

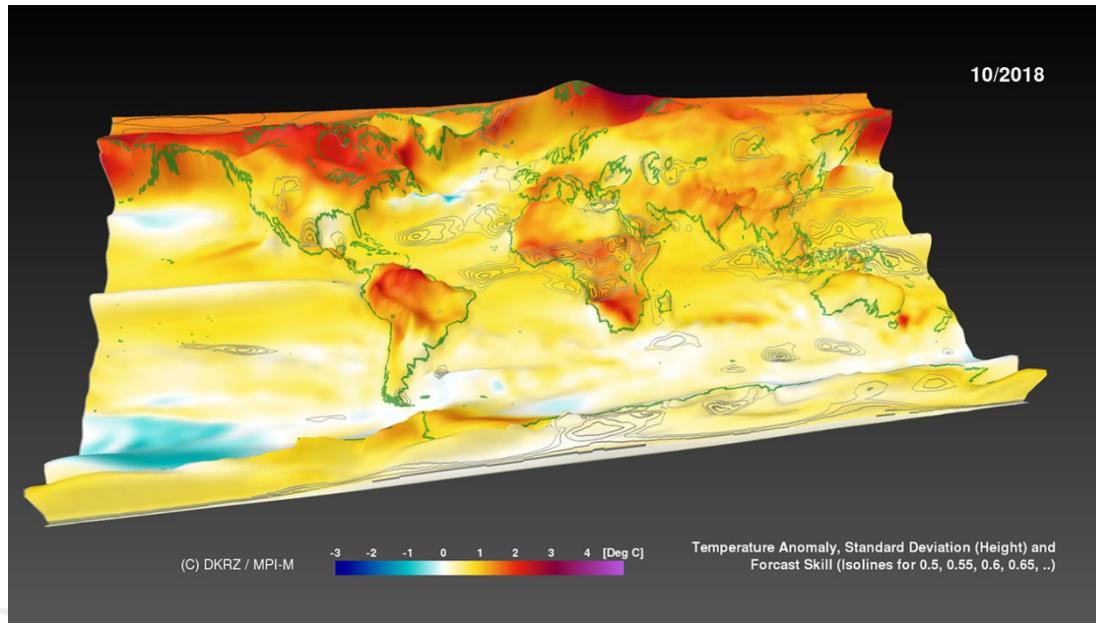
Visualization of 2D uncertainty in decadal climate predictions

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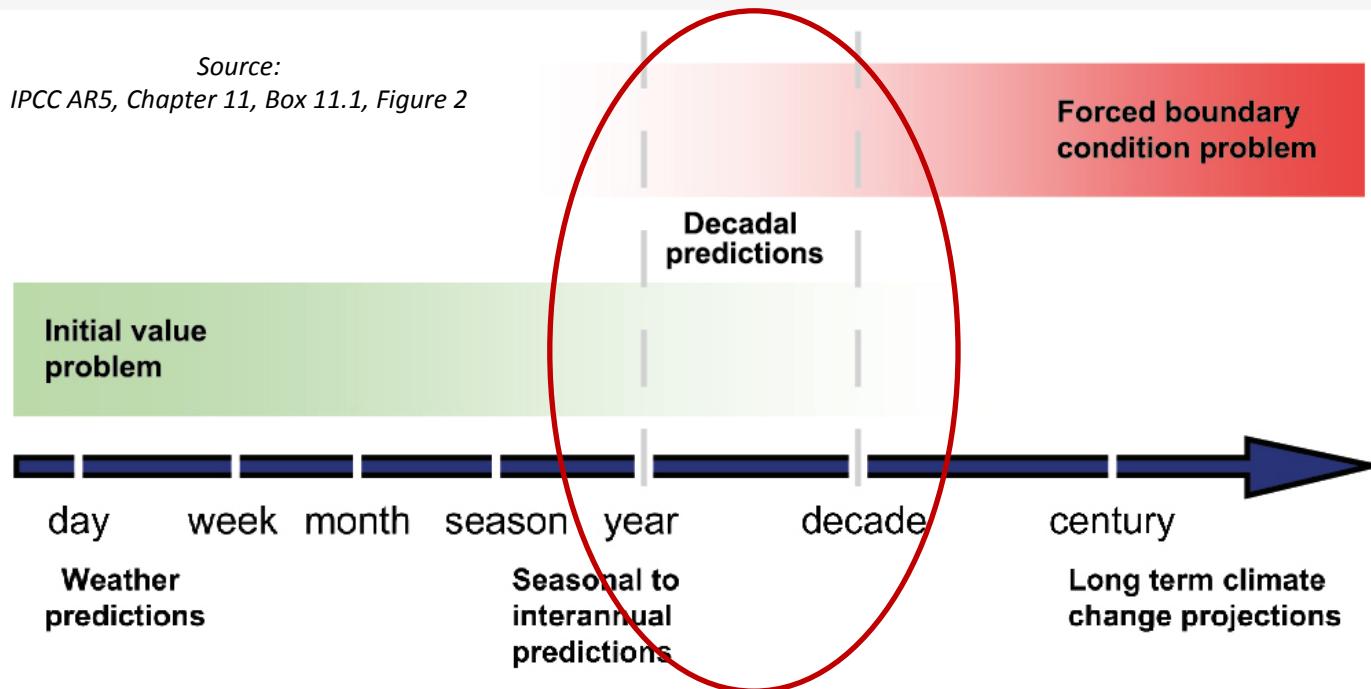


Uncertainty in Climate Simulations

“Uncertainty is the only certainty there is, and knowing how to live with insecurity is the only security.” (John Allen Paulos)

- Four categories of uncertainty:
 - Model uncertainty
 - Parameterization, numerical schemes
 - Spatial/temporal resolution
 - Processes
 - Internal variability and initial conditions uncertainty
 - Forcing and boundary condition uncertainty (past)
 - Scenario uncertainty (future)

Decadal Climate Predictions

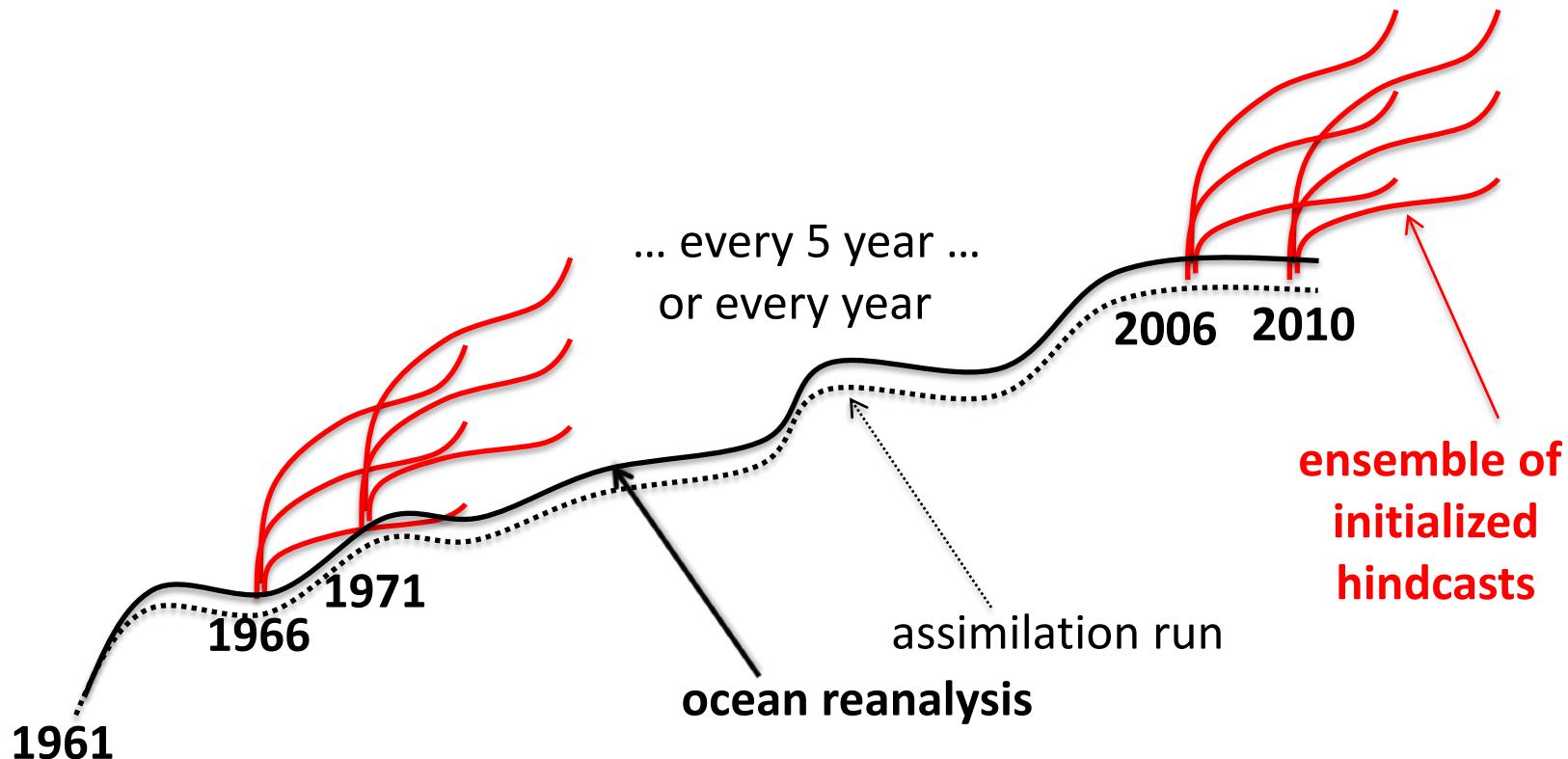


- Aim: predict natural **internal variability** over the next few years through knowledge of the observed climate state
- Initialization with observations (Atmosphere, Ocean, Sea Ice, Land, ...)
 - 3D ocean state (Reanalysis, Assimilation)
- Ensemble simulation techniques

