PAPERS

GENERAL PHYSICAL BACKGROUND OF BALANCES AND DYNAMIC EQUILIBRIUM STATES IN THE EARTH'S GREENHOUSE EFFECT

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November 15, 2018

The working paper is an excellent start to the realistic analysis of surface temperatures using the time dependent properties of the surface flux terms. Once these are understood, a completely different picture of the surface energy transfer emerges that can be related to the properties of both the local weather systems and the local diurnal heating effects. This approach also allows complexity theory to be introduced without the use of a large number of coupled non-linear equations. In addition to the changes in temperature, there is also a time delay or phase shift between the solar flux intensity and the temperature response. The seasonal phase shift is readily available from the weather station record. This can be used as a probe of ocean influence on the local weather station. The LWIR flux cannot be separated from the other flux terms and analysed separately. Small increases in the downward LWIR flux from the observed increase in atmospheric CO_2 concentration cannot couple into the surface thermal reservoirs in a way that can cause any measurable change in temperature, either at the surface or in the weather station record.

The current concept of a 'greenhouse effect' in the earth's atmosphere is based on the incorrect assumption of an 'equilibrium average infrared atmosphere' [Taylor, 2005; M&W, 1967]. The observed climate stability of the earth requires both a stable heat source – the sun, and an approximate long term average energy balance between the absorbed solar flux and the long wave IR (LWIR) radiation that is returned to space. However this does not lead to a requirement for an exact short term flux balance between an average solar flux and an average LWIR flux. The surface temperature simply needs to remain within relatively narrow bounds.

There is no thermal equilibrium in the climate system. The local solar flux is always changing on both a daily and seasonal time scale. The local temperature change has to be described as the cumulative change in heat content or enthalpy of the local thermal reservoir divided by the heat capacity. The various energy flux terms are rates of heating or cooling. The outgoing LWIR flux at the top of the atmosphere does not have the spectral distribution of a blackbody emitter and should not be converted to an 'effective emission temperature'. Measurement of the IR flux can be used to derive a local temperature at the time of the measurement. However, a change in IR flux applied to a thermal reservoir cannot be used to infer a change in temperature based on blackbody radiation alone.

The earth's surface cools through a combination of net LWIR flux emission, convection and evaporation. Convection is a mass transport process. As the warm, moist air rises through the troposphere it must perform mechanical work to overcome the earth's gravitational potential. This means that the rising air mass must cool and water vapor will condense and release heat above the saturation point. The earth also rotates and the rising air mass is coupled to the earth's angular momentum. This leads to the formation of the basic Hadley, Ferrell and polar convective cells and the trade winds that drive the ocean gyres. Energy transport in the oceans is also through a combination of convection and ocean currents. The mathematical description of fluid convection involves the solution of coupled non-linear equations. These give rise to mathematical instabilities that need to be analysed using complexity theory. However, the surface energy transfer processes can be simplified in such a way that the time dependent surface temperature can be analysed without use of fluid dynamics.

The starting point is that the greenhouse effect can be described as a non-equilibrium, time dependent LWIR exchange energy between the surface and the downward flux from the lower troposphere. This exchange energy limits the amount of heat that can be dissipated from the surface by net LWIR emission. The land-air and ocean-air interfaces have different energy transfer processes and need to be considered separately. Over land, the surface must warm up during the day as the excess absorbed solar flux is dissipated by convection. This can be described using a parametric heat loss term without consideration of the convection above the surface. Over the oceans, the surface temperature must increase until the water vapor pressure is sufficient to allow removal of the excess heat by wind driven evaporation. This can also be described as a bulk heat loss term involving in this case surface and air temperatures, humidity and wind speed [Yu et al, 2008]. The upper limit to the solar flux is the daily 'clear sky' flux that depends on latitude and season. This provides a basic framework for the analysis of the surface temperature. However, ~~some of the~~ absorbed heat is also stored below the surface and this must also be considered in the analysis [Clark, 2013a; 2013b].

