energy cycles
NOAA 11 (NOAA)	in service	Sept 1988 31 months	Polar, sun synchronous, 850km, pm crossing	AVHRR/2, HIRS/2, SSU, MSU, SBUV/2, S&R, ARGOS, SEM	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
METEOSAT 4 (EUMETSAT)	in service	Mar 1989 5 years	Geostationary	MVIRI	Atmospheric dynamics/water and energy cycles
GMS-4 Geostationary Meteorological Satellite 4 (JMA/NASDA)	in service	Sept 1989 5 years	Geostationary	VISSR	Atmospheric dynamics/water and energy cycles
SPOT 2 (CNES)	in service	Jan 1990 3 years	Sun synchronous	HRV	Land
MOS 1b Marine Observation Satellite (NASDA)	in service	Feb 1990 2 years	Sun synchronous	MSR, VTIR, MESSR	Ice and snow, Atmospheric dynamics/water and energy cycles, Ocean dynamics, Land
METEOSAT 5 (EUMETSAT)	in service	Mar 1991 5 years	Geostationary	MVIRI	Atmospheric dynamics/water and energy cycles
NOAA 12 (NOAA)	in service	May 1991 31 months	Polar, sun synchronous 850km, am crossing	AVHRR/2, HIRS/2, MSU, ARGOS, SEM	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
ERS-1 European Remote Sensing Satellite (ESA)	in service	July 1991 3 years	Polar	AMI (SAR & SCAT), RA, ATSR	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles
IRS-1b Indian Remote Sensing Satellite (ISRO)	in service	Aug 1991 3 years	Polar, sun synchronous	LISS I&II	Land

Mission (Agency)	Status	Launch Date/ Duration	Orbit Details	Instruments	Primary Application Areas
UARS Upper Atmosphere Research Satellite (NASA)	in service	Sept 1991 3 years	57 degree inclination	PEM, SOLSTICE, SUSIM, WINDII, HRDI, HALOE, MLS, ISAMS, CLAES, ACRIM II	Atmospheric chemistry, Atmospheric dynamics/water and energy cycles
NOAA I (NOAA)	in service	Sept 1991 2.5 years	Near polar, sun synchronous, pm crossing	AVHRR/2, HIRS/2, SSU, MSU, SBUV/2, S&R, ARGOS, SEM, MAXIE, EHIC	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
SCD-1 (INPE)	in service	1992 1 year	25 degree inclination	Data Collection Platform Transponder	Relays data gathered by DCPs on ground
JERS-1 Japanese Earth Resources Satellite (NASDA)	in service	Feb 1992 2 years	Sun synchronous	OPS, SAR	Land
INSAT IIa (ISRO)	firm	1992 7 years (series)	Geostationary	VHRR, S&R, DWS, DCP	Atmospheric dynamics/water and energy cycles
IRS-1e Indian Remote Sensing Satellite (ISRO)	firm	1992 3 years	Polar, sun synchronous	MEOSS, LISS I	Land
TOPEX/ POSEIDON Topography Experiment (CNES/NASA)	firm	July 1992 5 years	66 degree inclination, 1336km	DORIS, SSALT, ALT, TMR, LRA, GPSDR	Ocean dynamics
LAGEOS II (ASI/NASA)	firm	Sept 1992 10000 years design life	52 degree inclination, 5900km	Laser retroreflectors	Crustal motion, Gravity field
INSAT IIb (ISRO)	firm	1993 7 years (series)	Geostationary	VHRR, S&R, DWS, DCP	Atmospheric dynamics/water and energy cycles
SCD-2 (INPE)	probable	1993 2 years	25 degree inclination	Data Collection Platform Transponder, plus technical instruments	Relays data gathered by DCPs on ground
IRS-P2 Indian Remote Sensing Satellite (ISRO)	firm	1993 3 years	Polar, sun synchronous	LISS II & others	Land
LANDSAT 6 (NOAA)	firm	Jan 1993 5 years	Near polar, sun synchronous, am crossing	ETM	Land

Mission (Agency)	Status	Launch Date/ Duration	Orbit Details	Instruments	Primary Application Areas
SPOT 3 (CNES)	firm	Mar 1993 3 years	Sun synchronous	HRV	Land
PRIRODA (DARA/ Russian Academy of Sciences)	probable	Apr 1993 2 years	51.6 degree inclination, 300km (MIR space station)	MOS	Oceans, Land
SeaStar (NASA)	firm	Aug 1993 5 years		SeaWIFS	Ocean biology
ScaRaB (CNES/DARA/ CIS)	firm	Sept 1993 2 years	50 degree inclination	ScaRaB	Radiation budget
METEOSAT 6 (EUMETSAT)	firm	Sept 1993 5 years	Geostationary	MVIRI	Atmospheric dynamics/water and energy cycles
TOMS Earth Probe (NASA)	firm	Dec 1993 2 years	Sun synchronous, 966km	TOMS	Atmospheric chemistry
NOAA J (NOAA)	firm	Dec 1993 2.5 years	Near polar, sun synchronous, am crossing	AVHRR/2, HIRS/2, SSU, MSU, S&R, ARGOS, SEM, RAIDS	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
GOES I Geostationary Operational Environmental Satellite (NOAA)	firm	Dec 1993 5 years	Geostationary	IMAGER, SOUNDER, WEFAX, DCS, SEM	Atmospheric dynamics/water and energy cycles
IRS-1c Indian Remote Sensing Satellite (ISRO)	firm	1994 3 years	Polar, sun synchronous	PAN, LISS III, WIFS	Land
NOAA K (NOAA)	firm	1994 2.5 years	Near polar sun synchronous afternoon orbit	AMSU A, AMSU B, HIRS/3, AVHRR/3, ARGOS, SEM, SBUV/2, S&R	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
SSR-1 (INPE)	probable	1994 2 years	Sun synchronous	CCD camera	Land
ScaRaB (CNES/DARA/ CIS)	probable	1994	50 degree inclination	ScaRaB	Radiation budget
INSAT IIc (ISRO)	possible	1994 7 years (series)	Geostationary	VHRR, S&R, DWS, DCP	Atmospheric dynamics/water and energy cycles

Mission (Agency)	Status	Launch Date/ Duration	Orbit Details	Instruments	Primary Application Areas
GOES J Geostationary Operational Environmental Satellite (NOAA)	firm	1994 5 years	Geostationary	IMAGER, SOUNDER, WEFAX, DCS, SEM	Atmospheric dynamics/water and energy cycles
GMS-5 Geostationary Meteorological Satellite 5 (JMA/NASDA)	firm	Feb 1994 5 years	Geostationary	VISSR	Atmospheric dynamics/water and energy cycles, Oceans
ERS-2 European Remote Sensing Satellite (ESA)	firm	April 1994 3 years	Polar	GOME, AMI (SAR & SCAT), RA, ATSR-2, PRARE	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric Chemistry
CBERS-1 (INPE/CHINA)	probable	Sept 1994 2 years	Sun synchronous	CCD camera, IR scanner, DCP transponder, scientific instruments	Land
RADARSAT (CSA)	firm	1995 5 years	Sun synchronous pm crossing, 789km	SAR	Ice and Snow, Land, Oceans
SSR-2 (INPE)	probable	1995 2 years	Sun synchronous	CCD camera	Land
CBERS-2 (INPE/CHINA)	probable	1995 2 years	Sun synchronous	CCD camera, IR scanner, DCP transponder, scientific instruments	Land
INSAT IId (ISRO)	possible	1995 7 years (series)	Geostationary	VHRR, S&R, DWS, DCP	Atmospheric dynamics/water and energy cycles
IRS-P3 Indian Remote Sensing Satellite (ISRO)	possible	1995 3 years	Polar, sun synchronous	SCIAMACHY, ROSIS	Atmospheric chemistry, Ocean biology
LAGEOS III (ASI)	possible	1995 10000 year design life	70 degree inclination, 5900km	Laser retroreflectors	Crustal motion, Gravity field
METEOSAT 7 (EUMETSAT)	firm	Dec 1995 5 years	Geostationary	MVIRI	Atmospheric dynamics/water and energy cycles
SPOT 4 (CNES)	firm	1996 5 years	Sun synchronous	HRVIR, VEGETATION	Land