Decadal Climate Predictions

- Verification of climate predictions?
- Not possible for forecasts
- Instead, use hindcasts to derive the skill of the system

Initialized retrospective predictions



Slide: Thanks to Iuliia Polkowa, Institute of Oceanography, University of Hamburg

Forecast Skill

- Quantify success of hindcasts/predictions
- Various definitions/methods used in literature
 - (Pearson's) Correlation (used here)
 - Root Mean Square Skill Score (RMSSS)
 - etc.

Related Work

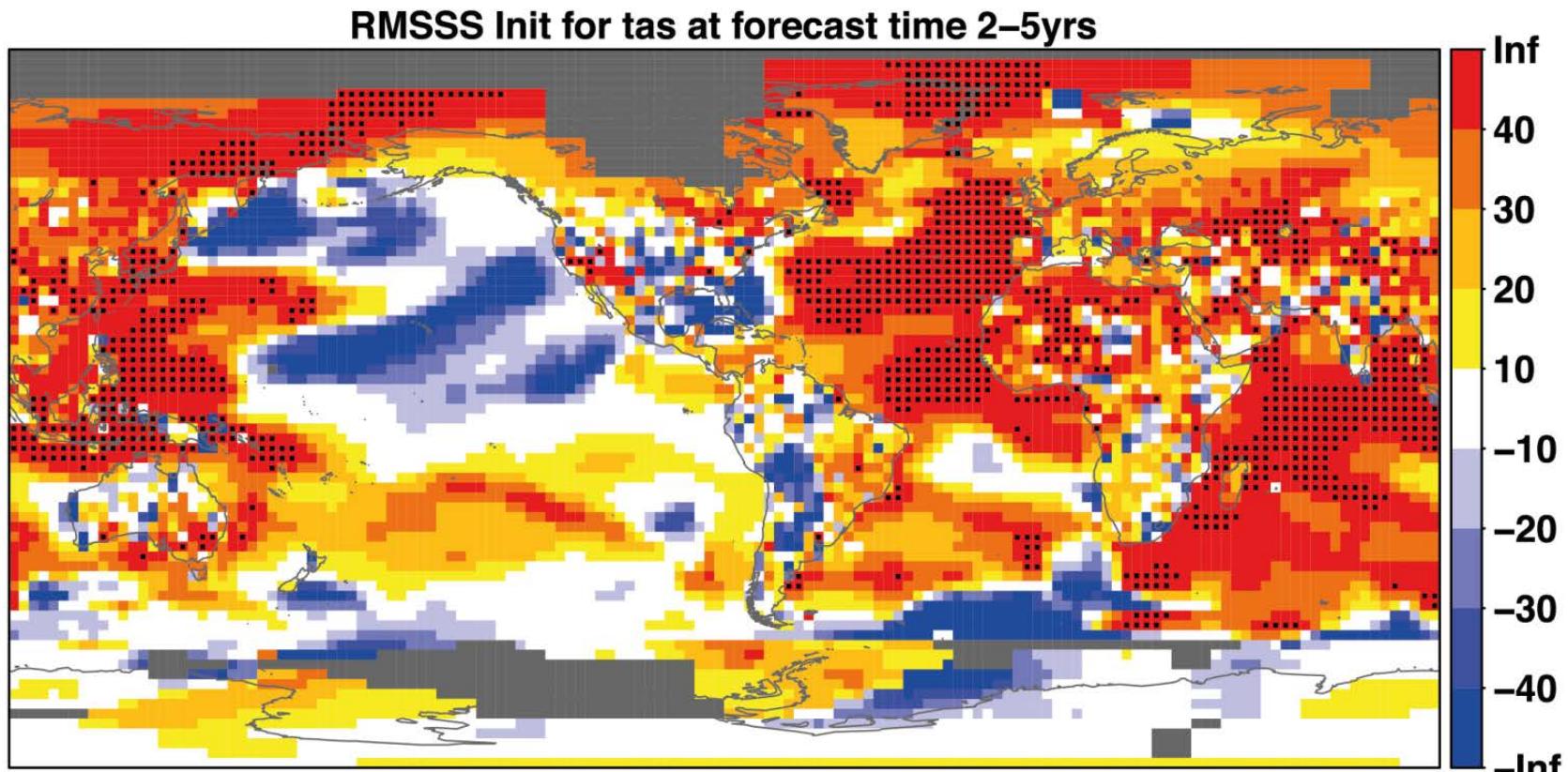
- Uncertainty Visualization
 - Potter et al. 2009: Ensemble Vis
 - Sanyal et al. 2010: Noodles: A Tool for Visualization of Numerical Weather Model Ensemble Uncertainty
 - Brodlie et al. 2012: Review of Uncertainty in Data Visualization
 - Bonneau et al. 2014: State of the Art of Uncertainty Visualization
 - Obermaier et al. 2014: Future Challenges for Ensemble Visualization: feature based methods vs. location based methods
- Decadal climate predictions
 - Smith et al. 2007: First paper preparing the ground for decadal climate predictions
 - Meehl et al. 2009,2013: Overview on the field, challenges
 - IPCC AR5 WG1, 2013: Chapter 11, Kirtman & Power 2013: Near-term climate change: State of the Art Review

Visualization Software used in the domain

- 2D
- Script based
- Domain specific (Weather, Climate Oceanography)
- Examples:
 - NCL
 - GrADS
 - VCDAT
 - Ferret
 - GMT
 - Python
 - ...

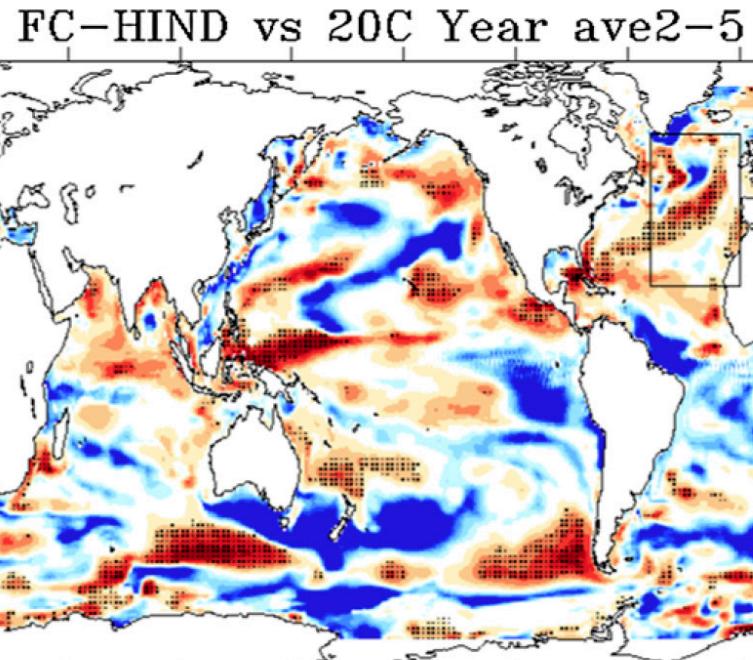
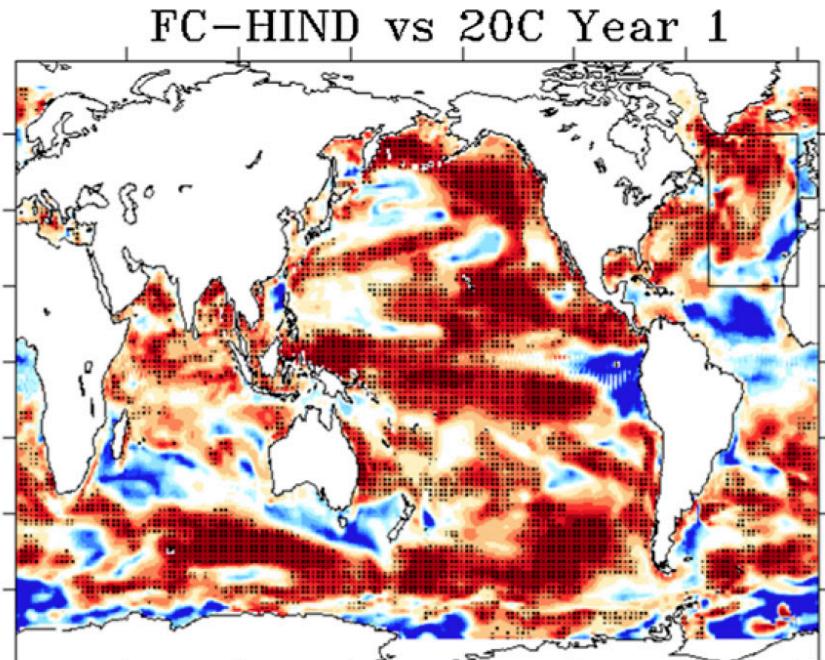
Multivariate 2D Visualizations used in the Domain

