Contribution of GRACE/GRACE-FO for drought monitoring

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Droughts

- complex, multifaceted slow-onset hazards
- affect several regions world-wide
- increase due to climate change

- severe consequences for human wellbeing, environment and economy
  - Since 1900 ~2 bill. affected, ~11 mio fatalities (FAO), reduces rainfed crop yield by 30%
  - Germany: Agriculture losses: > 300 mio. €/a (floods: ~ 70 mio. €/a)

- South Africa heavily affected by drought impacts
  - smallholders (rainfed crops) highly susceptible to drought
  - water stress intensifies existing problems, decline agricultural output
  - gap between CC progression and farmer's adaptation, lack of adaptive capacities

GlobalDrought Project

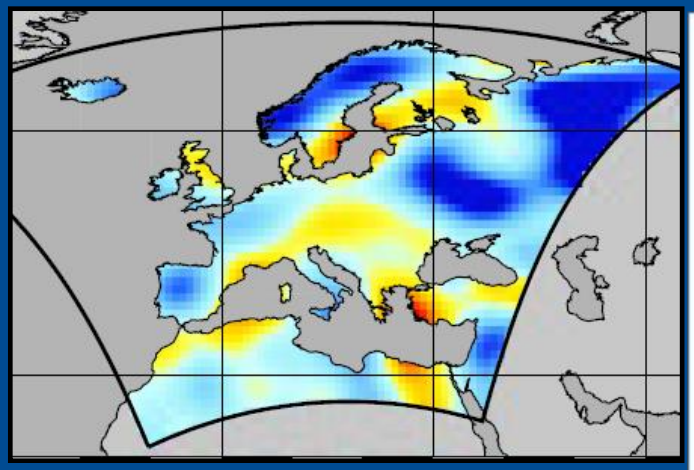
- 2018-2020
- Partners: U Göttingen, U Bonn IGG+ZFL, U Frankfurt, UNU-EHS, Remote Sensing Solutions, Welthungerhilfe
- Associate Partners: U Free State RSA, U Zimbabwe, GEO, NASA
- Develop a web-based integrated drought information system:
  - past droughts, drought risks on global scale
  - detailed analysis for selected regions
  - (composite) drought indicators
  - impact on food trade flow
  - WGHM + Crop model + GRACE DA

- https://grow-globedrought.net/

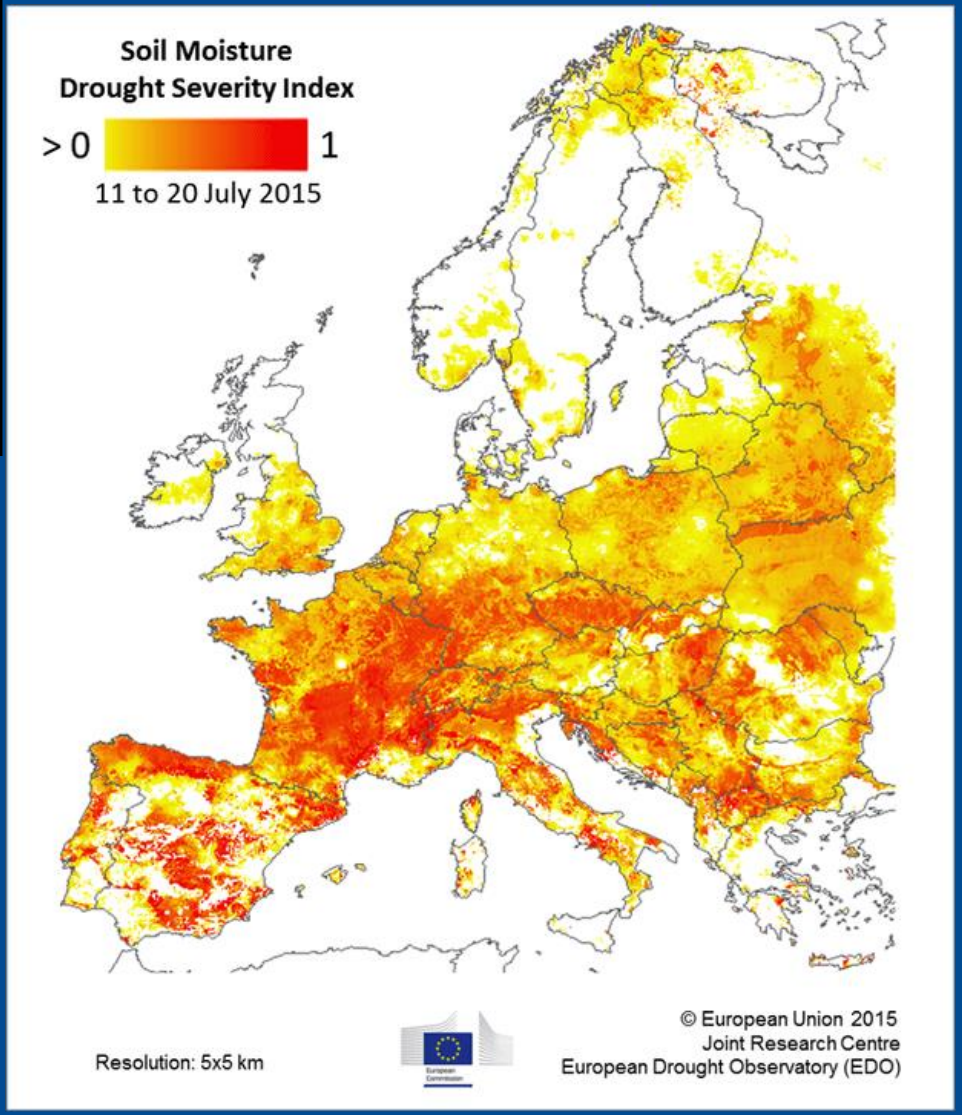
Objectives

- How can we make best use of GRACE/GRACE-FO for improving drought monitoring systems
- What is the benefit of GRACE/GRACE-FO data, how can we quantify this
- What data product would be required from a user point of view?
- Increase spatial resolution!!!

