WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS
OPAG ON INTEGRATED OBSERVING SYSTEMS

EXPERT TEAM ON
OBSERVATIONAL DATA REQUIREMENTS AND REDESIGN OF THE GLOBAL OBSERVING SYSTEM
Seventh Session

Geneva, Switzerland, 12-16 July 2004

Distr.: RESTRICTED

CBS/OPAG-IOS/
ODRRGOS-7/Doc. 7.5(1)

(1.VII.2004)

Item 7

Original: ENGLISH

REPORT ON MOLNIYA ORBITS

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Summary and Purpose of Document

This document summarizes the contributions to the Global Observing System possible with environmental remote sensing of satellites in Molniya orbits.

ACTION PROPOSED

The meeting is invited to take the information contained in this document, into account during its discussion about the redesign of the Global Observing System.

METEOROLOGICAL IMAGING FROM MOLNIYA ORBIT

Lars Peter Riishojgaard, June 17, 2004

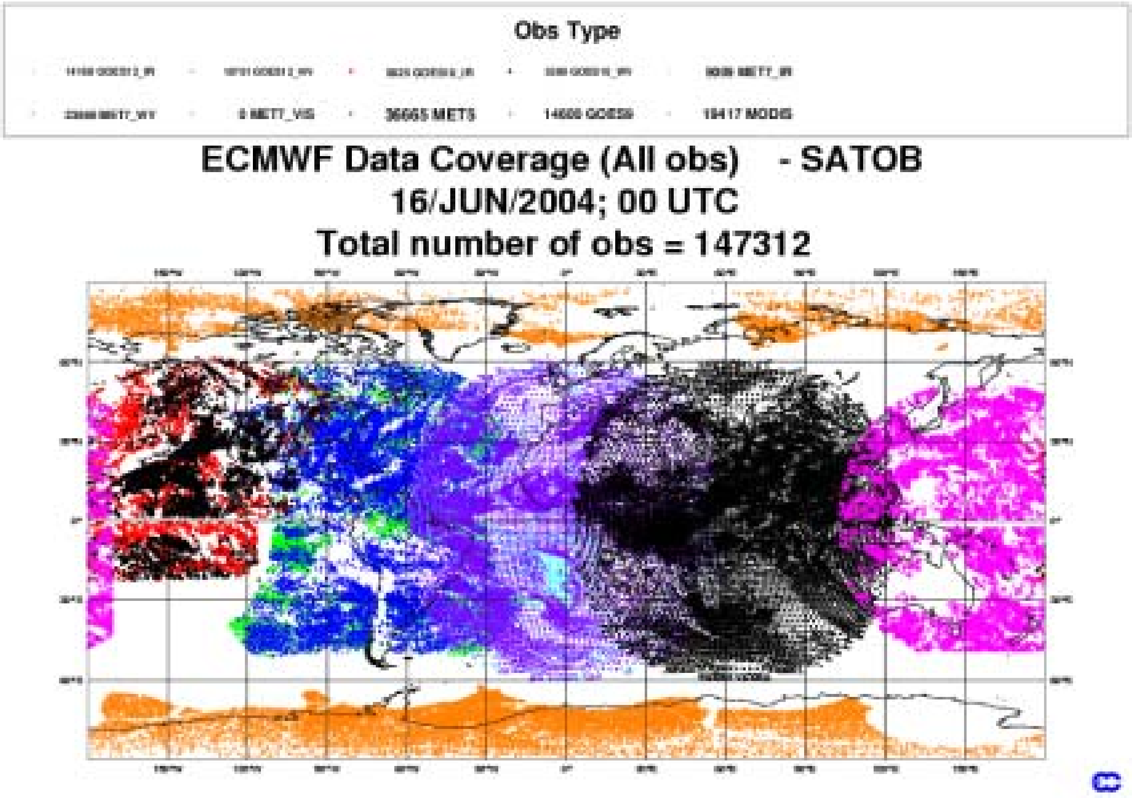
Over the course of the last couple of decades, meteorological imagery has proven to be immensely useful for a number of different purposes related to monitoring and forecasting the evolution of different types of weather systems and phenomena.

The prime example of this is the extensive use of images obtained from geostationary orbit for short-range tracking and nowcasting as well as for deriving information about the atmospheric flow for data assimilation and numerical weather prediction. Many of these applications are made possible by the fact that these satellites are in stationary positions as seen by an observer on the ground, and they are therefore eminently suitable for providing the required time-continuous imaging capabilities. However, an important limitation of these data is the fact that due to the nature of the geostationary orbit, coverage generally is not available for latitudes higher than roughly 62^o, and due to the rapidly decreasing horizontal resolution and increasingly oblique viewing angle, many derived products are not available beyond 55^o of latitude.

Polar orbiters can provide images from low earth orbit all the way to the pole in both hemispheres, thereby extending the imaging capabilities to the entire globe. However, at any given instant only a limited area is visible from a low earth orbiter. Time continuity is therefore prohibitively expensive to provide from this orbit, since it would require a large number of satellites in addition to an extensive and complex ground segment.

It is worth pointing out that some applications traditionally reserved for data obtained by continuous imagers have recently been transferred to images obtained from polar orbiters. An example of this is the polar winds derived from MODIS images (Key et al., 2003). Even though neither the orbit nor the instrument is optimized for this purpose, the MODIS winds have had a substantial impact on assimilation and forecast skill, and these data have thereby helped demonstrate the value of additional high-latitude wind observations for operational numerical weather prediction.

