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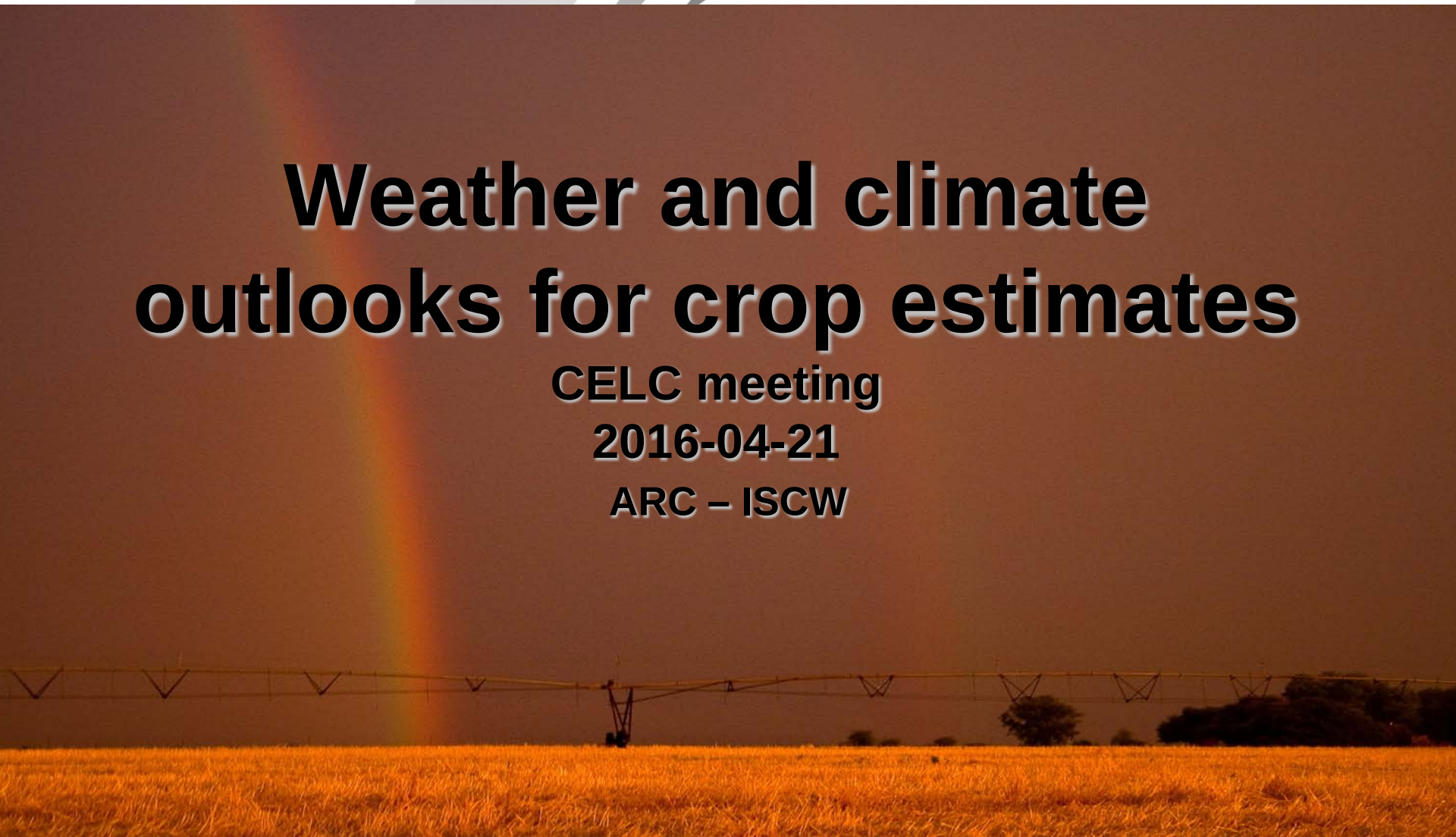


Weather and climate outlooks for crop estimates

CELC meeting

2016-04-21

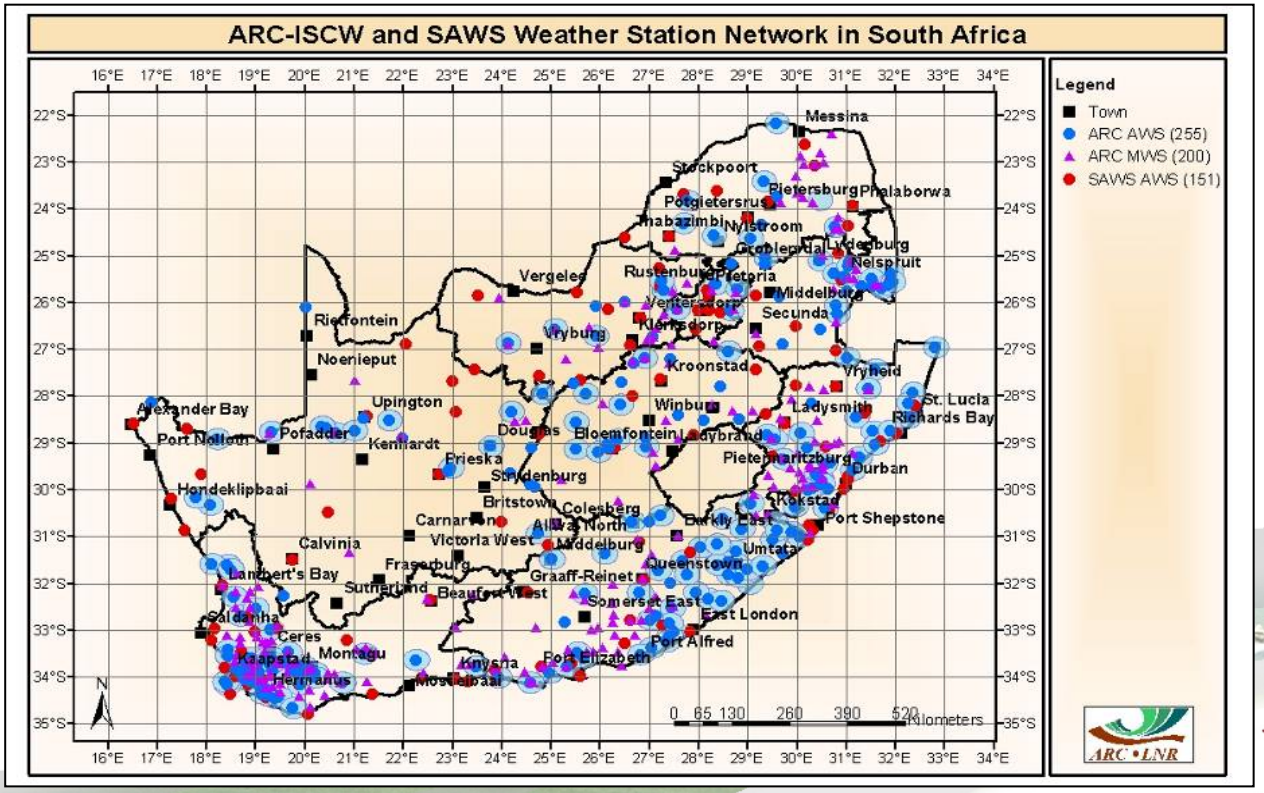
ARC – ISCW

Introduction

- **Observed weather data**
- **Modeled weather data**
  - **Short-range forecasts**
  - **Seasonal forecasts**
  - **Climate change scenario data**

Introduction

- **Observed weather data**
  - **•ARC-ISCW automatic weather station network**
    - **Hourly data**
      - **Rainfall**
      - **Temperature**
      - **Relative Humidity**
      - **Wind**
      - **Solar Radiation**



