



Study of the impact of TSEN data in the assimilation of the global weather forecasting system of Météo-France

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Stratéole-2 campaigns & balloon fleets



- Aiming at a better understanding of Tropical UTLS processes in relation with climate, with 3 field campaigns deploying instrumented stratospheric balloons.
- Stratospheric Pressurized Balloons (SPBs) are launched in the Seychelles and can circumnavigate the globe. CNES operates these devices.
- Various flight/scientific configurations at either 18 or 20km
- All balloons fitted with the TSEN gondola (T, P, 4D position).
- TECHNO (or C0 2019-2020) with 8 SPBs (balloons).
- C1 (2021-2022) : 17 SPBs.
- Wind derived from positions

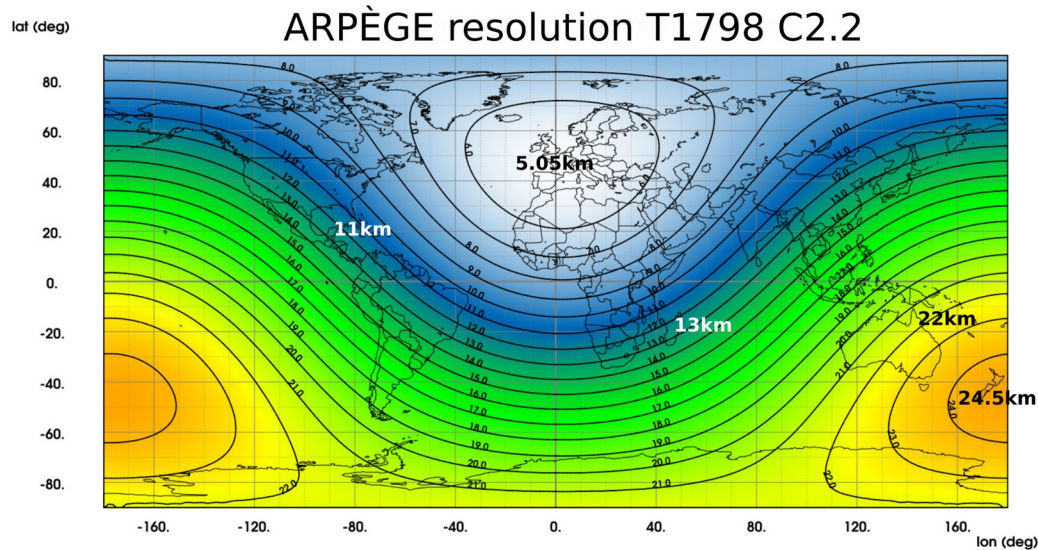
1. Launch preparation (Mahé)
2. Just after launch (Mahé)
3. 12 m super-pressurized envelope (Toulouse)
4. C0 balloons' trajectories