RMSSS (color) and Significance > 95 % (black dots)

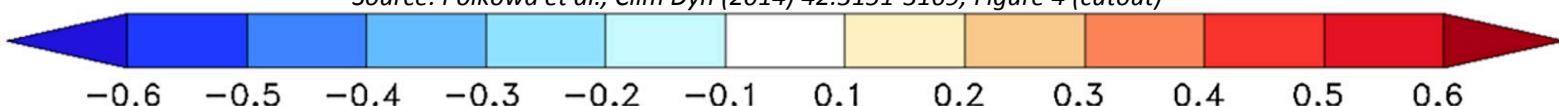


Source: IPCC AR5, WG1, Chapter 11, Figure 11-04

Multivariate 2D Visualizations used in the Domain



Source: Polkova et al., Clim Dyn (2014) 42:3151-3169, Figure 4 (cutout)

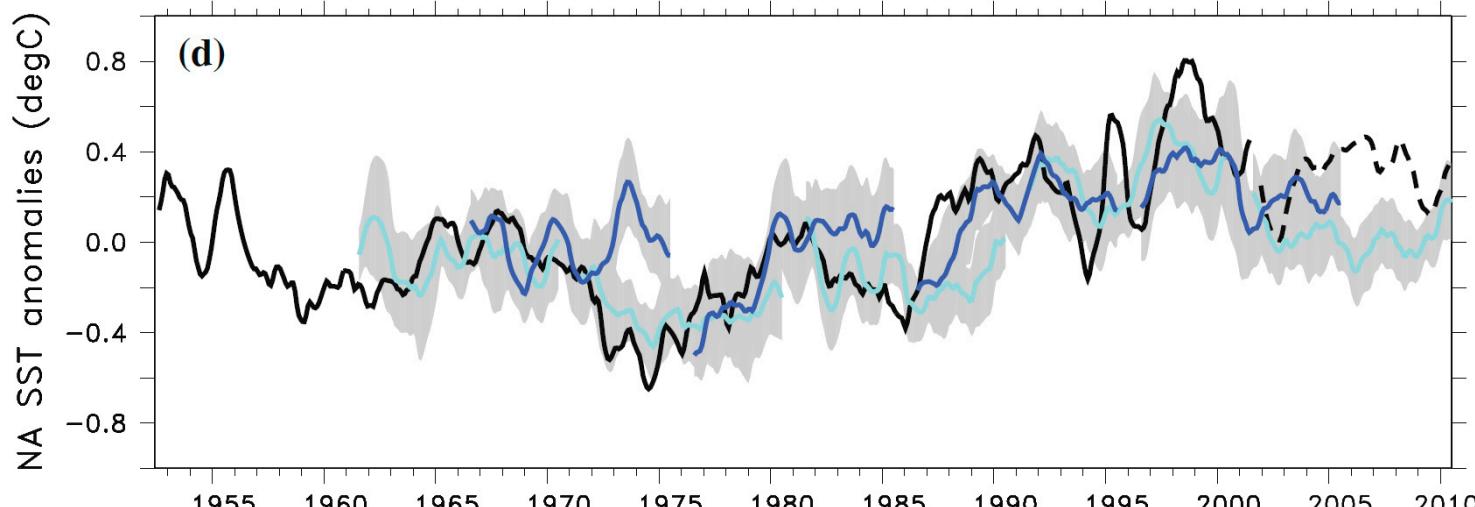


SST RMSS. Hatched regions: significant skill at 90% level

Figure shows temporal means for year 1 and year 2-5.

- Only limited information on the spatio-temporal structure of the skill!
- Only one threshold value visualized

Temporal Analyses

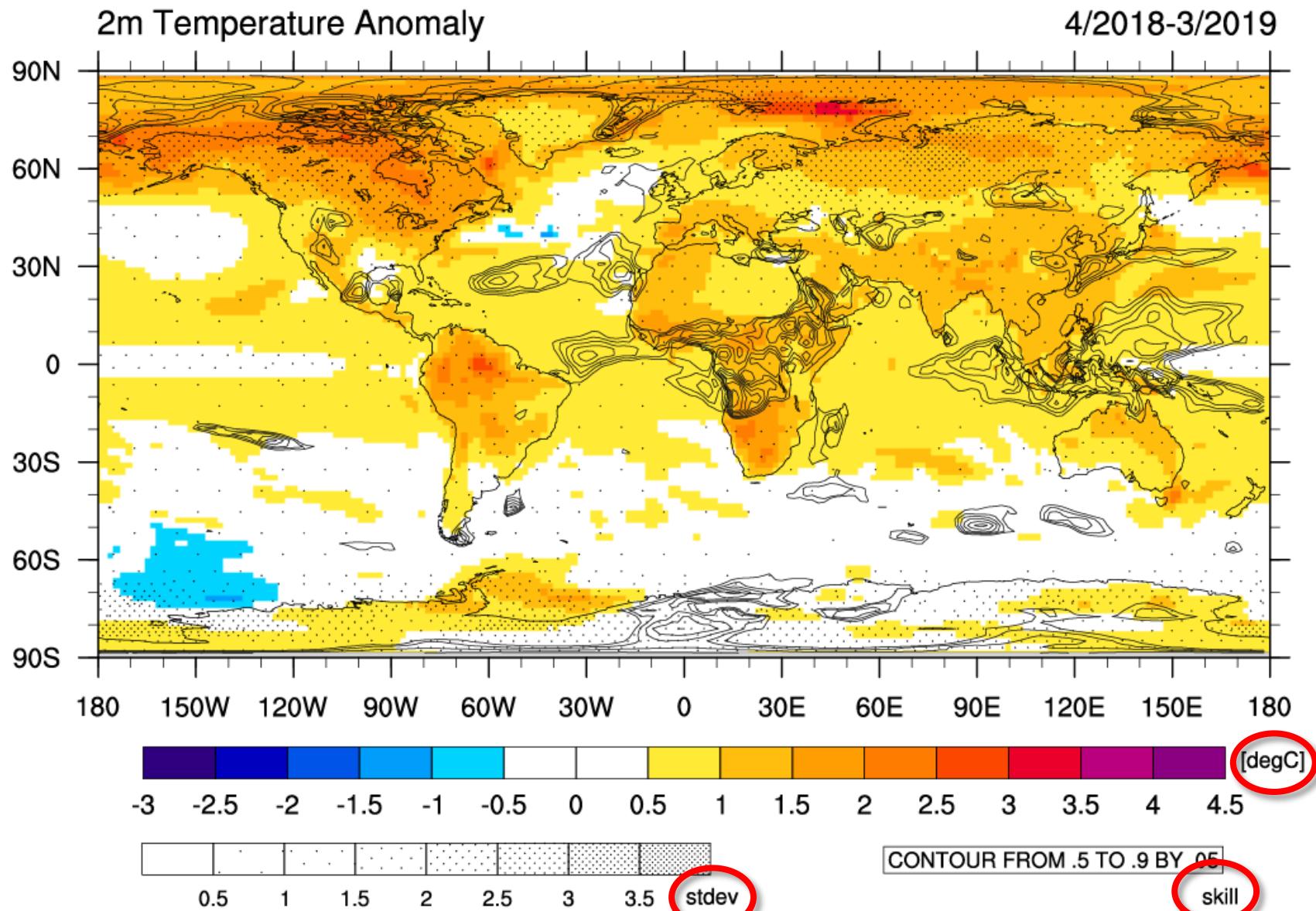


- Temporal development for a spatial mean (here: 50°W - 10°W , 20°N - 60°N)
- Limited information on spatiotemporal patterns
- Alternative: time animations of 2D fields