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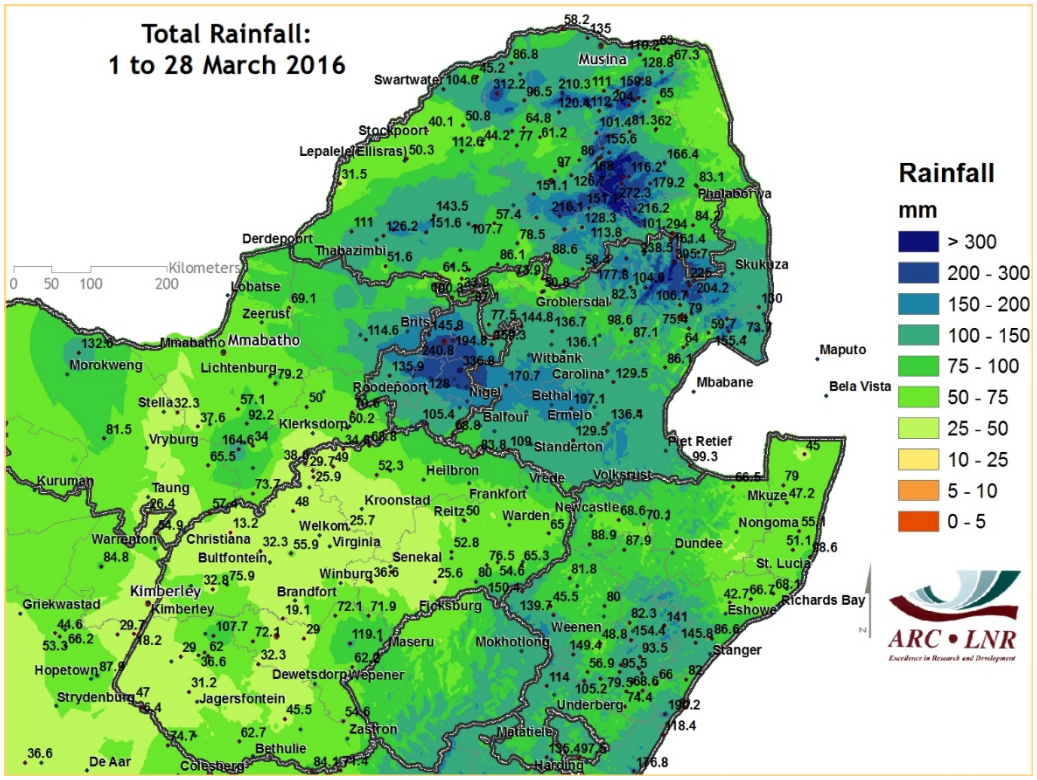
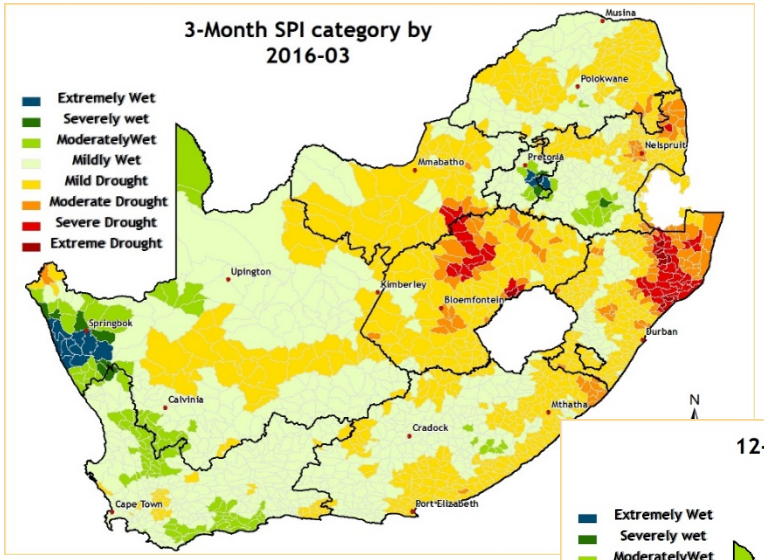
Weather data spatialized

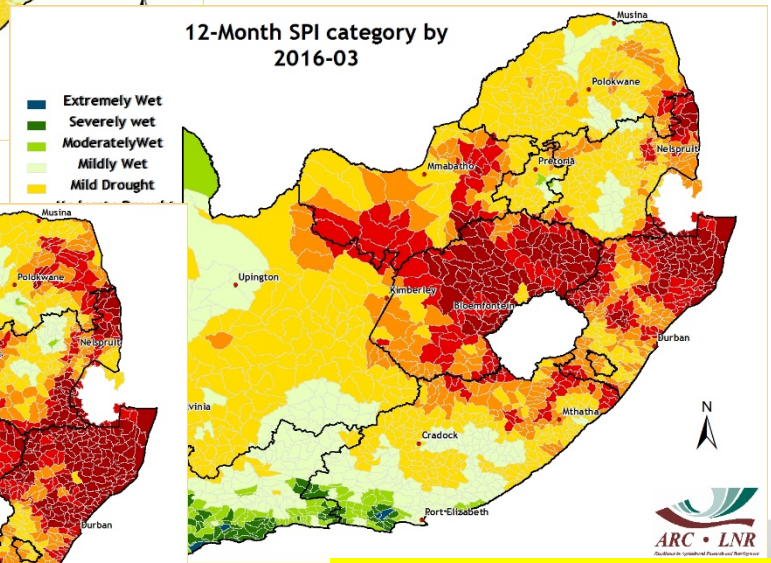
These maps provide:

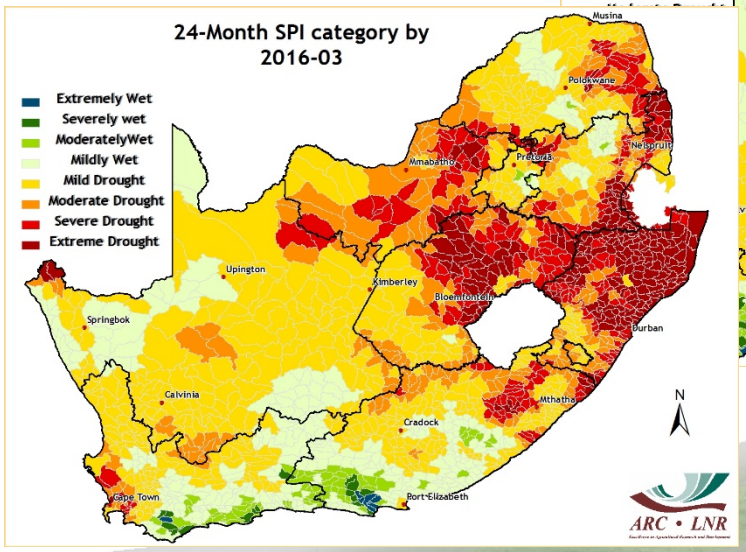
- Indications of areas with excessive or deficient rainfall / anomalous temperatures etc.
- Change in conditions or possible relief from existing conditions such as drought
- Archive: 10-daily
- Planned: Daily data (Rain, Tx, Tn)



Weather data spatialized







These maps provide:

