Water cyclE changes characterised from ATmospHeric moisturE Recycling (WEATHER)

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LIVING PLANET FELLOWSHIP
ATMOSPHERE

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL
UNIVERSITY OF LEICESTER

Outline

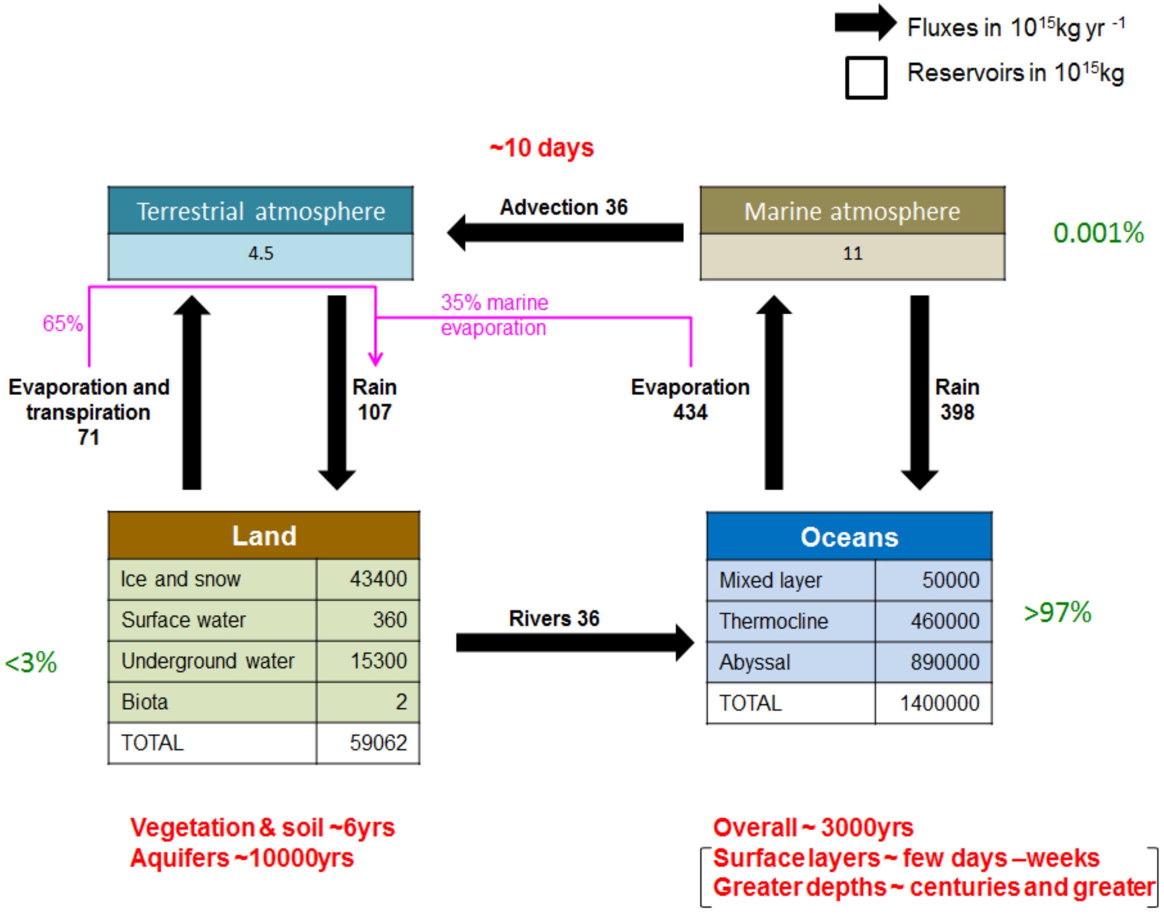
- Introduce my self and a brief motovation behind fellowship
- Overview of aims and objectives of first 8 months of fellowship
- Describe current work undertaken

