International Earth Surface Working Group (IESWG)

Presented to CGMS-51 Working Group II session, agenda item 3.7

IESWG Co-chairs: Benjamin Ruston (UCAR/JCSDA), Gianpaolo Balsamo (ECMWF)
Rapporteur: Benjamin Ruston (UCAR)

SEPTEMBER 2023 Update presented to WG-II

Coordination Group for Meteorological Satellites

Executive summary

Updated IESWG ToR iterated between the CGMS WG-II, IESWG and ITWG

The IESWG continues to work towards CGMS recognition as there is a need for a group with the unique combination of data assimilation and Earth surface modeling experts to fully exploit existing and future observations.

The IESWG has a distinct vocation towards earth surface data assimilation, observation operators and modelling developments that can advance coupled land-atmosphere assimilation in numerical weather prediction and climate/environmental reanalyses.

The three main topical areas in the IESWG are:

1) Snow ice and cryosphere-atmosphere interaction
2) Vegetation and land-atmosphere fluxes
3) Soil moisture, river-discharge and water cycle

Additional Details

Next Working Group meeting IESWG-5 meeting 26-28Sep2023

IESWG is conducting survey of land surface DA systems for IESWG-5

The IESWG participants typically report on Earth surface-atmosphere coupling and data assimilation with particular focus on methodologies, algorithmic and modelling advances that can enhance satellite observations uptake from present missions and prepared for upcoming ones.

Focusing on operational oriented product development, guaranteeing the uniqueness of the international contribution vs other international groups (i.e., CEOS Land Product Validation subgroup)

The planned activities within IESWG will include modelling and assimilation preparatory for future missions such as EPS-SG, FLEX, CIMR, CRISTAL, BIOMASS, CO2M … to list a few. As well as existing missions like SMOS and SMAP for which data uptake has been suboptimal.

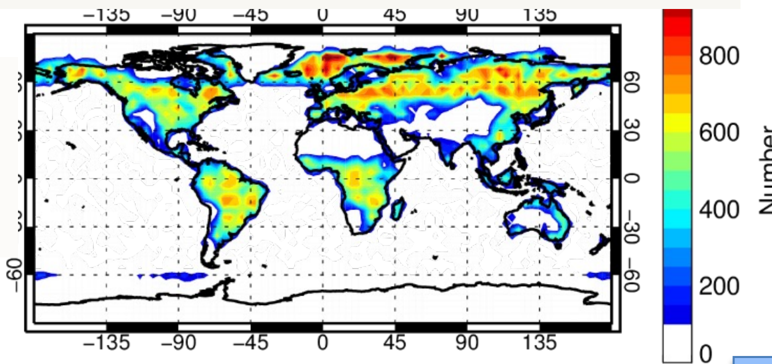
Which key issues of relevance to CGMS will be crucially supported by the IESWG:

- **CGMS HLPP 1.2.6** Work towards ensuring low frequency microwave imagery … from at least 2 sun-synchronous orbits;
- **CGMS HLPP 1.2.7** Establish observational requirements for microwave observations (sounder and imager) for NWP and precipitation and perform gap analysis against CGMS baseline;
- **CGMS HLPP 4.6.3** continue to improve microwave radiative transfer models to include complex surfaces (e.g. snow, desert, etc.) … to support improved algorithm development for current and future sensors;
- **IESWG/(P)A50.01** - Create ToR and proposal to establish a new CGMS International Science Working Group, propose Benjamin Ruston as rapporteur

Operational example of IESWG relevance : All-sky All-surfaces data assimilation

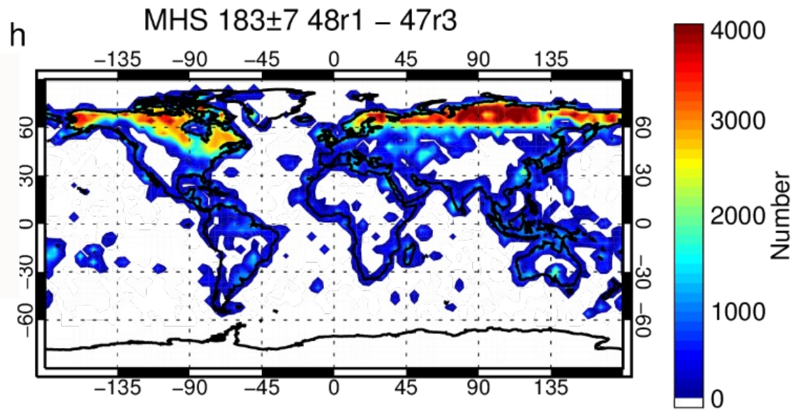
Increased use of **MW imagers** (e.g. **AMSR2** 89 GHz v-pol)