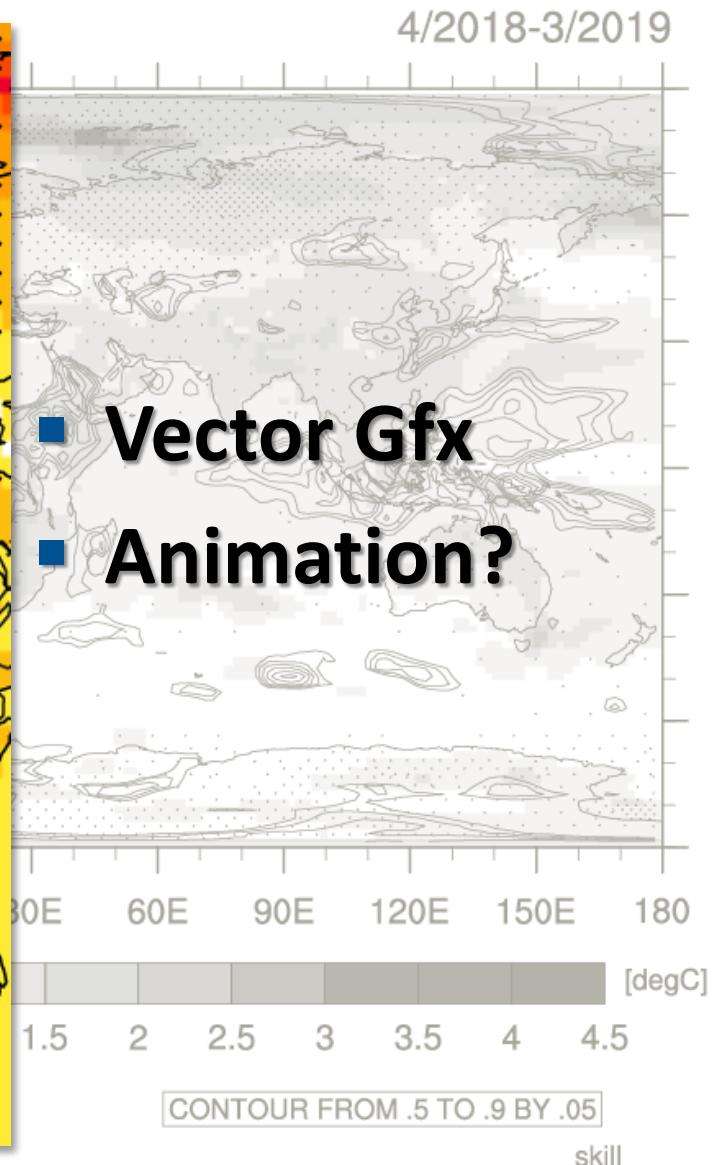
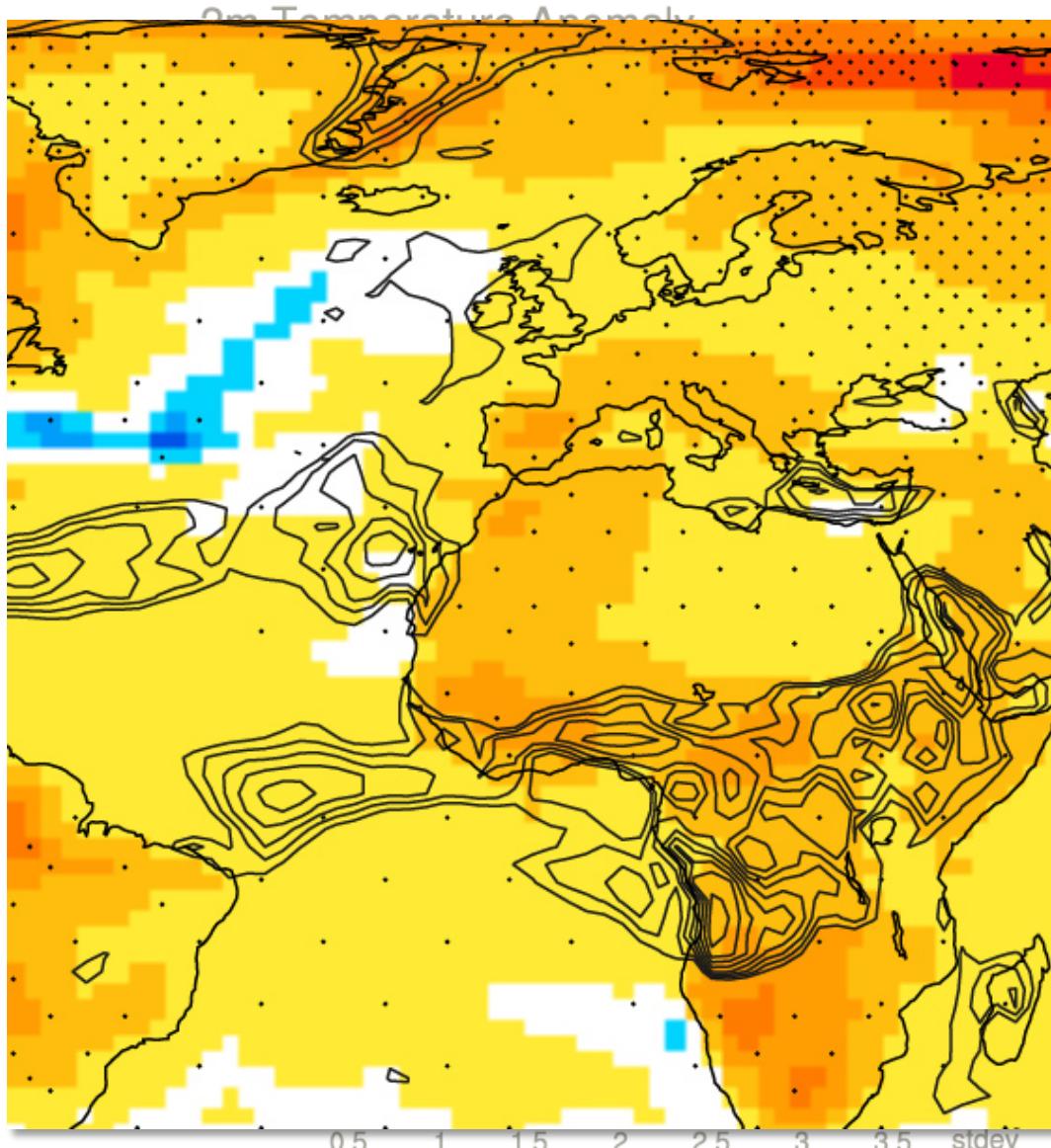
The Data used

- Model system
 - MiKlip Baseline 1
 - MPI-ESM Earth System Model (T63L47 /1.5 deg L40)
 - Initialization with ORAS4 ocean reanalyses (T & S anomalies), ERA40/ERA-Interim
 - Yearly initialization for 1961-2010
 - 10 ensemble members
 - Described in Pohlmann et al., GRL 2013, DOI:
[10.1002/2013GL058051](https://doi.org/10.1002/2013GL058051)
- 3 Quantities
 - **2m temperature anomalies** over 2014-2023, ensemble mean (12 months running mean)
 - **Predictive skill:** correlation between prediction and reanalysis (based on hindcasts)
 - Ensemble **standard deviation**