Global Numerical Weather Prediction at Météo-France



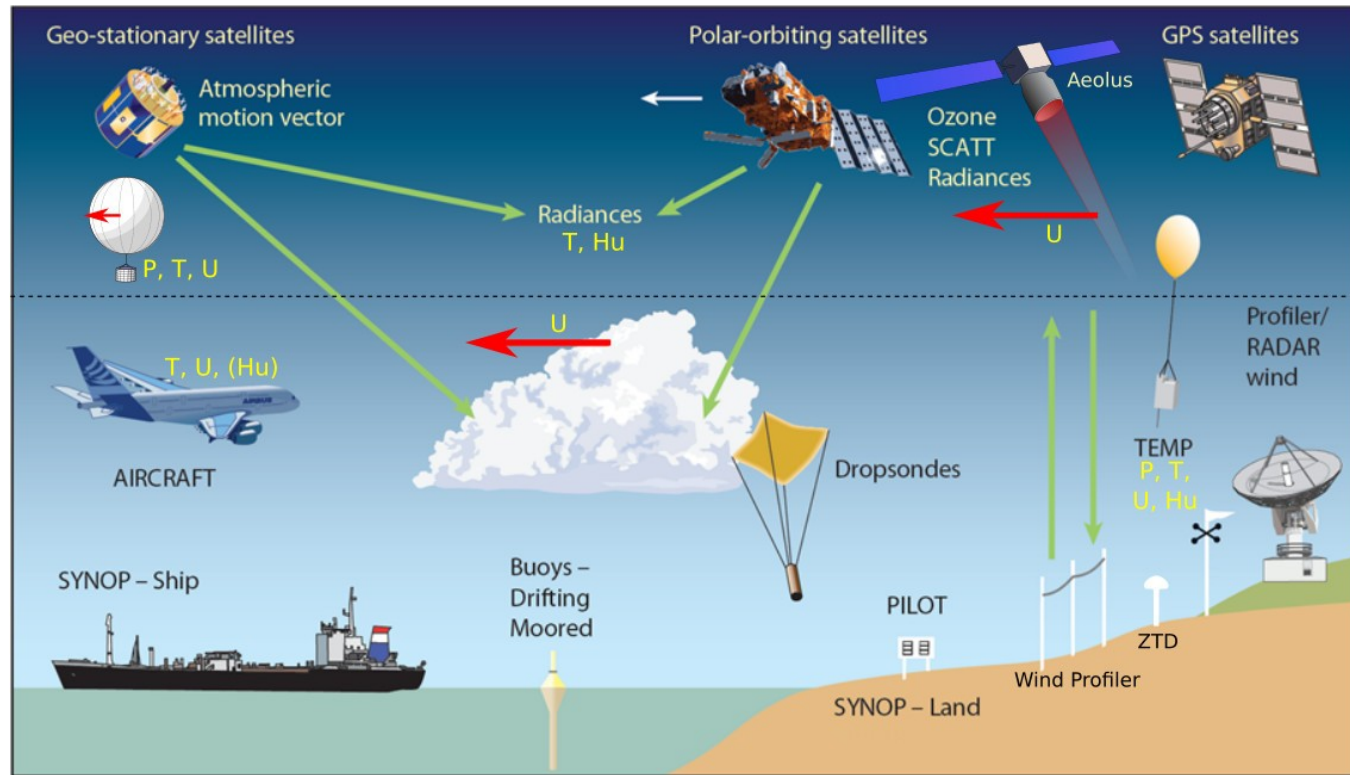
- ARPÈGE is the global NWP system at Météo-France
- Spherical harmonics and stretched and tilted grid with highest resolution over France (below), 105 vertical levels
- Data assimilation system is a 6-hour 4D-Var with B-matrix partially derived from ensemble of data assimilation
- Forecasts are up to 102-hours, 4 times a day



Global Data Assimilation at Météo-France



- ARPÈGE data assimilation system is similar to ECMWF one, but with 6-hour data assimilation 30 min time slots, among other differing aspects.



Stratéole-2 in NPW systems



- For NWP community, Stratéole-2 dataset is an opportunity:
 - access to very high quality in-situ data in near-real time as an attempt to improve wind analysis/forecasts in the stratosphere
 - possibly a synergy with lidar data from Aeolus
 - regular, well-spaced out campaigns to allow time for the studies needed to capitalize on the results.
- Lessons from 2019 TECHNO campaign:
 - Assimilation of the filtered TSEN data (as pseudo-aircraft) yields positive impacts on wind and temperature forecasts, when compared to radiosoundings.
 - STR2 signal is consistent with Aeolus impact (in test at that time).
 - Monitoring of STR2 data shows better statistics when Aeolus data are assimilated.
 - However, STR2 data seem too few to bring the model to a new equilibrium.



TECHNO campaign (12/2019 – 02/2020)