Observations used over **land surfaces and polar oceans** for the first time

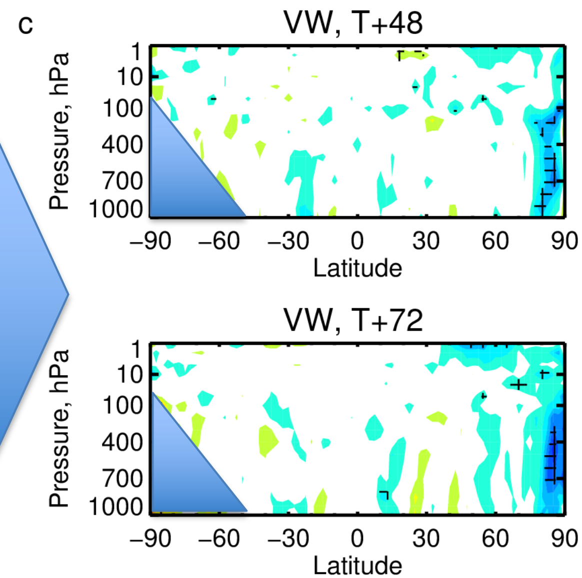


Increased use of **MW humidity sounders** (e.g. **MHS** 183±7 GHz)

Observations used over **polar land and mixed scenes** (e.g. coasts, lakes) for the first time



Reduced Wind Day+3 Forecast errors (RMSE) in Northern Polar regions



European Centre for Medium-Range Weather Forecasts

Submitted to CGMS:

- Proposed to CGMS-51 to establish a new CGMS International Science Working Group on the Earth Surface
- For endorsement Benjamin Ruston as rapporteur of IESWG

Approved by CGMS in 2023:

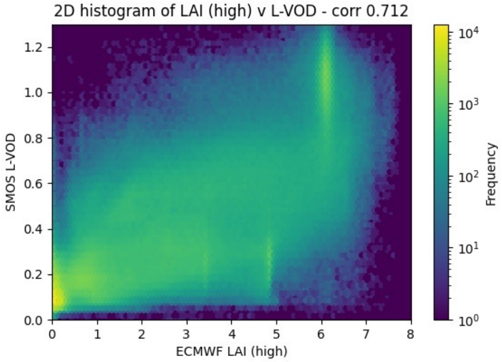
- CGMS-51 has endorsed the International Science Working Group on the Earth Surface

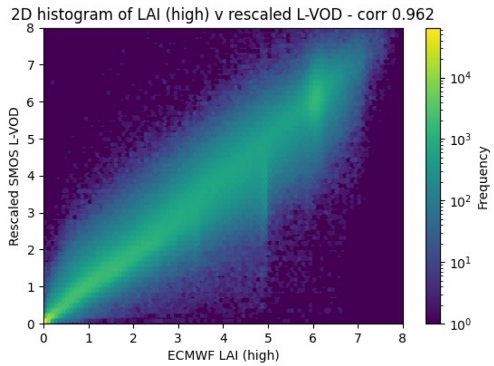
2023 evidence of EO surface impact (some ECMWF's examples):

- Vegetation and Satellite VOD impact in near surface Weather
- Snow and VIS/IR Satellite snow cover impact in Prediction & Monitoring