NCL: 2D Visualization of multivariate data

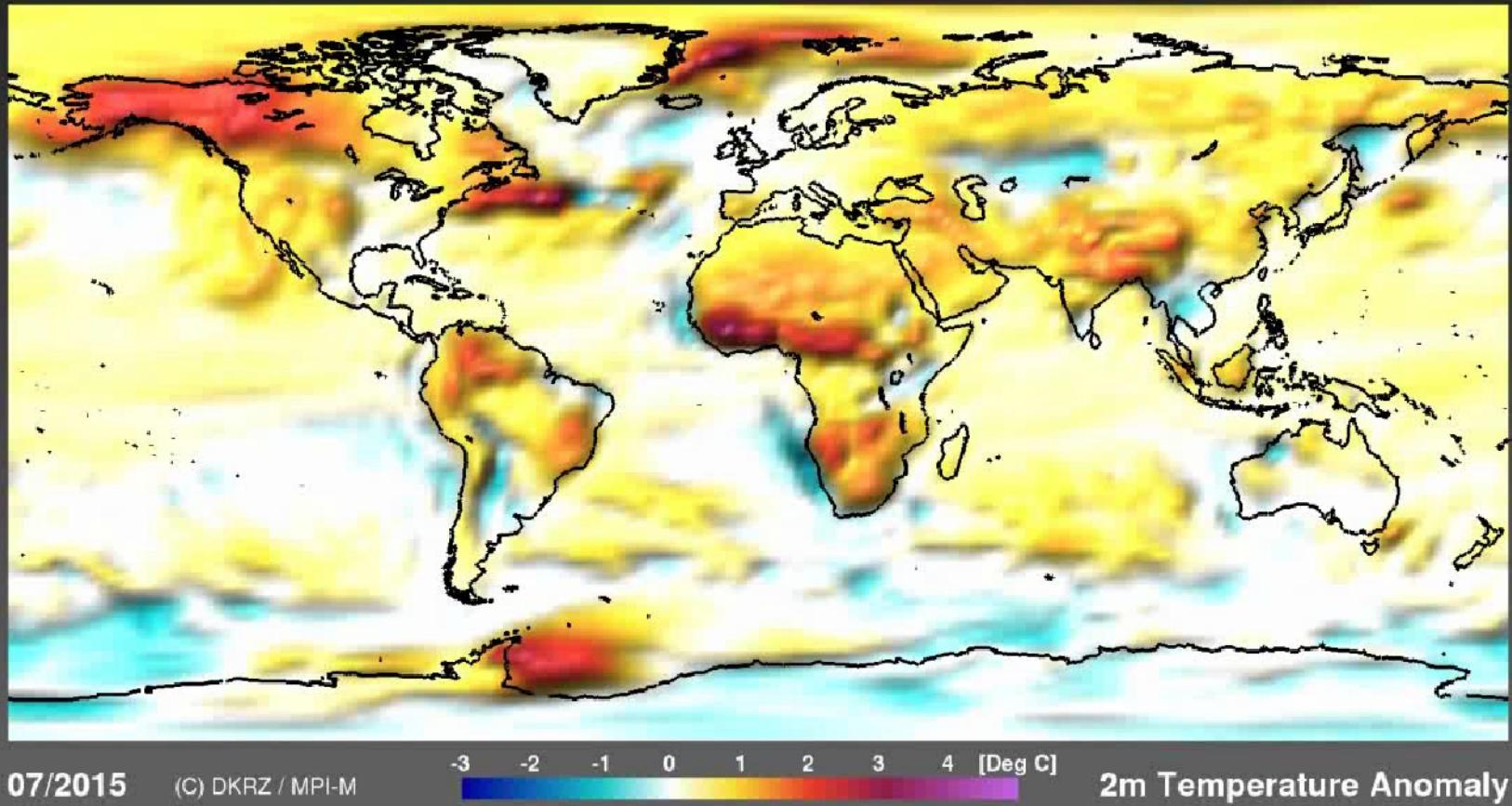


NCL: 2D Visualization of multivariate data

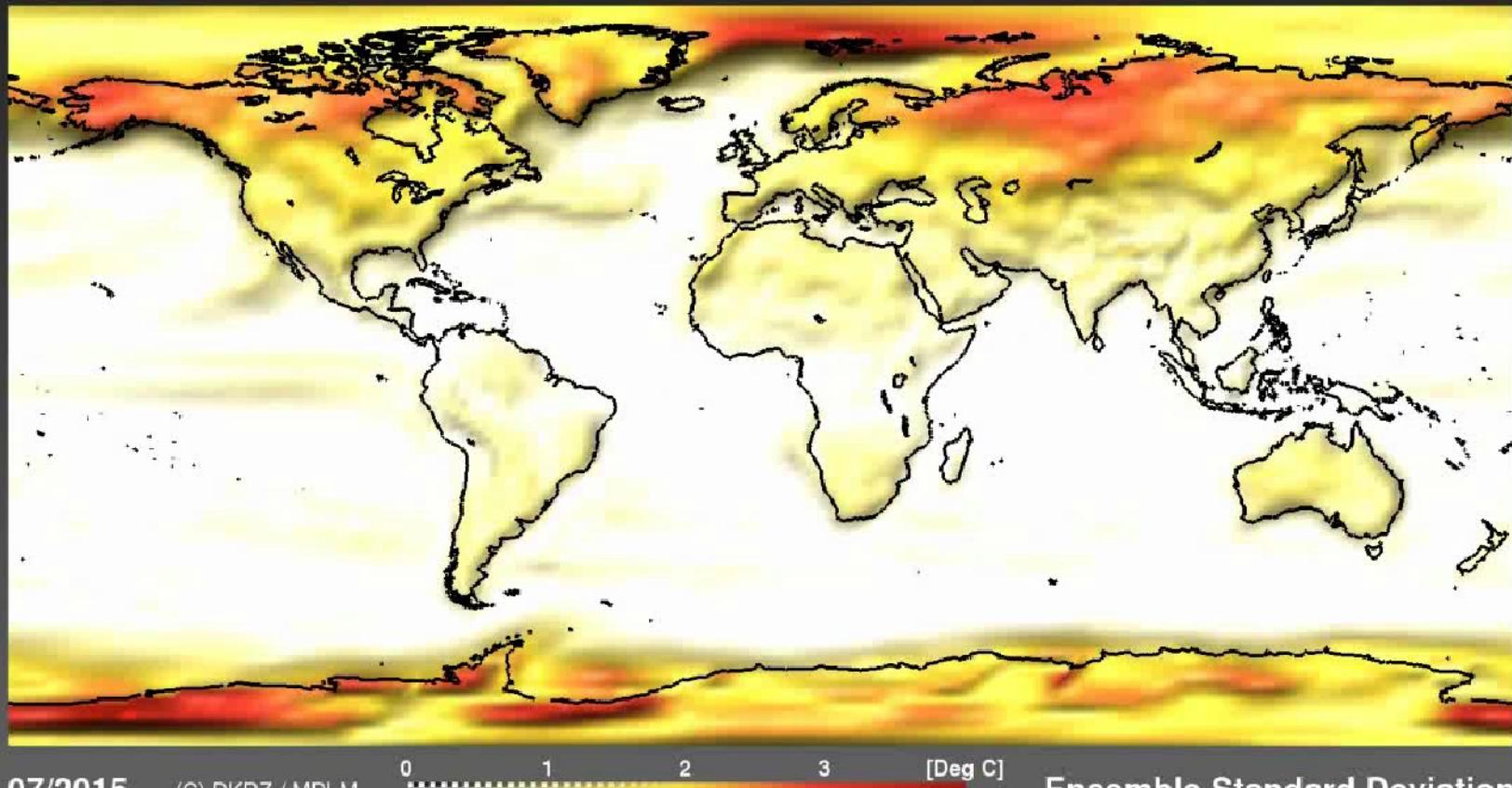


- Vector Gfx
- Animation?

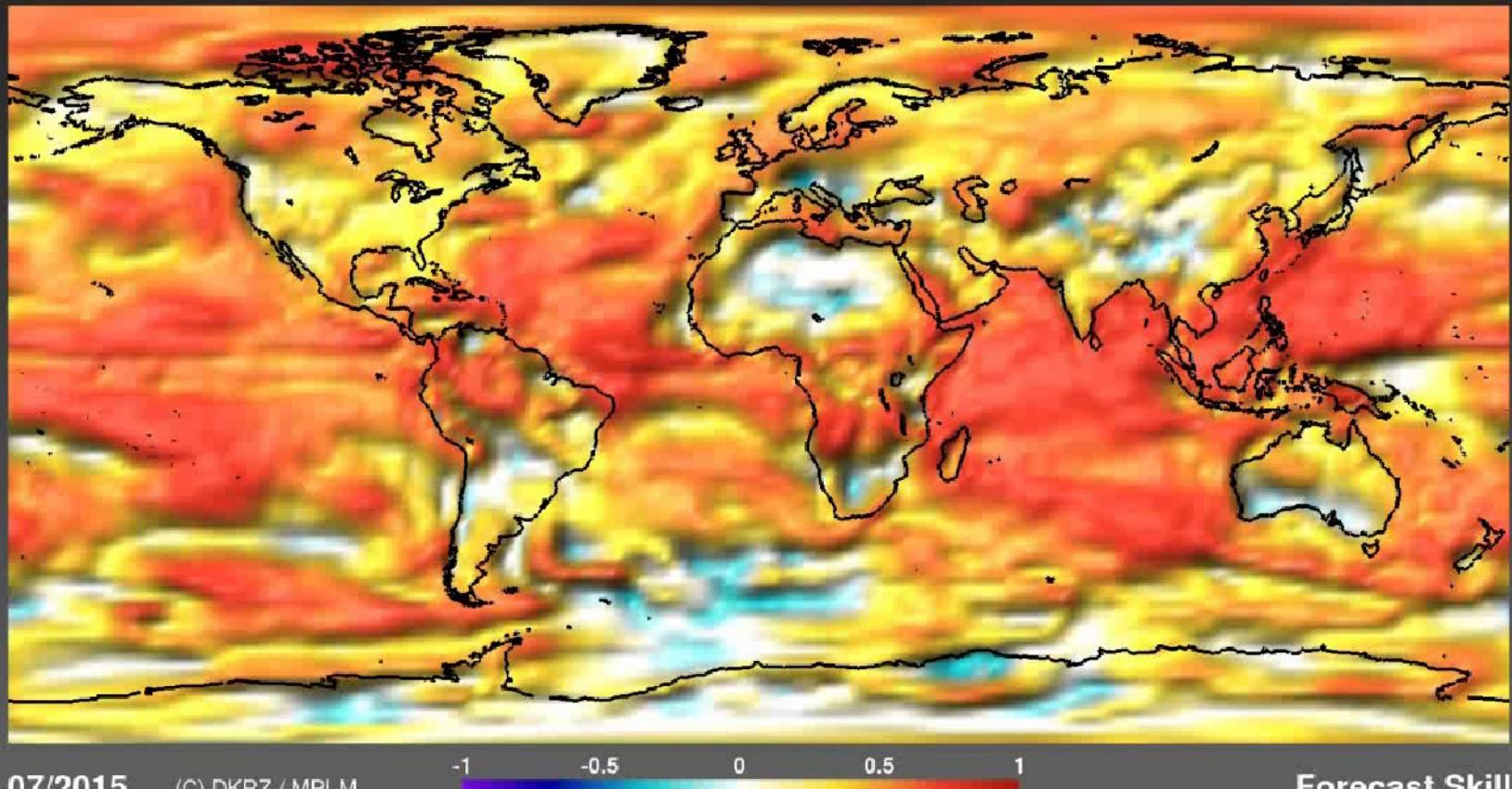
Temporal Patterns: 2m Temperature Anomaly



