Even Cooler Insights:

On the Power of Forests to (Water the Earth and) Cool the Planet

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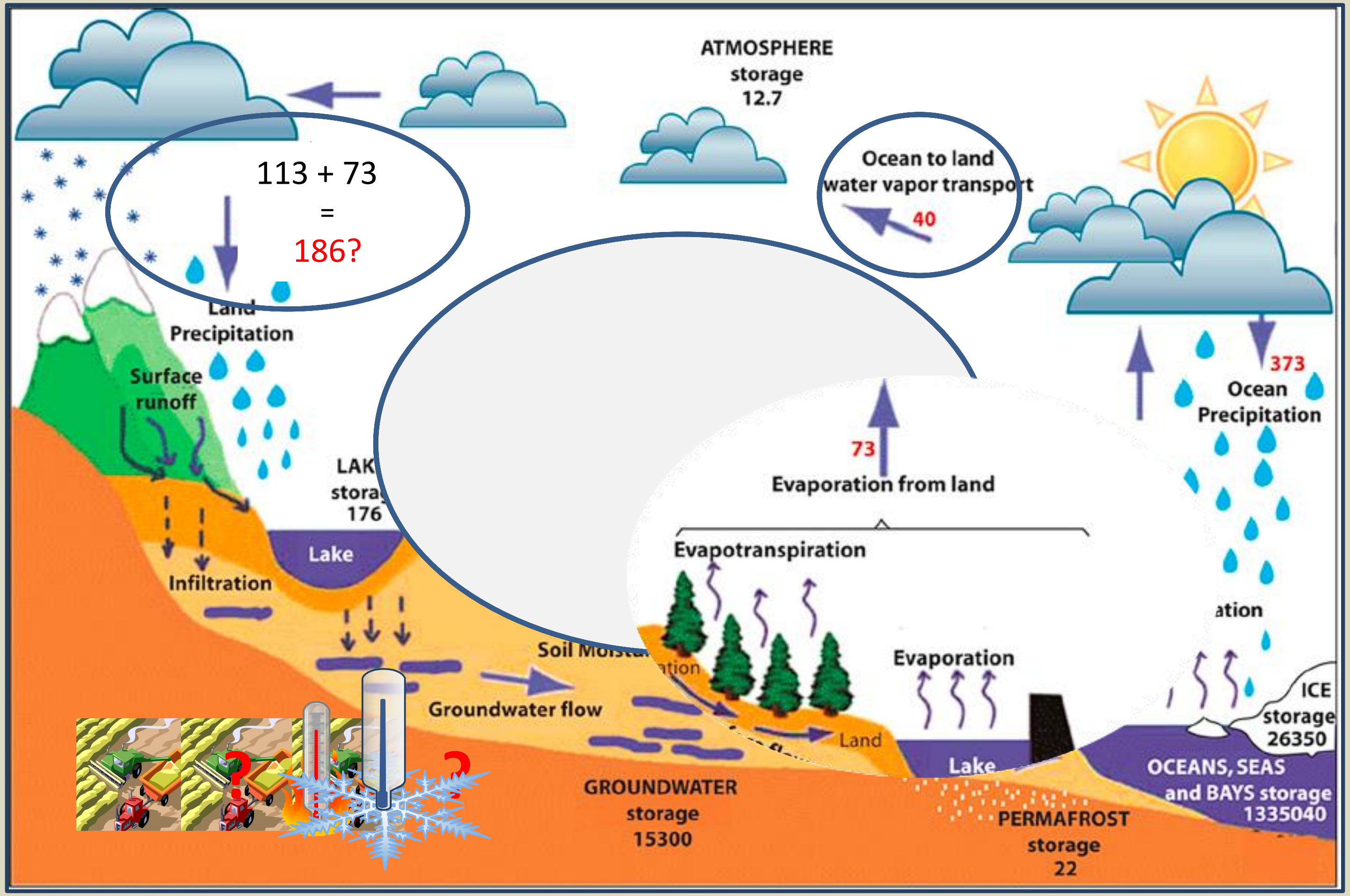
Global Hydrologic Cycle and Variations in Land Cover



(Gimeno et al 2012)

There are large and important benefits from increased wetland and forest cover!

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Debate on the Advantages of Forests for Cooling/Warming

In line with past findings, the IPCC's AR6 WGI report states, "land use and land cover changes over the industrial period introduce a negative radiative forcing by *increasing the surface albedo*. This effect has increased since 1750, reaching current values of about –0.20 Wm^2 (medium confidence)…"

There have been repeated findings across several decades that deforestation in the Norther Hemisphere across both the temperate and the boreal zone has led to cooling instead of warming.

Some of these articles date back to the early 90's (and may date even further back). Among some of the most recent findings are Lawrence et al. (2022), Windisch et al. (2021).

These findings are troubling because they do not sit well with the observational data on surface temperature change and other analyses of the role and impact of tree and forest cover.

There is clearly disagreement over the impact of forests on cooling/warming at both global and local scales.

Lawrence et al., (2022) – The Unseen Effects of Deforestation: Biophysical Effects on Climate

- ET
- Snow covered surfaces

The Boreal is "energy-limited", not "water-limited"!

Winter days are short or non-existent.