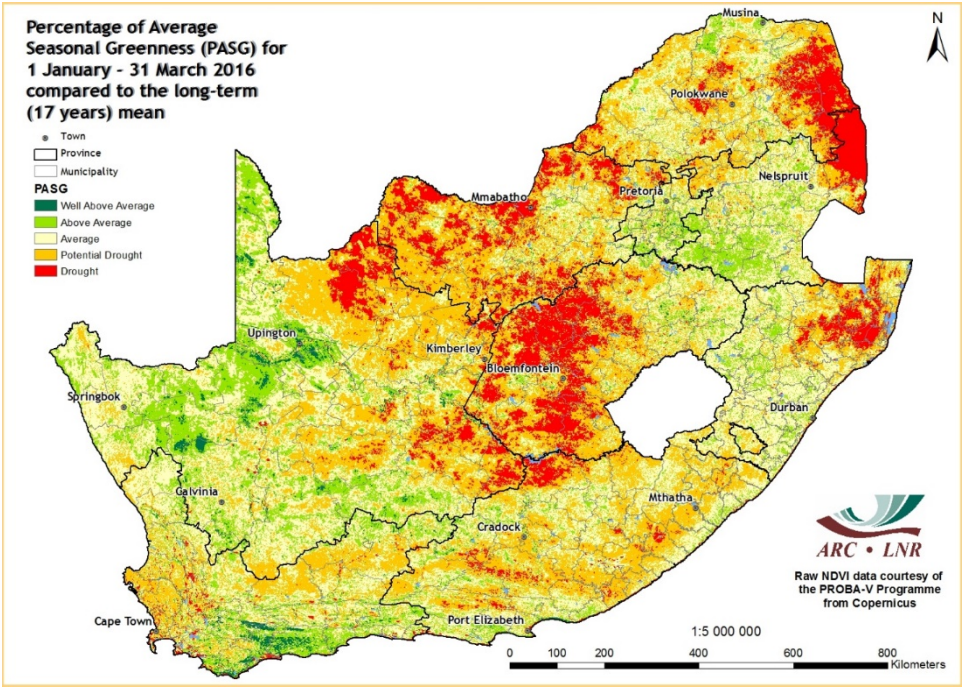
- Context for current weather effects on grain crops
- Track the evolution of drought
- Provide background to understand impacts of drought – e.g. the hydrological impacts of a long-term drought situation

The Standardized Precipitation Index (SPI) is a widely used index to characterize meteorological drought on a range of timescales. On short timescales, the SPI is closely related to soil moisture, while at longer timescales, the SPI can be related to groundwater and reservoir storage. - See more at: https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi#sthash.GJHXGzaD.dpuf

Earth observation data – vegetation activity

These maps provide:

- Overview of cumulative effect of weather conditions as a season progresses as reflected in vegetation/crop vigor relative to the long-term mean
- Track the evolution of drought



Monitoring the Future?

- 2015/2016 Drought
- Monitor maize crop
- Vegetation indices + Climate data
- Based on basics
- Forecasting maize crop
- Vegetation indices + Climate data
- Different indices
- Different sensors / platforms
- Climate change
- Gaps in knowledge

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2015/2016 Drought

- El Niño
- South Africa maize production areas
- *“Maize prices in South Africa record highs*
- *The CEC has forecast crop 27 percent lower in 2016 at 7.255 million tons*
- *SA importing Argentine, Ukrainian yellow maize*
- *Ordered Mexican white maize”*
- (Sunday Times Business, 2016-03-09)

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Monitor Maize Crop

- Monitor drought and observe crop failure
- Vegetation indices + Climate data
- *“Large-scale failed crop in the Free State*
- *Due to a severe drought that has destroyed the majority of their crops”*
- (Sunday Times News, 2015-03-01)

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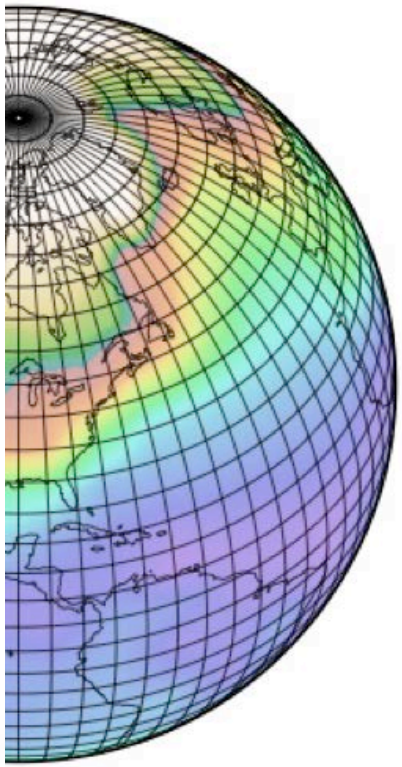
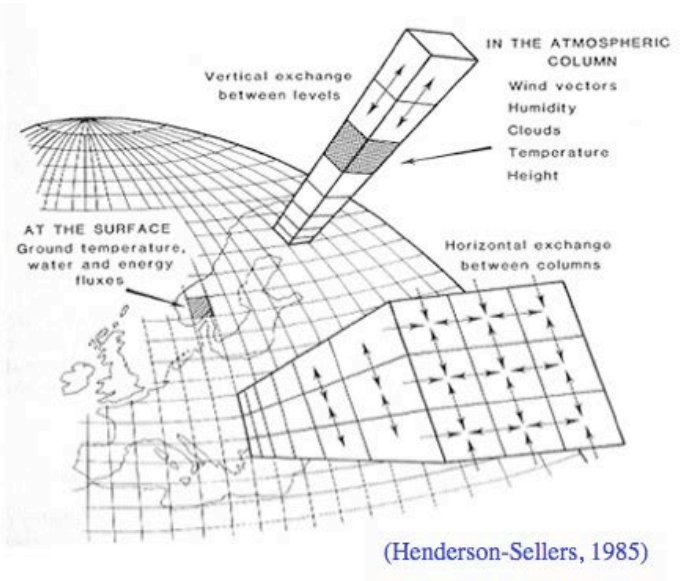
Introduction – Modeled Weather Data
Global Climate Models (GCMs)

- GCMs simulate earth system components mathematically
  - Atmosphere
  - Oceans
  - Land surface – including vegetation, and the cryosphere (ice and snow)
- GCMs divide the atmosphere, oceans, and land into a 3-dimensional grid system
- Calculations are performed to simulate change within and interactions between grid points
- GCMs currently used for daily forecasts, seasonal forecasts and climate change simulations

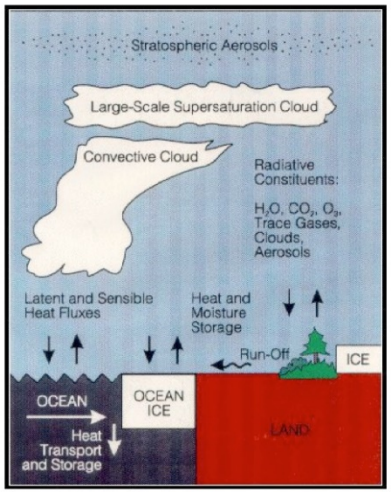
Grid Point Models





(Henderson-Sellers, 1985)

Physical Processes Simulated by GCMs



- Seasonal and Diurnal Cycles
- Latent and Sensible Heat Fluxes
- Clouds and Convection
- Planetary Boundary Layer
- Greenhouse Gases
- Aerosols
- Sea Ice
- Ground Hydrology
- Ocean Heat Transport
- *Ocean Circulation*
- *Dynamic Vegetation*
- *Dynamic Ice Sheets*
- *Carbon Cycle Chemistry*

Images courtesy of Mark Chandler, EdGCM

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Introduction – Global Climate Models (GCMs)

Large improvements in short-term and seasonal forecasts since 1980s:

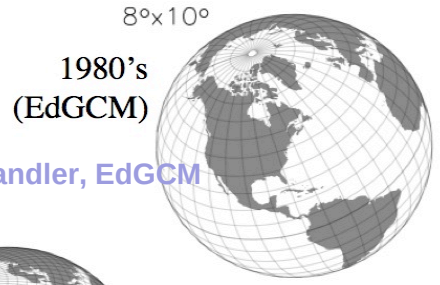
•Improved computing power enables:

- **Higher temporal resolution**
- **Higher spatial resolution (horizontal and vertical)**
- **More iterations**
- **More sophisticated calculations**
- **Inclusion of more elements (on land/Atmosphere/ocean)**

