CHAPTER 4

TIMELINES AND NEAR-TERM EMPHASIS

4.1 Timelines

The ability of the federal agencies to develop and improve space weather capability to meet the goals and objectives of the NSWP is dependent on the state of the science, the availability of needed observations, communications and computing capacity, and the budgetary environment to support these efforts. The following timelines have been developed with these constraints in mind but still represent an aggressive schedule that should be pursued. This section is broken down into operational sensors and models and research sensors and models. Each examines the evolution of these systems over the period of the NSWP and beyond.

4.1.1 Operational Sensors and Models

4.1.1.1 Operational Sensor Timeline

The emphasis in the sensor timeline is on obtaining measurements of key physical parameters in the spatial domains of space weather from the Sun to the near-Earth environment. The strategy for obtaining the data as quickly and efficiently as possible combines ongoing operational sensors with the use of real-time data from research satellites and sensors. Recent experience has demonstrated that data from research sensors can be made available for space weather operations, at little additional cost, provided planning and coordination for this is included in the mission definition phase of the program. Transmitters compatible with inexpensive ground-based tracking systems have allowed real-time acquisition of data from the ACE satellite and similar transmitters will be employed with the NASA IMAGE mission. Data made available under similar arrangements from future research satellites can also be most useful to operations. Data from the Solar Heliospheric Observer (SOHO) has proven to be extremely valuable in space weather forecasting even while the mission is still in its research phase. Without additional action, the end of SOHO operations will begin a gap in such data until another research mission is flown or an operational mission can be programmed, funded, scheduled, built, and flown—typically a lag of about 10 years. The sensor timeline (Fig. 4-1) shows several such gaps.

Another aspect of the sensor timeline is the evolution from current to desired sensors. The GOES satellite will have a solar x-ray imager beginning in 2002, but the SOHO experiences have shown that the x-ray imager provides better service if accompanied by an EUV solar telescope and a solar coronagraph. A probable platform for these sensors is a GOES weather satellite at geostationary orbit, but sensors on the GOES are defined until at least 2010. SOHO is not expected to remain in reliable operation through that time. The evolution from initial capability to full capability on solar satellite images in the sensor timeline reflects this gap.

Likewise, energetic particle sensors are available on the GOES and these will be upgraded to include lower energy particles. These have been shown to be valuable for satellite anomaly analysis by the Defense Support Program geosynchronous satellites. GOES will begin flying these sensors in 2002, well after the sensors are dropped from the Defense Support Program.

The coverage of energetic particle measurements in the magnetosphere will not be complete until the Compact Environment Anomaly Sensor (CEASE) program or an equivalent is in place later in the decade. That improvement is reflected in the upgrade of the magnetospheric particle sensor program in about 2008.

4.1.1.2 Operational Model Timeline

Current space weather modeling, especially for operational use, is still in its first or second generation. The NSWP promotes evolutionary upgrading by emphasizing funding for developing improved models and providing for their transfer into operations. Improvements will come in an ongoing series of smaller steps that take advantage of new physical knowledge, new observations, and expanded computing capability. The models will be increasingly linked as successive modules in a physical chain extending from the Sun through the terrestrial atmosphere are developed and validated. Another objective with the operational models is to develop ensembles of models describing the same environment. Forecasts can be made from several models of the same phenomena, providing alternative and complementary views of the various aspects of the environment in question. The timeline in Figure 4-2 illustrates the evolution from first generation models through models that have improved capability to meet most requirements but may still fail in some critical situations. The final, fully capable models are able to meet most all of the requirements and projected needs. This includes critical capabilities to adequately describe unusual or intense situations.