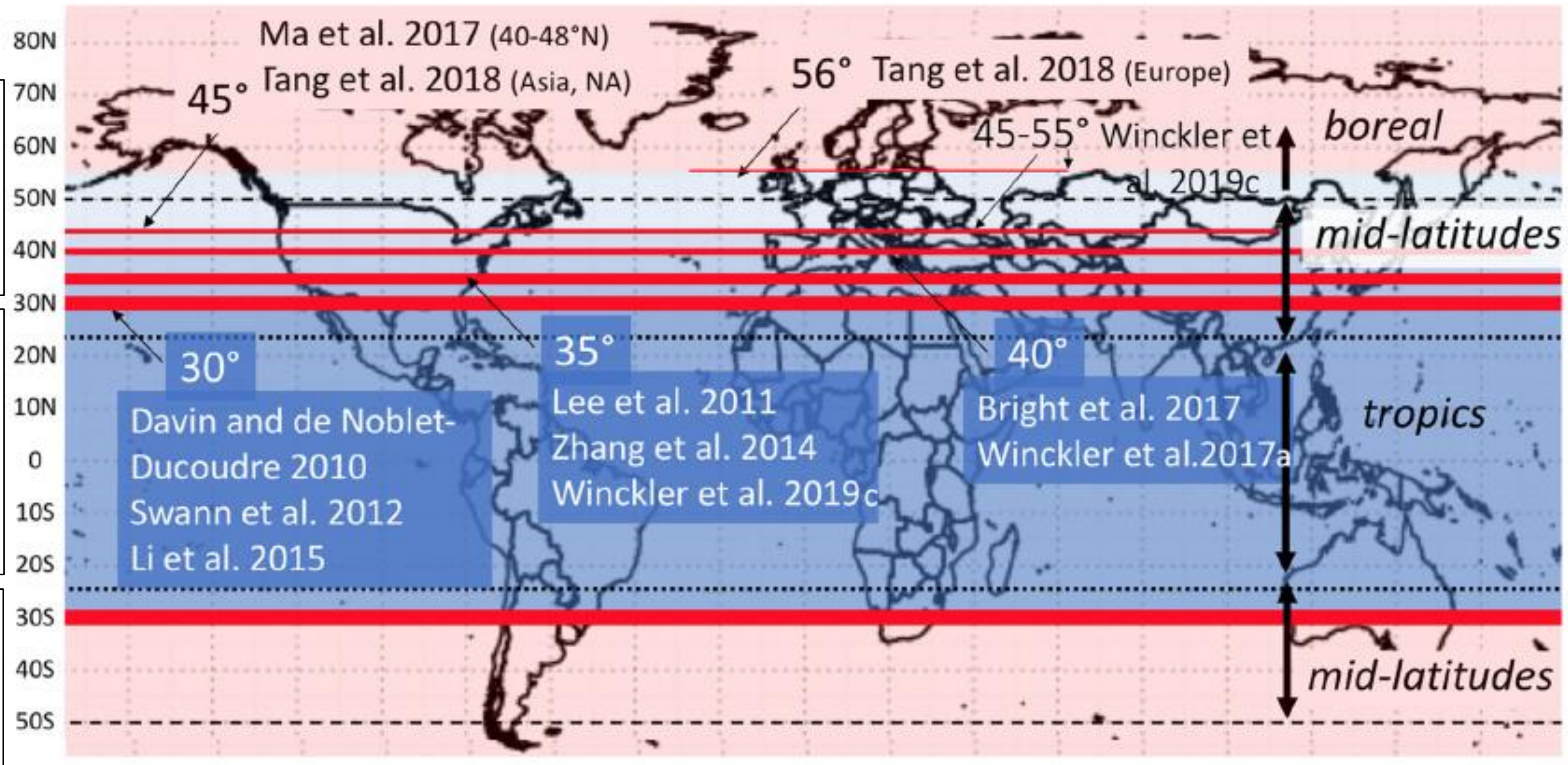

FIGURE 1 | Latitude of net zero biophysical effect of forests on local temperature varies from 30 to 56°N. Above the line, forest cover causes local warming; below the line, forest cover causes local cooling. The thickness of the line indicates the number of studies that show forest cooling up to that threshold. Data sources as indicated.

Principal causal pathways by which wetlands and TFVC (tree, forest and vegetation cover) influence temperature and the climate

- Carbon sequestration (& respiration)

Principal focus of UNFCCC

- Surface albedo effects
- Latent heat production (ET)
- Cloud production

Largely ignored by UNFCCC

⇒ Different studies focus on different causal pathways, little consistency across studies

⇒ Almost no studies integrate cloud production with all the other causal pathways

- However, many of these studies are frequently sold as “net effects” models?