•Improved observations

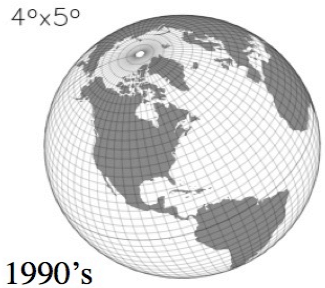
- **Landsurface and ocean temperatures**
- **Clouds**
- **Winds**
- **Aerosols**

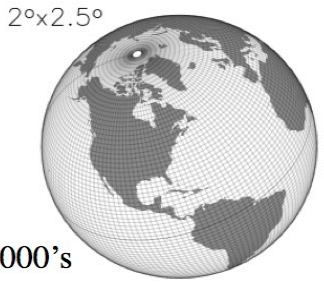
Increased Resolution Requires Increased Computing Resources

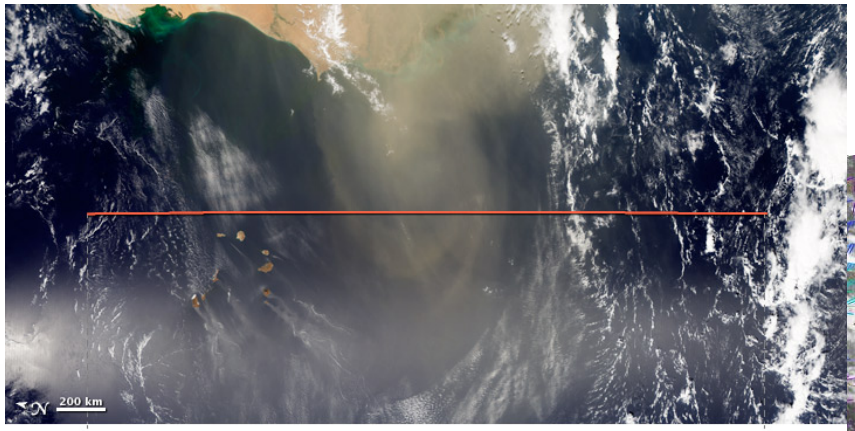


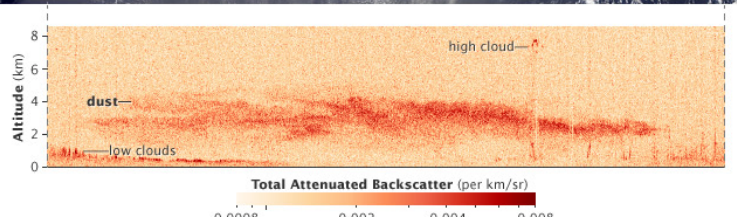
Rule of thumb: 10X more CPU for a doubling of resolution

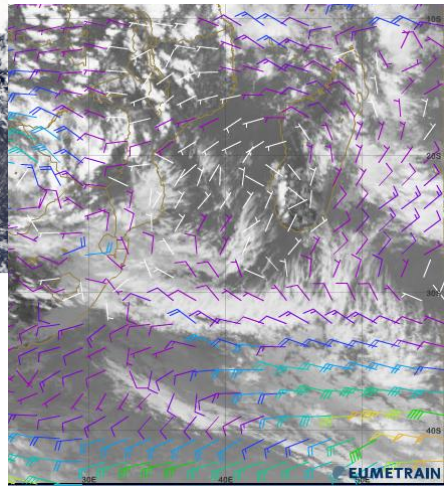
Image courtesy of Mark Chandler, EdGCM











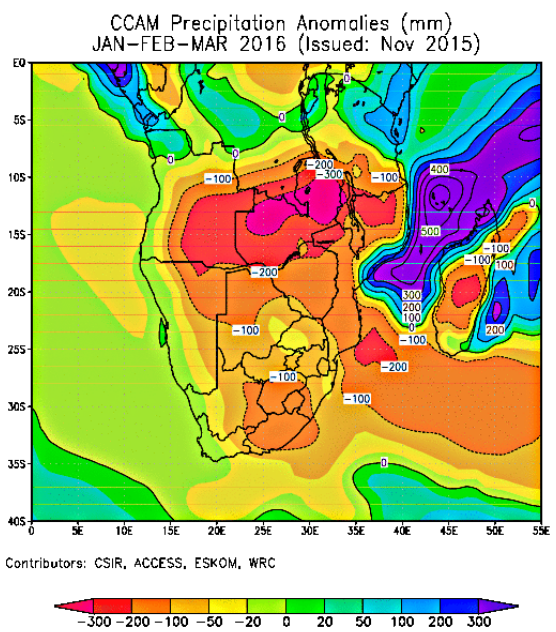
Currently available forecasts

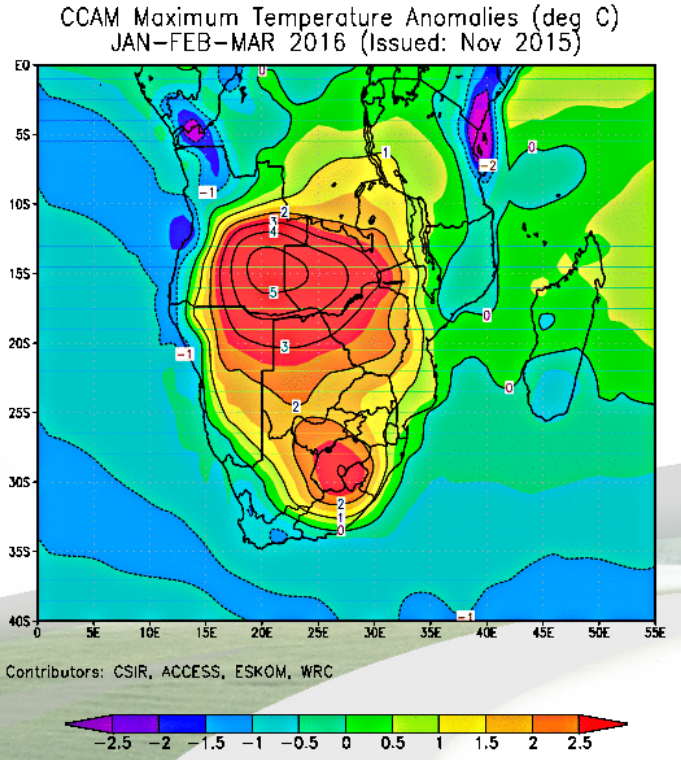
- Issued by various international institutions – also:
  - SAWS
  - CSIR
  - UCT

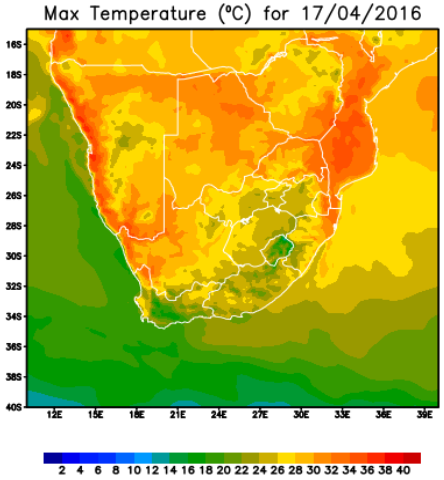
- Hourly – to seasonal forecasts
- Seasonal forecasts
  - Temporal resolution: Forecast provided in monthly to 3-monthly increments – but based on hourly to daily outputs
  - Spatial Resolution: >= 50km

- Daily to weekly forecasts
  - Temporal resolution: Hourly
  - Spatial Resolution: >= 8km

- Variables relevant for agriculture produced:
- Temperatures (TX, TN)
- Precipitation
- Wind
- Relative Humidity
- Solar Radiation/ Cloud Cover







Produced by: The Climate Studies, Modelling and Enviromental Health Group of the CSIR.