Resolution



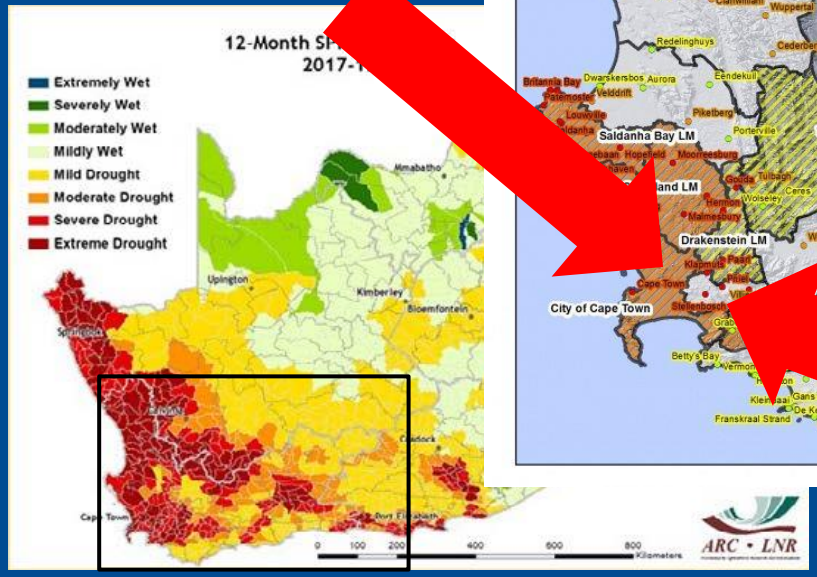
GRACE ~ 300km

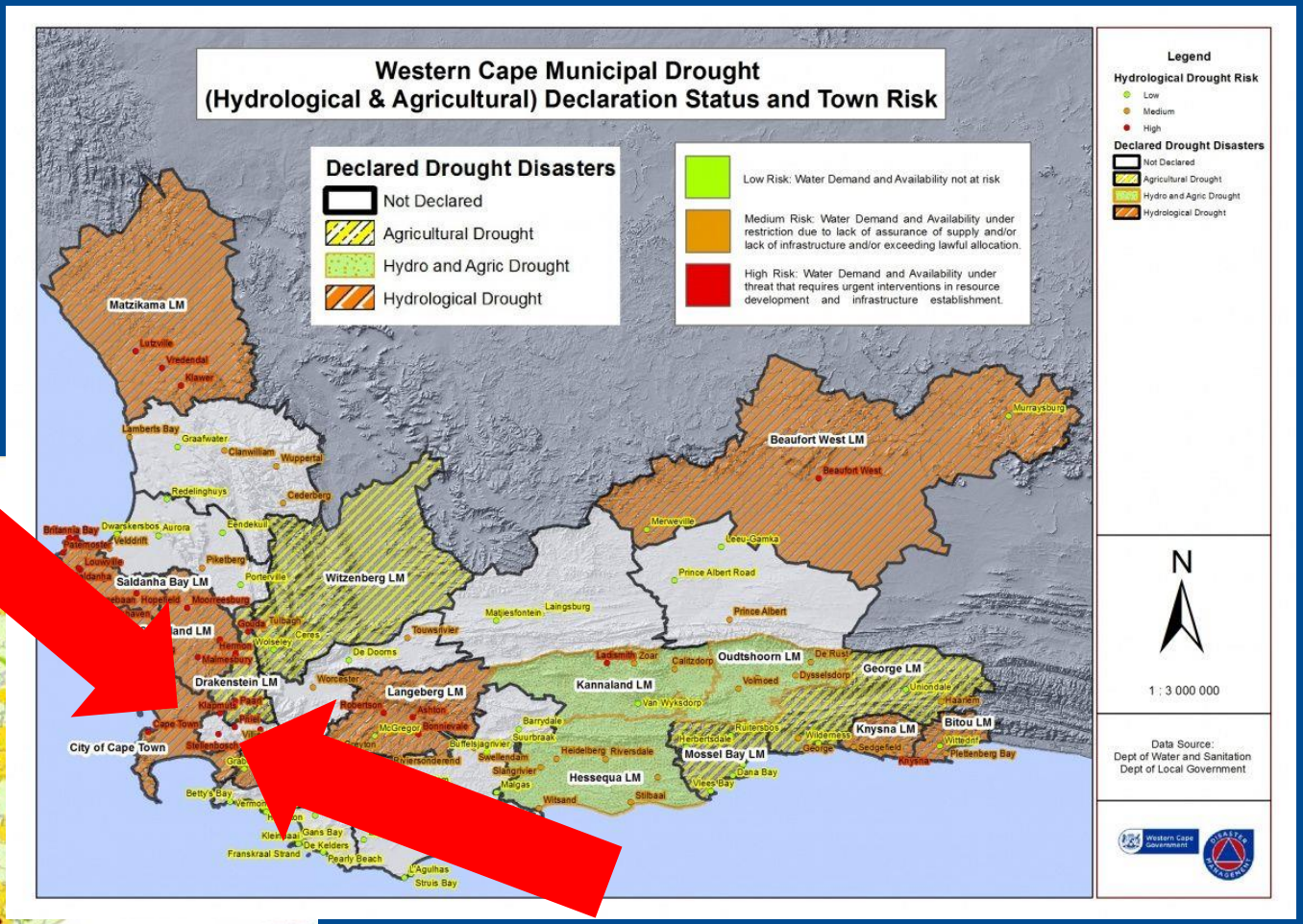


EDO Drought Severity Map: 5km

Resolution

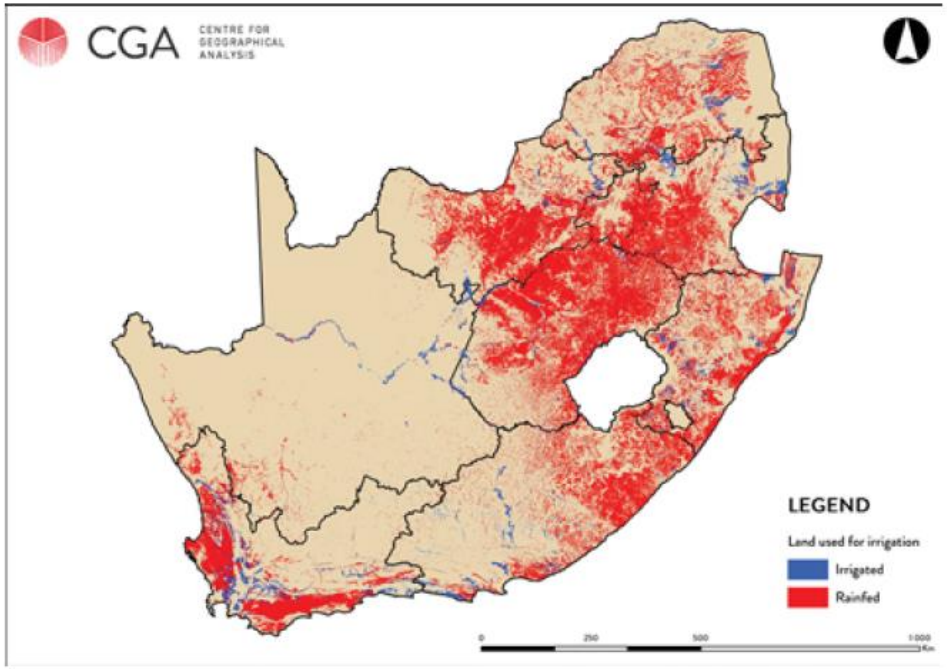
Drought





No drought

South Africa



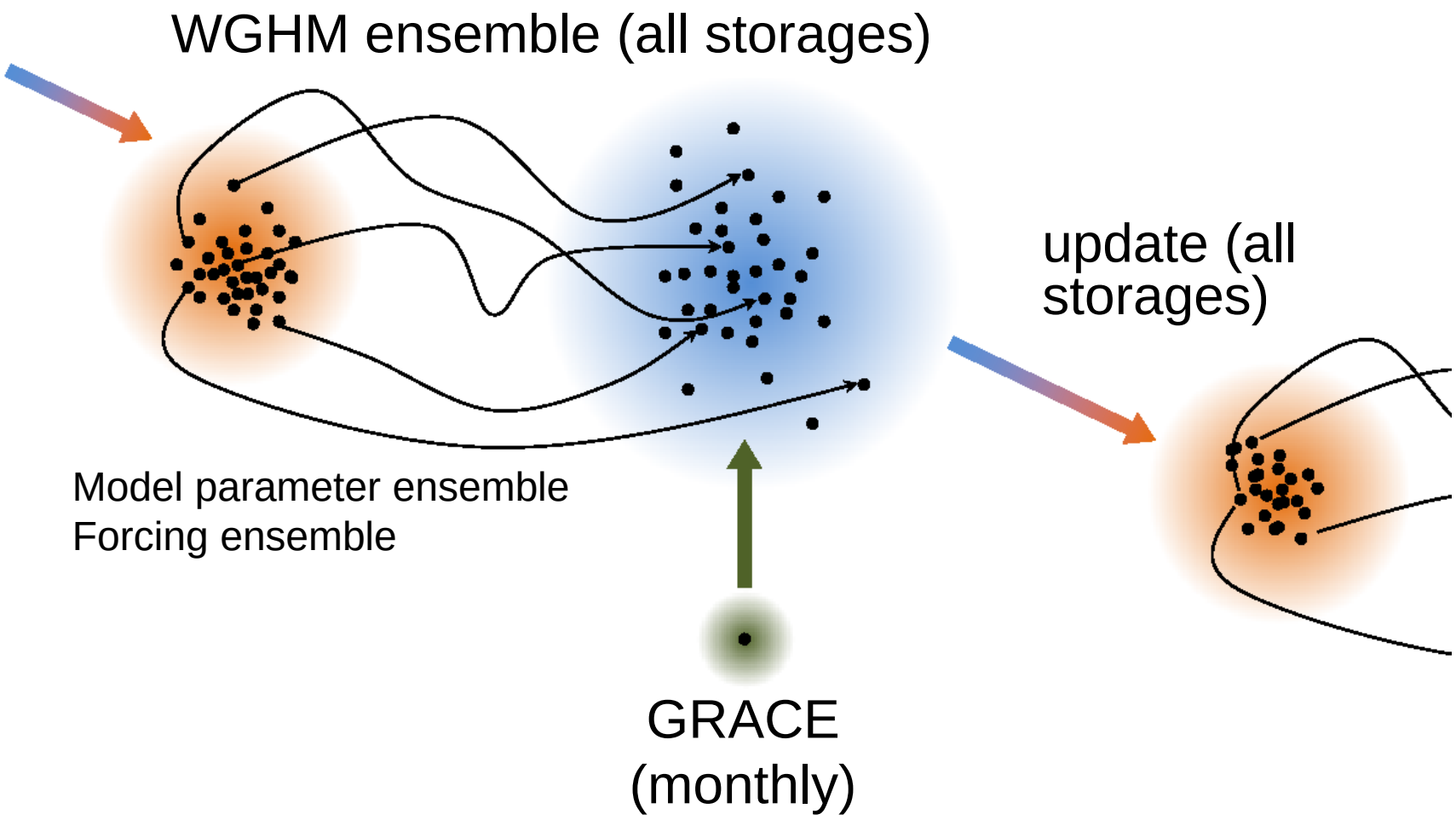
Actively irrigated agricultural areas for the year 2015/15 are shown in blue on this map of South Africa, while rainfed areas are depicted in red.

Stellenbosch University

Downscaling GRACE by Data Assimilation (DA)

- Global hydrological model (WGHM, Döll et al., 2003) as „first guess“