Direct causal effects of CO2 Emissions/Removals

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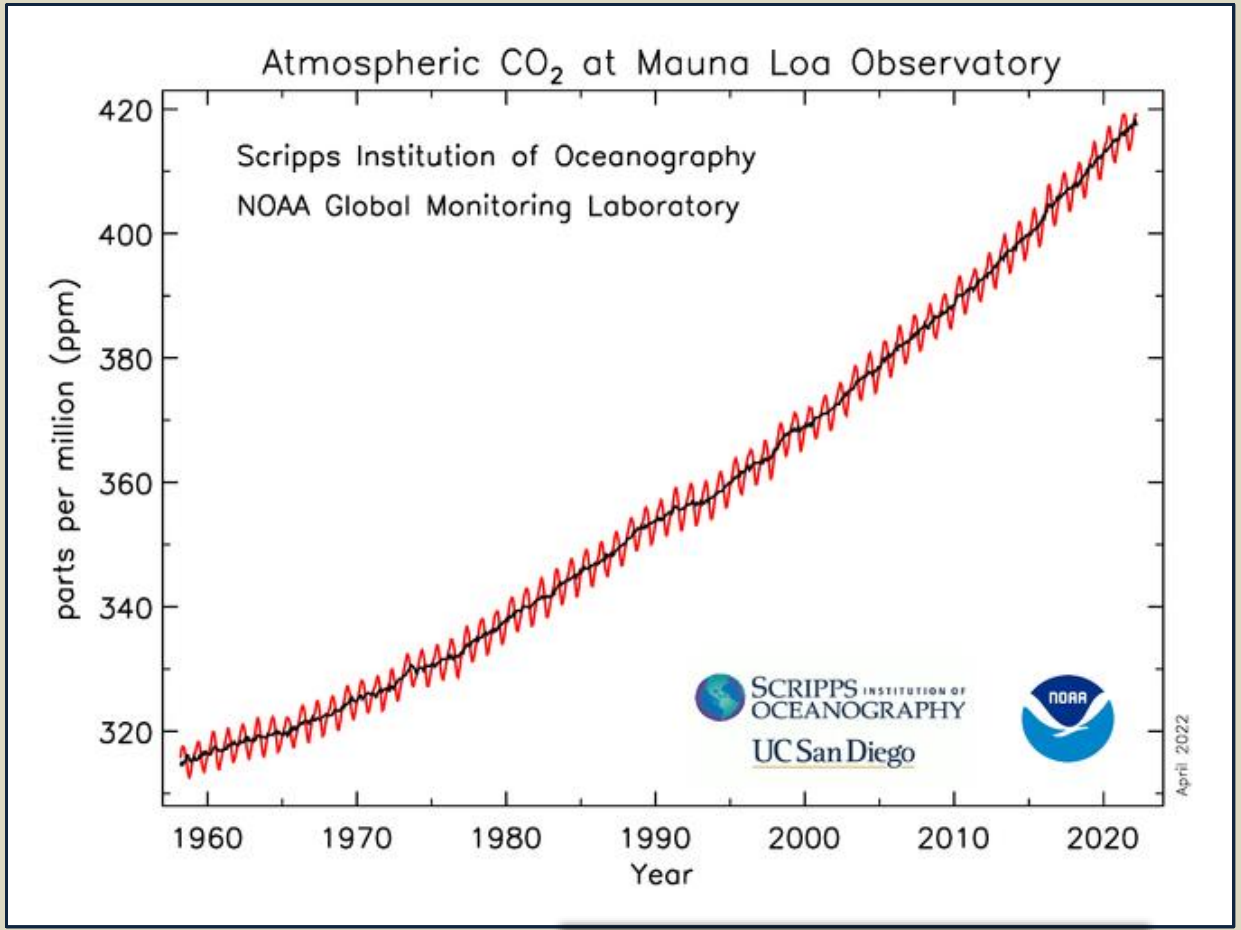
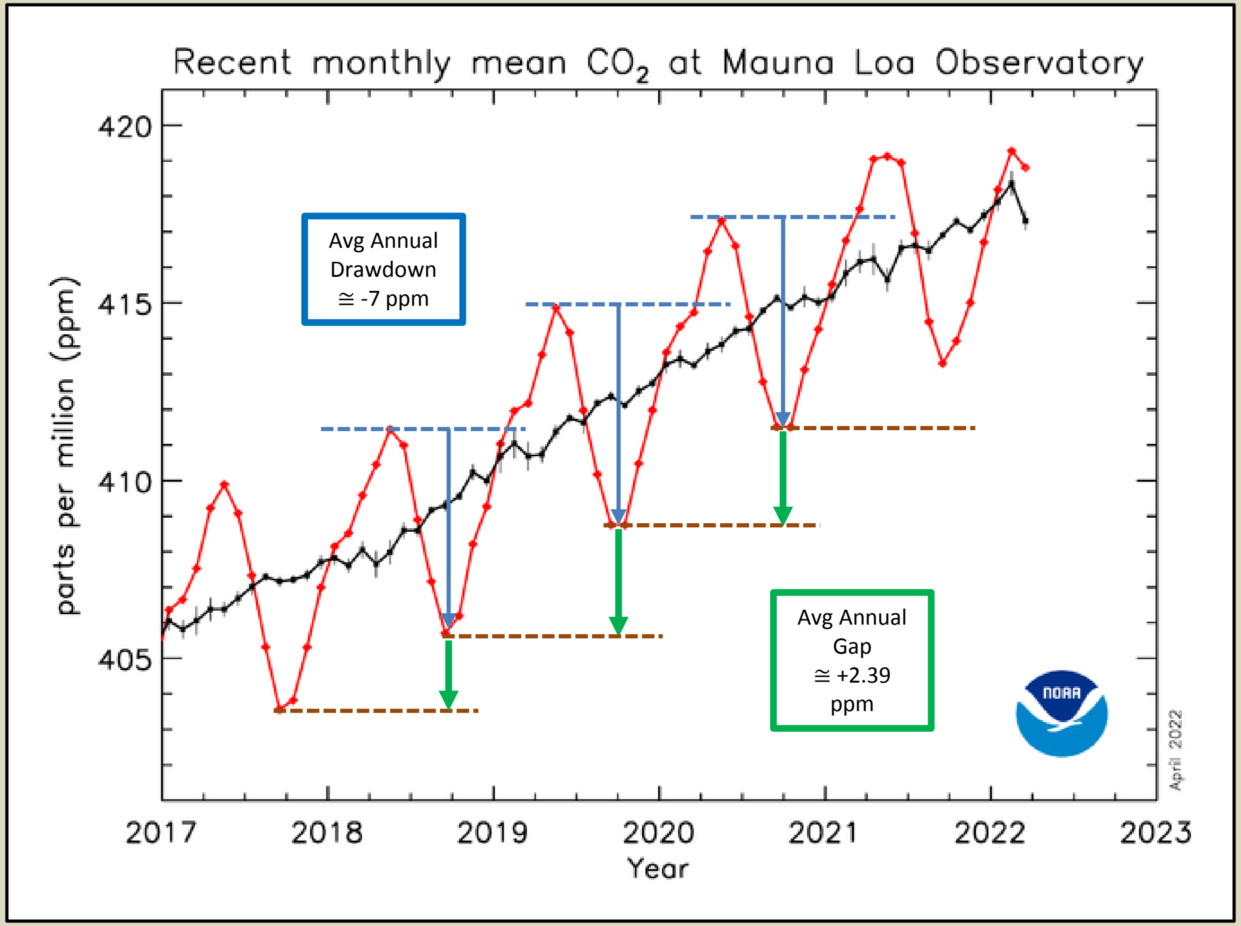


The annual drawdown/re-emission gap (imbalance) is growing:
1960: +0.82 ppm
2020: +2.39 ppm
(IPCC AR6 WGI Ch5).



Direct causal effects of CO2 Emissions/Removals

The current total land use-based drawdown is approximately
-12.5 ± 3.2 GtCO_2-eq yr $^{-1}$ (IPCC AR6 WGIII Ch7)

Closing the 2.39 ppm gap would require approximately
-8.53 GtCO2-eq yr $^{-1}$
in additional removals (or reduced emissions) per year to stabilize,
but not reduce, atmospheric CO2 concentrations.