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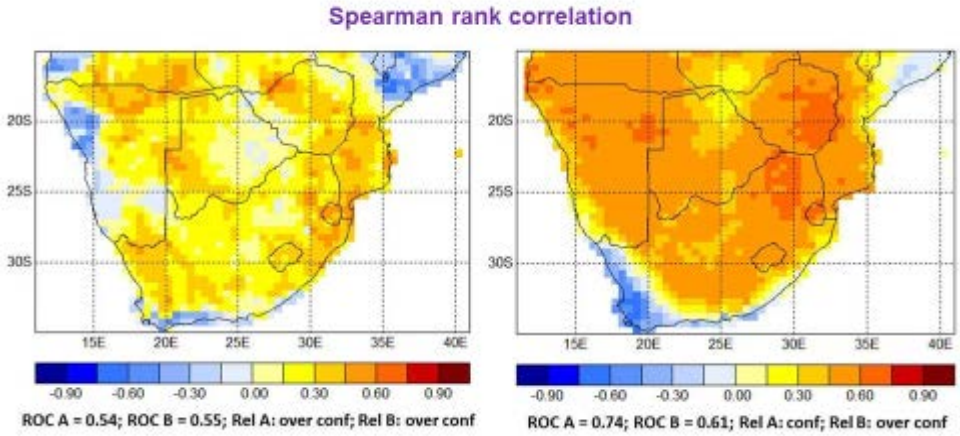
Short-term to monthly and seasonal forecasts have improved to levels that demonstrate usefulness in South Africa

- Semi-arid nature of SA makes inter-annual variability of rainfall and temperature a key aspect determining the success of agriculture
- Management of water is also a crucial aspect of planning and risk assessments
- Daily temporal resolution of forecasts (short-term to seasonal) provides opportunity for broad range of implementation possibilities
- Opportunity for seasonal forecasts to be considered in agricultural planning

Skill at a 1-month lead-time: DJF precipitation and maximum temperatures



Current GCMs, such as those used by the CSIR and the SAWS, indicate useable skill (warm colors) over southern Africa, including the maize production region of SA for rainfall (left) and temperatures (right)

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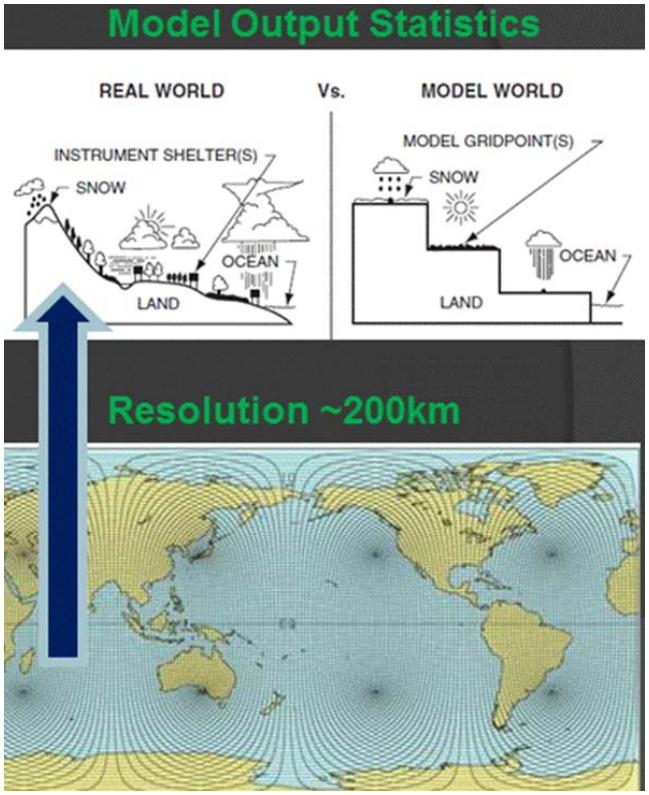
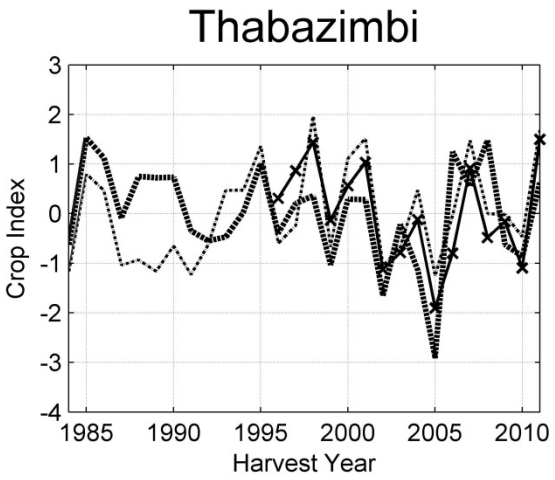
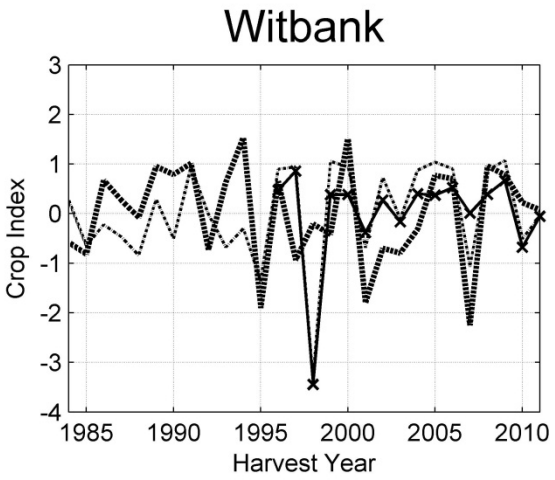
Direct correlation between certain fields produced by GCMs in the past and agricultural production

Current and historical seasonal forecasts used to obtain correlation:

- Correlation, based on historical data, used for an estimate of maize production
- Biases in global model rainfall over southern Africa have been shown to be minimised through statistical post-processing – employing the results: Model Output Statistics (***MOS***)
- MOS equations developed by using the principal component regression between GCM fields and historical maize yields / reservoir levels
- ***Provides an estimate, before growing season, of deviations from the average in maize production***
- Have demonstrated useful skill at district level







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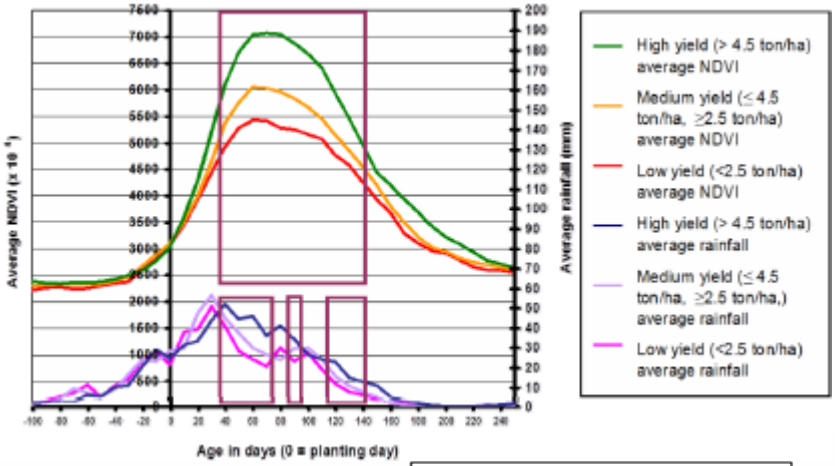
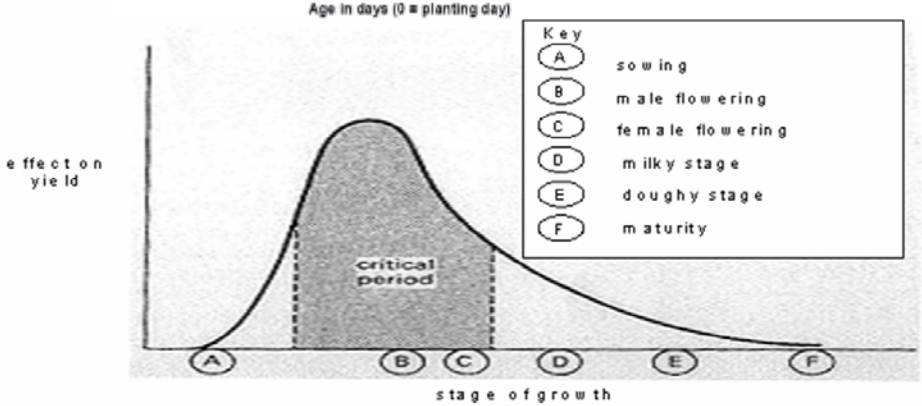
Indices and Climate Data