EO for Vegetation: Motivation & Observations availability

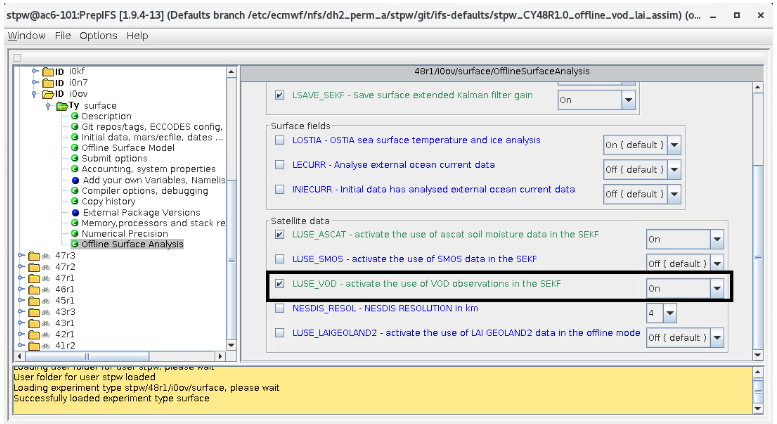
- Leaf area index and vegetation cover are currently fixed climatologies
  - No inter-annual changes are considered
- Use satellite vegetation optical depth observations due to their daily global coverage and insensitivity to clouds (cf. optical LAI observations)
- VOD observations from SMOS (L-band) and AMSR2 (C-, X-band)
  - Basic quality control applied (e.g. RFI, mountains, wetlands)
  - Using observations from 2016-2021
- Model LAI taken from monthly CONFESS CDR data:
  - LAI for high and low vegetation considered separately
- No physically-based observation operator used, so a CDF-matching to rescale VOD to LAI is applied:
  - 2016-2017 data used for rescaling (validated on 2018-2019)





Assimilating VOD to Analyse LAI Leaf Area Index

- Changes to offline LDAS to:
  - Ingest VOD observations (L-, C- and X-band separately)
  - Perform rescaling, using pre-computed CDF-matching params
  - Extend control vector to include LAI (high and low)
  - Assimilate rescaled obs to produce daily LAI analysis
- Analysed LAI ingested into IFS in place of fixed climatology
- Experiments covering 2018-2021



Observation vector

$$\mathbf{y} = \begin{bmatrix} \mathrm{T}_{2\mathrm{m}} \\ RH_{2m} \\ ASCAT_{sm} \\ VOD_{hi} \\ VOD_{lo} \end{bmatrix}$$

Control vector

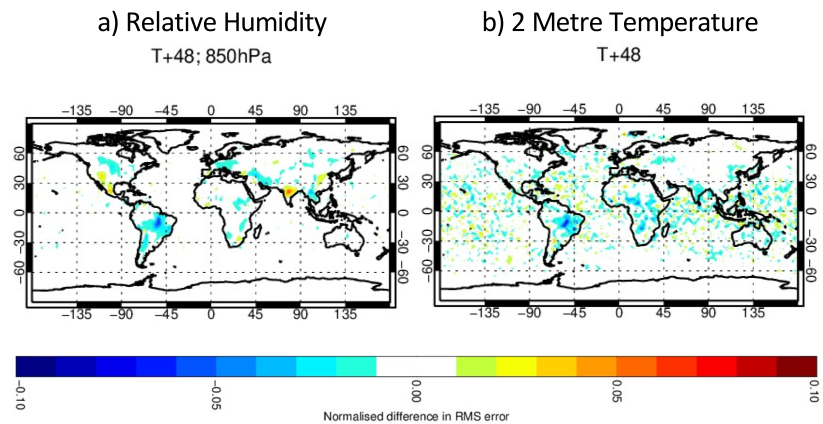
$$\mathbf{x_b} = \begin{bmatrix} SM_{l1(t)} \\ SM_{l2(t)} \\ SM_{l3(t)} \\ LAI_{hi} \\ LAI_{lo} \end{bmatrix}$$