Much of this could already be achieved by reversing current land use emissions
(i.e., deforestation),
+5.9 ± 4.1 GtCO_2-eq yr-1

The additional required removals could potentially be achieved with additional
reforestation and forest landscape restoration
-2.63 GtCO_2-eq yr $^{-1}$

By way of example, Roe et al., (2021) argue that additional, cost-effective land-based
mitigation potential represents approximately -8 to -13.8 GtCO_2-eq yr $^{-1}$

Restoring a significant share of historically lost forest cover
could likewise have a significant impact,
from -8.3 to -12.5 GtCO_2-eq yr $^{-1}$

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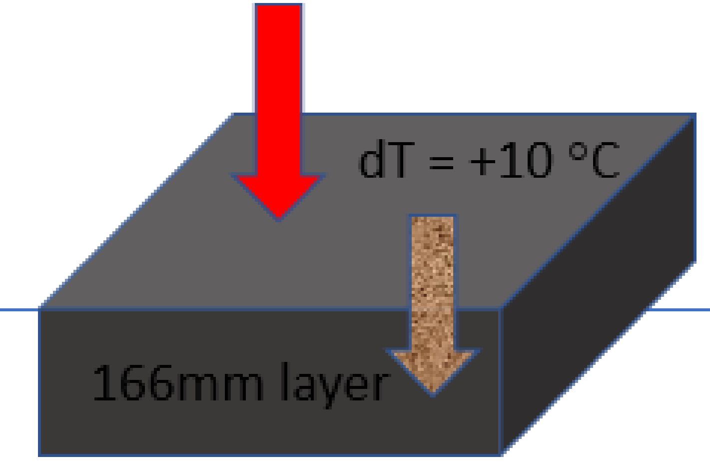
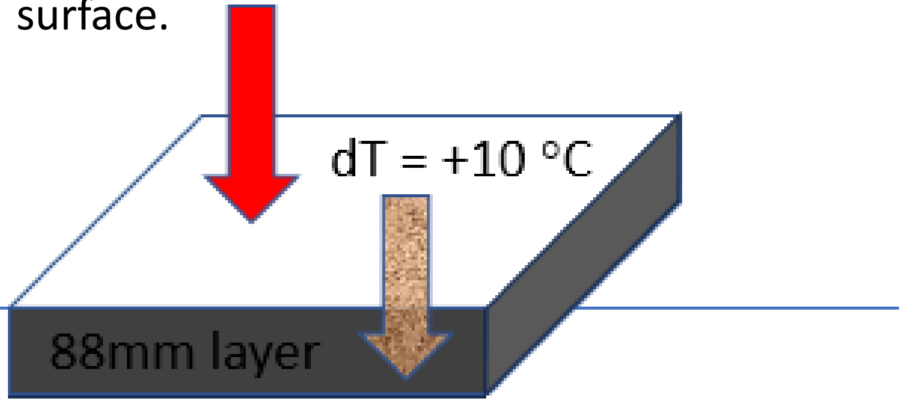
The Consequences of Albedo on Different Kinds of Surfaces

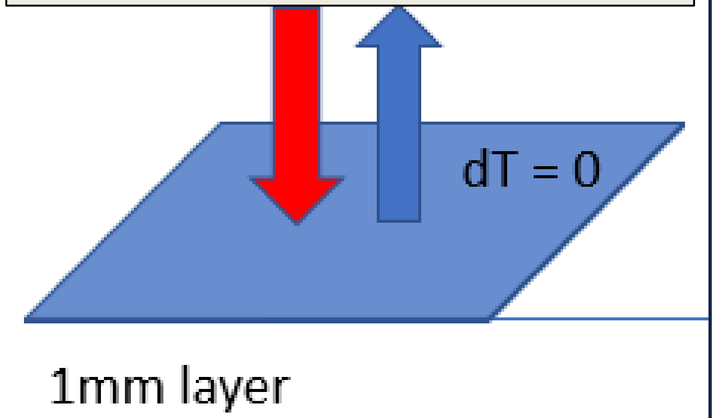
2,480 kj of energy will warm 288 kg of dark-colored concrete by 10°C. The energy remains stored on the surface.



The same amount of energy (2,480 kj) will warm 144 kg of light-colored concrete by 10°C. Some energy is reflected back toward space. The remaining energy is stored on the surface.



The same amount of energy (2,480 kj) is needed to evaporate 1mm of water from a 1m^2 surface. The surface temperature does not change.



Tree and Forest Cover facilitate evapotranspiration for two principal reasons

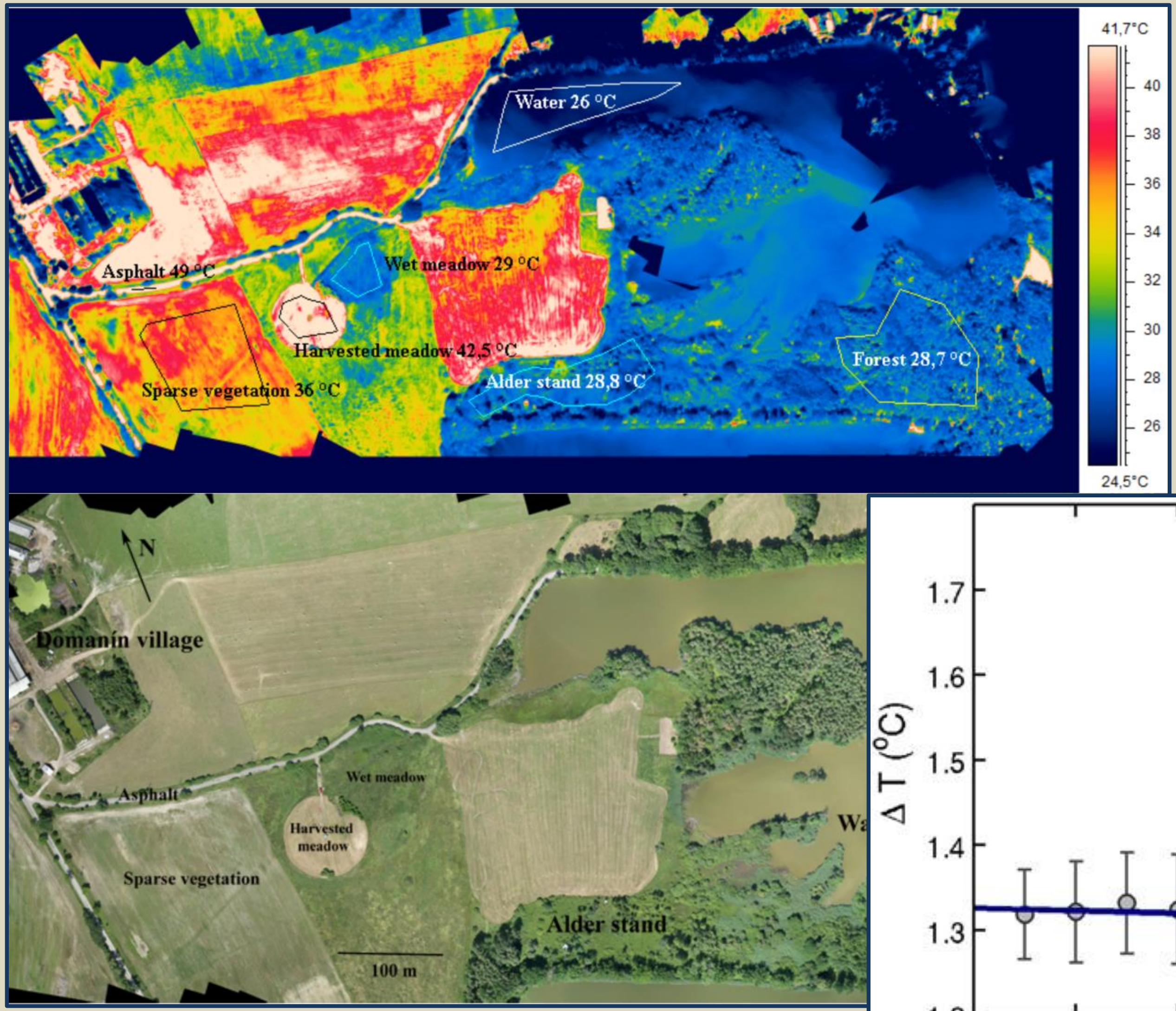
1) The help store water on terrestrial surfaces