- Area ✓
- Yield?
- NDVI – Kriegler, 1969
- General quantity and vigour of green vegetation
- Terra MODIS 16-day NDVI
- Window model
- NDVI + Temperature + Rainfall
- Graphs

Based on Basics

- Basic elements stay the same
- Water
- Temperature
- Phenology
- Drought stress stages of growth
- Window of opportunity
- Window model
- Top graph: 2004/2005 Average NDVI & average rainfall curves
- Bottom graph: Effects of water deficiency at different stages of growth on maize yield (FAO, 2012).





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Platforms/Sensors

- 2016/04/13: "*The ASTER and MODIS sensors on-board the Terra satellite are back to normal Science Mode following the satellite entering Safe Mode on 2016/02/18. Both ASTER and MODIS data are available; however, there will be no MODIS data from 2/19 through 2/27*"
- Light at the end of the tunnel was (temporarily) switched off…
- Consider other sensors/platforms……

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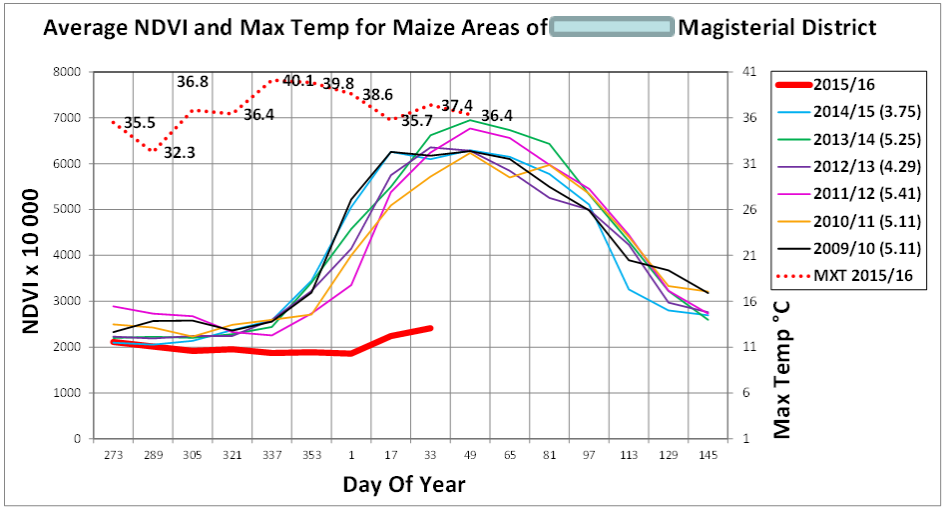
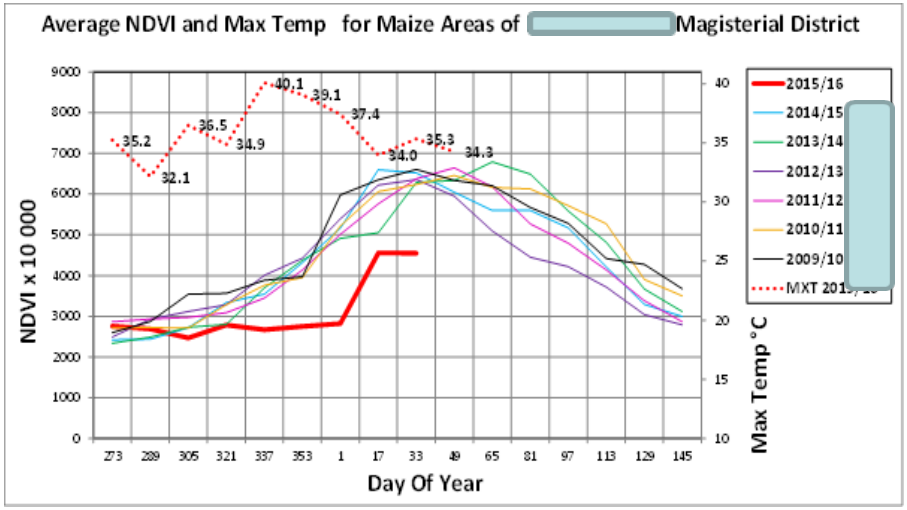
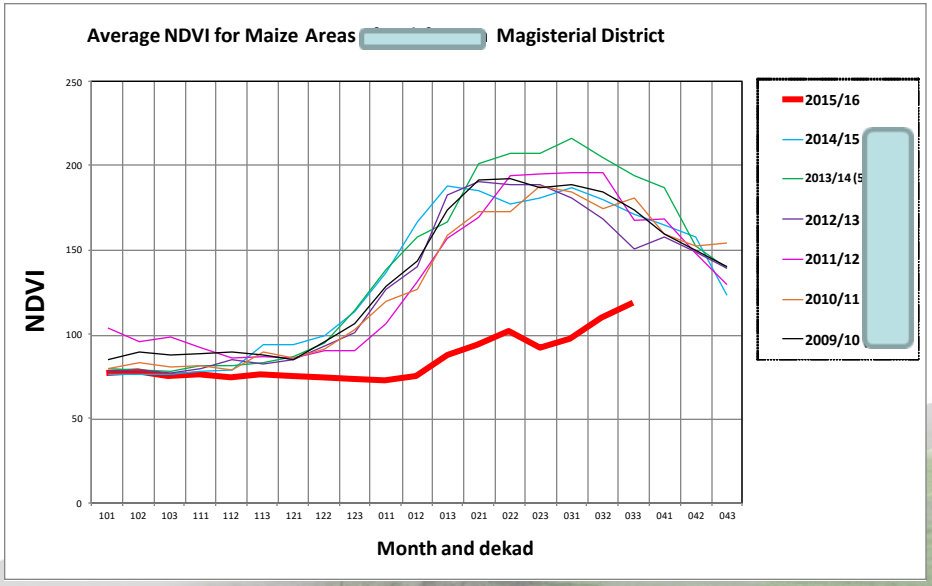
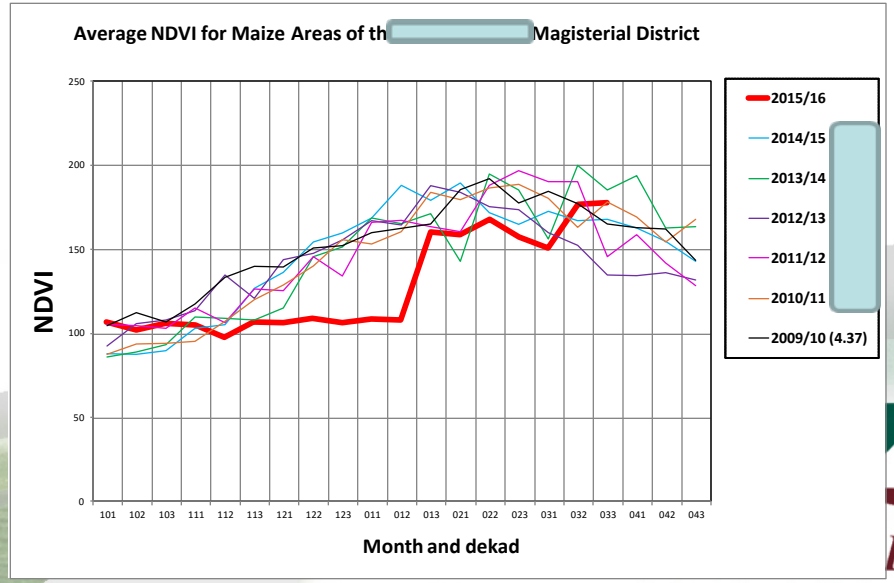
Terra MODIS & Copernicus