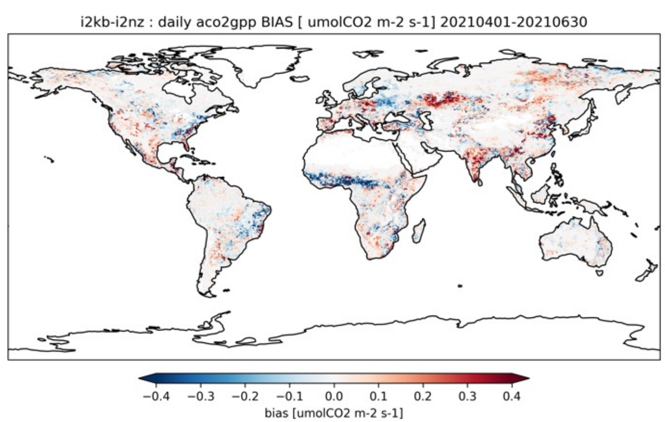
Observation operator

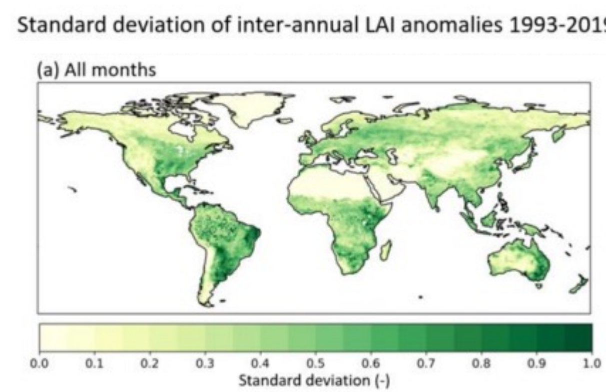
$$\mathcal{H}\,[\mathbf{x_b}]) = \begin{bmatrix} \mathrm{T}_{2\mathrm{m}} \\ RH_{2m} \\ SM_{top} \\ LAI_{hi} \\ LAI_{lo} \end{bmatrix}$$

VOD (Vegetation Optical Depth) Assimilation Results

- Small but significant improvements to 2 metre temperature and lower tropospheric humidity forecasts
  - Especially over forested areas e.g. Amazon
  - Impacts are collocated with largest inter-annual variations in CONFESS project time-varying vegetation
- Small but mixed impact on the carbon cycle when verified against FLUXCOM GPP observations:
  - Biases reduced over tropical Africa; increased over Asia







From Alessandri, 2022 CONFESS report

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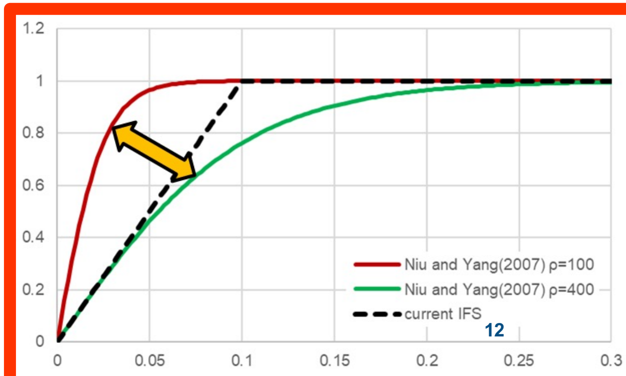
Snow DA changes and revised SCF in CY49R1

	Current system	CY49R1
IMS mask	based on altitude (>1500m)	based on SDFOR* (>250m)
IMS thinning	select 1 from every 36	select closest 1 to a gaussian grid of 40km
IMS snow depth (SD_{IMS})	5cm	3cm
Condition to assimilate SD_{IMS}	IMS=1 & SD_{model} < 10^{-9}cm	IMS=1 & SD_{model} < 1cm
Capping value for snow depth	1.4m	3.0m
Vertical correlation length in OI	800m	500m

- To improve snow cover fraction for shallow snow, a new SCF parameterization following Niu and Yang (2007)