Scores in the Tropics



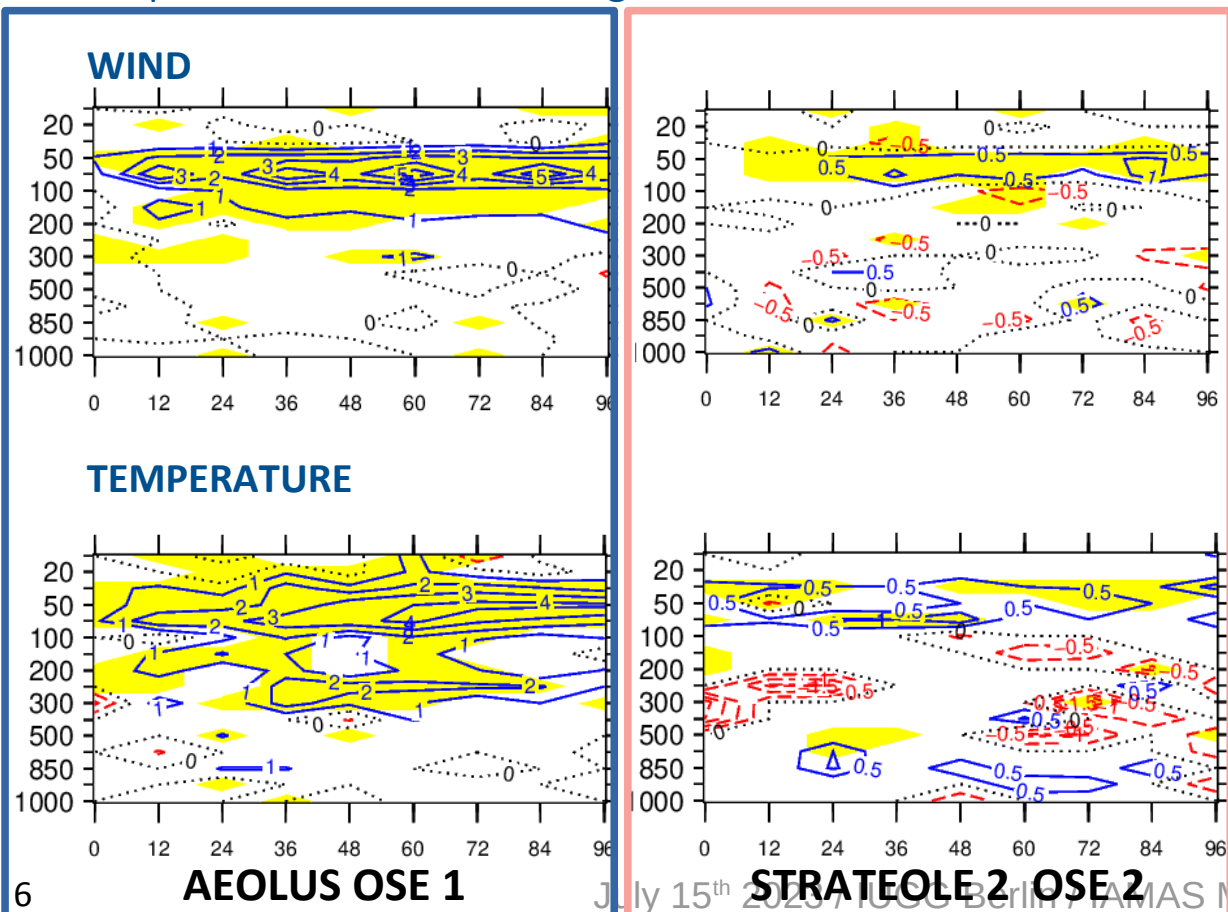
Relative diff RMS(O-F) : REF(ARPEGE oper) – Test Experiment
 Comparison with **radiosoundings data**

09/12/2019 – 28/02/2020
78 simulations

Significant positive influence for temperature and wind at balloon's altitude in the Tropics from short range to long range forecasts. Same model sensitivity to observations in low stratosphere for both experiments