SA JECAM site: Free State West

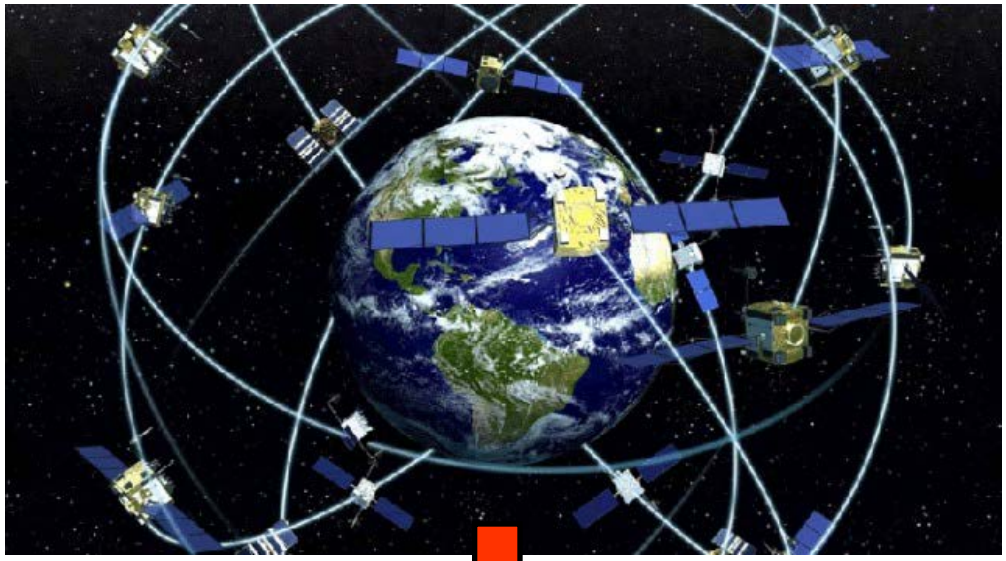




Forecast Maize Crop

- Area
- Yield

- Broad Band Greenness Vegetation indices + Climate data
- GNDVI
- Less affected by atmosphere
- EVI to calculate LAI
  LAI=(3.618*EVI-0.118)
- Broad correlations have been found between the broadband greenness VIs and canopy LAI
- Different sensors / platforms (NPP VIIRS, AQUA MODIS, Sentinel 2, NOAA, ASTER, Landsat…)



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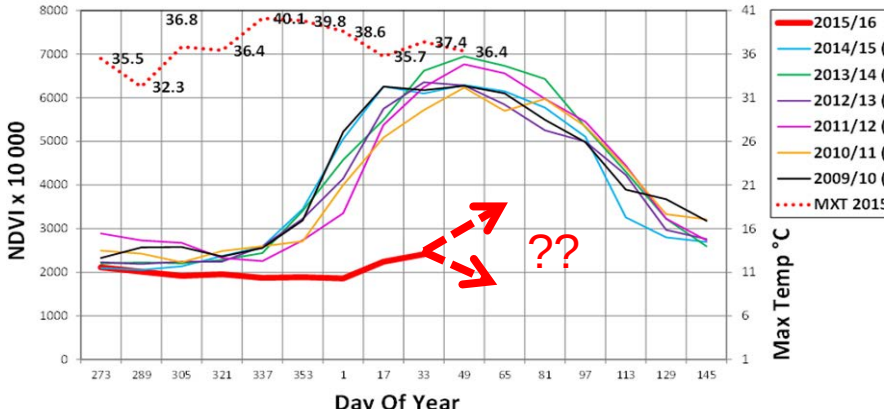
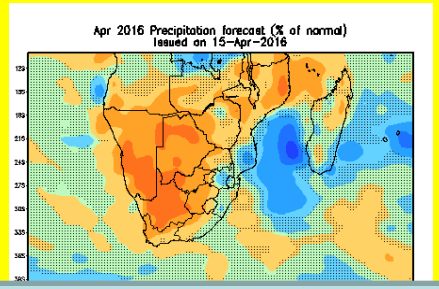
EO growth curve and short-term to seasonal forecast combined throughout the growing season



Observed vegetation and expected weather conditions combined:

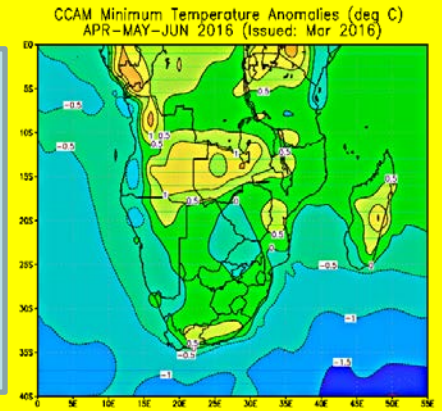
- EO data representing vegetation vigour used to assess the expected yield relative to previous years
- Focussed specifically on maize production areas as masked through use of EO data
- Observed rainfall and temperatures data (station data/ rainfall/temperature estimates) used to understand deviations
- Observed weather data used to determine direction of deviation for next few days
- Monthly to seasonal outlook used to determine direction of deviation based on expected conditions for the rest of the growing season
- ***Provides an estimate, during the growing season, of maize yield relative to previous seasons***



Monthly forecast to identify stresses/improvements for days 1 - 30

Observed EO data curve, compared to previous summers

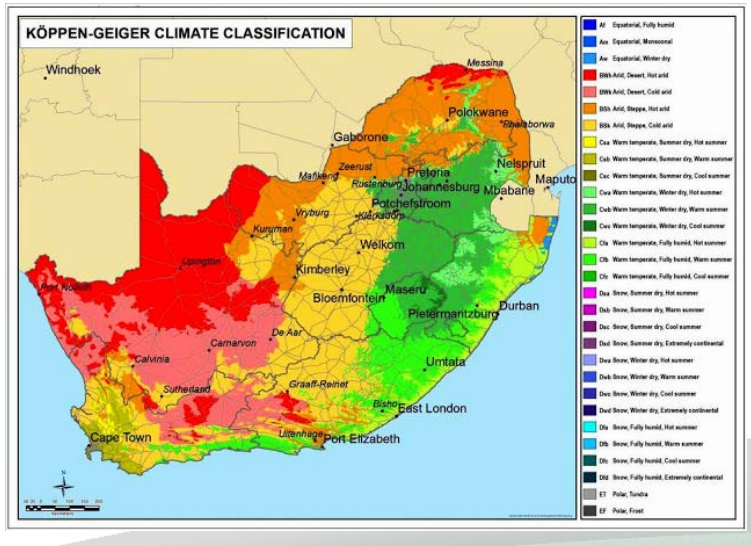
Forecast EO data graph slope



Seasonal forecast to provide direction for days 31 to end of the growing season

Climate Change

- *Rising temperatures threaten SA agriculture*
- *Temperatures in Southern Africa are increasing at twice the global rate!*
- *This may threaten the sustainability of agriculture, livestock farming, biodiversity, water and food security* (Sunday Times, 2015-03-01)
- *Lichtenburg in the North West* (Sunday Times, 2015-02-25)
- Super El Nino's to intensify in frequency
- Change / spatial shift in climate zones