Over land, the surface heating establishes a thermal gradient that conducts heat below the surface during the morning and early afternoon. The thermal gradient then reverses as the surface cools and the stored heat is released back into the troposphere later in the day. Over the oceans, the surface is almost fully transparent to the solar flux. Approximately 90% of the solar flux is absorbed within the first 10 m layer. The surface-air temperature gradient is quite small, usually less than 2 K. The excess absorbed solar heat is removed through a combination of net LWIR flux emission and wind driven evaporation. These two processes combine to produce cooler water at the surface. This then sinks and is replaced by warmer water from below. This is a Rayleigh-Benard convection process, not simple diffusion. The upwelling warm water allows the wind driven ocean evaporation to continue at night. As the cooler water sinks, it carries with it the surface momentum or linear motion produced by the wind coupling at the surface. This establishes the subsurface ocean gyre currents.

The subsurface thermal storage also leads to another concept that is not usually considered in the surface temperature analysis. This is the time delay or phase shift between the peak solar flux and the peak surface temperature. There is both a daily and a seasonal time delay. The daily phase shift is typically near 2 hours over land for clear sky conditions. Over the oceans, the phase sift is similar, but it also depends on the wind speed and decreases with increasing wind speed. The seasonal phase shift at most latitudes outside of the tropics is near 6 weeks. However, heat transfer calculations show that this phase shift can only be produced by ocean heating. It can also be seen in Argo float data [NOAA, PML 2012]. The heat capacity of the land thermal reservoir is too small. The diurnal depth variation only extends 1 to 2 m below the land surface and almost all of the heat is dissipated in the same day that it is absorbed. This leads to another important concept: the diurnal convection transition temperature.

Over land, the surface cools by convection each evening until the surface and surface air temperatures are approximately equal. However, the local weather systems are continuously changing. The equalization temperature or diurnal convection transition temperature changes each day with the local weather system. In many regions, there is a seasonal phase shift of approximately 6 weeks that can only come from weather systems that were formed over the ocean. This explains the observation of ocean oscillations such as the Pacific Decadal Oscillation (PDO) the Atlantic Multi-decadal Oscillation (AMO) in the weather station temperature record [Clark, 2013b].

It is also important to understand that the various flux terms are coupled together in the surface layer and that the LWIR flux cannot be averaged and analysed separately. Again the land and ocean surfaces are different. Over land, all of the various flux terms, the solar flux, the net LWIR cooling, the sensible and latent heats and the subsurface conduction are mixed into a single surface layer. Any change in surface temperature is coupled to the heat capacity of the land diurnal thermal reservoir. Over the oceans, the penetration depth of the LWIR flux into the surface layer is 100 μm or less and the evaporation involves the removal of water molecules from a thin surface layer. This means that the wind driven evaporation and the net LWIR flux must be fully coupled together at the surface and treated as one cooling flux. The cooler water produced by these two processes combine then sinks and cools the bulk ocean layers below. The wind driven evaporative cooling is much larger and more variable than the small increase in LWIR flux from CO_2. This means that there can be no global warming from CO_2. The small temperature change from the increase in LWIR flux from CO_2 is overwhelmed by the evaporation.

In the original radiative convective equilibrium climate model described by Manabe and Wetherald in 1967 the various flux terms interacted with a 'blackbody surface' that had zero heat capacity [M&W, 1967]. The relative humidity was fixed so that a small increase in surface temperature from an increase in atmospheric CO_2 concentration was amplified, by definition by 'water vapor feedback'. This created global warming as a mathematical artefact of the modelling assumptions. Later, for example in the 1981 paper by Hansen et al, the weather station record had been substituted for the surface temperature without any modification to the flux interaction terms [Hansen et al, 1981]. The weather station temperature is the meteorological surface air temperature (MSAT). This is the air temperature measured in a ventilated enclosure located 1.5 to 2 m above the ground. Historically, the minimum and maximum MSATs were recorded using Six's thermometer. These are typically averaged together and processed to generate a 'temperature anomaly' that is compared to climate model output. Neither the average MSAT nor the climate model output have any real physical meaning.

Information on the surface energy transfer physics can be derived from the weather station record by considering the minimum and delta (max-min) MSATs separately. The minimum MSAT is approximately the bulk air temperature at the base of the weather system as it is passing through. It is also an approximate indicator of the minimum land surface temperature. The delta MSAT is a measure of the local surface heating convectively coupled to the MSAT thermometer. It is an approximate measure of the combined effects of the solar flux, cloud cover, sensible and latent heat terms. Temperature comparisons should also be limited to those within local climate zones. A global average temperature anomaly has no useful physical meaning.

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