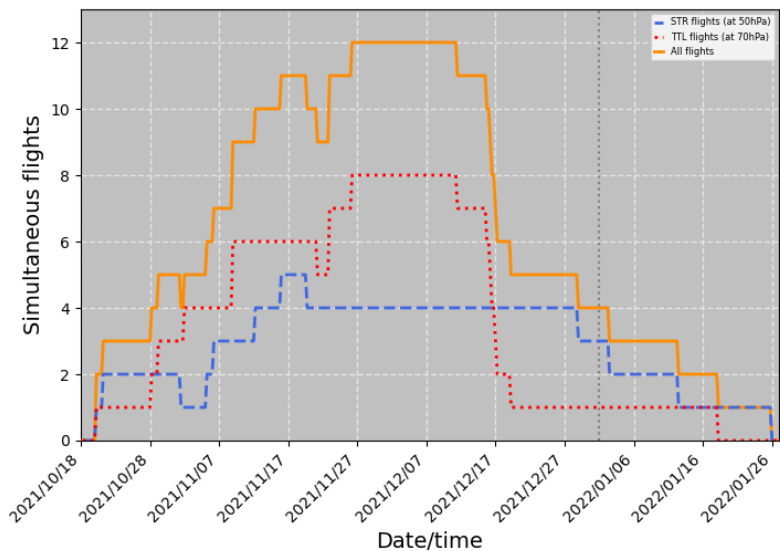
significant



C1 campaign (10/2021 – 01/2022) - Monitoring STR2 data



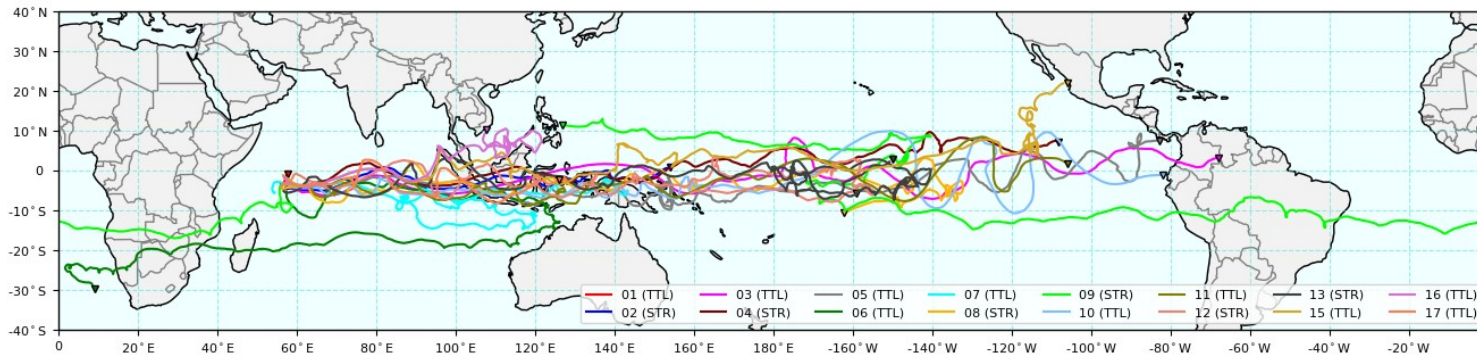
Stratéole-2 simultaneous flights (TTL and STR)



- Up to 12 simultaneous flights.
- Pseudo-aircraft data used in OPER after 22nd of Nov 2021.
- Most of trajectories bwn 60°E & 120°W (half of globe).
- Balloon 9, no T, but nearly a full circum drift.
- Aeolus is operational

ballons du 2021/10/20 au 2022/01/25 @ 18Z
: vol à 18km, STR : vol à 20km.

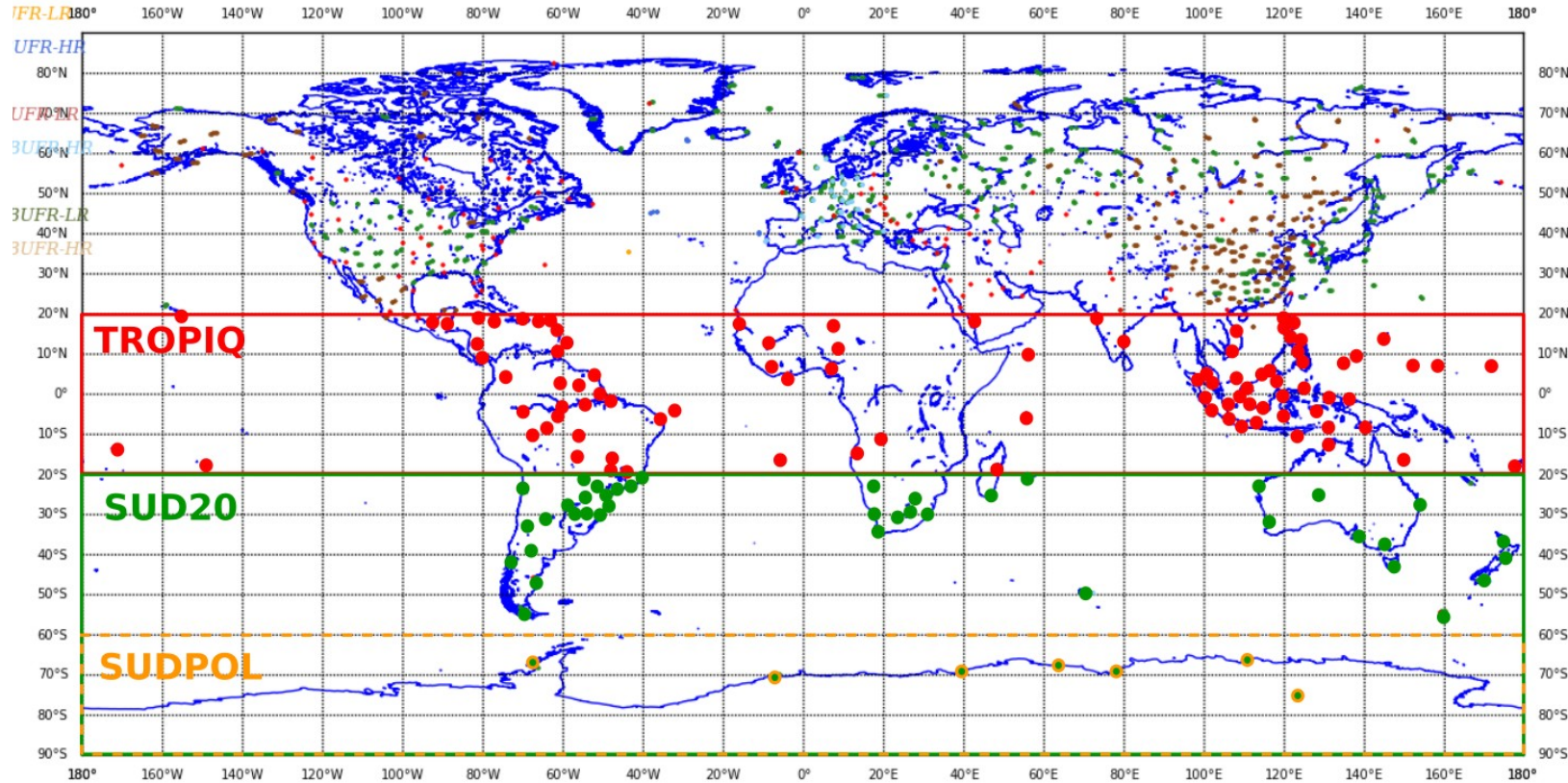
Les triangles indiquent l'extrémité des trajectoires des vols terminés.