Mission (Agency)	Status	Launch Date/ Duration	Orbit Details	Instruments	Primary Application Areas
NOAA L (NOAA)	firm	1996 2.5 years	Near polar, sun synchronous, afternoon orbit	AMSU A, AMSU B, HIRS/3, AVHRR/3, ARGOS, SEM, S&R	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmopsheric chemistry
ADEOS Advanced Earth Observing System (NASDA)	firm	Feb 1996 3 years	Sun synchronous	POLDER, TOMS, NSCAT, IMG, ILAS, RIS, AVNIR, OCTS	Atmospheric dynamics/water and energy cycles, Atmospheric chemistry, Land, Ocean dynamics, Ocean biology
IRS-1d Indian Remote Sensing Satellite (ISRO)	firm	1996-1997 3 years	Polar, sun synchronous	PAN, LISS III, WIFS	Land
NOAA M (NOAA)	firm	1997 2.5 years	Near polar, sun synchronous, afternoon orbit	AMSU A, AMSU B, HIRS/3, AVHRR/3, ARGOS, SEM, SBUV/2, S&R	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
TOMS Earth Probe (NASA)	firm	1997 2 years	Sun synchronous, 966km	TOMS	Atmospheric chemistry
METEOSAT 8 (EUMETSAT)	possible	mid 1997 5 years	Geostationary	MVIRI	Atmospheric dynamics/water and energy cycles
TRMM Tropical Rainfall Measuring Mission (NASA/ NASDA)	firm	Aug 1997 3 years	35 degree inclination, 350km	TMI, PR, CERES, VIRS, LIS	Atmospheric dynamics/water and energy cycles
LANDSAT 7 (USA)	firm	1998 5 years	Near polar, sun synchronous, am crossing	ETM	Land
ARISTOTELES (NASA/ESA)	possible	1998 4 years	Quasi-polar, 200km for 6 months, 480km for 3 years	Gravity gradiometer, GPS receiver, Vector and Scalar Magnetometer	Ocean dynamics, Land
POEM-1 (ESA)	firm	1998 5 years	Polar	VIRSR, IRTS, IASI(?), MTS, MHS, SEM, S&R, MERIS, MIPAS, MIMR(?), RA-2, AMI (ASAR(?)), SCIAMACHY, GOMOS, AATSR, ScaRaB or CERES, PRAREE	Atmospheric dynamics/water and energy cycles, Atmospheric chemistry, Ocean dynamics, Ocean biology, Land, Ice and Snow
EOS COLOR Earth Observing System COLOR (NASA)	approved	1998 3 years	TBD	Ocean color	Ocean biological parameters
GLOBSAT (CNES)	possible	1998 5 years	Sun synchronous, 850km, am crossing	ScaRaB, MERIS, MIPAS, SCIAMACHY, IASI, GOMOS, ATSR, AMAS (TBC)	Atmospheric chemistry, Oceans, Atmospheric dynamics/water and energy cycles, Land, Ice and snow
GOES K Geostationary Operational Environmental Satellite (NOAA)	firm	1998 5 years	Geostationary	IMAGER, SOUNDER, WEFAX, DCS, SEM	Atmospheric dynamics/water and energy cycles

Mission (Agency)	Status	Launch Date/ Duration	Orbit Details	Instruments	Primary Application Areas
EOS-AM 1 Earth Observing System AM 1 (NASA)	approved	June 1998 5 years	Polar, sun synchronous, am crossing	ASTER, CERES, MISR, MODIS-N, MOPITT	Atmospheric dynamics/water and energy cycles, Atmospheric chemistry, Ocean biological parameters, Land
MSG series Meteosat Second Generation (EUMETSAT)	probable	Dec 1998 series expected to last for at least 10 years	Geostationary	SEVIRI - basic imaging mission, SEVERI - air mass analysis mission	Atmospheric dynamics/water and energy cycles
ADEOS II Advanced Earth Observing System (NASDA)	probable	1999 5 years	Polar	AMSR, GLI, AVNIR and others	Land, Ocean and Atmospheric studies
NOAA N (NOAA)	firm	1999 2.5 years	Near polar sun synchronous afternoon orbit	AMSU A, AMSU B, HIRS/3, AVHRR/3, ARGOS, SEM, SBUV/2, S&R	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
SPOT 5 (CNES)	possible	1999 5 years	Sun synchronous	Enhanced HRVIR, VEGETATION	Land
GOES L Geostationary Operational Environmental Satellite (NOAA)	firm	1999 5 years	Geostationary	IMAGER, SOUNDER, WEFAX, DCS, SXI(TBC), SEM	Atmospheric dynamics/water and energy cycles
ESA Future Missions (ESA)	possible	2000 onwards	Polar	POEM-1 instruments, ALADIN, AMAS, ASCATT, ATLID, Rain/Cloud radar	TBC
EOS-AERO 1 Earth Observing System AERO 1 (NASA)	approved	2000 3 years	57 degree inclination	SAGE III	Atmospheric chemistry
BEST Bilan Energetique du Systeme Tropical (CNES)	possible	2000 3 years	28 degree inclination, 430km	Rain radar, Wind lidar, DIAL, Microwave radiometer, ScaRaB, POLDER	Atmospheric dynamics/water and energy cycles
SPOT RADAR (CNES)	possible	2000 5 years	Sun synchronous	SAR (TBC)	Land, Oceans, Ice and Snow
EOS-PM 1 Earth Observing System PM 1 (NASA)	approved	Dec 2000 5 years	Polar, sun synchronous, pm crossing	MIMR, MODIS-N, AMSU A, MHS, AIRS, CERES	Atmospheric dynamics/water and energy cycles, Ice and Snow, Land, Ocean biology
NOAA O (NOAA)	firm	2001 3 years	Near polar, sun synchronous, afternoon orbit	VIRSR, IRTS, MTS, MHS, SEM, LEFI, SBUV/3, TOMS, ARGOS, S&R	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry

Mission (Agency)	Status	Launch Date/ Duration	Orbit Details	Instruments	Primary Application Areas
EPS series European Polar System (EUMETSAT)	possible	2002 series expected to last at least 10 years	Polar, sun synchronous, approximately 800km	VIRSR, MTS, MHS, IRTS, IASI, ARGOS, S&R, SEM	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
EOS-CHEM 1 Earth Observing System CHEM 1 (NASA)	approved	2002 5 years	Polar	SAGE III, STIKSCAT, TES, HIRDLS	Atmospheric chemistry, Atmospheric dynamics/water and energy cycles
EOS-ALT 1 Earth Observing System ALT 1 (NASA)	approved	2002 5 years	Polar	GLRS-A, GGI, ALT	Ocean dynamics, Ice and Snow, Land
LANDSAT 8 (USA)	possible	2003 5 years	Near polar	ETM	Land
GOES M Geostationary Operational Environmental Satellite (NOAA)	firm	2003 5 years	Geostationary	IMAGER, SOUNDER, WEFAX, DCS, SXI(TBC), SEM	Atmospheric dynamics/water and energy cycles
EOS-AERO 2 Earth Observing System AERO 2 (NASA)	approved	2003 3 years	57 degree inclination	SAGE III	Atmospheric chemistry
EOS-AM 2 Earth Observing System AM 2 (NASA)	approved	Jun 2003 5 years	Polar, sun synchronous, am crossing	CERES, MODIS-N, MISR, HIRIS, EOSP	Atmospheric dynamics/water and energy cycles, Atmospheric chemistry, Ocean biology, Land
NOAA P (NOAA)	firm	2004 3 years	Near polar, sun synchronous, afternoon orbit	VIRSR, IRTS, MTS, MHS, SEM, LEFI, SBUV/3, TOMS, ARGOS, S&R	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry
EOS-PM 2 Earth Observing System PM 2 (NASA)	approved	Dec 2005 5 years	Polar sun synchronous pm crossing	MIMR, MODIS-N, AMSU-A, CERES, (AIRS/MHS) or replacement	Atmospheric dynamics/water and energy cycles, Ice and Snow, Land, Ocean biology
EOS-AERO 3 Earth Observing System AERO 3 (NASA)	approved	2006 3 years	57 degree inclination	SAGE III	Atmospheric chemistry
NOAA Q (NOAA)	firm	2007 3 years	Near polar, sun synchronous, afternoon orbit	VIRSR, IRTS, MTS, MHS, SEM, LEFI, SBUV/3, TOMS, ARGOS, S&R	Oceans, Land, Ice and Snow, Atmospheric dynamics/water and energy cycles, Atmospheric chemistry

B SATELLITE INSTRUMENTS

B.1 Introduction

This annex lists all instruments alphabetically. For each instrument, the following information is given:

- the mission(s) that the instrument is expected to fly on. Details of the mission can be found in annex A;
- the measurements that the instrument can perform.