2) They facilitate evapotranspiration, moving water from the land surface into the atmosphere

We Know ET Cools the Land Surface, But What does Albedo Tell Us?

E V A P O T R A N S P I R A T I O N

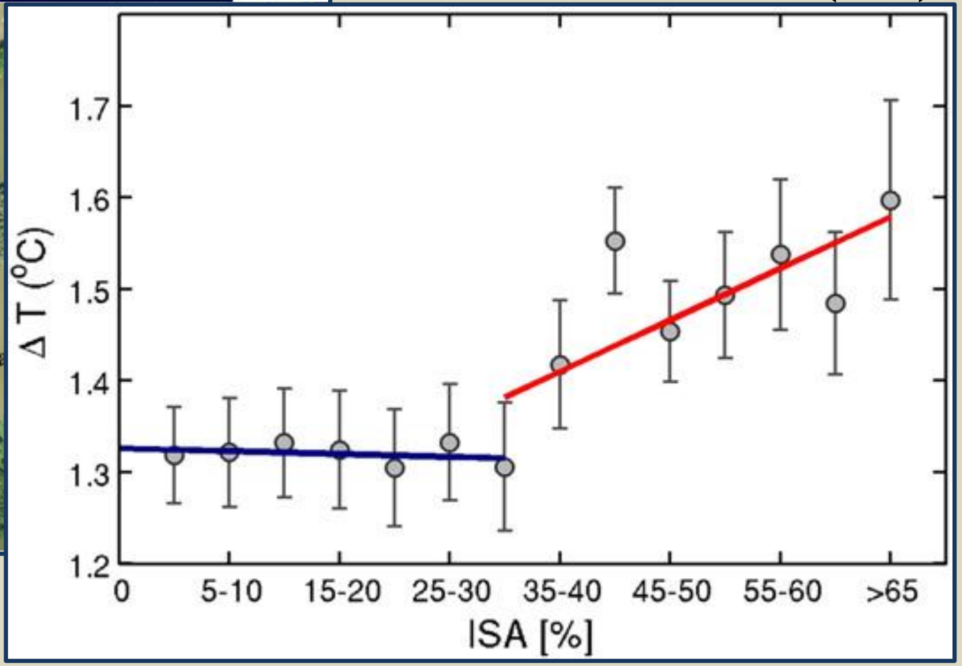
(ET)



(Pokorny, Hesslerova et al., 2013)

- Forest-water interactions ***dissipate solar energy***
- ***Transpiration and Evaporation*** require energy
- ***Surface cooling*** is the result.

Urban Areas above/below 35% Impervious Surface Area (ISA)



(Bounoua et al., 2015)

Evidence suggests E/ET are "*vegetation-dependent*"

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(ET)

On terrestrial surfaces, very little E/ET is produced without the presence of vegetation and/or wetlands.

⇒ The previously dominant paradigm suggested that E/ET can occur in areas without vegetation (TFVC).

If we comb the literature on Transpiration, Interception, Soil Moisture Evaporation, we come to a different conclusion:

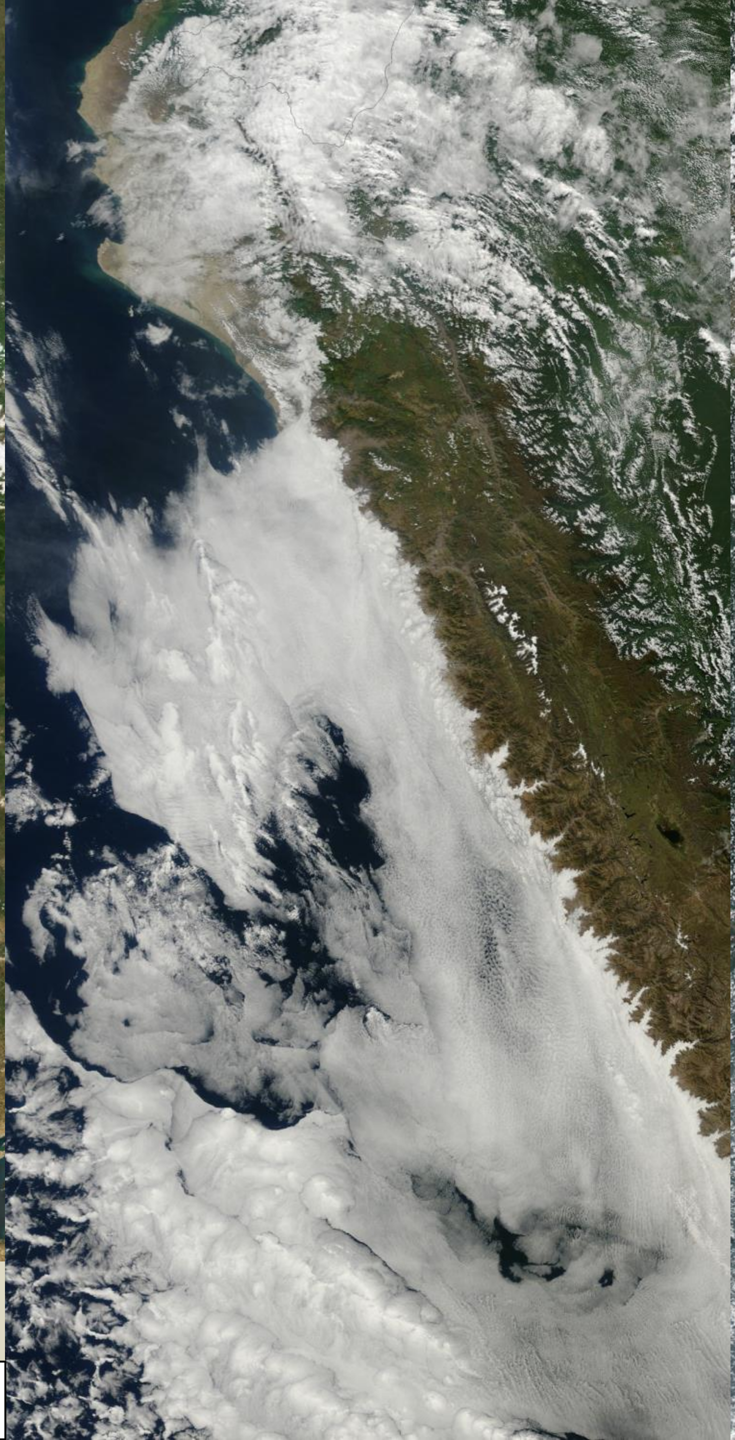
• Transpiration:	60 – 64% (of terrestrial E)
• Interception:	18 – 25%
• Soil Moisture E:	10%