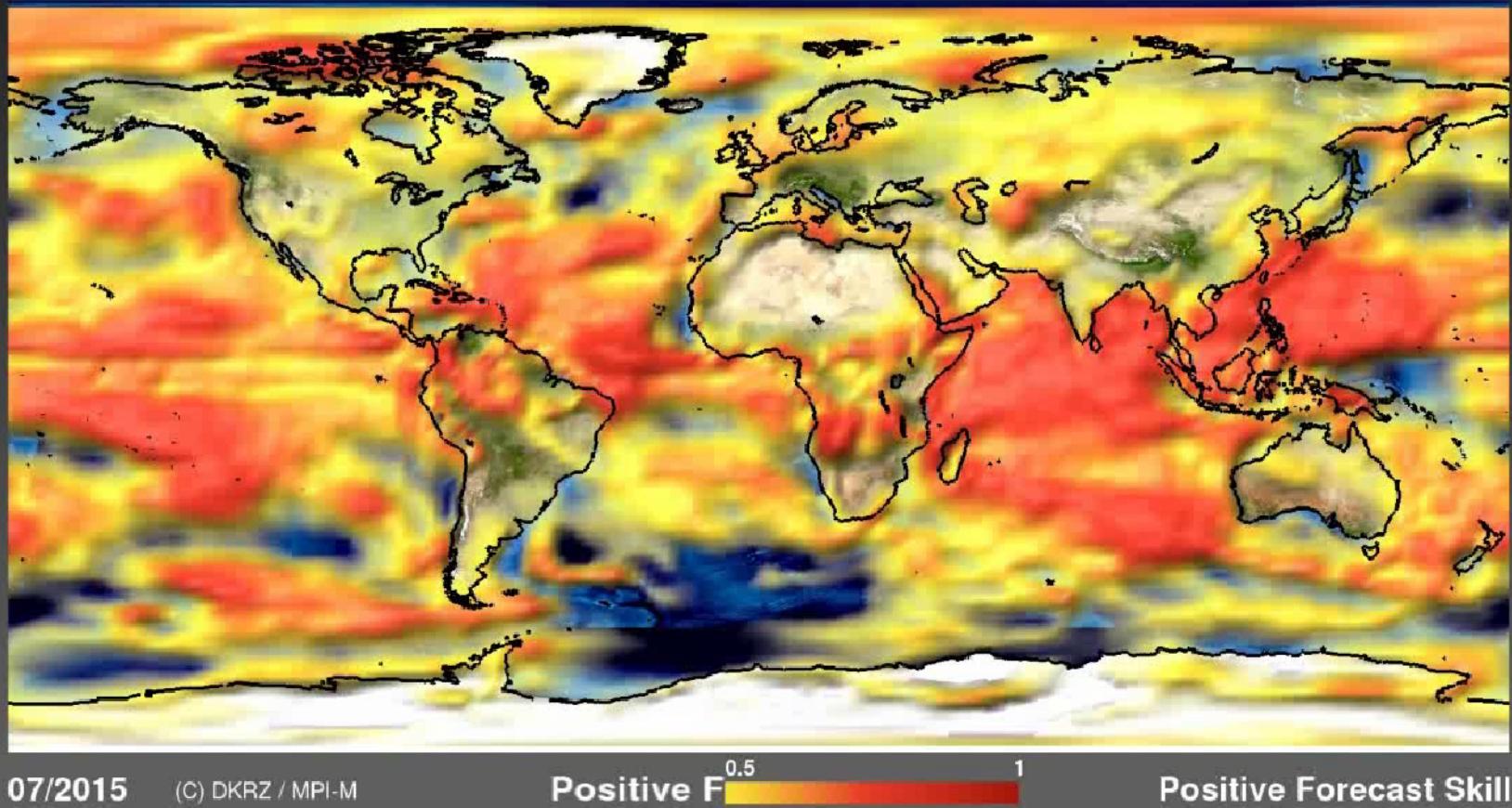
Temporal Patterns: Ensemble Standard Deviation