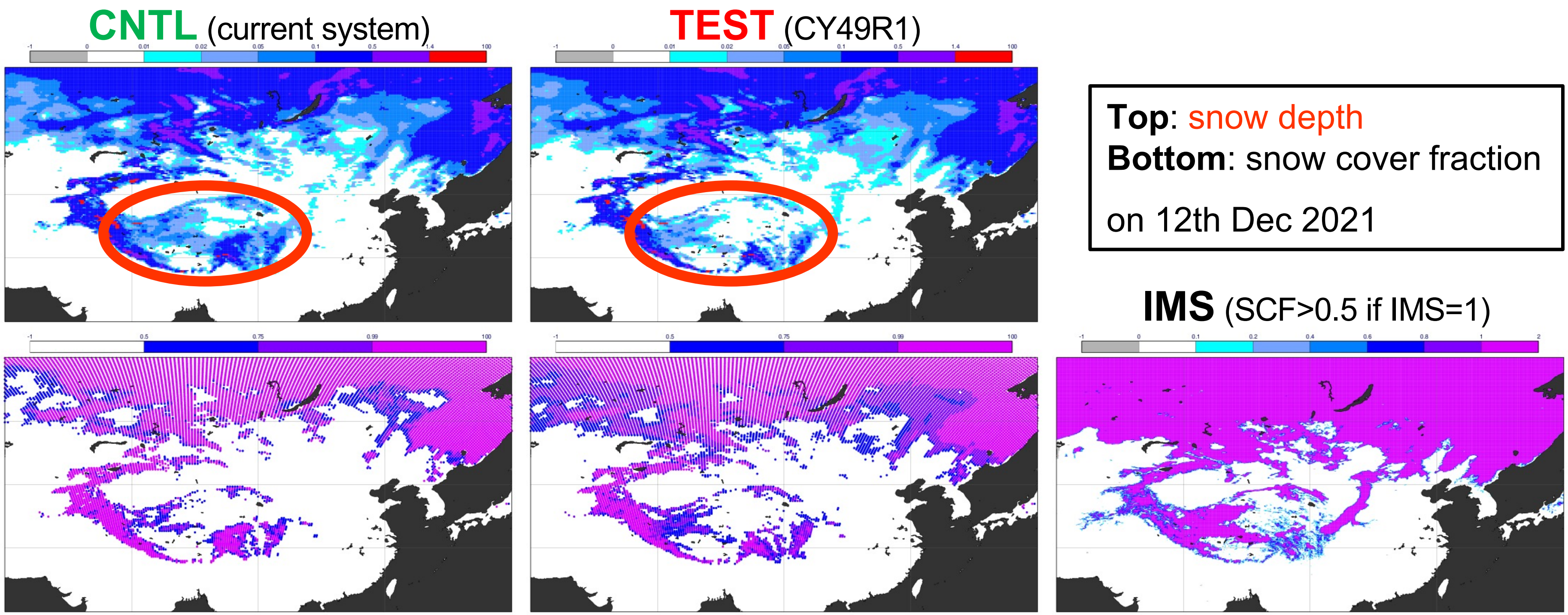
$$f_{sno} = \tanh\left(\frac{h_{sno}}{2.5 z_{0g} (\rho_{sno}/\rho_{new})^m}\right)$$

- $z_{0g} = 0.1, \rho_{new} = 100, m = 1$ as with CLM4, CLM4.5



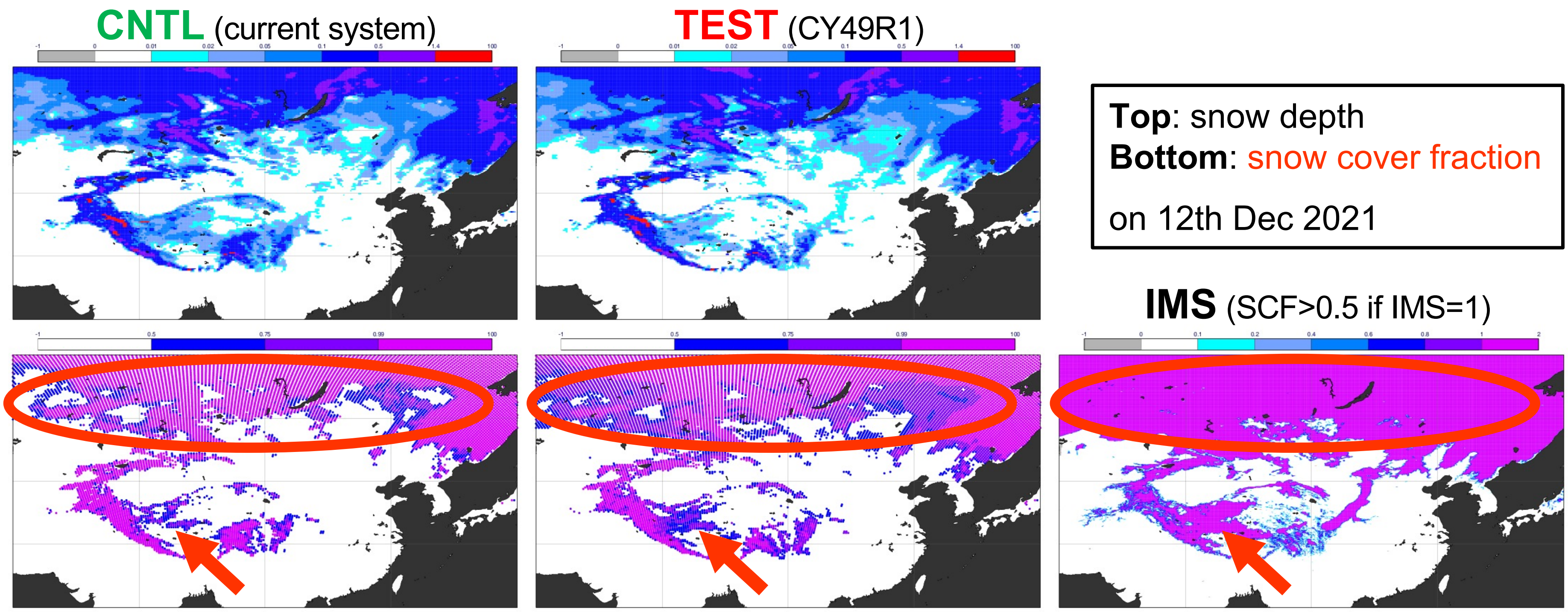
* Standard deviation of filtered subgrid orography