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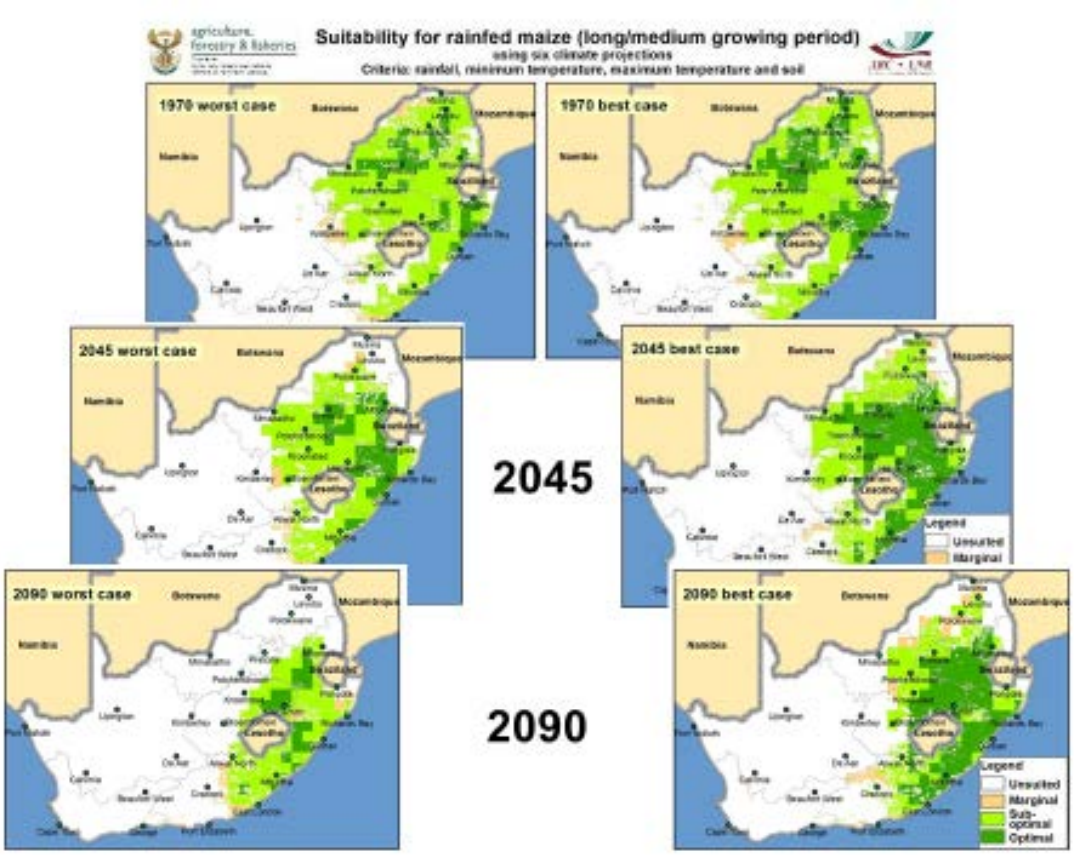
Maize suitability

- Change / spatial shift in agricultural production zones
- Spatial econometrics: How maize fields move
- Crop suitability: Consider planting a different crop

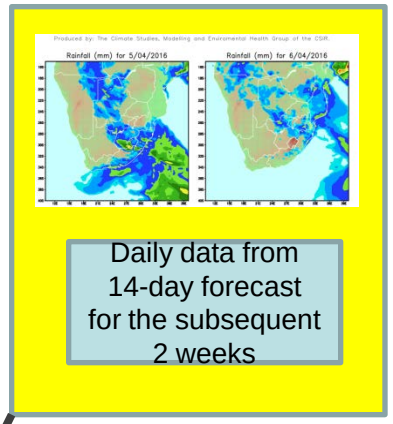


Weepener, et.al., 2014

Crop modelling + forecasts

Crop models, observed and forecast weather data:

- Dynamic crop model systems
  - Decision supporting tools
  - evaluate possible agricultural consequences from interannual climate variability and/or climate change
  - The Decision Support System for Agrotechnology Transfer (***DSSAT***) version 4.0 (Jones et al. 2003) is used to perform crop yield simulations for SA
    - Integrates the effects of crop phenotype, soil profiles, weather data, and management options into a crop model
    - The impact of weather, soils, and management decisions on a crop yield can be well estimated
    - Current methodology utilizes observed climate data from a single season up-to-date and projected climate using a weather analogue model allows for crop yield estimates to be made and summarised to provincial level as required by the Crop Estimates Committee
    - ***Short-range to seasonal forecasts can be used to refine the choice of analogue years, and can provide input data for the rest of the growing season directly***
    - ***Modelled output provide forecast for yields at end of season.***



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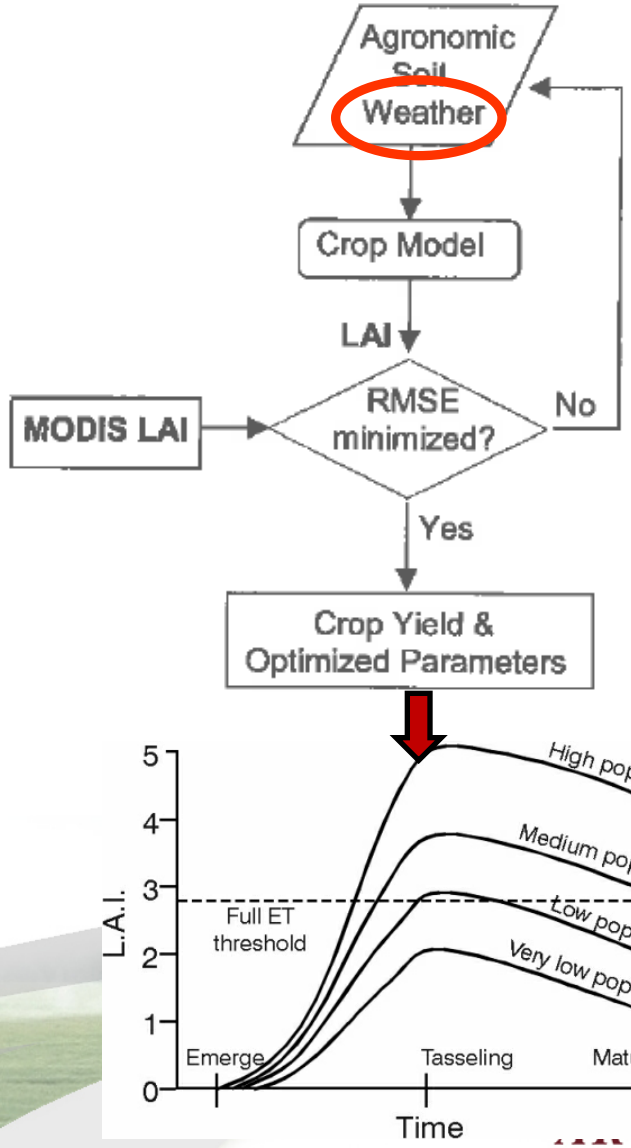
Gaps in Knowledge

- Mechanistic models and RS data
- LAI to estimate foliage cover and to forecast crop growth and yield
- DSSAT
- CERES maize
- ICSM inversion loop structure
- Recalibrate CERES LAI with MODIS LAI to predict yield and final LAI (Fang, 2008)
- Linear, cubic polynomial & exponential regression relationships between yield and VIs
- **Input climate forecast data to predict LAI and yield**



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In Summary

Forecasts for crop outlooks – how can we make better use of these?

- Use of **statistical relationship** between climate output variables on seasonal basis and crop yields, as developed in **historical data** (Downscaled data – Model Output Statistics)
- **Combine EO** data up to **present** with **observed weather and forecast** (seasonal and short term) data
- **Combine modeled crop data**, based on **observed weather data**, with seasonal and short-term outlooks
- **Use climate change projections** for **crop suitability** in future

Thank You

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