Vegetation-Dependent E:	88 – 99% (of terrestrial E)
E from barren surfaces:	1 – 12% (of terrestrial E)

(Most overland flow => will end up as river runoff. Tree and Vegetation cover loss promotes soil degradation and overland flows).

Albedo is an evolutionary principle…!!!

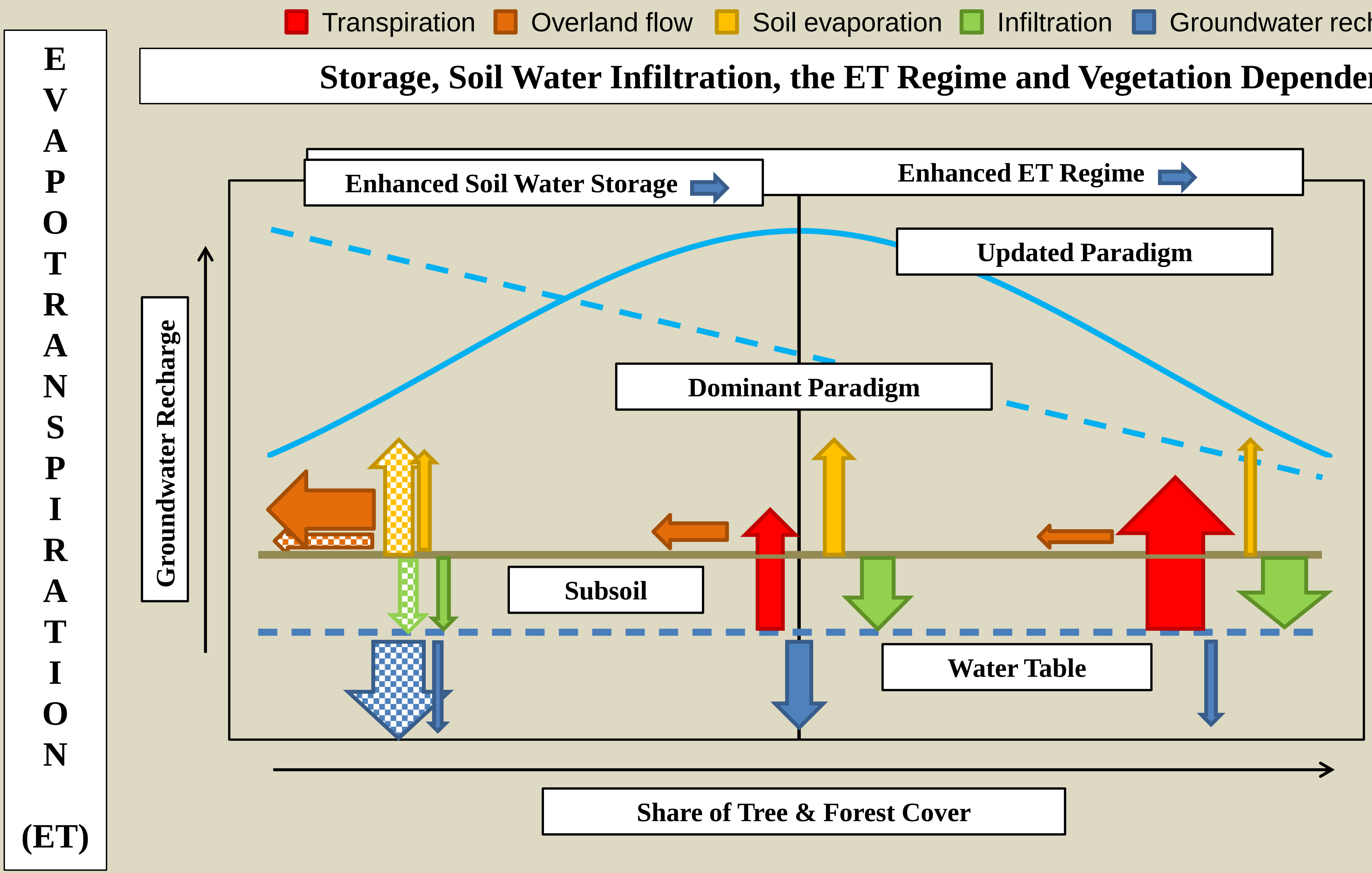
Kaukasus



Peru

Amazon

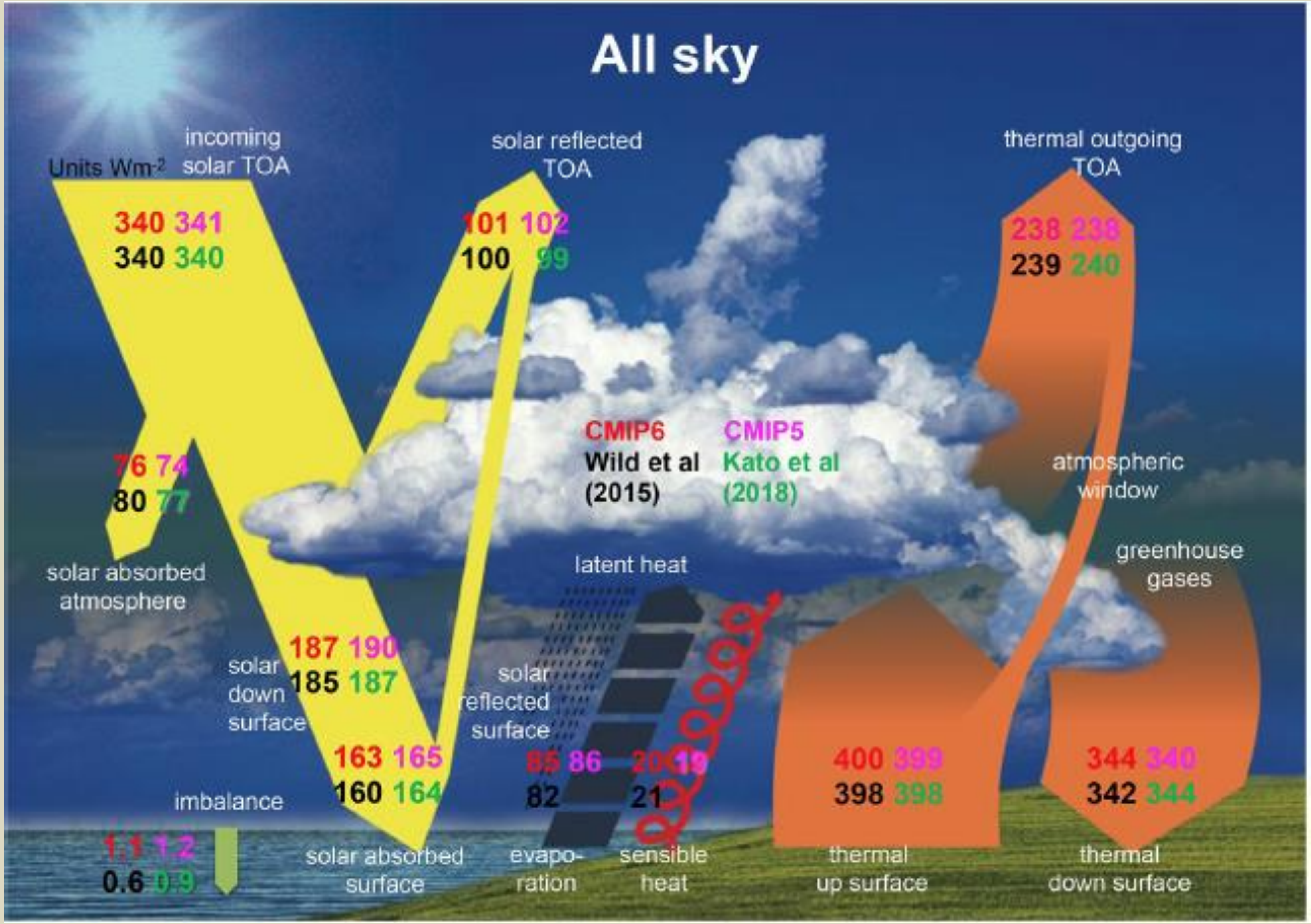
Storage, Soil Water Infiltration, the ET Regime and Vegetation Dependence