Impact on snow depth and snow cover fraction



- Snow depth is reduced by assimilating IMS on the Tibetan Plateau
- SCF is increased around snow lines by the revised SCF parameterization

Impact on snow depth and snow cover fraction



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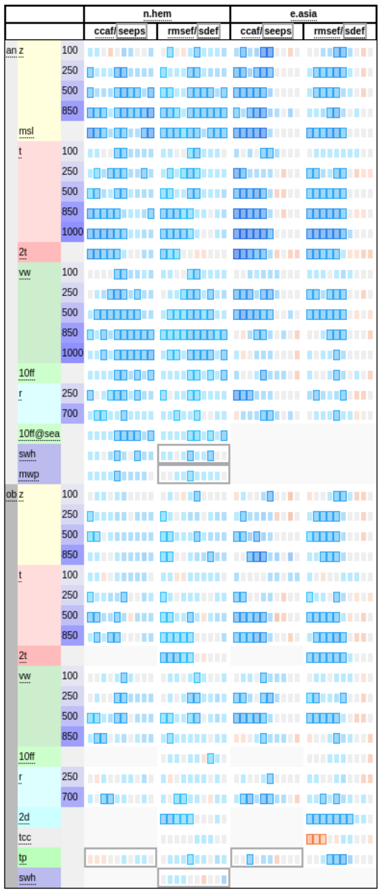
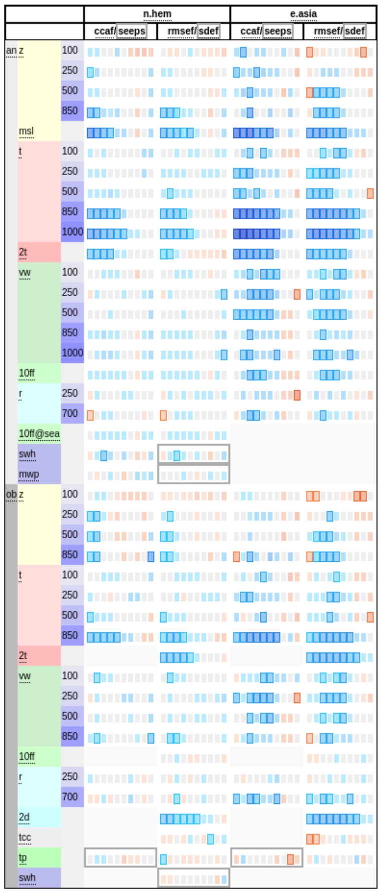
Impact on Weather forecast skill over 2 winter seasons

