# GEOMETRIC CLOUD MOTION WINDS IN A CONVOY OF SATELLITES

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## Abstract

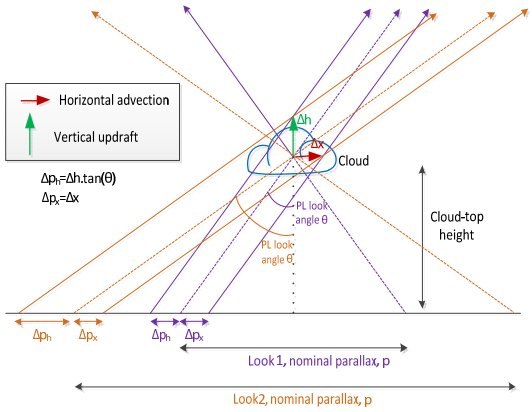
To investigate the potential that spacecraft constellations and formations present for Earth Observation, this paper provides an overview of some of the progress made on the theme 'Atmosphere' in the ESA convoy studies.

To date, mesoscale winds are not well exploited in global NWP and climate models and phenomena of turbulence and convection are not explicitly represented in these models. The geometric Clouds Motion Winds (gCMW) concept targets the measurement of height-resolved wind fields exploiting the effect of parallax.

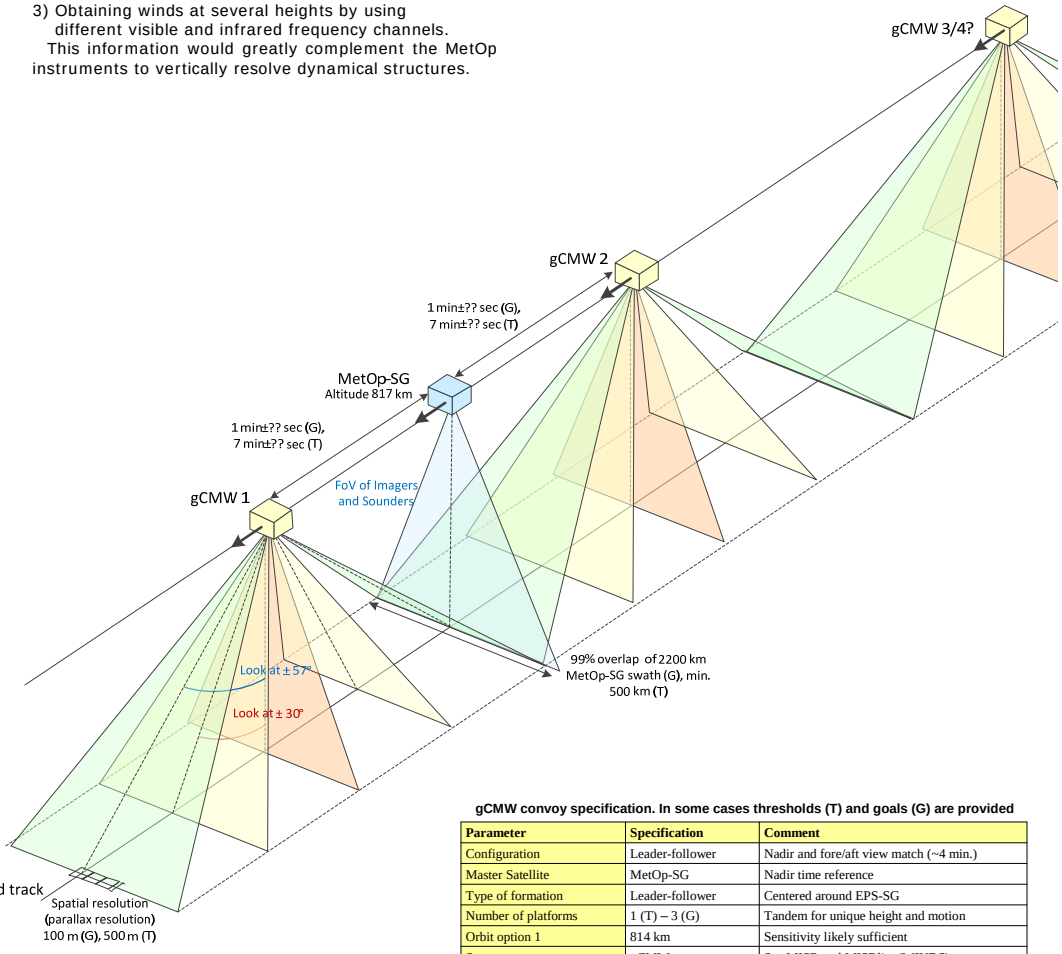
A multi-angle imaging spectro-radiometer (cf. MISR) is targeted for providing cloud top heights and height-resolved wind, vertical motion, aerosol and cloud structures using a multi-angle imager and geometric optics. Enhanced performance with respect to earlier flown missions may be achieved by

1) Launching a tandem of gCMW satellites, e.g., one leading and one following MetOp-SG,
2) Allowing night-time measurements by using infrared channels and
3) Obtaining winds at several heights by using different visible and infrared frequency channels.

This information would greatly complement the MetOp instruments to vertically resolve dynamical structures.