Instrument	Mission(s)	Measurements
ACRIM-II - Active Cavity Radiometer Irradiance Monitor	UARS	Broadband radiation budget (solar irradiance)
AIRS - Advanced Infrared Sounder	EOS-PM 1&2	Atmospheric temperature, Surface emissivity, Total O_3, Snow cover, Ice cover, Cloud top height
ALADIN - Atmospheric Laser Doppler Instrument	ESA Future Missions	3-D winds
ALT - Dual Frequency Radar Altimeter	TOPEX/ POSEIDON	Ocean currents and topography, Ocean wind stress, Water on land
ALT - Altimeter	EOS-ALT 1	Ocean ice sheet topography maps, Along track sea surface height, Ocean Wind Stress, Water on land, Wave heights, Ocean topography
AMAS - Advanced Millimetre wave Atmospheric Sounder	ESA Future Missions, GLOBSAT	Temperature profiles, Trace gases in upper troposphere to mesosphere including ClO, O_3, H_2O, CO
AMI - Active Microwave Instrument	ERS-1, ERS-2, POEM-1	Surface wind fields, Wave spectra, Ice mapping, All weather images, Snow cover, Sea state, Ocean stress, Soil moisture
AMSR - Advanced Microwave Scanning Radiometer	ADEOS II	Atmospheric water vapour and liquid water content over ocean, Sea ice and snow on land
AMSU-A - Advanced Microwave Sounding Unit A	NOAA K-N, EOS-PM 1&2	Atmospheric temperature profiles, Cloud liquid water content, Ice boundary, Precipitation
AMSU-B - Advanced Microwave Sounding Unit B	NOAA K-N	Atmospheric humidity profiles, Cloud cover, Cloud liquid water content, Ice boundaries, Precipitation
ARGOS	NOAA 9-12, I-Q, EPS series	Data collection and location system
ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer	EOS-AM 1	High resolution surface and cloud imaging, Stereoscopic imaging, Local surface digital elevation maps, Cloud heights, Volcanic plumes, Surface temperature and emissivity
ATLID - Atmospheric Lidar	ESA Future Missions	Cloud top heights, Vertical distribution of clouds, Upper atmosphere composition, Aerosol profiles, Tropopause height, Boundary layer height
ATSR - Along Track Scanning Radiometer	ERS-1, GLOBSAT	Sea surface temperature, Land surface temperature, Precipitation, Cloud cover and height, Albedo, Snow cover, Soil moisture, Water on land, Ice sheets, Aerosols, Vegetation
ATSR-2 - Along Track Scanning Radiometer	ERS-2	Sea surface temperature, Land surface temperature, Precipitation, Cloud cover and height, Albedo, Snow cover, Soil moisture, Water on land, Ice sheets, Aerosols, Vegetation
(A)ATSR - Advanced Along Track Scanning Radiometer	POEM-1	Sea surface temperature, Land surface temperature, Precipitation, Cloud cover and height, Albedo, Snow cover, Soil moisture, Water on land, Ice sheets, Aerosols, Vegetation

Instrument	Mission(s)	Measurements
AVHRR/2 - Advanced Very High Resolution Radiometer	NOAA 9-12, NOAA I-J	Sea surface temperature, Land surface temperature, Precipitation, Cloud cover, Albedo, Snow cover, Soil moisture, Water on land, Ice sheets, Aerosols, Vegetation
AVHRR/3 - Advanced Very High Resolution Radiometer	NOAA K-N	Sea surface temperature, Land surface temperature, Precipitation, Cloud cover, Albedo, Snow cover, Soil moisture, Water on land, Ice sheets, Aerosols, Vegetation, Additional new channel for snow/cloud discrimination
AVNIR - Advanced Visible and Near Infrared Radiometer	ADEOS, ADEOS II	High resolution land and coastal zone imaging
CCD Camera	MECB (SSR1&SSR2)	Vegetation monitoring
CCD Camera	CBERS-1&2	Vegetation monitoring
CERES - Clouds and Earth's Radiant Energy System	POEM-1, TRMM, EOS-AM 1&2, EOS-PM 1&2	Radiation budget, Albedo, Cloud cover, Cloud liquid water content, Shortwave and longwave optical depths,
CLAES - Cryogenic Limb Array Etalon Spectrometer	UARS	Stratospheric profiles of minor gases including N_2O, NO, NO_2, ClO, H_2O, O_3, CH_4
DCP - Data Collection Platform Transponder	CBERS-1&2	Repeater of information gathered by DCPs on ground
DIAL - Differential Atmospheric Lidar	BEST	Atmospheric temperature profiles, Atmospheric humidity profiles, Trace gas profiles
DORIS - Doppler Orbitography and Radio Positioning Integrated by Satellite	TOPEX/ POSEIDON	Satellite ranging instrument
EHIC - Energetic Heavy Ion Composition Experiment	NOAA I	Energetic solar flare particles and trapped energetic particles in the magnetosphere
EOSP - Earth Observing and Scanning Polarimeter	EOS-AM 2	Global maps of radiance and linear polarisation, Global aerosol distribution, Optical thickness and phase of clouds
ERBE - Earth's Radiation Budget Experiment	NOAA 9, 10	Earth radiation gains and losses
ETM - Enhanced Thematic Mapper	Landsat 6, 7, 8	Surface radiance and emittance, Ice sheets
GGI - GPS Geoscience Instrument	EOS-ALT 1	Global geodesy, Accurate platform positioning, Temperature profiles

Instrument	Mission(s)	Measurements
GLI - Global Imager	ADEOS II	Ocean colour, Sea surface temperature
GLRS-A - Geoscience Laser Ranging System - Altimeter only	EOS-ALT 1	Ocean altimetry
GOME - Global Ozone Monitoring Experiment	ERS-2	Tropospheric and stratospheric O_3 profiles, Total column amounts of other minor species and aerosols
GOMOS - Global Ozone Monitoring by Occultation of Stars	GLOBSAT, POEM-1, ESA Future Missions	Stratospheric profiles of O_3, NO_2, H_2O, ClO_x, Aerosols, Temperature profiles
GPS receiver	ARISTOTELES	Pseudo-range (10cm) and carrier phase shift (2mm) determination
GPSDR - GPS Demonstration Receiver	TOPEX/POSEIDON	Decimeter platform tracking
Gravity gradiometer	ARISTOTELES	High precision determination of gravity field gradient tensor
HALOE - Halogen Occultation Experiment	UARS	Stratospheric profiles of hydrofluoric and hydrochloric acids, CH_4, O_3, H_2O, NO, NO_2 and other minor species
HIRDLS - High Resolution Dynamics Limb Sounder	EOS-CHEM 1	Upper troposphere to mesosphere profiles of temperature, Aerosols, O_3, H_2O, N_2O, NO_2, CH_4, and other minor species, Location of polar stratospheric clouds and cloud tops, Horizontal winds
HIRIS - High Resolution Imaging Spectrometer	EOS-AM 2	Vegetation, Soil minerals, APAR, Snow distribution and characteristics, Aerosol optical depth, Column ozone, Cloud cover
HIRS/2 - 20 channel High Resolution Infra-red Sounder	NOAA 9-12, NOAA I-J	Atmospheric temperature profiles, Humidity soundings, Water vapour, Total ozone content, Cloud cover
HIRS/3 - High Resolution Infra-red Sounder	NOAA K-N	Atmospheric temperature profiles, Humidity soundings, Water vapour, Total ozone content, Cloud cover
HRDI - High Resolution Doppler Imager	UARS	Stratospheric wind measurements
HRV - High Resolution Visible	SPOT 1, 2 & 3	High resolution images
HRVIR - High Resolution Visible and Infrared	SPOT 4	High resolution images - one more channel than SPOT 3 HRV
IASI - Infra-red Atmospheric Sounding Interferometer	POEM-1, EPS series, GLOBSAT, ESA Future Missions	Tropospheric moisture and temperature, Column integrated contents of O_3, CO, CH_4, N_2O, Aerosols
ILAS - Improved Limb Atmospheric Spectrometer	ADEOS	Stratospheric minor species measurements (O_3, CH_4, NO_2, N_2O, H_2O, CFC12, HNO_3, Aerosols, Temperature, Pressure) in high latitude areas