C1 campaign (10/2021 – 01/2022) Verifying STR2 impact with scores



- Reference (truth) are radiosoundings or IFS analysis
- Various domains (see examples below)



Balloon impact with T+U+V, no thin, AMDAR $\sigma\sigma$



Scores STR2-balloon[T+U+V] / no-STR2

Period: 2021/10/21 - 2022/01/25

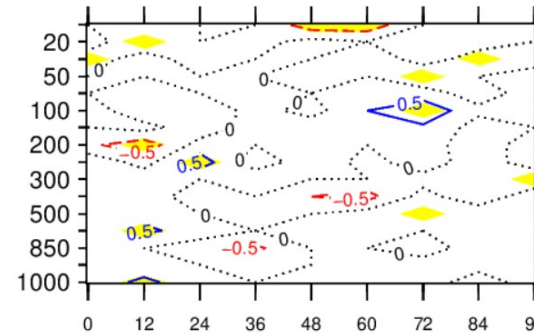
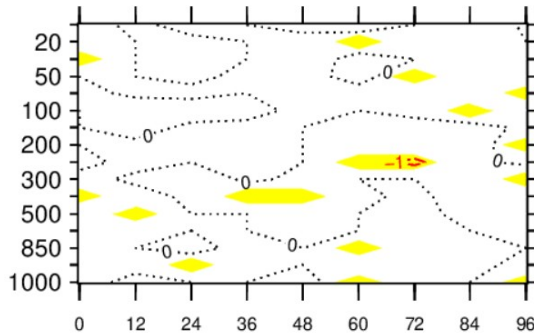
Reference: Radiosoundings

TROPICS

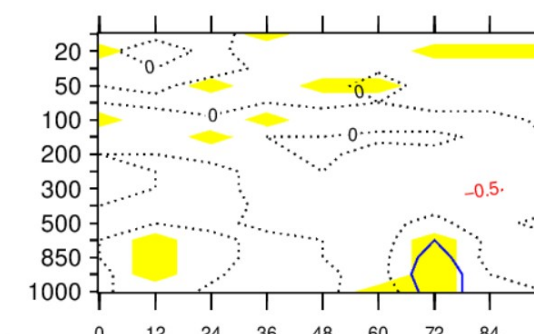
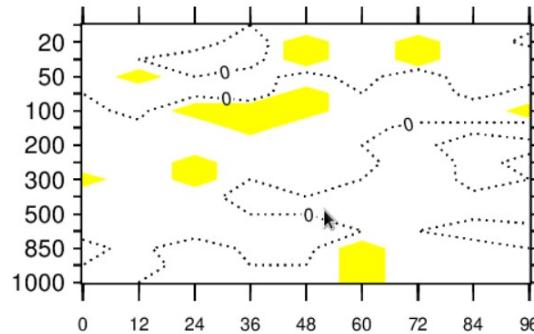
00TU