Schematic of the measurement principle for two different instrument looks




| Priority | Gap ID | Application Description | Notes/Technique |
|---|---|---|---|
| Key | M-G1 | Initialisation of NWP models, both regional and global. Particularly wind. Improved weather forecasts | Improved winds will in particular improve short-term (extreme) wind forecasts and tropical initialisation of convection. |
| | M-G1 | Improved global and regional circulation models on both small and large scales; improved climate predictions. | The tropical circulation, convective processes and UTLS dynamics are poorly known and key in climate prediction. This is synergistic with the above application. |
| | M-G1 | Quality Control and cal/val of satellite observations | Better use of existing satellite observations, particularly AMVs |
| | M-G5 | Modelling of cloud-scale processes | Combined knowledge of cloud and wind to model convection; one of the forthcoming main challenges in NWP |
| Secondary | M-G4 | Aerosol distribution modelling | Little 3D information due to horizontally uniform targets |
| | M-G5 | Cloud distribution modelling | 3D cloud structure (by geometrical techniques) |

Summary of the primary mission objectives for the gCMW convoy in formation with MetOp-SG

## Introduction

The idea of using satellite constellations and formations as a way to accomplish complex Earth Observation (EO) scientific objectives by exploiting synergies between different missions is not new and the success of these missions has further increased the interest within ESA and the wider European EO community for further applications of this concept [1].

The MetOp and MetOp Second Generation series of polar-orbiting meteorological satellites operated by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) are planned to provide long-term, continuous EO data streams into the post-2020 timeframe and provides an ideal mission operation context for an 'Atmosphere' convoy proposal as elaborated by ESA.

For the meteorology theme the gCMW concept has been selected by ESA for further assessment and both the 'Atmosphere' meteorology theme and the selected concept are addressed in this paper.

## Meteorology

The important role of satellite observing systems for these observations is well documented in the World Meteorological Organisation Rolling Requirements Review (WMO RRR [2]) and in Atmosphere Theme Report of the Integrated Global Observing Strategy (IGOS) [3]. They have been crucial in reaching our current level of understanding of the atmosphere; however, there are still major challenges which limit our understanding and ability to model key atmospheric processes. Accurate description of the 3D wind is fundamental for advancing numerical weather prediction (NWP), and the assessment and prediction of climate change. To obtain accurate estimates of initial conditions, advanced data assimilation systems and observations are needed. To date, mesoscale winds are not well exploited in global NWP and climate models and phenomena of turbulence and convection are not explicitly represented in these models. These phenomena are however initiating atmospheric dynamics and are the basis of the interaction of the troposphere with the surface and stratosphere.

When going to mesoscales (< 500 km) wind rather than temperature and pressure determine the evolution of the atmosphere in a regime of 3D turbulent flow. Wind measurements are thus of prime importance. Additional cloud and aerosol information is important to characterize cloud-scale processes, such as entrainment, heating/cooling and transport, which in turn affect larger-scale dynamics and radiation balance.

The technical challenge of convoy missions is in satellite formation flying (within minutes), which is obviously useful to observe fast processes. Convective scales are only a few tens of minutes and a few hundred meters in horizontal scale, posing further requirements to temporal and horizontal resolution if one wanted to follow these. Convection process studies need cases with high resolution of coincident dynamics and clouds. While geostationary satellites may provide adequate temporal resolution for processes associated with clouds, i.e., typically 10 minutes, they lack in particular vertical resolution. LEO satellites may provide somewhat improved vertical resolution, but lack time resolution. To better understand these physical processes, simultaneous height-resolved measurements of wind, humidity, temperature, cloud, aerosol and precipitation would be required with preferably a very high temporal resolution.

**gCMW convoy specification. In some cases thresholds (T) and goals (G) are provided**

| Parameter | Specification | Comment |
|---|---|---|
| Configuration | Leader-follower | Nadir and fore/aft view match (~4 min.) |
| Master Satellite | MetOp-SG | Nadir time reference |
| Type of formation | Leader-follower | Centered around EPS-SG |
| Number of platforms | 1 (T) – 3 (G) | Tandem for unique height and motion |
| Orbit option 1 | 814 km | Sensitivity likely sufficient |
| Sensor | gCMW | See MISR and MISRlite (WINDS) |
| Wavelength/Frequency | IR, VIS | Day and night coverage, diverse heights |
| Polarisation | | Control cloud polarization effects |
| Swath | 1500 km | Goal |
| Incidence angle | ±50º and 0º | To obtain accurate geometric heights |
| Pixel on surface | 100(G)-500 m (T) | To obtain accurate geometric heights |
| Spatial resolution | 1 (G) – 50 km (T) | Depending on atmospheric targets |
| Vertical resolution | 500 m | |
| NeDT | < 50 mK | Resolution preferred above low noise |

## Conclusions

To investigate the potential that spacecraft constellations and formations present for Earth Observation, three ESA "Earth Observation Sentinel Convoy" studies are currently underway as part of the Support to Science Element (STSE) of the Earth Observation Envelope Programme (EOEP) of the European Space Agency (ESA). The gCMW concept has been identified to provide height-resolved day-and-night mesoscale winds near cloud tops. After a technical feasibility assessment, several of its characteristics may be further optimized for measuring, e.g., convective-scale clouds.

## References and further information

[1] 1st International Earth Observation Convoy and Constellation Concepts Workshop - Science and application opportunities from novel multi-satellite approaches, 9-11 October 2013, ESA-ESTEC, Noordwijk, The Netherlands, http://congrexprojects.com/2013-events/13m12/home.
[2] Rolling Requirements Review and GCOS, http://www.wmo.int/pages/prog/sat/RRR-and-SOG.html
[3] Integrated Global Atmospheric Chemistry Observations Theme (IGACO) (2004) of IGOS, ESA SP-1282, Report GAW No. 159 (WMO TD No. 1235)
[4] Observing Systems Capability Analysis and Review Tool, OSCAR, www.wmo-sat.info/oscar
[5] MISR, http://www-misr.jpl.nasa.gov/