- Minimum tree cover requirement (restoration)
- Optimal tree cover density? (may be much higher)
- Think about the implications here of models like the Palmer Drought Severity Index (PDSI) for land cover?
- Which is better for improving soil moisture storage and water availability across space?

Global Energy Budget under Skies with Clouds

C L O U D F O R M A T I O N



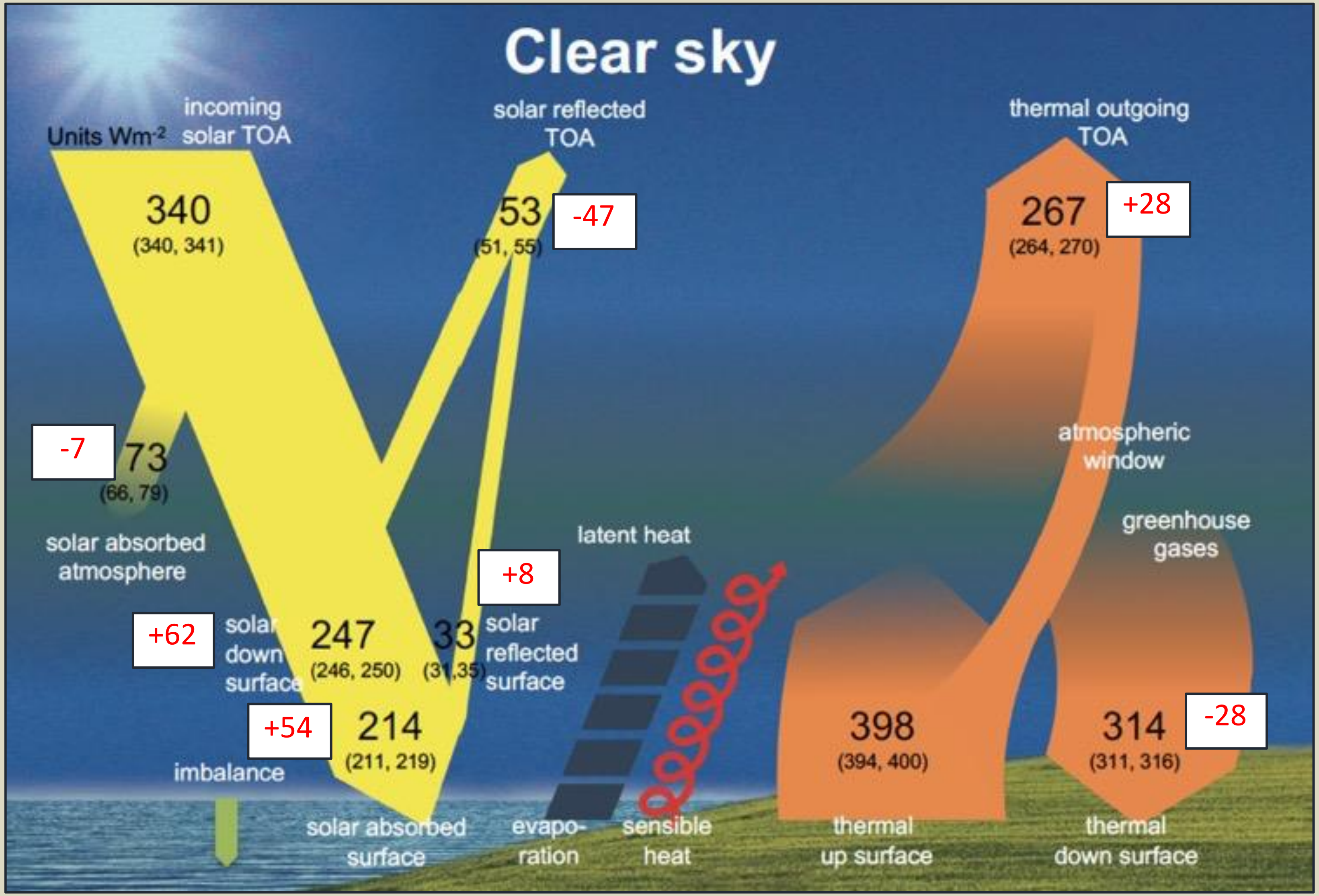
Wild et al., (2020)