Figure 4-2 reflects the transition timeline for models in space weather operations. The models evolve from no capability, or limited capability, to models fully capable of meeting most of the currently foreseen space weather requirements. Most of the models are not envisioned to be fully capable until the second decade of the new century. Part of the basis for this extended period, in addition to the time needed to develop physical

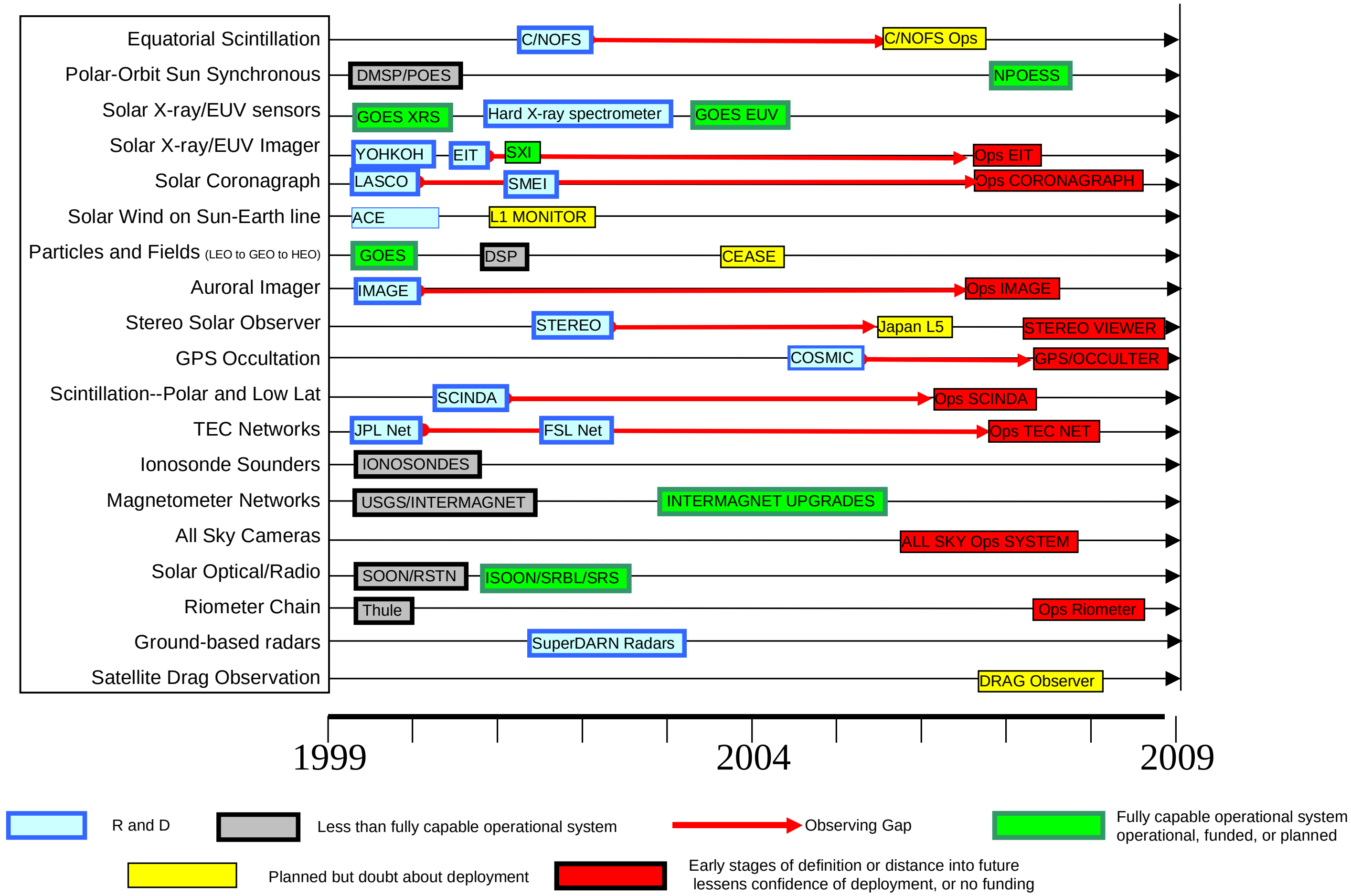

Figure 4-1. Operational Sensor Timeline

understanding, is an investment strategy that envisions the very large funding need for model development to be spread over two decades. Acceleration of the time to reach full capability can be achieved to some extent by higher levels of funding, but the areas of most benefit need to be carefully balanced against other limitations such as scientific progress and computational capability.