About me

- Background predominantly in IR remote sensing of trace gases+surface properties:
  - HIRS, AIRS, IASI and MTG-IRS water vapour retrievals
  - AVHRR, AATSR and MODIS LST
  - IASI aerosol and SST
  - Limb products of T, H2O and other GHG +CFCs from ACE, MIPAS, MLS, COSMIC
  - MW TCWV products
  - More recently working with SWIR instruments GOSAT and TROPOMI
- Involvement with a number of H2020 and ESA projects (EUSTACE, FIDUCEO, GlobTemperature, WV_cci, S5P-I)
- Fellowship builds on experience and ongoing inter-national collaborations through the GEWEX Water Vapor Assessment (G-VAP).
  - Key output: WCRP report (2017) on performance of current state-of-the-art records, supported by ~28 peer reviewed publications generated by the group.
  - Phase 2 inter-journal special issue ACP, AMT, ESSD and HESS: "*Analysis of atmospheric water vapour observations and their uncertainties for climate applications*" - open until Q4 2021
    https://acp.copernicus.org/articles/special_issue1118.html

Motovation (1/2)

- The circulation of water between the surface and atmosphere is the largest movement of any substance on Earth.
- Water vapour is an essential greenhouse gas in the Earth climate system. On global scales, the mean residency time (the time between evaporation and precipitation) of water vapour is roughly ten days.
- Under climate change, water vapour is expected to increase at a rate of 6-7%/K (under constant relative humidity) in line with the Clausius-Clapeyron relationship.
- This Fellowship will focus on changes in hydrological sensitivity, initially looking the relationship between water vapour and precipitation.



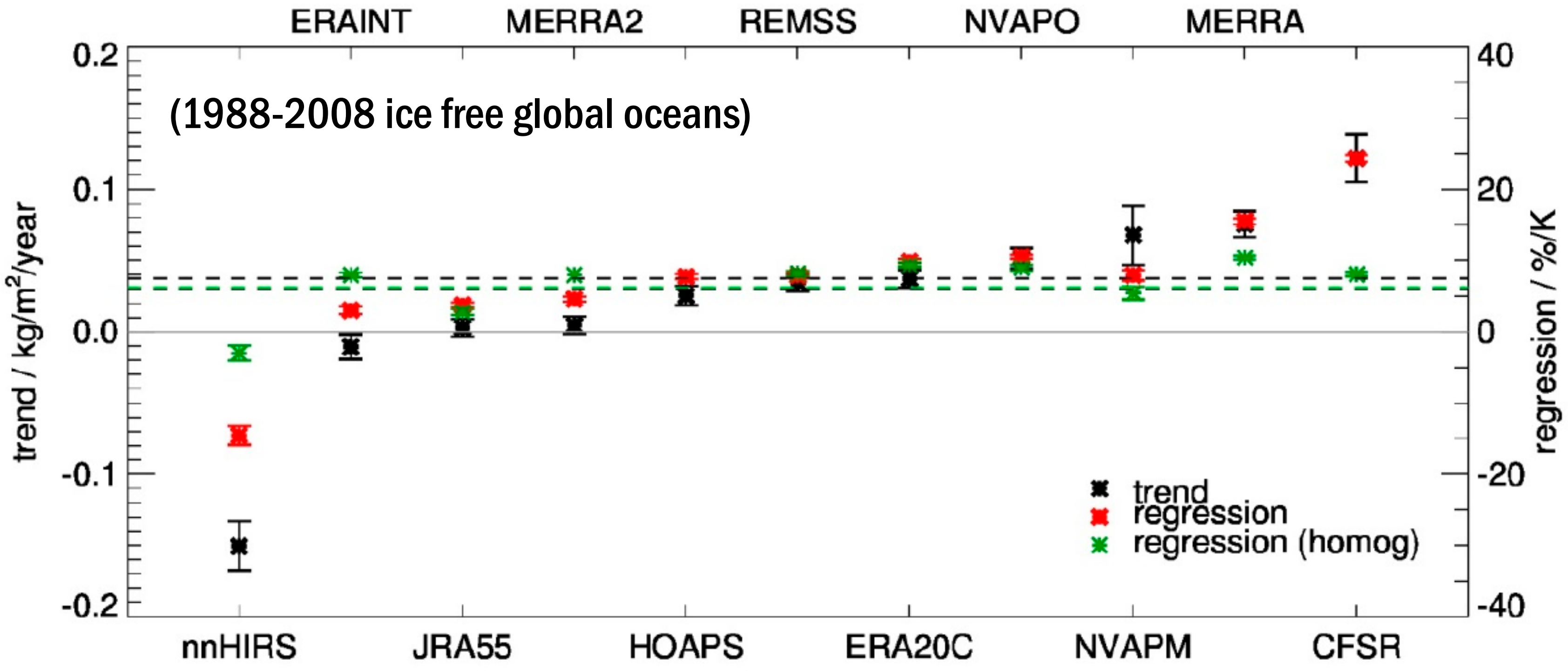
Estimates of the global hydrological cycle, its fluxes and reservoir's adapted from Chahine (1992).