Temporal Patterns: Predictive Skill / 2m Temperature

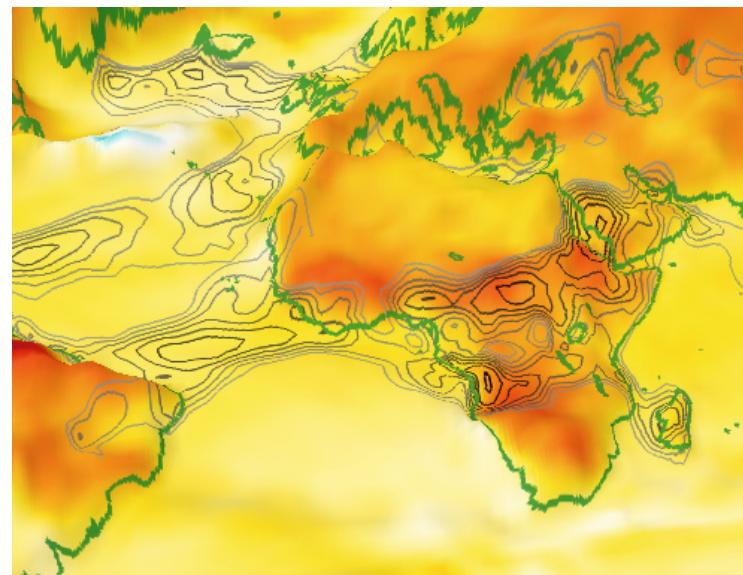


Temporal Patterns: Positive Skill / 2m Temperature

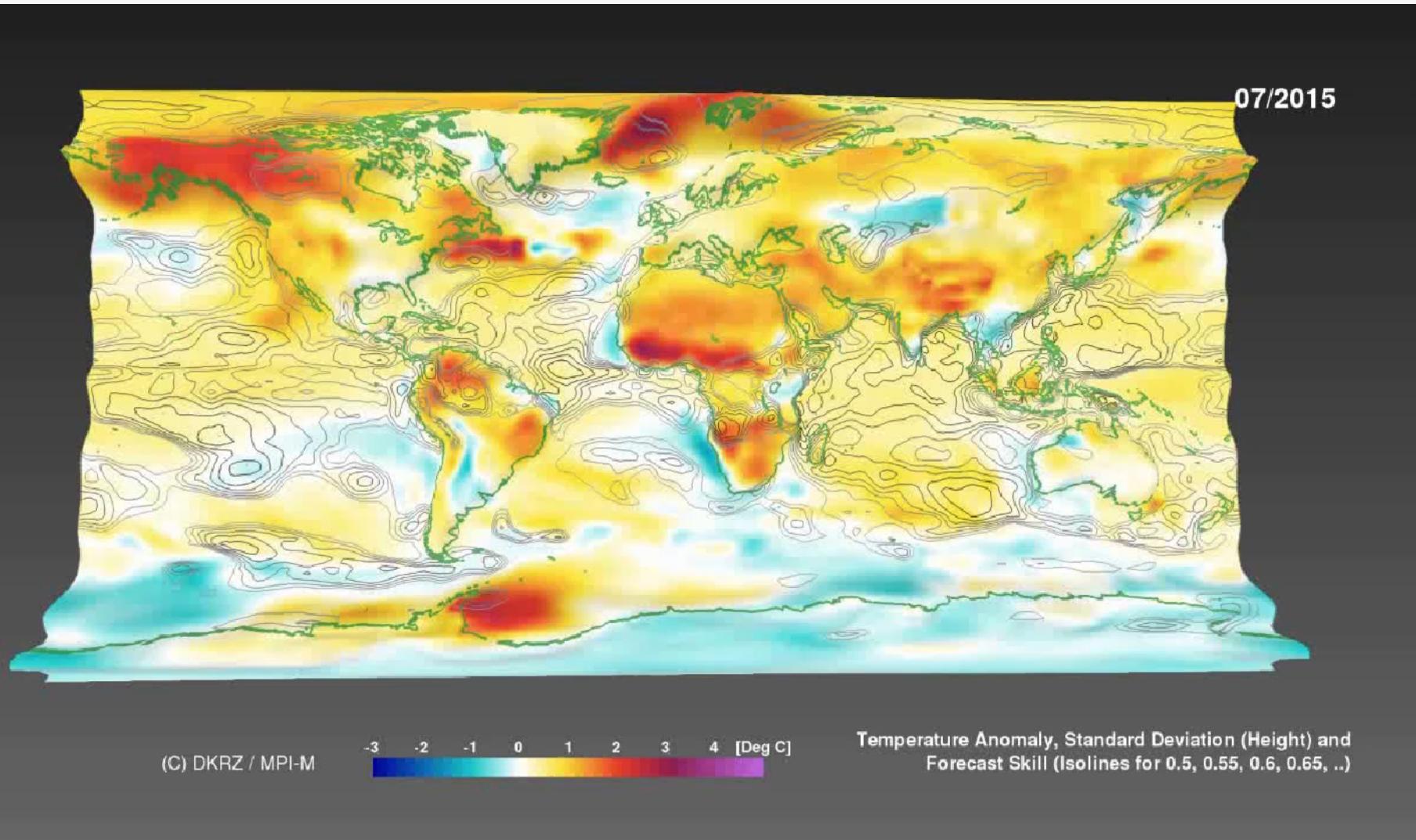


Avizo: 2.5D + Animation

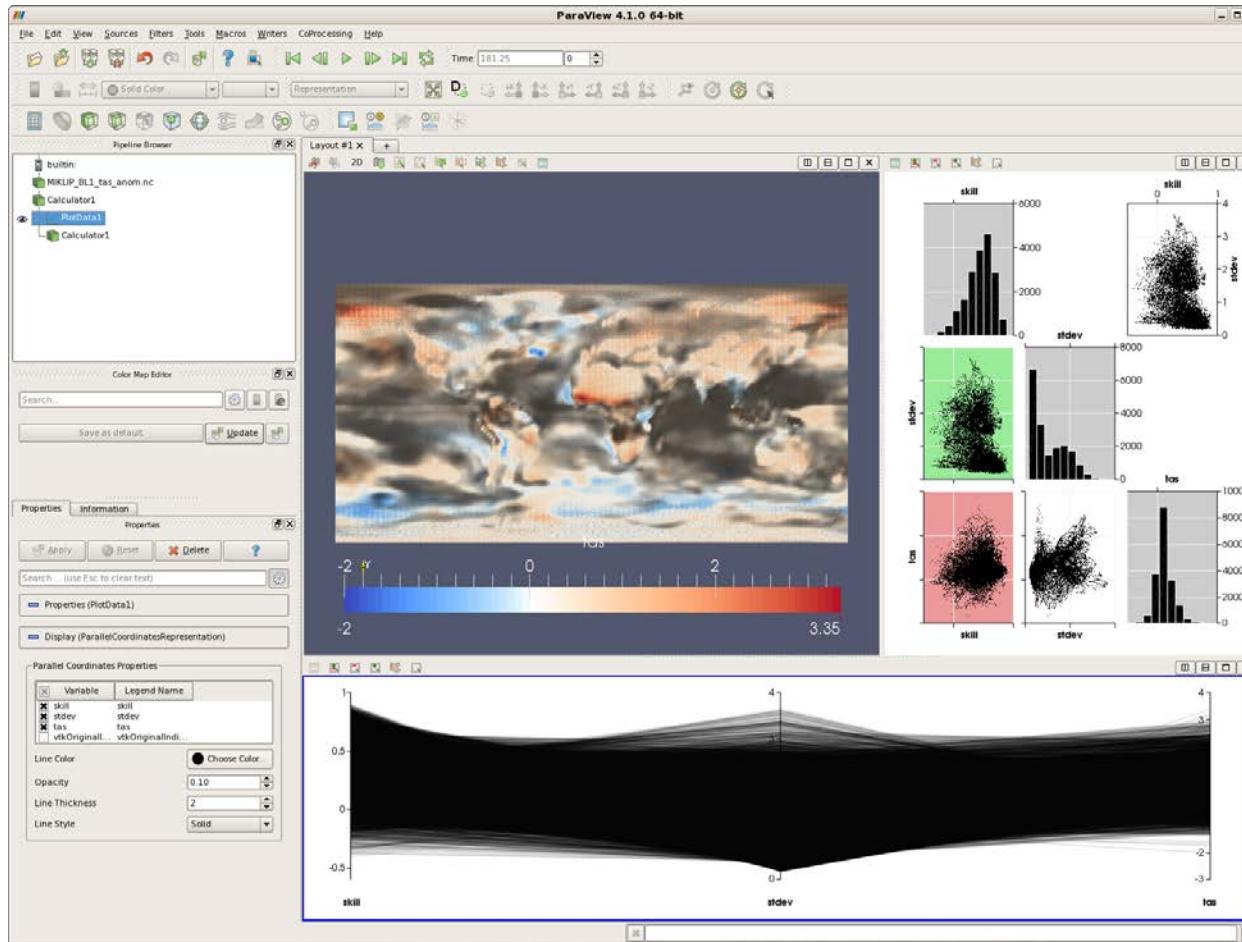
- Avizo Green (commercial 3D visualization system)
- Heightfield method
 - Color mapping according temperature anomaly
 - Surface deformation according to ensemble spread (STDEV)
 - Isolines showing the predictive skill mapped onto surface
- Geographical mapping
- Geographical context
- NetCDF CF
- Time animation



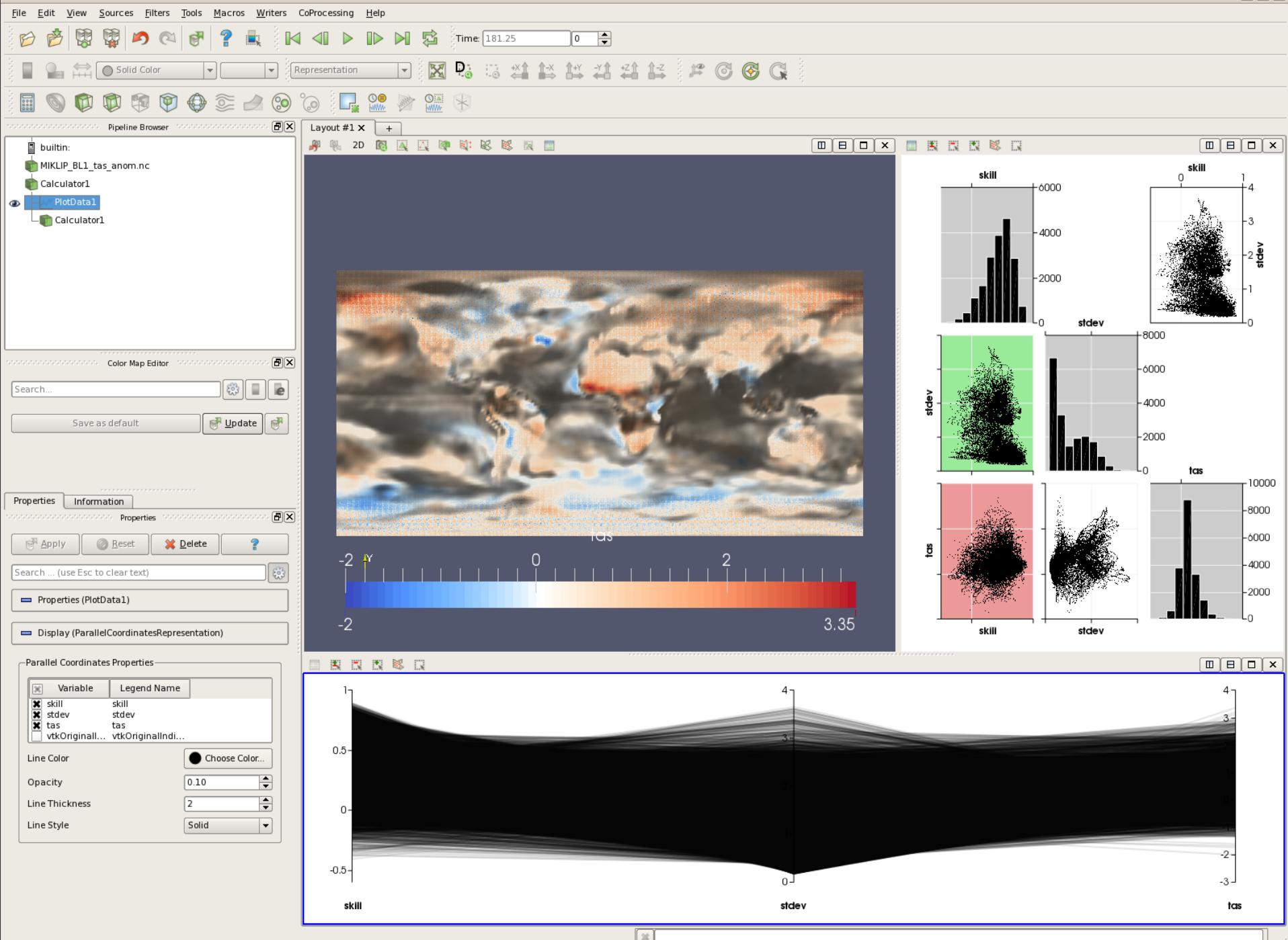
2m Temperature Anomaly, Standard Deviation, and Skill