Does terrestrial surface cooling (ET) lead to global cooling?

- Perhaps not, reduces outgoing LW radiation.
- **But ET does lead to cloud formation!**
- **And this increases top-of-cloud reflectivity (albedo)**

Global Energy Budget under Clear Skies

CLOUD FORMATION



- **This may be about as close as we can get to an estimation of the deforested state (i.e., without clouds).**
- The net result of the increase in the downward solar radiation flux and the increase in the upward thermal heat flux is equivalent to about **+20 Wm2**.
- Suggests that deforestation should bring significant warming (not cooling)
- The loss of cloud cover is important!

Numbers in red compare the clear sky to the energy budget with clouds.

Wild et al., (2019)

How much of an impact could increased cloud cover have?

C L O U D F O R M A T I O N

Estimated Effect of Increased Forest Cover on the Net Radiative Balance (EEI) and TFVC Drawdown	Estimated Historical Forest Cover Loss (FCL)		Formulas	Logic
	-40%	-50%	(FAO estimate)	cropland + urban settlement conversions
Land Latent Heat Flux (LHF, Wm^2)	38.0	38.0	(Wild, 2015)	Terrestrial Latent Heat Flux
Current Annual TFVC CO_2 Drawdown ($GtCO_2$ -eq yr-1)	-12.5	-12.5	IPCC AR6 WGIII Ch7	Annual TFVC Drawdown
Lost Latent Heat Flux (compared to 100% Forest Cover, Wm^2)	-25.3	-38.0	= (LHF/FC) * (1-FC)	Lost terrestrial latent heat flux (assuming all land can be converted)
Potential LHF (PLHF) with cropland conversion to forest (Wm^2)	10.1	15.2	= (x * .80) * (1 - 0.5)	Potential additional terrestrial latent heat flux assuming only agricultural land (80% of total loss) can be converted - Cropland LHF = 50% * forest LHF)
% Increase in Latent Heat Flux (assume 100% cropland conversion to forest, minus cropland ET Flux)	21%	29%	= PLHF/LHF	Potential % increase in LHF
Change in top-of-cloud OLW (assuming initial 28 Wm^2 OLW flux)	1.7	2.3	= (28 * (PLHF/LHF)) * .29	Estimated change in outgoing LW flux (adj. for 29% land cover) - increases in cloud cover reduce the OLW flux
Change in top-of-cloud OSW (assuming 64 Wm^2 outward reflectivity)	-3.9	-5.3	= -(64* (PLHF/LHF)) *.29	Estimated change in outgoing SW flux (adj. for 29% land cover) - increases in cloud cover increase the OSW flux
Estimated Change in EEI from change in cloud cover (Wm^2)	-2.2	-3.0	= SUM (ΔOLW + ΔOSW)	Potential Change in EEI from Increased Cloud Cover
Estimated Change in Total Annual TFVC Drawdown ($GtCO_2$-eq yr-1)	-8.3	-12.5	= (DD/FC) * (1-FC)	Potential Change in TFVC Drawdown from Increased TFVC

IPCC AR6 WGI Ch7: the EEI is estimated at 0.5 ± .185 Wm^2 (for the period 1971-2006), and 0.79 ± .27 Wm^2 for the period 2006-2018

These back-of-the-envelope calculations presumably overestimate factors such as reduced temperatures (with more TFVC), E over water bodies, magnitude, etc.

Is the Role of Albedo Over-Emphasized?

Mother Nature is and has been far less concerned about albedo effects than we seem to be.

Prior to the current state of historical deforestation (and prior to all global warming and climate change impacts), existing tree and forest cover had no *negative*, potentially *climate-warming* consequences.

Thus, it is unlikely we need all the albedo-related cooling power of snow cover that would come with outer latitude deforestation
(though clearly, we must eliminate GHG's from industrial processes and the atmosphere).

Deforestation has many other negative consequences that should likewise be considered:
loss of precipitation recycling, loss of soil water infiltration and groundwater recharge, loss of hydrologic intensity, loss of terrestrial surface cooling potential, loss of natural water purification processes, etc. …

Thus, it is highly likely that albedo impacts are greatly *over-estimated* and other tree and forest cover impacts *neglected* and *under-estimated* (e.g., modeled data *misrepresents/under-estimates* the surface cooling power of forests and thereby *overstates* albedo impacts).

Some Conclusions:

Wetland, tree, forest, and vegetation cover play an important role in providing the potential for increased ET production and thus hydrologic intensity across land surfaces.

Increased wetland, tree, forest and vegetation cover contributes dramatically to many significant and beneficial outcomes:

- The cross-continental transport and recycling of water and atmospheric moisture
- The cooling of terrestrial surfaces (lowering of surface temperatures) requires TFVC!
- More wetlands and forests can also bring extensive global cooling:
    - Reduction of atmospheric CO_2 (carbon sequestration).
    - Increase in cloud cover and top-of-atmosphere reflectivity.

➢ The benefits of increased wetland, tree, forest and vegetation cover, irrespective of where they occur, should not be ignored.

➢ The Boreal is neither expendable, nor negotiable:
- Stores: 272 ± 23 Pg C; Annual flux removes: -3.4 to -4.4 $GtCO2^{-1}$

Thanks for Listening!

Comments Welcome (EllisonDL@Gmail.com)