Motovation (2/2)

- Results from G-VAP phase 1 show inconsistencies between 11 main long-term TCWV records (20+ years).

- In comparison to water vapour, precipitation is more complicated as it is controlled by atmospheric circulation and cloud microphysics. Therefore, even being correlated with extreme events and at local scales, the global relationship between precipitation and temperature is non-trivial – i.e. no simple global correlation with changes in temperature.

- Therefore, understanding the links between the residence time of water vapour in relationship to trends in global precipitation has great importance for climate studies.



Black dashed lines: expected range of trends

Green dashed line: trend based observed SSTs

Image taken from: Schröder, M.; Lockhoff, M.; Shi, L.; August, T.; Bennartz, R.; Brogniez, H.; Calbet, X.; Fell, F.; Forsythe, J.; Gambacorta, A.; Ho, S.-P.; Kursinski, E.R.; Reale, A.; Trent, T.; Yang, Q. The GEWEX Water Vapor Assessment: Overview and Introduction to Results and Recommendations. Remote Sens. 2019, 11, 251

Aims and Objectives (M1-M8)

- SQ1: “What disparity do we see observe in models + Obs regarding the relationship between increases in global TWCV and precipitation? What is the significance?”

- This study aims to investigate how efficiently changes in water vapour translate into changes in precipitation from satellite datasets, reanalysis and climate models.

- Approach uses the non-dimensionalised ratio of precipitation and water vapour sensitivity, i.e. the recycling rate of atmospheric moisture which is linked with hydrological cycle intensity (Chahine et al., 1997 and Li et al., 2011):