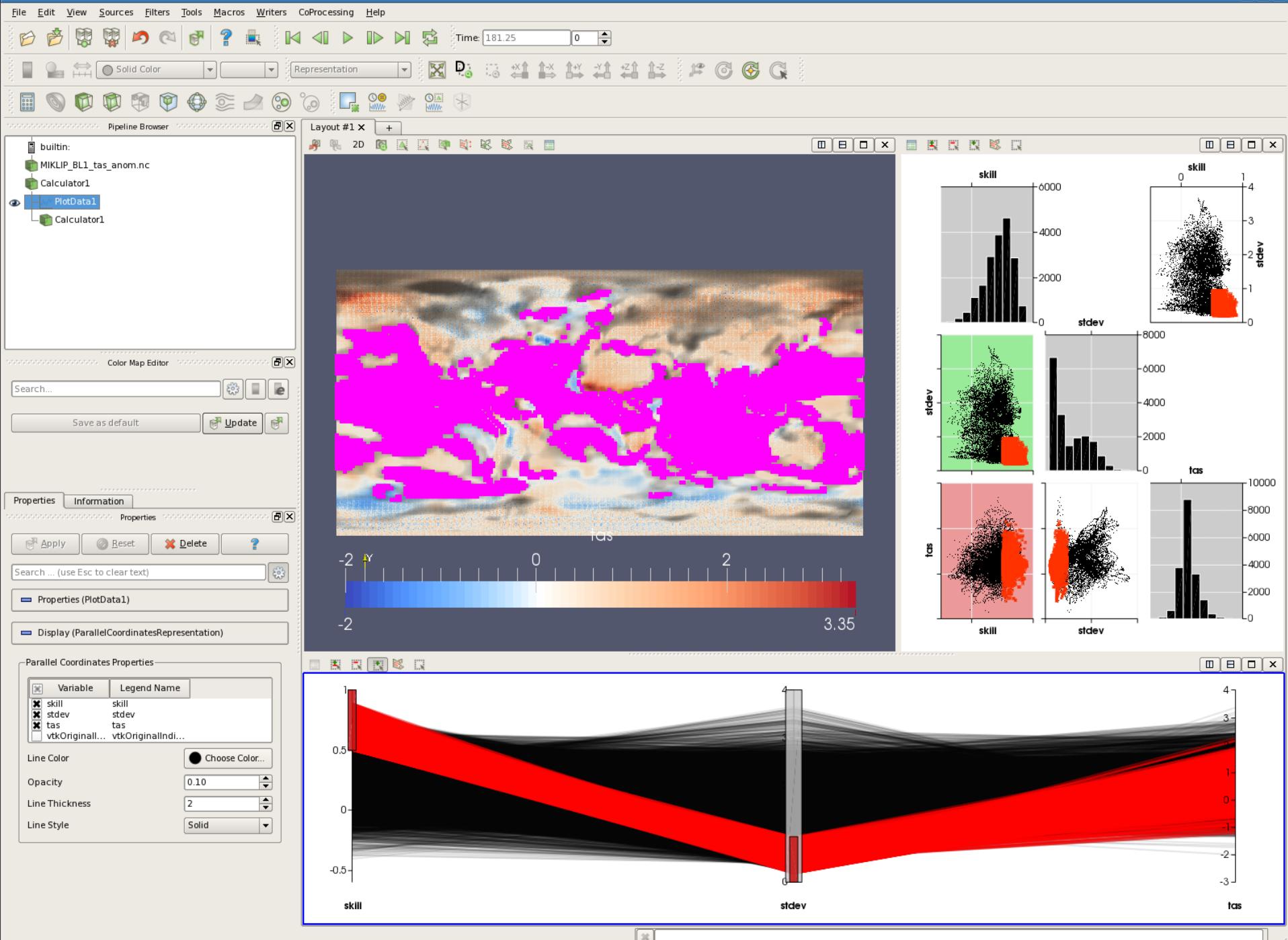


Paraview: Interactive Visual Data Analysis

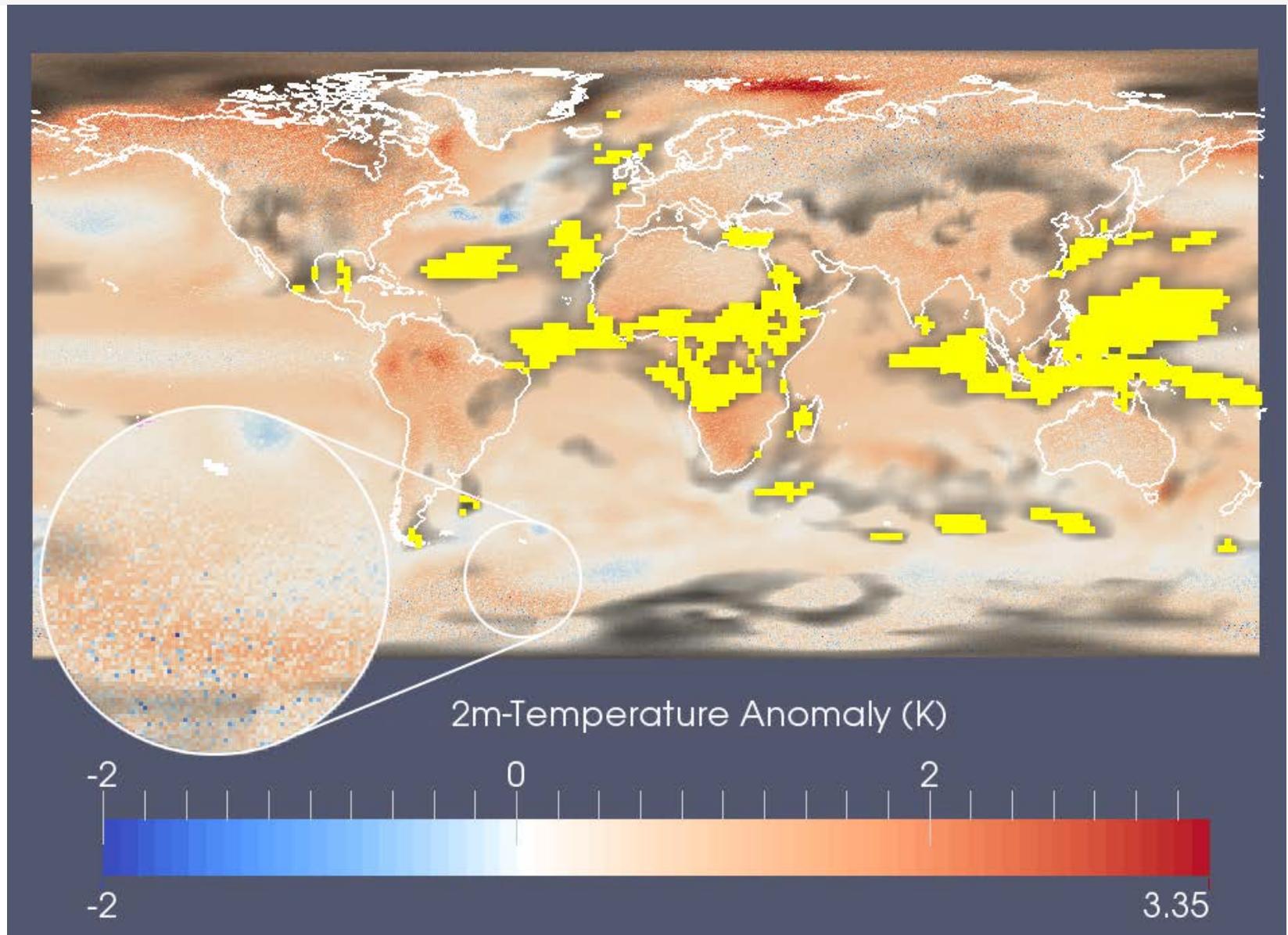


ParaView 4.1.0 64-bit





Paraview: Uncertainty surface (ensemble spread)



Conclusions

- Joint analysis of data and related uncertainty data
 - 2m temperature anomaly
 - predictive skill
 - internal variability (standard deviation)
- Solutions for 3 different visualization tools
 - NCL: 2 line based techniques for overlay
 - Avizo: 3D visualization of 2D data
 - Paraview: interactive analysis based on linked views & brushing
 - No swiss army knife found – each tool has strengths and weaknesses
- Future work
 - Focus on spatio-temporal analyses

Thank You!

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