12TU

Wind



Geop



Balloon impact with T+U+V, no thin, AMDAR σ



Scores STR2-balloon[T+U+V] / no-STR2

Period: 2021/10/21 - 2022/01/25

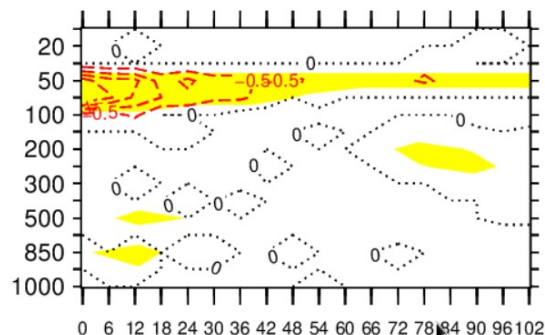
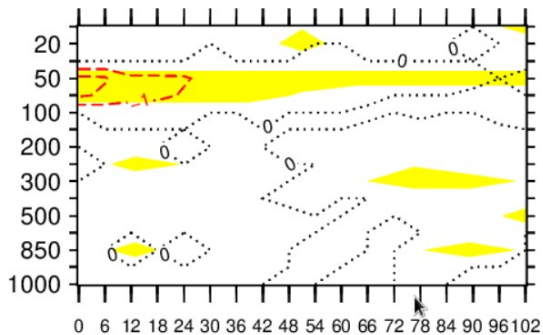
Reference: IFS analysis

TROPICS

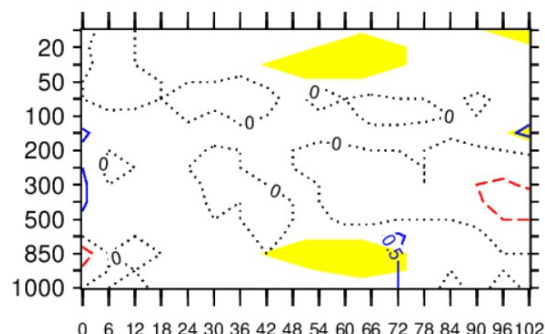
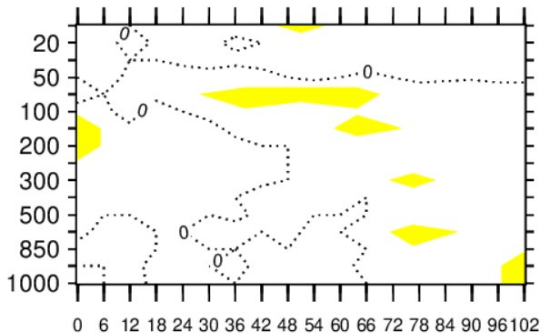
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Wind



Geop



Pseudo-aircraft impact with T+U+V



Scores STR2-aircraft[T+U+V] / no-STR2

Period: 2021/10/21 - 2022/01/25

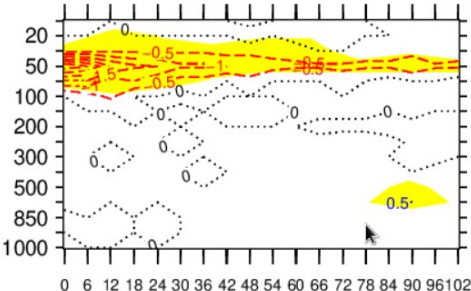
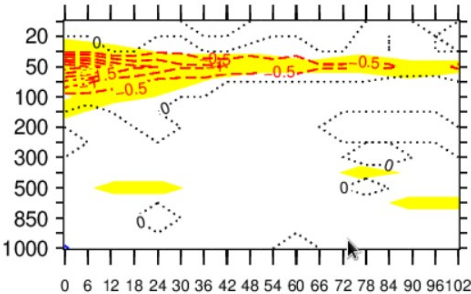
Reference: IFS analysis

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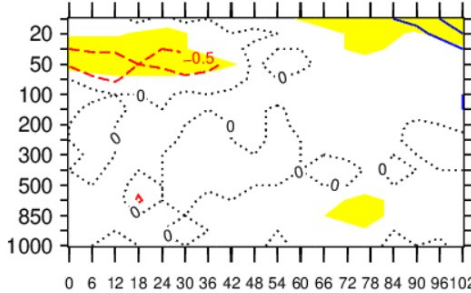
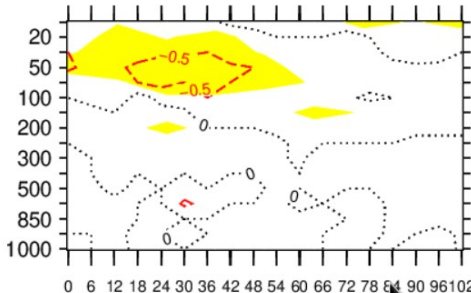
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Wind