Varied percentage of precipitation

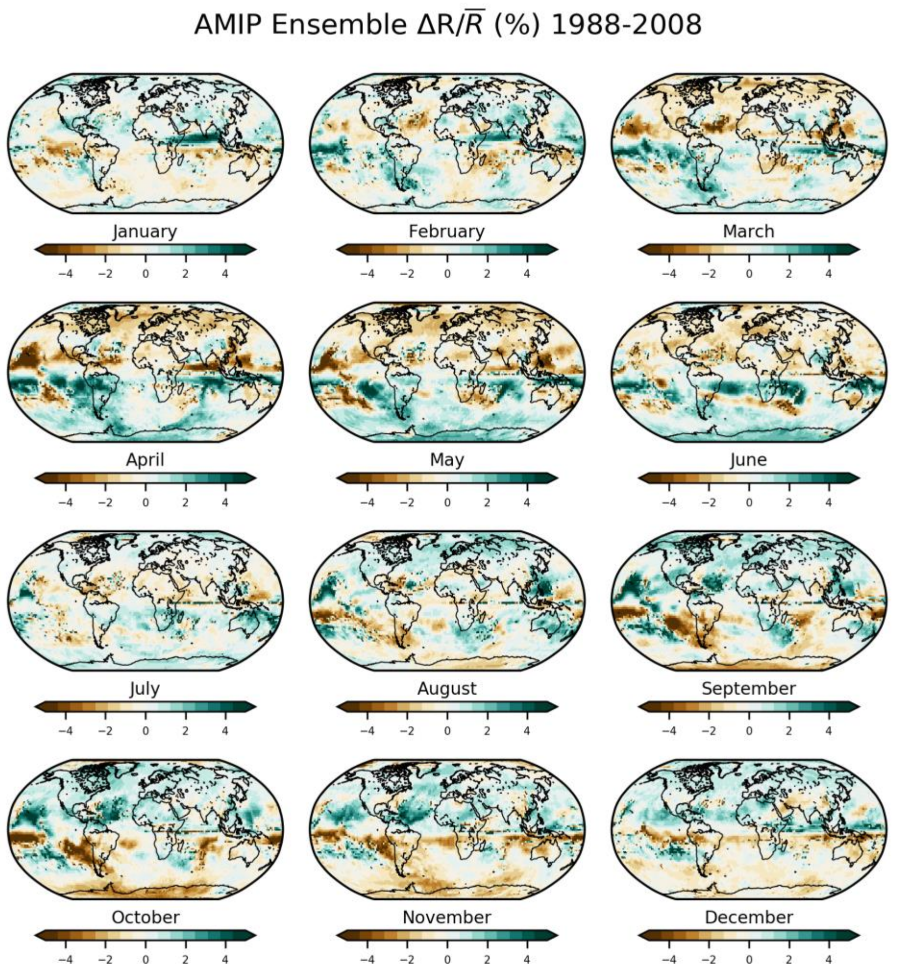
Temporal variation of recycling rate

$$\frac{\Delta R}{\bar{R}} = \frac{\Delta P}{\bar{P}} - \frac{\Delta W}{\bar{W}}$$

Varied percentage of total column water vapour

- A key objective of this study is to use ensemble of both observations (satellite and reanalysis) and climate models to assess hydrological sensitivities (+ve ΔR/R == precip increasing at a greater rate relative to TCWV).

- Therefore a significant focus will be on performance/quality of the observational datasets as well as their trends.



Initial look at recycling in CMIP6 ensemble between 1988-2008

Aims and Objectives (M1-M8)

- Trend analysis will use approach from G-VAP which uses a level shift regression model (Weatherhead et al. 1998, Mieruch et al. 2014)

$$Y_t = \mu + \omega X_t + \delta U_t + \epsilon_t$$

Y_t: WV anom; μ: intercept; ω: trend; X_t: Time index; δU_t: Step function; ϵ_t: Fit residuals

Step function $\quad \delta = magnitude, \qquad U_t = \begin{cases} 0, t < T_0 \\ 1, t \geq T_0 \end{cases}$

- Fits 4 freq (asymmetric fitting of the annual cycle) and ENSO strength simultaneously.
- Penalized maximal F test (PMF) test applied to anomaly differences for break detection (Wang et al. 2008a, b).