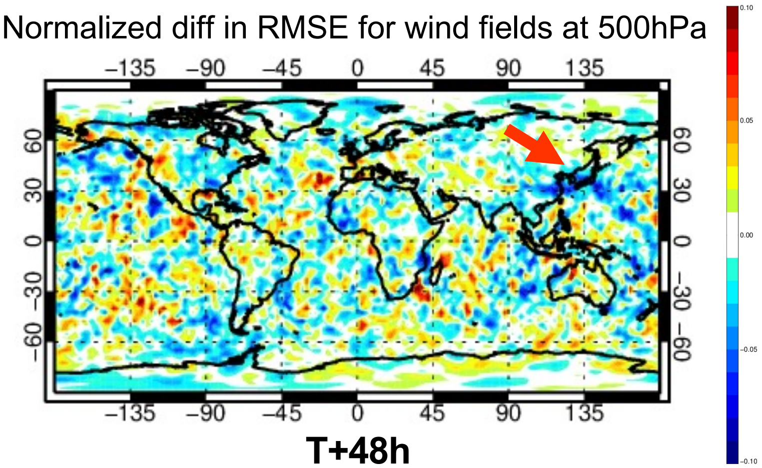
Winter 2020/21



Winter 2021/22



Normalized diff in RMSE for wind fields at 500hPa



T+48h

- Significant improvements in the NH, especially in East Asia
- Large impact of snow on forecast skill

ESA CCI Snow cover assimilation for CY49R2 (SEAS6, ERA6)

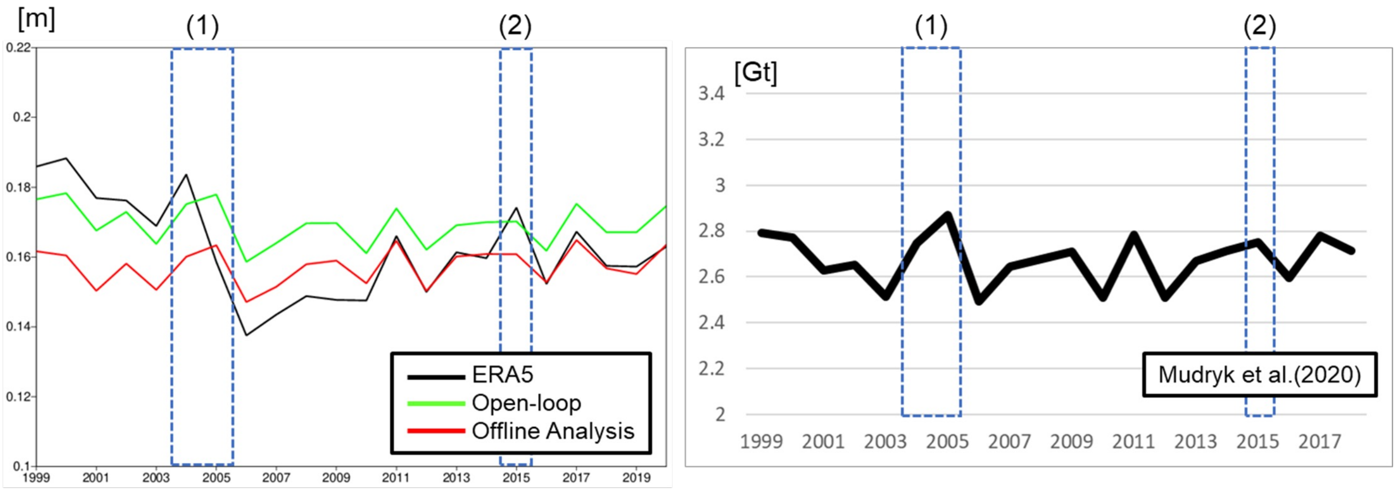


Figure. *Time series of (left) snow depth averaged over the NH in January and (right) total snow mass over the NH retrieved from the multi-dataset historical snow water equivalent by Mudryk et al.(2020)*

- ERA5 snow data record has (1) inconsistency in 2004/05 and (2) discontinuity in 2014/15
- More consistent for longer years with the offline LDAS → Land ICs for **SEAS6, ERA6-Land**
- Testing with the coupled LDAS → **ERA6**

IMS: available from 2004
ESA CCI: available from 1982 to 2018

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IESWG state of play:

- EO-Uptake improvement generally happen via concerted actions of Model-improvements + Assimilation innovation. IESWG aim at bridging Modeling & DA communities
- Future Reanalyses (eg. ERA6) are recipient of EO surface assimilation innovations for improve Climate Data Records CDRs. IESWG already reach out to some CDR data providers.
- Environmental Monitoring activities (eg. GHGs, Droughts & Fires, Floodings) do benefit from advances in L-A coupled data assimilation. IESWG does not yet reach out to Env communities.