- Physically consistent integration – hydrological simulation constrained by GRACE (optimization problem)
  - Ensemble Kalman Filter (EnKF)
- Calibration of model parameters through DA improves forecast skills (Uni Bonn approach)
  - Eicker et al. (2014), Schumacher et al. (2017, 2018)
- Numerically efficient implementation PDAF (Nerger and Hiller 2013)
  - Schulze et al. (in prep.)

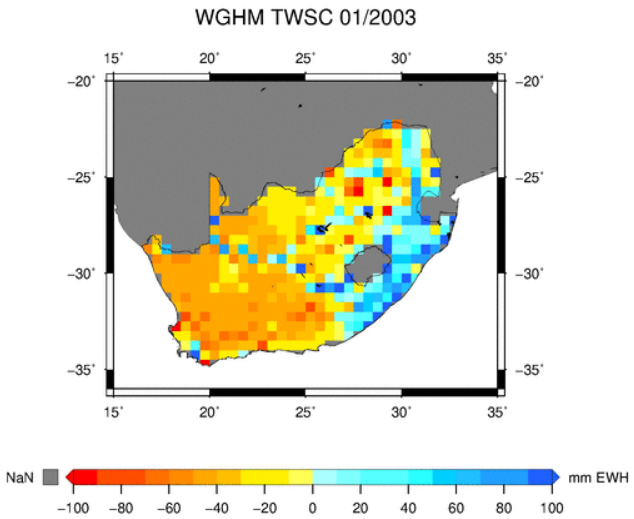
Downscaling GRACE by Data Assimilation (DA): Ensemble Kalman Filter

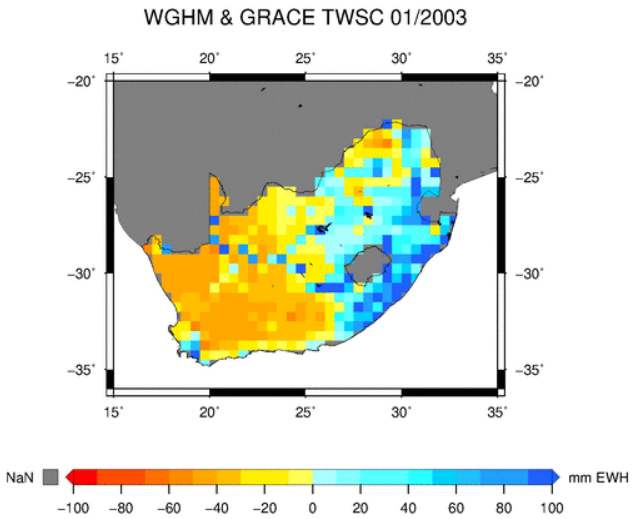


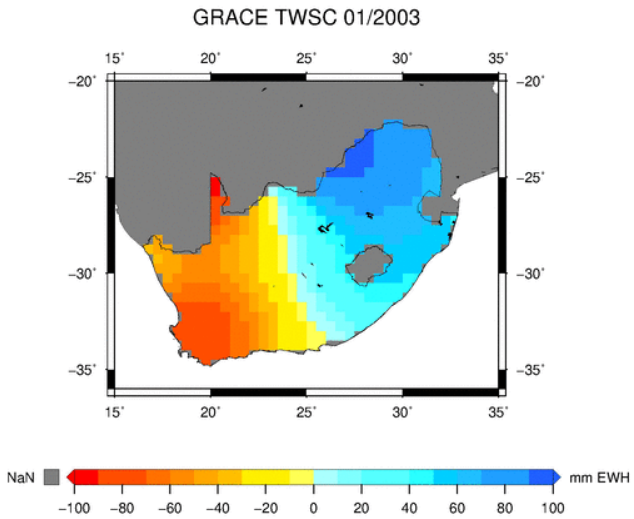
U Ghent (modified)