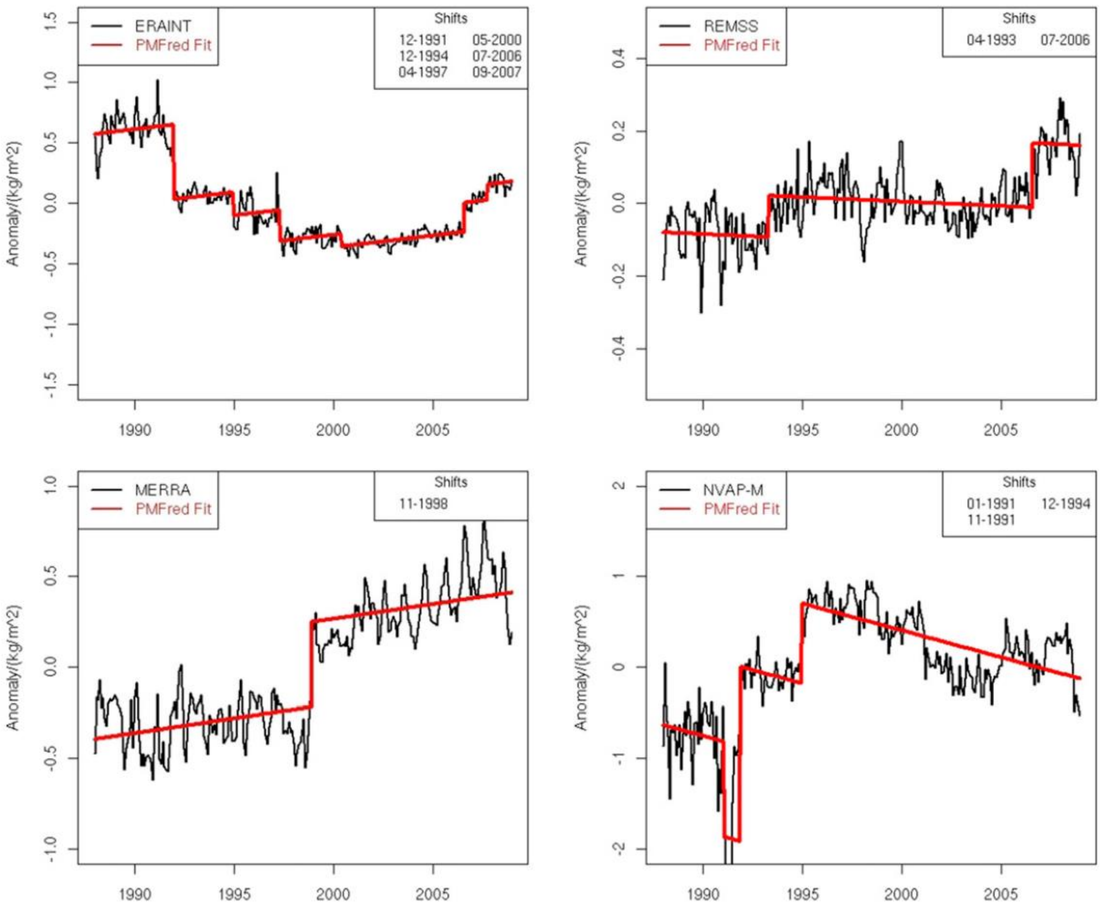
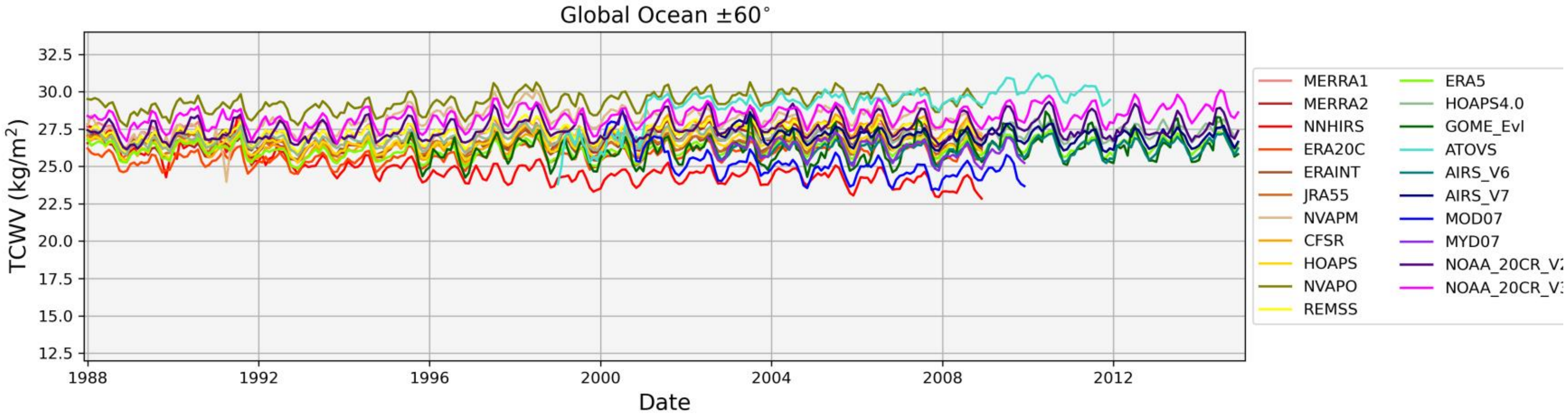


