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地球天候モデルを用いた軌道物体観測計画立案
Orbital object observation strategy based on a global weather model

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地球天候モデルを用いることで, 地上観測網を効率的に運用する手法について提案する. 地表からの光学観測は主にコスト, 分解能の面で軌道上物体監視に適しているが, 天候の影響を強く受ける. 本研究は以下の二つの手法によって, 光学観測効率に対する天候の影響を低減することを図る.
1)地球全体の年間平均雲量分布を天候モデルから求めることで, 高効率な観測が期待できる地点を選定する.
2)各観測地における天候予報データおよび, 監視対象物体リストから効率的な観測計画を立案する.
また同観測計画立案・管理用ソフトウェアについても合わせて紹介する.

This study proposes a methodology to plan observations for orbital objects based on a global weather model. Optical observations from the surface has advantages in cost and resolution however their operation efficiency is strongly affected by weather condition. The methodology aims to reduce the efficiency degradation by following two steps.
1) site location selection using global cloud coverage database
2) automatic observation strategy planning using weather forecast data
An observation strategy planning and management software is also introduced.

Orbital object observation strategy based on a global weather model

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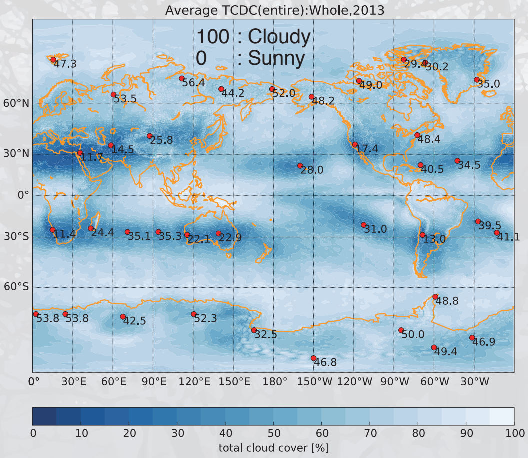
This study proposes a methodology to plan observations for orbital objects based on a global weather model. Ground-based optical observations have advantages in cost and resolution. However, their operation efficiency is strongly affected by weather condition. We aim to reduce the efficiency degradation by following two steps.
1) Site location selection using global cloud coverage database
2) Automatic observation strategy planning using weather forecast data
We also introduce an observation strategy planning and management software.

Site location selection

Average TCDC [%] (Total ClouD Cover) is calculated by using a global weather model.



The TCDC data is retrieved from the **NOAA/GFS** archive service. The TCDCs of local night time are extracted to assess an observation availability.

Left figure shows the average TCDC of 2013. Each red dot corresponds to a local minimum of the average TCDC. **An effective observatory can be designed by using the data.** The figure indicates that latitude regions around +30 or -30 degrees have an advantage in efficiency of observations.

It should be noted that the TCDC distribution uses "entire" cloud layer. Therefore, the data contains overestimations for high altitude places.

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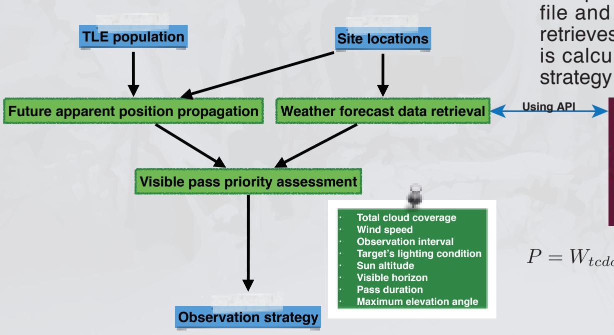
Automatic observation strategy planning

Observation strategy is planned by as follows.



Two preliminary data are required to proceed the planning, an object population file and a site location file. The method propagates each object' s orbit and retrieves **weather forecast data** for each site. Next, **a priority of a visible pass** is calculated by using propagated and retrieved data. Finally, a observation strategy can be planned by sorting the priorities.

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Using the following global forecast models,
+Global Forecast System (NOAA)
+Integrated Forecast System (ECMWF)
+The Global Multi-scale Model (RPN, MRB, CMC)
Mesoscale models, ensemble forecasts,
and weather data of the following agencies or services
+NOAA (USA), Environment Canada, ECMWF (Europe), JMA (気象庁 ,Japan)
+METAR data from airports, APRS, more than 40000 of private weather stations

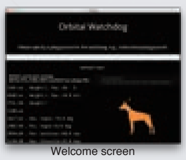
$$P = W_{tcdc}S_{tcdc} \times W_{wind}S_{wind} \times W_{itvl}S_{itvl} \times B_{ilmn} \times B_{salt} \times B_{vhrz} \times B_{drtn} \times B_{elvn}$$

P : Priority, $tcdc$: total cloud cover, $salt$: Sun altitude
W : Weight, $wind$: wind speed, $vhrz$: visible horizon
S : Score, $itvl$: observation interval, $drtn$: pass duration
B : Boolean, $ilmn$: target lighting condition, $elvn$: maximum elevation

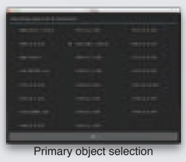
Two Line Element (TLE), European Centre for Medium-Range Weather Forecasts (ECMWF), Recherche en Prévision Numérique (RPN), Meteorological Research Branch (MRB), Canadian Meteorological Centre (CMC),Japan Meteorological Agency (JMA), Meteorological Terminal Aviation Routine Weather Report (METAR), Automatic Packet Reporting System (APRS)

Observation strategy planning and management software

Orbital Watchdog


Welcome screen

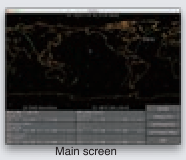

Pass details viewer

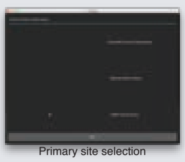

Primary object selection

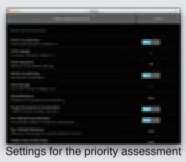
A software is developed to **plan and manage** the observation strategy with graphical user interface.

The **parameters** in the visible pass priority assessment can be changed in this software.

This software also enables to confirm an orbit of a target and **details of a visible pass**.


Main screen


Primary site selection


Settings for the priority assessment