4.1.2 Research Sensors and Models

In many instances it is difficult to clearly distinguish between operational and research sensors and models. This section examines the timeline for sensors not expected to provide routine observations but that are still critical to achieving NSWP milestones and breakthroughs. The research model timeline is much harder to distinguish from the operational timeline because it is expected that successful and usable research models will be transitioned to operations. While the operational timelines were broken out by space weather domain, the research timelines are broken down into three different categories: solar/solar wind; magnetosphere; and ionosphere/thermosphere. The timelines are shown in Figures 4-3, 4-4, and 4-5.

Each figure shows the evolution from 1999 to 2009 of both the research model timeline and the observations timeline, with the models shown on top. The various text boxes are color coded to indicate the current status of each model or sensor system. Green indicates a system that is operating, funded, or has a high confidence of deployment. Yellow indicates models or systems that are planned but confidence in actual deployment is lower. Red indicates models or systems in the early stages of definition and confidence in deployment is low due to their distance into the future, the state of the science, and/or budget issues. Many of the model text boxes contain one or more codes such as I5, M21, or S8. These codes refer to the numbering in the first column of Tables 3-1, 3-2, and 3-3 in Chapter 3 to allow the reader to link specific research modeling efforts to the timelines.

Models in each of the physical domains require information from other domains as input parameters and initial or boundary conditions. Research modeling efforts will increasingly focus on coupling of the various models to ultimately determine the present and future state of the Sun-Earth space weather environment. Underlying the entire process, but not indicated in the figures, is a broad and continuous research effort aimed at acquiring a deep understanding of the physical processes that drive the space weather system. The success of the NSWP depends on a sustained effort in the study of these basic processes.