Instrument	Mission(s)	Measurements
IMAGER	GOES I-M	Cloud cover, Cloud motion vectors
IMG - Interferometric Monitor for Greenhouse Gases	ADEOS	Measurements of CO_2, CH_4, N_2O and other greenhouse gases
IR scanner	CBERS-1&2	
IRTS - Infra-red Temperature Sounder (successor to HIRS/3)	POEM-1, NOAA O-Q, EPS series	Atmospheric temperature soundings, Humidity soundings, Water vapour, Total ozone content, Cloud cover
ISAMS - Improved Stratospheric and Mesospheric Sounder	UARS	Stratospheric profiles of NO_x, O_3, Water vapour, CH_4, CO, Aerosols
LEFI - Local Electric Field Instrument	NOAA O-Q	Ambient vector electric field
LIS - Lightning Imaging Sensor	TRMM	Used in conjunction with other TRMM sensors to determine global rates, amounts and distribution of precipitation
LISS I - Linear Imaging Self Scanning System	IRS-1e, IRS-1a&b	Regional land cover
LISS II - Linear Imaging Self Scanning System	IRS-P2, IRS-1a&b	Regional land cover
LISS III - Linear Imaging Self Scanning System	IRS-1c, IRS-1d	Regional land cover
LRA - Laser Retroreflector Array	TOPEX/POSEIDON	Precision orbit tracking
MAXIE - Magnetospheric Atmospheric X-ray Imaging Experiment	NOAA I	Intensities and energy wave spectra of X-rays produced by electrons that precipitate into the atmosphere
MEOSS - Monocular Electro Optic Stereo Scanner	IRS-1e	Stereo images for use in regional land cover studies
MERIS - Medium Resolution Imaging Spectrometer	POEM-1, GLOBSAT, ESA Future Missions	Vegetation, Ocean biological parameters
MESSR - Multispectral Electronic Self Scanning Radiometer	MOS 1b	Atmospheric and oceanic measurements, Land surface imaging

Instrument	Mission(s)	Measurements
MHS - Microwave Humidity Sounder (successor to AMSU-B)	POEM-1, EOS-PM 1&2, ESA Future Missions, EPS series, NOAA O-Q	Atmospheric humidity profiles, Cloud cover, Cloud liquid water content, Ice boundaries, Precipitation
MIMR - Multi frequency Imaging Microwave Radiometer	POEM-1, EOS-PM 1&2, ESA Future Missions	Precipitation, Cloud liquid water content, Cloud cover, Water vapour, Temperature profiles, Sea surface roughness, Sea surface winds, Sea surface temperature, Sea ice (boundary), Snow cover, Soil moisture, Ice sheets
MIPAS - Michelson Interferometric Passive Atmosphere Sounder	POEM-1, GLOBSAT, ESA Future missions	Upper troposphere to mesosphere profiles of O_3, ClO_x, CH_4, H_2O, NO_x and other minor species
MISR - Multi angle Imaging Spectro Radiometer	EOS-AM 1&2	Radiation budget, Albedo, Cloud cover, Aerosol opacities, Vegetation cover, Bidirectional reflectance
MLS - Microwave Limb Sounder	UARS	Stratospheric profiles of ClO, H_2O, O_3, Horizontal mesospheric wind component
MODIS-N - Moderate Resolution Imaging Spectrometer - Nadir	EOS-AM 1&2, EOS-PM 1&2	Ice sheets, Vegetation, Ocean biological parameters, Land surface temperature, Sea surface temperature, Snow cover, Cloud cover, Aerosol properties
MOPITT - Measurements of Pollutants in the Troposphere	EOS-AM 1	Tropospheric profiles of CO, Column CH_4
MOS - Modular Optoelectronic Scanning Spectrometer	PRIRODA	Ocean colour imaging, Land vegetation, Atmospheric turbidity
MSR - Microwave Scanning Radiometer	MOS 1b	Sea ice, Snow cover, Atmospheric water vapour (over oceans), Liquid water content (over oceans)
MSS - Multi-spectral Scanner System	LANDSAT 4-5	Surface radiance
MSU - Microwave Sounding Unit	NOAA 9-12, NOAA I-J	Temperature soundings (through cloud), Precipitation
MTS - Microwave Temperature Sounder (successor to AMSU A)	POEM-1, NOAA O-Q, ESA Future Missions, EPS series	Atmospheric temperature profiles, Cloud liquid water content, Ice boundary, Precipitation
MVIRI - METEOSAT Visible and Infra Red Imager	METEOSAT 3-7	Cloud cover, Cloud motion winds, Cloud top heights, Upper troposphere humidity values, Precipitation estimates
NSCATT - NASA Scatterometer	ADEOS	Surface wind over the sea, Ocean currents and topography
Ocean color	EOS COLOR	Ocean Biological Parameters

Instrument	Mission(s)	Measurements
OCTS - Ocean Colour and Temperature Scanner	ADEOS	Ocean biological parameters, Sea surface temperature
OPS - Optical Sensors	JERS-1	High resolution optical land imaging
PAN - Panchromatic sensor	IRS-1c, IRS-1d	Stereo images for use in regional land cover studies
PEM - Particle Environment Monitor	UARS	UV and charged particle energy inputs
POLDER - Polarisation and Directionality of the Earth's Reflectance	ADEOS, BEST	Surface Albedo, Aerosols, Surface reflectance, Primary production over land and ocean, Earth's shortwave radiation
PR - Precipitation Radar	TRMM	Rainfall rates over land and oceans
PRARE - Precise Range and Range Rate Equipment	ERS-2	Satellite ranging data
PRAREE - Precise Range and Range Rate Equipment Extended version	POEM-1, ESA Future Missions	Satellite ranging data, Plate motion, Crustal deformation, Gravity field
RA - Radar Altimeter	ERS-1, ERS-2	Sea ice, Ocean currents and topography, Ocean wind stress, Water on land, Ice sheets
RA-2 - Radar Altimeter 2	POEM-1, ESA Future Missions	Ocean currents and topography, Ocean wind stress, Sea ice, Water on land, Ice sheets
RAIDS - Remote Atmospheric and Ionospheric Detection System	NOAA J	Ionospheric electron density through limb scanning
Rain radar	BEST	Precipitation
RIS - Retroreflector In Space	ADEOS	Ozone, Fluorocarbons, CO_2 and other minor species
ROSIS - Reflective Optics System Imaging Spectrometer	IRS-P3	Water pollution, Marine biology and ecology, Carbon and nitrogen cycles, Aerosol load
SAGE-III - Stratospheric Aerosol and Gas Experiment III	EOS-CHEM 1, EOS-AERO 1,2&3	Stratospheric profiles of O_3, H_2O, NO_2, OClO, Other minor species, Aerosols, Temperature and Pressure
SAR - Synthetic Aperture Radar	SPOT RADAR	Soil moisture, Ice mapping, Wind fields, Wave spectra, All weather images, Ice/snow cover, Vegetation, Water on land
SAR - Synthetic Aperture Radar	JERS-1	Soil moisture, Ice mapping, Wind fields, Wave spectra, All weather images, Ice/snow cover, Vegetation, Water on land
SAR - Synthetic Aperture Radar	RADARSAT	Soil moisture, Ice mapping, Wind fields, Wave spectra, All weather images, Ice/snow cover, Vegetation, Water on land
(A)SAR - Advanced Synthetic Aperture Radar	POEM-1 (TBC), ESA Future Missions	Soil moisture, Ice mapping, Wind fields, Wave spectra, All weather images, Ice/snow cover, Vegetation, Water on land