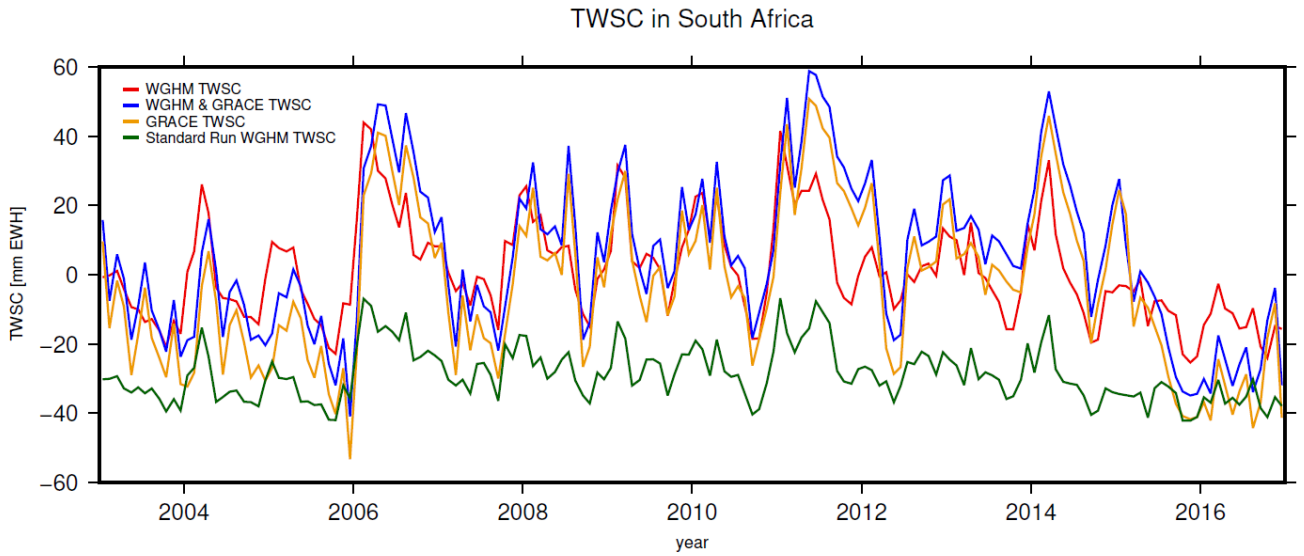
Model run and GRACE

Total Water Storage Change









Model run and GRACE

- DA pulls the simulation towards GRACE
- But keeps the spatial detail from the simulation
- How about drought identification?

GRACE Hydrological Drought Indicators

Drought Severity Indicator DSI (Zhao et al, 2017)

$$\text{TWSC-DSI}_{i,j} = \frac{x_{i,j} - \tilde{x}_j}{\tilde{\sigma}_j}$$

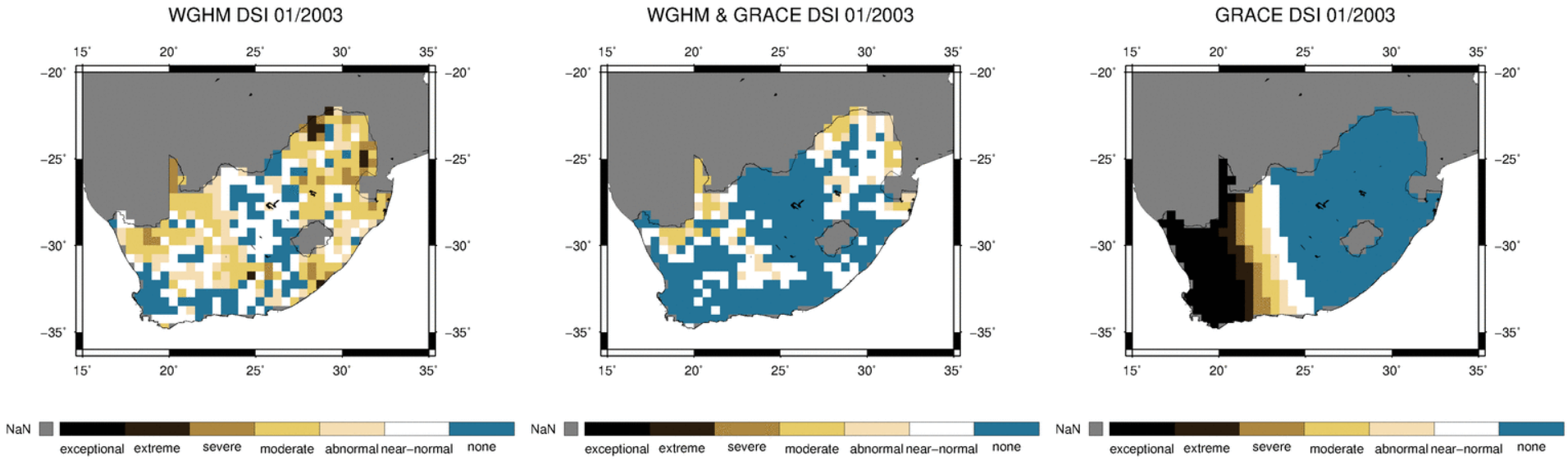
$$x_{i,j} = \overline{\Delta s}(t_{i,j})$$

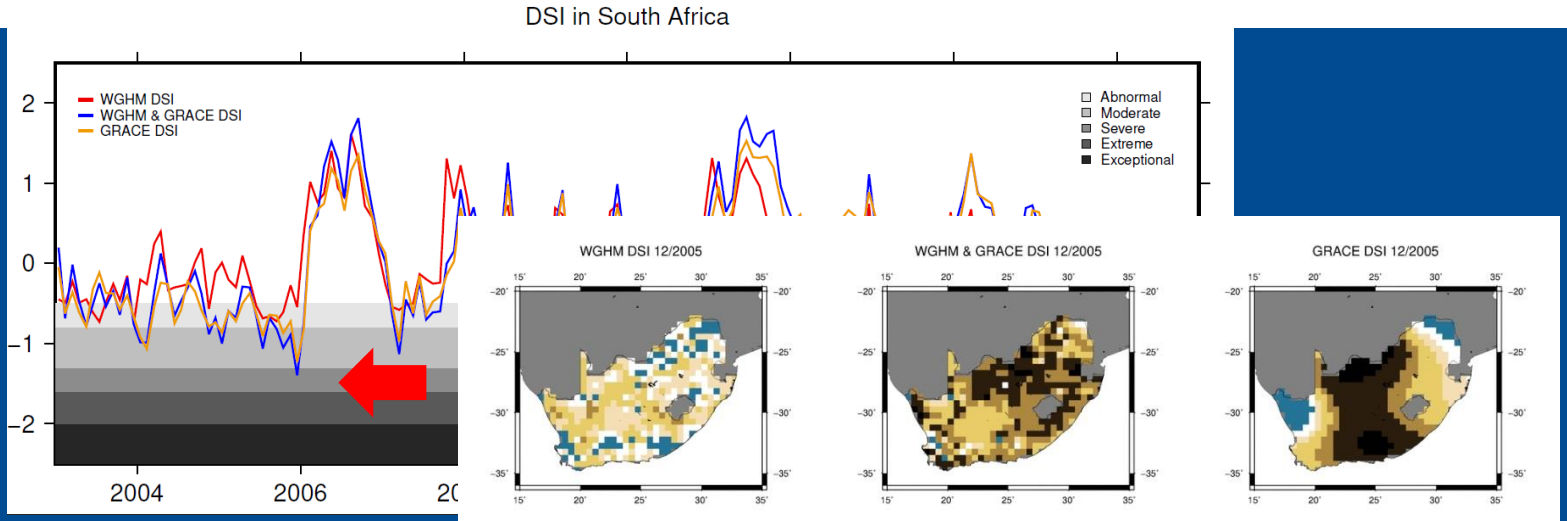
$$\tilde{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{i,j}$$

DSI: How does the water deficit for a given month (vs. climatology) compare w.r.t. variability?