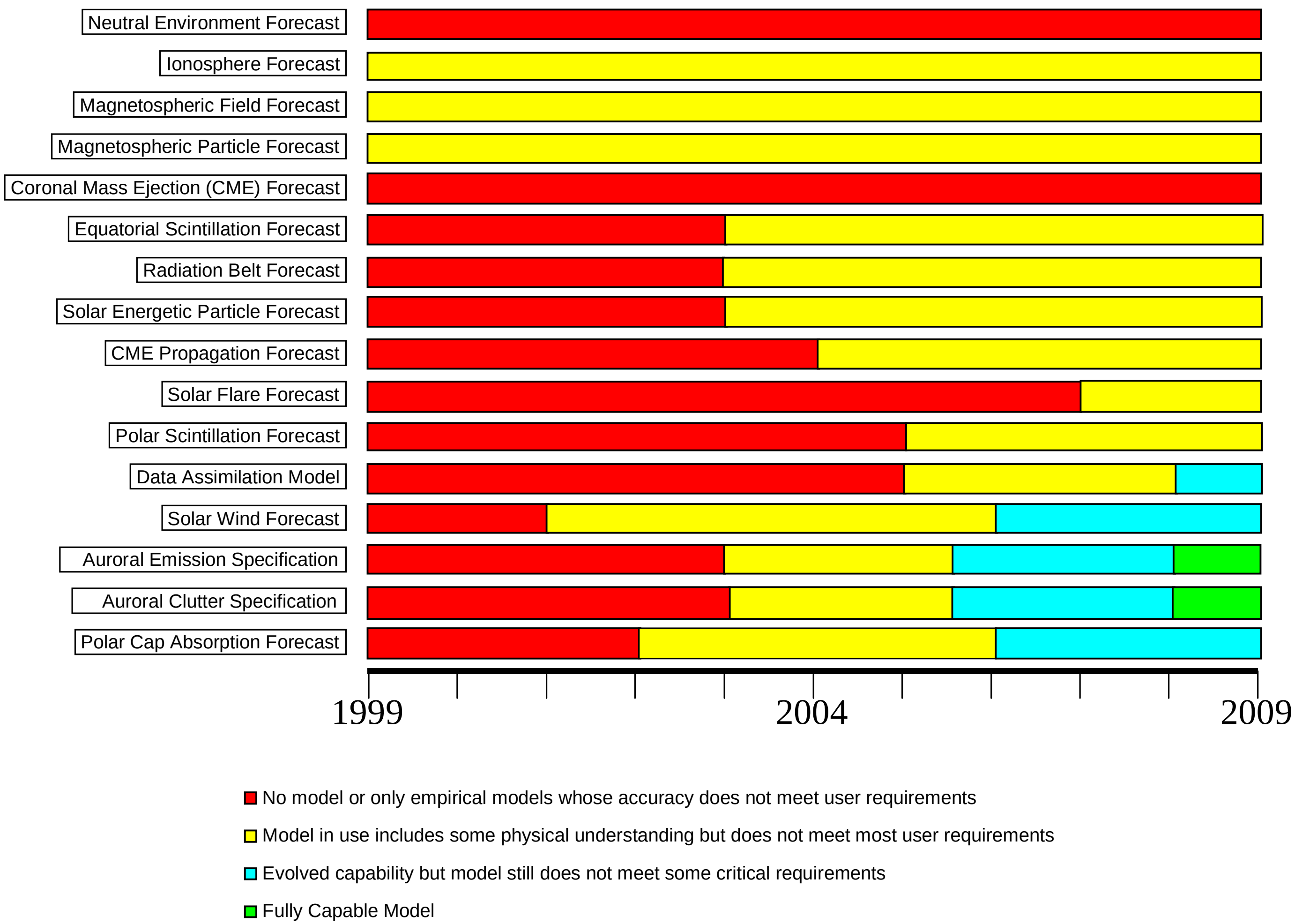

Figure 4-2. Operational Models Timeline

4.2 Near-term Emphasis

The timelines described above indicate the longer-term milestones that must be achieved to reach the goals of the National Space Weather Program. In addition to these long-term goals, there are also a number of near-term objectives. These near-term objectives will be reviewed and updated approximately biennially.

Physical Understanding. Initially, several broad research areas will be targeted for emphasis. These represent significant gaps in present understanding and need to be addressed early in the Program. They are as follows:

- Understanding and prediction of processes affecting solar activity and solar wind, such as coronal mass ejections and solar flares
- Coupling between the solar wind and the magnetosphere
- The origin and energization of magnetospheric plasma
- The triggering and temporal evolution of substorms and storms
- Improved global ionospheric specification and forecast, including the evolution of ionospheric irregularities, particularly at low latitudes, and with emphasis on those processes affecting communication and navigation systems
- Improved specification of thermospheric dynamics and neutral densities

Models. There is a critical need for model development, validation and testing in all areas of the space weather system. Near-term emphasis will be placed on the following:

- Validation and enhancement of space weather models to improve specification and prediction capabilities, with emphasis on the application of data assimilation techniques
- Continued development of research models that are nearly ready to transition to operations
- Development and application of numerical methods for event forecasting

Observations. In the area of observational requirements, it is important to maintain and continue to improve existing ground-based networks for solar, magnetic, and ionospheric observations. Similarly, space-based measurements must be continued, both for routine observations and to address critical problems in understanding the space weather system. In particular, emphasis should be placed on the following:

- Maintaining ground-based observing systems such as magnetometers and radio and optical solar remote sensing capabilities
- Maintaining sensors on polar-orbiting and geosynchronous satellites
- Progressing with NASA's Sun-Earth Connections satellites and acceleration of their schedules through the "Living with a Star" initiative

- Taking advantage of data from existing satellites such as International Solar-Terrestrial Physics (ISTP), Fast Auroral Snapshot (FAST) and Midcourse Space Experiment (MSX)
- Deploying an operational solar x-ray imaging instrument
- Establishing a new ground-based facility within the magnetic polar cap

Technology Transfer. The challenges of technology transfer for modeling have been addressed very early in the program and the Community Coordinated Modeling Center and Rapid Prototyping Centers (see Chapter 5) show great promise as a means by which research quality models can be prepared for transfer to the operational arena. Progress has been made in technology transfer in the sensor and observational arena through efforts such as the real-time data flowing to the operational centers from the ACE satellite. However, significant challenges remain.