The longer term potential of the MODIS winds and similar products is subject to limitations that are intrinsic to the low earth orbit: The image repeat frequency is tied to the orbital period of roughly 100 minutes. This limits the scale of phenomena and features that can be tracked to synoptic scale or larger. It also imposes a minimum delay with respect to real time in the delivery of the observations. Currently, the MODIS winds are available 4 to 6 hours after the nominal time of the observations. Using the direct broadcast capabilities of the satellites rather than orbital dumps may be able to cut this delay down to the 3 to 3 ½ hour range. This would still be too late for the forecast run for most operational weather services.

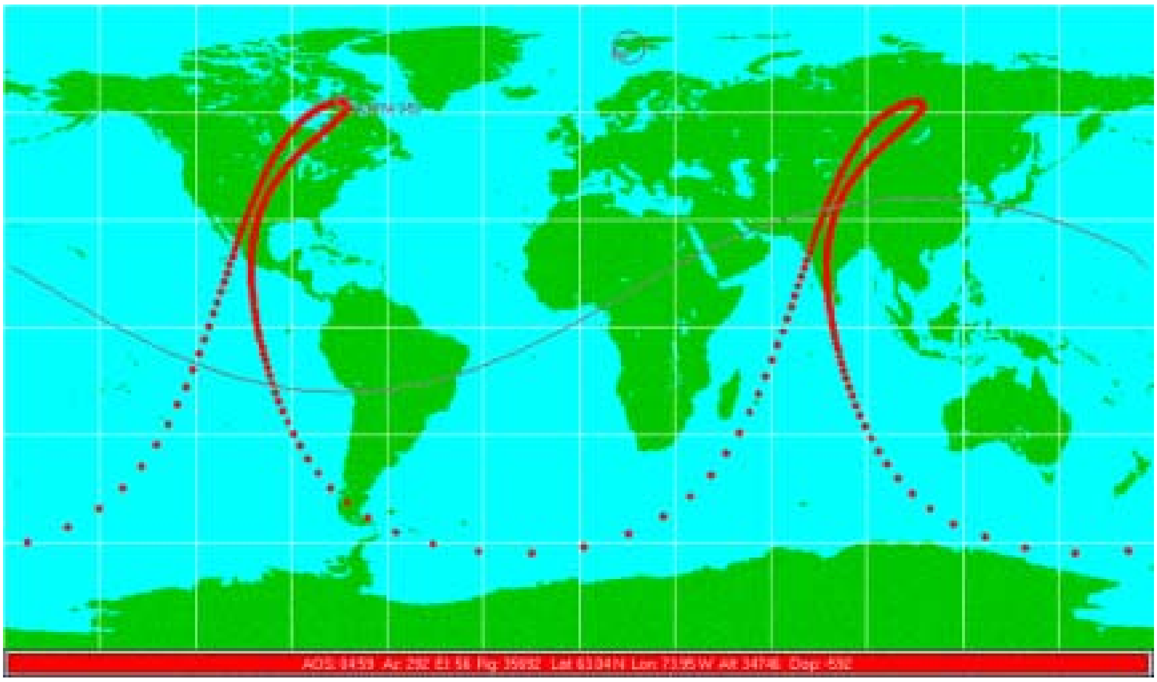


The figure above shows the typical coverage of satellite winds as used in the ECMWF analysis. The limits of geostationary coverage – generally in the 45^o to 60^o range, depending on the satellite and hemisphere – are clearly seen. Also clearly evident is the latitudinal gap in coverage between the geostationary winds and the experimental polar winds from MODIS.

The Molniya orbit (Kidder and Vonder Haar, 1990) provides an attractive alternative for meteorological imaging of those latitude bands that are beyond reach of the geostationary observatories. The Molniya orbit is a highly eccentric orbit with a stable high-latitude apogee. Due to the second Kepler law of planetary motion, the satellite spends about two thirds of the time near its apogee where it provides what is very close to a stationary perspective centered over the high latitudes. This will provide an extension of coverage of the time-continuous imagery all the way to the pole and will enable the near-real time (30 minutes or better) production of high-latitude winds using high refresh rate imagery, including one or more water vapor channels.

One satellite in Molniya orbit would provide coverage of the middle and high latitudes during 16 hours per day. Two satellites would provide continuous coverage of one hemisphere, while a constellation of four satellites would provide constant coverage of the middle and high latitudes for both hemispheres, thereby extending the time-continuous imaging capabilities to the entire globe.

Since a Molniya imager hovers in a nearly stationary location in the sky as seen from the ground during the imaging part of its orbit, real-time downlinking and dissemination can be achieved with a very simple ground segment consisting of a single primary ground station. This is in contrast to the polar orbiters that rely on an extensive net of stations supplemented by onboard data storage capabilities.



Example ground track of a Molniya orbiter plotted at 100 s intervals. It is evident that the satellite spends the bulk of the time near the apogee locations (the cusps of the orbital track). All locations north of the sinusoidal line are visible from the western apogee located over NE Canada. A simulated ground station located in Svalbard (indicated by the circle) will be able to see the satellite during 85% of the orbit.