Geop



Other (unexpected) impacts



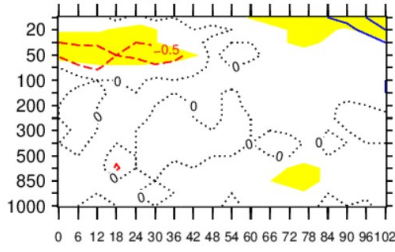
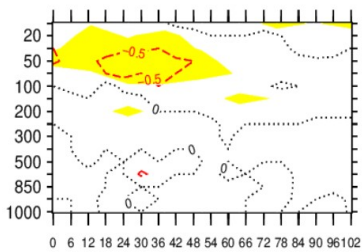
Scores STR2-aircraft[T+U+V] / no-STR2
Period: 2021/10/21 - 2022/01/25

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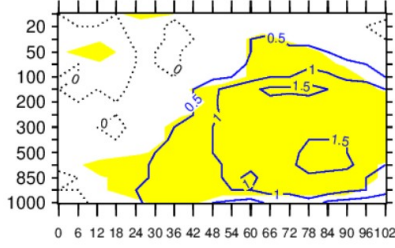
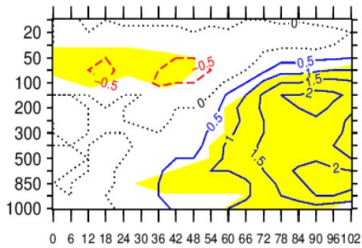
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Geop

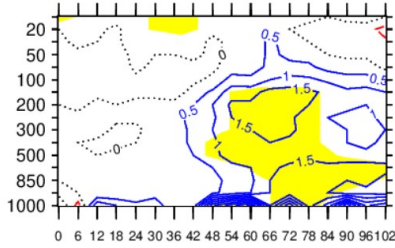
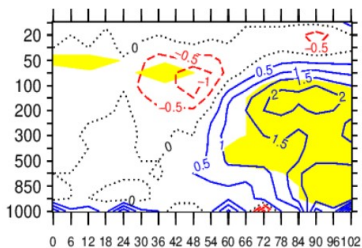
TROPIQ



SUD20



SUDPOL



Reference: IFS analysis

- Significant positive impact on geopotential on southern hemisphere when compared to IFS !
- But neutral impact with respect to soundings...
- Also neutral with balloon data except if Z is added (see next) !
- We keep cautious (there might be a problem)...

Impact of adding geopotential height Z



Scores STR2-balloon[Z+T+U+V] / STR2-balloon[T+U+V]

Period: 2021/10/21 - 2022/01/25

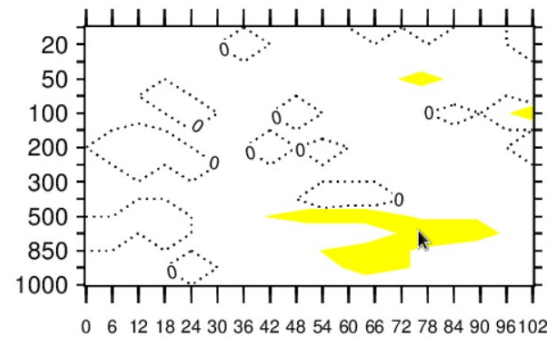
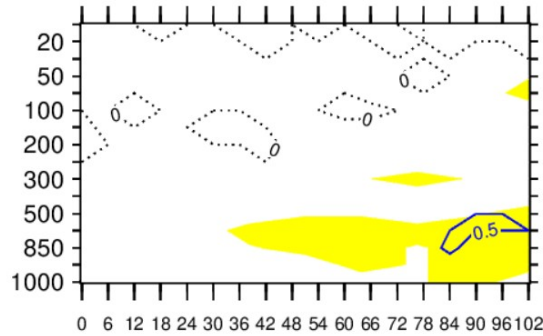
Reference: IFS analysis