Instrument	Mission(s)	Measurements
SBUV/2 - Solar Backscatter Ultra-Violet Instrument	NOAA 9, 11, NOAA I, K, M, N	Trace gases including ozone distribution
SBUV/3 - Solar Backscatter Ultra-Violet Instrument	NOAA O-Q	Trace gases including ozone distribution
ScaRaB - Scanner for Earth's Radiation Budget	ScaRaB missions, GLOBSAT, POEM-1, BEST	Top of atmosphere shortwave radiation budget and total radiation budget, Cloud detection
(A)SCATT - Advanced Scatterometer	ESA Future Missions	Surface wind over the sea, Ocean currents and topography
SCD1&SCD2	MECB	Repeater of data gathered by DCPs on ground
SCIAMACHY - Scanning Imaging Absorption Spectrometer for Atmospheric Cartography	POEM-1, GLOBSAT, ESA Future Missions, IRS-P3	Middle atmosphere temperature, Tropospheric and stratospheric profiles of O_3, CO, NO_2, CH_4, H_2O, ClO, OClO and other minor species, Aerosols
SeaWiFS - Sea viewing Wide Field Sensor	SeaStar	Ocean Biological Parameters
SEM - Space Environment Monitor	GOES-7, GOES I-M, NOAA 9-12, NOAA K-N, EPS series, POEM-1	Flux of charged particles, Electric and magnetic fields at satellite altitude
SEVIRI - Spinning Enhanced Visible and Infrared Imager	MSG series	Cloud cover, Cloud top height, Precipitation estimates, Cloud motion winds, Vegetation, Radiative fluxes, Convection monitoring, Air mass analysis, Cirrus cloud discrimination, Tropopause monitoring, Stability monitoring, Total ozone
SOLSTICE - Solar/Stellar Irradiance Comparison Experiment	UARS	UV and charged particle energy inputs
SOUNDER	GOES I-M	Atmospheric soundings
SSALT - Single Frequency Solid State Radar Altimeter	TOPEX/POSEIDON	Ocean currents and topography, Ocean wind stress, Sea ice, Water on land, Ice sheets
SSU - Stratospheric Sounding Unit	NOAA 9-11, NOAA I-J	Temperature profiles, Top of atmosphere radiation budget

Instrument	Mission(s)	Measurements
STIKSCAT - Stick Scatterometer	EOS-CHEM 1	Surface wind speeds and direction
SUSIM - Solar Ultraviolet Spectral Irradiance Monitor	UARS	UV energy input
S&R - Search and Rescue	NOAA 9-11, NOAA I-Q, POEM-1, EPS series	Monitoring distress calls
SXI - Solar X-ray Imager	GOES L or M only	X-ray emissions from the sun
TES - Tropospheric Emission Spectrometer	EOS-CHEM 1	Tropospheric profiles of O_3, CO, CH_4, H_2O, NO_x, Acid rain precursors, Gas exchange leading to stratospheric O_3 depletion
TM - Thematic Mapper	LANDSAT 4-5	Surface radiance, Ice sheets
TMI - TRMM Microwave Imager	TRMM	Rainfall rates over oceans (and less accurately over land). Used in conjunction with PR instrument on TRMM
TMR - TOPEX Microwave Radiometer	TOPEX/POSEIDON	Water vapour corrections for altimeter
TOMS - Total Ozone Mapping Spectrometer	NOAA O-Q, NASA Earth Probe, ADEOS	Total ozone changes, Changes in UV radiation, Observation of SO_2
VAS - Visible and Infrared Spin Scan Radiometer	GOES-7	Visible and IR images of the Earth's surface and atmosphere, Winds
Vector and scalar magnetometer	ARISTOTELES	Earth's gravity field
VEGETATION	SPOT 4 & 5	Global monitoring of the continental biosphere
VHRR	INSAT IIa-d	Visible and infrared images of the Earth
VIRS - Visual Infrared Scanner	TRMM	Used in conjunction with CERES instrument to determine cloud radiation
VIRSR - Visible and Infrared Scanning Radiometer (successor to AVHRR)	EPS series, POEM-1, ESA Future Missions, NOAA O-Q	Sea surface temperature, Land surface temperature, Precipitation, Cloud cover, Albedo, Snow cover, Soil moisture, Water on land, Ice sheets, Aerosol profiles, Vegetation, Snow/cloud discrimination, Water vapour/cirrus discrimination
VISSR - Visible and Infrared Spin Scan Radiometer	GMS-4&5	Clouds, Cloud motion winds, Sea surface temperature, Atmospheric water vapour (GMS-5)
VTIR - Visible and Thermal Infrared Radiometer	MOS 1b	Cloud coverage, Sea surface temperature
WEFAX - Weather Faxsimile	GOES-7, GOES I-M, GMS 4&5, METEOSAT 3-8	Low resolution transponded image and other data
Wide Field Imager	CBERS 1&2	

Instrument	Mission(s)	Measurements
WIFS - Wide Field Sensor	IRS-1c, IRS-1d	Vegetation index mapping
WINDII - Wind Imaging Interferometer	UARS	High altitude wind measurements
Wind lidar	BEST	3-D winds

C ENVIRONMENTAL PROGRAMMES AND AGENCIES

C.1 Introduction

This annex gives a brief background description of the environmental programmes included in the assessment of satellite data requirements. The list of programmes is not exhaustive and will continue to evolve as new programmes are defined. The programmes of principal interest in this document are those which address global environmental issues but it also includes regional projects (eg on polar ice caps, rain forests) which provide information of interest in the global context.

C.2 World Meteorological Organization (WMO)

Draft WMO satellite data requirements were presented at the April 1992 CEOS meeting in London, based on the results of the WMO Executive Council Panel of Experts on Satellites which met in March 1992. It is expected that the WMO Executive Council will endorse the list as representative of the needs of WMO programmes in June 1992 and that the list will be used to guide satellite operators and instrument designers and as a basis for continued iteration with the Technical Commissions and other bodies implementing WMO programmes.

The Panel/Working Group recommended that the various user communities operating under the auspices of WMO should be divided into three groups:

- operational meteorology;
- climate and environment monitoring and change;
- hydrology, hydrometeorology and agrometeorology.

The satellite data requirements of these groups were then defined in terms of area coverage, the horizontal and vertical resolution, frequency and accuracy of measurements. WMO Technical Commissions and Programmes and Projects supported by WMO contributing to the formulation of the requirements were:

- Commission for Agricultural Meteorology;
- Commission for Atmospheric Science;
- Commission for Climatology;
- Commission for Marine Meteorology;
- Commission for Aeronautical Meteorology;
- Commission for Basic Systems;
- Commission for Hydrology;
- World Climate Research Programme (also see section C.4, below);
- International Satellite Cloud Climatology Project;
- International Satellite Land Surface Climatology Project.

A qualitative summary of the requirements is presented in the diagrams in section 2. It can be seen that the WMO satellite data requirements match well with other environmental programmes and agencies, although in the case of atmospheric chemistry other programmes and agencies have more stringent and specific satellite data requirements. The detailed quantitative requirements are to be reviewed, through correspondence between the WMO Secretariat and the Presidents of the Technical Commissions, in the light of currently available instruments, those under development for flight on firm/approved missions and those foreseen as achievable but not yet under active development. Requirements will also be prioritised and used as the basis for further dialogue with CEOS and other relevant organisations.

