Uncertain climate models impair long-term climate strategies

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A new paper published in *Philosophical Transactions of the Royal Society A*, explains weaknesses in our understanding of climate change and how we can fix them. These issues mean predictions vary wildly about how quickly temperatures will rise. This has serious implications for long term political and economic planning. The paper's lead author is Dr Nigel Fox of The National Physical Laboratory, The UK's National Measurement Institution.

The Earth's climate is undoubtedly changing, but how fast and what the implications will be are unclear. Our most reliable models rely on data acquired through a range of complex measurements. Most of the important measurements - such as ice cover, cloud cover, sea levels and temperature, chlorophyll (oceans and land) and the radiation balance (incoming to outgoing energy) – must be taken from space, and for constraining and testing the forecast models, made over long timescales. This presents two major problems.

Firstly, we have to detect small changes in the levels of radiation or reflection from a background fluctuating as a result of natural variability. This requires measurements to be made on decadal timescales – beyond the life of any one mission, and thus demands not only high accuracy but also high confidence that measurements will be made in a consistent manner.

Secondly, although the space industry adheres to high levels of quality assurance during manufacture, satellites, particularly optical usually lose their calibration during the launch, and this drifts further over time. Similar ground based instruments would be regularly calibrated traceable to a primary standard to ensure confidence in the measurements. This is much harder in space.

The result is varying model forecasts. Estimates of global temperature increases by 2100, range from ~2-10◦C. Which of these is correct is important for making major decisions about mitigating and adapting to climate change: for instance how quickly are we likely to see serious and life threatening droughts in which part of the world; or if and when do we need to spend enormous amounts of money on a new Thames barrier. The forecasted change by all the models is very similar for many decades only deviating significantly towards the latter half of this century.

Dr Nigel Fox, head of Earth Observation and Climate at NPL, says: "Nowhere are we measuring with uncertainties anywhere close to what we need to understand climate change and allow us to constrain and test the models. Our current best measurement capabilities would require >30 yrs before we have any possibility of identifying which model matches observations and is most likely to be correct in its forecast of consequential potentially devastating impacts. The uncertainties needed to reduce this are more challenging than anything else we have to deal with in any other industrial application, by close to an order of magnitude. It is the duty of the science community to reduce this unacceptably large uncertainty by finding and delivering the necessary information, with the highest possible confidence, in the shortest possible time."

The solution put forward by the paper is the TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio- Studies) mission, a concept conceived and designed at NPL. This which would see a satellite launched into orbit with the ability to not only make very high accuracy measurements itself (a factor ten improvement) but also to calibrate and upgrade the performance of other Earth Observation (EO) satellites in space. In essence it becomes "NPL in Space".

The TRUTHS satellite makes spectrally resolved measurements of incoming solar radiation and that reflected from the ground, with a footprint similar in size to half a rugby field. The unprecedented accuracy allows benchmark measurements to be made of key climate indicators such as: the amount of cloud, or albedo (Earth's reflectance) or solar radiation, at a level which will allow differences in climate models to be detected in a decade (1/3 that of existing instruments). Its data will also enable improvements in our knowledge of climate and environmental processes such as aerosols, land cover change, pollution and the sequestration of carbon in forests.

However, not only will it provide its own comprehensive and climate critical data sets but can also facilitate an upgrade in performance of much of the world's Earth observing systems as a whole, both satellite and ground data sets. By performing reference calibrations of other in-flight sensors through near simultaneous observations of the same target, it can transfer its calibration accuracy to them. Similarly its ability to make high accuracy corrections of atmospheric transmittance allow it to calibrate ground networks measuring changes at the surface e.g. flux towers and forests and other reference targets currently used by satellites such as snowfields of Antarctica, deserts, oceans and the Moon. In this way it can even back correct the calibration of sensors in-flight today.

TRUTHS will be the first satellite to have high accuracy traceability to SI units established in orbit. Its own measurements and in particular the calibration of other sensors will not only aid our understanding of climate change but also facilitate the establishment and growth of commercial climate and environmental services. One of the barriers to this markets growth is customer confidence in the results and long-term reliability of service. TRUTHS enable a fully interoperable global network of satellites and data with robust trustable guarantees of quality and performance.

The novelty of TRUTHS lies in its on-board calibration system. The instruments on the TRUTHS satellite will be calibrated directly against an on-board primary standard – an instrument called a CSAR (Cryogenic Solar Absolute Radiometer). This compares the heating effect of optical radiation with that of electrical power – transferring all the difficulties associated with existing space based optical measurements (drift, contamination, etc) to more stable electrical SI units. In effect, this mimicks the traceability chain carried out on the ground in orbit.

This would make climate measurements ten times more accurate and give us models on which we could make important decisions about the future.

The project, which would be led by NPL, is being considered by different organisations. The European Space Agency has recommended looking into ways to take it forward, possibly as a collaboration with other space agencies. NASA is also keen to collaborate formally.

Nigel concludes: "Taking this forward would be an excellent investment for the UK, or any other country which supports it. This is not only an effective way to address the problem of understanding climate change, but also an excellent opportunity for business. It would grow expertise in Earth Observation and showcase the UK's leading space expertise – an industry which is growing by 10 per cent a year. It would also provide a platform to underpin some of the carbon trading which will be a big international business in the near future."

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