Education. Another important area of early concentration in the Program is customer education. There must be a well-defined procedure by which the scientific community, the forecasting community, and the customers can interact and exchange information. Progress has been made through an NSF grant to the Space Sciences Institute and through ongoing efforts at the SEC and within DOD to educate users and to integrate space weather into normal daily operations. More work needs to be done.

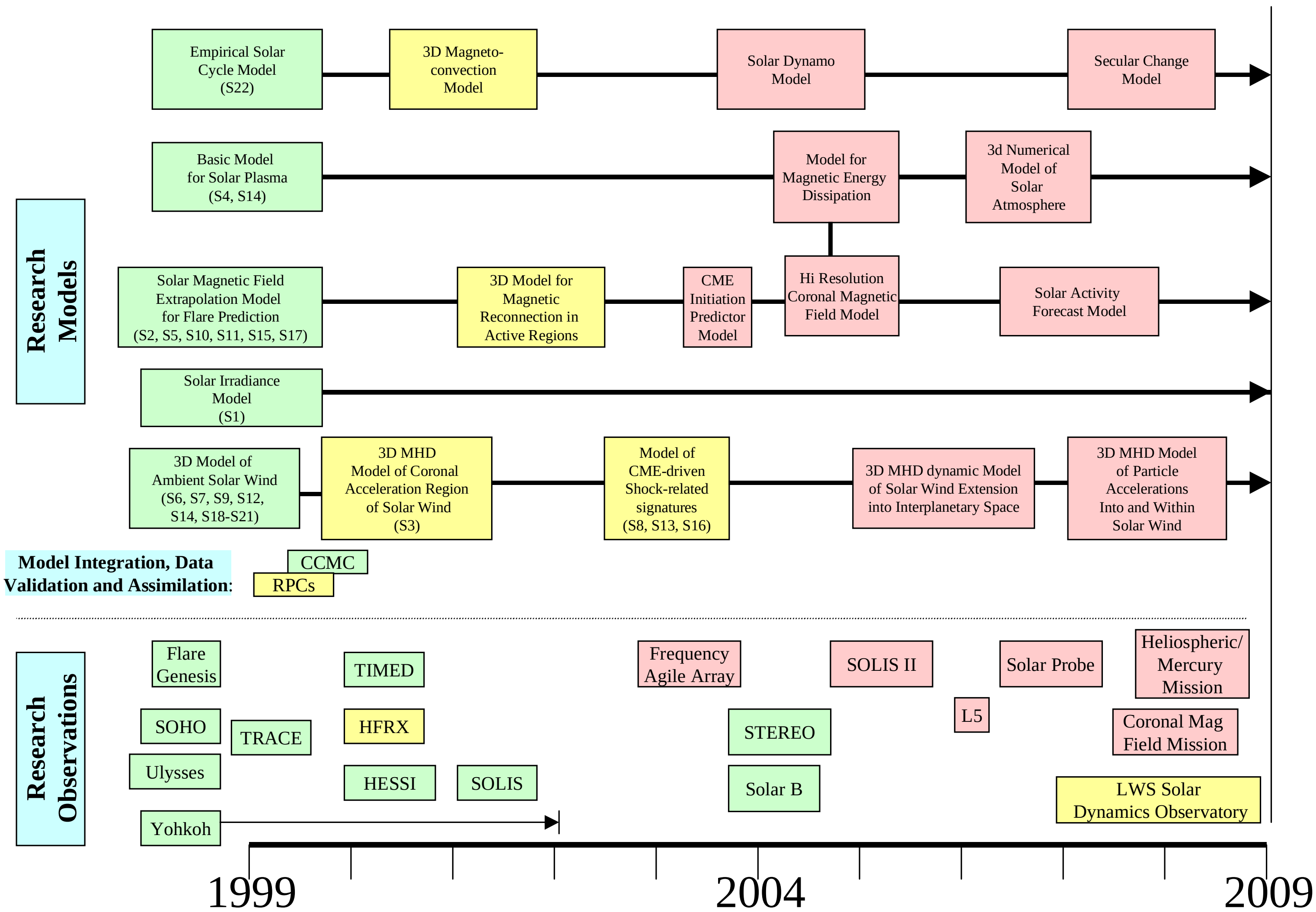

Figure 4-3. Solar/Solar Wind Research Timelines

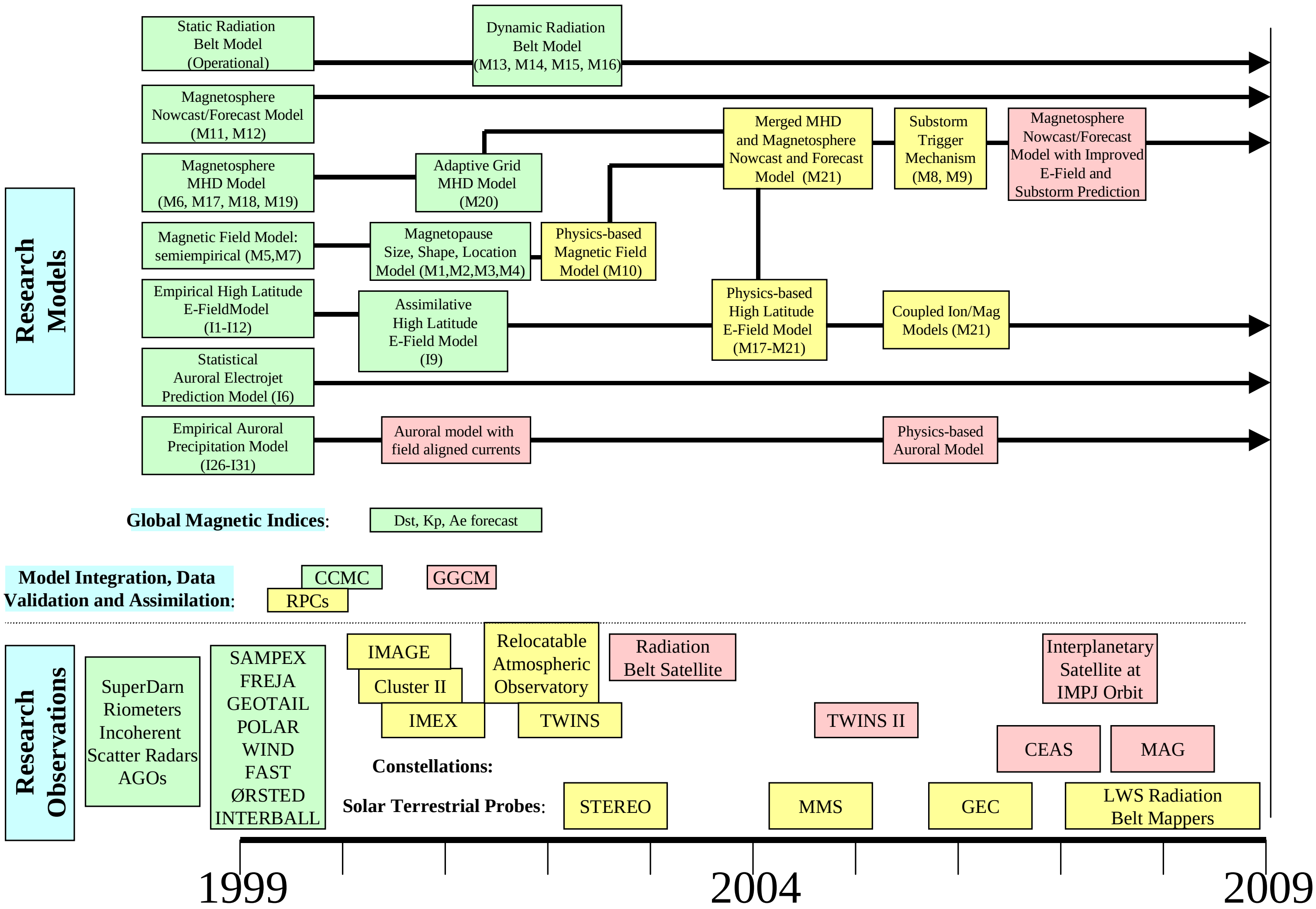

Figure 4-4. Magnetosphere Research Timelines

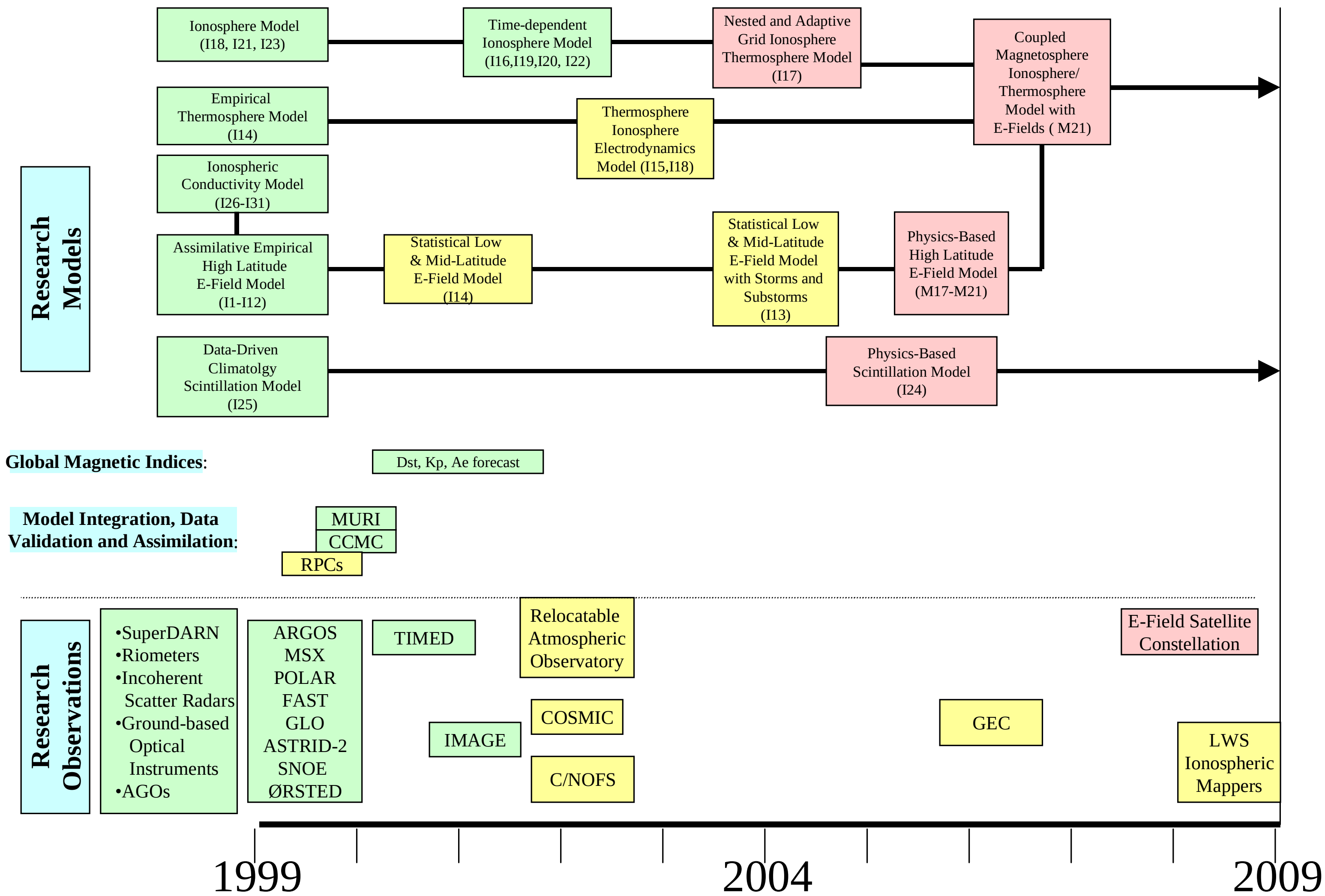

Figure 4-5. Ionosphere/Thermosphere Research Timelines