Figure adapted from Schroeder et al. .2016

Current work

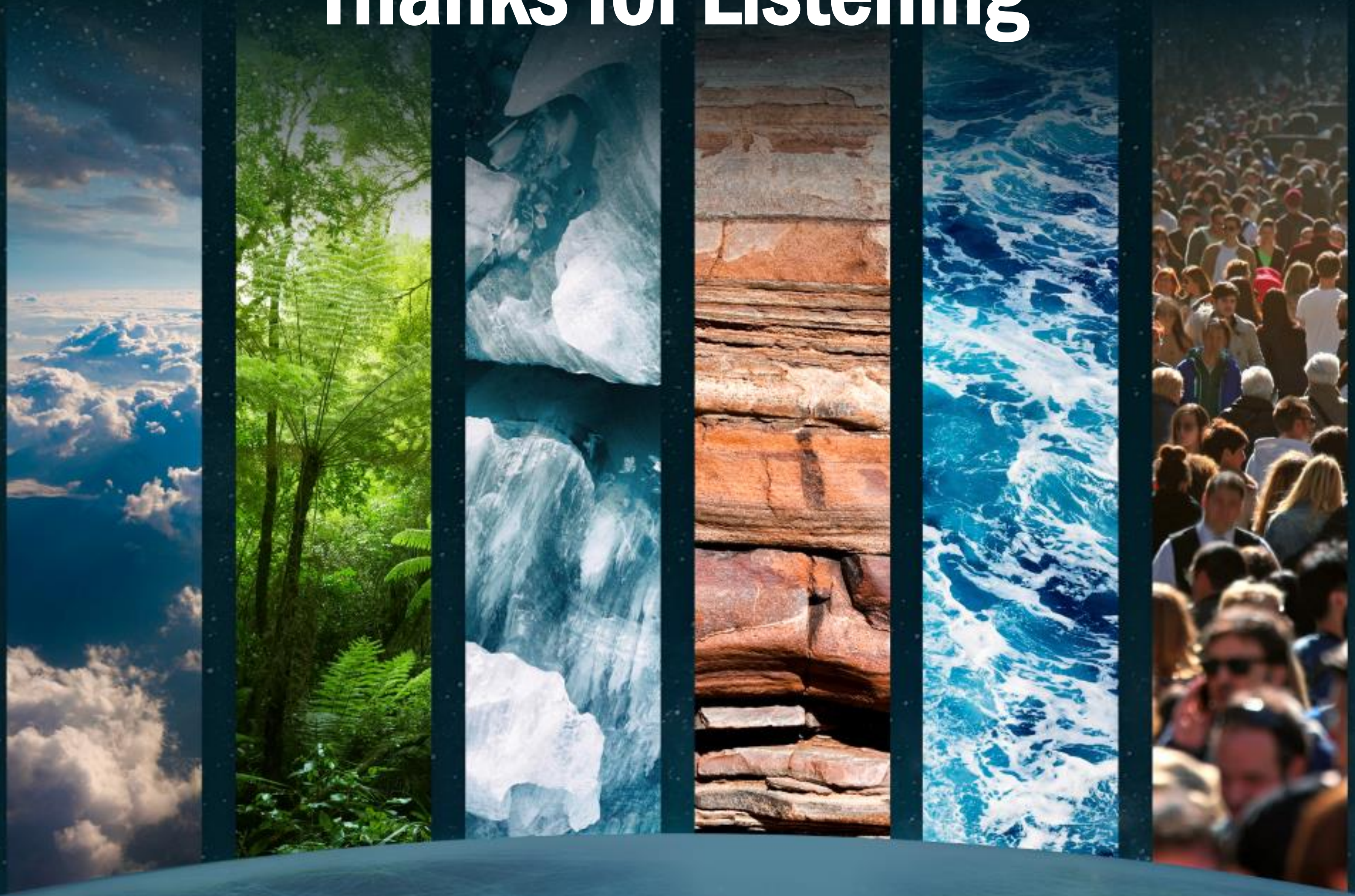
- Built datapool currently containing 41 data products (15 AMIP, 9 reanalysis and 14 satellite) of TCWV, precip and surface temperatures.
- More datasets will be added in the 4-6 weeks, e.g. WV_cci (early access).
- Begun working with the data, preparing code with the work flow.
- Observational records have been processd to a common grid format based on coarsest product (2.5x2.5 deg – GPCP).
- Discussion with colleagues from WC_cci and G-VAP for harmonisation of methologies for trends & break points.