GRACE Hydrological Drought Indicators

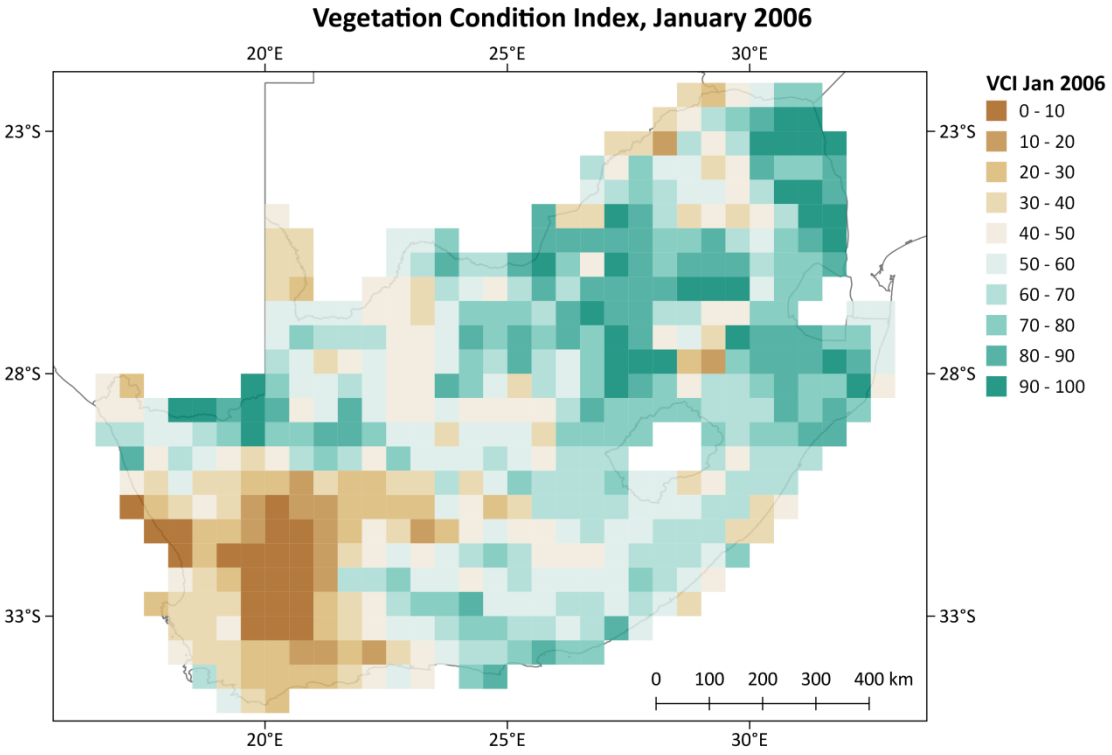
Drought Severity Indicator DSI (Zhao et al, 2017)

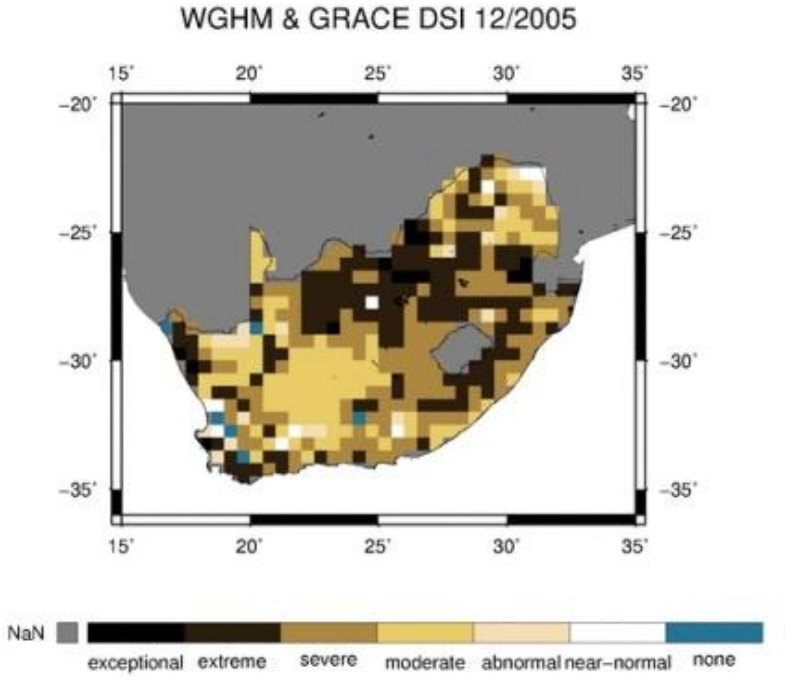




GRACE Hydrological Drought Indicators

Comparison to MODIS: Vegetation Condition Index (VCI)