C.3 Global Climate Observing System (GCOS)

The GCOS concept was outlined at the Second World Climate Conference in 1990 and is now accepted by the main international organisations involved, namely, the WMO, the Intergovernmental Oceanographic Commission (IOC), the United Nations Environment Programme (UNEP) and the International Council of Scientific Unions (ICSU). Its goals, as currently defined, are:

- climate system monitoring, climate change detection and response monitoring, especially in terrestrial ecosystems;
- data for application to national economic development;
- data for research towards improved understanding, modelling and prediction of the climate system;
- eventually, a comprehensive observing system for climate forecasting.

Top level data requirements for the data acquisition systems have been identified as follows:

- to upgrade the World Weather Watch (WWW) system;
- to accelerate the development of additional facilities for programmes such as Global Atmosphere Watch (GAW);
- over the next two decades, to build on existing operational and research ocean programmes to develop a Global Ocean Observing System (GOOS);
- to maintain and enhance operational and research monitoring programmes of changes in terrestrial ecosystems, clouds and the hydrological cycle, the Earth's radiation budget and the cryosphere.

Satellite data will play a key role in satisfying these requirements, although quantitative specification of the required measurements is still being formulated. The GOOS requirements are discussed in section C.6, as provided by the IOC. The WMO data requirements discussed in section C.2 have been examined by the Joint Scientific and Technical Committee (JSTC) of GCOS, including WMO satellite data requirements.

C.4 World Climate Research Programme (WCRP)

The WCRP was established in 1979 as a joint undertaking of the ICSU and WMO to determine to what extent climate can be predicted and the extent of man's influence on climate. IOC is also sponsoring WCRP. To achieve its goals, the WCRP requires a quantitative understanding of the four major components of the physical climate system, namely:

- the global atmosphere;
- the world oceans;
- the cryosphere, which comprises the continental ice sheets, ice caps, glaciers, sea ice and snow cover;
- the land surface with its surface and groundwater flow systems.

The WCRP has instituted three major projects to investigate climate change processes, as follows:

- The Tropical Ocean and Global Atmosphere (TOGA) project: This studies the interactions between the tropical ocean and global atmosphere which are the principal mode of climatic variation from year to year. The programme includes a combination of systematic measurements of oceanic temperature, salinity, atmospheric pressure and sea level.
- The World Ocean Circulation Experiment (WOCE): The aim of the WOCE experiment is to assemble, for the first time, almost simultaneous observations of all oceans, as a basis for the development of mathematical models of global ocean circulation and heat transport. Measurements include precision hydrography and geochemical tracers across ocean basins, moored arrays and several lagrangian drifter programmes, as well as the satellite measurements identified in section 2.
- The Global Energy and Water Cycle Experiment (GEWEX): This experiment aims to determine the fluxes of water and energy globally from observations and by computational models of atmospheric processes. The primary purpose is to quantify the energetic processes of the Earth's climate system and the forcing functions on the ocean, land, ice and vegetation.

Two further projects are planned to start later this decade, namely the Climate Variability and Prediction Research Programme (CLIVAR) which is aimed at improving the understanding of the coupled dynamics of the global ocean-atmosphere system, and the Arctic Climate System Study (ACSYS) which includes a basin-wide study of the Arctic ocean and a basic monitoring programme for the Greenland ice sheet.

The timelines of the WCRP projects and a qualitative indication of how current and planned satellites can help to meet the data requirements of the projects are presented in section 2 of this document. Not all requirements for data can be met. For example, measurement of near surface atmospheric temperature and moisture from space require the development and flight of differential absorption lasers (DIAL), which are not expected before the turn of the century. GEWEX is particularly demanding in its requirements for satellite data, requiring simultaneous measurements of properties at the top of the atmosphere (cloud tops, Earth radiation budget) and underlying vertical profiles of temperature, moisture and clouds. Precipitation measurements are also needed in conjunction with the profiles of clouds and atmospheric properties. A number of new instrument developments are required to meet the GEWEX objectives, including a millimetre wave radar imager or radar profiler to measure cloud particle profiles and instruments to measure soil moisture and 3-D winds.

C.5 International Geosphere-Biosphere Programme (IGBP)

In 1986, ICSU decided to launch the International Geosphere-Biosphere Programme, a study of global change. The objective of IGBP is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the changes that are occurring in this system and the manner in which they are influenced by human activities.

IGBP is an evolving programme that selects from the broad array of subjects that comprise the science of the Earth system, those questions that are deemed to be of greatest importance in contributing to the understanding of the changing nature of the global environment on timescales of decades to centuries, that most affect the biosphere, that are most susceptible to human perturbations and that will most likely lead to a practical, predictive capability.

The research questions and the projects that make up the programme are expected to evolve with new insights and understanding, but the initial operational phase of the programme focuses on seven key questions:

1 How is the chemistry of the global atmosphere regulated and what is the role of biological processes in producing and consuming trace gases?
   - International Global Atmosphere Chemistry (IGAC) project, an established IGBP Core Project;

2 How do ocean biogeochemical processes influence and respond to climate change?
   - Joint Global Ocean Flux Study (JGOFS), an established IGBP Core Project;
   - Global Ocean Euphotic Zone Study (GOEZS), a potential IGBP Core Project;

3 How are changes in land use affecting the resources of the coastal zone and how will changes in sea level and climate alter coastal ecosystems?
   - Land-Ocean Interactions in the Coastal Zone (LOICZ), a proposed IGBP Core Project;

of the century. GEWEX is particularly demanding in its requirements for satellite data, requiring simultaneous measurements of properties at the top of the atmosphere (cloud tops, Earth radiation budget) and underlying vertical profiles of temperature, moisture and clouds. Precipitation measurements are also needed in conjunction with the profiles of clouds and atmospheric properties. A number of new instrument developments are required to meet the GEWEX objectives, including a millimetre wave radar imager or radar profiler to measure cloud particle profiles and instruments to measure soil moisture and 3-D winds.

C.5 International Geosphere-Biosphere Programme (IGBP)

In 1986, ICSU decided to launch the International Geosphere-Biosphere Programme, a study of global change. The objective of IGBP is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the changes that are occurring in this system and the manner in which they are influenced by human activities.

IGBP is an evolving programme that selects from the broad array of subjects that comprise the science of the Earth system, those questions that are deemed to be of greatest importance in contributing to the understanding of the changing nature of the global environment on timescales of decades to centuries, that most affect the biosphere, that are most susceptible to human perturbations and that will most likely lead to a practical, predictive capability.

The research questions and the projects that make up the programme are expected to evolve with new insights and understanding, but the initial operational phase of the programme focuses on seven key questions:

1 How is the chemistry of the global atmosphere regulated and what is the role of biological processes in producing and consuming trace gases?
   - International Global Atmosphere Chemistry (IGAC) project, an established IGBP Core Project;

2 How do ocean biogeochemical processes influence and respond to climate change?
   - Joint Global Ocean Flux Study (JGOFS), an established IGBP Core Project;
   - Global Ocean Euphotic Zone Study (GOEZS), a potential IGBP Core Project;

3 How are changes in land use affecting the resources of the coastal zone and how will changes in sea level and climate alter coastal ecosystems?
   - Land-Ocean Interactions in the Coastal Zone (LOICZ), a proposed IGBP Core Project;

4 How does vegetation interact with physical processes of the hydrological cycle?

- Biospheric Aspects of the Hydrological Cycle (BAHC), an established IGBP Core Project;

5 How does global change affect global ecosystems?

- Global Change and Terrestrial Ecosystems (GCTE), an established IGBP Core Project;

6 What significant climate and environmental changes have occurred in the past and what were their consequences?

- Past Global Changes (PAGES), an established IGBP Core Project;

7 How can our knowledge of components of the Earth system be integrated and synthesised in a numerical framework that provides predictive capacity?