TROPICS

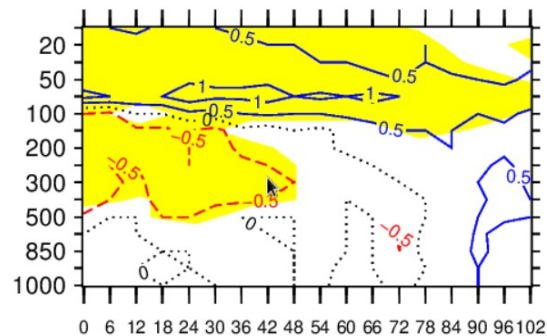
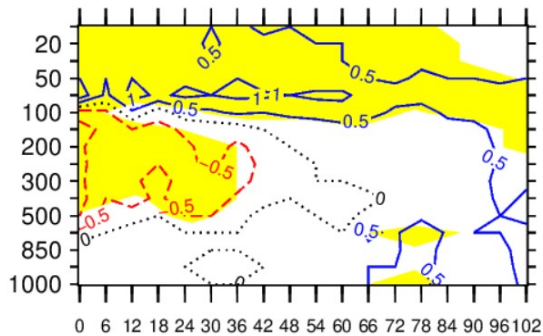
Wind

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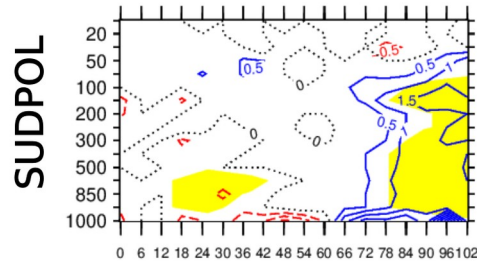
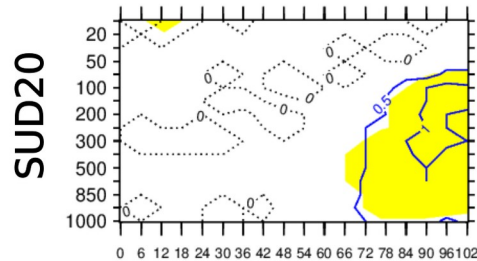
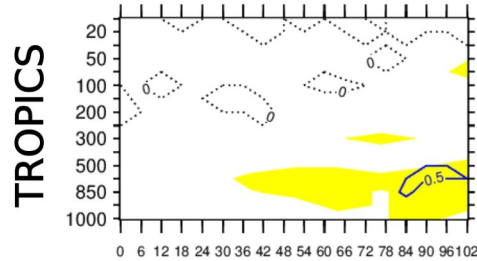
Geop



Impact of adding geopotential height Z



Impact of Z (TUV assimilated) (STR2-balloon)



Ref = IFS analysis

Impact on wind (00 UTC)

- Significant positive impact on geopotential in upper stratosphere in the Tropics
- Positive impact on wind in the southern hemisphere
- Impact wrt to soundings is really noisy !





- C1 results are not as clear cut and positive as for the TECHNO campaign:
Aeolus is to blame ?
 - During the last 2 months of the TECHNO campaign, Aeolus was already assimilated in the IFS (09/01/2020), but not in our ARPEGE system (neither control NWP experiment nor STR2 tests with TECHNO data).
 - Good scores (wrt IFS) of TECHNO tests with STR2 showed that balloons acted in the same direction as Aeolus (cf. slides 6-7)
 - In C1, Aeolus is assimilated in both ARPEGE and IFS. Aeolus and STR2 may compete in the tropical UTLS. This does not necessarily imply a degradation of forecasts (cf. impact differences when switching the reference from IFS to radiosoundings). A slight positive impact wrt radiosoundings is found anyway !
- We started to reproduce the results of the TECHNO by running STR2 OSEs on C1 including a denial of Aeolus data.

Summary



- Ongoing tests on balloon data thinning (results not yet ready).
- Observations "uncertainty" (real uncertainty + representativeness) adjustment tests are in progress (use of Desroziers diagnostics).
- Porting of balloon operator + thinning developments to future ARPEGE versions (48 & 49). We expect that 49 will be the version in use during C2 (late 2025-early 2026).
- Promising results with Z, but continue to liaise with the community on Z-biases (we suspect that they do not originate from the model alone) and consider either blacklisting of the three balloons or constant bias correction.
- Further tests will be done assimilating the NOAA "WindBorne" dataset
- Stratéole2 data available from <https://strateole2.aeris-data.fr/catalogue/>