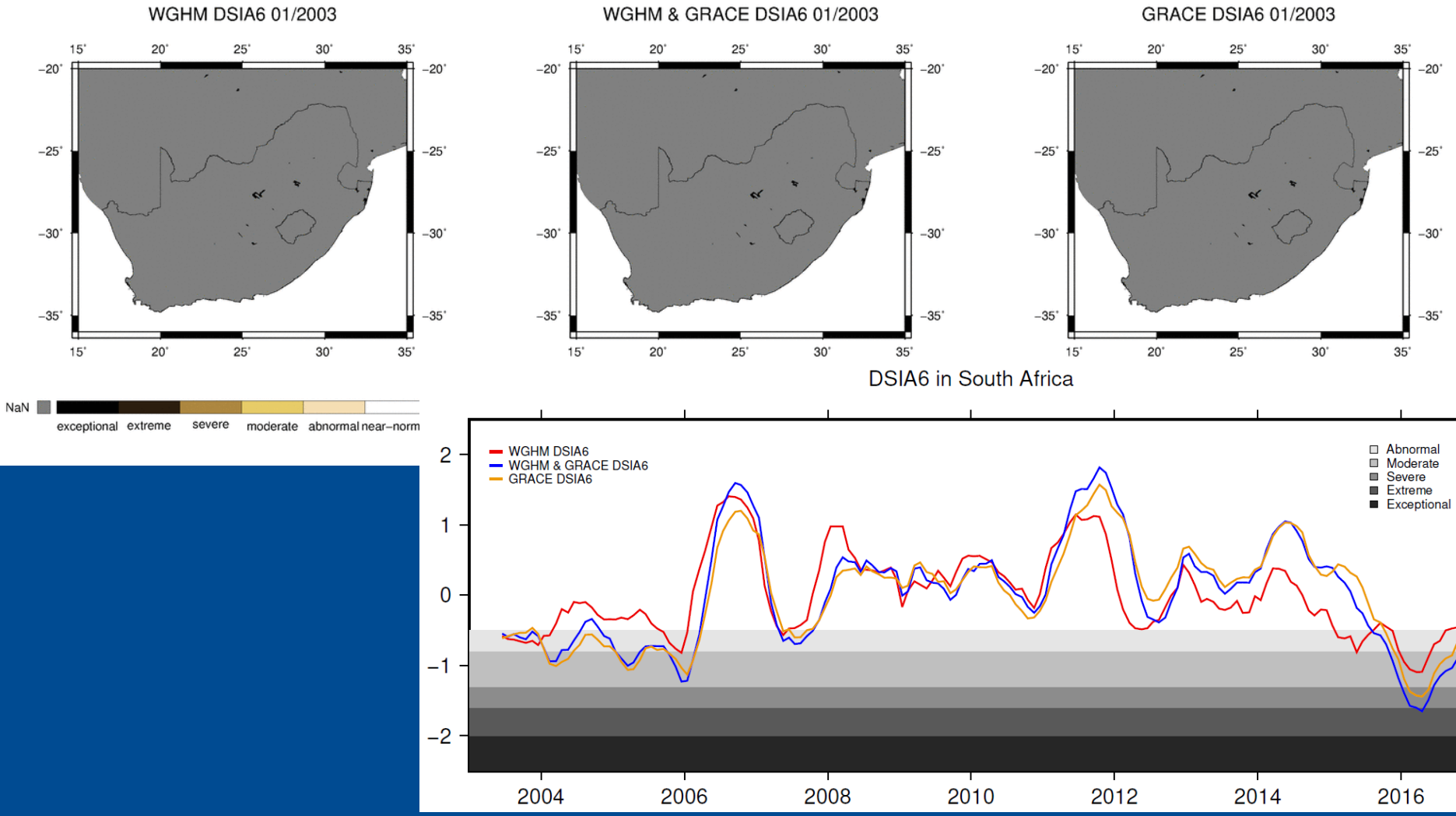


Model run and GRACE

- GRACE suggests stronger drought severity as compared to the model, in particular in the 2015-2017 drought in Cape Province
- but one month does not constitute a drought
- → moving 6-month period (DSI6)

GRACE Hydrological Drought Indicators

6-month accumulated DSI6 (Gerdener et al, 2019)



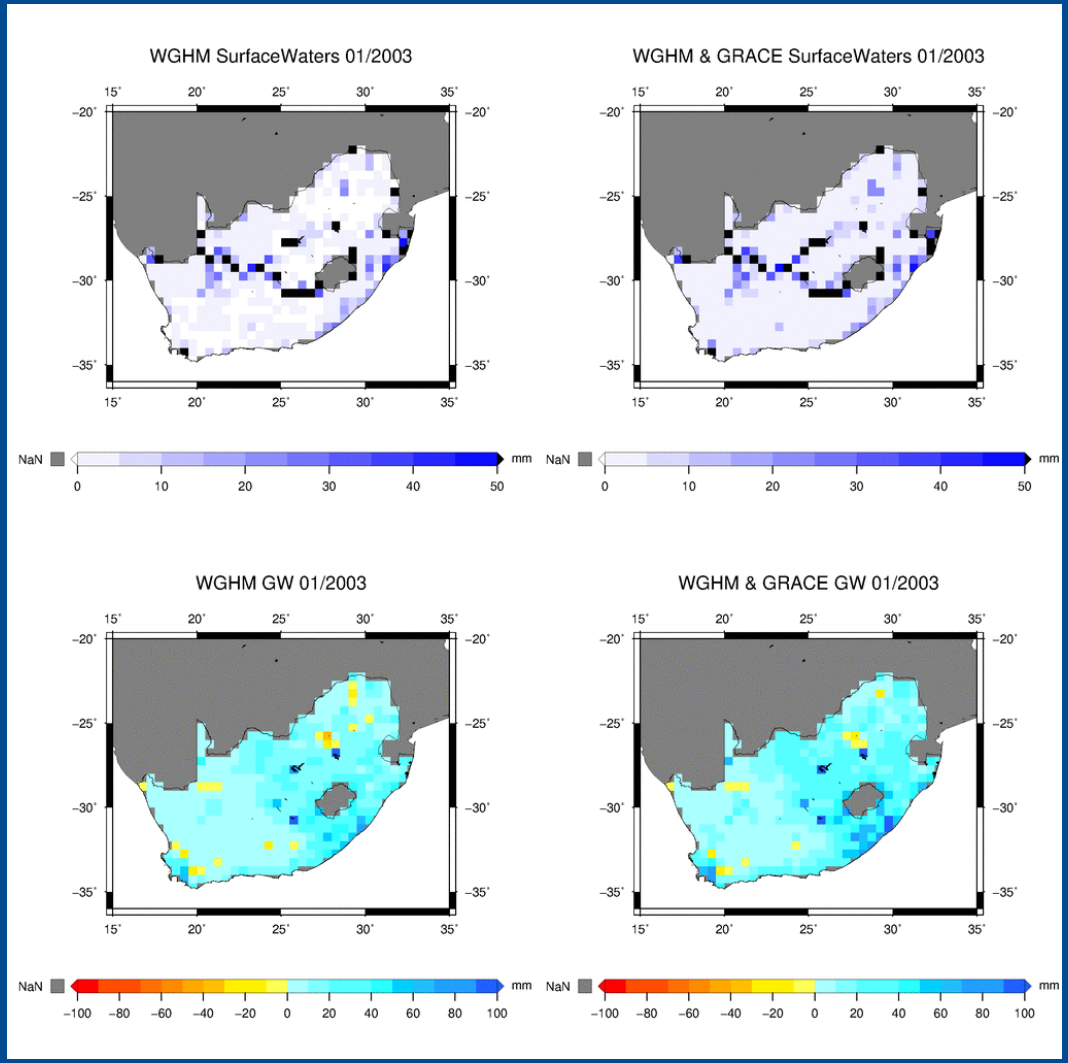
Model run and GRACE

- GRACE has no vertical resolution…
- Surface water and groundwater contributions?
- Data Assimilation provides vertical disaggregation of GRACE

GRACE Hydrological Drought Indicators

Surface Water (lakes, rivers, reservoirs, snow, wetlands)

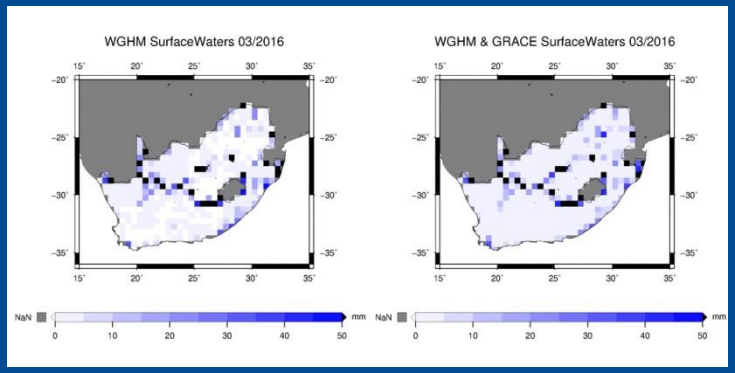
Groundwater
(Schumacher et al 2018)