- Global Analysis, Interpretation and Modelling (GAIM), a task force of the Scientific Committee for IGBP.

For the established projects, international Core Project Offices have been set up to prepare implementation plans and help develop a coordinated international research effort. As the IGBP Core Projects begin to be defined and the research becomes formulated, attention will be focused on specific needs for global monitoring, including observation from space. Although a measurement strategy for these projects is only beginning to be formulated, it is clear that the measurements will be needed over the long term (decades) for a large number of variables related to the physical state of the atmosphere, land and oceans; chemical changes in the atmosphere, oceans and land; and the biological state of land cover and the upper layer of the oceans.

The IGBP needs satellite data for three overriding reasons. These are:

- to document precisely global scale changes in key variables to assess the way the planet as a whole is evolving with time;
- to measure the long term trends in the forcing functions of global change;
- to simultaneously measure several parameters to study interactive processes which regulate the Earth system.

For the purposes of this document six projects have forwarded their satellite data requirements, namely IGAC, JGOFS, LOICZ, BAHC, GCTE and GAIM. An indication of how current and planned satellite instruments will help to meet these data requirements is given in section 2. The launch, in 1993, of SeaWiFS to measure ocean colour is critical to the success of JGOFS and LOICZ and will curtail the gap in measurements since 1986. The development of techniques to measure soil moisture and the concentrations of a variety of trace gases in the lower atmosphere are also required. There are no scheduled measurements of trace gas profiles (other than CO) in the lower atmosphere before EOS-CHEM (2002).

C.6 Intergovernmental Oceanographic Commission (IOC)

The IOC coordinates and disseminates worldwide information and data on the state of the world's oceans. This is achieved through a number of research and support services organised in conjunction with member states and other international agencies. For example, IOC (together with WMO) supports and develops IGOSS (Integrated Ocean Services Station System) and IOC has developed and established GLOSS (Global Sea Level Observing System). As noted in section C.4, it is co-sponsoring WCRP.

Together with the WMO, ICSU and UNEP, the IOC is also participating in the programme to establish GCOS. As a major contribution to that programme, the IOC is embarking on the development of GOOS, a complex system for collecting, analysing and distributing physical, chemical and biological data from the oceans. The climate related aspects of the GOOS system will be developed jointly with WMO. Coastal monitoring components will be developed with UNEP and WMO.

The IOC-UNEP programme on Global Investigations of Pollution in the Marine Environment (GIPME) concentrates on studies of pollution distribution and impacts, particularly in the coastal zones. It also considers the inputs of pollutants to coastal zones and open ocean areas.

GOOS, GIPME and other IOC programmes may be expected to have an increasing interest in satellite data, particularly measurements of ocean parameters such as sea surface temperature, ocean currents, wind stress and biological properties.

C.7 United Nations Environment Programme (UNEP)

Satellite remote sensing data are used for many activities of UNEP, notably by the Global Environment Monitoring System (GEMS) and the Global Resource Information Database (GRID), as well as by the Desertification Control Programme Activity Centre (DC/PAC), Oceans and Coastal Areas Programme Activity Centre (OCA/PAC), Terrestrial Ecosystems Branch (TEB), and Support Measures (SM).

GEMS is a UN system wide programme to acquire the data needed for the management of the environment at global, regional and local levels. It includes monitoring programmes in the fields of atmosphere and climate (background air pollution, acid rain, stratospheric ozone, climate), environmental pollution (urban air, surface waters, food, nuclear radiation) and renewable resources (tropical forests, land degradation, oceans, ecological monitoring, biological diversity). Although for some specific issues regional data may be used, the global aspect is predominant for many activities. GEMS' specific Earth observation data requirements are (i) global coverage, (ii) temporal dynamics of data, (iii) manageable data volumes, (iv) simple and reliable sensors, and (v) reasonable costs of data.

Global coverage implies that high spatial resolution is not required and that a resolution of 1kmx1km may be sufficient to characterise and assess the most important phenomena. Temporal dynamics of data means that satellite systems should be designed to cover a time span appropriate to the environmental phenomena concerned. Manageable data volumes facilitate the use of data by end-users. Simple and reliable sensors are needed for the observation of different types of vegetation, for determining atmospheric gas concentrations, and sea/land temperatures. Finally, the costs of Earth observation data must be reasonable enough to enable the whole community to access and use the data.

GRID is a world-wide service system for users of Earth observation data. Through its many collaborating centres, GRID provides access to existing Earth observation data and reference to other existing geo-referenced data which can be linked with remote sensing data. In addition, the GRID system provides support of geographical information and image processing systems for users from the international science and development communities and brokers training through appropriate international and regional bodies.

Other UNEP units (DC/PAC, OCA/PAC, TEB, SM) are users of satellite Earth observation data, too. However, their data needs vary for the specific projects carried out. Data requirements depend on the specific environmental problems addressed and on existing and/or new international conventions, which need to be controlled or enforced through Earth observations by satellites.

C.8 Food and Agriculture Organisation (FAO)

The Remote Sensing Centre of the United Nations Food and Agriculture Organisation provides advisory services to governments, training in Earth observation applications, assists in research and development, including monitoring, and supports FAO headquarters' units and field projects with technical services. It conducts a range of pilot studies and supports national projects using Earth observation data in areas such as mapping, resource management and environmental monitoring.

The ARTEMIS project (Africa Real Time Environmental Monitoring using Imaging Satellites) is an example of on-going activity which may be classed within the scope of this document. The project operationally monitors precipitation and vegetation in Africa based on semi-automatic processing of image data from METEOSAT and NOAA satellites.

C.9 Commission of the European Communities (CEC)

The CEC undertakes a variety of environmental projects which depend on satellite data. For projects such as TREES (Tropical Ecosystem Observation by Satellite) and MARS (Monitoring Agriculture with Remote Sensing) plus many other projects undertaken under the auspices of the Framework Programme, the main requirement is for visible, infrared and radar data of the Earth's surface, provided at present by sensors on board the SPOT, LANDSAT, NOAA polar orbiters, ERS-1 and JERS-1 satellites. A range of such sensors are expected to be available for the near future.

Ocean programmes undertaken within the CEC (eg Marine Science and Technology (MAST) and the joint CEC/ESA project Ocean Colour European Archive Network (OCEAN)) require both ocean colour and sea surface temperature data. Sea surface temperature data are currently assured via AVHRR on the NOAA polar orbiters and ATSR on ERS-1. There is currently no source of ocean colour data, although this should be provided in 1993 by SeaWiFS.

To satisfy future CEC requirements, the main developments of interest are the introduction of high spectral resolution imagers, such as MERIS (on POEM-1 from 1998) and MODIS-N (on EOS-AM 1 from 1998 and subsequent missions) and of advanced synthetic aperture radars (SARs).

D LIST OF CEOS MEMBERS, OBSERVERS AND AFFILIATES

This annex lists, alphabetically, the organisations that comprise CEOS.

CEOS members	**Organisation**
Australia	Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Brazil	Instituto Nacional de Pesquisas Espaciais (INPE)
Canada	Canadian Space Agency (CSA)
Europe	European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
	European Space Agency (ESA)
France	Centre National d'Etudes Spatiales (CNES)
Germany	Deutsche Agentur für Raumfahrt-Angelegenheiten (DARA)
India	Indian Space Research Organisation (ISRO)
Italy	Agenzia Spaziale Italiana (ASI)
Japan	Science and Technology Agency (STA)
Sweden	Swedish National Space Board (SNSB)
United Kingdom	British National Space Centre (BNSC)
United States	National Aeronautics and Space Administration (NASA)
	National Oceanic and Atmospheric Administration/National Environmental Satellite, Data and Information Service (NOAA/NESDIS)

CEOS observers	**Organisation**
Canada	Canada Centre for Remote Sensing (CCRS)
Europe	European Community (EC)
New Zealand	Department of Scientific and Industrial Research (DSIR)
Norway	Norwegian Space Centre (NSC)

CEOS affiliates

International Council of Scientific Unions (ICSU)
International Geosphere-Biosphere Programme (IGBP)
Intergovernmental Oceanographic Commission (IOC)
World Climate Research Programme (WCRP)
World Meteorological Organization (WMO)

E ABBREVIATIONS

This annex provides a list of the abbreviations used in the text with the exception of satellite mission and instrument names. The reader is referred to annexes A and B respectively for these.