Pearson Corrleation between Global TCWV and Ts Anomalies from Satellite and Reanalysis ±60°

	Ocean					Land		
	ESA_CCI_SST	ERA5_TSKIN	ERA5_T2M	NOAA_OI_SST	EUSTACE_TAS	ERA5_TSKIN	ERA5_T2M	EUSTACE_TAS
MERRA1 1988-01 to 2008-12	0.68	0.8	0.51	0.17	0.73	0.94	0.94	0.94
MERRA2 1988-01 to 2008-12	0.75	0.83	0.52	0.18	0.72	0.94	0.94	0.94
NNHIRS 1988-01 to 2008-12	0.09	0.07	0.38	0.04	0.62	0.86	0.86	0.86
ERA20C 1988-01 to 2008-12	0.76	0.84	0.52	0.2	0.72	0.92	0.92	0.92
ERAINT 1988-01 to 2008-12	0.64	0.69	0.51	0.17	0.72	0.94	0.93	0.94
JRA55 1988-01 to 2008-12	0.71	0.79	0.51	0.17	0.71	0.94	0.93	0.94
NVAPM 1988-01 to 2008-12	0.54	0.6	0.52	0.17	0.7	0.93	0.93	0.93
CFSR 1988-01 to 2008-12	0.65	0.72	0.54	0.2	0.72	0.94	0.94	0.94
HOAPS 1988-01 to 2008-12	0.79	0.87	0.91	0.82	0.77			
NVAPO 1988-01 to 2008-12	0.79	0.87	0.88	0.8	0.72			
REMSS 1988-01 to 2008-12	0.82	0.9	0.91	0.85	0.74			
ERA5 1988-01 to 2014-12	0.75	0.83	0.51	0.2	0.56	0.94	0.93	0.93
HOAPS4.0 1988-01 to 2014-12	0.86	0.89	0.89	0.87	0.49			
GOME_Evl 1995-07 to 2014-12	0.54	0.67	0.51	0.19	0.59	0.94	0.94	0.94
ATOVS 1999-01 to 2011-12	0.47	0.59	0.62	0.3	0.67	0.87	0.87	0.88
AIRS_V6 2002-09 to 2014-12	0.75	0.87	0.55	0.26	0.61	0.94	0.94	0.94
AIRS_V7 2002-09 to 2014-12	0.62	0.74	0.56	0.27	0.59	0.93	0.93	0.94
NOAA_20CR_V2C 1988-01 to 2014-12	0.47	0.64	0.48	0.14	0.55	0.94	0.94	0.94
NOAA_20CR_V3 1988-01 to 2014-12	0.77	0.84	0.56	0.25	0.59	0.94	0.94	0.94

Thanks for Listening



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