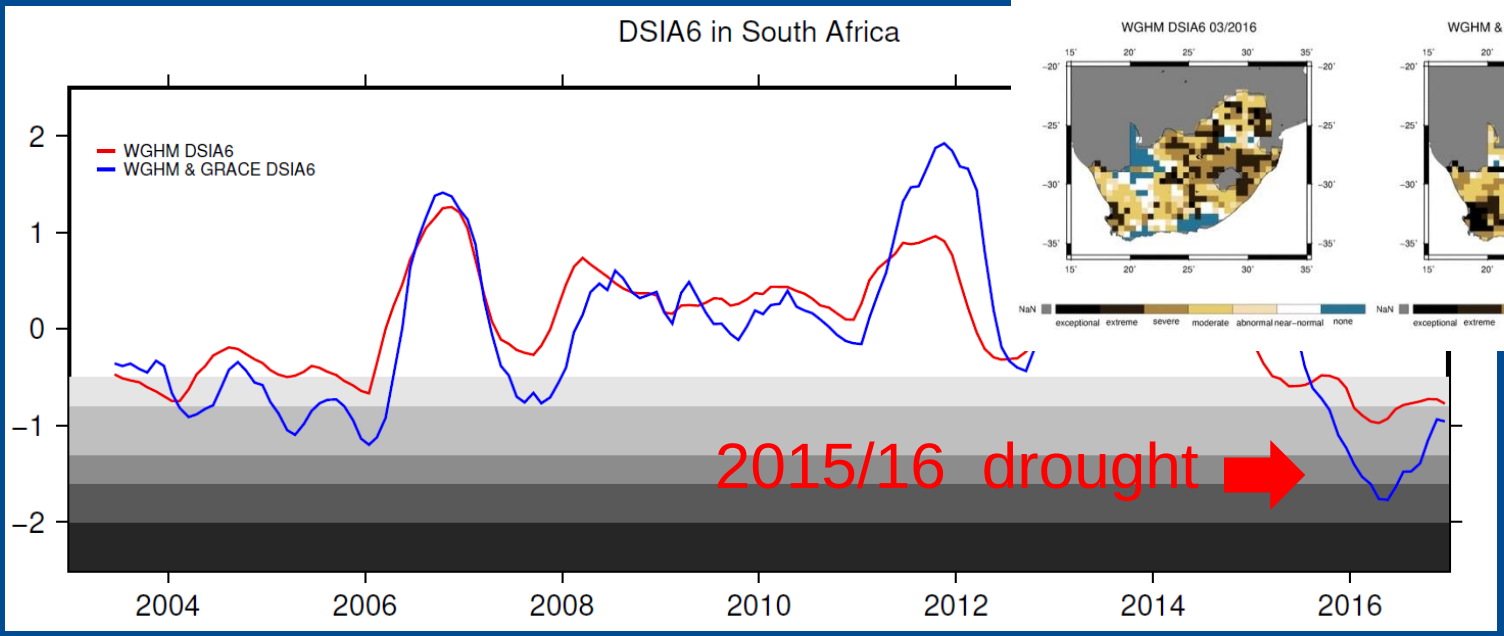


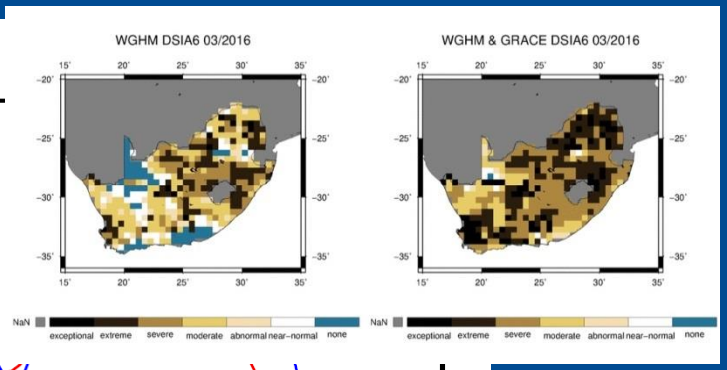
GRACE Hydrological Drought Indicators

Groundwater drought in Model and GRACE-DA, DSI6

Model-GRACE difference more pronounced that TWS drought

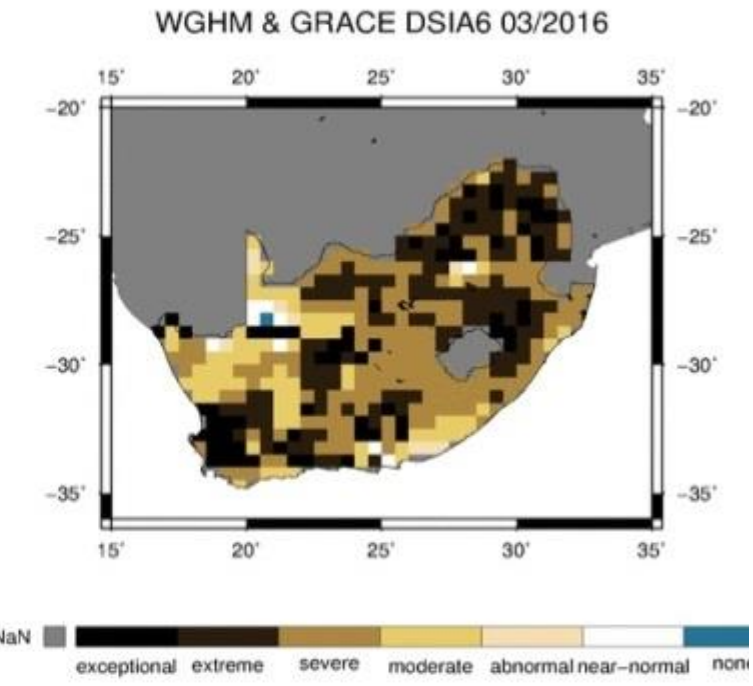


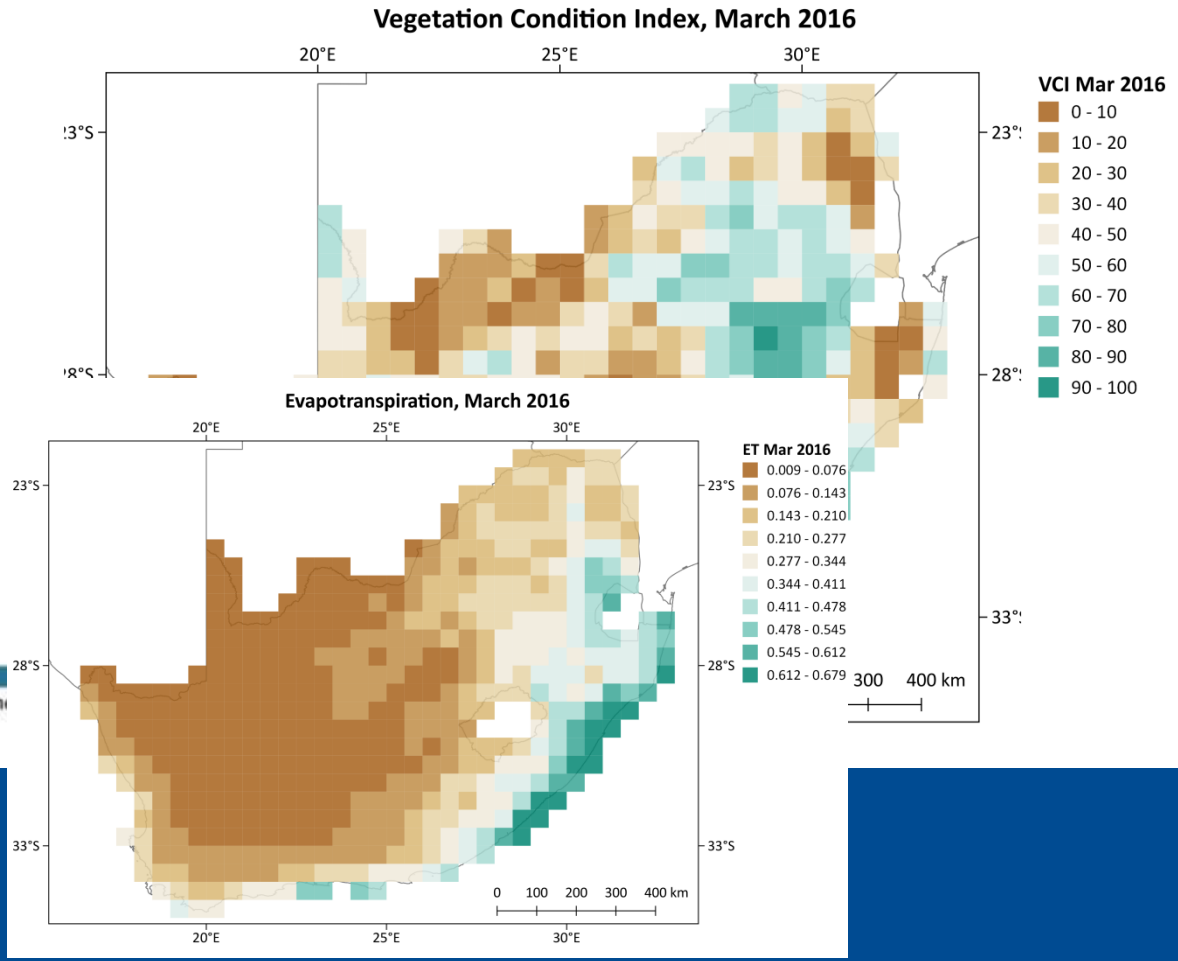




GRACE Hydrological Drought Indicators

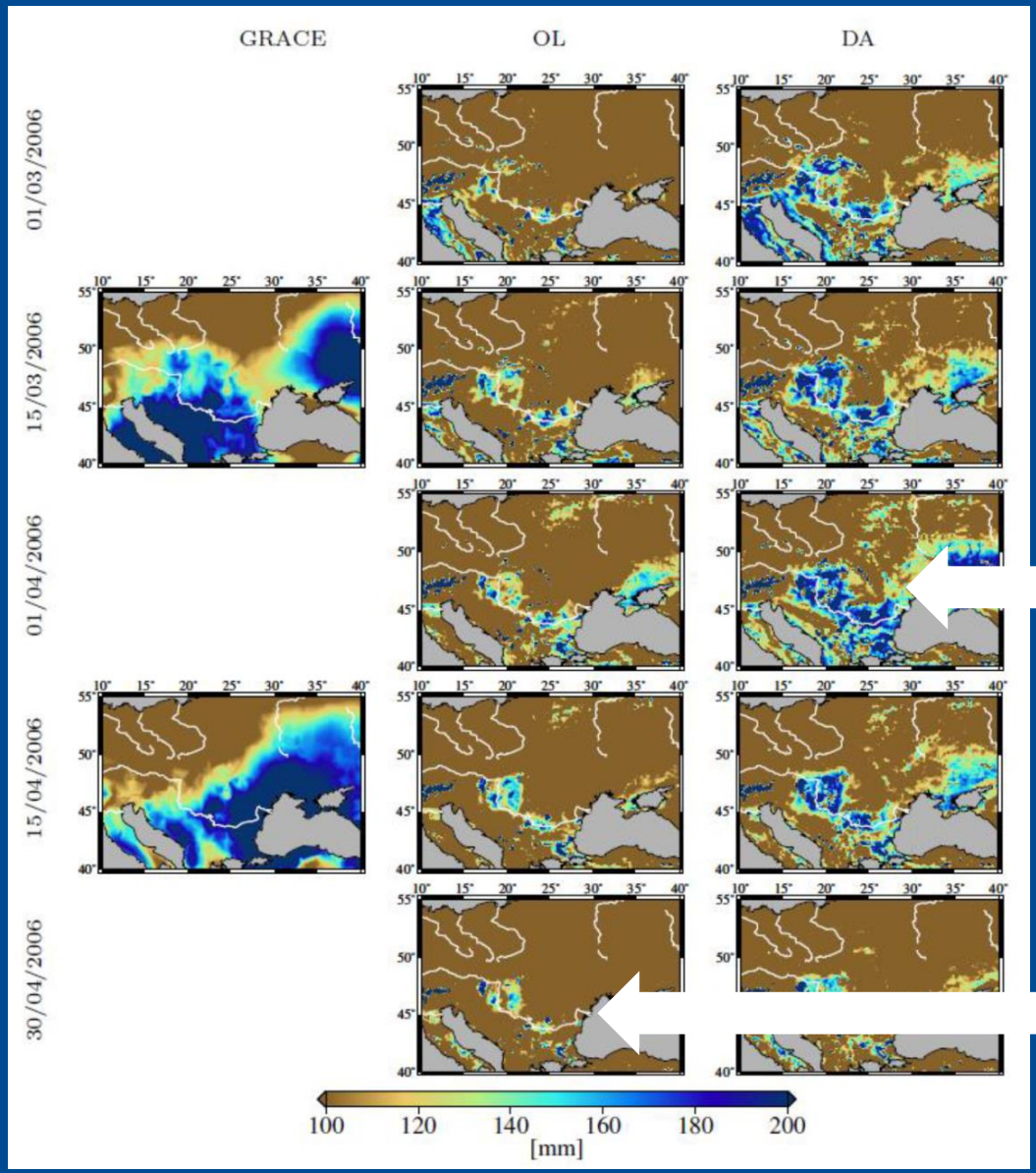
Comparison to MODIS: Vegetation Condition Index (VCI)





Can we downscale GRACE/-FO to even higher spatial and temporal resolution…?

GRACE



GRACE Integrated in CLM

CLM (12,5 km, 1h resolution)

Yes! E.g. Danube Flood 2006

(Springer 2019, Springer et al., 2019)

Contribution of GRACE/GRACE-FO for drought monitoring

Next steps in the project

- Integration into the Drought Information System by RSS (ongoing)
- Methods/testing/validation under revision in HESSD
- Risk assessment paper under revision in NHESS

- Testing impact of GRACE on groundwater drought indicators
- Testing impact at 12,5 km resolution
- Going global: 2021-23

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Hydrology and Earth System Sciences
Discussions

A framework for deriving drought indicators from GRACE

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Natural Hazards and Earth System Sciences
Discussions

Global-scale drought risk assessment for agricultural systems

Isabel Meza[1], Stefan Siebert[2], Petra Döll[3,6], Jürgen Kusche[4], Claudia Herbert[3], Ehsan Eyshi Rezaei[2], Hamideh Nouri[2], Helena Gerdener[4], Eklavyya Popat[3], Janna Frischen[1], Gustavo Naumann[5], Jürgen V. Vogt[5], Yvonne Walz[1], Zita Sebesvari[1], Michael Hagenlocher[1]

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Contribution of GRACE/GRACE-FO for drought monitoring

Perspectives

- GRACE/DA clearly identifies a groundwater drought situation around 2015-2016 that the model does not see
- we are ready to produce a downscaled GRACE/GRACE-FO TWSC product of at least daily / 50 km resolution
- this enables moving from meteorological to model-based hydrologic drought monitoring concept
- fundamental research in DFG-GlobalCDA: algorithm improvement, multisensor integration (gauge/satellite discharge), validation
- First steps towards operationalization have been taken, but more is required here! Could this be a Copernicus topic?