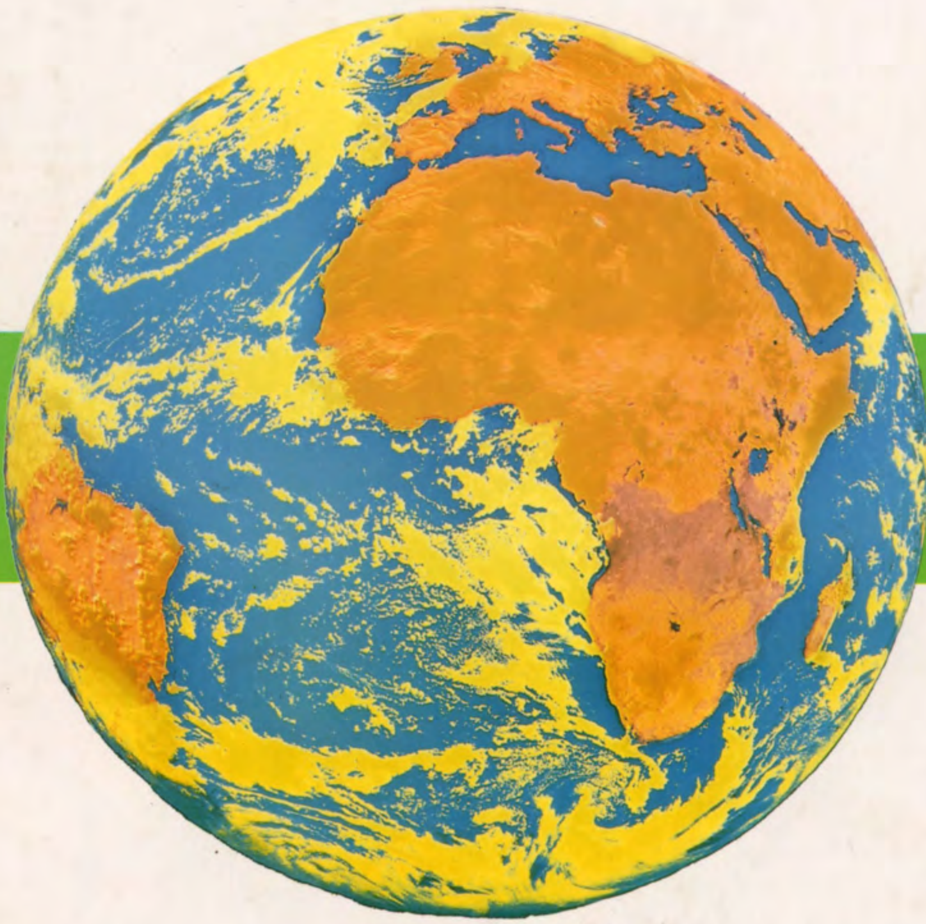
ACSYS	Arctic Climate System Study
ARTEMIS	Africa Real Time Environmental Monitoring using Imaging Satellites
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
BAHC	Biospheric Aspects of the Hydrological Cycle
BNSC	British National Space Centre
CCRS	Canada Centre for Remote Sensing
CEC	Commission of the European Communities
CEOS	Committee on Earth Observations Satellites
CIS	Commonwealth of Independent States
CLIVAR	Climate Variability and Prediction Research Programme
CNES	Centre National d'Etudes Spatiales (French Space Agency)
CSA	Canadian Space Agency
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DARA	Deutsche Agentur für Raumfahrt-Angelegenheiten (German Space Agency)
DC	Desertification Control
DMSP	Defense Meteorological Satellite Programme
DRS	Data Relay Satellite
DSIR	Department of Scientific and Industrial Research
EC	European Community
EPS	European Polar Segment
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAO	Food and Agriculture Organisation
GAIM	Global Analysis, Interpretation and Modelling
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GCTE	Global Change and Terrestrial Ecosystems
GEMS	Global Environment Monitoring System
GEWEX	Global Energy and Water Cycle Experiment
GIPME	Global Investigations of Pollution in the Marine Environment
GLOSS	Global Sea Level Observing System
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GRID	Global Resource Information Database
ICSU	International Council of Scientific Unions
IEOSC	International Earth Observation Satellite Committee
IGAC	International Global Atmosphere Chemistry Project

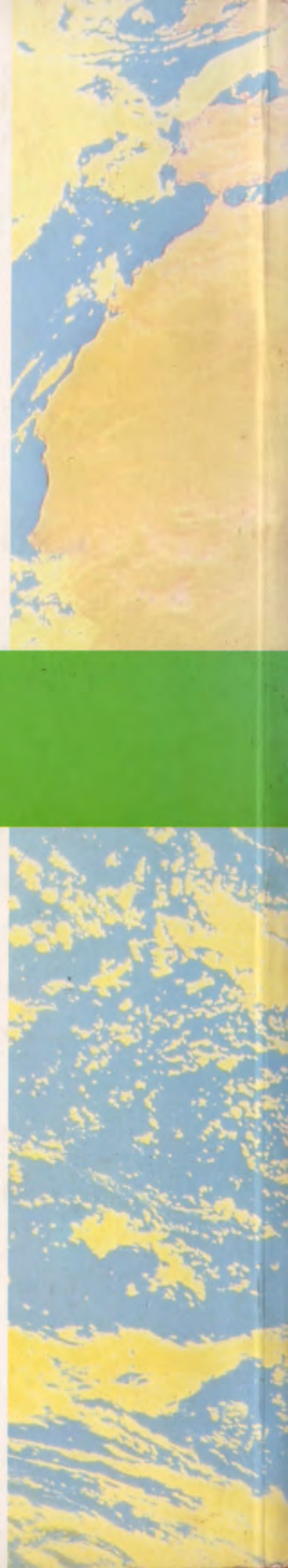
IGBP	International Geosphere-Biosphere Programme
IGOSS	Integrated Ocean Services Station System
INPE	Instituto Nacional de Pesquisas Espaciais (Brazilian Space Agency)
IOC	Intergovernmental Oceanographic Commission
ISCCP	International Satellite Cloud Climatology Project
ISLSCP	International Satellite Land Surface Climatology Project
ISRO	Indian Space Research Organisation
JGOFS	Joint Global Ocean Flux Study
JMA	Japanese Meteorological Agency
JSTC	Joint Scientific and Technical Committee
LOICZ	Land-Ocean Interactions in the Coastal Zone
MARS	Monitoring Agriculture with Remote Sensing
MAST	Marine Science and Technology
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency (Japan)
NESDIS	National Environmental Satellite, Data and Information Service
NOAA	National Oceanic and Atmospheric Administration
NSC	Norwegian Space Centre
OCA	Oceans and Coastal Areas
OCEAN	Ocean Colour European Archive Network
PAC	Programme Activity Centre
SM	Support Measures
SNSB	Swedish National Space Board
SSM/I	Special Sensor Microwave Imager
STA	Science and Technology Agency
TBC	To be confirmed
TBD	To be decided
TDRSS	Tracking and Data Relay Satellite System
TEB	Terrestrial Ecosystems Branch
TOGA	Tropical Ocean and Global Atmosphere
TREES	Tropical Ecosystem Observation by Satellite
UNEP	United Nations Environment Programme
USSR	Union of Soviet Socialist Republics
VLBI	Very Long Baseline Interferometry
WCRP	World Climate Research Programme
WOCE	World Ocean Circulation Experiment
WMO	World Meteorological Organization
WWW	World Weather Watch

This document has been prepared on behalf of CEOS by the 1992 secretariat:

BNSC

British National Space Centre
Dean Bradley House, 52 Horseferry Road,
London, SW1P 2AG, UK





CEOS

Committee on Earth Observations Satellites